PYRENEES SHIRE

Raglan Flood Investigation

Draft Report on Flood Damages and Structural Options

Revision 1
May 2020

Catchment Simulation Solutions

Raglan Flood Investigation

Draft Report on Flood Damages and Structural Mitigation Options

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1 INTRODUCTION

1.1 Overview

The Raglan Flood Investigation was commissioned by Pyrenees Shire Council with financial support from the Victorian and Australian Governments as well as technical support from Glenelg Hopkins Catchment Management Authority (GHCMA). The purpose of the Raglan Flood Investigation is to develop information fundamental to provision of effective flood controls, flood response planning and building community resilience to flooding.

The following report provides a summary of the flood damage assessment undertaken to inform the flood investigation as well as assessment of potential structural mitigation options for mitigating the flood impacts on Raglan.

1.2 Catchment Description

The village of Raglan is located within the Fiery Creek catchment. Fiery Creek generally flows in a north-south direction and drains a catchment of just under 50 square kilometres to Raglan. The catchment upstream of Raglan comprises rural residential development, cleared grazing land and forested areas. In addition to Fiery Creek, there are a number of smaller unnamed tributaries that drain through Raglan and into Fiery Creek.

Raglan is home to around 230 people living primarily on rural residential lots comprising mostly low set single storey houses (Australian Bureau of Statistics, 2016). Most properties in Raglan also have other significant infrastructure such as large sheds. A public hall is also located within Raglan.

There is limited stormwater infrastructure within the town with no formalised stormwater system. The roadside areas are most commonly drained by roadside ditches which convey runoff to dedicated cross-drainage structures (e.g., culverts).

The floodplain is traversed by a number of significant roads, including Raglan-Elmhurst Road which is the major transportation link between Raglan and Elmhurst. This particular road embankment is typically elevated around 300 mm above the adjoining floodplain elevation and forms a significant hydraulic control. The Western Highway is located about 6 kilometres south of Raglan and forms the major east-west link between Beaufort and Ararat. This roadway embankment also serves as a significant hydraulic control, being elevated by more than 3 metres above the floodplain.

The Fiery Creek channel in the vicinity of Raglan is a natural channel of variable width/depth and condition. The creek width varies from around 6 metres upstream of Raglan to around 20 metres downstream of Raglan. Although much of the creek channel is well vegetated with good structural integrity, other sections of the creek show notable erosion. This is particularly evident directly north of Old Beaufort Road.

The study area for the flooding investigation extends along Fiery Creek from Pitchers Lane (located about 3 km upstream of Raglan) down to the Western Highway (located about 6 km downstream of Raglan). It also incorporates each of the major tributaries draining through Raglan and into Fiery Creek.

2 FLOOD DAMAGE ASSESSMENT

2.1 Property Database

A property database was developed as part of the study to enable flood damages calculations to be completed. The database was developed in GIS and included all habitable buildings located within the Probable Maximum Flood (PMF) extent. The following information was included as additional fields within the GIS database for each building:

- Generic property type (i.e., residential, shed etc);
- Building floor level – refer to the following sections for further information on how the building floor levels were defined;
- Building floor area; and
- Residential building type (i.e., two storey, single level high set or single level lowset).

The information contained in the property database was used with the design flood level information and depth-damage curves to establish a tangible flood damage estimate for each building located within Raglan for each design flood. Further information on how the flood damage estimates were established is provided below.

2.2 Building Floor Levels

It is necessary to have information describing the floor height / level of every building within the PMF extent to enable the number of properties subject to above floor flooding (and the associated damage cost) to be estimated.

For this study, a licensed surveyor was engaged by Pyrenees Shire Council to survey the floor levels of buildings within the PMF extent. This database covered all the residential properties located within the study area and included the following property information:

- Address/coordinates
- surveyed floor levels

The ground survey included all properties within the PMF extent, some additional properties were also estimated where they were within 100 m of the PMF in case the proposed mitigation measures affected these properties.

The floor levels for the additional properties were estimated using the following approach:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground (e.g., using standard step or brick heights as a guide);
2. The ground level at the point where the floor height was estimated was extracted from the available LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1 to the ground elevation (calculated in step 2).

It was found that all residential properties within the study area were single storey low set (generally less than 0.5 m above ground). There were also no commercial or industrial premises and residential property sheds were treated as residential external buildings.

In some instances, it appears that sheds have been converted to residences, however this cannot be confirmed Additionally, some sheds may contain farm or other industrial machinery, however treating all sheds as industrial premises would likely significantly skew the results. In both cases, all sheds on residential properties have been treated as residential external buildings.

2.3 Flood Damage Approach

The damage costs associated with inundation can be broken down into a number of categories, as shown in Plate 1. However, broadly speaking, damage costs fall under two major categories;

- tangible damages;
- and intangible damages.

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by floodwaters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

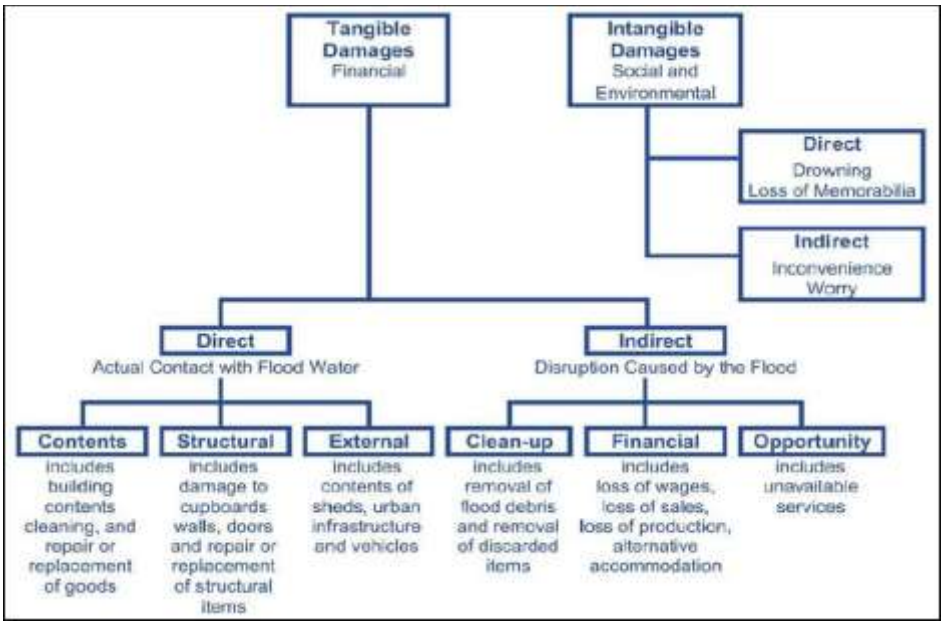

Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with floodwater coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific flood event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Direct tangible flood damages are typically calculated using stage-damage tables that assign a dollar value to the damage based on the depth of flooding above the ground or floor level. There are several different studies that have determined methodologies for deriving flood

damage curves. In this study we have utilised the O2 (2012) and the NSW Governments (2007) stage-damage curves.

Indirect damages are difficult to quantify and therefore typically applied as a percentage of the direct tangible damages. This is typically between 15% (based on ANUFLOOD, 1992) and 30% (based on the RAM method, NRE, 2000). In this study we have adopted 15% for the indirect tangible damages as it is recommended in the O2 methodology and is most commonly used when applying the NSW Governments flood damage estimate methodology.

Due to the difficulty associated with assigning monetary values to intangible damages, only tangible damages were calculated as part of this study and included in the economic assessment, however some discussion of intangible flood damages is included.

The NSW Government (Department of Planning, industry and Environment, Formally Department of Environment and Climate Change) has prepared a spreadsheet that provides a standardised approach for deriving depth-damage curves for residential properties (version 3.00, October 2007). The spreadsheet requires a range of default parameters to be defined to enable a meaningful flood damage estimate to be derived that is appropriate for the local catchment. The parameters that were adopted for the Raglan study area are summarised in Table 1.

Table 1 Parameters used in the NSW governments Flood Damage Calculator

Parameter	Value	Comment
Regional Cost Varitation	1.01	Rawlinsons
Post 2001 Adjustments	1.79	Uses change in AWE 2001 - 2020
Post Flood Inflation Factor	1.3	Middle of recommended Range
Typical Duration of Immersion	3 hours	From model results
Building Damage Repair Factor	0.85	NSW Government recommended value
Typical house size	150 m^2	Measured from buildings
Contents Damage Repair Factor	0.75	NSW Government Recommended value
Level of Flood Awareness	Low	Required to be low unless justified
Effective Warning Time	2 hours	From model results
Typical Table Height	0.9	Recommended value
External Damage	$6,700	NSW Government Recommended Value
Clean up costs	$4,000	NSW Government Recommended Value
Time in alternate accommodation	3 weeks	Standard value
Additional accommodation costs	$220 / week	NSW Government Recommended value

The O2 methodology uses a few scaling factors; a regional cost variation (1.01 applied based on Rawlinson's 2018), post flood inflation factor (1.3 applied based on NSW Government methodology) and an actual versus potential damage (0.8 based on the available warning time). The resulting damage curves were then scaled by CPI to obtain estimates in 2020 dollar values.

The resulting stage-damage curves for Raglan are presented in Plate 2. The O2 Damages have been broken down into Internal and External Damages, where internal damages are based on the water depth above flood and external damages are based on the water depth above ground level.

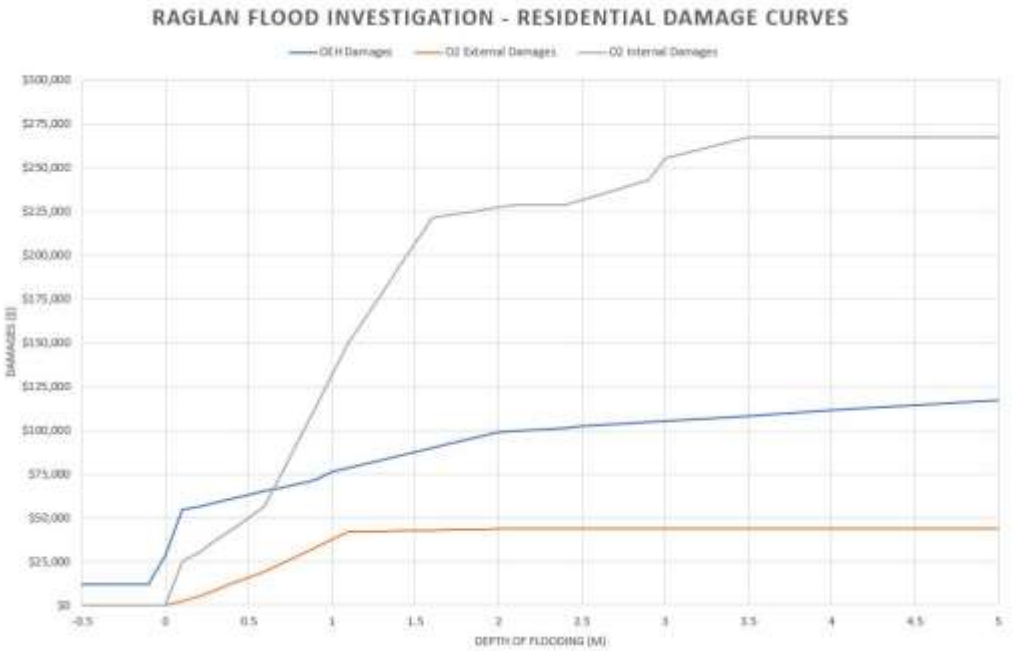

Plate 2 Stage- Damage Curves for Raglan

The floor level for each property was represented using a single point. This point was positioned in a location considered to be most representative of the flood level in the vicinity of property (usually at the front of the building or the side upstream of the building)

Building floor areas were calculated for each building using GIS building polygons. The building floor area serves as one of the residential damage curve inputs. A typical representative building floor area of 150 m^2 was adopted for the study area and was used as input to develop the residential damage curves.

The NSW Governments flood damage calculation spreadsheet includes allowances for the following flood damage components:

- Damage to building contents (direct cost);
- External damage (e.g., cars, sheds, fences, landscaping) (direct cost);
- Clean up costs (indirect cost); and,
- Alternate accommodation costs while clean up occurs (indirect cost).

2.4 Flood Damages

The flood damages for the current case for the Raglan study area are presented in Table 2, which includes direct and indirect tangible damages.

The building polygons that were digitised and used as part of the flood model have been utilised to determine whether a property is inundated. For each simulated flood event, the

maximum water surface elevation of the computational cells that are in contact with the building is assigned as the flood level for that property. The flooded properties are then further categorised as:

- Below Floor Flooded: This is where there is some flooding against the building but it has not exceeded the floor level, typically a small amount of flood damage is incurred as out buildings such as sheds and garages as well as gardens may be affected. This is also referred to as Above Ground Flooding.
- Above Floor Flooded: The flood level exceeds the floor level of the building and it is assumed that water has entered the building and has begun to damage the buildings structure as well as contents.

For events up to the 1% AEP there are no properties with above floor flooding and the damage estimate is comprised entirely of external damage. Between the 1% AEP and the 0.2% AEP the number of properties with above floor flooding rises from 1 to 4, and then to 19 during the PMF event.

In the 20% AEP there is one property with below flood flooding. In all events up to the PMF the number of properties with below floor flooding is much greater than the number with above floor flooding. This suggests that most flooding around residences is fairly shallow. In the PMF a greater proportion of the properties with above ground flooding also have above floor flooding.

In reality, the cost of flooding fluctuates from next to nothing most years when only minor flooding is experienced, to large values in years with big floods. Therefore, to get an estimate of the overall flood damages across a longer period, damages are often expressed as average annual damages (AAD). AAD is essentially the cost of flooding each year, on average over a very long period of time. Overall, the flood damages at Raglan are relatively low, with an average annual damage (AAD) approximately $7,800 (O2 method) to $11,800 (NSW Government method).

Another way to express flood damages is using the Net Present Value (NPV) of damages. This is calculated by adding the AAD for a specified period of time (typically 50 years) while discounting damages in future years (i.e. damage that occurs in 50 years' time has less value today in today's dollar values). For Raglan, using a standard 7% discount rate, the NPV of damages ranges between $106,800 and $162,200.

The NPV figure is important as the cost of structural options is assessed against the reduction in the NPV of flood damages induced by the option.

Table 2 Summary of base case flood damages

Event (AEP %)	Number of Below Floor Flooded	Number of Above Floor Flooded	Total Damages ($) (OEH)	Total Damages ($) (O2)
20	1	0	13,754	5,890
10	2	0	27,507	11,238
5	3	0	29,159	13,385
2	7	0	99,120	61,892
1	9	1	184,545	91,464
0.5	14	3	307,398	123,655
0.2	15	4	386,715	160,087
PMF	23	19	1,446,390	792,631

3 Structural Mitigation Options

As discussed in Section 2, a number of properties in the town of Raglan are exposed to flood risk. This risk may be due to flood waters entering the property directly or due to access issues caused by floodwaters inundating roads. In order to mitigate the flood risk at Raglan structural mitigation options were investigated as part of this study.

Structural mitigation options were raised during Project Reference Group meetings and through Community Consultation. A Community consultation session was held on the 9th of December 2019 at the Raglan Community Hall between 3pm and 6pm to discuss specific mitigation options. Three residents attended and provided a range of feedback.

The following options were suggested at the reference group meetings and community consultation:

1. Raise Old Beaufort Road which can act as a levee to prevent the breakout via Drews Lane
2. Raise Raglan-Eurambeen Rd to above the 1% AEP design flood level
3. Raise Raglan-Elmhurst Road through the main section of town
4. Expand the Raglan-Elmhurst Road bridge over Fiery Creek
5. Investigate a drainage solution along Raglan-Elmhurst Road between Codrington Street and Vaughan Street
6. Improve flow conveyance through regular clearing of the creek and drains

The modelled options are presented in Plate 3 and described further following.

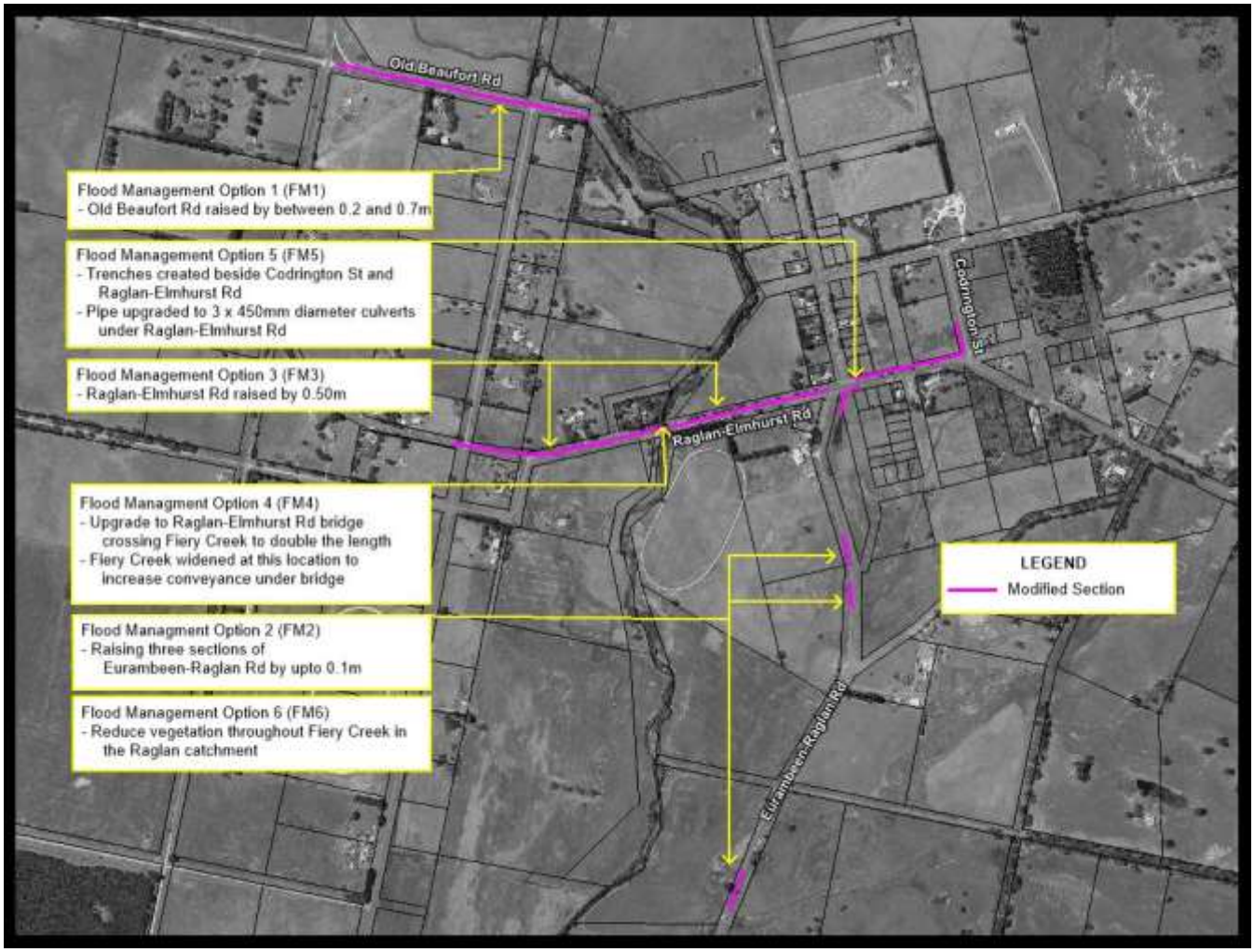

Plate 3 Modelled Structural Mitigation Options

FM1. Raise Old Beaufort Road on the Western Side of the Fiery Creek

Old Beaufort Road runs parallel to the main Fiery Creek breakout (near the shearing shed) that flows down Drews Lane. Therefore, raising of the Old Beaufort Rd on the western side of Fiery Creek would essentially act as a levee and close off this flow path and decrease damages impacted by the breakout along Drews Lane. However, this option would then force additional flow onto the eastern side of the Fiery Creek and adversely impact properties in this area.

The road crest has been designed such that it would not overtop in the 1% AEP event with an additional 0.2 m freeboard.

FM2. Upgrade culverts along Eurambeen-Raglan Road for better access

The existing design flood modelling shows that the Eurambeen- Raglan Road is cut in a few locations just south of the town in the 1% AEP. This road would likely act as the main evacuation route or egress from Raglan during a flood event, with traffic flowing south towards the Western Freeway.

Therefore, slight road raising has been modelled to give the road immunity to the 1% AEP design flood level (with a freeboard?). Currently it is only cut in events of the 1% AEP or

greater. By increasing the road height, this will likely increase flood levels upstream of the road, while decreasing those downstream.

FM3. Raise Raglan-Elmhurst Road

Raglan-Elmshurst Road is the main arterial road into and out of Raglan and connects properties on the western side of the Fiery Creek to Beaufort and Ballarat. Raising the road would therefore increase flood access for those properties and potentially decrease flooding downstream of the road.

The road embankment already acts to some extent as a barrier to flow along Fiery Creek. Therefore, any road raising would likely cause additional backwater upstream of the road and potentially cause increased flood damages. The road has been raised in the model to give 1% AEP immunity.

FM4. Upgrade Raglan-Elmhurst Road Bridge over Fiery Creek

The Raglan-Elmshurst Road Bridge and abutments acts as a constriction to flow through the town and can cause backwatering effects upstream of the bridge. Therefore increasing the length of the bridge, and waterway area available beneath it, would potentially decrease flood levels and therefore flood damages.

In this option, the bridge length has been doubled and the channel approaches to the bridge have also been widened. No piers have been added in although this may be required in reality.

FM5. Investigate a drainage solution along Raglan-Elmhurst Road between Codrington Street and Vaughan Street

Overland flow along the Raglan-Elmshurst Road between Codrington and Vaughan St is potentially causing flood damages to more recently developed properties. An existing drainage channel follows this flowpath, however it is poorly formed and has limited capacity. Therefore a new drainage swale along Vaughan Street and Raglan-Elmshurst Road was investigated and sized such that it would convey the 1% AEP flow (1 m deep and 6 m wide).

FM6. Improve flow conveyance through regular clearing of the creek and drains

Fiery Creek is largely over-grown with reeds in some sections and encroached by willows and debris in others. The effect of this is to reduce conveyance capacity in the creek channel which would exacerbate flooding. Clearing of the creeks and drainage system would likely decrease flooding in the some areas, but potentially increase the damages in other locations.

The option has been modelled by reducing the channel surface roughness from medium and dense vegetation (up to around 0.08 Manning's n) down to light vegetation, effectively grass (0.04 Manning's n). This option would require regular maintenance to maintain this conveyance capacity, with an assumed 50% of the initial clearing occurring every 10 years. This option may also have significant environmental impacts that would need to be investigated.

Given the limited number of structural options to investigate, a detailed assessment was undertaken on each option rather than a two-stage preliminary and then detailed assessment.

4 Assessment Methodology

Each flood risk management option will generally be a compromise as it is unlikely that an option will provide only benefits (e.g., there may be an adverse environmental impact or significant costs associated with the implementation of the option). In general, if the advantages associated with implementing the option outweigh the disadvantages, it will afford a net positive outcome and may be considered viable for future implementation. Therefore, each option was evaluated against a range of criteria to provide an initial appraisal of the potential feasibility of each option.

Each flood and property modification option was evaluated against the following criteria, where sufficient information was available:

- Hydraulic impacts
- Emergency responses impacts
- Change in number of buildings inundated above floor level
- Technical feasibility
- Environmental impacts
- Economic feasibility
- Community acceptance

Further details on each of these evaluation criteria is presented below. The scoring system that was used to rank each option against these criteria is also provided in Table 3.

4.1.1 Hydraulic Impacts

Flood modification options will alter the distribution of floodwaters. Although this aims to reduce the extent and depth of inundation across populated areas, it may divert floodwaters elsewhere, thereby increasing the flooding risk across other areas. Therefore, it is important that the potential flood impacts associated with implementing each option is understood.

To assess the hydraulic impact of each flood modification option, the TUFLOW hydraulic model that was used to define existing flood behaviour was updated to include each flood modification option. The updated TUFLOW models were then used to re-simulate each of the design floods. The flood level and extent results from the revised simulations were compared against the flood level and inundation extent results from the existing conditions / do nothing scenario to prepare "difference mapping". The difference mapping shows the magnitude and location of changes in flood levels and inundation extents associated with implementation of the option.

4.1.2 Change in Number of Buildings Inundated Above Floor Level

An assessment of the change in the number of buildings subject to above floor inundation during each design flood was also completed for each option.

4.1.3 Emergency Response Impacts

Emergency response is arguably one of the most important measures for managing the continuing flood risk across any study area, particularly during very large floods where flood modification options may not be overly effective. Therefore, the potential for each option to

impact on current emergency response processes was considered as part of the assessment of each option.

4.1.4 Technical Feasibility

If a structural option is proposed, it needs to be physically possible to construct the option giving consideration to the option itself as well as any local constraints. Therefore, an assessment of any technical impediments was completed for each option to determine if there would be any "show stoppers" that may render the option impractical.

4.1.5 Environmental Impacts

Any flood risk management option that involves structural works on the floodplain has the potential to impact on local flora and/or fauna. At the same time, some options may provide an opportunity to improve the local environment (e.g., some options may reduce gross pollutants reaching downstream waterways). Therefore, the potential environmental impact was considered as part of the evaluation of each structural option.

4.1.6 Economic Feasibility

A preliminary economic assessment of each flood modification and selected property modification options was completed to assist in determining the financial viability of each option. The assessment was completed by estimating the 'costs' and 'benefits' that could be expected if the option was implemented. This enabled a benefit cost ratio (BCR) to be prepared for each option. A BCR of greater than 1.0 shows that the present value of benefits outweighs the present value of costs of the option and provides an indicator that the option may be financially viable.

From a flooding perspective, economic 'benefits' were quantified as the reduction in flood damage costs if the option is implemented. The benefits of each option were estimated by preparing damage estimates for each design flood event with the option in place and using this information to prepare a revised average annual damage (AAD) estimate. In order for a BCR to be estimated, it is necessary to modify the 'base' AAD estimates (which reflect the average damage that is likely to be incurred in a single year) to a total damage that could be expected to occur over the life of each flood risk management option. Accordingly, the AAD estimates were accumulated over a 50-year period and then discounted to a present-day value by applying a discount rate of 7%.

Cost estimates have also been prepared for each option. The cost estimate includes capital costs as well as ongoing costs (e.g., maintenance) to provide a total life cycle cost for each option. It was assumed that each option has a design life of 50 years for the purposes of establishing the life cycle cost.

The cost estimates were prepared using the best available information and based on a concept design for each option. Precise cost estimates can only be prepared following detailed investigations and once design plans have been prepared. Therefore, the cost estimates presented in this report should be considered approximate only. Nevertheless, they are considered suitable for providing an initial appraisal of the financial viability of each option.

4.1.7 Community Acceptance

Floodplain risk management options do have the potential to impact on the broader community in both beneficial and adverse ways. For example, a levee may reduce the potential for inundation of a property but may also impact aesthetics. Therefore, the community's attitudes can have a significant impact on the viability of an option.

A community questionnaire was distributed to residents and business owners within the study area during earlier stages of the project. The questionnaire provided the community with a list of potential flood risk management options that were being considered as part of the study and sought feedback from the community regarding each of these options (i.e., whether they opposed or supported the option).

There was limited feedback during both the Community Questionnaire (with respect to flood mitigation options) and the community consultation session. The main feedback being received was that the community generally favoured creek and drain clearing.

Table 3 Adopted Evaluation Criteria and Scoring System for Assessment of Flood Risk Management Options

Criteria	Ranking/Score				
	- -	-	-N-	+	++
Hydraulic Impacts	Significant increases in levels (>0.1m) / extents	Minor increases in levels (<0.1m) / extents	Negligible changes in levels / extents	Minor decreases in levels (<0.1m) / extents	Significant decreases in levels (>0.1m) / extents
Change in number of buildings inundated above floor level	Significant increase in number of buildings impacted by above floor flooding	Small increase in number of buildings impacted by above floor flooding	No Change in number of buildings impacted by above floor flooding	Small decrease in number of buildings impacted by above floor flooding	Significant decrease in number of buildings impacted by above floor flooding
Emergency Response Impacts	Significant adverse impact on emergency response	Small adverse impact on emergency response	Negligible impact on emergency response	Small improvement to emergency response	Significant improvement to emergency response
Technical Feasibility	Significant technical challenges	Moderate technical challenges	Minor technical challenges	Negligible technical challenges	No technical challenges
Environmental Impacts	Significant negative environmental impact	Small negative environmental impact	Negligible environmental impacts	Small opportunity for environmental enhancement	Significant opportunity for environmental enhancement
Economic Feasibility	BCR <0.5 and / or high capital / ongoing costs	0.5 < BCR < 0.8	0.8 < BCR < 1.0	1.0 < BCR < 1.2	BCR > 1.2 and / or low capital / ongoing costs
Community Acceptance	Majority of community opposed	Some opposed	Neutral	Some community support	Majority of community support

5 Assessment Results

A description of the results of the options assessment is presented in the following sections. The financial costs of each option are presented in Appendix A while a summary of the benefits and costs is in Table 4. Where the reduction in NPV (i.e. benefit) is minimal, it has just been assumed it is effectively zero and a cost-benefit of 0 has been applied.

Table 4 Benefit - Cost Assessment of Mitigation Options

Structural Option	NPV of Damages (OEH Method)	Reduction from Existing NPV	Estimated Cost of Option	Benefit Cost Ratio
FM1. Raising Old Beaufort Road	$105,562	$35,464	$390,000	0.09
FM2. Raising Eurambeen – Raglan Rd	$141,014	$12 (effectively zero)	$130,000	0
FM3. Raising Raglan – Elmshurst Rd	$159,544	- $18,518 (increase in damages)	$800,000	Negative
FM4. Widening Fiery Ck Crossing	$140,431	$595 (effectively zero)	$1,320,000	0
FM5. Codrington and Vaughan St Drainage	$140,851	$175 (effectively zero)	$40,000	0
FM6. Channel Clearing	$127,829	$13,197	$630,000*	0.02

*Projected over a 50 year timeframe with ongoing maintenance

5.1 FM1 Raising Old Beaufort Road

Assessment of raising Old Beaufort Road is presented in Table 5 and the impact on flood extents for the 1% AEP is shown in Plate 4. The option has a significant re-distributive effect, effectively blocking a large amount of the flow down Drews Lane and the western side of the Fiery Creek while increase flood levels and extents on the Eastern side. The impacted area is largely undeveloped and so there are no adverse impacts on existing infrastructure or residential dwellings. On the western side, one property is no longer flooded above floor in the 1% AEP design flood event and two properties no longer flooded in the 0.5 and 0.2% AEP design flood events.

This option would have significant capital costs and the benefits are largely limited to those two properties in extreme flood events. The overall BCR is 0.09 which indicates that the option is not financially viable. Also worth noting is that the affected landholders to the east would need to be heavily consulted as this would potentially have a significant impact on the development potential of their land.

Table 5 Evaluation outcomes on the raising Old Beaufort Rd option

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	Beneficial reductions in flood levels and extents across western Raglan, however this is offset by impacts on the eastern side of Fiery Creek and increases in the Fiery Creek channel.
Inundated Buildings	+	1 building no longer inundated above floor level during 1% AEP event, 2 buildings no longer flooded in the 0.5 and 0.2% AEP but same number of buildings flooded above floor level in the PMF. No new inundated buildings
Emergency Response	-N-	Increase flood levels at the Raglan-Elmshurst Road which offset any gains in trafficability along Drews Lane and the western side of Raglan
Technical Feasibility	+	The project would be a fairly straight forward road raising, although it would need to be merged with existing driveways which may requiring regrading on private property
Environmental Impacts	-N-	The area impacted by the works is an existing road and road reserve with limited environmental impacts
Economic Feasibility	- -	Low BCR (0.09) with a high capital cost
Community Acceptance	-N-	No community feedback on this issue.

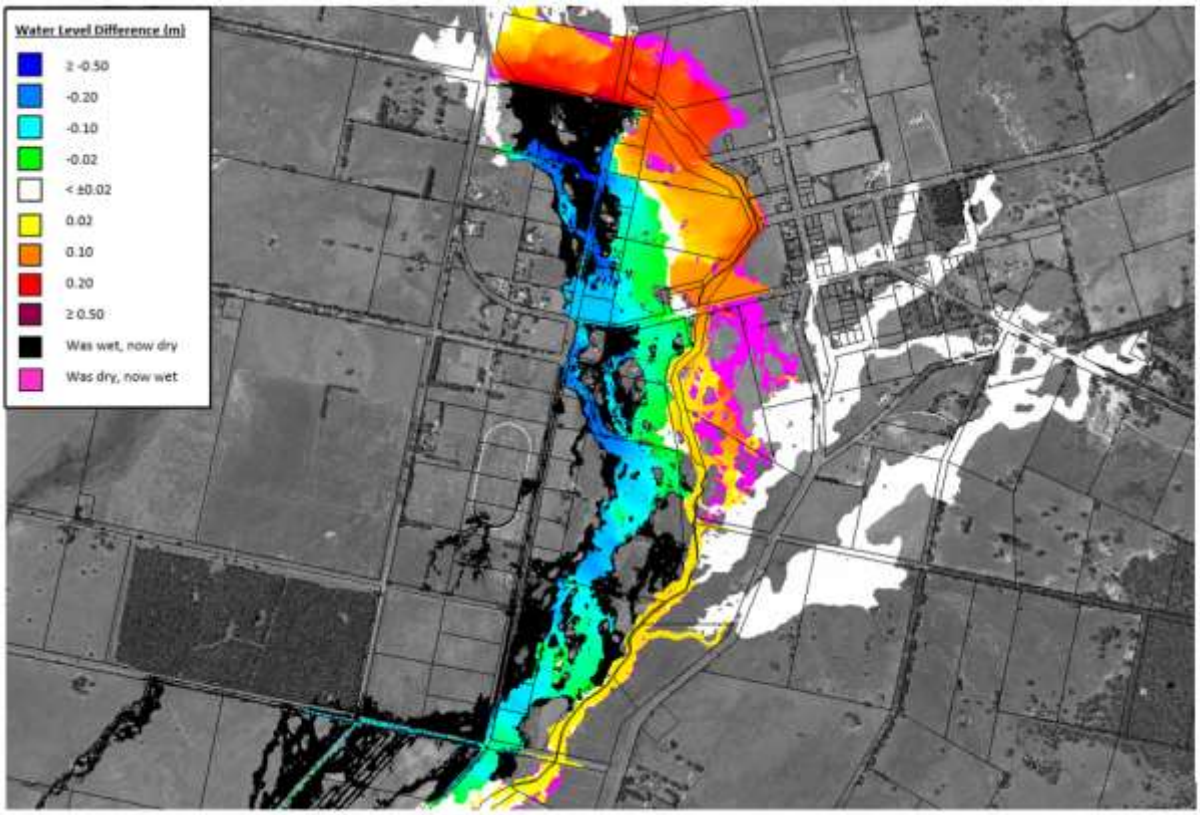

Plate 4 1% AEP change in flood levels due to raising Old Beaufort Rd

5.2 FM2 Raising Eurambeen - Raglan Road

The assessment summary of the raising Eurambeen – Raglan Road is presented in Table 6 and the redistribution of flood water for the 1% AEP is shown in Plate 5. Overall the option has very limited impact on flooding, reducing the inundated area downstream of where the road has been raised and slightly increasing levels upstream.

No properties are affected (either positive or negative) in this option and therefore there is no financial benefit from the project. The main benefit is associated with the improved road access during large floods where properties may be cut off from Beaufort or Ballarat. While this option does improve that access which would be of benefit to the emergency services during a flood event, many properties will still be isolated internally within Raglan, particularly those on the western side of the Fiery Creek.

Given that the road is only cut in relatively large and infrequent events (> 2% AEP), flood duration is relatively short (likely to be inundated for less than a few hours) and there are other internal flood access constraints. There is likely to be little benefit gained from this option.

Table 6 Evaluation outcomes on the Raising Eurambeen - Raglan Road

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	Minimal difference in flood extents, slight increase inside road reserve
Inundated Buildings	-N-	No impact on inundated buildings
Emergency Response	++	Would allow flood free access to Western Highway and to Beaufort in events up to the 1% AEP design flood event
Technical Feasibility	+	The project would be a fairly straight forward road raising
Environmental Impacts	-N-	The area impacted by the works is an existing road and road reserve with limited environmental impacts
Economic Feasibility	- -	BCR is effectively zero as there is no impact on flood damages
Community Acceptance	-N-	No community feedback on this issue

Plate 5 1% AEP change in flood levels due to raising Eurambeen - Raglan Road

5.3 FM3 Raising Raglan-Elmshurst Road at Fiery Ck Crossing

Assessment of raising Raglan-Elmshurst Road is presented in Table 7 and the 1% AEP redistribution is shown in Plate 6. The aim of raising the road is to prevent water over-topping the bridge or roadway up to the 1% AEP design flood level, however this causes significant ponding behind the raised road embankment that inundates additional properties. While there is a reduction in flood levels and extents on the western side of Fiery Creek downstream of the road, the flood affectation of residential buildings does not change.

While the option would increase the connectivity between the eastern and western parts of Raglan during a flood, the town itself would likely be cut off from the surrounding area. There are limited services within the town that would need to be accessed during a flood and therefore limited benefit to improving the eastern and western connectivity during flood events. This option would be of limited benefit to emergency services as roads in to and out of town would still be cut off during flood events.

Overall, the option causes an increase in flood damages within the study area and would have very significant capital costs. Therefore it is considered unviable.

Table 7 Evaluation outcomes on the raising Raglan - Elmshurst Road

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-	Significant increase in flooding upstream of the road raising, some decrease downstream on the western side of Fiery Creek (increase on the eastern side)
Inundated Buildings	- -	Additional building inundated in the 2% AEP event and two additional buildings in the 0.2% AEP event
Emergency Response	+	Would maintain connection between eastern and western sides of Raglan during events up to and including the 1% AEP
Technical Feasibility	-N-	The project would be a fairly straight forward road raising, raising the existing bridge deck would introduce technical challenges. Diversions could be put in place via Lucardies Road during construction
Environmental Impacts	-N-	The area impacted by the works is an existing road and road reserve with limited environmental impacts
Economic Feasibility	- -	BCR is negative as it increases overall flood damages
Community Acceptance	-N-	No community feedback on this issue

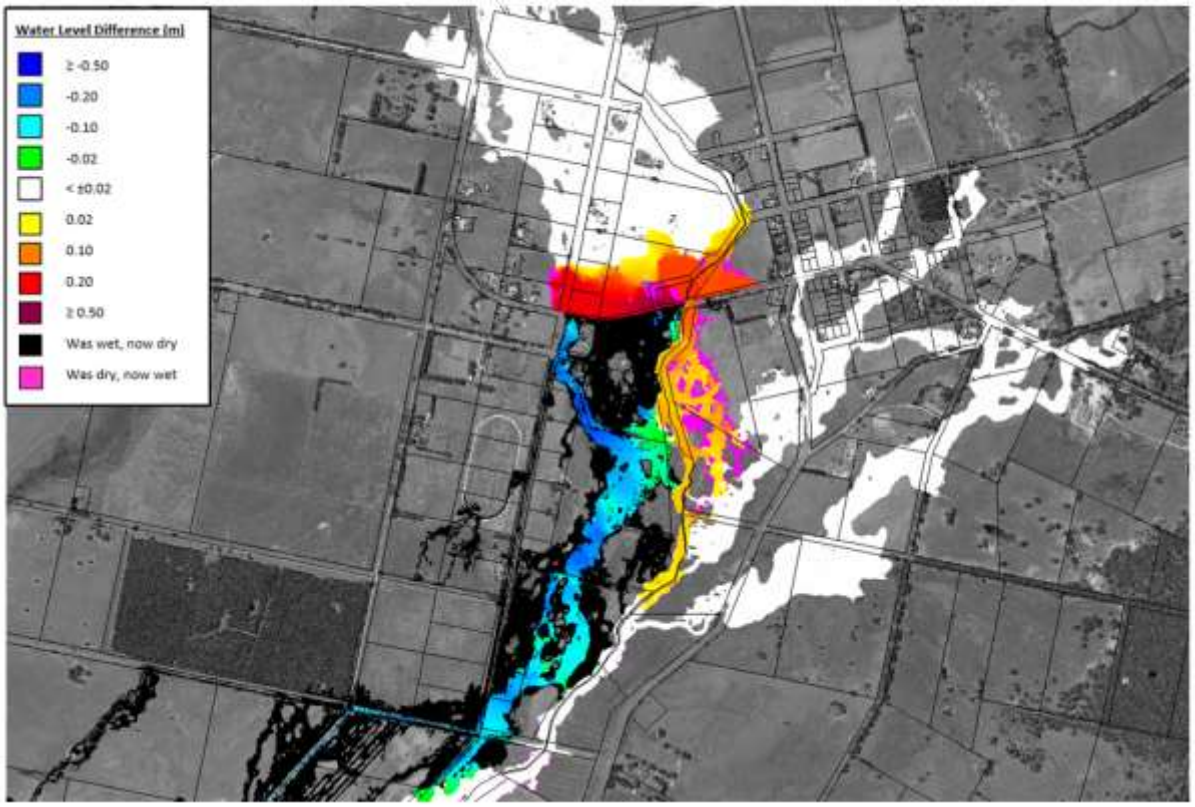

Plate 6 1% AEP change in flood levels due to raising Raglan - Elmshurst Road

5.4 FM4 Widening Fiery Creek Crossing at Raglan-Elmshurst Road

The assessment of widening the Fiery Creek crossing at Raglan-Elmshurst Road is presented in Table 8 and the 1% AEP flood level and extent redistribution is shown in Plate 7. The effect of the option is to reduce the flood levels immediately upstream of the bridge and along the creek corridor for approximately 500 m with only very minor increases downstream.

While having a net benefit in reducing flood levels during the 1% AEP design flood event, the option has no impact on the number of buildings impacted by flooding and therefore has an effective BCR of zero. In addition, the option would require significant (construction/earthwork/civil?) work in and around the Fiery Creek channel and may have environmental impacts.

While there is a clear (but limited) benefit to this option with little to no flood impacts, the option is the most expensive option considered as part of this study and is financially unviable.

Table 8 Evaluation outcomes on widening Fiery Ck crossing at Raglan - Elmshurst Rd

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Decrease in flood extents on the north side of the Raglan-Elmshurst Bridge with minimal offsetting increase
Inundated Buildings	-N-	No change in inundated buildings
Emergency Response	-N-	Would likely increase the flood immunity of Raglan-Elmshurst Road marginally
Technical Feasibility	-	The bridge and channel widening may present some technical challenges, particularly given the proximity of the building on the north western side of the channel. Diversions could be put in place via Lucardies Road during construction
Environmental Impacts	-	There is potential for environmental impact by altering the Fiery Ck channel
Economic Feasibility	- -	The BCR is effectively zero as it has no impact on inundated buildings
Community Acceptance	-N-	No community feedback on this issue

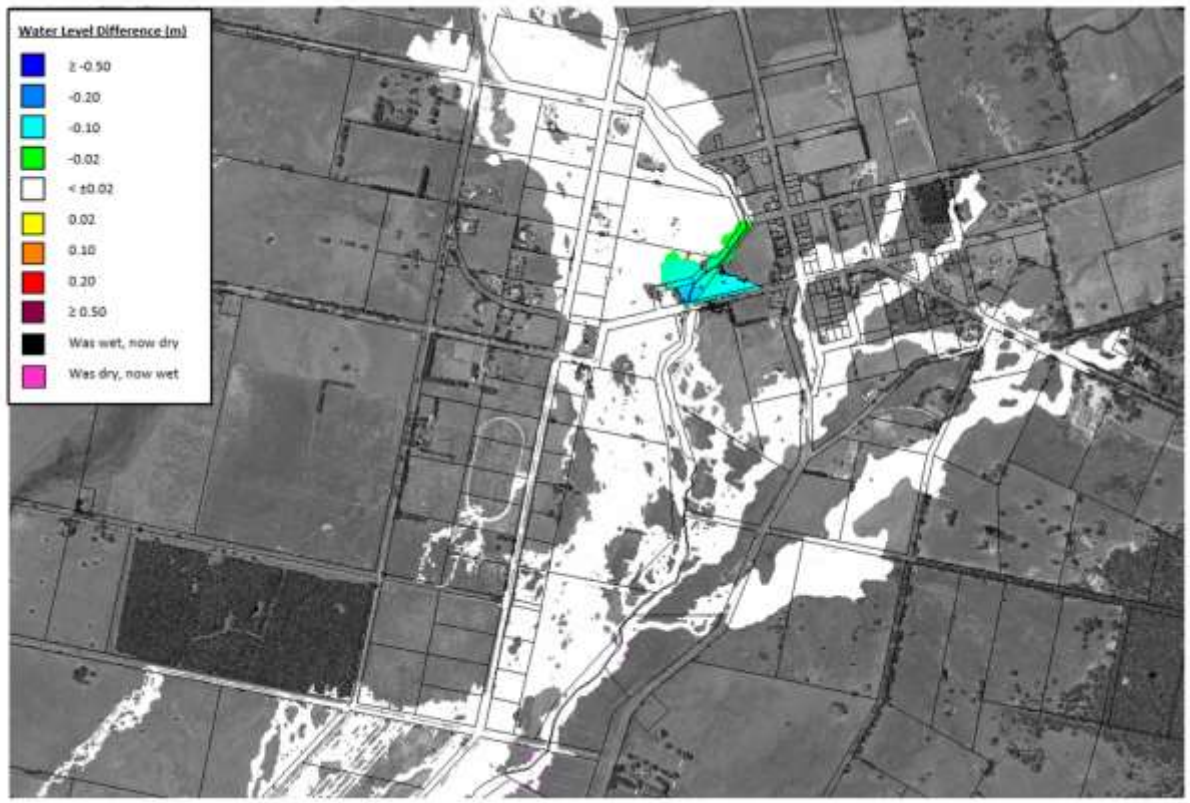

Plate 7 1% AEP change in flood levels due to widening the Fiery Ck crossing at Raglan - Elmshurst Rd

5.5 FM5 Improving Drainage along Codrington and Vaughan St

The assessment summary for the improving drainage along Codrington and Vaughan Streets is presented in Table 9 and the flood level and extent redistribution is presented in Plate 8.

This option was considered as it was widely expected that new development that had occurred in Raglan would be heavily impacted by flooding. However, these properties are largely unaffected until floods greater than the 1% AEP design flood event, indicating the option will have very limited flood damage benefits. The channel, currently designed to contain the 1% AEP flow, would need to be significantly greater and likely unfeasible to protect against larger floods and this would also afford those properties a level of protection that is generally not considered in floodplain management (i.e. greater than the 1% AEP design flood event).

The option also has a negative impact on properties downstream, by reducing flood storage and increasing conveyance across Raglan – Elmshurst Road. While these lots are currently undeveloped, the owners would need to be consulted as it may impact their ability to develop their land in the future.

The community has expressed some desire for improved drainage through Raglan, however this would need to be a much wider ranging drainage plan so as not to adversely impact some properties to the benefit to others. The overall NPV of the Raglan flood damages is approximately $100,000 – $150,000 and this small section of drainage improvement costs approximately $40,000. Therefore, a town wide drainage improvement scheme would likely cost many times more than the total NPV of flood damages, while not actually eliminating most of the flood damage which is sourced from Fiery Creek rather than local drainage. Therefore any drainage improvements would need to justified from a nuisance flooding and stormwater planning perspective rather than from a mainstream flood perspective.

Table 9 Evaluation outcomes on the Codrington and Vaughan St Drainage

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Decrease in flood extents on the north side of the Raglan-Elmshurst Bridge with minimal offsetting increase
Inundated Buildings	-N-	No change in inundated buildings
Emergency Response	-N-	Would likely increase the flood immunity of Raglan-Elmshurst Road marginally but impact Raglan – Eurumbeen Road
Technical Feasibility	+	The channel would fit in existing road reserves and would be relatively simple
Environmental Impacts	-N-	The work would be undertaken in an existing road reserve and table drain
Economic Feasibility	- -	The BCR is effectively zero as it has no impact on inundated buildings
Community Acceptance	+	Community has expressed interest in improving local drainage in general, however no specific support for this option

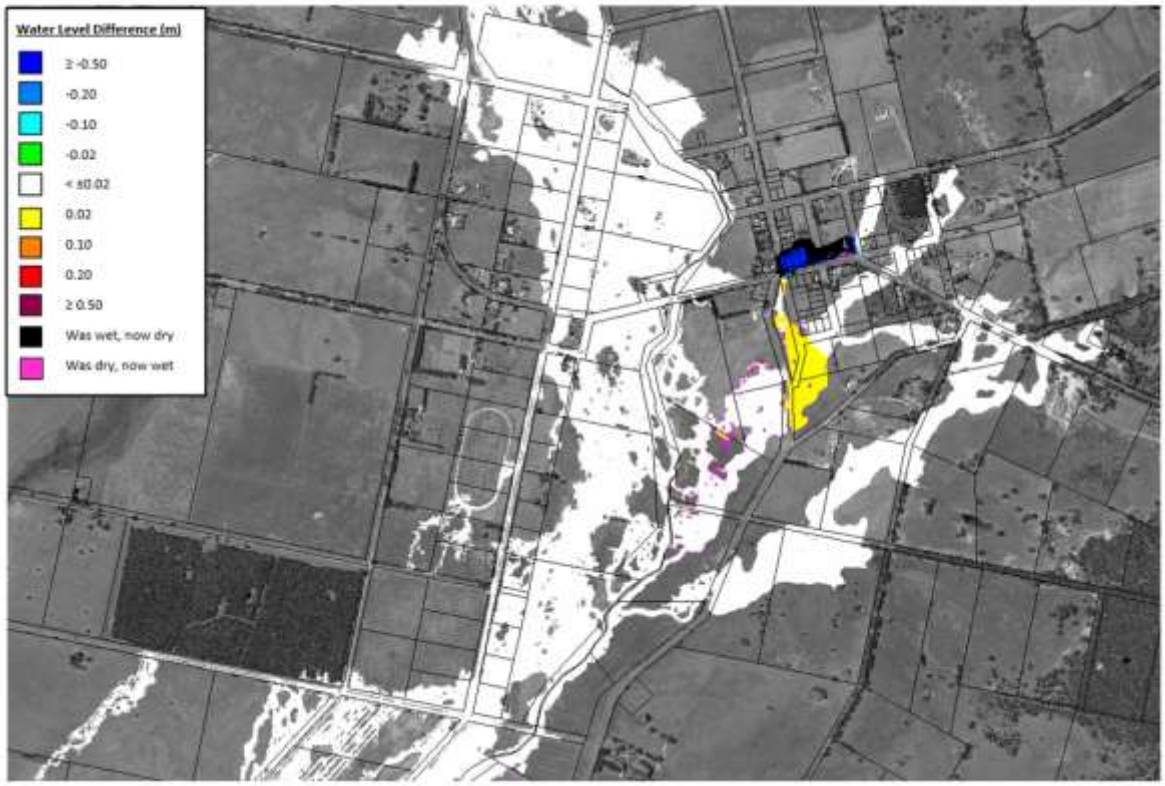

Plate 8 1% AEP change in flood levels due Codrington and Vaughan Streets Drainage Option

5.6 FM6 Channel Clearing

Assessment of the channel clearing option is presented in Table 10. This option leads to relatively minor decreases in flood levels (0.02 – 0.1 m in the 1% AEP design flood event) across large sections of the town, however only one building goes from being inundated above floor to not inundated above floor in the 0.5% and 0.2% AEP design flood events.

The option has been costed at $630,000 and reduces the NPV of flood damages by $13,200. This indicates a very significant cost for minimal financial benefit. Similarly, the option would have significant environmental approval hurdles as it would require a large amount of vegetation and habitat removal which may make the project unfeasible from that perspective. This option would have no impact on emergency services response during a flood event.

A potential alternative to this option would be to establish a culvert clearing and table-drain clearing program. This could be undertaken as part of the regular Council roadside maintenance works and included in Councils asset management program.

While this would have fairly minimal benefit for large floods perspective (studied here), it may improve nuisance flooding that occurs during common storms and therefore improve community sentiment towards this nuisance flooding.

Table 10 Evaluation outcomes on the channel clearing option

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	There are decreases in flood extent and level in various parts of the town, particularly along the channel corridor
Inundated Buildings	+	One building less inundated above floor in the 0.5 and 0.2% AEP events. No changes in other events.
Emergency Response	-N-	Would have minimal impact on egress and flood immunity
Technical Feasibility	-N-	There would be minor technical challenges around maintain bank stability and ensuring no channel erosion occurs. Options around this, such as planting or matting have not been included in the cost.
Environmental Impacts	- -	There is potential for significant environmental impact by clearing the length of the Fiery Creek Channel
Economic Feasibility	- -	The BCR is very low (0.02) and would require significant upfront and ongoing work
Community Acceptance	+ +	Significant community support for this option

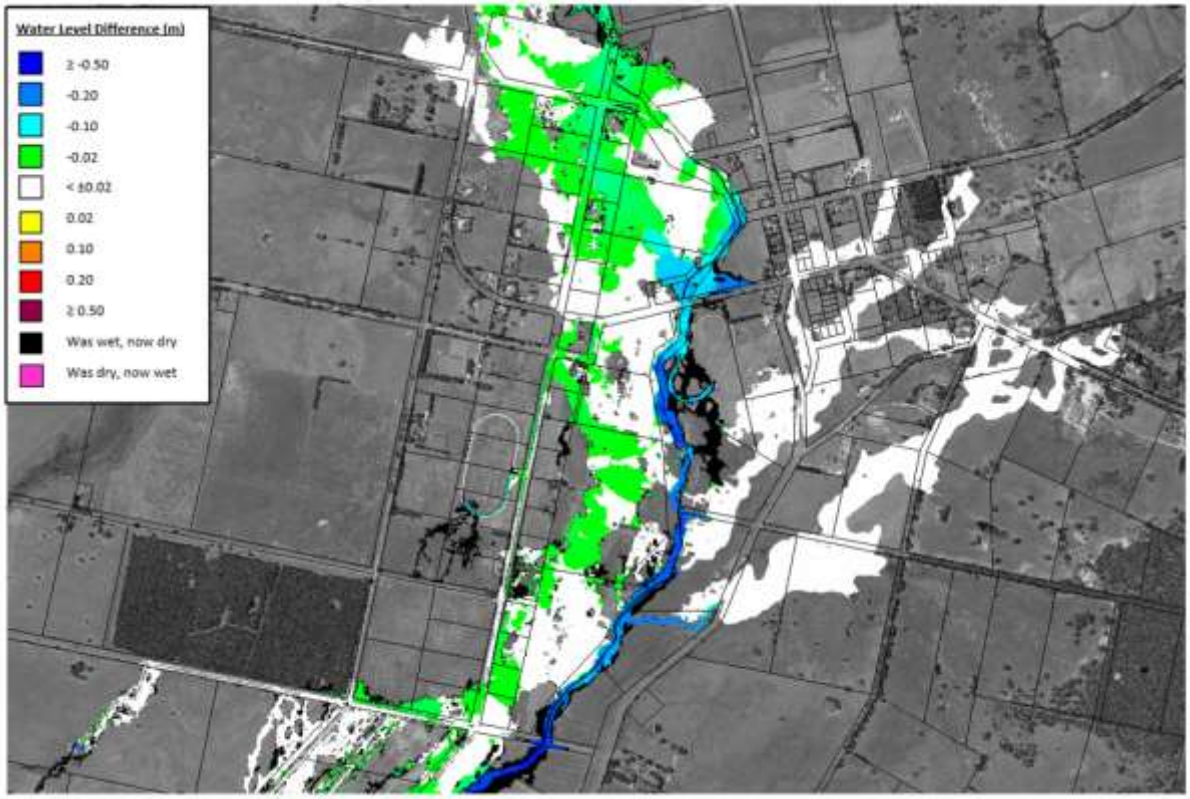

Plate 9 1% AEP change in flood levels due to channel clearing

6 SUMMARY

Six structural mitigation options were raised through the Project Reference Group meetings and community consultation. These were analysed by implementing the proposed option in the TUFLOW model and then re-running the range of design flood events.

For each option, the resulting differences in flood levels against the existing case were analysed. A benefit-cost ratio was calculated by comparing the reduction in NPV of flood damages to the calculated cost of constructing each option. Additional analysis was undertaken regarding other key aspects of each option, such as the impact on emergency response, technical feasibility, environmental impacts and community acceptance.

Table 11 is a summary of the analysis of each option. Two of the options scored an overall negative, two options were neutral and two options (raise Raglan – Eurambeen Rd and Codrington – Vaughan St drainage) were slightly positive. Generally, options that have a strong overall positive value would be recommended for further analysis or implementation. Note that no weighting has been undertaken for the different evaluation criteria.

A critical factor that is perhaps lost in this analysis is that each option has a significant capital, and in some cases significant ongoing maintenance costs with very little reduction in overall flood damages. This is primarily due to:

- There are not many at risk properties within Raglan that suffer extensive damage as a result of flooding over their floor levels
- Above floor flooding only occurs in rare events, such as at or above the 1% AEP design flood event
- Development throughout the study area is generally at a very low density and therefore mitigation measures that have specific localised effects will only benefit a few properties

Overall, the flood risk at Raglan is relatively low and there are no feasible structural mitigation options that are considered viable to reduce this risk. It is likely that other mitigation options that are examined in this study such as; improved planning and development controls, community education and simplified flood warning (signage and gauge boards) will be more cost effective and likely have a broader reach in the community.

The community raised the issue during community consultation that the local road drainage system is overgrown with vegetation and debris. While this would have minimal impact on the large-scale flooding examined as part of this study, smaller nuisance flooding from local runoff may be better managed if Council were to implement more regular maintenance of the local stormwater drainage system. This would need to be weighed against other competing priorities for Council resources and considered in their asset management program of all council assets.

Table 11 Summary of Structural Mitigation Measure Assessments

Potential Measures	Evaluation Criteria / Score							
	Change in Flood Levels / Extents	Inundated Buildings	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Raise Old Beaufort Rd	0	1	0	1	0	-2	0	0
Raise Raglan-Eurambeen Rd	0	0	2	1	0	-2	0	1
Raise Raglan – Elmshurst Rd	-1	-2	1	0	0	-2	0	-4
Widen Fiery Ck crossing at Raglan – Elmshurst Rd	1	0	0	-1	-1	-2	0	-3
Upgrade Drainage	1	0	0	1	0	-2	1	1
Channel Clearing	1	1	0	0	-2	-2	2	0

7 REFERENCES

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- Laurenson, E. M., Mein, R. G. & Nathan, R. J. Australia. (2010). RORB Version 6, Runoff Routing Program: User Manual.
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APPENDIX A – COST ESTIMATES FOR FLOOD MITIGATION OPTIONS

Preliminary Cost Estimate

Flood Management Option 1

- Raising an extent of Old Beaufort Rd to prevent overtopping in the 1% AEP
- Refer to concept design figure for the section of road modified

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal of existing roadbase**				
1.1	Remove existing road layer	4,240	$18.09	sqm	$76,701.60
	SUB TOTAL				**$76,701.60**
2	**Forming new road layer at higher levels**				
2.1	Fill material, including placement, shaping and compaction	2,850	$10.15	cum	$28,927.50
2.2	Pavement construction subbase and top coat A/C	4,240	$33.70	sqm	$142,888.00
	SUB TOTAL				**$171,815.50**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$49,703.42
3.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$24,851.71
	SUB TOTAL				**$74,555.13**
			TOTAL:	Melbourne	$323,072.23
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$326,302.95
	Contingency			20%	$65,260.59
			TOTAL (Rounded to nearest $10,000)		**$390,000**

Preliminary Cost Estimate

Flood Management Option 2

- Regrading Eurambeen-Raglan Rd to allow flood free access in the 1% AEP
- Refer to concept design figure for the sections of road modified

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal of existing roadbase**				
1.1	Remove existing road layer	1,520	$18.09	sqm	$27,496.80
	SUB TOTAL				**$27,496.80**
2	**Forming new road layer at higher levels**				
2.1	Fill material, including placement, shaping and compaction	510	$10.15	cum	$5,176.50
2.2	Pavement construction subbase and top coat A/C	1,520	$33.70	sqm	$51,224.00
	SUB TOTAL				**$56,400.50**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$16,779.46
3.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$8,389.73
	SUB TOTAL				**$25,169.19**
			TOTAL:	Melbourne	$109,066.49
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$110,157.15
	Contingency			20%	$22,031.43
			TOTAL (Rounded to nearest $10,000)		**$130,000**

Preliminary Cost Estimate

Flood Management Option 3

- Raising the extent of Raglan-Elmhurst Rd crossing Fiery Creek to prevent overtopping in the 1% AEP
- Refer to concept design figure for the section of road modified

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal of existing roadbase**				
1.1	Remove existing road layer	6,160	$18.09	sqm	$111,434.40
	SUB TOTAL				**$111,434.40**
2	**Forming new road layer at higher levels**				
2.1	Fill material, including placement, shaping and compaction	3,830	$10.15	cum	$38,874.50
2.2	Pavement construction subbase and top coat A/C	6,160	$33.70	sqm	$207,592.00
	SUB TOTAL				**$246,466.50**
3	**Raising Bridge Deck**				
3.1	Raise existing bridge deck by 0.50m and reinforce existing structure for any extra load	1	$150,000	unit	$150,000.00
	SUB TOTAL				**$150,000.00**
4	**Project Management and generic project costs**				
4.1	Detail Design & Documentation	1	20%	unit	$101,580.18
4.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$50,790.09
	SUB TOTAL				**$152,370.27**
			TOTAL:	Melbourne	$660,271.17
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$666,873.88
	Contingency			20%	$133,374.78
			TOTAL (Rounded to nearest $10,000)		**$800,000**

Preliminary Cost Estimate

Flood Management Option 4

- Widening Fiery Creek under Raglan-Elmhurst Rd
- Doubling the existing bridge length and channel width at the structure

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Demolition**				
1.1	Demolish existing bridge structure and road	176	$93.09	sqm	$16,383.84
1.2	Remove existing channel lining (concrete)	184	$115.00	sqm	$21,160.00
	SUB TOTAL				**$37,543.84**
2	**Bulk earthworks**				
2.1	Excavation earthworks	800	$8.70	cum	$6,960.00
	SUB TOTAL				**$6,960.00**
3	**New Bridge Structure**				
3.1	Composite price for conventional 2-lane bridge	360	1800	sqm	$648,000.00
3.2	Channel lining and embankment stabilisation	304	475	sqm	$144,400.00
	SUB TOTAL				**$792,400.00**
4	**Project Management and generic project costs**				
4.1	Detail Design & Documentation	1	20%	unit	$167,380.77
4.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$83,690.38
	SUB TOTAL				**$251,071.15**
			TOTAL:	Melbourne	$1,087,974.99
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$1,098,854.74
	Contingency			20%	$219,770.95
			TOTAL (Rounded to nearest $10,000)		**$1,320,000**

Preliminary Cost Estimate

Flood Management Option 5

- Diverting overland flow between Codrington St and Vaughan St through increased road drainage
- Refer to concept design figure for the proposed works

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Channel works**				
1.1	Excavation earthworks	2,200	$8.70	cum	$19,140.00
	SUB TOTAL				**$19,140.00**
2	**Culvert upgrade**				
2.1	450mm diameter culvert	40	$191.50	m	$7,660.00
	SUB TOTAL				**$7,660.00**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$5,360.00
3.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$2,680.00
	SUB TOTAL				**$8,040.00**
			TOTAL:	Melbourne	$34,840.00
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$35,188.40
	Contingency			20%	$7,037.68
			TOTAL (Rounded to nearest $10,000)		**$40,000**

Preliminary Cost Estimate

Flood Management Option 6

- Reducing vegetation in Fiery Creek

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk mangement options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Channel works**				
1.1	Removing medium vegetation from a creek	123,800	$1.70	sqm	$210,460.00
1.2	Removing heavy vegetation from a creek	22,500	$2.80	sqm	$63,000.00
	SUB TOTAL				**$273,460.00**
2	**Maintenance**				
2.1	Maintenance schedule to remove medium vegetation from creek at 50% of the original quantity				
	- Maintenance 1 @ 10 years with NPV of 7%	73,150	$0.86	sqm	$62,909.00
	- Maintenance 2 @ 20 years with NPV of 7%	73,150	$0.44	sqm	$32,186.00
	- Maintenance 3 @ 30 years with NPV of 7%	73,150	$0.22	sqm	$16,093.00
	- Maintenance 4 @ 40 years with NPV of 7%	73,150	$0.11	sqm	$8,046.50
	- Maintenance 5 @ 50 years with NPV of 7%	73,150	$0.06	sqm	$4,389.00
	SUB TOTAL				**$123,623.50**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$79,416.70
3.2	Allowance for preliminaries, site establishment and sediment control	1	10%	unit	$39,708.35
	SUB TOTAL				**$119,125.05**
			TOTAL:	Melbourne	$516,208.55
	Local factor Rawlinsons (Ararat)	1.01	TOTAL:	Ararat	$521,370.64
	Contingency			20%	$104,274.13
			TOTAL (Rounded to nearest $10,000)		**$630,000**