DOES WATER SENSITIVE DESIGN DELIVER BENEFICIAL NET ECONOMIC OUTCOMES?

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ABSTRACT (300 WORDS MAXIMUM)

Councils across New Zealand face a number of significant stormwater problems arising from the growth, development and redevelopment of urban centres. Water sensitive design (WSD) has been offered up as a solution to addressing the effects of stormwater discharges. There has been much research undertaken to document the environmental protection and social benefits of WSD. However, a key impediment to its implementation is the perception that WSD costs more than conventional stormwater management approaches in both implementation and operation. Previous papers by the authors have described the life cycle costing model used to estimate costs associated with different urban development scenarios within a decision support system (DSS) called "Urban Planning that Sustains Waterbodies" (UPSW). UPSW is a catchment-scale spatial tool that discriminates between catchment development scenarios in terms of their impacts on receiving waterbodies. The outcomes of each scenario are portrayed through a set of indicators that reflect their influence on the environmental, social, economic, and cultural wellbeings associated with the receiving waterbodies. Economic wellbeing is understood in terms of scenario stormwater implementation and management costs, the ensuing economic benefits (losses) associated with receiving waterbody condition that arise from stormwater management measures, and amenity benefits created by WSD technology. Valuation of the benefits / losses that eventuate is derived from non-market valuation studies and spatial econometric analysis of house price data. This paper describes refinements made to the life cycle costing model that allow users to compare the costs and benefits of conventional and WSD stormwater management for future catchment development scenarios. In this way users can determine whether beneficial net economic outcomes can be obtained from WSD stormwater management. The refinements integrate 'real world' costing data with findings from an international literature review which investigated cost comparisons between WSD and conventional stormwater management.

KEYWORDS

Water sensitive design, life cycle costing, economic outcomes, spatial decision support system

PRESENTER PROFILE

Sue Ira is the Director of Koru Environmental Consultants Limited. She is an environmental scientist with a number of years' experience working in stormwater management. Sue has extensive experience in catchment management planning, peer review and stakeholder consultation. She was the primary developer of the $COST_{NZ}$ Model and has developed a catchment-scale stormwater LCC model for NIWA and the Cawthron Institute.

1 INTRODUCTION

Councils across New Zealand face a number of significant stormwater problems arising from the growth, development and redevelopment of urban centres. Water sensitive design (WSD) has been offered up as a solution to addressing the effects of stormwater discharges. There has been much research undertaken to document the environmental protection and social benefits of WSD. However, a key impediment to its implementation is the perception that WSD costs more than conventional stormwater management approaches in both implementation and operation.

Since 2009, a Ministry for Science and Innovation funded research programme entitled Urban Planning that Sustains Waterbodies (UPSW) has been underway. The purpose of the UPSW programme has been previously described by Moores et al., 2014. In short, it has led to the development of a catchment-scale spatial decision-support system (DSS) which aids the evaluation of the effects of urban development on freshwater and estuarine urban waterbodies in terms of four wellbeings: environmental, cultural, social and economic. The DSS model discriminates between catchment development scenarios in terms of their impacts on receiving waterbodies. The outcomes of each scenario are portrayed through a set of indicators that reflect their influence on the environmental, social, economic, and cultural wellbeings associated with the receiving waterbodies. Economic wellbeing is understood in terms of scenario stormwater implementation and management costs, and the ensuing economic benefits (losses) associated with waterbody condition that arise from stormwater management measures. Valuation of the benefits / losses that eventuate is derived from non-market valuation studies.

Previous papers by the authors have described the life cycle costing model used to estimate costs associated with different urban development scenarios the DSS (UPSW) (Ira et al., 2012a and Ira et al., 2012b). The purpose of this paper is to describe refinements made to the life cycle costing model that allow users to compare the costs and benefits of conventional and WSD stormwater management for future catchment development scenarios. In this way users can determine whether beneficial net economic outcomes can be obtained from WSD stormwater management. The refinements integrate 'real world' costing data with findings from an international literature review which investigated cost comparisons between WSD and conventional stormwater management.

2 METHODS

For the pilot DSS, the authors developed a life cycle costing module to assist with quantifying costs of water quality treatment, water quantity attenuation and riparian management (Ira, 2011, Ira et al., 2012a and 2012b). The second phase of the project was commissioned in order to more accurately quantify the costs associated with WSD. A two-pronged approach to refining the model was taken, namely:

1. An international literature review, which investigated cost comparisons between WSD and conventional developments, in order to determine if cost savings can be obtained from WSD developments, was undertaken.
2. Further modelling, using COSTnz, was undertaken in order to develop the updated LCC module for the DSS.

2.1 LITERATURE REVIEW

An international literature review of comparative case studies was undertaken in an attempt to quantify the cost differential between WSD and conventional developments. Approximately 41 reports/ papers were sourced and reviewed (Ira, 2014).

2.2 LCC MODELLING

In order to more accurately quantify the costs associated with WSD, a number of refinements were undertaken to the existing LCC models within the DSS. These included:

i. The sand filter model runs were removed from the "at source" device options.

ii. The rain garden costs were updated based on work undertaken by Auckland Council for the Unitary Plan (Kettle and Kumar, 2013). It is noted that the report mainly used COSTnz data for swales and infiltration trenches, so these costs were not updated.

iii. The "at source" and "combination" (i.e. scenarios using both "at source" and "end of pipe" treatment) modelling scenarios were re-run.

iv. A sensitivity analysis of the new scenarios and options was undertaken in order to inform which scenarios should be used in the UPSW DSS. This analysis included a comparison of the results with the differences between traditional and WSUD costs as determined through the literature review.

v. Costing work related to adaptability of stormwater devices (with respect to long term resilience of infrastructure) was investigated in order to see if a cost 'factor' could be included in the DSS for the different devices.

2.2.1 UPDATED MODELLING ASSUMPTIONS

2.2.1.1 LIFE CYCLE COSTING ASSUMPTIONS

No changes were made to the life cycle costing assumptions used in the original model runs. A summary of the original costing and discounting assumptions used within the COSTnz models are as follows (see Ira et al., 2012a for further detail and explanations around these assumptions):

- COSTnz provides a low, mean and high estimate of costs. For all scenarios the low value was used.

- The base year for the COSTnz model is 2007. As a result, all costs were inflated to a base year of 2011 using a 2.8% inflation rate.

- A life cycle analysis period and life span of 50 years was used for all scenarios.

- A discount rate of 3.5% was used.

2.2.1.2 TOTAL ACQUISITION COSTS (TAC)

Only the TAC for rain gardens was updated. The formula which was used for TAC was taken from the Auckland Council Unitary Plan Costing Report (Kettle and Kumar, 2013) and is:

$$\textit{Low Cost} = \$2000 + \$300/m^2 \textit{ rain garden area} \quad (1)$$

In order to ensure consistency with the original modelling, the "low cost" formula from the Unitary Plan Costing Report was used (Kettle and Kumar, 2013). It is noted that, with respect to larger rain gardens, the Unitary Plan Costing Report (Kettle and Kumar, 2013) states that costs from COSTnz were reasonably comparable to their data. TAC costs for rain gardens have therefore been determined using this statistical relationship rather than the unit costing approach used previously. The models have been updated on this basis.

2.2.1.3 MAINTENANCE COSTS

Through a sensitivity analysis and iterative process it was discovered that the routine maintenance and corrective maintenance costs used within the Auckland Council Unitary Plan Costing Report (Kettle and Kumar, 2013) lead to higher maintenance costs for the medium and large rain gardens than what was modelled using COSTnz. As a result, the original COSTnz maintenance cost data was used in the updated models.

3 RESULTS

3.1.1 LITERATURE REVIEW

An international literature review was undertaken to ascertain whether or not it is possible to quantify the cost differential between WSD and conventional developments. The majority of available cost information from actual case studies related to design and construction costs (i.e. TAC), and actual long term maintenance costing of WSD devices was generally not available. Table 1 provides a general overview of the cost differential from 4 countries comprising 53 case studies. According to research undertaken by the USEPA, and based on 3 case studies, total life cycle costs of WSD are on average 24% cheaper than conventional developments (Jaffe, et al, 2010). However, when examining the case studies more closely, it is clear that there is a difference between the northern hemisphere studies and those undertaken in Australia and New Zealand. The Australasian case studies tend to indicate increased costs associated with WSD, namely:

- TAC of WSD incur 16.9% increased costs,

- MC of WSD incur 26.8% increased costs (another study found them to be 7 – 15x greater than traditional costs), and

- Life cycle costs incur 33.2% increased costs.

This difference could be due to a number of different reasons, one of which is economies of scale. On-site stormwater management is relatively new in New Zealand, and it is anticipated that as the use of WSD becomes more common, the market will mature, and innovation and competition may reduce pricing. However, it is difficult to quantify exactly how directly comparable the different case studies are with New Zealand's approach to WSD. In many of the UK and USA studies, the purpose for implementing WSD relates to the reduction of combined sewer overflows. Comparison of WSD with the costs of wastewater infrastructure (as opposed to stormwater infrastructure) may therefore not be relevant in this case. It is also noted that in many studies, landscaping and on-going landscaping maintenance costs were assumed to be the same for both conventional and WSD subdivision (i.e. costs relating to landscaping a flowerbed are the same as for landscaping a rain garden). Finally, many of the case studies in the UK and USA assumed that no piped network was necessary if permeable paving or infiltration practices are used. With some of New Zealand's clay soils and steep slopes, this may not always be a viable scenario. It is noted that in New Zealand's most detailed WSD case study (Long Bay), a 12% increase in TAC, on a per lot basis, was predicted for the WSD scenario (Auckland Council WSD Case Studies - Long Bay Structure Plan, Auckland. Accessed at http://www.acwsd.org/ on 8 October 2013).

Table 1 Summary of cost differentials from international and national literature

Case Study Locality	WSUD Type	Objectives for WSD	Percentage Difference (Ave)	Cost Type
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-55.5%	LCC
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-27.7%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	-13.5%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	7 - 15x greater	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-9.6%	TAC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-26.8%	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-11.0%	LCC
United Kingdom	Open storage	Reduce WW overflows	15.0%	TAC
United Kingdom	Open storage	Reduce WW overflows	-23.0%	MC
USA	Rain gardens, swales, porous paving, wetlands	Treatment, attenuation, reducing WW overflows	23.0%	TAC
USA	Rain gardens, bush trees, swales, green roof, wetlands	Treatment, attenuation, reducing WW overflows	24.0%	LCC
INTERNATIONAL AVERAGE*			**-2.6%**	**TAC**
INTERNATIONAL AVERAGE*			**-24.9%**	**MC**
INTERNATIONAL AVERAGE*			**-15.7%**	**LCC**

*Average derived from 53 case studies across 4 countries

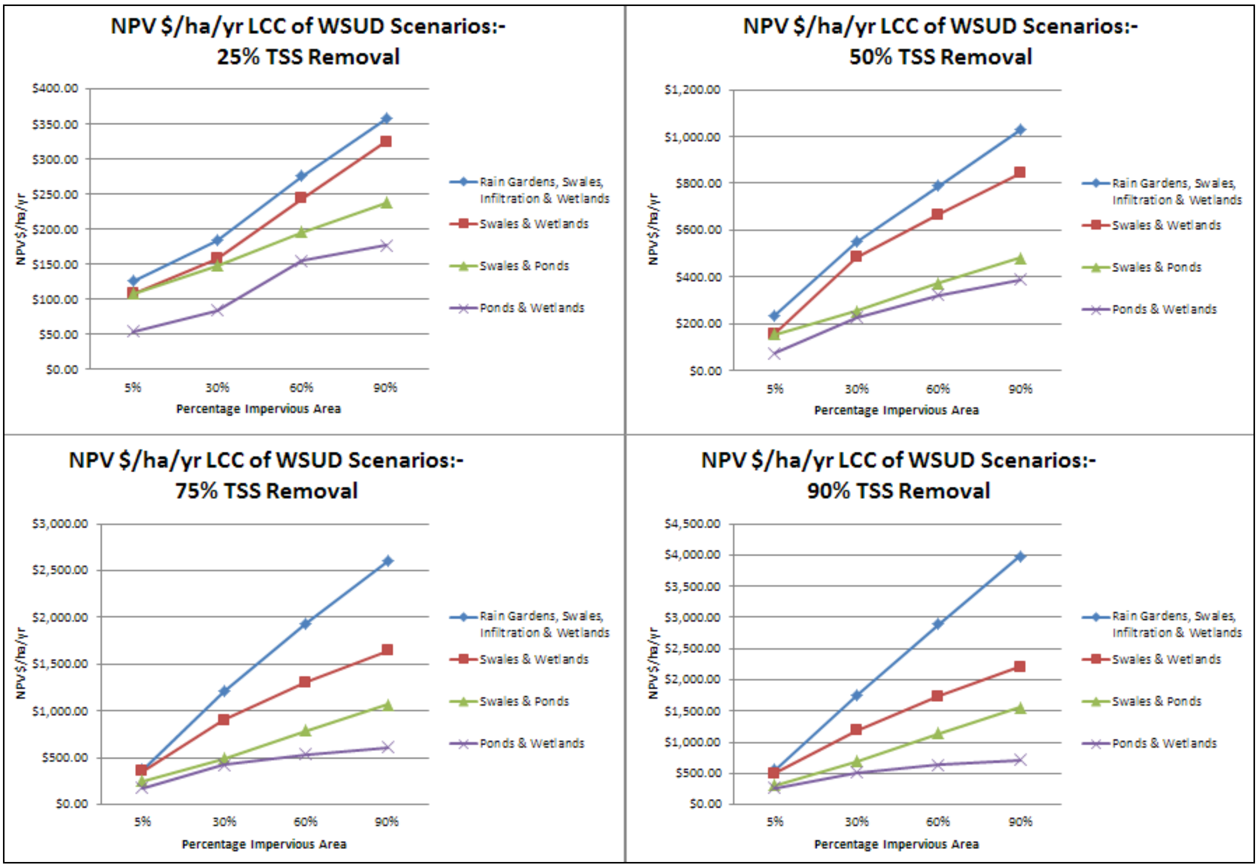
3.1.2 UPDATED DSS COSTING MODEL RESULTS

The results from the updated DSS costing model results are shown in

Figure *1*. The graphs are provided for net present value (NPV) dollar per hectare per year ($/ha/yr) for the different treatment scenarios, treatment levels and percentage impervious areas.

The graphs clearly highlight that a combination of at source treatment (rain gardens, swales, infiltration) along with wetlands is more expensive over a 50 year life cycle than end of pipe treatment devices such as ponds and wetlands.

Figure 1 NPV $/ha/yr costs over a 50 year life cycle for differing treatment and impervious levels for a range of stormwater management options



A number of WSD, "combination" and "end of pipe scenarios" were modelled and compared (7 in total), and Table 2 shows that, on average, WSD is 59% – 70% more expensive than "end of pipe" solutions (NPV LCC). These costs are reasonably comparable to the majority of studies undertaken in Australia, which suggests an average 55% increase in costs with WSD.

Table 2 Average percentage LCC difference between WSD and End of Pipe stormwater treatment scenarios

Average difference between WSUD and End of Pipe	5% Imperv	30% Imperv	60% Imperv	90% Imperv
Undiscounted	-70.0%	-75.0%	-79.4%	-83.2%
Discounted	-62.5%	-59.4%	-64.4%	-70.2%

4 DISCUSSION

The literature review has highlighted the difficulty in quantifying a cost differential between WSD and traditional developments due to the high number of variables which change for each individual situation. These variables relate mainly to the catchment size, impervious area to be treated, device type and the jurisdiction in which the works are located.

Both the literature review and modelling has shown that WSD stormwater devices incur greater costs over their life cycle than end of pipe solutions. As mentioned in Section

3.1.1, many of the studies provided within the USA and UK show large cost savings associated with WSD. However, these are often compared against the cost of separating large scale combined wastewater systems. In addition, studies from the UK and USA, as well as some New Zealand theoretical case studies (ARC, 2000), show a clear saving of TACs for WSD over traditional developments. On closer inspection of the literature this saving is related to the "***avoided costs***" of site earthworking, preparation, concreting and reduced piping rather than the costs of the stormwater management devices themselves.

The literature review highlighted that there is little actual data available regarding maintenance costs. Both the Auckland Council Unitary Plan Costing Report (Kettle and Kumar, 2013) and modelling undertaken for the DSS demonstrated that WSD maintenance costs are higher than end of pipe costs. On average, WSD costs tend to be approximately 59% – 70% more expensive that end of pipe costs (NPV LCC over 50 years). This difference is, on average, generally consistent with the Australasian literature which suggests an increased cost range of, on average 55% in Australia.

5 CASE STUDY

Given that WSD stormwater management costs can be an order of magnitude greater than "end of pipe" costs, the question that decision-makers need to ask is:

Do the benefits received through WSD treatment outweigh the costs?

The DSS therefore needs to be able to ascertain whether or not WSD can deliver net beneficial economic outcomes. In its current state of development the economic wellbeing (EW) associated with a receiving water body (i) and generated through changes to the current development state by a proposed urban development option (UDO) (j), is expressed as the ratio of benefits (B) to costs (C).

$$EW_{i,j} = \frac{B_{i,j}}{C_{i,j}} \tag{4}$$

Economic costs and benefits associated with receiving water body (i) and generated through changes to the current development state by a proposed UDO (j) are captured as net benefits arising through ecosystem services derived from water body (i), and are assessed through non market valuation of changes to the characteristics of water body (i) under UDO (j). A life cycle costing approach is utilised to quantify the economic costs of stormwater mitigation.

The assessment of benefits and EW methodology has previously been reported in Ira et al., 2012a and 2012b and Batstone and Sinner, 2009). The research (Batstone and Sinner, 2009) found that the estuarine attributes of most importance to people were water clarity, the quality of underfoot conditions and ecological health. A WSD approach would therefore need to be adopted in order to meet these aspirations.

The benefits that can be harvested from a WSD approach lie in three areas. First, as modelled in the DSS are improvements to the condition of the receiving water bodies of stormwater. These benefits are not generated only by WSD, but can also be achieved under other stormwater management regimes, however to a lessor extent. They are experienced to various degrees by residents adjacent to the receiving water bodies. Second, WSD devices such as rain gardens and wetlands create amenity benefits that people experience. The extent of those benefits is reflected in premiums paid for houses adjacent to the devices. They may be valued through the l comparative analysis of the prices of homes, in contrast to those more distant in a process known as hedonic price analysis that employs spatial econometric techniques. These benefits are not achievable by end of pipe techniques, and accrue to householders in the development. They do not currently appear in the DSS benefit calculation, but provide an opportunity for further sophistication of the tool. Lastly, there are a number of categories of avoided costs such as reduced seismic disaster response costs which are currently near uninsurable and are borne by local authorities that, along with reduced construction costs of WSD developments (from reduced piping, impervious areas, earthworking, etc.) which are to date are not considered in the DSS benefit calculation.

In order to demonstrate the concepts underlying the construction of the economic wellbeing indicator including its additional potential scope, and to determine whether or not WSD can deliver net beneficial economic outcomes, a case-study has been undertaken for a hypothetical estuary (such as might be found in the Auckland region) and an adjacent catchment subject to urban development. In the case study we consider the updated LCC, and benefits in two domains: (1) benefits that arise from improved amenity values from the condition of receiving estuary waterbody, and (2) the benefits that are experienced as biophyllic responses to rain gardens themselves as experienced by households located in close proximity to the devices.

The case study is located within a catchment in the Auckland region where the accumulation of zinc and copper in harbour sediments is of concern for the health of estuarine ecosystems. The population in the hypothetical catchment is projected to grow at 4% per annum for the next 50 years. Continued urban growth of this nature has the potential to lead to further impacts on estuarine ecosystem services and values. The case-study catchment is approximately 177 ha in area, is of relatively flat topography and drains to the harbour by way of three main streams. The existing land-use is currently rural, with a limited area of residential land use. The current level of imperviousness in the case-study catchment is 9%, rising to an estimated 60% by 2050 under a conventional development scenario. Under a WSD development scenario, future imperviousness will increase to 40% (the reduced impervious area is reflective of the WSD design philosophy of clustering and reducing hard-stand areas). The future land-use will be a mixture of industrial, commercial and residential zonings.

Two kinds of stormwater management approaches, each with a number of sub-options, have been considered. The first utilises conventional stormwater treatment (ponds/ wetlands); the second uses a combination of WSD solutions. The first approach results in improvements in estuarine water clarity (for instance, as a result of a reduction in the delivery of sediment derived from stream erosion) while the second also leads to improvements in estuary ecological health (for instance, reflecting a reduction in the delivery of both sediments and other contaminants). Table 3 summarises the assessment of economic benefits associated with the two approaches.

Assessment of the benefits that accrue to the various stormwater management scenarios is achieved by the practice of "benefit transfer" where values derived from studies other than the case under question are applied, or "transferred in". Optimal conditions for this practice are congruence between the geographical, population, and jurisdictional characteristics of the original and applied studies. In this case the estuary receiving waterbody benefits are derived from a choice experiment and subsequent estimation of a discrete choice model conducted in Auckland in 2008 (Batstone & Sinner, 2009) and the rain garden benefits are derived from the spatial econometric analysis of house prices in inner Sydney over the period 2008-2014 (Polyakov et al. 2015).

Table 3 Description and Assessment of the economic benefits within the hypothetical case study scenarios

Source of benefit	Method	Assessment Units	Transfer units	Beneficial Population
Estuary receiving water body (RWB)	Non-market Valuation: Choice experiment (Batstone & Sinner, 2009)	Willingess to pay (WTP) $ per household per m^2 Auckland region Upper harbour areas per year	Present value of $ per household per m^2 case study estuary area per year over 50 years of the analysis	population adjacent to the estuary
Rain garden (RB)	Spatial econometric analysis of house sales price data (Polyakov et al. 2015)	% differential between prices achieved within and beyond 200m of rain garden for median price homes	Present value of premium value in year five following construction ($)	Number of households within 200m of rain garden

Table 4 presents three kinds of information relating to the different treatment options (representing the removal of a lesser/greater range of contaminants and enhanced environmental benefits) that correspond to the benefits specified in Table 3. The first column shows the NZ$/ ha costs for a range of treatment device scenarios for 60% imperviousness for the conventional development, and 40% imperviousness for the WSD development. Both scenarios incorporate 75% TSS removal. The second column provides the net present value (NPV) life cycle cost assessments using a discount rate of 3.5%, and the final column shows the benefit-cost ratios (i.e. the economic wellbeing indicator) for the levels of benefit shown in Table 3.

Table 4 Combined analysis: cost effectiveness and benefit-cost ratios

Objective	Impervious Area	Treatment	NPV Cost $/ha over 50 years	Catchment NPV (50 year LCC)	RWB Benefit: Cost Ratio*	RG Benefit: Cost Ratio*	Combined RWB+RG Benefit Cost ratio
Conventional Stormwater Treatment - focus on 75% TSS removal	60%	Wetlands & Ponds	$27,500	$4,867,500.00	2.56		2.56
WSD Approaches - focus on 75% TSS removal and metal removal	40%	Rain gardens, swales, infiltration	$95,000	$16,815,000.00	1.59	2.93	4.51
	40%	Wetlands, rain gardens, swales & infiltration	$77,500	$13,717,500.00	1.94	3.59	5.53
	40%	Wetlands & swales	$55,000	$9,735,000.00	2.74		2.74
	40%	Ponds & swales	$30,000	$5,310,000.00	5.02		5.02

*The ratio is derived by dividing the NPV – estuary adjacent households (*Table 3*) by the Catchment NPV - 50 year LCC (Table 4).

Using the combined receiving water body (RWB) and rain garden (RB) cost benefit ratio, Table 4 indicates that the WSD option of using wetlands, rain gardens, swales and infiltration has the highest cost benefit ratio (5.53 - combined receiving water body

(RWB) and rain garden (RB) score). Ponds and swales also score highly (5.02), and this is likely due to the low cost of the ponds, combined with the receiving water body benefits (contaminant removal) of the swales. The research has highlighted a number of key issues for consideration when comparing WSD and 'end of pipe' stormwater management. These include:

- Additional benefits of WSD over traditional developments through a reduced contaminant load in the receiving environment due to reduced impervious areas;
- There is econometric analysis of actual house price data which captures the monetized quantum of the benefits of rain gardens, suggesting a direction for research in terms of achieving the same for other WSD devices and practices.
- This analysis is conservative in that it does not capture benefits such as avoided costs which are realized through a WSD approach (e.g. reduced costs from reduced impervious surfaces, less earthworking, fewer pipes, insurance of infrastructure, resilience, etc.).
- Inclusion of device specific benefits improves cost-benefit ratios by a factor in the order of 50%.

The hypothetical case study has shown that there are clearly net economic benefits of WSD.

6 CONCLUSIONS

In this paper we have described refinements made to the life cycle costing module, within NIWA's DSS model, that allow users to compare the costs and benefits of conventional and WSD stormwater management for future catchment development scenarios. The refinements integrate 'real world' costing data with findings from an international literature review which investigated cost comparisons between WSD and conventional stormwater management.

Overall, the research has highlighted the difficulty in quantifying a cost differential between WSD and traditional developments due to the high number of variables which change for each individual situation. These variables relate mainly to the catchment size, impervious area to be treated, device type and the jurisdiction in which the works are located. There is little actual data available in the international literature regarding long term maintenance costs. Furthermore, the literature suggests that savings realized in WSD developments are generally related to "avoided" costs of site earthworking, preparation, concreting and piping rather than the costs of the stormwater management devices themselves.

Additional modelling has shown that WSD solutions are 59% – 70% more expensive than "end of pipe" solutions (NPV LCC) in New Zealand, and that these percentages are generally consistent with research undertaken in Australia.

Using the DSS economic indicator, combined with additional information as to device specific benefits, we have been able to determine differing cost benefit ratios for a range of treatment scenarios. The modelling has shown that, whilst on-site stormwater management is relatively new in New Zealand, net economic benefits can be realized through a combination of WSD at source and end of pipe devices. Future research should focus on further refining these benefits, including investigating the benefits of other types of WSD practices and avoided costs of WSD. It is anticipated that as the use of WSD becomes more common, the market will mature, and innovation and competition may reduce pricing. This, together with economies of scale realized by larger developments, will further increase the cost benefit ratio of WSD solutions.

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