Integrating non-market values in economic analyses of flood mitigation: a case study of the Brown Hill and Keswick creeks catchment in Adelaide

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Abstract: This study undertakes an economic analysis of flood mitigation options for a high flood risk catchment in Adelaide, South Australia: the Brown Hill and Keswick creeks catchment. Several proposals for flood mitigation investments have been presented, including creek capacity upgrades, high flow bypass culverts and detention dams. For flood managers to know which option or options provide the best value for money, it is necessary to compare the costs and the benefits of all available options. To date, economic analyses have focused primarily on estimating the tangible (market) costs and benefits of mitigation strategies, but have largely ignored the intangible (non-market) costs and benefits. This analysis improves upon previous studies by conducting a cost benefit analysis that incorporates the intangible costs and benefits of mitigation. We used the benefit transfer method to include eight different intangible values that can be affected by floods or by the implementation of the proposed mitigation options. We found that for this particular case study in the Brown Hill and Keswick creeks catchment, the inclusion of intangible values does not change the results of the analysis significantly; the results with and without intangibles are relatively similar. This is because intangible values are relatively small compared to the potential tangible flood damages as intangible value losses represent only between 6 and 21% of total damages. In order to better understand people's preferences and the trade-offs they make, a survey based nonmarket valuation research would need to be conducted amongst the residents at risk of flooding. Such a study would provide values that are specific to the catchment and could be compared with the intangible values from the literature that have been assembled for this study.

Key words: Non-market values, benefit transfer, flood mitigation, economic analysis

JEL classifications: Q54 Natural Disasters and Their Management, Q58 Government Policy

1. Introduction

The extent of damages caused by floods can be great. In 2002, for example, floods in Germany, Austria and the Czech Republic caused about €15 billion in damages. In Australia, floods are the most frequent natural disaster resulting not only from excess rainfall but also as a consequence of storms and cyclones. It is estimated that 80% of the overall costs of Australian natural disasters are the consequence of flooding and this, on average, costs approximately AU$600 million per annum (Gentle et al. 2001; Productivity Commission 2015).

These average figures do not reflect the severity of the impact that some floods can cause. For example, the magnitude and extent of the 2011 Queensland floods was vast. About 210 towns were affected by the flooding and 13 rivers reached their highest peak levels. Vital infrastructure was critically affected including some 50,000 kilometres of road that was damaged across the state and needed replacement or repair. With water purification systems flooded, clean-up efforts were also hampered and access to safe drinking water was limited. The overall cost of flood damage is estimated to have exceeded AU$6.8 billion.

There is a growing recognition that Australia's disaster funding arrangements are not efficient and do not create the right incentives for managing risks (Productivity Commission 2015). There is underinvestment in disaster mitigation and overinvestment in post-disaster interventions. Across Australia, flood maps have become a major mitigation strategy. As a consequence of these maps, State Authorities are better able to apply urban and land use planning mitigation strategies as Australia's population increases and urban areas expand. Other mitigation strategies include structural solutions such as levees, dams, diversion channels, floodgates, detention basins as well as non-structural solutions such as early warning and evacuation systems and community education programs. The investment in structural solutions are typically capital intensive and costly.

For optimal and equitable investment in mitigation, it is important to understand the full range of costs and benefits and also how these costs and benefits are distributed among different segments of the community. However, economic assessments of flood mitigation benefits generally tend to be incomplete and focused on tangible and direct benefits only. Indirect and intangible costs are rarely included in this type of assessments. Intangible values can be large and in some cases they can be the most dominant values, but they are often excluded from benefit-cost analysis. As a result, economic evaluations may often be incomplete. A panel of experts convened under the European Union's Costs of Natural Hazards project (CONHAZ) recently identified key areas for improvement in benefit-cost analyses including the need for more focus on non-structural measures, and indirect and intangible costs (Meyer et al. 2015).

The purpose of this study is to address this shortcoming and include intangible values in an analysis of flood mitigation options for the Brown Hill and Keswick creeks catchment in Adelaide. The catchment includes both rural and urban areas in five local government councils: Adelaide, Burnside, Mitcham, Unley and West Torrens. This analysis focuses on a set of flood mitigation options that have been under consideration following a public consultation. An earlier analysis done on these options (BHKCP, 2016) indicated that the benefits of mitigation did not exceed the costs (i.e. benefit-cost ratios are below 1). However, the analysis did not include intangible values. In this report, our aim is to identify the range of intangible values that need to be recognised, develop a set of estimates for these values based on the published literature and investigate how the inclusion of intangible values changes the results from benefit-cost analyses.

2. Flood damage costs

Floods may cause damages both during and after a flood event. These damages occur primarily in the flooded area but can also extend beyond it, and some of them may be expressed in monetary values (also referred to as market values). Many authors have developed cost categories for flood damages based on the original classification by Parker et al. (1987), which classifies damages as direct or indirect and tangible or intangible. The context for the appraisal of flood mitigation has been evolving (Penning-Rowsell and Green 2000) and the importance of indirect and intangible costs is now widely recognized. However, there is still too much emphasis on tangible and direct impacts rather than intangible and indirect impacts, mostly due to a lack of data on the latter (Merz et al. 2010).

2.1. Tangible costs

Tangible costs are damages to assets and economic opportunities that have observable market values and are thus relatively easy to assess in monetary terms. These values are commonly classified into direct or indirect damage costs. However, recent work by a panel of experts on a European project on the Costs of Natural Hazards (CONHAZ) has extended the standard classification by considering business interruptions as a separate category to direct and indirect costs and also by explicitly including risk mitigation costs as a major category (Green 2011; Meyer et al. 2013).

We summarise the different cost categories, including business interruptions in Table 1. Direct damage costs are the most visible or easily recognisable components. These costs relate to the physical damage to buildings, road and other infrastructure and also to the destruction of commodities and other assets. Flood direct damages are commonly estimated as a function of a single parameter (e.g. depth of inundation) and in some cases as a function of multiple parameters. Both types of models, using single or multiple parameters to estimate damages, have been subject to criticism.

Business interruptions costs occur in areas directly affected by the flood when people are not able to undertake their business activities because of accessibility problems or damages to the workplace (Meyer et al. 2013). They can be similar to 'direct damages' if they result from direct impact on production infrastructure; but can also be categorised as 'indirect damages' when they result from the interruption of economic activity. Business disruption costs include losses in business income and employee wages.

Indirect costs do not directly result from the physical flood damages. They are consequences of direct damages and business interruptions. These costs can occur inside or outside the flooded area but typically involve a time lag and can span over a longer period. They stem from the disruption of public service, transport and supply activities affecting downstream or upstream clients of the companies directly affected by floods.

The implementation of mitigation strategies (e.g. structural works) generates costs that can also be classified as direct and indirect. Direct costs are the expenditure on research, design, construction and maintenance of mitigation infrastructure (Meyer et al. 2013). Indirect costs relate to the externality effects on other sectors of the economy that result from mitigation expenses (e.g. through competition for resources or labour).

TABLE 1. FLOOD DAMAGE AND MITIGATION COSTS CATEGORIES

Type of damage or cost		Tangible	Intangible
Damage	Direct	(Inside the flooded area) Damage to buildings, infrastructure and other property, evacuation and rescue expenses, clean-up costs	Loss of life, injuries, psychological distress & other health effects, loss of memorabilia, water quality problems and loss of environmental goods
	Business interruption	(Inside the flooded area) Losses due to damaged production assets or accessibility problems	Nonmarket losses (e.g. ecosystem services) due to interruption
	Indirect	(Outside the flooded area) Losses imposed on consumers and producers, upstream and downstream of directly affected companies; (market) cost of traffic disruption	Nonmarket aspects of traffic and other disruption suffered, inconvenience of post-flood recovery, trauma, loss of trust and increased sense of vulnerability
Mitigation costs	Direct	Direct setup or capital costs of infrastructure and running and maintenance costs	Cultural heritage and environmental damage resulting from flood infrastructure (e.g. dams) and other changes
	Indirect	Costs imposed on other economic sectors	Loss of recreational values because of mitigation investment or structure

Source: Adapted from Meyer et al. (2013)

2.2. Intangible values

Tangible costs provide only a partial picture of the consequences of floods (EA-DEFRA 2005, Meyer et al. 2013, ten Veldhuis 2011, Joseph et al. 2015). Floods can also cause direct and indirect damages to assets and services that do not have market values or cannot be easily measured in monetary terms. These intangible values may include environmental assets, health impacts and social values such as cultural heritage. Gibson et al. (2016) provide a summary of the different types of intangible values affected by natural hazards and these are reproduced in Table 2 below.

Health effects range from loss of life (or mortality), to physical injuries and psychological distress, all of which are direct intangible impacts. There is research evidence showing that floods cause numerous psychological effects that are adverse to health. For instance, a study conducted by the UK Environmental Agency and the Department of Environment, Food and Rural Affairs (EA-DEFRA 2005) indicates that a large proportion of flood-affected people (about 80%) suffer from anxiety when it rains, about two thirds (65%) report increased levels of stress, and more than half report sleeping problems (EA-DEFRA 2005). Other health effects include morbidity, trauma and loss of trust in authorities (Merz 2010).

Natural assets and ecosystem services can also be affected by floods, which generally lead to the loss of intangible values. In some cases the effects of floods can be beneficial. These effects also depend on the speed of flooding and whether wildlife has had the chance to escape. For example, the Queensland floods of 2011 had adverse impacts on marine and terrestrial biodiversity, including some threatened species such as the cassowary, but had positive effects on freshwater systems such as those on the Murray River (Reid 2011). Other environmental impacts include water quality problems generated by floods such as water contamination and hypoxic blackwater, which are detrimental to fish (Whitworth et al. 2012).

TABLE 2. NON-MARKET VALUES IMPACTED BY NATURAL HAZARDS

Health	Environment	Social
Mortality, morbidity, injury, stress/anxiety, pain, trauma, grief, increased vulnerability among flood survivors	Wildlife loss, ecosystem degradation, water quality problems, invasive species	Recreation values, amenity values, safety, social disruption, cultural heritage, animal welfare, loss of memorabilia

Source: Adapted from Gibson et al. (2016)

Even small floods can cause disruptions to traffic in urban environments, and these disruptions can add up to significant damages especially if the floods occur regularly (ted Veldhuis and Clemens 2010). Larger floods can cause substantial population displacements causing prolonged social disruption. Other social intangible flood damages include: loss of recreational opportunities and amenity values; increased risk of loss of life; loss of cultural heritage and memorabilia; and harm to animals.

3. Flood mitigation strategies

The current Stormwater Management Plan (BHKCP 2016) is the result of collaboration between the five councils concerned and involves mitigation works in the four major watercourses serving the catchment, namely the Brown Hill, Keswick, Glen Osmond and Parklands creeks. The main objective of the plan is to mitigate risk and reduce the impact of major flooding on properties within the catchment, up to and including a 100-year average recurrence interval (ARI) flood. Mitigation works under the Plan fall under two categories (Part A and Part B). Part A works have been agreed to and are aimed at mitigating flooding generated from the mainly urban sub-catchment in the lower Brown Hill creek (downstream of Anzac Highway). Part B works aim to mitigate flooding from the upper Brown Hill creek (upstream of Anzac Highway).

In this study we evaluate the implementation of Part A works alone, and Part A and Part B works together (the implementation of Part B works happens only after the completion of Part A works). Part A works involves the construction of detention basins, creek capacity upgrades, flow diversions, diversion culverts, and a flood-control dam in Glen Osmond creek (BHKCP 2016). Part B works involves the construction of flood-control dams in the rural parts of the catchment, high flow bypass culverts (or covered concrete channels) to avoid creek overflows in low capacity sections, and creek capacity upgrade works (including bridge upgrades).

The options were presented for public consultation and subsequently narrowed down primarily because there were strong community based campaigns against some of the mitigation measures, such as the construction of culverts, which were viewed as interventions that would destroy valued streetscapes such as trees. There was also some opposition from the residents towards the construction of dams in the upper reaches of the Brown Hill creek. Our analysis focuses on three of the eight options initially considered for Part B works, which were designed to provide the same level of flood protection. These options are shown in Table 3 below.

TABLE 3. DETAILS OF EVALUATED FLOOD MITIGATION WORKS

Component Options	B1	B2	D
Detention dam location[1]	Brown Hill Creek Recreation Park	Ellison's Gully	Not required
Estimated number of properties requiring creek capacity upgrade works; requiring an agreement or easement	29	22	66
Number of properties where land acquisition is required	0	2	0
Number of properties requiring an easement for Dam Site 2	0	3	0
Number of public bridge upgrades	4	4	10
Creek rehabilitation works	Full length of creek	Full length of creek	Full length of creek
Capital costs	AU$ 40.9 M	AU$ 44.1 M	AU$ 35.5 M

Source: BHKCP (2016)

Among the three options, option D has been identified as the preferred option by the councils and the community because it satisfies the following factors: 1) it has the lowest capital and maintenance costs; 2) it does not require the construction of culverts; 3) it provides better than 100-year ARI protection for short duration storms; and 4) it satisfies community preferences for 'no dam' solution. The option involves upgrading the capacity of the creek at critical sections, including some specific creek choke points such as bridges (BHKCP 2016). It is designed to mitigate flooding at a catchment scale. However, the option would involve upgrade works on 66 private properties, 36 in the Unley Council area and 30 in the Mitcham Council area (BHKCP 2016). By comparison, the number of private properties that would need to be involved in the case of options B1 and B2 are, respectively, 26 and 19. Therefore, while the cost estimates are slightly lower for option D, it is likely to involve very high transaction costs, which are currently not included in the total costs for the option. Hence, evaluating options B1 and B2 as possible alternatives is of interest to the stakeholders.

4. Intangible cost and benefit estimates

Economists use nonmarket valuation techniques to estimate intangible values. They generally involve surveys where people are asked to state their preferences and value an intangible asset (stated preference methods) or techniques where the values are inferred from investigating people's behaviour in existing markets, such as the housing market (revealed preference methods). An alternative to these options

[1] The detention dam on the Brown Hill Creek Recreation Park would be 12 meters high with a capacity of 11 megalitres, while the dam on Ellisons Gully, a tributary to the Brown Hill Creek, would have a height of 19.5 meters with a capacity of 355 megalitres.

is a method called benefit transfer, where the value estimates from an existing study (for a different population and site) are adapted to the desired location (see Gibson et al. 2016). In this study we have used the benefit transfer method.

The mitigation options considered here are likely to have impacts on health and social values, less so on the environment. Health related issues, for example, include mortality and morbidity. Social values in this case include recreation, social disruptions and cultural heritage. Below, we provide an assessment of the likely magnitude of these values. However, we would like to emphasise that there is great uncertainty around these values, since they were not obtained from a survey of the residents at risk of flooding in the catchment studied.

4.1. Mortality

Depending on their severity, flood events may result in fatalities. Historical data show that, compared to other States, South Australia has a low probability of death from floods. For the period since 1900, a total of 68 flood-related deaths have been recorded in South Australia, compared to 702 in Queensland, 683 in New South Wales and 245 in Victoria (Haynes et al. 2016). Furthermore, the number of flood fatalities in South Australia has decreased significantly over time. Only 17 were recorded for the period 1950 to 1999 while the number for the first half of the century was 46 (Haynes et al. 2016). And no flood fatalities have been recorded since the year 2000. However, Haynes et al. (2016) do not provide information on the severity or location of the floods responsible for the fatalities. Without such information, it is difficult to estimate the probability of flood-related deaths for different ARI events and generate figures suitable for the Brown Hill and Keswick creeks catchment. Thus, we use other methods to estimate the probability.

A few studies have estimated mortality as a function of flood depth (e.g. Boyd et al., 2005; Jonkman 2001, 2007). They defined mortality as the proportion of the population affected that is killed by the flood. We used equation (1), developed by Boyd et al. (2005), to estimate the number of fatalities for different ARI events in the Brown Hill and Keswick creeks catchment:

$$\boldsymbol{F_D = \frac{0.34}{(1 + e^{(20.37 - 6.18h)})}} \qquad (1)$$

where F_D is the mortality rate and h is the average flood depth in meters. The number of fatalities is calculated by multiplying the mortality rate F_D by the number of people affected by the flood event, as shown in equation (2).

$$\boldsymbol{D = P * F_D} \qquad (2)$$

where D is the number of flood fatalities and P is the number of people affected by the flood. Using the flood maps in BHKCP (2016) (see Appendix 1), we estimated the approximate average flood depth for each ARI event to use in equation (1). Boyd et al. (2005) derived this function from observations of seven flood events in the Netherlands, England, United States, Japan and Bangladesh, where the populations at risk are much larger than in the Brown Hill and Keswick creeks catchment. Because the population at risk in the catchment is comparatively low (see Appendix 1), the estimated number of flood fatalities we derive is also very low (see Table 4). However, our estimates are consistent with expert opinion, which suggests that potential deaths from floods in the catchment would be expected to be low (Ed Pikusa, personal communication 2016).[2]

TABLE 4. ESTIMATED NUMBER OF FLOOD FATALITIES PER EVENT

Type of event	Number of fatalities per event		
	Base case	Part A works	Part A + Parts B works
10 year ARI	0.000000350	0	0
20 year ARI	0.000001360	0	0
50 year ARI	0.000007411	0.000000625	0.000000028
100 year ARI	0.000033552	0.000002609	0.000000069

There are many estimates of the value of a human life in the literature. The non-market valuation literature has mainly focused on the concept of a statistical life (value of a statistical life or VSL). The VSL essentially measures the rate of substitution between wealth (or income) and reductions in the risk of dying (Cropper et al. 2011). VSL estimates in the literature vary greatly depending on the country where the study was conducted. Three factors have been identified as the drivers for this variation: GDP per capita; the causes of mortality risk; and whether the risk affects others (Lindhjem et al. 2011). Thus, for the analysis of non-market values in the Brown Hill and Keswick creeks catchment, it is more appropriate to use VSL estimates for Australia only. The Department of the Prime Minister and Cabinet (DPCM, 2014) estimated the VSL for Australia to be around AU$4.2 million in 2014 dollars (i.e. AU$4.32 in 2016 dollars). To estimate the dollar value of lives lost per flood event in the Brown Hill and Keswick creeks catchment, we multiplied the estimated fatalities by the VSL. These results are shown in Table 5.

[2] The estimated depth of inundation, mortality rate and population at risk per flood event are detailed in Appendix 1.

TABLE 5. MORTALITY COSTS PER EVENT WITH AND WITHOUT MITIGATION

Type of event	Mortality values (AU$)		
	Base case	Part A works	Part A + Parts B works
10 year ARI	2	0	0
20 year ARI	6	0	0
50 year ARI	32	3	0.1
100 year ARI	145	11	0.3

4.2. Morbidity

Floods can also have an impact on physical and psychological health. These health impacts may be the result of the flood event itself, problems arising while recovering from a flood event, or anxiety about the risk of a flood reoccurring (EA-DEFRA 2005, Joseph et al. 2015, Bichard and Kazmierczak 2009). Studies have demonstrated that floods may cause short-term physical and psychological health impacts, but more significantly, they may result in long-term psychological effects. The most common long-term effects are increased levels of stress, anxiety (particularly when it rains) and loss of sleep (EA-DEFRA 2005, Clemens et al. 2013, North et al. 2004, Ginexi et al. 2000, Joseph et al. 2015). Other health impacts, although less common, include grief, a reduced immune system response and increased susceptibility to certain illnesses (EA-DEFRA 2005, Joseph et al. 2015). A range of factors may affect the extent of a flood-generated health impact, including socio-demographic factors such as prior health status and age, as well as flood characteristics such as flood depth and the frequency of flood events (EA-DEFRA 2005).

There are a large number of studies examining people's WTP to reduce morbidity risks. Most of these studies relate to acute diseases such as cancer, heart diseases, diabetes, Alzheimer, respiratory diseases, and chronic pain (Bala et al. 2000, Bosworth et al. 2009, Cameron and Deshazo 2013, Chuck et al. 2009, Gerking et al. 2014, Hammitt and Haninger 2011, Nielsen 2003, Nielsen et al. 2012, Robinson et al. 2013, Stieb et al. 2012, Viscusi et al. 2012). WTP values for morbidity vary greatly with the type and severity of the risk evaluated (e.g. migraine vs. cancer) and the duration of the morbidity (e.g. 1 month, 1 year, 5 years, or longer). These values can range from AU$3.7 per person per year for a 1% reduction in morbidity risk (e.g. Nielsen 2003) to AU$4.2 per person for a micro-risk reduction in risk (one-millionth reduction) (e.g. Cameron and Deshazo 2013).[3] In some cases, WTP estimates can be high. For example, the WTP for reduction in the intensity of pain was estimated at AU$1,706 per person per month (see Chuck et al. 2009). Some of the health states studied in this literature may be relevant to natural hazards, such as respiratory

[3] The rate used throughout this study to convert Danish krones to Australian dollars is 0.2 and the rate used to convert US dollars to Australian dollars is 1.38. All estimates were first converted to their equivalent in 2015 for each currency.

diseases caused by bushfire smoke (Kochi et al. 2010); however, they have little relevance for morbidity caused by floods, as floods are rarely the cause of these illnesses (Ginexi et al. 2000, Joseph et al. 2015).

Other studies have focused on indirect ways of estimating the health costs of floods. These include analysing people's WTP for flood insurance, WTP to reduce flood risk, or WTP to reduce flood impacts, which may include people's WTP to reduce flood-generated health impacts. WTP estimates vary significantly depending on the level of risk to which respondents are exposed, their level of income, and the country of residence. For instance, Lo (2013) investigated WTP for flood insurance amongst households affected by the 2011Queensland flood, which is considered a 120 year ARI flood event according to Babister and Retallick (2011). He found that non-insured households were willing to pay on average AU$55 per household per month for flood insurance. Two studies in the Netherlands have estimated mean WTP for flood insurance at AU$10 for a 400 year ARI event (Botzen and van den Bergh, 2012) and AU$235 per household per month for a 10 year ARI event (Botzen et al., 2013).[4]

Studies have also attempted to estimate people's WTP to prevent flood risk or flood frequency from worsening. In a Wisconsin study, for example, the mean WTP per person per year among people at risk of a 100 year ARI flood was estimated to be AU$144 (Clark et al., 2002) and AU$154 (Clark et al., 2005). Overall, WTP estimates to reduce potential flood impacts vary between AU$40 and AU$1,864 per household per year. These studies have estimated a mean WTP value of between AU$40 and AU$66 for respondents in Japan[5] (Zhai et al. 2006), between AU$133 and AU$1,454 for respondents in the UK (Joseph et al. 2015, Brouwer and Bateman 2005, Owusu et al. 2015) and a mean WTP of AU$1,864 for respondents in the US (Londoño Cadavid and Ando 2013). However, these estimates include people's WTP to reduce both tangible and intangible damages, and it is not possible to separate flood morbidity impacts from these values.

WTP estimates specific to flood-generated health impacts are scarcely available in the literature. To the best of our knowledge, only EA-DEFRA (2005) and Joseph et al. (2015) have provided such estimates. EA-DEFRA (2005) conducted a choice experiment in the UK to determine average annual WTPs per household for people that had previously experienced flooding. They found that households are willing to pay AU$541 per year to avoid flood related health impacts.[6] They also investigated WTP values among respondents who were at risk of flooding but had not previously experienced a flood event and obtained an annual mean WTP value of AU$425 per household.[7] Interestingly, the EA-DEFRA (2005) study showed that respondents who had been flooded multiple times were not willing to pay more than those who had been flooded only once; thus the same WTP values could apply to households at risk

[4] The rate used throughout this study to convert Euros to Australian dollars is 1.55.
[5] The rate used throughout this study to convert Japanese yen to Australian dollars is 0.013.
[6] The rate used throughout this study to convert British pounds to Australian dollars is 1.85.
[7] These WTP values were obtain from surveys of households located within the indicative floodplain bounded by the 100 years ARI flood.

of more frequent flooding (i.e. 10, 20 and 50 year ARI floods).

In a more recent study on the UK, Joseph et al. (2015) used contingent valuation (a survey based method) to estimate the mean WTP to avoid intangible flood impacts using a method that allows for a distinction between values related to health and non-health impacts.[8] They estimated the mean WTP to avoid all intangible impacts at AU$1,177 per household per year. Their results indicate the mean WTP to avoid flood-generated psychological impacts is AU$473 while the mean WTP to avoid other (not health related) flood-generated intangible impacts amounts to AU$704 per household per year.

In summary, in the literature examining the WTP to avoid or reduce flood-related health impacts, values range between AU$473 and AU$541 per household per year for previously flooded respondents but are lower for non-flooded respondents (about AU$425). Because widespread flooding has not occurred in the Brown Hill and Keswick creeks catchments since the 1930s (BHKCP 2016), it is more sensible to use the WTP estimates for non-flooded respondents. We adjusted this value to account for differences in income between the UK and Australia. On average, annual income in Australia is 21% higher than in the UK. The adjusted WTP value is AU$515.6. Thus, in this study a value of AU$515.6 per household per year is used as the value for flood-related morbidity.

Because the literature has shown that people are willing to pay the same amount per year to reduce flood-related health impacts, regardless of the number of times they have been previously flooded (EA-DEFRA, 2005), morbidity costs are calculated as annual costs rather than per event.

To calculate annual morbidity costs of floods in the Brown Hill and Keswick creeks catchment, we multiplied the morbidity value (AU$515.6) by the total number of households that would still be at the risk of a 100 year ARI event under the different mitigation options (see Table 6). We selected this number of households for two reasons: first, the WTP values in EA-DEFRA (2005) were obtained from surveys of households located within an indicative floodplain bounded by the 100 years ARI flood; and second, all intangible values in this study are calculated for a 100 year ARI or more frequent events.[9]

[8] In Joseph et al. (2015) all respondents had been flooded at least once.

[9] The intangible values for less frequent events (e.g. 500 year ARI flood) are integrated in the results using a different method. The reasons for this are explained in the Results section.

TABLE 6. MORBIDITY COSTS

	Base case	Part A works	Part A + Part B works
Number of households at risk of a 100 year ARI flood	2,089	604	31
Total annual morbidity costs	1,077,047	311,411	15,983

4.3. Recreation

It is also important to assess if flood mitigation works generate recreational values losses or gains. The construction of a dam, for example, may lead to a deterioration in the natural scenery of a park and generate losses in amenity values for the people who visit the area. This would be the case if option B1 or B2 are implemented, because these options require new dams in the Brown Hill Creek and Ellisons Gully Recreation Parks, respectively. The resulting amenity value losses would need to be included as part of the total cost of these options. If the dams are not constructed, recreational values from the Brown Hill Creek and Ellisons Gully Recreation Parks would remain unchanged. Thus, first we need to estimate the current value of amenities provided by the parks, and, second, we need to estimate by how much this value would be reduced if any of the dams were built.

Worldwide, there have been numerous publications investigating the value of recreation in natural sites. Most of this literature has been published recently, with the vast majority of studies published in the last decade. The majority of natural sites investigated in this literature are located in Europe and Asia (e.g. Tu et al, 2016; Salazar and Menendez, 2007; Martinez-Jauregui et al., 2016; Saengsupavanich et al., 2008), and usually contain forests or natural landscapes that are protected with national park status (e.g. Rathnayake 2016; Saraj et al., 2009; Rossi et al., 2015). Other types of recreational sites investigated include water bodies such as lakes, rivers, estuaries and oceans, which are valued for the recreational activities they provide such as fishing, swimming, visiting coral reefs, and enjoying the beach (e.g. Smallwood et al., 2013; Sale et al., 2009; Prayaga et al., 2010). Only a few studies have investigated the value of recreation for urban parks.

In Australia, there have been a handful of studies estimating the value of recreation in natural sites. Some of these have focused on marine sites. For instance, Stigner et al. (2016) compared recreational use and conservation values in the Moreton Bay Marine Park in Queensland, and showed that recreational use affects ecological values, but the conflict between the two can be avoided with better conservation zoning. Prayaga et al. (2010) estimated the value of recreational fishing in the Great Barrier Reef at $166.82 per person per trip. Others have looked at the value of recreation in national parks; for instance, Rolfe and Dyack (2011) estimated the value of recreation in the Coorong National Park in South Australia at $120 per adult visitor per day. Nillesen et al. (2005) estimated the value of hiking and camping in the Bellenden Ker National Park in Queensland at AU$516 per visitor. Fleming and Cook (2008) estimated the annual value of recreation in Lake McKenzie, located in the Great Sandy National Park in Fraser Island, Queensland at AU$243 per visitor. Very few studies have estimated the value of urban green spaces in Australia. Some examples include MacDonald et al. (2010) and Tapsuwan et al. (2012). Both of these studies estimated changes in property values as a function of house attributes (e.g. type of house, house condition, number of bedrooms and bathrooms, proximity to a river or a green space, etc.)

One study investigated the value of urban green spaces close to the Brown Hill Creek and Ellisons Gully Recreation Parks, MacDonald et al. (2010), but this study used a different method that relies on property values to estimate intangible values and their results cannot be used in our analysis. MacDonald et al. (2010) estimated the change in property values with proximity to public green spaces in the 'Leafy Eastern Suburbs' of the eastern Adelaide plains (between Adelaide CBD and the Adelaide Hills). They found that property value increases as the property is located further away from a reserve. Their model estimated that the value of a property increases by AU$ 11 for every additional metre the property is away from a large reserve. They suggest that factors such as increased fire risk or the presence of poisonous snakes during summer may overwhelm the recreational value of these areas and explain this result. The results from MacDonald et al. (2010) suggest that there is no recreational value for parks, and therefore, no value that would be affected by the construction of the dams. However, the opposition from the population in the Brown Hill and Keswick creeks catchment to the construction of the dams in options B1 and B2 (Natalie Fuller and Associates and UPRS, 2015) suggests that the Brown Hill Creek and Ellisons Gully Recreation Parks provide important recreational values without the dams that need to be accounted for in the analysis.

Since the Brown Hill Creek Recreation Park is not classified as a national park, values estimated for national parks in Australia cannot be used for this analysis because national parks have a larger recreational value than recreational parks. The value estimated for an urban park would provide a better estimate for the Brown Hill Creek and Ellisons Gully Recreation Parks, since their purpose is to create a large area for public recreation in a natural setting. To the best of our knowledge only Lockwood and Tracy (1995) have provided a WTP estimate for recreation on an urban park in Australia. They estimated the intangible benefits of using Centennial Park in Sydney and found a mean WTP per household per year of AU$42 for users of the park and AU$20 for the non-users. In order to use these values for the Brown Hill Creek catchment, we adjusted them to account for the difference in the level of income in Adelaide compared to Sydney. On average, a person in Adelaide earns 17% less than a person in Sydney (ABS 2016). Thus, using the simple assumption that WTP estimates in Adelaide will be 17% less than in Sydney, the adjusted values are AU$34.89 for the users of the park and AU$16.62 for the non-users of the park. We used these adjusted values and the number of user and non-user households of the Brown Hill Creek and Ellisons Gully Recreation Parks to estimate the recreational value of the parks.

The number of households that visit the park per year was calculated using information from the rangers that manage the Brown Hill Creek Recreation Park. Around 5,000 people visit the park per year (personal communication, Dinan 2016 and Wilson 2016), and this corresponds to approximately 2,080 households.[10] However, this assumes that each visitor is unique and will not visit the park more than once a year, which is unlikely. But given the limited amount of information we have on the number of park visitors per year, we used the total number of visitors to calculate the number of user households.

To estimate the number of non-user households, we used the population in the surrounding suburbs. We only looked at the population in the surrounding suburbs and not in the Greater Adelaide area because the Brown Hill Creek Recreation Park is likely to be significant to or used by locals. There are other parks in the area that people are also likely to use (e.g. Belair National park, Cleland Conservation Park). The closest is Belair National Park, which is located at a distance of approximately 3 km. Given the proximity of other parks, non-user households whose values could be affected by the construction of a dam are assumed to be located in the suburbs within a 1.5 km distance from the park (which is half of the distance between Brown Hill Creek Recreation Park and Belair National park). This radius of 1.5 km from the Brown Hill Creek Recreation Park includes the suburbs Springfield, Torrens Park, Brown Hill Creek, Belair, Kingswood, Lower Mitcham, Lynton and Clapham. It is assumed here that people living at a distance greater than 1.5 km from the Brown Hill Creek Recreation Park would visit other neighbouring parks or be more concerned about what happens in other parks. The combined population of these suburbs is approximately 13,758 (ABS, 2006), which corresponds to approximately 5,730 households (13,758/2.4). Since the number of user households is 2,080, the estimated number of non-user households would be 3,650 (i.e. 5,730 – 2,080).

The total recreational value of the park to local residents is the sum of values for users and non-users. The value to users is obtained by multiplying the adjusted WTP estimates for users (AU$34.89) by 2,080 and is AU$72,576 per year. The value for non-users living close by is estimated by multiplying the adjusted WTP estimate for non-users (AU$16.62) by 3,650 and is AU$60,646 per year. Therefore, total recreational value for the Brown Hill Creek Recreation Park is estimated to be AU$133,221 per year (AU$72,576 + AU$60,646).

The construction of a dam in the park would reduce this value. The question is by how much? There have been some studies in the literature investigating the impact

[10] Calculated using the average number of people per household in the area, which is 2.4 (see ABS 2013).

of constructing dams or removing dams on tourism and on demand for non-fishing recreation (e.g. Dias-Sardinha and Ross 2015, McKean et al. 2012, Loomis 2002); however, these studies relate to the construction (or removal) of dams that create artificial lakes, which can be used for intensive irrigated farming and may enhance recreation and tourism opportunities (Dias-Sardinha and Ross 2015). The impact on recreational and use values of the construction of a dam in the Brown Hill Creek Recreation Park is principally aesthetic and there have been no relevant previous studies.

Therefore, we have relied on the information available in the community consultation process (Natalie Fuller and Associates and UPRS, 2015) to estimate the reduction in recreational values.[11] This consultation process did not ask respondents if they agreed with, or were opposed to, the construction of a dam, but it showed that 85% of the respondents supported option D and only 9% supported the construction of a dam. The considerable support for option D and low support for the construction of a dam indicates that options B1 and B2 may result in a substantial reduction in the recreational and use values of the park. What is not clear is what proportion of the 85% respondents opposing the construction of a dam were users of the park. It could be argued that the people opposed to the construction of the dams would be mostly the users of the park, but since we do not have evidence of this, we have used the simple assumption the disapproval rating among users and non-users is the same. Thus, we estimate the number of households opposing the dam to be 1,768 (or 2,080×0.85) park users and 3,103 (or 3,650×0.85) non-users.

Not all of the recreational values may be lost with the construction of a dam (although in some cases it may). It is likely that some of the regular users of the park will continue to use it, albeit less frequently, while others may choose to recreate in a different park. In this case, their WTP would be similar to the WTP of the non-users. This would correspond to a loss of AU$18.28 in the value of recreation per user household (AU$34.89−AU$16.62). We multiplied this estimated loss in value by the number of users opposed to the construction of the dam (85% of the users = 1,768), and obtained a total loss in recreation of AU$32,313 for options B1 and B2. Table 7 summarises the annual recreation loss for each mitigation option.

[11] A community consultation process was conducted in 2015 by a consultancy to evaluate the proposed works associated with the Brown Hill Keswick Creek Stormwater Management Plan (Natalie Fuller and Associates and UPRS, 2015). This consultation evaluated the support for different options from the owners of properties traversed by upper Brown Hill Creek and the wider community. In this consultation process, from 816 respondents (including 88 property owners traversed by the creek and 728 respondents from the public), 85% supported option D, 8% supported option B2 and 1% supported option B1 (6% were either unsure, supported other options, or did not respond to some of questions in the survey).

TABLE 7. LOSS IN RECREATION VALUES

Intangible value	Base case	Part A works	Part A + Parts B works		
			B1	B2	D
Annual loss in recreation values	0	0	32,313	32,313	0

It is important to note that options B1 and B2 may affect recreational values differently, because they involve building dams in different locations. The community consultation process revealed that there is less support from the population for option B1 (only 1%) than for option B2 (around 8% of the community supports this option). However, there is not enough information in the community consultation to differentiate the impacts on recreation from option B1 and B2. Thus, the loss in recreation for both options is assumed to be the same (i.e. AU$32,313).

4.4. Social disruption

Social disruption from natural disasters is a complex issue for which there are no accessible, comprehensive and uniform metrics for assessing its economic impact. Natural disasters such as flood can disrupt services that are important to the functioning of communities, such as electricity (Hensher et al. 2014) and regular road traffic. The disruption to these services causes inconveniences to the communities (Messner 2007). Floods can also result in large numbers of people having to be displaced from their homes and generate large economic consequences (Landry et al. 2007). We analyse four types of social disruptions including electricity outage, road traffic annoyance, traffic delays and displacement of people for different flood events.

4.4.1. Electricity outage

If the flooding is severe enough to cause over-floor flooding, electric power supply will be disrupted. Table 8 shows the number of houses that would experience over-floor flooding under the base case (no mitigation) and the two mitigation scenarios. For instance, a 50 year ARI flood would cause 550 households to experience over-floor flooding, while a 100 ARI would result in 1,172 houses with over-floor flooding. Mitigation works would reduce the number of households affected by a substantial amount (see Table 8). If Part A works are implemented, a 100 year ARI flood would result in only 261 houses with over-floor flooding. The implementation of Part B works would reduce this number even further, to only 6 houses. As shown in Table 8, Part A works alone would be sufficient to eliminate over-floor flooding caused by less severe flooding events (10 and 20 year ARI floods).

TABLE 8. NUMBER OF HOUSES WITH OVER-FLOOR FLOODING WITH AND WITHOUT MITIGATION

Type of event	Base case	Part A works	Part A + Parts B works
10 year ARI	58		
20 year ARI	158		
50 year ARI	550	110	3
100 year ARI	1,172	261	6

Source: BHKCP (2016)

In the Stormwater Management Plans, there is no information on the potential duration of the floods, which could be used to derive the length of electricity outage for over-floor flooded properties. The flood maps for different floods were generated by overlapping the maximum flood extent of three possible storm events (a 90 minute storm, a 6 hour and a 36 hour storm) in different parts of the catchment and taking the outer envelope of the three, but there is no information on how long it would take for flood waters to recede after each storm event. In parts of the catchment and under a mitigation scenario, the duration of inundation for a 100 ARI flood would be about 4 hours (e.g. Ridge Park Reserve). The maximum flow rate in other parts of the catchment would be at least 3 times higher under no mitigation, thus it is assumed that the duration of inundation would be at least 3 times higher (i.e. at least 12 hours). Since there is no information for other ARI events, we have taken the same duration for all events. This may underestimate the total duration of inundation in the catchment, but in the absence of more precise information, we have taken this conservative number and used sensitivity analysis to evaluate the impact of intangible losses associated with electricity outages on the results.

There have been several studies investigating the non-financial cost of electricity outage (i.e. the cost created by the inconvenience of not having electricity). Carlsson and Martinsson (2007) provide willingness to pay estimates for both planned and unplanned outages for Sweden (see Table 9) and how values vary with duration. They show that in the case of an unplanned outage, the amount households are willing to pay (WTP) to avoid a 24 hour-long electricity outage is about 24 times larger than the amount they are willing to pay to avoid a one hour-long outage. In this case, the relationship between the duration of the outage and the willingness to pay to avoid it is roughly linear.

TABLE 9. WILLINGNESS TO PAY TO AVOID ELECTRICITY OUTAGE IN SWEDEN (AU$)*

Hours	Mean	Standard deviation	Max
Planned			
1 hour	1.1	7	89
4 hours	5	17.9	179
8 hours	15	36	359
24 hours	34	60.6	539
Unplanned			
1 hour	1.6	8.1	89.9
4 hours	6	18.3	134
8 hours	19	43	359.7
24 hours	40	77	539

Source: Carlsson and Martinsson (2007).
* Australian dollars converted from Swedish Krona at 0.17

WTP to avoid the inconvenience of electricity outages have been estimated in several other countries (see Table 10). These values range from AU$0.35 to AU$49 per hour for the US, AU$1.21 to AU$23.1 per hour for Canada and AU$0.4 to AU$3.94 per hour for Sweden. Hensher et al. (2014) conducted a similar analysis for Canberra and estimated that households are willing to pay on average AU$91 to avoid a 12 hour electricity outage (which corresponds to about $AU7.55 per hour). Although the average WTP estimates in Hensher et al. (2014) are higher compared to other studies in the literature, it is better in our context to use a study conducted in Australia. To use Hensher et al. (2014) WTP values for the Brown Hill Creek catchment, we also adjusted them to account for the difference in the level of income in Adelaide compared to Canberra. On average, a person in Greater Adelaide earns 22% less than a person in Canberra (ABS 2016). Thus, WTP to avoid a 12 hour electricity outage in Greater Adelaide is estimated at AU$71. We multiplied this estimate by the number of households that experience over-floor flooding during different ARI flood events.

TABLE 10. WILLINGNESS TO PAY PER HOUR TO AVOID ELECTRICITY OUTAGE

Country	Region	WTP per hour of outage in 2016 AU$
USA		0.8-80 (mean of 49)
	California	1.24-80 (mean of 24.19)
	New York	1.97-15.7 (mean of 9.52)
	North Carolina	9.5-10.5
	Midwest Region	1.82-4.1 (mean of 3)
	Wisconsin	0.8-3.43 (mean of 1.68)
Australia	Adelaide	3
Canada		1.21-23.1 (mean of 3.38)
Brazil		6.58
Sweden		0.4-3.94 (mean of 1.44)
Nepal		0.138-1.58 (mean of 0.35)
North Cyprus		1.46

Sources: USA: Layton and Moeltner (2005); California: Doane et al. (1988), Goett et al. (1988), Keane et al. (1988), Ozbafli (2012); New York: Doane et al. (1989), Ozbafli (2012); North Carolina: Sullivan et al. (1996); Midwest Region: Chowdhury et al. (2004), Ozbafli (2012); Wisconsin: Sanghvi (1983), Ozbafli (2012); Canada: Wacker et al. (1983), Tollefson et al. (1994); Brazil: Munasinghe (1980); Sweden: (Carlsson and Martinsson (2006, 2007, 2008); Nepal: Billinton and Pandey (1999); North Cyprus: Ozbafi et al. (2015). Values converted from USD at 1.38.

Table 11 shows our aggregate WTP estimates to avoid electricity outage. In the absence of mitigation works, the electricity outage costs for a 100 ARI flood would be AU$83,304. These costs would be reduced to only AU$18,551 with Part A works and to AU$426 with Part B works.

TABLE 11. WTP TO AVOID ELECTRICITY OUTAGE FOR OVER-FLOOR FLOODING WITH AND WITHOUT MITIGATION ($AU)

Type of event	Base case	Part A	Part A + Part B works
10 year ARI	4,123	0	0
20 year ARI	11,230	0	0
50 year ARI	39,093	7,819	213
100 year ARI	83,304	18,551	426

4.4.2. Road traffic annoyance

Noise is recognized as a serious health problem in modern times and is one the most commonly cited environmental pollution factors cause by transportation. Unwanted sound or noise is considered a nuisance and an environmental stressor (Stansfeld and Matheson 2003) that can trigger undesirable symptoms and has the potential to cause adverse health outcomes (Dratva et al. 2010). An increasing body of literature has shown that traffic noise has adverse health effects (Babisch 2006; Bluhm et al. 2007; Stansfeld et al. 2000 de Kluizenaar et al. 2007).

Although natural hazards can result in road blockages and increased traffic in unaffected areas, there has been no research on road traffic related noise annoyance in relation to natural hazards. In addition, studies estimating WTP to avoid road traffic noise is limited. Istamto et al. (2014) estimated the perceived economic values of traffic-related air pollution and traffic noise within the framework of a large European project and conducted surveys in the UK, Finland, Germany, the Netherlands and Spain. Other studies also provided WTP estimates for other countries in Europe like Fosgerau and Bjørner (2006) in Denmark and Navrud (2000) in Norway. Among these studies, Istamto et al. (2014) had the largest sample and obtained WTP estimates from different countries, therefore we used the values provided in their study and adjusted them for income differences between the five European countries where the survey was distributed and Australia. The average WTP to avoid increases in noise-related road traffic annoyance in Istamto et al. (2014) is AU$167 per person per year (in 2016 AUD). However, average wages in the countries surveyed are on average 15% lower than in Australia. The WTP adjusted for income is therefore AU$192 per person per year. This translates into an average daily value of AU$0.53 per person (192/365).

There is no information on the duration of inundations for different events, so assumptions have to be made on this regard. It is assumed here that traffic would be disrupted for at least the duration of the storm (1.5 hours to 36 hours, for which the flood maps were modelled), the time the flood waters recede (at least 12 hours, as indicated for electricity outage) and the time necessary for clean-up activities (potentially several days, one day at the very least). The minimum for these three stages to take place and for traffic to resume its normal flow would be then three days. Although it could be a lot more for severe floods, we have used conservative numbers throughout the study.

The WTP to avoid increases in noise-related road traffic annoyance for three days is therefore AU$1.58 (0.53×3). To convert this figure into an aggregate WTP, an estimate of the size of the traffic disruption is required, because this determines the number of people affected. However, estimating the number of people affected by road traffic annoyances is not very easy and requires matching population distribution data and information about flood coverage. Using the flood maps in BHKCP (2016), we estimated the extent of the flooded areas in km^2 (see Table 12) and this can be used as a proxy for the extent of the area affected by road traffic annoyance at the periphery of the flooded areas.

TABLE 12. FLOODED AREA SIZE WITH AND WITHOUT MITIGATION (KM^2)

Type of event	Base case	Part A works	Part A + Parts B works
10 year ARI	0.97	0	0
20 year ARI	1.32	0	0
50 year ARI	1.8	0	0
100 year ARI	5.7	2.1	0.015

Source: estimated using maps in BHKCP (2016)

Australian census data indicate that the density of settlement in the area between the Adelaide Airport, the City and the surrounding suburbs (where floods would have the highest impact) is 2,100 people per km^2 (ABS 2014). This would mean that the WTP to avoid traffic annoyance can be estimated to be AU$3,309 per km^2 (AU$1.58×2100). Multiplying this value with the flooded area estimates in Table 12, we estimated the intangible value of road traffic annoyance for different ARI events as shown in Table 13.

TABLE 13. WTP TO AVOID ROAD TRAFFIC ANNOYANCE (AU$)

Type of event	Base case	Part A works	Part A + Part B works
10 year ARI	3,226		
20 year ARI	4,384		
50 year ARI	6,204	2,283	16
100 year ARI	19,108	7,031	50

4.4.3. Road traffic delays

The intangible value losses related to traffic are not limited to noise annoyance. Because flooded roads would likely be closed, people would have to take alternative routes; and this would increase traffic travel time and cause significant traffic delays. Traffic delays results in non-market economic losses associated with travel time unreliability. Therefore, the analysis needs to take into account the value of time that will be lost due to flood-related traffic disruptions.

Table 14 presents the value of time in different studies. These values are about AU$32 per hour. The value of time reported in Lam and Small (2001) and van Amelsfort et al. (2008) is AU$33 per hour which is close to the value of time unreliability (AU$32 per hour). The average wage in South Australia is AU$38 per hour (ABS, 2015), which can be interpreted as the value of time. This value is close to the estimates by Lam and Small (2001) and van Amelsfort et al. (2008). Therefore we assume that the value of time unreliability in Adelaide is about AU$38 per hour.

TABLE 14. VALUE OF TIME

Average value of travel-time	Value of time (VOT)	Reference
32.2 AU$/hour		Brownstone and Small (2002) in van Amelsfort et al. (2008)
32.4 AU$/hour	33.12 AU$/hour	Lam and Small (2001), van Amelsfort et al. (2008)

To estimate the number of people who could be subjected to delays in traffic, we overlaid the map of flood affected areas for a 100 year ARI flood from BHKCP (2016) with a map of average daily traffic flow estimates (Government of South Australia, 2016). For the base case scenario (no mitigation), the values for a 100 year ARI flood were first calculated and then scaled down (using data on the extent of the floods) to obtain estimates for less severe floods (10, 20 and 50 year ARI floods). BHKCP (2016) maps show that, once part A works are implemented, the number of people affected under 10, 20, and 50 year ARI floods would be very small and we have set these values to zeros (see Table 15).

Traffic statistics in Adelaide shows that there are, on average, 1.2 passengers per car (Krause 2016). We calculated the number of affected people by multiplying the average number of passengers (1.2) by the number of affected cars (see Table 15). Flood maps in BHKCP (1026) show that if part B works are implemented, the flood volume would be limited and traffic would not be affected by street blockages, even under a 100 year ARI flood.

TABLE 15. NUMBER OF CARS AND NUMBER OF PEOPLE AFFECTED BY ROAD TRAFFIC DELAYS

Type of event	Base case	Part A works	Part A + Parts B works
Number of cars affected			
10 year ARI	29,000	0	0
20 year ARI	110,500	0	0
50 year ARI	267,300	0	0
100 year ARI	409,700	223,400	0
Number of people affected			
10 year ARI	34,800	0	0
20 year ARI	132,600	0	0
50 year ARI	320,760	0	0
100 year ARI	491,640	268,080	0

Sources: Government of South Australia (2016), BHKCP (2016), Krause (2016).

In addition to the number of people affected, the analysis requires an estimate of the extent of the traffic time delays. Using Google maps to calculate the distance and time required for rerouting, we estimated that the average travel time across (around) flooded areas would increase from 7 to 17 minutes (i.e. a delay of 10 minutes). This means that, for instance, in the event of a 100 year ARI flood, even after the implementation of Part A works, about 268,080 passengers would spend at least 10 additional minutes to go around the flooded areas. We recognise that in the event of a flood, traffic delays could be much longer than 10 minutes, because too many cars would try to use alternative roads. However, there is no data on road traffic delays caused by floods in the catchment, and thus to avoid overestimating the delays and the benefits of mitigation works, we use a conservative delay value of 30 minutes (i.e. 3 times the 10-minute delay calculated).

The value loss due to traffic delays can then be calculated by multiplying the number of people affected, by the value of time reliability (AU$38) and the average duration of the delay (0.5 hours). The intangible economic loss estimates for traffic delay are presented in

Table 16.

TABLE 16. ROAD TRAFFIC DELAY COSTS DUE TO FLOODING ($AU)

Type of event	Base case	Part A works	Parts A + Part B works
10 year ARI	661,200	0	0
20 year ARI	2,519,400	0	0
50 year ARI	6,094,440	0	0
100 year ARI	9,341,160	5,093,520	0

4.4.4. Inability to return home

The effects of floods in residential areas are not limited to power outages and traffic related problems. In some cases, people have to be displaced and need to find alternative accommodation for at least 48 hours if their houses are over flooded (Pikusa, 2016). There have not been many studies estimating what people are willing to pay to avoid the inconvenience of being displaced. Landry et al. (2007) is a rare case estimating WTP among New Orleans residents after Hurricane Katrina. The inability to return home may be caused by damage to dwellings or the community, uncertainty related to the habitability of a dwelling, loss of critical infrastructure (such as roads, power, or flood protection), distance travelled for evacuation, or some combination of these factors. For a sample of relatively poor households, the study estimated a WTP to return home of US$1.94 per hour in 2005 (i.e. AU$3.28 in 2016 dollars).

The difference in average annual income between the survey sample and Greater Adelaide is substantial, so it is important to adjust for income differences. Average annual income in Greater Adelaide is about 66% higher than the average annual income of the population surveyed. The income adjusted WTP to return home is therefore AU$5.44 per hour.

The aggregate number of hours of inability to return home for different ARI floods and mitigation options are presented in Table 17. These values are obtained by multiplying 48 (i.e. number of hours for inability to return home for Adelaide) by the number of houses with over-floor flooding presented in Table 8.

TABLE 17. ESTIMATED AGGREGATE HOURS OF DISPLACEMENT AS RESULT OF OVER-FLOOR FLOODING

Type of event	Base case	Part A works	Part A + Parts B works
10 year ARI	2,784	0	0
20 year ARI	7,584	0	0
50 year ARI	26,400	5,280	144
100 year ARI	56,256	12,528	288

The cost of inability to return home for different flood mitigation options and ARI floods are presented in Table 18. This table is produced by multiplying the hourly cost of inability to return home (AU$5.44 per hour) and the aggregate number of hours presented in Table 17.

TABLE 18. COST OF INABILITY TO RETURN HOME WITH AND WITHOUT MITIGATION

Type of event	Base case	Part A works	Part A + Parts B works
10 year ARI	15,155	0	0
20 year ARI	41,285	0	0
50 year ARI	143,715	28,743	784
100 year ARI	306,243	68,199	1,568

4.5. Cultural heritage

Humans can form deeply personal attachments to natural features or to 'things' such as historical monuments, architectural styles, significant landmarks and monumental trees. Although there are no markets for the exchange of these features, humans attach a value to them based on cultural (shared) or spiritual (individualistic) meanings. These values can be affected by flood events or by the infrastructure built for mitigation. In the case of the Brown Hill and Keswick creeks catchments, the construction of a dam in Site 1 as part of option B1 would adversely impact one of the old Stone Pine trees. These trees are known locally as the Seven Pines and are listed on the National Trust of South Australia's Register of Significant Trees. They are regarded as several of the largest and oldest living Stone Pines in the world (BHKCP 2016) and are highly valued by the community in the catchment. Since the construction of a dam would result in the removal of one of these trees, cultural and social costs associated with this should be taken into account.

In the non-market valuation literature, there has been little discussion on environmental services that are cultural, spiritual or symbolic (Laband 2013). Asciuto et al. (2015) is one of the rare studies that have evaluated the existence value of monumental trees. They conducted a survey using contingent valuation (CV) to evaluate the existence value for monumental trees in a protected area. The survey was distributed to the resident households of the Madonie Park (Sicily, Italy). Their findings indicate that conservation demand for monumental trees is quite important to the residents of the Madonie area. They estimated a mean WTP for the protection of 18 monumental trees of AU$21.06 per household, or AU$1.2 per household per tree. However, average annual income in Italy is 32% lower than in Australia. Therefore, we adjusted the value for income differences. The adjusted WTP for the protection of 18 monumental trees is $31 per household, or AU$1.7 per household per tree. As in the case of the monumental trees in Asciuto et al. (2015), the community considers that the Seven Pines in Adelaide are irreplaceable.

Given the number of households (5,730) in the nearby suburbs (within a 1.5 km radius from the Brown Hill recreation park), the aggregate WTP for one monumental tree is AU$9,853. Since a dam in Site 1 would adversely impact one of the old Stone Pine trees, AU$9,853 is used as an estimate of the loss in cultural heritage caused by the construction of the dam.

5. Summary of intangible values

Here we present a summary of the intangible values described in the previous section for easy reference. We estimated the potential damage for eight intangible values in the Brown Hill creek catchment, which correspond to damage cause by flood events, or the risk of flooding, or by the implementation of the mitigation options. Five of these values belong to the first category (i.e. they are the direct result of flood events): mortality; electricity outage; road traffic annoyance; road traffic delays; and inability to return home. These values are presented by type of flood event in Table 19.

TABLE 19. INTANGIBLE DAMAGES DIRECTLY CAUSED BY A FLOOD EVENT (AU$)

Type of event	Intangible value	Base case	Part A works	Part A + Part B works
10 year ARI	Mortality	2	0	0
	Electricity outage	4,123	0	0
	Road traffic annoyance	3,226	0	0
	Road traffic delays	661,200	0	0
	Inability to return home	15,155	0	0
20 year ARI	Mortality	6	0	0
	Electricity outage	11,230	0	0
	Road traffic annoyance	4,384	0	0
	Road traffic delays	2,519,400	0	0
	Inability to return home	41,285	0	0
50 year ARI	Mortality	32	3	0.1
	Electricity outage	39,093	7,819	213
	Road traffic annoyance	6,204	2,283	16
	Road traffic delays	6,094,440	0	0
	Inability to return home	143,715	28,743	784
100 year ARI	Mortality	145	11	0.3
	Electricity outage	83,304	18,551	426
	Road traffic annoyance	19,108	7,031	50
	Road traffic delays	9,341,160	5,093,520	0
	Inability to return home	306,243	68,199	1,568
500 year ARI*	Mortality	515	216	216
	Electricity outage	296,054	123,861	123,861
	Road traffic annoyance	67,908	28,411	28,411
	Road traffic delays	33,197,575	13,888,995	13,888,995
	Inability to return home	1,088,358	455,340	455,340
PMF*Φ	Mortality	1,186	1,186	1,186
	Electricity outage	681,591	681,591	681,591
	Road traffic annoyance	156,341	156,341	156,341
	Road traffic delays	76,429,062	76,429,062	76,429,062
	Inability to return home	2,505,670	2,505,670	2,505,670

* Note: Intangible damages for a 500 year ARI flood and for the PMF were estimated using the proportional increase in tangible damages reported in BHKCP (2016) from a 100 year ARI to a 500 year ARI flood and to the PMF for the base case scenario. The reduction in intangible damages due to the implementation of each strategy was estimated using the proportional decrease in tangible damages reported in BHKCP (2016).
Φ Probable Maximum Flood (PMF).

The most significant intangible damage directly caused by flood events is road traffic delays. This is because a large number of people would be affected by the delays caused by road closures if a flood occurs. The second most significant intangible damage is the inability to return home when the house is flooded, but it is substantially smaller than road traffic delays (between 30 to 60 times smaller). The smallest intangible damage corresponds to mortality, which is explained by the very low number of fatalities expected from flooding in the catchment.

The damage estimates for different flood events can be converted into average annual damages (AAD) using the probability values for each event. We use the formula in equation (3) to calculate AAD, which estimates the area under the probability curve. In equation (3), d denotes flood damage per event and P denotes the annual probability of occurrence for the flood event. This is the method used in

BHKCP (2016) to convert tangible damages per event to tangible annual average damages. Intangible AAD are presented in Table 20.

$$\begin{aligned}\boldsymbol{AAD} = {} & \boldsymbol{d_{500}(P_{500} - P_{PMF}) + \frac{(d_{PMF} - d_{500})(P_{500} - P_{PMF})}{2}} \\ & \boldsymbol{+ d_{100}(P_{100} - P_{500})} \\ & \boldsymbol{+ \frac{(d_{500} - d_{100})(P_{100} - P_{500})}{2}} \\ & \boldsymbol{+ d_{50}(P_{50} - P_{100})} \\ & \boldsymbol{+ \frac{(d_{100} - d_{50})(P_{50} - P_{100})}{2}} \\ & \boldsymbol{+ d_{20}(P_{20} - P_{50}) + \frac{(d_{50} - d_{20})(P_{20} - P_{50})}{2}} \\ & \boldsymbol{+ d_{10}(P_{10} - P_{20}) + \frac{(d_{20} - d_{10})(P_{10} - P_{20})}{2}}\end{aligned} \quad (3)$$

TABLE 20. AVERAGE ANNUAL DAMAGE FOR INTANGIBLE VALUES (AU$)

Intangible value	**Base case**	**Part A works**	**Part A + Part B works**
Mortality	5	2	2
Electricity outage	3,862	1,507	909
Road traffic annoyance	1,149	373	208
Road traffic delays	550,215	166,248	101,421
Inability to return home	14,199	5,540	3,343

Other intangible values were calculated on an annual basis rather than per flood event, either because they are affected by the implementation of a mitigation option (i.e. recreation and cultural heritage) or because they arise from the risk of flooding instead of being the result of a flood event (i.e. morbidity). These values are presented in Table 21. In the absence of mitigation, the losses from flood risk related to morbidity are the most important intangible values (AU$1,077,047 per annum), followed by road traffic delays (AU$550,215).

TABLE 21. INTAGIBLE VALUES ESTIMATED ON AN ANNUAL BASIS (AU$)

	Base case	Part A works	Part A + Part B works		
			B1	B2	D
Values affected by the implementation of a mitigation option					
Annual loss in recreation	0	0	32,313	32,313	0
Annual loss in cultural heritage	0	0	9,853	0	0
Values arising from the risk of flooding					
Annual morbidity costs	1,077,047	311,411	15,983	15,983	15,983

6. Results

Below, we summarise tangible and intangible flood damages together for the different mitigation scenarios: base case (no mitigation); Part A works; and Part A plus Part B works. The results are shown in Table 22. Tangible damages were extracted from BHKCP (2016) while intangible values are based on the calculations described in the previous section. Table 22 shows how the combined tangible and intangible flood damages decline under the different mitigation options.

In some cases, mitigation has a relatively bigger effect on tangible than on intangible damages; and in other cases, the opposite is the case. For instance, for a 100 year ARI flood, which is the target of the mitigation works currently under consideration, tangible flood damages under the base case scenario were estimated around AU$122 million and intangible flood damages around AU$9.7 million. With the implementation of Part A works, tangible damages would be reduced to AU$31 million (i.e. a reduction of about 75%) and intangible damages would be reduced to AU$5 million (i.e. a reduction of 47%). In contrast, for a 50 year ARI flood, the implementation of Part A works would reduce tangible damages from AU$45 million to AU$9 million (a reduction of 80%), while intangible damages are reduced from AU$6 million to AU$40,000 (a much larger reduction of 99.4%). However, it is important to remember that the values estimated per event correspond to the potential damages that would be caused by the floods directly and do not include recreation, cultural heritage and morbidity (which are estimated on an annual basis and do not depend on the severity of the flood).

TABLE 22. COMBINED TANGIBLE AND INTANGIBLE FLOOD DAMAGE ESTIMATES PER FLOOD EVENT (AU$'000)*

ARI in years	Type of values	Base case scenario	Part A works	Part A + Part B works
10	Tangible	4,800	0	0
	Intangible	700	0	0
	Total	5,500	0	0
20	Tangible	10,600	0	0
	Intangible	2,600	0	0
	Total	13,200	0	0
50	Tangible	45,000	9,000	400
	Intangible	6,300	40	1.0
	Total	51,200	9,000	400
100	Tangible	122,200	30,500	810
	Intangible	9,700	5,200	0
	Total	132,000	35,700	820
500	Tangible	434,400	181,700	181,700
	Intangible	34,700	14,500	14,500
	Total	469,000	196,200	196,200
PMF	Tangible	1,000,000	1,000,000	1,000,000
	Intangible	79,800	79,800	79,800
	Total	1,079,800	1,079,800	1,079,800

* Includes only those intangible items that can be quantified per event; that is, mortality, electricity outage, road traffic annoyance, road traffic delays, and inability to return home. Values in this table have been rounded to facilitate the readability of the results.

6.1. Benefit-cost analysis

Converting damage values into AAD makes it easier to appreciate the differences between tangible and intangible values. Table 23 shows the AAD for tangible and intangible values for different mitigation scenarios. Intangible damages are substantially smaller than tangible damages across all scenarios. Intangibles represent 21% of total damages for the base case scenario, about 18% for Part A works, and between 6 and 8% for Part A + Part B. In the case of options B1 and B2, there are intangible costs related to the construction of dams. These costs are AU$42,166 per year for option B1 (consisting of AU$32,313 for recreation and

AU$9,853 for cultural heritage value losses) and AU$32,313 per year for option B2 (recreation only). These intangible value losses caused by the construction of the dams have the effect of reducing the total benefits generated by these options compared to options D. As a result, the damage reduction benefits obtained with Options B1 and B2 are lower than those obtained with Option D (AU$5.56 million).

TABLE 23. TANGIBLE AND INTANGIBLE AVERAGE ANNUAL DAMAGES FOR DIFFERENT SCENARIOS (AU$ MILLION)*

Type of damage	Base case	Part A works	Part A + Part B works		
			Part A + B1	Part A + B2	Part A + D
Tangible^	5.96	2.23	1.92	1.92	1.92
Intangible	1.65	0.49	0.16	0.15	0.12
Total	7.61	2.71	2.08	2.07	2.04
Reduction in AAD		4.89	5.52	5.53	5.56

* The values have been rounded to facilitate the readability of the results
^ Source: BHKCP (2016)

The economic attractiveness of an option is evaluated against the base case scenario by considering the reduction in AAD that can be expected from its implementation. In our case, the base case scenario used is the one without any of the mitigation works; that is, without parts A or B (

Appendix **2** presents results from an analysis using a different base case scenario, as it was done in the preliminary version of this study). The reduction in AAD following the implementation of an option is compared to the cost of implementation to assess if the benefit exceeds the cost. Table 24 shows the costs of the different mitigation options. The costs of options B1, B2 and D are AU$41, AU$44 and AU$36 million respectively. These options (Part B works) are considered only as an add-on to Part A works. Therefore, the total costs considered are those for Part A alone and the costs of the combined implementation of Parts A and B works.

TABLE 24. TOTAL COST OF THE MANAGEMENT OPTIONS (AU$ MILLION)

Option →	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
Cost^	111	152	155	147

^ Source: BHKCP (2016)

Not only the amount but also the trajectory of capital costs has an effect on present value calculations and benefit-cost ratios. We follow the approach in BHKCP (2016) to define the stream of costs for each option and assume that outlays are spread over a period of seven years. We also adopt their discount rate of 6% and 30 years as the relevant time horizon in our calculation of present values. Finally, the benefits of mitigation are assumed to be realised starting from year 3 as in BHKCP (2016). More precisely, we assume that 10% of the benefits from mitigation will be delivered in years 3 and 4, 20% in years 5 and 6, 40% in year 7, 50% in year 8, 70% in year 9, 80% in year 10 with the full benefits of mitigation delivered in year 11 and beyond.

The present value of costs and benefits and the benefit-cost ratios for different mitigation scenarios are summarised in Table 25. Part A works are estimated to generate benefits of about AU$38.5 million over a 30 year horizon. The present value of the costs for Part A works is about AU$88.5 million. As a result, Part A works has a benefit-cost ratio of about 0.4. This means that every dollar invested in Part A generates only AU$0.4 in benefits.

Among Part B works, the option that generates the highest incremental benefits is option D. The present value of benefits from Part A + option D are AU$44.3 million. The cost, however, is much higher (AU$116.8 million), leading to a benefit-cost ratio of 0.38, which is smaller than the ratio for Part A works alone. Options B1 or B2 generate slightly smaller benefit-cost ratios. In summary, for the baseline analysis, none of the options considered pass the benefit-cost ratio test.

TABLE 25. PRESENT VALUES OF TANGIBLE AND INTANGIBLE COSTS AND BENEFITS FOR ALTERNATIVE MITIGATION OPTIONS ($AU MILLION)

Values	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
Present value of benefits	38.5	44.0	44.0	44.3
Present value of costs	88.5	121.1	123.7	116.8
Net present value	-50.0	-77.2	-79.7	-72.5
Benefit cost ratios	0.44	0.36	0.36	0.38

As indicated before, however, it should be noted that we have used what we believe are conservative (lower-bound) values for most of our intangible values. And since no survey has been conducted in the case study area to assess people's willingness to pay for intangible mitigation benefits, there is a high level of uncertainty attached to the figures employed above. Therefore, it is useful to evaluate how sensitive the modelling results are to changes in intangible values.

6.2. Sensitivity analysis

For the sensitivity analysis, we increased the value of all intangible items simultaneously and considered increases that ranged from doubling (100% increase), to tripling (200% increase) and higher changes, including increases of 500, 700, 800 and 1000%. With these increases in intangible values, the present values increase (see Table 26 and Table 27), but at a disproportionately lower rate because intangibles are still dominated by tangibles. The increases in intangible values required for present values to be positive are large, as shown in Table 27. The option that generates the largest benefits is still the combination of Part A works with option D from Part B, regardless of the size of the increase in intangible values (Table 27). However, on the basis of benefit to cost ratios, Part A works alone generate higher returns up until intangibles are increased by 500% (see Table 28). When intangibles are increased by 700% or more, the combination of Part A works with option D from Part B generates the highest BCR.

Note that the benefit-cost ratios are equal or larger than 1 only when intangible values are increased by at least 700%. This is a considerable increase in intangible values relative to our baseline estimates. For such values to be valid, households located within the floodplain of a 100 year ARI flood would have to be willing to pay roughly AU$6,000 per household per year to avoid the intangible damages caused by floods. However, this is unlikely to be the case, unless people are exposed to much more frequent flooding. As the literature on this topic shows, people are on average willing to pay between AU$40 and AU$1,864 per household per year to reduce potential flood impacts (Brouwer and Bateman 2005, Joseph et al. 2015, Londoño Cadavid and Ando 2013, Owusu et al. 2015, Zhai et al. 2006), and about AU$1,177 per household per year to avoid intangible impacts from floods (Joseph et al. 2015).

TABLE 26. PRESENT VALUES OF BENEFITS (TANGIBLE AND INTANGIBLE COMBINED) FOR DIFFERENT SCENARIOS ($AU MILLION)

Increase in intangible values	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
0%	38.5	44.0	44.0	44.3
100%	47.3	56.4	56.5	57.1
200%	56.0	68.7	68.9	69.8
500%	82.2	105.9	106.4	108.0
700%	99.7	130.7	131.3	133.5
800%	108.4	143.1	143.8	146.2
1000%	125.9	167.9	168.7	171.7

TABLE 27. NET PRESENT VALUES (TANGIBLE AND INTANGIBLE COMBINED) FOR DIFFERENT SCENARIOS ($AU MILLION)

Increase in intangible values	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
0%	-50	-77	-80	-73
100%	-41	-65	-67	-60
200%	-33	-52	-55	-47
500%	-6	-15	-17	-9
700%	11	10	8	17
800%	20	22	20	29
1000%	37	47	45	55

TABLE 28. BENEFIT-COST RATIOS FOR DIFFERENT SCENARIOS

Increase in intangible values	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
0%	0.44	0.36	0.36	0.38
100%	0.53	0.47	0.46	0.49
200%	0.63	0.57	0.56	0.60
500%	0.93	0.87	0.86	0.92
700%	1.13	1.08	1.06	1.14
800%	1.22	1.18	1.16	1.25
1000%	1.42	1.39	1.36	1.47

7. Conclusion

This research has identified some of the intangible values that need to be considered in the assessment of flood mitigation options and integrated them into an economic analysis. We used intangible values already available in the literature and adapted them to the context of the Brown Hill and Keswick creeks catchment in Adelaide, South Australia. The results show that the most substantial intangible values in terms of AAD are morbidity (i.e. WTP to reduce flood-related health effects) and road traffic delays (i.e. WTP to avoid road traffic delays caused by flood events). However, intangible values remain relatively small compared to the potential tangible damages that floods may cause in the area; they represent only between 6 and 21% of total damages.

All options generate benefit-cost ratios smaller than 1, even when intangible values are included in the analysis. The option that generates the largest benefits is the combination of Part A works with option D from Part B, but the high costs of implementation reduce the value for money that this option can provide. We used what we consider conservative values in this analysis and evaluated the changes in the results if intangible values were more significant. A sensitivity analysis showed that intangibles would have to be substantially higher than our current estimates for any of the flood mitigation options to generate a benefit-cost ratio equal or larger than 1. However, it is unlikely that such high intangible values would be consistent with the reality in the catchment, given that in most of the published literature average WTP estimates to avoid flood (intangible) impacts are usually smaller.

This study has shown that, although intangible values are important, their inclusion did not alter the fact that flood mitigation options had benefit-cost ratios that were below unity. It should be emphasised, however, that there is a lot of uncertainty about the magnitude of the intangible values. We have taken relatively conservative estimates. The values could change going forward into the future.

Intangible values are likely to increase over time with increases in income and/or improvements in living standards. They are also likely to increase if households in the catchment are subjected to more frequent flooding, which could be a result of climate change as it has been the case in other parts of Australia and the world. Finally, to better understand the trade-offs that households are willing to make and their WTP to avoid the flood damages in the area, additional information could be obtained by conducting a non-market valuation survey in the Brown Hill and Keswick creeks catchment. Such a study would generate willingness to pay (WTP) estimates that could be compared with the threshold estimates provided above and provide more specific information on people's preferences for risk levels and for mitigation options.

8. References

ABS, 2006. Census data, QuickStats Greater Adelaide (Greater Capital City Statistical Area). http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/4GADE?opendocument&navpos=220 Accessed 3/06/2016

ABS, 2011.Census QuickStats. http://www.abs.gov.au/websitedbs/censushome.nsf/home/quickstats Accessed 8/06/2016

ABS, 2014. Consumer Price Index, Australia, Mar 2014. Catalogue Number: 6401.0

ABS, 2013. Census data, QuickStats (State suburbs). http://abs.gov.au/websitedbs/censushome.nsf/home/quickstats?opendocument&navpos=220 Accessed 10/06/2016

ABS, 2015. Regional Population Growth, Australia, 2013-14. Catalogue Number: 3218.0 http://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/3218.0Main%20Features352013-14?opendocument&tabname=Summary&prodno=3218.0&issue=2013-14&num=&view= Accessed 10/06/2016

ABS, 2016. Average Weekly Earnings, Australia, May 2016. Catalogue Number: 6302.0 http://www.abs.gov.au/ausstats/abs@.nsf/mf/6302.0 Accessed 9/12/2016

Asciuto, A., Borsellino, V., D'Acquisto, M., Di Franco, C.P., Di Gesaro, M. and Schimmenti, E., 2015. Monumental trees and their existence value: Case study of an Italian natural park. J. FOR. SCI, 61(2), pp.55-61.

Babisch, W. (2006). Transportation noise and cardiovascular risk: updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise and Health, 8(30), 1–29. 5.

Babister, M., Retallick , M., 2011. Brisbane river 2011 flood event – flood frequency analysis. Final report prepared for the Queensland flood commission of inquiry. WMA water, Sydney, Australia.

Bala, M.V., Zarkin, G.A., 2000. Are QALYs an appropriate measure for valuing morbidity in acute diseases? Health Economics 9(2), 177-180.

(BHKCP) Brown Hill Keswick Creek project Steering Group (2016) Stormwater Management Plan, March 2016. Developed by the Cities of Adelaide, Burnside, Mitcham, Unley and West Torrens. Available at bhkcstormwater.com.au

Bichard, E., Kazmierczak, A., 2009. Resilient homes: reward-based methods to motivate householders to address dangerous climate change. A report for the Environment Agency. University of Salford, Manchester, UK.

Billinton, R., Pandey, M., 1999. Reliability worth assessment in a developing country – residential survey results. IEEE Trans. Power Syst. 14 (4), 1226–1231.

Boyd, E., Levitan, M. and van Heerden, I. (2005) Further specification of the dose-response relationship for flood fatality estimation. Paper presented at the US-Bangladesh workshop on innovation in windstorm/storm surge mitigation construction. National Science Foundation and Ministry of Disaster and Relief, Government of Bangladesh. Dhaka, 19-21 December 2005.

Bluhm, L. G., Berglind, N., Nordling, E., & Rosenlund, M. (2007). Road traffic noise and hypertension. Occupational and Environmental Medicine, 64(2), 122–126. 6.

Bosworth, R., Cameron, T.A., DeShazo, J.R., 2009. Demand for environmental policies to improve health: Evaluating community-level policy scenarios. Journal of Environmental Economics and Management 57(3), 293-308.

Botzen, W.J.W., de Boer, J., Terpstra, T., 2013. Framing of risk and preferences for annual and multi-year flood insurance. Journal of Economic Psychology 39, 357-375.

Botzen, W.J.W., van den Bergh, J.C.J.M., 2012. Risk attitudes to low-probability climate change risks: WTP for flood insurance. Journal of Economic Behavior & Organization 82(1), 151-166.

Briere, J. and Elliott, D., 2000. Prevalence, characteristics, and long-term sequelae of natural disaster exposure in the general population. Journal of traumatic stress, 13(4), pp.661-679.

Brouwer, R., Bateman, I.J.C.W., 2005. Temporal stability and transferability of models of willingness to pay for flood control and wetland conservation. Water Resources Research 41(3)

Brownstone, D. and Small, K.A., 2003. Valuing time and reliability: Assessing the evidence from road pricing demonstrations. University of California Transportation Center.

Brownstone, D., Ghosh, A., Golob, T.F., Kazimi, C., Van Amelsfort, D., 2003. Drivers willingness-to-pay to reduce travel time: evidence from the San Diego I-15 Congestion Pricing Project. Transportation Research A 37, 373–387. Calfee, J., Winston, C., 1998. The value of automobile travel time: implications for congestion policy. Journal of Public Economics 69, 83–102.

Cameron, T.A., DeShazo, J.R., 2013. Demand for health risk reductions. Journal of Environmental Economics and Management 65(1), 87-109.

Carlsson, F. and Martinsson, P., 2007. Willingness to pay among Swedish households to avoid power outages: a random parameter Tobit model approach. The Energy Journal, pp.75-89.

Carlsson, F., Martinsson, P., 2006. Do experience and cheap talk influence willingness to pay in an open-ended contingent valuation survey? Working Papers in Economics, No. 190, School of Business Economics and Law, Göteborg University. Available at: 〈 https://gupea.ub.gu.se/handle/2077/2732〉 (accessed May 2016).

Carlsson, F., Martinsson, P., 2007. Willingness to pay among Swedish households to avoid power outages – a random parameter Tobit model approach. Energy J. 28 (1), 75–90.

Carlsson, F., Martinsson, P., 2008. Does it matter when a power outage occurs? – a choice experiment study on the willingness to pay to avoid power outages. Energy Econ. 30 (3), 1232–1245.

Chowdhury, A.A., Mielnik, T.C., Lawion, L.E., Sullivan, M.J., Katz, A., 2004. Reliability worth assessment in electric power delivery systems. IEEE Power Eng. Soc. Gen. Meet. 1, 654–660.

Chuck, A., Adamowicz, W., Jacobs, P., Ohinmaa, A., Dick, B. and Rashiq, S., 2009. The Willingness to Pay for Reducing Pain and Pain- Related Disability. Value in Health, 12(4), pp.498-506.

Clark, D.E., Griffin, R., Novoty, V., 2005. Assessing the Determinants of Willingness to Pay for Urban Flood Control: The Role of Locational, Demographic and attitudinal Factors. IDEAS Working Paper Series from RePEc. Federal Reserve Bank of St Louis, St. Louis.

Clark, D.E., Novotny, V., Griffin, R., Booth, D., Bartošová, A., Daun, M.C., Hutchinson, M., 2002. Willingness to pay for flood and ecological risk reduction in an urban watershed. Water Science and Technology 45(9), 235-242.

Clemens, S.L., Berry, H.L., McDermott, B.M., Harper, C.M., 2013. Summer of sorrow: measuring exposure to and impacts of trauma after Queensland's natural disasters of 2010–2011. The Medical Journal of Australia 199(8), 552-555.

Coates, L., 1999. Flood fatalities in Australia, 1788-1996. Australian Geographer, 30(3), pp.391-408.

Cropper, M.L., Hammitt, J.K. and Robinson, L.A., 2011. Valuing mortality risk reductions: progress and challenges (No. w16971). National Bureau of Economic Research.

de Kluizenaar, Y., Janssen, S. A., van Lenthe, F. J., Miedema, H. M., & Mackenbach, J. P., 2009. Long-term road traffic noise exposure is associated with an increase in morning tiredness. Journal of the Acoustical Society of America, 126(2), 626–633.

Defra. The appraisal of human related intangible impacts of flooding. Defra, Flood management division, R&D Technical Report FD2005/TR, London, UK. 2004.

Dias-Sardinha, I., Ross, D., 2015. Perceived Impact of the Alqueva Dam on Regional Tourism Development. Tourism Planning & Development 12(3), 362-375.

Doane, M., McClelland, G.H., Schulze, W.D., Woo, C.K., 1989. The value of electrical power outages: a contingent valuation study. Report submitted to Niagara Mohawk Electric Power Company.

Doane, M.J., Hartman, R.S., Woo, C.K., 1988. Households' perceived value of service reliability: an analysis of contingent valuation data. Energy J. 9, 135–151.

(DPCM) Department of the Prime Minister and Cabinet (2014). Best Practice Regulation Guidance Note Value of statistical life. Department of the Prime Minister and Cabinet, Office of Best Practice Regulation.

Dratva, J., Zemp, E., Dietrich, D.F., Bridevaux, P.O., Rochat, T., Schindler, C. and Gerbase, M.W., 2010. Impact of road traffic noise annoyance on health-related quality of life: Results from a population-based study. Quality of life research, 19(1), pp.37-46.

BHKCP 2011 . Draft Stormwater Management Plan, Brown Hill Keswick Kreek stormwater project, Worley Parsons.

EA-DEFRA, 2005. The appraisal of human related intangible impacts of flooding. Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme. R&D Technical Report FD2005/TR. DEFRA Flood Management Division, London, UK.

FitzGerald, G., Du, W., Jamal, A., Clark, M. and Hou, X.Y., 2010. Flood fatalities in contemporary Australia (1997–2008). Emergency Medicine Australasia, 22(2), pp.180-186.

Fleming, C.M. and Cook, A., 2008. The recreational value of Lake McKenzie, Fraser Island: An application of the travel cost method. Tourism Management, 29(6), pp.1197-1205.

Fosgerau, M. and Bjørner, T.B., 2006. Joint models for noise annoyance and willingness to pay for road noise reduction. Transportation Research Part B: Methodological, 40(2), pp.164-178.

Gerking, S., Dickie, M., Veronesi, M., 2014. Valuation of human health: An integrated model of willingness to pay for mortality and morbidity risk reductions. Journal of Environmental Economics and Management 68(1), 20-45.

Gibson, F., Pannell, D., Boxall, P., Burton, M., Johnston, R., Kragt, M., Rogers, A. and Rolfe, J., 2016. Non-market valuation in the economic analysis of natural hazards (No. 236941).

Ginexi, E.M., Weihs, K., Simmens, S.J., Hoyt, D.R., 2000. Natural Disaster and Depression: A Prospective Investigation of Reactions to the 1993 Midwest Floods. American Journal of Community Psychology 28(4), 495-518.

Goett, A., McFadden, D., Woo, C.K., 1988. Estimating residential electricity outage cost with market research data. Energy J. 9, 105–120.

Government of South Australia (2016). Department of Planning Transport and Infrastructure http://dpti.sa.gov.au/traffic_volumes#rural accessed 31th May 2016.

Green, C., Viavattene, C., and Thompson, P. 2011. Guidance for assessing flood losses: CONHAZ Report, http://www.mdx.ac.uk/__data/assets/pdf_file/0031/49189/floodsWP_FINALREPORT sept11.pdf

Hammitt, J. and Haninger, K., 2011. Valuing Morbidity Risk: Willingness to Pay per Quality-Adjusted Life Year. IDEAS Working Paper Series from RePEc. Federal Reserve Bank of St Louis, St. Louis.

Haynes, K., Coates, L., Dimer de Oliveira, F., Gissing, A., Bird, D., van den Honert, R., Radford, D., D'Arcy, R. and Smith, C. (2016) An analysis of human fatalities from floods in Australia 1900-2015. Report for the Bushfire and Natural Hazards CRC.

Hensher, D.A., Shore, N. and Train, K., 2014. Willingness to pay for residential electricity supply quality and reliability. Applied Energy, 115, pp.280-292.

http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6302.0Nov%202015?OpenDocument accessed July 2016. Average Weekly Earnings, Australia, Catalog 6302.0

Istamto, T., Houthuijs, D. and Lebret, E., 2014. Willingness to pay to avoid health risks from road-traffic-related air pollution and noise across five countries. Science of the total environment, 497, pp.420-429.

Jonkman, S.N. (2005) Global perspectives of loss of human life caused by floods. Natural Hazards 34(1), 151-175.

Jonkman, S.N. (2007) Loss of life estimation in flood risk assessment – theory and applications. PhD thesis, Delft University.

Joseph, R, Proverbs, D., and Lamond, J. 2015. Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures, Natual Hazards, 79, 1275-1297.

Joseph, R., Proverbs, D., Lamond, J., 2015. Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures. Natural Hazards 79(2), 1275-1297.

Keane, D.M., MacDonald, L., Woo, C.K., 1988. Estimating residential outage cost with market research data. Energy J. (Special Issue) 9, 151–159.

Kochi, I., Donovan, G.H., Champ, P.A. and Loomis, J.B., 2010. The economic cost of adverse health effectsfrom wildfire-smoke exposure: a review. International Journal of Wildland Fire, 19(7), pp.803-817.

Krause, Andrew 2016. Traffic Management Centre, South Australian Government. 1st June 2016.

Laband, D.N., 2013. The neglected stepchildren of forest-based ecosystem services: cultural, spiritual, and aesthetic values. Forest Policy and Economics, 35, pp.39-44.

Lam, T.C. and Small, K.A., 2001. The value of time and reliability: measurement from a value pricing experiment. Transportation Research Part E: Logistics and Transportation Review, 37(2), pp.231-251.

Landry, C.E., Bin, O., Hindsley, P., Whitehead, J.C. and Wilson, K., 2007. Going home: Evacuation-migration decisions of Hurricane Katrina survivors. Southern Economic Journal, pp.326-343.

Landry, C.E., Bin, O., Hindsley, P., Whitehead, J.C. and Wilson, K., 2007. Going home: Evacuation-migration decisions of Hurricane Katrina survivors.Southern Economic Journal, pp.326-343.

Layton, D.F., Moeltner, K., 2005. The cost of power outages to heterogeneous households: an application of the mixed gamma-lognormal distribution. Applications of simulation methods. In: Scarpa, R., Alberini, A. (Eds.), Environmental and Resource Economics. Springer Publishing, Dordrecht, The Netherlands, pp. 35–54.

Lindhjem, H., Navrud, S., Braathen, N.A. and Biausque, V., 2011. Valuing Mortality Risk Reductions from Environmental, Transport, and Health Policies: A Global Meta-Analysis of Stated Preference Studies. Risk Analysis 31(9), 1381-1407.

Lo, A.Y., 2013. Household Preference and Financial Commitment to Flood Insurance in South-East Queensland. Australian Economic Review 46(2), 160-175.

Lockwood, M. and Tracy, K., 1995. Nonmarket economic valuation of an urban recreation park. Journal of Leisure Research, 27(2), p.155.

Londoño Cadavid, C. and Ando, A. W., 2013. Valuing preferences over stormwater management outcomes including improved hydrologic function. Water Resources Research 49(7), 4114-4125.

Loomis, J.B., 2002. Quantifying recreation use values from removing dams and restoring free-flowing rivers: a contingent behavior travel cost demand model for the Lower Snake river. Water Resources Research 38(6), 2-1 - 2-8.

MacDonald, D. H., Crossman, N. D., Mahmoudi, P., Taylor, L. O., Summers, D. M. and Boxall, P. C., 2010. The value of public and private green spaces under water restrictions. Landscape and Urban Planning 95(4), 192-200.

Martinez-Jauregui, M., Herruzo, A. C., Campos, P. and Solino, M., 2016. Shedding light on the self-consumption value of recreational hunting in European Mediterranean forests. Forest Policy and Economics 69, 83-89.

McKean, J.R., Johnson, D., Taylor, R.G., 2012. Three approaches to time valuation in recreation demand: A study of the Snake River recreation area in eastern Washington. Journal of Environmental Management 112, 321-329.

Merz, B., Kreibich, H., Schwarze, R., and Thieken, A. 2010. Assessment of economic flood damage: Review article. Natural Hazards Earth Systems Science, 10, 1697-1724.

Messner, F., 2007. Evaluating flood damages: guidance and recommendations on principles and methods. Helmholz Unweltforschungszentrum (UFZ).

Meyer, V., Becker, N., Markantonis, V., Schwarze, R., van den Bergh, J.C.J.M. , Bouwer, L.M., Bubeck, P., Ciavola, P., Genovese, E., Green, C., Hallegatte, S., Kreibich, H., Lequeux, Q., Logar, I., Papyrakis, E., Pfurtscheller, C., Poussin, J., Przyluski, V., Thieken, A.H. and Viavattene, C. 2013. Assessing the costs of natural hazards – state of the art and knowledge gaps: Review article, 13, 1351-1373.

Munasinghe, M., 1980. Costs incurred by residential electricity consumers due to power failures. J. Consum. Res. 6 (4), 361–369.

Natalie Fuller and Associates and UPRS, 2015. Consultation findings on the Brown Hill Keswick Creek Stormwater Project Part B. Report prepared for the Brown Hill Keswick Creek Stormwater project Steering Group.

Navrud, S. (2000) Economic Benefits of a Program to Reduce Transportation and Community Noise Contingent Valuation Survey. In Proceedings of Internoise (Vol. 5, pp. 3395-3400).

Nielsen, J.B., 2003. Impact of Socio-demographic Factors on Willingness to Pay for the Reduction of a Future Health Risk. Journal of Environmental Planning and Management 46(1), 39-47.

Nielsen, J.S., Gyrd-Hansen, D., Kjær, T., 2012. Valuation of morbidity and mortality risk reductions. Does context matter? Accident Analysis & Prevention 48, 246-253.

Nillesen, E., Wesseler, J. and Cook, A., 2005. Estimating the recreational-use value for hiking in Bellenden Ker National Park, Australia. Environmental Management, 36(2), pp.311-316.

North, C.S., Kawasaki, A., Spitznagel, E.L., Hong, B.A., 2004. The Course of PTSD, Major Depression, Substance Abuse, and Somatization after a Natural Disaster. Journal of Nervous & Mental Disease 192(12), 823-829.

Prayaga, P., Rolfe, J. and Stoeckl, N., 2010. The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model. Marine Policy 34(2), 244-251.

Owusu, S., Wright, G., Arthur, S., 2015. Public attitudes towards flooding and property-level flood protection measures. Natural Hazards 77(3), 1963-1978.

Ozbafli, A. and Jenkins, G.P., 2015. The willingness to pay by households for improved reliability of electricity service in North Cyprus. Energy Policy,87, pp.359-369.

Ozbafli, A., 2012. Estimating the willingness to pay for a reliable electricity supply in the Turkish Republic of Northern Cyprus (Doctoral dissertation, University of Birmingham).

Parker, D.J, Green, C.H., Thompson. P.M. 1987. Urban Flood Protection Benefits: A Project Appraisal Guide. The Technical Press, Aldershot.

Penning-Rowsell, E.C. and Green, C., 2000. New Insights into the Appraisal of Flood-Alleviation Benefits: (1) Flood Damage and Flood Loss Information. Water and Environment Journal, 14(5), 347-353.

Pikusa, E. (2016). Personal communication. Australian Emergency Risk Management Guidelines, Policy and Programs.

Productivity Commission 2014, Natural Disaster Funding Arrangements, Inquiry Report no. 74, Canberra. JEL code: H77, H84.

Queensland Reconstruction Authority (QRA), 2012. Planning for stronger, more resilient electrical infrastructure. Improving the resilience of electrical infrastructure during flooding and cyclones.

Rathnayake, R. M. W., 2016. Economic values for recreational planning at Horton Plains National Park, Sri Lanka. Tourism Geographies 18(2), 213-232.

Reid, K. 2011, Flooding expected to be beneficial to river ecosystem, ABC online news, http://www.abc.net.au/local/stories/2011/01/25/3121051.htm

Robinson, L.A., Hammitt, J.K., 2013. Skills of the trade: valuing health risk reductions in benefit-cost analysis. Journal of Benefit-Cost Analysis 4(1), 107-130.

Rolfe, J. and Dyack, B., 2011. Valuing Recreation in the Coorong, Australia, with Travel Cost and Contingent Behaviour Models. Economic Record 87(277), 282-293.

Rossi, S. D., Byrne, J. A. and Pickering, C. M., 2015. The role of distance in pen-urban national park use: Who visits them and how far do they travel? Applied Geography 63, 77-88.

Saengsupavanich, C., Seenprachawong, U., Gallardo, W. G. and Shivakoti, G. P., 2008. Port-induced erosion prediction and valuation of a local recreational beach. Ecological Economics 67(1), 93-103.

Salazar, S. D. and Menendez, L. G., 2007. Estimating the non-market benefits of an urban park: Does proximity matter? Land Use Policy 24(1), 296-305.

Sale, M. C., Hosking, S. G. and du Preez, M., 2009. Application of the contingent valuation method to estimate a recreational value for the freshwater inflows into the Kowie and the Kromme Estuaries. Water Sa 35(3), 261-270.

Sanghvi, A.P., 1983. Optimal electricity supply reliability using customer shortage costs. Energy Econ. 5 (2), 129–136.

Saraj, B. S., Yachkaschi, A., Oladi, J., Teimouri, S. F. and Latifi, H., 2009. The recreational valuation of a natural forest park using travel cost method in Iran. Iforest-Biogeosciences and Forestry 2, 85-92.

Smallwood, C. B., Beckley, L. E. and Moore, S. A., 2013. Effects of adjacent land tenure on visitor use of Ningaloo Marine Park, Western Australia. Australasian Journal of Environmental Management 20(2), 130-146.

Stansfeld, S. A., & Matheson, M. P., 2003. Noise pollution: Nonauditory effects on health. British Medical Bulletin, 68, 243–257

Stansfeld, S., Haines, M., & Brown, B., 2000. Noise and health in the urban environment. Reviews on Environmental Health, 15(1–2), 43–82. 7.

Stieb, D.M., De Civita, P., Johnson, F.R., Manary, M.P., Anis, A.H., Beveridge, R.C., Judek, S., 2002. Economic evaluation of the benefits of reducing acute cardiorespiratory morbidity associated with air pollution. Environmental Health 1, 7-7.

Stigner, M. G., Beyer, H. L., Klein, C. J. and Fuller, R. A., 2016. Reconciling recreational use and conservation values in a coastal protected area. Journal of Applied Ecology 53(4), 1206-1214.

Sullivan, M.J., Suddeth, N.B., Vardell, T., Vojdani, A., 1996. Interruption costs, customer satisfaction and expectations for service reliability. IEEE Trans. Power Syst. 11 (2), 989–995.

Tapsuwan, S., MacDonald, D. H., King, D. and Poudyal, N., 2012. A combined site proximity and recreation index approach to value natural amenities: An example from a natural resource management region of Murray-Darling Basin." Journal of Environmental Management 94(1), 69-77.

Ten Veldhuis, J.A.E, 2011. How the choice of flood damage metrics influences urban flood risk assessment, Journal of Flood Risk Management, 4, 281-287.

Tollefson, G., Billinton, R., Wacker, G., Chan, E., Aweya, J., 1994. A Canadian customer survey to assess power system reliability worth. IEEE Trans. Power Syst. 9 (1), 443–450.

Tu, G. Y., Abildtrup, J. and Garcia, S., 2016. Preferences for urban green spaces and peri-urban forests: An analysis of stated residential choices. Landscape and Urban Planning 148, 120-131.

van Amelsfort, D., Bovy, P.H.L., Bliemer, M.C.J., Ubbels, B., 2008. Travellers' responses to road pricing: value of time, schedule delay and unreliability. In: Verhoef, E.T., Bliemer, M.C.J., Steg, L., van Wee, B. (Eds.), Pricing in Road Transport: A Multi-Disciplinary Perspective, Edward Elgar, Northampton, pp. 64–85.

Viscusi, W.K., Huber, J., Bell, J., 2012. Heterogeneity in Values of Morbidity Risks from Drinking Water. Environmental and Resource Economics 52(1), 23-48.

Wacker, G., Wojczynski, E., Billinton, R., 1983. Interruption cost methodology and results – a Canadian residential survey. IEEE Trans. Power Appar. Syst. 102, 10.

Whitworth, Kerry L., Baldwin, Darren S., Kerr, Janice L. 2012. Drought, floods and water quality: Drivers of a severe hypoxic blackwater event in a major river system (the southern Murray–Darling Basin, Australia), Journal of Hydrology, Vol. 450-451, pp.190-198

Zhai, G., Sato, T., Fukuzono, T., Ikeda, S., Yoshida, K., 2006. Willingness to pay for flood risk reduction and its determinants in Japan. JAWRA Journal of the American Water Resources Association 42(4), 927-940.

Appendix 1

The following tables show the estimated depth of inundation, the estimated mortality rate and the estimated population affected per flood event used to calculate the number of fatalities for each ARI event.

Table A.1 shows the average depth of inundation for each type of flood under the base case scenario (no mitigation), which was estimated using the flood maps in BHKCP (2016). For the inundation depth under part A works and part A+B works, only one map is available in BHKCP (2016): the flood map for a 100 year ARI event after implementation of part A. This map shows that the average depth of inundation is reduced by about half, because most of the areas with deeper inundation levels around the airport would no longer be flooded. Using this ratio as an indicator of the impact of mitigation, the inundation depth was halved after implementation of part A works and halved again after implementation of part B works for 50 year and 100 year ARI events. Since after implementation of part A there are no properties affected by 10 year and 20 year ARI events, the inundation depth of these events is assumed to be zero for both mitigation scenarios.

TABLE A.1. AVERAGE DEPTH OF INUNDATION

Type of event	Estimated average depth of inundation (metres)		
	Base case	**Part A**	**Parts A and B**
10 year ARI	0.125	0	0
20 year ARI	0.175	0	0
50 year ARI	0.275	0.14	0.07
100 year ARI	0.425	0.21	0.11

Table A.2 shows the estimated mortality rate calculated using the function developed by Boyd et al. (2005). Table A.3 shows the estimated population affected for each flood event for different mitigation scenarios. The population affected per event in each scenario was estimated by multiplying the number of households that would be affected (SMP 2016) by the average number of people per household in the area (i.e. an average of 2.4 people per household).

TABLE A.2. MORTALITY RATE

Type of event	Mortality rate (%)		
	Base case	Part A	Parts A and B
10 year ARI	0.00000000105	0.00000000048	0.00000000048
20 year ARI	0.00000000143	0.00000000048	0.00000000048
50 year ARI	0.00000000265	0.00000000122	0.00000000051
100 year ARI	0.00000000669	0.00000000143	0.00000000055

TABLE A.3. POPULATION AT RISK

Type of event	Number of properties affected			Estimated population affected		
	Base case	Part A	Parts A and B	Base case	Part A	Parts A and B
10 year ARI	139	0	0	334	0	0
20 year ARI	397	0	0	953	0	0
50 year ARI	1166	230	16	2798	552	38
100 year ARI	2089	604	31	5014	1450	74

Source for the number of properties affected: SMP (2016)

The number of fatalities per event for each scenario is calculated by multiplying the mortality rate by the population affected.

Appendix 2

Instead of using the no-mitigation scenario as the baseline for estimating the benefits, here we used a different baseline for the analysis, which corresponds to the completion of Part A works. We assumed that Part A works are done and estimated the additional benefits generated by the implementation of Part B works (options B1, B2 and D). Thus, we only focus on the incremental value produce by Part B works compared to Part A works.

Table A.4 shows the present value of the costs and benefits, the net present values and the benefit-cost rations of part B works when compared to Part A works. In this exercise, Part B works become considerably less attractive. The benefit-cost ratios for all options are well below 1. This indicates that after Part A works are implemented, the additional benefits generated by Part B works do not exceed the additional costs of the works, even when intangible values are included.

TABLE A.4. PRESENT VALUES OF TANGIBLE AND INTANGIBLE COSTS AND BENEFITS FOR ALTERNATIVE MITIGATION OPTIONS RELATIVE TO PART A WORKS ($AU MILLION)

Values	Part B works (relative to Part A)		
	Option B1	Option B2	Option D
Present value of benefits	5.4	5.5	5.8
Present value of costs	32.6	35.2	28.3
Net present value	-27.2	-29.7	-22.5
Benefit cost ratios	0.17	0.16	0.20