KANGAROO FLAT GOLDEN SQUARE FLOOD MITIGATION STUDY FINAL REPORT

SEPTEMBER 2020

PREPARED FOR

City of Greater Bendigo

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A	Draft Study Report
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1 INTRODUCTION

1.1 BACKGROUND

Water Modelling Solutions were engaged by City of Greater Bendigo to undertake a flood mitigation study of Kangaroo Flat and Golden Square. Kangaroo Flat and Golden Square are suburbs of the City of Greater Bendigo with populations of approximately 10,400 and 8,800 respectively (2016 ABS Census). They both contain predominantly residential areas and have undergone steady growth in recent years with numerous multi-lot residential developments, including several in close proximity to Bendigo Creek and its tributaries.

Bendigo Creek flows through the study area from south to north and was heavily modified as a result of habitation and extensive mining activity through the area. The catchment area Bendigo Creek upstream of the study area is approximately 20 km^2.

This study initially involved assessing the existing flood risk through the study area using hydrological and hydraulic modelling. Community consultation was undertaken in July/August 2019 and through that process a large number of options were collated to reduced flood risk which had been suggested by the Community, Council and other stakeholders. 41 of those options underwent preliminary assessment in late 2019. Following that analysis ten options (or combinations of options) were selected to be studied in detail.

Ten options underwent detailed assessment which included detailed modelling the full range of design events, preliminary costing, desktop environmental assessment, damages assessment and benefit-cost analysis. A second round of consultation was undertaken in February/March 2020 where the community had the opportunity to provide feedback on the detailed options.

1.2 EXISTING FLOOD RISK

The early stage of the study involved determining the existing level of flood risk through Kangaroo Flat and Golden Square. This included updating and modifying existing models to represent current conditions and to ensure consistency with current best practice. This process ensured the modelling complied with relevant guideline included Australian Rainfall and Runoff 2019. Details regarding the model updates can be found the Template Report (Water Modelling Solution 2019) The modelling of existing conditions determined that significant areas of the study area are susceptible to riverine inundation across a range of flood events. As part of this process 263 buildings had their floor levels surveyed so their level of risk could be determined.

A damages assessment was undertaken and it was found that in the 1% AEP event 101 residential buildings and 31 commercial buildings are subject to above floor flooding. The results of the damages assessment for existing conditions are summarised below in Table 1-1. Flood maps for the 1% AEP flood event under existing conditions are provided in Appendix A.

Table 1-1 Flood Damages in Existing Conditions

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	49	101	114
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded	1	11	30	67	132	149
Total Damage Cost		**$1,060,257**	**$2,049,326**	**$3,543,228**	**$7,155,734**	**$14,316,650**	**$17,790,266**

2 MODEL VALIDATION - JANUARY 2015 EVENT

2.1 OVERVIEW

In order to validate the updated hydrologic and hydraulic models the January 2015 event was modelled and the results compared to available information. This included calibrating the RORB model to the gauge record and then comparing the subsequent TUFLOW results to photos taken within the study area as well as the gauge record at the Bendigo Creek at Bendigo Creek.

2.2 HYDROLOGIC MODELLING AND CALIBRATION

2.2.1 Hydrological Modelling

The updated RORB model was used to model the January 2015 event, with the event calibrated to the gauge record at the Bendigo Creek at Bendigo gauge. Historic rainfall was gathered from the BOM as well as from numerous records from local residents, which had been collated by North Central CMA in 2015 following the event.

The temporal pattern for the event was adopted from the nearest available pluviograph gauge record at Bendigo Airport (shown in Figure 2-1). The records show that the bulk of the rainfall fell on the afternoon of 9th January 2015 which is consistent with anecdotal reports from the community.

A rainfall spatial pattern for the event was developed from the available rainfall data which included BOM daily gauges as well as a number of community gauge records which were collated following the event by North Central CMA. When mapped it can be seen there was a particularly significant band of rainfall over the Golden Square/Kangaroo Flat area with recorded rainfalls in excess of 100mm for the event. This is considerably larger than the nearest BOM gauge at Bendigo airport which only recorded 39mm for the same period.

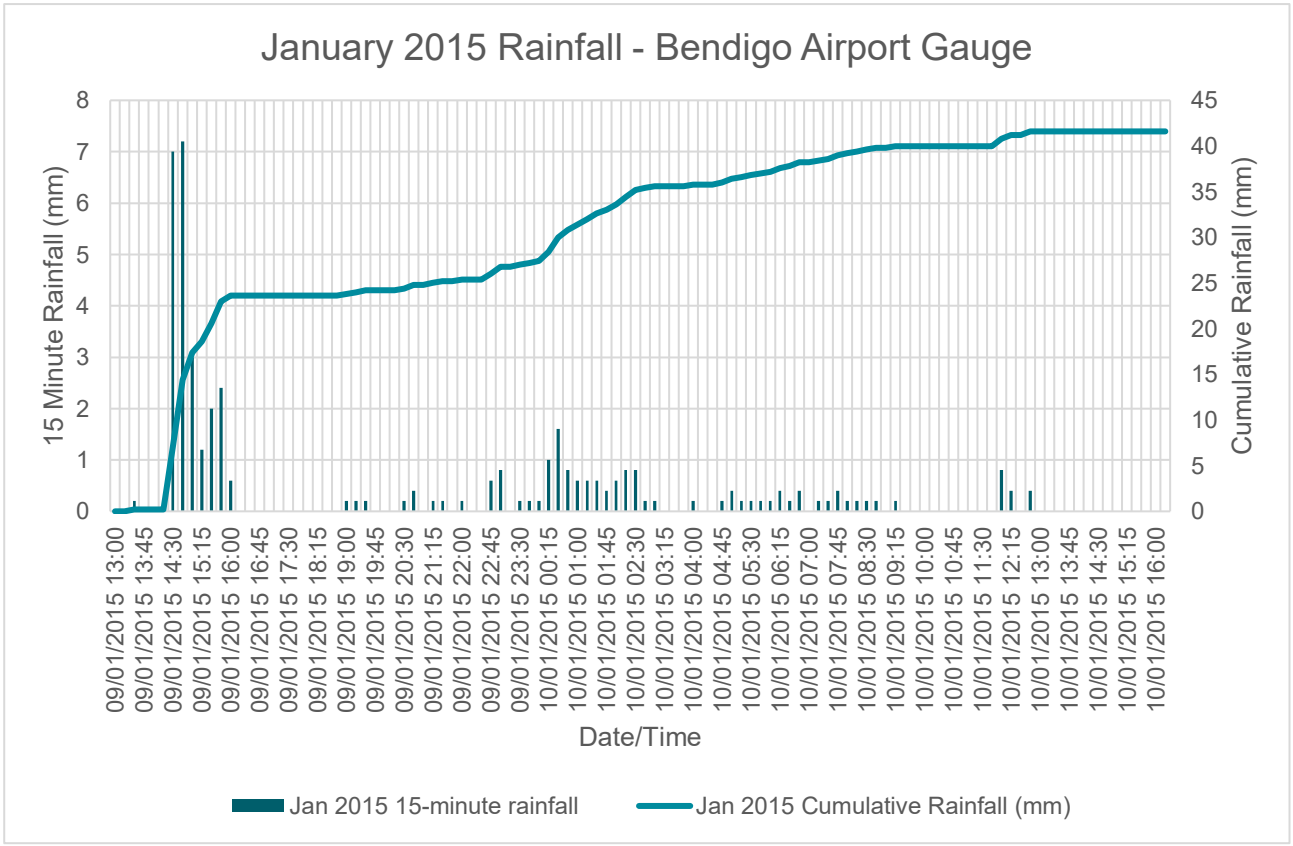


Figure 2-1 January 2015 15-minute and cumulative rainfall from the pluviograph station at Bendigo Airport

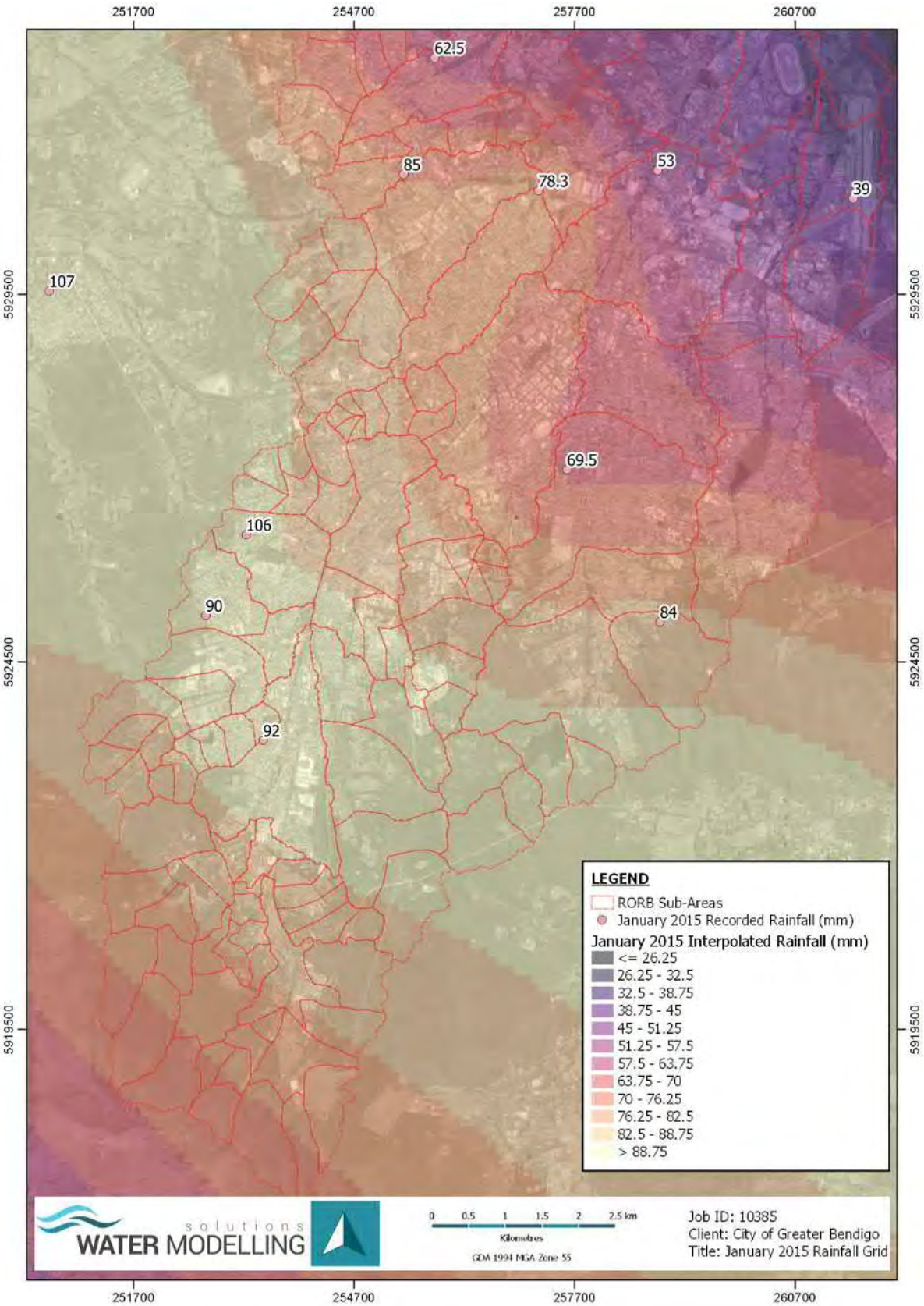


Figure 2-2 January 2015 Event - Gridded Spatial Pattern of Rainfall

2.2.2 Model Calibration

The event was calibrated to the gauge record at the Bendigo Creek at Bendigo Gauge. The results of the calibration are shown in Figure 2-3 below. The adopted parameters are shown further below in Table 2-1. The Kc and m values did not require adjusting from the design values. The initial and continuing losses were modified to fit the peak flow and timing of the rising limb in the recorded hydrograph. It can be seen a good calibration was achieved, in terms of both shape and peak flow, indicating that the design routing parameters adopted in the KFGS RORB model produce realistic flood behaviour. There is some delay in the timing of the first peak, compared to the gauge record, which is likely related to the only available pluviograph data being from the Bendigo Airport gauge. The community-sourced rainfall records and anecdotal records indicate some very intense, isolated bursts occurred across Bendigo and the airport gauge will likely not have captured some of those intense bursts.

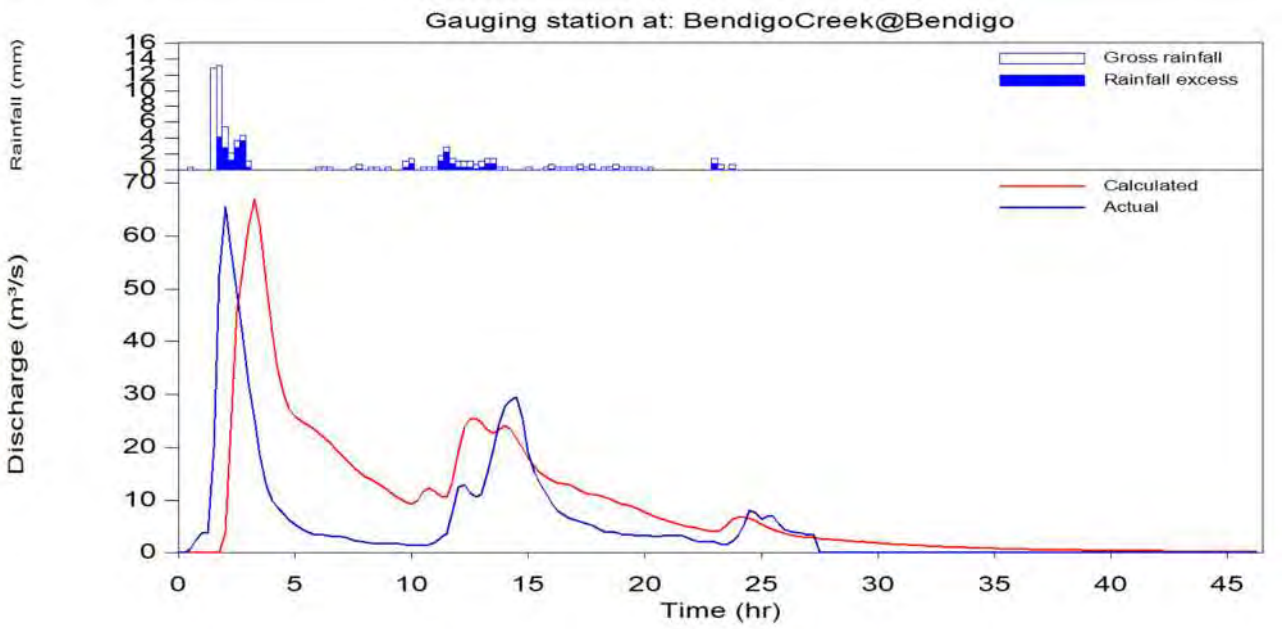


Figure 2-3 January 2015 Calibration at Bendigo Creek at Bendigo gauge

Table 2-1 January 2015 Calibration – Adopted Parameters

Parameter	Value
Kc	As per design modelling, varies across Interstations (see Template report)
m	0.8
Initial Loss (mm)	35
Continuing Loss (mm/hr)	4.0

2.3 JANUARY 2015 MODELLING RESULTS

Figure 2-4 January 2015 Flooding at Bay Street Bridge imagery vs. model result

There are no recorded flood levels available for the 2015 event and so as a form of validation the TUFLOW results were compared to available photos of the event. North Central and COGB provided such evidence of the January 2015 flood event at several locations in Golden Square. It should be noted that flood images rarely capture the peak of flood events and therefore should be treated with a level of caution.

Figure 2-4 above compares the impact of the January 2015 flood at Bay Street bridge. The resulting flood extent from modelling showed Bendigo Creek flood water breaking both banks and inundation up to 3 properties (16, 18 and 20 Bay St) southeast from the bridge. This observation was consistent with photo evidence provided. Flood depths of approximately 200 mm observed at the depth indicator gauge is also similar to the model finding.

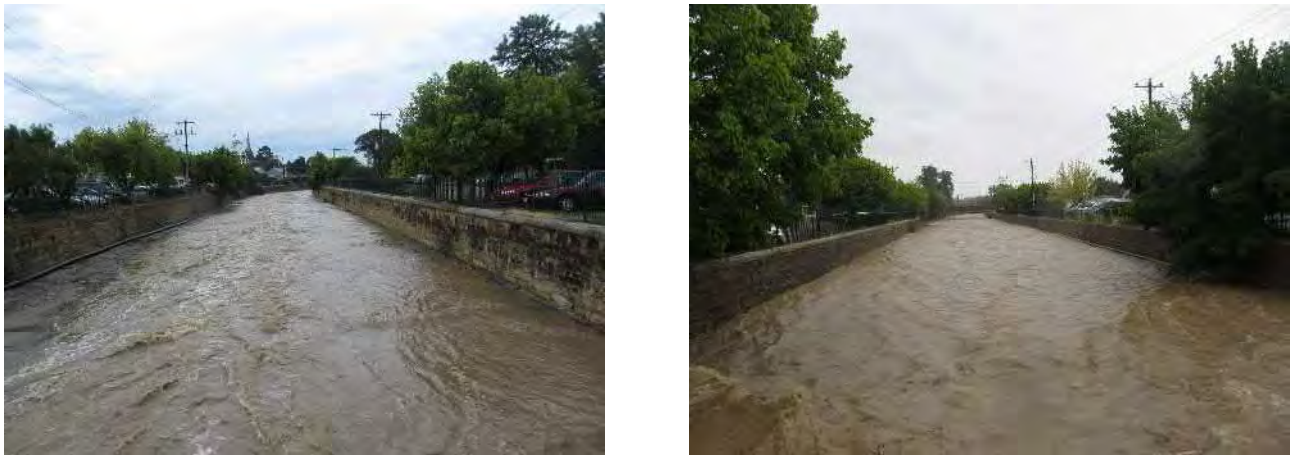


Figure 2-5 January 2015 Flood Event Imagery Looking Upstream and Downstream at Lily Street

Figure 2-6 January 2015 Flood Event Model Result at Lily Street

Figure 2-5 and Figure 2-6 compared flood behaviour inside the Bendigo Creek channel between photo evidence and model result at Lily Street. It was noted that the overland flooding shown in the model result was caused by a sheet flow flooding due to a tributary joining from northwest of the shown area. The model indicates this shallow flow ends up flowing into the Bendigo Creek channel (as opposed to water breaking out from Bendigo Creek). There was no photo evidence available to confirm the sheet flow however, photo evidence of levels inside the channel are generally consistent with the model result.

Figure 2-7 January 2015 Flood Event Imagery at High Street bridge looking Downstream and towards Hargreaves Street

Figure 2-8 January 2015 Flood Event Model Result at High Street and Hargreaves Street

Figure 2-7 and Figure 2-8, compared flood behaviour at a Bendigo Creek tributary between available imagery and the model result at High Street. It is noted that the creek water does not break out from the bank in both the imagery and model results. The model results showed a slight overtop of the road at Hargreaves Street. The photo indicates water did not overtop Hargreaves Street however it is unlikely to have captured the peak of the event in that tributary.

2.3.1 Model Limitations

The model validation indicates that the model is generally performing through much of the study area. There are some locations, particularly in the fully urbanised catchments, where further localised modelling would be recommended as part of the next stage of design.

3 PRELIMINARY OPTIONS

3.1 SUMMARY OF PRELIMINARY OPTION ASSESSMENT

An initial consultation period was undertaken during July to September 2019 in which ideas for mitigation options were collated. During the period of consultation, more than 80 mitigation options and comments were collated. The full list included a number of duplicate or very similar options as well a number of general comments that didn't relate to specific locations.

From this list a total of 44 options were found to be appropriate for modelling, either for preliminary modelling or for sensitivity testing. The results of the preliminary modelling were made available to the project control group in late 2019. The full list of options and modelling results for these options can be found the KFGS Preliminary Options Summary Report (Water Modelling Solutions 2019)

The outcomes from these options were reviewed by the project control group and ten options (or combination of options) were selected for detailed modelling. The results of the detailed modelling are presented in this document. Selection criteria was based on degree of flood impact improvement effectiveness, consequential adverse impacts, environmental risks and feasibility.

Figure 3-1 Photos from the first community workshop in Kangaroo Flat held on the 5th September 2019

4 DETAILED MITIGATION OPTION ASSESSMENT

4.1 OVERVIEW

The section below presents the results of detailed mitigation modelling of 10 options (or combinations of options) aimed at reducing flood risk through Kangaroo Flat and Golden Square. The location of the modelled options is shown in below.

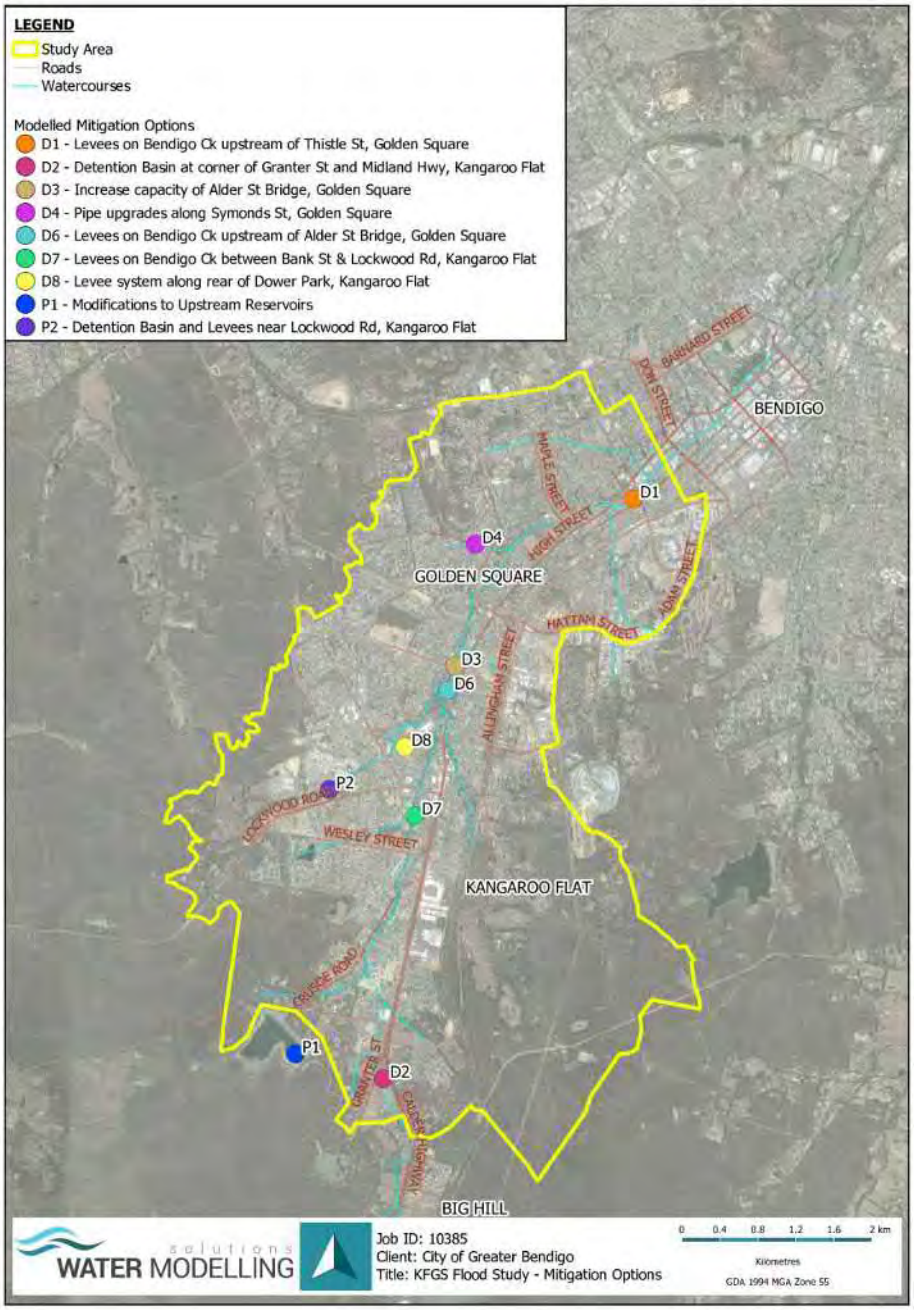


Figure 4-1 Location of Detailed Mitigation Options

A number of options or scenarios were suggested for modelling which aren't true structural mitigation options but nonetheless add considerable value to the study in term of understanding flood behaviours and future impacts related to increased

development and climate change. The following options have been classed as options for sensitivity modelling and have also been modelled and assessed:

- A climate change sensitivity analysis involved increasing design rainfall intensity based on recommendations in relevant guidelines. Both mid and high-range projected increases in rainfall intensity will be modelled.
- Land use sensitivity involved modelling increased development to understand the future development capacity of existing drains and future requirements.

The section below details the keys area of assessment for each mitigation option which are presented further below.

4.1.1 Hydraulic Impacts

The full range of design events were modelled for each mitigation options and the hydraulic impacts of each option is described for the 1% and 10% AEP events. Map are also included for both those events. The maps compare the results of mitigated conditions to existing conditions, with differences in flood levels shown as well as those areas which become flood-free as a result of the mitigation option, the afflux maps also allow areas to be identified where flood levels are increased as a result of the option.

4.1.1.1 Damages Assessment

A flood damages assessment was undertaken for the study area under existing conditions as well as all mitigation options. The flood damage assessment determined the monetary flood damages for the modelled design floods, namely the 20%, 10%, 5%, 2%, 1% and 0.5% AEP flood events. The damages assessment was all undertaken in WaterRIDE software and used NSW OEH damages curves, which have been adjusted for CPI. It should be noted that secondary buildings, outbuildings and garages have not been explicitly included in the damages assessment. Floor level survey was gathered of the primary dwelling or commercial building at each impacted property which is a typical approach when undertaking damages assessments in flood studies.

The damages assessments allowed the reduction in flood damages as a result of the mitigation works to be assessed. Damages as a result of flooding each year on average. Calculating AAD allows a direct comparison to be made between the different mitigation options, showing which are more effective in reducing flood damage in the long-term.

The damages assessment for the mitigation scenarios has been compared to the damages assessment for existing conditions which is summarised below, in order to understand the benefit in terms of the reduction in properties flooded across the range of design events.

Table 4-1 Flood Damages Summary for Existing Conditions

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	49	101	114
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded	1	11	30	67	132	149
Total Damage Cost		**$1,060,257**	**$2,049,326**	**$3,543,228**	**$7,155,734**	**$14,316,650**	**$17,790,266**

4.1.2 Preliminary Costing

All options have undergone preliminary costing at a concept design level. The following have been used to determine mitigation option costs:

- Melbourne Water's standard rates for earthworks and pipe/culvert construction costs.
- Rawlinson's Handbook Rates
- VicRoads regarding bridge and culvert works costs
- Experience in costing mitigation works in other flood studies

- Comments from City of Greater Bendigo regarding initial costings.

In addition, the following assumptions have been made with regards to the costing:

- A 600 mm freeboard in 1% AEP storm event has been adopted for all levees.
- 5% admin fees, 15% engineering fees, 20% contingency adopted across all options
- 1.5% maintenance has been assumed for earthen levees
- 0.5% maintenance has been assumed for other structures

The costings are recommended to be revised as part of the next phase of functional and detailed design.

4.2 STANDALONE MITIGATION OPTIONS

4.2.1 Option D1 – Levees along Bendigo Creek upstream of Thistle Street, Golden Square

4.2.1.1 Location and Description

Option D1 was recommended for detailed investigation and consists of levees along Bendigo Creek in Gold Square. Figure 4-2 shows the proposed the construction of levees along both banks of the section of Bendigo Creek between High Street and Thistle Street, Golden Square. Retaining walls are used in place of earthen levee where there is unlikely to be insufficient space for a traditional earthen levee fill. The earthen levee has been designed with 1 in 5 batters on both sides, 600 mm freeboard and 500 mm crest width.

The western levee extends from High Street bridge along the property boundary of the properties corner of High Street and Shamrock Street and ties into the Thistle Street bridge. The earthen levee section is approximately 123 m long while the retaining wall section is approximately 97 m long. The required levee height varies from 600 to 900 mm to achieve 600 mm freeboard.

The eastern levee commences near the footpath from Hargreaves Street and ties into the Thistle Street bridge. The earthen levee section is approximately 176 m long while the retaining wall section is approximately 101 m long. The required levee height varies from 600 to 1300 mm to achieve 600 mm freeboard.

4.2.1.2 Flood Impacts

Option D1 was modelled for the full range of design events. The impacts in the 1% and 10% AEP event are described below and mapped further below to understand the impact of this option on flood behaviour.

Figure 4-3 shows the impacts on 1% AEP peak flood level as a result of Option D1. This option prevents creek water from breaking out from both sides of the creek in this area. Flood levels in the surrounding areas, and north of the levee location are significantly reduced. The 1% AEP flood extent is also significantly reduced. Flood levels near the corner of Thistle St and High St are reduced by up to 200 mm. There are some increases in floods levels downstream of the levees of up to approximately 100 mm within the Bendigo Creek channel.

Figure 4-4 shows the impacts on 10% AEP peak flood level as a result of Option D1. No significant benefits or adverse impacts was noted in the smaller flood event.

4.2.1.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Mapping of the location of Option D1 relative to the environmental and heritage overlays can be found in Appendix B.

It is found that while no environmentally significant feature is present in the vicinity of Option D1. It is noted that the levees are located at the boundary of the Neighbourhood Characteristic Overlay upstream of Thistle St. The levees are situated inside an Aboriginal Cultural Heritage Sensitive area. A cultural heritage assessment would be required as part of the next stage of design.

4.2.1.4 Damages Assessment

A damage cost assessment has been undertaken to enable the benefit of the option in terms of reducing damages to residential and commercial buildings to be determined. The AAD for final Option D1 was calculated to be $673,583. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 127 properties. Over a long period of time through a range of flood events, the AAD may be reduced by approximately $29,234 per year by implementing this package of works. Table 4-2 summarises the Option D1 flood damages assessment.

Table 4-2 Flood Damages Summary for Option D1

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	49	100	112
	Commercial Properties	1	5	11	17	27	29
	Total Properties Flooded Above Floor	1	11	31	66	127	141
Reduction in above floor flooded properties		0	0	1	1	5	8
Total Damage Cost		**$1,065,568**	**$2,063,061**	**$3,542,007**	**$6,915,001**	**$12,850,949**	**$15,857,965**

4.2.1.5 Preliminary Costing

Preliminary costing has been undertaken of this option. Table 4-3 shows an estimation of the cost of option D1 and includes engineering, admin and contingency costs.

Table 4-3 Summary of cost of Mitigation Option D1

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
West Levee - Earthen	$39,850	$598
East Levee - Earthen	$15,854	$238
West Levee - Raised Wall or Sheet Piling	$388,000	$1,940
East Levee - Raised Well or Sheet Piling	$404,000	$2,020
Environmental and Cultural Heritage Management Plans	$120,000	
Sub-total 'A'	*$847,704*	
'A' x Engineering Fee @ 15%	*$127,156*	
Sub-total 'B'	*$1,094,859*	
'B' x Administration Fee @ 5%	*$54,743*	
Sub-total 'C'	*$1,149,602*	
'A' x Contingencies @ 20%	*$169,541*	
OPTION D1 FORECAST EXPENDITURE	**$1,319,143**	**$4,796**

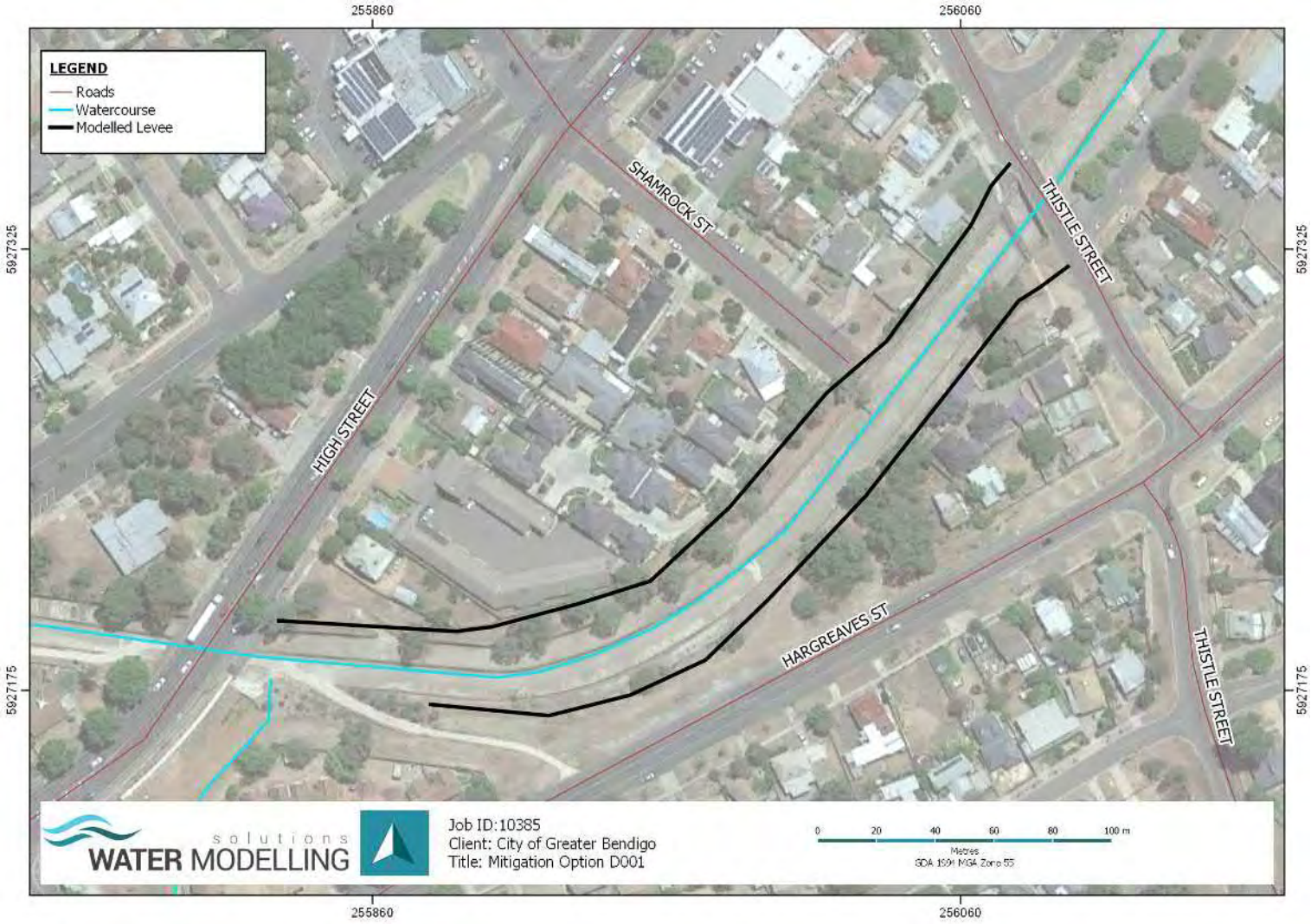


Figure 4-2 Location of Option D1

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Bridge Upgrade
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

LILY STREET
CREEK STREET N
CREEK STREET S
THISTLE STREET
SHAMROCK ST
HIGH STREET
LILY STREET
HARGREAVES ST
THISTLE STREET

Mitigation Option D001

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:2000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 20 40 60 m

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D001

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:2000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 20 40 60 m

4.2.2 Option D2 - Detention Basin at corner of Granter St and Calder Highway, Kangaroo Flat

4.2.2.1 Location and Description

Option D2 involves the construction of a large, detention basin at the corner of Granter St and Calder Highway, Kangaroo Flat. Figure 4-5 shows the location of the basin which has a capacity of approximately 20,000 m^3.

The basin bed, elevation and spillway are 274.7 m AHD and 275.5 m AHD respectively. The basin outlet would consist of an array of 6 x 1200 mm x 900 mm box culverts which discharges into the waterway downstream of Granter St. An alternative version of this option has also been modelled with the basin discharging into another drainage line, closer to the Calder Highway.

The spillway is located on the eastern embankment of the spillway, near the northern corner. The spillway would discharge into the corridor between the basin and the Calder Highway, noting that the Calder Highway is raised by more than 1 metre through this area. The spillway discharge would then flow north under, and across Granter Street (in large events).

For larger flood events, in excess of the 10% AEP events, the spillway would be engaged. Based on the modelling undertaken it would not be feasible to construct a basin that could detain the 1% flow without spilling – the required storage would be too large for the area available.

4.2.2.2 Flood Impacts

Figure 4-6 shows the impacts on 1% AEP peak flood level as a result of Option D2. The modelling result indicates that peak flood levels are reduced by up to 100 mm downstream of the basin and the impacts extend up to 5 km downstream of the basin. Peak flood levels are higher than under existing conditions immediately downstream of the basin. Flood levels adjacent to the downstream waterway are increased by up to 100 mm. The basin reduces flood levels at a large number of properties including 16 buildings which are flooded above floor level in the 1% AAEP event.

Figure 4-7 shows the impacts on 10% AEP peak flood level as a result of Option D2. Flood levels decreased along adjacent to Bendigo Creek up to 3 km downstream from the basin. Several properties became flood-free with this option. Peak flood levels are higher than under existing conditions immediately downstream of the basin. Flood levels adjacent to the downstream waterway are increased by up to 100 mm.

4.2.2.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact this option. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option D2 in relative to environmental and heritage overlays can be found in Appendix B.

An Environmentally Significant overlay is located along the waterway which flows through the centre of the proposed basin. An environmental impact assessment would be required as part of the next stage of design.

The available data indicates that Option D2 is not located within an area of cultural heritage importance.

4.2.2.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of reducing damages to residential and commercial buildings. The AAD for mitigation option D2 was calculated to be approximately $646,934. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 116 properties. Over a long period of time across a range of flood events, the AAD may be reduced by approximately $55,883 per year by implementing this package of works. Table 4-4 summarises flood damages with Option D2 implemented.

Table 4-4 Flood Damages Summary for Mitigation Option D2

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	41	88	106
	Commercial Properties	1	5	10	14	28	33
	Total Properties Flooded Above Floor	1	11	29	55	116	139
Reduction in above flood flooded properties		0	0	1	11	16	10
Total Damage Cost		**$1,053,663**	**$2,047,116**	**$3,331,959**	**$6,336,938**	**$12,473,965**	**$15,547,063**

4.2.2.5 Preliminary Costing

Preliminary costing has been undertaken of this option. Table 4-5 shows an estimation of the cost of option D2 and includes engineering, admin and contingency costs.

Table 4-5 Summary of cost of Mitigation Option D2

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Basin Earthwork	$3,245,844	$16,229
Culvert Outlet	$155,568	$778
Spillway	$50,000	$250
Land Purchase and Legal Costs	$1,471,894	
Landscaping	$200,000	
Environmental Management Plan	$60,000	
Sub-total 'A'	*$3,451,412*	
'A' x Engineering Fee @ 15%	*$517,712*	
Sub-total 'B'	*$5,701,018*	
'B' x Administration Fee @ 5%	*$285,051*	
Sub-total 'C'	*$5,986,069*	
'A' x Contingencies @ 20%	*$690,282*	
OPTION D2 FORECAST EXPENDITURE	**$6,676,352**	**$17,257**

4.2.2.6 Alternative Outlet Pipe Alignment

The Option D2 outlet pipe was modelled discharging under Granter Street and into the designated watercourse on the opposite side of the road. Under that arrangement significant afflux was noted at the outlet, inundating a nearby residential property. An alternative outlet location was considered to minimise the adverse impacts. In this alternative scenario, the basin outlet discharged into a drainage line downstream of Granter St, closer to the Calder Highway. Considerably longer pipe or box culverts would be required for this option for the outlet.

This alternative option was modelled for the 1% events and the results show that the residential buildings at 6 and 8 Granter Street are now flood-free. The redirected outflow instead causes an increase in flood levels at the driveways of Karinya Gardens Residential Village, with increases of approximately 100-150 mm through that area.

Figure 4-5 Location of Option D2

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Basin

Difference in Peak Water Level (m)

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D002

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:16000
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 100 200 300 m

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Modelled Basin

Difference in Peak Water Level (m)

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D002

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:16000
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 100 200 300 m

4.2.3 Option D3 – Increase capacity of Alder Street Bridge

4.2.3.1 Location and Description

Option D3 consists of increasing the capacity under the Alder Street road bridge. Figure 4-8 shows the proposed upgrade of Alder St Bridge over Bendigo Creek, to increase the flow capacity by approximately 50%. This would involve earth works on either side of the bridge and replacement of the existing structure. The current bridge is a dual lane road bridge with a single pedestrian walkway on the northern side.

Downstream from the Alder Street bridge, the mitigation option includes an earthen levee around Cooinda Park corner of Mackenzie Street West and Norma Street to prevent water from flooding the properties south of the park and reduce flooding along Belinda Ave.

4.2.3.2 Flood Impacts

Figure 4-9 shows the impacts on 1% AEP peak flood level as a result of Option D3. Flood levels are significantly reduced (up to 400 mm) upstream of the bridge and a number of properties become flood-free. Flood levels are reduced at 7 buildings which currently experience above floor flooding, to below floor level. Several properties on the northern side of Alder Street become flood-free. Flood levels are reduced up to 50 mm along Belinda Ave. Alder Street no longer overtops in this event ensuring safer access to vehicles and pedestrians. Water level are increased by up to 100 mm inside Cooinda Park.

Figure 4-10 shows the impacts on 10% AEP peak flood level as a result of Option D3. No significant benefits or adverse impacts were noted.

4.2.3.3 Environmental and Heritage Impacts

A map of the location of Option D3 in relative to environmental and heritage overlays can be found in Appendix B. Option D3 is located on Bendigo Creek which is associated with Environmentally Significance Overlays. A detailed environmental impact assessment would be required in the phase of design for this mitigation option.

Option D3 is also located within an Aboriginal cultural heritage sensitivity overlay and would require a cultural heritage impact assessment.

4.2.3.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option D3 was calculated to be approximately $684,000. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 125 properties. Over a long period of time across a range of flood events, the AAD may be reduced by approximately $18,817 per year by implementing this package of works. Table 4-6 summarises flood damages with Option D3 implemented.

Table 4-6 Flood Damages Summary for Mitigation Option D3

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	48	94	107
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded Above Floor	1	11	30	66	125	142
Reduction in above flood flooded properties		0	0	0	1	7	7
Total Damage Cost		**$1,051,271**	**$2,044,206**	**$3,488,811**	**$6,926,572**	**$13,651,014**	**$16,941,497**

4.2.3.5 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-7 shows an estimation of the cost of option D3.

Table 4-7 Summary of cost of Mitigation Option D3

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Levee	$80,096	$1,201
Earthworks Around Bridge	$33,959	$170
Bridge Upgrade (estimated lump sum)	$1,200,000	$6,000
Landscaping	$20,000	
Traffic Management	$5,500	
Environmental and Cultural Heritage Management Plans	$120,000	
Sub-total 'A'	*$1,314,055*	
'A' x Engineering Fee @ 15%	*$197,108*	
Sub-total 'B'	*$1,656,663*	
'B' x Administration Fee @ 5%	*$82,833*	
Sub-total 'C'	*$1,739,496*	
'A' x Contingencies @ 20%	*$262,811*	
OPTION D3 FORECAST EXPENDITURE	**$2,002,307**	**$7,371**

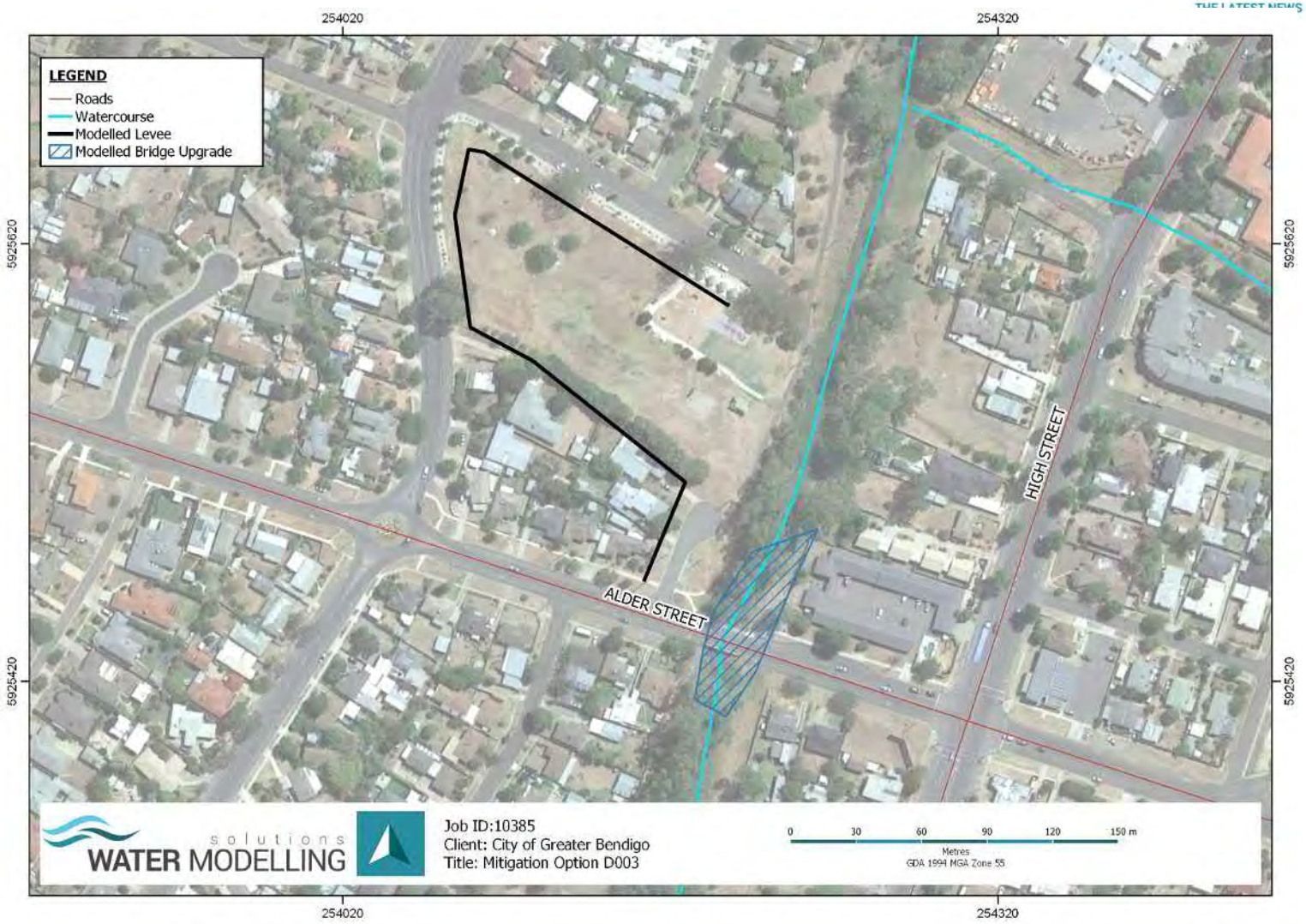


Figure 4-8 Location of Option D3

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Bridge Upgrade
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D003

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:3000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 30 60 90 m

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Modelled Bridge Upgrade
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D003

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:3000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 30 60 90 m

4.2.4 Option D4 – Pipe upgrades along Symonds St, Golden Square

4.2.4.1 Locations and Description

Option D3 involves pipe upgrades along Symonds Street, Golden Square. The modelling indicates a significant overland flowpath through numerous properties. The pipe upgrades are designed to capture some of that overland flow, reducing the flood impacts at the surface. Figure 4-11 shows the proposed construction of additional drainage pipes along Symonds St, with a doubling of the capacity of the existing pipes line currently under the properties along Symonds St.

The size of the pipe upgrades varies, and has been designed to match the increase in pipe capacity along the existing drainage line. The modelled pipe capacity is shown in the location map below and consists of 1500mm and 1650mm diameter pipes.

Due to the some of the modelling limitations described earlier in this report, it is recommended that should this option be pursued it should be further investigated as part of the next phase of design. This should include modelling the stormwater network in this catchment at a higher level of detail to better understand the service level of the existing network and what can be achieved with the proposed pipe upgrades.

4.2.4.2 Flood Impacts

Figure 4-12 shows the impacts on 1% AEP peak flood level as a result of Option D3. Peak flood level is noted to decrease by up to 100 mm through numerous properties along Symonds St and Bay St.

Figure 4-13 shows the impacts on 10% AEP peak flood level as a result of Option D3. Minor reduction (less than 100 mm) in peak floods level was noted through several properties along Symonds St and Mackenzie Street West.

Pipe upgrades generally provide fairly modest benefit in large flood events, as the volume that can be piped is relatively minor compared to the total volume of surface flow.

4.2.4.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option D3 in relative to environmental and heritage overlays can be found in Appendix B. Option D4 was not found to be associated with any environmental or cultural heritage overlays.

4.2.4.1 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option D4 was calculated to be approximately $667,057. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 128 properties. Over a long period of time across a range of flood events, the AAD may be reduced by approximately $35,760 per year by implementing this package of works. Table 4-8 summarises flood damages with Option D4 implemented.

Table 4-8 Flood Damages Summary for Mitigation Option D4

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	17	44	97	111
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded Above Floor	1	11	28	62	128	146
Reduction in above floor flooded properties		0	0	2	5	4	3
Total Damage Cost		**$1,026,639**	**$2,037,439**	**$3,267,798**	**$6,674,873**	**$13,570,036**	**$16,805,547**

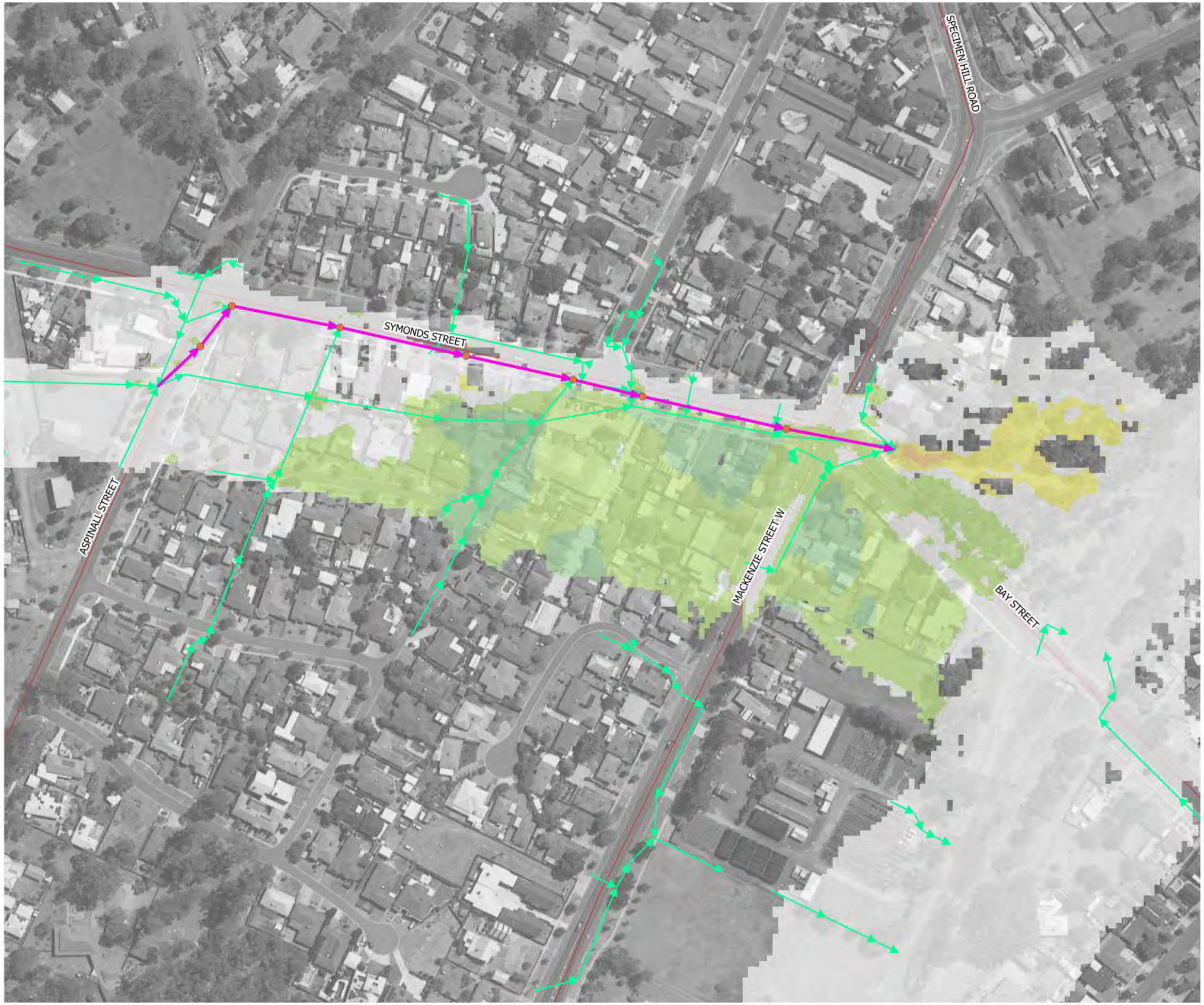
4.2.4.2 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-9 shows an estimation of the cost of option D4.

Table 4-9 Summary of cost of Mitigation Option D4

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
1500mm Pipe Cost	$312,695	$1,563
1650mm Pipe Cost	$299,338	$1,497
Traffic Management	$1,500	
Cultural Heritage Management Plan	$60,000	
Sub-total 'A'	$612,033	
'A' x Engineering Fee @ 15%	$91,805	
Sub-total 'B'	$765,338	
'B' x Administration Fee @ 5%	$38,267	
Sub-total 'C'	$803,605	
'A' x Contingencies @ 20%	$122,407	
OPTION D4 FORECAST EXPENDITURE	**$926,011**	**$3,060**

Figure 4-11 Location of Option D4



solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Existing Pipes
- Modelled Pipe Upgrades

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D004

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:2000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 20 40 60 m

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

SYMONDS STREET
SPECIMEN HILL ROAD
ASPINALL STREET
MACKENZIE STREET W
BAY STREET

Legend

- Roads
- Existing Pipes
- Modelled Pipe Upgrades

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D004

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:2000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 20 40 60 m

4.2.5 Option D6 – Levees along Bendigo Creek upstream of Alder Street Bridge

4.2.5.1 Locations and Description

Option D6 involves the construction of levees upstream of the Alder Street bridge. Figure 4-14 shows the proposed construction of levees along both banks of the section of Bendigo Creek upstream from Alder Street bridge. Retaining walls are used in place of earthen levee where there is insufficient space for levee fill. The earthen levee is designed to have 1 in 5 batters on both sides, 600 mm freeboard and a 500 mm crest width.

The western levee starts from the end of John Street and follows the boundary of the properties along Beverly Street then tie to Alder Street bridge. The earthen levee section is approximately 165 m long while the retaining wall section is approximately 157 m long. The required levee height varies from 600 to 1300 mm to achieve 600 mm freeboard.

The eastern levee commences at the rear of the property corner of Gordon Street and Calder Highway and follows the boundary of the properties parallel to the Calder Highway and ties to Alder Street bridge. The levee is proposed to be fully earthen and is 251 m long. The required levee height varies from 600 to 1100 mm to achieve 600 mm freeboard.

4.2.5.2 Flood Impacts

Figure 4-15 shows the impacts on 1% AEP peak flood level as a result of Option D6. This option prevents significant breakout flows through properties on either side of Bendigo Creek. It is noted that properties on both side of the creek, including 8 at-risk buildings (which are flooded above floor level) become flood-free. Flood levels inside the levees are increased by up to 100 mm but this is confined to the waterway reserve and no private properties are adversely impacted.

Figure 4-16 shows the impacts on 10% AEP peak flood level as a result of Option D6. No significant benefits or adverse impacts was noted in the smaller flood event.

4.2.5.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option D6 in relative to environmental and heritage overlays can be found in Appendix B.

Option D6 is located along Bendigo Creek section which is associated with Environmentally Significant Overlays. A detailed environmental impact assessment would be required as part of the next stage of design.

The levees are also situated inside an Aboriginal Cultural Heritage Sensitive area. A detailed cultural heritage impact assessment would also be required.

4.2.5.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option D6 was calculated to be approximately $673,110. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 124 properties. Over a long period of time across a range of flood events, the AAD may be reduced by approximately $29,707 per year by implementing this package of works. Table 4-10 summarises flood damages with Option D6 implemented.

Table 4-10 Flood Damages Summary for Mitigation Option D6

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	48	93	104
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded Above Floor	1	11	30	66	124	139

	Annual Exceedance Probability					
	20%	10%	5%	2%	1%	0.5%
Reduction in above floor flooded properties	0	0	0	1	8	10
Total Damage Cost	**$1,055,533**	**$2,078,598**	**$3,217,206**	**$6,873,721**	**$13,635,923**	**$16,770,756**

4.2.5.5 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-11 shows an estimation of the cost of option D6.

Table 4-11 Summary of cost of Mitigation Option D6

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
West Levee	$68,068	$1,021
East Levee	$39,026	$585
West Levee - Raised Wall or Sheet Piling	$628,000	$3,140
Vegetation Offset	$95,075	
Environmental and Cultural Heritage Management Plan	$120,000	
Sub-total 'A'	$735,094	
'A' x Engineering Fee @ 15%	$110,264	
Sub-total 'B'	$1,060,433	
'B' x Administration Fee @ 5%	$53,022	
Sub-total 'C'	$1,113,455	
'A' x Contingencies @ 20%	$147,019	
OPTION D6 FORECAST EXPENDITURE	**$1,260,473**	**$4,746**

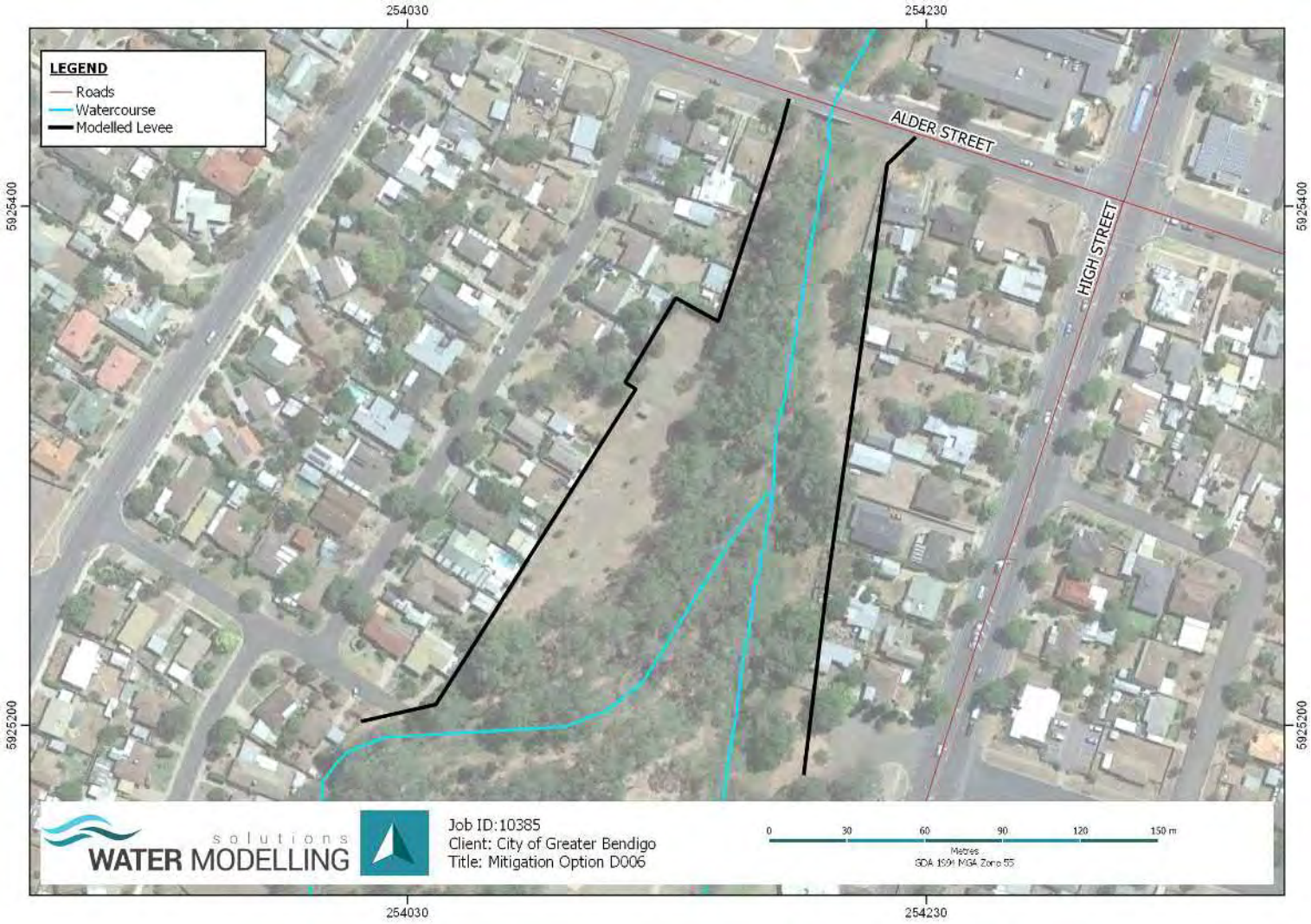


Figure 4-14 Location of Option D6

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D006

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:1500
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 10 20 30 m

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D006

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:1500
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 10 20 30 m

4.2.6 Option D7 – Levees on Bendigo Creek between Bank St and Lockwood Rd

4.2.6.1 Location and Description

Option D7 involves the construction of levees on both sides of Bendigo Creek between Bank Street and Lockwood Road. Figure 4-17 shows the proposed alignment of the levee along western bank of the section of Bendigo Creek between Station Street and Lockwood Road and eastern bank of the section of Bendigo Creek between Lockwood Road and Bank Street. Retaining walls are used in place of earthen levee where there is insufficient space for an earthen levee. The earthen levee is designed to have 1 in 5 batters on both sides, 600 mm freeboard and 500 mm crest width.

The western levee starts from the Lockwood Road bridge and follows the boundary of the properties along Neil Street then tie to Station Street bridge. Due to insufficient space, the entire western levee will be retaining walls and approximately 275 m in length. This increases the cost significantly. The required levee height varies from 600 to 1600 mm to achieve 600 mm freeboard.

The eastern levee starts at the end of Bank Street and follows the boundary of the properties along Chifley Avenue and Carpenter Street then ties to Lockwood Road bridge. The earthen levee section is approximately 385 m long while the retaining wall section is approximately 101 m long. The required levee height varies from 600 to 1600 mm to achieve 600 mm freeboard.

4.2.6.2 Flood Impacts

Figure 4-18 shows the impacts on 1% AEP peak flood level as a result of Option D7. This option prevents creek water from breaking out from both sides of the creek in this area. Flood level in the immediately surrounding areas of levees' locations location experience a significant reduction in peak water level and reduced flood extent. Flood level between the levees and High Street is reduced by up to 300 mm. It is noted that properties on the left of western levee and on the right of the eastern levee, including 16 at-risk buildings (which are flooded above floor level) become flood-free. However, flood levels inside the levees are increased by up to 100 mm but this is confined to the waterway reserve and no private properties are adversely impacted

Figure 4-19 shows the impacts on 10% AEP peak flood level as a result of Option D7. There are some minor benefits as 2 properties became flood free but considerably less than the 1% AEP event.

4.2.6.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option D7 in relative to environmental and heritage overlays can be found in Appendix B.

Option D6 is located along Bendigo Creek section which is associated with Environmentally Significant Overlays. A detailed environmental impact assessment would be required as part of the next stage of design.

The levees are also situated inside an Aboriginal Cultural Heritage Sensitive area. A detailed cultural heritage impact assessment would also be required.

4.2.6.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option D7 was calculated to be approximately $656,399. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 116 properties. Over a long period of time with a range of flood events, the AAD may be reduced by approximately $46,418 per year by implementing this package of works. Table 4-12 summarises flood damages with Option D7 implemented.

Table 4-12 Flood Damage Summary for Mitigation Option D7

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	19	45	94	106
	Commercial Properties	1	5	8	9	22	29
	Total Properties Flooded Above Floor	1	11	27	54	116	135
Reduction in above floor flooded properties		0	0	3	13	16	14
Total Damage Cost		**$1,062,333**	**$2,049,181**	**$3,394,699**	**$6,458,605**	**$12,747,026**	**$15,812,046**

4.2.6.5 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-13 shows an estimation of the cost of option D7.

Table 4-13 Summary of cost of Mitigation Option D7

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
East Levee - Earthen	$120,107	$1,802
West Levee - Raised Wall or Sheet Piling	$1,100,000	$5,500
East Levee - Raised Well or Sheet Piling	$404,000	$2,020
Vegetation Offset	$84,997	
Environmental and Cultural Heritage Management Plan	$120,000	
Sub-total 'A'	*$1,624,107*	
'A' x Engineering Fee @ 15%	*$243,616*	
Sub-total 'B'	*$2,072,720*	
'B' x Administration Fee @ 5%	*$103,636*	
Sub-total 'C'	*$2,176,356*	
'A' x Contingencies @ 20%	*$324,821*	
OPTION D7 FORECAST EXPENDITURE	**$2,501,178**	**$9,322**

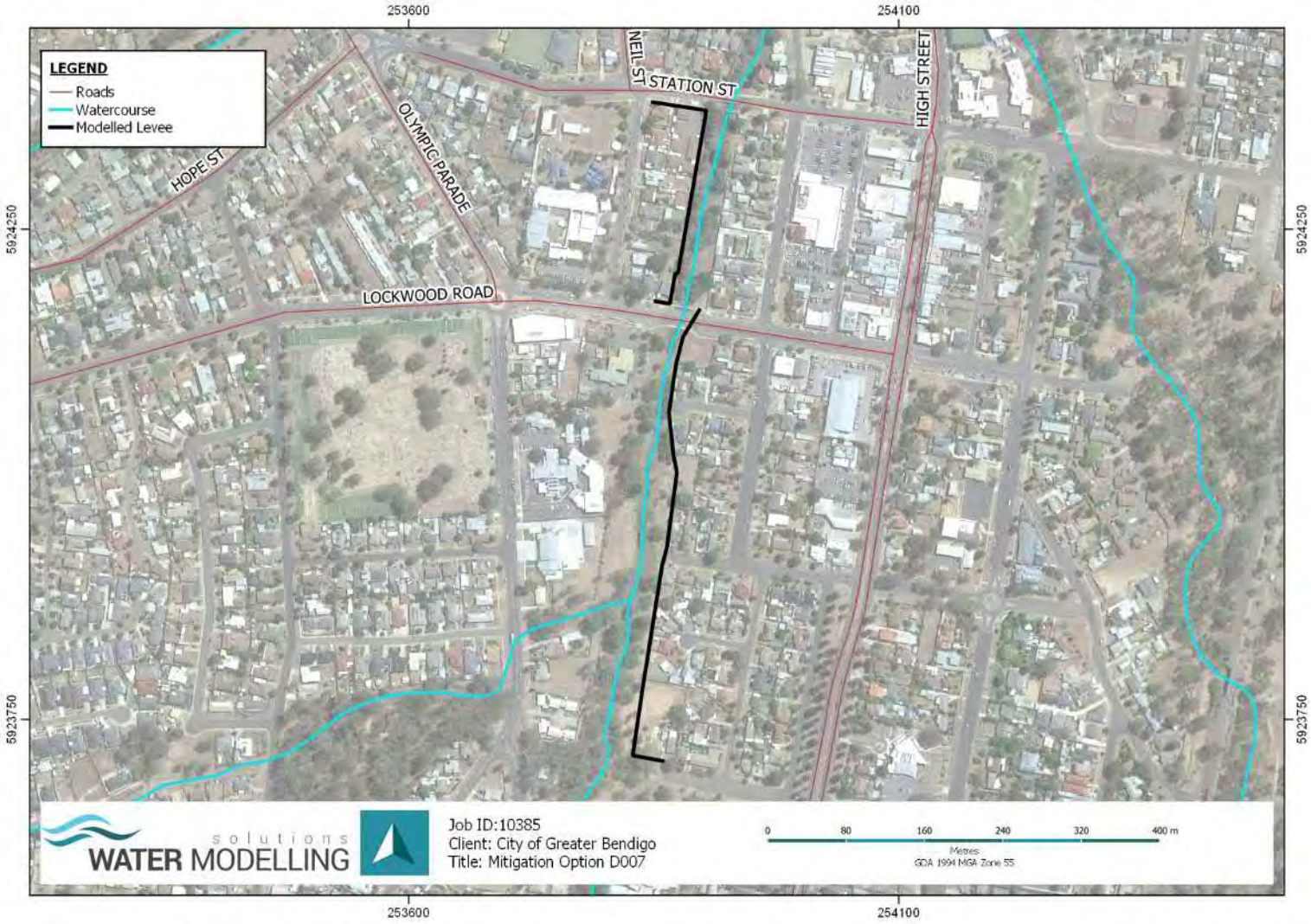


Figure 4-17 Location of Option D7

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D007

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:4000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 40 80 120 m

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D007

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:4000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 40 80 120 m

4.2.7 Option D8 – Levee system along the eastern boundary of Dower Park

4.2.7.1 Location and Description

Option D8 consists of a levee system along the eastern boundary of Dower Park. Figure 4-20 shows the proposed earthen levee follows the eastern boundary of Dower Park to protect properties in the vicinity of Neil Street. A section of levee would also be required along Mackenzie Street West. Retaining walls are used in place of earthen levee where there is insufficient space for an earthen levee. The earthen levee is designed to have 1 in 5 batters on both sides, 600 mm freeboard and 500 mm crest width.

The western levee starts from Brian Street and follows the boundary of property along Mackenzie Street West then ties to Neil Street. The western levee is fully earthen and is approximately 318 m long. The required levee height varies from 600 to 1700 mm to achieve 600 mm freeboard.

The eastern levee follows the boundary of Dower Park Oval and the properties along Neil Street then ends near the corner of Neil Street and Mackenzie Street West. The earthen levee section is approximately 284 m long while the retaining wall section is approximately 433 m long. The required levee height varies from 600 to 2100 mm to achieve 600 mm freeboard.

Some channel enlargement works would also likely be required to the waterway near the intersection of Neil Street and Mackenzie Street West.

4.2.7.2 Flood Impacts

Figure 4-21 shows the impacts on 1% AEP peak flood level as a result of Option D8. More than 30 properties become flood-free in the vicinity of Neil Street including 4 buildings which currently flood above floor level. Increased flood levels of up to 1200 mm are likely on the upstream side of the levee however this is generally confined to parkland and carpark areas. This option would need to be combined with a flood response plan to ensure the evacuation of this area prior to a flood event.

Figure 4-22 shows the impacts on 10% AEP peak flood level as a result of Option D8. There was flood level increase of up to 1000 mm on the upstream side of the levee however this is generally confined to parkland and carpark areas. More than twenty properties become flood-free in the vicinity of Neil Street with this option in the 10% AEP event.

4.2.7.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option D8 in relative to environmental and heritage overlays can be found in Appendix B.

No environmental significance overlays were found in the vicinity of Option D8.The proposed works levee are however situated inside an Aboriginal Cultural Heritage Sensitive area. A detailed cultural heritage impact assessment would be required as part of the next stage of design.

4.2.7.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option D8 was calculated to be approximately $668,273. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 128 properties. Over a long period of time with a range of flood events, the AAD may be reduced by approximately $34,543 per year by implementing this package of works. Table 4-14 summarises flood damages with Option D8 implemented.

Table 4-14 Flood Damages Summary for Mitigation Option D8

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	18	47	97	110
	Commercial Properties	1	5	11	18	31	35
	Total Properties Flooded Above Floor	1	11	29	65	128	145
Reduction in above floor flooded properties		0	0	1	2	4	4
Total Damage Cost		**$1,006,958**	**$1,940,343**	**$3,319,276**	**$6,784,037**	**$13,865,422**	**$17,060,899**

4.2.7.5 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-15 shows an estimation of the cost of option D8.

Table 4-15 Summary of cost of Mitigation Option D8

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
East Levee – Earthen Section	$186,918	$2,804
West Levee – Raised Wall or Sheet Piling	$1,272,000	$6,360
East Levee – Raised Well or Sheet Piling	$1,732,631	$8,663
Cultural Heritage Management Plan	$60,000	
Sub-total 'A'	$3,191,549	
'A' x Engineering Fee @ 15%	$478,732	
Sub-total 'B'	$3,730,281	
'B' x Administration Fee @ 5%	$186,514	
Sub-total 'C'	$3,916,795	
'A' x Contingencies @ 20%	$638,310	
OPTION D8 FORECAST EXPENDITURE	**$4,555,105**	**$17,827**

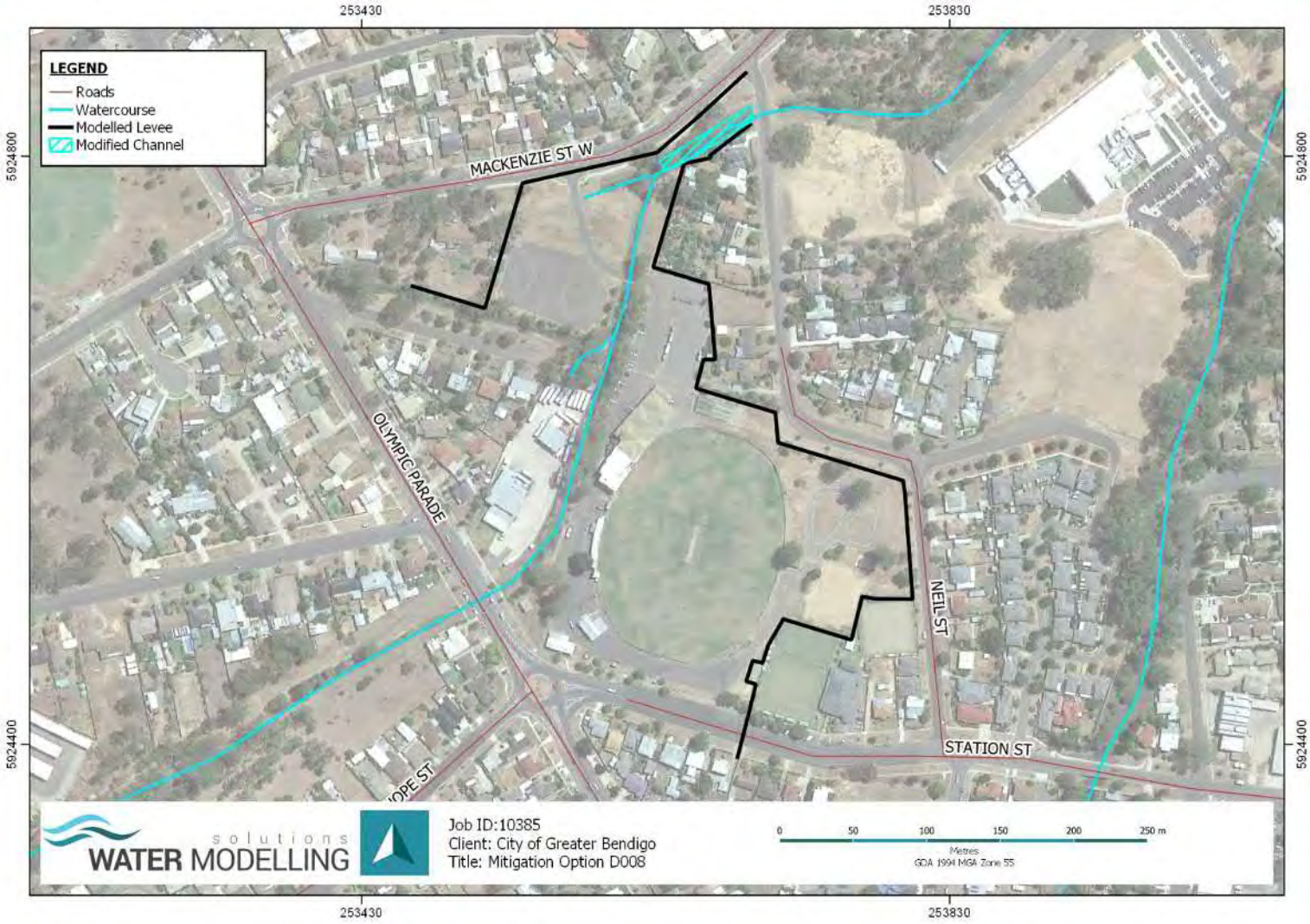


Figure 4-20 Location of Option D8

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Modelled Channel
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

MACKENZIE ST W
OLYMPIC PARADE
NEIL ST
HOPE ST
STATION ST
HIGH STREET

Mitigation Option D008

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:3500
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 40 80 120 m

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Channel
- Modelled Levee

Difference in Peak Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option D008

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:3500 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 40 80 120 m

4.3 PACKAGED MITIGATION OPTIONS

4.3.1 Package Option P1 – Modifications to Upstream Reservoirs

4.3.1.1 Location and Description

Option P1 was recommended for detailed investigation and consists of modifications to the upstream reservoirs. Figure 4-23 shows the proposed combination of increasing the flood storage capacity of Crusoe Reservoir and redirect runoff from between Sandhurst and No 7 Reservoirs into Crusoe Reservoir using a catch drain system.

The available flood storage capacity at Crusoe Reservoir was increased by lowering the low flow outlet and full supply water level by 2m below current levels from 286.5 m AHD to 284.5 m AHD. The water level at the beginning of the event was set at the revised full supply level.

Option P1 also involves upgrading the historic drain/channel between Sandhurst Reservoir to No 7 Reservoir to a catch drain approximately 4,929 metres long to divert all runoff from the upstream catchments into No. 7 Reservoir which then flows into Crusoe Reservoir. It is noted that a catch drain exists along some of the proposed alignment, however the condition and capacity of the existing drain is not known. It is highly likely the existing drain would not have 1% AEP capacity, and is known to be incomplete with sections missing or degrading. For the purpose of costing this option a new excavated catch drain, and low-level levee or bund is proposed. The option would also need to include culverts under the Melbourne-Bendigo railway and Calder Highway.

4.3.1.2 Flood Impacts

Figure 4-24 shows the impacts on 1% AEP peak flood level as a result of Option P1. The modelling result show that with the additional storage in the dam the primary spillway does not spill in the 1% AEP event, despite the additional catchment inflows. Downstream flood levels are reduced by up to 200 mm along the flow path from Big Hill for more than 5 km downstream in the 1% AEP event. 19 at-risk buildings (which are flooded above floor level) are located in the areas where flood levels are reduced. A number of properties become flood-free.

Figure 4-25 shows the impacts on 10% AEP peak flood level as a result of Option P1. The results show that with the additional storage in the dam the primary spillway does not spill in the 10% AEP event.

4.3.1.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option P1 in relative to environmental and heritage overlays can be found in Appendix B.

Location of Option P1 does not interfere with any areas of environmental significant overlays however is it known that there is extensive vegetation along the proposed catch drain, in close proximity to the required works. An extensive environmental assessment would be needed to fully understand the impacts of this option, including the undertaking of tree surveys.

The option is also located in very close proximity to areas of Aboriginal cultural sensitivity thus, a cultural heritage impact assessment is recommended. Given the amount of disturbance likely required with this option a cultural heritage assessment should be undertaken.

4.3.1.4 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option P1 was calculated to be approximately $634,883. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 113 properties. Over a long period of time with a range of flood events, the AAD may be reduced by approximately $67,934 per year by implementing this package of works. Table 4-16 summarises flood damages with Option P1 implemented.

Table 4-16 Flood Damages with Mitigation Option P1 Implemented

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	12	33	85	97
	Commercial Properties	1	5	10	17	28	33
	Total Properties Flooded Above Floor	1	11	22	50	113	130
Reduction in above floor flooded properties		0	0	8	17	29	19
Total Damage Cost		**$1,048,612**	**$1,997,252**	**$3,279,335**	**$6,365,995**	**$11,927,501**	**$15,152,591**

4.3.1.5 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-17 shows an estimation of the cost of option P1.

Table 4-17 Summary of cost of Mitigation Option P1

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Catch Levee	$52,162	$782
Catch Drain - Sandhurst Reservoir to Highway Section	$66,989	$335
Catch Drain - Highway to No.7 Reservoir Section	$87,360	$437
Catch Drain - No.7 Reservoir to Crusoe Reservoir Section	$133,984	$670
Culvert Works	$825,000	$4,125
Dam Lowering	$250,000*	
Environmental and Cultural Heritage Management Plan	$240,000	
Sub-total 'A'	$1,415,495	
'A' x Engineering Fee @ 15%	$212,324	
Sub-total 'B'	$1,867,820	
'B' x Administration Fee @ 5%	$93,391	
(Land Acq only) 'B' x Administration Fee @ 1%	$0	-
Sub-total 'C'	$1,961,211	
'A' x Contingencies @ 20%	$283,099	
OPTION P1 FORECAST EXPENDITURE	$2,244,310	$6,349

* Feedback to be sought from Coliban Water and CoGB on this item

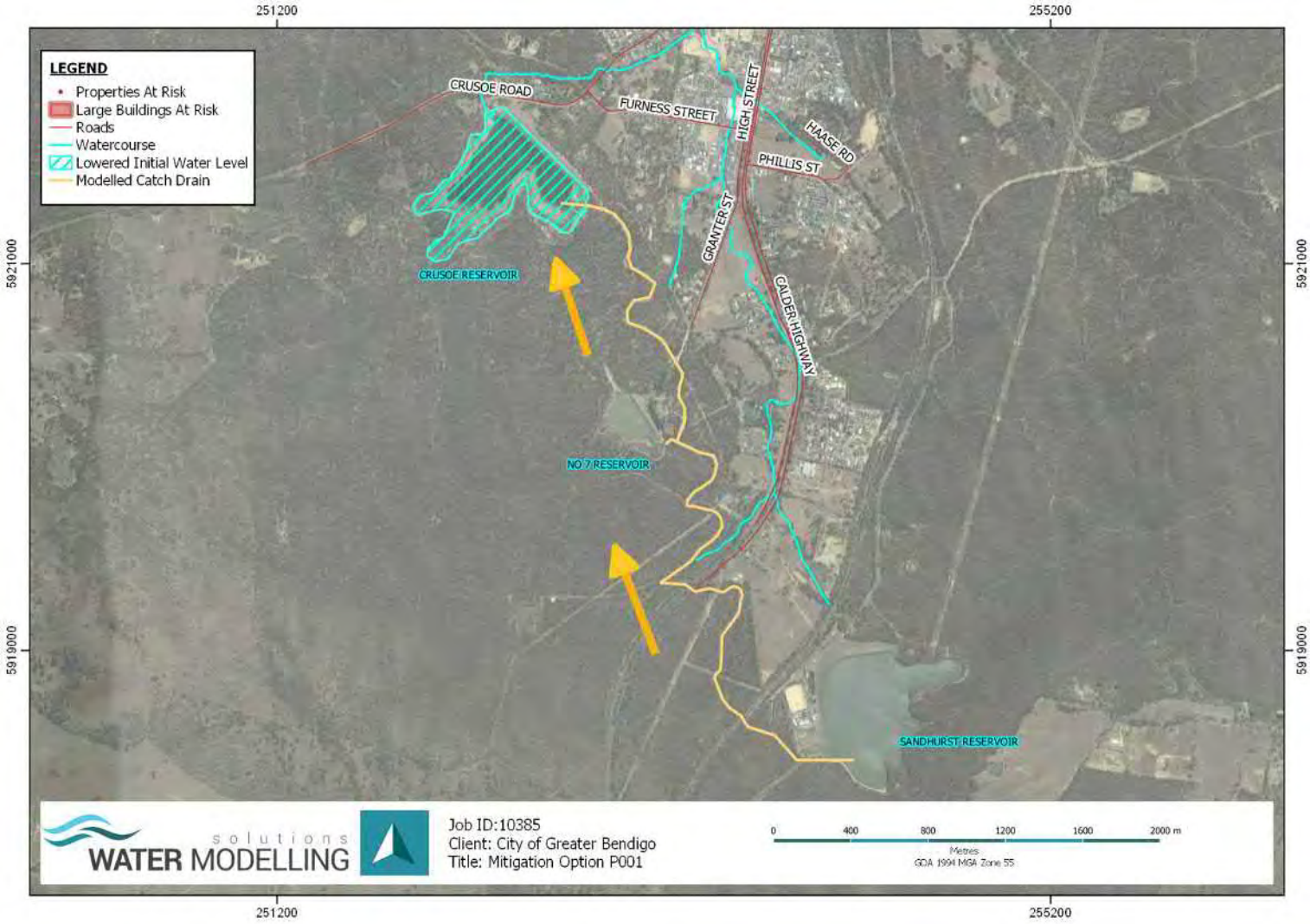


Figure 4-23 Location of Option P1

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Lowered Initial Water Level
- Modelled Catch Drain

Difference in Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option P001

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:25000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 200 400 600 m

solutions
WATER MODELLING

Kangaroo Flat
Golden Square
Flood Mitigation Study

Legend

- Roads
- Lowered Initial Water Level
- Modelled Catch Drain

Difference in Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option P001

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:25000
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 200 400 600 m

4.3.2 Package Option P2 – Detention Basin and Levees near Lockwood Road, Kangaroo Flat

4.3.2.1 Location and Description

Option P2 was recommended for detailed investigation and consists of a combination of levees and a detention basin upstream of Lockwood Road, Kangaroo Flat. Figure 4-26 shows the proposed construction of a detention basin on undeveloped land situated within an industrial zone to the north of Lockwood Rd, approximately 600 m upstream of Olympic Parade.

The basin bed elevation and spillway were modelled at 255.7 m AHD and 258.7 m AHD respectively. The basin has a capacity of approximately 35,000 m^3. The basin outlet would consist of 2 x 1200 mm pipes which discharge into the waterway immediately downstream of the basin. The height of the basin embankment (1:5 slope) would be up 3 metres at its highest point and 5 metres crest width.

The levee extends from the end of Hope Street and follows along the rear boundaries of properties on Hope Street. The earthen levee section is approximately 232 metres long while the retaining wall section is approximately 320 metres long. The required levee height varies from 600 to 900 mm to achieve 600 mm freeboard.

4.3.2.2 Flood Impacts

Figure 4-27 shows the impacts on 1% AEP peak flood level as a result of Option P2. The benefits on flood events are extensive and extend for approximately 5 km downstream of the basin into central Bendigo. Numerous properties on Hope Street and Jamison Park Drive behind the levee became flood-free. Flood levels are reduced by up to 200 mm downstream of the basin, including across numerous properties. The combined option reduces water levels at 5 at-risk buildings (which are flooded above floor level).

Figure 4-28 shows the impacts on 10% AEP peak flood level as a result of Option P2. The 10% AEP flood extent is reduced in numerous areas. The combined option reduces water levels at 1 at-risk buildings (which are flooded above floor level).

4.3.2.3 Environmental and Heritage Impacts

A desktop environmental and heritage impact assessment of the study area has been undertaken to identify constraints that may impact the proposed levee alignments. Environmental, planning, and Aboriginal cultural sensitivity overlays were obtained from Vicmap to aid the investigation. Map of location of option P2 in relative to environmental and heritage overlays can be found in Appendix B.

The location of option P2 was found to have not have any cultural heritage importance. However, a portion of the basin is located within an Environmental Significance Overlay thus an environmental impact assessment would be required as part of the next stage of design.

4.3.2.1 Damages Assessment

A damage cost assessment has been undertaken to the benefit of the option in terms of damages to residential and commercial buildings. The AAD for mitigation option P2 was calculated to be approximately $636,457. During a 1% AEP event, the option reduces the total number of properties inundated from 132 properties to 127 properties. Over a long period of time with a range of flood events, the AAD may be reduced by approximately $66,360 per year by implementing this package of works. Table 4-18 summarises flood damages with Option P2 implemented.

Table 4-18 Flood Damages Summary for Mitigation Option P2

		Annual Exceedance Probability					
		20%	10%	5%	2%	1%	0.5%
Properties Flooded Above Floor Level	Residential Properties	0	6	18	47	97	108
	Commercial Properties	1	4	11	18	30	33
	Total Properties Flooded Above Floor	1	10	29	65	127	141

	Annual Exceedance Probability					
	20%	10%	5%	2%	1%	0.5%
Reduction in above floor flooded properties	0	1	1	2	5	8
Total Damage Cost	**$1,027,884**	**$1,745,034**	**$3,205,888**	**$6,401,626**	**$13,251,453**	**$16,644,219**

4.3.2.2 Preliminary Costing

A damage cost assessment has been undertaken to provide understanding of the feasibility of the proposed option. Table 4-19 shows an estimation of the cost of option P2.

Table 4-19 Summary of cost of Mitigation Option P2

Work Description	Estimated Construction Cost	Estimated Annual Maintenance Cost
Earth Levee	$15,426	$231
Levee Raised Retaining Wall or Sheet Piling	$1,281,034	$6,405
Basin Earthwork	$1,243,564	$6,218
Outlet pipe	$60,372	$302
Spillway	$40,000	$200
Basin Land Acquisition	$573,000	
Basin Vegetation Offset	$7,606	
Levee Vegetation Offset	$45,636	
Legal Cost	$15,000	
Environmental Management Plan	$60,000	
Sub-total 'A'	$2,640,395	
'A' x Engineering Fee @ 15%	$396,059	
Sub-total 'B'	$3,737,697	
'B' x Administration Fee @ 5%	$186,885	
Sub-total 'C'	$3,924,581	
'A' x Contingencies @ 20%	$528,079	
OPTION D2 FORECAST EXPENDITURE	**$4,452,661**	**$13,356**

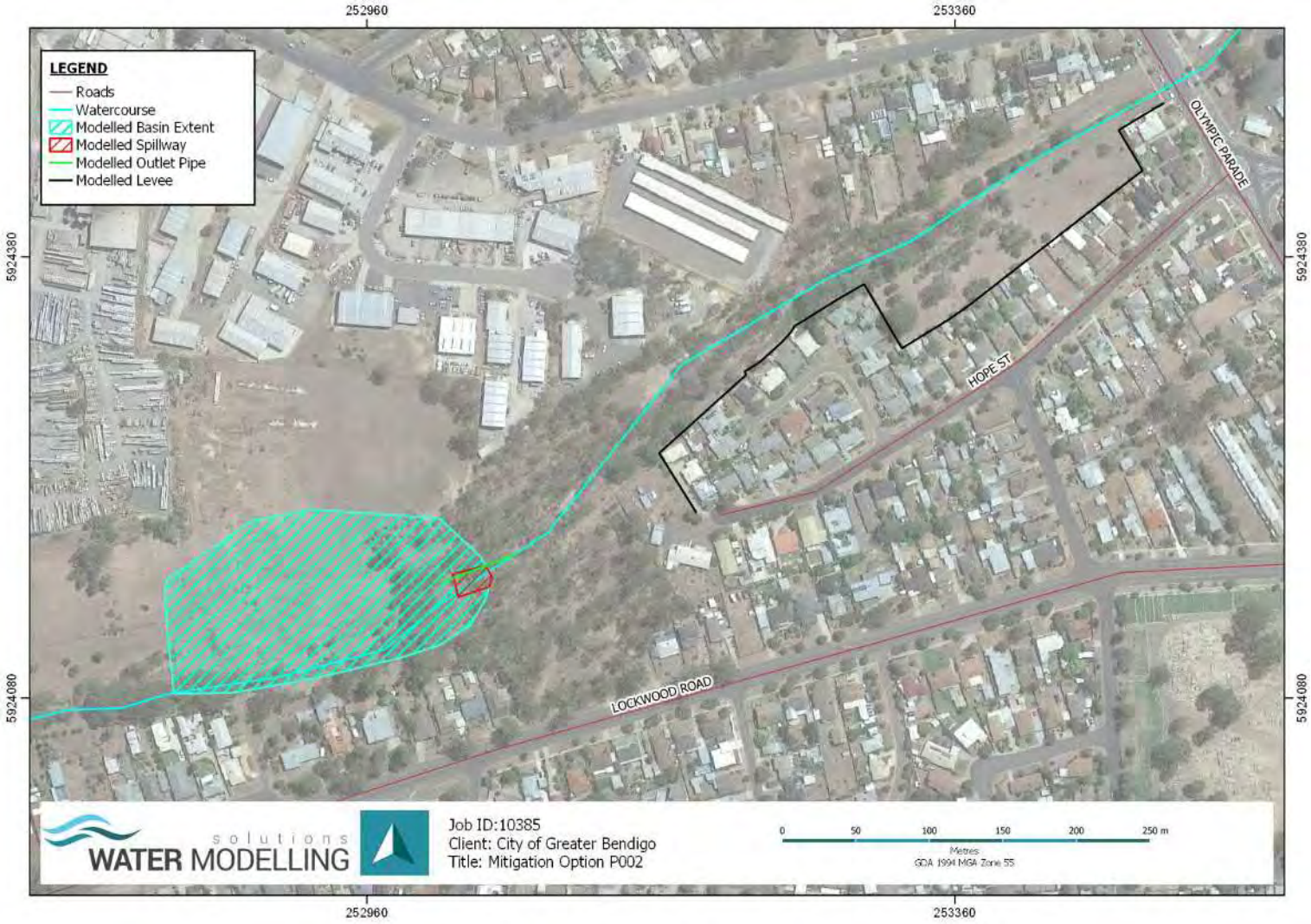


Figure 4-26 Location of Option P2

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee
- Modelled Basin

Difference in Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option P002

Difference in Water Level (m)
1% AEP Storm Event

A3 Scale: 1:13000 Job ID: 10385
GDA 1994 / MGA Zone 55 27/05/2020

0 100 200 300 m

solutions
WATER MODELLING

Kangaroo Flat Golden Square Flood Mitigation Study

Legend

- Roads
- Modelled Levee
- Modelled Basin

Difference in Water Level

- <= -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.03
- -0.03 - 0.03
- 0.03 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- WAS WET NOW DRY
- WAS DRY NOW WET

Mitigation Option P002

Difference in Water Level (m)
10% AEP Storm Event

A3 Scale: 1:13000
GDA 1994 / MGA Zone 55

Job ID: 10385
27/05/2020

0 100 200 300 m

4.4 CLIMATE CHANGE SENSITIVITY ASSESSMENT (OPTION D5)

4.4.1 Background

CSIRO has released climate change scenarios based on four scenarios greenhouse gas representative concentration pathways (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) for the year 2090. The RCP represents the potential concentration of greenhouse gasses within the atmosphere at a given year. RCP 4.5 and RCP 8.5 have been adopted for the climate change assessment of the Kangaroo Flat, Golden Square Flood Mitigation Study. RCP 4.5 assumes emissions peak around 2040 and then slowly decline thereafter. RCP 8.5 is the most severe emissions case and assumes emissions continue to rise throughout the 21st century and into the 22nd. The adoption of a medium and high greenhouse gas projection provides an appropriate level of testing to understand the sensitivity of flooding in Kangaroo Flat and Golden Square with regards to current climate change prediction.

A climate change sensitivity has been undertaken for all critical durations of the 1% AEP and 20% AEP storm events. The ARR2019 datahub recommends rainfall intensity increase of 11.5% for RCP 4.5 and 20.2% for RCP 8.5 values for the study area. The resulting intensities for the 1% AEP event and 20% AEP event were compared to current intensities in Table 4-20 and Table 4-21 respectively.

Table 4-20 Climate Change IFD Comparison - 1% AEP

Critical Duration	Current Depth (mm)	2090_RCP4.5 Depth (mm)	2090_RCP8.5 Depth (mm)
45min	41.15	45.88	49.46
60min	45.88	51.16	55.15
120min	56.63	63.14	68.07
180min	62.72	69.93	75.39
360min	76.51	85.31	91.97

Table 4-21 Climate Change IFD Comparison - 20% AEP

Critical Duration	Current Depth (m)	2090_RCP4.5 Depth (mm)	2090_RCP8.5 Depth (mm)
30min	16.12	17.97	19.38
60min	21.11	23.54	25.37
120min	26.85	29.94	32.27
180min	30.81	34.35	37.03
360min	39.71	44.28	47.73
720min	51.12	57.00	61.45

4.4.2 Result

The modelling result for both climate change scenarios are shown in Appendix C. An overall increase in peak water level was observed throughout the entire study area as would be expected. The increases occur in both the 1% and 20% AEP flood event with the highest increase occurs within the creek. Overland flowpaths were also noted to be more extensive specifically in the 1% AEP event.

In the 1% AEP event, scenario RCP 4.5 shows significant increases in peak water level along the tributaries at culvert crossings such as at Station Street and Hattam Street. The increase in flood extent is most significant at the Myrtle Street Bridge where water level increases up to 300 mm and flood reaches up to 20 metres on both ends of the bridge. Scenario RCP 8.5 flood event behaves similarly to RCP 4.5 with higher water levels noted across the entire study area. The increase in flood extent encroaches approximately 20 metres further in many areas than the RCP 4.5 scenario.

In the 20% AEP event, scenario RCP 4.5 shows minor differences compared to the existing scenario with flood water still largely confined within the waterways. The most significant difference in flood extents occur near the corner of Granter Street and Calder Highway where flood water forms an additional flow path on the east side of the highway, and Dower Park where the flood extent

is noted to encroach a further 10 metres in several directions. Scenario RCP 8.5 doesn't show any significant difference to scenario RCP 4.5 with the exception of the sheet flow at the corner of Lily Street High Street being more apparent.

4.5 LAND USE SENSITIVITY ASSESSMENT (OPTION D11)

4.5.1 Background

A land use sensitivity assessment has been conducted to assess flooding behaviour under future development of the catchment.

The latest planning zone overlay was obtained from Vicmap to provide the most recently available land-use data. All undeveloped residential land-use lots were updated and modified to have a fraction impervious of 0.6 while commercial and industrial land-use zones were updated and modified to have fraction impervious of 0.8. The inflows of 1% and 20% AEP flood event for future land-use scenario were produced by RORB, using the new FI inputs. Note that this option has not considered any on-site detention for future development and so the results can be considered conservative. The total increase in runoff volume is considered accurate, however.

4.5.2 Result

The modelling result for land use sensitivity scenarios are shown in Appendix D. An overall peak water level increase was observed throughout the entire study area in both the 1% and 20% AEP flood event with exception of the area between Wesley Street and Kangaroo Flat Bushland Reserve experiencing lowered flood level which is thought to be related to different timing of the tributary inflows. Overland flowpaths were also noted to be more extensive specifically in the larger 1% AEP event.

In the 1% AEP event, the land use sensitivity scenario shows additional overland flow path occurring along Crusoe Road. The area between Wesley Street and Kangaroo Flat Bushland Reserve and corner of Helm Street and Morrison Street experience a slight decrease in peak flood level, due to differences in tributary timing. Most of the eastern tributaries of Bendigo Creek was noted to have higher peak higher water level in this scenario while the western tributaries experience generally similar peak water level to existing conditions, which is indicative of the land use types and potential for further development in those areas of the study area.

In the 20% AEP event, the land use sensitivity scenario shows no additional overland flow paths, and flood water is largely confined within existing waterway corridors. In contrary to the 1% AEP event, the 20% AEP event results show an increase in water level in the area between Wesley Creek and Kangaroo Flat Bushland Reserve. Most of the tributaries of Bendigo Creek experience an increase in peak water level with the exception of the outflow from Ritchie Dam. which experiences a slightly lower peak water level, thought to be related in a difference in timing of peak flows from the sub-catchments which feed that tributary.

5 FEASIBILITY DISCUSSION

5.1 DAMAGES ASSESSMENT

The damages assessment shows that a number of mitigation options achieve a significant impact in reducing flood damages and Average Annual Damage (AAD) through the study area. Mitigation Option D3 achieves the least reduction, whilst Option P1 and P2 achieves the greatest reduction. A summary of the AAD for existing conditions and each mitigation package is shown in Table 5-1. The four options with the greatest reduction in AAD are shown in bold.

Table 5-1 Summary of Mitigation Option Damages Assessments

Options	Average Annual Damage	Reduction in AAD
Existing Conditions	$478,013	
Option D1	$673,583	$29,234
Option D2	**$646,934**	**$55,883**
Option D3	$684,000	$18,817
Option D4	$667,057	$35,760
Option D6	$673,110	$29,707
Option D7	**$656,399**	**$46,418**
Option D8	$668,273	$34,543
Option P1	**$634,883**	**$67,934**
Option P2	**$636,457**	**$66,360**

5.2 BENEFIT COST

A benefit-cost analysis has been undertaken based on the damages assessment and costings described tin the previous sections. The results are summarised in Table 5-2 below. It can be seen that the Benefit Cost Ratio is low across all options, and below the ratio of 1 which is generally the minimum required for a scheme to be considered feasible i.e. for every dollar spent on the scheme, at least a dollar is saved in terms of reduced flood damage. The analysis assumes 50 year design life for all works.

The reason for the low benefit-cost ratio is predominately a result of there being limited damage until large flood events, hence the options generally provide little benefit in the smaller, more frequent flood events.

The four options with the highest benefit-cost ratio are shown in bold in the table below.

Table 5-2 Cost Benefit Ratio Summary (assumes 50 year design life)

Levee Option	Capital Cost Estimate	Annual Maintenance	Reduction in AAD	Benefit			Benefit Cost Ratio		
				11% NPV	7% NPV	4% NPV	11% NPV	7% NPV	4% NPV
Option D1	$1,319,143	$4,796	$29,234	$221,511	$339,847	$531,601	0.17	0.26	0.40
Option D2	$6,676,352	$17,257	$55,883	$350,107	$537,141	$840,217	0.05	0.08	0.13
Option D3	$2,002,307	$7,371	$18,817	$103,748	$159,172	$248,984	0.05	0.08	0.12
Option D4	**$926,011**	**$3,060**	**$35,760**	**$296,391**	**$454,729**	**$711,305**	**0.32**	**0.49**	**0.77**

Levee Option	Capital Cost Estimate	Annual Maintenance	Reduction in AAD	Benefit			Benefit Cost Ratio		
				11% NPV	7% NPV	4% NPV	11% NPV	7% NPV	4% NPV
Option D6	**$1,260,473**	**$4,746**	**$29,707**	**$226,245**	**$347,110**	**$542,962**	**0.18**	**0.28**	**0.43**
Option D7	**$2,501,178**	**$9,322**	**$46,418**	**$336,246**	**$515,876**	**$806,952**	**0.13**	**0.21**	**0.32**
Option D8	$4,555,105	$17,827	$34,543	$151,521	$232,466	$363,633	0.03	0.05	0.08
Option P1	**$2,244,310**	**$6,349**	**$67,934**	**$558,214**	**$856,424**	**$1,339,651**	**0.25**	**0.38**	**0.60**
Option P2	$4,452,661	$13,356	$66,360	$480,428	$737,083	$1,152,974	0.11	0.17	0.26

It is noted that Option D4 has the highest benefit cost ratio with a BCR of 0.49 (assuming 7% NPV). Option P1 has the second highest benefit cost ratio with a BCR of 0.38 (assuming 7% NPV), while also providing the largest reduction in AAD. A number of levee options have high cost and lower feasibility partly from the incorporation of retaining walls where there is insufficient space for earthen levee which drives up the cost. This cost is most apparent for Option D8 as retaining wall was assumed through most of its length within Dower Oval Park.

While the analysis has found the benefit cost ratio of the options are generally low in monetary terms it does not consider the intangible impacts of flooding and the emotional toll it can have on a community. Intangible damages relate to the social cost of flooding and are much more difficult to quantify. Intangible damages include the impacts of isolation, disruption to family, physical ill-health and psychological ill-health. Intangible damages cannot be given a dollar value but must be considered when assessing flood mitigation options.

5.3 COMMUNITY SUPPORT

The modelling result of the detailed mitigation was presented to the community during the second round of consultation. A summary of community opinion on the options was documented in Table 5-3.

Table 5-3 Summary of Community Feedback on Proposed Mitigated Options

Option ID	No. of positive responses / show of support	No. of negative responses / opposition
Option D1	1	-
Option D2	**4**	-
Option D3	**3**	2
Option D4	2	1
Option D6	1	-
Option D7	2	-
Option D8	2	-
Option P1	**8**	-

Option ID	No. of positive responses / show of support	No. of negative responses / opposition
Option P2	**5**	-

Option P1 was the most well received mitigation option with a total of 8 positive responses. Options involving retarding basin were generally supported. Common themes which community members frequently raised, included cost efficiency, minimal disruption and impact on the environment.

6 SUMMARY AND RECOMMENDATIONS

Based on the findings above and consideration for the feedback form the community the following recommendations are made:

- **Option P1 (Modifications to Upstream Reservoirs and Catchment Diversions)** is considered the most feasible option and it is recommended that it undergo further investigation. This option has the second highest benefit-cost ratio, had strong support from the community and results in a significant reduction in Average Annual Damage (AAD). Due the limited data available along the alignment of this option it is recommended that Option P1 proceed to the next stage of assessment which would consist of survey, a detailed feasibility investigation and preliminary design. Depending on the outcome of the next stage of investigation the option could then progress to detailed design and construction.
- **Option D4 (Symonds St Pipe Upgrades)** was found to have moderate community support with some opposition. The option had the highest BCR but the fifth highest reduction in AAD. Given this option predominantly involves pipe upgrades it is recommended that Council consider this option as part of future drainage upgrades within its capital works program.
- **Options D6 (Bendigo Creek Alder Street Levees) and D7 (Bendigo Creek Bank St/Lockwood Levees)** – if future investigation determines that P1 is not a feasible option, it is recommended that Options D6 and D7 be further considered and undergo detailed feasibility assessment. Both options achieve some of the benefit of P1 in terms of benefiting properties along Bendigo Creek and have two of top five BCRs. Both options had some community support and no opposition.