

APPENDIX N – Economic Flood Damages

N Economic Flood Damages

N.1 Damage Categories

In order to quantify the economic impacts of flooding, a flood damage assessment has been undertaken. A property may suffer economic impacts from flooding through several ways. These are broadly grouped into three categories, as summarised in **Table N. 1**.

Table N. 1 Flood Damages Categories

| Type of Flood Damages | | Description |
|-----------------------|-----------------|--|
| Tangible | Direct | Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.) Infrastructure |
| | Indirect | Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services) |
| Intangible | | Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage |

Damage dealt directly to a property or its contents (direct damages) are only a component of the total damages accrued during a flood event. Indirect costs, while also tangible, arise as a result of consequences of the flood event, such as clean-up costs, opportunity costs, and other financial impacts.

In addition to tangible damages, there are also a category of damages referred to as intangible damages. Intangible costs relate to social impacts, such as insecurity and depression, that arise as a result of major flood event, or general inconveniences that occur during the post-flood stage. The intangible costs are difficult to calculate in economic terms.

N.2 Property Survey

Detailed floor level survey was available for a total of 1,606 properties within the Woy Woy study area. The floor levels of the remaining properties (11,513) were estimated using aerial imagery, Google Street view and site inspections, whilst the ground level was estimated using the LiDAR derived ground surface DEM. Where it was not possible to get a good reading of the floor level of a property, the damages assessment assumed that the floor level was 0.3 metres higher than the ground level. A total of 13,119 properties were assessed in terms of floodplain damages, with a breakdown of their survey source provided in **Table N. 2**.

Table N. 2 Property Survey in Woy Woy Study Area

| Survey Source | Residential Single Storey | Residential Double Storey | Commercial | Total |
|----------------|---------------------------|---------------------------|------------|--------|
| Woy Woy | 138 | 24 | 3 | 165 |
| Brisbane Water | 680 | 256 | 89 | 1,025 |
| Kahibah Creek | 245 | 0 | 2 | 247 |
| Kahibah | 167 | 0 | 2 | 169 |
| 'Estimated' | 11,300 | N/A | 213 | 11,513 |
| Total | 12,530 | 280 | 309 | 13,119 |

Due to the large number of properties estimated through aerial imagery and Google Maps, the damages assessment assumed that these properties were single storey. A full list of assumptions and inputs is provided in the following section.

N.3 Methodology, Assumptions and Inputs

The damage assessment undertaken for this study has examined the tangible damages only, using the Excel template (Version 3.00) developed by the Department of Environment and Climate Change (DECC) (now DPIE) in 2007. The spreadsheet provides damage curves for three residential building types:

1. Single storey, high set
1. Single storey, slab on ground
2. Two storey, slab on ground.

Damage curves for commercial buildings were derived using ANUFLOOD, with values indexed to present day dollars (\$2021).

The spreadsheet is subject to a number of assumptions and inputs, which are detailed in **Table N. 3**. The residential and commercial damage curves applied to the analysis are illustrated in **Figure N. 1**. The sudden jump in the two storey damage curve at a depth of 2.60m indicates that the flooding is starting to impact the upper storey, significantly increasing the damages incurred.

Table N. 3 List of assumptions and inputs in the damages assessment

| Assumption / Input | Value | Justification |
|--------------------------------|---------|---|
| Regional cost variation factor | 1.02 | Obtained from Rawlinsons – Regional Indices. Gosford is 1.02, relative to Sydney (1.00), and is the closest location to Woy Woy |
| Inflation adjustments | 2.02 | Based on Average Weekly Earning (AWE): November 2020: \$1,711.60 November 2001: \$848.70 |
| Post-flood inflation factor | 1.50 | Large scale impacts in a regional area, with more than 150 properties affected |
| Typical duration of immersion | 6 hours | Assumed |

| Assumption / Input | Value | Justification |
|---|-------------------------|--|
| Building damage repair limitation factor | 0.85 | Short duration |
| Typical house size | 170 m ² | Estimated, based on aerial imagery of a range of representative properties |
| Contents damage repair limitation factor | 0.75 | Short duration |
| Level of flood awareness | Low | Assumed |
| Effective warning time | 0 hours | Assumed |
| Interpolated Damage Reduction Factor | 1.00 | Assumed |
| Likely time and cost in alternate accommodation | 6 weeks, \$220 per week | Recommended values |
| Clean-up costs | \$4,000 | Recommended value, per property |
| External/Garden damage: Major cost | \$5,000 per property | Triggered if depth of inundation above ground level is greater than 0.50 metres |
| External/Garden damage: Minor cost | \$500 per property | Triggered if depth of inundation above ground level is greater than 0.15 metres but less than 0.50 metres |
| Single Storey Properties | High-Set | All single storey properties within the study area are assumed to be high-set (as opposed to slab on ground) |
| Commercial and Industrial properties | Low value | All commercial and industrial properties within the study area are assumed to be of low value (as opposed to medium or high) |

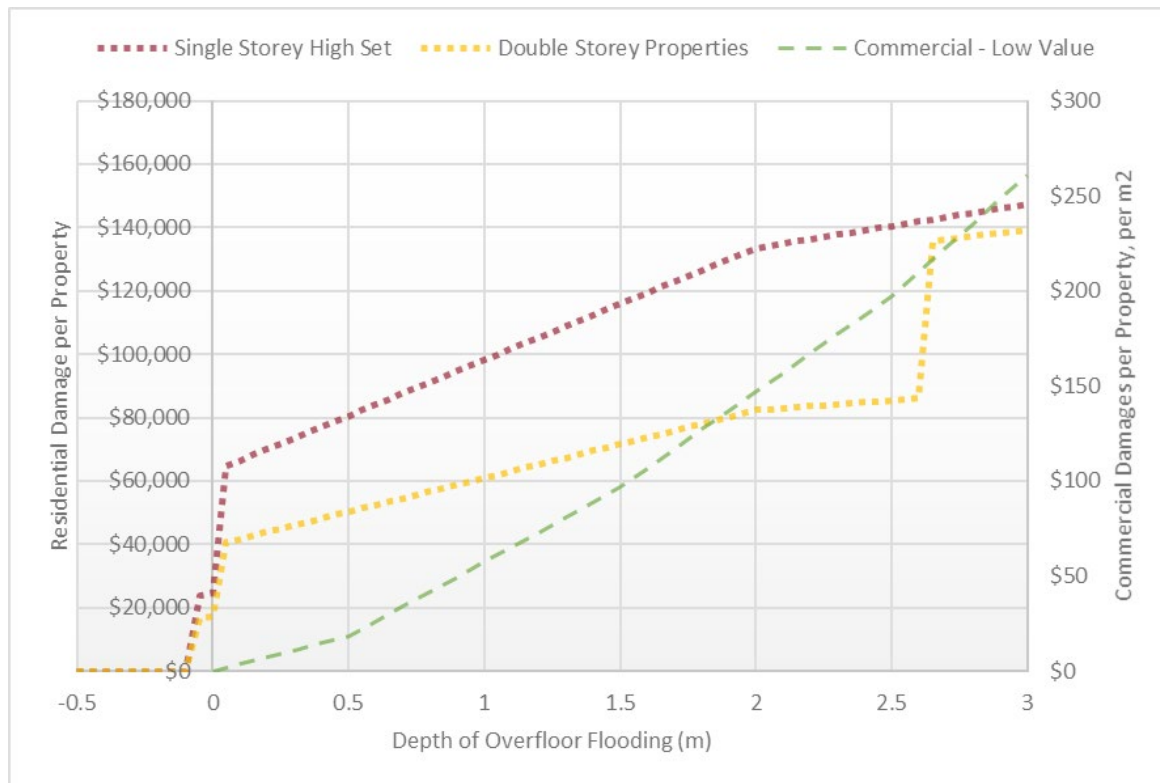


Figure N. 1 Damage Curves

The following events were modelled in terms of catchment flooding to form the basis of the floodplain damages assessment:

- PMF
- 1% AEP
- 10% AEP
- 20% AEP

N.3.1 Technical Note: Damages Calculation

The floodplain damages associated with the base case were calculated based on the median temporal pattern for the critical storm across the mitigation option locations. The change in damages associated with each floodplain management option was calculated based on the difference between the median temporal pattern and critical duration of the flood event, as detailed below:

- PMF: 2 hour critical duration
- 1% AEP: 6 hour critical duration, temporal pattern 09
- 10% AEP: 3 hour critical duration, temporal pattern 04
- 20% AEP: 1 hour critical duration, temporal pattern 03

N.4 Results: Existing (Base Case)

The results from the damage assessment are summarised in **Table N. 4**. The average annual damage (AAD) for the Woy Woy study area under existing conditions is \$2,911,637. Over a 50-year assessment period and under a seven per cent discount rate, this is equivalent to a Net Present Value (NPV) of \$40.2 million. Note that these damages were calculated based on the tangible damages only.

Table N. 4 Woy Woy – Existing Damages Assessment Results

| AEP | Properties with Over-Floor Flooding | Max Over-Floor Depth (m) | Average Over-Floor Depth (m) | Total Damages |
|---------|-------------------------------------|--------------------------|------------------------------|---------------|
| PMF | 2,138 | 2.07 | 0.23 | \$165,207,840 |
| 1% AEP | 36 | 1.54 | 0.25 | \$2,603,748 |
| 10% AEP | 19 | 1.36 | 0.25 | \$1,459,712 |
| 20% AEP | 16 | 0.32 | 0.12 | \$1,152,774 |

As there are 2,138 properties in the damages assessment that experience over-floor flooding in the PMF, this equates to an AAD per property of \$620.

The removal of garden damages has a negligible impact on the result of the damages assessment, suggesting that the outcome of the damages is not sensitive to this assumption.

As an additional sensitivity test, an assessment was undertaken for the assumption of all buildings using floor levels estimated based on ground LiDAR values. The assumed value of 0.3m above ground level was based on a combination of site inspections, Google Streetview and aerial imagery. **Table N. 5** shows the impact of increasing this value on over floor flooding and total damages.

Table N. 5 Existing Damages Assessment Results – Sensitivity to Estimated Floor Level Heights

| | | 0.3m Above Ground Level | 0.4m Above Ground Level | 0.5m Above Ground Level | 0.6m Above Ground Level |
|-----------------------|-------------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| PMF | Properties with Over-Floor Flooding | 2,138 | 1,538 | 1,127 | 823 |
| | Total Damages | \$165,207,840 | \$121,392,367 | \$89,602,079 | \$67,738,650 |
| 1% AEP | Properties with Over-Floor Flooding | 36 | 35 | 34 | 34 |
| | Total Damages | \$2,603,748 | \$2,575,765 | \$2,530,196 | \$2,463,699 |
| 10% AEP | Properties with Over-Floor Flooding | 19 | 19 | 18 | 18 |
| | Total Damages | \$1,459,712 | \$1,456,185 | \$1,391,451 | \$1,367,448 |
| 20% AEP | Properties with Over-Floor Flooding | 16 | 16 | 15 | 15 |
| | Total Damages | \$1,152,774 | \$1,086,729 | \$1,062,274 | \$1,062,274 |
| Average Annual Damage | | \$1,324,615 | \$1,090,814 | \$918,702 | \$803,890 |

The estimated floor level above ground level has a minor impact on the resultant AAD (potentially a 18% to 39% reduction when increased 0.1m to 0.3m, respectively). This reduction is mostly attributed to reduction in damages in the PMF event. In the smaller modelled events, over floor flooding is largely experienced by dwellings which have had their floor levels surveyed, hence the reduction of only one or two properties experiencing a change when the estimated floor level elevation is increased.

N.5 Results: Options

The flood damages assessment is a useful tool for comparing the merits of various options, it is not a precise flood risk analysis tool and the limitation associated with the assessment should be considered when interpreting the results. The outcomes of the damages assessment for the seven options that were assessed in detail are provided in the following sections.

The PMF event was removed from the damages assessment, as it was concluded that the modelled flood mitigation options have minimal effect on design flood levels and the effect on reduction in AAD is negligible.

The economic evaluation of each of these options was also assessed by considering the reduction in the amount of flood damages incurred for the design events and by then comparing this value with the cost of implementing the measure.

The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C or BCR), which is based on the net present value (NPV) of the benefits (reduction in AAD) and the costs (capital and ongoing), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure, relate to its cost of construction and maintenance:

- Where the benefit-cost ratio is greater than 1, the economic benefits are greater than the costs of implementing the measure;
- Where the benefit-cost ratio is less than 1 but greater than 0, there is still an economic benefit from implementing the measure but the cost of implementing the measure is greater than the economic benefit;
- Where the benefit-cost is equal to zero, there is no economic benefit from implementing the measure; and
- Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

The following sections detail the damage assessment results for each of the seven options. The Figure below displays the difference in Annual Average Damage (AAD) between the floodplain mitigation option and the Base Case (existing scenario).

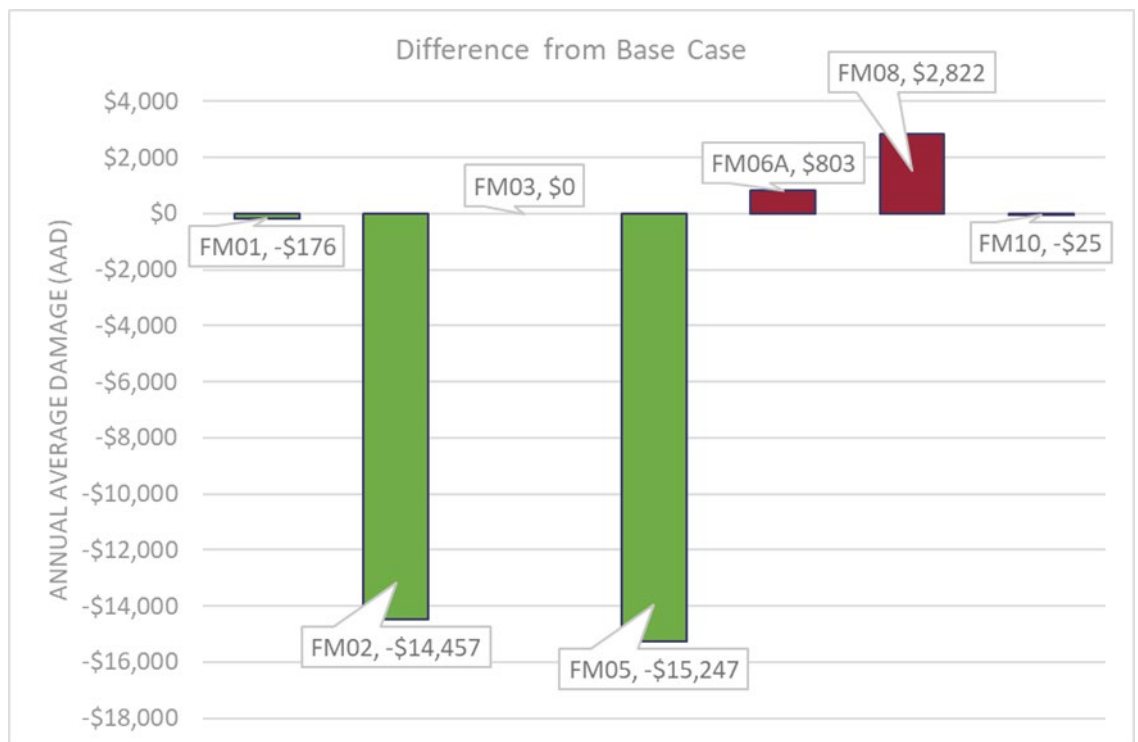


Figure N. 2 Difference in AAD between floodplain options and the Base Case (existing scenario)

N.5.1 FM01

FM01 considers mitigation of flooding around Woy Woy CBD which is low-lying area close to the coastline.

The table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show a marginal reduction in the AAD (\$176). There is also a negligible change in the number of properties affected by over-floor and overground flooding as a result of implementing this mitigation option.

Table N. 6 FM01: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages |
|---------|-------------------------------------|------|---------------------------|------|------------------------|-------------|----------------------|
| | Existing | FM01 | Existing | FM01 | Existing | FM01 | |
| 1% AEP | 36 | 36 | 239 | 239 | \$2,603,748 | \$2,600,221 | \$3,527 |
| 10% AEP | 19 | 19 | 92 | 92 | \$1,459,712 | \$1,459,712 | \$0 |
| 20% AEP | 16 | 16 | 73 | 73 | \$1,152,774 | \$1,152,774 | \$0 |
| AAD | | | | | \$1,324,615 | \$1,324,439 | \$176 |

The cost of implementing Option FM01 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table K.1 FM01: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | NPV | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|--------------|--------------------|
| FM01 | \$1,708,840 | \$500 | \$1,603,947 | \$2,434 | -\$1,601,513 | 0.00 |

N.5.2 FM02

FM02 considers the increase of drainage capacity at Dulkala Road to Karingal Close including the utilization of the public space north of Dulkala Road and west of St John the Baptist Catholic Primary School. Modifications include increase of the drainage pipe sizes and gradient changes to Karloo Rd and Lentara Rd to reduce flow entering to properties.

The table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show a minor reduction in the AAD (\$14,457), despite a negligible change in the number of properties affected by over-floor and overground flooding as a result of implementing this mitigation option.

Table N. 7 FM02: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages |
|---------|-------------------------------------|------|---------------------------|------|------------------------|-------------|----------------------|
| | Existing | FM02 | Existing | FM02 | Existing | FM02 | |
| 1% AEP | 36 | 35 | 239 | 238 | \$2,603,748 | \$2,559,888 | \$43,861 |
| 10% AEP | 19 | 19 | 92 | 92 | \$1,459,712 | \$1,421,498 | \$38,215 |
| 20% AEP | 16 | 16 | 73 | 73 | \$1,152,774 | \$1,109,607 | \$43,167 |
| AAD | | | | | \$1,324,615 | \$1,310,158 | \$14,457 |

The cost of implementing Option FM02 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table N. 8 FM02: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | NPV | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|------------|--------------------|
| FM02 | \$653,100 | \$500 | \$617,274 | \$199,512 | -\$417,762 | 0.32 |

N.5.3 FM03

FM03 considers the installation of infiltration devices along streets with ponding. A number of infiltration devices were tested in several locations of the Woy Woy peninsula previously and showed improvements to local drainage issues, while the maintenance of devices has been a challenge.

The Table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show no reduction in the AAD, and no change in the number of

properties affected by over-floor and overground flooding as a result of implementing this mitigation option.

The cost of implementing Option FM03 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table N. 9 FM03: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | NPV | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|------------|--------------------|
| FM03 | \$144,200 | \$6,000 | \$217,571 | \$0 | -\$217,571 | 0.00 |

N.5.4 FM05

FM05 considers increasing the capacity of the drainage along The Rampart, Greenhaven Drive, Australia Avenue, and Glenhaven Close and navigating more ponding water to the drainage system.

The Table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show a minor reduction in the AAD (\$15,247), despite a negligible change in the number of properties affected by over-floor and overground flooding as a result of implementing this mitigation option.

Table N. 10 FM05: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages |
|---------|-------------------------------------|------|---------------------------|------|------------------------|-------------|----------------------|
| | Existing | FM05 | Existing | FM05 | Existing | FM05 | |
| 1% AEP | 36 | 35 | 239 | 237 | \$2,603,748 | \$2,601,532 | \$2,216 |
| 10% AEP | 19 | 19 | 92 | 92 | \$1,459,712 | \$1,435,709 | \$24,003 |
| 20% AEP | 16 | 16 | 73 | 73 | \$1,152,774 | \$1,088,493 | \$64,281 |
| AAD | | | | | \$1,324,615 | \$1,309,368 | \$15,247 |

The cost of implementing Option FM05 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table N. 11 FM05: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | Net Present Value | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|-------------------|--------------------|
| FM05 | \$163,520 | \$0 | \$152,822 | \$210,424 | \$57,601 | 1.38 |

N.5.5 FM06A

Council has been undertaking a routine vegetation maintenance program at the Kahibah Creek system established following the *Kahibah Creek Floodplain Management Plan* (Willing & Partners, 1996) as well as development controls along the drainage reserves along the channels.

The Baseline model was modified to increase surface roughness along the creek riparian area, representing a scenario prior to when the routine maintenance started taking place. This option determines the viability of the current maintenance program by comparing the benefits it produces against the cost of its implementation.

The table below shows a comparison between the forecasted results of the vegetation maintenance program against the scenario where it is not implemented. The results show a marginal decrease in the AAD (\$803).

Table N. 12 FM06A: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages |
|---------|-------------------------------------|-------|---------------------------|-------|------------------------|-------------|----------------------|
| | Existing | FM06A | Existing | FM06A | Existing | FM06A | |
| 1% AEP | 36 | 36 | 239 | 243 | \$2,603,748 | \$2,613,625 | \$9,877 |
| 10% AEP | 19 | 20 | 92 | 92 | \$1,459,712 | \$1,462,298 | \$2,586 |
| 20% AEP | 16 | 16 | 73 | 73 | \$1,152,774 | \$1,153,091 | \$317 |
| AAD | | | | | \$1,324,615 | \$1,325,418 | \$803 |

The cost of implementing the vegetation maintenance program is compared against the reduction in AAD to provide a benefit cost ratio (see table below).

Table N. 13 FM06A: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | Net Present Value | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|-------------------|--------------------|
| FM06A | \$0 | \$320,000 | \$4,416,239 | \$11,079 | \$4,405,160 | 0.00 |

N.5.6 FM08

Palmtree Grove Detention Basin stores flow from the upper catchment originating on the escarpment. It is registered as a declared dam and requires significant maintenance costs for Council. FM08 considers the impact on flood risk in case that the basin storage is reduced. To minimize the impact, alternative mitigation measures are proposed.

The table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show a minor increase in the AAD (\$2,822). This is resulting from the behaviour of the dam producing additional flood flows towards properties in the 20% AEP, while in larger events, these flood levels are reduced because a greater proportion of flow is directed along Palmtree Grove.

Table N. 14 FM08: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages [^] |
|--------|-------------------------------------|------|---------------------------|------|------------------------|-------------|-----------------------------------|
| | Existing | FM08 | Existing | FM08 | Existing | FM08 | |
| 1% AEP | 36 | 34 | 239 | 238 | \$2,603,748 | \$2,576,510 | \$27,238 |

| | | | | | | | |
|---------|----|----|----|----|-------------|-------------|-----------|
| 10% AEP | 19 | 19 | 92 | 92 | \$1,459,712 | \$1,453,449 | \$6,264 |
| 20% AEP | 16 | 16 | 73 | 74 | \$1,152,774 | \$1,176,667 | -\$23,893 |
| AAD | | | | | \$1,324,615 | \$1,327,437 | -\$2,822 |

[^] A negative reduction corresponds to an increase in flood damages

The cost of implementing Option FM08 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table N. 15 FM08: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | Net Present Value | Benefit Cost Ratio* |
|--------|--------------|-------------------------|--------------|-------------------------|-------------------|---------------------|
| FM08 | \$295,400 | -\$30,000 | -\$137,948 | -\$38,943 | \$99,005 | 3.54 |

[^] This BCR interprets the negative benefits as costs and negative costs as benefits.

N.5.7 FM10

FM10 considers increasing the capacity of the drainage at Neera Road and navigating more ponding water to the drainage system.

The Table below shows a comparison between the forecasted results of the mitigation option and the Base Case. The results show no significant reduction in the AAD (\$25). There is also no change in the number of properties affected by over-floor and overground flooding as a result of implementing this mitigation option.

Table N. 16 FM10: Comparison with Existing Damages

| | Properties with Over-Floor Flooding | | Flood affected properties | | Total Damages (\$2021) | | Reduction in Damages |
|---------|-------------------------------------|------|---------------------------|------|------------------------|-------------|----------------------|
| | Existing | FM10 | Existing | FM10 | Existing | FM10 | |
| 1% AEP | 36 | 36 | 239 | 239 | \$2,603,748 | \$2,603,248 | \$500 |
| 10% AEP | 19 | 19 | 92 | 92 | \$1,459,712 | \$1,459,712 | \$0 |
| 20% AEP | 16 | 16 | 73 | 73 | \$1,152,774 | \$1,152,774 | \$0 |
| AAD | | | | | \$1,324,615 | \$1,324,590 | \$25 |

The cost of implementing Option FM10 is compared against the reduction in AAD (compared to the existing case) to provide a benefit cost ratio (see Table below).

Table N. 17 FM10: Economic Results

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | Net Present Value | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|-------------------|--------------------|
| FM10 | \$138,880 | \$0 | \$129,794 | \$345 | -\$129,449 | 0.00 |

N.6 Results Summary: Economic Outcome of Options

The economic assessment considers the comparative costs and benefits of the proposed floodplain management options against the existing scenario (base case). The economic merit of the options was determined by comparing the present value (PV) of the change in AAD (compared with the base case) less the change in capital and maintenance costs.

The Table below and **Figure N. 3** summarises the results of the economic assessment of floodplain damages for the seven options, across a 50-year assessment period. A positive NPV and BCR greater than one support a claim for the program to be considered as economically feasible.

Table N. 18 Economic Summary of Floodplain Management Options

| Option | Capital Cost | Recurrent Cost (Annual) | NPV of Costs | NPV of Reduction in AAD | Net Present Value | Benefit Cost Ratio |
|--------|--------------|-------------------------|--------------|-------------------------|-------------------|--------------------|
| FM01 | \$1,708,840 | \$500 | \$1,603,947 | \$2,434 | -\$1,601,513 | 0.00 |
| FM02 | \$653,100 | \$500 | \$617,274 | \$199,512 | -\$417,762 | 0.32 |
| FM03 | \$144,200 | \$6,000 | \$217,571 | \$0 | -\$217,571 | 0.00 |
| FM05 | \$163,520 | \$0 | \$152,822 | \$210,424 | \$57,601 | 1.38 |
| FM06A | \$0 | \$320,000 | \$4,416,239 | \$11,079 | \$4,405,160 | 0.00 |
| FM08 | \$295,400 | -\$30,000 | -\$137,948 | -\$38,943 | \$99,005 | 3.54 |
| FM10 | \$138,880 | \$0 | \$129,794 | \$345 | -\$129,449 | 0.00 |

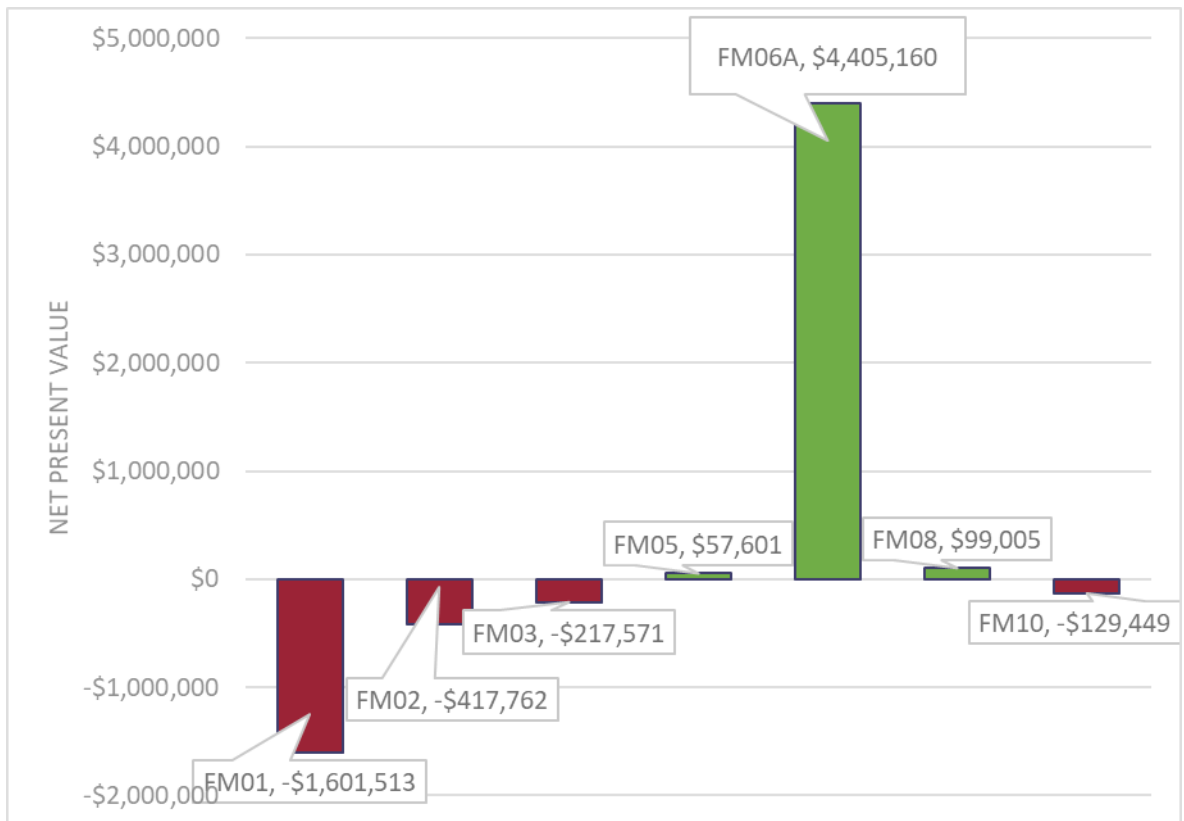


Figure N. 3 Net Present Value of Floodplain Management Options

The results show that FM05 and FM08 are the best performing options, with a BCR greater than 1. Both FM06A and FM08 result in increased flood damages to private properties.