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Valuing Environmental Services Provided by Local Stormwater Management

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Abstract:
Decentralized stormwater management systems deliver a number of environmental services that go beyond the reduction of flood risk, which has been the focus of con-ventional stormwater systems. Not all of these services may be equally valued by the public, however. This paper estimates households' willingness to pay (WTP) for im-provements in water security, stream health, amenity values, as well as the reduction in flood risk and urban heat island effect. We use data from nearly 1,000 personal interviews with residential homeowners in Melbourne and Sydney, Australia. Our re-sults suggest that the WTP for the highest levels of all environmental services is A$409 per household per year. WTP is mainly driven by the residents' positive valuation for exemptions in water restrictions, improvements in local stream health, and decreased peak urban temperatures. We further conduct a benefit transfer analysis and find that the WTP is not significantly different between the study areas. Our findings provide additional support that decentralized stormwater management systems have large non-market benefits and that, under certain conditions, benefit values can be transferred to different locations.

Keywords: quasi-public goods, non-market goods, stated preference

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1 Introduction

Increasing urban population growth and limited public funds necessitate the efficient allocation of resources to public investments, including the management of stormwater. Compared to conventional, more centralized stormwater systems with a focus on flood reduction, decentralized stormwater management offers a suite of additional ancillary environmental benefits. As such, decentralized stormwater management has the potential to yield higher economic net benefits compared to centralized systems, despite the greater implementation and operating costs (CWSC, 2011). Many policymakers and practitioners advocate for decentralized stormwater management, also called green infrastructure or low-impact development, as the preferable way to cope with the host of problems associated with urban stormwater.

Such a normative judgment requires an analysis that tests whether society assigns a sufficiently high value to all the ancillary environmental benefits associated with decentralized systems. In practice, these values are estimated by identifying peoples' willingness to pay (WTP) for the environmental services associated with local stormwater management. Some studies have estimated WTP for improvements in the quality of surface water (Carson and Mitchell, 1993; Kukielka et al., 2008; Van Houtven et al., 2007) and the prevention of flooding (Bin and Polasky, 2004; Zhai et al., 2006, 2007) in the context of local stormwater management projects. Londoño Cadavid and Ando (2013) are the first to combine flood prevention and stream health benefits in a non-market valuation study and show for their sample of 131 households in Champaign-Urbana, Illinois, that individuals have positive WTP for reductions in basement flooding, as well as improved water quality and stream health.

Other benefits, including increased water security, have received comparatively little attention in the literature (Cooper et al., 2011). Still other potential non-market benefits, such as combating the urban heat island effect with increased vegetation, have not yet been quantified in the stormwater context, making a comprehensive benefit-cost analysis of decentralized projects difficult. In addition, it remains an open question whether the WTP values estimated for a stormwater project in one location can be transferred to a stormwater project in another location. The transferability of WTP values is particularly important in the context of spatially distributed stormwater management and the limited resources available to conduct new valuation studies.

The purpose of this paper is to address these two challenges. We design a discrete choice experiment that allows us to estimates the marginal willingness to pay (MWTP) for five key environmental services associated with decentralized stormwater technologies. The data collection takes place in the two largest metropolitan areas in Australia, to test if the valuations are consistent across different geographic locations. This is important given that many large cities need to decide whether to pursue green infrastructure for stormwater management and the primary study estimating nonmarket benefits of decentralized stormwater management was conducted in a town of less than 100,000 people (Londoño Cadavid and Ando, 2013).

The environmental services, or attributes, analyzed in this study were identified by an interdisciplinary group of experts and stakeholders affiliated with Australia's Cooperative Research Centre for Water Sensitive Cities (CRCWSC). In a multi-step process, the group determined five key attributes representing the main environmental benefits from stormwater harvesting: (1) Reduction in Water Restrictions, (2) Reduction in Flash Flooding, (3) Improvements in Stream Health, (4) Improvements in Recreational and Amenity Benefits, and (5) Cooler Summer Temperatures. The team also identified feasible levels of improvement for each attribute and the range of costs associated with these improvements.

We surveyed a randomized sample of almost 1,000 households in Melbourne and Sydney. Residents were personally interviewed to elicit their MWTP for each of the five attributes in the discrete choice experiment. The respondents' choices are analyzed using a mixed logit model, which makes it possible to identify the average respondent's preferences for individual attributes as well as the diversity of preferences across the sample population.

We find that respondents, on average, place a significant and positive value on the environmental benefits of local stormwater management. Across both Melbourne and Sydney, the mean WTP for a project delivering the maximum levels of environmental services across all attributes, which we call a "gold standard" project, is A$ 409 per year and household. However, there is wide range of potential WTP values with the 95% confidence interval for this mean value spanning from A$12 to A$806. The positive total WTP is mainly driven by the high and significant MWTP values for the Reduction in Water Restrictions (A$100), Improvements in Stream Health (A$122), and Cooler Summer Temperatures (A$40). These findings provide further support for previous results that identify a positive WTP for stream health (Londoño Cadavid and Ando, 2013) and water security (Cooper et al., 2011).

Since it is costly to develop original non-market valuation studies in every location considering decentralized stormwater projects, determining the validity of benefit transfer is desirable. Previous studies identified differences in attitudes between Sydneysiders and Melbournians (Forrest and Dunn, 2010), perhaps owing to the somewhat different immigration and assimilation patterns in these two cities (Edgar, 2014). Moreover, there are distinct climatic differences between the two cities. Therefore, one cannot *a priori* dismiss the possibility that the benefits of stormwater management are valued differently in Melbourne and Sydney. We test this hypothesis using a benefit transfer framework. Benefit transfer has been applied widely in the water literature and was the subject of a special *Water Resources Research* issue in 1992. We use contemporary benefit transfer tests (Poe et al., 2005) to compare the marginal WTP for each attribute in Melbourne and Sydney. We then test for differences in compensating surplus, defined as the improvements gained by some positive combination of the attributes relative to the status quo, using the method developed by Morrison et al. (2002). We find that benefit transfer tests work well; the marginal WTP and compensating surplus are not significantly different across the study sites.

This analysis makes three primary contributions to the literature. Firstly, we estimate WTP for additional environmental benefits associated with stormwater management. Secondly, we estimate the value of nonmarket benefits in two cities, which may have different values than existing studies conducted in areas with low population. Lastly, we implement benefit transfer techniques to evaluate the differences in WTP between distinct metropolitan areas. We test for the equality of marginal willingness to pay for changes in ecosystem services and the equality of compensating surplus measures to determine if the benefits of stormwater management can be transferred between two regions.

The paper is organized as follows: section 2 describes the design, the survey and the study area; section 3 introduces the data; section 4 describes the empirical framework; section 5 presents the results; section 6 concludes.

2 Survey and Study Area

2.1 Survey

Surveys were conducted in four councils in Australia. Warringah and Fairfield are located in the greater Sydney metropolitan region. Moonee Valley and Manningham are located in the greater Melbourne metropolitan region. The data were collected in two waves. In the first wave, from February 2, 2013 to October 7, 2013, a randomized sample of 981 householders were interviewed about their willingness to pay for the benefits from local water management. The second wave took place from November 26, 2014 to December 21, 2014, approximately one year after the conclusion of the first wave, resampling 318 of the wave 1 households and using an identical survey instrument. Households were asked about their preferences for increased water security, reduction in flash flooding, improvements to stream health, improvements to the recreational and amenity benefits of local green spaces and water ways, and reductions in the heat island effect. The values were elicited using a choice experiment also described in detail in Brent et al. (2014).

Both survey waves were carried out by a professional survey company. Personal interviews, instead of phone, mail, or internet surveys, were used to ensure that the necessary support could be provided if respondents found the information difficult to understand. The choice sets were presented using clear visual images and were programmed into iPads to provide the respondents with a user-friendly interface. Supplementary visual aids were also made available throughout the choice experiment so that respondents could easily remind themselves of how attributes and their levels were defined.

The survey comprises three sections: (1) A brief explanatory statement outlines the purpose of the survey (see Appendix, Figure A.1). (2) A discrete choice experiment elicits householders' WTP for the benefits associated with local water management. The experiment consists of two choice tasks. The first choice task is described below and evaluates the benefits associated with stormwater management. This is immediately followed by the second choice task, designed to elicit attitudes towards alternative sources of water. For this study, only the first choice task is relevant. (3) A demographic questionnaire collects data on socioeconomic characteristics and attitudes towards environmental goods and services.

The main objective of the survey is to provide input into the planning, scoping and the development of a range of water management projects by ascertaining the monetary value of the key benefits of stormwater harvesting. We do not specify a specific project (e.g. a rain garden) since the elicited values for specific attributes were aimed to help policymakers maximize the ancillary non-market benefits from different forms of green infrastructure. Not commonly priced in markets, these benefits are difficult to value using revealed preference methods and hence a discrete choice experiment is used to elicit householders' willingness to pay. Specifically, an unlabeled choice experimental design is used, where householders are asked to choose amongst three water management options. One option describes the status quo, while the remaining two describe water management projects that yield benefits to varying degrees and come at a cost to the household. This design encourages respondents to pay attention to the variation in benefit levels between the non-status quo alternatives instead of making a pro-project versus anti-project decision and is a common design choice in comparable settings (Rolfe and Bennett, 2009). Each respondent selected the preferred option in 10 different choice sets, where the water management alternatives presented varied across five attributes describing the key benefits from stormwater management as well as costs. Figure A.2 in the Appendix provides an example of such a choice set.

The selection and development of attributes and attribute levels in the discrete choice experiment occurred over a rigorous 18-month process of expert and stakeholder consultation through the Cooperative Research Centre for Water Sensitive Cities (CRCWSC). The CRCWSC holds regular meetings to facilitate the exchange and interaction between researchers and industry partners. During one of these meetings the participants were divided into small groups, each containing at least one representative of local councils, water authorities and providers, as well as researchers from various disciplines (engineering, hydrology, climate science, urban studies, economics, law, sociology, and political science). The groups were asked to compile a list of the 10 most important benefits of stormwater harvesting. These were subsequently discussed in a plenary forum and distilled into five choice attributes in addition to the cost attribute, namely: Reduction in Water Restrictions, Reduction in Flash Flooding, Improvements in Stream Health, Recreational and Amenity Benefits, and Cooler Summer Temperatures. We collaborated with CRCWSC researchers from the relevant disciplines in order to define appropriate attribute levels. For example, researchers in hydrology, engineering and climate science formed a task group to determine realistic levels of reduction in flash flooding, while the improvement levels to stream health were defined by a group of hydrologists, biologists and ecologists.

The attribute *Reductions in Water Restrictions* is designed to elicit preferences for greater water security and has three levels. The lowest level represents the status quo with the full range of restrictions to outdoor water use being applicable to the local area. Level 2 (Restrictions 3,4) provides exemptions from the more benign restrictions such as lawn watering only being permitted on specified days of the week, while level 3 (No Restrictions) means that households in the local area are exempt from all water restrictions.

The second attribute, *Reduction in Flash Flooding*, describes the frequency of local street level pluvial floods as these are a direct consequence of local water management. There is no change in the frequency of flash flooding under the status quo level, while level 2 (Flood half) is characterized by the number of flash floods over a five year period being halved and level 3 (Flood never) means that flash floods will be virtually non-existent in the neighbourhood.

Improvements in Stream Health relate to the ecological health of the local water way. Local water management can lead to improvements to the status quo of continued bank erosion, presence of litter, low biodiversity and high populations of nuisance species and achieve, as an intermediate level (Stream Medium), reductions in bank erosion with banks being free of litter, greater biodiversity and the return of some iconic species. Level 3 (Stream High) represents a healthy local stream characterized by a natural channel form and function, high species diversity and low populations of nuisance insects.

Local water management can result in greater *Recreational and Amenity Benefits* by improving the water quality in local water ways as well as irrigating public green areas. Under the status quo, local sports grounds, parks and street line vegetation are not watered and will appear brown or may die during dry summers. Also, the local water way is fit for paddling but not swimming. Level 2 involves irrigation to ensure that local parks and sports grounds are green all year round and that mature trees on residential streets are not lost during periods of drought. Under level 3, irrigation is complemented with greener streetscapes via the planting of additional trees as well as improvements to the water quality that result in local water ways being fit for paddling as well as swimming.

The fifth attribute, *Cooler Summer Temperatures*, recognizes the shading and evaporative cooling effects from artificial water bodies and green, inner-city vegetation that are supported via local water management projects. This attribute has two levels. No change in local summer temperatures describes the status quo (level 1), while level 2 (Temp -2) is characterized by hot summer days being 2 degrees C cooler.

As the benefits from stormwater harvesting are also weather dependent and therefore subject to variation, we allow for outcome risk affecting two of the five benefits - water restrictions and stream health. Outcome risk is described as the probability that the specified improvement relative to the status quo will occur. The probability of achievement ranges from 40% to 100%.

The *Cost* attribute is described as an annual increase to the water bill owing to the cost of the selected water management option. Specifically, the cost attribute is explained as follows: "These are the costs per household per year of providing the water management option. These costs would be added to your annual water bill." The levels of increases to the water bill were discussed with legal and policy experts and represent realistic upper bounds for an increase in the annual fixed water charge. They range from AUD$0 to AUD$30 and are also sufficiently high to cover the per household cost of the proposed water management projects. From a legal perspective, water charge increases are the most plausible payment mechanism that would be used to fund stormwater management projects at the communal level.

The survey concluded with a questionnaire about the participant's experience with the different attributes of the choice experiment, their exposure to natural hazards and attitudes towards water management. Demographic information in the form of the respondent's age, gender, education and income was also collected.

The survey was piloted with a group of 10 Manningham and Mooney Valley City Councils (VIC) employees, who were working in areas other than local water management and volunteered for the study. The pilot was attended by a trained social psychologist, who evaluated the information content, wording, length and cognitive demands of the survey instrument and provided recommendations. The revised survey was tested on 10 randomly selected homeowner residents in Warringah (NSW) before the final version was rolled out. The survey was fielded by professional enumerators who received in depth training about the objectives of the survey as well as the survey instrument prior to commencing field work.

2.2 Study Area

Both Melbourne and Sydney are large metropolitan areas, but each region has distinctive characteristics. Climatically, the two cities are measurably different. During the study period, Melbourne has a wider range of temperatures, higher average rains, and lower peak rains than Sydney. Melbourne experienced a monthly mean temperature ranging from 14.5 to 31.3 degrees C and totaled 19 to 150 mm of rain per month. Sydney's monthly mean temperature ranged from 17.5 to 29.3 degrees C and monthly precipitation totaled 6.4 to 206 mm of rain. Demographically, the cities may be different, too. Sydney and Melbourne are the two main immigrant receiving cities in Australia. The assimilation patterns differ somewhat with some immigrant groups being more concentrated in Sydney than in Melbourne (Edgar, 2014). This has been identified as a likely explanation for Sydneysiders' and Melbournians' differing attitudes, for example towards multi-culturalism (Forrest and Dunn, 2010).

In addition to standard demographic data, survey respondents were asked questions about environmental preferences and activities that are likely to affect the willingness to contribute to a water management project. These questions include whether individuals engage in nature activities (*Nature*), if they are currently facing watering restrictions (*Restrictions*), their concern for water quality (*Water Quality*), if they think a flash flood is likely or if they recently experienced a flood (*Flood*) and whether they are concerned about increasing summer temperatures (*Summer Heat*).

Table 1 displays the means and sample sizes of demographic and attitudinal variables for the populations in Melbourne and Sydney. The populations are not significantly different across income, age, values toward nature or experience with water restrictions. They are different in exposure to flood and exposure to summer heat. In both cases, the Melbourne populations has greater exposure. As a result, an F-test rejects joint equality of means across the two study locations. The differences in important attributes between Melbourne and Sydney motivates the benefit transfer analysis that we present below.

3 Methods

The analysis takes place in three steps. First we estimate an econometric model of preferences based on the respondents' selections in the choice experiment. Using the estimated parameters we then proceed in two subsequent steps: first we quantify the benefits at each study site in dollar terms. We then test whether the benefit transfer across the two sites. We quantify the benefits and conduct benefit transfer tests using two different methods: the marginal willingness to pay (MWTP) distributions for each of the attributes and the compensating surplus for a suite of attributes. We provide details for calculating the monetary values and conducting the benefit transfer tests below.

3.1 Econometric Model

In order to quantify the preferences for stormwater management we fit an econometric model to the respondents' choice data. We assume that the respondents select their preferred alternative in each choice set based on a random utility model (RUM), as seen in equation 1.

$$U_{ijt} = V_{ijt} + \epsilon_{ijt} \tag{1}$$

The respondent's utility, U_{ijt}, is decomposed into a deterministic component, V_{ijt}, and an unobserved, or random component ϵ_{ijt}. In our setting V_{ijt} is comprised of the attributes present in each alternative stormwater management project. In this framework, respondent i chooses alternative j in choice t if that is the option that yields the highest level of utility.

The probability of this choice occurring is displayed in equation 2.

$$\begin{aligned}\pi_{ijt} &= Pr(Y_{it} = j) = Pr(U_{ijt} > U_{iht}) : \forall : h \neq j \\ &= Pr(V_{ijt} + \epsilon_{ijt} > V_{iht} + \epsilon_{iht}) : \forall : h \neq j\end{aligned} \tag{2}$$

We model ϵ_{ijt} as a type I extreme value distribution leading to the logit specification shown in equation 3.

$$Pr(Y_{it} = j) = \frac{\exp(V_{ijt})}{\sum_{h \in J} \exp(V_{iht})} \tag{3}$$

In our setting, the respondents select one of three alternatives from each choice set, requiring a model that accommodates multiple categories. Based on the results of a Hausman test (Hausman and McFadden, 1984) we reject the independence of irrelevant alternatives assumption that restrict substitution patterns. Therefore we eliminate the standard multinomial logit as a valid econometric model, and use the mixed logit (MXL), which McFadden and Train (2000) show can accommodate any set of substitution patterns, as our preferred specification. Additionally, the MXL model is popular in the applied literature estimating WTP from discrete choice experiments; see among others Revelt and Train (1998); Greene and Hensher (2003); Greene et al. (2006); Balcombe et al. (2011); Londoño Cadavid and Ando (2013). The MXL allows for individual level heterogeneity by estimating a distribution of parameters as opposed to a fixed coefficient, and the probability that respondent i selects alternative j for choice t is

$$P_{ijt} = \int \frac{\exp(X'_{ijt}\beta)}{\sum_{h \in J} \exp(X'_{ijt}\beta)} f(\beta|\theta) d\beta. \tag{4}$$

The choice probabilities of the MXL model therefore are weighted averages of the observable component of utility. The weights are determined by the density $f(\beta|\theta)$, where θ are the distributional statistics such as the mean and variance that are estimated from the data. There is no closed form for the parameters in the model and therefore the estimates are approximated through numerical simulation (Train, 2009). We model all attributes as normally distributed random parameters with the exception of cost which is distributed lognormally.

3.2 Benefit Transfer Tests

Given the climatic and, in some cases, attitudinal differences between Sydney and Melbourne, we conduct two benefit transfer tests to assess whether the values elicited in the two cities are comparable. The first benefit transfer method tests for the equality of the MWTP for specific attributes of stormwater management using the complete combinatorial approach of Poe et al. (2005). The MWTP is calculated by dividing each of the attributes by the negative of the cost coefficient.

$$MWTP_i = -\frac{\beta_{attribute_i}}{\beta_{cost}} \tag{5}$$

We use the mean of the attributes ($\beta_{attribute_i}$) and the median of the cost coefficient to estimate the average MWTP. The median of the cost coefficient is preferred to the the mean because the mean of the lognormal distribution is a function of the standard deviation, which can inflate the denominator in the MWTP equation. Since MWTP is a nonlinear combination of attributes we estimate the confidence intervals using Krinsky-Robb (KR) parametric bootstrapping (Krinsky and Robb, 1986) with 1,000 draws.

Poe et al. (2005) develop a statistical test to assess if the MWTP for attributes varies systematically across sites by utilizing the individual draws from the KR bootstrapping method. The complete combinatorial test replicates the first draw for Melbourne 1,000 times and subtracts each of the 1,000 draws from Sydney. We then repeat this procedure for each of the 1,000 draws for Melbourne, resulting in $1,000 \times 1,000$ calculated differences. The proportion of the differences less than zero has the interpretation of the p-value for a one-sided test.

The next benefit transfer test determines whether the compensating surplus is equal across the two study sites. Compensating surplus is the dollar value of the benefits from a hypothetical project, defined as some combination of the attributes, relative to the status quo. For example, a hypothetical project could improve stream health to a medium level, provide recreation amenities, and lower summer temperature, but not reduce the risk of flooding or remove any water restrictions.

We use a benefit transfer method developed by Morrison et al. (2002) that tests whether differences in compensating surplus (CS) between Melbourne and Sydney are statistically significant. Our choice set has five attributes; three of the attributes have three levels and two have two levels, resulting in $3^3 \times 2^2$ (108) possible combinations of attribute levels. We select a one-ninth subset (12) of the full set of possible combinations to conduct benefit transfer tests following Morrison et al. (2002) and Interis and Petrolia (2016). Selecting a random subset of combinations reduces the chance that the hypothesis tests depend on the selected combination of attributes.

4 Results

The results from the MXL regression for the pooled sample can be found in column (1) of Table 2. The level of each attribute is modeled as a dummy variable equal to one if that attribute-level is present for a given alternative within a choice set. The coefficients presented are the means of the randomly distributed parameters. The standard deviations are suppressed to save space, and are available upon request. Standard errors clustered at the respondent level are presented below the coefficients in parentheses. The coefficients represent the impact of that variable on the respondent's utility so respondents prefer attributes with positive coefficients. We pool recreation medium and recreation high into one attribute in the econometric model.

The negative and significant coefficient on the status quo variable shows that respondents prefer a water management project to the status quo, all else being equal. The respondents do not value all the attributes of stormwater management equally. Based on the full sample, respondent have statistically significant positive preferences for the removal of water restrictions, improved stream health, and cooler temperatures. However, preferences for flood protection and improved recreation are not statistically significant. Based on the parameters in the choice model the preferences appear stable across Melbourne and Sydney. Although the coefficients between the two models are not directly comparable due to the scale term, most of the coefficients that are statistically significant in Melbourne are also significant in Sydney. The relative ranking of the attributes is similar for Melbourne and Sydney.

In order to contextualize the parameters from the choice model, we quantify the benefits of decentralized stormwater management in dollar terms. We generate two relevant values: the MWTP for the individual attributes, and the compensating surplus from implementing a hypothetical project defined by a combination of attributes. In order to gauge the stability of preferences for stormwater management across urban areas in a way that is robust to issues of scale, we conduct two formal benefit transfer tests based on each of these metrics as described above.

4.1 Marginal Willingness to Pay

Table 3 shows the estimates of the MWTP as shown by equation 5. The MWTP represents the annual value per household of the specific benefits from stormwater management. The first and second columns show the mean MWTP for Melbourne and Sydney respectively with the 95% confidence intervals using the KR method shown in parentheses. There is a statistically significant MWTP for eliminating exposure to water restrictions (A$218 in Melbourne and A$118 in Sydney), maximally improved stream health (A$278 and A$104), and reduced peak summer temperatures in Sydney (A$47). On average, Melbourne and Sydney residents are not willing to incur increases in their water bills for the improved protection from street-level flooding or improvements to recreational amenities. This could indicate that they are satisfied with the current levels of service. Alternatively, they may not agree that improvements to these services should be funded through increases in their water bill. It is important to note that there is a large degree of heterogeneity in preferences for the attributes and cost, as evidenced by large and significant standard deviations in the random parameters. Additionally, the sampling variation generates relatively large confidence intervals for MTWP. In general the attributes with statistically significant MWTP in Melbourne are also significant in Sydney and vice versa.

The mean difference in MWTP between Melbourne and Sydney is presented in the third column of Table 3, and the p-value from the complete combinatorial benefit transfer test is presented in the fourth column. None of the differences between Melbourne and Sydney are statistically significant. Therefore, we conclude that the MWTP for specific benefits of stormwater management are consistent across Melbourne and Sydney. Since the benefits transfer between the two sites, we also calculate the MWTP based on the pooled sample. Using the pooled sample allows us to use all the data, thus improving the precision of the estimates. The pooled MWTP, shown in the last column of Table 3, represents our preferred estimates for the value of specific benefits of stormwater estimates. In general the pooled MWTP values are lower than the MWTP for Melbourne and higher than Sydney.

4.2 Compensating Surplus

Next we present the CS, which quantifies the benefits from a combination of the attributes relative to the status quo. Table 4 displays the mean CS for Melbourne and Sydney as well as the difference and p-value for the hypothesis test that the difference is equal to zero. On average the CS is higher in Melbourne than in Sydney, however, this difference is not statistically significant in any of the hypothetical projects or averaged across all selected projects. The lack of a statistically significant difference between Melbourne and Sydney is in part due to the sampling variation in the estimates of CS. The average CS for Melbourne is not statistically significant (p=0.12), whereas Sydney is significant at the 10% level (p=0.06). The sampling variation is one potential reason for why we see relatively large differences but no rejections of the benefit transfer tests. The last column in Table 4 shows the CS for the pooled model, with an average value of approximately A$270 per household per year.

5 Conclusion

Using a discrete choice experiment this study estimates the monetary values for non-market benefits associated with stormwater management. We conducted nearly 1,000 personal interviews with homeowners in Melbourne and Sydney, Australia to elicit MWTP for Reduction in Water Restrictions, Reduction in Flash Flooding, Improvements in Stream Health, Improvements in Recreational and Amenity Benefits, and Cooler Summer Temperatures. Respondents significantly value three of these attributes: Reduction in Water Restrictions, Improvements in Stream Health, and Cooler Summer Temperatures. We do not find statistically significant positive MWTP for Reduction in Flash Flooding or Improvements in Recreational and Amenity Benefits. All of the findings relate to the value of additional environmental services, given the services already provided. These results do not suggest that residents in established suburbs do not value flood protection. It may mean that they are satisfied with the current level of flood protection or that they do not agree with mitigating flood risk by increasing water bills.

We then compare WTP estimates between the Melbourne and Sydney to evaluate the potential of benefit transfer. Benefit transfer tests indicate that findings are not significantly different between the study areas. This indicates that nonmarket benefits of decentralized stormwater management can successfully be transfered across cities that exhibit differences within the range existing between Melbourne and Sydney. We also quantify the overall value for a project that provides a set of environmental services. The "gold standard" is a project that implements the highest level of environmental services across all attributes. We find that households are willing to pay A$409 per household per year for a "gold standard" project, with the 95% confidence interval ranging from A$12 to A$806 per household per year. Though this interval is large, results reveal that people value the environmental services associated with local stormwater management.

If all of the approximately 1.5 million households in Melbourne and Sydney were delivered "gold standard" level local stormwater management projects, there is potential to generate

A$613 million per city per year in benefits. This dollar value is conditional on current levels of service. Over time, implementing more stormwater projects would improve the status quo and subsequently reduce the benefit from additional projects, resulting in lower WTP estimates.

Though these benefits may initially seem high, they are roughly consistent with other expressed values for water benefits. For example, the public-private partnership in a desalination facility costs Melbourne A$610 million per year (Melbourne Water, 2013). While currently not in use, the plant provides the benefit of water security.

Our results have important implications for urban stormwater policy: residents in established neighborhoods value increases in the ancillary environmental services of decentralized stormwater management systems, beyond the service of flood protection. Our results provide monetary values for these non-market environmental benefits that can be used in establishing a business case for the implementation of decentralized stormwater management systems.

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Table 1: Balance on Observables

	$Mean_M$	N_M	$Mean_S$	N_S	Difference	p-value
Low Income	0.25	450	0.25	456	0.01	0.848
Medium Income	0.64	450	0.65	456	-0.01	0.671
High Income	0.11	450	0.10	456	0.01	0.696
Age	54.23	485	54.73	494	-0.51	0.626
Nature	0.36	486	0.38	495	-0.02	0.523
Restrictions	0.24	647	0.21	334	0.03	0.2231
Flood	0.46	460	0.19	493	0.28	0.000
Summer Heat	0.70	483	0.36	490	0.34	0.000
Joint Significance						48.76

Notes: All variables except age are indicator variables and the means are sample proportions, and age is measured in years.

Table 2: Mixed Logit Regression Results by City

	(1) All	(2) Melbourne	(3) Sydney
Mean			
Status Quo	-1.4840***	-1.7404***	-1.2813***
	(0.0930)	(0.1286)	(0.1305)
Log Cost	-6.5806***	-6.8519***	-6.0499***
	(0.4379)	(0.4461)	(0.3493)
Flood half	0.0267	0.0377	-0.0074
	(0.0415)	(0.0560)	(0.0625)
Flood never	0.0578+	0.0639	0.0633
	(0.0442)	(0.0629)	(0.0620)
Restrictions 3,4	0.0875*	0.0753	0.1107*
	(0.0451)	(0.0616)	(0.0670)
No Restrictions	0.2008***	0.1806***	0.2423***
	(0.0421)	(0.0581)	(0.0598)
Stream Medium	0.1084**	0.0863	0.1132+
	(0.0520)	(0.0731)	(0.0721)
Stream High	0.2214***	0.2192***	0.2107***
	(0.0470)	(0.0669)	(0.0640)
Recreation	0.0140	0.0168	-0.0110
	(0.0412)	(0.0589)	(0.0586)
Temp -2	0.0735***	0.0596+	0.0931**
	(0.0281)	(0.0385)	(0.0414)
BIC	22,755.24	11,424.09	11,398.16
AIC	22,613.33	11,295.34	11,269.43
Observations	12,954	6,480	6,474
Individuals	981	486	495

Notes: The coefficients presented are the mean of the random distributions, except for Status Quo which is modeled as a fixed coefficient. All attributes are normally distributed except Cost, which is lognormally distributed. Standard errors clustered at the respondent level are presented in parentheses. The columns designate different samples. *** p<0.01, ** p<0.05, * p<0.1, +p<0.2

Table 3: Marginal Willingness-to-Pay Values for Attributes

Attribute	Mean_M (95% CI)	Mean_S (95% CI)	Difference	p-value	Mean_P (95% CI)
Flood Half	50 (-113, 296)	0 (-66, 81)	50	.277	16 (-57, 172)
Flood Never	98 (-73, 420)	32 (-26, 129)	66	.335	41 (-29, 233)
Recreation	33 (-124, 289)	-2 (-56, 64)	35	.375	8 (-63, 142)
Stream High	278 (63, 1058)	104 (34, 266)	174	.138	122 (66, 750)
Stream Medium	119 (-65, 499)	58 (-10, 185)	61	.363	55 (1, 379)
Temp -2	81 (-24, 362)	47 (5, 143)	34	.386	40 (9, 263)
Water None	218 (43, 842)	118 (42, 315)	100	.247	110 (54, 739)
Water 3 & 4	102 (-60, 486)	56 (-10, 186)	46	.404	54 (-6, 353)

Notes: The first two columns presents the mean MWTP for Melbourne and Sydney respectively, with the 95% confidence created using the Krinsky-Robb method in parentheses. The third column shows the mean difference in the MWTP between Melbourne and Sydney, and the fourth shows the p-value from the full combinatorial benefit transfer test of Poe et al. (2005). The final column shows the MWTP for the pooled model, combining the data from Melbourne and Sydney.

Table 4: Compensating Surplus Values and Transfer Error

	Melbourne	Sydney	Difference	(p-value)	Pooled
Hypothetical Project 1	369	217	152	0.53	318
Hypothetical Project 2	511	254	257	0.41	409
Hypothetical Project 3	190	80	110	0.52	160
Hypothetical Project 4	486	224	262	0.36	387
Hypothetical Project 5	286	157	129	0.61	246
Hypothetical Project 6	179	79	101	0.54	145
Hypothetical Project 7	386	168	218	0.39	305
Hypothetical Project 8	411	198	213	0.45	327
Hypothetical Project 9	286	157	129	0.61	246
Hypothetical Project 10	204	87	117	0.55	171
Hypothetical Project 11	351	171	180	0.45	286
Hypothetical Project 12	284	112	172	0.40	211
Average Project	329	159	170	0.46	268

Notes: The compensating surplus is calculated based on the linear combination of attributes normalized by the median cost coefficient. The standard errors are calculated via the delta method. The p-value is for the hypothesis test that the mean compensating surplus for Melbourne minus the mean compensating surplus for Sydney is equal to zero. Hypothetical projects are determined by a one-ninth subset of all possible combinations of attributes. The pooled compensating surplus is calculated using the estimates for the full sample.

Appendix

Figure A.1:

Introduction Letter

MONASH University

CRC for Water Sensitive Cities

Your household has been randomly selected to take part in an **important study about water.**

The interviewer will assist you with completing the study. It will take approximately **25 minutes** to complete.

Participation is **voluntary and confidential**. Your details will not be stored with your responses and will not be passed on to any third party. You will not receive any phone calls or junk mail as a result of participating.

Details of study

Title of study

Analysis of how individuals make decisions with respect to water management in Australia.

Benefits of the study

The findings from this study will be used to help design **water management policies** in your community and Australia in general. You will also receive a monetary amount to thank you for participating, in addition to a certain amount being contributed to a water project in your local community.

What you will need to do

There are three short components to this study:

One and two: Activities to examine how important the various benefits associated with different ways of managing water are to you and your community.

Three: A short questionnaire.

Researchers:

This study is being conducted by I-view on behalf of Monash University researchers [redacted]

To find out more:

For more **information** on the study or to be informed of the findings after the project is complete, please contact [redacted] Monash University

☎ [redacted]

✉

If you have any **concerns** about how this study is conducted, please contact the **Executive Officer** at the Monash University Human Research Ethics Committee, quoting reference number: CF12/2511 – 2912001358:

☎03 9905 2025

✉ muhrec@monash.edu

An Australian Government Initiative

CRC AUSTRALIA

Figure A.2: Explanation Document

Explanation for Salient (without Risk) Group

ACTIVITY 1

Local water management initiatives can carry a number of benefits for residents. These benefits are improvements in five key attributes, which will be explained now. Note that the improvement in two attributes, water restrictions and stream health, can be subject to uncertainty due to climatic conditions. We have therefore included pie-charts (circles) that illustrate the likelihood of a successful improvement in these attributes. The implementation success of the remaining three attributes can be considered as certain.

[USE INSTRUCTIONS CHOICE SET 1 HERE AND EXPLAIN DIFFERENT ATTRIBUTE LEVELS]

We want to understand how important these different benefits are to you. You will now be asked to make a series of 10 choices between the current situation (Status Quo) and alternative options, which involve improvements in some or all of the attributes explained above.

Example: Here is an example of one choice set that you may see on the screen.

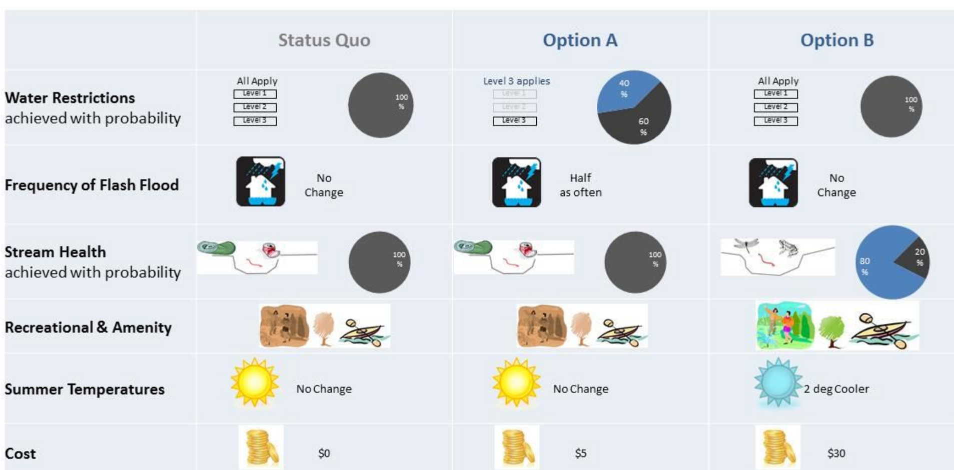
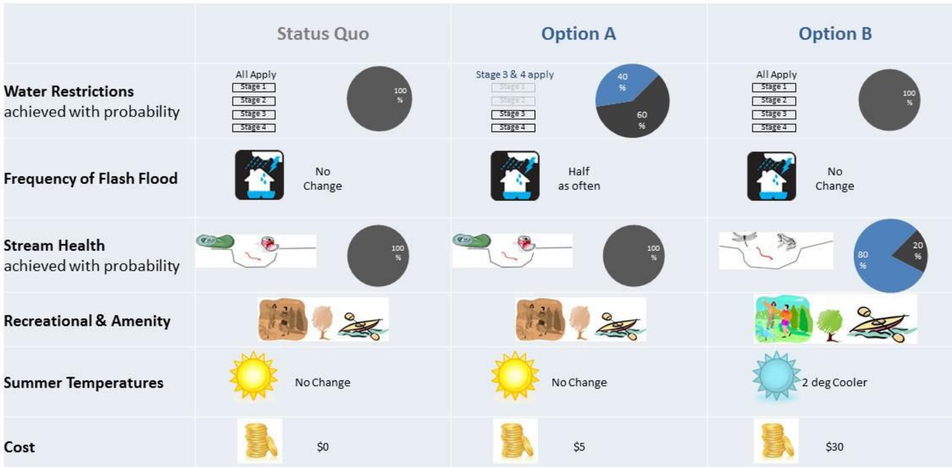


Figure A.2: Explanation Document (cont.)



- You can choose between the **Status Quo** option, **Option A** and **Option B** and you can only choose 1 option per choice set.
- The **Status Quo** option will mean:
  - No change in the current situation of water management in your council area.
  - The costs to you are zero.
- **Option A** offers **two** benefits compared with the **Status Quo**:
  - One: there is a 40% chance (as indicated by the blue area in the circle) your neighbourhood will be exempt from all future [Stage 1 and 2 [IF VIC], Level 1 and 2 [IF NSW]] water restrictions that are imposed. But, a 60% chance (as indicated by the grey area in the circle) remains that all water restrictions will apply as they do currently.
  - Two: the number of flash floods occurring in your neighbourhood will be reduced by half.
  - Choosing **Option A** would increase your annual water bill by $5. So, if this choice set were selected for payment today, $5 would be taken off your total interview earnings.
- **Option B** compared with the **Status Quo** this option
  - Carries no benefits in terms of improved water security or reduction in the frequency with which flash floods occur.
  - But, there is an 80% chance (as indicated by the blue area in the circle) that the condition of your local stream improves to medium health. A 20% chance (as indicated by the grey area in the circle) remains that there will be no improvement to local stream health compared with its current condition.
  - There are recreational and amenity benefits from keeping all local sportsgrounds and parks green and all local street trees watered during dry months.
  - Under **Option B** your local area would also be about 2 degrees Celsius cooler during the hot summer months.

Figure A.2: Explanation Document (cont.)

- **Option B** would add $30 to your annual water bill. If this choice set was randomly selected for payment today and you had chosen **Option B**, $30 would be deducted from your interview earnings.

- Which Option would you choose? The **Status Quo**, **Option A** or **Option B?**

Your choices in this activity will help decision making on how water is managed within the community and Australia in general.

PLEASE TAKE IN TO CONSIDERATION THAT THERE ARE NO CORRECT OR WRONG DECISIONS. THESE DECISION PROBLEMS ARE NOT DESIGNED TO TEST YOU.

However, we are interested in your truthful answer about your value for these different benefits. Therefore, you should make your decisions knowing that one of the 10 choice sets will be randomly drawn by you and your final payment from this survey will be your earnings so far minus the cost of the option you have selected. Your final pay-out will always be positive but can range between $0.60 and $53.10. The full amount of money subtracted from your earnings will be donated by CRC and Monash University towards [INSERT COUNCIL WATER PROJECT], which is a project in your local area. The total amount collected from all participants will be published in [INSERT LOCAL PUBLICATION AND ISSUE DATE].

After you have completed all activities in this survey, the interviewer will ask you to randomly draw a number between **1 and 10**. This number will indicate which choice set is selected for payment and the cost of your chosen option will be deducted from your interview earnings and be put towards [INSERT COUNCIL WATER PROJECT].

In this example, **your final earnings** would have been equal to the following:

If you had chosen the Status Quo:

Your final earnings: = initial payment– $0.

If you had chosen Option A:

Your final earnings: = initial payment– $5.

If you had chosen Option B:

Your final earnings: = initial payment– $30.

Do you have any questions?