Feasibility Report

Rochester Mitigation Study

Campaspe Shire Council

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1 INTRODUCTION

Following on from the Rochester Flood Management Plan[1], Campaspe Shire Council engaged Water Technology to undertake the Rochester Flood Mitigation Study.

The Rochester Flood Management Plan delivered an improved understanding of the impacts of flooding throughout Rochester for a range of event magnitudes, and made recommendations regarding potential flood mitigation improvements, some of which Shire of Campaspe has already committed to delivering. Flood mitigation works to offset the removal of channel irrigation infrastructure has already taken place, a new streamflow gauge has been installed on the Kyabram Rochester Road bridge and work with the Bureau of Meteorology has commenced on improved flood warning systems. This investigation has been commissioned to review and examine the recommended township mitigation works on areas beyond the initial study boundary.

The study area extends the previous modelling area adopted in the Rochester Flood Management Plan. This study maintains the current model area along the Campaspe River floodplain but has extended it east into the Nanneella Depression.

A summary report (previously submitted and included within this report) was the first milestone for the study and found that several alternative mitigation options in Rochester (storages upstream, flow attenuation, increased flow capacity of structures, and raised floor levels) have low feasibility and do not warrant further analysis at this stage. When comparing the range of options considered in both this study and the original Rochester Flood Management Plan the only option likely to be feasible and worth further analysis is the preferred mitigation scheme from the original study which aims to better engage the drainage line to the east of Rochester.

Using the extended model, several mitigation arrangements were tested to assess their impact on flooding east of Rochester along the Nanneella Depression. This report documents the results and analysis of these modelled mitigation options and presents a final mitigation scheme which has undergone detailed costing and feasibility assessment. The results of extensive community consultation are also provided.

[1] Rochester Flood Management Plan (Water Technology, 2013)

2 STUDY AREA

Rochester is a township of approximately 3,100 residents (2011 Census), located 180 km north of Melbourne in Central Victoria. The flat landscape is traversed by irrigation channels managed by Goulburn Murray Water. The catchment area of the Campaspe River upstream of Rochester is approximately 3,345 km^2 and extends south to Daylesford, Kyneton and Woodend. The steeper gradients of the northern slopes of the Great Dividing Range in the upper catchment contrasts with the very flat grades of the northern plains which extend to the Murray River at Echuca.

Rochester is located downstream of Lake Eppalock, a large storage (over 300 GL in volume) which is used to impound water for urban supply to Bendigo and irrigation along the Campaspe River within the Campaspe Irrigation District.

Rochester is situated on the Campaspe River floodplain. The area has little topographical relief, and the river channel at Rochester has limited capacity. In large floods, flood waters leave the channel and breakout across the floodplain to the east and west. In the January 2011 event, most of the town was impacted by floodwaters resulting in widespread flood damage.

FIGURE 2-1 JANUARY 2011 FLOODING IN ROCHESTER

3 BACKGROUND

3.1 Previous Investigations

A number of previous flood and drainage investigations have occurred in the study area, however the most relevant to this study is the Rochester Flood Management Plan[1]. The key recommendations from that study relating to flood mitigation are summarized in the Rochester Flood Study Extension Summary Report (Water Technology, 2016).

3.2 Hydrological and Hydraulic data

The hydraulic modelling in this study is based on the same hydrology as the Rochester Flood Management Plan [1]. Given that this study was recent and no significant hydrological events have occurred since (which might impact on design hydrology), there was no need to recalculate design flows for the study area. For further information regarding the hydrological analysis that the modelling is based on please refer to the final report of the Rochester Flood Management Plan[1]. The adopted design flood flows for this investigation are listed below in Table 3-1.

TABLE 3-1 RORB MODEL DESIGN PEAK FLOWS AND CRITICAL STORM DURATIONS AT CAMPASPE WEIR

AEP (%)	Campaspe River at Campaspe Weir	
	Peak flow (m^3/s)	Duration (hrs)
20	248	30
10	350	30
5	492	30
2	684	30
1	860	30
0.5	1,116	30

The numerical hydraulic model developed in 2012-2013 for the Rochester Flood Management Study was extended for this study. The model was calibrated against observed flood data during the events in November 2010 and January 2011. The model results for these floods replicated the observed flood behaviour through the town quite accurately; this was confirmed by a comparison to observed flood marks, aerial images as well as community feedback during public consultation.

The model was considered appropriate for use for design flood modelling and mitigation options investigation. Figure 3-2 shows the previous model calibration results.

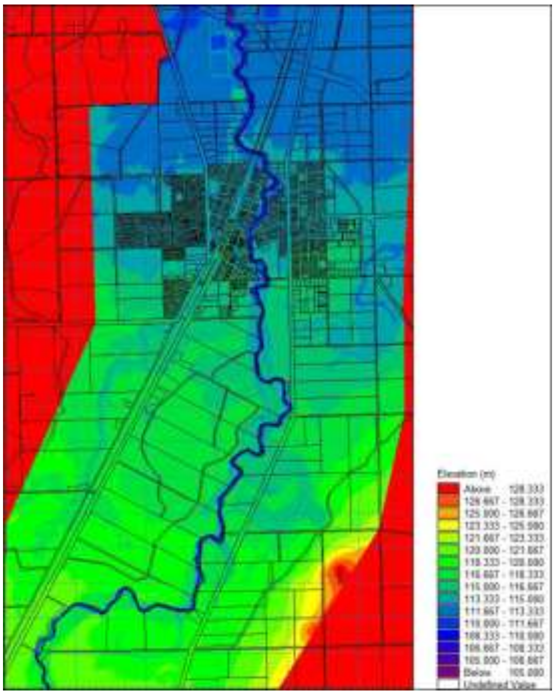


Figure 3-1 Rochester Hydraulic Model Schematisation (2013)

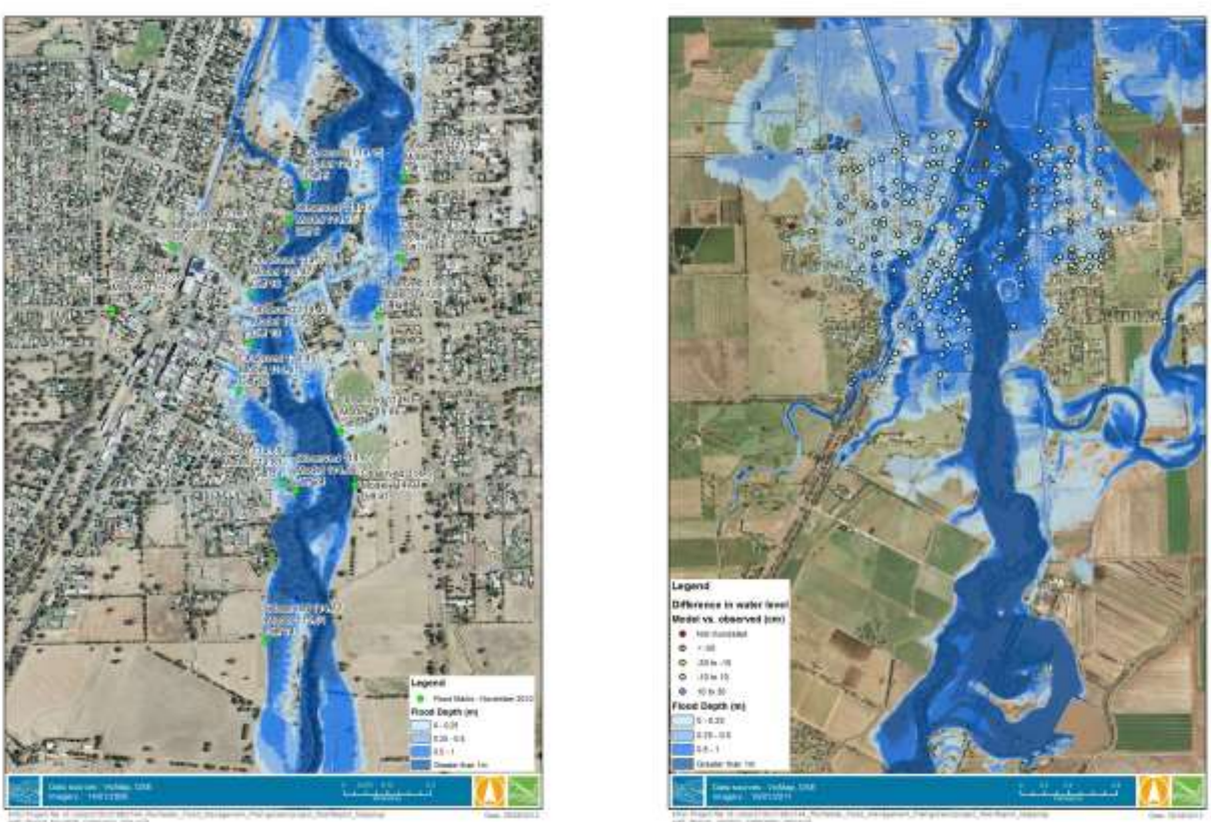


FIGURE 3-2 HYDRAULIC MODEL CALIBRATION PLOT – NOV 2010 (LEFT) AND JAN 2011 (RIGHT)

3.3 Topographical Data

Two sources of topographic data were used to prepare the hydrological and hydraulic models in the Rochester Flood Management Plan. These included:

- Light detection and ranging (LiDAR) data provided by North Central CMA (referred to as Broken Creek data) which was a 5 m grid
- Structure Survey of bridges and culverts

The main structures within the study area, included in the hydraulic model, were:

- Kyabram-Rochester Road Bridge over the Campaspe River;
- The railway bridge over the Campaspe River;
- The railway crossing adjacent to Rochester-Strathallan Rd near Sullivan Street;
- The Waranga Channel and the Campaspe Syphon; and
- Drainage structures at various locations in the floodplain, such as culverts under the railway and roads, and major drainage pipes through the township.

FIGURE 3-3 LOCATION OF MAIN HYDRAULIC STRUCTURES

3.4 Model extension

The existing model has been extended to include the eastern drainage line along the Nanneella Depression, about 17 km east of Rochester. The decommissioned Channel 2/2 and updated syphons have been incorporated to existing topography.

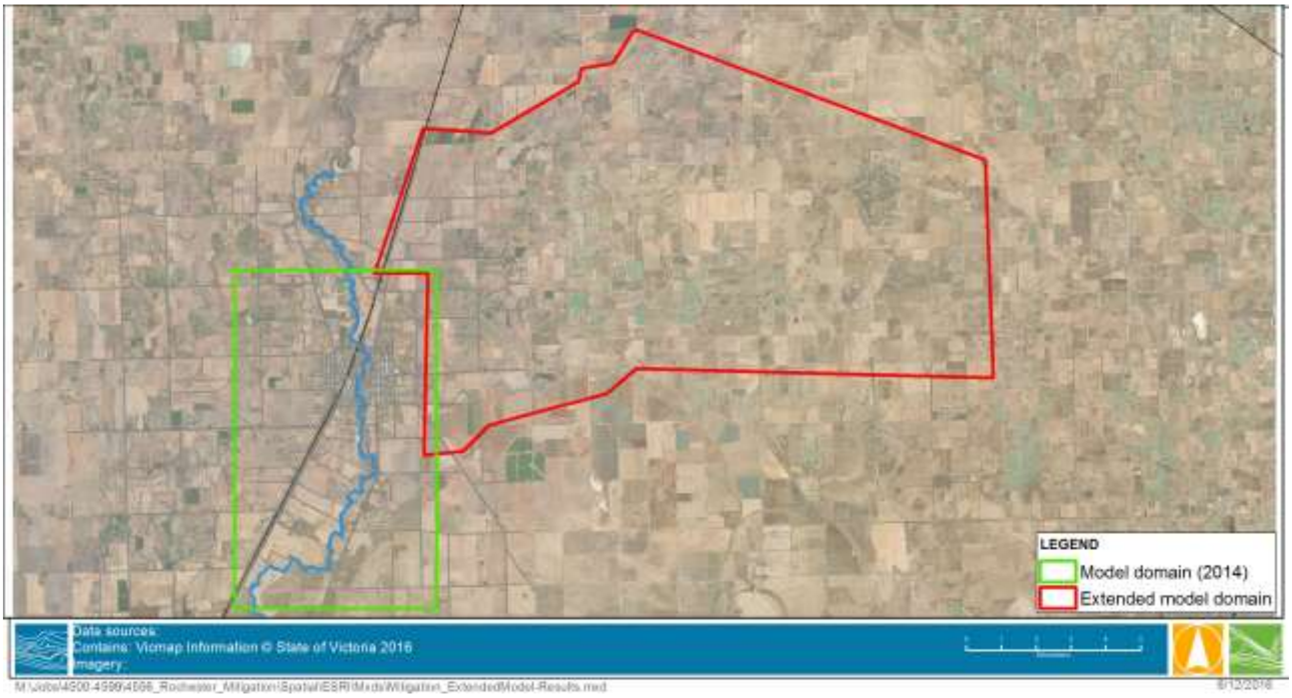


FIGURE 3-4 EXISTING AND EXTENDED MODEL DOMAINS

Additional LiDAR was flown early in 2017 to complete the existing set of available data which had a gap of up to 3 km as shown Figure 3-5.

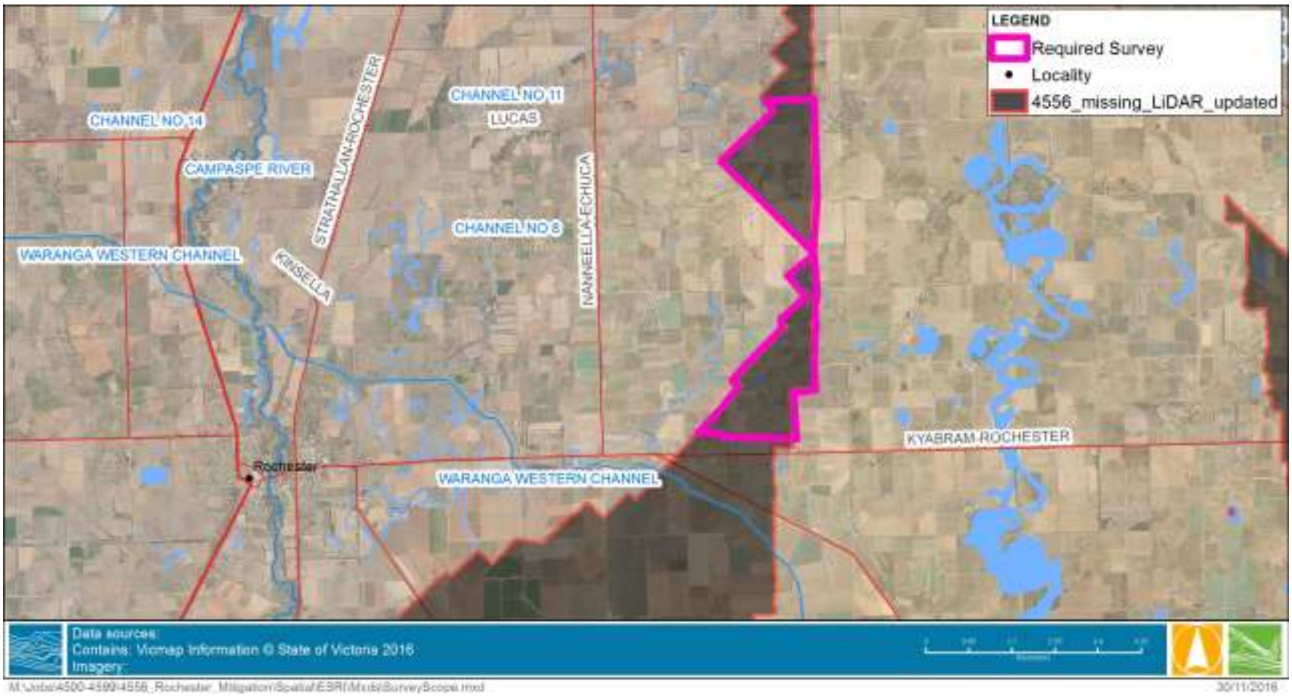


FIGURE 3-5 LIDAR GAP EAST OF ROCHESTER, AREA OF INTEREST NORTH OF THE WARANGA CHANNEL

The hydraulic structures along the extended area were also included in the model. A total of 11 structures (mainly road crossings) were added and are shown in Figure 3-6.

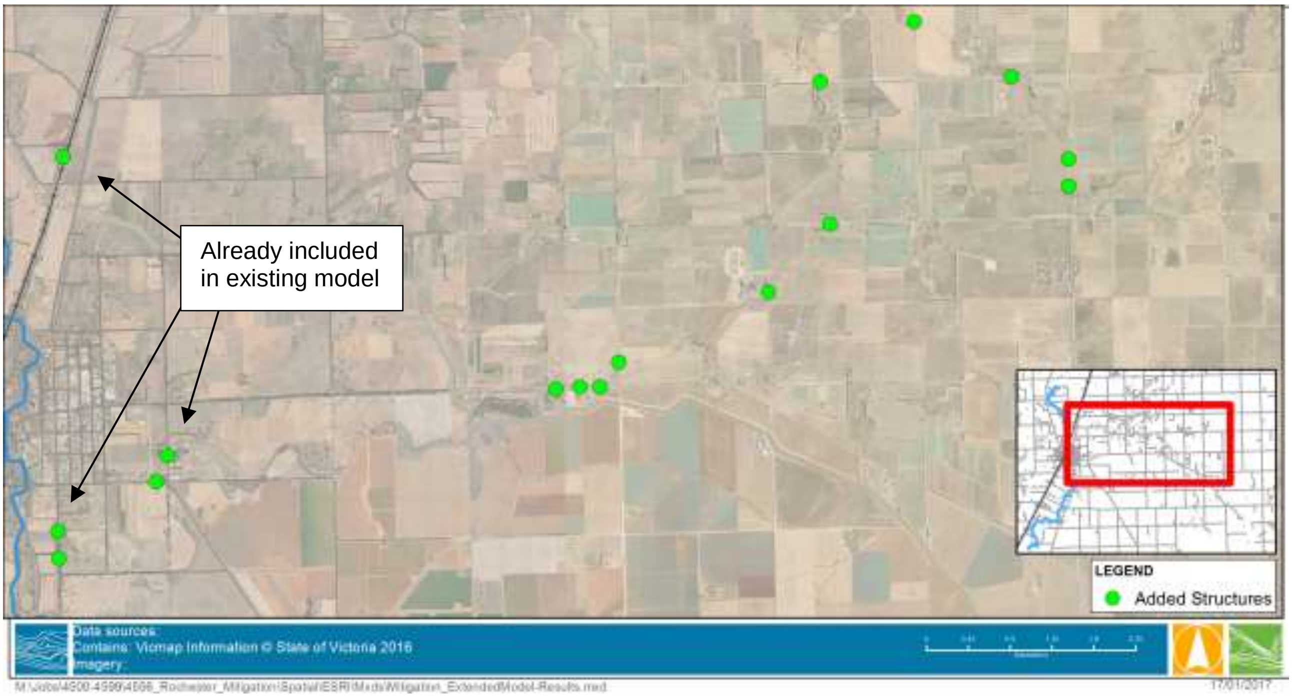


FIGURE 3-6 STRUCTURES ALONG THE NANEELLA DEPRESSION

4 PRELIMINARY OPTIONS ASSESSMENT (SUMMARY REPORT)

This section is the summary report which was previously submitted and presents the assessment of several additional mitigation options that have been raised by various stakeholders during the consultation phase of the Rochester Flood Management Plan. These options include upstream flow retardation/attenuation, increased capacity of the Kyabram Rochester Road bridge and railway bridge and retro-fitting flood protection measures to impacted buildings. These options were not considered in the original flood study and the community has requested that these options be investigated to ensure the community has all the necessary information regarding flood mitigation options in Rochester.

This assessment aimed to make a preliminary estimate of the benefit and indicative cost of each option and therefore the likely feasibility of each option. Recommendations were then made regarding whether further detailed analysis and investigation is warranted.

4.1 Option 1a – Upstream Flow Retardation/Attenuation

4.1.1 Overview

This option was raised by community members during the period of consultation at the conclusion of the Rochester Flood Management Plan.

The existing hydrological (RORB) model was utilised to understand the benefits that could be achieved through retarding flows upstream through construction of storages or retarding basins and the size and cost of works that would likely be required to achieve a material benefit at Rochester.

An initial sensitivity test was conducted to understand the impact if all runoff from the largest tributary, Mt Pleasant Creek, was removed from the catchment.

A more detailed assessment was then undertaken with respect to the current design flood flows in Rochester, i.e. what size storage would be required to reduce the current Campaspe River 1% AEP design flow to the current 2% AEP design flow. By basing the assessment on design events, a clearer understanding of the benefits of the works can be understood given each event has been analysed in detail in terms of the impacts and properties inundated as part of the Rochester Flood Management Plan.

4.1.2 Method

Mt Pleasant Creek is one of the largest tributaries of the Campaspe River with a catchment area of approximately 250 km^2. The initial sensitivity test on Mt Pleasant Creek simply involved removing the entire tributary from the hydrologic model. The model was then run for the 1% AEP, 2% AEP and 5% AEP design floods. It was found that the removal of Mt Pleasant Creek had a very limited impact on peak flows at Rochester as shown in Table 4-1, with around 5% reduction in peak design flow for the 1% AEP flood. This would result in a limited benefit in terms of flood risk at Rochester. This modelling highlighted that flows from further upstream, including Lake Eppalock, are the dominant contributor to flooding at Rochester.

TABLE 4-1 IMPACT ON PEAK FLOW AT ROCHESTER THROUGH REMOVAL OF MT PLEASANT CREEK FROM MODELLING

Design Flood Event	Peak Flow at Rochester (m^3/s)	
	Existing Conditions	Mitigated Conditions (removal of Mt Pleasant Creek flow)
1% AEP	860	820
2% AEP	676	615
5% AEP	484	428

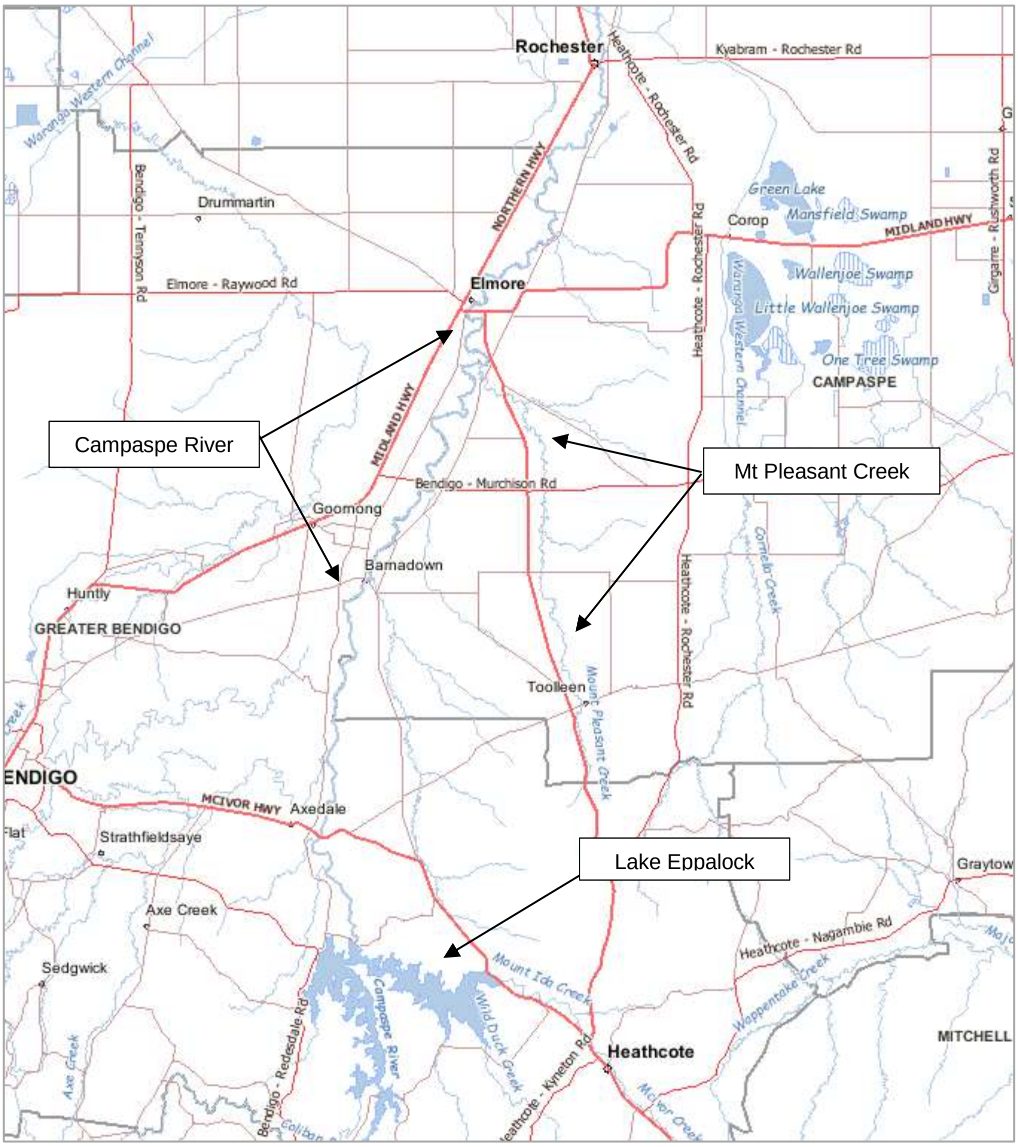


FIGURE 4-1 LOCATION OF MT PLEASANT CREEK WITH RESPECT TO ROCHESTER

A more detailed analysis was then undertaken looking at the potential for an additional storage or large retarding basin on the Campaspe River upstream of Rochester. In order to model the impact of an additional storage, the Rochester Flood Management Plan findings were first reviewed to understand what sort of reduction in peak flow would be needed to achieve an appreciable reduction in flood damages. A review of the hydrology and damages assessment indicated that to achieve a significant benefit, a reduction of approximately 200 m^3/s in the peak flow rate would be required. This would have the effect of reducing the current 1% AEP flood event to a 2% AEP flood event and in doing so, likely reduce the number of properties flooded above floor from 266 to 157. This corresponds to a reduction in damages of approximately $4 million in the 1% AEP design flood.

Testing in the hydrologic model determined that to achieve the required reduction in peak flow, a storage of approximately 100,000 ML would be required. This is a very significant storage which equates to approximately one third of the capacity of Lake Eppalock. The storage would also need to remain empty most of the time to have the required impact in major flood events. It is noted that, to our knowledge, a storage of this size has never been constructed in Australia for the primary purpose of flood mitigation.

4.1.3 Benefit

The benefit of this option is that the impacts of a 1% AEP event could potentially be reduced significantly by reducing the 1% AEP peak flow to a 2% AEP peak flow. Based on the damages assessment conducted in the Rochester Flood Management Plan the benefit from a damages perspective is approximately $4 million in the 1% AEP event with approximately 109 houses protected from above floor flooding. There would also be some benefit in smaller events although this would depend on the outlet arrangement of the storage and the event the storage is designed to mitigate against.

It should be noted that while the peak flow is reduced to that of a 2% AEP event, the volume is unchanged. While peak flow is a key driver of flood impacts, flood volumes are also very significant, particularly in floodplain areas such as Rochester. As a result, the benefits are likely to be slightly less than those shown in Table 4-2.

TABLE 4-2 POTENTIAL BENEFITS FROM CONSTRUCTION OF AN UPSTREAM STORAGE DESIGNED TO REDUCE 1% AEP PEAK FLOW TO 2% AEP PEAK FLOW

Scenario	Existing Conditions (1% AEP event)	Mitigated Conditions (equivalent to a 2% AEP event peak flow)
Properties Flooded above floor	266	157
Properties Flooded Below Floor	878	816
Total Damage Cost (2013 Estimate)	$11,761,145	$7,540,981

4.1.4 Cost

The cost of a 100,000 ML storage is estimated to be as high as $1 billion. This is based on the Federal Government's Water Infrastructure Options Paper[2] which contains indicative costings of major storages. It should be noted that due to the relatively flat terrain a dam of this magnitude would have a very large footprint and impact a large number of agricultural properties which would drive up costs significantly. Table 4-2 indicates with this option the damage cost for a 1% AEP event would be reduced by $4.2 million. The resulting

[2] Australian Government, *Water Infrastructure Options Paper*, 2015 (accessed at http://www.agriculture.gov.au/SiteCollectionDocuments/srm/water-infrastructure-ministerial-working-group/water-infrastructure-options-paper.doc)

benefit cost ratio for this option is estimated at less than 0.01 assuming the storage costs $1 billion. Assuming a very low capital cost estimate of $100 million results in a benefit cost ratio of approximately 0.05.

It should also be noted that, to our knowledge, a reservoir of this size has never been constructed purely for mitigation purposes in Australia and would need to remain empty before a flood to be effective.

Benefit-Cost Summary – Option 1a

The option of constructing an upstream storage on the Campaspe River has an extremely low feasibility with costs likely to be upwards of $100s of millions to achieve a significant benefit at Rochester. The storage would need to remain empty to be effective and no storage of this size has ever been built in Australia exclusively for flood mitigation purposes. It is extremely unlikely that such a proposal would ever attract funding.

Based on this assessment it is recommended that this option not be further considered.

4.2 Option 1b – Flow attenuation through revegetation immediately upstream of Rochester

4.2.1 Overview

Another option raised by community members during the period of consultation at the conclusion of the Rochester Floodplain Management Plan was to slow or attenuate the peak of the flood at Rochester by reinstating denser vegetation including trees along the waterway and across the floodplain upstream of Rochester. This was tested through representing denser vegetation by increasing the roughness in the hydraulic model. The model extends for approximately 8.5 km upstream of Rochester so this was the waterway extent that was investigated for increased vegetation.

The flow resistance inherent to the roughness of the river bed and surrounding terrain was increased in the upstream part of the model to represent the potential impact of increased vegetation in the channel and floodplain. The results were then analysed and compared to previous results to understand the benefits that could be achieved through retarding flows upstream, and the size and cost of works that would likely be required to achieve such a benefit.

The assessment was undertaken with respect to the current Campaspe River 1% AEP design flow.

4.2.2 Method

The roughness coefficient in the 2D model taking into account the flow resistance in the river bed as well as the surrounding floodplain upstream of Rochester was increased by 50%. The image below presents the area with the increased roughness coefficient.

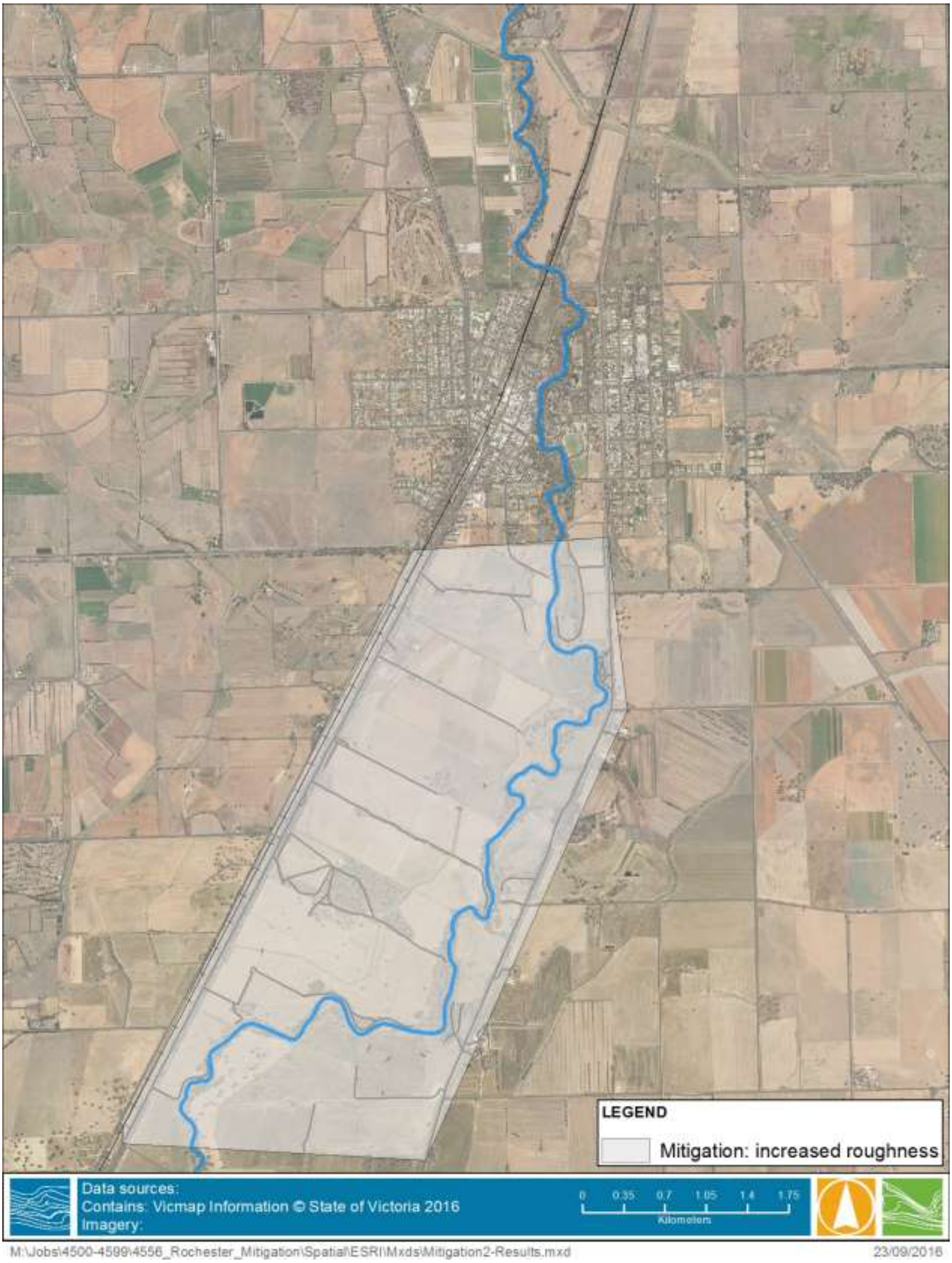


FIGURE 4-2 INCREASED ROUGHNESS AREA UPSTREAM OF ROCHESTER

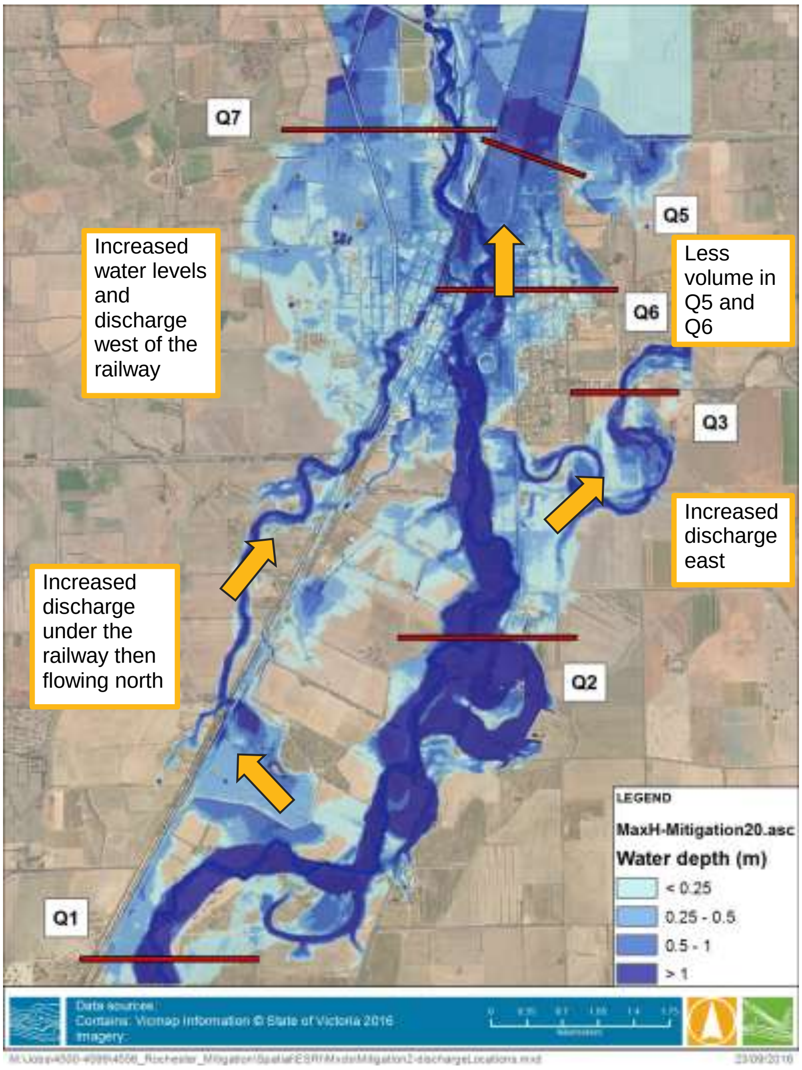
4.2.3 Summary of modelling

The applied Manning's "n" roughness coefficient of 0.08 is a value commonly used to represent very rough land in regard to flow resistance (i.e. dense vegetation). This was applied over approximately 8.5 km of floodplain along the Campaspe River upstream of Rochester.

The results show the significant impact of the increased roughness on the water levels and subsequent flood behaviour.
Figure 4-3 highlights the expected major impacts of heavily vegetating the 8.5 km section upstream of Rochester for the 1% AEP flood event. Flow changes are described at several sections within the Rochester floodplain.

Figure 4-5 below displays the difference in water levels between the existing conditions and the mitigation option tested here. Note the increase in flood extents and levels upstream of the bifurcation of flows towards the east (Nanneella depression). The increased roughness causes the water to slow down thereby raising water levels for the same inflow. Furthermore, additional water travels through the Black Culvert south of the township to join the western floodplain, before flowing north in the direction of Rochester.

Comparative plots of discharges calculated in different locations in the study area are shown in Figure 4-4. These highlight the redistribution of flows after the change in water levels in the floodplain.



Q1: the same design events are used for modelling; therefore, the upstream inflow is identical (855 m^3/s, calculated as a check)

Q2: the discharge in Q2 is 7% lower (855 to 793 m^3/s) because a greater part of the flooding is travelling west of the railway

Q3: the discharge of floodwaters going east is increased by approximately 166% (60 to 100 m^3/s)

Q5 and Q6: downstream of the eastbound floodway, peak discharge in the floodplain has been dropped by 30 m^3/s approximately.

Q5: 269 to 239 m3/s (-12%)

Q6: 422.5 to 389 m3/s (-8%)

Q7: Discharge in Q7 has risen by 20 m^3/s (+14%)

FIGURE 4-3 SCHEMATIC OF INCREASED ROUGHNESS IMPACTS

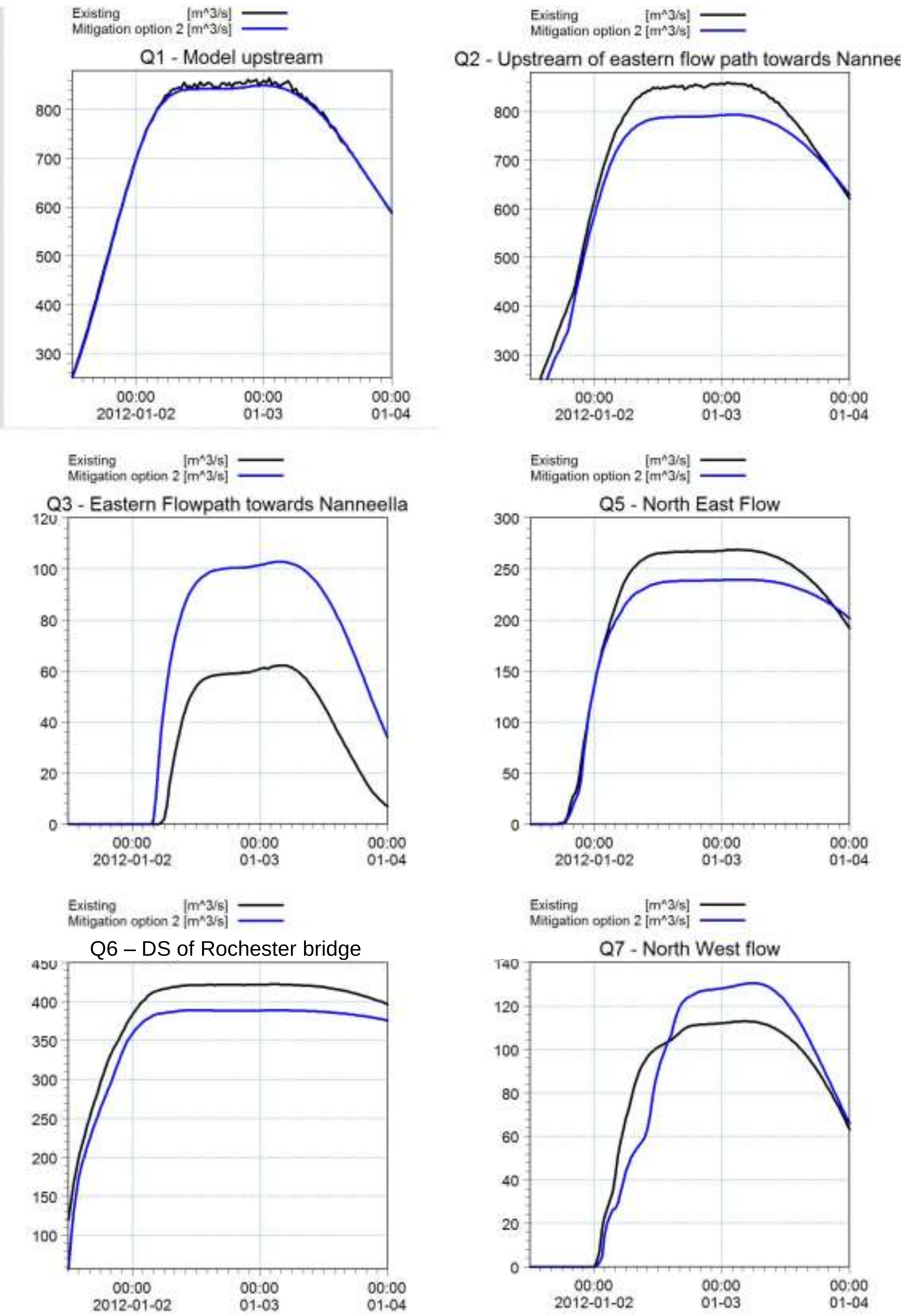


FIGURE 4-4 DISCHARGE CALCULATIONS IN EXISTING CONDITIONS AND WITH MITIGATION OPTION 2

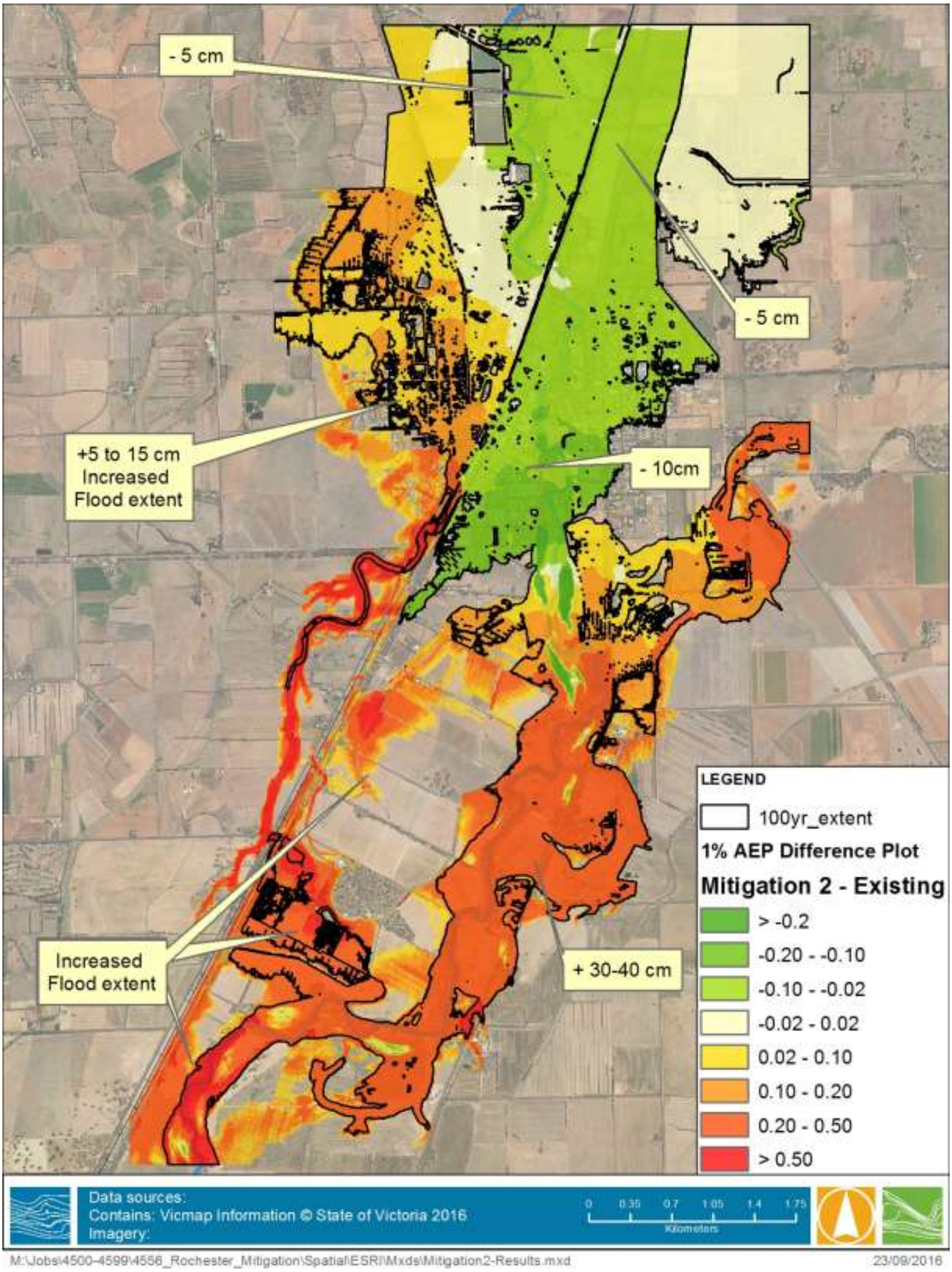


FIGURE 4-5 DIFFERENCE PLOT OF EXISTING AND INCREASED ROUGHNESS CONDITIONS. NEGATIVE VALUES INDICATE LOWER LEVELS WITH AN INCREASED ROUGHNESS. THE BLACK CONTOUR SHOWS THE FLOODING EXTENT UNDER EXISTING CONDITIONS

4.2.4 Benefit

The impact of this mitigation option in the urbanised areas of Rochester, in terms of flooding, are different on either side of the railway. Water levels are reduced on the eastern side, whereas they are higher on the western side. It is noted that where the water levels have been reduced, by about 10 cm east of the railway, the flood extent is like the existing conditions. West of the railway, water levels as well as flooding extents have increased.

The benefits of this option are limited, as certain areas experience adverse effects which negates the benefits in other areas. Overall a greater number of houses have higher water levels and above floor flooding occurs in more houses with the increased roughness option. Comparison of flooded buildings with the 1% AEP design event is summarized in Table 4-3.

TABLE 4-3 COMPARISON OF IMPACTED BUILDINGS – MITIGATION OPTION 1B (1% AEP EVENT)

	Number of buildings		(cm)
Properties with higher water levels under mitigation conditions	611	Average water level increase	0.12
Properties with lower water levels under mitigation conditions	487	Average water level decrease	0.07
Flooded above floor: existing conditions	266		
Flooded above floor: mitigated conditions	276		

4.2.5 Cost

An indicative cost of $3.25 million for revegetation costs has been estimated to achieve the increase in roughness represented in the modelling. This is based on revegetation across 460 hectares of wetted floodplain in the 1% AEP event. The revegetation costs assume $4.50 per plant for supply and labour and a density of 1500 plants per hectare. The costs also include re-fencing costed at $8 per metre with an assumed 17 km of fencing required. These costs are consistent with revegetation costs undertaken in several projects in recent years across Victoria. The costs exclude compensation costs which would likely be required as much of the area assumed to be revegetated is located on prime agricultural land on private property. These costs are likely to exceed the revegetation costs.

4.2.6 Revegetation Works Further Up the Catchment

Revegetation works further up the catchment have also been suggested with the aim of slowing and attenuating flow to improve flood conditions at Rochester. The options modelled in Option 1a and Option 1b demonstrate that both revegetation works and formal retardation works are not feasible given the significant costs involved to achieve any benefit.

A similar conclusion can be reached regarding revegetation further up the catchment. Very significant works would be required to achieve any differences in flood levels at Rochester and even then, the benefit is unlikely to be significant. It should also be noted that the further up the catchment the works are located, the larger the works required to achieve any material benefit at Rochester. There would also be significant compensation costs associated with the adverse impacts on agricultural land near the works further reducing the feasibility of this option.

It should also be considered that for such a scheme to be effective there would need to be significant floodplain storage available above the current flood level that is not currently being utilised. There are limited areas upstream of Rochester where such additional storage could be found with much of the reach being confined to a deep channel and narrow floodplain.

Based on the above, we believe revegetation works further up the catchment is not a feasible option and not worth further consideration at this stage.

Benefit-Cost Summary – Option 1b

The option of flow retardation through increased vegetation along the waterway and floodplain upstream of Rochester has a low feasibility. The modelling has found there would be no significant benefit from a flood risk perspective with many properties adversely impacted and costs likely to be in the region of $3.25 million (excluding compensation costs). This assumed revegetation of a relatively small area as opposed to catchment-wide revegetation.

Based on this assessment it is recommended that this option not be further considered.

4.3 Option 2 – Increased capacity of Highway and Railway Bridges

4.3.1 Overview

This option was assessed as part of the original Rochester Flood Management Plan and consisted of an increase in the flow capacity of the road and railway bridges to reduce losses through these structures and allow water to flow through Rochester more easily. The locations of these structures are presented in Figure 4-6.

FIGURE 4-6 LOCATION OF STRUCTURES MODELLED WITH INCREASED CAPACITY

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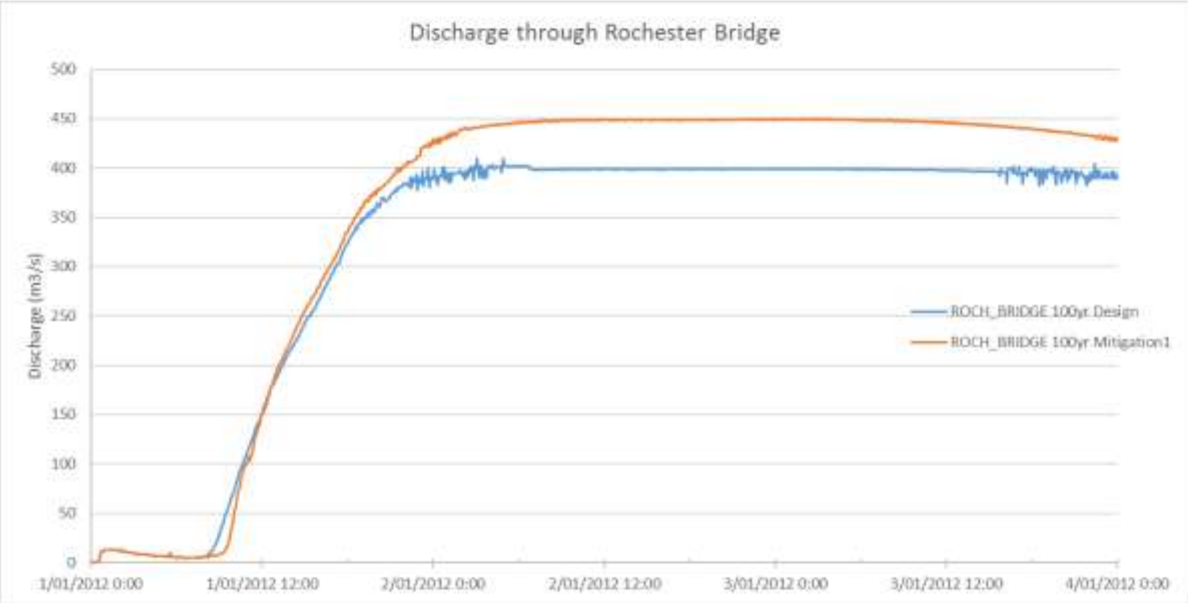
4.3.2 Method

This option was modelled by increasing the flow capacity of both the railway and road bridges by 25% and increasing the capacity of the waterway upstream and downstream of each structure to ensure the structure capacity could be fully utilised.

The results indicate that a significant increase in the capacity of both the rail and road bridges has minimal impact on flood levels and extents around Rochester. The map below presents the results of the simulation in a difference plot of the modelled water depths. The maximum impact on water levels is located immediately upstream of the Rochester Bridge with a reduction of 3-4 cm over a limited extent.

The impact on the discharge through the structures is shown in the plots below. The maximum discharge through the road bridge reaches 450 m^3/s compared to the existing conditions peak flow of 400 m^3/s.

The discharge through the railway bridge is only marginally modified by the change of geometry as shown in the second plot below which is likely a result of downstream control and water breaking away to the north, upstream of the bridge.



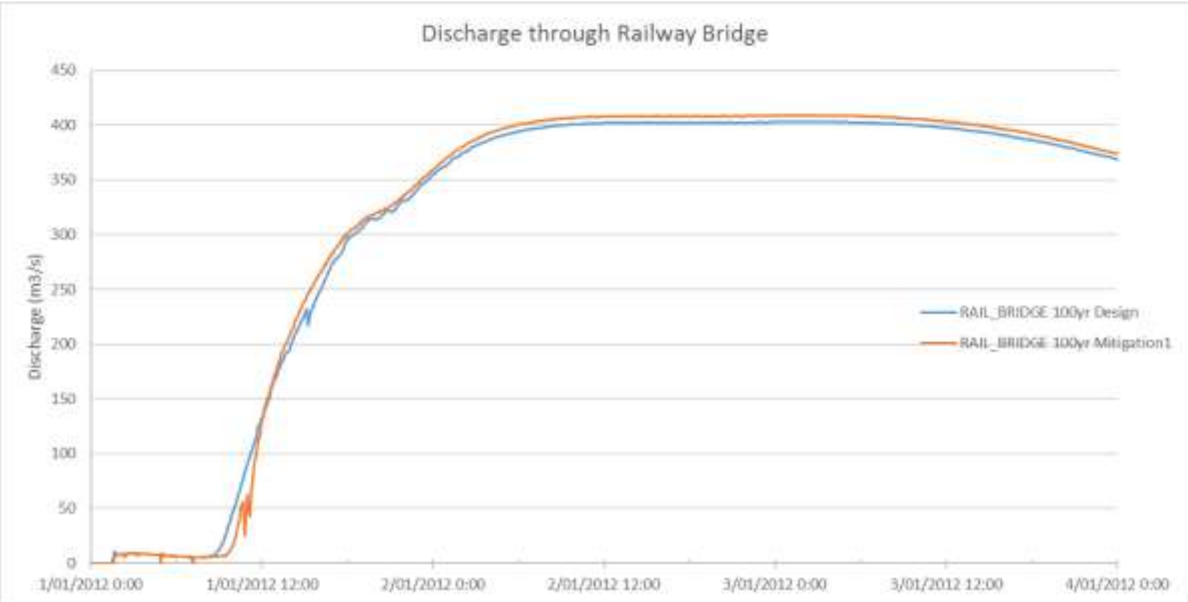


FIGURE 4-7 DISCHARGES THROUGH THE ROAD AND RAILWAY BRIDGES UNDER DESIGN AND MITIGATION CONDITIONS

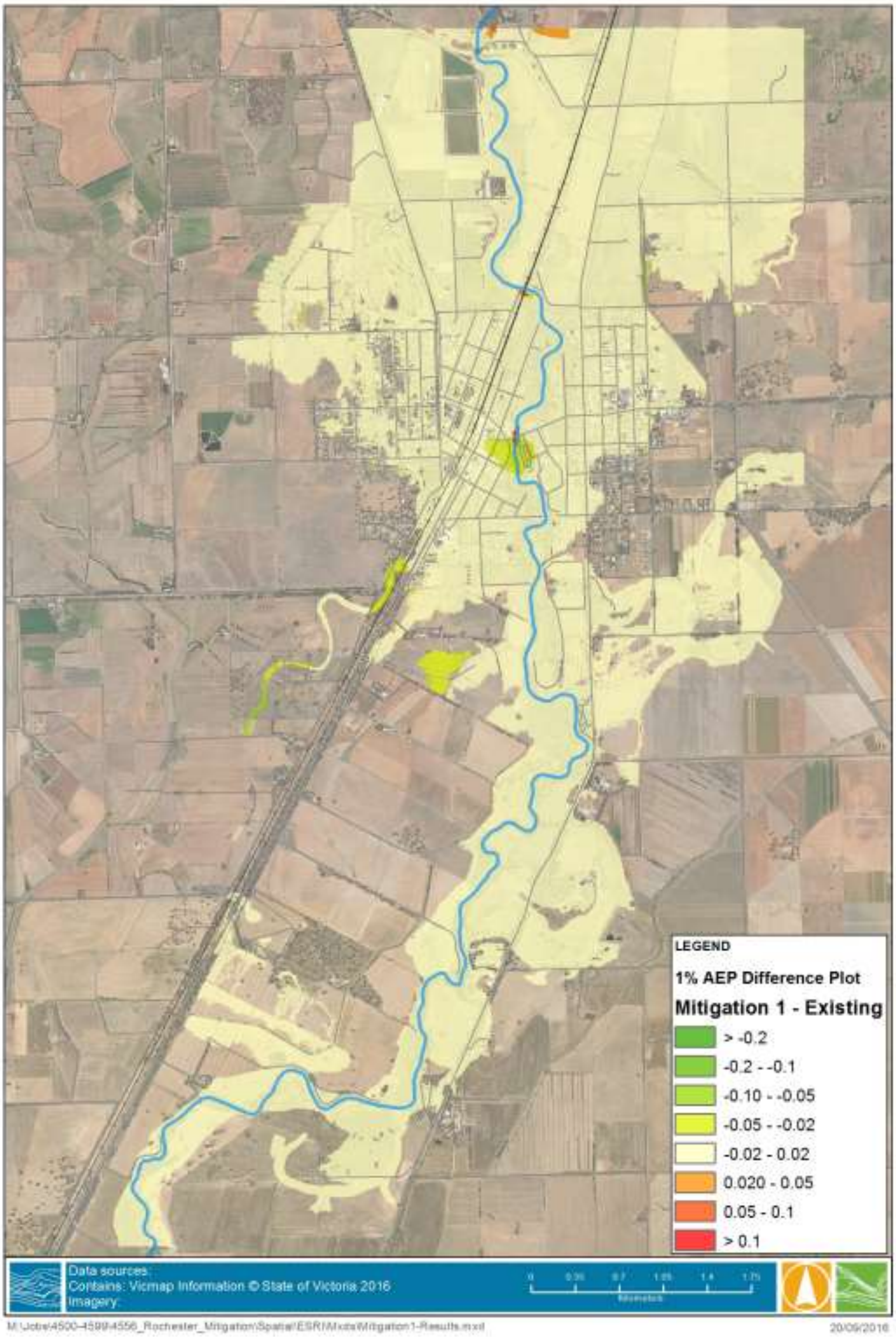


FIGURE 4-8 DIFFERENCE PLOT OF WATER LEVELS OBTAINED AFTER IMPLEMENTING THE MITIGATION OPTION (INCREASED CAPACITY OF HYDRAULIC STRUCTURES). NEGATIVE VALUES INDICATE LOWER WATER LEVELS ASSOCIATED WITH THE GREATER FLOW CAPACITY OF THE STRUCTURES.

4.3.3 Benefit

Increasing the flow capacity of the road and railway bridges was suggested to stop water backing up behind these structures and allow water to flow through Rochester more easily. This option was modelled by increasing the flow capacity of both the railway and road bridges by 25%. The impact on flood levels is shown below in Table 4-4 and in Figure 4-8 above.

The results indicate that a significant increase in the capacity of both the rail and road bridges has a minimal impact on flood levels and extents around Rochester.

TABLE 4-4 IMPACT ON WATER LEVELS THROUGH INCREASING ROAD AND RAIL BRIDGE CAPACITY

Location	1% AEP event
Immediately Upstream of Road Bridge	4 cm
Immediately Upstream of Rail Bridge	Less than 2 cm
Through residential areas upstream of the Road Bridge	Minimal, generally less than 1 cm

4.3.4 Cost

The cost to upgrade both structures would be in the region of $20-25 million. This is based on costings available from ARTC, VicRoads and Water Technology.

The key sources for this estimate are described below:

- An ARTC Inland Rail study working paper[3] which estimates the costs for replacement of bridges at $55,100 to $70,000 per metre length in brownfield locations. It is likely the entire structure would need to be replaced to achieve the increased capacity which, with an assumed length of 220 metres, would cost $12-15 million. Note the costs have not been adjusted for CPI.
- An estimate of $8-10 million was made for the replacement road bridge based on costing of similar Vicroads structures in other flood studies at Carisbrook[4] and Traralgon[5].

Benefit-Cost Summary – Option 2

The option of increased capacity through the main road and railway bridges in Rochester has a low feasibility. The modelling found there would be very limited benefit from a flood risk perspective with differences of generally less than 1 cm in residential areas. Cost are likely to be upwards of $20 million.

Based on this assessment it is recommended that this option not be considered further.

[3] ARTC, *Melbourne-Brisbane Inland Rail Alignment Study Working Paper No, 11* (accessed at http://www.artc.com.au/library/IRAS_WP11%20Stage%202%20Capital%20Works%20Costings%20-%20Full%20Paper.pdf)

[4] Water Technology, *Carisbrook Flood and Drainage Management Plan*, June 2013
[5] Water Technology, *Traralgon Flood Study*, March 2016

4.4 Option 3 – Retro-fitting Flood Protection to Existing Buildings

4.4.1 Overview

Retro-fitting flood protection works including raising floor levels was an option raised by community members in 2014. The mitigation option would consist of raising all floor levels (where practical) above the 1% AEP flood level. Costs for this will vary significantly depending on the size and type of buildings. Homes built on slabs will cost considerably more to raise than those on stumps.

Costings for this option is based on the following:

- Number of properties found to be inundated in the 1% AEP event
- Floor types for different types of dwelling
- Cost estimate of lifting floor levels

The Rochester Flood Management Plan indicates that a total of 266 properties are flooded above floor in a 1% AEP event.

The Glenorchy Feasibility Study[6], prepared by the CT Management Group, gives several case studies assessing an indicative cost of raising floor heights for different types of dwellings. Table 4-5 below shows the 2012 cost per dwelling from the Glenorchy study and the 2016 cost adjusted for CPI. It should be noted that the Glenorchy costs only cover the site works to raise the dwelling. They do not consider external/landscaping works, asbestos removal, planning/project management costs and building permits which are likely to increase the cost significantly.

Based on the above, and including significant contingency, a cost range for each dwelling type was adopted. The results are shown in Table 4-6 and includes the total cost for Rochester which was determined to be $12.37 million. The estimated number of dwellings for each dwelling type was based on a combination of on-ground assessment by Council and desktop assessment by Water Technology.

It should also be noted that in some cases it will be too impractical and expensive to raise the floor levels depending on the method of building construction, particularly those constructed on slabs. In these locations where raising the floor is impractical, the costs estimated below would be directed towards localised mitigation works such as a flood wall or ring levees. The costs are indicative but should reasonably cover such works.

TABLE 4-5 DWELLING COSTS FROM GLENORCHY FEASIBILITY

Building Type	2012 Cost Per Dwelling (CT Management Group)	2016 Adopted Cost Per Dwelling (adjusted for CPI)
Low Clearance Timber Dwelling (on stumps)	$34,700	$37,000
Timber Dwelling with Reasonable Sub-Floor Clearance (on stumps)	$19,700	$21,000
Timber Framed Dwelling on Concrete Slab	$48,200	$51,400
Steel Framed Dwelling on Concrete Slab	$31,300	$33,400

[6] CT Management Group, *Glenorchy Feasibility Study*, August 2012

TABLE 4-6 ESTIMATED COST FOR RAISING DWELLINGS ABOVE 1% AEP FLOOD LEVEL AT ROCHESTER

Building Type	Estimated Number (Indicative Only)	Adopted Cost Range Per Dwelling	Total Cost (based on mid-point of adopted range)
Low Clearance Timber Dwelling (on stumps)	66	$30,000-$60,000	$2.97 million
Timber Dwelling with Reasonable Sub-Floor Clearance (on stumps)	120	$20,000-$50,000	$4.20 million
Timber Framed Dwelling on Concrete Slab	53	$50,000-$100,000	$3.98 million
Steel Framed Dwelling on Concrete Slab	27	$30,000-$60,000	$1.22 million
Total Cost			$12.37 million

- Excludes relocation of occupants for up to 8 weeks (potentially an additional $5-10K per dwelling)
- Excludes garages and outbuildings where significant damage costs can also be incurred

4.4.2 Benefit

The benefit of this option is that up to 266 properties would be protected from above floor flooding in the 1% AEP design flood should that be selected as the level of protection required. It should be noted that there would still be significant external damages including damage to garages and outbuildings. The intangible damages would also remain significant due to the stress related to external damages and potential isolation. Significant clean-up costs would also still be incurred.

By raising floors impacted in the 1% AEP design flood to 300 mm above 1% AEP flood level, several properties would also be protected in more frequent events in which they would have otherwise been inundated above floor level. The following table summarises the number of properties which would benefit based on raising floors to above 1% AEP design flood level.

TABLE 4-7 BENEFIT OF RAISING FLOOR LEVELS ABOVE 1% AEP FLOOD LEVEL

Design event	1% AEP	2% AEP	10% AEP	20% AEP
Total number of houses no longer flooded above floor	266	157	32	3
Reduction in Above Floor Damages	$7.16 million	$3.85 million	$0.66 million	$0.01 million

The Average Annual Damages (AAD) estimate for Rochester under existing conditions is $431,000 and was determined as part of the flood damage assessment in the Rochester Flood Management Study. The AAD is a measure of the flood damage per year averaged over an extended period. Based on a preliminary assessment, the AAD resulting from raising floors above the 1% AEP flood level would remain quite high at around $290,000. This is due to the costs associated with external and infrastructure damages and clean-up costs which would remain essentially unchanged despite the reduction in above-floor flooding. The reduction in AAD is therefore estimated at approximately $150,000 with this option.

4.4.3 Cost

The following table summarises the costs for raising buildings to provide a 20, 50 and 1% AEP level of protection. Assuming 1% AEP level protection the total cost is likely to be of order $9 million. This is an indicative figure and, should this option be investigated further in the future, a detailed feasibility study would be required to refine the estimated costs.

TABLE 4-8 COST OF RAISING FLOOR LEVELS FOR DIFFERENT LEVELS OF PROTECTION

Level of Protection	Number Of Floors Raised	Total Cost
5% AEP Event	32	$1.03 million
2% AEP Event	157	$1.49 million
1% AEP Event	266	$12.37 million

Benefit-Cost Summary – Option 3

The option of retro-fitting flood protection measures to 1% AEP impacted properties has a low feasibility. The analysis has found that if all properties impacted above floor in the 1% AEP were protected the capital cost would likely be in the region of $12-13 million. Many of those properties would still suffer isolation and incur significant external damages and clean-up costs in the 1% AEP event. The reduction in average annual damages was determined to be in the region of $150,000.

Based on this assessment it is recommended that this option not be considered further unless all other options prove to be unviable. Smaller scale more targeted floor raising for vulnerable properties may be more economically viable.

5 COMPARISION OF MITIGATION OPTIONS

The table below compares the range of options and scenarios considered both in the Summary Report (2017) and the original Rochester Flood Management Plan. A description of each option is provided as well as the benefit and estimated cost. Scenario 3, the final preferred scenario from the Rochester Flood Management Plan, is the only option or scenario determined to have a benefit-cost result greater than low.

TABLE 5-1 COMPARISON OF ROCHESTER MITIGATION OPTIONS

Option	Description	Benefit	Estimated Cost	Benefit-Cost
Rochester Flood Management Plan Options (2013)				
Scenario 1	Removal of several decommissioned levee banks around Rochester	Determined that the levee banks play an important role in flood risk, some will need to be replaced with formal levee banks.	Not determined as option was a sensitivity test	Not applicable
Scenario 2	Diverting flow to the west of Rochester using levee banks near Campaspe Channel No. 1	Significant benefit to Rochester but results in widespread inundation of agricultural land which would be associated with very high easement and compensation costs	$85 million (indicative)	Low
Scenario 3 (Final Preferred Scenario)	Combination of levees and excavation of high land to reinstate the eastern drainage line	Protects 125 properties from above flood flooding in the1% AEP events and 19 properties in the 5% AEP event. Reduction in AAD (annual average damages) of $160,000.	$1.8 million (note: determined in the original Rochester Flood Study, doesn't include compensation/ acquisition costs or impacts through Nanneella Depression)	High (Preliminary Benefit-Cost Ratio of 1.1)
Additional Mitigation Options (2016)				
Option 1a	Construction of upstream storages	Has potential to reduce flood risk in Rochester but very large storages would be required to achieve an appreciable difference	$1 billion (indicative)	Low
Option 1b	Revegetation of the waterway and floodplain upstream of Rochester	Reduction in flood levels in some areas but no net benefit due to widespread adverse impacts to agricultural and residential areas.	$3.25 million (indicative)	Low
Option 2	Increasing hydraulic capacity of railway and road bridges	Very limited benefit (flood levels lowered by approximately 1 cm)	$20 million (indicative)	Low

Option	Description	Benefit	Estimated Cost	Benefit-Cost
Option 3	Raising floor levels above 1% AEP flood level	Up to 266 properties protected from above floor flooding in 1% AEP event. Reduction in Average Annual Damages (AAD) of approximately $150,000.	$12-13 million (indicative)	Low

5.1 Comparison of Feasibility between Raising Floor Levels and reinstating the Eastern Drainage Line

The two mitigation options which have been discussed most frequently by key stakeholders have been raising of floor levels and reinstating the eastern drainage line. Based on preliminary data, the eastern drainage line has a higher feasibility than raising floor levels with a preliminary benefit-cost ratio of approximately 1.1 determined in the original Rochester Flood Management Plan. The feasibility for the eastern drainage line option has now been examined in more detailed and is presented in Section 10.

Table 5-2 below displays a comparison of the preliminary benefit-cost ratio of the two mitigation options. An indicative benefit-cost ratio has been determined for the floor raising scenario based on the preliminary costing and benefits described earlier in this report. The floor raising scenario has a very low benefit-cost ratio indicating that it is unlikely that such a scheme would attract government funding.

TABLE 5-2 COMPARISON OF FEASIBILTY BETWEEN FLOOR RAISING AND EASTERN DRAINAGE LINE

Option	Description	Preliminary Estimated Cost	Indicative Benefit-Cost Ratio
Reinstating Eastern Drainage Line	Combination of levees and excavation of high land to reinstate the eastern drainage line	$1.8 million (Water Technology, 2012)	**1.1**
Raising Floor Levels	Raising floor levels above 1% AEP flood level	$12-13 million (indicative) (Water Technology, 2017)	**0.2**

6 PRELIMINARY OPTIONS ASSESSMENT (SUMMARY REPORT) SUMMARY

Several alternative mitigation options to improve flood risk at Rochester were analysed and a pre-feasibility assessment was undertaken. The analysis found:

- Option 1a: The construction of upstream storages can be effective at reducing flood risk in Rochester but a very large storage (one third the capacity of Lake Eppalock) is required to achieve a meaningful benefit. The costs associated with these options would be very high and so the feasibility of this option is considered low. It is unlikely this option would be able to secure funding given the prohibitive cost and likely low benefit-cost ratio.
- Option 1b: Revegetation of the waterway and floodplain upstream of Rochester in order to slow/attenuate peak flows was investigated but found to offer no significant benefit in terms of flood risk, with many properties adversely impacted. The cost associated with this option is high and with the lack of benefit in terms of flood risk, the feasibility of this option is considered low.
- Option 2: Increasing the hydraulic capacity of the Rochester and Railway bridges was found to have limited impact on flood behaviour around Rochester. There was no material benefit to flood risk across the town and the relative cost associated with this option is considered high, therefore the feasibility of this option is considered low.
- Option 3: Raising buildings above the 1% AEP flood level is effective at protecting from above floor flooding, although significant damage costs remain associated with external damages and clean-up. The cost associated with this option is considered high, with a minor-moderate level of benefit. This feasibility of this option is considered low and does not warrant further investigation unless all other options are found to be unviable. It is possible that smaller scale targeted floor raising for the most vulnerable buildings may be more economically viable.

The summary above shows that all the additional mitigation options were found to have a low feasibility and do not warrant further analysis at this stage. When comparing the range of options considered in both this study and the original Rochester Flood Management Plan the only option or scheme found to be feasible is the preferred mitigation scheme from the original study which aims to better engage the drainage line to the east of Rochester.

Based on these findings the use of the eastern drainage line remained the most viable option to achieve a material improvement in flood risk at Rochester. Based on this it was agreed that the scheme be further investigated through detailed modelling, survey and benefit-cost analysis.

7 PRELIMINARY EASTERN DRAINAGE MODELLING

This section presents the results of modelling several variations on the eastern drainage line mitigation option prior to a final package of works being determined for more detailed analysis. The following scenarios were all tested in the extended hydraulic model, which includes the Nanneella Depression. These scenarios involved variations of reinstating the eastern drainage line.

7.1 Reinstating the Eastern Drainage Line (Original Flood Management Plan Scenario)

It was determined previously in this report that the final preferred mitigation scenario from the Rochester Flood Management Plan was the only option likely to make a significant improvement in flood risk to Rochester and be feasible to implement. It consisted of a combination of levees and excavation of a man-made embankment on the eastern bank of the Campaspe River aiming to reinstate the eastern drainage line which flows on to the Nanneella Depression. The locations of key features of the scenario around Rochester are presented in Figure 7-1. These features are described in more detail in Section 8 (Final Mitigation Scheme).

It should be noted that the northern excavation which was included in the original Rochester Flood Management Plan scenario was not included in this modelled scenario. It was noted that recent works have been undertaken in this area including construction of a large shed across the proposed flow path so the option was omitted to see if similar benefit could still be achieved without that measure. The feature is included as an optional item in the final mitigation scheme.

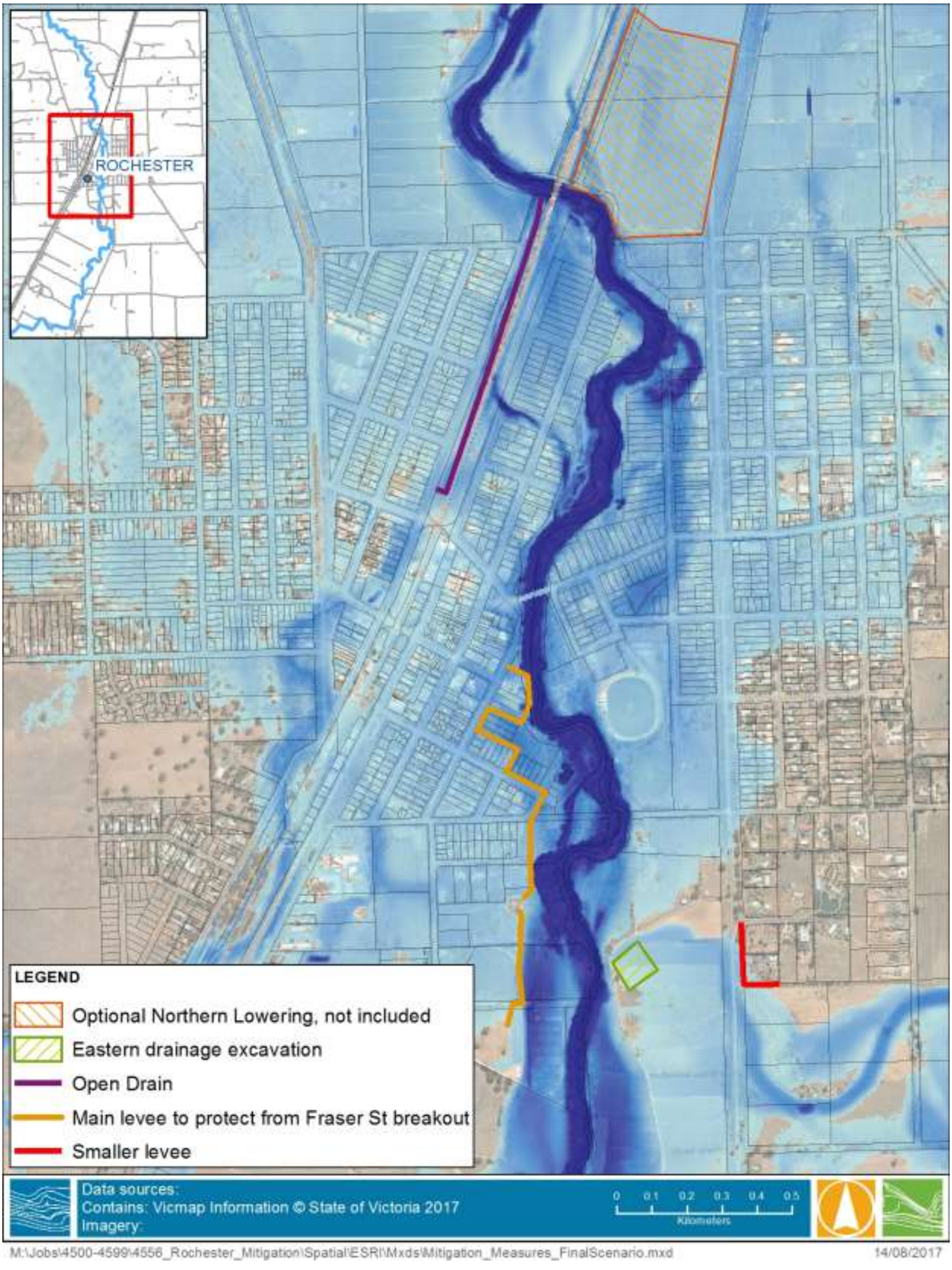


FIGURE 7-1 KEY FEATURES OF THE SCHEME TO BETTER ENGAGE THE EASTERN DRAINAGE LINE

To better understand the impacts along the eastern drainage line, floor level survey was captured for 82 buildings through this reach which might be adversely impacted by the scheme. Figure 7-2 shows the impact on flooding of re-engaging the eastern drainage line on flood behaviour through the impacted area to the north-east of Rochester. The results show that the increased engagement of the drainage line results in significantly larger flood extents and depths of flooding.

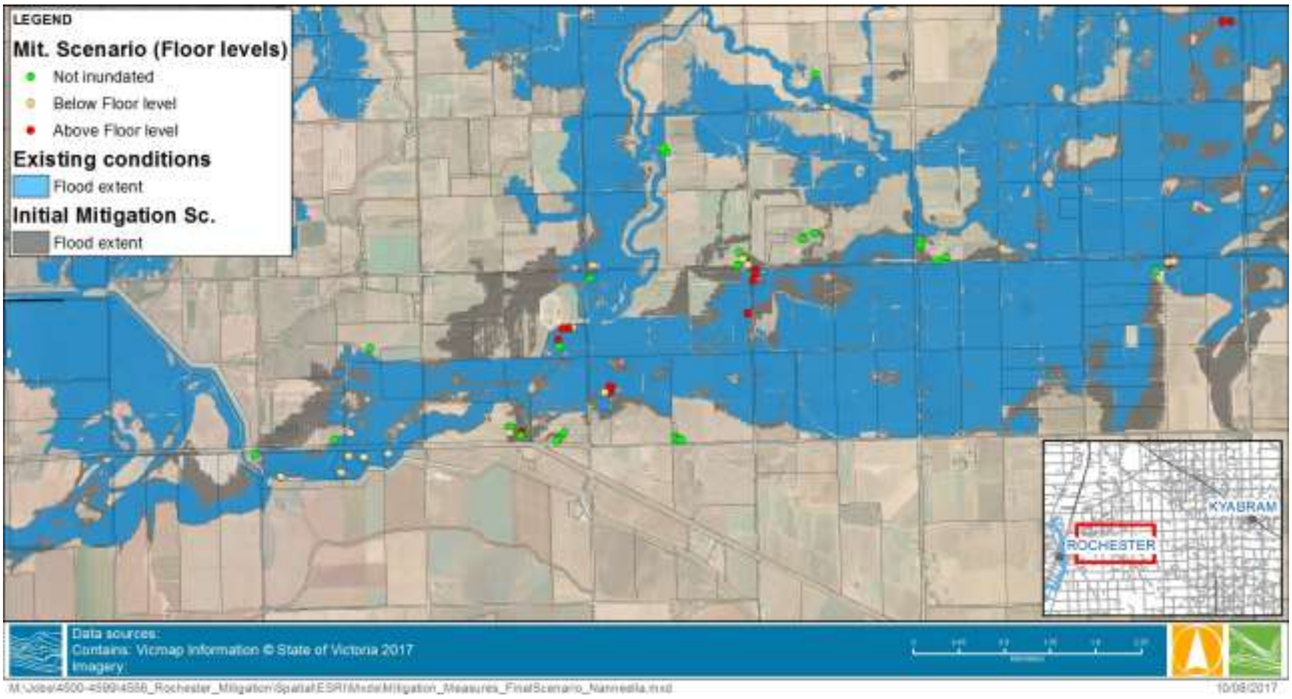


FIGURE 7-2 FLOOR LEVEL SURVEY AND IMPACT ON FLOODING OF RE-ENGAGING THE EASTERN DRAINAGE LINE

The preliminary modelling results indicate the following impacts along the eastern drainage line under this scenario:

- Under the mitigation scenario, 1% AEP peak water levels are increased by 50 to 190 mm through this reach with a mean increase of 130 mm;
- 12 properties were flooded under existing conditions, 29 properties are flooded under mitigation conditions.
- 76% of the buildings that don't flood under current conditions in the 1% AEP event remain flood-free in this scenario (i.e. 53 out of a total of 70 initially flood free buildings don't flood under mitigated conditions);
- Of the 17 newly inundated properties caused by the increased flows along the Nanneella depression, 9 are now flooded above floor level, and
- Under existing conditions, 12 buildings along the drainage line are impacted by flooding with 3 of those flooded above floor level. Under the eastern drainage line mitigation scheme an additional 13 properties are flooded above floor level (total of 16 flooded above floor level, assuming no local protection is provided).

Based on the impacts described above many additional scenarios were tested to mitigate the adverse impacts along the eastern drainage line and to better understand flooding through this area. It should be noted that the following model runs (Scenarios 1, 2 and 3) were undertaken before the new LiDAR became available for the study area. The results below therefore focus on the properties where good topographical data was available along the Nanneella Depression between the intersection with the Waranga Channel and the Echuca-Nanneella Rd. LiDAR was then available for the final mitigation scheme modelling.

7.2 Scenario 1 – Increased structure capacity and flow diversion

7.2.1 Overview

The results shown that many properties are susceptible to inundation where the eastern drainage line crosses Webb Road with several residential and agricultural buildings located in this area. It is also noted that the drainage line weaves back and forth across the road along this section with the roadway being overtopped for a significant distance.

This scenario aimed to direct flow north of the road and avoid the pocket of buildings on the south of the road, also reducing the volume of water which must cross multiple culvert structures. It was hoped that the works would lower flood levels around the properties south of the road. The excavated channel along the north side of Webb Road aims to ensure the properties to the north of the road aren't adversely impacted. The channel was set to be 10m wide and approximately 1.5m deep. The dimensions purposely large to test the potential impact on surrounding flood levels.

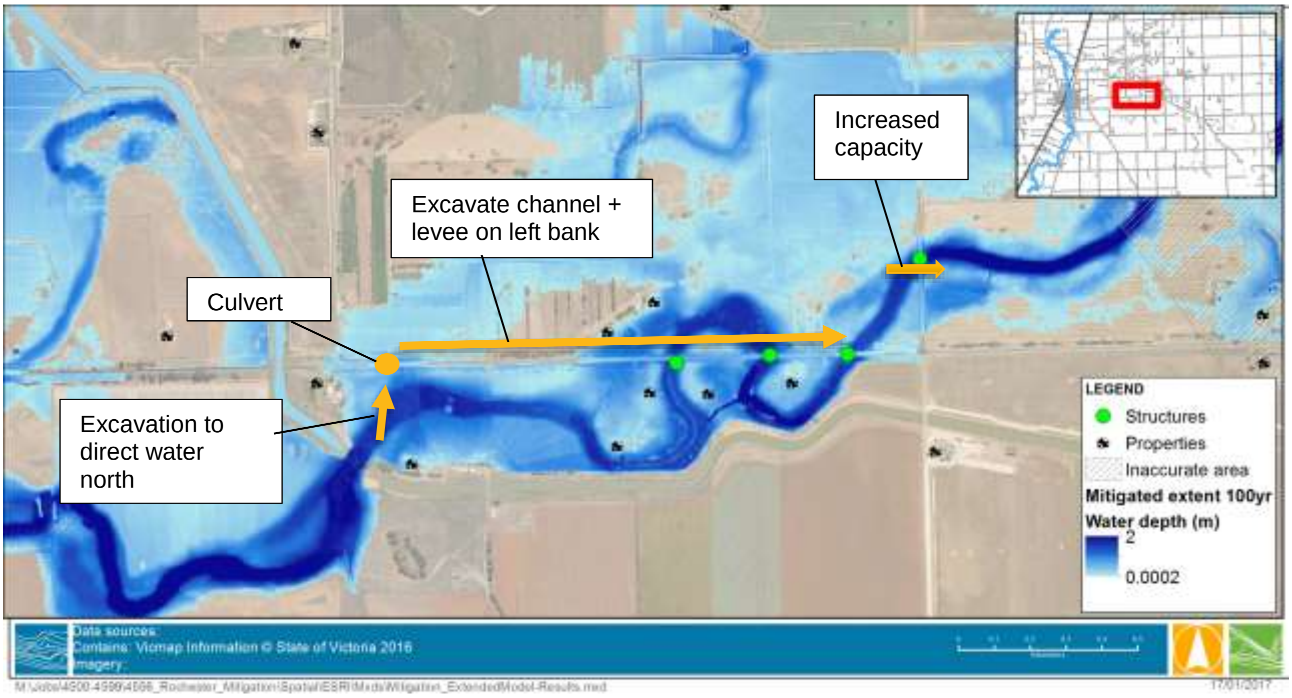


FIGURE 7-3 SCENARIO 1 FEATURES

7.2.2 Results

The difference map below (Figure 7-4) presents the comparison of results between the initial configuration of reinstating the eastern drainage line and the Scenario 1 local options described above aimed at mitigating the adverse impacts of the eastern drainage scenario.

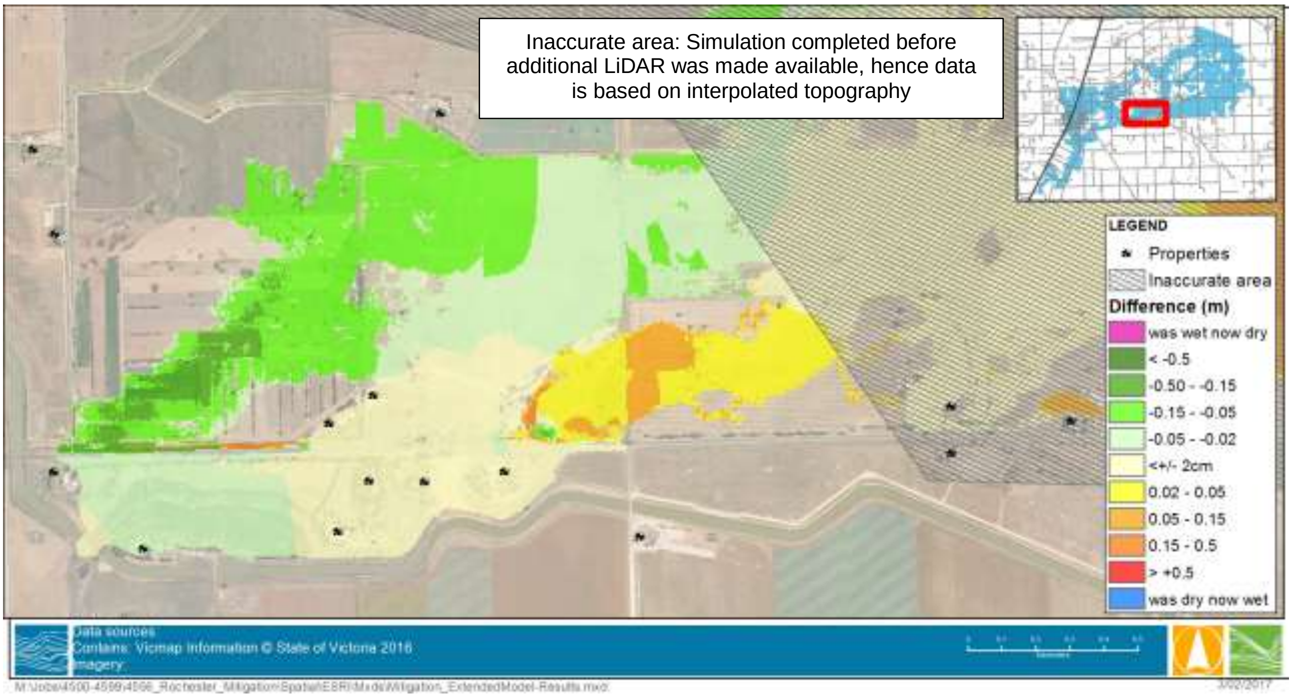


FIGURE 7-4 DIFFERENCE MAP – SCENARIO 1

The results of this scenario show that peak flood levels are lowered by a maximum of 50 mm with the impacts occurring very locally, which marginally improves the flooding at one property where the maximum water level is decreased by 2cm. For the other properties, the benefits are negligible compared to the mitigation scenario with no variation. Indeed, the discharge passing the Waranga channel is above 100 m^3/s. Diverting and controlling that volume of water through a channel would require works at a large scale, which would be cost prohibitive.

Further downstream, the water being redirected through the excavated channel along Webb Rd and through the increased capacity of culverts under the Echuca-Nanneella Rd causes an increase in levels which extends for approximately 800 metres downstream.

The results show that the scenario offers no benefit in terms of providing a significant improvement to flood risk or reducing above floor flooding.

7.3 Scenario 2 – Local protection works

7.3.1 Overview

This scenario was also aimed at mitigating the adverse impacts to the pocket of properties along Webb Road and consisted of providing local protection by installing ring levees around each building, with the levees providing 1% AEP flood protection. The scenario also included improving flow along the drainage line by increasing culvert capacity, as well as excavating sections of the channel to increase capacity and lower adjacent flood levels.

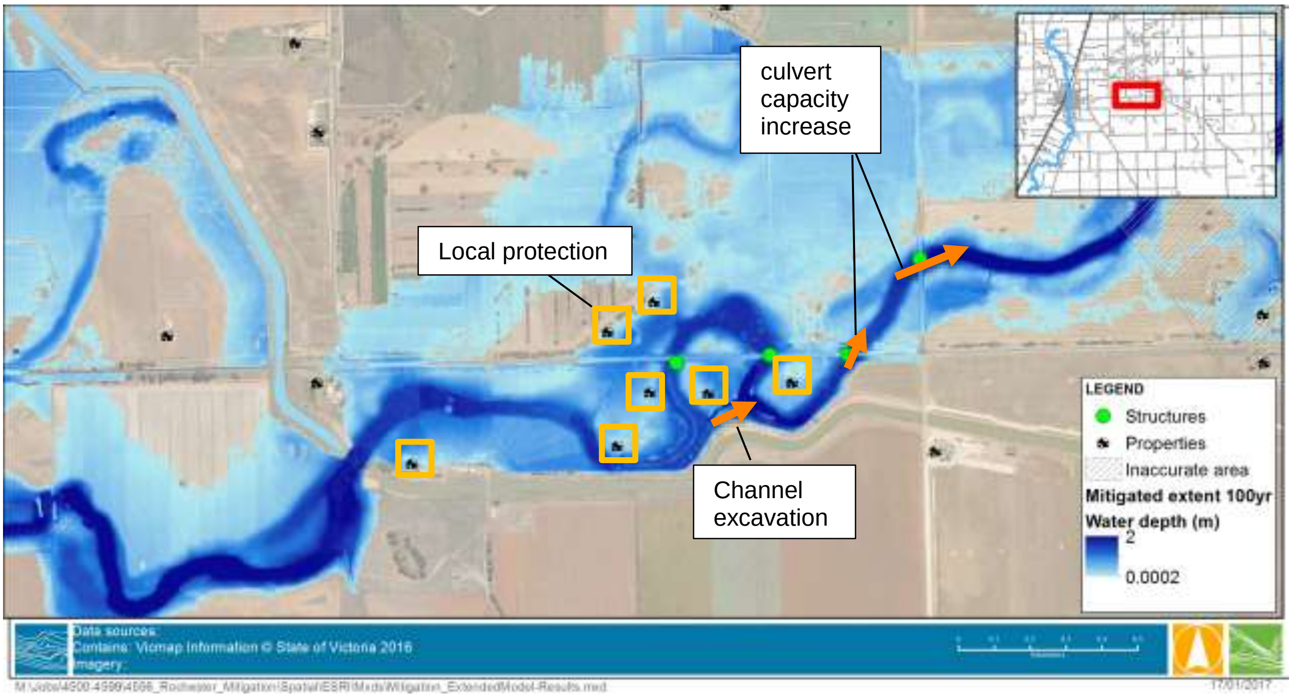


FIGURE 7-5 SCENARIO 2 FEATURES

7.3.2 Results

The difference map below (Figure 7-6) presents the comparison of results between the initial eastern drainage line scenario and the Scenario 2 local options described above.

The ring levees are effective in keeping the buildings flood-free and the comparison with the initial set-up shows no adverse impacts on surrounding water levels as a result of the local works. This is due to the negligible volumes that represent the blocked areas compared to the total flow across the flood path.

The difference map also shows some increased water levels downstream which is a result of the increased flow capacity due to the excavated channel and increased culvert capacity. The adverse impacts extend for approximately 1,200 metres downstream. The culvert and excavation works appear to offer little benefit in terms of lowering adjacent or upstream water levels.

This result indicates that local levees can be used to locally protect properties from flooding without adversely impacting maximum flood levels across the flow path.

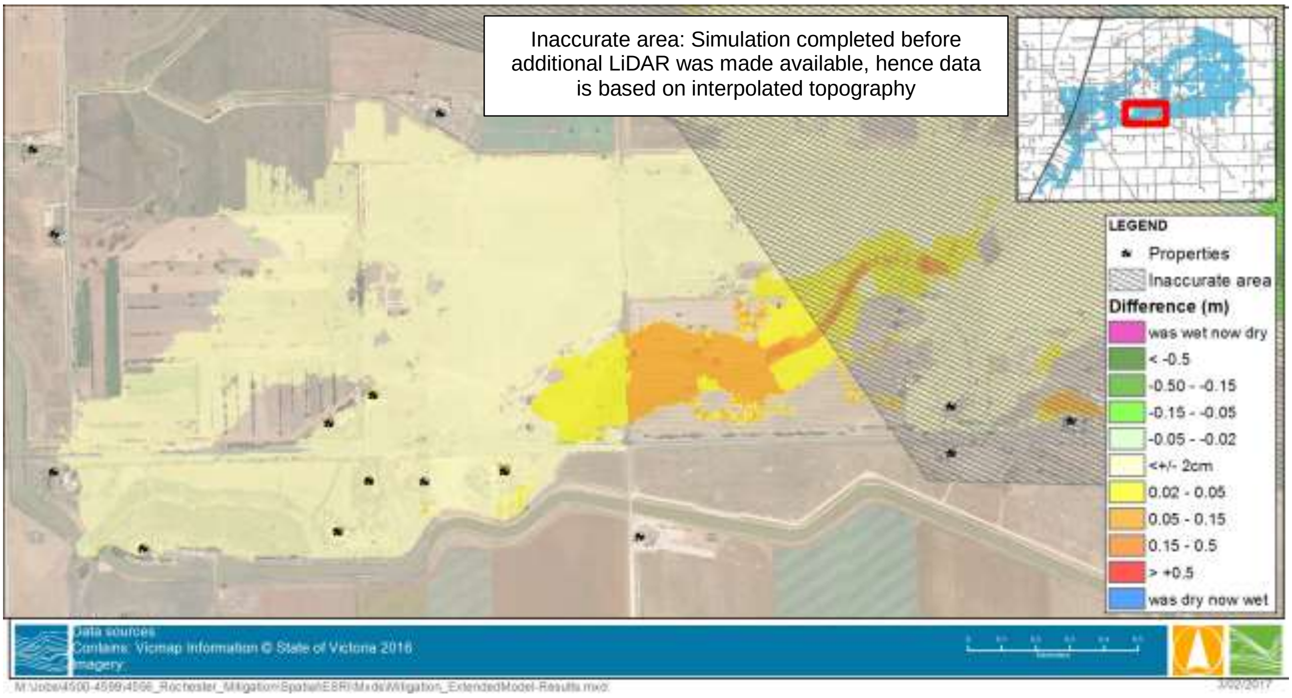


FIGURE 7-6 DIFFERENCE MAP – SCENARIO 2

7.4 Scenario 3 – flow diverted around residential properties

7.4.1 Overview

This scenario was also aimed at mitigating the adverse impacts to the pocket of properties along Webb Road and consisted of directing more flow to the north of the pocket of properties by excavating a new channel, lowering Webb Road (floodway) and constructing a partial blockage of the existing drainage line to limit flow along that flow path. The scenario also includes a floodway across the Nanneella Road further downstream to improve flow capacity along the new flow path. The key features of the scenario are shown in Figure 7-7.

It was hoped that the excavation of the flow path to the north and partial blockage of the existing drainage line would lower the water levels around the pocket of properties in this area.

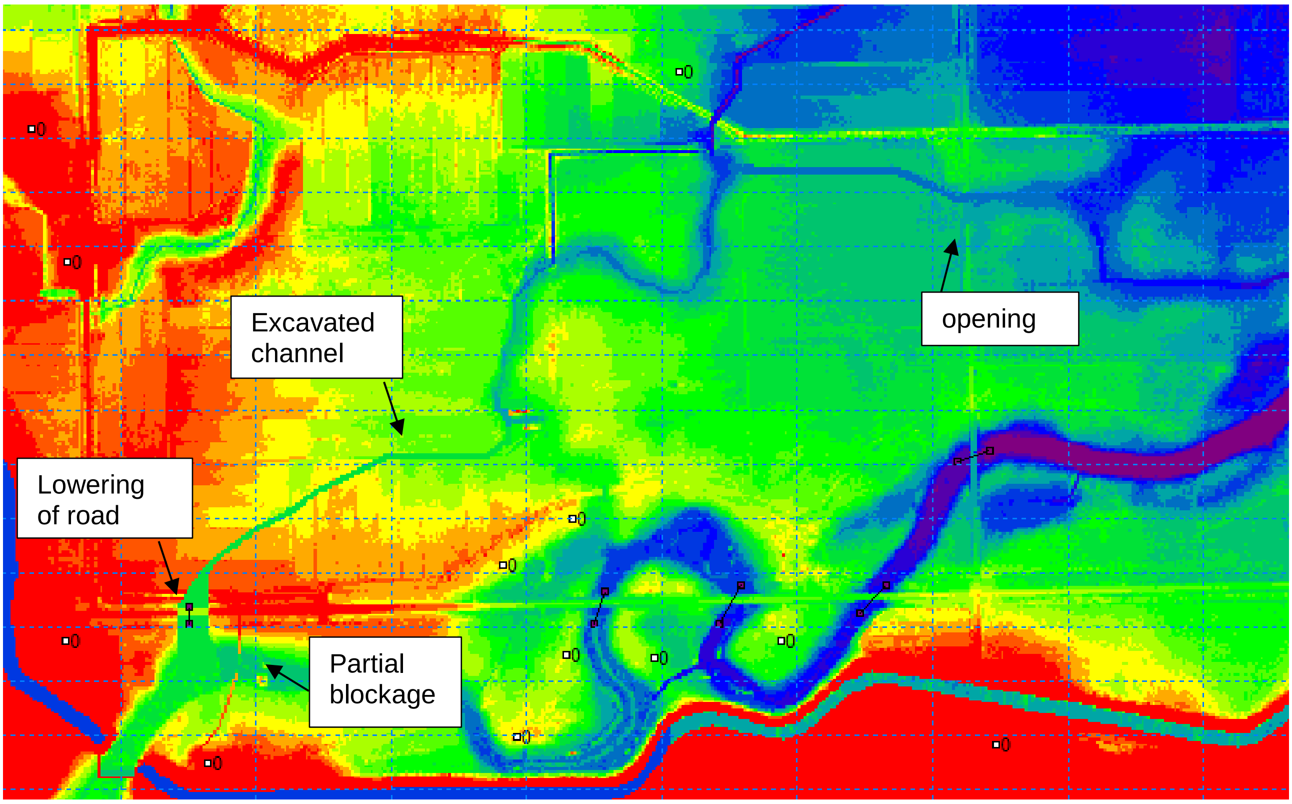


FIGURE 7-7 SCENARIO 3 FEATURES

7.4.2 Results

The difference map below (Figure 7-8) presents the comparison of results between the initial eastern drainage line scenario and the Scenario 3 options described above.

The results show that features in Scenario 3 have directed 25% of the total flow to the north across Webb Rd, compared to only 7.6% of the flow under current conditions. Peak water levels are reduced generally by 60 to 100 mm between the Waranga Channel and along Webb Rd. Although levels have been lowered, the impacted properties through this area are still inundated. A review of the floor level survey also demonstrates that this scenario has not resulted in any improvement in above floor flooding. Overall, this scenario did not result in a significant improvement in flood risk in this area.

Based on the results of Scenarios 1 to 3, it was deemed that local protection works in the form of ring levees is the best option to mitigate adverse impacts in this area. Attempting to direct flow or increase conveyance makes minimal difference to flood risk in this area due to the flat nature of the terrain.

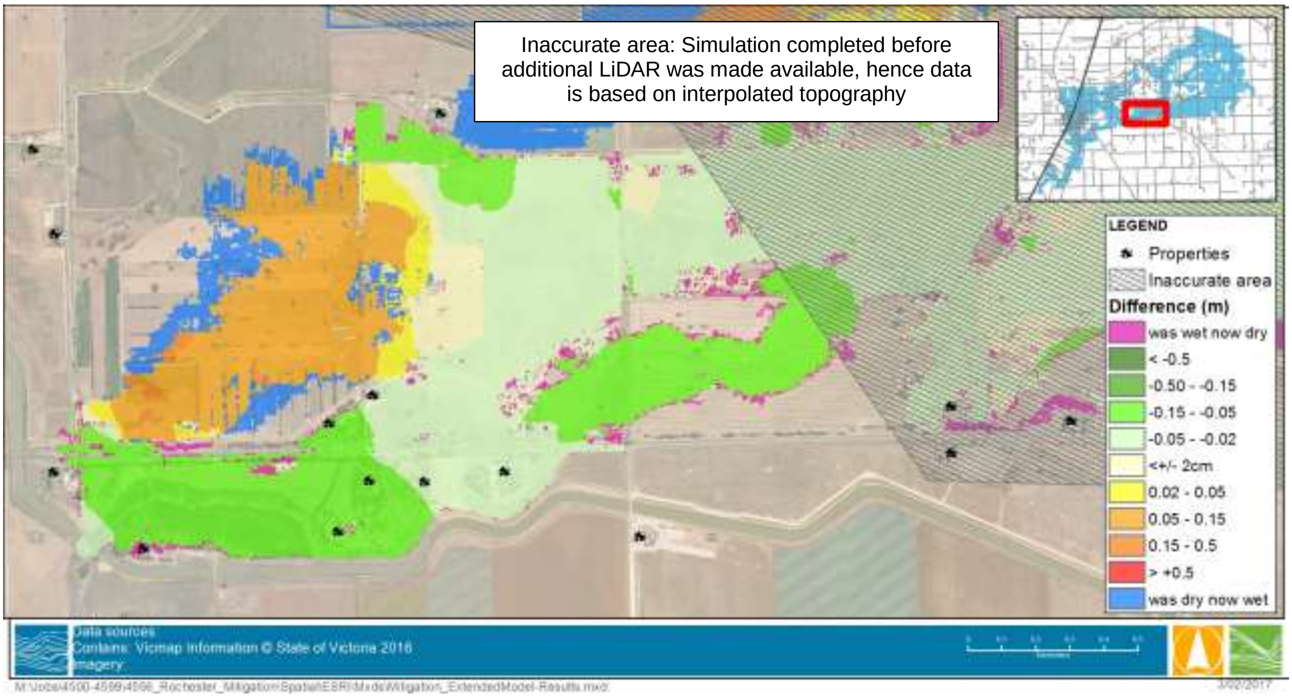


FIGURE 7-8 DIFFERENCE MAP – SCENARIO 3

7.5 Sensitivity Scenario – Local Runoff

7.5.1 Overview

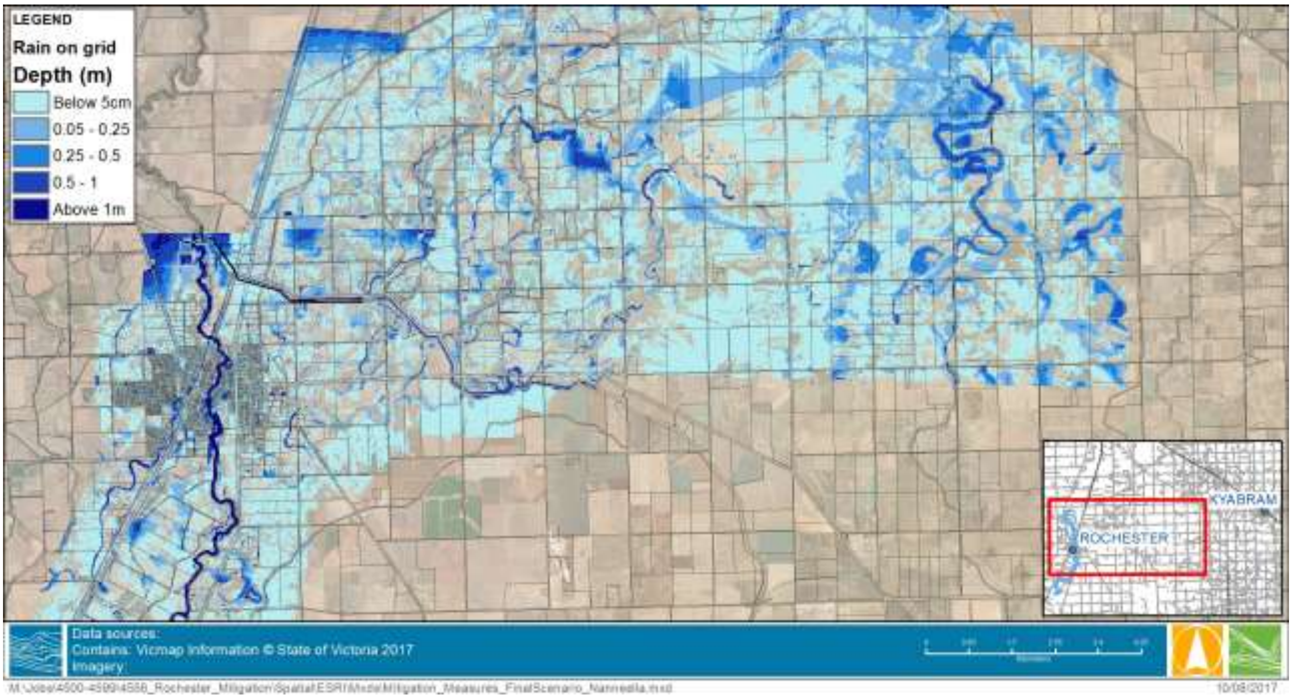
Some of the feedback provided by local landholders in early consultation in this project was that local runoff should be considered in the modelling of the Nanneella Depression as it can be a significant mechanism of inundation and can be responsible for a significant proportion of inundation even when breakouts from the Campaspe River occur such as during the January 2011 flood event

To assess the potential impacts on peak flood levels caused by local runoff, a "worst case" scenario was run whereby the 1% AEP flood in the Campaspe River was run with initial conditions set as the consequence of a prior 1% AEP, 24-hour duration rainfall event. This scenario aimed to understand how much worse flooding along the eastern drainage line would be because of significant prior local rainfall.

7.5.2 Method

The 1% AEP 24-hour rainfall event was applied to the local catchments in the study area. This was achieved via rain-on-grid modelling for the surrounding catchments and allowing the water to flow and drain for 48 hours.

The water ponding in the floodplain on and around the eastern drainage line was then used as initial conditions at the start of the 1% AEP flood from the Campaspe River.



7.5.3 Results

The modelling results of this scenario shows that in the areas affected by riverine flooding, the initial ponding has little to no impact on maximum water levels (less than 2 cm) and that the riverine breakout remains the dominant mechanism of inundation. Nonetheless it is noted to have a marginal effect on the speed of propagation of the flood. Results indicate that the maximum flood level is reached 1-2 hours earlier at the downstream end of the model compared to previous scenarios.

Overall the result showed that the consideration of a large volume of local runoff resulted in a very minor difference to peak flood levels in the 1% AEP event.

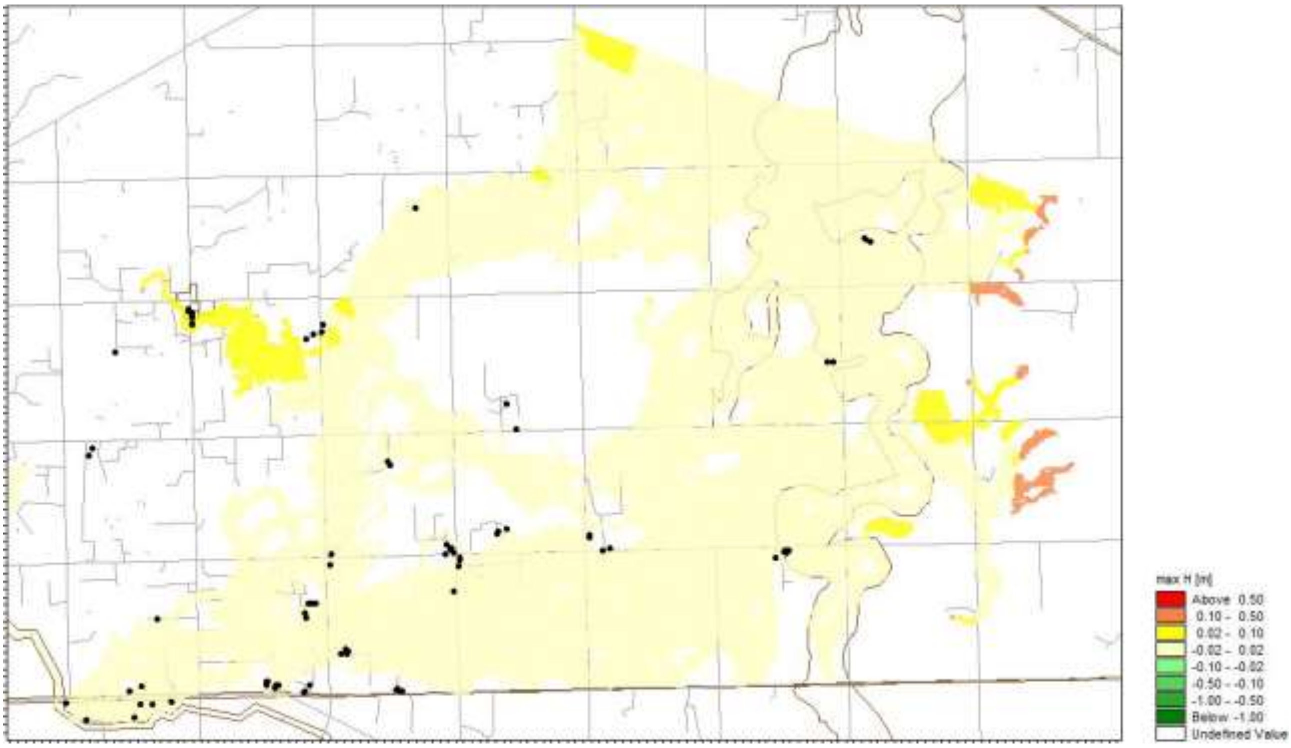


FIGURE 7-9 IMPACT OF INITIAL PONDING. DIFFERENCE PLOT ON WATER LEVELS ALONG THE NANNEELLA DEPRESSION, DOWNSTREAM OF THE WARANGA CHANNEL CROSSING.

7.6 Scenario 4 – Controlled flow around the township and back to the Campaspe River

7.6.1 Overview

An additional mitigation scenario was run which had quite a different aim to the previous scenarios. This option aims at assessing the impact of redirecting flood waters from the eastern drainage line back into the Campaspe River through the agricultural land to the north-east of Rochester, situated between Tasker and Murdoch Roads. The objective of the scenario was, while still reengaging the eastern drainage line, to limit the adverse impacts through the Nanneella depression.

The model set-up for this scenario consisted of the following modifications to the existing conditions model:

- Inclusion of the mitigation options within Rochester to reinstate the eastern drainage line
- Lowering of Kyabram-Rochester Road crossings
- addition of a flow restriction where the eastern drainage line crosses the Waranga Channel (aiming to limit flow by 50% in the 1% AEP event)
- levee placed along High Street to guide water north

channel excavation along the Waranga channel and railway as shown in Figure 7-10. The flow capacity along the eastern drainage line at the Waranga channel siphon was throttled by 50%. Water backing up behind the channel was then directed north via two excavated channels that are pre-existing, past the Kyabram-Rochester Road. The changes to the topography shown in the following map were aimed at redirecting water west and back into the Campaspe River north west of the Rochester township, after the peak of the flood has passed.

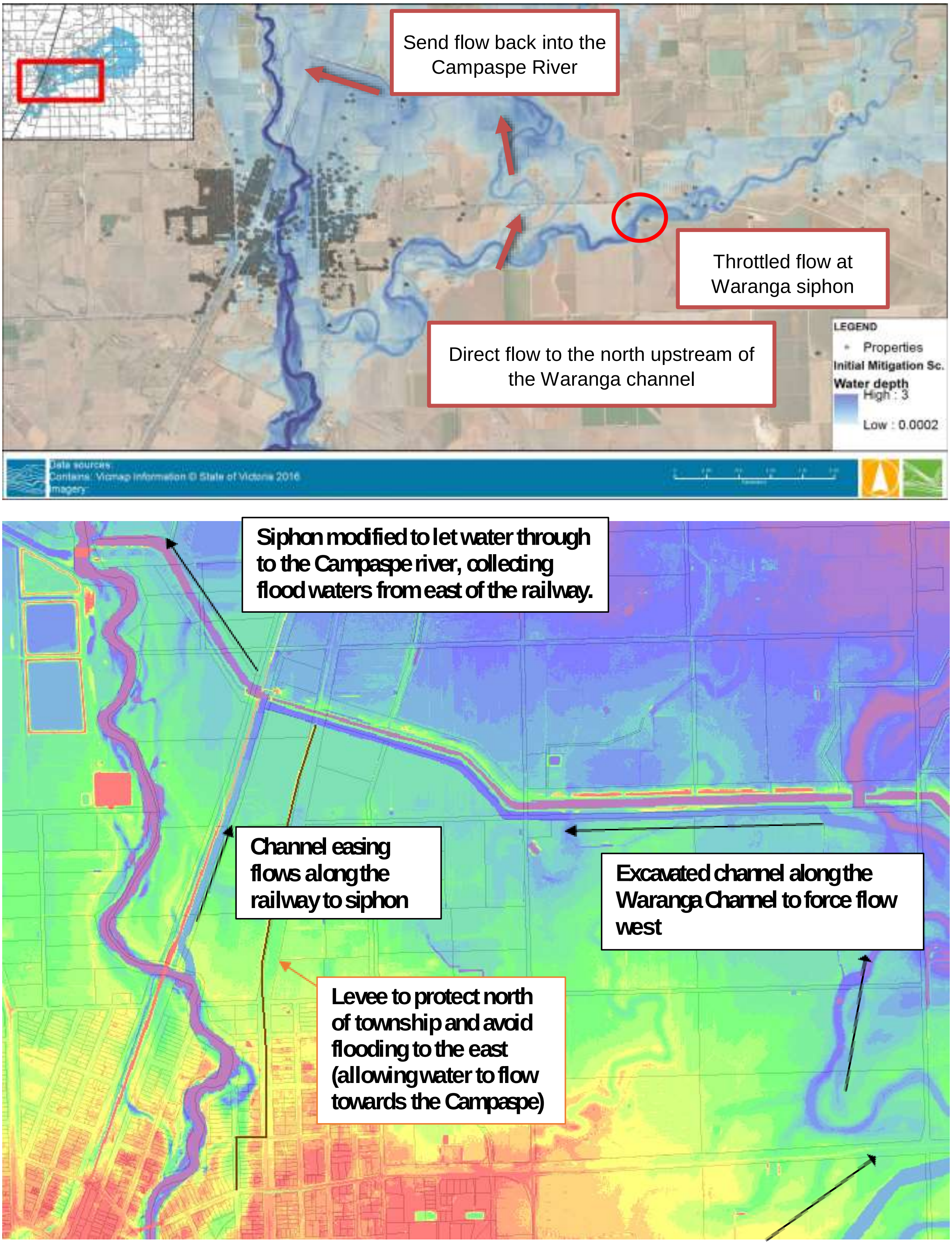


FIGURE 7-10 SCENARIO 4 OBJECTIVE AND FEATURES

7.6.2 Results

The results from this scenario show that the scheme is moderately effective but that the topography and the timing of inundation through the north-east of the township do not allow for the flows to be easily diverted back to the Campaspe River whilst at the same time efficiently reducing the impact of flooding within Rochester and along the Nanneella depression. The flow through the Nanneella depression is lowered but the flooding extent is only marginally reduced further east (compared to the base case eastern drainage line mitigation scenario). An area of higher ground located midway between the eastern drainage line and the railway line/Waranga Channel intersection makes it difficult to direct significant flow back towards the Campaspe River.

A difference plot which compares peak flood levels in this scenario to current conditions is provided below in Figure 7-11. The benefits to the centre of Rochester are largely achieved, however the scenario still results in significant adverse impacts along the eastern drainage line, particularly downstream of the Waranga Channel, despite the throttling of flow.

Figure 7-12 provides a comparison between 1% AEP flood extents under this scenario compared to the base case eastern drainage line scenario. Despite the throttling of flow at the Waranga Channel, the 1% AEP flood extent has only marginally reduced compared to the base case eastern drainage line scenario.

Overall this scenario demonstrated that the concept of directing flow back towards the Campaspe River has merit, but is challenging, and would need much more refinement to be feasible. It would also be associated with very high capital costs due the works required particularly the new crossings across the railway line and the Waranga Channel adjacent to the railway line.

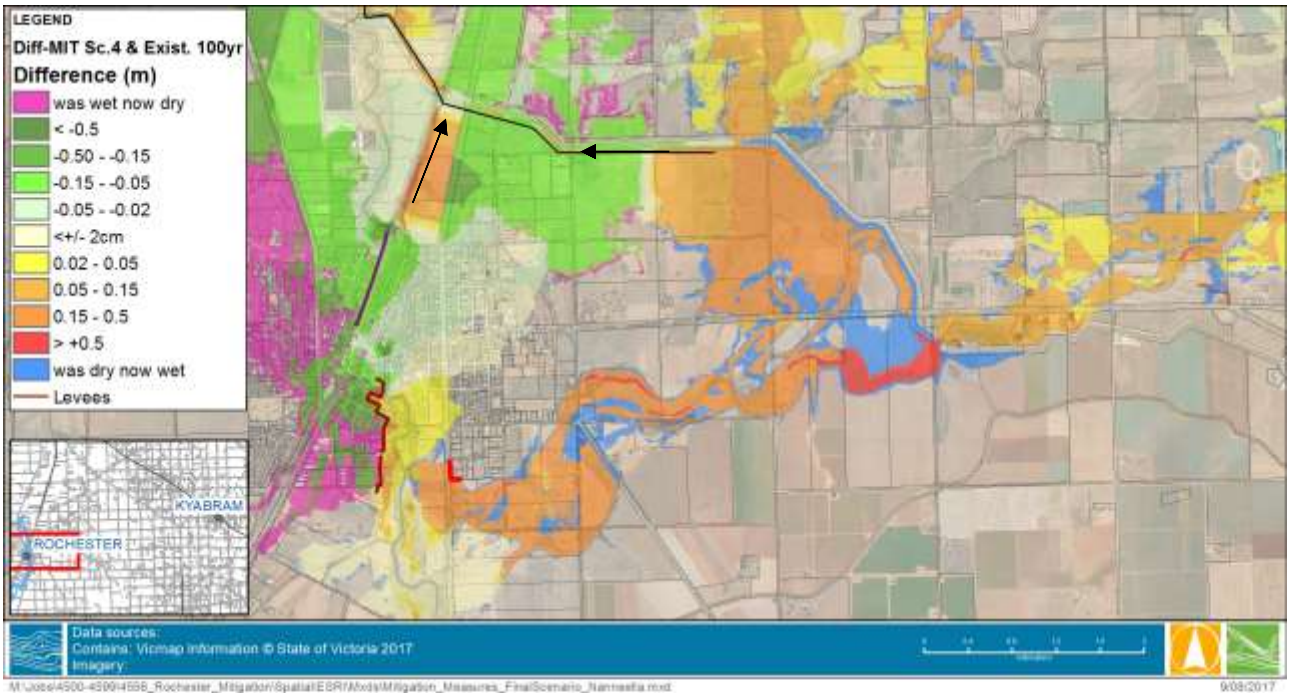


FIGURE 7-11 DIFFERENCE PLOT – SCENARIO 4

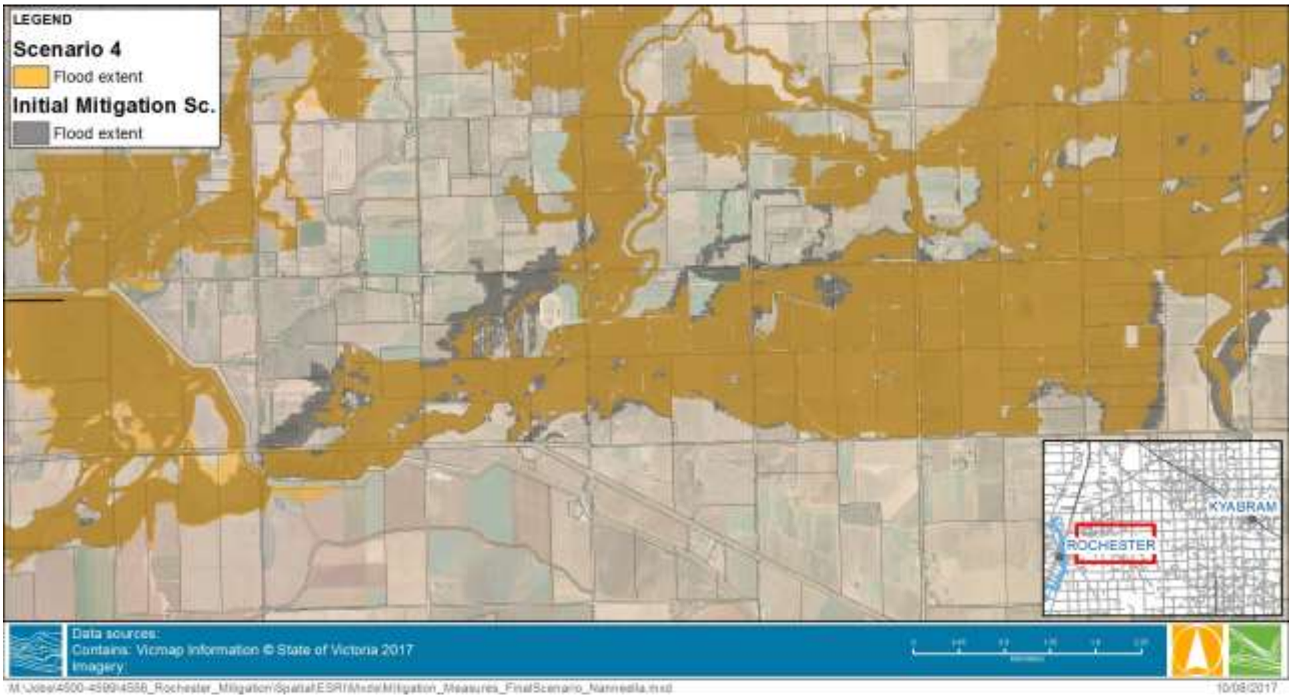


FIGURE 7-12 DIFFERENCE PLOT – SCENARIO 4 AND FINAL MITIGATION SCENARIO EXTENT COMPARISON ALONG THE NANNEELLA DEPRESSION. RESULTS SHOW THE EXTENT IS ONLY REDUCED MARGINALLY WHEN REDIRECTING WATER BACK TO THE RIVER UPSTREAM OF THE WARANGA CHANNEL

8 FINAL MITIGATION SCHEME

8.1 Background

Based on the above preliminary scenarios and original modelling as part of the Rochester Flood Management Plan the following scenario was selected as the preferred combination of options to undergo detailed modelling and benefit-cost analysis. The scenario largely comprised the original package of works from the Rochester Flood Management Plan with the inclusion of local protection works along the eastern drainage line to protect those properties adversely impacted. It is noted that while the package does provide significant benefit to the township it does result in significant impacts to a large geographical area, particularly through the Nanneella Depression.

8.2 Key Features

The key features of the scheme consist of:

Rochester Township Mitigation Features

- Excavation of land between the Campaspe River and Bonn Road (near Jess Drive) to better engage the watercourse which flows eastwards from Rochester. Under existing conditions this drainage line is well utilised in a 1% AEP event but not in a 5% AEP event and lower. Approximately 5,800 m^3 of soil would need to be excavated. This work is effectively removing an artificial barrier on the floodplain and reinstating the historic drainage line.
- Construction of a strategic levee along the left bank of the Campaspe River between the water treatment plant on Campaspe St and the eastern end of Morton Street. The levee aims to protect from a large breakout which flows north-west through this area in the 5% AEP event and greater. The levee would be approximately 1,100 m long and have an average height of 1.1 m. This levee has been costed as a retaining wall/ flood wall for the northern 600 m of the alignment due to the limited space at the rear of residential properties. The remainder has been costed as an earthen levee as it passes through agricultural land.
- Construction of a smaller levee along Bonn Road which will protect properties from the increased engagement of the eastern drainage line. The levee would be approximately 280 m long and have an average height of 0.7 m. This has been costed as an earthen levee given there is a significant road corridor that could be utilised and agricultural land.
- Construction of an open drain in the existing drainage easement between the railway line and Ramsay Street from Elizabeth Street to the Campaspe River. This option is aiming to assist drainage of flood water and local runoff in that area. Approximately 3,900 m^3 of soil would need to be excavated to construct the drain.
- Optional: An optional feature not included in the current packages of works is excavation of land to the east of the railway bridge on the north side of the Campaspe River to allow additional flow northwards across the floodplain and through the railway culvert located 200 m north of the railway bridge. This was included in the original package in the Rochester Flood Management Plan. This option provides a small benefit in lowering levels in central Rochester by 10-20 mm. Approximately 10,800 m^3 of earth would need to be excavated. As mentioned these works were defined during the original study[1], but there is potential for a narrower channel to be developed between the newly built shed and the railway line which would still provide some benefit. The original flood study modelling has shown that this option, despite having benefits, can cause water to back up behind the Waranga channel increasing flood levels, and may need to be combined with additional local mitigation works such as ring levees for several buildings located between the Campaspe River and the Waranga Channel to the east of the railway line.

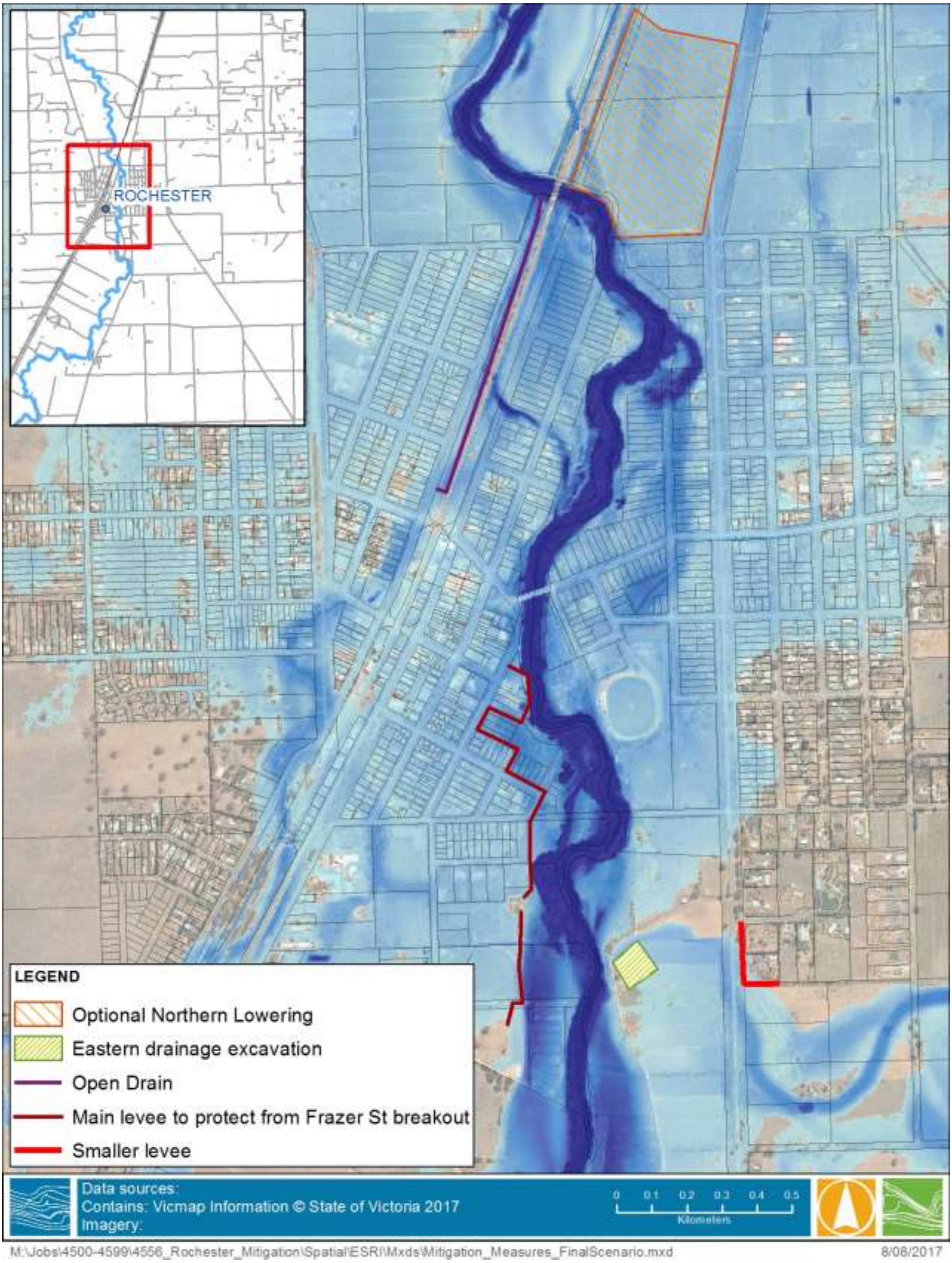


FIGURE 8-1 FINAL MITIGATION SCHEME KEY FEATURES – ROCHESTER TOWNSHIP

Eastern Drainage Line Mitigation Features

- Six sections of extended levees consisting of:
  - Extended Levee 1 – located to the south of Kyabram-Rochester Road, against the Waranga Channel. The levee would be approximately 180 m in length with an average height of 0.53 m.
  - Extended Levee 2 – located to the north of Kyabram-Rochester Rd, just west of the intersection with Winter Rd. The levee would be approximately 435 m in length with an average height of 0.75 m.
  - Extended Levee 3 – located to the west of Gibson Road, protecting properties located between the floodway to the south and a channel to the north. The levee would be approximately 435 m in length with an average height of 0.45 m.
  - Extended Levee 4 – located to the east of Gibson Road, protecting properties located between Kyabram-Rochester Road and MacGregor Road. The levee would be approximately 315 m in length with an average height of 0.7m.
  - Extended Levee 5 – located to the south-eastern corner of the intersection of Doherty and MacGregor Roads. The levee would be approximately 430 m in length with an average height of 0.4 m.
  - Extended Levee 6 – located along Mac Gregor and Doherty Road, the levee will protect the properties located north-west of the intersection. The levee would be approximately 230 m in length with an average height of 0.5 m.
- 15 individual earthen ring levees to provide local protection to rural dwellings located on the floodplain along the eastern drainage line. A unit cost of $30,000 ex. GST has been utilised for each levee. More detailed costing would be determined as part of a detailed design should the package be further considered
- Increased capacity for culverts under roads at 5 locations:
  - Pascoe Street: addition of a third culvert. The three box culverts will have the same dimensions as downstream, i.e. 1200x900 mm.
  - Heathcote-Rochester Road: addition of a third box culvert that has the same size as the two other 1200x900 mm culverts.
  - 2 crossings through Kyabram-Rochester Road: The existing structures will be upgraded to three 1200x900 mm box culverts.
  - Echuca-Nanneella Road: addition of a third box culvert that has the same size as the two other 1200x900 mm culverts.

FIGURE 8-2 FINAL MITIGATION SCHEME KEY FEATURES – NANNEELLA DEPRESSION

8.3 Results

The results are presented below and are discussed as impacts through Rochester township and impacts along the eastern drainage line.

8.3.1 Impacts within Rochester

The mitigation option modelling has demonstrated a significant improvement in flood risk for many parts of Rochester across a range of AEP events. The option has achieved its aim of providing protection to a significant number of properties up to and including the 1% AEP event.

The original goal of this package was to achieve significant benefit in the smaller 20% AEP event however significant benefits are also achieved in the 1% AEP event. Water levels in central Rochester and on the western side of the railway line are significantly improved with reductions of up to 500 mm in those areas. Figure 8-3 and Figure 8-4 show difference plots within Rochester between existing and mitigated conditions in the 1% AEP and 2% AEP events. There are large areas of southern and western Rochester which are now protected with this option including approximately 60 properties around Northcote, Hopetoun and Queen Streets. These improvements are largely a result of the strategic levee preventing water from breaking out through the central township and over the railway line. Water levels are marginally higher in a small area near the southern end of High Street, the blockage created by the levee increases water levels locally by up to 40 mm for 17 properties in the 1% AEP event. This increase is 20 mm for 12 properties for the 2% AEP event. North of Bridge Road, on the eastern side of the Campaspe River water levels are also generally lower however the difference is small and in the order of 30-50 mm.

In the 5% AEP event, the large breakout near Fraser and Pascoe Streets has been prevented resulting in many properties in that area being protected. The package has also resulted in lower flood levels at many properties in central and northern Rochester because of the additional flow into the eastern drainage line and floodplain to the north. Inundation and access around the hospital has also been improved.

The eastern drainage line is significantly better engaged with increases in water level of up to 500 mm through that area. The additional flow occurring down the eastern drainage line with this option was measured. It was found that in the 1% AEP peak flows increased from 5,100 ML/d to 9,500 ML/d.

The Rochester Cemetery is located very close to the eastern drainage line, within a meander bend, east of Heathcote-Rochester Road. Under existing conditions, the Cemetery is impacted by floodwaters only for the 1% AEP event. The extent of flooding is restricted to the parking area. Re-engaging the eastern drainage causes flooding of the cemetery to occur for both the 1% and 2% AEP events.

In the 2% AEP event, under mitigated conditions, model results show only the northern part, mainly the parking area, is flooded. Water depths do not exceed 20 cm.

In the 1% AEP event, water levels are increased by approximately 35 cm and the extent of flooding covers most of the cemetery area. Water depths are mostly under 10 cm in areas where existing graves are located.

Results indicate many properties in Rochester (residential and commercial) are protected from flooding above floor level in mitigated conditions. For the 1% AEP event, the number of flooded properties above floor level is reduced from 330 to 196. For the 2% and 5% AEP events, the number of flooded properties (above floor level) is reduced from 207 to 104 and from 50 to 17 respectively.

TABLE 8-1 FINAL MITIGATION SCHEME - SUMMARY OF IMPACTED PROPERTIES

Event (AEP)	Properties flooded above floor level	
	Existing	Mitigated
1%	335	172
2%	207	106
5%	50	17
10%	3	3
5%	0	0

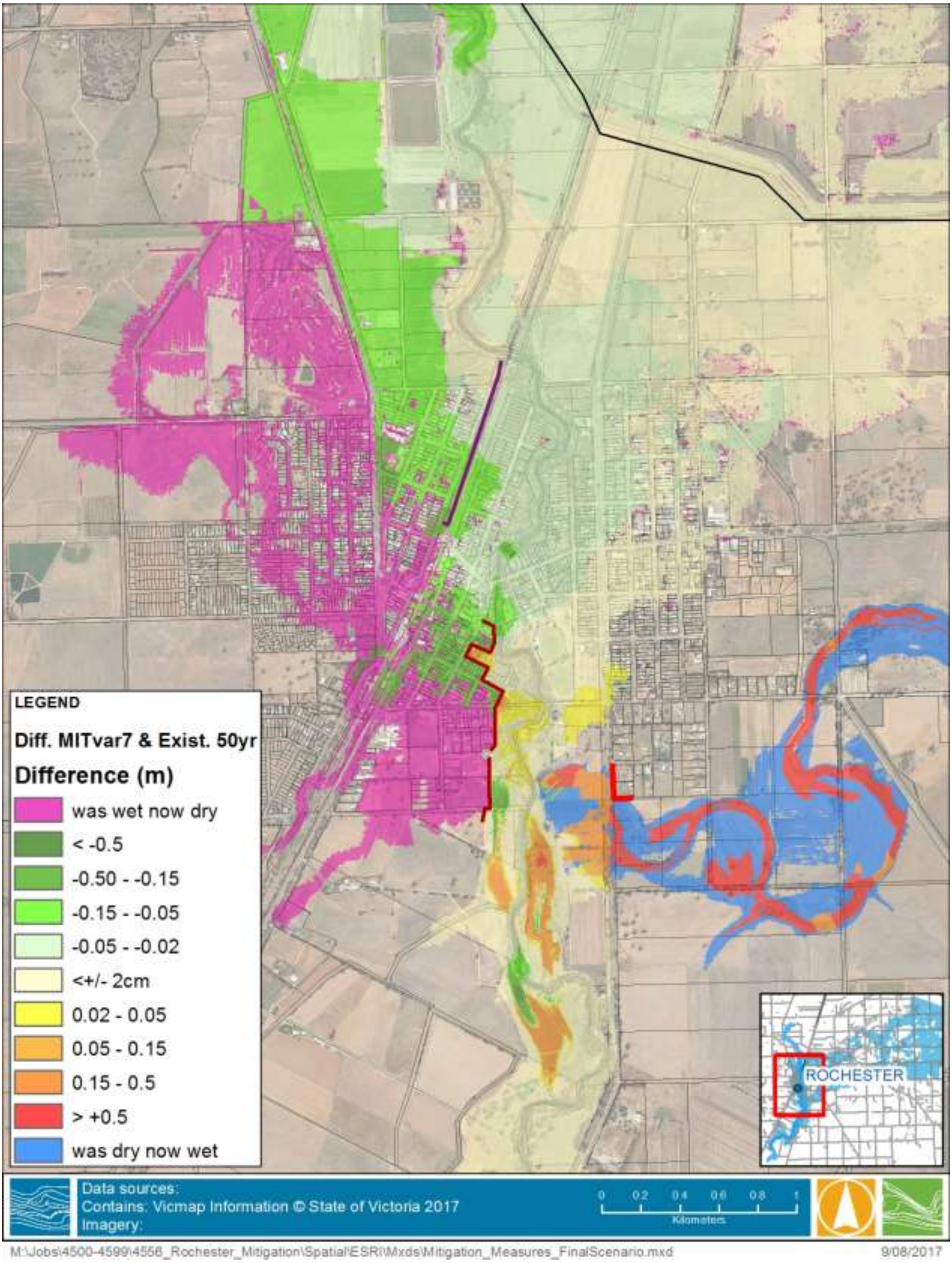


FIGURE 8-3 DIFFERENCE PLOT FOR THE 2% AEP EVENT, COMPARISON BETWEEN EXISTING AND – MITIGATED CONDITIONS (ROCHESTER)

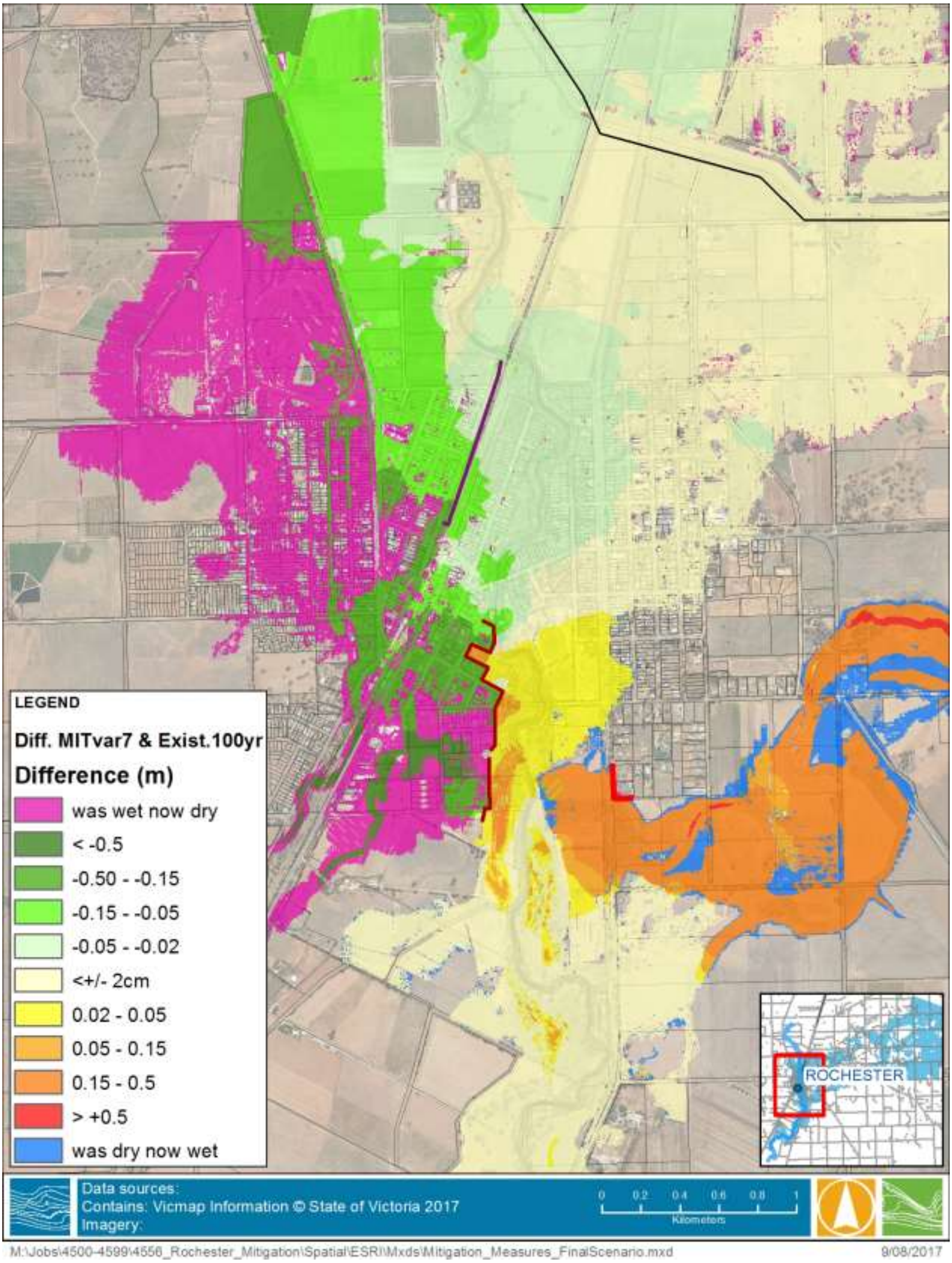


FIGURE 8-4 DIFFERENCE PLOT FOR THE 1% AEP EVENT, COMPARISON BETWEEN EXISTING AND – MITIGATED CONDITIONS (ROCHESTER)

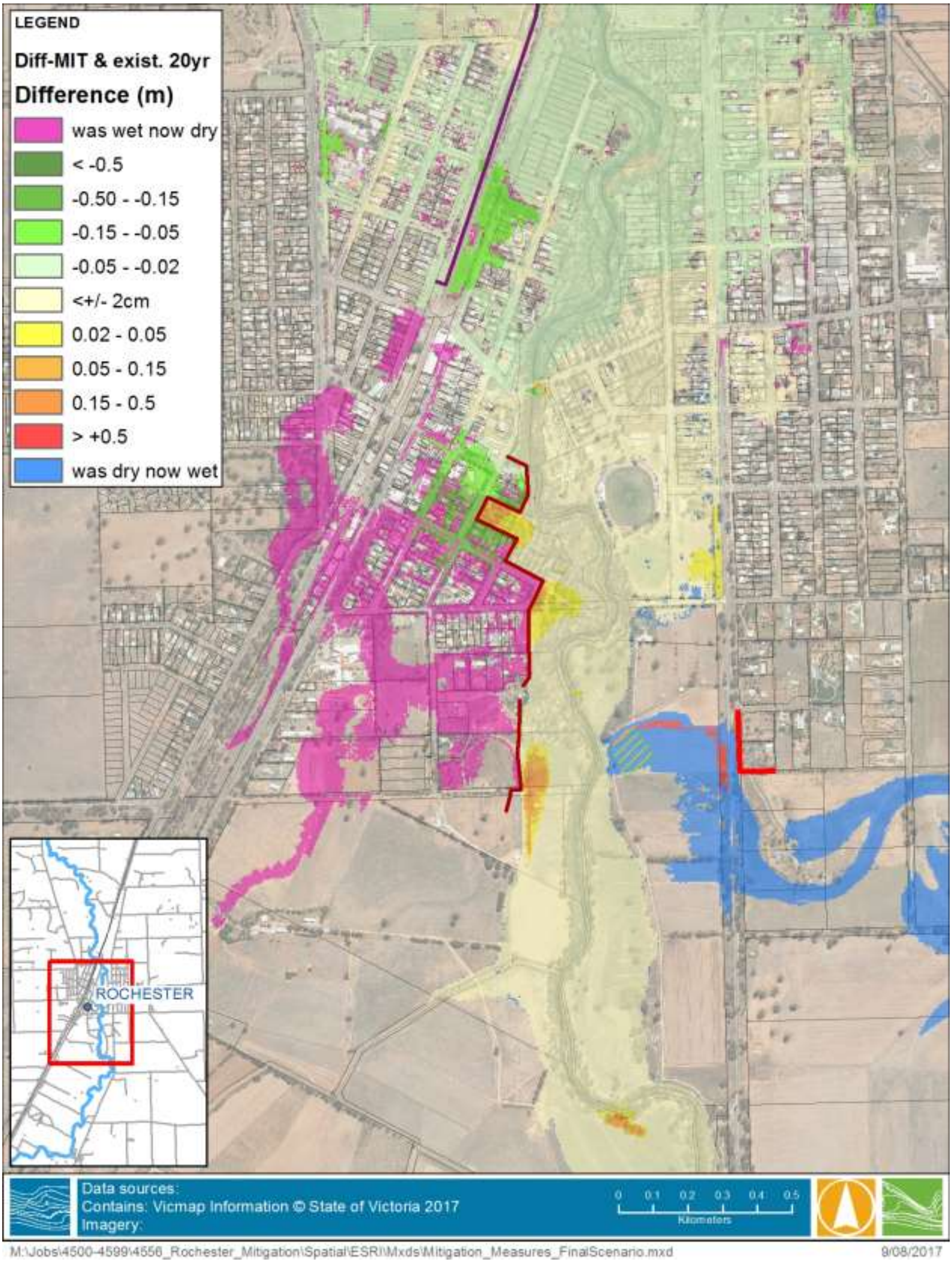


FIGURE 8-5 DIFFERENCE PLOT FOR THE 5% AEP EVENT, COMPARISON BETWEEN EXISTING AND – MITIGATED CONDITIONS (ROCHESTER)

8.3.2 Impacts along the Eastern Drainage Line

The modelling results show that the eastern drainage line is engaged by flood waters for the 5% AEP and rarer events under mitigated conditions as compared to 2% AEP and rarer events under current conditions. Flows to the east are considerably increased, both in terms of volume and peak discharge, as shown in Figure 8-6. In terms of volume, the total amount of water crossing the Waranga Channel is multiplied by a factor 2.5 for the 1% AEP event, and 14.5 times larger for the 2% AEP event. The flows extracted at the Waranga Channel crossing are shown in Figure 8-6.

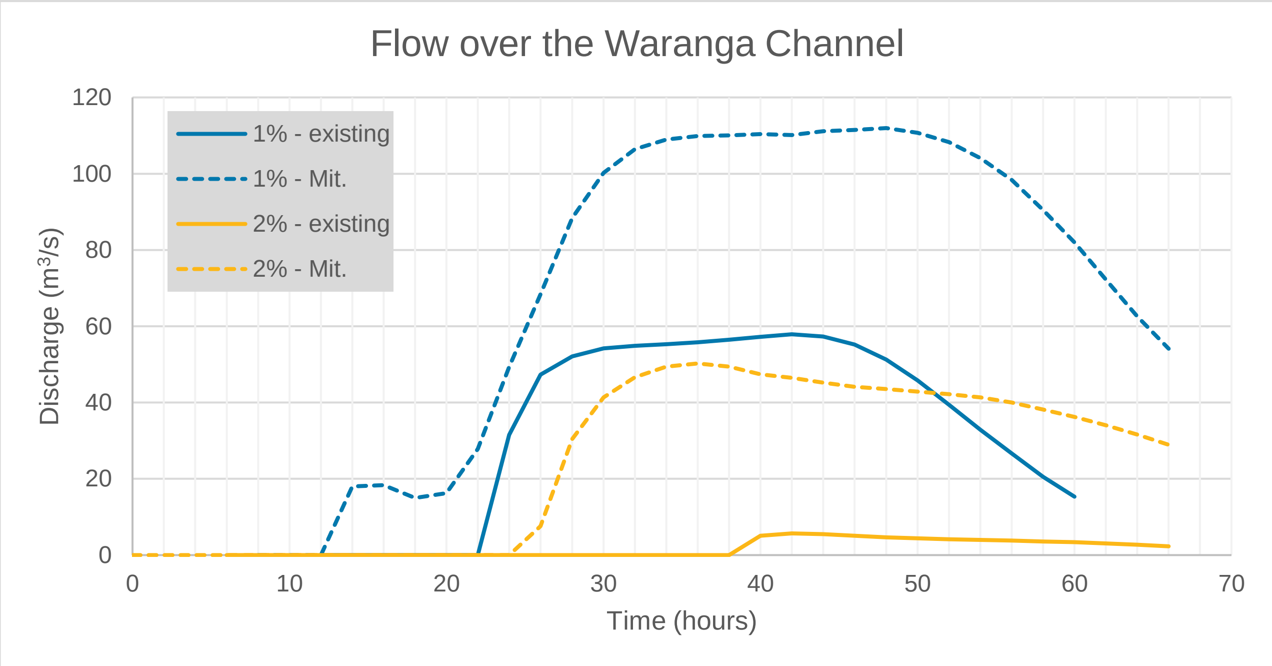


FIGURE 8-6 DISCHARGE OVER THE WARANGA CHANNEL SIPHON

The modelling demonstrates that the arrival of the breakout (initial flood flow) occurs 8 hours earlier in mitigated conditions for the 1% AEP event. The first flood water arrives 12 hours earlier for the 2% AEP event under mitigated conditions.

At the Waranga channel siphon (near Webb Rd), the graph above indicates flows above 50 m^3/s lasts approximately 19 hours under existing conditions 1% AEP event. The flow is above the 50 m^3/s threshold for at least 46 hours in mitigated conditions, an increase of 27 hours. The flooding duration is expected to be a minimum of 24 hours longer in mitigated conditions for the 1% AEP event along the Nanneella depression, as compared to current conditions. The impacts on durations at the lower end of the Nanneella Depression will be quite dependent on antecedent conditions including existing water levels through that area and the Mosquito Depression.

Flood extents and depths between existing and mitigated conditions are compared in the following figures for the 1% AEP event (Figure 8-7) and 2% AEP event (Figure 8-8). The results show the flood extent is considerably increased for the 2% AEP event in the Nanneella depression (Figure 8-8). Water levels are increased by 0.45 to 0.8 m, and a large breakout from Gibson Road to the east occurs in mitigated conditions, resulting in widespread inundation comparable to the flooding observed for the 1% AEP event.

In existing conditions only three properties are at risk of being flooded above floor level for the 1% AEP event, and only one property for the 2% AEP event. Under mitigated conditions, with the increase in flow directed to the eastern drainage line, for the 1% AEP event, 29 properties would be at risk of flooding, of which 12 are potentially above floor level. However, the key features presented in section 8.2 (local protection levees) ensure all adversely impacted properties are protected from flooding above floor level. For the 2% AEP event, only one property is flooded under existing conditions (below floor level) and this property is protected by local works in the mitigation scenario.

TABLE 8-2 FINAL MITIGATION SCHEME - SUMMARY OF IMPACTED PROPERTIES (NANNEELLA DEPRESSION)

Event (AEP)	Number of inundated buildings (residential and commercial)					
	Existing Conditions		Mitigated conditions (no local works)		Mitigated conditions with local works	
	Total Impacted	Flooded Above Floor	Total Impacted	Flooded Above Floor	Total Impacted	Flooded Above Floor
1%	12	**3**	29	**12**	0	**0**
2%	1	**0**	12	**2**	0	**0**

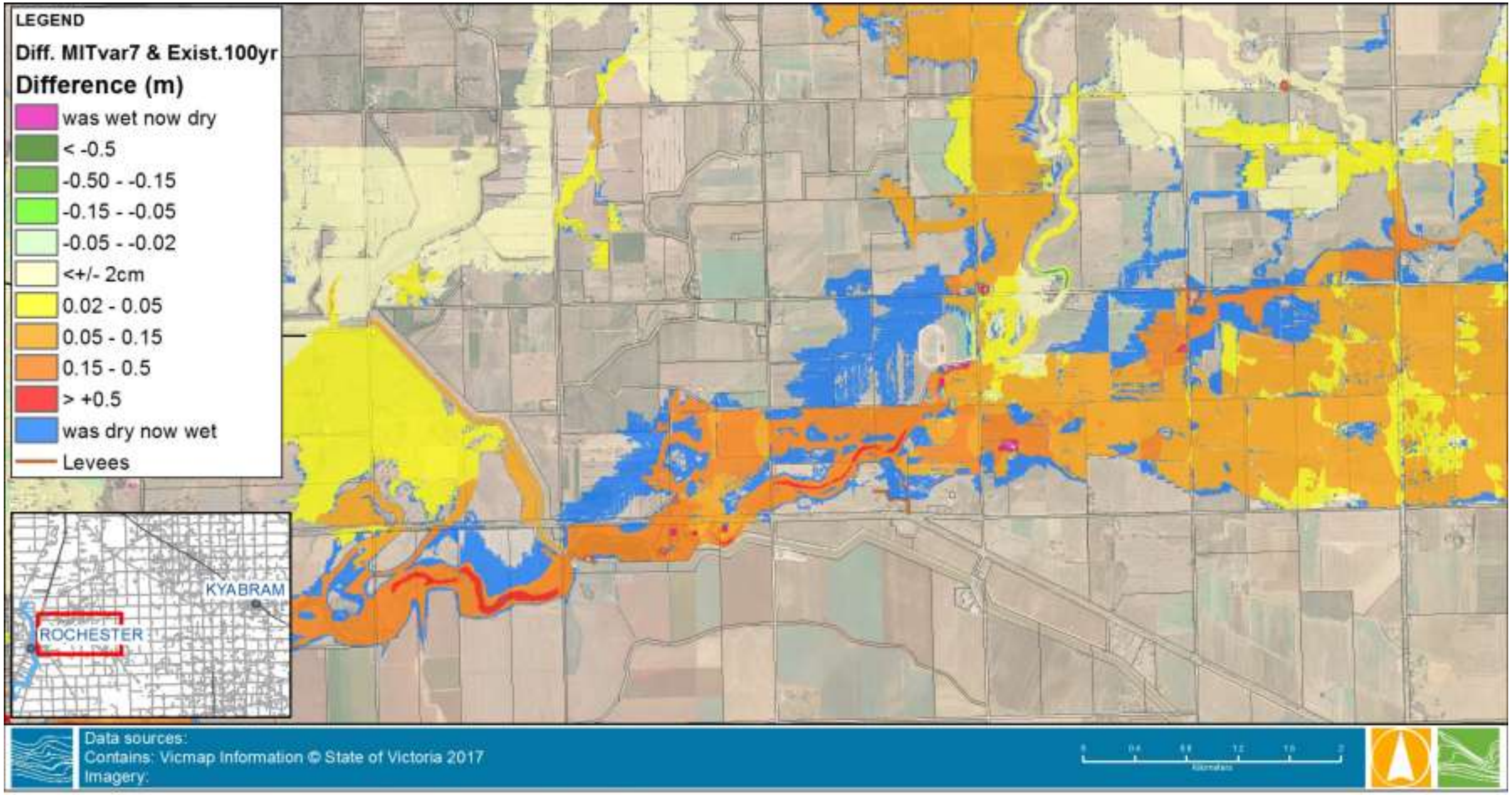


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FIGURE 8-7 DIFFERENCE PLOT FOR THE 1% AEP EVENT, COMPARISON BETWEEN EXISTING AND MITIGATED CONDITIONS (NANNEELLA DEPRESSION)

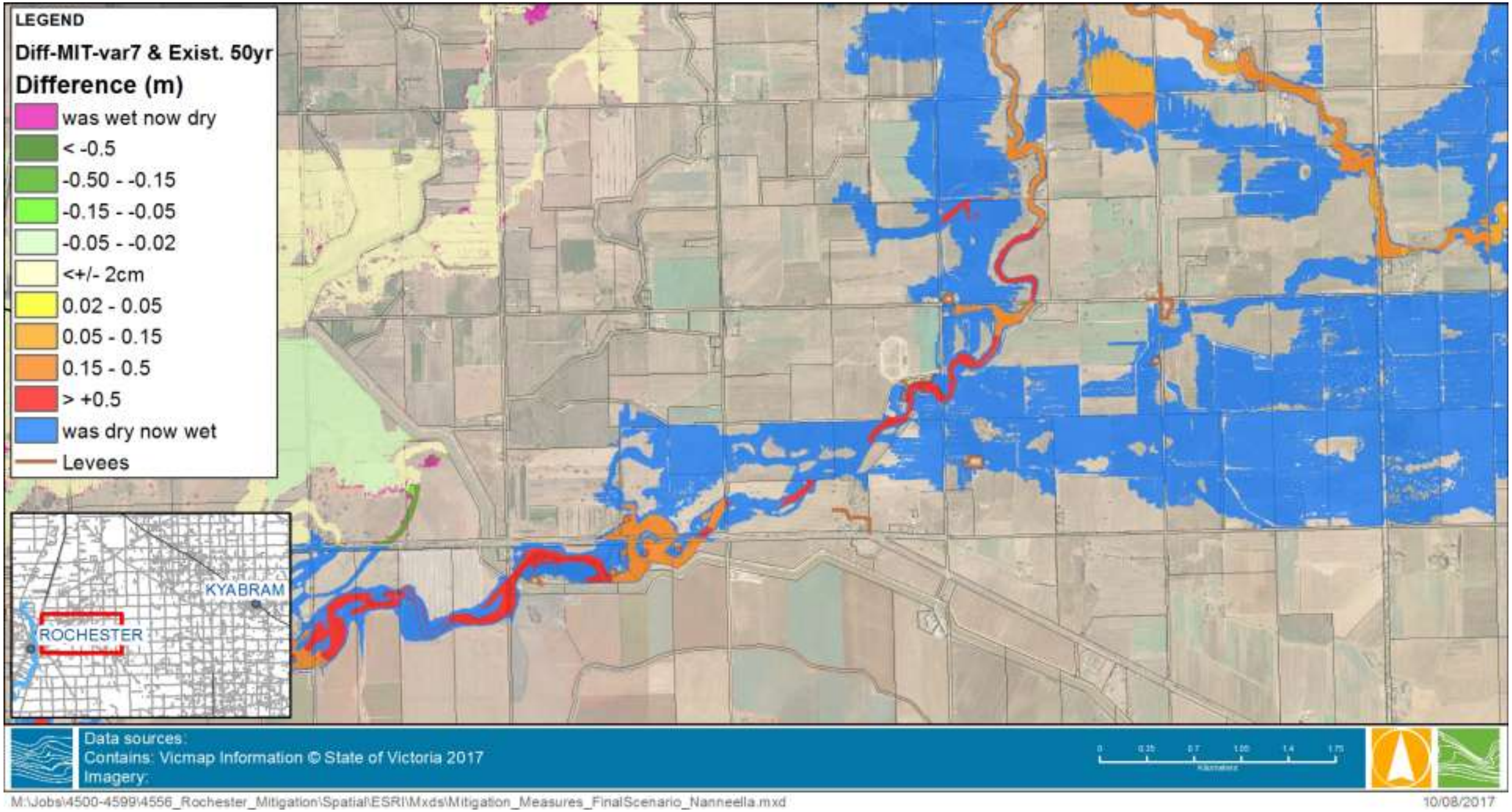

FIGURE 8-8 DIFFERENCE PLOT FOR THE 2% AEP EVENT, COMPARISON BETWEEN EXISTING AND MITIGATED CONDITIONS (NANNEELLA DEPRESSION)

9 FLOOD DAMAGES ASSESSMENT

9.1 Overview

A flood damages assessment was undertaken for the study area under existing and mitigated conditions. The flood damage assessment determined the monetary flood damages for the modelled design floods (20%, 10%, 5%, 2% and 1% AEP).

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for many studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. A recent review of ANUFLOOD stage damage curves has demonstrated that they significantly underestimate flood damages, particularly at shallow above floor depths and below floor flooding. The stage damage curves developed by the New South Wales Office of Water have been used for this project. The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. Also, agricultural land was included in the assessment, separating the properties between high value horticultural land and irrigated pastures. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated. A summary of the damages assessment methodology is provided in Appendix B.

9.2 Existing Conditions

The 1% AEP flood damage estimate for existing conditions was calculated to be just under $26 million. A total of 1,499 properties are flooded in a 1% AEP event, with 335 of those properties flooded above floor level. The January 2011 event is estimated to be approximately a 1% AEP event although some temporary mitigation works were implemented during the event to protect parts of the town. The total number of properties flooded in the 1% AEP event is similar to the reports of numbers flooded during the January 2011 event.

The Average Annual Damage (AAD) was determined as part of the flood damage assessment. The AAD is a measure of the flood damage per year averaged over an extended period. The AAD for existing conditions for the study area is estimated at **$810,280**. This is effectively a measure of the amount of money that must be put aside each year in readiness for the event that a flood may happen in the future.

TABLE 9-1 SUMMARY OF FLOOD DAMAGES ASSESSMENT – EXISTING CONDITIONS

ARI (1 in Y)	1 in 100	1 in 50	1 in 20	1 in 10	1 in 5
AEP (%)	**1%**	**2%**	**5%**	**10%**	**20%**
Buildings Flooded Above Floor	335	207	50	3	0
Properties Flooded Below Floor	1164	1071	623	227	72
Total Properties Flooded	**1499**	**1278**	**673**	**230**	**72**
Total Cost	**$25,928,168**	**$14,766,212**	**$5,359,276**	**$1,972,043**	**$460,817**

9.3 Final Mitigation Package

The AAD for the final mitigation package as described in Section 8 was calculated to be **$696,782**. During a 1% AEP event, the package reduces the total number of properties inundated from 1,499 properties to 1,001 properties, with the number of properties flooded above floor reduced from 335 to 172. Over a long period of time with a range of flood events, the AAD may be reduced by approximately $113,500 per year by implementing this package of works.

TABLE 9-2 SUMMARY OF FLOOD DAMAGES ASSESSMENT – MITIGATED CONDITIONS

ARI (1 in Y)	1 in 100	1 in 50	1 in 20	1 in 10	1 in 5
AEP (%)	**1%**	**2%**	**5%**	**10%**	**20%**
Buildings Flooded Above Floor	172	106	17	3	0
Properties Flooded Below Floor	829	717	471	212	71
Total Properties Flooded	**1001**	**823**	**488**	**215**	**72**
Total Cost	**$20,367,419**	**$13,289,969**	**$4,083,001**	**$1,909,888**	**$451,680**

9.4 Average Annual Damage Summary

The damage assessment shows that the mitigation scheme has a significant impact on reducing flood damages and AAD in Rochester. The final mitigation package reduces AAD by approximately $113,500. A summary table of the AAD for existing conditions and each mitigation package is shown in Table 9-3.

TABLE 9-3 AVERAGE ANNUAL DAMAGE SUMMARY FOR ROCHESTER AND FINAL MITIGATION SCHEME

Scenario	Average Annual Damage
Existing Conditions	$810,280
Final Mitigation Scheme	$696,782
Reduction in AAD	*$113,498*

10 BENEFIT COST ANALYSIS

10.1 Overview

A benefit cost analysis was undertaken to assess the economic viability of the final mitigation packages. The estimated benefit-cost ratio is based on the construction cost estimates and average annual damages. For the analysis, a net present value model was used, applying a 6% discount rate over a 30-year project life.

10.2 Mitigation Option Costs

The mitigation works were costed based on a number of key references:

- Melbourne Water's standard rates for earthworks and pipe/headwall construction costs.
- Rawlinson's Australian Construction Handbook Rates
- Advice from VicRoads regarding bridge and culvert works costs
- Comparison to cost estimates for similar mitigation works for other flood studies
- Council and CMA estimates of works costs

A summary of the cost estimates for the final mitigation package is provided in Table 10-1 below. A detailed breakdown of the costing is included in Appendix A.

The largest cost element for the package is for construction of the main Rochester levee. The cost for the northern section of this levee has been calculated based on typical retaining wall costs based on a unit length. This has been adopted due to the relatively narrow corridor of the northern levee section however if it is believed an earthen levee could be adopted for that section the capital cost would be considerably lower. Ring levees through the Nanneella Depression have been based on a unit cost.

A 15% contingency cost has been added along with engineering and administration costs. Annual maintenance costs of 0.5% of the construction cost was factored in for retaining/flood wall sections of the levee while 1.5% of construction was factored in for earthen levees and all other drainage works.

TABLE 10-1 MITIGATION COST BREAKDOWN

Option	Total Construction Cost	Annual Maintenance
Final Mitigation Scheme	$7,116,111	$31,102

10.3 Benefit Cost Analysis

A benefit cost analysis was undertaken for the final mitigation package. The results of the benefit cost analysis are shown below in Table 10-2. The analysis found a low benefit cost ratio of 0.2. Typically, a ratio greater than 1 is preferred to justify funding and indicates the benefits of the proposed scheme exceed the costs over the 30-year life span of the works. The low benefit cost ratio of the eastern drainage line scheme reflects the significant costs associated with construction of the scheme, and due to the benefits of the scheme not being seen until relatively large flood events. Re-engaging the Nanneella depression considerably increases flood impacts, thus substantially increasing the associated damage and mitigation costs. These additional impacts and costs are the main reasons the benefit-cost ratio is considerably lower than that determined in the original flood study which only considered the impacts and costs of works within Rochester and the immediate surrounds.

It should be noted that the analysis does not include the cost of land acquisition or compensation associated with this scheme and these costs are likely to be very significant, further reducing the economic viability of this scheme.

TABLE 10-2 BENEFIT COST ANALYSIS RESULTS

	Existing Conditions	Final Mitigation Scheme
Average Annual Damage	$810,280	**$696,782**
Annual Maintenance Cost		**$31,102**
Annual Cost Saving		**$82,396**
Net Present Value (6%)		**$1,158,686**
Capital Cost of Mitigation		**$7,116,111**
Benefit – Cost Ratio		**0.2**

11 COMMUNITY AND STAKEHOLDER CONSULTATION

The study has involved considerable consultation with key stakeholders, community members and landholders along the eastern drainage line/Nanneella Depression. This section documents the consultation that has occurred, and the feedback received regarding the eastern drainage line option.

11.1 Consultation Overview

A reference panel was appointed at the beginning of the project which consisted of community, local industry and Goulburn Murray Water. The reference panel provided input as the study progressed. Several reference group meetings were held and in which the results of analysis and modelling were presented to the panel and feedback received.

The draft feasibility report for the study was released for community comment in October 2017. Stakeholders, community members and landholders in both the township and along the eastern drainage line/Nanneella Depression were engaged to provide feedback on the scheme. Consultation included:

- Two public meetings were held on Wednesday 1st of November at the Rochester and Recreation Reserve at 2:30 pm and 7:00 pm.
- Survey forms were distributed at the public meetings and were also available at the Council offices. They were also mailed out to landholders along the eastern drainage line.
- The draft feasibility report was made available online and hard-copy copies were available at the Council offices in Rochester

11.2 Feedback

The following section summarises the feedback received by Council regarding the eastern drainage line option. Across all formats of consultation, a low level of support was received for the scheme.

11.2.1 Public Meeting Feedback

The eastern drainage line scheme was presented at the public meetings along with the modelling results, impacts and benefit-cost analysis. There was an opportunity for questions and feedback at these meetings. Most of the community members who provided comments at the meetings were not supportive of the scheme and it was felt the impacts of the scheme, particularly the economic impacts to agricultural properties, were too great. The majority of the comments were related to the following:

- The impacts on farming properties along the eastern drainage line would be too great. It was felt that despite the benefits to the township, the adverse impacts are too significant. Farms would be flooded more often and for longer durations and there would be significant costs to famers livelihoods as a result of this.
- Lake Eppalock should be used for flood mitigation purposes.
- Local drains should be improved and better maintained.

11.2.2 Survey Feedback

Survey forms were distributed at the public meetings and were also available at the Council offices. They were also mailed out to landholders along the eastern drainage line. 190 survey forms were completed and returned to Council of which 78 included additional comments or feedback regarding the eastern drainage line scheme.

The following summarises the feedback received by Council on the eastern drainage line option:

- Overall there was a low level of support for the scheme with 26% of all respondents supporting the proposal.
- The survey indicates a low level of support from townspeople with 35% of returned surveys supporting the proposal.
- The survey forms indicate virtually no support (2%) for the proposal from the rural community east of Rochester along the Eastern Depression even though the proposal provided for flood proofing of all of the buildings in the flood path including those that currently flood.
- Support is also relatively low at 35% in favour amongst those who suffered below or above floor flooding in the 2011 flood event. Support is at 32% for those respondents who weren't flooded in the 2011 flood event.
- 41% of responses provided comments, some of which are provided below. The most common themes of the comments were related to not flooding farms and rural areas, a desire to see local drains improved, regulating Lake Eppalock to provide flood mitigation and improved flood warning and sandbagging.
- A sample of feedback and comments from the survey is provided below. The full record of comments has been tabulated by Council and is available in a separate document.
  - *"I would strongly oppose a flood mitigation scheme using the Nanneella depression - too many people and valuable farm land affected with no information on long term damage"*
  - *"The quoted cost and potential legal problems should negate proposal"*
  - *"Not viable to potentially inundate farmland with floodwaters whose owner's livelihood will be put in jeopardy"*
  - *"The sooner these works are completed the better"*
  - *"We need accurate predictions and sandbags from the Shire"*
  - *"It is unfair to divert the water and make it someone else's problem"*
  - *"Thank you for providing the Rochester Flood report. It is encouraging to see some practical and worthwhile recommendations"*

11.2.1 Reference Panel Feedback

Comments from the Community Reference Panel echoed comments received in the survey and indicate the rural community are more concerned with the impact on farming operations, livestock and crops than affected buildings. Members of the panel were concerned that the impacts on farming operations would be significant, with many properties along the drainage line already inundated for lengthy periods of time following flood events due to the flat nature of the terrain. Panel members were concerned the scheme would only exacerbate these extended periods of inundation and result in significant additional costs to landholders. It was expressed by several panel members that the adverse impacts of the scheme to rural areas outweigh the benefits within the township.

11.2.1.1 Extended Siphon Option

Following consideration of the survey responses, the Community Reference Panel sought investigation of one further option involving removing the channel banks and extending the Waranga Western Channel siphons from the Campaspe River to the eastern side of High Street to restore flow capacity to the north. An investigation of this option shows the 1% AEP flood level at the upstream end of the pool impounded by the Waranga Western Channel banks is approximately 600m downstream and 1.2 metres in elevation below the flood levels in the nearest urban areas. As a result, the fall of the ground and distance between the Township and the siphons and existing channel banks means the effects of removing the channel banks will not extend upstream as far as the Rochester Township so there would be very limited benefit unless combined with other options.

Specifically, the investigation found that:

- Extending the siphon to High St would result in a total length siphon of 1400 metres and a very large structure. The cost would likely be a minimum of $5-10 million dollars and likely considerably more once the interface with the VicTrack easement and railway embankments are considered.

FIGURE 11-1 MAP OF EXTENDED SIPHON OPTION

- An analysis of 1% AEP water levels on the western side of the railway line shows a fall in water level of more than 1 metre from the nearest residential areas in Rochester (around Charles/Victoria Streets). A cross-section is provided below which shows this fall and shows the Campaspe channel banks are a key hydraulic control themselves through this area. Removing the Waranga Channel is unlikely to have a significant benefit to flood risk on residential properties in Rochester given the fall that exists and the presence of other hydraulic controls in between.

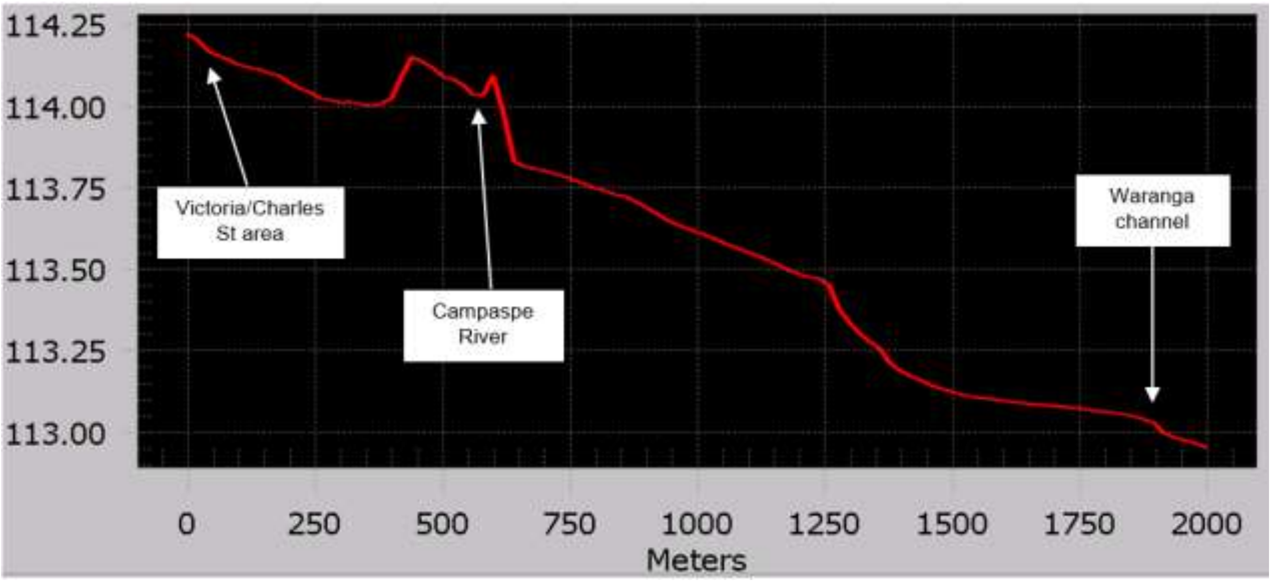

FIGURE 11-2 CROSS-SECTION 1 OF 1% AEP WATER LEVELS BETWEEN ROCHESTER AND THE WARANGA CHANNEL TO THE WEST OF THE RAILWAY LINE

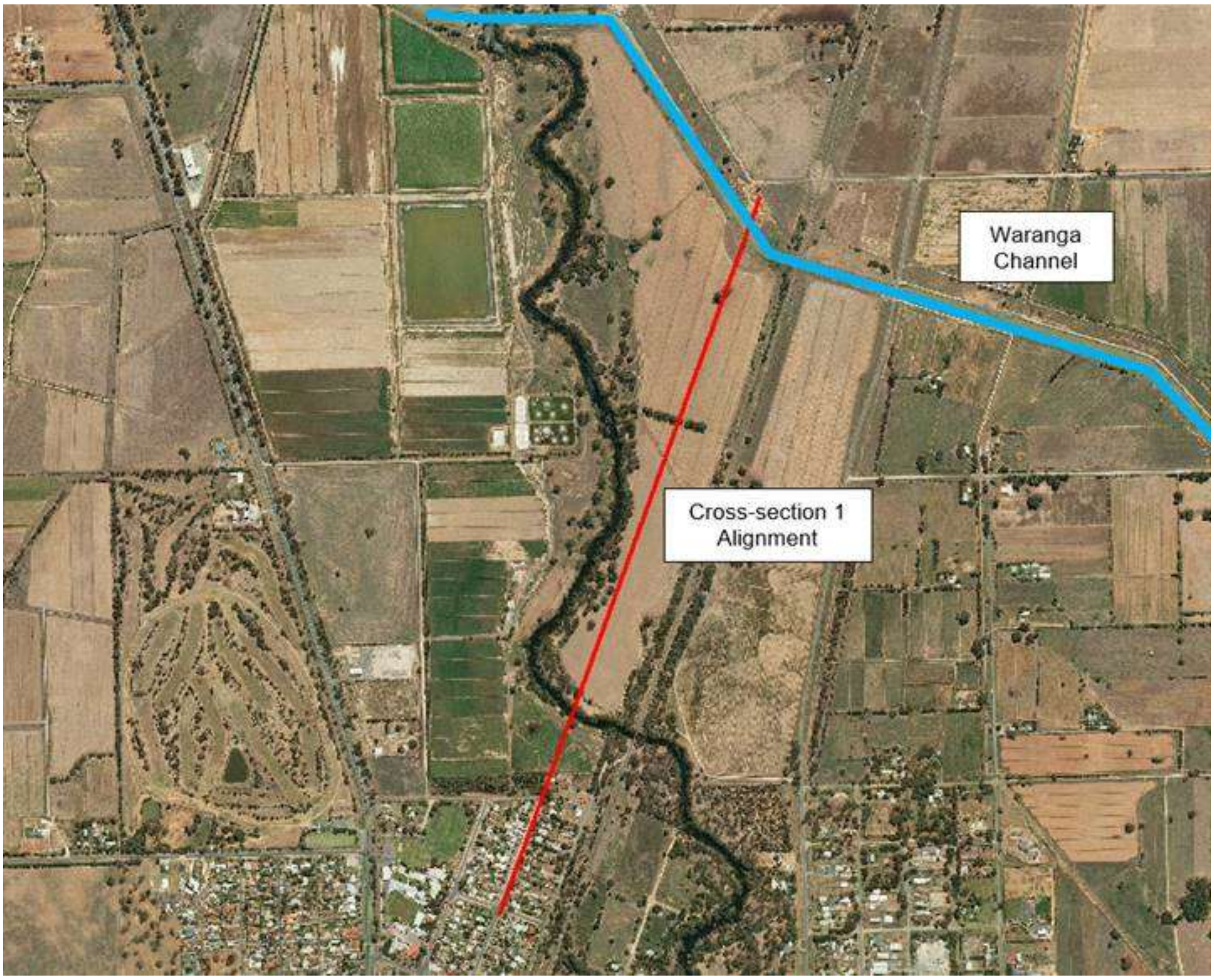

FIGURE 11-3 ALIGNMENT OF CROSS-SECTION 1 TO THE WEST OF THE RAILWAY LINE

- An analysis of 1% AEP water levels on the eastern side of the railway line also shows a fall in water level of around 1.5 metres from the nearest dense residential area (around High/Lowry Streets). A cross-section is provided below which shows this fall and shows the extent of water backing up behind the Waranga channel banks. The chart indicates that water backs up for 600-700m upstream while the nearest residential areas are more than 1200 metre upstream from the channel. Again, removing the Waranga Channel is unlikely to have a significant benefit on flood risk at residential properties in Rochester given the fall that exists and distance from the properties sot at risk. While it would certainly help flood water drain to the north, as a standalone option it's unlikely to have a big benefit in the residential areas of Rochester that are most at risk.

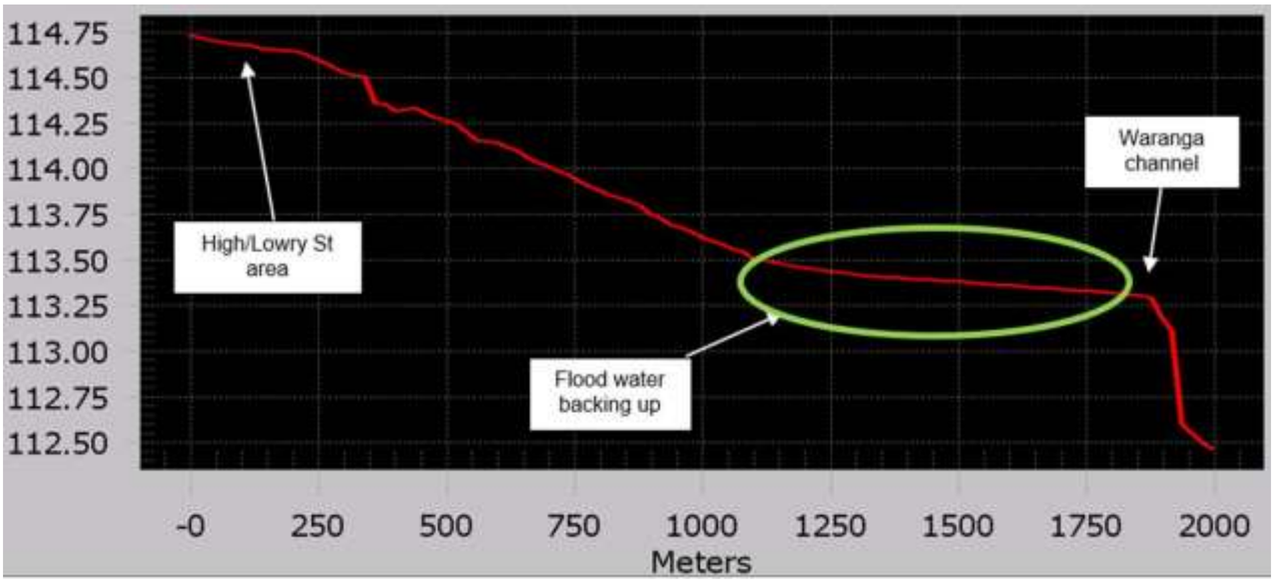

FIGURE 11-4 CROSS-SECTION 2 OF 1% AEP WATER LEVELS BETWEEN ROCHESTER AND THE WARANGA CHANNEL TO THE EAST OF THE RAILWAY LINE

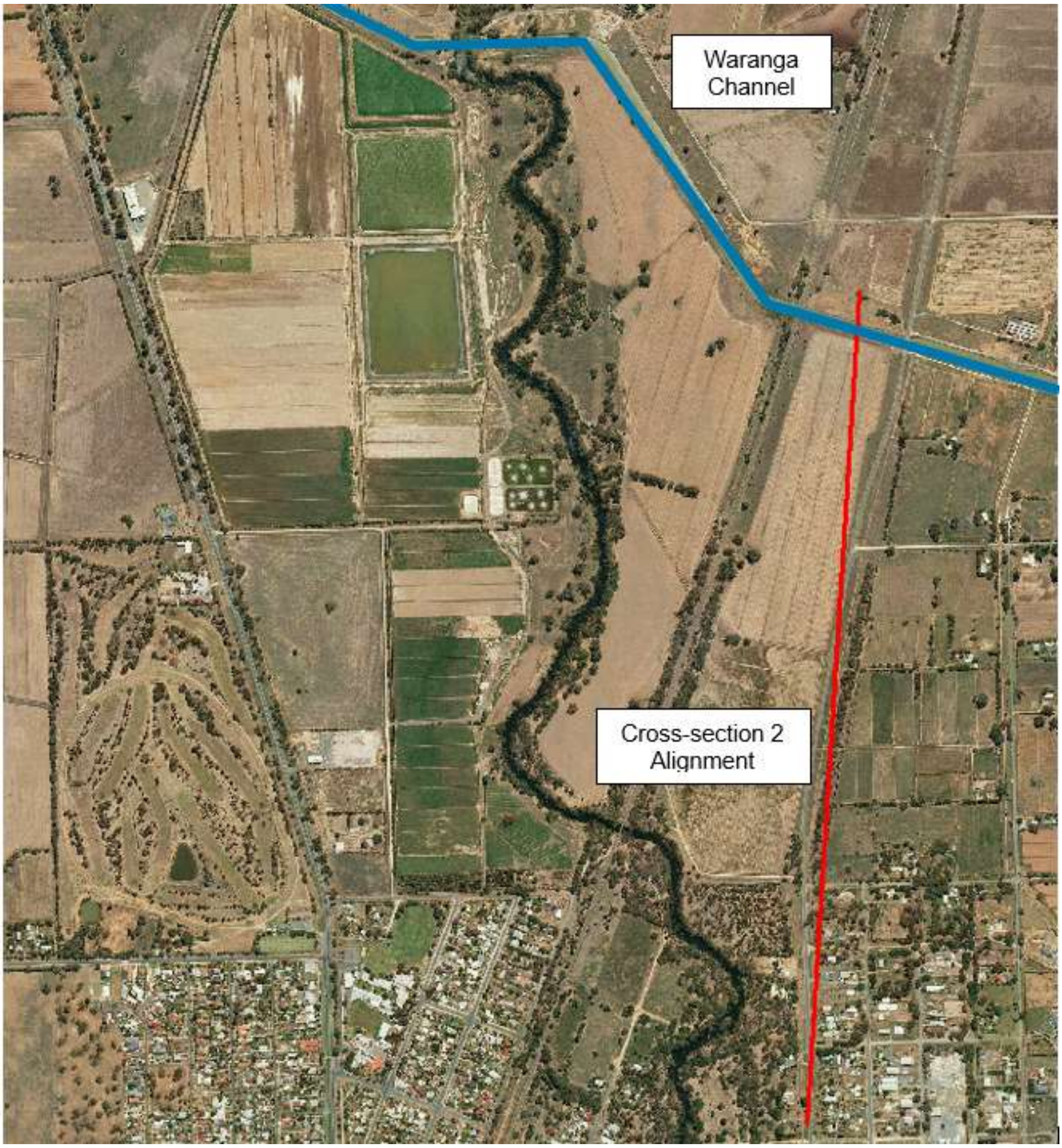

FIGURE 11-5 ALIGNMENT OF CROSS SECTION 2 TO THE EAST OF THE RAILWAY LINE

Based on the above findings it is not recommended that this option be further investigated. The investigation has shown that the option is likely to have a limited impact on flood levels in the residential areas of Rochester whilst having a very high cost associated with the works.

12 SUMMARY AND RECOMMENDATIONS

The study has considered a wide range of mitigation options and has examined in detailed the preferred mitigation scheme from the Rochester Flood Management Plan. The final key findings and recommendations from this study are presented below:

- Many preliminary options were considered including upstream storages, floor raising, clearing of vegetation and a large upgrade of the railway bridge. These options underwent a preliminary feasibility assessment. and it was deemed that all of them, except for floor raising are highly unlikely to be feasible due to limited benefit and high costs. Floor raising was deemed to be more feasible but would still be associated with very high costs. Target floor raising for the most vulnerable buildings may be more economically viable.
- The preliminary options above were compared with the options from the Rochester Flood Management Plan and based on that comparison only two options were deemed likely to be feasible - floor raising and the eastern drainage line mitigation scheme. The eastern drainage line scheme was deemed to be more feasible than the floor raising option.
- The eastern drainage line scheme was assessed in detail and a package of works developed which provide significant benefit to Rochester whilst aiming to protect many properties along the eastern drainage line from increased flood risk because of the diversion of additional flow along that route.
- The mitigation scheme was found to have a capital cost of just over $7.1 million and an annual maintenance cost of $31,000. The scheme reduces Annual Average Damages from $810,280 to $696,782 and was found to have a low benefit-cost ratio of 0.2. The costing has not yet included land acquisition or compensation costs.
- The study has involved considerable consultation to date with key stakeholders and community members. Feedback from the community and the community reference panel shows that the scheme has a low level of support in the community. From a total of 190 community survey responses the scheme received support from 35% of respondents.
- 41% of community survey responses also provided comments regarding the proposal. The most common themes of the comments related to not flooding farms and rural areas, a desire to see local drains improved, regulating Lake Eppalock to provide flood mitigation and improving flood warning and sandbagging.

Council considered the results of the draft feasibility report at its meeting on the 20 February 2018 where it resolved to:

- 1. Note:
  - a. Successful implementation of the southern levee and flood warning system as recommended in the Rochester Flood Management Plan 2013;
  - b. The relatively low benefit cost ratio of less than 0.2 associated with the preferred structural flood mitigation option identified in the Rochester Flood Management Plan 2013 as investigated in the 'Draft Feasibility Report – Rochester Flood Mitigation Strategy' dated September 2017 prepared by Water Technology Pty Ltd;
  - c. The extensive community consultation process and relatively low level of support for the preferred structural flood mitigation option shown by respondents to the community survey; Rochester Township (support from 35% of respondents) and Eastern (Nanneella) Depression (2%) and those who suffered above floor flooding in 2011 (45%);
  - d. The views of the Reference Panel comprising representatives from within the Township and along the Eastern Depression that:
    - 1. The preferred mitigation option is not feasible and should not be further pursued; and
    - 2. Efforts should be directed to further developing the flood warning system and flood response programs;
  - e. None of the other alternatives identified during preparation of the Rochester Flood Management Plan June 2013, the Preliminary Options Assessment Report 2017 or Draft Feasibility Report – Rochester Flood Mitigation Strategy September 2017 are economically feasible; and
  - f. Investigation of the one new option arising from the consultation process comprising pipelining and removal of the Waranga Western Channel banks between the Campaspe River and High Street to restore the Campaspe river flood plain width shows no benefit to the Rochester urban area
- 2. Having considered the 'Draft Feasibility Report – Rochester Flood Mitigation Strategy' and associated community comment provided through the consultation process, conclude that the preferred structural mitigation option is neither economically feasible nor adequately supported by the community to meet the Campaspe Shire Council Meeting Agenda 20 February 2018 13 State and Federal capital works funding guidelines for flood mitigation works or to warrant Council funding for it to be implemented;
- 3. Determine it is neither feasible, worthwhile nor in the community's overall best interests to proceed with stage 2 of this project to invest funds in preparing functional designs for this infrastructure;
- 4. Work with the State Emergency Service to assist it further develop the flood warning and response systems and other non-structural flood mitigation measures to continue to grow the Rochester community's resilience to flooding events until such time as a feasible structural mitigation option is identified with a particular focus on:
  - a. Installation of flood height markers at strategic locations throughout Rochester;
  - b. Installation of floor height level markers on all township dwellings; and
  - c. Establishing an evacuation plan which provides for flood-free havens and access routes to them, and locations for supplies of sandbags;
- 5. The community's requests for improvements to the township and rural drainage systems and consider implementing improvements in conjunction with the infrastructure renewal program and as the opportunity arises; and
- 6. Thank the members of the Rochester Community Reference panel for their time and efforts in assisting with this study.

APPENDIX A
SUMMARY OF DETAILED MITIGATION COSTING

Scenario	Works Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Final Mitigation Scheme	Eastern Drainage Line Extended Levees	$147,186	$2,208
	Eastern Drainage Line Ring levees (x15)	$375,000	$5,625
	Culverts - Nannella Depression	$258,139	$3,872
	Main Rochester Levee (northern retaining wall section)	$3,061,884	$15,309
	Main Rochester Levee (southern earthern section)	$58,911	$884
	Eastern Drainage Line Small Levee	$46,193	$693
	Eastern drainage Excavation	$465,954	
	Drain upgrade between Ramsey Street & Railway Line	$167,428	$2,511
	Sub-total 'A'	$4,580,696	
	'A' x Engineering Fee @ 15%	$687,104	
	Sub-total 'B'	$5,267,800	
	'B' x Administration Fee @ 9%	$474,102	
	(Land Acq only) 'B' x Administration Fee @ 1%	-	-
	Sub-total 'C'	$5,741,902	
	'A' x Contingencies @ 30%	$1,374,209	
	FORECAST EXPENDITURE	**$7,116,111**	**$31,102**

Notes

1 Annual maintenance of 1.5% assumed for earthen levee and andall other components, 0.5% assumed for retaining wall section

2 No provision for cost of land acquisition, easements and compensation costs

3 The above cost estimates prepared by Water Technology should be considered preliminary only

4 Water Technology recommends that Quantity Surveyors be engaged when more accurate costs are required and occur as part of functional and detailed design stages

APPENDIX B
DAMAGES ASSESSMENT METHODOLOGY

Three primary sources for flood damage calculations were used, the original ANUFLOOD cost curves (CRES 1992), the RAM methodology (Reed Sturgess and Associates (RSA) 2000) and revised damages curves developed by the NSW OEH (2007). Further details on the ANUFLOOD methodology are provided in a guidance report produced by DNR (2002). ANUFLOOD cost curves cover residential and commercial direct costs applicable for townships. The RAM methodology incorporates the ANUFLOOD approach and extends it to include indirect and intangible costs resulting from flooding and provides guidance on costs for agricultural enterprises. A major study of the Economics of Natural Disasters in Australia by the Bureau of Transport Economics (BTE 2001) provides some further information on indirect costs and a recent study by Geoscience Australia (Middelmann-Fernandes 2010) provides information for accounting for the impact of velocity in flood damage assessments. A recent review by economists Aither on behalf of DELWP has led to the conclusion that ANUFLOOD stage damage curves underestimate flood damages, particularly at shallow above floor depths and below floor flooding. The stage damage curves developed by the New South Wales Office of Water have been recommended by Aither in personal communication and were used for this study for above floor flooding. The key references are described below.

- Bureau of Transport Economics (2001). Economic Costs of Natural Disasters in Australia. Report 103. Bureau of Transport Economics, Canberra.
- CRES (1992). ANUFLOOD : A field guide, prepared by D.I. Smith and M.A. Greenaway, Centre for Resource and Environmental Studies, ANU, Canberra.
- Department of Natural Resources and Mines (DNR) (2002). Guidance on assessment of Tangible Flood Damages. Queensland Department of Natural Resources and Mines, September 2002.
- Middelmann-Fernandes, M.H. (2010). Flood damage estimation beyond stage-damage functions: an Australian example. *Journal of Flood Risk Management* 3 (2010): 88-96.
- Reed Sturgess and Associates (2000). Rapid Appraisal Method (RAM) for floodplain management. May 2000. Report prepared for the Department of Natural Resources and Environment.

- Before any stage damage curves from the literature were applied in the Rochester flood damage assessment they were adjusted to today's value by scaling using a ratio of today's CPI and the CPI at the time of development of the stage-damage curve. A number of stage damage curves are included below, representing the value at the time of development (i.e. prior to CPI adjustment).

This appendix does not include a detailed methodology of how the damage assessment was carried out but does include the majority of the source data sets that were used in the development of the methodology.

Table D1 Above floor level stage damage relationships for residential properties (from NSW OEH (2007 and adjusted for CPI)

		Damages ($)
Depth over floor level	0 m	$27 895
	0.1 m	$61 537
	0.6 m	$74 461
	1.5 m	$103 321
	1.8 m	$112 276
	5	$137 613

Table D2 Size categories for commercial properties (from ANUFLOOD 1992; reproduced from DNR 2002)

Size category	Guideline
Small	< 186 m2
Medium	186 – 650 m2
Large	650 m2

Table D3 ANUFLOOD Commercial properties cost curve (reproduced from DNR 2002 and subsequently adjusted for CPI)

	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	$1297
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

Table D4 External / below floor damage per building (from DPIE Floodplain Management in Australia 1992 and adjusted for CPI)

Depth above ground (m)	External Damage ($)
0	0
0.065	0
0.26	$3 353
0.5	$7 317
0.75	$11 279
1	$15 243
2	$15 243

Table D5 Unit damages for roads and bridges (per kilometre of road inundated) (From DNR 2002 and adjusted for CPI)

	Initial road repair ($)	Subsequent accelerated deterioration of roads ($)	Initial bridge report and subsequent increased maintenance ($)	Total cost to be applied per km of road inundated ($)
Major sealed road	50, 661	25 331	17 415	93 406
Minor sealed road	15 832	7 916	5 541	29 288
Unsealed road	7 124	3 562	2 533	13 219

Table D6 Actual to Potential Damages Ratio from RAM (RSA 2002)

	Actual to Potential Damages Ratio	
Warning time (hrs)	Past Flood Experience	No Flood Experience
0	0.8	0.9
2	0.8	0.8
7	0.6	0.8
12	0.4	0.8
12	0.4	0.7
96	0.4	0.7

Table D7 Rural damages from RAM (RSA 2002 and adjusted for CPI)

	Cost per ha. From RAM ($)
Irrigated broadacre	491
Irrigated pasture	622
Dryland pasture	87
Dryland broadacre	261
Horticulture	7227

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