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economics
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Mitigating the impacts of flooding on Thornton Bridge, Shire of Murrindindi

A Resilient Public Estate Asset Vulnerability Assessment Case Study: Final report

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A Marsden Jacob Report

Prepared for South East Councils Climate Change Alliance
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Executive Summary

Introduction

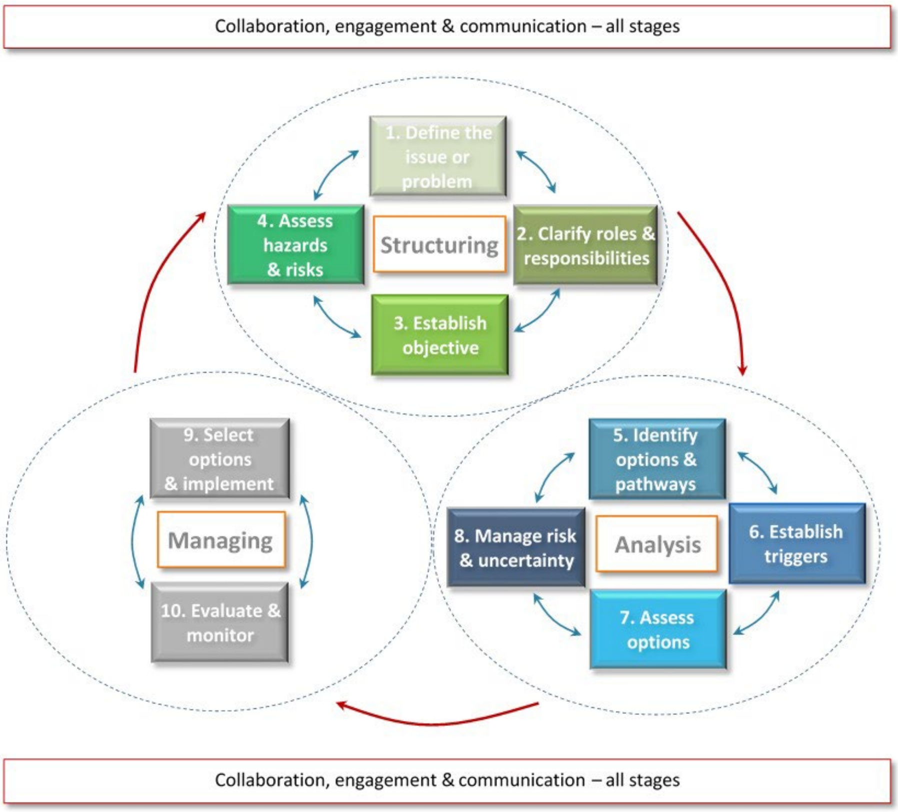
Goulburn Murray Climate Alliance (GMCA) member councils are seeking to better understand how their buildings, roads, drains, other built assets, natural assets and associated services will be impacted by climate change. The *Climate Change Asset Vulnerability Assessment* project seeks to provide councils with this information. Guidelines on climate change adaptation decision making have been developed as part of the project. The purpose of the case studies is to provide practical examples of the adaptation decision-making process as set out in the guidelines.

This case study focusses on assessing options to mitigate the impacts of flooding on the Thornton Bridge, which crosses the Goulburn River at Thornton in the Shire of Murrindindi. The Bridge provides a key access route to the township of Eildon and to tourist attractions and other accommodation in the district.

Climate change adaptation decision making

A sound decision-making process provides the foundation for effective climate change adaptation. Figure ES 1 identifies the key stages and steps comprising 'good practice' adaptation decision making.

Figure ES 1: Stages in the decision-making process



Working with the Shire of Murrindindi we have undertaken preliminary analysis relating to Steps 1 through 8 in that process, however the primary focus of our analysis has been on options assessment (Step 7).

Problem definition

Thornton Bridge is a road bridge that crosses the Goulburn River immediately to the north of Thornton township in Taungurung country, in the Shire of Murrindindi. The bridge marks commencement of the Back Eildon Road, which provides access to the township of Eildon and to other tourist attractions and accommodation in the district.

Flood modelling undertaken about 10 years ago indicates a 1% annual exceedance probability (AEP) flood would likely overtop the bridge. Without modelling that incorporates climate projections it is not possible to be definitive about an AEP flood that will threaten the bridge in the future. However, noting that climate change projections for the region suggest the potential for the intensity of extreme rainfall events (ARI 20) to increase by up to 38% by 2050, a flood at or above a 10% AEP could feasibly threaten the bridge in the future. If a flood were to remove the bridge, loss of the Thornton Bridge would adversely impact on local businesses and residents and visitors to the region.

Adaptation options

Essentially, there are two options available to Council beyond the business-as-usual (BaU) option of leaving the current bridge in place until the end of its useful life (assumed to be 2050 for this analysis):

- **Option 1 (Betterment)**: Replace the bridge as soon as practical with an upgraded bridge that meets best practice design standards for a bridge of its size and level of use. This upgrade would virtually eliminate the risk of the bridge being destroyed by floods, for the life of the bridge, even under a worst-case climate change scenario (e.g. RCP 8.5). (further details of design).
- **Option 2 (Current design standards):** Replace the bridge as soon as practical with a 'like-for-like' bridge, albeit a bridge that meets current design standards and is therefore an improvement on the existing bridge, significantly reducing flood risk to the bridge.

Analysis of options

The approach applied to the analysis of adaptation options was a scenario-based cost-benefit analysis (CBA). The CBA assessed the costs and benefits of each of Options 1 and 2 incrementally to Business as Usual (BaU), with BaU being the option of leaving the current bridge in place until the end of its useful life.

Results

Results of the analysis are presented in Table ES.1. The results are based on the following central assumptions:

- 4% real discount rate[1] (with sensitivities of 2% and 7%)
- 50 year analysis period
- an AEP of 2% (i.e. a 1 in 50 year flood)
- all cost and benefit values are in 2024 dollars.

Table ES.1 shows that Option 2 – replacing the existing bridge with a bridge that meets current minimum design standards – achieves the best CBA results under the base assumptions listed above. Option 2 records an NPV of $1.33 million and a BCR of 2.60. Option 1 –betterment – records a lower NPV of $541,000 (BCR of 1.31). The main driver for this is the higher upfront capital costs under Option 1, which is only partially offset by avoided repair costs.

Table ES. 1: CBA results Option 1 and 2 compared to BaU

	Option 1 (Betterment)	Option 2 (Current design standards)
Capital Cost	$1,718,000	$829,000
Operation & Maintenance	-	-
PV Total Cost	**$1,718,000**	**$829,000**
Avoided Repairs	$253,000	$179,000
Avoided Travel Delays[(a)]	$2,005,000	$1,978,000
PV Total Benefits / Avoided Cost	**$2,259,000**	**$2,157,000**
NPV	**$541,000**	**$1,328,000**
BCR	1.31	2.60

a. *We have allowed for (probability weighted) travel delay costs for 7 days under Option 2 to account for bridge closures due to repairs after a major flood event.*

Additionally, a threshold analysis was undertaken to determine the minimum AEP flood probability assumed to destroy the existing bridge that is necessary to justify investment in a replacement bridge. The results of the threshold analysis indicate that Option 1 returns a positive NPV for an AEP of 1.63% or higher. Option 2 returns a positive NPV for an AEP of 1.025% or higher.

Sensitivity testing has been undertaken to clarify which assumptions can materially change the results. The sensitivity analysis indicates that:

- Option 2 achieves a positive NPV under changes to nearly all key assumptions. The one exception, previously discussed, is if a flood AEP of 1.03% or less (under a future climate) is required to destroy the existing bridge.
- Option 1 achieves a positive NPV under changes to a number of the key assumptions but continues to

[1] The discount rate is interest rate used to determine the present value of future cash flows (costs and benefits) in a discounted cash flow (DCF) or cost benefit analysis (CBA). This helps determine if the future benefits from a project will be worth more than the capital costs needed to implement the project in the present.

have a lower NPV than Option 2 in most cases.

- However, if climate change significantly increases the probability of a flood destroying the bridge over time, then Option 1 might achieve a higher NPV than Option 2.

Conclusions

Flooding poses significant risks to the Thornton Bridge and therefore to access along the Back Eildon Road. Loss of the bridge is likely therefore to involve significant costs. This risk is likely to increase with a changing climate. The preliminary cost benefit analysis indicates that implementing Option 2 (upgrade bridge to existing standards, which will significantly mitigate the flood risk), is very likely to result in net benefits to the community. Implementing Option 1 (bridge betterment, which will almost eliminate flood risk to the bridge), is also likely to result in a net benefit. The analysis indicates that Option 2 is likely to be the preferred option under most scenarios but current data uncertainties, especially relating to the risk posed by flooding to the existing bridge, means that the preference for Option 2 over Option 1 is not conclusive. Notably, if climate change significantly increases the probability of a flood destroying the bridge over time, then Option 1 could become the preferred option. Either Option 1 or Option 2 is preferred over the BaU option of keeping the existing bridge.

1. Introduction

Goulburn Murray Climate Alliance (GMCA) member councils are seeking to better understand how their buildings, roads, drains, other built assets, natural assets and associated services will be impacted by climate change. The *Climate Change Asset Vulnerability Assessment* project seeks to provide councils with this information.

Guidelines on climate change adaptation decision making have been developed as part of the project. The purpose of the case studies is to provide practical examples of the adaptation decision-making process as set out in the guidelines. Each case study goes through a systematic process of identifying and assessing adaptation options[2] for a priority asset or service that was identified through the vulnerability assessment. Two studies were selected for the case study phase following a review of case study proposals that were nominated by GMCA councils.

This case study focusses on assessing options to mitigate the impacts of flooding on the Thornton Bridge, which crosses the Goulburn River at Thornton in the Shire of Murrindindi. The Bridge provides a key access route to the township of Eildon and to tourist attractions and other accommodation in the district.

We emphasise that the case study presents a preliminary assessment and, as such, provides initial guidance on the potential direction of future adaptation. Decisions on proceeding with the option are likely to require more detailed analysis at some stages of the decision-making process discussed in the following sections.

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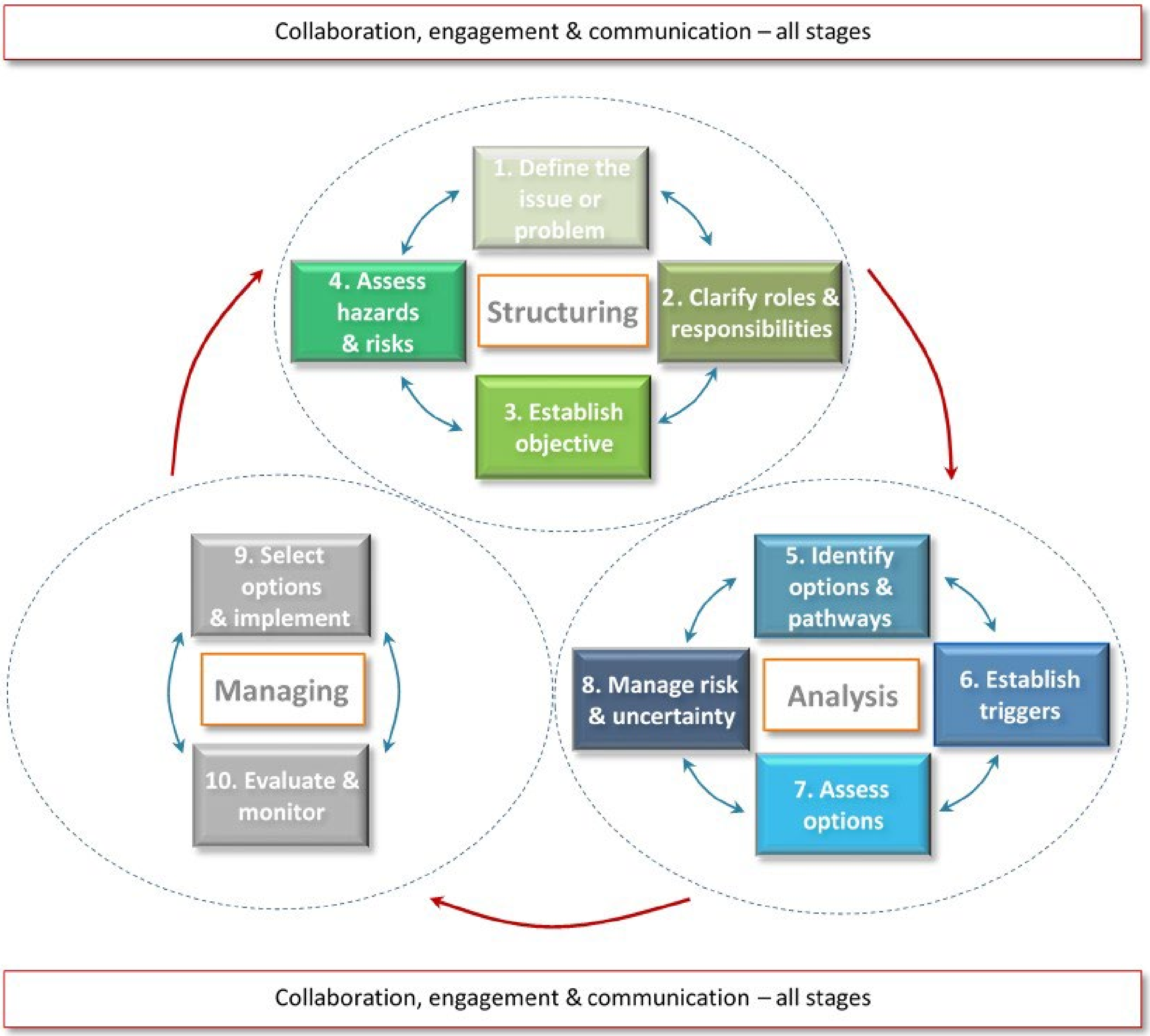
[2] Climate change adaptation can be defined as actions taken in response to actual or anticipated climate change impacts that lead to a reduction in risks or a realisation of benefits.

2. Climate change adaptation decision-making process

A sound decision-making process provides the foundation for effective climate change adaptation. Figure 3 identifies the key stages and steps comprising 'good practice' adaptation decision making (Marsden Jacob 2024). Working with the Shire of Murrindindi we have undertaken some preliminary analysis relating to Steps 1 through 8 in the process, however the primary focus of our analysis has been on assessing adaptation options (Step 7) and consideration of uncertainties in the analysis (Step 8). Steps 1 to 6 are discussed briefly in this section, with more detailed discussion of Steps 7 and 8 provided in the following sections.

Figure 1: Stages in the decision-making process



Source: Marsden Jacob Associates

2.1 Problem definition: threat of climate change to Thornton Bridge

Thornton Bridge is a road bridge that crosses the Goulburn River immediately to the north of Thornton township in Taungurung country, in the Shire of Murrindindi. The bridge marks commencement of the Back Eildon Road, which provides access to the township of Eildon. Eildon is located on Lake Eildon and is a popular destination for water-related recreational activities such boating, fishing and camping. The Back Eildon Road also provides access to other tourist attractions and accommodation in the district, as well as to local residents and businesses.

The current bridge is a two-lane, reinforced concrete bridge approximately 76 metres in length. It was constructed in the early 1960s and has a remaining useful life of about 30-40 years. Bridge clearance is 4.5m, which is about a 5.25m flood depth[3]. This means that the bridge deck will be over-topped at or above a 6m flood depth. As the bridge deck has columns on individual pad foundations, the bridge would likely be swept off these pads if the bridge deck is overtopped.

Flood modelling undertaken about 10 years ago indicates a 1% annual exceedance probability (AEP) flood would likely overtop the bridge. However, that modelling is based on historical climate data and does not incorporate climate change projections. During the 2022 floods, significant impacts on the Thornton bridge and township were avoided because relatively low rainfall occurred upstream of Lake Eildon and release of water at Eildon Dam was averted. If flood gates at the Eildon Dam need to be opened however, when an event of a similar scale to the 2022 occurs in the future, impacts on the bridge as well as the township could be substantial. Without modelling that incorporates climate projections it is not possible to be definitive about an AEP flood that will threaten the bridge in the future. However, noting that climate change projections for the region suggest the potential for the intensity of extreme rainfall events (ARI 20) to increase by up to 38% by 2050[4], a flood at or above a 10% AEP could feasibly threaten the bridge in the future.

If a flood were to remove the bridge, access to Eildon town and the attractions along the Back Eildon Road is available using the Goulburn Valley Highway. However, that route is longer and more circuitous than the Back Eildon Road, so loss of the Thornton Bridge would adversely impact on local businesses and residents and visitors to the region. Moreover, some heavy transport vehicles cannot use the Goulburn Valley Highway route to Eildon, which would likely have further impacts on local businesses and residents.

2.2 Roles & responsibilities

The Thornton Bridge is a municipal road bridge and, as such, Murrindindi Shire Council has responsibility for its maintenance and upgrade. However, any decision on upgrading the bridge will likely involve liaison with the Department of Transport and Planning through Vic Roads (which has responsibility for transport planning) and Regional Roads Victoria (which has responsibility for maintenance and upgrade of arterial roads in Murrindindi, including the Goulburn Valley Highway.

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[3] The major flood level at Thornton where the river breaks its banks is 40,000 ML/d or about 5m.

[4] CSIRO 2019

2.3 Objective(s)

A clearly defined objective(s) is important to assist Council with the process of identifying and assessing adaptation options and for guiding decision-making on whether an adaptation action should be undertaken, which action or actions from those available should be undertaken, and when the action should be implemented. Council's objectives for Thornton Bridge (as with all other assets managed by Council) are clearly spelt out in its *Assets Management Policy* (2020), which is aimed at ensuring that:

- Council assets are well managed throughout their lifecycle and fully utilised to achieve agreed desired service levels.
- Council assets support triple bottom line outcomes of environmental, financial and social sustainability.
- Asset management decisions are based on an integrated process, which includes community participation, has a long term focus, and balances competing social, financial and environmental priorities.
- Council is accountable to the community regarding asset performance and its asset management activities.
- Non-discretionary funding for the maintenance, operation and renewal of existing assets is prioritised ahead of discretionary funding of new assets.
- Council's exposure to risk is minimised, in regard to asset failures, property risk exposure, damage, loss and climate change.

The first and last listed objectives are especially pertinent noting the likely significant risk that major flooding poses to the bridge, the impact that losing the bridge will have on regional access and the likelihood that climate change will increase that risk. The other objectives are all also relevant however, and it is important that any decisions on future management of the bridge take account of community views and triple bottom line outcomes.

2.4 Hazard assessment

As previously noted, available flood modelling for the middle Goulburn in the Thornton area does not incorporate climate change projections. We understand that Goulburn-Broken CMA is currently overseeing an updated flood study for the Goulburn River that will incorporate climate change projections but that outputs of the study are not available to Council within the timeframe of this assessment. Ideally, the completed flood study will incorporate climate change projections for different timeframes (e.g. 2030, 2050 and 2070) and for different climate change scenarios (e.g. RCP 4.5 and 8.5[5]).

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[5] RCP scenarios are labelled according to their assumed radiative forcing in the year 2100. For example, the RCP8.5 trajectory assumes a radiative forcing of 8.5 W/m^2 in the year 2100, while the RCP4.5 trajectory assumes a radiative forcing of 4.5 W/m^2 in the year 2100. Recent (2019) radiative forcing is estimated to be approximately 2.6 W/m^2 (IPCC, 2018). RCP8.5 is broadly described by the IPCC as "…. a scenario without additional efforts to constrain emissions" (IPCC, 2013). RCP2.6 is described as a

In the absence of an updated flood study, we have relied upon outputs from the older flood study in combination with expert judgement. Essentially, this entailed setting feasible lower and upper bound flood AEPs under a future climate that would destroy the Thornton Bridge. Conservatively, these were set at 1% and 5% respectively, with an AEP of 2% used as the central or most likely case. Monte Carlo simulation was then applied to test the extent to which the NPV and BCR results calculated in the CBA would change with a change in the AEP. This was done by calculating NPV and BCR results for a random sample of 1000 AEPs that would threaten the bridge within bounds of 1% and 5% (see section 3.4.1 for further discussion).

We emphasise that the analysis should be updated when results of the Goulburn-Murray CMA flood study for the area become available.

2.5 Adaptation options, pathways and timing

2.5.1 Options selected for analysis

In some instances, there may be only one or two feasible adaptation options for addressing the identified hazard. This is the case with respect to addressing the risk of flooding to Thornton Bridge. Essentially, there are two options available to Council beyond the business-as-usual (BaU) option of leaving the current bridge in place until the end of its useful life (assumed to be 2050 for this analysis):

- **Option 1 (Betterment)**: Replace the bridge as soon as practical with an upgraded bridge that meets best practice design standards for a bridge of its size and level of use. This upgrade would virtually eliminate the risk of the bridge being destroyed by floods, for the life of the bridge, even under a worst-case climate change scenario (e.g. RCP 8.5). (further details of design).
- **Option 2 (Current design standards):** Replace the bridge as soon as practical with a 'like-for-like' bridge, albeit a bridge that meets current design standards and is therefore an improvement on the existing bridge, significantly reducing flood risk to the bridge.

2.5.2 Pathways and timing

As previously discussed, climate change poses significant uncertainties, with a range of plausible future flood scenarios under climate change. Typically, this situation calls for a flexible and adjustable approach to adaptation - avoiding premature redundancy of valuable infrastructure, while ensuring that risks to communities and assets are minimised. Flexibility can be achieved by identifying a suitable adaptation pathway by sequencing complementary adaptation options over time. It can also be achieved by taking a staged or incremental approach to implementing a preferred adaptation option.

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stringent mitigation scenario that aims to keep global warming likely below 1.5°C above pre-industrial temperatures, while RCP4.5 is described as an intermediate concentration scenarios between these two bookends.

With respect to this issue however, there is minimal scope for flexibility. The two options are mutually exclusive (i.e. they can't be sequenced, at least not in the timeframe being considered for this analysis), and neither option is amenable to a staged approach (i.e. either a replacement bridge is built or it is not).

Moreover, lack of up-to-date flood modelling means that it is not really feasible to consider how an increase in flood risk over time could influence timing of the adaptation option.

3. Analysis of options

3.1 Overview of approach

The approach applied to the analysis of adaptation options was a scenario-based cost-benefit analysis (CBA). CBA is an economic method that compares monetary costs and benefits associated with each option. As far as possible we have attempted to include broader economic costs and benefits in the analysis including some benefits that are not typically valued in markets. In this way. the CBA enables comparison of alternative options to determine which option will provide the greatest net benefit to the community and not just to Council.

The CBA assessed the costs and benefits of each of Options 1 and 2 incrementally to Business as Usual (BaU), with BaU being the option of leaving the current bridge in place until the end of its useful life. Economic impacts (costs and benefits) were assessed in an economic model by aggregating discounted annual estimates of each cost and benefit over the analysis timeframe. The aggregated costs and benefits are expressed for each option as an NPV and a BCR, providing a consistent basis for comparing the options.

NPV is the Present Value (PV) of benefits delivered by the option less the PV of costs incurred. NPV measures the expected benefit (or cost) of implementing the policy expressed in monetary terms. The BCR is a ratio of the benefits over the costs. A BCR of 2.0, for example, indicates that the option yields two dollars in return for every dollar spent.

The CBA has been undertaken consistent with the Victorian Guide to Regulation (CBR 2016) and the Economic Evaluation for Business Cases Technical Guidelines (DTF 2013). Major features of the CBA are:

- the analysis was undertaken over a 50-year timeframe (following implementation of options)
- use of a central discount rate of 4% real was applied, with sensitivity analysis using discount rates of 2% and 7% real;
- the major cost assessed under each of the options was the capital cost of replacing the bridge;
- the major benefits assessed under each of the options were the avoided additional travel costs, avoided bridge replacement costs and avoided repair and clean-up costs associated with destruction of the existing bridge due to flood impacts (probability weighted);
- sensitivity analysis was undertaken to test changes in flood probabilities on results; and
- further sensitivity analysis was undertaken based on changes to other key variables.

3.2 Results

Results of the analysis are presented in Table 1 and Table 2.

The results are based on the following central assumptions:

- 4% real discount rate[6] (with sensitivities of 2% and 7%)
- 50 year analysis period
- an AEP of 2% (i.e. a 1 in 50 year flood)
- all cost and benefit values are in 2024 dollars.

Table 1 shows that Option 2 – replacing the existing bridge with a bridge that meets current minimum design standards – achieves the best CBA results under the base assumptions listed above. Under the base assumptions listed above. Option 2 records an NPV of $1.33 million and a BCR of 2.60. Option 1 –betterment – records a lower NPV of $541,000 (BCR of 1.31). The main driver for this is the higher upfront capital costs under Option 1, which is only partially offset by avoided repair costs.

Table 2: CBA results Option 1 and 2 compared to BaU

	Option 1 (Betterment)	Option 2 (Current design standards)
Capital Cost	$1,718,000	$829,000
Operation & Maintenance	-	-
PV Total Cost	**$1,718,000**	**$829,000**
Avoided Repairs	$253,000	$179,000
Avoided Travel Delays[(a)]	$2,005,000	$1,978,000
PV Total Benefits / Avoided Cost	**$2,259,000**	**$2,157,000**
NPV	**$541,000**	**$1,328,000**
BCR	1.31	2.60

b. *We have allowed for (probability weighted) travel delay costs for 7 days under Option 2 to account for bridge closures due to repairs after a major flood event.*

Additionally, a threshold analysis was undertaken to determine the minimum AEP flood probability assumed to destroy the existing bridge that is necessary to justify investment in a replacement bridge. The results shown in Table 2 indicate that Option 1 returns a positive NPV for an AEP of 1.63% or higher. Option 2 returns a positive NPV for an AEP of 1.025% or higher.

[6] The discount rate is interest rate used to determine the present value of future cash flows (costs and benefits) in a discounted cash flow (DCF) or cost benefit analysis (CBA). This helps determine if the future benefits from a project will be worth more than the capital costs needed to implement the project in the present.

Table 3: Threshold analysis on AEP

	Option 1 (Betterment)	Option 2
AEP of 1.025%		
NPV	- 836,000	1,000
BCR	0.60	1.00
AEP of 1.62%		
NPV	4,000	811,000
BCR	1.00	1.83

3.2.1 Sensitivity analysis

The threshold analysis is necessarily based on a series of assumptions, which means that there is a significant degree of uncertainty around the results. Sensitivity testing has been undertaken to clarify which assumptions can materially change the results. The following sensitivity tests have been undertaken:

- discount rates of 2% and 7%;
- changes in capital cost of betterment (Option 1) or replacement (BaU, Option 2) of both a 20% increase and decrease;
- AEPs ranging from 1% to 5%; and
- Increase in the timeframe during which local residents and tourists will face travel delays after the existing bridge is destroyed during a flood (BaU).
- Climate change increases the probability of a flood destroying the bridge over time – increasing by 0.05% per year from 2% AEP in 2024 to 3.3% AEP in 2050.

Sensitivity analysis results are presented in Table 2.

Table 4: Summary of sensitivity and threshold analysis results NPV

	Option 1	Option 2
Central assumptions	**541,000**	**1,328,000**
Discount rate 2%	1,871,000	2,583,000
Discount rate 7%	- 602,000	187,000
Capital costs +20%	197,000	1,162,000
Capital costs -20%	884,000	1,494,000
AEP – 1%	- 872,000	- 33,000
AEP – 5%	4,777,000	5,413,000
AEP – 2%, increasing by 0.05% per year	1,447,000	2,184,000

	Option 1	Option 2
Travel delay costs over 3 years (BaU)	1,543,000	2,331,000

The results indicate that:

- Option 2 achieves a positive NPV under changes to nearly all key assumptions. The one exception, previously discussed, is if a flood AEP of 1.03% or less (under a future climate) is required to destroy the existing bridge.
- Option 1 achieves a positive NPV under changes to a number of the key assumptions but continues to have a lower NPV than Option 2 in most cases.
- However, if climate change significantly increases the probability of a flood destroying the bridge over time, then Option 1 might achieve a higher NPV than Option 2.

3.3 Key assumptions

The following sections set out the key underlying assumptions, including the capital cost of ungraded bridge, and the benefits obtained through access to the region via the Thornton bridge and Back Eildon Road.

Cost item	**Cost**	**Apply to**		
		BaU	**Option 1**	**Option 2**
Capital Cost	$2,200,000	✓		✓
Capital Cost (Betterment)	$3,000,000		✓	
Project Management	10% of capex	✓	✓	✓
Contingencies	20% of capex	✓	✓	✓
Maintenance	$3,000 per year	✓	✓	✓
Repairs & Clean-Up (existing bridge/ minor floods)	$40,000 every 2 years	✓		
Repairs & clean up – new bridge (major flood)	$200,000	✓		✓
Repairs & clean up – new bridge (minor floods)	$3,500 every 2 years		✓	✓
Travel delay costs	$3,795,942	✓		
Time without bridge (if destroyed by flood)	2 years	✓		

3.3.1 Capital costs of replacement bridge

Capital cost estimates for replacing the bridge were provided by Council staff.

The CBA assumes that under both BaU and Option 2 a 'like-for-like' replacement of the bridge will incur capital cost of $2.2 million. We note, that 'like-for-like' in this case means replacement with a bridge that meets current minimum design standards. Under BaU the bridge will be replaced in 2050, assuming a remaining life of 26 years. Option 2 brings the replacement of the bridge forward to 2027.

Capital costs for upgrading the bridge to a higher standard (Option 1, betterment) have been estimated at $3 million. The construction of the bridge is assumed to take place in 2027.

We have also allowed for project management cost (10% of capital costs) and contingencies (20% of capital & project management cost) under all options.

Given the long life of the asset – assumed to be 80 years for this analysis – the CBA model accounts for the residual asset values at the end of the analysis period, as recommended in DTF (2013).

3.3.2 Operation & Maintenance costs

Maintenance costs are assumed to be the same across all options. This includes, for example, regular inspections of the bridge.

3.3.3 Repairs and Clean-up costs

We've included two different types of repair and clean-up costs in the analysis:

- Repairs and clean-up costs after minor floods, such as cleaning up debris. These are $40,000 every two years for the existing bridge. Under both Option 1 and 2 these would reduce to $3,500 every two years.
- Repairs and clean-up costs after major floods. These apply to Option 2 only. While the "like-for-like" replacement bridge does not get destroyed by major floods, it would still requires significant repairs after major flooding has occurred. These repair and clean-up costs have been estimated at $200,000 and are probability weighted based on the AEP.

3.3.4 Bridge utilisation & travel delay costs

Travel delay cost (both additional time and vehicle costs) are incurred by residents and visitors, who need to take detours due to the Thornton Bridge being closed. These travel delay costs have been estimated based on travel count data for Thornton Bridge provided by Council and the assumptions outlined in Table 2. The total additional costs are estimated at $3.80 million for every year without the Thornton Bridge.

The CBA assumes that it will take up to 3 years to replace the bridge once it is destroyed by a flood.

Table 5: Cost of travel delays

Road use information	Thornton to Eildon	Thornton to Big 4 Holiday Park	Assumptions
Length of detour, one-way (kms)	1.6	10.2	Estimated using Google Maps, with the centre of Thornton as starting point
Estimated delay per one-way trip (min)	2	10	Estimated using Google Maps, with the centre of Thornton as starting point
Cost of time delay ($/hrs)	18.27	18.27	Standard rate for the value of recreational time of 35% of the median wage[7]
Vehicle cost ($/km)	0.85	0.85	Standard vehicle operating cost[8]
Number of (one-way) trips per year	277,400	277,400	Based on estimated daily traffic of 1,520 across Thornton Bridge
Additional travel time (hrs)	9,247	46,233	
Additional distance travelled (km)	443,840	2,829,480	
Additional annual cost of travel time ($/a)	168,937	844,683	
Additional annual vehicle cost ($/a)	377,264	2,405,058	

3.4 Uncertainties and gaps in analysis

3.4.1 AEP of flood that destroys bridge

The benefits generated under each option are primarily a function of the average recurrence interval (ARI) or AEP of flooding that overtops (and therefore destroys) the existing bridge. Implementing a Monte Carlo simulation allows us to test the extent to which the NPV results outlined in the previous section are resilient to mis-specification. The Monte-Carlo simulation procedure varies the AEPs of flooding overtopping the existing bridge 1,000 times using the RAND function in Excel. The RAND function was set to allow random numbers to be generated within upper and lower bounds set at 1% and 5%, respectively. All other assumptions are held constant, as set out in section 3.1.

The CBA was re-evaluated at the completion of each Monte-Carlo simulation, thereby generating a distribution of NPV results for Option 1 and Option 2. This procedure for analysing the sensitivity of the CBA outcome to varying degrees of risk is consistent with and draws on the approach outlined in DTF 2013.

The Empirical Cumulative Distribution Function (ECDF) charts depicted in Figure 2 to Figure 3 are powerful visual tools to capture the distribution of NPVs obtained from the Monte Carlo analysis for

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[7] Source: ABS Average Weekly Earnings, Australia, November 2023. Sourced at: https://www.abs.gov.au/statistics/labour/earnings-and-working-conditions/average-weekly-earnings-australia/latest-release, April 2024.

[8] Source: Australian Taxation Office, 2024

Option 1 and Option 2 respectively. The ECDF curve illustrates the cumulative percentage of observations falling below particular NPV values, providing a condensed visual representation of the simulation outcomes. Each of the Figures mark the 50th percentile of the distribution (measured on the vertical axis) and the corresponding NPV value (in $'000) on the x-axis - $1.9 million and $2.6 million for Options 1 and 2, respectively. The expected NPV is the average result across the 1,000 simulations. Each of the Figures also marks the percentile at which the NPV is $0 – 15th percentile and 0.7th percentile for Options 1 and 2 respectively.

Figure 2: Empirical distribution function – Option 1 (Betterment) for AEPs ranging from 1% to 5%

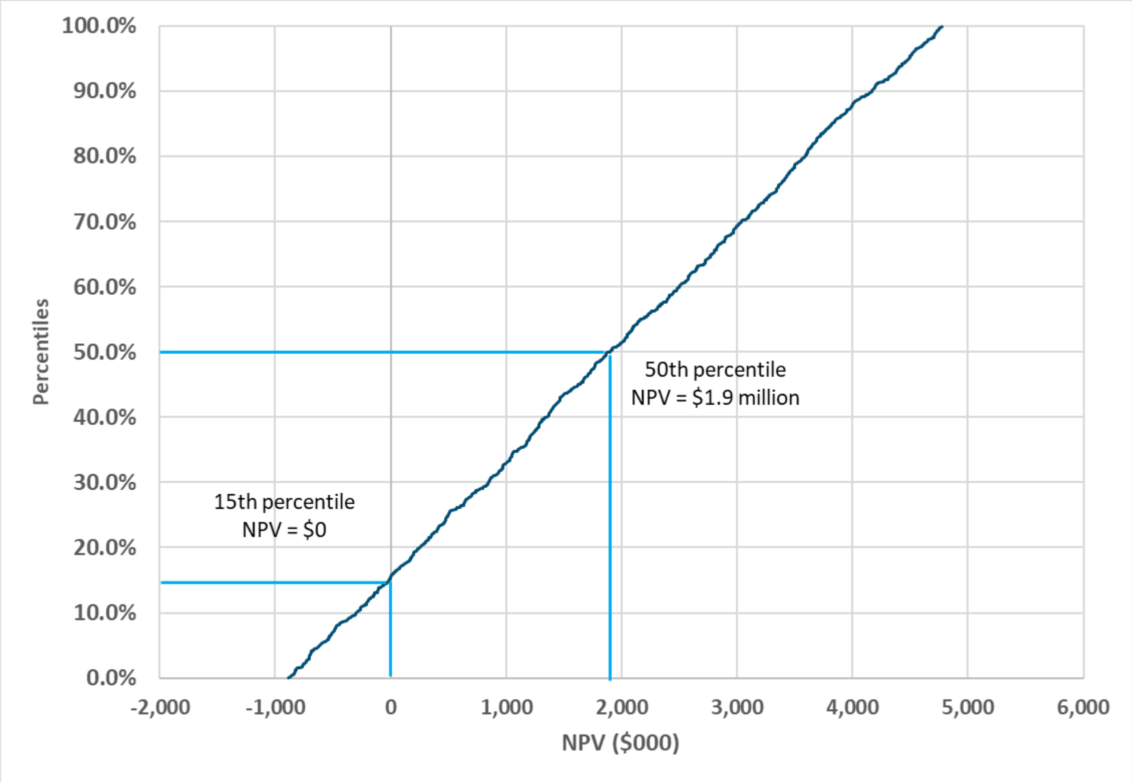
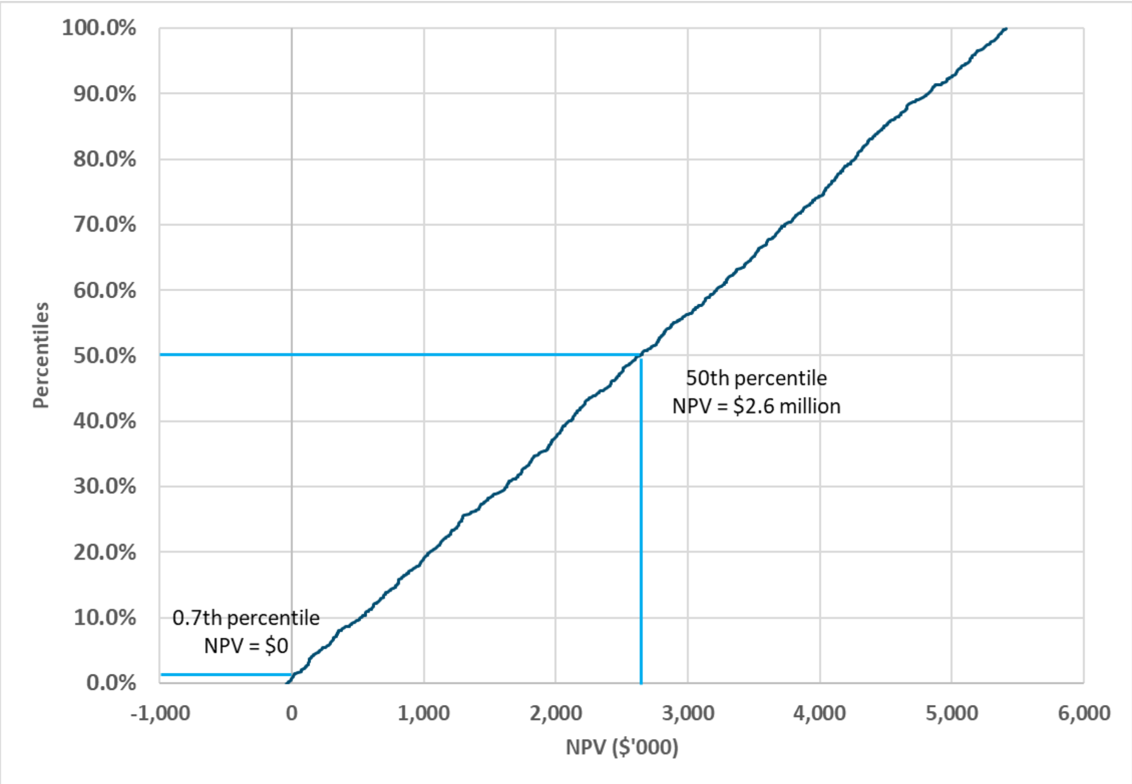


Figure 3: Empirical distribution function – Option 2 (Replacement to current standards) for AEPs ranging from 1% to 5%



3.4.2 Impacts of destruction of bridge on freight movement and tourism visitation

As discussed in section 2.1, some heavy transport vehicles cannot use the Goulburn Valley Highway route to Eildon, which means that if the Thornton Bridge were destroyed by a flood freight to Eildon and to businesses along the Back Eildon Road would likely be affected. The likely impact would be a requirement for that freight to be shifted in smaller vehicles or in extreme circumstances some freight might not be able to be delivered. The benefits, under Options 1 and 2, of avoiding this outcome have not been assessed in the analysis. This means that the net benefits of the two options are likely to be understated.

3.4.3 Costs and benefits of complementary revegetation and rail trail initiatives

We understand that initiatives including revegetation of the Goulburn River and/or extension of the Great Victorian Rail Trail, could potentially be implemented as complementary initiatives to the Thornton Bridge replacement. The costs and benefits of these initiatives have also not been assessed as part of the analysis.

4. Conclusions and next steps

4.1 Conclusions

Flooding poses significant risks to the Thornton Bridge and therefore to access along the Back Eildon Road by local residents and businesses and by tourists. Loss of the bridge is likely therefore to involve significant costs. This risk is likely to increase with a changing climate. The preliminary cost benefit analysis undertaken for this study indicates that implementing Option 2 (upgrade bridge to existing standards, which will significantly mitigate the flood risk), is very likely to result in net benefits to the community. Implementing Option 1 (bridge betterment, which will almost eliminate flood risk to the bridge), is also likely to result in a net benefit.

The analysis indicates that Option 2 is likely to be the preferred option under most scenarios but current data uncertainties, especially relating to the risk posed by flooding to the existing bridge, means that the preference for Option 2 over Option 1 is not conclusive. Notably, if climate change significantly increases the probability of a flood destroying the bridge over time, then Option 1 could become the preferred option. Either Option 1 or Option 2 is preferred over the BaU option of keeping the existing bridge.

4.2 Next steps

Upgrades to this analysis that incorporate results of the flood study that is currently being undertaken by Goulburn-Broken CMA when they become available. It may also be useful obtain further information on how loss of the Thornton Bridge would affect heavy freight movements in the region.

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