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BANANA SHIRE FLOOD STUDY STAGE 2

Volume 1—Structural Measures Report

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Structural Measures Report

Prepared for:

BANANA SHIRE COUNCIL
PO Box 412
BILOELA QLD 4715

Prepared by:

Kellogg Brown & Root Pty Ltd
ABN 91 007 660 317
Level 11, 199 Grey Street, SOUTH BANK QLD 4101
Telephone `(07) 3721 6555, Facsimile (07) 3721 6500

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Revision History

Revision	Date	Comment	Signatures		
			Originated by	Checked by	Approved by
A	18/8/2016	Issue for Client Review	A. Chapman	H. Betts	A. Chapman
B	1/9/2016	Re-issued for review	A. Chapman	J. Arunakumaren	A. Chapman

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1 Introduction

Flood management is defined as the management of flood risk by integrated measures of legislation, economy, administration, structures, technologies and education. (Simonovic, 2008).

Flood emergency management is the art of understanding and controlling the temporary storage of excess rainfall that has fallen on a catchment to a point where existing flood management measures are overwhelmed. A flood emergency manager's role is to protect communities and their assets whilst reducing the adverse economic and social consequences of flooding.

Every nation-state accepts the need for measures to protect and preserve the lives and property of its citizens, whether from external threats or internal hazards. (COA, 2004a).

1.1 PURPOSE

This report describes options and issues associated with a range of possible structural measures that have the potential to reduce the risk of flooding within the Banana Shire Council (BSC) local government area.

It builds upon an earlier Flood Study Report (BEW455-TD-WE-REP-0001) that outlines the extent of flooding in the 10 major communities within the BSC Local Government Area (LGA).

Flood mitigation strategies within catchments are aimed at reducing residual risk, for improving safety and minimising damage by reducing peak flood levels and depths, improving warning times and reducing flow velocities.

Structural flood mitigation measures are generally directed to changing the way water flows through a catchment, as distinct from non-structural measures that are generally directed to changing people's behaviour.

Structural measures include delaying runoff from entering major streams, providing barriers to flood flows, channelization and accelerating flows from the catchment.

Reductions in peak flood flows and depths are usually achieved with detention or retention basins and dams, or by providing space for water through widening of flow paths and improving floodplain capacity. Accumulations of floodwater within a hydraulic system are usually avoided by improving conveyance through the system. It is usual to commence such improvements at the downstream end or at the point of discharge from the system.

This report is the first stage of an investigation strategy for structural measures for the 10 towns within BSC's LGA. The mitigation investigations in this report assess the likelihood of achieving positive results without adversely impacting on adjacent properties or land use such as agriculture. The next stage is to undertake preliminary sizing and cost estimates for the mitigation elements. Flood damage assessments are also required to assess the benefit cost assessment for structural mitigation measures.

A preferred measure, or combination of measures, will be selected for each town. Council can then adopt a strategy for further site investigations and revised cost estimates can be produced and funding arrangements identified.

1.2 STRUCTURAL FLOOD MITIGATION WORKS

Flood mitigation is usually separated into structural and non-structural measures. Structural measures include dams, levees, conveyance improvements, gates, weirs, diversion channels and house lifting. The latter includes land use planning, development control, transfers of risk such as to insurance companies, community education and awareness, flood emergency planning and disaster planning. All are intended to reduce the amount of damage that might occur by changing the behaviour of those who might otherwise be adversely affected by flooding.

Structural measures are usually undertaken when the residual risk is excessive. This occurs when the:

- consequences of flooding are considered beyond the financial and social capacity of the community to absorb
- threat to life and injury is not acceptable
- residual risk is beyond the capacity of a community's emergency management systems and resources (when orderly evacuation is no longer possible and rescue operations begin).

Once the safety of the community can be secured, structural mitigation works should be directed to protecting property.

1.3 COMMUNITY CONSULTATION

The demand on local governments and communities to efficiently manage water resources adds pressure to flood studies, as expectations are high with beneficial and justifiable results being desired by the public. Therefore, flood management projects require a measured and strategic approach to communications and community consultation.

Feedback received from stakeholders during community drop-in sessions conducted on Monday 11 July and Tuesday 12 July 2016 is reflected in the modelling examined in this Report. Feedback was received in person during community drop-in sessions at Jambin, Biloela and Theodore.

Attendees of the sessions were given a copy of the survey related to their town, a reply paid envelope and a project fact sheet. Many attendees chose to take additional copies of the survey to distribute to neighbours and friends, and some asked for surveys related to other towns. An additional stakeholder briefing was conducted in Theodore with several key community members who expressed considerable interest in the project.

The survey asked the community to indicate their support for different types of structural mitigation measures. The options listed were levees, house protection, house lifting and evacuation routes. Based on the surveys received there is support for levees in Biloela but not in Jambin/Goovigen. House lifting is supported in Biloela, Jambin, Wowan and Dululu. In Theodore there was mixed feedback on all structural measures.

When discussing concept ideas for structural mitigation measures, a number of factors and recommendations were highlighted by the community at the drop-in sessions. Table 1.1 outlines each town visited on Monday 11 July and Tuesday 12 July 2016 and the mitigation concepts that were highlighted and discussed by the community.

Table 1.1 Structural mitigation concepts

Town	Mitigation concepts discussed and/or highlighted by the community
Biloela	Levee system around Muirs Road
	Levee system around Valentines Plains Road and Baileys Lane
	Lowering Dawson Highway to the north of town or constructing a bridge to allow water to continue on its natural course
	Widen and straighten Kroombit Creek to prevent break out flows
	Earthworks at Valentines Plaines Road that allows Kroombit Creek to enter Washpool Gully
	Lift Callide Creek culverts to allow early release of dam water
Jambin	Small, localised levees
	Levee around Jambin hotel
	Consider lifting height of the road outside the school to allow eased evacuation and install culverts to prevent the road acting as a levee
	Additional gauges to provide improved notification
Theodore	Nathan Dam to regulate water flows
	Alternative evacuation route across Woolthorpe Road or Gibbs Road
	Improved evacuation route could also serve as a levee and a short levee into the old railway bank would protect houses around the engineering works and timber mill
	Small levee at ‘fruit salad corner’ between Lonesome and Castle Creeks
	Additional flood level triggers/gauges upstream in Castle Creek
	Widen the natural constriction south of Theodore
	Protection from floods up to 14 m on the gauge (about 142 mAHD?)
	Modelling needed for Castle Creek

The options modelled and tested in this Report reflect the concepts discussed with the community during these sessions.

1.4 BACKGROUND

BSC commissioned Kellogg Brown & Root Pty Ltd (KBR) to undertake a floodplain management study and plan for ten towns within BSC’s Local Government Area (LGA).

This project is building a set of flood modelling tools that will provide a detailed understanding of flooding in BSC’s area of responsibility, assess a range of structural and non-structural measures to manage flooding, and develop a plan to reduce the impact of flooding on the community.

As part of the floodplain management study and plan, a flood study was undertaken to inform the management plan. The flood study estimates peak flood flows, levels, and timings used for emergency planning, flood damage assessment and potential mitigation options.

2 Existing flood risk

2.1 DEFINITION

In the current context, a number of towns and evacuation routes are at considerable flood risk and both structural and non-structural flood mitigation measures can reduce that risk. These are intended to reduce the residual risk. Residual risk is defined as the flood risk that remains after all other flood management measures are overwhelmed (SCARM, 2000).

Because we do not know what the 1% AEP flood level will be in the future and we expect flooding to worsen over time, our planning options must include:

- setting a 1% AEP flood level based on what we now know, but applying an appropriate freeboard (Council currently recommends the minimum floor level for habitable buildings in flood prone areas is set at a minimum of 600 mm above a 1% AEP flood level)
- modifying the design standard as more information is provided on design hydrology
- setting a larger flood as the design standard with a lower freeboard (preferred and often less conservative on finished floor levels).

The current Planning Scheme does not include any allowance for the effects of climate change on the future flood risk of properties within the Shire. In this report, reference is made to the Designated Flood Event (DFE). For the purposes of this report we have, as a result of discussions with Council, used the flood which would occur from a 1% AEP design rainfall with the additional allowance of a 20% increase in design rainfall intensity to account for increased flooding from climate change. This is in line with the Inland Rivers Study (DERM, 2010) and follows guidance provided by Australian Rainfall and Runoff (2016).

Therefore, to determine whether flood mitigation is required to protect property, flooding under the DFE is examined for each of the major towns. Flood damage has been assessed for multiple flood event magnitudes to assist in the decision making process for both structural and non-structural measures.

2.2 LOCALITIES

There are 10 towns that form part of the floodplain management study within BSC's LGA. In the following sections, flood depths for each town are presented for the DFE as well as identifying evacuation routes and the flood event which restricts access.

A complete set of flood maps for all towns including historic and design flood events are provided in Volume 2 of Flood Study Report (BEW455-TD-WE-REP-0001).

Thangool

Flooding at Thangool is primarily governed by breakout flows from Kariboe Creek.

The majority of Thangool itself is located outside of the Kariboe Creek floodplain and remains flood free for more frequent flood events. However, due to its location, it can become isolated as roads become flooded.

Properties within Thangool are not affected by flows from Kariboe Creek for flood events up to the 5% AEP. Break out flows from Kariboe Creek in a 5% AEP flood event affect the runway at Thangool Airport. During a 2% AEP flood event, some properties adjacent to Kariboe Creek are inundated, including the Primary School and the majority of Thangool Airport runway is inundated. For increasing flood events, more properties become flood affected.

During a 5% AEP flood event, the Burnett Highway (north) towards Biloela is severed. Thangool becomes completely isolated during a 2% AEP flood event as the Burnett Highway in both directions is severed by flood waters. During large flood events, access to Thangool could be cut for several days.

Figure 2.1 depicts the extent of flooding under the DFE in Thangool.

Biloela

Flooding at Biloela is primarily caused by the Washpool Gully breakout from Kroombit Creek approximately 9 km upstream of Biloela that runs through the town. Callide Creek also floods a large area when the full supply level of Callide Dam is exceeded causing the spillway gates to open.

The majority of Biloela itself is located outside of the floodplain of even large events. However, due to its location between two major creeks, it can become isolated as roads become flooded.

During the 2015 severe flood event, the Callide Dam spillway gates opened due to the flood of water from the catchment. This caused flood levels in Callide Creek near Biloela to rise and spill onto the floodplain. A short while later the Callide Creek water level is reported to have risen very rapidly due to increased releases from the dam. The timeframe in which this occurred was very short meaning some residents, like those at the end of Muirs Road, are significantly exposed to flood risk.

Biloela is not flood affected by the Washpool Gully breakout for events up to the 5% AEP flood event. During the 2% AEP flood event, breakout flows from Washpool Gully quickly impact properties along Bailey’s Lane and those fronting Tognolini Baldwin Road. A larger number of properties are affected by the 1% AEP flood event; however the majority of properties within Biloela are located above the PMF flood event.

Figure 2.2 depicts the extent of flooding under the DFE in Biloela.

Figure 2.1
THANGOOL DFE FLOOD INUNDATION

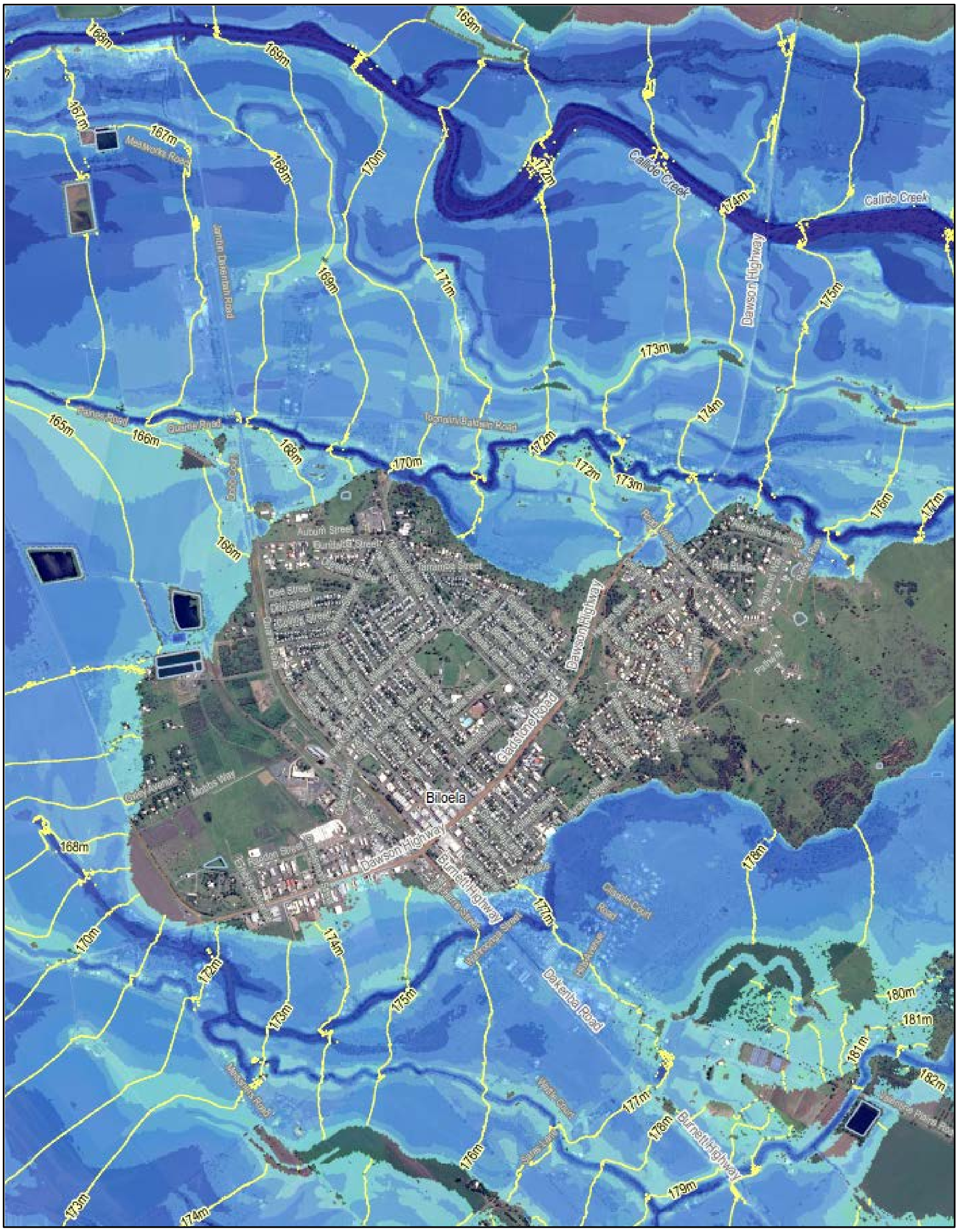

Figure 2.2
BILOELA DFE FLOOD INUNDATION

Jambin

Jambin is affected by flooding from the upstream Callide Creek and Kroombit Creek catchments. The town is situated between the Callide Creek main channel and an eastern secondary channel. During significant events, flood levels are influenced by the existing railway embankment that traverses the floodplain at Jambin and the Burnett Highway embankment.

There is a portion of Jambin that is inundated in the 10% AEP flood event and the entire town is completely inundated in a 2% AEP flood event.

The Burnett Highway (south), Jambin Dakenba Road and Biloela Duaringa Road are all severed during a 10% AEP event. Jambin becomes completely isolated during a 5% AEP flood event as the Burnett Highway in both directions is severed by flood waters. During large flood events, access to Jambin could be cut for several days.

Figure 2.3 depicts the extent of flooding under the DFE in Jambin.

Goovigen

Flooding at Goovigen is primarily governed by local flooding from Camp Creek. Flooding from Callide Creek has an impact on residents' ability to access areas outside of the Township.

Goovigen is flood affected by Callide Creek when floods approach a 0.05% AEP flood event. Some of the properties along Biloela Duaringa Road and Stanley Street are flood affected during a PMF event.

The main access roads from Goovigen (Biloela Duaringa Road and McCabes Road) are severed for all modelled flood events. During large flood events in Callide Creek, access to Jambin could be cut for several days.

There may be alternative access to the west of Goovigen via either prospect Creek Goovigen Road and Patersons Road. However, flood free access on Patersons Road may be compromised by local Camp Creek flooding. The Queensland Reconstruction Authority's (QRA) Goovigen Level 2 Flood Investigation (Report number 0914-01-E) shows that Patersons Road is severed during a 2% AEP local flood event from Camp Creek.

Figure 2.4 depicts the extent of flooding under the DFE in Goovigen.

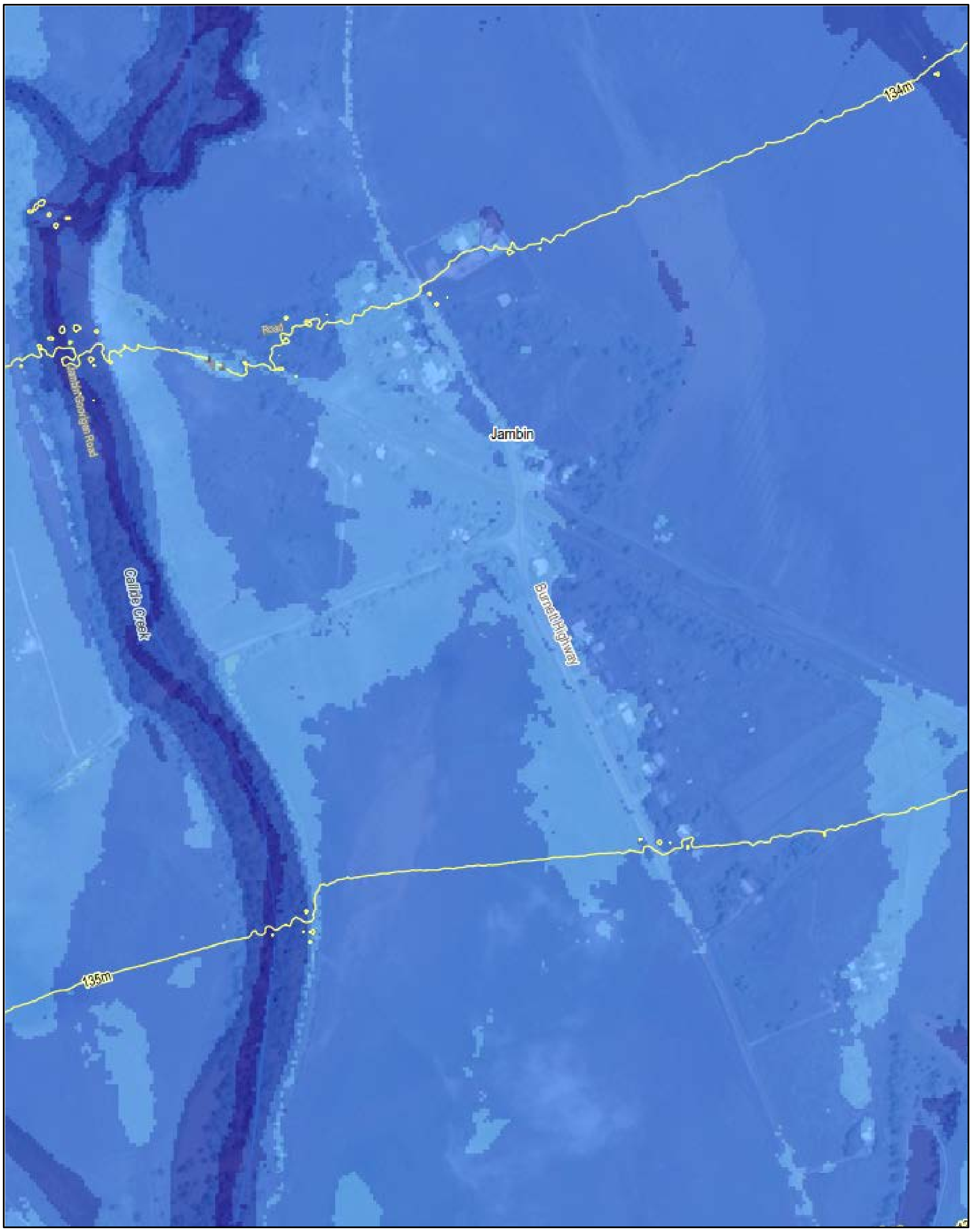

Figure 2.3
JAMBIN DFE FLOOD INUNDATION

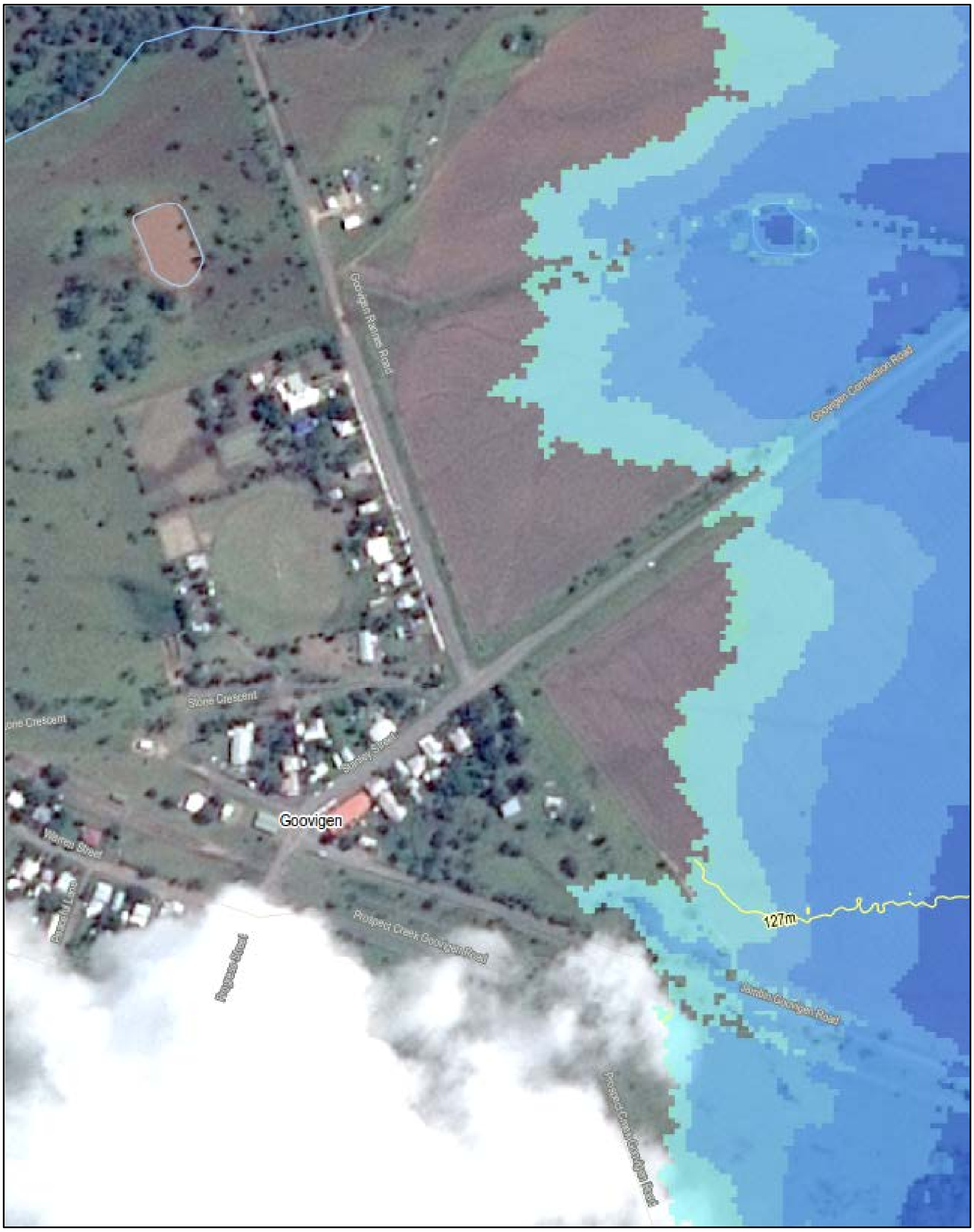

Figure 2.4
GOOVIGEN DFE FLOOD INUNDATION

Dululu

Flooding in Dululu is primarily governed by breakout flows from the Dee River. A small gully runs through Dululu, conveying breakout flows through town to the downstream floodplain.

The town is flood affected in a 2% AEP flood event, which impacts the majority of the buildings in Dululu.

The Burnett Highway both south and east of Dululu is severed in a 5% AEP flood event. Access west via the Leichhardt Highway is restricted in a 2% AEP flood event.

Figure 2.5 depicts the extent of flooding under the DFE in Dululu.

Wowan

Wowan is situated approximately 1.5 km west from the Dee River floodplain. The Dee River floodplain conveys significant flows from the upstream river breakouts. The majority of Wowan is located outside of the Dee River floodplain and is not vulnerable to regional flooding in most storm events. Flooding in Wowan is primarily governed by local flooding from Pocket Creek (a tributary of the Dee River).

Wowan remains flood free up to the 5% AEP flood event. In the 2% AEP flood event, Pocket Creek breaks its banks and inundates properties with the Township. Peak flood levels within Wowan are governed by breakout flows from Pocket Creek.

The Leichhardt Highway east is severed at Dululu in a 5% AEP flood event and to the west in a 2% AEP flood event. Westwood Wowan Road to the north of town becomes severed during a 1% AEP flood event.

It should be noted that flooding from Pocket Creek was not the focus of modelling in this study. The regionally focussed study indicated that flooding in Wowan begins in the 2% AEP flood event; however this may occur for more frequent flood events focussed on the Pocket Creek catchment. It is recommended flooding from this creek is investigated in more detail.

Figure 2.6 depicts the extent of flooding under the DFE in Wowan.

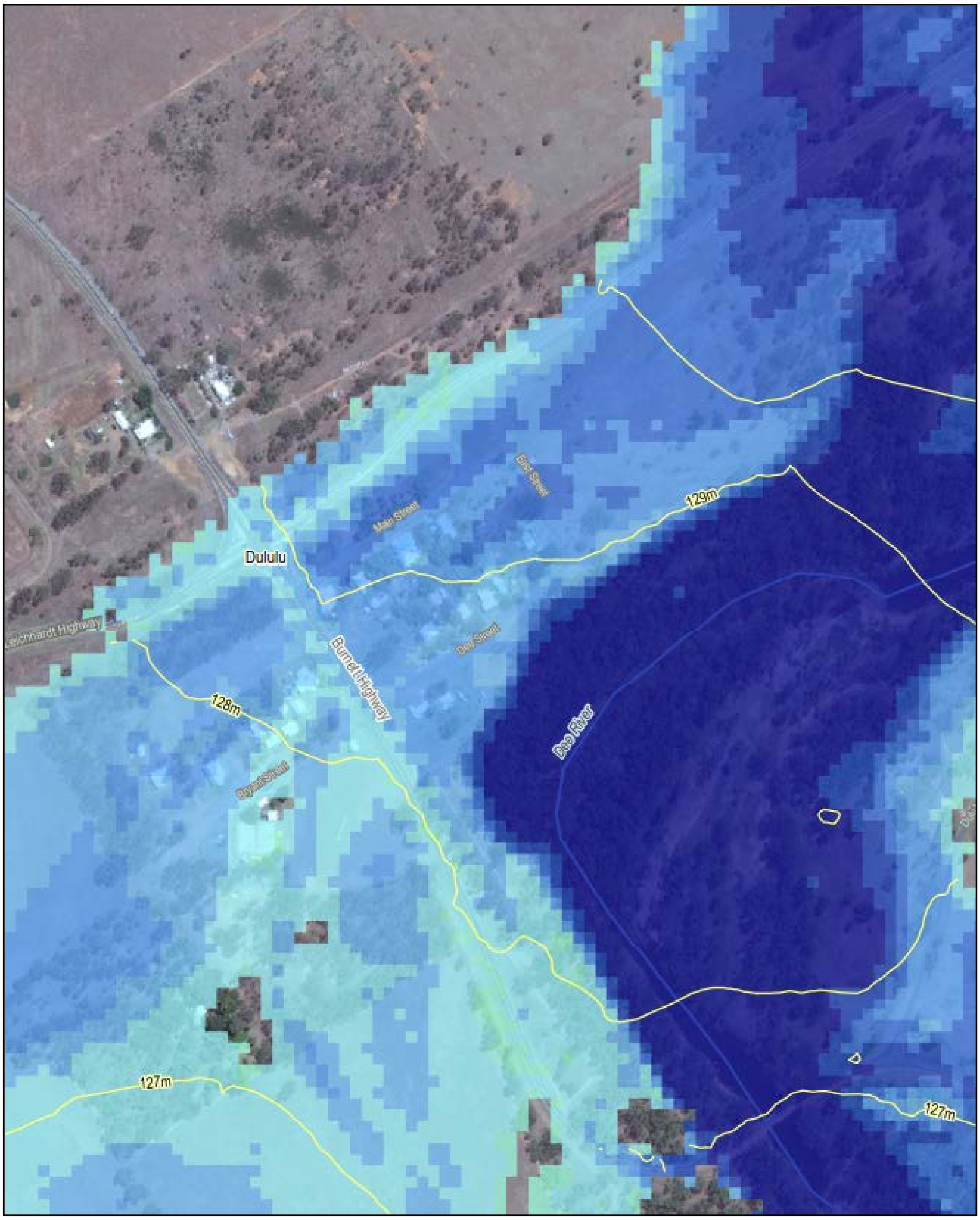

Figure 2.5
DULULU DFE FLOOD INUNDATION

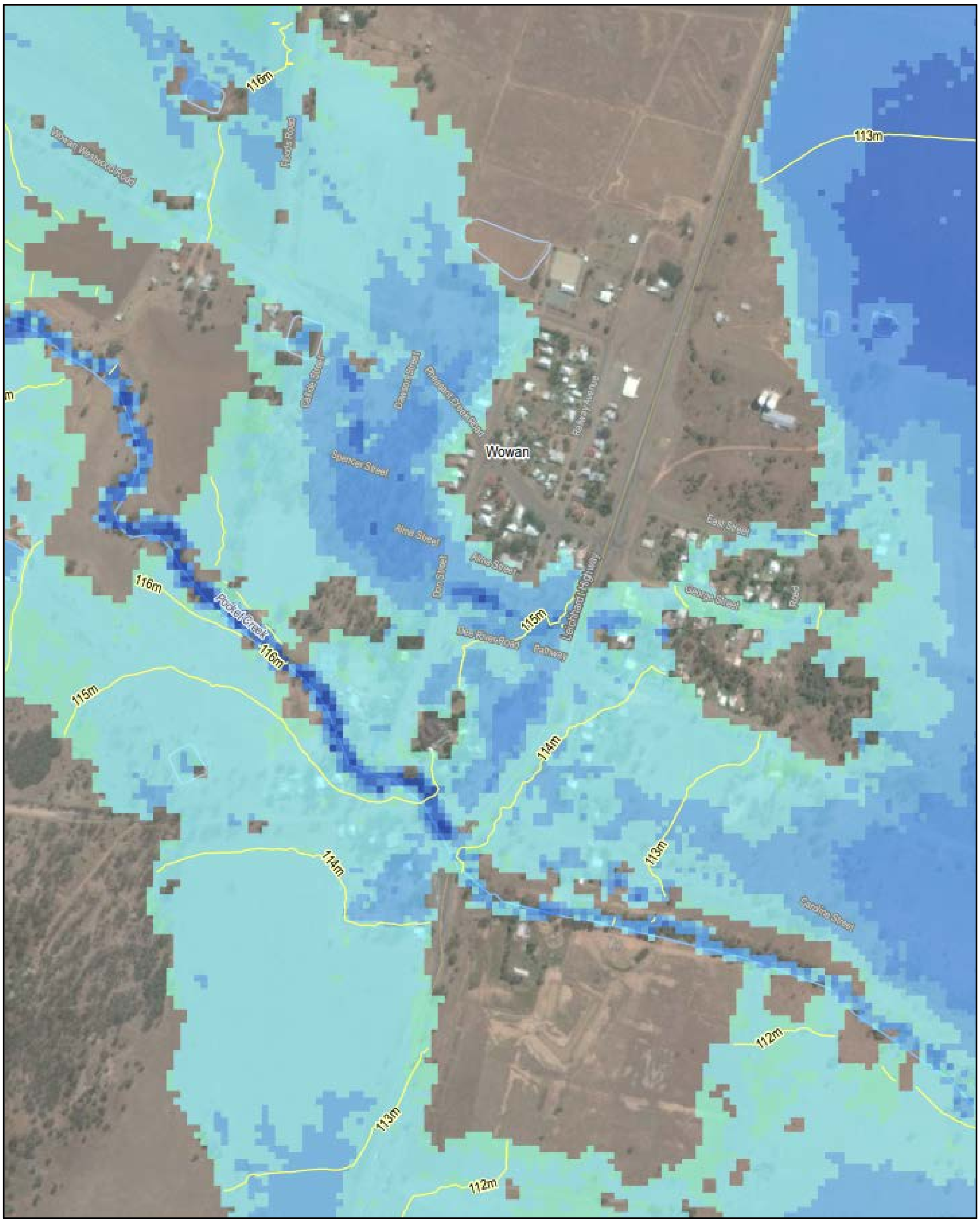

Figure 2.6
WOWAN DFE FLOOD INUNDATION

Taroom

Taroom Township is located significantly higher than the surrounding Dawson River floodplain to the west of the town. Flooding at Taroom is affected by the Leichhardt Highway crossing of the Dawson River. The town is mainly flood free.

A small number of properties within the lowest lying areas located on the western side of Taroom (around Lion's Park and some lower areas to the west of Dawson Street) are inundated in the 5% AEP flood event. The majority of Taroom remains flood free up to the PMF.

The Leichhardt Highway north from Taroom is significantly inundated in the 5% AEP flood event. During large flood events, access to the north would be cut for several days.

Figure 2.7 depicts the extent of flooding under the DFE in Taroom.

Theodore

Flooding at Theodore is primarily controlled by Theodore Weir on the Dawson River for flood events contained within the river's banks. As floodplain flow is activated, flooding is controlled by the natural constriction point in the terrain approximately 1.5 km downstream of the weir. Theodore Township is vulnerable to flooding in large events as high flows struggle to pass through the constriction point, causing upstream areas to act as a flood basin. As flow increases, water levels upstream rise, flooding farmland and eventually properties in the main town.

The lower lying areas surrounding Theodore are inundated in the 5% AEP event as well as low lying areas of the Theodore township around Eleventh Avenue. Most of Theodore, up to Third Avenue, is inundated in the 2% AEP event and by the 1% AEP event, the entire town in flooded.

During a 2% AEP flood event, there is an isolated, flood free area at the southern end of The Boulevard which has the highest elevation in the town.

Flood inundation of Eidsvold Theodore Road and the Leichhardt Highway north occurs during the 10% AEP flood event. As a result, flood free access from Theodore is only available via the Leichardt Highway from the south for flood events up to and including the 5% AEP flood event. Theodore becomes completely isolated during a 2% AEP as the Leichardt highway is cut off by flood water. During large flood events, access to Theodore would be cut for several days or weeks depending on damage to roads sustained by flooding.

Local flooding from Castle Creek has also been investigated. Flows are fairly well contained within the creek and floodplain by raised irrigation channels and private flood protection works up to the 2% AEP flood. In the Castle Creek DFE flows break across these raised embankments and inundate agricultural land and a small number of houses at the north of town. The Leichhardt Highway is accessible up to the 5% AEP flood.

Figure 2.8 depicts the extent of regional flooding under a DFE Dawson River flood event in Theodore. Figure 2.9 presents the local catchment flood extent based on DFE Castle Creek flows.

Figure 2.7
TAROOM DFE FLOOD INUNDATION

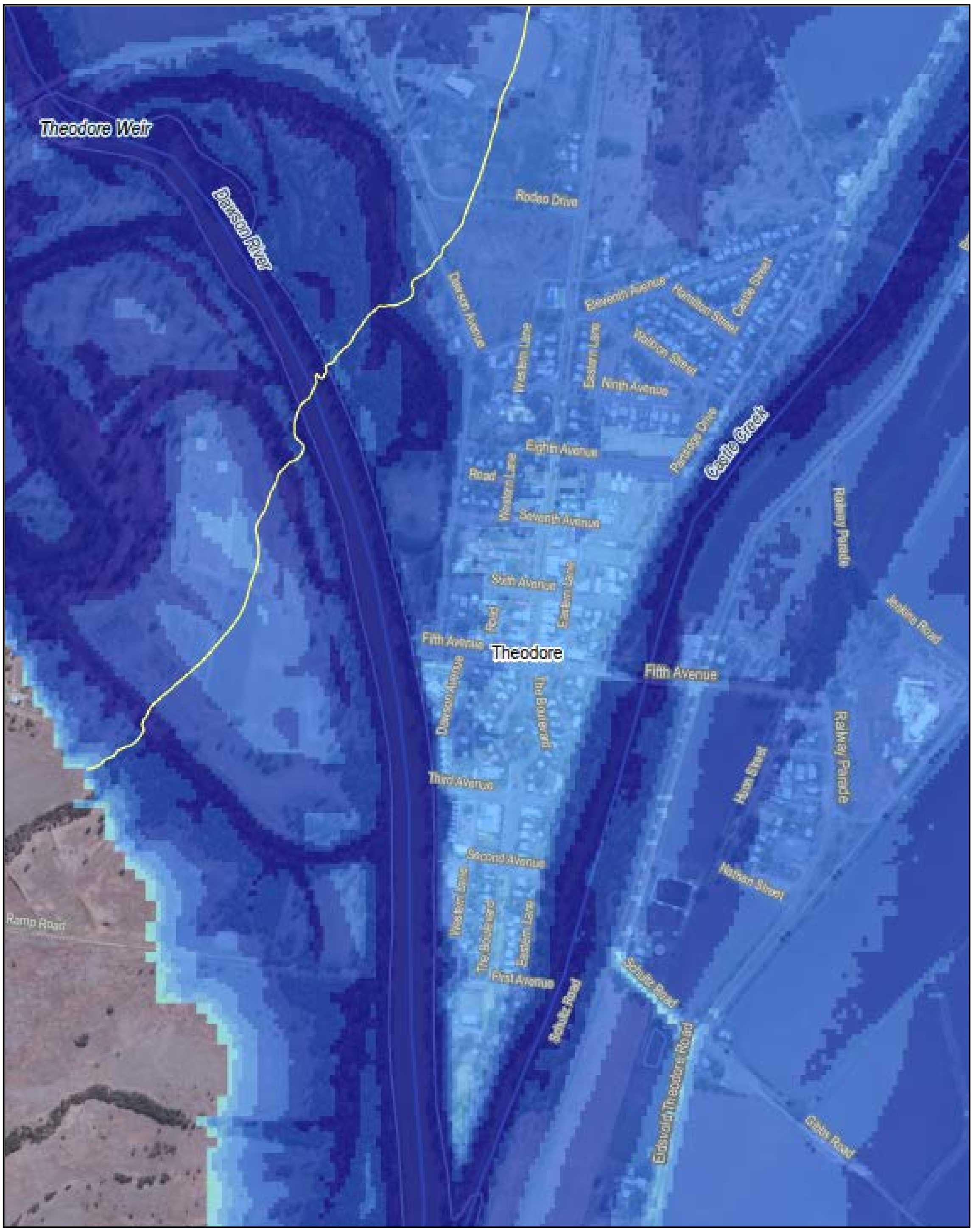

Figure 2.8
THEODORE DFE DAWSON RIVER FLOOD INUNDATION

Figure 2.9
THEODORE DFE CASTLE CREEK FLOOD INUNDATION

Moura

Flooding in the Dawson River at Moura is controlled by both the Moura Weir and the Dawson Highway crossing of the Dawson River. Moura Township itself is not vulnerable to flooding from the Dawson River. The Township is approximately 7 km from the main channel and 30 m above the floodplain.

There are a small number of rural residential properties on Saleyards and River Road to the west of the Township that are flood affected in a 1% AEP flood event. The Township of Moura remains flood free in the PMF event.

Access on the Dawson Highway to the west of Moura is severed in a 5% AEP flood event. During large flood events, access to the south would be cut for several days or weeks depending on damage to roads sustained by flooding.

Figure 2.10 depicts the extent of flooding under the DFE in Moura.

Baralaba

Flooding in the Dawson River at Baralaba is controlled by the Neville-Hewitt Weir located at the town and the Baralaba anabranch weir located approximately 1.7 km upstream. The anabranch directs water to the north-west around the Baralaba Mine, re-joining the main channel 5 km downstream of Neville-Hewitt Weir.

Baralaba is located adjacent to the Dawson River and sits mostly above the Dawson River floodplain. During large flood events (events rarer than the 1% AEP event), the lower part of the Baralaba State School is vulnerable to flooding.

Access from Baralaba across the Dawson River is severed even in smaller flood events including the 5% AEP event. During large flood events, access to the north would be cut for several days.

Figure 2.11 depicts the extent of flooding under the DFE in Baralaba.

Figure 2.10
MOURA DFE FLOOD INUNDATION

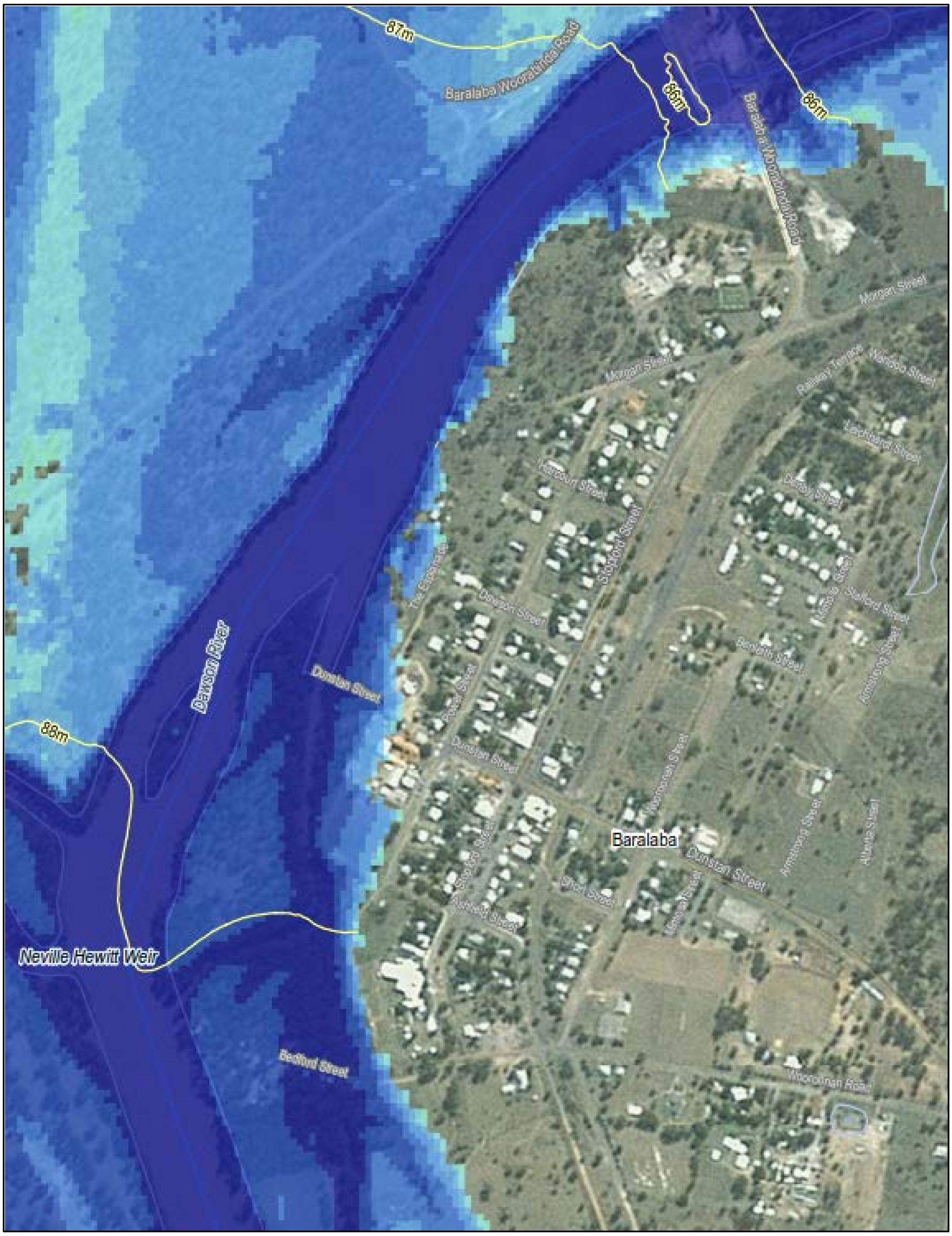

Figure 2.11
BARALABA DFE FLOOD INUNDATION

3 Flood damage assessment

The purpose of the Flood Damage Assessment (Appendix A) is to allow BSC to gain an understanding of the magnitude of assets at risk from flooding. This is a key component of floodplain management and can ultimately be used for benchmarking and assessment of structural mitigation measures. The flood damage assessment was undertaken for the ten towns considered within this study.

3.1 ASSESSMENT PROCESS

Flood damages to residential and commercial/industrial land parcels were assessed by taking into account:

- property information (property area (i.e. size), type and use of the building)
- floor level data (actual survey, or estimated by other means)
- flood level data for a range of flood events (using the hydraulic models prepared in this study)
- various stage-damage curves (depending on building type, use and area).

Property information, floor and flood level are analysed using Geographical Information System (GIS) techniques with stage-damage curves applied to each property and building. With respect to building damage this is to:

- determine if over floor flooding is expected for each building
- calculate the depth of over floor flooding
- calculate associated flood damage.

This process is repeated for each design event. The sum of the individual property damages are then aggregated to give the total damage.

3.2 FLOOD DAMAGE CLASSIFICATION

Queensland's guidance on damage assessment (DNRM, 2002) divides flood damage into two basic divisions: tangible damages (being direct and indirect) and intangible damages.

Tangible damages are financial in nature and are assessed by determining the damage or loss caused by flooding. They are subdivided into direct and indirect damages, whereby the direct cost component is costs that occur immediately as a direct exposure to floodwater. Indirect costs are consequential additional financial losses. Intangible costs are costs as a consequence of social disruption and change. The adverse social impacts of flooding are extremely difficult and almost impossible to quantify given the long duration of such impacts.

3.3 METHODOLOGY

A number of floor levels in Biloela were surveyed by BSC as part of the Callide Valley Flood Mitigation Study (CVFMS) being undertaken by the Department of Energy and Water Supply (DEWS). DEWS also digitized an additional 136 residential properties within the 2015 flood extent and made assumptions on floor levels. KBR adopted the floor levels provided by DEWS.

Additional buildings were digitized and classified in the Callide Valley, as well as Taroom, Theodore, Moura, Baralaba, Dululu, and Wowan. Classification was done using available aerial photography. An assumed floor level of 0.6 m above ground level was assumed for all the properties digitized by KBR. This was estimated by taking the floor levels that were surveyed, subtracting the ground level, and then averaging the resulting values.

Using the surveyed and estimated flood level data, the flood damage function within waterRIDE was used to calculate flood damages. A range of stage-damage curves were used for the various components of flood damage. This included application of:

- Geoscience Australia (2012) damage indices to estimate damages to the fabric and contents of residential buildings
- Maroochy Shire Curves, WRM Water & Environment Pty Ltd (2006), to estimate external residential flood damage
- Queensland's guidance on damage assessment (DNRM, 2002) for commercial flood damage estimates.

For further details refer to the Flood Damage Assessment in Appendix A.

3.3.1 Direct flood damage

In order to calculate direct flood damage a series of different data sets were required, which is summarised below.

Residential – Internal

- Flood damage curves: available from Geoscience Australia (2012) based on surveyed Queensland residential properties following the 2010/11 flood event.
- Flood levels: flood surfaces were available from hydraulic model results.
- Property levels: some provided by BSC within Callide Valley and the remainder estimated by KBR.

Residential – External

- Flood damage curves: Maroochy Shire Curves.
- Flood levels: flood surfaces were available from hydraulic model results.
- Property levels: waterRIDE uses the external property level from the centroid of the property lot.

Commercial/Industrial

- Flood damage curves: DNRM, 2002.
- Flood levels: flood surfaces were available from hydraulic model results.
- Property levels: seven properties provided by BSC. Where levels were missing, a value of 0.2 m above the buildings centroid level was used for all commercial properties digitized by KBR.

Infrastructure

Infrastructure damage has not been considered as part of this assessment. The flood damage assessment outputs are primarily used to cost the benefit of flood mitigation options which are focused around the towns themselves. For this reason large stretches of linear infrastructure would not receive benefit and remain consistent between existing and post-mitigation scenarios.

It is noted that infrastructure damage can be reduced by management practices such as closing flooded stretches of road and waiting until they are dry before re-opening.

Agriculture

Flood damage to agriculture is difficult to estimate. Lawrence Consulting (2009) reported a total reduction in agriculture, forestry and fishing turnover by over $40 million, from $695 million, following the 2008 flood event across the Central Highlands region. Lawrence Consulting (2011) reported an additional fall in turnover to $508 million for 2008/2009. This indicates that there is a lag effect in this industry as a result of flood damage.

Further uncertainty exists with respect to agricultural damage in terms of the time of year when flooding occurs, dominant type of crops being produced, weather conditions, value of produce and stock to market.

Agricultural damage was therefore not considered as part of this assessment. The damage assessment is also primarily used to calculate the benefit of flood mitigation options which are focused around the towns themselves. For this reason agricultural areas would not receive benefit and remain consistent between existing and post-mitigation scenarios

3.3.2 Indirect damage

As outlined in DNRM (2002) indirect damages (e.g. clean-up costs) for residential and commercial properties are difficult to estimate and are commonly assessed as a proportion of direct damages.

The following percentages are recommended in the ANUFLOOD model:

- Indirect residential damages = 15% of direct residential damages
- Indirect commercial damages = 55% of direct commercial damages.

The value of 15% was adopted for residential damages. However a value of 80% for commercial damages was assumed for this study. This was derived through a study by Lawrence Consulting (2009) for the neighbouring Central Highlands region, which estimated indirect damages to range from approximately 55% to 125% of the direct costs.

The costs of emergency management are classified as indirect damage, i.e. the costs are a consequence of flooding, not directly affected by floodwater. Emergency management costs were scoped in BTE (2001) and were found to vary in accordance to the duration and severity of flooding and the number of people engaged in disaster management. Previous work by KBR for the City of Victor Harbor suggested that these could be 12% of the indirect costs of residential damage because emergency response is designed to the number of people directly affected.

3.3.3 Intangible costs of flooding

Intangible damages cannot be calculated with any degree of accuracy, and it is probably impossible to do so given the attribution of future or ongoing physical or mental illness responses to a specific event. They are, however, commonly believed to be in the order of 50% to 100% of the tangible damage bill for a community that is not flood aware or has not experienced floods of the magnitude under consideration (pers. comm. DI Smith and HW Betts (KBR)). Consequently, intangible costs have not been otherwise accounted for in this report.

3.4 RESULTS

The results of the damage assessment are summarised in Table 3.1 for the worst historic flood, the 1% AEP plus climate change event, and the Average Annual Damage (AAD). A detailed breakdown of flooded properties of each town is presented in Appendix A.

The AAD presented does not include damages associated with infrastructure, agriculture, etc. Furthermore, intangible damages are excluded from the calculation of AAD.

The results show that Theodore has the highest flood damage costs for the historic flood event and design flood events. It also has the highest AAD, with a value of $1,381,000 which is almost double that of the next highest town, Biloela ($792,063).

Flood damages in Theodore were estimated for flooding from both the Dawson River and Castle Creek. Flooding from Dawson River was found to cause significantly higher damages in Theodore, however flooding from Castle Creek still returned an AAD of $388,000 which is the second highest, with Biloela the only town returning a higher AAD.

Biloela has the second highest AAD with a value of $792,063, and one of two towns that experience over-floor flooding in all flood events modelled. Many of the affected areas are located outside of the town proper and are situated on the lower floodplain areas surrounding the town.

Table 3.2 Flood damage summary: 1% AEP climate change and worst historic flood

Town	Worst historic flood				1% AEP + climate change				AAD ($'000)
	Number of buildings		Damages ($'000)		Number of buildings		Damages ($'000)		
	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial	
Biloela*	147	11	$10,520	$1,300	219	16	$19,150	$3,340	$792
Thangool*	7	4	$520	$620	16	5	$1,030	$1,000	$100
Jambin*	12	5	$1,000	$370	18	6	$1,790	$700	$174
Goovigen*	2	0	$70	$0	5	0	$460	$0	$13
Theodore (Dawson River)#	172	100	$14,290	$7,720	245	109	$26,720	$17,560	$1,381
Theodore (Castle Creek)‡	-	-	-	-	31	29	$2,310	$2,270	$388
Dululu*	8	3	$550	$280	12	6	$910	$450	$63
Wowan†	1	14	$10	$350	2	16	$30	$750	$41
Taroom#	10	12	$790	$1,400	12	23	$1,050	$1,980	$233
Moura#	1	6	$70	$300	3	17	$130	$960	$100
Baralaba#	2	7	$240	$1,260	2	7	$270	$1,540	$134

* *worst historic flood on record is 2015*

worst historic flood on record is 2010

† *worst historic flood on record is 2013*

‡ *no historic flood event modelled*

The worst historic flood for the Dawson River occurred early in the 20th century but given the level of development is not directly compatible with current development levels, and flood level data from that time may not be accurate across the Shire, we have excluded it from our calculations.

4 Structural mitigation

Structural measures are generally intended to satisfy one or more of the following mitigation strategies:

- reducing or delaying flows from upstream catchments (retention or detention basins and/or dams)
- increasing the rate at which flood waters discharge downstream (channelisation and accelerating flows, improving floodplain conveyance)
- alter the way flood waters flow through the area at risk (diversion channels, detention systems and/or levees).

The structural measures investigation strategy follows the risk identification and treatment process. This involves identifying the risk and then treating or eliminating the risk such that risk-impacts are reduced or that the vulnerability or exposure to the community is lessened.

The local mitigation measures discussed in this report have been developed to protect against flooding up to the DFE (1% AEP with climate change allowance) unless otherwise stated. In some towns BSC may choose to adopt a lower standard of protection for structural mitigation measures based on severity of flooding, cost, function and logistics of implementing mitigation measures to protect against the DFE.

All measures assume that access to land for structural measures is not an impediment to construction. The structural mitigation measures may need to be staged meaning short term adverse impacts which BSC and the community would have to approach under traditional risk management principles.

Some mitigation measures may be within BSC's capacity and authority to implement within its normal time and budgetary constraints. Other structural measures may be within the authority of BSC but beyond its fiscal capacity, in which case it will need to seek flood mitigation funding assistance from the state and/or the federal government for eligible structural flood mitigation work.

A pragmatic approach to structural measures has been adopted for this study, which typically results in a number of smaller localised measures rather than large-scale measures that protect multiple areas. Refer to Section 3.4 for a discussion on regional scale flood mitigation measures.

4.1 TYPES OF STRUCTURAL MEASURES

4.1.1 Types of levees

We have identified 12 permanent levee configurations ranging from earth embankments to concrete and combinations with concrete elements on earthen banks.

The easiest levees to construct are earthen embankments with side slopes of 1:3 to 1:6 depending on local amenity, whether they are useful for community purposes and to suit maintenance requirements. Levees can be keyed into the native ground and may have clay cores if the embankment material is not particularly cohesive. Soft or hard armouring is required for this material. If the underlying material is weak, ground support can be provided.

Reinforced concrete walls can be constructed as parapets, perhaps with elevated walkways if space is a premium. Concrete sections can range from L to h shapes depending on the space loads and other uses.

Reinforced concrete walls are often supported on piles although without cut-off there are risks to underflow and washouts even though the wall may still be structurally sound.

Reinforced earth walls with one or two vertical faces can provide an alternative to an L shaped wall. Tops of vertical walls need safety fences which in attractive areas can be made from pool safety glass.

It should be remembered that levees have limitations. There is a residual risk if they are overtopped with potential for peak velocities and flows to be higher. Also there can be greater residual risk behind a levee if further development is not constrained. Levees should not result in an intensification of development as this will increase residual risk.

4.1.2 House lifting

The cost of raising a dwelling varies with the size of the building, type of construction, whether slab on ground, timber or brick and the space available around the building.

From previous Flood Management Plans and Studies in Central Queensland, costs to raise a slab on ground house can be $250,000 or more and the costs to raise a timber house are approximately $80,000. It is recommended that these figures are confirmed by Council through regional suppliers for more appropriate figures for the BSC LGA.

The makeup of flood affected house type (slab on ground, low set and high set) is only known for limited parts of the Callide Valley. In other areas the house type is speculated based on aerial imagery and from staff site inspections. The ability of each flood affected property to be raised has to be assessed on a case by case basis as the cost of raising a building is affected by building area, ease of access, services, etc.

There are some indirect benefits of raising homes instead of building levees. This includes reduced property insurance premiums for individuals. Council would also benefit by not paying insurance for a levee, avoid additional public liability insurance and save on maintenance of the levee. These benefits have not been taken into account at this stage.

4.1.3 Building removal

Where no alternative structural measures are suitable for a property and the residual flood risk is too high, building buyback by Council and removal is an option. The 2013 BSC Statistical Profile (stat.abs.gov.au) suggests that the median house price for the BSC LGA is $277,500 (standard 3 bedroom including land).

BSC may then remove the building and rezone the land for other purposes that are commensurate with the high flood risk.

4.1.4 Temporary barriers

Temporary barriers may be erected prior to flood events to provide some level of flood protection to properties. Some temporary barriers include inflatable barriers, floodgates and stop logs and wall-type barriers.

All of these systems will have the same hydraulic effect as permanent levees placed in the same location for the same level for protection. Therefore before making a decision on their use they need to be assessed with the same rigour as permanent structures and also consider the resources and time available for assembly during an emergency.

In addition, temporary barriers introduce extra issues that need to be considered in relation to their use including their storage, maintenance and asset management and logistic issues in relation to:

- accessibility during an event
- handling, transport and erection limits, equipment requirements and availability
- availability and training of staff
- time for collection, handling, delivery and erection relative to effective warning times.

Temporary barriers are not a permanent solution to flood problems up to the DFE and cannot replace proper planning or floodplain risk management practices.

4.1.5 Intra-regional transport links

It should not be forgotten that intra-regional transport links are also susceptible to flooding and may adversely affect evacuation. However, when these links are damaged, they are usually repaired to the pre-flood design standard. Wherever possible they should be enhanced to reduce their level of exposure, inundation and to reduce the vulnerability of the crossing to flood risk.

These links are primary the responsibility of the Department of Transport and Main Roads, BSC and Aurizon. Most of the main regional links are constructed to provide a reasonable degree of flood immunity, but the regional flood modelling has indicated a number of roads are still at risk of flooding. Whilst there are no reasonably cost effective measures to reduce flooding of key transport routes, they can in time be reconstructed either to a higher level, or with a higher resilience to flooding.

Roads damaged to the extent they are no longer serviceable are repaired reasonably quickly after the event, but those still serviceable often have their residual life reduced and have to be reconstructed sooner than otherwise might be planned. It is this hidden cost that needs to be considered in long term budgets.

4.2 LOCAL MEASURES

Opportunities to reduce flood risk at a local level include stream and floodway diversions, levees (or road embankments) to prevent floodwater entry, afflux reductions at bridges and waterway constrictions, and possible measures to accelerate flood waters from low-conveyance areas.

In relatively confined and complex hydraulic flood plains, any redirection or change in flow pattern has the potential to disadvantage another area.

The flood impact mapping presented in this report can be used to identify options that have minimal adverse impact on adjacent areas. At this stage each mitigation measure has been investigated using the largest historic flood in each town and the DFE. This information will be used to shortlist the option with greatest potential for further assessment and then further assessment against all design flood events will be undertaken.

Decisions to construct mitigation measures in a staged construction approach will also impose a transitional risk in the area. For this reason, it is advisable (where possible) to allow floodwaters to discharge from downstream areas first, thereby improving the overall conveyance rate through the system. To commence floodplain conveyance mitigation works upstream is likely to disadvantage downstream areas (perhaps for an extended period).

Mitigation sequencing strategies need to be developed before construction, and based on impacts and consequences. Minor improvements that have substantial impacts might be able to be constructed early if they have minimal consequences downstream.

4.2.1 Thangool

Flood inundation in Thangool is primarily governed by breakout flows and backwater from Kariboe Creek. The structural measures identified that may reduce the flood risk for flood events within Thangool are provided in Table 4.1.

Table 4.1 Thangool flood mitigation options

Option ID	Description	Comment
THA-01	Local levee to protect properties on the edge of the floodplain up to the DFE. 1.1 km long up to 1.5 m high (without freeboard).	There is space for this levee to be built; construction is feasible and impacts are minor.
THA-02	Local levee to protect the Primary School up to the DFE. 0.5 km long up to 1.5 m high (without freeboard).	There is space for this levee to be built; construction is feasible and impacts are minor. A 1.0 m high levee (without freeboard) would protect up to the 2% AEP flood.
THA-03	Instead of THA-01, raise flood affected homes in Thangool	Likely to cost less than THA-01 and can be implemented in stages.
THA-04	Instead of THA-02, relocate primary school to flood free location in Thangool	Moving the school would be expensive.

The location and extent of these structural measures is presented in Figure 4.1. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that protecting Thangool residents and the primary school with local levees increases water levels at Thangool Airport by about 100 mm in the DFE. This impact is only observed a short distance upstream of the levees. Changes in peak velocity are minor.

A review of aerial imagery taken over Thangool after Tropical Cyclone Marcia shows that most homes along the flood affected streets of Leslie Street and Britten Street are timber frame on low stumps or two storey. There is an alternate option to levee THA-01 where homes in the floodplain could be raised above the DFE.

Surveyed flood levels captured by Council at Thangool are available for four properties on Leslie Street. The flood level of these properties is about the same as the DFE. Therefore it is likely that only a handful of properties would need modification making this option less expensive to implement than a levee. House lifting can also be staged over several years, focussing on the most vulnerable homes first.

Also, instead of levee THA-02, the primary school could be relocated to a nearby flood free land parcel. This would be more expensive than building a levee however could be attractive to the Department of Housing and Public Works.

Figure 4.1
POTENTIAL STRUCTURAL MITIGATION AT THANGOOL

4.2.2 Biloela

Flood inundation in Biloela is governed by breakout flows from Washpool Gully and flood levels in Callide Creek. The structural measures identified that may reduce the flood risk for flood events within Biloela are provided in Table 4.2.

Table 4.2 Biloela flood mitigation options

Option ID	Description	Comment
BIL-01	Local levee to protect properties on Baileys Lane up to the DFE. 1.8 km long up to 1.7 m high (without freeboard).	There is space for this levee to be built; construction is feasible. There are some large impacts with flood levels adjacent the golf course club house increase by 0.5 m and up to 1.5 m higher on the fairways.
BIL-02a	Local levee to protect properties on Hills Ave up to the DFE. 2.1 km long up to 1.6 m high (without freeboard).	There is space for this levee to be built; construction is feasible. Flood impacts are less than 300 mm. Due to flood levels in the DFE, this levee would need to completely enclose the properties of Hills Ave.
BIL-02b	Local levee to protect properties on Joe Kooyman Drive up to the DFE.0.8 km long and up to 2.3 m high (without freeboard).	Space for this levee is constrained by Browns Gully so it would be constructed as a vertical concrete wall. This option would be considered in combination with BIL-02a and has minor flood impacts.
BIL-03a	Raise Tognolini Baldwin Road and Dawson Highway to protect properties facing washpool gully up to the DFE and to provide an evacuation route into town.2.0 km long and up to 1.0 m high (without freeboard).	The levee would be constructed by raising existing road embankments. The culverts under the Dawson Highway would be sized to restrict flows in washpool gully to bank full. Flood impacts are 300-400 mm close to the raised Dawson Highway.
BIL-03b	Local levee to protect properties on Alexandria Ave up to the DFE.0.5 km long and up to 0.7 m high (without freeboard, although some sections over 5.0 m high due to a local drain.	There is space for this levee although some sections are very high (5.0 m) and provision for local drainage is needed through the levee. Flood impacts are minor. Currently only 3–4 properties in the flood zone would be protected by this levee.
BIL-04	Raise Muirs Road to 300 mm below the 2015 peak flood level so residents have access to an evacuation route for longer. 1.3 km long and up to 0.8 m high.	The levee would be constructed by raising the existing road embankment. Flood impacts are minor.
BIL-05	Raise Valentine Plains Road to protect flood affected areas in Biloela from flows in Washpool Gully. Over 10.0 km long and around 1.5 m high (excluding freeboard).	The levee would be constructed by raising the existing road embankment. While this option can deliver substantial benefits to residential areas, flood impacts are major with levels rising over 2.0 m in some areas. Consideration of overtopping flows and pavement levels may be complex in detailed design.
BIL-06	Valentine Plains raised crossing of Brown's gully and widened drain.	Completed by Council in 2016.
BIL-07	Where Baileys Lane crosses Washpool Gully, create a diversion channel to direct flows from Washpool into Callide Creek.	May not make a substantial improvement unless the channel is 50–100 m wide. Timing of flows between Callide and Kroombit would be problematic. Option discarded.
BIL-08	Most vulnerable homes on Muirs Rd are raised or acquired.	The homes at the southern end of Muirs Road can be exposed to severe flood risk that is unsafe for people during large flood events.

The location and extent of these structural measures is presented in Figures 4.2 and 4.3. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that substantial benefits can be achieved for residential and rural-residential areas of Biloela, but this is balanced by impacts on adjacent areas. The areas adversely impacted by some of these mitigation options are generally agricultural, although some properties and businesses are within the impact zone. Mitigation options BIL-01 through to BIL-04 have been combined for the purposes of initial testing.

The Baileys Lane levee (BIL-01) provides complete protection up to the DFE; however there are some large flood impacts upstream and adjacent to the levee due to redirection and ponding of water on the floodplain. The golf course and agricultural land along Van Itallies Road have increases in depth of 0.5 to 1.5 m and new areas of flooding. Also some properties along Washpool Gully experience moderate impacts. Due to redirected flows around the levee, peak velocities increase by over 0.5 m/s along a short length of Washpool Gully and around Van Itallies Road.

The Hills Avenue (BIL-02a) levee creates flooding impacts of 300 mm immediately west of the levee including the Council Chambers. Peak velocities along a short length of Valentine Plains Road adjacent to the levee increase by more than 0.5 m/s. There are also benefits outside the levee to the Wahroonga Retirement Village and properties on Meissners Road. This levee needs to completely enclose the properties on Hills Avenue and construction of the levee could be combined with upgrading Valentine Plains Road north-west out of the floodplain.

The Joe Kooyman Drive (BIL-02b) levee has no adverse impacts in combination with the Hills Avenue levee.

Raising the existing Tognolini Baldwin Road and Dawson Highway (BIL-03a) can protect properties facing washpool gully up to the DFE and provide an evacuation route into town. Flood impacts are 300–400 mm in the Jim Hooper Park. One property on the Dawson Highway and two on Tognolini Baldwin Road are impacted by about 200 mm. In a few areas of the floodplain north of Tognolini Baldwin Road peak velocities increase by more than 0.3 m/s. Additional flow is directed through Jim Hooper Park and under Valley View Drive with peak velocities increasing by more up to 1.0 m/s. There is also an extensive area of additional benefit downstream (west) of this option past Jambin Dakenbah Road.

The local levee to protect properties on Alexandria Ave (BIL-03b) causes small flood impacts of about 10 mm to a few properties north from the levee on Tognolini Baldwin Road. The levee does not cause any substantial changes in flow velocity.

Raising Valentine Plains Road along Kroombit Creek (BIL-05) can protect many flood affected areas in Biloela from flows in Washpool Gully. While this option has substantial benefits it also creates significant impacts on adjacent areas. Flood levels along the road are increased by up to 2.5 m in the DFE. Impacts of around 1.0 m extend to the Burnett Highway and increases of 0.5 m to the Dawson Highway. The commercial/industrial area between Dunn Street and Exhibition Ave is also flood affected but was previously dry. Flow velocities also increase by 0.5 to 1.0 m/s along the raised road and down to the Dawson Highway.

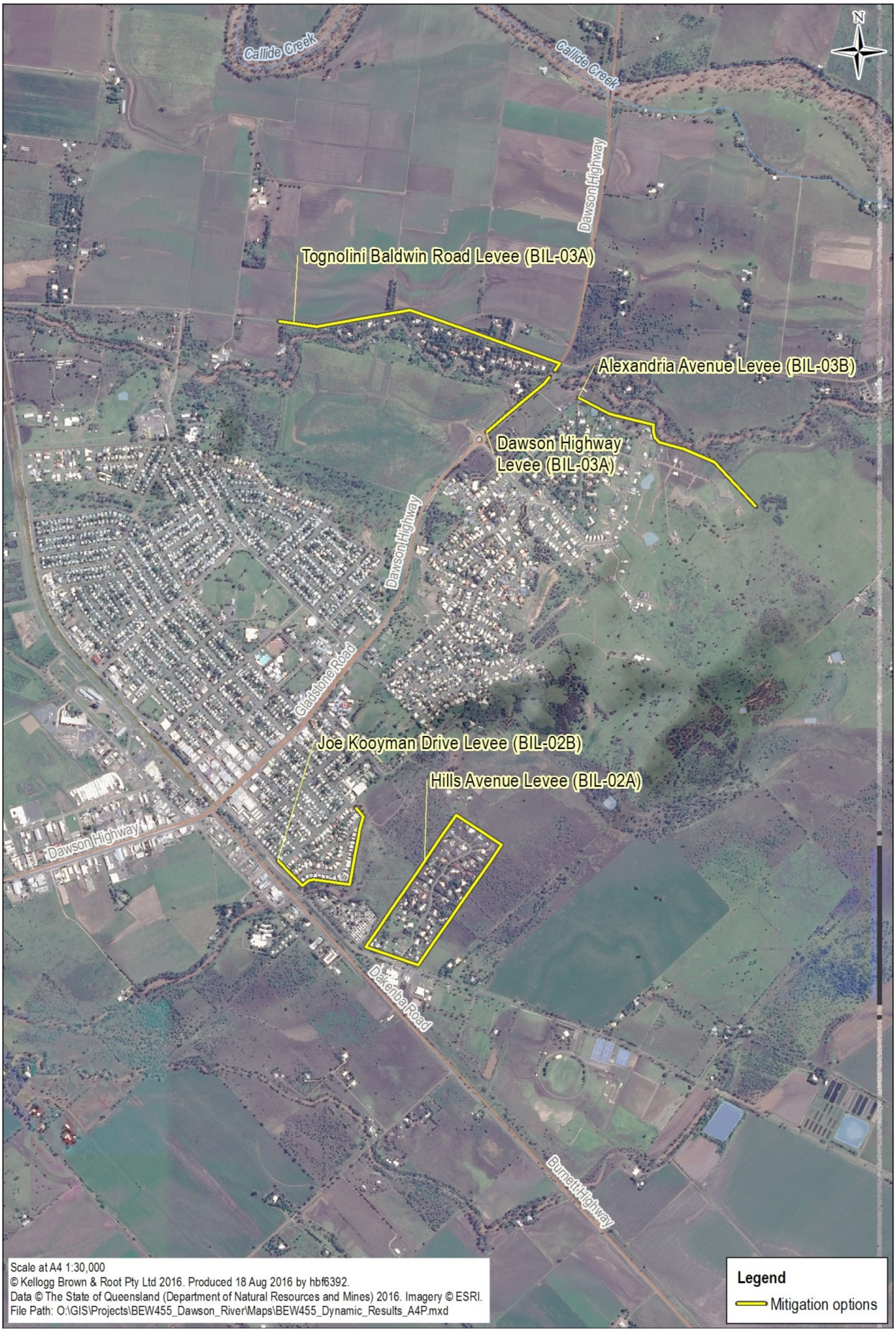

Figure 4.2
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN BILOELA

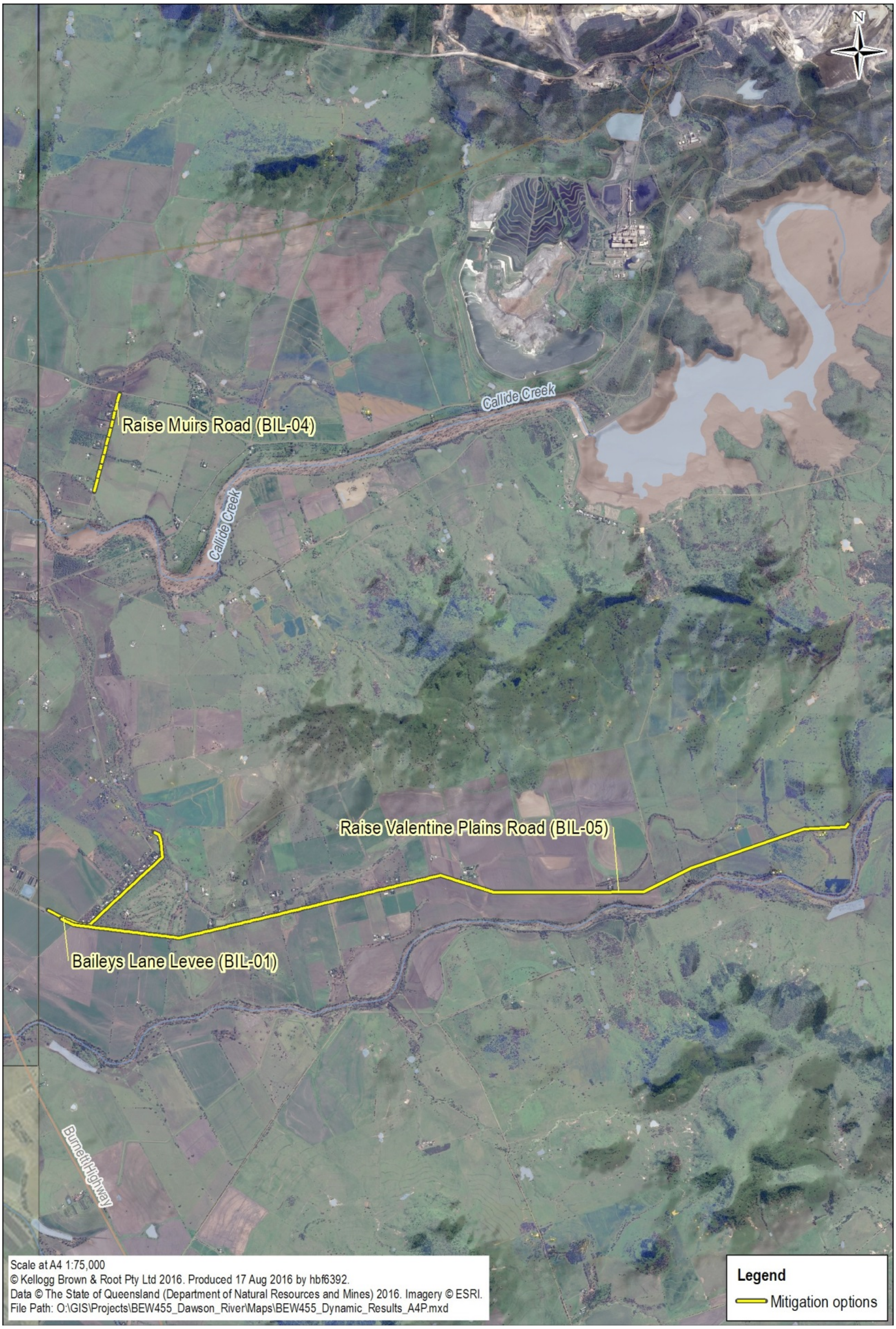

Figure 4.3
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN BILOELA

4.2.3 Jambin

Flood inundation in Jambin is predominantly governed by flows from Callide Creek and Kroombit Creek, and the town's position within the floodplain. There are limited opportunities to provide feasible structural measures to remove the flood risk from Jambin. The structural measures identified that may reduce the flood risk within Jambin are provided in Table 4.3.

Table 4.3 Jambin flood mitigation options

Option ID	Description	Comment
JAM-01	Local levee to protect the Jambin Hotel and two neighbouring properties.	There is space for this levee to be built; construction is feasible. Impacts are less than 100 mm adjacent the levee and reduce to less than 50 mm at the closest property.
JAM-02	Construct a 400 m long bridge over Callide Creek on the Burnett Hwy north of Jambin to improve conveyance of flows away from Jambin.	This option would be very costly and creates only 10 mm difference in Jambin for the DFE.
JAM-03	Lower the Burnett Hwy north of Jambin by 0.5 m to improve conveyance of flows away from Jambin.	This option would reduce the emergency evacuation access for Jambin and only creates less than 10 mm benefit in the town.
JAM-04	Raise stumped houses in combination with levee option JAM-01.	The flood affected properties in Jambin are all raised above the ground on low stumps. These homes can be raised above the DFE, starting with the most vulnerable.

The location and extent of these structural measures is presented in Figure 4.4. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that protecting the Jambin Hotel with a local levee increases water levels on one property by less than 50 mm. This impact is only observed in the area immediately adjacent to the levee.

Flood mitigation options JAM-02 and JAM-03 show that additional cross drainage structures and lowering the pavement on the Burnett Highway north of town has very little benefit to Jambin. Flood benefits are limited to 10mm in the DFE and 20mm in the 2015 flood event.

Surveyed flood levels captured by Council at Jambin are available for all properties in the floodplain. When compared to the DFE, just under half of the properties have floor levels above the flood. Therefore only about half of the properties would need modification under option JAM-04 making this option much more economical than a long levee around Jambin. House lifting can also be staged over several years, focussing on the most vulnerable homes first. This option would likely be undertaken in combination with JAM-01.

Figure 4.4
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN JAMBIN

4.2.4 Goovigen

As flood inundation in Goovigen is primarily governed by local flooding from Camp Creek, there is only minimal flood risk exposure of flooding from Callide Creek. As a result of the minimal flood risk exposure, it is not economically feasible to completely remove the flood risk from Goovigen.

4.2.5 Dululu

Flood inundation in Dululu is primarily governed by breakout flows from the Dee River. The structural measures identified that may reduce the flood risk for flood events within Jambin are provided in Table 4.4.

Table 4.4 Dululu flood mitigation options

Option ID	Description	Comment
DUL-01	Local levee to protect properties on the floodplain up to the DFE. 0.5 km long up to 2.0 m high (without freeboard).	There is space for this levee to be built and construction is feasible. Flood level impacts are moderate and velocities increase by over 1.0 m/s.
DUL-02	Most homes in Dululu are high set and raising floor levels above the DFE is an alternative to DUL-01.	The most vulnerable homes could be raised first.

The location and extent of these structural measures is presented in Figure 4.5. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that protecting Dululu residents with a local levee increases water levels upstream and over the Burnett Highway by up to 600 mm in the DFE. However there are few built structures except for some sheds on the upstream property. The levee protects the properties north of Dee Street but would need to be extended to protect properties west of the Burnett Highway. Redirecting the floodplain flow causes peak velocities to increase around the levee by over 1.0 m/s near the bank of the river and near the old Dululu Store. This change in velocity can substantially increase the destructive power of flood waters.

A review of available imagery for Dululu shows that most homes along the flood affected streets are high set timber frame or two storeys. There is an alternate option to levee DUL-01 where homes in the floodplain could be raised above the DFE. House lifting can be staged over several years, focussing on the most vulnerable homes first.

Figure 4.5
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN DULULU

4.2.6 Wowan

Flood inundation in Wowan is primarily governed by breakout flows from Pocket Creek. The structural measures identified that may reduce the flood risk for flood events within Wowan are provided in Table 4.5.

Table 4.5 Wowan flood mitigation options

Option ID	Description	Comment
WOW-01	Local levee to protect the school up to the DFE. 0.3 km long and 0.5 m high (without freeboard).	There is space for this levee to be built; construction is feasible and impacts are relatively minor.
WOW-02	Local levee to protect the fuel station up to the DFE. 0.2 km long and 0.5 m high (without freeboard).	Space is more constricted to build this levee, however construction is feasible and impacts are minor.
WOW-03	Raise high set houses in combination with levee options WOW-01 and WOW-02.	Many flood affected properties in Wowan are high set and can be raised above the DFE, starting with the most vulnerable.

The location and extent of these structural measures is presented in Figure 4.6. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that protecting the school and fuel station with a local levee increases water levels upstream at Don Street by 30 mm and up to 60 mm for properties at Pocket Creek Road. The levee around the school would be a low earth bund but due to space restrictions the fuel station levee would be a vertical wall. The fuel station levee may slightly increase flow velocities for the adjacent properties at 1-7 Pocket Creel Road.

A review of available imagery for Wowan shows that most homes along the flood affected streets are high set. Floor level data for homes in Wowan is not available so the number of properties with floor levels below the DFE cannot be determined.

WOW-03 is an option to raise houses and would be more cost effective that trying to protect the entire flood affected areas in Wowan with levees. This option would likely be undertaken in combination with WOW-01 and WOW-02 and can be staged over several years focussing on the most vulnerable homes first.

It should be noted that flooding from Pocket Creek was not the focus of modelling in Wowan. The Banana Shire Flood Study is focussed on regional flooding. Therefore both the Dee River DFE and the 2013 flood level in Wowan should be considered when deciding on preferred option in Wowan. It is recommended flooding from Pocket Creek is investigated in more detail.

Figure 4.6
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN WOWAN

4.2.7 Taroom

Flood inundation in Taroom is governed by Dawson River flooding and to some degree, the Leichhardt Highway crossing of the Dawson River. As a result, only a small number of feasible Structural Measures are provided in Table 4.6 that may reduce the flood risk to affected properties in Taroom.

Table 4.6 Taroom flood mitigation options

Option ID	Description	Comment
TAR-01	Lions Park Levee to protect properties on the edge of the floodplain up to the DFE. 0.8 km long up to 4.5 m high (without freeboard).	There is space for this levee to be built; construction is feasible and impacts are minor. However the levee is impractical for access to the Taroom roadhouse because of the levee height.
TAR-02	Instead of TAR-01, relocate Taroom Roadhouse to a flood free block and raise high set buildings.	Many flood affected properties are high set and can be raised above the DFE, starting with the most vulnerable.

The location and extent of these structural measures is presented in Figure 4.7. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results show that protecting the flood affected properties of Taroom with local levee TAR-01 would create almost no impacts elsewhere, which is expected due to the size of the floodplain. Whilst this levee would protect properties up to the DFE, it has logistic challenges. The large levee crosses the Leichhardt Highway which would require substantial re-grading and access to the roadhouse on the corner of Hutton Street would be difficult. A few other alignment options could be investigated, but all require a large levee embankment over 4m high which would be obtrusive to local residents. Alternatively, a lower standard of protection could be considered that would make the levee more feasible to incorporate into the existing infrastructure.

A review of available imagery for Taroom shows that most homes in the flood affected streets are high set timber frame or two storeys. TAR-02 is an alternate option to levee TAR-01 where homes in the floodplain could be raised above the DFE. House lifting can be staged over several years, focussing on the most vulnerable homes first. The Taroom roadhouse appears to be low set and would need to be relocated to a flood free site, possibly on the corner of Yaldwyn Street and Dawson Street.

Figure 4.7
POTENTIAL STRUCTURAL MITIGATION OPTIONS FOR TAROOM

4.2.8 Theodore

Flood inundation in Theodore is governed by flows from the Dawson River. In small flood events the town weir influences peak levels, but for major flood events a natural constriction in the terrain downstream of the town controls water peak level in the town. Flooding of the northern end of the town is also vulnerable to Castle Creek flows which have also been investigated as part of this study.

A range of Structural Measures are provided in Table 4.7 that may reduce the flood risk to affected properties in Theodore.

Table 4.7 Theodore flood mitigation options

Option ID	Description	Comment
THE-01	A shorter evacuation route to the Theodore airstrip via Gibbs Road. Also a connecting local levee to protect houses around the engineering works and timber mill up to the DFE. 2.8 km long up to 1.5 m high (without freeboard).	There is space for this levee to be built; construction is feasible. Impacts in town are minor but moderate on the floodplain. It is proposed that Gibbs Road be raised over 1.3 km to the 20% AEP Dawson River flood level.
THE-02	A local levee beside Castle Creek utilising the old railway alignment to a level of 142 mAHD. 4.0 km long up to 1.0 m high (without freeboard).	This levee extends along Partridge Drive from Fifth Ave to Walloon Street, then connecting to the old railway embankment out to the Leichhardt Hwy. Impacts are around 200 mm in the agricultural areas to the west of Castle Creek.
THE-03	A local levee to protect residents in town up to flood levels of 142 mAHD. 3.0 km long up to 1.0 m high (without freeboard).	There is space for this levee to be built; construction is feasible. Impacts in town are minor for the DFE but up to 150 mm in the 2010 event.
THE-04	In combination with levee option THE-03, raise stumped houses outside levee.	High set houses can be raised above the DFE, starting with the most vulnerable.
THE-05	Raised stumped houses that are below 2% AEP.	High set houses can be raised above the flood level, starting with the most vulnerable.
THE-06	Migrate the town to Moura	Provided for discussion.
DAM-01	Nathan Dam	Regional mitigation.

The location and extent of these structural measures is presented in Figure 4.8. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

In mitigation option THE-01, the local levee would connect and raise sections of the old railway embankment, Jenkins Road and Letchford Road behind the timer mill, along Eidsvold-Theodore Road and Shultz Road to Brownlies Road and back to the railway. This levee would protect the residents in this area, timber mill, engineering works and water treatment plant.

For option THE-01 the results show that impacts are less than 10mm around the levee and Gibbs Road in the Castle Creek DFE. For the Dawson River DFE there is moderate impact of 200 mm upstream (south) of Gibbs Road due to flows spilling over the raised road embankment. In the historic 2010 event the impacts in this location are up to 300 mm. A series of culverts under Gibbs Road have been included to minimise this impact.

The local levee beside Castle Creek (THE-02) has been raised to a level of 142 mAHD. This provides protection to the town in flood events up to the Castle Creek 2% AEP; however the levee is overtopped in the Castle Creek DFE and Dawson River DFE. Therefore the current impact mapping does not demonstrate any meaningful benefit to the town, although agricultural areas to the west of the levee still obtain benefits in the DFE. There is a widespread area to the east of Castle Creek that is impacted by this levee with flood levels increasing by 300–400 mm in the Castle Creek DFE. In the Dawson River DFE there are minor impacts. Further testing with smaller flood events will demonstrate the benefits of this option.

The local levee to protect the lower part of Theodore (THE-03) would be a combination of raised roads, earthen levees and low concrete walls to a level of 142 mAHD. This provides protection to the town from moderate flood events in the Dawson River and Castle Creek. However the levee is overtopped in the 2010 flood and Dawson River DFE. Behind the levee flood impacts are up to 20 mm in the Dawson River DFE and up to 150 mm in the 2010 event. Flood events in initial testing overwhelm levee but lower order events would have benefits. Further testing with smaller flood events will demonstrate the benefits of this option.

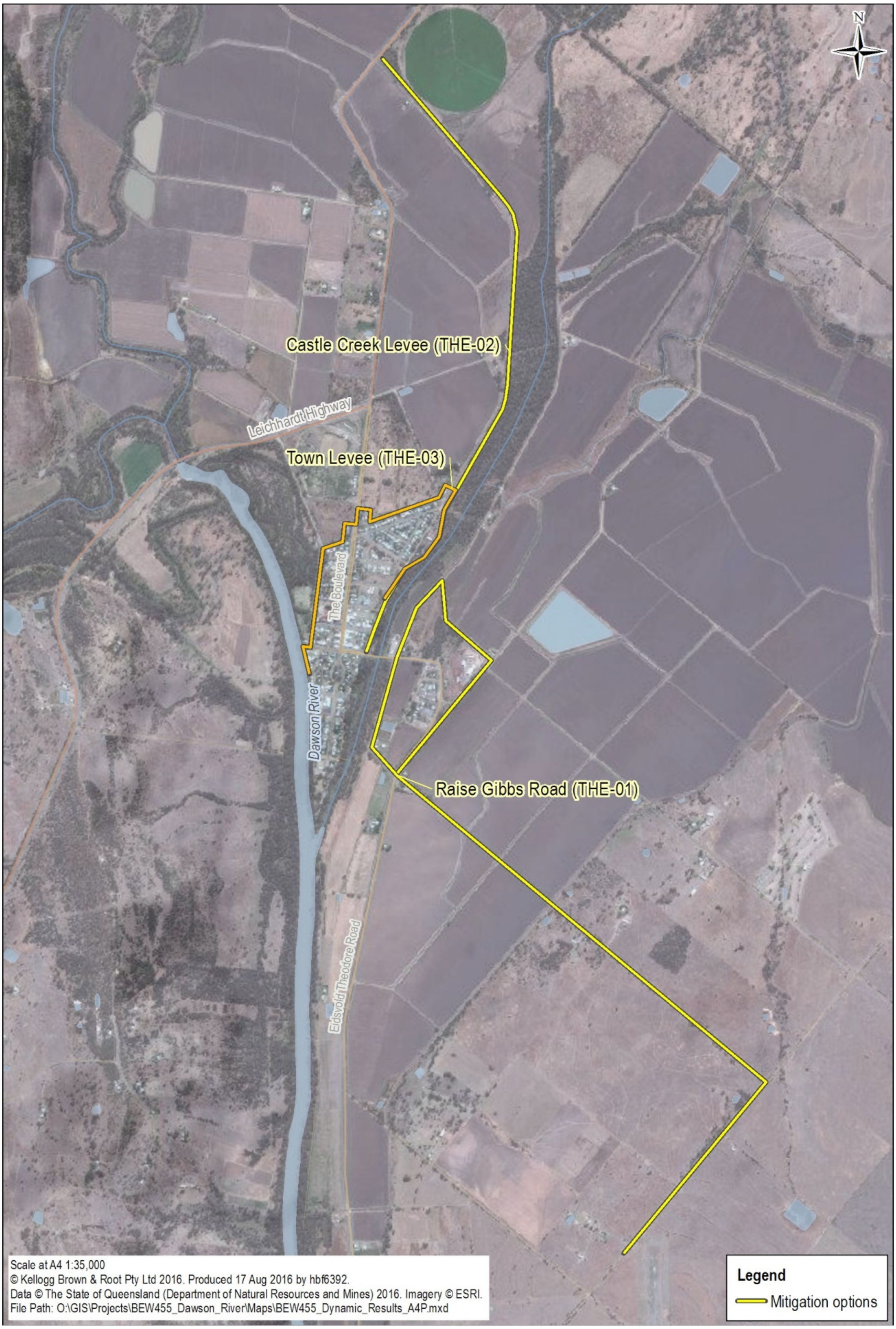

Figure 4.8
POTENTIAL STRUCTURAL MITIGATION OPTIONS FOR THEODORE

4.2.9 Moura

Flood inundation in Moura is limited to the rural residential properties at risk within the expansive Dawson River floodplain. The structural measures identified that may reduce the flood risk for flood events within the floodplain at Moura are provided in Table 4.8.

Table 4.8 Moura flood mitigation options

Option ID	Description	Comment
MOU-01	Local levee to protect rural residential properties on the bank of the river up to the DFE. 3.8 km long and 1.0 m high (without freeboard).	There is space for this levee to be built; construction is feasible and impacts are minor.
MOU-02	Instead of MOU-01, raise stumped houses	Likely to cost less than MOU-01 and can be implemented in stages.
DAM-01	Nathan Dam	Regional mitigation option.

The location and extent of these structural measures is presented in Figure 4.9. Changes in maximum flood level (afflux) and velocity maps for measures listed above are presented in Volume 2 of this report.

The results indicate that a local levee built around the rural residential properties along River Road and Saleyards Road (MOU-01) can be protected up to the DFE. The levee needs to completely enclose the properties. A small number of properties and agricultural facilities are not within the levee. This option has very limited and localised impacts due to the expansive Dawson River floodplain.

MOU-02 is an alternate option to levee MOU-01 where homes in the floodplain could be raised above the DFE. Floor level data for homes in Moura is not available so the number of properties with floor levels below the DFE cannot be determined. Also it is not known whether the homes are slab on ground, high set or two storeys. If feasible, house lifting can be staged over several years, focussing on the most vulnerable homes first.

Figure 4.9
POTENTIAL STRUCTURAL MITIGATION OPTIONS IN MOURA

4.2.10 Baralaba

A portion of the Baralaba State School site is the only property currently at risk from Dawson River DFE flooding within the town. Therefore no local structural mitigation measures are proposed for Baralaba.

A potential structural measure for the Dawson River catchment is the construction of Nathan Dam upstream of Baralaba as part of SunWater's long term reliable water storage in the area and the greater Dawson-Callide region. However initial testing by KBR indicates the proposed dam would not provide a flood mitigation benefit at Baralaba.

4.3 FURTHER INVESTIGATIONS

At some point it will be necessary to confirm the engineering feasibility of those measures deemed hydraulically beneficial and undertake an optimisation study. This would include determination of the final alignment of levees, their optimum level of flood immunity to be provided based on benefit-cost analyses and BSC's funding model, and the development of the mitigation plan.

Optimisation will include site selection based on site restrictions: land availability, costs of purchase (if required) geotechnical, cultural and environmental considerations.

Potential Scopes of Service are outlined below.

4.3.1 Geotechnical

Under general direction and specification of the engineer (including definition of the following minimum requirements are likely to be necessary: inundation duration, flood levels, flood velocities, etc., for a range of flood events):

- inspect the sites
- provide advice on geotechnical investigation methods
- under take physical tests to
  - investigate levee loading on sub-strata
  - determine permeability of underlying material and potential mitigation measures, e.g. curtain cut off walls, curtain grouting, curtain bentonite, advise costs, impact, feasibility
- interpret data and report on
  - potential for sand boils behind levees
  - potential for erosion of base of levee and erosion of river bed
  - mitigation options if risks are high
  - liaise with a surveyor who will locate boreholes, test pits, points of interest, etc.
- undertake geotechnical interpretation; prepare report including costs of mitigation/remedial works, and/or potential options including relocation of levees.

The geotechnical consultant should also advise during the detailed design phase, review design drawings and confirm (in writing) that detailed design drawings adequately consider geotechnical limitations of the various sites.

4.3.2 Cultural Heritage

A Cultural Heritage Advisor should be engaged to identify sacred sites or scar trees that might be impacted by the construction of levees or access roads for their maintenance, to provide advice during the concept and detail design phases, and to act as cultural liaison officer with the local Aboriginal community prior to detailed design commencing, to assist with design review before design finalisation.

4.3.3 Survey

A survey will be need to identify land boundaries, features (fence types, services, trees, buildings, driveways, road alignments (kerb and guttering, edge of shoulder and pavement, signage, etc.), culverts, topographic features (river bank alignment, river bathymetry (perhaps), bank slopes etc. positioned to the correct map grid zone and levels to Australian Height datum.

Survey and locate points of interest as identified by the geotechnical engineer and aboriginal cultural advisor.

4.3.4 Floodplain stability

Most of the structural mitigation measures presented in this report are small when considering the size of the floodplain at each town, however levees in particular are designed to block and redirect flows. This can alter flow patterns and velocity in the channels and floodplain downstream which could result in erosion.

Guidance on fluvial geomorphology for levee management should be considered for any preferred levee options as building levees in one area has potential to adverse erosion issues in downstream locations.

4.4 REGIONAL MEASURES

4.4.1 Callide Valley

The Department of Energy and Water Supply (DEWS) is currently investigating a number of upstream Structural Mitigation measures that are directed to reducing flood risk in the overall Callide Valley. These include adjustments to the Callide Dam (physical and operational), and other dams south of Biloela. If these Structural Measures are put in place, there is potential to lower the flood risk at Biloela. Note that this is the focus of a separate study to BSC’s Floodplain Management Study and Plan and will be made available to the community by DEWS.

DEWS is assessing the value and expense separately to this Flood Management Plan and Study.

4.4.2 Nathan Dam

The proposed Nathan Dam is located on the Dawson River approximately 70 km downstream of Taroom and immediately upstream of Nathan Gorge. The dam’s aims are to provide long-term reliable water supplies to the Surat Coal basin and the Dawson-Callide sub-region of Central Queensland.

In the Nathan Dam EIS (Chapter 14), 1% AEP flood inflows are predicted to reduce from 4,030 m^3/s to 3,100 m^3/s. Corresponding flows for the 0.1% AEP event reduce from 5,940 m^3/s to 4,460 m^3/s respectively. This chapter of the EIS is available on the SunWater website:

> http://www.sunwater.com.au/__data/assets/pdf_file/0011/8759/Chapter-14-Surface-Water.pdf

The proposed dam location, flood inundation extents and major transport link from Taroom is shown below.

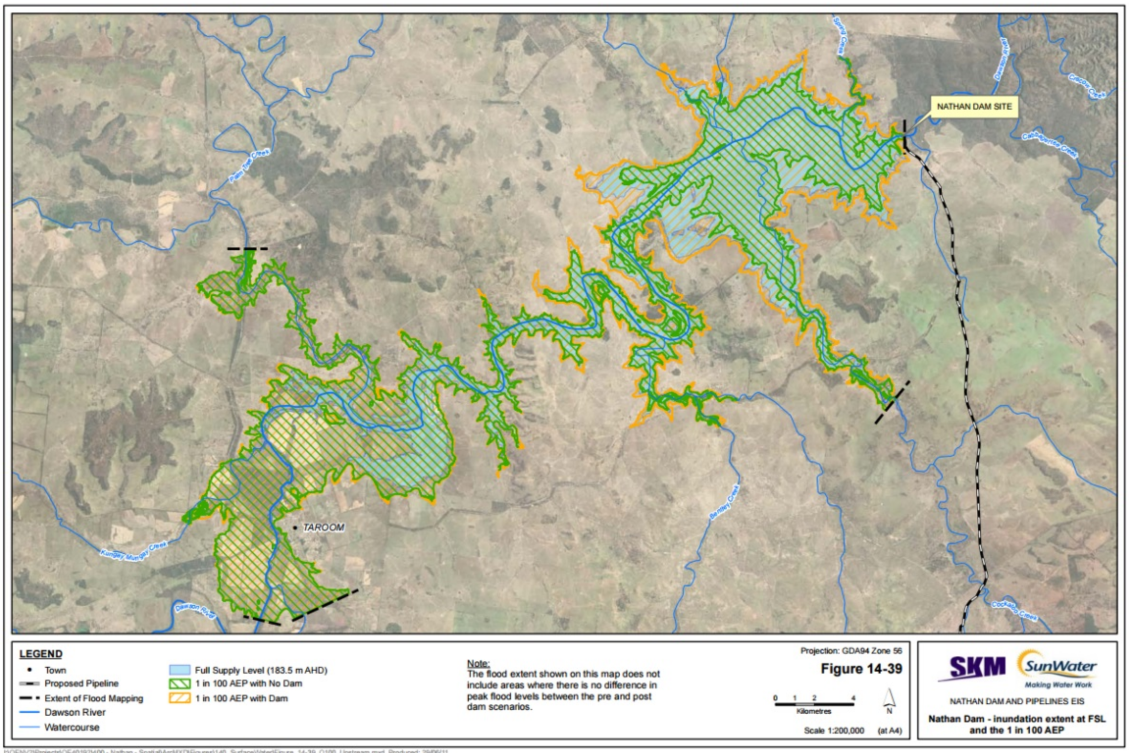

Figure 4.10
PROPOSED NATHAN DAM LOCATION AND INUNDATION EXTENTS

5 Scenario evaluation

The preceding section on structural mitigation summarises the flood mitigation options that have been tested by using the various hydraulic models developed as part of the project. A selection of local levees and house lifting for suitable properties has been assessed to provide some level of flood protection to flood affected properties for the towns of Biloela, Jambin, Thangool, Dululu, Moura, Taroom, Theodore and Wowan.

Many options described in the previous section have been combined together for scenario evaluation. This has been done because the options complement each other in providing a greater level of protection for each town. Some options have remained as standalone measures and have been noted as such.

All mitigation testing reported earlier had been undertaken using the 1% AEP plus climate change event and the worst historic flood for reference. However, when undertaking benefit cost analyses there is a need to test proposed mitigation options against a range of floods.

The main parameter that influences construction cost is the design event against which the option is tested. This section evaluates mitigation scenarios that are designed to resist the Design Flood Event (DFE). This flood is based on the 1% AEP flood plus an allowance for increased rainfall in the expectation of future climate change (as discussed in Section 2.1). This flood is larger than the largest historic flood in all towns, but less than the 0.2% AEP flood. Flood levees in the following discussion have been set to a level above the pre-mitigation DFE level, except for Theodore where levee have been set to a lower standard.

The purpose of a flood mitigation strategy is typically intended to reduce flooding in a subject area. The assessment will evaluate the benefits of the flood mitigation strategy, but adverse impacts may also be caused beyond the subject area. The impacts of the flood mitigation strategy typically affect:

- flooding of existing development and the associated cost of flood damages
- flooding of transport infrastructure and agriculture
- mobility during flooding
- risk to life
- emotional, social and psychological trauma of residents.

Table 5.1 identifies which options (combined or standalone) for each town are considered for further assessment. The mitigation scenarios need to be considered in combination with finished floor levels, over floor flooding and flood damage assessments. Preliminary cost estimates for the structural measures are also required.

The revised flood damage assessment and construction cost estimates will form the basis of a benefit cost assessment. The hydraulic investigations and cost benefit assessment will be considered and a preferred option can be recommended for each town.

Table 5.1 Options for further investigation

Option ID	Description	Comment	Further assessment
Thangool			
THA-01	Local levee to protect Thangool properties	There is space for this levee to be built; construction is feasible and impacts are minor.	THA-Combination 1
THA-02	Local levee to protect the Primary School	There is space for this levee to be built; construction is feasible and impacts are minor.	THA-Combination 1
THA-03	Raise flood affected homes	Likely to cost less than THA-01 and can be implemented in stages.	Standalone
THA-04	Relocate primary school	To be considered by the Department of Housing and Public Works	
Biloela			
BIL-01	Baileys Lane Levee	Benefits to residents behind the levee. Some large impacts to adjacent areas.	BIL-Combination 1
BIL-02a	Hills Ave levee	Benefits to residents behind the levee. Flood impacts are less than 300 mm.	BIL-Combination 1
BIL-02b	Joe Kooyman Drive Levee	Benefits to residents behind the levee. Constrained by Browns Gully.	BIL-Combination 1
BIL-03a	Tognolini Baldwin Road levee	Benefits to residents behind the levee. Flood impacts are 300-400 mm immediately upstream of the raised Dawson Highway.	BIL-Combination 1
BIL-03b	Alexandria Ave Levee	Benefits to residents behind the levee. Some sections of levee would be very high (5.0 m).	BIL-Combination 1
BIL-04	Raise Muirs Road	Provides additional evacuation time.	Standalone
BIL-05	Raise Valentine Plains Road	Deliver substantial benefits to residential areas. Major adverse flood impacts	No
BIL-06	Valentine Plains crossing of Brown's gully	Completed by Council in 2016.	No
BIL-07	Washpool Gully diversion into Callide Creek	Implementation would be problematic	No
BIL-08	Buyback and removal of most vulnerable homes on Muirs Rd	No other suitable alternatives.	Standalone
Jambin			
JAM-01	Jambin Hotel levee	There is space for this levee to be built; construction is feasible and impacts are minor.	JAM-Combination 1
JAM-02	Burnett Highway Bridge Extension	Insufficient benefits to Jambin	No
JAM-03	Burnett Highway Lowering	Insufficient benefits to Jambin, impacts evacuation capability.	No
JAM-04	Raise flood affected homes	Raised flood affected properties in combination with JAM-01.	JAM-Combination 1

Option ID	Description	Comment	Further assessment
Dululu			
DUL-01	Dululu Levee	Benefits to residents behind the levee. Consider extending to Dee Street. Flood impacts are moderate.	Standalone
DUL-02	Raise flood affected homes	Likely to cost less than DUL-01 and can be implemented in stages.	Standalone
Wowan			
WOW-01	School levee	There is space for this levee to be built; construction is feasible and impacts are minor.	WOW-Combination 1
WOW-02	Fuel station levee	Constrained space but construction feasible and impacts are minor.	WOW-Combination 1
WOW-03	Raise flood affected homes	Raise high set houses in combination with WOW-01 and WOW-02.	WOW-Combination 1
Taroom			
TAR-01	Lions Park Levee	Construction is feasible and impacts are minor. Impractical for access to the Taroom roadhouse.	Standalone
TAR-02	Raise flood affected homes and relocate roadhouse	Relocate Taroom Roadhouse to a flood free block and raise high set buildings.	Standalone
Theodore			
THE-01	Raise Gibbs Road & Levee	Benefits to residents behind the levee. Raising Gibbs Road has moderate impacts.	Standalone
THE-02	Castle Creek Levee	Levee built along old railway.	Standalone
THE-03	Town Levee	Town levee for protection up to 142 mAHD. Impacts in town of 150mm in the 2010 event.	THE-Combination 1
THE-04	Raise flood affected homes	In combination with levee option THE-03, raise stumped houses outside levee.	THE-Combination 1
THE-05	Raise flood affected homes	Raised stumped houses that are below 2%AEP	Standalone
THE-06	Migrate the town to Moura	Provided for discussion.	No
DAM-01	Nathan Dam	Regional mitigation presented for discussion	No
Moura			
MOU-01	River Road levee	Benefits to residents behind the levee. Flood impacts are minor.	Standalone
MOU-02	Raise flood affected homes	Likely to cost less than MOU-01 and can be implemented in stages.	Standalone
DAM-01	Nathan Dam	Regional mitigation presented for discussion	No

5.1 FLOOD DAMAGE CALCULATIONS

As part of the structural mitigation assessment, the flood damage estimates are re-calculated to evaluate their monetary effectiveness. The structural mitigation scenarios for selected towns were run for all of the design flood events in the hydraulic models to allow a full suite of damage values to be estimated. The flood damage methodology is outlined in Section 3 and also Appendix A. An understanding of the flood damage costs associated with the structural mitigation scenarios allows the economic benefit to be derived.

5.1.1 Thangool

Flood inundation in Thangool is primarily governed by breakout flows and backwater from Kariboe Creek. The structural measures identified that may reduce the flood risk within Thangool are provided in Table 5.2.

Options THA-01 and THA-02 were combined into THA-Combination 1. This includes a local levee to protect Thangool properties and the Primary School. The modelling and damage estimates are inclusive of all those options in the combination. THA-03 involves house raising for residential properties impacted by the DFE in Thangool.

Table 5.2 presents the existing flood damage in Thangool and the reduction in flooded residential and commercial buildings resulting from each mitigation option/combination. Results for the worst historical flood (2015) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

Properties in Thangool have been built on the edge of the floodplain and many are above the DFE level. Therefore the reduction in flooded buildings is not very significant for the mitigation options. There is a moderate reduction in AAD for the levee combination due to the number of residential properties saved.

Table 5.2 Thangool Flood Damage Costs

Flood Event	Measure	Thangool Existing	THA – Combination 1	THA – 03
Worst historic flood	Number of residential buildings	7	7	7
	Residential damages ($’000)	$520	$520	$520
	Number of commercial buildings	4	3	4
	Commercial damages ($’000)	$620	$160	$620
1% AEP + climate change	Number of Residential buildings	16	14	14
	Residential damages ($’000)	$1,030	$900	$900
	Number of commercial buildings	5	4	5
	Commercial damages ($’000)	$1,000	$340	$1,000
AAD	($)	$100,160	$70,629	$99,352

5.1.2 Biloela

Flood inundation in Biloela is governed by breakout flows from Washpool Gully and flood levels in Callide Creek. The structural measures identified that may reduce the flood risk within Biloela are provided in Table 5.3.

Mitigation options BIL-01, BIL-02a, BIL-02b, BIL-03a, and BIL-03b have been combined into BIL-Combination1. This includes multiple local levees at Baileys Lane, Hills Ave, Joe Kooyman Drive, Tognolini Baldwin Road and Alexandria Ave. The modelling and damage estimates are inclusive of all those options in the combination.

Mitigation option BIL - 08 involves voluntary house purchase and house raising for the most vulnerable homes on Muirs Road near Callide Creek.

Table 5.3 presents the existing flood damage in Biloela and the reduction in flooded residential and commercial buildings resulting from each mitigation option/combination. Results for the worst historical flood (2015) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

As expected, the levee combination makes a substantial difference to the total number of residential buildings flooded in Biloela and this is reflected in the revised AAD.

Table 5.3 Biloela Flood Damage Costs

Flood Event	Measure	Biloela Existing	BIL - Combination 1	BIL - 08
Worst historic flood	Number of residential buildings	147	79	144
	Residential damages ($'000)	$10,520	$5,070	$10,290
	Number of commercial buildings	11	10	11
	Commercial damages ($'000)	$1,300	$1,020	$1,300
1% AEP + climate change	Number of Residential buildings	219	108	214
	Residential damages ($'000)	$19,150	$8,980	$18,730
	Number of commercial buildings	16	16	16
	Commercial damages ($'000)	$3,340	$3,100	$3,340
AAD	($)	$792,063	$558,540	$784,357

5.1.3 Jambin

Flood inundation in Jambin is primarily governed by flows from Callide Creek and Kroombit Creek, and the town's position within the floodplain. The structural measures identified that may reduce the flood risk within Jambin are provided in Table 5.4.

Options JAM-01 and JAM-04 were combined into JAM-Combination 1. This includes a local levee to protect the Jambin Hotel and house raising for residential properties impacted by the DFE. The modelling and damage estimates are inclusive of all those options in the combination.

Table 5.4 presents the existing flood damage in Jambin and the reduction in flooded residential and commercial buildings resulting from the mitigation combination. Results for the worst historical flood (2015) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

The mitigation combination makes a substantial difference to the total number of residential buildings flooded in Jambin and this is reflected in the revised AAD.

Table 5.4 Jambin Flood Damage Costs

Flood Event	Measure	Jambin Existing	JAM - Combination 1
Worst historic flood	Number of residential buildings	12	5
	Residential damages ($'000)	$1,000	$440
	Number of commercial buildings	5	4
	Commercial damages ($'000)	$370	$230
1% AEP + climate change	Number of Residential buildings	18	7
	Residential damages ($'000)	$1,790	$690
	Number of commercial buildings	6	5
	Commercial damages ($'000)	$700	$470
AAD	($)	$174,654	$127,554

5.1.4 Dululu

Flood inundation in Dululu is primarily governed by breakout flows from the Dee River. The structural measures identified that may reduce the flood risk for flood events within Jambin are provided in Table 5.5.

Option DUL-01 includes a local levee to protect the residential properties at most risk. Option DUL-02 includes house raising for residential properties impacted by the DFE based on assumed floor levels.

Table 5.5 presents the existing flood damage in Dululu and the reduction in flooded residential and commercial buildings resulting from the mitigation options. Results for the worst historical flood (2015) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

Both option reduce the number of flooded residential buildings by a similar amount, however the levee option (DUL-01) also saves some commercial buildings and reduces residential property damage. Therefore the revised AAD for the levee option is considerably lower than the house lifting option (DUL-02). The cost of building a levee is much greater than house lifting and this is taken into consideration in the benefit cost analysis in Section 5.3.

Table 5.5 Dululu Flood Damage Costs

Flood Event	Measure	Dululu Existing	DUL - 01	DUL - 02
Worst historic flood	Number of residential buildings	8	3	2
	Residential damages ($'000)	$550	$230	$180
	Number of commercial buildings	3	1	3
	Commercial damages ($'000)	$280	$90	$280
1% AEP + climate change	Number of Residential buildings	12	3	2
	Residential damages ($'000)	$910	$300	$220
	Number of commercial buildings	6	4	6
	Commercial damages ($'000)	$450	$220	$450
AAD	($)	$63,061	$27,174	$49,696

5.1.5 Wowan

Flood inundation in Wowan is primarily governed by flows from Pocket Creek. The structural measures identified that may reduce the flood risk within Wowan are provided in Table 5.6.

Options WOW-01, WOW-02, and WOW-03 were combined into WOW-Combination 1. This includes local levees to protect the school and fuel station and house raising for residential properties impacted by the DFE. The modelling and damage estimates are inclusive of all those options in the combination.

Table 5.6 presents the existing flood damage in Wowan and the reduction in flooded residential and commercial buildings resulting from the mitigation combination. Results for the worst historical flood (2013) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

The results show that a small number of residential and commercial buildings are saved by the mitigation combination and for this reason the reduction in AAD is not very substantial.

Table 5.6 Wowan Flood Damage Costs

Flood Event	Measure	Wowan Existing	WOW - Combination 1
Worst historic flood	Number of residential buildings	1	0
	Residential damages ($'000)	$10	$0
	Number of commercial buildings	14	11
	Commercial damages ($'000)	$350	$230
1% AEP + climate change	Number of Residential buildings	2	1
	Residential damages ($'000)	$30	$20
	Number of commercial buildings	16	13
	Commercial damages ($'000)	$750	$670
AAD	($)	$41,928	$35,658

5.1.6 Taroom

Flood inundation in Taroom is governed by Dawson River flooding. The structural measures identified that may reduce the flood risk within Thangool are provided in Table 5.7.

Option TAR-01 includes a local levee to protect Taroom properties up to the DFE. Option TAR-02 involves house raising for residential properties impacted by the DFE and relocation of the roadhouse to a flood free location.

Table 5.7 presents the existing flood damage in Taroom and the reduction in flooded residential and commercial buildings resulting from each mitigation option/combination. Results for the worst historical flood (2010) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

Both option reduce the number of flooded residential buildings by the same amount, however the levee option (TAR-01) also saves some commercial buildings and reduces residential property damage. Therefore the revised AAD for the levee option is lower than the house lifting option (TAR-02). However, the cost of building a levee is much greater than house lifting and this is taken into consideration in the benefit cost analysis in Section 5.3.

Table 5.7 Taroom Flood Damage Costs

Flood Event	Measure	Taroom Existing	TAR - 01	TAR - 02
Worst historic flood	Number of residential buildings	10	0	0
	Residential damages ($'000)	$790	$0	$0
	Number of commercial buildings	12	5	12
	Commercial damages ($'000)	$1,400	$520	$1,400
1% AEP + climate change	Number of Residential buildings	12	0	0
	Residential damages ($'000)	$1,050	$0	$0
	Number of commercial buildings	13	8	13
	Commercial damages ($'000)	$1,980	$1,510	$1,980
AAD	($)	$233,714	$196,234	$224,337

5.1.7 Theodore

Flood inundation in Theodore is governed by flows from the Dawson River. In small flood events the town weir influences peak levels, but for major flood events a natural constriction in the terrain downstream of the town controls water peak level in the town. Flooding of the northern end of the town is also vulnerable to Castle Creek flows which have also been investigated as part of this study. A range of Structural Measures are provided in Table 5.8 that may reduce the flood risk to affected properties in Theodore.

Mitigation option THE-01 involves raising Gibbs Road to create a shorter evacuation route to the Theodore airstrip and a connecting levee to protect houses around the engineering works and timber mill up to the DFE. Option THE-02 is a local levee beside Castle Creek utilising the old railway alignment to a level of 142 mAHD.

Mitigation options THE-03 and THE-04 were combined into THE-Combination1. This includes a local levee to protect residents in town up to flood levels of 142 mAHD and house raising for residential properties outside the levee impacted by the 2% AEP flood. The modelling and damage estimates are inclusive of all options in the combination.

Mitigation option THE - 05 involves house raising for residential properties impacted by the 2% AEP flood.

Table 5.8 presents the existing Dawson River flood damage in Theodore and the reduction in flooded residential and commercial buildings resulting from each mitigation option/combination. Results for the worst historical flood (2010) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

Option THE-01 reduces the number of flooded residential and commercial buildings around the engineering works and timber mill. This results in a small reduction in AAD. There are some small impacts in town during the DFE from raising Gibbs Road.

Option THE-02 restricts the natural flow of water around the floodplain to the north-east of Theodore. In smaller events the levee protects Theodore from Castle Creek and Dawson River flooding and there is some benefit to the town. However water levels east of Castle Creek are increased in the larger Castle Creek and Dawson River flood events which adversely impact the town. There may be some scope to refine this option by extending the levee past Third Avenue, but currently it makes flooding in the town slightly worse.

Option THE-Combination 1 is effective at protecting the town from all Castle Creek flooding and the smaller Dawson River floods. For the 1% AEP Dawson River flood the downstream section of the levee slightly increases water levels in town. There may be some scope to refine this option by extending the levee past Third Avenue on the upstream side and optimising the downstream levee heights to reduce impacts in town.

Option THE-05 includes raising 71 properties assumed to be flood affected by the 2% AEP event. This option doesn't show any improvement for flood events larger than 2% AEP but provides more resilience to the town.

Table 5.8 Theodore Flood Damage Costs (Dawson River)

Flood Event	Measure	Theodore Existing	THE - 01	THE - 02	THE-Combination 1	THE - 05
Worst historic flood	Number of residential buildings	172	164	179	172	172
	Residential damages ($'000)	$14,290	$13,350	$14,670	$13,820	$13,220
	Number of commercial buildings	100	87	101	100	100
	Commercial damages ($'000)	$7,720	$5,990	$8,390	$8,510	$7,720
1% AEP + climate change	Number of Residential buildings	245	237	245	245	245
	Residential damages ($'000)	$26,720	$25,590	$26,740	$26,720	$25,830
	Number of commercial buildings	109	97	109	109	109
	Commercial damages ($'000)	$17,560	$14,970	$17,620	$17,660	$17,560
AAD	($)	$1,381,000	$1,193,851	$1,407,581	$1,495,946	$1,255,220

5.1.8 Moura

Flood inundation in Moura is limited to the rural residential properties at risk within the expansive Dawson River floodplain. The structural measures identified that may reduce the flood risk within Moura are provided in Table 5.9.

Option MOU-01 includes a local levee to protect the rural residential at risk from the Dawson River DFE. MOU-02 involves house raising for residential properties impacted by the DFE instead of a levee.

Table 5.9 presents the existing flood damage in Thangool and the reduction in flooded residential and commercial buildings resulting from each mitigation option/ combination. Results for the worst historical flood (2010) and DFE (1% AEP climate change) are shown but the AAD assessment includes all modelled design flood events.

It is currently assumed that the rural residential properties along Saleyards Road and River Road are high set approximately 0.6m above the ground. Therefore the flood impacts are not significantly improved by the levee option or house raising.

Table 5.9 Moura Flood Damage Costs

Flood Event	Measure	Moura Existing	MOU - 01	MOU - 02
Worst historic flood	Number of residential buildings	1	1	0
	Residential damages ($'000)	$70	$60	$0
	Number of commercial buildings	6	5	6
	Commercial damages ($'000)	$300	$290	$300
1% AEP + climate change	Number of Residential buildings	3	1	0
	Residential damages ($'000)	$130	$80	$0
	Number of commercial buildings	17	11	17
	Commercial damages ($'000)	$960	$120	$960
AAD	($)	$100,403	$96,916	$89,970

5.2 COST ESTIMATES

This desktop study has reviewed the cost components (i.e. capital and operational costs) of the proposed structural flood risk mitigation scenarios. The capital works proposed largely consist of flood levee construction, either as earthen bunds or vertical concrete walls. Some options also consider lifting high set timber houses and voluntary house purchasing.

The cost estimates completed look at various mitigation options for eight towns – Thangool, Biloela, Jambin, Dululu, Wowan, Taroom, Theodore, and Moura. Each of the options were priced for the purpose of the benefit-cost analysis and comparison with other alternative scenarios where applicable and should be considered with reference to the commentary in this report.

The cost estimates generated for this study are Class 4 (Concept Study, Pre-Feasibility, Selection and or Pre-Funding Stage) Capex estimate. Adequate historical rates and project norms have been used to provide an accuracy of +/- 40%.

It is noted that investigation of mitigation options is at a preliminary stage, and it is expected that more detailed investigations will be undertaken by BSC, including geotechnical assessments, preliminary design and more detailed capital cost estimates if the benefit-cost analysis has a positive outcome.

It is advised that allocation of project budgets or implementation of proposed schemes should not be considered until feasibility level design is completed, following which cost estimates could be refined to a more accurate level.

The mitigation options and scenarios from Table 5.1 are listed in Table 5.2 with estimated construction costs. More detailed information on the calculation of cost estimates for the structural mitigation options is provided in Appendix B.

Table 5.10 Summary of estimated mitigation capital costs

Option ID	Description	Total Option Cost ($'000)	Total Scenario Cost ($'000)
Thangool			
THA-01	Local levee to protect Thangool properties	$4,850	THA-Combination 1 $6,849
THA-02	Local levee to protect the Primary School	$1,999	
THA-03	Raise flood affected homes	$160	$160
THA-04	Relocate primary school	KBR is unable to estimate this cost	
Biloela			
BIL-01	Baileys Lane Levee	$11,235	BIL-Combination 1 $39,516
BIL-02a	Hills Ave levee	$9,725	
BIL-02b	Joe Kooyman Drive Levee	$3,694	
BIL-03a	Tognolini Baldwin Road levee	$13,116	
BIL-03b	Alexandria Ave Levee	$1,746	
BIL-04	Raise Muirs Road (additional evacuation time)	$2,567	$2,567
BIL-05	Raise Valentine Plains Road	Not recommended	
BIL-06	Valentine Plains crossing of Brown's gully	Completed	
BIL-07	Washpool Gully diversion into Callide Creek	Not recommended	
BIL-08	Voluntary buyback and removal of homes on Muirs Road with extreme flood risk	$1,190	$1,190
Jambin			
JAM-01	Jambin Hotel levee	$2,346	JAM-Combination 1 $3,066
JAM-04	Raise flood affected homes	$720	
JAM-02	Burnett Highway Bridge Extension	Not recommended	
JAM-03	Burnett Highway Lowering	Not recommended	
Dululu			
DUL-01	Dululu Levee	$4,846	$4,846
DUL-02	Raise flood affected homes	$800	$800
Wowan			
WOW-01	School levee	$286	WOW-Combination 1 $736
WOW-02	Fuel station levee	$370	
WOW-03	Raise flood affected homes	$80	
Taroom			
TAR-01	Lions Park Levee	$9,136	$9,136
TAR-02	Raise flood affected homes and relocate roadhouse (estimate excludes the cost for relocating the roadhouse)	$960	$960

Option ID	Description	Total Option Cost ($'000)	Total Scenario Cost ($'000)
Theodore			
THE-01	Raise Gibbs Road & Levee	$25,254	$25,254
THE-02	Castle Creek Levee at 142 mAHD	$7,865	$7,865
THE-03	Town Levee up to 142 mAHD	$8,529	THE-Combination 1 $9,729
THE-04	Raise flood affected homes that are below 2% AEP and outside THE-03 levee	$1,200	
THE-05	Raise flood affected homes that are below 2% AEP	$5,680	$5,680
THE-06	Migrate the town to Moura	Not recommended	
DAM-01	Nathan Dam	KBR is unable to estimate this cost	
Moura			
MOU-01	River Road levee	$8,123	$8,123
MOU-02	Raise flood affected homes	$240	$240
DAM-01	Nathan Dam	KBR is unable to estimate this cost	

5.3 ANALYSIS

As part of the benefit-cost analysis the impact of the proposed flood mitigation scenarios have explicitly considered the monetary impact upon flood damage costs associated with existing development.

The economic justification of each flood mitigation scenario has been assessed through the calculation of a benefit-cost ratio (BCR).

The (economic) benefit of the flood mitigation scenario is calculated through the analysis of changes to costs associated with flood damage. The flood damage analysis was undertaken for the existing conditions and the associated Average Annual Damages (AAD) were calculated (refer to Section 3). This was also undertaken for the mitigation scenarios (refer Section 5.1).

The costs (i.e. capital and operational costs) of the flood mitigation scenarios have been estimated. The costs are preliminary and are subject to more detailed investigation. Further details can be found in Section 5.2 and Appendix B.

Prior to the calculation of the BCR, the benefit and cost of the flood mitigation scenario must be calculated through a Net Present Value (NPV) analysis. The NPV analysis compares two cases:

- Existing conditions: The 'do nothing' case, where the NPV of the currently estimated Average Annual Damage (AAD) is determined.
- Mitigation scenario: This case considers the capital and operational costs of structural mitigation schemes in combination with the estimated AAD that is lowered (saved) as a consequence of the mitigation measures.

The options that provide the greatest hydraulic benefit will protect the greatest number of buildings and properties, and the level of protection afforded to evacuation routes. A number of rural properties may experience adverse impacts associated with the options.

It should be remembered that the construction costs are calculated on a levee height based on flood levels produced by the DFE under the existing situation with an addition of a 0.3 m freeboard. Levees constructed at higher or lower levels will result in different construction costs, which would in turn influence the calculated benefit-cost ratios.

The benefit-cost ratio can be determined for each of the structural mitigation options (combination or standalone) using the existing damage estimates and construction cost estimates. The following assumptions have been made in assessing the benefit-cost ratios:

- all construction is undertaken in year 2016/2017
- the NPV analysis extends only for 25 years from construction to 2041/2042
- annual costs are inflated by 2.5% per annum
- annual maintenance costs are assumed as a percentage of capital costs per annum and are different for each mitigation scenario
- ongoing costs are depreciated at 5% per annum.

5.3.1 Conservative approach

In the following NPV calculations we have deliberately adopted a conservative approach in our calculations:

- excluded reductions in insurance premiums as a benefit
- taken present values of building from property sales information rather than actual replacement/new building costs
- excluded intangible costs such as those outlined in DNRM (2002) and the delays to resumption of productive activities.

The impact of adoption of conservative building damage costs could mean an understatement of damage by 30% or more.

The intangible costs of flood damage are often taken as 50% to 100% of the tangible costs. If we assume rural residents are probably more resilient than their urban counterparts then intangible costs could be taken as 50% of the tangible costs. However consideration has also to be given to the ability of rural residents to access financial and other support following a flood event which could increase the say 50% to a higher number.

Accordingly, it would not be unreasonable to double the BCR derived below for internal justification processes and a BCR of 0.5 might seem an appropriate benchmark for approval.

5.3.2 Results

Table 5.11 presents the results of the benefit-cost analysis for all towns with structural flood mitigation options/combinations. The BCR for all structural mitigation options is less than 1.0 and therefore cannot be justified on economic grounds alone. It should be noted that structural flood mitigation options rarely have a positive BCR

The highest BCR is 0.8 for MOU-02 and there are a few options with a BCR of between 0.3-0.4. The remaining options have a BCR less than or equal to 0.2 due to a high construction cost estimate or less flood benefits than envisaged.

However, if the intangible benefits are considered some options may be considered viable. Also, some options were such not expected to be justified on economic grounds alone. For example, THE-01 includes a greater level of protection afforded to the evacuation route out of town and BIL-08 includes voluntary buyback of properties with very high flood risk.

Some options like THE-02 and THE-Combination1 have unexpected impacts in Theodore which actually worsen the revised flood damages. Further investigation is required to refine these levees and it is expected the BCR will improve.

It should be noted that the more extreme events included in the AAD calculation can skew the benefits and is perhaps not a fair reflection of the protection achieved by many of the options in the lower order events.

Table 5.11 Summary of benefit-cost analysis for all structural mitigation options

Estimate ($'000)	BIL - Comb #	BIL - 08	THE - 01	THE - 02	THE - Comb	THE - 05	THA - Comb	THA - 03	JAM - Comb	DUL - 01	DUL - 02	WOW - Comb	TAR - 01	TAR - 02	MOU - 01	MOU - 02
Existing AAD (do nothing)	$790	$790	$1,380	$1,380	$1,380	$1,380	$100	$100	$170	$60	$60	$40	$230	$230	$100	$100
Existing AAD (do nothing) NPV	$15,050	$15,050	$26,240	$26,240	$26,240	$26,240	$1,900	$1,900	$3,320	$1,200	$1,200	$800	$4,440	$4,440	$1,910	$1,910
Capital cost	$39,520	$1,190	$25,250	$7,870	$8,530	$5,680	$6,850	$160	$2,350	$4,850	$800	$660	$9,140	$960	$8,120	$240
Capital cost NPV	$39,520	$1,190	$25,250	$7,870	$9,730	$5,680	$6,850	$160	$3,070	$4,850	$800	$740	$9,140	$960	$8,120	$240
Operational cost NPV	$3,560	$-	$2,270	$710	$770	$-	$620	$-	$210	$440	$-	$60	$820	$-	$730	$-
Total cost NPV	$43,070	$1,190	$27,530	$8,570	$10,500	$5,680	$7,470	$160	$3,280	$5,280	$800	$800	$9,960	$960	$8,850	$240
Option AAD	$560	$780	$1,190	$1,410	$1,500	$1,260	$70	$100	$130	$30	$50	$40	$200	$220	$100	$90
Option NPV	$10,620	$14,910	$22,690	$26,750	$28,430	$23,860	$1,340	$1,890	$2,420	$520	$940	$680	$3,730	$4,260	$1,840	$1,710
Total benefit	$4,440	$150	$3,550	-$510	-$2,190	$2,380	$560	$20	$900	$680	$250	$120	$710	$180	$70	$200
BCR	0.1	0.1	0.1	-0.1	-0.2	0.4	0.1	0.1	0.3	0.1	0.3	0.1	0.1	0.2	0.0	0.8

 # Short for 'Combination'

6 Community

Flood mitigation projects need to be assessed and justified to the affected communities and when seeking funding from external sources. Justification can be based by answering three questions.

- Is community disruption and damage too great?
  - damage cost calculations
  - social and financial imperatives
  - community confidence.
- What can be constructed?
  - affordable
  - satisfies community concerns
  - will help the community to develop
  - adaptable to future change
  - statutory approvals.
- How can we analyse?
  - quantifiable indicators
  - subjective assessments.

The following information seeks to respond to these questions.

6.1 SOCIAL CONSIDERATIONS

Major social disruption occurred following the recent flood events across the BSC area through flooding of homes and businesses. Without mitigation similar implications are likely following the next major flood event.

The construction of flood mitigation schemes are likely to introduce social disruption of their own, through the loss of amenity space, impacts on visual appearance, acquisition of land and social disconnection of local communities from the river and floodplain.

Some property owners may feel that living next to a levee is intolerable and feel forced to relocate. On doing so they would lose their immediate community and local support, feel isolated and may require some time before they felt ‘at home’ in new surroundings. There have been reports elsewhere where remaining elderly people who would have relied on those who have left, have felt isolated and insecure and have doubts about their own future.

Some residents living next to rivers do so for lifestyle reasons and to be close to nature. Removal of aquatic and arboreal habitat could be seen as a major loss to local amenity.

Community engagement is required to gain a better understanding of the preferences held by the local people. This will help to inform the development of a suitable scheme.

6.2 COMMUNITY INVOLVEMENT

A number of common concerns that communities often wish to have addressed as part of ongoing flood mitigation investigations are considered as follows:

How are land purchases, acquisitions or resumptions addressed in the costing exercise?

Land purchases, acquisitions or resumptions were not considered in the costings estimation. KBR is an engineering firm and is unable to comment on or assess land values. The area of land that is needed for flood mitigation works will depend on the nature of the project, element footprint and access requirements needed for construction and maintenance. This would need to be addressed by BSC.

How are impacts on stormwater drainage addressed in the costing exercise?

Stormwater drainage items were costed depending on the requirements of each specific component. For instance, for culvert upgrades, replacement culverts were sized and the quantity determined, along with individual requirements such as stripping of topsoil, excavation, replacement/insertion of culverts, backfilling, grassing and erosion protection.

How are the costs with road and rail crossings addressed?

At this stage there is no allowance for co-ordination costs to allow for down time of transport infrastructure.

How is the cost of maintenance addressed?

Where applicable ongoing operation and maintenance costs over the life of the item are included in the Net Present Value (NPV) assessments.

Is the impact on Council and state-owned infrastructure by the increased depth and velocity of water considered?

The costs on existing infrastructure that result from impacts due to changing flow conditions after undertaking a proposed mitigation option were not considered in this analysis. We consider this has to occur in a later design optimisation phase.

How are the costs of compensation for impacts on privately owned land addressed?

Compensation for impacts on privately owned land due to changes in the flow conditions after performing a mitigation option were not considered in this analysis.

As part of the assessment of levee performance how have the number of properties protected been identified?

The number of properties and buildings protected has been identified for the all of the mitigation scenarios presented within this report.

As part of the assessment of levee performance how have the number of properties adversely affected been identified?

The number of properties (residential and commercial) that are adversely affected by floodwater have been considered in the updated flood damage assessment for each mitigation option.

As part of the assessment of levee performance the full cost per property protected must be identified

The cost of the mitigation scenarios has been identified per property, which is based upon our estimated costs, which are at a stated accuracy of ±40%.

As part of the assessment of levee performance risk to lives during events must be identified

Flood maps have been prepared for the mitigation scenarios, which are included in the second volume of this report.

The timeframe required to complete levee construction should be identified

The timeframe to complete the works will depend on a number of factors including the complexity and scope of the planned works, the duration of the community engagement and consultation process, the duration of geotechnical and other investigations, detailed design and documentation, funding and the construction duration itself and whether there will be a need for staged construction.

How to satisfy the town and insurance companies that steps are being taken

This is a matter for BSC to progress.

Can the option be expanded on without becoming redundant?

This will depend on the option and the likely changes in hydrologic and hydraulic response over time. We envisage the flood conditions will worsen to the end of the century and have recommended that any flood mitigation works constructed in the near future can be adapted and/or augmented so as to be able to cope with changed circumstances.

7 Discussion

Structural mitigation measures designed to reduce the impact of flooding usually do so by holding back floodwaters upstream, improving conveyance downstream, modifying the flow of water through the area that is the target of structural measures or improving flood resilience for assets and facilities that cannot be protected.

There are some towns within the BSC LGA area that is at severe risk of flooding particularly at Jambin and Theodore, but other towns at risk for which structural measures are desirable include Biloela, Thangool, Dululu, Moura, Taroom and Wowan.

In this report KBR has presented a range of flood mitigation structural measures for the flood affected towns which include levees, improved evacuation routes and house lifting. Where no alternatives are suitable for a property and the residual flood risk is too high, voluntary building buyback and removal are recommended.

The mitigation investigations assessed in this report include hydraulic impacts for each option. The flood impact mapping helps identify options that have minimal adverse impact on adjacent areas. Each mitigation measure has been investigated using the largest historic flood and all design flood events. Changes in maximum flood level (afflux) and velocity maps for each option are presented in Volume 2 of this report.

The cost components (i.e. capital and operational costs) of the proposed structural flood risk mitigation options have been estimated. The capital works proposed largely consist of flood levee construction, either as earthen bunds or vertical concrete walls. Some options also consider lifting high set timber houses and voluntary house purchasing.

Flood damage calculations have been made to assess the benefit cost assessment for each structural mitigation option or combination. This represents the level of investment that could be provided for flood mitigation each year. Property damages are based on single average values for all townships. We have made no allowances for value differences between townships. Floor level data surveyed by Council was available for some properties in the Callide Valley but the remainder were estimated by KBR. If Council favours a particular option the estimated flood levels should be reviewed as this could affect the construction cost estimate and damages which may alter the BCR for that option.

Flood damage can vary significantly from one place to another and within different parts of a city/town depending on factors such as age of buildings, socio-economic backgrounds, etc. The flood damage curves used within this study were not derived from local data in the BSC region. Therefore, this could lead to an inaccurate estimate of flood damage. However, steps have been undertaken in an attempt to reduce uncertainty.

Table 7.1 presents a high level summary of the benefit-cost analysis for all towns with structural flood mitigation options/combinations. The benefit-cost ratio (BCR) for all structural mitigation options is less than 1.0 and therefore cannot be justified on economic grounds alone. It should be noted that structural flood mitigation options rarely have a positive BCR.

The highest BCR is 0.8 for Moura (MOU-02) and there are a few options with a BCR of between 0.3–0.4. The remaining options have a BCR less than or equal to 0.2 due to a high construction cost estimate or less flood benefits than envisaged. However, if the intangible benefits are considered some options may be considered viable.

Also, some options are not expected to be justified on economic grounds alone. For example, Theodore option THE-01 includes a greater level of protection afforded to the evacuation route out of town and Biloela option BIL-08 includes voluntary buyback of properties with very high flood risk.

Some options like Theodore THE-02 and Theodore Combination1 have unexpected impacts in town which actually worsen the revised flood damages. Further investigation is required to refine these levees and it is expected the BCR will improve.

It should be noted that the more extreme events included in the AAD calculation can skew the benefits and is perhaps not a fair reflection of the protection achieved by many of the options in the lower order events.

The towns of Goovigen and Baralaba have minimal flood risk and no structural measures are currently proposed.

Flooding in Wowan from Pocket Creek was not the focus of modelling in this study. However this may be more critical to the town of Wowan than Dee River flooding. It is recommended flooding from Pocket Creek is investigated in more detail.

Much of the transport system through the region is also subject to flood damage and roads are generally reinstated so as to be less susceptible to flooding. However transport links that are flooded often see a drop in their residual life and their earlier reconstruction should be included in long term capital budget programs.

Table 7.1 Summary of benefit-cost analysis for all structural mitigation options

Mitigation Option	Description	Mitigated Flood Event	Number of buildings saved in the DFE		AAD savings	Cost Estimate (+/-40%)	Benefit Cost Analysis	Comments
			Residential	Commercial	($'000)	($'000)		
BIL-Combination1	Local levees around Biloela to protect residential buildings	DFE (1% AEP climate change)	111	0	233.5	39,516	0.1	The levees protect a large number of buildings, however the estimated cost is high.
BIL-08	Voluntary House Purchase and House Raising for vulnerable homes on Muirs Rd	DFE (1% AEP climate change)	5	0	7.7	1,190	0.1	There are some properties at the end of Muirs Road that are in a very high risk zone. The benefic cost analysis is very low but it is recommended this option is further investigated.
THA-Combination1	Local levees to protect Thangool residential properties and the Primary School	DFE (1% AEP climate change)	2	1	29.5	6,849	0.1	Whilst there are some protected buildings and properties, the benefits are insufficient for the cost.
THA-03	Raise flood affected homes	DFE (1% AEP climate change)	2	0	0.8	160	0.1	Based on the available information there are only 2 properties below the DFE in Thangool. While the benefit cost analysis is similar to THA-Combination1, this option could still be implemented in stages.
JAM-Combination1	Jambin Hotel levee and lifting flood affected homes	DFE (1% AEP climate change)	11	1	47.1	3,066	0.3	This options protects a number of properties. The benefic cost analysis is higher than most other options.
THE-01	Evacuation along Gibbs Road with local levee to protect residential and commercial buildings around the engineering works and timber mill	DFE (1% AEP climate change)	8	12	187.1	25,254	0.1	This option protects a number of buildings. The estimated cost is very high because it includes upgrading Gibbs Road to become the evacuation route for Theodore. Also the levee around the engineering works and timber mill makes allowance for intermittent traffic. Further refinement is recommended to reduce the construction cost.

Mitigation Option	Description	Mitigated Flood Event	Number of buildings saved in the DFE		AAD savings	Cost Estimate (+/-40%)	Benefit Cost Analysis	Comments
THE-02	Castle Creek Levee at 142 mAHD	2% AEP Dawson River Flood	0	0	-26.6	7,865	-	This option attempts to restrict flow from Castle Creek entering town. However in the 1% AEP event it raises water levels near the engineering works and timber mill and also in town. The AAD savings are negative meaning flood impacts from this option are worse than the existing case. Further investigation is required to refine the levee and potentially recalculating AADs without the extreme flood events.
THE-Combination1	Town Levee and lifting flood affected homes	2% AEP Dawson River Flood	0	0	-114.9	9,729	-	Similar to the Castle Creek levee, the town levee increases water levels in the town during the 1% AEP event. This results in greater damages compared to the existing case. Further investigation is required to refine the levee and potentially recalculating AADs without the extreme flood events.
THE-05	Raise flood affected homes	2% AEP Dawson River Flood	0	0	125.8	5,680	0.4	This option involves raising homes assumed to be lower than the 2% AEP flood (71 in total). The benefit cost is better than most other options and house lifting can be implemented in stages.
DUL-01	Local levee to protect residential buildings	DFE (1% AEP climate change)	9	2	35.9	4,846	0.1	This levee needs to be up to 2.0m high so the cost estimate is high compared to the number of buildings saved.
DUL-02	Raise flood affected homes	DFE (1% AEP climate change)	10	0	13.4	800	0.3	Based on the available information a number of buildings in Dululu are below the DFE and could be lifted. This option could still be implemented in stages.
WOW-Combination1	Local levees around the school and fuel station plus lifting flood affected homes	DFE (1% AEP climate change)	1	3	6.3	736	0.1	Building small levees for the school and fuel station is not cost effective. Based on the available information there are limited residential buildings at risk from the Dee River DFE. It is recommended that flooding from Pocket Creek is investigated as this may cause greater impacts.

Mitigation Option	Description	Mitigated Flood Event	Number of buildings saved in the DFE		AAD savings	Cost Estimate (+/-40%)	Benefit Cost Analysis	Comments
TAR-01	Local levee to protect residential buildings	DFE (1% AEP climate change)	12	5	37.5	9,136	0.1	This levee needs to be very high (up to 4.5m) and would be impractical for access to the roadhouse.
TAR-02	Raise flood affected homes and relocate roadhouse	DFE (1% AEP climate change)	12	0	9.4	960	0.2	Based on available information a number of properties below the DFE in Taroom could be raised. The benefit cost analysis is slightly better than TAR-01 and this option could still be implemented in stages.
MOU-01	Local levee to protect residential buildings	DFE (1% AEP climate change)	2	6	3.5	8,123	0.0	This levee is not very high (up to 1.0 m) but is very long to protect the rural residential properties along River Road and Salesyard Road. The benefit cost analysis of this option will improve as more properties are at risk that has been assumed.
MOU-02	Raise flood affected homes	DFE (1% AEP climate change)	3	0	10.4	240	0.8	This option has the highest benefit cost analysis.

8 Recommendations

The following mitigation measures are recommended for further investigation and optimisation based on the flood benefits, evacuation improvements and flood risk reduction they provide:

- BIL-Combination1: Local levees around Biloela to protect residential buildings
- BIL-08: Voluntary House Purchase and House Raising for homes on Muirs Road (Biloela) with very high flood risk
- THA-03: Raise flood affected homes in Thangool
- JAM-Combination1: Jambin Hotel levee and lifting flood affected homes
- THE-01: Evacuation along Gibbs Road in Theodore with local levee to protect residential and commercial buildings around the engineering works and timber mill
- THE-Combination1: Theodore town levee and lifting flood affected homes outside the levee that are below the 2% AEP level
- THE-05: Raise flood affected homes in Theodore with more accurate information on property types, floor levels and house lifting costs
- DUL-02: Raise flood affected homes in Dululu
- TAR-02: Raise flood affected homes and relocate roadhouse in Taroom
- MOU-01: Local levee to protect residential buildings with consideration of raising River Road as a dual levee and evacuation route upgrade
- MOU-02: Raise flood affected homes with more accurate information on property types, floor levels and house lifting costs.

A preferred measure, or combination of measures, can be selected for each town. Council can then adopt a strategy for further site investigations. Site investigations should include geotechnical investigations, determination of other site constraints utilising the services of a surveyor and cultural heritage advisor. Once these investigations are complete a revised cost estimate can be produced and funding arrangements identified.

The following recommendations arise from this report:

- BSC adopts as its Designated/Defined Flood Event the flood that is derived from a 1% AEP flood where the design rainfall has been increased by 20% to account for climate change.

- It is recommended hydrologic modelling of design flood events in Pocket Creek is investigated in more detail as this may be more critical to the town of Wowan than Dee River flooding.
- The flood damage estimates have been undertaken using the best information available, but should be regarded as illustrative. There are numerous opportunities to improve the accuracy of the estimates, such as collecting additional floor level data

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Appendix A

FLOOD DAMAGE ASSESSMENT

1 Introduction

1.1 PURPOSE

The purpose of the 'Banana Shire Council Floodplain Management Study and Plan – Flood Damage Assessment' is to provide Banana Shire Council (BSC) with a range of potential flood damage estimate, which can ultimately be used for benchmarking and assessment of mitigation measures. Fundamental to the delivery of these estimates is the application of the results from the township hydraulic models, which allow flood level data to be derived.

1.2 BACKGROUND

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by BSC to provide a Floodplain Management Study and Plan for 10 towns located within the Dawson River Catchment. The project has built a set of flood modelling tools that will provide a detailed understanding of flooding in the area, assess a range of structural and non-structural measures to manage flooding, and develop a plan to reduce the impact of flooding on BSC residents.

During the conduct of the study a number of documents will be provided to BSC. This report documents how flood damages were estimated and makes up an appendix of the Structural Mitigation Report (BEW455-TD-WE-REP-0002).

Banana Shire is located in Central Queensland within the Dawson River Catchment, situated east of Central Highlands Regional Council, west of Gladstone Regional Council, and south of Rockhampton Regional Council. The Dawson River catchment is part of the Fitzroy basin and constitutes approximately a third of its total catchment area. The Dawson River's confluence with Mackenzie River marks the start of the Fitzroy River and the northern boundary of the BSC LGA. There are a number of communities within BSC including; Biloela, Theodore, Jambin, Goovigen, Dululu, Wowan, Taroom, Moura, and Baralaba.

The town of Theodore is located at the confluence of Castle Creek and Dawson River. The town is subject to flooding from both catchment systems and as a consequence flood damages were assessed from both sources of flooding.

The administrative area of BSC, the Dawson Catchment, and settlements area presented in Figure A1.

Figure A1
ADMINISTRATIVE AREA OF CHRC

1.3 FLOOD DAMAGE ESTIMATION PROCESS

Flood damages to residential and commercial/industrial land parcels are assessed by taking into account property information (property area, type, size and use of building), floor level data (actual survey, or estimated by other means), flood level data for a range of flood events and various stage-damage curves (often depending on building type, use and area).

Property information, floor and flood level are compared using GIS techniques with stage-damage relationships applied to each property and building. The sum of the individual property damages are then aggregated to give the total damage.

A detailed discussion of the methodology is outlined in Section 3.

1.4 REPORT OUTLINE

The sections of this report are briefly summarised below:

- Chapter 2: Describes the data available for this study and how it was applied.
- Chapter 3: The methodology is summarised within this section.
- Chapter 4: Presents the results of the damage analysis.
- Chapter 5: Describes a brief discussion on some of the key limitations and areas of uncertainty.
- Chapter 6: Summarises the conclusions of the study and recommendations to improve the quality of flood damage estimation.

2 Flood damage classification

Queensland's guidance on damage assessment (DNRM, 2002) divides flood damage into two basic divisions: tangible costs (being direct and indirect) and intangible costs which are outlined in Figure A2. Tangible costs are those that can be measured directly in monetary terms with the direct cost component being those costs that occur immediately and as a direct exposure to floodwater. Indirect costs are consequential. Intangible costs cannot be measured in monetary terms.

Figure A2
OUTLINE OF DISASTER COST FRAMEWORK (BASED ON BTE, 2001)

2.1 TANGIBLE COSTS

Tangible damages are financial in nature and are assessed by determining the damage or loss caused by floodwater. They are subdivided into direct and indirect damages as set out in Figure A2:

(i) direct damages are caused by the wetting of items and assessed as either equal to the cost of repairs and loss of value, or the replacement cost of the item

(ii) indirect damages are the additional financial losses caused by a flood, such as the extra cost of food and accommodation, loss of wages, loss of production and opportunity cost to the public caused by the closure or limited operation of public facilities.

Practitioners often refer to the following sources to which when calculating potential flood damage in Australia.

(i) ANUFLOOD is a program originally developed by Smith and Greenway (1992) and contains stage-damage relationships for residential and commercial property. Blong (1999) developed ANUFLOOD to a further level of sophistication for application in NSW.

(ii) Flood damage calculation methodologies were reviewed by Read Sturgess (2000) for the Victorian Government who developed the Rapid Appraisal Method (RAM) for floodplain management. Read Sturgess updated ANUFLOOD curves and incorporated those into the RAM.

(iii) This was followed by the Queensland Government publishing guidelines to assess tangible flood damage (DNRM, 2002) for residential and commercial buildings that had experienced over-floor flooding. Its information was based on the earlier ANUFLOOD data, actual damage reports and other information gathered to classify damage by value class and building area.

(iv) The NSW Department of Environment, Climate Change and Water provides a Residential Flood Damage and supporting calculation spreadsheet on its website www.environment.nsw.gov.au/floodplains/StandardFloodplainRiskManagement.htm which is used by local authorities to justify expenditures for flood mitigation projects.

(v) The computer program WaterRIDE originally developed by Patterson Britton & Partners (PBP, 2004) contains a module for determining residential property, building and contents damage and damage to industrial and commercial premises.

(vi) Residential contents flood damage was based on an insurance loss assessor's estimate of replacement cost based on the location and elevation of items within a home which we understand was first done after the Nyngan, NSW floods (Water Studies, 1990). Gold Coast City Council's flood damage system took this approach (pers. comm. D. Wheelan[1], Betts & Carroll 2001, WRM 2006).

As far as we are aware there is no one single damage calculation system that encapsulates most of the significant items in one package.

[1] D. Wheelan is an insurance loss assessor who developed the dwelling contents stage-damage curves for Gold Coast City Council, 2000.

2.2 TYPICAL EXCLUSIONS

With the exception of linear infrastructure (taken to mean damage to roads), most flood damage assessment processes ignore the damage to water supply, sewerage and drainage infrastructure, sealed pathways in parklands, pump stations and major electrical installations. These usually are protected by levees or are built on platforms at or near the 1% AEP flood level and so are usually not on the flood damage calculation 'radar'. However, if affected in major events, the resulting damage can be significant and skew what might otherwise be a relatively benign average annual damage (AAD) measure.

The consequences of flooding a sewerage system can be a loss of service and health authorities, which may lead to ordering an evacuation. Consequent absences from home could be for a considerable time until services are restored. Rehabilitation of wastewater treatment plants could include restoration of the bio-mass in an activated sludge process, ongoing testing and rectification of specific damage (pers. comm. H. Betts and C. Reynolds, Sept 2010). The cost impacts associated with silt removal from sewer systems and pump stations, cleaning buried water meter boxes, cleaning hydrant and valve boxes, replacing water meters, repairing main washouts, restoration of subsided trenches, clean-up of sewage overflows, and replacement of sewer and stormwater manhole lids do not seem to be included in damage literature. Many of these are repaired after the main clean up and associated costs are likely to be absorbed within a local authority's normal operational expenses. Councils are required to estimate their flood damages within a very short period after a disaster to claim subsidies and may exclude these items.

2.3 DEPTH-DAMAGE CURVES

The stage-damage curves for dwellings published in the Queensland flood damage guidelines (DNRM, 2002) are based on building areas that are probably no longer realistic. A small house is assumed to be less than 80 m^2, and a large house is over 140 m^2 and/or 3+ bedrooms. Both the scale definitions and stage-damage relationships need to be updated. Many of the existing stage-damage curves appear to have been generated from a mix of dwellings that included a small proportion that were completely destroyed at the time the original curves were developed. Given the addition of newer housing stock that is arguably built to higher construction standards further research is required (Betts, 2011).

Geoscience Australia has recently released a flood damage indices based upon survey of existing housing stock which were affected by the flooding in Queensland in 2011. This information has been used within this study and is discussed in Section 3 and Section 4.

2.4 STRUCTURAL DAMAGE TO BUILDINGS

A factor that is often overlooked in stage-damage calculations is the velocity of floodwaters that can affect the structural integrity of buildings (Dale et al 2004, Middelmann-Fernandes 2010). Typically, Australian design rules ignore such loadings as new houses and other buildings are required to be above the 1% AEP flood level (Qld 2003, ABCB 2010). Queensland building policy requires buildings exposed to floodwaters to be structurally designed against forces associated with flood flows.

2.5 INTANGIBLE COSTS

Costs are not only derived as a consequence to damage of property or infrastructure, but also in terms of the social disruption and change. The adverse social impacts of flooding are extremely difficult and almost impossible to quantify given the long duration of such impacts. Indirect costs are probably the most insidious due to the social disruption.

Social scientists define hazard as:

> Some aspect of the physical environment that threatens the well-being of individuals and their society. (Nigg, 1996)

These threats can be to social, economic and political systems as well as to the built environment. Nigg also suggests a disaster occurs:

> When the built and social environments are so disrupted that the resources of the social system are overwhelmed and the system is unable to meet the demands placed on it for goods and services that are routinely expected by its citizens.

Intangible costs are almost impossible to determine as there are no benchmarks against which to estimate (BTE, 2001). BTE reported on two studies within the United States (Stern, 1976) and cited Allee et al (1980) who, when analysing separate events concluded that the intangible costs were about the same as direct damages. Rumi (2002) includes as adverse social effects the decrease in earning ability, financial hardship in regaining a previous position, occupational displacement and low income levels.

Read Sturgess (2000) suggested that one social measure was Average Annual Population Affected (AAPA) to be calculated in much the same manner as AAD. Unfortunately this measure excludes the extrinsic value of community infrastructure that contributes to society as a whole.

2.6 OVERVIEW

The discussion outlined above has informed the basis of our methodology, which is discussed in Section 4. Our methodology has also been steered by key data availability. The data available for this study is discussed in Section 3.

3 Data

3.1 FLOOR LEVELS AND PROPERTY DATA

A number of floor levels in Biloela were surveyed by BSC as part of the Callide Valley Flood Mitigation Study (CVFMS) being undertaken by the Department of Energy and Water Supply (DEWS). DEWS undertook processing of this data, including auditing for quality, and classification of the buildings. DEWS also added buildings not surveyed, making assumptions on floor level and building classification. DEWS made this data available for use by KBR.

The CVFMS scope included only the building affected by the 2015 flood in Callide Valley. For this assessment, flood damage estimates were required for all 10 towns included in the BSC Floodplain Management Study and Plan, and the calculation of AAD require events up to the PMF be assessed. Additional buildings were therefore digitized and classified in the Callide Valley, as well as building in Taroom, Theodore, Moura, Baralaba, Dululu, and Wowan. Classification was done using Google Street View where available, and aerial photography.

Classification split buildings into residential and commercial (including all non-residential), then further classified based on attributes such as number of storeys and size (area). These attributes were used in the damage assessment to further delineate the estimated costs.

3.2 FLOOD LEVELS

Flood level data is available from the hydraulic models prepared by KBR for the various townships identified in Section 1.1. These are available in digital form for application within WaterRIDE to calculate flood depth over property floor level at individual buildings.

3.3 DEPTH-DAMAGE CURVES

Geoscience Australia (Flood Vulnerability Functions for Australia Buildings, November 2012) recently completed a study which included survey of flood damaged buildings in south-east Queensland following the 2010/2011 floods. This incorporated eleven residential building types in Brisbane and Ipswich. The report presented flood damage indices for each of the eleven buildings, which can be used to estimate flood damage for similar buildings based upon value and flood depth. Indices are available to estimate damage to building fabric and contents.

As part of this damage assessment, we have updated the stage-damage curves available from The Department of Natural Resources and Mines (DNRM, 2002) for commercial/industrial buildings.

4 Methodology

The flood damage function within WaterRIDE was used to calculate flood damages. Pre and post processing of data was undertaking using ArcGIS. The various sections outlined below detail the methodology adopted.

4.1 RESIDENTIAL – INTERNAL

As stated in Section 3.1, buildings were classified into residential or commercial type. To assess the residential damages, these buildings were further classified into house, townhouse, duplex, or unit. This would affect the value prescribed to the property, which in turn would affect the estimated flood damage, which is discussed below.

Sheds and carports were not included in this part of the damage estimation.

4.1.1 Flood damage curves

The Geoscience Australia (2012) damage indices have been adopted in this study to estimate damages to the fabric and contents of residential buildings. Damage indices are based upon water depth, for insured and uninsured scenarios. They also consider whether actions are taken to save contents or not, for each property type. An example from one property type is shown in Figure A3. The uninsured category was used for the estimation of fabric damages. In terms of contents, each town was assessed based on warning time and ability to save their contents, and categorised into:

- uninsured/saved goods
  - Taroom
  - Moura
  - Baralaba
- uninsured/no action
  - Theodore (both Dawson River and Castle Creek flooding)
  - Biloela
  - Thangool
  - Jambin
  - Goovigen
  - Dululu
  - Wowan.

Fabric

In order to estimate residential fabric damage, each property type was categorised in accordance with the Geoscience Australia property types. It was not considered realistic to assign all buildings to the closest match out of the eleven property types in the Geoscience Australia study due to insufficient data available. Therefore, it was considered appropriate that the buildings included in the Geoscience Australia study should themselves be categorised based upon trends that could be identified with respect to building type, etc.

All buildings in the Geoscience Australia study were described, which considered the construction materials, level of living accommodation etc. The area of each property was supplied separately from Geoscience Australia upon request. However, no clear trend could be identified between these attributes and the damage indices. The only trend that was identified was with respect to the number of stories. Contents and fabric damage indices are significantly smaller for two story buildings, especially at depth less than 2.4 m. Consequently, all residential buildings were categorised as one or two story.

Mean flood indices were established for one and two story buildings. This was found to be more acceptable for one story buildings because associated flood indices demonstrate a relatively small range. For two storey buildings this range was larger and application of mean flood indices would be less appropriate. Sub-sets of double storey buildings could be established. However the data available is not of sufficient detail to allow this. Furthermore, two storey buildings are understood to be in the minority in BSC and errors introduced by this method are likely to be relatively small.

It should be noted that the Geoscience Australia study categorised highset houses, with living accommodation on the second floor only, as two storey buildings. The lower floor could be used for laundry, storage or as a garage, etc.

Once each property had been categorised as one or two storey, it was necessary to estimate values of all each property. For simplicity we applied the current median house values for Biloela (available at http://realestate.com.au/), which states that 'the most recent median house price for Biloela is $277,500' (accessed 2/06/2016). The median price of land was found to be $117,500 (researched using a number of real estate sites). The price of a house in Biloela was assumed to therefore be worth $160,000. This price, however, was considered to be below what the true median would be. Using the prices assumed by DEWS in the CVFMS, and relevant experience in the area, a final assumed fabric value of $184,000 was adopted.

Median unit or townhouse values were unavailable for the area. From KBR's experience in the neighbouring Central Highlands region, the price of a unit is approximately two thirds that of a house and a value of $125,000 was adopted. This was applied to units, townhouses, and retirement accommodations (units, dongas, etc.).

NO.	BUILDING TYPE	STOREYS	NOTES	PHOTO
FCM5	SoG, WB cladding, partial lower floor, PB lining	2	Residential	

Table 5:- Summary of calculated damage indices for FCM5

GENERIC HOUSE TYPE	FCM5 (TWO STOREY, SLAB ON GRADE LOWER FLOOR COVERING ONLY PART OF THE PLAN AREA, TIMBER UPPER FLOOR, INTEGRAL GARAGE ON THE LOWER FLOOR)							
INSURANCE REGIME	INSURED				UNINSURED			
WATER DEPTH (M)	FABRIC DI	CONTENTS DI (SAVE GOODS)	CONTENTS DI (NO ACTION)	CONTENTS DI (EXPOSE GOODS)	FABRIC DI	CONTENTS DI (SAVE GOODS)	CONTENTS DI (NO ACTION)	CONTENTS DI (EXPOSE GOODS)
-0.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.05								
0.1	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00
0.3	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00
0.5	0.05	0.00	0.01	0.01	0.05	0.00	0.01	0.01
1.0	0.06	0.00	0.01	0.01	0.06	0.00	0.01	0.01
1.5	0.09	0.00	0.01	0.01	0.09	0.00	0.01	0.01
2.0	0.09	0.00	0.01	0.01	0.09	0.00	0.01	0.01
2.4	0.12	0.00	0.02	0.02	0.12	0.00	0.02	0.02
2.5								
2.7								
2.8	0.36	0.24	0.31	0.46	0.24	0.23	0.31	0.43
3.0	0.39	0.24	0.36	0.54	0.35	0.24	0.36	0.54
3.1								
3.3								
4.0	0.52	0.28	0.66	0.66	0.48	0.28	0.66	0.66
5.1	0.66	0.47	0.69	0.69	0.57	0.47	0.69	0.69
5.4								

Figure A3
EXAMPLE OF GEOSCIENCE AUSTRALIA FLOOD INDICES

Contents

Property value is likely to be a reasonable indicator of the value of the contents. However, as the mean house/unit price was adopted for the damage to fabric, it was considered appropriate to apply a mean contents value. The Australian Bureau of Statistics provides the following information:

> Home contents are the most commonly held household asset with almost every household reporting some items of value. In 2009–10, the average value of a household's home contents

(e.g. clothing, jewellery, hobby collections, furniture, appliances, paintings, works of art) was $61,000[2]).

On this basis a contents value of $61,000 was inflated by Average Weekly Earnings (AWE) and applied to all buildings for multiplication against the mean damage indices, for either one or two story buildings. The value adopted was approximately $64,000.

4.1.2 Flood levels

Flood level data was available for the various simulated events from the hydraulic models prepared by KBR.

4.1.3 Property levels

BSC surveyed 201 residential properties within the Callide Valley as part of the CVFMS. DEWS also digitized an additional 136 residential properties within the 2015 flood extent and made assumptions on floor levels. KBR adopted the floor levels provided by DEWS.

As part of the flood damage assessment, KBR calculated the AAD for each town which requires a damage estimate from the largest modelled flood. The Probable Maximum Flood (PMF) was modelled by KBR for all towns as part of the flood study and therefore additional properties were required to be digitized and classified. KBR subsequently digitized an additional 378 residential properties in the Callide Valley that fall within the PMF flood extent. KBR also digitized 50 residential properties in Taroom, 259 residential properties in Theodore, 29 in Moura, 14 in Baralaba, and a total of 106 residential properties along the Dee River in Dululu and Wowan.

An assumed floor level of 0.6 m above ground level was assumed for all the properties digitized by KBR. This was estimated by taking the floor levels that were surveyed, subtracting the ground level, and then averaging the resulting values. This value is consistent with the Central Highland region that surveyed a number of properties in Emerald as part of their Floodplain Management Study and Plan in 2012.

4.2 RESIDENTIAL – EXTERNAL

The Geoscience Australia study had no information on external damage. External damage can be significant, because a larger proportion of properties are affected externally than internally. External damage rates were estimated using data extracted from the Maroochy Shire Curves, WRM Water & Environment Pty Ltd (2006) and adjusted by Queensland Average weekly earnings (AWE). A single external flood damage curve was derived which was based upon an average of the various property types.

External lots were derived using GIS cadastre data sourced from DNRM.

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[2] See http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10Dec+2011#Contents5 Downloaded 2 May 2013

4.2.1 Flood levels

Flood level data are available for the various simulated events from the hydraulic models prepared by KBR.

4.2.2 Property levels

External property damages are based upon the external property level. This is an automated process using WaterRIDE, which extracts a level at the centroid of the property.

4.3 COMMERCIAL/INDUSTRIAL

4.3.1 Flood damage curves

The Geoscience Australia (2012) damage indices included commercial/industrial buildings based upon buildings surveyed in Sydney. Furthermore, the indices only considered the damage to the fabric of the building. The contents of commercial/industrial buildings can be extremely valuable and need to be established by other means.

A study prepared by DNRM, 2002, provides stage-damage information for commercial premises. It includes depth-damage relationships for commercial and industrial buildings, which are applied on gross building area or a rate per m^2, as shown in Table A1.

Table A1 Depth-damage relationships for commercial buildings

	Small commercial properties (<186m²)					Medium commercial properties (186–650m²)					Large commercial properties (>650m²)*				
Value class	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
0.25	$2 202	$4 405	$8 809	$17 618	$35 237	$6 975	$13 948	$27 896	$55 791	$111 583	$7	$15	$32	$61	$122
0.75	$5 506	$11 011	$22 023	$44 046	$88 092	$16 884	$33 768	$67 537	$135 074	$270 147	$39	$78	$154	$308	$619
1.25	$8 258	$16 518	$33 034	$66 069	$132 137	$25 693	$51 387	$102 773	$205 574	$411 094	$81	$162	$326	$649	$1297Ł
1.75	$9 176	$18 352	$36 705	$73 410	$146 819	$28 445	$56 893	$113 785	$227 570	$455 140	$132	$267	$533	$1065	$2129
2	$9 726	$19 454	$38 907	$77 814	$155 628	$30 281	$60 564	$121 126	$242 252	$484 504	$159	$318	$636	$1 272	$2 545

* units of $/m²

Various stage-damage curves are available based upon the value class of the property, as shown in Figure A4. These depth-damage relationships were inflated by AWE.

A single value class was applied to all commercial/industrial buildings. This was adjusted through comparison with information outlined in an economic study prepared for the Central Highlands region following the 2010/11 flood event (Lawrence Consulting, 2011).

The economic study suggested that an average direct cost per affected business for flood damages in the 2010/11 event across the region was approximately $98,000. The medium value class was assigned to commercial/industrial buildings in Emerald and a comparative rate of $89,000 was used. We consider this slightly reduced rate to be appropriate due to the likelihood of behavioural changes since 2011.

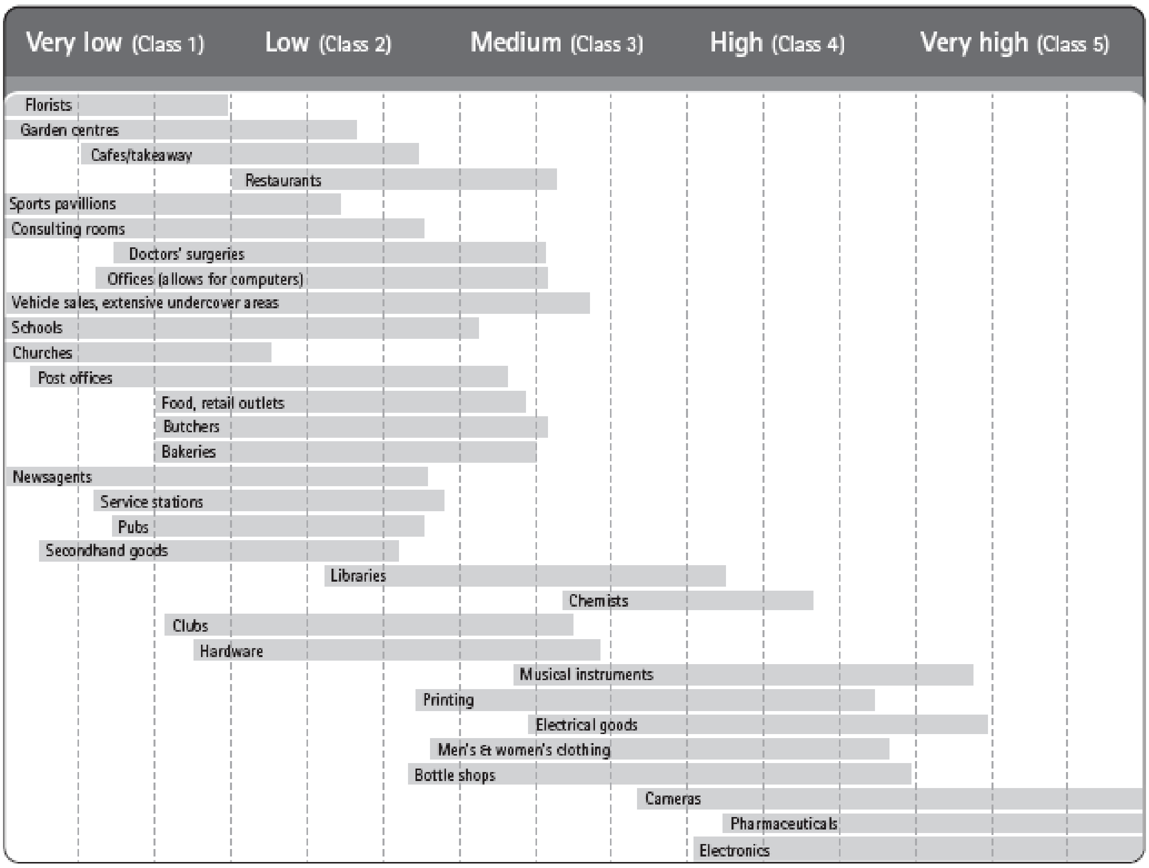

Figure A4
DAMAGE CATEGORIES FOR COMMERCIAL PROPERTIES

4.3.2 Flood levels

Flood level data is available for the various simulated events from the hydraulic models prepared by KBR.

4.3.3 Property levels

BSC surveyed seven commercial properties within the Callide Valley as part of the CVFMS. DEWS also digitized one additional commercial property within the 2015 flood extent and made an assumption on floor level. KBR adopted the floor levels provided by DEWS.

As part of the flood damage assessment, KBR calculated the AAD for each town which requires a damage estimate from the largest modelled flood. The Probable Maximum Flood (PMF) was modelled by KBR for all towns as part of the flood study and therefore additional properties were required to be digitized and classified. KBR subsequently digitized an additional 133 residential properties in the Callide Valley that fall within the PMF flood extent. KBR also digitized 63 residential properties in Taroom, 117 residential properties in Theodore, 32 in Moura, 25 in Baralaba, and a total of 67 residential properties along the Dee River in Dululu and Wowan.

An assumed floor level of 0.2 m above ground level was assumed for all commercial properties digitized by KBR. This was estimated using surveyed levels taken in the nearby town of Emerald as part of their Floodplain Management Study and Plan in 2012.

4.4 INFRASTRUCTURE

Infrastructure damage has not been considered as part of this assessment. The flood damage assessment outputs are primarily used to cost the benefit of flood mitigation options which are focused around the towns themselves. For this reason large stretches of linear infrastructure would not receive benefit and remain consistent between existing and post-mitigation scenarios.

It is noted that infrastructure damage can be reduced by management practices such as closing flood stretches of road until waiting until they are dry before re-opening.

4.5 AGRICULTURE

Agricultural damage is difficult to estimate. Lawrence Consulting (2009) reported a total reduction in agriculture, forestry and fishing turnover by over $40 million, from $695 million, following the 2008 flood event across the Central Highlands region. Lawrence Consulting (2011) reported an additional fall in turnover to $508 million for 2008/2009. This indicates that there is a lag affect in this industry as a result of flood damage.

The lag affect may have continued beyond 2009, but no further data appears to be available. Due to the wider impact of the 2010/11 flood event the impacts on agriculture, forestry and fishing turnover are likely to have been larger. Unfortunately, this was not reported.

Further uncertainty exists with respect to agricultural damage in terms of the time of year when flooding occurs, dominant type of crops being produced, weather conditions, value of produce and stock to market. Damage to fencing was reported as $5,000/km in 2000 (BTE 2001) and is likely to be significantly higher now. It is unknown whether this applies to all inundated fences or just those damaged.

Agricultural damage was therefore not considered as part of this assessment. The assessment is also primarily used to cost the benefit of flood mitigation options which are focused around the towns themselves. For this reason agricultural areas would not receive benefit and remain consistent between existing and post-mitigation scenarios.

4.6 INDIRECT DAMAGE

As outlined in DNRM (2002) indirect damages (e.g. clean-up costs) for residential and commercial properties are difficult to estimate and are commonly assessed as a proportion of direct damages.

The following percentages are recommended in the ANUFLOOD model:

- Indirect residential damages = 15% of direct residential damages
- Indirect commercial damages = 55% of direct commercial damages.

The value of 15% was adopted for residential damages. However a value of 80% for commercial damages was assumed for this study. This was derived through a study by Lawrence Consulting (2009) for the neighbouring Central Highlands region, which estimated indirect damages to range from approximately 55% to 125% of the direct costs.

The costs of emergency management are classified as indirect damage, i.e. the costs are a consequence of flooding, not directly affected by floodwater. Emergency management costs were scoped in BTE (2001) and were found to vary in accordance to the duration and severity of flooding and the number of people engaged in disaster management. Previous work by KBR for the City of Victor Harbor suggested that these could be 12% of the indirect costs of residential damage because emergency response is designed to the number of people directly affected.

4.7 INTANGIBLE COSTS OF FLOODING

Intangible damages cannot be calculated with any degree of accuracy, and it is probably impossible to do so given the attribution of future or ongoing physical or mental illness responses to a specific event. They are, however, commonly believed to be in the order of 50% to 100% of the tangible damage bill for a community that is not flood aware or has not experienced floods of the magnitude under consideration (pers. comm. DI Smith and HW Betts (KBR)).

Handbook 7 of Australian Emergency Management Handbook Series (AEMI, 2013) suggests that the intangible costs of flooding are about the same as the tangible costs. The reason for this escalation is not stated but given the increased awareness of mental health issues and greater accessibility to medical advice, the higher figure is recommended. The combined figure should be included in any economic analysis.

Read Sturgess suggest that average annual population affected (AAPA) that can be calculated in the same manner as AAD, is a measure of societal impact.

Intangible costs have not been otherwise accounted for in this report.

4.8 TOWN DEFINITIONS

Individual models were developed for many of the towns assessed in this study. However recent innovations in the software allowed the building of larger models and in some locations, such as the Callide Valley, it made sense to develop one hydraulic model that encompassed all towns within the area.

Many flood prone properties are located outside of town centres and fall within the floodplain between neighbouring towns and it can become ambiguous as to which town the property belongs. The ‘locality boundaries’ GIS layer from DNRM was used to define town boundaries to eliminate qualitative definitions. The assumed local boundaries are listed below:

- Biloela—Biloela, Valentine Plains, Prospect, Mount Murchison, Dakenba, Orange Creek, Callide Creek
- Thangool—Thangool
- Jambin—Argoon, Greycliffe, Smoky Creek
- Goovigen—Goovigen
- Theodore—Theodore, Lonesome Creek, Isla
- Dululu—Dululu
- Wowan—Wowan, Dixalea

- Taroom—Taroom
- Moura—Moura, Kianga, Warnoah
- Baralaba—Baralaba, Alberta, Barnard.

5 Existing flood damage results

The results of the damage assessment are summarised in Table A2 for the worst historic flood, the 1% AEP plus climate change event, and the AAD. A detailed breakdown of flooded properties of each town is presented in Table A3 to A13, and of the damage costs in Table A14 to A24.

The AAD presented does not include damages associated with infrastructure, agriculture, etc. Furthermore, intangible damages are excluded from the calculation of AAD

Table A2 - Flood damage summary: 1% AEP climate change and worst historic flood

Town	Worst historic flood				1% AEP + climate change				AAD ($)
	Number of residential buildings	Residential damages ($'000)	Number of commercial buildings	Commercial damages ($'000)	Number of Residential buildings	Residential damages ($'000)	Number of commercial buildings	Commercial damages ($'000)	
Biloela*	147	$10,520	11	$1,300	219	$19,150	16	$3,340	$792,063
Thangool*	7	$520	4	$620	16	$1,030	5	$1,000	$100,160
Jambin*	12	$1,000	5	$370	18	$1,790	6	$700	$174,654
Goovigen*	2	$70	0	$0	5	$460	0	$0	$13,078
Theodore (Dawson River)#	172	$14,290	100	$7,720	245	$26,720	109	$17,560	$1,381,000
Theodore (Castle Creek)‡	-	-	-	-	31	$2,310	29	$2,270	$388,000
Dululu*	8	$550	3	$280	12	$910	6	$450	$63,061
Wowan†	1	$10	14	$350	2	$30	16	$750	$41,928
Taroom#	10	$790	12	$1,400	12	$1,050	13	$1,980	$233,714
Moura#	1	$70	6	$300	3	$130	17	$960	$100,403
Baralaba#	2	$240	7	$1,260	2	$270	7	$1,540	$134,255

* *worst historic flood on record is 2015*

\# *worst historic flood on record is 2010*

† *worst historic flood on record is 2013*

‡ *no historic flood event modelled*

The results show that Theodore has the highest flood damage costs for the historic flood event and design flood events. It also has the highest AAD, with a value of $1,381,000, which is almost double that of the next highest town, Biloela ($792,063).

Flood damages in Theodore were estimated for flooding from both the Dawson River and Castle Creek. Flooding from Dawson River was found to cause significantly higher damages in Theodore, however flooding from Castle Creek still returned an AAD of $388,00, which is the second highest, with Biloela the only town returning a higher AAD.

Biloela has the second highest AAD with a value of $792,063, and one of two towns that experience over floor flooding in all modelled events. Many of the affected areas are located outside of the town proper and are situated on the lower areas surrounding the town.

Taroom has the third highest AAD with a value of $233,714. There are a number of properties on the western side of town, particularly near the Leichhardt Highway, that are affected by flooding down to the 5% AEP, and experience over floor flooding in the 2% AEP event or greater.

Jambin has the fourth highest AAD with a value of $174,654. Jambin is not a big town, however the majority of the buildings are vulnerable to flooding and is the second of the two towns that experience over floor flooding in all events.

Table A3 Number of properties and buildings affected in Biloela

	Flood event											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential (external)	26	45	159	279	336	353	380	445	37	42	94	287
Residential buildings	5	9	57	135	219	244	290	440	7	8	29	147
Mean residential flood depth (m)†	0.14	0.24	0.32	0.38	0.62	0.72	0.93	1.69	0.20	0.38	0.27	0.37
Commercial & industrial buildings	1	1	4	10	16	17	41	99	1	2	3	11
Mean commercial flood depth (m)†	0.35	0.60	0.45	0.35	0.46	0.54	0.42	1.04	0.55	0.47	0.53	0.32

† *calculated based on flooded properties only*

Table A4 Number of properties and buildings affected in Thangool

	Flood event											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential (external)	3	10	31	39	45	49	61	104	3	19	22	38
Residential buildings	0	2	6	7	16	17	24	76	0	3	4	7
Mean residential flood depth (m)†	-*	0.08	0.22	0.34	0.27	0.32	0.39	1.28	-*	0.21	0.21	0.32
Commercial & industrial buildings	0	0	1	4	5	5	5	9	0	1	1	4
Mean commercial flood depth (m)†	-*	-*	0.65	0.45	0.61	0.71	0.98	1.76	-*	0.24	0.16	0.44

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A5 Number of properties and buildings affected in Jambin

	Flood event											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential (external)	21	29	35	37	39	39	43	47	34	33	36	40
Residential buildings	1	3	9	16	18	22	28	45	5	5	12	12
Mean residential flood depth (m)†	0.37	0.22	0.47	0.54	0.78	0.77	1.00	2.88	0.19	0.40	0.48	0.52
Commercial & industrial buildings	1	2	4	5	6	7	11	15	4	3	4	5
Mean commercial flood depth (m)†	0.20	0.17	0.60	0.78	0.93	0.92	0.91	3.11	0.13	0.36	0.79	0.61

† *calculated based on flooded properties only*

Table A6 Number of properties and buildings affected in Goovigen

	Flood event											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential (external)	0	1	4	5	5	5	6	21	1	2	5	5
Residential buildings	0	0	0	4	5	5	5	18	0	0	2	2
Mean residential flood depth (m)†	-*	-*	-*	0.17	0.50	0.68	1.17	1.43	-*	-*	0.05	0.05
Commercial & industrial buildings	0	0	0	0	0	1	1	13	0	0	0	0
Mean commercial flood depth (m)†	-*	-*	-*	-*	-*	0.21	0.78	0.84	-*	-*	-*	-*

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A7 Number of properties and buildings affected in Theodore by Dawson River flooding

	Flood event									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2010	2013
Residential (external)	6	82	196	224	231	232	234	238	224	0
Residential buildings	0	9	74	186	245	247	253	259	172	0
Mean residential flood depth (m)†	-*	0.21	0.30	0.56	1.06	1.25	1.93	5.77	0.48	-*
Commercial & industrial buildings	1	19	47	103	109	110	111	116	100	0
Mean commercial flood depth (m)†	0.18	0.24	0.55	0.68	1.30	1.50	2.19	5.99	0.58	-*

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A8 Number of properties and buildings affected in Theodore by Castle Creek flooding

	Flood event							
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF
Residential (external)	0	5	19	129	133	203	230	237
Residential buildings	0	0	5	21	31	139	246	258
Mean residential flood depth (m)†	-*	-*	0.08	0.33	0.37	0.42	1.01	3.55
Commercial & industrial buildings	0	0	6	26	29	81	109	115
Mean commercial flood depth (m)†	-*	-*	0.35	0.43	0.54	0.48	1.25	3.78

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A9 Number of properties and buildings affected in Dululu

	Flood event									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2013	2015
Residential (external)	0	0	15	18	20	20	21	23	18	18
Residential buildings	0	0	5	8	12	14	18	21	5	8
Mean residential flood depth (m)†	-*	-*	0.22	0.25	0.37	0.43	0.62	1.44	0.28	0.26
Commercial & industrial buildings	0	0	3	3	6	7	10	15	3	3
Mean commercial flood depth (m)†	-*	-*	0.54	0.65	0.48	0.51	0.62	1.11	0.58	0.65

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A10 Number of properties and buildings affected in Wowan

	Flood event									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2013	2015
Residential (external)	0	0	19	19	30	43	53	77	33	8
Residential buildings	0	0	1	1	2	3	7	67	1	0
Mean residential flood depth (m)†	-*	-*	0.02	0.02	0.02	0.09	0.19	0.35	0.02	-*
Commercial & industrial buildings	0	0	6	11	16	20	23	48	14	7
Mean commercial flood depth (m)†	-*	-*	0.12	0.15	0.26	0.32	0.46	0.90	0.12	0.17

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A11 Number of properties and buildings affected in Taroom

	Flood event					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential (external)	4	6	14	19	40	17
Residential buildings	0	3	5	12	35	10
Mean residential flood depth (m)†	-*	0.24	0.65	0.80	3.34	0.60
Commercial & industrial buildings	3	3	7	13	55	12
Mean commercial flood depth (m)†	1.39	2.21	1.40	1.35	13.67	1.13

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A12 Number of properties and buildings affected in Moura

	Flood event					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential (external)	0	10	21	26	28	20
Residential buildings	0	0	1	3	29	1
Mean residential flood depth (m)†	-*	-*	0.29	0.22	0.98	0.20
Commercial & industrial buildings	0	3	10	17	30	6
Mean commercial flood depth (m)†	-*	0.17	0.19	0.27	1.39	0.23

† *calculated based on flooded properties only*

* *no over floor flooding*

Table A13 Number of properties and buildings affected in Baralaba

	Flood event					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential (external)	2	2	2	2	9	2
Residential buildings	1	2	2	2	9	2
Mean residential flood depth (m)[†]	1.02	1.21	1.67	2.21	2.32	1.76
Commercial & industrial buildings	3	5	6	7	23	7
Mean commercial flood depth (m)[†]	0.96	1.35	1.55	1.91	3.15	1.41

† *calculated based on flooded properties only*

Table A14 Biloela flood damage summary

Direct flood damage	Potential Flood Damage ($'000)											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential property (external)	$300	$710	$3,380	$6,610	$10,890	$12,220	$14,140	$19,300	$530	$670	$1,810	$6,930
Residential property (internal & structural)	$250	$530	$3,850	$9,820	$19,150	$22,220	$29,270	$54,900	$460	$520	$1,590	$10,520
Commercial & industrial	$80	$130	$560	$1,270	$3,340	$4,520	$8,160	$36,110	$120	$250	$530	$1,300
Total direct flood damage	$640	$1,370	$7,790	$17,700	$33,390	$38,960	$51,570	$110,310	$1,110	$1,430	$3,930	$18,750
Indirect flood damage	$150	$290	$1,540	$3,480	$7,180	$8,780	$13,040	$40,020	$250	$380	$930	$3,660
Total tangible damage	$790	$1,660	$9,320	$21,180	$40,570	$47,740	$64,600	$150,330	$1,360	$1,810	$4,860	$22,400

Table A15 Thangool flood damage summary

Direct flood damage	Potential Flood Damage ($'000)											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential property (external)	$40	$120	$540	$810	$1,100	$1,220	$1,630	$4,200	$20	$330	$380	$780
Residential property (internal & structural)	$0	$80	$390	$530	$1,030	$1,210	$1,780	$9,280	$0	$210	$240	$520
Commercial & industrial	$0	$0	$260	$640	$1,000	$1,140	$1,540	$2,790	$0	$60	$40	$620
Total direct flood damage	$40	$210	$1,190	$1,970	$3,120	$3,580	$4,940	$16,270	$20	$590	$670	$1,930
Indirect flood damage	$10	$30	$350	$710	$1,120	$1,280	$1,740	$4,250	$0	$130	$130	$690
Total tangible damage	$40	$240	$1,530	$2,680	$4,240	$4,860	$6,680	$20,520	$30	$720	$790	$2,620

Table A16 Jambin flood damage summary

Direct flood damage	Potential Flood Damage ($'000)											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential property (external)	$200	$530	$1,200	$1,430	$1,570	$1,630	$1,780	$2,230	$690	$880	$1,320	$1,360
Residential property (internal & structural)	$90	$200	$680	$1,360	$1,790	$2,020	$3,070	$7,140	$270	$390	$930	$1,000
Commercial & industrial	$20	$30	$300	$500	$700	$780	$1,140	$5,110	$40	$110	$400	$370
Total direct flood damage	$300	$760	$2,180	$3,290	$4,060	$4,430	$5,990	$14,480	$1,010	$1,380	$2,650	$2,730
Indirect flood damage	$60	$130	$520	$820	$1,060	$1,170	$1,640	$5,490	$180	$280	$660	$650
Total tangible damage	$360	$890	$2,700	$4,110	$5,120	$5,590	$7,640	$19,980	$1,190	$1,650	$3,310	$3,380

Table A17 Goovigen flood damage summary

Direct flood damage	Potential Flood Damage ($'000)											
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	1978	2010	2013	2015
Residential property (external)	$0	$10	$60	$170	$240	$240	$250	$810	$10	$10	$130	$130
Residential property (internal & structural)	$0	$0	$0	$240	$460	$500	$620	$1,820	$0	$0	$70	$70
Commercial & industrial	$0	$0	$0	$0	$0	$50	$160	$1,110	$0	$0	$0	$0
Total direct flood damage	$0	$10	$60	$420	$700	$800	$1,040	$3,730	$10	$10	$200	$190
Indirect flood damage	$0	$0	$10	$60	$100	$160	$260	$1,280	$0	$0	$30	$30
Total tangible damage	$0	$10	$70	$480	$800	$950	$1,300	$5,010	$10	$10	$230	$220

Table A18 Theodore flood damage summary (Dawson River flooding)

Direct flood damage	Potential Flood Damage ($'000)									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2010	2013
Residential property (external)	$80	$1,120	$4,900	$9,110	$10,840	$10,940	$11,150	$11,420	$8,470	$0
Residential property (internal & structural)	$0	$560	$4,380	$16,060	$26,720	$28,750	$34,190	$43,930	$14,290	$0
Commercial & industrial	$10	$610	$3,530	$9,120	$17,560	$19,910	$25,430	$27,620	$7,720	$0
Total direct flood damage	$90	$2,290	$12,800	$34,290	$55,120	$59,610	$70,780	$82,970	$30,480	$0
Indirect flood damage	$20	$740	$4,210	$11,070	$19,680	$21,880	$27,150	$30,400	$9,590	$0
Total tangible damage	$120	$3,030	$17,020	$45,370	$74,800	$81,490	$97,930	$113,370	$40,070	$0

Table A19 Theodore flood damage summary (Castle Creek flooding)

Direct flood damage	Potential Flood Damage ($'000)							
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF
Residential property (external)	$0	$40	$490	$2,450	$3,300	$7,060	$10,700	$11,380
Residential property (internal & structural)	$0	$0	$230	$1,690	$2,310	$10,960	$26,110	$42,490
Commercial & industrial	$0	$0	$280	$1,690	$2,270	$5,080	$16,990	$27,290
Total direct flood damage	$0	$40	$1,000	$5,820	$7,880	$23,110	$53,790	$81,150
Indirect flood damage	$0	$10	$330	$1,970	$2,650	$6,770	$19,110	$29,910
Total tangible damage	$0	$50	$1,330	$7,790	$10,530	$29,880	$72,900	$111,070

Table A20 Dululu flood damage summary

Direct flood damage	Potential Flood Damage ($'000)									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2013	2015
Residential property (external)	$0	$0	$380	$460	$610	$690	$850	$1,030	$420	$470
Residential property (internal & structural)	$0	$0	$380	$540	$910	$1,190	$1,730	$2,770	$420	$550
Commercial & industrial	$0	$0	$240	$280	$450	$570	$980	$2,280	$250	$280
Total direct flood damage	$0	$0	$1,000	$1,290	$1,970	$2,460	$3,570	$6,080	$1,090	$1,300
Indirect flood damage	$0	$0	$300	$380	$590	$740	$1,170	$2,400	$330	$380
Total tangible damage	$0	$0	$1,300	$1,670	$2,550	$3,200	$4,740	$8,480	$1,420	$1,680

Table A21 Wowan flood damage summary

Direct flood damage	Potential Flood Damage ($'000)									
	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC	0.2% AEP	0.05% AEP	PMF	2013	2015
Residential property (external)	$0	$0	$210	$240	$380	$640	$860	$3,040	$380	$50
Residential property (internal & structural)	$0	$0	$20	$20	$30	$140	$450	$4,850	$10	$0
Commercial & industrial	$0	$0	$150	$350	$750	$1,120	$1,690	$5,140	$350	$240
Total direct flood damage	$0	$0	$380	$600	$1,160	$1,900	$3,000	$13,030	$740	$290
Indirect flood damage	$0	$0	$160	$320	$660	$1,010	$1,550	$5,290	$340	$200
Total tangible damage	$0	$0	$540	$920	$1,830	$2,910	$4,550	$18,320	$1,070	$490

Table A22 Taroom flood damage summary

Direct flood damage	Potential Flood Damage ($'000)					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential property (external)	$140	$230	$450	$780	$1,740	$660
Residential property (internal & structural)	$0	$210	$390	$1,050	$4,440	$790
Commercial & industrial	$450	$600	$910	$1,980	$14,060	$1,400
Total direct flood damage	$590	$1,040	$1,760	$3,810	$20,240	$2,840
Indirect flood damage	$380	$550	$850	$1,860	$12,170	$1,330
Total tangible damage	$980	$1,590	$2,610	$5,660	$32,410	$4,170

Table A23 Moura flood damage summary

Direct flood damage	Potential Flood Damage ($'000)					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential property (external)	$0	$90	$320	$620	$1,340	$240
Residential property (internal & structural)	$0	$0	$80	$130	$2,700	$70
Commercial & industrial	$0	$120	$390	$960	$6,590	$300
Total direct flood damage	$0	$220	$800	$1,710	$10,630	$610
Indirect flood damage	$0	$110	$370	$880	$5,880	$290
Total tangible damage	$0	$330	$1,170	$2,590	$16,510	$900

Table 24 Baralaba flood damage summary

Direct flood damage	Potential Flood Damage ($'000)					
	5% AEP	2% AEP	1% AEP	1% AEP + CC	PMF	2010
Residential property (external)	$50	$90	$100	$100	$410	$100
Residential property (internal & structural)	$90	$210	$240	$270	$880	$240
Commercial & industrial	$520	$950	$1,200	$1,540	$4,910	$1,260
Total direct flood damage	$660	$1,250	$1,540	$1,900	$6,200	$1,600
Indirect flood damage	$440	$800	$1,010	$1,280	$4,120	$1,060
Total tangible damage	$1,100	$2,050	$2,550	$3,190	$10,320	$2,660

6 Mitigation

As part of the BSC Floodplain Management Study and Plan, a number of structural mitigation options were proposed that have the potential to reduce the risk of flooding throughout the BSC.

The structural mitigation options are generally directed to changing the way water flows through a catchment, and aimed to reduce residual risk and improve the safety of the community.

As part of the structural mitigation assessment, the flood damage estimates are re-calculated to evaluate their monetary effectiveness.

6.1 STRUCTURAL MITIGATION OPTIONS

Local and regional measures were proposed as part of the structural mitigation option assessment. A number of those options have either been discarded, or not priced due to effectiveness, practicality, or funding source. Only the priced options have had flood damage estimates re-calculated.

The mitigation options are detailed in the following sections. Many options have been combined together in the modelling and have been noted as such.

6.1.1 Biloela

Flood inundation in Biloela is governed by breakout flows from Washpool Gully and flood levels in Callide Creek. The structural measures identified that may reduce the flood risk for flood events within Biloela are provided in Table A25.

Options BIL-01, BIL-02a, BIL-02b, BIL-03a, and BIL-03b have been combined in the modelling and damage estimates are inclusive of all those options in the combination.

Table A25 Biloela flood mitigation options

Option ID	Description	Combined option
BIL-01	Local levee to protect properties on Baileys Lane up to the DFE. 1.8 km long up to 1.7 m high (without freeboard).	Combination-1: BIL-01, BIL-02a, BIL-02b, BIL-03a, BIL-03b
BIL-02a	Local levee to protect properties on Hills Ave up to the DFE. 2.1 km long up to 1.6 m high (without freeboard).	Combination-1: BIL-01, BIL-02a, BIL-02b, BIL-03a, BIL-03b
BIL-02b	Local levee to protect properties on Joe Kooyman Drive up to the DFE.0.8 km long and up to 2.3 m high (without freeboard).	Combination-1: BIL-01, BIL-02a, BIL-02b, BIL-03a, BIL-03b

Option ID	Description	Combined option
BIL-03a	Raise Tognolini Baldwin Road and Dawson Highway to protect properties facing washpool gully up to the DFE and to provide an evacuation route into town.2.0 km long and up to 1.0 m high (without freeboard).	BIL-Combination1: BIL-01, BIL-02a, BIL-02b, BIL-03a, BIL-03b
BIL-03b	Local levee to protect properties on Alexandria Ave up to the DFE.1.9 km long and up to 0.7 m high (without freeboard, although some sections over 5.0 m high due to a local drain.	BIL-Combination1: BIL-01, BIL-02a, BIL-02b, BIL-03a, BIL-03b
BIL-08	Most vulnerable homes on Muirs Rd are raised or acquired.	Not combined

6.1.2 Thangool

Flood inundation in Thangool is primarily governed by breakout flows and backwater from Kariboe Creek. The structural measures identified that may reduce the flood risk for flood events within Thangool are provided in Table A26.

Options THA-01 and THA-02 were combined and separately THA-03 was assessed as a stand-a-lone option.

Table A26 Thangool flood mitigation options

Option ID	Description	Combined options
THA-01	Local levee to protect properties on the edge of the floodplain up to the DFE. 1.1 km long up to 1.5 m high (without freeboard).	THA-Combination1: THA-01, THA-02
THA-02	Local levee to protect the Primary School up to the DFE. 0.5 km long up to 1.5 m high (without freeboard).	THA-Combination1: THA-01, THA-02
THA-03	Instead of THA-01, raise flood affected homes in Thangool	Not combined

6.1.3 Jambin

Flood inundation in Jambin is predominantly governed by flows from Callide Creek and Kroombit Creek, and the town’s position within the floodplain. There are limited opportunities to provide feasible structural measures to remove the flood risk from Jambin. The structural measures identified that may reduce the flood risk within Jambin are provided in Table 3.3.

Options JAM-01 and JAM-04 were combined and damage estimates are inclusive of all those options in the combination.

Table 3.3 Jambin flood mitigation options

Option ID	Description	Combined options
JAM-01	Local levee to protect the Jambin Hotel and two neighbouring properties.	JAM-Combination1: JAM-01, JAM-02
JAM-04	Raise stumped houses in combination with levee option JAM-01.	JAM-Combination1: JAM-01, JAM-02

6.1.4 Goovigen

No mitigation options were proposed for Goovigen

6.1.5 Theodore

Flood inundation in Theodore is governed by flows from the Dawson River. In small flood events the town weir influences peak levels, but for major flood events a natural constriction in the terrain downstream of the town controls water peak level in the town. Flooding of the northern end of the town is also vulnerable to Castle Creek flows which have also been investigated as part of this study. A range of Structural Measures are provided in Table A27 that may reduce the flood risk to affected properties in Theodore.

Options THE-03 and THE-04 were combined and damage estimates are inclusive of all those options in the combination.

Table A27 Theodore flood mitigation options

Option ID	Description	Combined options
THE-01	A shorter evacuation route to the Theodore airstrip via Gibbs Road. Also a connecting local levee to protect houses around the engineering works and timber mill up to the DFE. 2.8 km long up to 1.5 m high (without freeboard).	Not combined
THE-02	A local levee beside Castle Creek utilising the old railway alignment to a level of 142 mAHD. 4.0 km long up to 1.0 m high (without freeboard).	Not combined
THE-03	A local levee to protect residents in town up to flood levels of 142 mAHD. 3.0 km long up to 1.0 m high (without freeboard).	THE-Combination1: THE-03, THE-04
THE-04	In combination with levee option THE-03, raise stumped houses outside levee.	THE-Combination1: THE-03, THE-04
THE-05	Raised stumped houses that are below 2%AEP	Not combined

6.1.6 Dululu

Flood inundation in Dululu is primarily governed by breakout flows from the Dee River. The structural measures identified that may reduce the flood risk for flood events within Jambin are provided in Table A28.

Table A28 Dululu flood mitigation options

Option ID	Description	Combined options
DUL-01	Local levee to protect properties on the floodplain up to the DFE. 0.5 km long up to 2.0 m high (without freeboard).	Not combined
DUL-02	Most homes in Dululu are high set and raising floor levels above the DFE is an alternative to DUL-01.	Not combined

6.1.7 Wowan

Flood inundation in Wowan is primarily governed by breakout flows from Pocket Creek. The structural measures identified that may reduce the flood risk for flood events within Wowan are provided in Table A29.

Options WOW-01, WOW-02, and WOW-03 were combined and damage estimates are inclusive of all those options in the combination.

Table A29 Wowan flood mitigation options

Option ID	Description	Combined options
WOW-01	Local levee to protect the school up to the DFE. 0.3 km long and 0.5 m high (without freeboard).	WOW-Combination1: WOW-01, WOW-02, WOW-03
WOW-02	Local levee to protect the fuel station up to the DFE. 0.2 km long and 0.5 m high (without freeboard).	WOW-Combination1: WOW-01, WOW-02, WOW-03
WOW-03	Raise high set houses in combination with levee options WOW-01 and WOW-02.	WOW-Combination1: WOW-01, WOW-02, WOW-03

6.1.8 Taroom

Flood inundation in Taroom is governed by Dawson River flooding and to some degree, the Leichhardt Highway crossing of the Dawson River. As a result, only a small number of feasible Structural Measures are provided in Table A30 that may reduce the flood risk to affected properties in Taroom.

Table A30 Taroom flood mitigation options

Option ID	Description	Combined options
TAR-01	Lions Park Levee to protect properties on the edge of the floodplain up to the DFE. 0.8 km long up to 4.5 m high (without freeboard).	Not combined
TAR-02	Instead of TAR-01, relocate Taroom Roadhouse to a flood free block and raise high set buildings.	Not combined

6.1.9 Moura

Flood inundation in Moura is limited to the rural residential properties at risk within the expansive Dawson River floodplain. The structural measures identified that may reduce the flood risk for flood events within the floodplain at Moura are provided in Table A31.

Table A30 Moura flood mitigation options

Option ID	Description	Combined options
MOU-01	Local levee to protect rural residential properties on the bank of the river up to the DFE. 3.8 km long and 1.0 m high (without freeboard).	Not combined
MOU-02	Instead of MOU-01, raise stumped houses	Not combined

6.1.10 Baralaba

No options for Baralaba had flood damages estimated.

7 Mitigation flood damage estimates

The results of the mitigation option damage assessment are summarised in Table A32 for the worst historic flood event, the 1% AEP plus climate change, and the AAD.

The calculated AAD has decreased for all mitigation options with the exception of THE-02, and THE-Combination1. The levee positioning and height in these options are causing an increase in depth and damages to the properties in Theodore for events between the 2% AEP and 0.05% AEP.

BIL-Combination1 results in the greatest absolute reduction in flood damages, with a reduction of approximately $233,500 in AAD. This option however includes a number of levees in combination. Individual levee options, and their benefits, within Biloela have not been assessed.

The damage assessment for the mitigation options have not included recalculating the flood damages that would be caused by local flooding from Castle Creek. Flood damages caused by Dawson River in Theodore are much greater, and therefore are assumed to be critical.

Table A31 Mitigation flood damage summary: 1% AEP climate change and worst historic flood

Mitigation Option	Worst historic flood				1% AEP + climate change				AAD
	Number of residential buildings	Residential damages ($'000)	Number of commercial buildings	Commercial damages ($'000)	Number of Residential buildings	Residential damages ($'000)	Number of commercial buildings	Commercial damages ($'000)	($)
BIL-Combination1*	79	$5,070	10	$1,020	108	$8,980	16	$3,100	$558,540
BIL-08*	144	$10,290	11	$1,300	214	$18,730	16	$3,340	$784,357
THA-Combination1*	7	$520	3	$160	14	$900	4	$340	$70,629
THA-03*	7	$520	4	$620	14	$900	5	$1,000	$99,352
JAM-Combination1*	5	$440	4	$230	7	$690	5	$470	$127,554
THE-01#	164	$13,350	87	$5,990	237	$25,590	97	$14,970	$1,193,851
THE-02#	179	$14,670	101	$8,390	245	$26,740	109	$17,620	$1,407,581
THE-Combination1#	165	$13,820	100	$8,510	230	$24,630	109	$17,660	$1,495,946
THE-05#	172	$13,220	100	$7,720	245	$25,830	109	$17,560	$1,255,220
DUL-01*	3	$230	1	$90	3	$300	4	$220	$27,174
DUL-02*	2	$180	3	$280	2	$220	6	$450	$49,696
WOW-Combination1†	0	$0	11	$230	1	$20	13	$670	$35,658
TAR-01#	0	$0	5	$520	0	$0	8	$1,510	$196,234
TAR-02#	0	$0	12	$1,400	0	$0	13	$1,980	$224,337
MOU-01#	1	$60	5	$290	1	$80	11	$120	$96,916
MOU-02#	0	$0	6	$300	0	$0	17	$960	$89,970

* *worst historic flood on record is 2015*

\# *worst historic flood on record is 2010*

† *worst historic flood on record is 2013*

8 Discussion

It is important to note that flood damage can vary significantly from one place to another and within different parts of a city/town depending on factors such as age of buildings, socio-economic backgrounds, etc. The flood damage curves used within this study were not derived from local data in the BSC region. Therefore, this could lead to an inaccurate estimate of flood damage. However, steps have been undertaken in an attempt to reduce uncertainty, such as applying local data (i.e. house prices) were applied, albeit, mean values.

The flood damage estimates have been undertaken using data available. Steps have been undertaken in an attempt to improve these estimates, but they should be treated with a certain level of caution. Further justification for this level of caution is discussed below.

The buildings used within the Geoscience Australia study were of medium quality in terms of fit-out. The effect of different qualities of fit-out has not been considered.

The application of mean house prices on residential damage estimation could significantly skew the results, if only certain suburbs are affected by flooding which are of a higher or lower social-economic status. Application of a mean value assumes that a range of socio-economic suburbs will be equally affected.

It should be noted that structural damage has not been incorporated into the damage assessment and if structural damage is possible, additional damage assessment is needed. We have examined the velocity profile across residential areas and do not consider these to be above the depth-velocity threshold derived by Dale et al (2004) and later examined by Middelmann-Fernandes (2010) for destruction of property.

In the past tangible damages have been reduced by a factor that represents prior flood experience and warning time as suggested by Read Sturgess (2000). The reduced figure is referred to as the likely actual damage. However, as part of this study the residential depth-damage indices prepared by Geoscience Australia assume that residents act to protect their property, so for residential damage, the difference between potential flood damage and likely actual flood damage may be similar.

9 Conclusions and recommendations

Flood damages have been estimated for Biloela, Thangool, Jambin, Goovigen, Theodore, Dululu, Wowan, Taroom, Moura, and Baralaba. The analysis was undertaken using flood level data when available, and assumed levels elsewhere. Flood levels were taken from the hydraulic modelling prepared as part of the wider project.

The calculated Average Annual Damage (AAD) was calculated for both towns and is presented below:

- Biloela $792,063
- Thangool $100,160
- Jambin $174,654
- Goovigen $13,078
- Theodore $1,381,000
- Dululu $63,061
- Wowan $41,928
- Taroom $233,714
- Moura $100,403
- Baralaba $134,255.

This represents the level of investment that could be provided for flood mitigation each year.

Flood damages estimates are significantly larger for Theodore and Biloela, which is attributed to the greater number of buildings affected by flooding. It should also be noted that the AAD presented does not include damages associated with infrastructure, agriculture, etc.

Flood damages were also assessed for a number of mitigation options. The resulting AAD for these options are presented below:

- BIL-Combination1 $558,540
- BIL-08 $784,357
- THA-Combination1 $70,629
- THA-03 $99,352
- JAM-Combination1 $127,554

- THE-01 $1,193,851
- THE-02 $1,407,581
- THE-Combination1 $1,495,946
- THE-05 $1,255,220
- DUL-01 $27,174
- DUL-02 $49,696
- WOW-Combination1 $35,658
- TAR-01 $196,234
- TAR-02 $224,337
- MOU-01 $96,916
- MOU-02 $89,970.

The following recommendations can be made:

- The damage estimates have been undertaken using the best information available, but should be regarded as illustrative. There are numerous opportunities to improve the accuracy of the estimates, but the benefits may not provide sufficient justification.
- Often Councils are required to estimate their flood damages within a very short period after a disaster to claim subsidies. Thought should be given to including some of the longer term clean-up costs, hidden repairs that arise later, etc., which otherwise might be excluded from a disaster claim.

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Appendix B

COST ESTIMATES

Appendix B
Cost estimates

BACKGROUND

KBR has been engaged by the Banana Shire Council (BSC) Queensland, Australia, to complete a Floodplain Management Study and Plan. As part of this study, KBR is required to complete cost comparisons for flood mitigation options proposed.

This desktop study has reviewed the cost components (i.e. capital and operational costs) of the proposed structural flood risk mitigation options and scenarios. The capital works proposed largely consist of flood levee construction, either as earthen bunds or vertical concrete walls. Some options also consider lifting high set timber houses and voluntary house purchasing.

The cost estimates completed look at various mitigation options for eight towns – Thangool, Biloela, Jambin, Dululu, Wowan, Taroom, Theodore, and Moura. Each of the options was priced for the purpose of the benefit-cost analysis and comparison with other alternative scenarios where applicable.

SUMMARY

The mitigation schemes are listed below and the estimated scenario costs are summarised in Table B1. More information on each option is provided in Section 4.2 of the Structural Measures Report including figures showing the layout of each flood mitigation option.

The cost estimates prepared for this study are considered a Class 4 Capex estimate (Concept Study, Pre-Feasibility, Selection and or Pre-Funding Stage). Adequate historical rates and project norms have been used to provide an accuracy of +/ 40%.

The bulk earthwork rates used assume at least 1 km of levee is built in a single location. In the event of a smaller length of levee being built the rates will need to be reviewed accordingly.

It is noted that the investigation of mitigation options is at a preliminary stage and it is expected that more detailed investigations will be undertaken by Council. This includes geotechnical assessments, preliminary design and more detailed capital cost estimates if the benefit-cost analysis has a positive outcome.

It is advised that allocation of project budgets or implementation of proposed schemes should not be considered until feasibility level design is completed, following which cost estimates could be refined to a more accurate level.

These cost estimates have been prepared to inform the benefit-cost analysis only and should be considered with reference to the commentary in this report.

Table B1 Summary of estimated mitigation capital costs

Option ID	Description	Comment	Total Option Cost ($'000)	Total Scenario Cost ($'000)
Thangool				
THA-01	Local levee to protect Thangool properties	There is space for this levee to be built; construction is feasible and impacts are minor.	$4,850	THA-Combination 1 $6,849
THA-02	Local levee to protect the Primary School	There is space for this levee to be built; construction is feasible and impacts are minor.	$1,999	
THA-03	Raise flood affected homes	Likely to cost less than THA-01 and can be implemented in stages.	$160	$160
THA-04	Relocate primary school		KBR is unable to estimate this cost	
Biloela				
BIL-01	Baileys Lane Levee	Benefits to residents behind the levee. Some large impacts to adjacent areas.	$11,235	BIL-Combination 1 $39,516
BIL-02a	Hills Ave levee	Benefits to residents behind the levee. Flood impacts are less than 300 mm.	$9,725	
BIL-02b	Joe Kooyman Drive Levee	Benefits to residents behind the levee. Constrained by Browns Gully.	$3,694	
BIL-03a	Tognolini Baldwin Road levee	Benefits to residents behind the levee. Flood impacts are 300-400 mm immediately upstream of the raised Dawson Highway.	$13,116	
BIL-03b	Alexandria Ave Levee	Benefits to residents behind the levee. Some sections of levee would be very high (5.0 m).	$1,746	
BIL-04	Raise Muirs Road	Provides additional evacuation time.	$2,567	$2,567
BIL-05	Raise Valentine Plains Road		Not recommended	
BIL-06	Valentine Plains crossing of Brown's gully		Completed	
BIL-07	Washpool Gully diversion into Callide Creek		Not recommended	
BIL-08	Buyback and removal of most vulnerable homes on Muirs Rd	No other suitable alternatives.	$1,190	$1,190
Jambin				
JAM-01	Jambin Hotel levee	There is space for this levee to be built; construction is feasible and impacts are minor.	$2,346	JAM-Combination 1 $3,066
JAM-04	Raise flood affected homes	Raised flood affected properties in combination with JAM-01.	$720	
JAM-02	Burnett Highway Bridge Extension		Not recommended	
JAM-03	Burnett Highway Lowering		Not recommended	

Option ID	Description	Comment	Total Option Cost ($'000)	Total Scenario Cost ($'000)
Dululu				
DUL-01	Dululu Levee	Benefits to residents behind the levee. Flood impacts are moderate.	$4,846	$4,846
DUL-02	Raise flood affected homes	Likely to cost less than DUL-01 and can be implemented in stages.	$800	$800
Wowan				
WOW-01	School levee	There is space for this levee to be built; construction is feasible and impacts are minor.	$286	WOW-Combination 1 $736
WOW-02	Fuel station levee	Constrained space but construction feasible and impacts are minor.	$370	
WOW-03	Raise flood affected homes	Raise high set houses in combination with WOW-01 and WOW-02.	$80	
Taroom				
TAR-01	Lions Park Levee		$9,136	$9,136
TAR-02	Raise flood affected homes and relocate roadhouse	Relocate Taroom Roadhouse to a flood free block and raise high set buildings. The estimate excludes the cost for relocating the roadhouse.	$960	$960
Theodore				
THE-01	Raise Gibbs Road & Levee	Benefits to residents behind the levee. Raising Gibbs Road has moderate impacts.	$25,254	$25,254
THE-02	Castle Creek Levee	Levee built along old railway.	$7,865	$7,865
THE-03	Town Levee	Town levee for protection up to 142 mAHD. Impacts in town of 150mm in the 2010 event.	$8,529	THE-Combination 1 $9,729
THE-04	Raise flood affected homes	In combination with levee option THE-03, raise stumped houses outside levee.	$1,200	
THE-05	Raise flood affected homes	Raised stumped houses that are below 2% AEP	$5,680	$5,680
THE-06	Migrate the town to Moura		Not recommended	
DAM-01	Nathan Dam		KBR is unable to estimate this cost	
Moura				
MOU-01	River Road levee	Benefits to residents behind the levee. Flood impacts are minor.	$8,123	$8,123
MOU-02	Raise flood affected homes	Likely to cost less than MOU-01 and can be implemented in stages.	$240	$240
DAM-01	Nathan Dam		KBR is unable to estimate this cost	

BASIS OF QUANTITIES

Quantities were developed by the design engineers from concept level sketches (shown below), and standard engineering practices associated with an assumed levee alignment, depths of fill required and drainage needs. No design drawings have been completed and no geotechnical or surveying has been done at this stage of this study.

Volumes for minor levees, civil works and vegetation clearing were generally estimated using appropriate GIS tools and aerial imagery. Structures such as concrete walls, concrete box culverts, kerbs and road resurfacing quantities were developed from existing drawings of similar works.

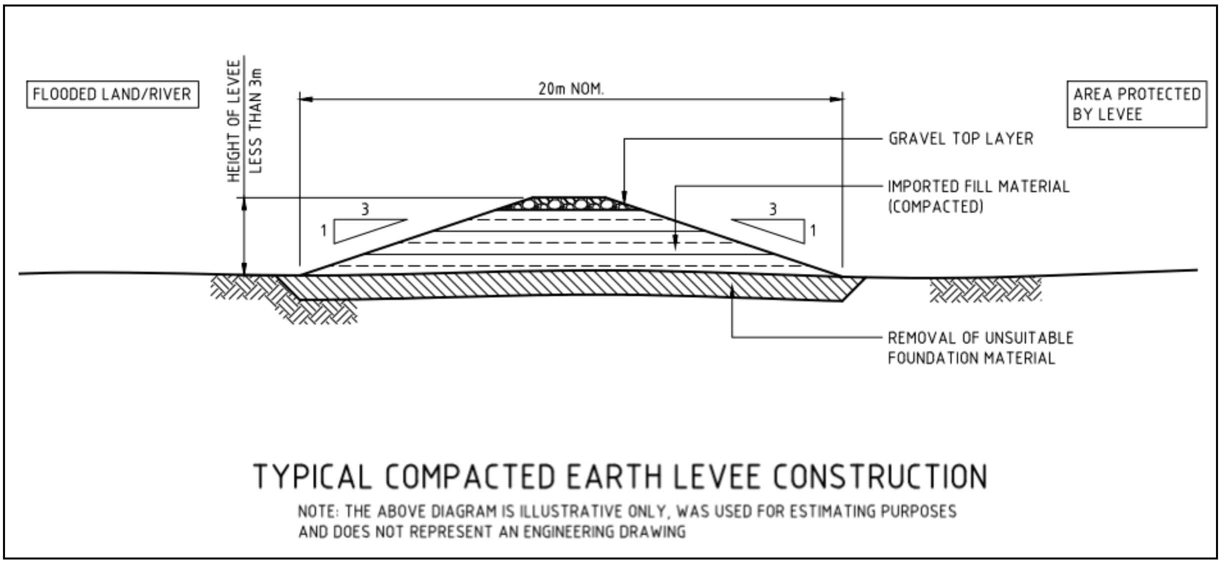

Figure B1
TYPICAL COMPACTED EARTH LEVEE CONSTRUCTION

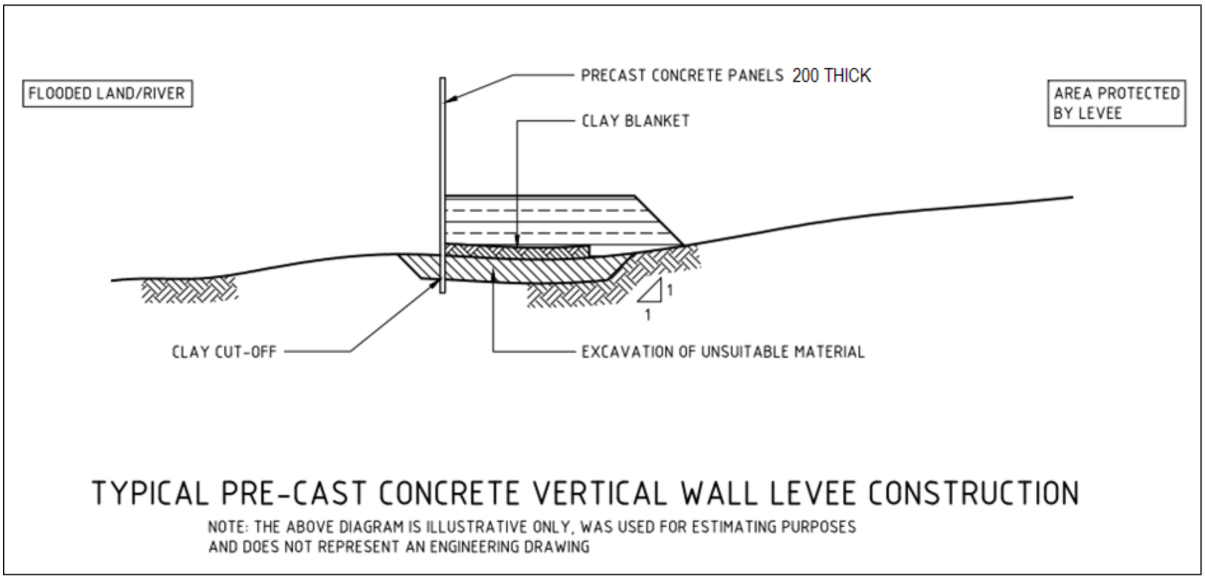

Figure B2
TYPICAL PRE-CAST CONCRETE VERTICAL WALL LEVEE CONSTRUCTION

BASIS OF ALL-IN RATES

Levee Construction

The majority of the all-in unit rates used in this cost estimate are generally made up by three major components: material cost; labour cost and contractor distributable. These rates have been benched marked against the KBR in-house rate library, known project costs in the area and ‘Rawlinson’s Estimating Manual 2016’.

The all-in unit rates have been compiled as follows:

- Material: Budgetary quotations obtained from suppliers and or from previous projects and or historical escalated material rates
- Labour: Current all-in composite labour rates for all required trades
- Distributable: Historical allowance applied against labour cost consisting of contractor field construction plant & associated indirects.

The estimates for construction of earth levees and vertical L-shaped concrete levees typically comprise 60% pricing from the KBR in-house rate library and project experience, 15% from budget quotations and 25% from ‘Rawlinson’s Estimating Manual 2016’. The estimates for construction of street levees typically comprise 70% pricing from the KBR in-house rate library and project experience and 30% from ‘Rawlinson’s Estimating Manual 2016’.

The precast concrete panels for vertical L-shaped levees are nominally based on a 200 mm thick panel.

House lifting

The cost of raising a dwelling varies with the size of the building, type of construction, whether slab on ground, timber or brick and the space available around the building. From previous Flood Management Plans and Studies in Central Queensland, costs to raise a slab on ground house (standard 3 bedroom) can be $250,000 or more and the costs to raise a timber house (standard 3 bedroom) are approximately $80,000. If a large number of homes in one town were raised as a single project then a bulk rate may be negotiable to reduce the total project cost. It is recommended that these figures are confirmed by Council through regional suppliers for more appropriate figures for the BSC LGA.

The makeup of flood affected house type (slab on ground, low set and high set) is only known for limited parts of the Callide Valley. In other areas the house type is speculated based on aerial imagery and from staff site inspections. The ability of each flood affected property to be raised has to be assessed on a case by case basis as the cost of raising a building is affected by building area, ease of access, services, etc.

There are some indirect benefits of raising homes instead of building levees. This includes reduced property insurance premiums for individuals. Council would also benefit by not paying insurance for a levee, avoid additional public liability insurance and save on maintenance of the levee. These benefits have not been taken into account at this stage.

Building removal

Where no alternative structural measures are suitable for a property and the residual flood risk is too high, building buyback by Council and removal is an option. Council may then remove the building and rezone the land for other purposes that are commensurate with the high flood risk.

The 2013 BSC Statistical Profile (stat.abs.gov.au) suggests that the median house price for the BSC LGA is $277,500 (standard 3 bedroom including land).

LEVEL OF ACCURACY

The estimate is considered to be concept level only, complete for the purpose of benefit-cost analysis as a part of the BSC Floodplain Management Study. The level of accuracy is considered to be no better that ±40%.

It should be noted that the cost estimates are very sensitive to the unit rates associated with construction of levees. The greatest risk to this accuracy is geotechnical information which impacts the bulk civil works. Without geotechnical information to verify the source of material and likely construction methodology it is difficult to accurately quantify these construction costs. It is more likely that the costs would increase within the stated level of accuracy.

The estimates are however considered more than adequate for the comparison of flood mitigation options.

ASSUMPTIONS

The following assumptions/statements are relevant to the completed cost estimates:

- The estimate base date is Q3 2016. No forward escalation is included.
- It is assumed that no contaminated material will be encountered during the work such as asbestos, oil contaminant etc.
- Levee height has been preliminary based on the existing DFE flood level plus 0.3 m freeboard allowance. Final levee height and alignment is subject to further study.
- No geotechnical studies, or design works have been completed for any of the structural mitigation components discussed. Levee costs are based on an assumed construction methodology and on assumed levee heights and locations.
- There have been no detailed environmental or cultural heritage investigations, and as such additional costs are entirely possible, or levee alignments and heights may be affected.
- There has been no detailed site investigation undertaken.
- Levee alignments for the purpose of cost estimation have been refined using a combination of aerial photographs, cadastres and DEM.
- It is assumed that works are complete as a single project/programme of works. Staged construction methodology may result in additional costs (e.g. mobilization/demobilization costs for contractor, loss of efficiencies, etc.).
- The estimate has been compiled based on a D&C project delivery methodology and 90% of local labour utilisation.

Unit rates for several cost items are based on Brisbane estimates with an additional 20% to account for regional location differences as per Rawlinsons 2016.

The following allowances have been made with respect to project implementation costs:

- Allowance for design and quantities growth – 5%
- Preliminaries – 0% (contractor pricing, pre-site establishment, project management, set up costs are included in the All-in rates contractor distributable component)
- Contractor overheads and profit – 0% (included in the All-in rates contractor distributable component)
- Project delivery fee – 6% (allowance for BSC project delivery, oversight and approvals)
- Design fee allowance – 10% (allowance for design fee cost including 2% for geotechnical studies)
- Estimating contingency – additional 20% to entire project cost to account for omissions and estimation errors (based on limited design works and lack of geotechnical information).

EXCLUSIONS

- There is no allowance for resumption of land, or compensation to land owners in the vicinity of the levees, or special cultural heritage and environmental requirements cost and schedule related issues.
- Detailed refinement of levee alignments is yet to occur.
- The prepared levee estimates do not include lighting or permanent fencing along the top of the levee banks.

- The prepared levee estimates cover only the capital cost of the project. Ongoing costs of maintenance, operational and periodic rework costs are included in a separate present value (NPV) calculations.
- House lifting estimates do not include internal renovations, stairwell extensions or landscaping. The temporary relocation of residents is also excluded.
- KBR is not able to provide a reliable estimate for relocation of the Taroom roadhouse (TAR 02) or the Thangool Primary School (THA-04).
- Goods and Services Tax (GST).

Appendix C

NPV CALCULATIONS

KBR

NPV Analysis - Biloela Scenario 1

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing		$ 792,063	= average annual damage																							
2013 Average Annual Damage (AAD) ($)	**15,053,995**	792,063	811,865	832,161	852,965	874,289	896,147	918,550	941,514	965,052	989,178	1,013,908	1,039,255	1,065,237	1,091,868	1,119,164	1,147,143	1,175,822	1,205,218	1,235,348	1,266,232	1,297,887	1,330,335	1,363,593	1,397,683	1,432,625

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18																										
CAPITAL COSTS ($)	**39,516,000**	$ 39,516,000																								
OPERATIONAL COSTS($)	**3,557,637**	n/a	202,520	207,582	212,772	218,091	223,544	229,132	234,861	240,732	246,750	252,919	259,242	265,723	272,366	279,175	286,155	293,309	300,641	308,157	315,861	323,758	331,852	340,148	348,652	357,368
TOTAL NPV ($)	**43,073,637**																									
Post mitigation Average Annual Damage (AAD)		$ 558,540	572,504	586,816	601,486	616,524	631,937	647,735	663,929	680,527	697,540	714,978	732,853	751,174	769,954	789,202	808,932	829,156	849,885	871,132	892,910	915,233	938,114	961,566	985,606	1,010,246
NPV of Reduced AAD	**10,615,643**																									
TOTAL	$ 53,689,280	Green if econoimc, red if not economic																								

Tangible costs only			
Total benefit	$ 4,438,351	BCR	0.10
Total cost	$ 43,073,637		

SUMMARY TABLE

		Estimate
Existing (do nothing) AAD	$	790,000
Existing (do nothing) AAD NPV	**$**	**15,050,000**
Capital cost	$	39,520,000
Capital cost NPV	$	39,520,000
Operational cost NPV	$	3,560,000
Total cost NPV	**$**	**43,070,000**
BIL-01 AAD	$	560,000
BIL-01 NPV	**$**	**10,620,000**
Total benefit	**$**	**4,440,000**
BCR		**0.10**

KBR

NPV Analysis - Biloela Scenario 2

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Option 0 Do nothing		$ 792,063	= average annual damage											
2013 Average Annual Damage (AAD) ($)	**15,053,995**	792,063	811,865	832,161	852,965	874,289	896,147	918,550	941,514	965,052	989,178	1,013,908	1,039,255	1,065,237

	14	15	16	17	18	19	20	21	22	23	24	25
	2029/30	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing												
2013 Average Annual Damage (AAD) ($)	1,091,868	1,119,164	1,147,143	1,175,822	1,205,218	1,235,348	1,266,232	1,297,887	1,330,335	1,363,593	1,397,683	1,432,625

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Scenario 18														
CAPITAL COSTS ($)	**1,190,000**	$ 1,190,000												
OPERATIONAL COSTS($)	**0**	n/a	6,099	6,251	6,407	6,568	6,732	6,900	7,073	7,249	7,431	7,617	7,807	8,002
TOTAL NPV ($)	**1,190,000**													
Post mitigation Average Annual Damage (AAD)		$ 784,357	803,966	824,065	844,667	865,783	887,428	909,614	932,354	955,663	979,554	1,004,043	1,029,144	1,054,873
NPV of Reduced AAD	**14,907,534**													
TOTAL	$ 16,097,534	Green if econoimc, red if not economic												

	14	15	16	17	18	19	20	21	22	23	24	25
	2029/30	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)	8,202	8,407	8,617	8,833	9,054	9,280	9,512	9,750	9,994	10,243	10,499	10,762
Post mitigation Average Annual Damage (AAD)	1,081,245	1,108,276	1,135,983	1,164,382	1,193,492	1,223,329	1,253,912	1,285,260	1,317,392	1,350,327	1,384,085	1,418,687

Tangible costs only				
Total benefit	$	146,461	BCR	0.12
Total cost	$	1,190,000		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	790,000
Existing (do nothing) AAD NPV	**$**	**15,050,000**
Capital cost	$	1,190,000
Capital cost NPV	$	1,190,000
Operational cost NPV	$	-
Total cost NPV	**$**	**1,190,000**
BIL-01 AAD	$	780,000
BIL-01 NPV	**$**	**14,910,000**
Total benefit	**$**	**150,000**
BCR		**0.12**

KBR

NPV Analysis - Theodore Scenario 1

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Option 0 Do nothing		$ 1,380,699	= average annual damage											
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,380,699	1,415,216	1,450,597	1,486,862	1,524,033	1,562,134	1,601,188	1,641,217	1,682,248	1,724,304	1,767,411	1,811,597	1,856,887

	Year:	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,903,309	1,950,892	1,999,664	2,049,655	2,100,897	2,153,419	2,207,255	2,262,436	2,318,997	2,376,972	2,436,396	2,497,306

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Scenario 18														
CAPITAL COSTS ($)	**25,254,000**	$ 25,254,000												
OPERATIONAL COSTS($)	**2,273,625**	n/a	129,427	132,662	135,979	139,378	142,863	146,434	150,095	153,848	157,694	161,636	165,677	169,819
TOTAL NPV ($)	**27,527,625**													
Post mitigation Average Annual Damage (AAD)		$ 1,193,851	1,223,697	1,254,290	1,285,647	1,317,788	1,350,733	1,384,501	1,419,114	1,454,592	1,490,956	1,528,230	1,566,436	1,605,597
NPV of Reduced AAD	**22,690,400**													
TOTAL	$ 50,218,025	Green if econoimc, red if not economic												

	Year:	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)		174,065	178,416	182,877	187,449	192,135	196,938	201,862	206,908	212,081	217,383	222,817	228,388
Post mitigation Average Annual Damage (AAD)		1,645,737	1,686,880	1,729,052	1,772,279	1,816,585	1,862,000	1,908,550	1,956,264	2,005,170	2,055,300	2,106,682	2,159,349

Tangible costs only				
Total benefit	$	3,551,244	BCR	0.13
Total cost	$	27,527,625		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	1,380,000
Existing (do nothing) AAD NPV	**$**	**26,240,000**
Capital cost	$	25,250,000
Capital cost NPV	$	25,250,000
Operational cost NPV	$	2,270,000
Total cost NPV	**$**	**27,530,000**
BIL-01 AAD	$	1,190,000
BIL-01 NPV	**$**	**22,690,000**
Total benefit	**$**	**3,550,000**
BCR		**0.13**

KBR

NPV Analysis - Theodore Scenario 2

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%

Inflate by CPI each year 2.50%	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 1,380,699	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,380,699	1,415,216	1,450,597	1,486,862	1,524,033	1,562,134	1,601,188	1,641,217	1,682,248	1,724,304	1,767,411	1,811,597

Inflate by CPI each year 2.50%	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	1,856,887	1,903,309	1,950,892	1,999,664	2,049,655	2,100,897	2,153,419	2,207,255	2,262,436	2,318,997	2,376,972	2,436,396	2,497,306

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**7,865,000**	$ 7,865,000											
OPERATIONAL COSTS($)	**708,088**	n/a	40,308	41,316	42,349	43,407	44,493	45,605	46,745	47,914	49,112	50,339	51,598
TOTAL NPV ($)	**8,573,088**												
Post mitigation Average Annual Damage (AAD)		$ 1,407,581	1,442,771	1,478,840	1,515,811	1,553,706	1,592,549	1,632,362	1,673,171	1,715,001	1,757,876	1,801,823	1,846,868
NPV of Reduced AAD	**26,752,565**												
TOTAL	$ 35,325,653	Green if econoimc, red if not economic											

	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18													
CAPITAL COSTS ($)													
OPERATIONAL COSTS($)	52,888	54,210	55,565	56,954	58,378	59,838	61,334	62,867	64,439	66,050	67,701	69,393	71,128
TOTAL NPV ($)													
Post mitigation Average Annual Damage (AAD)	1,893,040	1,940,366	1,988,875	2,038,597	2,089,562	2,141,801	2,195,346	2,250,230	2,306,485	2,364,148	2,423,251	2,483,832	2,545,928
NPV of Reduced AAD													
TOTAL													

Tangible costs only				
Total benefit	-$	510,921	BCR	-0.06
Total cost	$	8,573,088		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	1,380,000
Existing (do nothing) AAD NPV	**$**	**26,240,000**
Capital cost	$	7,870,000
Capital cost NPV	$	7,870,000
Operational cost NPV	$	710,000
Total cost NPV	**$**	**8,570,000**
BIL-01 AAD	$	1,410,000
BIL-01 NPV	**$**	**26,750,000**
Total benefit	**-$**	**510,000**
BCR		**-0.06**

KBR

NPV Analysis - Theodore Scenario 3

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Present Value	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28
Year:		1	2	3	4	5	6	7	8	9	10	11	12
Option 0 Do nothing		$ 1,380,699	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,380,699	1,415,216	1,450,597	1,486,862	1,524,033	1,562,134	1,601,188	1,641,217	1,682,248	1,724,304	1,767,411	1,811,597

	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41
Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	1,856,887	1,903,309	1,950,892	1,999,664	2,049,655	2,100,897	2,153,419	2,207,255	2,262,436	2,318,997	2,376,972	2,436,396	2,497,306

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Present Value	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28
Year:		1	2	3	4	5	6	7	8	9	10	11	12
Scenario 18													
CAPITAL COSTS ($)	**9,729,000**	$ 8,529,000											
OPERATIONAL COSTS($)	**767,868**	n/a	43,711	44,804	45,924	47,072	48,249	49,455	50,692	51,959	53,258	54,589	55,954
TOTAL NPV ($)	**10,496,868**												
Post mitigation Average Annual Damage (AAD)		$ 1,495,946	1,533,345	1,571,678	1,610,970	1,651,244	1,692,526	1,734,839	1,778,210	1,822,665	1,868,232	1,914,937	1,962,811
NPV of Reduced AAD	**28,432,035**												
TOTAL	$ 38,928,903	Green if econoimc, red if not economic											

	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41
Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
Scenario 18													
CAPITAL COSTS ($)													
OPERATIONAL COSTS($)	57,353	58,787	60,256	61,763	63,307	64,889	66,512	68,174	69,879	71,626	73,416	75,252	77,133
TOTAL NPV ($)													
Post mitigation Average Annual Damage (AAD)	2,011,881	2,062,178	2,113,733	2,166,576	2,220,740	2,276,259	2,333,165	2,391,494	2,451,282	2,512,564	2,575,378	2,639,762	2,705,756
NPV of Reduced AAD													
TOTAL													

Tangible costs only				
Total benefit	-$	2,190,391	BCR	-0.21
Total cost	$	10,496,868		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	1,380,000
Existing (do nothing) AAD NPV	**$**	**26,240,000**
Capital cost	$	8,530,000
Capital cost NPV	$	9,730,000
Operational cost NPV	$	770,000
Total cost NPV	**$**	**10,500,000**
BIL-01 AAD	$	1,500,000
BIL-01 NPV	**$**	**28,430,000**
Total benefit	**-$**	**2,190,000**
BCR		**-0.21**

Cost Breakdown	
House Raising	$ 1,200,000.00
Levee	$ 8,529,000.00

KBR

NPV Analysis - Theodore Scenario 4

Project Title:	Banana Shire Council Flood Study			
Input	JL		Project No.:	BEW455
Checked:	JA		Date:	24/08/16
Approved:	AC			

NPV Calculation

Discount Period for NPV Analysis 25 years
Discount Rate for NPV Analysis 5%
Inflate by CPI each year 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 1,380,699	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,380,699	1,415,216	1,450,597	1,486,862	1,524,033	1,562,134	1,601,188	1,641,217	1,682,248	1,724,304	1,767,411	1,811,597

	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing														
2013 Average Annual Damage (AAD) ($)	**26,241,644**	1,856,887	1,903,309	1,950,892	1,999,664	2,049,655	2,100,897	2,153,419	2,207,255	2,262,436	2,318,997	2,376,972	2,436,396	2,497,306

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**5,680,000**	$ 5,680,000											
OPERATIONAL COSTS($)	**0**	n/a	29,110	29,838	30,584	31,348	32,132	32,935	33,759	34,603	35,468	36,354	37,263
TOTAL NPV ($)	**5,680,000**												
Post mitigation Average Annual Damage (AAD)		$ 1,255,220	1,286,601	1,318,766	1,351,735	1,385,528	1,420,166	1,455,670	1,492,062	1,529,364	1,567,598	1,606,788	1,646,957
NPV of Reduced AAD	**23,856,783**												
TOTAL	$ 29,536,783	Green if econoimc, red if not economic											

	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18														
CAPITAL COSTS ($)	**5,680,000**													
OPERATIONAL COSTS($)	**0**	38,195	39,150	40,128	41,132	42,160	43,214	44,294	45,402	46,537	47,700	48,893	50,115	51,368
TOTAL NPV ($)	**5,680,000**													
Post mitigation Average Annual Damage (AAD)		1,688,131	1,730,335	1,773,593	1,817,933	1,863,381	1,909,966	1,957,715	2,006,658	2,056,824	2,108,245	2,160,951	2,214,975	2,270,349
NPV of Reduced AAD	**23,856,783**													
TOTAL	$ 29,536,783													

Tangible costs only				
Total benefit	$	2,384,861	BCR	0.42
Total cost	$	5,680,000		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	1,380,000
Existing (do nothing) AAD NPV	**$**	**26,240,000**
Capital cost	$	5,680,000
Capital cost NPV	$	5,680,000
Operational cost NPV	$	-
Total cost NPV	**$**	**5,680,000**
BIL-01 AAD	$	1,260,000
BIL-01 NPV	**$**	**23,860,000**
Total benefit	**$**	**2,380,000**
BCR		**0.42**

KBR

NPV Analysis - Thangool Scenario 1

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

Year:		1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 100,160	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**1,903,647**	100,160	102,664	105,231	107,861	110,558	113,322	116,155	119,059	122,035	125,086	128,213	131,419

Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	134,704	138,072	141,523	145,062	148,688	152,405	156,215	160,121	164,124	168,227	172,433	176,743	181,162

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

Year:		1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**6,849,000**	$ 6,849,000											
OPERATIONAL COSTS($)	**616,617**	n/a	35,101	35,979	36,878	37,800	38,745	39,714	40,707	41,724	42,767	43,836	44,932
TOTAL NPV ($)	**7,465,617**												
Post mitigation Average Annual Damage (AAD)		$ 70,629	72,395	74,205	76,060	77,961	79,910	81,908	83,956	86,055	88,206	90,411	92,671
NPV of Reduced AAD	**1,342,379**												
TOTAL	$ 8,807,996	Green if econoimc, red if not economic											

Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18													
CAPITAL COSTS ($)													
OPERATIONAL COSTS($)	46,056	47,207	48,387	49,597	50,837	52,108	53,411	54,746	56,114	57,517	58,955	60,429	61,940
TOTAL NPV ($)													
Post mitigation Average Annual Damage (AAD)	94,988	97,363	99,797	102,292	104,849	107,470	110,157	112,911	115,734	118,627	121,593	124,633	127,749

Tangible costs only				
Total benefit	$	561,268	BCR	0.08
Total cost	$	7,465,617		

SUMMARY TABLE

		Estimate
Existing (do nothing) AAD	$	100,000
Existing (do nothing) AAD NPV	**$**	**1,900,000**
Capital cost	$	6,850,000
Capital cost NPV	$	6,850,000
Operational cost NPV	$	620,000
Total cost NPV	**$**	**7,470,000**
BIL-01 AAD	$	70,000
BIL-01 NPV	**$**	**1,340,000**
Total benefit	**$**	**560,000**
BCR		**0.08**

KBR

NPV Analysis - Thangool Scenario 2

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis 25 years
Discount Rate for NPV Analysis 5%

Inflate by CPI each year	2.50%	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing			$ 100,160	= average annual damage																							
2013 Average Annual Damage (AAD) ($)		**1,903,647**	100,160	102,664	105,231	107,861	110,558	113,322	116,155	119,059	122,035	125,086	128,213	131,419	134,704	138,072	141,523	145,062	148,688	152,405	156,215	160,121	164,124	168,227	172,433	176,743	181,162

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year 2.50%
Operational costs = 0.50% of capital costs

		Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18																											
CAPITAL COSTS ($)		**160,000**	$ 160,000																								
OPERATIONAL COSTS($)		**0**	n/a	820	841	862	883	905	928	951	975	999	1,024	1,050	1,076	1,103	1,130	1,159	1,188	1,217	1,248	1,279	1,311	1,344	1,377	1,412	1,447
TOTAL NPV ($)		**160,000**																									
Post mitigation Average Annual Damage (AAD)			$ 99,352	101,836	104,382	106,991	109,666	112,408	115,218	118,098	121,051	124,077	127,179	130,358	133,617	136,958	140,382	143,891	147,489	151,176	154,955	158,829	162,800	166,870	171,042	175,318	179,701
	NPV of Reduced AAD	**1,888,290**																									
	TOTAL	$ 2,048,290	Green if econoimc, red if not economic																								

Tangible costs only				
Total benefit	$	15,357	BCR	0.10
Total cost	$	160,000		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	100,000
Existing (do nothing) AAD NPV	**$**	**1,900,000**
Capital cost	$	160,000
Capital cost NPV	$	160,000
Operational cost NPV	$	-
Total cost NPV	**$**	**160,000**
BIL-01 AAD	$	100,000
BIL-01 NPV	**$**	**1,890,000**
Total benefit	**$**	**20,000**
BCR		**0.10**

NPV Analysis - Jambin Scenario 1

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing		$ 174,654	= average annual damage																							
2013 Average Annual Damage (AAD) ($)	**3,319,484**	174,654	179,020	183,496	188,083	192,785	197,605	202,545	207,609	212,799	218,119	223,572	229,161	234,890	240,762	246,782	252,951	259,275	265,757	272,401	279,211	286,191	293,346	300,679	308,196	315,901

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18																										
CAPITAL COSTS ($)	**3,066,000**	$ 2,346,000																								
OPERATIONAL COSTS($)	**211,211**	n/a	12,023	12,324	12,632	12,948	13,271	13,603	13,943	14,292	14,649	15,015	15,391	15,776	16,170	16,574	16,989	17,413	17,849	18,295	18,752	19,221	19,701	20,194	20,699	21,216
TOTAL NPV ($)	**3,277,211**																									
Post mitigation Average Annual Damage (AAD)		$ 127,554	130,743	134,011	137,362	140,796	144,316	147,924	151,622	155,412	159,297	163,280	167,362	171,546	175,835	180,230	184,736	189,355	194,088	198,941	203,914	209,012	214,237	219,593	225,083	230,710
NPV of Reduced AAD	**2,424,299**																									
TOTAL	$ 5,701,510	Green if econoimc, red if not economic																								

Tangible costs only				
Total benefit	$	895,185	BCR	0.27
Total cost	$	3,277,211		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	170,000
Existing (do nothing) AAD NPV	**$**	**3,320,000**
Capital cost	$	2,350,000
Capital cost NPV	$	3,070,000
Operational cost NPV	$	210,000
Total cost NPV	**$**	**3,280,000**
BIL-01 AAD	$	130,000
BIL-01 NPV	**$**	**2,420,000**
Total benefit	**$**	**900,000**
BCR		**0.27**

Cost Breakdown	
House Raising	720000
Levee	2346000

KBR

NPV Analysis - Dululu Scenario 1

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing		$ 63,061	= average annual damage																							
2013 Average Annual Damage (AAD) ($)	**1,198,541**	63,061	64,638	66,253	67,910	69,608	71,348	73,131	74,960	76,834	78,755	80,723	82,741	84,810	86,930	89,104	91,331	93,614	95,955	98,354	100,812	103,333	105,916	108,564	111,278	114,060

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18																										
CAPITAL COSTS ($)	**4,846,000**	$ 4,846,000																								
OPERATIONAL COSTS($)	**436,287**	n/a	24,836	25,457	26,093	26,745	27,414	28,099	28,802	29,522	30,260	31,016	31,792	32,587	33,401	34,236	35,092	35,970	36,869	37,791	38,735	39,704	40,696	41,714	42,757	43,825
TOTAL NPV ($)	**5,282,287**																									
Post mitigation Average Annual Damage (AAD)		$ 27,174	27,853	28,550	29,263	29,995	30,745	31,514	32,301	33,109	33,937	34,785	35,655	36,546	37,460	38,396	39,356	40,340	41,348	42,382	43,442	44,528	45,641	46,782	47,952	49,150
NPV of Reduced AAD	**516,471**																									
TOTAL	$ 5,798,757	Green if econoimc, red if not economic																								

Tangible costs only				
Total benefit	$	682,070	BCR	0.13
Total cost	$	5,282,287		

SUMMARY TABLE

		Estimate
Existing (do nothing) AAD	$	60,000
Existing (do nothing) AAD NPV	**$**	**1,200,000**
Capital cost	$	4,850,000
Capital cost NPV	$	4,850,000
Operational cost NPV	$	440,000
Total cost NPV	**$**	**5,280,000**
BIL-01 AAD	$	30,000
BIL-01 NPV	**$**	**520,000**
Total benefit	**$**	**680,000**
BCR		**0.13**

KBR

NPV Analysis - Dululu Scenario 2

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

Year:		1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 63,061	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**1,198,541**	63,061	64,638	66,253	67,910	69,608	71,348	73,131	74,960	76,834	78,755	80,723	82,741

Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	84,810	86,930	89,104	91,331	93,614	95,955	98,354	100,812	103,333	105,916	108,564	111,278	114,060

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

Year:		1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**800,000**	$ 800,000											
OPERATIONAL COSTS($)	**0**	n/a	4,100	4,203	4,308	4,415	4,526	4,639	4,755	4,874	4,995	5,120	5,248
TOTAL NPV ($)	**800,000**												
Post mitigation Average Annual Damage (AAD)		$ 49,696	50,938	52,212	53,517	54,855	56,226	57,632	59,073	60,550	62,063	63,615	65,205
NPV of Reduced AAD	**944,525**												
TOTAL	$ 1,744,525	Green if econoimc, red if not economic											

Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)	5,380	5,514	5,652	5,793	5,938	6,086	6,239	6,395	6,554	6,718	6,886	7,058	7,235
Post mitigation Average Annual Damage (AAD)	66,836	68,506	70,219	71,975	73,774	75,618	77,509	79,447	81,433	83,468	85,555	87,694	89,886

Tangible costs only				
Total benefit	$	254,016	BCR	0.32
Total cost	$	800,000		

SUMMARY TABLE

		Estimate
Existing (do nothing) AAD	$	60,000
Existing (do nothing) AAD NPV	**$**	**1,200,000**
Capital cost	$	800,000
Capital cost NPV	$	800,000
Operational cost NPV	$	-
Total cost NPV	**$**	**800,000**
BIL-01 AAD	$	50,000
BIL-01 NPV	**$**	**940,000**
Total benefit	**$**	**250,000**
BCR		**0.32**

NPV Analysis - Wowan Scenario 1

Project Title:	Banana Shire Council Flood Study
Input	JL
Checked:	JA
Approved:	AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis 25 years
Discount Rate for NPV Analysis 5%
Inflate by CPI each year 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Option 0 Do nothing		$ 41,928	= average annual damage											
2013 Average Annual Damage (AAD) ($)	**796,886**	41,928	42,976	44,051	45,152	46,281	47,438	48,624	49,839	51,085	52,362	53,671	55,013	56,388

	Year:	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	**796,886**	57,798	59,243	60,724	62,242	63,798	65,393	67,028	68,704	70,422	72,182	73,987	75,836

Enter

MITIGATION OPTIONS
Inflate costs by CPI each year 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**
Scenario 18														
CAPITAL COSTS ($)	**736,000**	$ 656,000												
OPERATIONAL COSTS($)	**59,060**	n/a	3,362	3,446	3,532	3,621	3,711	3,804	3,899	3,996	4,096	4,199	4,304	4,411
TOTAL NPV ($)	**795,060**													
Post mitigation Average Annual Damage (AAD)		$ 35,658	36,549	37,463	38,400	39,360	40,344	41,352	42,386	43,446	44,532	45,645	46,786	47,956
NPV of Reduced AAD	**677,718**													
TOTAL	$ 1,472,778	Green if econoimc, red if not economic												

	Year:	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)	**59,060**	4,522	4,635	4,750	4,869	4,991	5,116	5,244	5,375	5,509	5,647	5,788	5,933
Post mitigation Average Annual Damage (AAD)		49,155	50,384	51,643	52,935	54,258	55,614	57,005	58,430	59,891	61,388	62,922	64,496

Tangible costs only				
Total benefit	$	119,168	BCR	0.15
Total cost	$	795,060		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	40,000
Existing (do nothing) AAD NPV	**$**	**800,000**
Capital cost	$	660,000
Capital cost NPV	$	740,000
Operational cost NPV	$	60,000
Total cost NPV	**$**	**800,000**
BIL-01 AAD	$	40,000
BIL-01 NPV	**$**	**680,000**
Total benefit	**$**	**120,000**
BCR		**0.15**

Cost Breakdown	
House Raising	80000
Levee	656000

NPV Analysis - Taroom Scenario 1

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 233,714	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**4,441,982**	233,714	239,557	245,546	251,684	257,977	264,426	271,037	277,813	284,758	291,877	299,174	306,653

	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	314,319	322,177	330,232	338,488	346,950	355,623	364,514	373,627	382,968	392,542	402,355	412,414	422,725

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**9,136,000**	$ 9,136,000											
OPERATIONAL COSTS($)	**822,517**	n/a	46,822	47,993	49,192	50,422	51,683	52,975	54,299	55,657	57,048	58,474	59,936
TOTAL NPV ($)	**9,958,517**												
Post mitigation Average Annual Damage (AAD)		$ 196,324	201,232	206,263	211,419	216,705	222,123	227,676	233,368	239,202	245,182	251,311	257,594
NPV of Reduced AAD	**3,731,345**												
TOTAL	$ 13,689,862	Green if econoimc, red if not economic											

	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)	61,435	62,970	64,545	66,158	67,812	69,508	71,245	73,026	74,852	76,723	78,641	80,607	82,623
Post mitigation Average Annual Damage (AAD)	264,034	270,635	277,401	284,336	291,444	298,730	306,198	313,853	321,700	329,742	337,986	346,435	355,096

Tangible costs only				
Total benefit	$	710,636	BCR	0.07
Total cost	$	9,958,517		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	230,000
Existing (do nothing) AAD NPV	**$**	**4,440,000**
Capital cost	$	9,140,000
Capital cost NPV	$	9,140,000
Operational cost NPV	$	820,000
Total cost NPV	**$**	**9,960,000**
BIL-01 AAD	$	200,000
BIL-01 NPV	**$**	**3,730,000**
Total benefit	**$**	**710,000**
BCR		**0.07**

NPV Analysis - Taroom Scenario 2

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%

Inflate by CPI each year 2.50%	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 233,714	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**4,441,982**	233,714	239,557	245,546	251,684	257,977	264,426	271,037	277,813	284,758	291,877	299,174	306,653

	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
		2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing														
2013 Average Annual Damage (AAD) ($)		314,319	322,177	330,232	338,488	346,950	355,623	364,514	373,627	382,968	392,542	402,355	412,414	422,725

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**960,000**	$ 960,000											
OPERATIONAL COSTS($)	**0**	n/a	4,920	5,043	5,169	5,298	5,431	5,567	5,706	5,848	5,995	6,144	6,298
TOTAL NPV ($)	**960,000**												
Post mitigation Average Annual Damage (AAD)		$ 224,337	229,945	235,694	241,586	247,626	253,817	260,162	266,666	273,333	280,166	287,170	294,350
NPV of Reduced AAD	**4,263,762**												
TOTAL	$ 5,223,762	Green if econoimc, red if not economic											

	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
		2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
OPERATIONAL COSTS($)		6,455	6,617	6,782	6,952	7,126	7,304	7,486	7,674	7,865	8,062	8,264	8,470	8,682
Post mitigation Average Annual Damage (AAD)		301,708	309,251	316,982	324,907	333,030	341,355	349,889	358,636	367,602	376,792	386,212	395,867	405,764

Tangible costs only				
Total benefit	$	178,220	BCR	0.19
Total cost	$	960,000		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	230,000
Existing (do nothing) AAD NPV	**$**	**4,440,000**
Capital cost	$	960,000
Capital cost NPV	$	960,000
Operational cost NPV	$	-
Total cost NPV	**$**	**960,000**
BIL-01 AAD	$	220,000
BIL-01 NPV	**$**	**4,260,000**
Total benefit	**$**	**180,000**
BCR		**0.19**

KBR

NPV Analysis - Moura Scenario 1

Project Title:	Banana Shire Council Flood Study		
Input	JL	Project No.:	BEW455
Checked:	JA	Date:	24/08/16
Approved:	AC		

NPV Calculation

Discount Period for NPV Analysis	25 years
Discount Rate for NPV Analysis	5%

Inflate by CPI each year 2.50%	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 100,403	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**1,908,265**	100,403	102,913	105,486	108,123	110,826	113,597	116,437	119,348	122,331	125,390	128,524	131,737

Inflate by CPI each year 2.50%	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing														
2013 Average Annual Damage (AAD) ($)	**1,908,265**	135,031	138,407	141,867	145,413	149,049	152,775	156,594	160,509	164,522	168,635	172,851	177,172	181,602

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year	2.50%	
Operational costs =	0.50%	of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**8,123,000**	$ 8,123,000											
OPERATIONAL COSTS($)	**731,316**	n/a	41,630	42,671	43,738	44,831	45,952	47,101	48,278	49,485	50,723	51,991	53,290
TOTAL NPV ($)	**8,854,316**												
Post mitigation Average Annual Damage (AAD)		$ 96,916	99,339	101,822	104,368	106,977	109,652	112,393	115,203	118,083	121,035	124,061	127,162
NPV of Reduced AAD	**1,841,991**												
TOTAL	$ 10,696,307	Green if econoimc, red if not economic											

	Year:	13	14	15	16	17	18	19	20	21	22	23	24	25
	Present Value	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18														
CAPITAL COSTS ($)	**8,123,000**													
OPERATIONAL COSTS($)	**731,316**	54,623	55,988	57,388	58,823	60,293	61,801	63,346	64,929	66,552	68,216	69,922	71,670	73,461
TOTAL NPV ($)	**8,854,316**													
Post mitigation Average Annual Damage (AAD)		130,341	133,600	136,940	140,363	143,872	147,469	151,156	154,935	158,808	162,778	166,848	171,019	175,294
NPV of Reduced AAD	**1,841,991**													
TOTAL	$ 10,696,307													

Tangible costs only				
Total benefit	$	66,274	BCR	0.01
Total cost	$	8,854,316		

SUMMARY TABLE

	Estimate	
Existing (do nothing) AAD	$	100,000
Existing (do nothing) AAD NPV	**$**	**1,910,000**
Capital cost	$	8,120,000
Capital cost NPV	$	8,120,000
Operational cost NPV	$	730,000
Total cost NPV	**$**	**8,850,000**
BIL-01 AAD	$	100,000
BIL-01 NPV	**$**	**1,840,000**
Total benefit	**$**	**70,000**
BCR		**0.01**

KBR

NPV Analysis - Moura Scenario 2

Project Title: Banana Shire Council Flood Study
Input: JL
Checked: JA
Approved: AC

Project No.: BEW455
Date: 24/08/16

NPV Calculation

Discount Period for NPV Analysis: 25 years
Discount Rate for NPV Analysis: 5%
Inflate by CPI each year: 2.50%

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Option 0 Do nothing		$ 100,403	= average annual damage										
2013 Average Annual Damage (AAD) ($)	**1,908,265**	100,403	102,913	105,486	108,123	110,826	113,597	116,437	119,348	122,331	125,390	128,524	131,737

	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Option 0 Do nothing													
2013 Average Annual Damage (AAD) ($)	135,031	138,407	141,867	145,413	149,049	152,775	156,594	160,509	164,522	168,635	172,851	177,172	181,602

Enter

MITIGATION OPTIONS

Inflate costs by CPI each year: 2.50%
Operational costs = 0.50% of capital costs

	Year:	1	2	3	4	5	6	7	8	9	10	11	12
	Present Value	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Scenario 18													
CAPITAL COSTS ($)	**240,000**	$ 240,000											
OPERATIONAL COSTS($)	**0**	n/a	1,230	1,261	1,292	1,325	1,358	1,392	1,426	1,462	1,499	1,536	1,575
TOTAL NPV ($)	**240,000**												
Post mitigation Average Annual Damage (AAD)		$ 89,970	92,219	94,525	96,888	99,310	101,793	104,338	106,946	109,620	112,360	115,169	118,048
NPV of Reduced AAD	**1,709,975**												
TOTAL	$ 1,949,975	Green if econoimc, red if not economic											

	13	14	15	16	17	18	19	20	21	22	23	24	25
	2028/29	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/35**	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**
Scenario 18													
CAPITAL COSTS ($)													
OPERATIONAL COSTS($)	1,614	1,654	1,696	1,738	1,781	1,826	1,872	1,918	1,966	2,015	2,066	2,118	2,170
TOTAL NPV ($)													
Post mitigation Average Annual Damage (AAD)	121,000	124,025	127,125	130,303	133,561	136,900	140,322	143,831	147,426	151,112	154,890	158,762	162,731

Tangible costs only				
Total benefit	$	198,290	BCR	0.83
Total cost	$	240,000		

SUMMARY TABLE

		Estimate
Existing (do nothing) AAD	$	100,000
Existing (do nothing) AAD NPV	**$**	**1,910,000**
Capital cost	$	240,000
Capital cost NPV	$	240,000
Operational cost NPV	$	-
Total cost NPV	**$**	**240,000**
BIL-01 AAD	$	90,000
BIL-01 NPV	**$**	**1,710,000**
Total benefit	**$**	**200,000**
BCR		**0.83**

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