COMMERCIAL IN CONFIDENCE

FINAL REPORT

Flood Mitigation Options for Wagga Wagga

Evaluation of options

Prepared for
Wagga Wagga City Council

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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BOXES, CHARTS AND TABLES

Glossary

AAD	Annual Average Damage - the expected yearly damage cost arising from all occurrences of a given hazard.
AEP	Annual Exceedance Probability
ARI	Annual Recurrence Interval
CBA	Cost Benefit Analysis
Net Benefit	Present Value of Benefits less Present Value of Costs presented in the Economic Analysis
PMF	Probable Maximum Flood
VHP	Voluntary House Purchase
VHR	Voluntary House Raising
Risk	Risk refers to a situation where the occurrence of a future event is not known, but its probability of occurring is known or can be estimated
WWCC	Wagga Wagga City Council

Summary

The CIE has been engaged by Wagga Wagga City Council (the Council) to undertake an evaluation of three alternative flood mitigation options to manage flood risks in the region, with a particular focus on North Wagga Wagga. The options include:

- **PR1: Voluntary House Raising** (VHR) and **Voluntary House Purchase** (VHP) for eligible properties on the floodplain (e.g. North Wagga, Oura and Gumly Gumly).
- **L4B: North Wagga Levee System Upgrade** to withstand a 5% AEP (1 in 20 chance) flood event combined with an increase in some road heights and bridges to provide a safe evacuation route for residents from North Wagga. This would also include conveyance improvements through Wilks Park. The North Wagga Levee system would be upgraded first (Stage 1 or option L4A) and, at a later stage, the surrounding works would be constructed (Stage 1).
- A **combined approach** that is staged and includes
  a) Upgrading the existing North Wagga Levee system (**option L4A**)[1] and offering VHR and VHP to those outside the levees, only where it is cost effective to do so.
  b) Increasing the road heights and bridges along Hampden Ave to provide a safe evacuation route (**Stage 2 of option L4B**).
  c) **VHP and VHR** for those inside the North Wagga Levee system, only where it is cost effective to do so.

This report presents the findings of our analysis of the merits of the options. The analysis utilises the flood modelling conducted by WMA Water for the region, the latest data from the Australian Bureau of Statistics, as well as land value and property sales data captured by the NSW Land Valuer General. The analysis also adopts the August 2023 *Flood Damage and Cost Benefit Assessment Tool* which was developed by the NSW Government to assess flood risk mitigation measures consistent with Flood Risk Management Measures Guide MM01.[2]

This tool accounts for both the flood frequency and severity. The tool provides specific guidance on parameter values to use for the calculation of damages including structural/internal damage to buildings, intangibles (e.g. injury/mortality, mental health costs) and external damage (including to roads and utility services). The tool utilises updated information from more recent flood events throughout NSW.

This evaluation does not provide guidance on how any chosen option should be funded (by government or the community). It also does not place greater weight on any particular part of the community and, therefore, does not provide a judgement on any equity issues.

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1 This includes the “temporary” embankments along Hampden Ave that were added in 2012.

2 https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

Key findings

The key findings from our analysis include:

- **The VHR scheme in North Wagga Wagga results in *net benefits* to the community of around $9.6m in present value terms over a 30 year period. The cost of around $120,000/property is relatively low and significantly reduces the Annual Average Damage (AAD) for the property. We have assumed that the floor level of the property is raised 3m above ground level which substantially reduces the AAD of properties. Based on a visual survey, there are around 165 properties in North Wagga Wagga that could potentially be raised, resulting in a cost of $19.8m and delivering benefits (i.e. risk reduction) equivalent to $29.4m in present value over 30 years. This results in a *net benefit* of $9.6m.**
  - **The VHR scheme, however, may prove challenging for certain members of the community that may find the access to be more challenging. Depending on the additional costs of improving access this could impact on the scheme. If, for example, the cost (including improved access) increases to $200,000/property this switches the net benefit to a *net cost* of $3.6m.**
  - **Benefits would be greater if every property were raised, but a subset of houses have either been raised already or cannot be raised at all. In North Wagga Wagga 44 properties were identified as being already raised, and an additional 59 cannot be raised.**
- **The VHP scheme in North Wagga Wagga performs much worse than VHR, resulting in a *net cost* of $55.9m (in present value terms) to the community. The purchase cost of around $400,000/property significantly outweighs the AAD for most properties.**
  - **The policy could be refined to only target the highest risk properties where the current risks exceed $400,000.**
  - **Further, rather than pre-emptively purchasing the properties the VHP scheme could be applied *after* a flood event has damaged a property. This could be in, for example, 10 years' time. This would also require pre-planning and providing a place for residents to move immediately.**
- **The L4B option (both levee and associated works) does substantially reduce the flood risks in some areas. However, the overall cost of option L4B is around $86m (excluding any biodiversity offset purchases) is substantial.**
  - **The reduction in risk can vary, depending on the assumptions adopted. For the central case, we assume that for residential properties the largest building is the main residence and incurs the main structural/contents damage. Other buildings on the property (e.g. shed/garages) are subject to a lower "external damages" cost estimate. For commercial/industrial properties we assume that all buildings on the lot will be subject to the (higher) structural damage/contents estimates. Under these assumptions, the *costs of L4B exceed the benefits* by around $66.5m (in present value terms over 30 years).**

- L4A removes the surrounding works but maintains the levee upgrade which results in maintaining a large portion of the benefits of L4B but at a fraction of the cost, giving an overall ***net benefit* of $16.1m**. The total cost of L4A is $10.3m, which achieves a benefit of $26.4m.
- Combining the L4B option with VHR and VHP applied to properties outside North Wagga Wagga does result in slightly improved results compared to the L4B option on its own, however, it still results in ***net costs* of $46.3m**. This assumes that the VHR and VHP options are only applied to 'high risk' properties.
- Similarly, combining L4A with VHR and VHP applied to high risk properties outside North Wagga Wagga results in a moderate improvement over L4A on its own. The ***net benefit of this approach is $21.3m***.
- Combining just the VHR and VHP, targeting the highest risk properties within and outside North Wagga results in ***net benefits of $17.7m***. This highlights the value of adopting a more strategic approach which targets the highest risk properties where there is greatest benefit from the risk reduction.

Conclusions

Based on the analysis conducted, the conclusions are:

- Of the different options that could be adopted:
  - the combined L4A with a targeted VHR/VHP to high risk residents outside North Wagga delivers the best outcome for the community. However, there may be challenges for some households due to accessibility issues which could result in additional costs above the assumed $120,000/property raising.
  - L4B by itself or in combination with any other strategies is too expensive to be cost effective, regardless of the size of potential benefits.
  - VHR and VHP delivers positive outcomes for the community where it is applied to high risk properties where the risk reduction is greater than the cost of the actions. This suggests a strategic approach to the application of these policies based on estimated risk reduction. Further, the VHP policy could be more efficient where the purchase applies only after flooding. A pre-emptive policy would immediately "destroy" the value of the property with certainty, compared to the comparatively low probability of this. An alternative would be to purchase a property pre-emptively but maintain it as part of the housing stock until it is damaged by a flood event which could be in, say, 10 years' time.
- In implementing the proposed levee it is important to recognise that water is diverted to other parts of the floodplain, potentially negatively impacting on some properties. However, where negative impacts occur these are typically only result in minor increases flood depths. The risk reduction benefits of the levee substantially outweighs the potential negative impacts on some properties.

1 Project Overview

Wagga Wagga has experienced riverine flooding on numerous occasions requiring large scale evacuations and causing considerable damage, loss of property, loss of revenue, disruption of services, disruption of lifestyle and significant inconvenience.

Understanding the chance of different sized floods occurring is important for managing flood risk. The chance of a flood event can be described using a variety of terms, but a common method is the Annual Exceedance Probability (AEP).[3] A flood with a 1% AEP has a 1 in 100 chance of being exceeded in any year. Other terms that express the same idea, such as a '1 in 100 year flood' can be misinterpreted as only occurring once in every 100 years.[4]

Since early settlement, Wagga Wagga has experienced numerous large floods, with four events (1852, 1853, 1870 and 1891) in the 1800's equalling or exceeding 10.5m at the Hampden bridge gauge. Following significant flooding in the 1950's the CBD Levee was constructed to provide flood protection to the township of Wagga Wagga.

The CBD Levee has recently been upgraded to a 1% AEP level of protection. There are a number other levees on the floodplain, including one encircling North Wagga and providing a level of protection of approximately an 12% AEP event, one at Gumly Gumly protecting for flood breakouts north of Lamprey Avenue (up to a 10% AEP level of protection), and the Riverina Water County Council (RWCC) which protects Wagga Wagga's potable water supply.

Wagga Wagga City Council (the Council) has commissioned a range of studies to understand the existing and future flood risk and identify options to manage this risk. The 2018 Floodplain Risk Management Study and Plan conducted by WMA Water analysed the flood risks and options to manage these risks. Since this report WMA Water has undertaken additional modelling which has informed our economic analysis.

Options considered in this study

A range of typical floodplain risk management measures have been previously assessed as to their appropriateness for providing additional protection for Wagga Wagga (table 1.1).

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3 https://arr.ga.gov.au/__data/assets/pdf_file/0006/40398/New-ARR-Probability-Terminology_final.pdf

4 https://www.chiefscientist.qld.gov.au/publications/understanding-floods/chances-of-a-flood

1.1 Flood Risk Management Measures considered

Flood modification	Property modification	Response modification
Levees	Land zoning	Community awareness
Temporary Defences	Voluntary purchase	Flood warning
Channel Construction	Building & development controls	Evacuation planning
Channel Modification	Flood proofing	Evacuation access
Major Structure Modification	House raising	Flood plan/ recovery plan
Drainage Network Modification	Flood access	
Drainage Maintenance		
Retarding Basins		

Source: WMAwater (2018), Wagga Wagga Revised Murrumbidgee River, Floodplain Risk Management Study and Plan, April.

Many of these management measures were deemed to be not appropriate for Wagga Wagga and were not considered further.

1.2 Options considered for the case study

For this study, a number of options have been considered for feasibility assessment:

- **PR1: Voluntary House Raising** (VHR) and **Voluntary House Purchase** (VHP) for eligible properties on the floodplain (e.g. North Wagga, Oura and Gumly Gumly).
- **L4B: North Wagga Levee System Upgrade** to withstand a 5% AEP (1 in 20 chance) flood event combined with increase in some road heights and bridges to provide a safe evacuation route for residents from North Wagga. This would also include conveyance improvements through Wilks Park. The North Wagga Levee system would be upgraded first (Stage 1, option L4A) and, at a later stage, the surrounding works would be constructed (Stage 1).
- A combined approach that is staged and includes
  a) Upgrading the existing North Wagga Levee system **(option L4A)**[5] and offering Voluntary House Raising and Purchase to those outside the levees, only where it is cost effective to do so.
  b) Increasing the road heights and bridges along Hampden Ave to provide a safe evacuation route **(Stage 2 of option L4B)**

VHP and VHR for those inside the North Wagga Levee system, only where it is cost effective to do so.

5 This includes the "temporary" embankments along Hampden Ave that were added in 2012.

Project objective

The central task for this project is to assess feasibility of the options above. The analysis considers the impacts across the whole floodplain but with specific focus on residential and non-residential properties impacted in the LGA. The options are expected to provide protection for some properties but the levee raising option has the potential to negatively impacts on other properties, as flood waters are diverted to other parts of the floodplain. The negative impacts could result from increased flooding upstream, environmental and social impacts, and to a lesser degree, a reduced level of flood protection for critical facilities in the broader region. There could also be negative impacts arising for some properties next to a levee bank that could face a loss in 'amenity value' with a higher levee structure.

2 Cost Benefit Analysis Methodology

The feasibility assessment needs to be undertaken in line with the NSW Government's *Guide to Cost-Benefit Analysis* (TPG 23-08).[6] In August 2023, the NSW Government also released specific guidance on conducting a CBA to assess different options that seek to manage flood risks. A specific Excel based tool has also been developed which specifies assumptions for the different parameters required to be modelled.[7]

Overview of a CBA

CBA is a tool designed to place the benefits and costs of particular actions or proposals on a common basis so that they can be compared and understood. It provides a basis on which the NSW Government can assess the net benefits of decisions around flood mitigation and adaptation.[8]

CBA provides a technique that allows a systematic treatment of trade-offs arising from Government decisions and the changes that they entail. It allows for quantification and valuation of the full range of potential impacts that might arise from changes in flood mitigation. It involves aggregation of these impacts across the various types of costs and benefits and through time into a single metric — *the expected present value of net benefits*[9] from a change relative to a 'reference case' (sometimes referred to as 'base case' or 'business as usual'). In the reference case, there may be specific responses that Government will take in the event of a flood (e.g. sandbagging, dredging). Any 'new' actions required will form part of the options to be evaluated.

A CBA framework is focused on the social welfare of the community. The policy option that delivers the highest *net social welfare* (across the community) is considered to be the best for society. The CBA does not place a greater weight on any particular group of residents within the community. As part of the CBA, however, we report on how impacts differ across the floodplain.

CBA is designed to take account of the full range of potential benefits and costs of particular actions. In this sense, it is wholistic and designed to include, for example, the

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6 https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis

7 https://flooddata.ses.nsw.gov.au/flood-projects/nsw-flood-damage-assessment-tool-dt01

8 In this report we use the term 'mitigation' to mean a range of current and future options which help the community to 'adapt' to flood risks.

9 The expected value is the probability weighted value. In this case the options will provide different levels of protection for each flood event. Each flood event has a specific probability of occurrence.

environmental, health and economic impacts of particular actions. A CBA places each of these impacts on a common basis so that they can be compared and understood.

A CBA framework also considers the timing of each of the impacts. Under a CBA approach, future impacts are 'converted' into today's terms so that they can be meaningfully compared. A CBA, for example, will enable an evaluation of policies that deliver different streams of benefits and costs over time.

The key principles of a CBA are presented in box 2.1.

2.1 Key steps in a CBA

- **Articulating the decision that the CBA is seeking to evaluate.** For example, in relation to flood mitigation, the decision may relate to whether to build a levee and to what height, or whether evacuation routes are improved or both. The way in which the CBA is framed and the information requirements will differ depending on the decision being evaluated.
- **Establishing the reference case** (or 'base case') against which to assess the potential socioeconomic and environmental impacts of changes. In the case of flood mitigation in the case study region, the natural reference case is no change from the policies in place today and no specific new flood mitigation investment. This would mean, for example, that existing Council planning controls such as land use restrictions for flood areas would remain as they currently are.
- **Quantifying the changes** from the base case resulting from the possible scenarios being considered. This will focus on the incremental changes to a range of factors (for example, environmental, economic, social) resulting from the decision. The changes may be certain or could also be defined in probabilistic terms. The quantification should focus on key changes that will be utilised in the valuation stage. For flood mitigation these changes will include changes in the *likelihood* of flood events and changes in the *consequences* of flood events.
- **Placing values on the changes** and aggregating these values in a consistent manner to assess the outcomes.
- **Generating the Net Present Value (NPV)** of the future net benefits cashflow stream, using an appropriate discount rate, and deciding on the **Decision Rule** on which to assess the different options.
- **Undertaking sensitivity analysis** on a key range of variables, particularly given the uncertainties related to specific environmental benefits and costs.

Deciding on which option is better for society. In practice, additional information, aside from the CBA, may also be utilised when deciding on the preferred option.

It is important to note that a CBA does not consider ***equity issues***. For example, the construction of a raised levee bank may reduce flood impacts in one part of the Wagga Wagga LGA but may increase flood risks for residents upstream. A CBA focuses on comparing the ***aggregate gains in total versus the total losses***, irrespective of which specific part of the community benefits or loses.

The feasibility analysis will, therefore, need to provide transparent information on the impacts of the alternative options. This will enable other information to be presented, in addition to the CBA results, to assist decision makers to assess the options. However, having a robust CBA will provide objective evidence on the quantum of positive and negative impacts on the community, thereby, reducing the need for subjective judgements.

Note that the issue of ***how to fund*** selected options is a separate task to the CBA. The CBA evaluates which options would generate the greatest welfare improvement. Once the options are selected the decision maker then needs to consider how best to fund the options (e.g. via rate increases, a differential flood levy on property owners on different parts of the floodplain, direct grants from state/federal governments).

Application of CBA to responses to mitigate the impacts of flooding

The basic framework for evaluating the costs of flood events and the costs of mitigation options should capture the following.

- The costs of flood events under the base case as well as each mitigation strategy, which comprises:
  - the *probability* of a given flood height/velocity occurring
  - the *consequences* of a given flood height/velocity occurring, such as:
    - property damage
    - loss of life/injury.
- The costs of each mitigation strategy including:
  - capital costs
  - ongoing operating costs
  - environmental impacts (e.g. biodiversity loss due to associated land clearing).

The costs of flood events under alternative strategies and the costs of the actions that form part of a strategy should be measured over a period of time (e.g. 30 years) and will be discounted back to 2023 dollars. The Treasury Guidelines require the use of a 5 per cent real discount rate, with sensitivity being undertaken at 3 per cent and 7 per cent.[10]

Further all costs should be measured as *economic costs.* Economic costs differ from financial costs because:

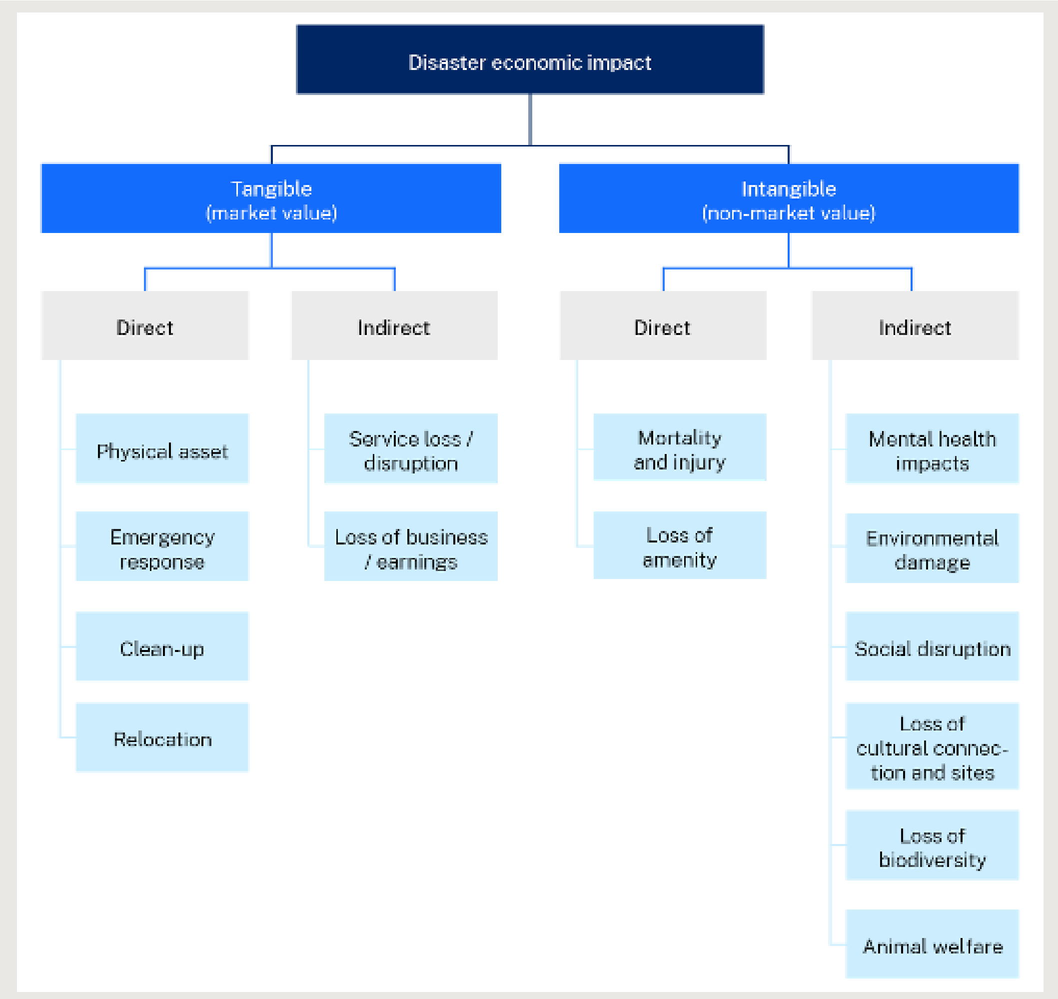
- economic costs include costs to those outside of the direct proponent
- economic costs do not include financial transfers, and
- resources used are valued at their opportunity cost, which may differ from their market price.

10 See page 94 of Treasury Guidelines https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

NSW Government Guidelines

The NSW Government's Disaster CBA Framework (TPG23-17, August 2023) presents different categories of impacts that should be considered in the analysis.

2.2 Categories of disaster impacts



Data source: NSW Treasury (2023), *Disaster Cost-Benefit Framework TPG23-17*, p25.

The specific assumptions for the different categories embedded in the Excel based calculator are summarised in Appendix B. Some key assumptions, such as the updated 'stage damage curves', are significantly higher than previously used (e.g. in WMA Water's April 2018 Floodplain Risk Management Study and Plan). Therefore, the results and findings from the previous studies could be substantially different to those reported in the earlier reports.

3 Current risks

This chapter presents information on the flood risks in the absence of any future actions/investments and how the risks change under the options considered. We utilise a number of sources to estimate the risks such as:

- A spatial GIS file of building footprint based on satellite imagery. The information was provided by Council.
- A spatial GIS file of 'properties' in the Wagga Wagga LGA, sourced from the NSW Government.[11]
- A spatial GIS file of 'Meshblocks' in the Wagga Wagga LGA, sourced from the ABS.[12] The MBs identify different categories including Residential, Commercial, Industrial, Education, Hospital/Medical, Primary Production, Parkland and Other.
  - This is combined with datasets of dwelling and population numbers for each Meshblock as reported in 2021 Census.
- A dataset of properties, land values and property sales in NSW sourced from the NSW Land Valuer General.[13]
- There has been some manual reclassification of properties as new information is obtained (e.g. from Google Earth and from Council's visual inspections of properties). This includes two newly built properties currently not reflected in GIS files. Some manual adjustments has also been undertaken to incorporate information on existing house raisings and also the potential for a house to be raised.

The spatial files noted above have been overlaid with spatial GIS flood layers provided by WMA Water, modelled for eight different flood events.[14] WMA Water has undertaken in line with the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017). The results in this chapter reflect the case where the existing levees do not "fail" under the flood event.

The results presented in this chapter may differ to WMA Water's April 2018 *Floodplain Risk Management Study and Plan*. This reflects, for example, updated population and dwelling numbers, as well as, updated flood modelling conducted by WMA Water.

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11 https://datasets.seed.nsw.gov.au/dataset/nsw-property-web-service

12 https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/digital-boundary-files

13 http://www.valuergeneral.nsw.gov.au/land_value_summaries/lv.php

14 This includes AEP events 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and PMF. For context, the AEP 1% equates to a 1 in 100 year event and AEP 20% equates to a 1 in 5 year event.

Existing flood risks with no new actions

Based on the 2021 Census the Wagga Wagga LGA has 67,609 persons and 28,151 dwellings, with an area of 4,826 sqkm.[15] The largest flood event, the Probable Maximum (PMF) flood event, floods around 154 sqkm or 3.2% of the LGA.[16]

The *potential* impact differs throughout the floodplain. Table 3.1 presents the suburbs that are impacted (to some extent) by the PMF flood event and the total number of persons, dwellings and land area in each suburb.

3.1 Characteristics of suburbs potentially impacted (to some extent) by PMF event

Suburb	Persons [a]	Dwellings [a]	Total Suburb Area
	no.	no.	sqkm
Gobbagombalin	2 184	767	44
Eunanoreenya	165	65	39
Alfredtown	80	32	75
North Wagga	679	291	17
Forest Hill (NSW)	3 081	938	35
Oura	246	95	142
Yarragundry	72	35	65
East Wagga Wagga	213	130	11
Gumly Gumly	450	149	12
Moorong	175	61	19
Wagga Wagga	7 198	3 960	9
Euberta	130	55	105
Bomen	40	15	28
Cartwrights Hill	169	77	3
Ashmont	3 747	1 674	2
Lake Albert (NSW)	6 291	2 519	25
Kooringal (NSW)	7 404	3 304	5
Boorooma	1 741	601	2
Estella	2 541	1 023	2
Brucedale	184	62	49
Turvey Park	3 572	1 536	4
Downside	124	46	80
San Isidore	349	122	5
Total	**40 835**	**17 557**	**777**

[a] This represents the total number of persons/dwellings in the suburb, not those impacted by each flood event.

Source: ABS 2021 Census QuickStats, https://www.abs.gov.au/census/find-census-data/quickstats/2021/SAL13024

15 https://abs.gov.au/census/find-census-data/quickstats/2021/LGA17750

16 A small proportion of land is within the flood extent but above the flood height. This land does not form part of our estimate of the flooded area in the PMF.

Land area impacted

Table 3.2 calculates the land area impacted (i.e. the flood extent) under the flood events modelled for this study, assuming no upgrades to the levees. North Wagga, for example, has a large proportion of area impacted by the three different flood events. In the Wagga Wagga suburb the PMF inundates 8.25sqkm (of the total 8.90sqkm in the suburb), but this falls to 1.92sqkm for the AEP 1% event. For other suburbs, such as Euberta, all flood events only impact on a small proportion of land.

3.2 Land area inundated, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Alfredtown	16.22	14.39	13.95	13.53	13.03	11.76	9.90	5.97
Ashmont	0.60	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Bomen	2.17	1.84	1.78	1.72	1.66	1.42	1.07	0.00
Boorooma	0.23	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Brucedale	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cartwrights Hill	0.93	0.72	0.68	0.65	0.62	0.59	0.56	0.44
Downside	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
East Wagga Wagga	9.91	8.63	7.41	6.36	5.21	2.85	2.51	2.21
Estella	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Euberta	5.91	5.49	5.27	4.97	4.63	2.94	2.69	1.54
Eunanoreenya	18.82	17.42	17.26	17.13	16.96	16.03	13.86	7.73
Forest Hill	12.95	10.54	10.29	10.03	9.58	6.76	5.34	2.72
Gobbagombalin	20.55	17.01	16.30	15.98	15.72	15.00	13.91	9.25
Gumly Gumly	9.35	8.72	8.65	8.55	8.10	3.80	3.19	2.09
Kooringal	0.35	0.14	0.01	0.01	0.00	0.00	0.00	0.00
Lake Albert	0.48	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Moorong	9.04	8.58	8.26	8.19	8.12	7.85	7.37	6.07
North Wagga Wagga	15.56	15.35	15.28	15.19	15.10	14.83	13.54	10.17
Oura	11.08	9.88	9.68	9.50	9.26	8.41	7.05	4.83
San Isidore	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turvey Park	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wagga Wagga	8.20	5.82	2.03	1.91	1.88	1.82	1.69	1.45
Yarragundry	10.28	9.76	9.60	9.39	9.13	7.54	5.54	1.77
Total	**152.85**	**134.45**	**126.43**	**123.08**	**118.99**	**101.60**	**88.21**	**56.25**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 3.3 presents the land area inundated by ABS Meshblock 2021 category.[17] The flood inundation occurs predominately on land classified for Primary Production. This is followed by Residential land. In the PMF event, there is also land used for hospital/medical services. In the AEP 5% to PMF events, there is also inundation of land providing educational services.

17 https://www.abs.gov.au/census/guide-census-data/mesh-block-counts/latest-release

3.3 Land area inundated. By Meshblock

Meshblock	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Residential	8.49	5.53	3.53	3.41	3.26	2.17	1.49	1.11
Commercial	0.88	0.45	0.15	0.14	0.13	0.07	0.05	0.03
Education	0.21	0.11	0.08	0.04	0.01	0.01	-	-
Hospital/Medical	0.04	-	-	-	-	-	-	-
Industrial	3.61	2.73	1.47	1.33	0.90	0.40	0.27	0.14
Parkland	2.69	2.34	0.90	0.82	0.81	0.78	0.72	0.71
Primary Product	132.29	118.82	116.06	113.14	109.74	94.34	82.26	51.50
Other	4.65	4.46	4.25	4.19	4.15	3.84	3.41	2.75
Total	**152.85**	**134.45**	**126.43**	**123.08**	**118.99**	**101.60**	**88.21**	**56.25**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Buildings impacted

Building footprint in GIS format based on satellite imagery was provided by Council. This includes small structures such as sheds and garages, as well as, residential dwellings, commercial/industrial and other buildings. A single 'property' (ie block of land) may have multiple buildings on it. Table 3.4 presents the total building footprint impacted in those suburbs with a building. If only a portion of the building is flood exposed we assume that the whole building is defined to be 'impacted'. Therefore, the calculations in the table are likely to be a slight overestimate.

3.4 Area of building footprint impacted, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Alfredtown	1 769	1 322	1 296	919	919	0	0	0
Ashmont	106 252	3 936	0	0	0	0	0	0
Bomen	4 456	2 809	2 700	2 700	2 323	924	313	0
Boorooma	14 306	1 437	0	0	0	0	0	0
Cartwrights Hill	8 305	4 952	4 539	4 539	4 192	3 946	3 946	3 946
East Wagga Wagga	540 292	490 836	307 825	285 523	166 514	57 178	30 385	16 855
Estella	3 655	2 130	0	0	0	0	0	0
Eunanoreenya	21 123	13 444	11 545	11 166	9 974	6 237	4 015	1 541
Forest Hill	13 289	5 825	5 697	5 641	5 250	4 579	3 834	633
Gobbagombalin	7 385	3 200	3 200	3 200	3 200	2 014	1 328	787
Gumly Gumly	81 908	78 300	75 917	73 997	55 497	13 071	5 064	1 520
Kooringal	27 766	4 454	0	0	0	0	0	0
Lake Albert	4 986	0	0	0	0	0	0	0
Moorong	36 270	25 570	1 578	1 558	534	435	427	396
North Wagga Wagga	119 950	117 970	116 271	110 181	106 985	92 561	26 522	7 156

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Oura	36 741	29 770	28 931	28 185	27 725	17 169	1 044	6
Turvey Park	2 628	0	0	0	0	0	0	0
Wagga Wagga	1 422 539	912 859	25 708	25 669	25 382	23 767	18 338	13 718
Total	**2 453 621**	**1 698 816**	**585 208**	**553 277**	**408 494**	**221 881**	**95 216**	**46 558**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Road area impacted

Inundated road area is determined using road corridor information provided in GIS format by Council. Table 3.5 presents the area (sqkm) impacted under each AEP

3.5 Road area inundated

PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
8.184	6.815	5.221	4.994	4.698	3.863	3.014	1.787

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Change in risks due to options

Option L4B - upgrade North Wagga Levee system and associated works

Table 3.6 presents the change in area inundated from the levee project. As expected, the levee project significantly reduces the inundation area in North Wagga Wagga for the AEP 20% to the AEP 2% events. There is also a reduction in inundation area in East Wagga Wagga (and a number of other suburbs) for the AEP 20% to AEP 5% events. There is also an increase in inundation area for some flood events in some areas, although these increases are typically minor (non-material).

3.6 Change in land area inundated due to Option L4B, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Alfredtown	0.000							
Ashmont								
Bomen	0.001	0.001						
Boorooma		-0.001						
Brucedale	0.000							
Cartwrights Hill				-0.001	-0.002	-0.002		
Downside								
East Wagga Wagga		0.009	0.011	0.019	0.014	-0.047	-0.044	-0.021
Estella								
Euberta			-0.000	-0.001	-0.000	0.003	0.002	0.003

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Eunanoreenya	0.000		0.001	0.001	0.002	-0.002	-0.003	-0.092
Forest Hill	0.000	0.001	0.001	0.001		-0.004	-0.007	
Gobbagombalin	-0.001	0.001		-0.002	-0.001	0.003	0.006	0.022
Gumly Gumly	0.000	0.002	0.002	0.002	0.003	-0.004	-0.002	-0.022
Kooringal		0.012						
Lake Albert	0.001	0.000						
Moorong		0.000			-0.001	0.003	0.001	0.012
North Wagga Wagga		-0.000	-0.000	0.003	-0.456	-0.754	-0.134	-0.306
Oura	0.000							
San Isidore								
Turvey Park								
Wagga Wagga	0.001	0.043	-0.003	0.001			-0.001	0.007
Yarragundry				-0.001	-0.000	0.010	0.010	0.002
Total	**0.005**	**0.067**	**0.011**	**0.022**	-0.442	-0.794	-0.171	-0.395

Note: A blank indicates that there was no flooding in the suburb for the flood event or there is no impact of the levee project. The data has been rounded to the 3rd decimal place.

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 3.7 presents the change in area inundated by Meshblock category. The levee project provides additional protection from residential land in the AEP 1% event and smaller. Commercial/Industrial land also gets some protection in the AEP 5% events and smaller. Some Meshblocks experience an increase in flooding in the larger flood events.

3.7 Change in land area inundated due to Option L4B, by Meshblock

Meshblock	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Residential	0.000	0.034		-0.003	-0.268	-0.459	-0.022	
Commercial	0.001	0.007	0.000	0.000	0.001	-0.003	-0.002	
Education		0.000	0.000	0.008	-0.004	-0.006		
Hospital/Medical								
Industrial		0.016	0.001	0.002	0.003	-0.015	-0.025	-0.002
Parkland		0.002	-0.003	0.001	-0.018	-0.028	0.004	0.008
Primary Product	0.002	0.007	0.012	0.012	-0.155	-0.282	-0.127	-0.410
Other	0.001	0.001		0.000		-0.002	0.001	0.008
Total	**0.005**	**0.067**	**0.011**	**0.022**	-0.442	-0.794	-0.171	-0.395

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 3.8 presents data on the building footprint impacted by the Option L4B. The option results in a substantial reduction in the buildings impacted in North Wagga Wagga for the AEP 1% and smaller events. There is also a substantial reduction in the building footprint impacted in East Wagga Wagga for the AEP 5% and AEP 10% events. However, there is also an increase in the building footprint impacted in some events, such as the AEP 0.2% (the '1 in 500' year event) in the Wagga Wagga CBD.

3.8 L4B change in area of building footprint impacted, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Alfredtown	0	0	0	0	0	0	0	0
Ashmont	0	0	0	0	0	0	0	0
Bomen	0	0	0	0	0	0	0	0
Boorooma	0	0	0	0	0	0	0	0
Cartwrights Hill	0	0	0	0	0	0	0	0
East Wagga Wagga	0	353	0	182	155	-5 278	-3 230	0
Estella	0	0	0	0	0	0	0	0
Eunanoreenya	0	0	0	0	0	0	0	0
Forest Hill	0	0	0	0	0	0	0	0
Gobbagombalin	0	0	0	0	0	0	0	0
Gumly Gumly	0	0	0	0	0	0	0	0
Kooringal	0	8	0	0	0	0	0	0
Lake Albert	0	0	0	0	0	0	0	0
Moorong	0	0	0	0	0	0	0	0
North Wagga Wagga	0	0	19	-450	-50 282	-68 485	-5 470	-759
Oura	0	0	0	0	0	0	0	0
Turvey Park	0	0	0	0	0	0	0	0
Wagga Wagga	0	12 717	0	0	0	0	0	543
Total	**0**	**13 078**	**19**	**-268**	**-50 127**	**-73 763**	**-8 700**	**-216**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

The protection provided by option L4B is largely related to Residential buildings, with protection also to buildings on primary production land, industrial land and also education facilities. In the AEP 0.2%, option L4B results in increased residential, commercial/industrial building damage in Wagga Wagga and East Wagga suburbs.

3.9 L4B change in area of building footprint impacted, by Meshblock

Meshblock type	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Residential	0	10 840	19	-621	-41 190	-56 841	-564	0
Commercial	0	2 177	0	0	64	-770	0	0
Education	0	0	0	0	-2 067	-2 705	0	0
Hospital/Medical	0	0	0	0	0	0	0	0
Industrial	0	61	0	182	0	-1 125	-3 230	0
Parkland	0	0	0	0	0	0	0	45
Primary Product	0	0	0	171	-6 934	-12 324	-4 906	-804
Other	0	0	0	0	0	0	0	543
Total	**0**	**13 078**	**19**	**-268**	**-50 127**	**-73 763**	**-8 700**	**-216**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Option L4A – upgrade North Wagga Levee system only

Option L4A is very similar in nature to option L4B, except it delivers a lower level of protection, both in North Wagga Wagga and in surrounding suburbs. Comparing table 3.10 and table 3.6, we see that the total flooded area in the LGA is higher in all flood levels if only the levee is constructed, although for AEP 1%, AEP 5% and AEP 10% floods this is still preferable to no levee.

However, a few suburbs have a smaller flood extent with L4A compared to L4B during small floods (up to AEP 2%). These include Euberta, Gobbagombalin, Moorong and Yarragundry.

3.10 Change in land area inundated due to Option L4A, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Alfredtown	0.000							
Ashmont		0.000						
Bomen	0.001	0.001	0.001	0.001	0.001			
Boorooma	0.000	-0.002						
Brucedale	0.000							
Cartwrights Hill			0.001	0.000	0.000	-0.000		
Downside								
East Wagga Wagga		0.021	0.115	0.056	0.042	0.019	0.001	
Estella								
Euberta		0.001		0.001	-0.003	0.002	0.000	
Eunanoreenya	0.001	0.000	0.003	0.002	0.004	0.001		
Forest Hill (NSW)	0.000	0.002	0.002	0.004	0.001			
Gobbagombalin		0.006		-0.002	-0.002	0.002		0.000
Gumly Gumly	0.001	0.002	0.004	0.005	0.009			
Kooringal (NSW)		0.026						
Lake Albert (NSW)	0.001	0.000						
Moorong		0.001			-0.002	0.003		-0.000
North Wagga Wagga		-0.001	0.001	0.004	-0.284	-0.715	-0.075	0.014
Oura	0.000							
San Isidore								
Turvey Park	0.000							
Wagga Wagga	0.001	0.089	-0.001	0.000	-0.001			
Yarragundry		0.002		-0.000	-0.002	0.007	0.001	
Total	**0.008**	**0.149**	**0.126**	**0.070**	**-0.236**	**-0.682**	**-0.072**	**0.014**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 3.11 shows the changes brought about by the levee split by Meshblock category. Most of the benefits are accruing in the AEP 10% through AEP 2% floods, primarily in residential, parkland and primary production.

Compared to L4B, L4A provides less protection than L4B in residential, commercial, industrial and primary production Meshblocks, but in some cases, higher protection to parkland and 'other' Meshblocks.

3.11 Change in land area inundated due to Option L4A, by Meshblock

Meshblock type	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Residential	0.001	0.068	0.001	-0.002	-0.238	-0.438	-0.022	
Commercial	0.001	0.016	0.000	0.001	0.002	0.002		
Education		0.000	0.002	0.023	-0.005	-0.006		
Hospital/Medical								
Industrial		0.038	0.092	0.012	0.009	0.007		
Parkland	0.000	0.007	-0.001	0.000	-0.023	-0.022	-0.001	0.000
Primary Production	0.005	0.020	0.030	0.034	0.020	-0.226	-0.050	0.014
Other	0.001	0.000	0.001	0.001	-0.001			
Total	**0.008**	**0.149**	**0.126**	**0.070**	**-0.236**	**-0.682**	**-0.072**	**0.014**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Focussing on buildings, L4A has substantially positive impacts in North Wagga Wagga in AEP 5%, AEP 2%, and marginal benefits in AEP 10%. East Wagga Wagga has slight increases in building area flooded across many flood types, and the levee results in a large increase in building area flooded in Wagga Wagga for large floods.

Again, not completing the extra works which are part of L4B results in decreased protection in North Wagga Wagga, and increased additional flooding in other suburbs due to redirected flows.

3.12 L4A change in area of building footprint impacted, by suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	Sqm
Alfredtown	0	0	0	0	0	0	0	0
Ashmont	0	0	0	0	0	0	0	0
Bomen	0	0	0	0	0	0	0	0
Boorooma	0	-8	0	0	0	0	0	0
Cartwrights Hill	0	0	0	0	0	0	0	0
East Wagga Wagga	0	5 493	1 018	2 333	155	3 524	0	0
Estella	0	0	0	0	0	0	0	0
Eunanoreenya	0	0	0	0	0	0	0	0
Forest Hill (NSW)	0	0	0	0	0	0	0	0
Gobbagombalin	0	0	0	0	0	0	0	0
Gumly Gumly	0	0	0	9	0	0	0	0
Kooringal (NSW)	0	3 847	0	0	0	0	0	0
Lake Albert (NSW)	0	0	0	0	0	0	0	0
Moorong	0	0	0	0	0	0	0	0

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
North Wagga Wagga	0	0	19	754	-44 381	-68 004	-5 115	95
Oura	0	0	0	0	0	0	0	0
Turvey Park	0	0	0	0	0	0	0	0
Wagga Wagga	0	30 376	0	0	0	0	0	0
Total	**0**	**39 708**	**1 037**	**3 096**	**-44 226**	**-64 480**	**-5 115**	**95**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

3.13 L4A change in area of building footprint impacted, by Meshblock

Meshblock type	PMF_B	500Y_B	200Y_B	100Y_B	50Y_B	20Y_B	10Y_B	5Y_B
	sqm	sqm	sqm	sqm	sqm	Sqm	sqm	sqm
Residential	0	23 851	19	-621	-40 399	-52 683	-564	0
Commercial	0	6 831	0	0	64	0	0	0
Education	0	0	0	0	-2 759	-2 705	0	0
Hospital/Medical	0	0	0	0	0	0	0	0
Industrial	0	9 026	1 018	2 333	0	2,745	0	0
Parkland	0	0	0	0	0	0	0	0
Primary Production	0	0	0	1 384	-1 133	-11 837	-4 551	95
Other	0	0	0	0	0	0	0	0
Total	**0**	**39 708**	**1 037**	**3 096**	**-44 226**	**-64 480**	**-5 115**	**95**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

VHR and VHP options

These options do not change the *frequency* or *extent* of flood events but change the *consequence* of each event. The next section presents additional information on the reduction in risk (i.e. Annual Average Damage) associated with these options. The precise application of this policy could change. Therefore, we presented a number of scenarios to guide the assessment of this policy.

4 *Economic Benefits*

This chapter presents the economic benefits from the reduction in flood risks associated with each option. The calculations draw on the results from the flood modelling (presented in the previous chapter) and utilise the NSW Government's Flood Damage Assessment Tool. For the central case results we assume that:

- For residential properties, the 'largest building' on the lot is classified as the main residence, with other buildings on the site assumed to be of lesser value (such as sheds/garages). The largest building was based on the building footprint estimated from the building data in GIS format and structural/contents damage was calculated based on the depth of the flood. Dwellings on rural zoned land were treated as residential properties as well.
- For commercial/industrial properties, all buildings on the lot were treated equally and structural/contents damage was calculated based on the depth of the flood.

Benefits from risk reduction

The primary benefit of the levee upgrade options comes through the reduction in expected flood damages over the evaluation period of 50 years. The majority of damage is incurred by residential and commercial properties. These damages are split into four components:

- Structural damage to the building
- Internal damage, primarily damage to contents
- External damage, including damage to roads
- Intangible damage, which includes:
  - Injury and mortality, and
  - Mental health costs to residents and government.

Specific assumptions for the calculation of each of the four main damage types are presented in table 4.1. The assumptions are designed to be in line with the August 2023 *Flood Damage and Cost Benefit Assessment Tool* which was developed by the NSW Government to assess flood risk mitigation measures consistent with Flood Risk Management Measures Guide MM01.[18]

18 https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

4.1 Calculation assumptions

Assumptions	Central case
Which buildings are included	Damages are measured for the largest building on each residential property, based on flood height. It is assumed that any damage done to other buildings on a property are included in the external damages. For commercial/industrial properties, full damages are calculated for each building. Note there are some cases which have been identified of multi-unit residential properties. In these cases, all buildings have been treated as if they were the largest.
Structural damage	Damage is drawn from stage damage curves for each building type and size combination. See Appendix B for these curves. Where the largest building is under 50 square metres, structural damage is given by the damage from a 'small' building, scaled down linearly according to size.
Internal damage	Calculated the same way as structural damage. The stage damage curve for commercial buildings is always zero, so these incur no internal damage.
External damage	A single external damage figure of $17,000 applies to each property, irrespective of the number of buildings on the lot.
Intangible damage	Injuries and fatalities are only included for the largest building on each property, calculated primarily using flood depth and velocity. Other intangibles are scaled with size for buildings under 50 square metres. This category does not apply to commercial/industrial properties.
Other parameters	Drawn from Flood Risk Management Guide MM01 (DPE, 2022) and ABS. For details see Appendix B.

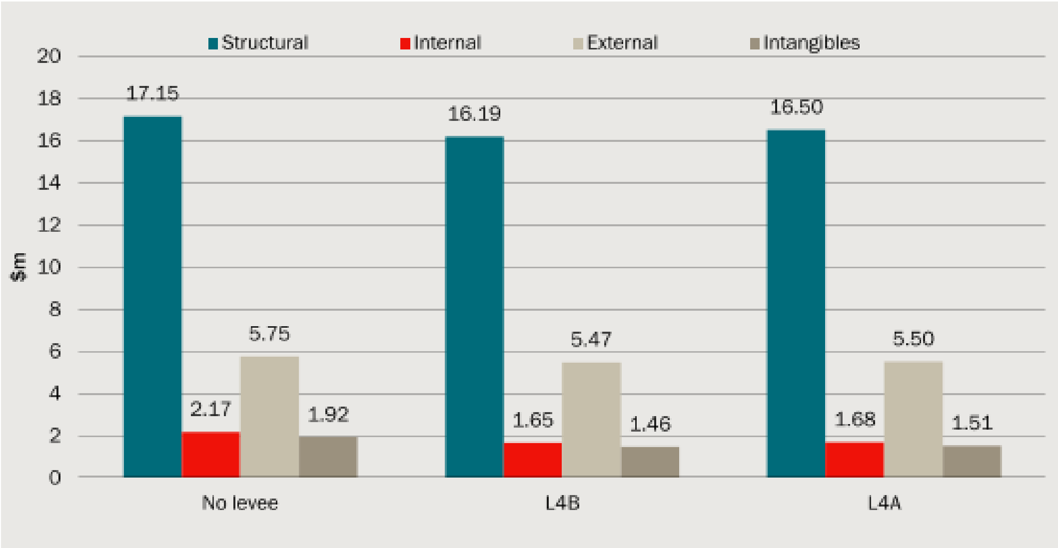
Source: The CIE.

Risk reduction - Options L4B and L4A

Chart 4.2 shows the reduction in AAD achieved by the levee upgrade with and without the surrounding works, split by damage type.

- On average the North Wagga Levee system on its own (i.e. option L4A) reduces AAD by $1.8m ever year in the central case, resulting in total risk reduction of $26.4m in present value terms over the 30 year period.
- Including the surrounding works reduce AAD by a further $0.5m, increasing total risk reduction to $34.6m.

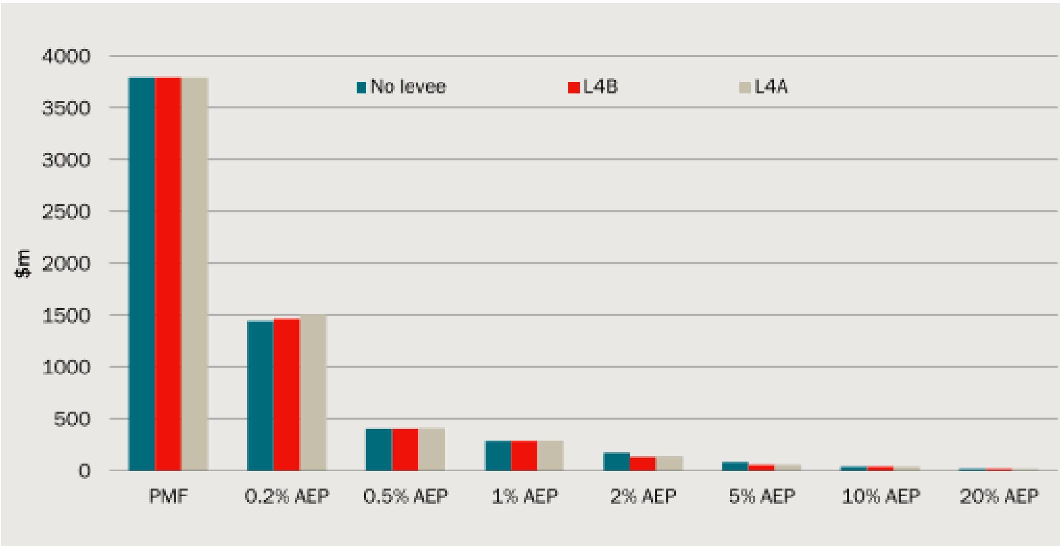
4.2 Impact of the L4B on annual average damage for a single year



Data source: The CIE.

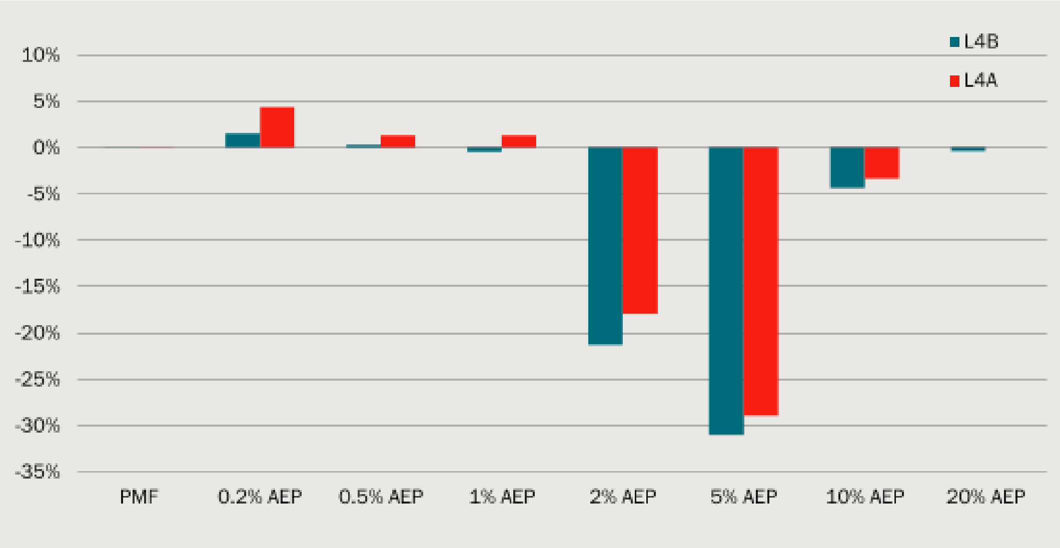
Breaking this damage down into contributions from each flood event, we can see that the benefits of the levee options are mostly achieved in the AEP 2% and the AEP 5% events. Chart 4.3 shows the level of damage in each flood event, and chart 5.4 shows the percentage change.

4.3 Total damage by AEP



Data source: The CIE.

4.4 Percentage change in damage in L4A and L4B relative to the base case



Data source: The CIE.

Table 4.5 shows the breakdown of damage in each AEP into damages from residential buildings, commercial buildings, and other damage types.

4.5 Detailed damage breakdown of L4A and L4B

	PMF	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
	$m	$m	$m	$m	$m	$m	$m	$m
No levee								
Residential	1557.6	484.1	108.8	87.3	66.1	32.4	6.5	0.9
Commercial	1989.8	864.8	238.2	148.7	62.4	17.3	11.7	6.9
Public	125.2	35.4	25.3	21.8	17.2	11.8	8.7	5.8
Injuries and fatalities	380.7	32.5	14.2	8.3	4.1	0.8	0.1	0.0
Mental health	57.1	24.9	5.6	4.7	3.7	1.6	0.3	0.0
Road repair	46.2	38.5	29.5	28.2	26.5	21.8	17.0	10.1
L4A								
Residential	1557.7	504.7	108.1	86.6	34.2	10.7	5.2	0.9
Commercial	1990.1	905.8	244.0	153.2	66.5	17.7	11.7	6.9
Public	125.2	35.8	25.4	21.7	15.0	11.1	8.7	5.8
Injuries and fatalities	380.8	35.1	13.7	8.1	1.9	0.6	0.1	0.0
Mental health	57.1	26.0	5.5	4.7	1.7	0.5	0.3	0.0
Road repair	46.3	38.8	29.6	28.3	26.6	20.4	16.9	10.1
L4B								
Residential	1557.7	490.4	108.0	84.7	33.0	10.4	5.1	0.9

	PMF	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Commercial	1990.0	879.7	240.1	150.1	62.9	16.4	11.3	6.9
Public	125.2	35.6	25.3	21.7	15.0	11.1	8.7	5.8
Injuries and fatalities	380.8	33.0	13.8	6.7	1.9	0.5	0.1	0.0
Mental health	57.1	25.3	5.5	4.6	1.6	0.5	0.3	0.0
Road repair	46.2	38.6	29.5	28.2	25.7	20.2	16.9	10.1

Note: There is some overlap between these categories. Residential damages include injuries, fatalities, and mental health.
Source: The CIE.

Risk reduction – VHR in North Wagga Wagga

Voluntary House Raising aims to reduce the damage to property in the flood plain area and reduce the risk to life of residents and potential rescuers. Residents would still have to evacuate as they do now.

There is a range of eligibility criteria for the VHR scheme. This includes, for example:

- Funding is only available for properties with buildings that were approved and constructed prior to 1986.
- Properties which are benefiting substantially from other floodplain mitigation measures –such as houses already protected by a levee or those that will be –may not be funded for VHR.
- VHR should generally return a positive net benefit in damage reduction relative to its cost. Consideration may be given to lower benefit-cost ratios where there are substantial social and community benefits or VHR is compensatory work for the adverse impacts of other mitigation works.
- Some houses may be unsuitable for raising due to construction methods.

For the purposes of the report we have modelled the VHR to apply to all targeted residential properties, noting that around 44 homes in North Wagga Wagga have already been raised. A further 59 homes have been identified as not being feasible to raise.

We have also assumed that the house will be raised 3m above the ground level for that property.

Raising houses will reduce structural, contents and intangible damages for a flood of the same size. Chart 4.6 shows the distribution of reduction in risk (i.e. AAD) per property in North Wagga Wagga before and after raising dwellings to 3m above ground level.[19]

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19 Note that only the largest building on each property was modelled as being raised to 3m off the ground. This does not apply to smaller buildings such as multiple sheds on the property.

4.6 Distribution of building AAD in North Wagga Wagga

Data source: The CIE

In total, there were 165 residential buildings raised in this analysis, with an average reduction in AAD by $12,154 per year for each raised building. However, there is a substantial level of variation across all the buildings of North Wagga Wagga, as indicated in the chart above.

Risk reduction – VHP in North Wagga Wagga

Voluntary House Purchase aims to reduce the number of people living in flood area and reduce the risk to life of residents and potential rescuers. The NSW Government has provided some further information about the scheme, particularly in relation to the February/March 2022 flooding in the Northern Rivers region. The factsheet for the Home Buyback Scheme states that,

> Homes being prioritised for a Home Buyback are in areas with more frequent, high and fast floods. There is a severe risk of future flood damage and a high risk to life in these areas. This includes the greatest risk to life to both residents and emergency response agencies sent to rescue them.[20]

Under the Scheme, a selection of the highest risk properties will be identified as potential candidates for further the buyback scheme. The buyback price is the market value of the property immediately prior to any flooding (i.e. pre-damage price).

For the purpose of this report, we have assumed that the policy applies to all residential properties in North Wagga Wagga. The purchase is assumed to occur immediately, rather than a delayed or staggered approach. Therefore, this would immediately eliminate the risks in North Wagga Wagga from current levels. The benefits (in terms of risk reduction) are equal to $50.5m in present value terms.

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20 https://www.nsw.gov.au/sites/default/files/2023-05/NRRC-Home-Buyback-Fact-Sheet-and-FAQs-May-2023.pdf

Risk reduction – combined options

For this study we have conducted further analysis of two alternative combined options. Note that the risks for each property changes following the levee construction. This changes the number of properties where it is cost effective to apply the VHP and VHR.

VHR and VHP

For this option we assume that the levee is not constructed. Instead, there is a combination of house raising and purchase which could apply in North Wagga Wagga, and to a limited extend other suburbs in the flood area.

- the house purchase option is applied to only those residential properties where the risks (AADs) currently exceed the proposed purchase price (assumed to be $400,000).
- the house raising option is then applied to the next group of properties where the risks are between $120,000 to $400,000.

This is likely to be the most economically feasible approach, if Council is seeking to provide a house purchase option for some owners which would eliminate the risks for these properties, including any risk to life.

4.7 Reduction in risk from combination of raising and purchasing

Region	Base Case AAD	Houses raised	Houses purchased	Project Case AAD	Risk reduction
	$m	no.	no.	$m	$m
North Wagga Wagga	57.2	78	19	27.6	29.6
All other suburbs	244.9	37	7	232.6	12.3
Total	302.1	115	26	260.2	41.9

Source: The CIE.

Combined VHR VHP and levee

For this option, the levee is constructed, and optionally the surrounding works. This provides protection for the North Wagga Wagga residents but it may increase the risk to properties outside North Wagga Wagga. The VHR and VHP options would then apply to residents *outside* North Wagga Wagga. We then assess the updated risks for properties outside North Wagga Wagga and apply the same $400,000 and $120,000 threshold rules noted above.

4.8 Reduction in risk from combination of levee, VHP and VHR

Chosen levee option	Base Case AAD	Houses raised	Houses purchased	Project Case AAD	Risk reduction
	$m	No.	No.	$m	$m
L4A	302.1	37	7	263.3	38.8
L4B	302.1	38	6	255.5	46.7

Note: Base case AADs are drawn from across the entire Wagga Wagga region, rather than just North Wagga Wagga.

5 Economic Costs

This chapter presents the economic costs associated with the options. The focus in this chapter is on the capital and ongoing operating costs with the options. There are also likely be some costs associated with loss of biodiversity due to clearing needed at Wilks Park for option L4B.[21] These additional biodiversity costs have not been accounted for in the costs below and will increase the costs further. Given this the costs below are likely to be an underestimate of the costs for L4B.

Voluntary house raising option – North Wagga Wagga

The cost of the house raising depends on a range of factors such as the types of homes and the height above ground level to which the property is raised. For the purpose of our analysis the Council has advised a construction cost of **$120,000 per property**, based on the recent experience in the Lismore flooding. The cost of $120,000 does not include any costs of improving the accessibility of the property (e.g. ramps). Therefore, the costs would be higher if residents required to improve access. Assuming that 165 homes are raised this equates to **$19.8m**.

We have assumed that this can raise the existing property by around 3m above ground level, although alternative raising levels are considered in the sensitivity analysis section later in this report.

Voluntary house purchase – North Wagga Wagga

For this option we have assumed that it would apply to all residential properties in North Wagga Wagga. Council has advised that, on average, the cost would be **$400,000/property**. This estimate aligns with the average property price estimate of $401,158/property based on publicly available data from the NSW Land Valuer General which indicates that there have been 19 residential property transactions in North Wagga Wagga in the calendar years 2022 and 2023.[22] Assuming that 266 homes are purchased equates to **$106m**.

There would also be additional costs if these homes are required to be demolished and, for example, turned into public land.

21 See separate report by NGH Consulting (2023), *Assessment of Environmental Constraints, North Wagga Flood Mitigation Options*, February.

22 https://valuation.property.nsw.gov.au/embed/propertySalesInformation

Option L4B and L4A

The option L4B is the high cost option and involves the construction of:

- A raised embankment
- Proposed road to adjoin existing abutment of Wiradjuri Bridge
- Proposed Bridge No.1 of 75m
- Proposed Bridge No.1 of 200m
- A 2.5m pathway adjacent to the proposed road.
- Concrete path to connect to the existing ATP network.

The estimated cost of the project (L4B) is **$86m (in present value terms)** including both the upfront capital costs and ongoing maintenance costs. These costs do not include the biodiversity offset costs associated with any land clearing required.

Upgrading the North Wagga Levee systems on their own (L4A) costs approximately **$10m.**

The detailed assumptions underpinning the cost estimates are available in a separate document from Council.

Combined options

As noted earlier, there are three separate options:

- The VHR and VHP options combined. This is applied to properties both in North Wagga Wagga and to properties in other flood impacted suburbs. It only applies to high risk properties where the estimated benefit exceeds the costs. The cost of this option is **$24.2m**, assuming that 115 houses are raised and 26 houses purchased.
- The L4A levee option, with the VHR and VHP options to high risk properties outside North Wagga Wagga. The lack of surrounding works means slightly more floodwater is deviated into surrounding suburbs, but only enough to justify the purchase of one additional property. A total of 37 houses are assumed to be raised and 7 purchased, with a combined cost of **$17.5m.**[23]
- The L4B levee option, with the VHR and VHP options combined. The L4B levee provides protection for properties in North Wagga Wagga. The VHR and VHP options would apply to properties outside this protection, and only applies to high risk properties where the estimated benefit exceeds the costs. The cost of this option is **$93.0m**, assuming that 38 houses are raised and 6 houses purchased.

Note that the number of properties raised and purchased in these options are also influenced by the discount rate chosen. Under the lower discount rate, this increases the value of the AAD reduction, therefore, there are more homes that exceed the $120,000 and $400,000 thresholds.

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23 We assume that the North Wagga Levee system is upgraded first and then we calculate the resulting AADs for the properties outside of North Wagga Wagga.

6 Cost benefit analysis results

Table 6.1 shows a summary of the overall costs and benefits of each option and combination of options modelled to date.

- **The best options are L4A, and a combination of L4A with VHR and VHP applied to high risk properties outside North Wagga Wagga.**

The high cost of L4B prevents it from being a worthwhile investment, even though it does achieve noticeable gains on top of L4A.

The majority of properties are not at sufficiently high risk to justify their purchase or raising, meaning that an optimal solution (from a cost effectiveness perspective) must target the highest risk properties for inclusion in VHP or VHR.

6.1 Summary of results

Option	Total benefit	Total cost	Net benefit	BCR
	$m	$m	$m	
L4A	26.4	10.3	**16.1**	**2.57**
L4B	34.6	86.0	**-51.4**	**0.40**
VHR	29.4	19.8	**9.6**	**1.48**
VHP	50.5	106.4	**-55.9**	**0.47**
L4A + VHR + VHP	38.8	17.5	**21.3**	**2.21**
L4B + VHR + VHP	46.7	93.0	**-46.3**	**0.50**
VHR + VHP	41.9	24.2	**17.7**	**1.73**

Source: The CIE.

VHR in North Wagga Wagga

A large number of residential properties in North Wagga Wagga are impacted by the floods, meaning that for many of them it is worthwhile to spend the $120,000 to raise the building by 3 metres. Table 6.2 shows the overall results from raising all homes which can be raised in North Wagga.

Overall, the option to raise every residential building in North Wagga results in benefits which exceed costs by **$9.6m**, with a benefit-cost ratio of **1.5**.

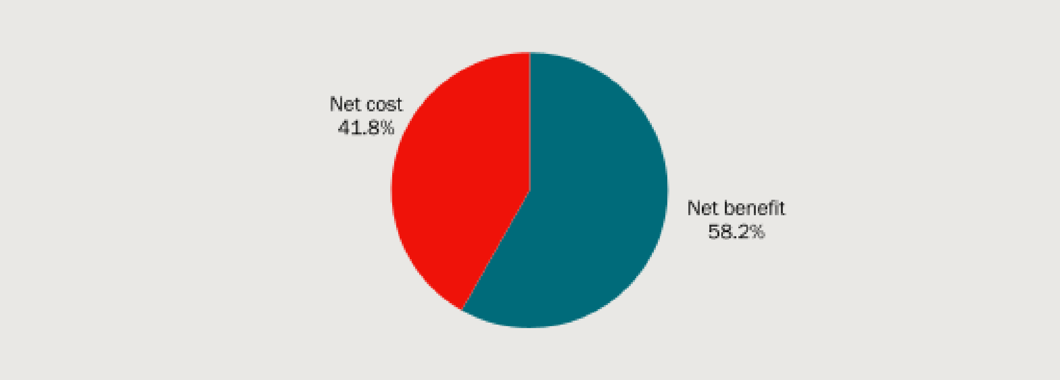
6.2 CBA results for voluntary house raising

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	19.8	74.4	36.2	38.2	18.4	1.9
0.05	**19.8**	**57.2**	**27.9**	**29.4**	**9.6**	**1.5**
0.07	19.8	45.3	22.1	23.3	3.5	1.2

Source: The CIE.

However, not every building sustains enough damage on average on floods for the investment to be worthwhile. Chart 6.3 shows that the proportion of buildings for which house raising constitutes a net economic benefit is slightly over half. If the program were restricted to only those buildings with expected damage over 30 years greater than $120,000, the net benefit would increase to $14m.

6.3 Proportion of raised building which receive net benefits from VHR scheme



Note: This only includes the buildings in North Wagga Wagga which can be raised and have not already been raised.
Data source: The CIE.

VHP in North Wagga Wagga

Unlike the house raising option, most residential properties in North Wagga on average do not sustain enough damage over 30 years to make the $400,000 purchase economical. Table 6.4 shows the impact of purchasing every residential property in the suburb.

For each building purchased, the entire stream of AAD is avoided. However, this does not entirely eliminate damage in the area, as there are still non-residential properties that would be damaged.

Comparing to the outcome of house raising in table 7.2, we can see that the house purchasing option delivers an additional $21.1m in benefits. The costs increase by $280,000 per property for the 266 properties purchased, overshadowing the marginal additional reduction in AAD.

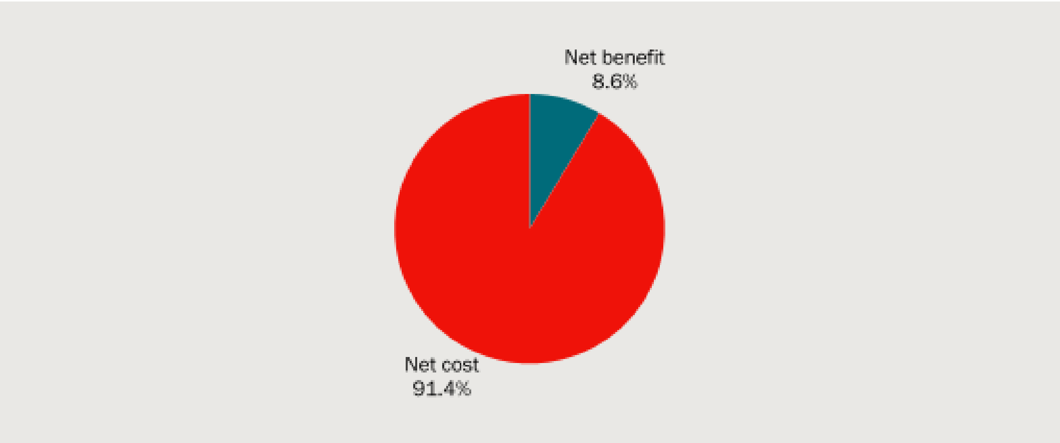
6.4 CBA results for voluntary house purchase

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	106.4	74.4	8.7	62.9	-43.5	0.59
0.05	**106.4**	**57.2**	**6.7**	**50.5**	**-55.9**	**0.47**
0.07	106.4	45.3	5.3	39.2	-67.2	0.37

Source: The CIE.

The maximum potential gains from the VHP option would be realised by only purchasing the houses where expected damage exceeds the purchase price of $400,000. There are only 19 such buildings across North Wagga Wagga. Purchasing only these properties would lead to a net gain of $10.8m.

6.5 Proportion of properties which receive net benefits from VHP scheme



Data source: The CIE.

Option L4B

The cost of building the raised embankment and all other components of the L4B option outweighs the benefits from the risk reduction. This option only substantially impacts floods in the 5 per cent and 2 per cent AEPs, with larger floods being unaffected. Table 6.6 shows the net benefit every year of the examination period of 30 years.

Table 6.7 shows the main CBA results for this option. The L4B option generates a **net loss** of $51.4m, with a corresponding BCR below 1. Table 7.7 shows that the levee does not have a positive return even if we (very generously) assume every building incurs the same level of structural and internal damage.

6.6 Cost and benefits of L4B over time

Year	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit
	$	$	$	$	$	$
2023	85 467 682	0	0	0	0	-85 467 682
2024	0	0	0	0	0	0
2025-2053	35 000	26 686 233	24 770 512	0	2 215 721	2 180 721
2054	35 000	26 686 233	24 770 512	9 689 255	11 904 976	11 869 976

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

6.7 CBA results of L4B

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	$m	
0.03	86.2	513.5	471.4	3.9	46.0	-40.1	0.53
0.05	**86.0**	**395.1**	**362.7**	**2.1**	**34.6**	**-51.4**	**0.40**
0.07	85.9	313.0	287.3	1.2	26.9	-59.0	0.31

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

Option L4A

Removing the additional works around the levee (road improvements, bridges, etc) drastically reduces the cost of the project. The corresponding drop in benefits is small relative to the size of this change in cost.

Yearly total benefits fell from $2.2m to $1.8m (tables 6.6 and 6.8 respectively), with total cost falling from $86m to $10m. This results in a final net benefit of **$16.1m**, and a BCR of **2.57**.

6.8 Costs and benefits of L4A over time

Year	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit
	$	$	$	$	$	$
2023	10 000 000	0	0	0	0	-10 000 000
2024	0	0	0	0	0	0
2025-2053	20 000	26 986 233	25 197 254	0	1 788 979	1 768 979
2054	20 000	26 686 233	25 197 254	1 133 675	2 922 654	2 902 654

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

6.9 CBA results of L4A

Year	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit
	$	$	$	$	$	$
2023	10 000 000	0	0	0	0	-10 000 000
2024	0	0	0	0	0	0
2025-2053	20 000	26 986 233	25 197 254	0	1 788 979	1 768 979
2054	20 000	26 686 233	25 197 254	1 133 675	2 922 654	2 902 654

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

Combined options

The combined options target properties that are high-risk, with raising or purchasing only being undertaken when it would result in a positive return. Consequently, by design, these options perform better than the blanket approach modelled in the individual risk mitigation strategies.

Table 6.10 shows the outcome of purchasing and raising at-risk properties across all of Wagga Wagga. The net benefit of $17.7m is the highest out of any option, with a BCR above 1.7.[24]

6.10 CBA results of combined targeted VHR and VHP options

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	37.7	392.7	328.9	63.9	26.2	1.69
0.05	**24.2**	**302.1**	**260.2**	**41.9**	**17.7**	**1.73**
0.07	18.9	239.3	209.7	29.7	10.8	1.57

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

This is a better result than using the levee L4B option to protect North Wagga Wagga and purchasing or raising properties in other parts of the township. Table 6.11 shows that the cost of this option remains prohibitively high, generating a **net cost** of $46.3m. Note that this is an improvement over L4B on its own, which had a net cost of $51.4m.

6.11 CBA results of combined L4B and VHR and HP outside North Wagga Wagga

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	97.6	392.7	346.4	46.3	-51.2	0.47
0.05	**93.0**	**302.1**	**255.5**	**46.7**	**-46.3**	**0.50**

24 Note that this BCR is smaller than that of L4A, even though VHR and VHP combined have a higher net benefit. This is because the cost is greater for VHR and VHP than for L4A.

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.07	90.3	239.3	216.9	22.5	-67.8	0.25

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

Finally, supplementing the already worthwhile L4A option with judicious use of VHR and VHP outside North Wagga Wagga results in the best net benefit out of the options modelled, at **$21.3m**. Table 6.12 shows the CBA results for this option.

6.12 CBA results of combined L4A and VHR and VHP outside North Wagga Wagga

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	22.1	392.7	355.8	37.0	14.9	1.68
0.05	**17.5**	**302.1**	**263.3**	**38.8**	**21.3**	**2.21**
0.07	15.0	239.3	221.5	17.9	2.8	1.19

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

A Flood probability terminology

Annual exceedance probability (AEP) should be used to assess the likelihood of a disaster occurring. AEP estimates the probability of a particular type of disaster, equal to or larger than a given magnitude, occurring in any year. The table below presents the AEP flood events modelled and their common equivalent presentation in 1 in X years.

A.1 Flood probabilities modelled

AEP	AEP
%	1 in X years
20	5
10	10
5	20
2	50
1	100
0.5	200
0.2	500
PMF	PMF

Source: WMA Water.

There are also alternative ways of expressing these probabilities which are a discussed further by Geosciences Australia.[25]

Average annual damage (AAD) estimates the expected yearly damage cost arising from all occurrences of a given natural hazard. AAD streamlines the calculation of expected damage and enables a like-for-like comparison between different risk mitigation options.

The expected AAD of any given year is the integration of the natural hazard risk density curve over all probabilities. Denoted by *D(p)*, the damage which occurs at the event with probability p, in the catchment with area A. The concept of AAD can be applied to all types of disasters.

$$AAD = \iint_{A\,p} D(p)\,dp\,dA$$

The NSW Government's *Disaster Cost-Benefit Framework TPG23-17* (section 3.5.2) issued in August 2023 presents an example of this calculation.

25 https://arr.ga.gov.au/__data/assets/pdf_file/0006/40398/New-ARR-Probability-Terminology_final.pdf

B CBA Tool Assumptions

This section discusses the key parameter values required to be used in the NSW Government's Flood Damage Assessment Tool and the assumptions adopted for this study.[26]

B.1 Residential

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Direct Tangible: Avoided residential property and content damages (structural, internal and external)	Avoided property damage costs due to external and internal flooding. Data is needed on the ground and floor level of each property for accurate measurement as internal flooding causes most damage. Stage-Damage Curves calculate the amount of damage that is incurred for a property, using inputs such as land use type, building types, and flood characteristics such as depth and velocity	Property sizes (floor area, per m2): ▪ Detached dwelling (single and double storey): 90 (small), 180 (medium), 240 (large), 220 (default) ▪ Unit or apartment: 100 ▪ Townhouse: 160 Structural replacement value (per m2): ▪ Detached dwelling (single storey): $2,280 ▪ Detached dwelling (double storey): $2,620 ▪ Unit: $2,730 ▪ Townhouse: $2,620 Contents value for residential properties (per m2): $550. External damage for residential properties (if ground flood depth exceeds 0.3 metres): $17,000 Damage downscale for units and townhouses: 30% Section 1.2.2 of Technical Note: Flood CBA Tool provides residential damage curve default values.

Source: NSW Treasury Flood Damage and Cost Benefit Assessment Tool

26 https://flooddata.ses.nsw.gov.au/flood-projects/nsw-flood-damage-assessment-tool-dt01

B.2 Direct Tangible damages

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Direct Tangible: Avoided **RESIDENTIAL** property and content damages (structural, internal and external)	Avoided property damage costs due to external and internal flooding. Data is needed on the ground and floor level of each property for accurate measurement as internal flooding causes most damage. Stage-Damage Curves calculate the amount of damage that is incurred for a property, using inputs such as land use type, building types, and flood characteristics such as depth and velocity	Property sizes (floor area, per m2): ▪ Detached dwelling (single and double storey): 90 (small), 180 (medium), 240 (large), 220 (default) ▪ Unit or apartment: 100 ▪ Townhouse: 160 Structural replacement value (per m2): ▪ Detached dwelling (single storey): $2,280 ▪ Detached dwelling (double storey): $2,620 ▪ Unit: $2,730 ▪ Townhouse: $2,620 Contents value for residential properties (per m2): $550. External damage for residential properties (if ground flood depth exceeds 0.3 metres): $17,000 Damage downscale for units and townhouses: 30% Section 1.2.2 of Technical Note: Flood CBA Tool provides residential damage curve default values.
Direct Tangible: Avoided **Commercial and Industrial** property and content damages	Commercial property damage depends on use. For instance, an electronics retailer would be expected to incur higher damages than a grocer. MM01 provides a practical approach categorising commercial property damage based on commercial use. The stage damage curve for commercial property is based on the square metreage of each property, which can be sourced from the local council. Data on the ground and floor levels of each property is also needed to determine when flooding overtops the external and internal components of the structure.	Property sizes (floor area, per m2), non-residential buildings: ▪ Average (default): 418 ▪ Low-to-medium value: 186 ▪ Medium-to-high value: 650 ▪ School: 17,000 ▪ Hospital: 28,000 ▪ Other public (government) buildings: 2,200 Section 1.2.3 of Technical Note: Flood CBA Tool provides commercial damage curve default values.
Direct Tangible: Avoided public infrastructure property and content damages	Public assets and infrastructure include high value assets such as bridges, roads, railways, and utility infrastructure (e.g. sewerage system, transmission lines and underground cabling).	Infrastructure damage uplift of total residential damage: 10% (drops to 5% if road damage is considered). External damage, road repair cost (per m2): $5.65. Section 1.2.4 of Technical Note: Flood CBA Tool provides public buildings stage-damage curve default values.

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
	Valuing infrastructure damage can be challenging. One approach is to apply an uplift to residential damages. Practitioners may also estimate the total replacement value of the asset and account for the AEP level at which the asset is inundated. Assets may fall into multiple AEP levels depending on the scale and nature of the asset, as well as the land that it encompasses. Additional detail may be needed to apportion asset replacement values across each AEP level. Geoscience Australia has developed the National Exposure Information System (NEXIS) dataset to capture exposure information for physical infrastructure assets and populations. Future improvements to the dataset will aim to provide replacement values for infrastructure assets at the local government level (Geoscience Australia, 2022).	
Direct Tangible: Avoided transport damage (roads, railways, train stations, bridges)	Transport infrastructure is vulnerable to flood damage, particularly when inundated for prolonged periods (Bureau of Transport Economics, 2001). Direct impacts include the cost of reconstruction and removing debris (The World Bank, 2016) as well as damage to the underlying structures (Tao & Mallick, 2020). Semi-rural and rural roads tend to be less resilient to flood damage, as they typically use more cost-effective materials.	External damage, road repair cost (per m2): $5.65.
Direct Tangible: Avoided vehicle damages	Flood water can compromise a vehicle's structural and electrical integrity leading to them being written off. Both commercial and private use vehicles should be considered.	Section 1.2.4 of Technical Note: Flood CBA Tool provides further guidance.
Direct Tangible: Avoided agricultural losses (crops and livestock)	Loss of crops and livestock will depend on the type of crop and the nature and duration of the flooding event. The season can also be relevant, as a crop has a higher value prior to harvest than when just planted. Under extended conditions of inundation, fungal and bacterial pathogens can further impact the crop, including through soil borne diseases.	May be included as a bespoke element.

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Direct Tangible: Avoided emergency services costs	An agricultural profile of the study area is required. The Australian Exposure Information Platform provides a summary of agriculture commodities by region.	Agriculture commodity (expected annual output per ha, per year):
Direct Tangible: Avoided clean-up costs	Clean-up costs relate to the time (opportunity cost of labour) and materials involved in cleaning up a property (residential or commercial). Estimated costs should reflect the extent of expected damage (e.g. ground floor flooding only).	Residential clean-up if affect by over-floor flooding (per property): $4,500. Non-residential clean-up cost and loss of trading: 30% of direct damage.

Source: NSW Treasury Flood Damage and Cost Benefit Assessment Tool

B.3 Intangibles

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Direct Intangible: Avoided mortality and injury	Floods have recorded one of the highest instances of fatalities, injuries and morbidities, among disasters in Australia (Commonwealth of Australia, 2020a).	Value of statistical life (Commonwealth Department of the Prime Minister and Cabinet, 2022) 2022 dollars:
Direct Intangible: Avoided environmental damages	Cost estimates should include the likely injury and loss of life. One method is the UK DEFRA Wallingford method, which estimates the potential reduction in risk to life associated with changes to flood behaviour (such as flood hazard: H1-H6). The method can be used to estimate losses across a study area but should not be used to estimate risk to life at the property scale.	
Indirect Tangible: Avoided business activity interruptions and loss of production	Lost production and forgone profit (difference between the price that a producer would have received and the marginal cost of production) due to business disruption. Lost production does not include damaged inputs or inventory, as these would have already been accounted for in commercial property and contents damage.	Non-residential indirect costs, comprising of clean-up costs and loss of trading: 30% of direct damages.
Indirect Tangible: Avoided service losses (damage to infrastructure and telecommunication networks)	Displacement should be considered as some lost production may be picked up by a non-flood affected business (e.g. revenue lost by a supermarket in a flood zone may be offset by increased revenue to another supermarket.	N/A
Indirect Tangible: Avoided accommodation and relocation costs	Some businesses may benefit, particularly if their goods or services are related to flood recovery.	Relocation cost (per week): $0

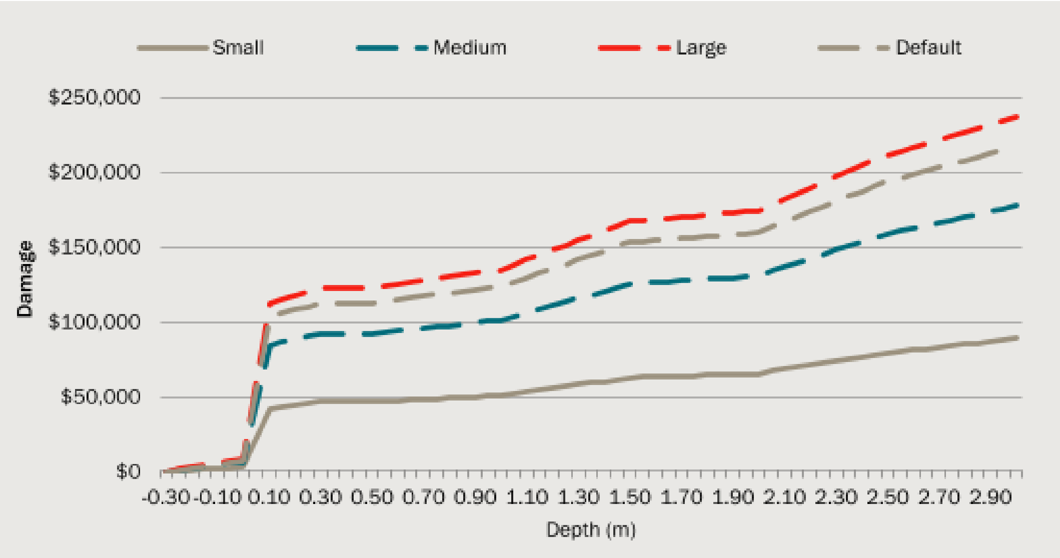
Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Indirect Intangible: Avoided stress, mental health and other health related impacts	Impacts may be estimated based on the cost of treatment, cost of work absenteeism and presenteeism and estimated increased prevalence due to floods. Longer displacements and higher levels of direct damage are associated with greater mental health impacts than brief displacements (Shih, 2022).	Mental health impacts based on food level, cost per household (2022 dollars):
Indirect Intangible: Avoided loss of social and cultural values	Further details are provided in Technical Note: Flood CBA Tool.	

Source: NSW Treasury Flood Damage and Cost Benefit Assessment Tool

Stage damage curves

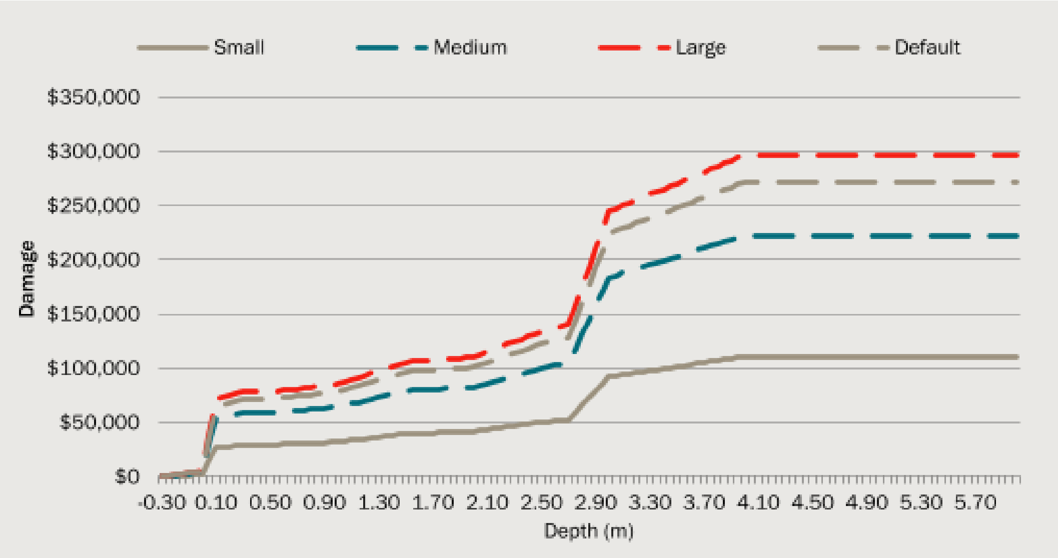
This section presents the stage damage curves used to determine residential and commercial structural and internal damages. Note that commercial internal damages are assumed to be zero everywhere, so that curve has been omitted.

B.4 Residential single story structural damage curve



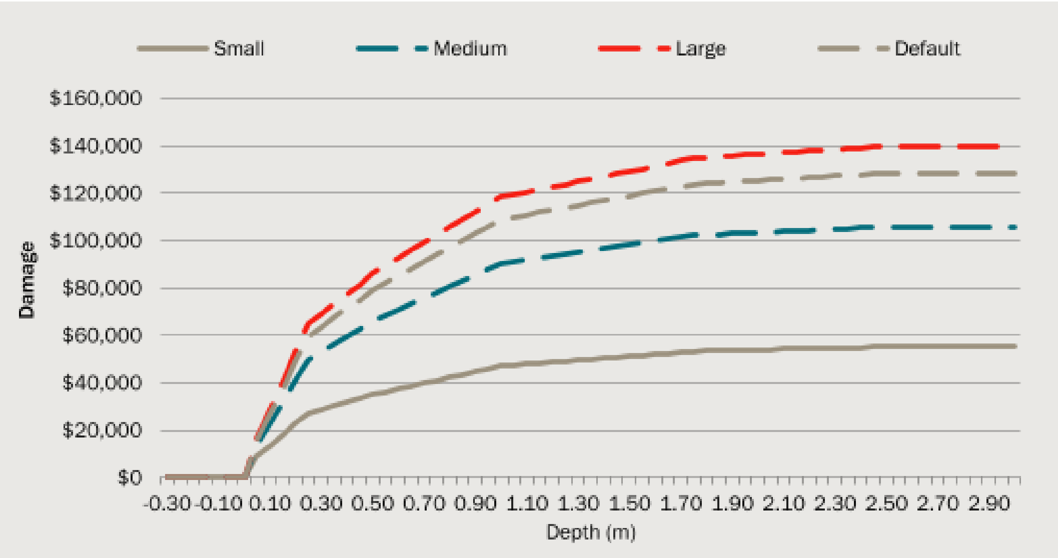
Data source: NSW Treasury Flood CBA Tool.

B.5 Residential double storey structural damage curve



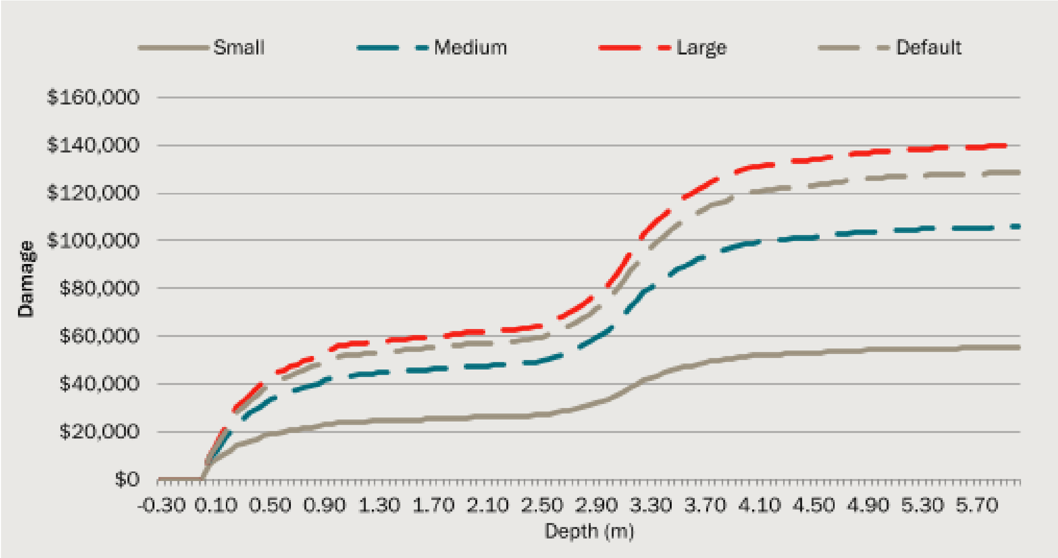
Data source: NSW Treasury Flood CBA Tool.

B.6 Residential single story internal damage curve



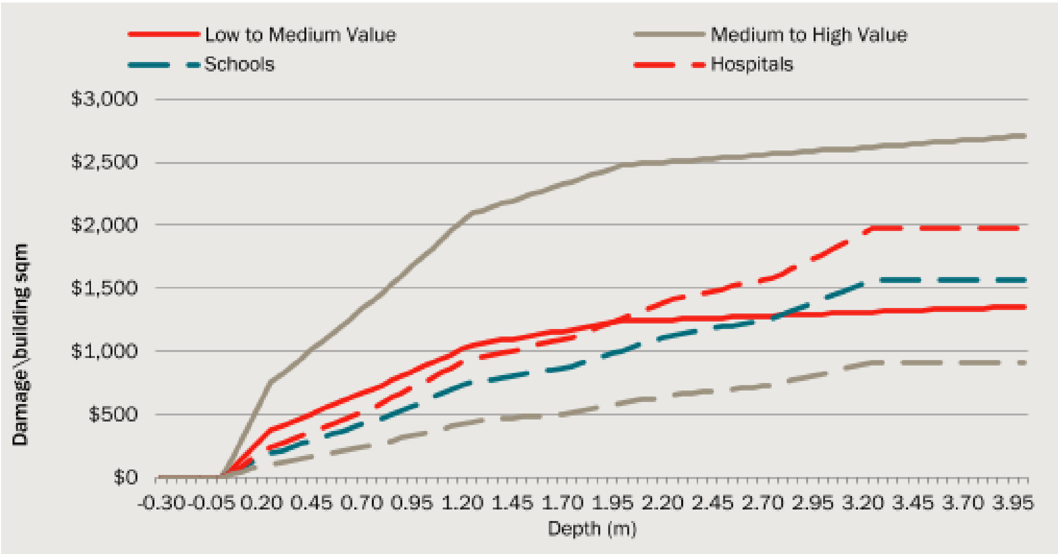
Data source: NSW Treasury Flood CBA Tool.

B.7 Residential double story internal damage curve



Data source: NSW Treasury Flood CBA Tool.

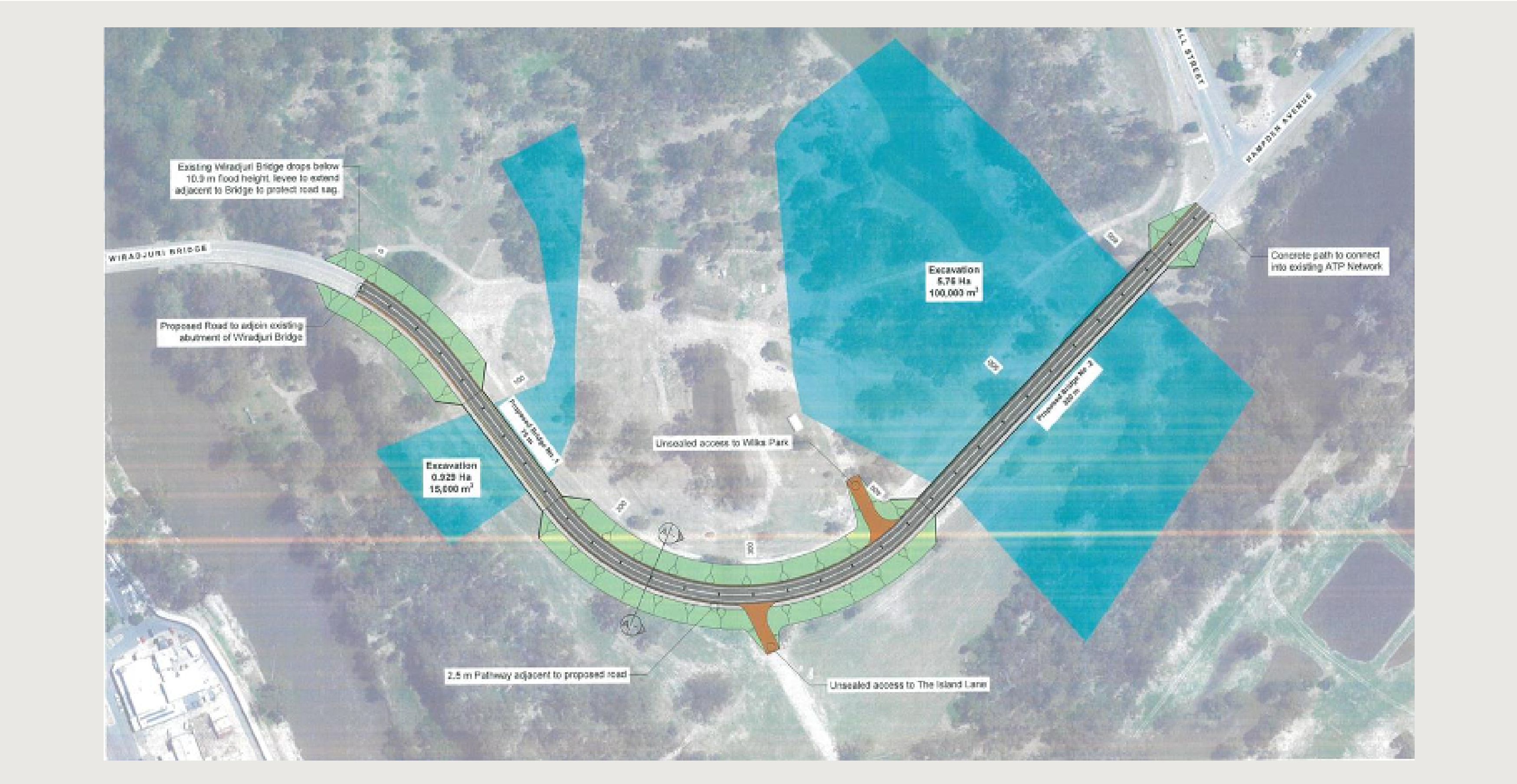
B.8 Commercial structural damage curve



Note: Commercial structural damage is given on a per square metre basis, as opposed to residential stage damage curves, which sorts buildings into size classes.

Data source: NSW Treasury Flood CBA Tool.

B.9 Option L4B Works required



Source: Wagga Council

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