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VALUE TOOL FOR NATURAL HAZARDS: GUIDELINES

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Health values

- Physical health
- Mental health

Environmental values

- Ecosystems
- Water quality

Social values

- Recreation
- Amenity
- Safety
- Cultural heritage
- Social disruption
- Memorabilia
- Animal welfare

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EXECUTIVE SUMMARY

The "Value Tool for Natural Hazards" comprises of a Value Tool Database, which provides a collection of non-market value estimates relevant to natural hazards, and these Value Tool Guidelines, which describe how to use the values collated in the Database. The purpose of the Value Tool is to provide an accessible list of non-market value estimates for policy makers to use in decision making about natural hazard management.

The non-market or intangible benefits and costs of natural hazards are large in many cases, and should be accounted for in prioritising investment in natural hazard mitigation. We recommend that non-market values should be considered in natural hazard decision making as follows:

❖ If the decision is sufficiently important, the impacts are anticipated to be large, or the investment is expensive, original non-market valuation studies should be conducted to provide the most accurate and robust estimates of affected non-market values.

❖ In other cases, where resources do not allow for original studies to be conducted, alternative approaches such as benefit transfer should be used. Benefit transfer is a process where the results of non-market values that have previously been estimated for original "study sites" are extrapolated to predict values for different "policy sites". The Value Tool Database is designed to provide a collection of values suitable for benefit transfer in natural hazard decisions.

❖ Sometimes it is not possible or practicable to follow the preceding recommendations, and practitioners cannot identify existing studies in the Value Tool Database that are reasonably matched to be useful for quantitatively informing their policy context. In this case, practitioners can instead use the results from study sites in the Database to inform qualitative judgements about people's preferences, which can be used conceptually to make judgements about different policy options.

The Guidelines provide an overview of non-market values and benefit transfer for natural hazard decision making as follows:

- The importance of considering non-market values in natural hazard decision making is established in Sections 1 and 2.
- A description of the different types of non-market values affected by natural hazards is provided in Section 3, along with a general overview of the usefulness of existing literature in providing value estimates for these value types.
- Guidance on how to search the Database to locate suitable estimates of value types is provided in Section 4.
- Advice on how to adapt values extracted from the Database to new decision contexts is provided in Section 5, with particular reference to the benefit transfer approach.
- An applied example on how to utilise the Database for benefit transfer is given in Section 6.
- Additional information is provided in the Appendix on an introductory understanding of non-market valuation theory and the methods available for applying it (Appendix

1), and on the search protocol used to locate studies for inclusion in the Database (Appendix 2).

The Value Tool Database and Guidelines provide guidance on how the non-market value estimates should be used, and the policy contexts under which they are best suited for use. We recognise that the non-market valuation literature is incomplete with respect to providing highly accurate value estimates for all of the value types that might be affected by a natural hazard (see Section 3). However, we advocate that the use of an approximate number is usually better than no number, when it comes to decision making. It is better to have some information about the intangible benefits of a decision, than to ignore them completely: the error, and decision bias, resulting from the latter is likely to be far greater than the error from using an inaccurate number.

Provided the policy maker is aware of the potential for this error, uses a conservative approach for transferring values, and undertakes appropriate sensitivity analysis in analyses that use those values, then the values can provide useful, quantitative information for decision making. As noted above, in some cases, where a value transfer is too unreliable, we don't recommend using the values in a quantitative analysis, but suggest using them in a qualitative manner to inform thinking about particular policies.

GLOSSARY

Benefit transfer: a process where the results of non-market values estimated for original "study sites" are extrapolated to predict values for different "policy sites".

Contingent valuation: a stated preference approach that estimates the value of non-market goods by directly asking individuals how much they would be willing to pay to implement a change or prevent an impact.

Discrete choice experiments: a stated preference approach that estimates how individuals make trade-offs between changes in different characteristics, or attributes, of a non-market good, including a trade-off with the cost of providing these changes.

Hedonic pricing method: a revealed preference approach which is used to investigate how the non-market characteristics of a good influence its market value (e.g. premiums paid for property near desirable environments).

Marginal utility: a measure of the utility (value) associated with an incremental change in the quantity or quality of an outcome.

Non-market valuation: a set of economic approaches for estimating intangible values in financial-equivalent terms.

Non-market values: the intangible, non-financial or non-economic values that people hold for goods and services that are not bought and sold through a market.

Non-use value: the value derived from the satisfaction of knowing a good exists without there being any planned or actual use of the good.

Policy site: the new site or decision context for which values are being extrapolated to in a benefit transfer.

Revealed preference method: a non-market valuation approach that uses information from markets associated with the non-market good being valued, or from observing people's behaviour in their use of the good, to infer an individual's willingness to pay for it.

Stated preference method: a non-market valuation approach that uses survey-based instruments to ask individuals how much they are willing to pay to achieve an outcome or about their preferences for making trade-offs between different outcomes.

Study site: the reference site in an existing study that is being used for benefit transfer.

Total economic value: the overall value of an asset, measured in dollars, including both market and non-market values, and use and non-use values.

Travel cost method: a revealed preference approach where the costs associated with making a trip to visit a site are used to infer how much people are willing to pay for each visit.

Use value: the value derived from the actual use of a good by an individual, or by the individual reserving the option to use it at some point in the future.

Utility: an economic measure of an individual's wellbeing or welfare.

Willingness to pay (WTP): a measure of the value an individual holds for an asset, or a change in an outcome, defined in terms of how much they would be willing to pay for that outcome.

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TABLE OF CONTENTS

SECTION 1: INTRODUCTION

The Value Tool for Natural Hazards combines a database and set of guidelines for decision makers to obtain financial estimates of the intangible values affected by natural hazards or their mitigation.

- The Value Tool Database provides a compilation of intangible values from existing studies that are suitable for use in benefit transfer for natural hazard decision making, including for bushfires, floods, storms and earthquakes.
- The Value Tool Guidelines provides guidance on how to locate relevant values in the Database and adjust them for use in a particular decision context.

Natural hazards can cause large economic damages and governments recognise the importance of mitigation to avoid these costs (Penman et al. 2011). Limited financial resources makes it critical to be able to prioritise mitigation actions efficiently. The use of economic frameworks such as Benefit: Cost Analyses enables the efficient allocation of funds by weighing up the financial benefits and costs of different mitigation programs (Ganewatta and Handmer 2006).

To effectively use these frameworks, it is important to account for the tangible, economic outcomes of proposed actions, and also the social, environmental and health-related outcomes. These latter, intangible outcomes can be important. For example, a Deloitte Access Economics report (2016) estimated that intangible losses of the 2009 Black Saturday bushfires amounted to $3.9 billion, and the intangible losses of the 2010-11 Queensland floods amounted to $7.4 billion. This is relative to estimated tangible losses of $3.1 billion and $6.7 billion, respectively. The report concludes by stating "it is clear that the total economic cost of natural disasters is at least double that of existing estimates when intangible costs are included" (Deloitte Access Economics 2016, p.65). These intangible costs equate to the intangible benefits that could be generated through mitigation activities that avoid social, environmental and health-related losses from occurring.

Economic methods known as non-market valuation methods can estimate intangible values in financial-equivalent terms. Original (new) studies applying non-market valuation are generally the preferred approach for providing non-market values for use in policy and decision making, as they offer the most accurate representation of values in a specific context. However, for various reasons, an original study is sometimes not justified or feasible (Rogers et al. 2015). In such cases, benefit transfer offers an alternative to conducting an original study.

Benefit transfer is, put simply, the "transfer" or application of data collected from one location to a new location of policy or management interest. As such benefit transfer relies on the use of non-market valuation results from pre-existing studies at one or more sites (often called "study sites") to predict willingness to pay (WTP) estimates or related information for other, typically unstudied sites (often called "policy sites, although they don't necessarily need to relate to policy) (Rolfe et al. 2015a). Benefit transfer is sometimes preferred for use in policy making, particularly for non-market values, because usually it is cheaper and takes less time than conducting original studies.

The Value Tool for Natural Hazards sets out the values and approaches necessary to conduct benefit transfers for natural hazard decision making.

SECTION 2. NON-MARKET VALUES AND DECISION MAKING

2.1 What are non-market values?

Non-market values are the intangible, non-financial or non-monetary values that people hold for goods and services that are not bought and sold through a market.

- Market goods involve exchanges between buyers and sellers, which indicates the financial value of the good.
- Non-market goods relate to environmental, social and health-related goods that are not traded in a market place. However, these goods still contribute to human wellbeing, and therefore generate economic value. This value can be represented as a non-market cost if it results in a negative contribution to human wellbeing, or a benefit if it has a positive contribution.

Different types of values exist, all of which contribute to what is known as the "total economic value" of a good or service (Figure 2.1). The core value types are:

- Use values, which relate to the actual use of a good by an individual, or by the individual reserving the option to use it at some point in the future.
  - This includes, for example, the consumption of resources (e.g. food) and recreational uses.
  - Some use values can be measured through markets, e.g. those related to consumption, or where a recreational activity is provided for a fee.
  - Other use values are non-market values, e.g. the aesthetic value derived from enjoying a nice environment.
- Non-use values, which relate to the satisfaction of knowing a good exists without there being any planned or actual use of the good.
  - This includes existence values (e.g. for biodiversity), and the altruistic and bequest values of knowing a good is available for others to use in the current and future generations, respectively.
  - All non-use values are non-market values.
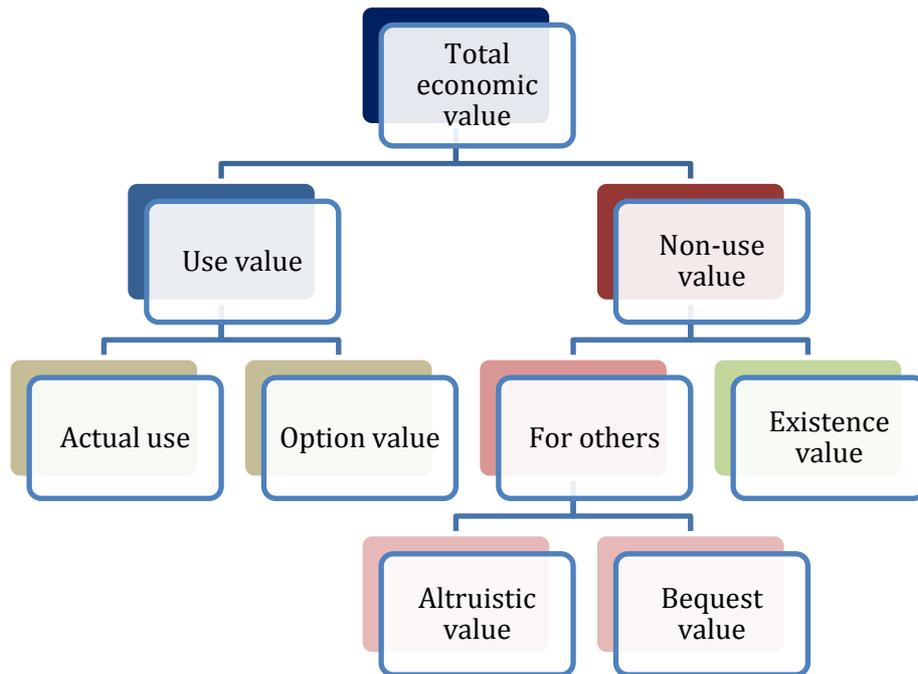
Figure 2.1 The different components that contribute to the total economic value of a good or service.

2.2 What is non-market valuation?

Non-market valuation comprises a set of economic approaches for estimating non-market values.

- Specifically, non-market valuation estimates how much people are willing to pay for a change in the quantity or quality of a non-market good, service or benefit.
- It enables the environmental and social outcomes of new policies, projects or investments to be quantified in financial-equivalent terms.
- Having environmental and social outcomes estimated in terms of dollar values enables comparison with the tangible, economic outcomes of decision making.

The main approaches used to estimate non-market values are described below, and discussed in more detail in Appendix 1.

- Revealed preference methods use information from markets associated with the non-market good being valued, or from observing people's behaviour in their use of the good, to infer an individual's willingness to pay for it. These methods measure use-related values only.
  These methods include:
  - ○ Travel cost method, where the costs associated with making a trip to visit a site are used to infer how much people are willing to pay for each visit.
  - ○ Hedonic pricing method, which is used to investigate how the non-market characteristics of a good influence its market value (e.g. premiums paid for property near desirable environments).

- Stated preference methods use survey-based instruments to ask individuals how much they are willing to pay to achieve an outcome or about their preferences for making

trade-offs between different outcomes. These methods can measure the total economic value of a non-market good, including both use and non-use related values. These methods include:

- o Contingent valuation, which estimates the value of non-market goods by directly asking individuals how much they would be willing to pay to implement a change or prevent an impact.
- o Discrete choice experiments, which are used to estimate how individuals make trade-offs between changes in different characteristics, or attributes, of a non-market good, including a trade-off with the cost of providing these changes.

2.2 Using non-market values in policy and decision making

There are two main ways in which non-market values can be used in policy and decision making (Pandit et al. 2015):

1. Conceptually, by improving the understanding of policy issues;
   - This relates to policy advocacy.
   - Advocacy can take the form of using non-market values to demonstrate the benefits of changing existing policy, or to retain existing policy.
   - This use is typically qualitative in nature.
2. Instrumentally, by directly influencing policy and management decisions.
   - Instrumental uses for non-market values are typically quantitative.
   - Includes using the values in damage assessment or compensation claims, in setting user fees for recreational resources, or in Benefit: Cost Analyses.

2.3 Australian Government requirements for non-market valuation

There are no specific Government requirements for the use of non-market valuation in Australian policy setting.

Benefit: Cost Analyses are a requirement for major programs and legislative processes, such as Regulatory Impact Statements. The Australian Government's Best Practice Regulation Handbook states that it "… is committed to the use of cost-benefit analysis to assess regulatory proposals to encourage better decision making" (Australian Government 2010, p.61). While the inclusion of non-market values is not a requirement within such analyses it is encouraged (Rogers et al. 2015).

Rogers et al. (2015) conducted a study on the use of non-market valuation in Australian environmental policy. They discovered that the majority of decision makers sampled thought non-market valuation provided useful information for decision making, but lack of awareness about the techniques and lack of time and resources often meant that such information was not used.

2.4 Benefit transfer of non-market values

Conducting new, original non-market valuation studies is the preferred approach for providing information about non-market values for use in policy and decision making, as they offer the most accurate representation of values.

However, for various reasons, an original study is sometimes not justified or feasible (Rogers et al. 2015). For example, the project or policy timeframe might not allow for the collection of

new data, the budget for analysis may be too small, or the decision to be made may be a relatively minor one.

In such cases, benefit transfer offers an alternative to conducting an original study (Johnston et al. 2015b).

Benefit transfer

A process where the results of non-market values estimated for original "study sites" are extrapolated to predict values for different "policy sites".

There are different ways of conducting benefit transfers, outlined further in Section 5. In general the process involves making some adjustments to the values estimated at the study site so that they are more appropriate for application to the policy site.

The process of transferring values from one site or decision context to another usually involves a degree of error, because no two sites or contexts are exactly the same. Benefit transfer is not as accurate as conducting an original study.

2.5 Is an approximate number better than no number?

There is a high probability of transfer errors occurring when undertaking benefit transfer. This begs the question of whether it is sensible to use benefit transfer at all.

There are four options for policy makers to consider with respect to including non-market values in decision making:

1. Undertake an original non-market valuation study;
2. Use values from a benefit transfer instrumentally (quantitatively) in the decision process, for example in a Benefit: Cost Analysis;
3. Use values from a benefit transfer conceptually (qualitatively) to advocate for or against an existing decision;
4. Exclude information about non-market values from the decision altogether.

Valuation of intangible benefits in quantitative terms is difficult, and economists are well aware that non-market valuation and its associated techniques, such as benefit transfer, are not perfect (Hausman 2012; Kling et al. 2012). However, these techniques offer a structured and transparent framework by which policy makers can include non-market values in decisions. We are of the view that it is preferable to include approximate information about non-market values in the decision process (options 1 to 3 above), than none at all. Excluding non-market values entirely is equivalent to assuming that they are zero, and there is a wealth

of evidence that they are often very different from zero. If the non-market values were the same for every decision option, this would not matter, but the chances of that being realistic are remote.

Pannell and Gibson (2016) simulated millions of decisions about environmental project prioritisation, and used the results to test whether it was preferable to omit poor-quality information or to include it despite its shortcomings. They evaluated the long-term environmental outcomes from the two approaches and found that it is clearly better to include information about a particular variable, such as a non-market value, than to ignore it, even if there is high uncertainty about the accuracy of the information. Therefore, our general view is that an approximate number is better than no number.

It should be recognised that omitting information about non-market values does constitute making an implicit assumption – that there are no differences in non-market values between the decision options – and this implicit assumption is highly likely to be wrong.

2.6 Recommendations on use of non-market values for natural hazard decisions

We recommend that non-market values should be considered in natural hazard decision making as follows.

❖ If the budget, time and expertise are available, and the decision is sufficiently important, original non-market valuation studies be conducted in favour of benefit transfer.

❖ If the policy context does not relate well to existing study contexts (e.g. of those studies included in the Value Tool Database), decision makers should enlist the help of an expert to conduct a benefit transfer using an advanced transfer approach (see Section 5.1 regarding benefit-function transfers).

❖ If the policy context can be reasonably matched to existing study contexts, decision makers can use the Value Tool Database to conduct a unit-value benefit transfer (see Section 5.2). In doing so:
   a) Appropriate adjustments should made to the transferred value (see Section 5.3).
   b) Sensitivity tests should be performed to determine how the value affects subsequent analyses (e.g. Benefit: Cost Analyses) (see Section 5.4).

❖ If it is not possible or practicable to follow the preceding recommendations, and practitioners cannot identify existing studies in the Value Tool Database that are reasonably matched to the policy context, the use of a quantitative estimate (with potentially large errors) in the decision process should be questioned. In such cases, practitioners can instead use the results from study sites to make qualitative assessments of people's preferences, such as whether values are positive or negative, and the magnitude of different values relative to each other. This assessment can be used conceptually to make judgements or to advocate for or against different policy options.

We recommend that users of benefit transfer should be conservative and transparent. Many of the decisions made in adjusting the data for a transfer will be subjective. Therefore, it is important to ensure that the procedure followed is transparent in order to enable those interpreting the information to make a basic assessment of the reliability of the transferred value, and any limitations that should be considered. Transparency includes outlining the data, methodology and assumptions used. More information on potential adjustments and limitations to consider is provided in Section 5.3.

SECTION 3: TYPES OF NON-MARKET VALUES FOR NATURAL HAZARD DECISION MAKING

3.1 Categorisation of non-market values

The Value Tool for Natural Hazards considers 11 types of non-market values that are commonly affected by natural hazards or their mitigation. These are grouped by health, environmental and social-related values (also see Table 4.1, Section 4.2).

Non-market values affected by natural hazards

- Health – physical and mental health;
- Environment – ecosystems and water quality;
- Social – recreation, amenity, safety, cultural heritage, social disruption, memorabilia and animal welfare.

The available literature on each value type and the general applicability of that literature for benefit transfer is discussed below. It offers a broad overview of the state of non-market valuation for the different value types: it is not always specific to the natural hazard policy context, and is international in scope.

The Value Tool Database provides examples of studies measuring each value type where possible: not all value types are adequately represented in the literature in the context of natural hazard decision making.

Of the studies discussed below, only those most relevant to the Australian natural hazard context are included in the Database. This often means that studies conducted in Australia but in contexts other than natural hazard policy are preferred for inclusion in the Database as evidence suggests that the range in values varies more widely between locations than between different decision contexts.

While the Database primarily includes out-of-context Australian studies, the international review provided below is useful to understand the value ranges and issues associated with estimating non-market values in a natural hazard context.

3.2 Health

3.2.1 Physical health

Physical health

Includes fatalities, injuries, illness, disease or pain caused by natural hazard events or their mitigation.

Applicability of existing non-market values for benefit transfer

- ❖ There is a large literature on value of a statistical life (VSL) which includes Australian studies, meta-analyses, and study contexts relevant to natural hazards.
- ❖ Physical health values are well documented and readily applicable to benefit transfer.

Physical health includes mortality and morbidity, which encompasses pain, injury, serious illness and disability. In relation to mortality, there are many general studies that estimate the value of a statistical life (VSL), which is used as a measure of the benefit that would be generated by preventing a death. For example, based on a literature review, the Australian Government recommends the use of AUD(2008) $3.5 million as a standard VSL in economic analyses of projects (Abelson 2008, Australian Government 2014). VSL has been estimated using both revealed-preference methods (e.g., Viscusi 2004) and stated-preference methods (e.g. Viscusi 2009, Carlsson et al. 2010a).

VSL is one of the non-market values that has been found to be sensitive to a natural hazard context. For example, Viscusi (2009) found that lives saved by reducing deaths from traffic accidents are valued almost twice as highly as lives saved by preventing natural-disaster deaths in the United States, with the latter value estimated at US(2008) $2,990,000 per life. Carlsson et al. (2010a) similarly find that the VSL for reducing lives lost due to fire and drowning, at SEK(2007) $13,231,000 and $12,643,000, respectively, are one third lower than for traffic accidents. The cause for fire and drowning deaths in this study is defined generically as accidental deaths and not specific to natural hazards. Viscusi (2009) discusses how these differences in values could relate to the perceived risks of natural hazards and traffic accidents. Natural hazard risks are unique with respect to deaths typically being clustered: events occur in a particular spatial location and the potential exists for large numbers of people to be affected, relative to traffic accidents which are diffusely distributed.

The range of VSL estimates is not only sensitive to context, but also location. A review of 244 international VSL studies by Access Economics (2008) found that the mean VSL was AUD(2006) $9.4 million, and the median $6.6 million. However, there was wide variation in point estimates with VSLs ranging from $0.1 million to $132.9 million depending on the country and the context. Average VSLs were highest when calculated in relation to the environmental protection sector, at $11.2 million, and lowest when estimated with respect to the health sector, at $4 million. Of the 14 countries for which specific VSL estimates were available South Korea had the lowest mean VSL ($1.6 million). France and Japan had estimates above the average VSL, along with the United Kingdom which had the highest mean VSL ($17.5 million). The other countries included in the review were all below the mean VSL, including Australia, Austria, Canada, Denmark, Hong Kong, New Zealand, Sweden, Switzerland, Taiwan and the United States.

The differences in VSL related to context and location mean that it is preferable to use a VSL estimated for the specific country and natural hazard of concern, if possible. Based on the Access Economics (2008) review, the range in values is greater by country than by context. Where a VSL estimate cannot be located for the relevant population *and* context, this would suggest that using a VSL for the relevant population, and calibrating for differences in context, is more important than prioritising a match in context.

The approach used to estimate VSL also has implications for the magnitude of the value. Access Economics (2008) found that the mean VSL for the revealed preference studies in their sample was AUD(2006) $9.6 million, compared to the VSL for stated preference studies with a mean of $11.2 million. This is consistent with the theoretical underpinnings of each approach, where revealed preference studies often provide a lower bound estimate of value.

Turning attention to other health impacts of natural hazards, there are studies that estimate values for morbidity. Morbidity describes a poor health state, and can be broadly separated into conditions arising from disease, and those from injury. The morbidity effects from natural hazards include water-borne disease, respiratory disease, cancer and stress related disease, amongst others (Nohara 2011; Dohrenwend et al. 2013; Kochi et al. 2010). The welfare impact from morbidity varies depending on the severity and duration of adverse health outcomes (Kochi et al. 2010).

Most morbidity impacts from natural hazards that have been quantified in monetary or monetary-equivalent terms in the literature are those related to wildfire smoke, with multiple studies from the United States. The majority of studies that estimate the health cost from exposure to wildfire smoke use the cost of illness approach, a cost-based approach that measures the financial cost of treatment and not the benefits from avoiding the impact (which are broader than avoidance of financial costs) (see Section 2) (Kochi et al. 2010). For example, Moeltner et al. (2013) estimated the treatment costs from the impacts of bushfire smoke for 350,000 residents in northern Nevada, US. They accounted for distance to the fire, fuel load and a four-year lag in health effects, finding that aggregate treatment cost for smoke-induced inpatients for this population was close to US(2008) $2.2 million. Some of the affected residents were 300 miles from the bushfire-impact zone.

Given the limitations of the cost-of-illness approaches, WTP approaches provide a more accurate and complete representation of the total benefits generated by reducing morbidity from wildfire smoke. Richardson et al. (2013) found that the estimates of the benefits of a reduction in symptom days for a wildfire-smoke-related illness were 30 times larger when using a WTP approach compared with a cost-of-illness approach: US(2009) $95.03 and $3.02 per person per symptom day, respectively, in California, USA. They also compared values estimated by the defensive behaviour method, which considers the costs associated with the actions people take to avoid exposure to the smoke. This method was more comparable to the WTP approach at $86.87 per person per symptom day.

O'Donnell et al. (2014) conducted a choice experiment in Flathead County, United States, to estimate the WTP of households to avoid smoke days. Households were willing to pay US(2009) $13.28 and $2.34 to avoid an additional unhealthy or moderate smoke day, respectively, per fire season for the next 10 years. The values may be smaller in this study relative to those estimated by Richardson (2013) because they refer to a smoke day which poses a risk to health, but does not necessarily result in illness, while Richardson estimated values associated with the realised symptoms of a smoke day.

Beyond the smoke-related illness caused by wildfire, natural hazards can cause injury and pain. While no context-specific valuations exist for these physical health impacts, other out-of-context studies can provide a useful reference point. Hensher et al. (2009) estimate WTP to avoid a range of injury types in the context of road traffic accidents, from a sample of New South Wales vehicle drivers, Australia. They distinguish between the accidents occurring in urban or non-urban areas. Willingness to pay to avoid a serious injury, where extended hospitalisation is required and which may result in permanent disability, was estimated at AUD(2007) $310,292 or $193,883 per injury for urban and non-urban areas, respectively. For hospitalised injuries, where treatment in hospital is required but full recovery is expected, WTP was $75,476 or $56,937 per injury for urban and non-urban areas. For minor injuries where medical treatment was required, but no hospitalisation, WTP was smaller for urban areas at $16,522 per injury compared to non-urban areas at $20,312 per injury.

Chuck et al. (2009) also provide a useful reference point with respect to WTP for a reduction in pain. Individuals from Alberta, Canada, indicated they would be willing to pay CAD(2007) $361 per person per month to improve pain-related disability to a mild condition, or $1067 per person per month to improve pain intensity to a mild condition.

3.2.2 Mental health

> **Mental health**
>
> Includes the grief, stress and anxiety caused by natural hazard events or their mitigation.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ The approaches used in the literature to measure changes in mental health do not capture WTP with respect to the non-market *benefits* of avoiding/improving mental health problems.
> ❖ Use of available estimates of mental health values for benefit transfer in the Australian natural hazard context is generally not possible.
> ❖ New, original stated preference studies would be required to measure WTP for mental health changes, in the context of natural hazards, to provide estimates appropriate for use in benefit transfer.
> ❖ The available literature can be used to assess the *costs* of mental health related treatment, which provide a partial indication of the benefits of avoiding mental health problems. Or, where mental health outcomes are similar to physical health outcomes (i.e. leading to hospitalisation or fatality), the estimates for physical health may be applied as a rough proxy.

Estimates of WTP for changes in mental health states are not well documented in the non-market valuation literature, particularly in the context of natural hazards. Substantial literature has been published regarding the psychological trauma and emotional impacts of bushfire and natural hazards, including not only the direct impacts of the event on mental health, but also the secondary and indirect effects on mental health resulting from stress, separation anxiety, failing relationships, and disintegrating friendships (Eriksen, 2013). A variety of natural hazard studies list psychological problems and mental health impacts as 'intangibles'. These

discussions frequently discuss the importance of acknowledging the importance of emotional or psychological impacts, but state that there are no agreed-upon methodologies for measuring these impacts (Handmer et al., 2002; Stephenson et al., 2013). Gould et al. (2013) acknowledge the importance of including the cost of psychological trauma (determined using stated-preference methods) in the parameters for determining the costs of wildland fires to improve the Canadian forest fire danger rating system, but do not specify what values to use or how to measure those values.

As with morbidity, cost-based approaches have been used to estimate the cost of adverse mental health resulting from natural hazards. Dunn et al. (2003) address the cost of post-fire emotional trauma within the context of services provided by non-profit organizations as a part of post-fire recovery and mitigation costs. They estimate the cost of these recovery efforts as being in the order of US$4.8 million. Unfortunately, this estimate does not separate post-fire emotional recovery efforts from home rebuilding costs, and does not report costs per household or per person.

Knowlton et al. (2011) included psychological impacts in their estimate of the cost of lost lives and health impacts in relation to the 2004 Florida hurricane season in the United States. The cost of physical health treatments from hospitalisations and emergency department visits equated to US(2008) $255,233,000. When the additional costs of hurricane-related treatment of post-traumatic stress disorder were included, this figure rose to $312 million. Using VSL, they equated the cost of premature deaths as US(2008) $1,137,600,000, generating a total health bill of $1.5 billion. Knowlton et al. (2011) normalise the cost of lives lost and physical health treatment to $80.16 per person, based on the Census Bureau population for the area affected by the event. Adding the mental health costs to this would increase the total health cost per person to approximately $83 per person.

Given the poor representation of non-market values for mental health aside from the cost-based measures, an alternative proxy is to utilise the valuations conducted for physical health impacts, where they can be related to a similar mental health outcome. For example, if risk of fatality due to suicide is anticipated following a natural hazard event, the VSL literature can be applied. Estimations of values for different injuries could also be adapted, for example the value of avoiding a hospitalised injury (Hensher et al. 2009) where mental illness may require admission to a health facility. However, given the contextual variations noted in WTP with respect to physical health values, it is highly likely that values estimated from these studies will not provide an accurate measure of WTP for mental health outcomes.

3.3 Environment

3.3.1 Ecosystems

Ecosystems

Includes the changes in the state of flora, fauna, endangered species, native vegetation cover and ecosystem functions due to natural hazard events or their mitigation.

Applicability of existing non-market values for benefit transfer

❖ There are very few cases where non-market valuation studies have estimated the value of protecting particular ecosystems or flora and fauna within ecosystems in the context of natural hazards.

❖ Australian studies on the non-market values of ecosystems exist, but are very specific to a variety of other decision contexts.

❖ Use of available estimates of ecosystem values for benefit transfer in the Australian natural hazard context is limited.

The literature on valuation of ecosystems includes values for particular ecosystems (e.g. Petrolia et al. 2014, Rajmis et al. 2009), or the species of flora and fauna that live within an ecosystem (e.g. Richardson and Loomis 2009) , as well as the values of ecosystem services provided to communities. There are many non-market valuation applications in contexts related to natural hazards for ecosystem services, including valuing the reduced risk of flood or storm damage to local communities as a result of maintaining healthy ecosystems such as wetlands, mangroves and coral reefs (e.g. Brander et al. 2013; Brander et al. 2006; Everard et al. 2014; van Zanten et al. 2014).

In their international review of studies estimating the value of wetlands for different regulating services, Brander et al. (2013) report that the median WTP for wetlands providing flood control is US(2007) $427 per hectare per year, and the mean WTP is $6923, summarised from 26 studies. Using a choice experiment, Petrolia et al. (2014) estimated how much households from across the United States were willing to pay to increase the level of storm surge protection in Louisiana through coastal restoration programs. They found that respondents' WTP was US(2011) $149 as a one-off payment to increase the percentage of households protected from storm surge from 5% of households to 30%, and $151 to increase it from 5% to 50% of households.

In fewer cases, non-market valuation efforts have estimated the value of protecting specific ecosystems, as opposed to the services they provide, and these are typically not in the context of natural hazards. In the context of a choice experiment on climate-change mitigation, German residents were willing to pay (2006)€27.54 each per year to improve the resilience of the Hainich National Park against insect pests and storms from a status quo medium level of resilience to a high level (Rajmis et al. 2009). Petrolia et al. (2014) in their evaluation of coastal restoration of Louisiana wetlands found that US households were willing to pay US(2011) $909 as a one-off payment to restore 50% of lost land.

With respect to species living within ecosystems, there exist numerous studies that aim to estimate the nonmarket values of threatened or native flora or fauna. However, these studies

again tend not to be in the context of natural hazards. One study was found on threatened species values in a natural hazard context. Loomis and Gonzalez-Caban (1998) estimated that residents in California and New England were willing to pay US$56 per household per year for a fire management plan that would result in 2570 fewer acres of critical habitat for spotted owls being burned by catastrophic fire.

In the broader literature on species values, because of the non-use, non-market nature of species' values, nearly all studies estimate these values using stated-preference methods (e.g. Aldrich et al., 2007; Blamey et al., 2000; Campbell, 2008; Kotchen and Reiling, 2000). While there exists a substantial literature on species valuation, it is difficult to draw inferences from this literature on average WTP for different types of species as the way in which species are described in the studies varies greatly. Much of the literature attempting to address the value of preventing the loss of endangered species focuses very specifically on individual species in particular geographic regions or areas (Cerda et al., 2014; Chakir et al., 2016; Kaval et al., 2007; Loureiro and Ojea, 2008). The remaining literature deals with the loss of endangered species in more generic terms: number of species, percent of area inhabited by species, physical area inhabited by species (Blamey et al., 2000; Kragt et al., 2016; Martin and Blossey, 2012; Polyakov et al., 2015; Rolfe et al., 2000). Some studies describe species in terms of the quantitative number of individuals (Carlsson et al., 2010b; Morrison et al., 1998), with others using qualitative descriptors of species' protection (e.g. conserved versus extinct in Campbell, 2008). Some studies estimate values for preventing a loss of endangered species (Aldrich et al., 2007; Blamey et al., 2000; Campbell, 2008; Kotchen and Reiling, 2000), while others look at the presence of rare species (Choi and Fielding, 2013; Kragt and Bennett, 2011; Subroy et al. 2018).

For example, Blamey et al. (2000) estimated the non-use value associated with preventing the loss of various aspects of the Desert Uplands region in Queensland. They found that Brisbane households were willing to pay a one-off levy of AUD(1997) $11.39 for each reduction in the number of (un-named) endangered species, $1.69 to avoid a percentage reduction in the population size of (un-named) non-threatened species, and $3.68 to avoid a percentage loss in the area of unique ecosystems. Subroy et al. (2018) on the other hand elicited WTP for increasing the population numbers of particular endangered Australian marsupials. They found that West Australian households were willing to pay each year, for five years, AUD(2016) $0.22 and $0.008 for an additional Numbat or Woylie, respectively, in the Dryandra Woodlands.

Given the variability of WTP estimates and the way in which they are defined, meta-analyses are a useful means of drawing comparative inferences from the broader literature. Loomis and White (1996) and Richardson and Loomis (2009) provide the only published meta-analyses of the economic value of rare and endangered species, focussed on studies in the United States. They showed that households' WTP varies greatly depending on what type of species is being valued. For example, WTP estimates for marine mammals and birds were significantly greater than WTP for other species such as land mammals and reptiles (Loomis and White, 1996; Richardson and Loomis, 2009). Specifically, the average lump sum WTP was highest for species such as the Bald eagle (US(2006) $297) and Humpback whale ($240), and lowest for species such as the Arctic grayling ($23) (Richardson and Loomis 2009). Other factors that increased the value attached to a species were larger changes in the size of the species population, if species was charismatic, and if the species had both use and non-use value as opposed to non-use value only (Richardson and Loomis, 2009).

3.3.2 Water quality

> **Water quality**
>
> Includes the changes in the condition of waterways, and elements of the environment with a strong influence on water quality such as riparian vegetation, due to natural hazard events or their mitigation.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ There are few cases where non-market valuation efforts have estimated the value of water quality improvements in the context of natural hazards. However, there are numerous studies available for more general contexts.
> ❖ Use of available estimates of water quality values for benefit transfer in the Australian natural hazard context is limited.

Like values for other types of environmental changes, WTP for water quality improvements are not commonly elicited within the context of purely *natural* hazards. Exceptions include estimates of WTP to reduce quality reductions caused by natural hazard events such as algal blooms (Roberts et al. 2008), stormwater runoff (Londoño Cadavid and Ando, 2013), and flooding-related contamination of drinking and surface waters (e.g., related to wastewater overflows; Veronesi et al. 2014). Roberts et al. (2008) found that people were willing to pay at least US(2006) $3.87 per visit to Tenkiller Lake in Oklahoma to avoid the occurrence of an algal bloom during the visit, where the bloom was caused by nutrient runoff in high rainfall events. Londoño Cadavid and Ando (2013) sampled residents in Champaign-Urbana, Illinois, and estimated that households were willing to pay US(2011) $0.49 per year for each 1% increase in water infiltration. The water infiltration improvements were achieved by stormwater management infrastructure and were stated to represent improvements in local environmental conditions through decreased runoff, increased water table recharge and decreased fluctuation in water flow speeds and volumes. Veronesi et al. (2014) found that Swiss households were willing to pay up to (2010) CHF260 per year to avoid a change from medium ecological risks to very high ecological risks of flood-related wastewater overflow.

Beyond the natural hazard applications of estimating values for changes in water quality, there is an extensive literature evaluating the non-market values of water-quality improvements (Bergstrom et al. 2001; Young and Loomis 2014), with thousands of publications to date. This literature is highly heterogeneous, reflecting the many ways in which different types of water-quality improvements, in different areas and water bodies, benefit different user and nonuser groups. Given the heterogeneity, there is a challenge in reconciling data and observations from different studies across the literature, so that valid inferences may be drawn, for example using meta-analysis.

Johnston et al. (2005) conducted a meta-analysis of studies estimating WTP for changes in water quality that affect aquatic life habitats. They found over 300 studies on surface water valuation, of which 34 studies with 81 WTP observations from the United States, conducted between 1973 and 2001, were included in their meta-analysis. They included variables to represent WTP for the impact of water quality changes of particular species, including fish, shellfish, multiple species and non-specified species. The analysis revealed that larger gains in

water quality were associated with higher WTP for these variables, providing evidence that WTP for water quality improvements is sensitive to scope (Johnston et al. 2005). Inferences such as this, while observed in a heterogeneous context, can be applied to natural hazard context-specific observations of WTP such as those cited above to provide an understanding of how WTP might change in different scenarios.

3.4 Social

3.4.1 Recreation

Recreation

Includes the effects of natural hazard events or their mitigation on changes in recreation activities.

Applicability of existing non-market values for benefit transfer

❖ WTP estimates exist in the context of recreational values related to bushfires, however not in Australia. There are numerous studies available for more general contexts.

❖ Values of a recreational trip are reasonably consistent across contexts, but the number of trips made varies by context.

❖ Use of available estimates for benefit transfer is possible, but require additional information about how recreational trip frequency may vary due to hazard events.

The best source of data on recreation impacts resulting from natural hazards involves wildfires. Raush et al. (2010) examined changes in trip frequency for campers in the Rocky Mountains, Canada, following a wildfire. Campers visited the eastern slopes of the mountains 2.56 times per year on average. If a wildfire affected the area, the visitation rate dropped to 1 visit per year, with the rate slowly increasing until it reached the pre-fire average 12 years after the burn. For a common type of camper, the consumer surplus per trip was CAD(2004) $161.29, which equates to the lost value of each trip not taken after a wildfire. The average trip duration was 5.26 days equating to a value of $30.46 per day per camper.

The nature of how the forest regenerates after a wildfire appears to effect willingness to pay to visit a recreational location. Using data collected via a permit system for Californian Wilderness areas between the years 1990-2004, Englin et al. (2008) found that visitors were willing to pay US $174.73 per hiking trip. The value of the trip increased significantly during periods of four to nine years after a burn, and decreased significantly once the period after a burn had extended past 30 years. Other time periods after the burn had little impact on value. The increase in WTP during the earlier time-period was assumed to be due to people's curiosity in the burned landscape, and the later decrease potentially related to the obstruction of view from the increasing density of the forest.

For the Mount Jefferson Wilderness area in Oregon, Brown et al. (2008) found visitation rates did not change significantly after a major wildfire incident. They also found that 70% of the recreationists did not change to a nearby substitute site after the fire. Comparatively, in the Canadian Shield region, Boxall and Englin (2008) found that backcountry recreationists who participated in wilderness canoeing experienced a loss in value due to dis-amenity one year

after a burn along the canoe route, an indifference in value 10 years after the burn, and an increase in value 30 to 65 years after the burn.

Raush et al. (2010) note that the value per trip estimated in their Rocky Mountain study is comparable to the consumer surplus calculated for other similar recreational demand studies, for example, the value elicited by Englin et al. (2008) in Californian Wilderness areas. The travel cost values estimated for changes in recreational behaviour following natural hazard events, in particular wildfire events, appear robust.

However, the geographical differences in how visitation rates are changed following wildfire events mean that it is important to consider the temporal impacts of a hazard event on recreation. Hazard managers will need to be aware of the temporal changes in visitation to be able to aggregate measures of willingness to pay appropriately. For example, in forests with a slow regeneration time after wildfire, such as Canada, there appears to be a decrease in visitation and subsequent loss in aggregate value for several years at least. In places like Australia, on the other hand, where forests regenerate relatively quickly after a wildfire, and where some plant species even require the heat and smoke chemicals to facilitate regeneration (Burrows 2008), one might expect visitation rates and values to only be affected for a short period of months up to a couple of years after a burn.

3.4.2 Amenity and safety

Amenity and safety

Amenity includes how the aesthetics of an area may change due to natural hazard events or their mitigation.

Safety includes the how individuals view their perceived safety given the proximity of a dwelling to hazard-prone areas or the ability of a construction to mitigate hazard impacts.

Applicability of existing non-market values for benefit transfer

❖ There is a large literature on WTP estimates for amenity and safety values which includes Australian studies and study contexts relevant to natural hazards.
❖ Amenity and safety values are well documented and readily applicable to benefit transfer.

In the context of natural hazards, the value placed on visual amenity is often linked to values associated with risks imposed on an individual's life and property, thus these value types are jointly discussed. Some people are attracted to live in areas that are more at risk from natural hazards, such as in forested areas, within flood plains and on the coast, because of the high amenity values of these regions. Other people prefer to avoid these areas because of safety concerns. The valuation of amenity and safety in relation to bushfires, floods and severe storms is reasonably common, with over 100 studies investigating these issues.

Daniel et al. (2009) provide a meta-analysis related to reduced risk from a natural hazard. The meta-analysis uses 19 revealed preference studies, with 117 observations, that estimate welfare values for reduced risk from flooding in the United States. They found that estimates of the marginal values of flood risk varied considerably. After controlling for observable and

unobservable differences across studies, the marginal effect of an increase in the probability of flood risk by 1% in a year amounts to a difference in price of an otherwise similar house of -0.6%.

Stetler et al. (2010) estimate the value of reducing bushfires in terms of reduced risk and increased amenity. The authors use the hedonic price method to identify the effects of 256 wildfires and environmental amenities on property values in northwest Montana between June 1996 and January 2007. Large positive effects on property values were contributed to by environmental amenities, including proximity to lakes, national forests, Glacier National Park and golf courses. Conversely, proximity to and view of wildfire burned areas had large and persistent negative effects on property values. Properties within 5km of a wildfire burned area experienced a 13.7% reduction in property values (US$33,232), and the value of those properties with a view of the wildfire burned area were reduced by a further US$6610.

Similarly, Athukorala et al. (2016) conducted a hedonic pricing analysis of property sales in wildfire affected areas of Rockhampton in Queensland, Australia, finding that sales dropped on average by 6.1% or AUD(2016) $22,606 relative to properties in unaffected areas. Comparatively, Rajapaksa et al. (2016) found that prices for properties in flood affected areas of Brisbane in Queensland, Australia, were also 6 to 7% lower for low and high income suburbs, respectively, than for unaffected areas. This suggests that WTP may be similar for reducing the risk of living in areas affected by different natural hazards.

There are a handful of studies on the value of reducing the risk of earthquake damage to life and property (Hidano et al. 2015; Naoi et al. 2009; Beron et al. 1997; Keskin 2008). For example, Hidano et al. (2015) found that between 2008 and 2012 property values in Tokyo, Japan, for zones with a low-risk of earthquakes were between 13,970 to 17,380 JPY higher than for properties in high-risk areas, depending on the type of seismic risk. They also found that sales prices were not significantly affected by information about seismic risk for newly-constructed earthquake-resistant apartments, providing evidence for the value of mitigation.

3.4.3 Cultural heritage

> **Cultural heritage**
>
> Includes changes in the state of indigenous, European and natural heritage, and sense of place, as a result of natural hazard events or their mitigation.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ There are no cases where non-market valuation studies have estimated the value of protecting cultural heritage in the context of natural hazards.
> ❖ There are a limited number of cases where non-market values have been estimated for indigenous heritage in other contexts.
> ❖ Use of available estimates of cultural heritage values for benefit transfer is extremely limited.

Impacts of natural hazards on cultural heritage can relate to changes in recreational use of heritage assets, in which case the recreational values discussed above are applicable. However, values may also relate to protection of cultural heritage from natural hazards,

including the non-use, existence values associated with such assets. There is a small literature on the values of cultural heritage, with very few studies on their non-use values. There are no studies that estimate values of cultural heritage in the specific context of natural hazards. Venn and Calkin (2011) attempted to include the valuation of cultural heritage into wildfire management in the United States, but found a lack of literature on the total economic valuation of cultural heritage. The majority of research reports values for ex-situ items (e.g. in museums) as opposed to in-situ heritage – the latter being of particular interest in natural hazard management.

There are two studies relevant to the value of protecting in-situ aboriginal cultural heritage. One is by Rolfe and Windle (2003), who found that indigenous and non-indigenous values for the protection of Aboriginal cultural heritage sites in Australia differed significantly. For a 1% increase in the number of sites protected in central Queensland (equating to 27 sites), the indigenous population of Rockhampton were willing to pay AUD(2001) $3.22. The general populations of Rockhampton and Brisbane had a WTP of -$2.08 and -$1.78, respectively, per 1% increase. This reflected an initial positive WTP for some additional site protection, up to a 20% increase from the status quo, but then a negative preference as the number of sites protected increased beyond this level. Rolfe and Windle (2003) pointed out that their results do not indicate how values changed with the quality of the heritage resource protected, only the quantity of sites protected. They acknowledge that more specific descriptions of cultural heritage sites would be beneficial to determine corresponding policy contexts for benefit transfer applications, relative to the generalised description used in their study.

In the other study, Boxall et al. (2003) studied recreation values associated with aboriginal cultural heritage and vandalism along two canoe routes in Manitoba, Canada, enabling a comparison of WTP for trips where aboriginal paintings were absent, in poor condition due to vandalism, or in pristine condition. They found that "pristine" paintings were valued between CAD(1995) $61.31 and $77.26 per trip, whereas vandalised paintings were valued at substantially lower levels between $3.96 and $8.39, relative to an absence of paintings. While the contextual differences make it difficult to extrapolate the WTP to the impacts of natural hazards, these results imply that WTP will vary between the complete destruction of cultural heritage, the partial destruction, or the protection of such heritage from hazard events.

Venn and Quiggin (2007) examine the array of problems involved in attempting to value indigenous cultural heritage with great specificity. These challenges include: communication issues and bias; perceived property rights; differences in perceptions of wealth; and, issues with aggregating responses not only between non-indigenous and indigenous respondents, but also distinguishing between traditional owner groups and local indigenous communities, which may not be the same.

3.4.4 Social disruption

> **Social disruption**
>
> Includes the breakdown of social networks, reduced moveability or availability of basic services, and displacement of people from homes and work places as a result of natural hazards.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ There are very few cases where non-market valuation studies have estimated the value of avoiding social disruption. These are either not in the context of natural hazards, or are not Australian studies.
>
> ❖ Use of available estimates of social disruption for benefit transfer in the natural hazard context is limited.

The disruption of services that are important to the functioning of communities, such as electricity, schools and government services, can cause a welfare loss to society. Paveglio et al. (2015) reviewed the social impact from wildfires and note that social disruption is a complex issue for which there is a lack of accessible, comprehensive and uniform metrics. One of the complications is that social impacts are likely to vary by population characteristics. For example, communities in developed countries are likely to better manage and absorb disruptive community impacts relative to communities in developing countries.

Landry et al. (2007) provide one of few studies of social disruption values in a natural-hazard context. They estimated WTP of New Orleans residents to return home following Hurricane Katrina. Individual's who were employed full time had an annual WTP to return home of US(2005) $3,954. Using a choice experiment with Flathead County residents in California, O'Donnell et al. (2014) estimated that households have a WTP of US(2009) $0.24 to avoid an additional home evacuation due to wildfire, per year for the next 10 years. While these studies have radically different values of WTP, they likely reflect the differences in study context: the flood situation in New Orleans led to extended absences for many residents whose homes and communities were completely destroyed. In the case of Flathead County, less than 5% of the sample had experienced an evacuation order due to wildfire, and no homes had been destroyed by wildfire in the county since 1988. Thus, although survey respondents were informed that evacuation orders would be given because properties were in danger of being damaged or destroyed, it is likely that respondents did not perceive this damage or the duration of absence to be extensive.

While there is minimal valuation research on the social disruption caused by natural hazard events, values from other contexts may be useful. Hensher et al. (2014) measured consumer WTP to avoid disruptions in electricity supply in Canberra, Australia. They found residential customers' average WTP to avoid a 1 hour electricity outage was AUD(2003) $37.48 per event, while their WTP to avoid a 24 hour outage was $73.38. The WTP based on length of the outage was in log form, meaning that an outage that lasted two hours was less than twice as inconvenient as an extra outage that lasted one hour. This is important, as power outages from natural hazards can be lengthy. Equally important to note is that WTP could be substantially larger for residents within natural hazard prone areas, as electricity is often needed for running water pumps, charging mobile phones and radio batteries.

Other types of disruption include the moveability of people to their place of employment or socialisation. For example, the non-market value of reduced moveability from traffic disruption is measured by Li et al. (2010) in a choice experiment of Australian commuters and non-commuters. They found the WTP per person per trip to avoid an hour late arrival is AUD(2008) $38.86 for commuters and $18.98 for non-commuters. In Sweden, a comparable value of travel time was expressed by vehicle drivers for all-purpose travel, at (2008) €10.90 per hour (Borjesson and Eliasson 2014). Passengers on board public transport expressed a value of travel time of €3.90 and €7.40 per hour for bus and train trips.

3.4.5 Memorabilia

> **Memorabilia**
>
> Includes the protection of personal memorabilia in residential dwellings from natural hazard events.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ There are no estimates available to use for benefit transfer of memorabilia values.
> ❖ New, original stated-preference studies would be required to measure WTP for memorabilia values, in the context of natural hazards, to provide estimates appropriate for use in benefit transfer.

Certain forms of memorabilia can be measured through market values (e.g. collectable items), but in the case of personal memorabilia that might be damaged in a natural hazard event, such as photographs and family heirlooms, stated preference methods would be required to provide a total value estimate that encompasses the unique irreplaceability of these values. We are not aware of any non-market valuation studies that attempt this in the context of natural hazards or otherwise.

3.4.6 Animal welfare

> **Animal welfare**
>
> Includes the displacement, death or injury to animals due to natural hazards or their mitigation. This may include domestic pets, livestock and native animals.
>
> **Applicability of existing non-market values for benefit transfer**
>
> ❖ There are no cases where non-market valuation studies have estimated animal welfare values in the context of natural hazards.
> ❖ Use of available estimates of animal welfare values for benefit transfer is extremely limited.

There are significant community concerns about the welfare of animals in natural hazards (Trigg et al. 2017). This relates to the values associated with the physical or mental wellbeing of individual animals, whether they be domestic pets, livestock or native animals, as opposed

to, for example, the values of protecting threatened species and communities – which relates to ecosystem-type values.

Studies valuing community preferences about animal welfare are often nested within broader topics such as sustainable agriculture, food production, farming systems and food labelling, and these usually relate to ethical agricultural management practices rather than natural hazards. These studies may be useful to provide an indication of animal welfare values for livestock. For example, there have been several studies valuing improved production methods (focused on cage production with chickens and pigs), and a number of studies focused on food label attributes that include information about farm animal welfare. Most studies have been conducted in Europe, with a smaller number in the United States. Cicia and Colantauoni (2010 conducted a meta-analysis of 23 international studies, with 88 observations of consumer WTP for farm animal welfare. They determined that consumers were willing to pay a 14.06% premium over the baseline price for meat products for a label declaring respect for animal welfare.

With respect to native animal welfare, Bach and Burton (2017) explored visitor preferences regarding the interactions of humans with the wild dolphin population at Monkey Mia, Western Australia. They estimated that people were willing to pay AUD(2012) $35.27 per visit for a 30% decrease in dolphin calf mortality.

SECTION 4: HOW TO USE THE VALUE TOOL DATABASE

4.1. What information can be found in the Value Tool Database

The Value Tool Database contains value estimates for the value types represented in Section 3, with the exception of memorabilia values, for which no known non-market value estimates exist.

The Value Tool Database is organised into five worksheets containing:

1) A table defining the 11 value types that are affected by natural hazard events or their mitigation
2) A tab for health values.
3) A tab for environmental values.
4) A tab for social values.
5) A CPI tab which provides the estimation of the consumer price index adjustments used to calculate present value estimates.
6) A notes section including a glossary of main terms and other important information.

////////////////////////////////////

4.2. Value types

Table 4.1. The 11 value types that are affected by natural hazards and their mitigation, described in terms of the changes in final outcomes that might result from a hazard event or mitigation action.

Value type	Final outcomes
Health values	
Physical health	Change in the number of **fatalities** Change in the number of **serious** *injury, hospitalised injury* and *minor injury* Change in the number of *illnesses* or *diseases* Change in *pain* to an individual
Mental health	Change in reported cases of *grief, stress and anxiety** Change in the number of *fatalities* (due to self-harm)
Environment values	
Ecosystems	Change in the number of flora and fauna *species* Change in the number of identified *endangered species*. Change in the status of identified *endangered species*. Change in *native vegetation* coverage Change in status of *ecosystem function* Change in status of identified *threatened ecosystems* Change in *carbon storage* in vegetation and soils
Water quality	Change in *riparian vegetation* coverage Change in *condition of waterways*
Social	
Recreation	Change in *recreation activity* within the area
Amenity	Change in *scenic amenity* of the area
Safety	Change in the *perceived safety* of a dwelling's location or construction
Cultural heritage	Change in *Indigenous heritage significance* Change in *European heritage significance** Change in *natural heritage significance** Impact to *sense of place** Change in *heritage related recreation*
Social disruption	Breakdown of existing family and support networks, such as *social networks** Change in *moveability,* such as traffic and public transport Change in availability of *basic services*, such as electricity outage Number of *displaced people* away from people's homes and work places Change in day to day functionality of *community facilities**
Memorabilia	Impact to *memorabilia* in residential dwellings and contents*
Animal welfare	Displacement, death or injury to *animals*

*NOTE: outcomes in grey text are not currently represented in the Database due to lack of suitable studies

4.3. Information contained within the value tabs

Within the health, environmental and social value tabs, the information is organised into five sections, outlined below.

4.3.1 Study identification and relevance

Figure 4.1 displays the first section of the database for the Health values tab. This section includes information to identify each study, and summarises its relevance for benefit transfer use in natural hazard decision making.

Figure 4.1. Study identification and relevance section of the database.

Specifically, the section contains the following:

- **"REFRESH SEARCH" button:** This button can be used to start a new search and clear any filters that you may have selected in various columns (see Figure 4.7 for illustration of filters; note you must macros enabled for the button to work).
- **Columns A and B**: An observation number and citation for the study entry, to make identification easy.
- **Column C:** A description of which hazard types the study provides useful information about (i.e. fire, flood, storm, earthquake, tsunami, heatwave)
- **Column D:** A description of which value types the study provides useful information about (i.e. referring to the 11 value types in Table 4.1).
- **Column E:** A summary of the study's objectives so that you can make a quick assessment of whether it might relate to your decision context.
- **Columns F to I:** A set of ratings about the study to provide you with an overview as to its relevance for use in benefit transfer, including:
  - Whether the study was conducted in a natural hazard decision making context
  - Whether the study is good quality, relative to best practice applications of the relevant methods

o   Whether the study was set out in a manner that makes it readily usable for benefit transfer

o   A descriptive recommendation based on the points above.

4.3.2 Willingness to pay

Figures 4.2 and 4.3 show the section of the database that provides the dollar value estimate for the relevant value entry, which can be used in benefit transfer.

Figure 4.2. Willingness to pay section of the database: description of the $ value estimate.

As shown in Figure 4.2, the section contains the following data:

- **Column J:** A definition of the marginal change – this is the specific physical or unit change in the outcome of the value being measured.
- **Column K:** Describes what specific hazard context the study was conducted in, or notes that the study was not specific to a natural hazard if conducted in a different context.
- **Column L:** Describes the specific outcome that is being measured by the study, as per the outcomes in Table 4.1 (column 2) above, or the 'Value type' tab of the Database.
- **Column M:** Provides the dollar estimate from the study, including the units of measurement (e.g. per person, per year). Note that this value is the original dollar amount from the study, and therefore reflects the year and currency that it was measured in the study.
- **Column N:** Provides the present dollar value estimate in 2017 Australian dollars, adjusted for exchange rates and inflation according to the Consumer Price Index (i.e. calculated by multiplying the values in columns Q and R).

- **Columns O and P:** The year and currency that the dollar value in Column M is measured in.
- **Column Q:** The dollar value, in Australian dollars, for the year that the study was conducted (i.e. where values in Column M are in a foreign currency, they are converted to Australian dollars using the appropriate exchange rate for the study year). As most studies are Australian, the values in this column are often the same as those values in Column M.
- **Column R:** Provides the Consumer Price Index ratio that must be multiplied by the value in Column Q to estimate the present value in Column N. The CPI ratio calculations are provided in the 'CPI adjustment' tab.

	S	T	U	V	W	X	Y
3	Other variables that significantly explain WTP (e.g. sample characteristics and survey attributes)	WTP measu	95% confidence interval: lower (if available)	95% confidence interval: upper	Standard Error (if available)	Standard deviation (if available)	p-values (if available)
4	Education, pre-exisiting health condition, health insurance, location	Mean	22.78 [90 % confidence interval]	610.42 [90 % confidence interval]	n/a	n/a	n/a
5	Smelled smoke, symptoms, gender, married, age, education,	Mean	76.56 [90 % confidence interval]	443.26 [90 % confidence interval]	n/a	n/a	n/a
6	n/a	Mean	5,361,400	6,710,500	n/a	n/a	<0.0001

Value type | **Health values** | Environmental values | Social values

Figure 4.3. Willingness to pay section of the database: supporting information and statistics for the $ value estimate.

Additional information on the willingness to pay is shown in Figure 4.3, and includes:

- **Column S:** A description of other information that was included in the model that the study used to estimate willingness to pay, e.g. variables such as age and gender.
- **Column T:** Describes whether the dollar estimate is a mean or median measure of willingness to pay.
- **Columns U-V:** Provide the lower and upper bound 95% confidence interval of the dollar estimate (or in some cases, the 90% confidence interval, where an alternative

interval % is noted in the relevant cell). Note these values are measured in the original study year and currency.

- **Columns W-Y:** Provide other measures of statistical significance, including the standard error, standard deviation or p-value for the dollar estimate.

4.3.3 Sample characteristics

The third section in the value tabs describes the characteristics of the sample collected in the study entry.

	Z	AA	AB	AC	AD	AE	AF	AG
1	SAMPLE CHARACTERISTICS							
3	Country/region studied	Country of source studi	Sampled population (The target population - e.g. this might be the whole population of the region, or it might be a specific subset of the whole population)	Range in years of data	Mean sample age (Measured in years)	% Male	Mean sample income	Income units (Units of measurement)
4	Los Angeles County, California	USA	Duarte, Monrovia, Sierra Madre, Burbank, Glendora	2009	59.11	60	$83,520	USD/year
5	Los Angeles County, California	USA	Duarte, Monrovia, Sierra Madre, Burbank, Glendora	2009	59.11	60	$83,520	USD/year
6	n/a	n/a	n/a	>1980	n/a	n/a	n/a	n/a

| ◄ ► | Value type | **Health values** | Environmental values | Social values | CPI adjustment | Notes |

READY

Figure 4.4. Sample characteristics section of the database

As shown in Figure 4.4, this section contains the following information:

- **Column Z:** Defines the region studied, in terms of the case study area.
- **Column AA:** Defines which Country the study region is in.
- **Column AB:** Defines the sampled population. This is often similar to the population of the region being studied, but can vary (e.g. it might target a subset of the region's population, or it might target the wider population beyond the study region).
- **Column AC:** Reports the year(s) in which data collection or sampling occurred.
- **Column AD:** Reports the mean age of the sample in years.
- **Column AE:** Reports the percentage of the sample that were male.
- **Columns AF-AG:** Reports the mean income of the sample and the currency/year the sample income was measured in.

4.3.4 Methods

The methods section of the value tabs describes the instruments used to collect data and the way the data were analysed.

Figure 4.5. Methods section of the database.

As shown in Figure 4.5, this section contains the following information:

- **Column AH:** Describes the method used to collect data, e.g. which non-market valuation approach was used.
- **Column AI:** Describes the analytical approach used to model the data.
- **Column AJ:** Reports the number of sampled individuals who were included in the model estimation (or the number of studies from which estimates were drawn for a meta-analysis).
- **Column AK:** Reports the number of observations in the model, which can sometimes be different to the number of individuals as people may provide more than one observation each.

4.3.5 Publication characteristics

The final section in each value tab describes the publication.

	AL	AM	AN	AO	AP
1	**PUBLICATION CHARACTERISTICS**				
3	**Authors** ▼	**Year published** ▼	**Peer reviewed ? (Yes or No)** ▼	**Journal name** ▼	**Additional notes**
4	Richardson, L., Loomis, J.B., Champ, P.A.	2013	Yes	Land Economics	Paper compares traditional cost of illness valuation me CVM WTPs.
5	Richardson, L., Loomis, J.B., Champ, P.A.	2013	Yes	Land Economics	Paper compares traditional cost of illness valuation me CVM WTPs. Paper utilizes a form of revealed preference behaviour method'
6	Access Economics	2008	No	n/a	The source studies and countries from the modelled st report, however the full list of studies canvassed inclu Denmark, Europe, France, Hong Kong, Japan, New Zeala Taiwan, UK, US and other.
					Serious injury: defined as an injury that requires hospit results in some permanent disability. An aggregated Va

| ◄ ► | Value type | **Health values** | Environmental values | Social values | CPI adjustment | Notes |

READY

Figure 4.6. Publication characteristics section of the database.

As shown in Figure 4.6, this section contains the following information:

- **Column AL:** Lists the authors of the study.
- **Column AM:** Reports the year the study was published.
- **Column AN:** States whether or not the study was peer reviewed.
- **Columns AO:** Provides the journal name (if relevant).
- **Column AP:** Provides notes on additional context for the study which may be useful to clarify whether the entry is appropriate for your decision context.
- **Column AQ (not shown):** Provides the full reference for the study.

4.4 Finding a non-market value estimate

Searching the database to find dollar values requires you to have a good understanding of your decision or policy context and which non-market values are affected by your policy.

4.4.1 Define the policy context

You will need this information firstly to be able to identify the most relevant entries in the database (particularly items 1, 4 and 5 below), and secondly to determine what sorts of adjustments will be required in the benefit transfer process (particularly items 2, 3 and 5).

You will need to define the following elements of your policy context:

1) What is the natural hazard context?
   Flood, fire, storm, earthquake, tsunami, heatwave.

2) What is the scale of the proposed change?
   What area is affected, and to what extent?

3) What are the socio-economic characteristics of the affected population?
   What are the mean income, age, and other demographic characteristics of the population?

4) Which values are affected by the hazard type or its mitigation?
   Which of the 11 value types are relevant (Table 4.1, column 1)?

5) How are those values affected, in terms of the physical changes that are likely to occur?
   From Table 4.1 (column 2), what specific changes in outcomes will result in relation to the values affected, and to what extent or scale will the changes occur?

4.4.2 How to search the database

Once you have a clear understanding of your policy context you can begin searching the database.

Note that in the cells at the top of each column in the value tabs there is an downward-pointing arrow icon (bottom right of cell) you can click on that will provide a pop-up box enabling you to filter your search results. You can use this to select the relevant entries to manage and refine your search (see Figure 4.7).
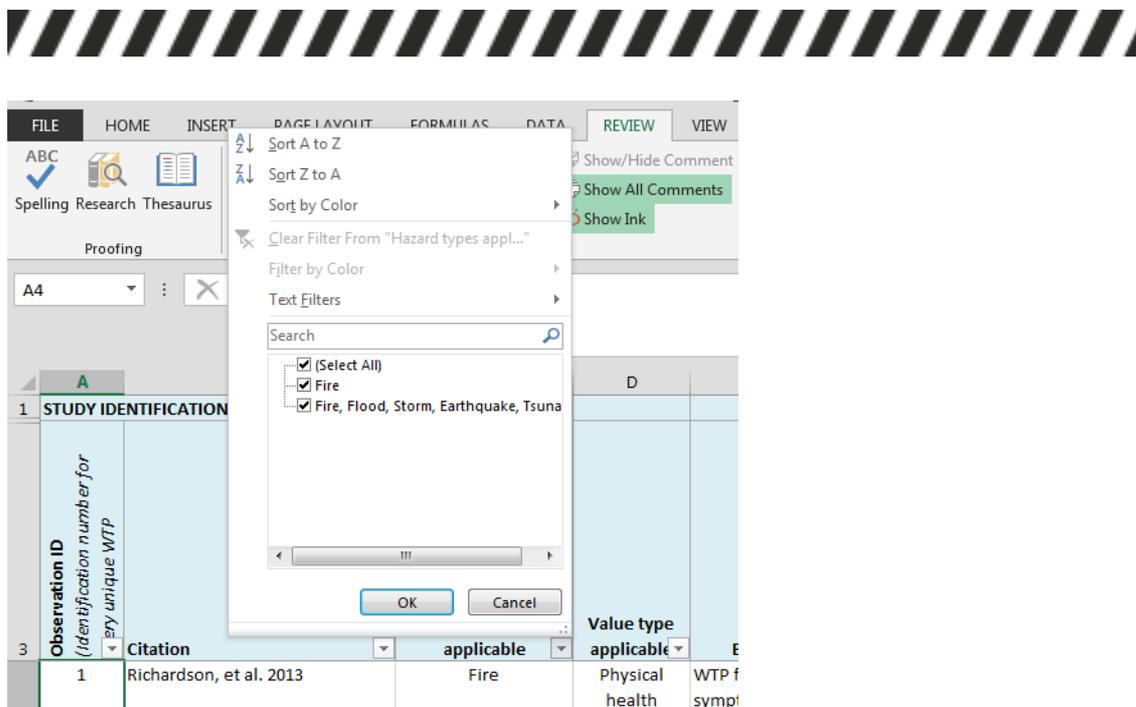
Figure 4.7. Pop-up up box enabling you to filter search results.

The following steps provide guidance on how to conduct your search.

1) Select the relevant value tab (worksheet): health values, environmental values or social values.

2) Define your hazard type.
   Search in **Column C: Hazard types applicable** to refine your search to the entries relevant to your hazard type (see Figure 4.1).

3) Define your value type.
   Search in **Column D: Value type applicable** to refine your search to the entries relevant to the non-market value type you are trying to find an estimate for (see Figure 4.1).

4) Define the specific marginal or physical change in the outcome for the value type.
   This step will require perusal of a number of columns in the value tab:
   - **Column E: Brief summary of study objective(s)** will provide general information on what the study measures, and can help you to determine whether an entry is worth investigating further (see Figure 4.1).
   - **Column L: Specific value type measured** can be used to refine your search based on the specific outcome that you are trying to measure (or the outcome that is most closely related to your decision context) (see Figure 4.2). You can also refer to the **Value type tab** for a summary table of the different value types and specific outcomes that are covered in the database (as per Table 4.1).
   - **Column J: Definition of physical or marginal change** is then used to select the entry that most closely matches your decision context in terms of what physical or unit change is being measured (see Figure 4.2).
   - **Column Z: Country/region studied** and **Column AB: Sampled population** might also be used, particularly if multiple entries remain, to refine your selection based

on the closest match in sample characteristics of the study relative to your region/population context (see Figure 4.4).

5) Select the most closely matched study for your decision context.
You will find the dollar value in **Column M: WTP estimate – original study value**. Note this value corresponds to the study's currency and year.
- Be careful to read the information related to the WTP estimate, including the unit description (e.g. per person or household; per day or year).
- **Column N: WTP estimate – present value** provides the current value of the estimate converted to 2017 Australian dollars.
- If you need are making a retrospective assessment and require the 'present value' to be in year earlier than 2017:
  o Note the study year (**Column O**)
  o Refer to the instructions in the **CPI adjustment** tab to determine the appropriate CPI ratio based on the study year and your policy/decision context year.
  o Multiply the value in **Column Q: WTP converted to $AU in original year from study** by the CPI ratio you have calculated.
- We also advise that you read all of the supporting information provided in the value entry row so that you have a good understanding of:
  o The general context of the study from which the estimate came,
  o The recommendations for using the estimate in benefit transfer
  o The sample characteristics, and
  o Any measures of confidence/significance for the willingness to pay estimate.

SECTION 5: HOW TO DO A SIMPLE BENEFIT TRANSFER

5.1 Benefit transfer

There are a number of ways to conduct a benefit transfer, which vary according to accuracy and expertise required. Two main approaches are unit-value transfer and benefit-function transfer (see Johnston et al. 2015b).

- Unit-value transfers involve the transfer of a single number or a set of numbers from study sites to the policy sites.
    - The number(s) can be adjusted to account for differences in, e.g. currency value across different time periods.
    - Adjustments are imposed ex post by the practitioner based on their knowledge of the policy site's characteristics, such as the sociodemographic profile of the population (i.e. the adjustments are not based on information provided by the original study, but are based on expert judgements or the collection of supplementary data).
    - Reliable approach if the study and policy sites are sufficiently similar, but can lead to substantial transfer errors (see below) otherwise (Bateman et al. 2011).
    - Relatively straightforward to implement.

- Benefit-function transfers use a "transfer function" to estimate and transfer values from study sites to policy sites.
    - The transfer function includes variables from the original study that describe the characteristics of the study site, such as socio-demographic characteristics or the number of substitute sites available.
    - Adjustments are based on information provided by the original study, and can account for observable differences between the study and policy sites using adjustments based on information provided by the original study.
    - The approach could be a parametric function, a meta-analysis (typically meta regression analysis), or a preference calibration based on a structural utility model.
    - In cases where the study and policy sites are dissimilar in some respects, benefit-function transfers are generally more accurate than unit-value transfers, but still require a high degree of similarity between the study and policy sites to minimise transfer errors (Bateman et al. 2011).
    - More difficult to implement than a unit-value transfer; generally requires an experienced analyst to conduct the transfer.

"Transfer errors" relate to the uncertainty of the accuracy of the transferred value. The errors are typically categorised as: 'measurement errors', which account for the difference between the true value and the value estimated at the study site; and, 'generalisation errors' which occur during the transfer process due to, for example, a mismatch between the study and policy sites, or scaling of values (Johnston et al. 2015b).

The recommendations in Section 2.6 should be referred to in determining the appropriate approach for your decision context.

- The process for implementing a unit-value transfer is set out in sections 5.2, 5.3 and 5.4 below, with examples of applying a transfer shown in Section 6.
- It is assumed that alternative approaches (benefit-function transfers, or original non-market valuation studies) will require engagement of an experienced analyst, and thus guidance is not provided here.

5.2 Unit-value transfers

5.2.1 Defining the context and matching study sites to policy sites

The policy context needs to be clearly defined (Rolfe et al. 2015b).

At a minimum, you need to be able to answer the set of questions in Section 4.4.1.

- The aim is to match the study and policy contexts as closely as possible across all of the elements of your policy context; that is:
    1. The natural hazard context.
    2. The scale of the proposed change.
    3. The socioeconomic characteristics of the affected population.
    4. The value types affected by the hazard type or its mitigation.
    5. How those values are affected, in terms of the physical changes likely to occur.

In matching the study and policy contexts (see Johnston et al. 2015b), specific aspects that you should consider for each site include:

- Biophysical conditions, and how those conditions are affected by the natural hazard, at each site.
- General socio-demographics of the population: e.g. age, gender, income, education.
- International differences between sites: e.g. currency conversion, wealth, cultural differences.
- Commodity definition: the quantity or quality of the good must be similar, but so must the impact on the good, and the intended use of the good. For example, assume fires reduce the water quality of reservoirs at sites A and B. Site A is used for recreation, Site B is used for water consumption. While the change in quality might be similar at both sites, the impact on use and the value attached to the change is probably not.
- Similarity of the economic framework and policy setting: e.g. if a study site measures willingness to pay it may not be appropriate to use to infer values for a policy context that needs to measure willingness to accept compensation.

Given it is rarely possible in practice to match all of the elements between the policy and study sites, making transparency in the benefit-transfer process critical: where assumptions are made, and limitations foreseen, they should be clearly documented.

In addition to matching the context of the study and policy sites, the quality of the original study is important. Any errors or biases that exist in the estimation of values for the original study site are likely to be transferred to the policy site. The studies in the Value Tool Database have been objectively assessed to provide a rating of study quality (see Figure 4.1, Column G).

5.2.2 Conducting the transfer

Unit-value transfers can be conducted using single or multiple values from study sites, and can be left unadjusted or have an adjustment imposed by the practitioner (Johnston et al. 2015b). These steps are described below, and illustrated by examples in Section 6.

Unadjusted transfers

For a single value unadjusted transfer, the process is:

1) Take the willingness to pay per person for a marginal, unit change in the good from the study site, and apply it to the policy site.
2) Aggregate the value by the population size at the policy site.

For a multiple value unadjusted transfer, the process is:

1) Take the willingness to pay per person for a marginal, unit change in the good from multiple study sites.
2) Take a measure of central tendency (e.g. the mean of the values), and apply it to the policy site.
3) Aggregate the value by the population size.

Adjusted transfers

Adjustments to the transferred value are made prior to aggregating the value by population size. Similar steps are followed as for the unadjusted transfers above:

1) Take the willingness to pay per person for a marginal, unit change in the good from the study site, and apply it to the policy site (using a measure of central tendency if using multiple values/studies).
2) Adjust the per person estimate for the policy site by some factor (e.g. multiply it by a price index, or a subjective expert weighting).
3) Aggregate the value by the population size.

5.2.3 Limitations

The advantage of unit-value transfers is that they are easy to implement and require minimal data (Johnston et al. 2015b). This approach can work well if there is a close match in study and policy sites (Bateman et al. 2011).

With respect to the non-market value literature on bushfire and natural hazards, the available data is minimal, lending some preference to this approach over the more data intensive approaches such as meta regression analysis. However, the available data is so limited that it may be impossible to identify a study site that is sufficiently similar to the policy site for benefit transfer to be a reasonable approach (see section 5.2.1 above for matching criteria).

Further, strong assumptions are made about the scaling of values in the unit-value transfer approach (discussed further below), and only simple ex post adjustments can be made to the transferred value (Johnston et al. 2015b). These factors mean that both the risk and potential size of transfer error is large. For this reason, sensitivity analysis is crucial (Section 5.4).

In general, adjusted unit-value transfers are preferred over unadjusted transfers, as careful adjustments provide some scope to minimise transfer errors (particularly generalisation errors).

5.3 Making adjustments to transferred values

Adjustments can be used to improve the accuracy of a transferred value. Some adjustments are necessary, but there are many that should be carefully considered.

5.3.1 Necessary adjustments

Conversion to Australian currency

- For international studies, the currency must be converted to Australian dollars.
- For entries in the Value Tool Database, this conversion has been made and is shown in Column Q (see Figure 4.2). The exchange rates were obtained through the Reserve Bank of Australia's historical data records (<http://www.rba.gov.au/statistics/historical-data.html>). The exchange rates used were for July 1 (or the closest possible date) of the original currency year (Column O of database).

Conversion to current dollars

- The dollar values from the study must be converted to current Australian dollars using the Consumer Price Index.
- For entries in the Value Tool Database, all dollar values have been converted to 2017$ (Column N of database), using the calculations shown in the CPI adjustment tab of the Database.

Aggregation for population size

- The approach for aggregation will depend on the type of value being transferred.
    - In most cases in the Value Tool Database, values are willingness to pay per person. These values are aggregated over the relevant population (i.e. multiply $ x number of people).
    - In some cases, e.g. for Value of Statistical Life (VSL), the values are already aggregated over the sampled population, and represent a value per case or occurrence of an incident.
    These values are aggregated over the number of incidents (e.g. for VSL, multiply $ x number of anticipated deaths).

- When determining how to aggregate by number of people, the following questions should be asked (Rolfe et al. 2015b):
    - Who is the relevant population for the policy site?
    - What proportion of that population is likely to have values that are similar to those held by the sampled population from the study site?
    - Whether any adjustments might be required for the population of interest, based on the answers to the questions above?

- A common consideration that requires adjustment is the effect of distance decay. Distance decay applies to the proximity of an individual to the good being valued. The further away from a site that an individual lives, the lower their value for the good at that site is likely to be. This is because they have a lower use value, and there may be substitute sites that are more closely located.

  For example, assume a study site population of 1 million, and an estimated willingness to pay of $50 per person for a particular good. The aggregate value at the study site is $50*1,000,000 = $50 million. Assume the policy site has a population of 2 million. A simple aggregation would imply $50*2,000,000 = $100 million. However, if the population at the policy site is spread over a greater distance in relation to the good being valued, compared to the population spread at the study site, this aggregation is likely to over-estimate the true value.

- Wide bounds in the sensitivity analysis are recommended where distance decay may be relevant (Section 5.4).

5.3.2 Recommended adjustments

Socio-demographic adjustments

- A section in the Value Tool Database describes the socio-demographics of the sampled population (see Figure 4.4). These demographics can be compared to the policy site demographics to consider appropriate adjustments.

- Adjusting the dollar values based on average income of the study vs policy populations is recommended.
    - Information about population income can be found on the Australian Bureau of Statistics website (<http://www.abs.gov.au/>) for the policy site, and also for Australian-based samples in the Value Tool Database.
    - In some cases the mean sample income is reported in the Value Tool Database (Column AF; note this number will be in the original study currency and year), which can be used for comparison with the population income.

Scaling over the quantity or quality of the good being valued

- The unit-value transfer assumes that utility (i.e. the measure of wellbeing) is linear with respect to increases in quantity or improvements in quality.

  However, there is often a diminishing marginal utility associated with increases in quantity of public goods. For example, a recreational fisher will value the 1st fish caught more highly than the 10th fish caught, because in the latter case they already have 9 other fish.

- When transferring values, if there is a mismatch in the scale of quantity or quality at the study and policy sites, the total value from the transfer could be over- or under-estimated (Johnston et al. 2015b). For example, if the study site estimates a value of $100/person for 10 units of the good being valued, and the value is being transferred to the policy site where there are 20 units of the good, a transferred value of $200/person is likely to be too high.

- Where there are large differences in scale of quantity or quality, using wide bounds in the sensitivity analysis will be important (Section 5.4).

Scaling over the geographic area

- The errors introduced when scaling over different geographic areas encompass those already described above. When using a value per unit area to transfer between a study and policy site, scaling up to larger areas will likely introduce errors due to diminishing marginal utility *and* distance decay.

- It is important to note that the potential to over-estimate values when scaling up between the study and policy sites can also mean the potential exists to under-estimate values when scaling down between the sites.

- Wide bounds in the sensitivity analysis are recommended for large differences in geographic scale (Section 5.4).

5.3.3 Alignment of values for gains and losses

It has been established that people are generally willing to pay more to avoid a loss than they are willing to pay for an equivalent sized gain (Cleland et al. 2015).

Ideally, if the policy context is measuring a gain (or a loss), the selected study from the Value Tool Database will also be measuring a gain (loss). However, there are likely to be cases when the best-matched study to the policy context is measuring the opposite. For example, the policy context may be about avoiding a 100 hectare loss of native vegetation, while the study might measure the value for restoring 100 hectares of native vegetation.

- If the study measures the value for a gain, and the policy context is about avoiding a loss, then the transferred value is likely to be a conservative (or under) estimate of actual value (all else being equal).
  Large upper bounds should be used in the sensitivity analysis (Section 5.4).

- If the study measures the value for a loss, and the policy context is about a gain, then the transferred value is likely to be an over-estimate of actual value (all else being equal).
  A lower bounds closer to zero should be used in the sensitivity analysis (Section 5.4).

5.4 Recommendations for sensitivity analysis

A sensitivity analysis is used to look at a range of "what if" scenarios. In particular, what if the assumptions you have made about the values used in a benefit transfer are inaccurate.

Sensitivity analysis enables testing of how robust a decision outcome is across a range of values. One can also investigate whether a different decision outcome exists that is less sensitive to changes in the value.

///

Sensitivity analysis should be a standard part of any decision-making process, and is relevant to all variables about which there is uncertainty or potential for error. Clearly, values transferred from an existing study to a new policy context fall into this category.

For all uses of non-market values, explicitly acknowledging uncertainty and its impact on decisions is important for transparent, credible and defensible decision making.

5.4.1 Approaches for sensitivity analysis

Sensitivity analysis involves re-solving a decision model with different input parameters, observing what happens to the model results, and considering these observations when making decisions. In many cases, the relevant decision model is a Benefit: Cost Analysis, in which non-market values can be included, alongside market values. Any of the non-market or market values could potentially be changed in a sensitivity analysis. So could any of the other parameters or variables, including technical assumptions and the discount rate.

Systems used to undertake sensitivity analysis vary widely. At the simplest end of the spectrum, you might vary parameters one at a time, testing one higher value and one lower value for each parameter and comparing the result to the base-case solution. At the complex end, you might define a probability distribution for each uncertain variable, define correlations between them, and undertake Monte Carlo simulations, where the model is solved hundreds or thousands of times for random combinations of changes in parameters. See Pannell (1997, in Section 7 Recommended Readings) for further discussion of the options.

Sensitivity analysis is relevant to benefit transfer in each of the following cases:

1. For a unit-value transfer that is being used conceptually/qualitatively (see Section 2.2)
2. For a unit-value transfer that is being used instrumentally/quantitatively in a subsequent economic model (e.g. Benefit: Cost Analysis) (see Section 2.2)
3. For more advanced benefit-function transfer approaches (see Section 5.1)

Section 5.4.2 provides guidance on how to establish the ranges of values to consider for a sensitivity analysis.

5.4.2 Selecting an appropriate range of values

In the discussion below, we assume that a relatively simple strategy for sensitivity analysis is being used, requiring identification of a high level and a low level for each uncertain variable, as well as the standard value. This could lead to a very simple sensitivity-analysis strategy, or one that is intermediate in complexity (e.g., see Pannell 2008). In some strategies, you may wish to identify more than three values – the discussion below is easily adjusted for that case.

The high and low levels for a variable should usually not be thought of as upper and lower bounds, because there is some small probability of the variable being even higher or lower.

Instead, think of them as defining a "confidence interval", as used in statistics. For example, a reasonable approach is to define the range for a 75% confidence interval – the range for which you judge there is a 75% chance of including the true value. This is subjective, of course, but it provides a discipline and a consistent approach you can apply to each variable. If you are using a sensitivity analysis approach that also requires you to assign probabilities to the outcomes, you can then use 25%, 50% and 25% for the low, standard and high values.

A first step is to identify which variables or parameters you are uncertain about. In some cases, there may be uncertainty related to the policy context itself (see Section 4.4.1 on defining the policy context). For example, you might not be certain about:

- The scale of the proposed change – in terms of what geographical area is affected at the policy site.
- The affected population – in terms of who the target population is and, in particular, what proportion of the target population is likely to hold similar values to the individuals in the study site sample.
- What the physical changes are likely to be in relation to the value type – in terms of the scale of the quantity or quality affected by the natural hazard.

Even if you are able to define your policy context accurately, there will still be uncertainty in the transferred value given the nature of benefit transfer, in terms of matching the policy context to a study site. This uncertainty may relate to a specific adjustment that is being made, or to the suitability of the study being used to provide the value.

With respect to adjustments, uncertainty is likely to be high when there are issues related to:

- Who in the policy site population will have similar values to the study site population, particularly given the effects of distance decay (see Section 5.3.1).
- Scaling over different quantities of the valued good, given the effects of diminishing marginal utility (see Section 5.3.2).
- Scaling over different geographical areas, given both the effects of distance decay and diminishing marginal utility (see Section 5.3.2).

With respect to suitability of the study for use in benefit transfer, uncertainty is likely to be high if:

- The original study was not based on an Australian case study (see Section 4.3.3, Figure 4.4, Columns Z-AB).
- The original study is conducted in a policy context unrelated to natural hazards (see Section 4.3.1, Figure 4.1, Column F).
- The original study is poor quality (see Section 4.3.1, Figure 4.1, Column G).
- The original study is not designed in a manner that readily lends itself to benefit transfer applications (see Section 4.3.1, Figure 4.1, Column H).

In each of these cases, the suggested approach is to imagine how widely an uncertain value might vary. When specifying the ranges, try to reflect realistically wide ranges for each variable. A common error is to use the same narrow range (e.g. +/− 20%) for each variable. Preferably, provide ranges that reflect the 75% confidence interval for each variable and consider how the ranges are likely to vary for different variables. Where uncertainty about a variable is higher, the range should be wider. We cannot provide specific guidance about the ranges that will apply generally, because each uncertain variable is context specific. However,

here we provide some advice about the uncertainty specifically due to the benefit transfer process.

Columns H and I in the Value Tool Database (Figure 4.1), and the text boxes at the beginning of each value type description in Section 3, provide a summation of how suitable the study is likely to be for a benefit transfer application in natural hazard decision making.

To account for the uncertainty related to study suitability and accuracy of adjustments, the mean dollar values that are calculated could be multiplied by suitable percentages to define the range to be considered in decision making and subsequent sensitivity analyses of economic models.

Tables 5.1, 5.2 and 5.3 provide suggested percentages you could use to multiply your values by, based on the anticipated uncertainty. Akter and Grafton (2010) address the issue of uncertainty for benefit transfer of species conservation values. They recommend multiplying values by 60% and 140% (i.e. +/- 40% of the mean value) to obtain a low-high value range for well-matched contexts, and by 0% and 200% (i.e. +/- 100% of the mean value) for poorly matched contexts. Our suggested percentages fall within this range, with the exception of the lower value for poorly matched studies (0%) which would imply that the value is 0. This is unlikely to be the case even when using a poorly matched study: while the actual value for the policy context may be closer to 0 than the study value, it is still likely to be a positive (or negative) number as per the study value.

Table 5.1. A guide to percentage multipliers for a unit transfer when there is a **good match** between the original study and the new policy context.

Adjustments required:	Lower level	Higher level
No adjustment issues	x 70%	x 140%
One adjustment issue likely to be present (e.g. distance decay; diminishing marginal utility)	x 60%	x 150%
Multiple adjustment issues present	x 40%	x 170%

Table 5.2. A guide to percentage multipliers for a unit transfer when there is a **moderate match** between the original study and the new policy context.

Adjustments required:	Lower level	Higher level
No adjustment issues	x 60%	x 150%
One adjustment issue likely to be present (e.g. distance decay; diminishing marginal utility)	x 50%	x 160%
Multiple adjustment issues present	x 30%	x 180%

Table 5.3. A guide to percentage multipliers for a unit transfer when there is a **poor match** between the original study and the new policy context.

Adjustments required:	Lower level	Higher level
No adjustment issues	x 50%	x 160%
One adjustment issue likely to be present (e.g. distance decay; diminishing marginal utility)	x 40%	x 170%
Multiple adjustment issues present	x 20%	x 190%

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SECTION 6: APPLIED EXAMPLES

Newstead is a suburb in Launceston, Tasmania. Launceston is prone to flooding, and has recently had works undertaken to upgrade and extend a network of existing flood levees. The suburb of Newstead was not included in the original plans for the upgrade, and a Benefit: Cost Analysis was subsequently conducted to determine whether it was worth extending the levee further to protect the suburb. The analysis included consideration of non-market values. Here, we use this case study to provide hypothetical examples[1] illustrating how to use the Value Tool Database. The examples follow the steps provided in these Guidelines on how to consult the Database and conduct the benefit transfer.

6.1 Defining the policy context

The questions from Section 4.4.1 must be answered before consulting the Value Tool database.

1) What is the natural hazard context?
   Flood mitigation by constructing an extension to an existing flood levee.

2) What is the scale of the proposed change?
   An additional 234 residential households in the suburb of Newstead would be protected from flood if the levee is extended.

3) What are the socio-economic characteristics of the affected population?
   The demographic characteristics of the Newstead population are:
   - *46% male, 54% female*
   - *Median age 41 years*
   - *Average of 2.3 people per household*
   - *Median weekly household income $1125*
   (Information available at:
   http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC60448)

4) Which values are affected by the hazard type or its mitigation?
   Multiple value types are affected. We will illustrate examples for:
   - *Physical health*
   - *Ecosystems*

5) How are those values affected, in terms of the physical changes that are likely to occur?
   The physical changes will be described below for each value type.

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[1] Note that we use only the underlying decision context as an illustrative example, and the figures reported here are not the actual figures used in the Benefit: Cost Analysis report. See Maqsood et al. (2017) for the report.

6.2 Physical health value

Continuing from Section 6.1 above, question 5 on defining the policy context – how is the value affected:

An increase in the number serious injuries is anticipated as a result of a flood event. It is estimated that approximately 10 serious injuries will result to people living in Newstead if there is no flood levee when a flood event occurs.

Table 4.1, column 2, shows that 'serious injury' is an outcome for which there are values in the Database.

6.2.1 Searching the database:

1. Select the health values tab.
2. Search in **Column C: Hazard types applicable** for entries that are relevant for *flood*.
3. Search in **Column D: Value type applicable** for entries that are relevant to *physical health*.
4. Read the information provided in **Column E: Brief summary of study objective(s)** to gain an understanding of the types of entries that might be relevant, and then refine the search further:
   a. Search in **Column L: Specific value type measured** for entries that are relevant to *serious injury.*
   b. Refer to **Column J: definition of marginal change** to establish which of the remaining entries most closely matches the decision context: there are two entries remaining, both measuring "Aggregate WTP to avoid one serious injury per event"
   c. Referring back to the study objectives in **Column E**, one of these studies is measuring WTP to avoid serious injury by traffic accident in urban NSW, and the other in non-urban NSW.
5. We are measuring values related to injuries that occur in an urban area, so we select the entry related to urban areas (Observation ID 4 in Database, see Figure 6.1)
   a. The WTP estimate is provided in **Column M**: $310,292 per serious injury, measured in Australian dollars (**Column P**) in 2007 (**Column O**).
   b. The 2017AUD WTP estimate, adjusted by CPI, is provided in **Column N**: $392,342 per serious injury

Figure 6.1. Value entries relevant for *physical health: serious injury*.

6.2.2 How well matched is the study?

Reflecting on the specific aspects listed in Section 5.2.1, we can determine how well matched the study is to our policy context.

Similarities include:

- Biophysical conditions: the setting for the injury occurrence is in an urban area, and the study measures values for the exact marginal/physical change that we are interested in, WTP for avoiding serious injury.
- International conditions: it is an Australian study, so cultural differences are minimal.
- Economic framework: both the study and policy contexts are framed as measures of WTP.

Differences include:

- Commodity definition: the study is not conducted in a natural hazard context, it is about avoiding serious injury from traffic accidents.
- General socioeconomic characteristics: Given the study is Australian differences should be minimal, but the study sample is from NSW, not Newstead (Tasmania), so there may be some demographic differences requiring a specific adjustment. In particular, median household weekly income in NSW is $1486 (Information available at: http://www.censusdata.abs.gov.au/census_services/getproduct/census /2016/quickstat/1?opendocument).

These similarities and differences suggest that there is an average match between the study and policy sites, which must be considered in sensitivity analysis (see Section 6.2.4).

6.2.3 Conducting the transfer

An adjusted unit transfer will be used to account for differences between the study and policy sites.

The Database estimate already accounts for adjustments to convert figures to 2017AUD.

It is recommended that an adjustment be made to account for the income differences between the study and policy site populations.

Income adjustment

- Median household weekly income NSW: $1486
- Median household weekly income Newstead: $1125
- Adjustment required = ($1125/$1486) x 100 = 75.71%

- ➢ Adjusted WTP (2017AUD) = $392,342 x 75.71% = $297,042 per serious injury

Aggregation of WTP

In this instance, the WTP value is already aggregated by person to give WTP per occurrence of an incident. Thus, the aggregation does not need to account for population size, and only needs to reflect the number of incidents.

> ➢ Aggregated WTP (2017AUD) = $297,042 x 10 serious injuries = $2,970,420

6.2.4 Sensitivity analysis

An appropriate range of values for use in sensitivity analysis are calculated according to tables 5.1 and 5.2.

- There is an average match between study and policy contexts.
- No adjustment issues are anticipated; a specific adjustment has already been made accounting for income.

> ➢ Lower bound WTP (2017AUD) = $2,970,420 x 50% = $1,485,210
> ➢ Upper bound WTP (2017AUD) = $2,970,420 x 150% = $4,455,630

6.3 Ecosystem value

Continuing from Section 6.1 above, question 5 on defining the policy context – how is the value affected:

The debris and pollutants entering the Launceston river system after a flood event can affect the ecosystem. It is anticipated that there will be a 3% decrease in population size of the native fish stock in the river if a flood event occurs and there is no levee to prevent debris and pollutants from developed land entering the river.

Table 4.1, column 2, shows that '*change in flora and fauna species*' is an outcome for which there are values in the Database.

6.3.1 Searching the database:

1. Select the environmental values tab.
2. Search in **Column C: Hazard types applicable** for entries that are relevant for *flood*.
3. Search in **Column D: Value type applicable** for entries that are relevant to *ecosystems*.
4. Read the information provided in **Column E: Brief summary of study objective(s)** to gain an understanding of the types of entries that might be relevant, and then refine the search further:
   a. Search in **Column L: Specific value type measured** for entries that are relevant to *species.*
   b. Refer to **Column J: definition of marginal change** to establish which of the remaining entries most closely matches the decision context: there are five entries form the same study related to "WTP for a 1% increase in native fish populations per household per year (max. 10 years)"
   c. Referring to **Columns Z and AB,** the region studied is the Murray River (Eastern States of Australia), with different samples collected. One of these samples includes the Tasmanian population.
5. As we are measuring values for a subset of the Tasmanian population, we select the entry that samples Tasmania (Observation ID 11 in Database, see Figure 6.2):
   a. The WTP estimate is provided in **Column M**: $1.71 per 1% increase per household per year, measured in Australian dollars (**Column P**) in 2009

(**Column O**). Also note that this per year value is to apply for a maximum of 10 years (**Column J**).

  b. The 2017AUD WTP estimate, adjusted by CPI, is provided in **Column N**: $2.15 per 1% increase per household per year, for a maximum of 10 years.

Brief summary of study objective(s)	Study conducted in the context of a natural hazard? (Yes or No)	Study quality (1=high, 2=average, 3=poor)	Benefits transfer applicability (1=highly, 2=moderately, 3=barely)	Recommendations (Applicability for benefit transfer in natural hazard context)	Definition of physical or marginal change (This is what is being measured, the value of the change in the outcome)	Hazard types identified	Specific value type measured	WTP estimate - original study value	WTP estimate - present value (2017 $AU)
WTP for improvements in environmental quality on River Murray for respondents from South Australia	No	1	2	Useful for BT in Australia; be aware of generalised context - not NH specific	WTP for a 1% increase in native fish populations per household per year (max. 10 years)	Drought, climate change	Species	$2.15 per 1% increase per household per year	$2.56
WTP for improvements in environmental quality on River Murray for respondents from Northern Territory, Western Australia, Queensland, Tasmania	No	1	2	Useful for BT in Australia; be aware of generalised context - not NH specific	WTP for a 1% increase in native fish populations per household per year (max. 10 years)	Drought, climate change	Species	$1.71 per 1% increase per household per year	$2.04

Figure 6.2. Value entries relevant for *ecosystems: species*.

6.3.2 How well matched is the study?

Reflecting on the specific aspects listed in Section 5.2.1, we can determine how well matched the study is to our policy context.

Similarities include:

- Biophysical conditions: the setting for the study is for an Australian river system, and the value measured is for a change in the native fish stock.
- International conditions: it is an Australian study, so cultural differences are minimal.
- Economic framework: both the study and policy contexts are framed as measures of WTP.
- General socioeconomic characteristics: given the study sample includes respondents from Tasmania any differences should be minimal.

Differences include:

- Biophysical conditions: the setting for the study is the Murray River in the Eastern States of Australia, which is a much larger scale river system with a multitude of different uses (and users) impacting on the condition of the river, relative to the Launceston River in Tasmania. The importance of the river systems may vary in relation to this difference in geographical scale.
- Commodity definition: the study is not conducted in a natural hazard context, it is about the impacts of climate change.
  The study also measures a percentage *increase* in native fish populations, while our policy context is about avoiding a percentage *decrease* in native fish populations. As per Section 5.3.3, using a value based on an increase should provide a conservative estimate of an equivalent decrease, given that people have a stronger aversion to loss.

These similarities and differences suggest that there is an average match between the study and policy sites, which must be considered in sensitivity analysis (see Section 6.3.4).

6.3.3 Conducting the transfer

An unadjusted unit transfer will be used given the similarities between the study and policy site demographics.

The Database estimate already accounts for adjustments to convert figures to 2017AUD.

Aggregation of WTP

The WTP must be aggregated by the number of units (a 3% decrease):

➢ WTP (2017AUD) = $2.15 x 3 = $6.45 per household per year, for a maximum of 10 years.

The WTP must also be aggregated by the relevant population size. While only 234 households are affected by the flood levee decision in Newstead, ecosystem related values are likely to have a non-use value component, meaning the population that could be affected is greater than those households directly impacted by the flood event. Here, we aggregate by the number of households in Launceston: 36,703 households (Information available at: http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/60201?opendocument)

➢ Aggregated WTP (2017AUD) = $6.45 x 36,703 households = $236,734 per year, for a maximum of 10 years.

6.3.4 Sensitivity analysis

An appropriate range of values for use in sensitivity analysis are calculated according to tables 5.1 and 5.2.

- There is an average match between study and policy contexts.
- One adjustment issue is likely to be present given the different geographical scales (and related importance) of the river systems for the study and policy sites.

➢ Lower bound WTP (2017AUD) = $236,734 x 30% = $71,020 per year, for a maximum of 10 years.
➢ Upper bound WTP (2017AUD) = $236,734 x 170% = $402,448 per year, for a maximum of 10 years.

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7. RECOMMENDED READING

- *For a detailed overview of benefit transfer:*

Johnston, RJ, Rolfe, J, Rosenberger, RS and Brouwer, R (Eds) 2015. *Benefit Transfer of Environmental and Resource Values A Guide for Researchers and Practitioners*. Springer, Dordrecht.

- *For further information on sensitivity analysis:*

Pannell, D.J. 1997. Sensitivity analysis of normative economic models: Theoretical framework and practical strategies. Agricultural Economics 16(2): 139-152.
http://dpannell.fnas.uwa.edu.au/dpap971f.htm

Pannell, D.J. 2008. Sensitivity analysis with economic models. *Pannell Discussions* 126,
http://www.pannelldiscussions.net/2008/06/126-sensitivity-analysis-with-economic-models/

- *For further review of the literature available on non-market values for natural hazards:*

Gibson, F.L., 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. Working Paper 1604, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia. Available at:
https://ageconsearch.umn.edu/record/236941/files/WP1604_Gibson%20et%20al_NMV%20in%20the%20economic%20analysis%20_corr_.pdf

- *For more information on stated preference techniques, including contingent valuation and discrete choice experiments:*

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., 2002. Economic valuation with stated preference techniques: a manual. Economic valuation with stated preference techniques: a manual. Edward Elgar, Cheltenham.

Pearce, D. and Ozdemiroglu, E. (2002) Economic Valuation with Stated Preference Techniques: Summary Guide, Department for Transport, Local Government and the Regions, London. Available at:
http://webarchive.nationalarchives.gov.uk/20120919162306/http://www.communities.gov.uk/documents/corporate/pdf/146871.pdf

- *For more information on non-market valuation technques generally, and revealed preference techniques including travel cost method and hedonic pricing:*

Hanley, N., Barbier, E.B., 2009. Pricing Nature: Cost-Benefit Analysis and Environmental Policy. Edward Elgar, Cheltenham.

Parsons G.R. (2013) Travel Cost Methods. In: Shogren, J.F., (ed.) Encyclopedia of Energy, Natural Resource, and Environmental Economics, volume 3, pp. 349-358 Amsterdam: Elsevier. Available at: https://works.bepress.com/george_parsons/35/download/

APPENDIX 1: NON-MARKET VALUATION THEORY

A1.1 Introduction to non-market values

This section provides an introduction to the theory underlying non-market valuation, and the main techniques that are used to estimate non-market values. It concludes with a brief discussion of how non-market values can be used in decision making.

A1.2 Consumer choice theory

The theory of consumer choice relates preferences of individuals to their consumption expenditures. The basic assumption behind consumer choice is that individuals maximise their utility subject to budget constraints. This represents consumers maximising the satisfaction from their consumption as measured by their preferences and subject to limitations on their budget (Suen, 2001). This discussion of consumer's preferences is key to all of the non-market valuation techniques described here and listed in the Value Tool Database.

Of course economists recognise that people do not rigorously analyse every decision and successfully maximise their satisfaction. The assumption of utility maximisation represents a tendency, rather than a literal truth. It allows us to think through the logic behind complex and subtle decisions.

In coming sections, we describe two approaches to estimating non-market values: revealed preference (what people reveal about their preferences and values from their behaviour) and stated preference (what people say they prefer and value). Both techniques for non-market valuation rely on the assumption that in maximising their utility, consumers are willing to make trade-offs between alternative benefits (including benefits related to health, social factors and the environment but also to consumer goods, such as televisions and cars). Money provides a metric for quantifying those trade-offs.

Many economic methods acknowledge or rely on the *law of demand*, which states that as the price of a good rises consumption falls as individuals choose other substitute goods (Suen, 2001). This can be demonstrated, for example, in recreation users choosing to visit one park over another because of rising fees or declining park conditions (Perman et al., 1999).

Additionally, choice experiments, hedonic pricing, and the travel-cost method are all based on the *characteristics theory of value* which states that the value of an asset or resource, such as a house, is explained in terms of characteristics or attributes of the house. Some of these attributes, such as the number of bedrooms or distance to public transit, may be easy to quantify. Other attributes, like scenic views or flood risk, are substantially more difficult to measure. Regardless, under the *characteristics theory of value*, each of these attributes contributes to the total value of the house. Choice experiments, hedonic pricing, and the travel-cost method all use different methods to take apart the total value of a good or service and place value on its characteristics, some of which may be environmental characteristics (Hanley and Barbier, 2009).

We will also distinguish between use values (values accruing to people who actually use or interact with an asset or resource) and non-use values (values that people obtain even if they never see the asset – such as the "existence value" than many people feel for threatened species).

Use values are the values of a good or service from its use. For example, people may value a view from their front window, but only if they are able to experience the view.

Non-use values, include *altruistic values*, which are based on a desire to protect a resource for others; *bequest values*, which stem from a desire to protect resources for future generations; and *existence values*, which are put on the existence of a resource, even if it may never be used.

Generally, revealed-preference techniques measure only the *use values* of a resource and do not capture the *non-use value*, which may often be substantial (Bateman et al., 2002; Hanley and Barbier, 2009). On the other hand, stated-preference techniques, based on surveys and interviews, provide the *total economic value*, which includes both *use* and *non-use* values (Bateman et al., 2002).

A1.3 Revealed-preference methods

Many of the studies listed in the Value Tool Database use revealed-preference methods, like hedonic pricing or the travel-cost method, to determine the non-market values of public goods or resources. Revealed-preference methods use information from markets associated with the resources being valued. Values derived from revealed-preference methods are often viewed as having more credibility than other methods as the values found using these methods are based on monetary values in actual markets (Bateman et al., 2002). As noted above, revealed-preference methods are limited as they can only be used to estimate 'use values', and cannot be used to measure 'non-use values' (Bateman et al., 2002; Perman et al., 1999).

The following sections describe the two primary revealed-preference methods used in the studies listed in the Value Tool Database: hedonic pricing and the travel-cost method. The theoretical basis is provided for each method as well as a summary of how the method is carried out. Finally, limitations, technical problems, and noted biases are presented for the two methods.

A1.3.1 Travel cost

The travel-cost method is the oldest form of non-market valuation for environmental resources. It works by finding the non-market value (NMV) of recreation at a specific site under current site conditions. This value is found by measuring the price that recreation users actually pay to visit the site, usually in terms of their travel costs. These costs include monetary expenses like fuel costs, food expenditures, entry fees, and other on-site purchases. The travel-cost method also takes into account non-monetary expenses, such as the implicit time cost for travel (Hanley and Barbier, 2009). Users of a recreation site pay a price in terms of travel costs which is typically a function of the user's distance from the site. As conditions at the recreation site change, or as travel costs change, so too do the number of trips made by the recreation users. By examining these differences, a value can be placed on the recreation site or on environmental goods or resources that are characteristic of that site.

Under the travel-cost method, a site of interest is selected either on its own merits and characteristics or for the environmental characteristics associated with the recreation site. Visitors to the site are given surveys which collect information on where they live, how much they spend on trips to the site, and how frequently they visit. This information is then analysed using a statistical model to estimate a relationship between the travel cost and the utilization

of the site, and this relationship can be interpreted as providing information about their valuation of the site, in terms of their willingness to pay to visit it.

Other information is often collected about what other recreation sites users frequent. Some surveys may make comparisons between sites and characteristics of those sites (Perman et al., 1999). The researchers break up the geographic area surrounding the site into zones and observe the relationship between the number of trips and cost per trip of visitors from each zone (Hanley et al., 2009). The total economic benefit of the site can then be extrapolated and the non-market value of characteristics of the site, including associated environmental services and resources, can be estimated.

The assumptions underlying the travel-cost method which allow it to work are also a source of many of its problems. The travel-cost method runs into problems with users making multi-purpose or multi-stop trips (Perman et al., 1999). Care must also be taken in determining how site characteristics are measured (Hanley and Barbier, 2009). The biggest problem and greatest source of debate for the travel-cost method, however, is how the opportunity cost for travel time is determined. There is little consensus on whether opportunity cost should be valued at a person's wage rate, a portion of their wage rate, or for those that enjoy the travel itself, if travel time should be valued as a benefit instead of a cost. The assumptions behind the value of opportunity cost can therefore under- or overestimate the economic benefit of the site (Hanley and Barbier, 2009; Perman et al., 1999).

The travel-cost method is an application of 'weak complementarity', a situation where, if travel to the site is too expensive, then no trips will be made, and any changes to the condition of the site or its environmental resources will no longer affect the users' utility. There are many instances, however, where users do care about the condition of sites even when they are unavailable or too expensive to visit. These represent non-use values that cannot be captured by the travel-cost method (Perman et al., 1999). Similarly, because of the specific nature of the characteristics of the recreation sites studied, the travel-cost method is limited in what problems it can be applied to (Hanley and Barbier, 2009).

A1.3.2 Hedonic pricing

Much as the travel-cost method estimates the value of environmental services and resources by breaking the total recreational experience into values associated with the attributes and characteristics of that recreation site, hedonic pricing similarly uses the relationship between housing prices and property characteristics to estimate the non-market value of public goods and services (Hanley and Barbier, 2009). While hedonic pricing has been used for areas such as labour wages and food labelling, it is usually applied to property markets where many environmental goods such as air quality, scenic views, and proximity to open space are implicitly traded (Hanley and Barbier, 2009; Perman et al., 1999). Individuals reveal their preferences for these and other environmental goods through decisions on what homes to purchase (Perman et al., 1999). The hedonic price function represents the statistical relationship between the differences in property characteristics and the housing prices shaped by buyers' bids and sellers' offers (Hanley and Barbier, 2009; Perman et al., 1999). This relationship provides an estimate of the implicit value of different housing characteristics (Hanley and Barbier, 2009).

In hedonic pricing, researchers decide on the environmental characteristic of interest and collect information on the sale price of individual properties in an area where the environmental characteristic can be found. The researchers must control for all of the other

characteristics of the property, so must also collect as much relevant information about the properties as is available. These other characteristics typically include house age, type, size, parking, and rooms as well as proximity to public transport and amenities, and neighbourhood characteristics (Perman et al., 1999). With this and the property sale price, a hedonic price function for the environmental characteristic can be estimated (Hanley and Barbier, 2009).

Hedonic pricing relies upon the property market to be at equilibrium, with sales occurring at the same rate as new properties being listed (Perman et al., 1999). Researchers must also be aware of differences between geographical locations affecting prices or market segmentation (Hanley and Barbier, 2009; Perman et al., 1999). Similarly, omitted variable bias can occur when characteristics the researchers did not include in the price function play a larger role than anticipated. Some property characteristics may be related in some ways, leading to issues of multicollinearity or autocorrelation which can distort estimated values (Hanley and Barbier, 2009).

Much like the travel-cost method, because hedonic pricing is reliant on the use of property market values to determine non-market values, the method is restricted in the types of environmental resources and services it can measure and is limited to measuring only use values (Hanley and Barbier, 2009).

A1.4 Stated preference methods

Stated preference methods rely on researchers asking individuals, in surveys or interviews, about their willingness to pay for or their willingness to make trade-offs for public goods, services, and resources (Hanley and Barbier, 2009). While revealed-preference methods, due to being reliant on market values, are limited to measuring 'use values', stated preferences are able to capture both 'use values' and 'non-use values'. Stated-preference methods utilize questionnaire-based techniques to elicit valuations from individuals either directly or indirectly.

This section describes the two primary stated-preference methods used in the studies listed in the Value Tool Database, contingent valuation and choice modelling. The theoretical basis is provided for each method as well as a summary of how the techniques are applied. As with the revealed-preference methods described previously, limitations, technical problems, and noted biases are also presented for the two methods.

A1.4.1 Contingent valuation

Contingent valuation uses surveys to determine how much individuals value improvements in a public resource (Hanley and Barbier, 2009; Perman et al., 1999). This can be done in a number of ways. One way is to directly ask how much someone is willing to pay for a specific public good. Alternatively, the individual could be asked how much he or she would be willing to accept, for example, for environmental degradation – how much they would need to be paid to be willing to put up with the environmental degradation (Hanley and Barbier, 2009). Contingent valuation is the most widespread of all non-market value techniques, but is also the most questioned for the reliability of its values (Hanley and Barbier, 2009).

Researchers performing contingent valuation begin with creating the survey instrument. The survey typically presents a hypothetical scenario regarding the public resource of interest and the potential improvement or degradation of that resource. In drafting the survey, the researchers must decide whether to ask individuals about their willingness to pay (WTP) or

willingness to accept (WTA) and frame the questions accordingly. An individual's WTP or WTA represents the benefit the person receives from an improvement or their loss of benefit from a degradation. The survey is also used to collect information about the respondent that may influence their attitudes toward the target resource, such as: income, age, gender, membership in environmental organizations, and other demographic information (Perman et al., 1999).

An alternative version of contingent valuation asks respondents a 'yes' or 'no' question to see if they would be willing to pay *at least* a certain amount. This can also be bounded by then asking the individual a second question to see if they would be willing to pay a *higher* amount than in the first question (Bateman et al., 2002; Hanley and Barbier, 2009). This is considered more reliable than asking open-ended questions about WTP or WTA.

Whichever approach is used, a statistical model is used to convert the collected data into estimates of WTP or WTA. These values, if provided by a representative sample of the population, can then be aggregated to provide an overall value for a public resource, accounting for both use and non-use values. As WTP is constrained by an individual's wealth, this influences respondents' WTP estimates. Respondents with more wealth may provide WTP values that are higher than respondents with less wealth. WTA, conversely, is not bounded by respondents' wealth and so values may be extremely high. Researchers should calibrate WTP and WTA values and validate them against other studies and benchmarks (Hanley and Barbier, 2009; Perman et al., 1999).

As noted previously, because contingent valuation is based on a respondent's attitudes about a hypothetical situation, the respondent does not typically pay or receive any money associated with the survey. As such, the survey may be seen as being non-consequential to the respondent and the realism of the values they provide can be debated (Bateman et al., 2002; Hanley and Barbier, 2009).

Surveys must also be carefully crafted to avoid biases introduced by anchoring responses to a suggested value, the sequencing of questions or values, the scaling of values, and the provision of information (Bateman et al., 2002; Hanley and Barbier, 2009; Perman et al., 1999). The proposed method of payment, whether it is voluntary (as a purchase or contribution) or involuntary (framed as a tax or imposed fee) can also affect respondents' responses (Hanley and Barbier, 2009). A variety of methods have been developed to minimize and counter these and other biases (Bateman et al., 2002; Hanley and Barbier, 2009).

A1.4.2 Choice modelling

Choice modelling uses a survey-based valuation technique in which monetary values are implicit within the choices provided to a respondent (Bateman et al., 2002; Perman et al., 1999). Choice modelling, or a discrete choice experiment as it is also known, provides individuals with sets of discrete alternatives and the respondent is instructed to identify their most-preferred alternative (Perman et al., 1999). Like hedonic pricing and the travel-cost method, choice modelling is based on the theory that the value of a public resource can be best explained in terms of the characteristics or attributes of that resource. As such, the value can be broken into the value of the specific attributes (Hanley and Barbier, 2009).

The alternative options presented to respondents in a choice-modelling survey are made up of a set of attributes (e.g. an environmental outcome, a health outcome, and a cost). In each choice question, respondents are asked to choose between several scenarios that have

different discrete levels of the attributes, usually with one attribute being the cost of that scenario. From a data set with the results of many such choices, a statistical model is used to estimate the trade-off relationships between the various attributes – how much of attribute A are people willing to give up to get more of attribute B, on average. Because one of the attributes is cost, the approach allows for the calculation of monetary values as attribute levels change (Perman et al., 1999).

Choice modelling begins with researchers identifying (a) the representative sample population to survey and (b) the main attributes of the resource to be studied. The researchers develop the survey, laying out the attributes, levels, and alternatives. Choice sets are compiled based on these combinations of attributes and levels and the surveys are distributed as questionnaires or given in interviews (Hanley and Barbier, 2009; Perman et al., 1999). A statistical model can then be used to calculate the average WTP for the public resource (Hanley and Barbier, 2009).

Like contingent valuation, choice modelling provides the ability to estimate both the use and non-use values of a resource, with the added benefit of being able to measure the value of differing levels and allowing those values to be used in different contexts (Perman et al., 1999). Choice modelling is not without its problems, however. Choice modelling suffers from some of the similar biases to contingent valuation, including the choices being ultimately non-consequential to the respondents (Bateman et al., 2002; Hanley and Barbier, 2009). Also, the cognitive effort required to complete a choice modelling survey is also greater than for contingent valuation. As such, researchers must be mindful that respondents that may simplify their decision-making to focus on a single attribute rather than making trade-offs between attributes (Perman et al., 1999). Similarly to hedonic pricing and the travel-cost method, choice modelling is dependent on the assumption that the value of a whole is equal to the sum of its parts (Bateman et al., 2002; Hanley and Barbier, 2009).

A1.5 Value of a Statistical Life

When assessing the costs and benefits of improvements to health and safety, it can be helpful to attach a monetary value to a statistical life (Perman et al., 1999). The life in question is a 'statistical life' because it relates to the probability of death, rather than a black-and-white decision about life and death (Abelson, 2008). The value of a statistical life (VSL) essentially measures the rate of substitution that people are willing to make between their wealth (or income) and the risk of dying (Cropper et al. 2011). For example, it is commonly observed that people are willing to take on relatively dangerous jobs if they are paid more than for safe jobs. This reveals the trade-off that they are willing to make between income and probability of death.

The calculation of a VSL is not a separate non-market valuation method in itself. Instead, a range of non-market techniques may be used to determine the VSL, including a form of hedonic pricing, the hedonic wage model, which analyses occupation, income, and other labour market data (Perman et al., 1999). Stated-preference methods can be used to directly estimate an individual's WTP to reduce their risk of death, which can be interpreted as a VSL. With large numbers of studies estimating VSL around the world associated with specific countries or causes of death, meta-analyses are frequently used to derive more general VSLs from these specific studies (Abelson, 2008). As with the other types of non-market values discussed here, VSLs are context-specific because they depend on culture, community attitudes, and economic prosperity.

As an alternative to valuing an entire statistical life, which is typically considered a young adult with 40 years of life ahead, in some situations researchers want to look at saving a single year or small number of years of life. This is often the case with studies looking at reducing the long-term health effects of smoke or injury (Abelson, 2008; Perman et al., 1999). With this in mind, researchers can take the VSL and using a set discount rate, determine the value of a statistical life year (VSLY). The value of a life year may also be described as a quality adjusted life year (QALY), which represents a year of perfect health (Abelson, 2008).

A1.6 Life satisfaction method

The life satisfaction approach uses non-market goods as explanatory variables along with income and other covariates as functions of life satisfaction. The coefficient for the non-market good can be estimated in terms of life satisfaction, which, when compared to income, provides an implicit value for the good in monetary terms (Frey et al., 2009). The life satisfaction method does not rely on the assumptions underpinning revealed preference methods, such as housing markets being in equilibrium for hedonic pricing, and does not ask individuals to directly value the non-market good. Evaluating respondents' life satisfaction is perceived to be less cognitively demanding than contingent valuation or choice modelling which require a respondent to have (at least some) specific knowledge about the good in question (Ambrey and Fleming, 2011).

The life satisfaction measures are obtained through self-reporting a life satisfaction value in panel surveys that also collect data on socio-economic and demographic characteristics. The life satisfaction variable is provided by the individual on a scale of 0 (totally dissatisfied with life) to 10 (totally satisfied with life). Variables for working hours, commute time, and personality traits are also measured in the survey and used to control for confounding effects. The non-market good to be valued and its characteristics are also surveyed on a rating scale from 1 (least liked) to 10 (most liked). This non-market good score can then be combined with the life satisfaction variables to derive the good's coefficient and estimate its non-market value (Ambrey and Fleming, 2011).

The life satisfaction method, however, does rely on the assumption that a respondent's life satisfaction is a proxy for their utility. Additionally, the life satisfaction approach requires respondents to reflect on their global evaluation on life, their stable inner state and their present life, and it must be comparable across a group of individuals (Ambrey and Fleming, 2011; Frey et al. 2009). The other major limitation of the life satisfaction model concerns income and evidence that individuals that are more satisfied with their lives earn more. This can bias the income coefficient downward (Ambrey and Fleming, 2011).

APPENDIX 2: UPDATING THE VALUE TOOL DATABASE – SEARCH PROTOCOL

This appendix outlines the process used to select relevant studies for inclusion in the Value Tool Database, and how to selectively update the database using this protocol.

A2.1 Selection process

For the review, we collated the relevant studies through a key word search in Web of Science and Google Scholar. The combinations of the key words used included:

willingness to pay, choice modelling, choice experiment, contingent valuation, preferences, non-market valuation and valuation, benefit transfer, hedonic price, travel cost

WITH

natural disaster, bushfire, wildfire, flood, flooding, earthquake, cyclone, storm surge, storm, severe weather, hurricane, tornedo, tsunami.

Studies that did not include monetary value estimates were then excluded.

Of the remaining studies, the following criteria were used to prioritising the selection of studies most relevant for inclusion in the database (with studies meeting the first criterion being the most relevant). These criteria were developed using guidance in the literature and consulting with experts in benefit transfer.

1. Values from an original Australian study, in the context of a natural hazard.
2. Values from a meta-analysis that includes Australian studies, in the context of a natural hazard.
3. Values from a meta-analysis that includes Australian studies, in a general context.
4. Values from an original Australian study, in a general context.
5. Values from an original developed country study, in the context of a natural hazard.
6. Values from a meta-analysis of developed country studies, in a general context.
7. Values from an original developed country study, in a general context.

A2.2 Search protocol for database updates

To update the Database, conduct a key word search in Web of Science, Scopus and Google Scholar using the key words 'willingness to pay', 'choice modelling', 'choice experiment', 'contingent valuation', 'preferences', 'non-market valuation', 'valuation' with each of 'flood', 'wildfire', 'bushfire', 'storm', 'earthquake', 'tsunami', 'heatwave', 'natural disaster' and 'natural hazard'.

A timeframe can be used to limit the search to locate only those studies that have been published since the last update of the Database.

For any new studies identified, the relevant information from the study should be recorded in the columns of the Database.

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