Assessing the Full Benefits of WSUD

Activating WSUD for Healthy Resilient Communities

Activating WSUD Aotearoa NZ

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National Science Challenges BUILDING BETTER HOMES, TOWNS AND CITIES Ko Ngā wā Kainga hei whakamāhorahora

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Funded by the Building Better Homes, Towns and Cities National Science Challenge

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Cover: Green infrastructure in Auckland's Wynyard Quarter provides a range of benefits, for example: stormwater management, microclimate moderation, amenity value and connectedness-with-nature (photo: J. Moores).

Contents

Executive Summary

The potential benefits of WSUD, relative to conventional urban development approaches, are typically expected to include better hydrology and water quality and healthier aquatic ecosystems. While there remain evidence gaps on the delivery of these outcomes, especially in New Zealand, monitoring and modelling methods for their assessment are well developed.

However, assessments of the benefits of WSUD that focus solely on these water-related outcomes are incomplete in their scope. WSUD has the potential to deliver a wide range of other environmental and social co-benefits, for instance: the preservation of natural soils; microclimate moderation; terrestrial habitat provision for native biodiversity; the provision of supplementary water supplies; better public safety; and improved health and wellbeing deriving from the use of green infrastructure (GI).

A number of tools developed overseas provide for assessments of the benefits of WSUD. These draw on established methods from the field of resource economics to infer economic benefits associated with the GI's delivery of a wide range of water-related and co-benefits. Combined with information on infrastructure costs, these methods can be used in assessments of cost-benefit and cost-effectiveness of WSUD compared to conventional water management approaches.

However, these tools are not readily applicable in New Zealand, for reasons that include uncertainty in benefit transfer from one jurisdiction to another, caution over the monetization of environmental benefits and an aspiration to adopt assessment methods that explicitly recognise Māori values. In recognition of the need to provide a 'quick win' method by which practitioners can demonstrate and communicate the wide-ranging benefits of WSUD, the Activating WSUD research team has developed the qualitative 'More Than Water' (MTW) assessment tool, described in full in a separate report.

We suggest that there is a need to reposition WSUD in New Zealand in a way that fully reflects its potential to deliver a wide range of water-related and non-water-related benefits. Many of these benefits (deriving from use of plants, especially trees) are only likely to be delivered with multi-disciplinary input, specific design, effective maintenance and a responsiveness to multiple dimensions of community well-being. The repositioning of WSUD should therefore aim to grow WSUD's reach and appeal, expand the community of practice and improve the delivery of multiple benefits, in order to activate the wider uptake of WSUD in New Zealand.

1. Introduction

1.1 Background

The Building Better Homes Towns and Cities National Science Challenge (BBHTC) is funding the 'Activating Water Sensitive Urban Design (WSUD) for healthy, resilient communities' research project. The project aims to deliver research and enhance capability to address critical current barriers to the uptake of WSUD in New Zealand.

In Phase 1 of the project, engagement with WSUD's community of practice guided the development of a programme of short term (9 to 12 month) research activities capable of delivering on high priority 'quick wins'[1]. One of three core activities identified was the development of guidance for "characterising, evaluating and demonstrating the full benefits of WSUD." The findings of phase 1 indicated that, without a better understanding of the full range of benefits and ways to evaluate those benefits, making the business case for WSUD in New Zealand will remain a significant challenge.

Many of the water-related benefits of WSUD, relative to conventional urban water management approaches, are well documented: better hydrology, improved water quality and healthier aquatic ecosystems. While there remain evidence gaps on the delivery of these outcomes, especially in New Zealand, methods for their evaluation are well developed.

However, assessments of the benefits of WSUD that focus solely on its water-related outcomes are incomplete. In this report we describe other non-water benefits (or "co-benefits") that can arise from WSUD's use of Green Infrastructure (GI): some of these are other environmental outcomes (for instance, moderation of air temperature), while others are consequential outcomes for people and communities (for instance, health benefits).

As well as these non-water benefits, special attention is also needed in New Zealand to considering the role of WSUD in recognising and providing for culturally-specific benefits for Māori. Identification of these benefits, both water- and non-water related, provides an opportunity to enhance the status of WSUD in New Zealand and motivate uptake as a concept that delivers against complementary objectives arising from Maori world views and a broader sustainability ethic.

1.2 Scope and structure of this document

This document describes the range of water- and non-water-related benefits of WSUD and approaches to assessing those benefits.

Section 2 describes the multiple benefits of WSUD. While the water-related benefits are well known, it is important to briefly summarise those, because this provides a foundation on which other co-benefits add further value. The section goes on to describe co-benefits of WSUD, meaning benefits that are unrelated (or not directly related) to receiving water body outcomes.

Section 3 provides a summary of existing approaches for benefits assessment. While there are a range of methods for assessing the water-related benefits of WSUD, some of these are probably less well known than others among WSUD practitioners and it is important to provide guidance on the approaches available, especially the various types of economic analysis that have been applied to

[1] Moores, J., Batstone, C., Simcock, R. and Ira, S. (2018). Activating WSUD for Healthy Resilient Communities – Discovery Phase: Results and Recommendations. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

WSUD. This chapter also summarises a number of assessment tools that have been developed overseas and comments on the potential for their application in New Zealand.

Section 4 summarises the main points of the report and makes recommendations for further research.

1.3 Complementary research

This report has been prepared as part of a suite of closely-related research activities conducted under the Activating WSUD project. As well as addressing the benefits of WSUD, the project has investigated how the costs and broader economic outcomes of WSUD compare with those associated with conventional urban development[2]. In addition, the project has explored WSUD from an explicit Aotearoa New Zealand perspective by investigating the benefits of WSUD through the lens of Te Ao Maori[3].

In combination, these research activities have contributed to the development of the 'More Than Water' (MTW) assessment tool. True to its name, the tool aims to provide a framework for identifying and assessing the full range of WSUD benefits and economic outcomes in Aotearoa New Zealand by repositioning WSUD as a concept that is about 'more than water'. The tool, and its application in case studies, is described in a complementary report[4] available on the Activating WSUD website.

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[2] Ira, S. and Simcock, R. (2019) Understanding Costs and Maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

[3] Afoa, E. and Brockbank, T. (2019) Te Ao Māori & Water Sensitive Urban Design. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

[4] Moores, J., Ira, S., Batstone, C. and Simcock R. (2019) The 'More than Water' WSUD Assessment Tool. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

2. Benefits of WSUD

2.1 Introduction

This section describes the multiple benefits of WSUD. While the water-related benefits are generally well known, it is important to briefly summarise those, because this provides a foundation on which other co-benefits add further value. The section goes on to describe co-benefits of WSUD, meaning benefits that are unrelated (or not directly related) to receiving water body outcomes. In doing so, it reflects an evolution in concepts and terminology evident in the international literature, with the emergence of the term 'Green Infrastructure' (GI) widely used to describe WSUD-like approaches that are often recognised for their wider (non-water) benefits. For the purposes of the remainder of this report, we use the term GI to broadly mean the physical infrastructure[5] (natural and built, but usually featuring plants) used in the implementation of a WSUD approach.

Several overseas agencies have previously characterised the benefits of WSUD and GI. The UK's Construction Industry Research and Information Association (CIRIA) conducted a comprehensive review[6] of international literature on the multiple benefits of Sustainable Drainage Systems (SuDS)[7] and ways of valuing these benefits. The review emphasised the importance of considering a broad range of environmental and social benefits from the perspective of concepts such as sustainability, liveability and well-being. It also recognised that many of the benefits of WSUD can be closely related to other components of the urban environment, including street design, sustainable building practices and the presence of green spaces.

The CIRIA's review presents several ways of attempting to group or structure the benefits of WSUD and GI. These include a 'needs category' approach whereby benefits are grouped according to their contribution to:

- Existence needs (physical and material needs), for example potable water, public health and public safety;
- Relatedness needs (social interaction and inter-personal relationships), for example recreation, aesthetics, comfort and ecological health; and
- Growth needs (societal self-esteem and self-actualisation), for example identity, social justice and intergenerational equity.

An alternative approach is to group benefits according to the provision of ecosystem services[8], of which there are four broad categories:

- Provisioning services (services that describe the material or energy outputs from ecosystems that can be used to support human needs), for example provision of food, freshwater and raw materials;
- Regulating services (services that ecosystems provide by regulating the quality of air and soil or providing flood and disease control, etc.), for instance local climate and air quality regulation, carbon sequestration, wastewater treatment and moderation of extreme events;

[5] It should be recognized that the implementation of WSUD and GI also involves 'soft infrastructure', meaning the political, economic and social institutions and services involved in enabling and delivering WSUD/GI.
[6] CIRIA Research Project RP993 Demonstrating the Multiple Benefits of SuDs, https://www.susdrain.org/files/resources/ciria_guidance/ciria_rp993_literature_review_october_2013_.pdf
[7] SuDS is the UK term for WSUD.
[8] "the benefits people obtain from ecosystems" from: Millennium Ecosystem Assessment, MA (2003). Ecosystems and human well-being. A framework for assessment. Island Press, Washington, DC.

- Habitat or Supporting services (services that underpin almost all other services but do not necessarily have direct economic value), for instance habitats for species and maintenance of genetic diversity;
- Cultural services (the non-material benefits people obtain from contact with ecosystems), for instance recreation, mental and physical health, tourism and aesthetic appreciation.

Other approaches reviewed by the CIRIA are based more on the physical characteristics and functioning of GI. A similar approach is adopted in a US guide for valuing GI projects[9] developed by the Center for Neighbourhood Technology and funded by the USEPA. The guide identifies 18 specific benefits and assesses the relevance of these each to five GI practices. Ways of assessing these benefits are then presented in eight broad categories: water; energy; air quality; climate change; urban heat island; community liveability; habitat improvement and public education. Similarly, the Australian Co-operative Research Centre for Water Sensitive Cities (CRCWSC) has assessed benefits of WSUD projects across six broad categories: freedom from water restrictions; healthy local waterways; cooler summer temperatures; greener streetscapes; greener suburbs; and street trees[10]. In current research, the CRC is developing an assessment tool that considers more than 20 specific benefits of WSUD projects (see Section 3).

While there are clearly a number of different ways that the benefits of WSUD and GI can be categorised, it is apparent that lists constructed according to different approaches have much in common. All approaches signal that the potential benefits of WSUD are wide-ranging and not solely confined to environmental outcomes in the water realm. There are also benefits relating to the terrestrial and atmospheric realms and to social well-being. Accordingly, the following sections summarise the benefits of WSUD by grouping them as water-related and non-water-related, with environmental and social sub-groups. While this is not necessarily a better system for organising benefits than any other system developed elsewhere, we have found it provides a convenient structure for demonstrating that benefits are about 'more than water.' This is important, because it signals the potential to deliver benefits to sectors that, under conventional approaches, have had little involvement in the implementation of WSUD/GI - with the public health sector being notable among these. While it may be the case that a stormwater management imperative initiates and largely funds a project, there may be major opportunities to add wider benefits, justifying input from a broader range of interests.

It is worth noting that while the list below is comprehensive, it may not be exhaustive. In other words, readers may wish to add to the list based on experience or knowledge of the application of WSUD and GI to specific projects.

2.2 Water-related benefits

This section deals with water-related benefits of WSUD. This is how we usually think about the benefits of WSUD. It is important to begin by summarising what we mean by WSUD in New Zealand, compared to internationally. While different jurisdictions around world place emphasis on different aspects of WSUD[11], the following concepts are particularly evident in a New Zealand 'understanding' of what WSUD comprises[12].

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[9] The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf

[10] Enhancing the Economic Evaluation of WSUD https://watersensitivecities.org.au/wp-content/uploads/2016/12/IdeasforSA_EnhancingtheEconomic_WEB.pdf

[11] Fletcher, T., W. Shuster, W. Hunt, R. Ashley, D. Butler, S. Arthur, S. Trowsdale, S. Barraud, A. Semadeni-Davies, J.-L. Bertrand-Krajewski, P. Mikkelsen, G. Rivard, M. Uhl, D. Dagenais, and V. Viklander. 2014. SUDS,

Firstly, WSUD aims to limit stormwater runoff and contaminant generation at source by minimising the construction of impervious surfaces, such as roads and roofs, and retaining areas of vegetation and natural soils. This can be achieved, for instance, by building clusters of multi-storey dwellings (and shared driveways) to deliver the same built capacity while retaining relatively large areas of green space and urban parks. Secondly, WSUD aims to maintain or restore the functioning of natural drainage systems, rather than replacing stream networks with piped systems and draining wetlands and springs. In combination, these practices aim to retain natural GI features in order to maintain characteristics of catchment hydrology, including infiltration, groundwater recharge and stream flow characteristics, similar to those that existed pre-development. Thirdly, WSUD uses green technologies (or the built component of GI) to better manage stormwater in a way that complements its approach to land use planning. Bioretention systems, or raingardens, provide for runoff control while providing treatment to improve stormwater quality via the removal of contaminants as stormwater infiltrates through an engineered soil media. Wetlands also provide stormwater treatment and runoff control, as well as providing habitat and amenity services. WSUD can also feature riparian planting (the revegetation of stream banks), to improve stream habitat quality and connectivity, including with terrestrial ecosystems. Lastly, WSUD can also include non-living devices such as rain tanks and unplanted permeable paving, which provide for the detention and attenuation of stormwater runoff.

In New Zealand, WSUD clearly has a strong focus on management of stormwater and receiving water bodies. Its potential role in the water supply and wastewater sectors has received little attention, however, a future-focused approach should recognise these other opportunities and areas of impact. For instance, in Australia taking a WSUD approach typically means providing an alternative water supply to enhance the drought resilience of meeting both potable and non-potable demand[13]. Melbourne, for example, features stormwater harvesting schemes providing water for landscape irrigation, particularly street trees as these deliver broader benefits and are costly to water with conventional potable supplies. While acknowledging the current stormwater focus of WSUD in New Zealand practice, it is important to recognise that a truly WSUD approach can include some or all of these wider potential water-related benefits.

As noted above, the benefits of WSUD can be grouped in a number of ways. Here we have chosen to adopt two categories. Firstly, **environmental benefits** reflect the difference that WSUD makes to the biophysical properties of the natural water bodies and their ecosystems. Secondly, there are a range of **social benefits**, some of which reflect the provision of ecosystem services supported by WSUD and others which are associated with WSUDs relationship with water infrastructure. Table 2-1 summarises water-related benefits in each of these two categories, while Figure 2-1 shows their relationships with each other and how they derive from three broad characteristics of WSUD: reduced footprint of the built environment; the retention or enhancement of natural environments and greenspace; and the use of visible green technologies. The first three benefits listed in the table (hydrology, water quality and aquatic habitat) are typically the WSUD benefits that currently receive most attention.

LID, BMPs, WSUD and more – the evolution and application of terminology surrounding urban drainage. Urban Water Journal 12(7): 525-542.

[12] For instance, in Auckland – see Lewis, M., J. James, E. Shaver, S. Blackbourn, A. Leahy, R. Seyb, R. Simcock, P. Wihongi, E. Sides, and C. Coste. 2015. Water Sensitive Design for Stormwater, Auckland Council Guideline Document GD2015/004. Auckland Council, Auckland, New Zealand, p.193.

[13] Activating WSUD for Healthy, Resilient Communities Study trip to Melbourne, November 2018 – Findings. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0005/178682/Findings-of-Activating-WSUD-visit-to-Melbourne-Nov-2018.pdf

Table 2-1 Water-related benefits of WSUD

Benefit	Summary description: outcomes that a WSUD approach aims to deliver
Environmental benefits	
More natural hydrological regime	Runoff volume, stream peak flows, time-to-peak, low flows and flow variability are more similar to those in an undeveloped catchment than is the case with a conventional development approach. This is most likely to be the case where soil permeability and water storage capacity are maintained , imperviousness is very low (e.g., <10%) and/or unconnected to streams and there is widespread use of green technologies mimicking natural infiltration processes.
Better water quality	Concentrations of contaminants such as suspended solids, metals, nutrients and microbes in receiving water bodies are more similar to those in an undeveloped catchment than is the case with a conventional development approach. This is most likely to be the case where imperviousness is very low (e.g., <10%) and/or unconnected to streams and there is widespread use of contaminant source control and green technologies providing stormwater treatment.
Better aquatic and riparian habitat quality	Stream channel geomorphology (e.g., channel form, pool and riffle sequences) and bed substrate are more similar to those in an undeveloped catchment than is the case with a conventional development approach. Stream banks are stable and largely lined with diverse native riparian vegetation, providing shade and woody debris inputs to streams and other waterbodies.
Drainage network and ecosystem connectivity	The natural drainage network is largely intact from its headwaters to the stream or river mouth, with few or no artificial barriers to fish passage and good habitat quality (instream and riparian, see above) maintained throughout.
Natural character	Characteristics of water bodies and riparian margins are largely the same as in undeveloped catchment: channel form and sinuosity, water clarity, riparian vegetation composition. No pipes directly discharge to the water bodies.

Table 2-1 (cont.)

Benefit	Summary description: outcomes that a WSUD approach aims to deliver
Social benefits	
Provisioning (e.g.: fishing, shellfish collection)	Wild food sources in receiving water bodies are abundant and carry a very low risk of human health effects from consumption. Water bodies are appealing for provisioning, for instance having good water clarity, sandy/rocky bed sediments and limited levels of algal growth.
Contact recreation (e.g.: swimming)	Receiving water bodies are well suited to contact recreation, having a very low risk of human health effects from water contact due to excellent water quality (i.e., concentrations of *E. coli* and/or enterococci indicator bacteria virtually always well below guideline values). Water bodies are appealing for wide range of recreation, for instance having good water clarity, sandy bed sediments and limited levels of algal growth.
Water-related connectedness with nature	Water bodies are celebrated as community assets and easily accessed, with stream and coastal margins in public ownership and well served by footpaths and accessways that allow views of the water in places. Characteristics of water bodies and riparian and coastal margins are largely the same as in undeveloped catchment: channel form and sinuosity, water clarity, riparian vegetation composition.
Drainage and flood management	Surface flooding is avoided or restricted to designated overland flow paths, flood storage basins and/or/reserve land, allowing peak flows to spread out with low energy. Out-of-bank stream or river inundations of natural floodplains occur at around the same frequency as in and undeveloped catchment, and do not impact on private property. This is most likely to be the case where the natural functioning of floodplains is respected by avoiding incursion of the built environment.
Supplementary water supply	Widespread harvesting and use of stormwater and wastewater: rainwater tanks are widely installed for domestic potable and non-potable uses; stormwater detained in ponds/wetlands is abstracted for landscape irrigation; and household and commercial grey water is recycled for non-potable uses: e.g. toilet flushing, garden watering.
Reduced wastewater / combined sewer system loading	Reduced discharge of wastewater as a result of grey-water recycling and/or water conservation and water use efficiency measures in domestic and commercial settings. Stormwater loading of combined sewer systems is avoided by source control and green technologies for retention and volume control.
Climate change adaptation	The planning and design of the built environment takes account of forecast sea level rise and increased flooding extent. Stormwater systems (networks and devices) are designed with spare capacity to accommodate increased rainfall intensity. Widespread use of rainwater tanks provides for supplementary water supply to mitigate against forecast increases in drought frequency.

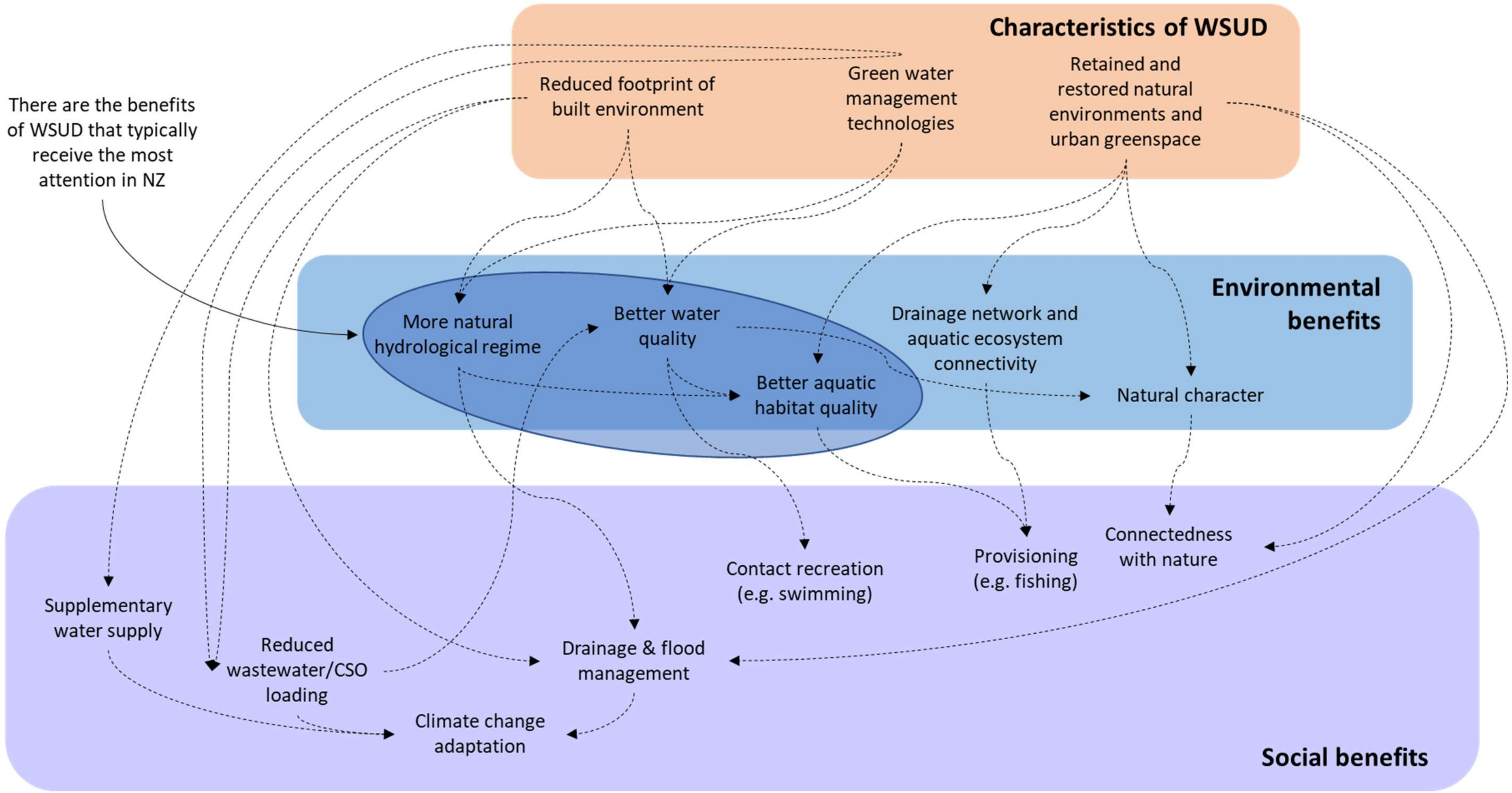

Figure 2-1 – Water-related benefits of WSUD

2.3 Non-water-related benefits

As with water-related benefits, we have also adopted the categories 'environmental' and 'social' to group the non-water-related benefits of WSUD. **Environmental benefits** reflect the difference that WSUD can make to the biophysical properties of the land and atmosphere. Similarly to water-related benefits, some of the **social benefits** reflect the provision of ecosystem services supported by WSUD while others are associated with WSUDs relationship with the built environment.

Table 2-2 summarises non-water-related benefits in each of these two categories, while Figure 2-2 shows their relationships with each other and how they derive from three broad characteristics of WSUD: reduced footprint of the built environment; the retention of natural environments and greenspace; and the use of green technologies.

Table 2-2 Non-water-related benefits of WSUD

Benefit	Summary description: outcomes that a WSUD approach aims to deliver
Environmental benefits	
Preservation of natural soils	Land development avoids the widespread removal of topsoil, preserving its productive capacity. This is most likely to be the case where urban design minimises the footprint of development. Soil from excavated areas is retained for on-site reinstatement that preserves the original soil quality and functioning.
Microclimate management	Trees are widespread throughout the built environment, with their canopy providing shading and screening to reduce public exposure to UV radiation, moderate high summer air temperatures and intercept atmospheric particulate matter. Abundant, well distributed green spaces provide 'oases' of moderated climate and better air quality. These benefits complement water-related features of WSUD in contributing to climate change adaptation (see Table 2-1).
Carbon sequestration and mitigation	Widespread vegetation, especially trees and wetland plants, acts as significant sink of carbon. These benefits complement water-related features of WSUD in contributing to climate change adaptation and mitigation (see Table 2-1).
Better terrestrial habitat quality	The presence of significant areas of relatively undisturbed or rehabilitated natural vegetation provides high quality terrestrial habitat.
Terrestrial ecosystem connectivity	Widespread green space is linked by vegetated corridors to maintain or restore a network of green corridors, including following the margins of the natural drainage network.
Natural character (land)	The presence of significant areas of relatively undisturbed natural landforms and vegetation, or revealed and rehabilitated landforms and vegetation (e.g. in brownfields settings), combined with sympathetic urban planning and design maintains natural character throughout built areas.

Table 2-2 (cont.)

Benefit	Summary description: outcomes that a WSUD approach aims to deliver
Social benefits	
Reduced building material consumption	Efficient design, for instance multi-storeys, clustering, shared access and narrow street design, limits use of concrete and asphalt. The widespread use of green technologies (swales) for stormwater conveyance avoids the need for constructed pipe networks.
Infrastructure resilience	Infrastructure is designed in accordance with a range of resilience principles, e.g.: multifunctionality, redundancy, modularity and diversity, providing for operational reliability under changed conditions. Infrastructure continues to function well during natural disasters such as earthquakes.
Food & fibre production	Multifunctional green spaces provide locations for community gardens, orchards, food-forests and wetlands for food, fibre and medicinal plants. Urban planning optimises the use of land resources by avoiding development of productive and versatile soils, retaining their use for food production. Grassed areas include areas of infrequently-mown meadows and with landscaping choices supports beneficial pollinator and predator insects.
Public safety	WSUD street design (e.g., narrower road widths, traffic calming measures, sight lines) promotes safety for pedestrians/cyclists. High quality urban design delivers appealing, well used and visible public spaces minimising crime potential. Areas of green space are well maintained providing accessible, safe locations for recreation.
Connectedness with nature (land)	Green space is celebrated as a community asset and is easily accessed: abundant, well distributed green spaces are in public ownership with plentiful provision of footpaths and accessways. Reserves incorporate significant areas of relatively undisturbed natural vegetation and meadows. These "nature doses" increase the frequency, duration and the intensity of urban human interactions with nature[14].
Community health and wellbeing	Multifunctional green spaces, including sports fields, walking/cycling tracks and seating/resting spaces provides plentiful opportunities for organised and informal forms of active recreation. Connectivity of green spaces and street design (e.g. designated shared biking/walking routes, traffic calming measures) encourages active transport modes. Mental well-being derives from visual and physical connectedness with nature (see above) with access to abundant green space, especially large trees, encouraging relaxation, intellectual stimulation and effective stress management.
Property values	Characteristics such as natural character, accessibility and public safety make urban neighbourhoods that promote health and wellbeing highly desired as locations to live, work and play, with knock-on effects for residential property values.

[14] Cox, D.T., Shanahan, D.F., Hudson, H.L., Fuller, R.A. and Gaston, K.J., 2018. The impact of urbanisation on nature dose and the implications for human health. Landscape and Urban Planning, 179, pp.72-80

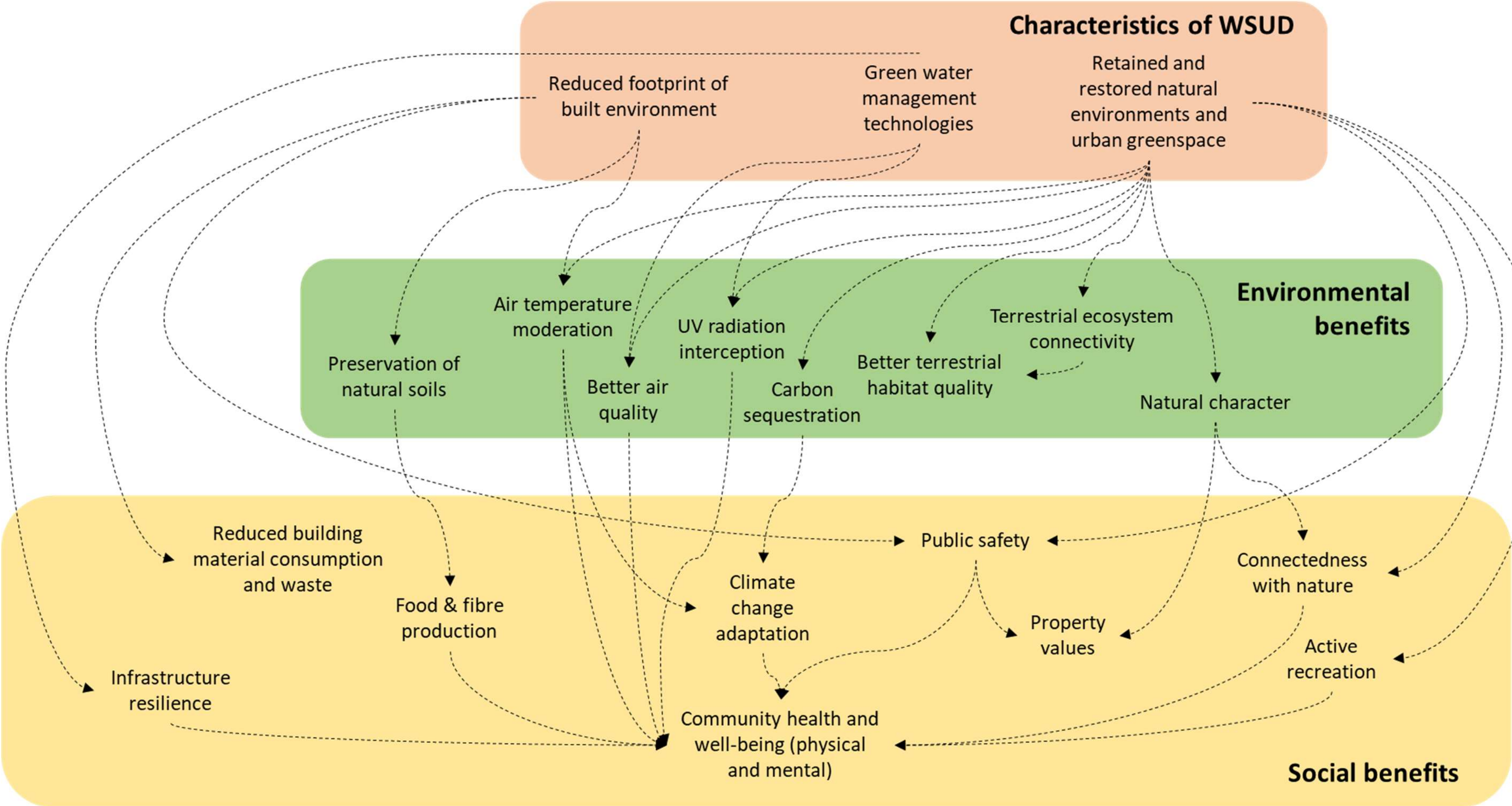

Figure 2-2 – Non-water-related benefits of WSUD

3 Methods for Assessing Benefits

3.1 Introduction

This section provides a summary of existing approaches for assessing the benefits of WSUD and GI, starting with a brief coverage of conventional environmental assessment methods. Probably less well known among WSUD practitioners are the various types of economic analysis that have been applied to WSUD assessments. As well as providing an overview of these methods, this section summarises economic assessment tools developed overseas and comments on the potential for their application in New Zealand. Links to various useful resources on assessment methods and tools are also listed in Appendix A.

3.2 Assessment methods - environmental

Assessments of the environmental benefits of WSUD projects can involve monitoring or modelling of hydrological, water quality and ecological outcomes. Assessments can be conducted over a range of scales, from evaluations of the performance of an individual GI device during a single rainfall event to the multi-decadal response of a receiving water body to catchment-wide GI interventions.

Device-scale monitoring can involve measuring flows and taking water quality samples at the inlet and outlet of a stormwater device such as a raingarden, wetland or green roof. This type of approach generates information that allows the performance of the system, in terms such as peak flow or contaminant load reduction, to be quantified. There have been a number of studies of WSUD devices in New Zealand (e.g. [15] [16]), while the results of many overseas studies are reported in the international literature and collectively in the International BMP database[17].

However, while monitoring at this scale provides very specific information on the stormwater performance of a GI device, it does not provide an assessment of whether or not wider environmental objectives are met. These wider objectives may reflect some of the non-water benefits described previously, for instance the terrestrial biodiversity value of GI. Additional (non-water) monitoring and surveys are required to assess these sorts of benefits. Although guidance is available[18] [19], there have been few reported studies of this nature in New Zealand.

Returning to water-related objectives, the assessment of whether WSUD delivers on environmental outcomes at a catchment scale requires monitoring has to be conducted in receiving environments. This can involve establishing hydrological and water or sediment quality monitoring sites and conducting ecological surveys (for instance macroinvertebrate sampling[20] and/or stream habitat

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[15] Trowsdale, S. A., and Simcock, R. (2011). Urban stormwater treatment using bioretention. *Journal of Hydrology* 387: 167–174.

[16] Voyde, E., Fassman, E. & Simcock, R. (2010). Hydrology of an extensive living roof under sub-tropical climate conditions in Auckland, New Zealand. Journal of Hydrology, 394, 384-395.

[17] http://www.bmpdatabase.org/

[18] Lewis M, Simcock R, Davidson G, Bull L. 2010. Landscape and ecology values within stormwater management. Prepared by Boffa Miskell for the Auckland Regional Council: Auckland Regional Council Technical Report TR2009/083.

[19] Ignatieva M, Meurk C, van Roon M, Simcock R, Stewart G 2008. How to put nature into our neighbourhoods: application of Low Impact Urban Design and Development (LIUDD) principles, with a biodiversity focus, for New Zealand developers and homeowners. Manaaki Whenua Press, Landcare Research Science Series, no. 35. 52 p.

[20] Allowing calculation of indices such as the Macroinvertebrate Community Index (MCI) which provide an assessment of stream ecological health: https://www.lawa.org.nz/learn/factsheets/benthic-macroinvertebrates/

surveys[21]) in rivers and streams. Monitoring may be required over long timeframes (years to decades) to establish whether trends, such as improvements in water quality or biotic indices, are evident in response to a catchment-scale intervention such as a GI retrofit. The design of monitoring should aim to compare water bodies with and without WSUD and/or before and after WSUD to reduce uncertainty over the interpretation of results. Other factors, such as changes in the rainfall regime or rural land cover, may need to be considered.

Overseas, there are a number of examples of catchment-scale studies to assess the hydrological and water quality impact of WSUD (e.g., [22] [23]). Notable among these is the Little Stringybark Creek study[24] in Melbourne which has been in progress for over ten years. The only example of catchment-scale monitoring to assess WSUD in New Zealand is a series of stream biological surveys conducted by the University of Auckland to compare the impact of alternative forms of urban development in the Flat Bush area of south Auckland[25]. However, a comprehensive programme of hydrological, water quality and biological monitoring is planned for the Mangakotukutuku Stream catchment near Hamilton in advance of the WSUD development of part of that catchment[26].

Often, the adoption of a monitoring-based assessment approach is not feasible. Comprehensive monitoring can be prohibitively expensive, logistically challenging and require a long-term (perhaps multi-decadal) commitment of resources. In other situations, the benefits of WSUD need to be assessed as part of the project planning and design phases. Modelling provides a way of assessing WSUD projects at a range of scales and in relatively quick fashion. Different designs or scenarios can be evaluated under a range of environmental conditions to provide decision-makers with detailed information on the pros and cons of adopting alternative approaches.

As with monitoring, different modelling approaches are suited to answering different questions and information needs. At one end, the design of GI stormwater systems can be informed by relatively simple rainfall-runoff calculations that provide estimates of (for instance) peak stormwater flows predicted to occur with a given recurrence interval. These types of calculation help designers to size GI devices to deliver an expected level of water quantity and quality performance[27].

Contaminant load models are another relatively simple type of model that estimate the quantity of different contaminants generated in a catchment or project area based purely on land cover characteristics and the type of stormwater interventions. Auckland Council's CLM[28], the best-known New Zealand model, was developed from a significant programme of stormwater monitoring in the early 2000s and has been used as a screening level assessment tool throughout the country.

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[21] Such as the Auckland Council's Stream Ecological Valuation (SEV) method for assessing the ecological functioning of streams: http://www.knowledgeauckland.org.nz/publication/?mid=1286

[22] Bedan, E. and Clausen, J. (2009). Stormwater runoff quality and quantity from traditional and low impact development watersheds. J. Am. Water Resour. Assoc., 45 (4): 998–1008.

[23] Winston, R., Page, J., and Hunt, W. (2013.) Catchment Scale Hydrologic and Water Quality Impacts of Residential Stormwater Street Retrofits in Wilmington, North Carolina. Proceedings of Green Streets, Highways, and Development 2013 conference: pp. 159-172. doi: 10.1061/9780784413197.014

[24] https://urbanstreams.net/lsc/index.htm

[25] van Roon, M. and Rigold, T, (2016). Urban form and WSUD in Auckland residential catchments determine stream ecosystem condition. Proceedings of 9th International Conference on Planning and Technologies for Sustainable Management of Water in the City (Novatech), 28 June – 1 July 2016, Lyon, France. http://documents.irevues.inist.fr/bitstream/handle/2042/60368/3A72-026VAN.pdf?sequence=1

[26] A joint initiative of NIWA and Hamilton City Council, potentially with further project partners.

[27] Although the expected level of performance is rarely validated through subsequent monitoring.

[28] Timperley, M., Skeen, M. and Jayaratne, J. 2010. Development of the Contaminant Load Model. Auckland Regional Council Technical Report 2010/004.

However, on its own, the use of this type of model is unable to provide an assessment of whether or not environmental objectives in receiving water bodies are likely to be met.

Catchment models which simulate continuous timeseries of stormwater, river flow and water quality over time are more complex and resource-intensive to run. This type of model can require a wide range of data inputs, typically characterising land cover, soils and topography and needing climate data from periods of several years. Where possible, they are calibrated against observations of river hydrology and water quality to provide confidence that they provide a realistic representation of reality. The models can then be run to assess hydrological and water quality outcomes under changed conditions, such as with additional urban development or increased rainfall intensity. Modellers can test alternative configurations of land cover and stormwater management devices to, for instance, compare how a WSUD approach compares to a conventional approach in the design of an individual subdivision or planning for future urban growth at the city-scale.

The Australian MUSIC model[29], developed by eWater, is a well-known continuous simulation model designed specifically for urban stormwater modelling. While the model defaults are reflective of Australian conditions, customisation for local conditions is possible and there are examples of New Zealand applications of MUSIC. Another well-known model specifically developed for stormwater device modelling is the USEPA's SUSTAIN[30]. With the input of US-based modellers, SUSTAIN is currently being applied as part of Auckland Council's development of a region-wide freshwater management tool[31].

Catchment models can also be used in combination with other models to provide assessments of water and sediment quality outcomes in coastal water bodies. This can involve taking the outputs from the catchment models (for instance flows and contaminant concentrations) to model the transport and deposition of contaminants in a harbour during storm events (using hydrodynamic models) or over the longer-term. This kind of approach has been used in Auckland to assess the response of contaminant levels in the sediments of parts of the Waitemata and Manukau Harbours to alternative stormwater management interventions (e.g. [32]). A simplified suite of catchment, stream and harbour models are linked together in the Urban Planning that Sustains Waterbodies (UPSW) decision support tool[33]. As well as providing assessments of a range of environmental indicators under alternative urban development scenarios (WSUD and non-WSUD), the tool also provides assessments of socio-economic indicators, based on some of the methods described in the

[29] https://ewater.org.au/products/music/

[30] https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain

[31] Grant, C., Hellberg, C., Bambic, D. and Clarke, C. 2018. Development of a Freshwater Management Tool to Support Integrated Watershed Planning for Auckland Waterways. WaterNZ Stormwater Conference 2018, 23-25 May 2018, Queenstown.

[32] Green, M. 2008. Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenario 1. Auckland Regional Council Technical Report 2008/043. http://www.aucklandcity.govt.nz/council/documents/technicalpublications/TR2008043.pdf
Green, M. 2008. Central Waitemata Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under Future Development Scenarios 2, 3 and 4. Auckland Regional Council Technical Report 2008/044.
http://www.aucklandcity.govt.nz/council/documents/technicalpublications/TR2008044.pdf

[33] Moores, J., Batstone, C., Gadd, J., Green, M., Harper, S., Semadeni-Davies, A. and Storey, R. (2014). Evaluating the Sustainability of Urban Development in New Zealand in Relation to Effects on Water Bodies. *The International Journal of Environmental Sustainability*, 9(4): 31-47.
http://ijse.cgpublisher.com/product/pub.272/prod.81

following section. This enables UPSW to be used in planning and policy settings, such as to evaluate the implications of implementing the NPS-FM in urban catchments[34].

3.3 Assessment methods – economic and social

WSUD outcomes have social, cultural and economic implications arising from the design, technologies, and the resultant outcomes for terrestrial, aquatic and marine receiving environments. This section briefly surveys methods to inform the assessment of those outcomes. The reader should consider this section in the context of international developments such as the CIRIA and USEPA documents described in Section 2 above.

Decision making about how land is used and managed, and how the associated trade-offs are understood, requires systematic accounting of the relationships between resource management, ecosystem services (ES) and their value generation. Three broad approaches have been recognized in the assessment of ecosystem services - ecological, socio-cultural and economic[35]. Ecological and other biophysical approaches focused on empirical assessment of ES effects arising from the implementation of WSUD have been discussed in the previous section. Those methods often form the point of departure for other assessment frameworks that evaluate the societal implications of changes to ecosystem service provision in terms of economic and socio-cultural outcomes.

Recent economic perspectives converge on the notion of Total Economic Value (TEV). Figure 2-1 describes the application of the TEV framework to ES assessment[36]. The figure illustrates how use and non-use, material and intangible contributions of ES to human wellbeing may be incorporated in an economic assessment of ES.

Economic methods for ES evaluation [37] in monetary terms include:

- Market price approaches,
- Market cost approaches,
- Replacement costs approaches,
- Damage cost avoided approaches,
- Production function approaches,
- Revealed preference methods:
    - Travel cost method,
    - Hedonic pricing method,
- Stated preference methods:
    - Choice modelling,
    - Contingent valuation,
- Participatory approaches to valuation.

[34] Moores, J., Gadd, J., Yalden, S. and Batstone, C. (2016). Urban Development and the NPS-FM: Lucas Creek Catchment Case Study. MPI Technical Paper No: 2016/66. https://www.mpi.govt.nz/protection-and-response/environment-and-natural-resources/fresh-water/
[35] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
[36] TEEB. (2011). TEEB Manual for Cities: Ecosystem Services in Urban Management. www.teebweb.org
[37] Christie, M., Fazey, I., Cooper, R., Hyde, T., Deri, A., Hughes, L., Bush, G., Brander, L., Nahman, A., de Lange, W., Reyers, B., 2008. An Evaluation of Economic and Non-Economic Techniques for Assessing the Importance of Biodiversity to People in Developing Countries. Defra, London.

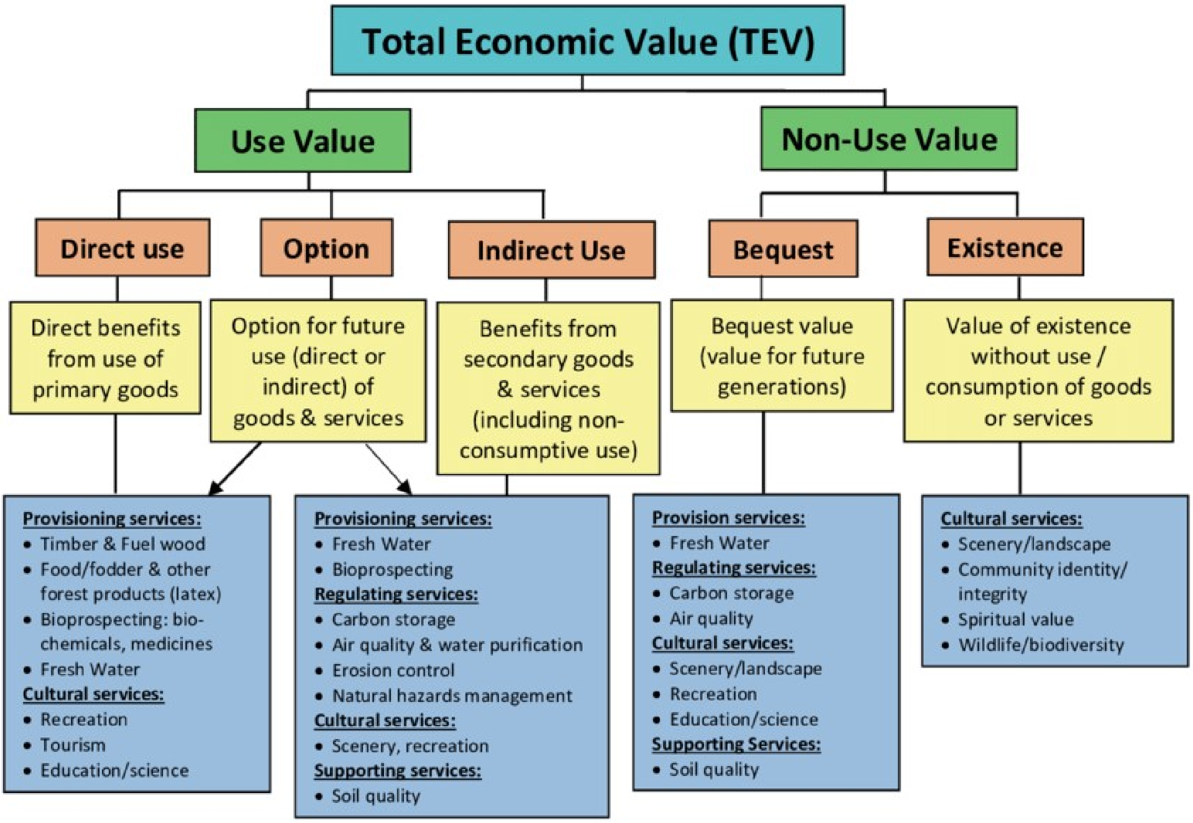

Figure 2-1 – Components of Total Economic Value (TEV) (source: TEEB, 2011).

Each method has strengths and weaknesses based on the type of value under consideration. Generally, preference is given to prices formed in markets that represent costs and benefits. However, markets do not exist for many of the components of TEV, so alternate survey-based methods that generate synthetic, inferred prices such as stated preference (choice experiments and contingent valuation) are used[38]. While there are other survey methods, such as travel cost, choice experiments are preferred to derive TEV estimates.

Such assessment methods require extensive and expensive data collection. Benefits Transfer is a practice used to estimate economic values for ES by transferring information available from studies already completed in one location or context to another. This can be done as a unit value transfer or a function transfer[39].

[38] Kaval and Baskaren (2013)[38] present a summary typology that matches ES valuation methods with specific ES, and the type of the value (use or non-use, direct or indirect). See Kaval, P. and Baskaran, R. 2013. Chapter 3 - Key ideas and concepts from economics for understanding the roles and value of ecosystem services. In the book: Ecosystem Services in Ecosystem Services in Agricultural and Urban Landscapes, authored/edited by Harpinder Sandhu, Steve Wratten, Ross Cullen and Robert Costanza.

[39] United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank, 2005, Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003, Studies in Methods, Series F, No.61, Rev.1, Glossary, United Nations, New York, para. 9.107

The most common assessment methods associated with benefits transfer are hedonic pricing (for example, spatial analysis of residential sales price data[40]), and stated preference methods (for example, choice experiments). The reliability of this practice is contingent on effectively matching the study site from which values are being transferred with the policy site (the site at which the assessment is being made) and the socioeconomic and cultural contexts of those sites[41].

The objective of monetized assessments of the benefits of changes to ES provision is to provide either indicators of the value to the economy of ES or, more contentiously, a metric for inclusion in cost benefit analysis (CBA). CBA is an economic and financial decision-making process that uses discounted cash flow methods to assesses the net present value of future flows of costs and benefits. Cost benefit analysis allows comparison of alternative projects, often across widely distributed domains (e.g. environment, health and defense), for example, in terms of return on investment (ROI).

Critiques of application of CBA to environmental decision making include: uncertainty around the quantum of monetized assessment of projected benefits or losses; the application of discount rates to costs and future benefits; and difficulties in identifying the portions of populations that have standing as beneficiaries. The number of households over which aggregation of the "per household" estimates to a population estimate is called the economic jurisdiction (Bateman et al., 2006[42]). It is the specification of the limit of the households to whom the benefits and losses associated with ecosystem services associated stormwater mitigation strategies accrue. The magnitude of the assumption about the extent of the economic jurisdiction associated with wellbeing effects of catchment development has a great influence on the final estimation of the monetised benefits / losses associated with development mitigation and development scenarios.

The uncertainty may arise from the use of assessment techniques including benefit transfer, the state of ecosystems and human populations and their preferences in the future, and whether the process of discounting those assessments to present values is appropriate.

Both international and local literatures provide examples of those critiques as they relate to ES. For example, Costanza et al., 2018[43] recognize that the assessment and valuation of ES is incomplete, concluding that, "the substantial contributions of ecosystem services to the sustainable wellbeing of humans and the rest of nature should be at the core of the fundamental change needed in economic theory and practice if we are to achieve a societal transformation to a sustainable and desirable future." In that view, current economic theory and the techniques that follow, for example, CBA, are not adequate to reliably assess ES and their flow on effects for humans. Locally, Murray (2013)[44]

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[40] See for example the use of residential sales price data to estimate the value of sunlight in NZ urban areas: Fleming, D., Grimes, A., Lebreton, L., Maré, D. and Nunns, P., 2018. Valuing sunshine. Regional Science and Urban Economics, 68, pp.268-276.

[41] For a NZ example consider Kerr and Sharp (2003). In that report the authors discuss the wide differences in outcomes of the same choice experiment assessing values associated with urban streams in Auckland, NZ undertaken at the same time over North Shore and Manukau City population samples. See Kerr, Geoffrey N., and Basil MH Sharp. 2003 Community mitigation preferences: a choice modelling study of Auckland streams. Lincoln University. Agribusiness and Economics Research Unit., 2003.

[42] Bateman, I. J., Day, B. H., Georgiou, S., & Lake, I. 2006. The aggregation of environmental benefit values: welfare measures, distance decay and total WTP. Ecological Economics, 60(2), 450-460.

[43] Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S. and Grasso, M., 2017. Twenty years of ecosystem services: how far have we come and how far do we still need to go? Ecosystem Services, 28, pp.1-16

[44] Murray, C (2013). An assessment of cost benefit analysis approaches to mangrove management. Auckland Council technical report, TR2013/006

argues that applying cost benefit analyses to ecological phenomena is inappropriate because of uncertainty and ensuing unreliability that accompanies monetized estimates of the worth of the outcomes, and the distortionary effect that discounting those outcomes, potentially across many human generations, creates.

Discount rates usually favour benefits that occur quickly (such as flood control and water supply), and underestimate those resulting from long term investments that may take decades to develop/reach maturity (such as large tree canopy, or waterbody rehabilitation). The practice of discounting future benefits occurs for two reasons. First, a dollar today is generally considered more valuable than a future dollar. Second, income and consumption now is favoured over that in the future (time preference, or impatience). Discounting has the effect of decreasing the value of benefits that occur in the future (e.g. the environmental domain) and disadvantaging future generations. The latter is especially relevant in public policy evaluation. Approaches to public policy-relevant social discount rates (SDR) have been developed that generally result in lower rates that decline over time. These give greater weight to the interests of future generations[45]. A recent survey of US economists favored SDR of the order of 2%[46]. The recovery of receiving waterbodies of urban stormwater contamination, especially sinks such as estuaries and lakes may be a generations long process.

Table 3-1 illustrates the importance of discount rate selection for analyses with long time horizons. The context is the selection of discount rate for the analysis of climate change mitigation strategies. The 1.4% and 2.7% figures arise from the UK's Stern Review[47]. The table presents the minimum return a $1 investment for the future should yield to be considered better than consuming the dollar now. The difference between the selection of discount rates is 1.89 over 50 years and 3.57 over 100 years.

Table 3-1 Influence of discount rate on estimates of future returns on investment of $1. Source: Fleurbaey and Zuber (2012)[48]

Horizon (years)	Discount rate = 1.4%	Discount rate = 2.7%	Ratio
50	$2.00	$3.79	1.89
100	$4.02	$14.36	3.57

In their discussion of long-term environmental policy analyses, the same authors[49] advocate a negative discount rate, a stance beyond low positive rates advocated by Stern. That recommendation is based on considerations that include: impartiality between generations; compatibility with ethical principles; and the opportunity costs of inadequate responses. Different sub-populations are impacted differently, and in the long run only the worst scenario for the worst-off portion of the population actually counts. Only a negative discount rate addresses those

45 Freeman, M.C. and Groom, B., 2016. How certain are we about the certainty-equivalent long term social discount rate?. Journal of Environmental Economics and Management, 79, pp.152-168;
46 Drupp, M., Freeman, M., Groom, B. and Nesje, F., 2015. Discounting disentangled: an expert survey on the determinants of the long-term social discount rate. Centre for Climate Change Economics and Policy Working Paper, 195.
47 Stern, N. and Stern, N.H., 2007. The economics of climate change: the Stern review. Cambridge University press.
48 Fleurbaey, M. and Zuber, S., 2012. Climate policies deserve a negative discount rate. Chi. J. Int'l L., 13, p.565.
49 Fleurbaey, M. and Zuber, S., 2015. Discounting, risk and inequality: A general approach. Journal of Public Economics, 128, pp.34-49.

considerations. While this debate continues, no mechanism and consensus for deriving negative discount rates has been established[50].

An alternative to CBA lies in cost effectiveness analysis (CE). In contrast to CBA where favored alternatives are established on the basis of competing return on investment outcomes, CE assesses the most cost-effective approach to achieve a selected outcome is derived from social processes such as collaborative governance and other participatory, often non-expert methods. While CE uses discounting to establish whole of lifecycle costs, benefits are not discounted.

While the TEV concept recognizes intangible values such as option and bequest values there are a range of values that are not explicitly considered. Foremost among these are cultural and non-material values. Kai et al. (2012)[51] note that while the monetary valuation of the material contributions of ecosystems to human well-being (use and option values) has been well advanced, important cultural[52] ES and non-material values may not be amenable to economic methods. Assessment of those social and cultural ES contributions focuses on three critiques of the economic approach:

- Non-material values are not amenable to reliable assessment using monetary methods[53];
- Making unambiguous linkages of changes in socioecological systems to changes in cultural and other benefits is difficult; and,
- Cultural and wider benefits may be associated with many services contemporaneously[54].

There are also other characteristics of ES[7] that present challenges for assessment, especially for social and cultural costs and benefits. These include:

- Multiple causality,
- Interdependence,
- Values pertaining to distribution and process-rights[55] and moral principles,
- Plural values[56],
- Incommensurable values – e.g. cultural identity and market values,
- Values held for or by collectives in contrast to individually held values,

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[50] Pindyck, R.S., 2019. The social cost of carbon revisited. Journal of Environmental Economics and Management, 94, pp.140-160.

[51] Kai M. A. Chan Anne D. Guerry Patricia Balvanera Sarah Klain Terre Satterfield Xavier Basurto Ann Bostrom Ratana Chuenpagdee Rachelle Gould Benjamin S. Halpern Neil Hannahs Jordan Levine Bryan Norton Mary Ruckelshaus Roly Russell Jordan Tam Ulalia Woodside, 2012, Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement, BioScience, Volume 62, Issue 8, 1 August 2012, Pages 744–756, https://doi.org/10.1525/bio.2012.62.8.7

[52] The non-material benefits people obtain from ecosystems are called 'cultural services'. They include aesthetic inspiration, cultural identity, sense of home, and spiritual experience related to the natural environment. In the NZ/Aotearoa instance, the term can be used both in conjunction with and separate from the use of the term "cultural" assigned to specifically Maori values.

[53] For example, "place attachment", defined as: feelings, moods and emotions that people experience in a variety of ways with reference to the paces they were, born, live and act. Giuliani, M.V., 2003. Theory of attachment and place attachment. na.

[54] Ibid

[55] Not all of the important values at stake are products of ES; some rights and moral principles pertain to the distribution of benefits and the process of management (e.g., equitable distribution of resources, restitution for past wrongs, the right to sovereignty over traditional territories (Kai et al., 2012).

[56] Most ES are valued for many kinds of reasons. To address these many values, one should employ a diversity of valuation approaches. Values should be represented in multiple formats, including influence diagrams, stories, and other visual and verbal summaries (Kai et al., 2012).

- Values embedded within worldviews at odds with nature as a service provider, and,
- Values that defy monetary valuation[57].

Non-economic methods (Christie et al., 2008) for evaluating human welfare effects of ES change include:

- Consultative methods:
    - Questionnaires,
    - In-depth interviews,
- Deliberative and participatory approaches:
    - Focus groups,
    - In-depth groups
    - Citizen juries
    - Health-based valuation approaches
    - Q-methodology[58]
    - Delphi surveys
    - Rapid rural appraisal
    - Participatory rural appraisal
    - Participatory action research
- Methods for reviewing information:
    - Systematic reviews.

The choice of economic and social methods for assessing ES outcomes of WSUD practices should consider strengths and weaknesses of each technique, or combination of techniques, with respect to method; practicality; epistemology; and policy. Methodological challenges include literacy and language barriers, lack of education and/or scientific knowledge, inappropriate, or lack of best practice guidelines. Practical challenges include lack of research capacity, difficulty expressing spiritual and cultural values and their nuances, and/or difficulty accessing marginal groups. Epistemological challenges include the validity of utilitiarian assumptions, social context and values. Policy challenges include awareness and/or commitment to the relevance of WSUD approaches and their outcomes[59].

Rather than framing the assessment of ES as a choice between economic and non-economic methods, blends of methods that complement and reinforce the strengths and weaknesses of each method may be more appropriate. This approach enables perspectives of multiple audiences to be addressed[60]. For example, monetized assessments, whether based in market transactions or survey methods, may be integrated in decision frameworks with qualitative, participatory and deliberative methods. The Aotearoa New Zealand context features varying examples of the span of these approaches, from technocentric, less consultative approaches to the collaborative methods that feature in Land and Water Forum[61] recommendations.

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[57] For example, in the Maori world view, the presence of an ancestral taniwha in a waterbody.
[58] Q Methodology provides a foundation for the systematic study of subjectivity. It is this feature which recommends it to persons interested in qualitative aspects of human behaviour. (Given, L.M. ed., 2008. The Sage encyclopedia of qualitative research methods. Sage publications)
[59] Christie, M., Fazey, I., Cooper, R., Hyde, T. and Kenter, J.O., 2012. An evaluation of monetary and non-monetary techniques for assessing the importance of biodiversity and ecosystem services to people in countries with developing economies. Ecological economics, 83, pp.67-78.
[60] Ibid
[61] http://www.landandwater.org.nz/

3.4 Assessment tools

This section summarises WSUD assessment tools developed in the UK and USA, and currently in development in Australia. Each of these tools provides a way of implementing components of the economic analyses described above, to enable benefit-cost comparisons of alternative projects and scenarios.

CIRIA B£ST

The UK's CIRIA has developed the Benefits of SuDs Tool (B£ST)[62] for qualifying and quantifying (monetizing) twenty types of benefits of WSUD projects. B£ST guides users through a structured assessment, beginning with an initial qualitative assessment to help users decide which benefits to value in detail. This screening assessment also identifies stakeholders for whom each benefit might be particularly relevant, enabling the tool's use to facilitate cross-sectoral support and funding. The tool also indicates where benefits may overlap so that care can be taken in recognizing the potential for double counting in the subsequent quantification of benefits.

In the next stage, B£ST provides monetized estimates of most (but not all) of the benefits of a project. Benefits are estimated as Net Present Value (NPV) using one of two approaches. The first is to apply NPV estimates of individual benefits from analyses conducted specifically for the project in question. Where these estimates are not available, B£ST uses benefit transfer to estimate NPV values from a 'values library' based on inputs provided by the user. For instance, water quality benefits are estimated from inputs such as the expected water quality improvement and length of river affected. A technical guide[63] available on the B£ST website explains the types of input information required.

Users of the tool can specify the confidence they have in relation to information inputs and calculation methods. This feeds into the estimation of confidence-adjusted results, specifically recognising the potential for benefits assessments to be highly uncertain. Similarly, the tool conducts sensitivity analyses, for instance examining the influence of adopting low, medium or high estimates from the values library. Benefits that are hard to quantify are excluded from the monetized estimate of benefits and can be summarized separately using a qualitative scoring approach[64].

B£ST compares results for alternative project scenarios using an ecosystem services or triple bottom line (TBL) framework. As well as showing how NPV estimates vary in relation to confidence and sensitivity analyses, the tool also shows the contribution that each benefit makes towards the total NPV estimate. This shows the ways in which a project might be expected to have greatest impact.

The developers of the tool emphasise that the monetary estimates provided by B£ST are best used for comparing project alternatives (including a do nothing baseline and/or business-as-usual scenarios), rather than being adopted as completely reliable absolute values. Guidance provided with the tool cautions that B£ST will not provide accurate estimates without significant local data collection and input. Users are also cautioned that B£ST is not a design tool for selecting GI devices, modelling their performance nor estimating their costs. While assessments of alternative scenarios

[62] https://www.susdrain.org/resources/best.html

[63] Horton, B., Digman, C.J., Ashley, R.M. and Gill, E. 2016. W045c BeST Technical Guidance, CIRIA RP993.

[64] For example, B£ST recognizes that a potentially large source of error in the monetization approach is in the area of intrinsic value. Valuation approaches are human centric, with the potential for understatement of intrinsic value considerations.

do consider costs, these are imported from external analyses rather than being calculated by the tool.

In summary, B£ST is designed to demonstrate the wide range of potential benefits of a WSUD project and the relevant magnitude of each benefit. The tool explicitly recognises the limitations of valuation approaches and is well supported by technical documentation to mitigate these aspects by providing a step-by-step guide to benefit assessment. Areas of significant uncertainty are revealed, enabling the need for further, more detailed and/or project-specific investigations to be identified. One aspect of particular relevance to the notion that WSUD/GI is about 'more than water' is the way B£ST identifies co-beneficiaries in and beyond the water sector. This gives users an early signal about other agencies that should be engaged in the planning (and potentially funding) of a WSUD project.

CRCWSC Benefit-Cost Analysis Tool

Researchers at the University of Western Australia are developing a benefit-cost analysis (BCA) tool[65] as part of the Australian CRCWSC's activities. A beta version of the tool is currently being tested by partnering organisations in Australia. While not yet available for review, the authors of this report were provided with an overview of the tool in a recent meeting hosted by the CRCWSC[66].

The BCA tool appears to have several similarities to the UK B£ST tool. It also provides a framework for capturing and aggregating estimates of a diverse range of benefits (over 20) and relies on established methods for monetizing benefits from contemporary economics research in the area of non-market valuation (NMV). Benefits are grouped into categories based on similarities in calculation methods. Data for benefit transfer is drawn from a library of relevant Australian valuation studies. Value estimates can also be imported from external project-specific analyses. The tool also enables unquantifiable benefits to be recorded in qualitative terms.

As with B£ST, the BCA tool conducts sensitivity analyses of benefit estimates by varying the underlying data between low and high values. However, this aspect of the BCA tool adopts a more sophisticated approach than B£ST, as it uses a Monte Carlo analysis (1000 simulations) of each scenario to generate results that present the benefits estimates in terms of likelihood. Other additional features of the BCA tool include consideration of project risks and negative benefits (e.g., impacts on housing affordability).

The developers of the BCA tool emphasise its potential for use in a range of applications. With plentiful data from relevant studies or project-specific analyses the tool can be used to provide a detailed benefit-cost analysis of project alternatives. Where specific data is absent, the tool can be used in an expert workshop setting, with specialists in WSUD and economics making informed judgements on the relevance and degree of confidence of data from other studies to arrive at a reasoned screening-level or comparative assessment of options.

US Green Values® National Stormwater Management Calculator

The CNT and USEPA have developed the web-based National Green Values® Calculator (GVC)[67] to compare the performance, costs and benefits of green infrastructure with that of conventional stormwater practices. The tool is designed to be used for project-scale (building or groups of

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[65] https://watersensitivecities.org.au/research/our-research-focus-2016-2021/integrated-research/irp2-wp3/

[66] Activating WSUD for Healthy, Resilient Communities Study trip to Melbourne, November 2018 – Findings. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0005/178682/Findings-of-Activating-WSUD-visit-to-Melbourne-Nov-2018.pdf

[67] http://greenvalues.cnt.org/national/calculator.php

buildings) analyses[68], with performance based on assessments of total annual runoff volume. Hydrological calculations are driven by user inputs relating to site characteristics, linked to a database of national rainfall characteristics. The tool calculates runoff under a conventional development scenario and then enables the user to evaluate runoff reductions under a range of GI configurations.

As well as these hydrological calculations, the GVC also differs from the tools described above in that it estimates GI costs for each scenario, rather than requiring these as inputs. Construction, annual maintenance and lifecycle costs are calculated from a look-up table of unit costs for land covers and GI devices.

The GVC provides information on 22 benefits, but the majority of these are covered by generic narrative statements, recognising there is insufficient information to quantify many GI benefits[69]. However, the tool does quantify six benefits based on benefit transfer from relevant studies: reduced air pollution, CO_2 sequestration, tree value, groundwater replenishment, reduced energy use and reduced stormwater treatment.

Results for runoff control and costs are presented as outcomes under conventional and GI scenarios. In contrast, benefits are only presented for the GI scenario, because these are understood to be the difference that GI makes, i.e. relative to the 'conventional' baseline. Use of the calculator to compare a range of GI scenarios would involve running each one independently and recording the performance, costs and benefits of each, relative to the 'conventional' baseline.

3.5 Discussion

Existing approaches to assessing the benefits of WSUD in NZ have tended to focus on water quantity and quality, using conventional hydrological approaches such as rainfall-runoff modelling. The only locally-developed tool we know of that has attempted to monetize benefits is the UPSW decision support system (see Section 3.2), which relies on benefit transfer from WTP studies for water quality improvements. No NZ tool has attempted to recognize or quantify the much wider range of water- and non-water-related benefits described in Section 2 of this report.

In contrast, the tools developed elsewhere, described above, provide for much broader recognition of the full benefits of WSUD and GI. While quantification of those benefits can be challenging, the three overseas tools reviewed at least provide a basis for demonstrating that these wide-ranging benefits exist. They also explicitly allow uncertainty in value of benefits to be assessed by providing for sensitivity analysis, estimating the likelihood of outcomes and allowing qualitative assessments of unquantifiable benefits. While aspects of the underlying economic methods may be subject to cautionary considerations, providing that limitations and caveats are explicitly expressed then these tools provide as sound a basis as any for assessing benefits. In particular, such tools provide a robust basis for comparing the relative value of benefits that may be derived from alternative WSUD scenarios and contrasting these with business-as-usual approaches.

Unfortunately, however, none of the tools above can simply be picked up and used in a New Zealand setting, because each has been developed using information from economic valuation studies specific to the country of development. Potentially, any one of these tools could be customized with New Zealand data, but such an exercise would currently be limited by the availability and

[68] An earlier version of the model (not linked to a national rainfall database) can be used for other settings: http://greenvalues.cnt.org/calculator/calculator.php.
[69] http://greenvalues.cnt.org/national/benefits_detail.php

applicability of data for benefit transfer[70]. Other challenges in the adoption of these tools include attitudes to the monetization of environmental outcomes, approaches to discounting and the general suitability of such methods for use in non-technical settings such as collaborative planning processes. Concerns over each of these matters have been raised in the NZ environmental management sector. None the less, the alternative of developing a NZ-focused quantitative assessment tool from scratch is limited by a lack of resourcing equivalent to that available to overseas developers. Customisation probably reflects a more cost-effective approach.

It may be possible to collaborate with CRCWSC to customize and apply the Australian BCA tool in a New Zealand context, once the current beta-testing and development stage is complete. Alternatively, a NZ application of the B£ST tool could be attempted: this has the advantage of already being available for use. In either case, any such customized tool would only suit applications in jurisdictions that are comfortable with the monetization approach.

In the shorter term there remains a need to provide a 'quick win' method by which practitioners can demonstrate and communicate the wide-ranging benefits of WSUD projects to decision-makers, communities and stakeholders. The Activating WSUD research team has addressed this need by developing a qualitative assessment method that is easy to use and provides graphic demonstration of the wide range of benefits that a project can deliver, and how these might vary under different scenarios. This method, the 'More Than Water' (MTW) assessment tool, and supporting information is available on the Activating WSUD website[71]. As well as benefits, the tool provides for assessments of the economic performance of WSUD projects, drawing on complementary research into aspects such as cost effectiveness and avoided costs of WSUD[72].

The continuing development of the MTW tool is also attempting to reflect Aotearoa New Zealand's cultural environment. Accordingly, the tool aspires to giving special recognition and provision to the values of Māori communities in the way in which benefits are described and assessed. Linking with complementary research to consider WSUD from the perspective of Te Ao Māori[73] is key towards pursuing this objective.

In concluding this section, we note the emergence of a growing body of research on the public health benefits of providing greener living environments. This is likely to provide a fruitful direction for the development of new assessment methods that better provide for a comprehensive assessment of the benefits of WSUD projects in New Zealand. The sources cited in the conclusion of this section and their contributing studies provide examples of combinations of methods: quantitative, qualitative, monetary and non-monetary.

In the area of community health and wellbeing there has been research reported[74] explicitly linking quantification of the scale of mitigation of mental and physical health conditions to urban design. Cox et al. (2018) describe a UK survey which showed statistically significant reductions in the incidence of patients reporting physical and mental health conditions associated with increased

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[70] Which leads to a recommendation (see Section 4) to conduct NZ-based valuation studies of WSUD benefits in order to assemble these data.

[71] https://www.landcareresearch.co.nz/science/living/cities,-settlements-and-communities/water-sensitive-urban-design/more-than-water-mtw-assessment-tool

[72] Ira, S. and Simcock, R. (2019) Understanding Costs and Maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

[73] Afoa, E. and Brockbank, T. (2019) Te Ao Māori & Water Sensitive Urban Design. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

[74] Cox, D.T., Shanahan, D.F., Hudson, H.L., Fuller, R.A. and Gaston, K.J., 2018. The impact of urbanisation on nature dose and the implications for human health. Landscape and Urban Planning, 179, pp.72-80

frequency and duration of "nature dose" in urban settings. This has particular relevance for the Aotearoa/NZ circumstance. A 2010 study by NZ Treasury[75] showed the direct and indirect cost of illness to the NZ economy through chronic illness of the order of 3.6 – 8.5% of GDP annually (between $5.4b – 12.8b)[76]. This astounding figure is generated through an estimated 1.3m of a total population of 4.8m being affected by chronic health disorders. Even if only a fraction of these costs could be avoided by the provision of greener, healthier living environments, then there appears to be a strong case for recognising and attempting to assess this co-benefit of WSUD/GI projects. Additionally, this line of reasoning supports a role for public health agencies as advocates and/or participants in the implementation of WSUD/GI in New Zealand urban areas.

It follows that there is a need to reposition WSUD in New Zealand in a way that fully reflects its potential to deliver a wide range of water-related and non-water-related benefits. Many of these benefits (deriving from use of plants, especially trees[77] [78]) are only likely to be delivered with multi-disciplinary input, specific design, effective maintenance and a responsiveness to multiple dimensions of community well-being. Some of the expertise required lies outside of the stormwater management sector, requiring collaboration with urban designers, ecologists, landscape architects and local community. The repositioning of WSUD should therefore aim to grow WSUD's reach and appeal, expand the community of practice and improve the delivery of multiple benefits, in order to activate the wider uptake of WSUD in New Zealand.

[75] Holt, H (2010) The Cost of Ill Health, NZ Treasury Working Paper 10/04.
[76] Direct costs are treatment costs, indirect costs are estimated on the basis of lost productivity to the workforce through absenteeism and fewer hours worked.
[77] The USDA Forest Service has developed an assessment tool – iTREE- to provide valuations and benefits assessments of urban trees: https://www.itreetools.org/about.php
[78] In the UK the tool CAVAT has been developed to provide valuations of urban trees which has been employed in legal proceedings. See Usborne, S., 2018, Treeconomics: How to put a fair price tag on urban forests, New Scientist Magazine, issue 3177.

4 Summary and recommendations

The potential water-related benefits of WSUD/GI, relative to conventional urban development approaches, are well documented. Typically, a successful WSUD project might be expected to deliver better hydrology, improved water quality and healthier aquatic ecosystems. While there remain evidence gaps on the delivery of these outcomes, especially in New Zealand, monitoring and modelling methods for their assessment are well developed.

However, assessments of the benefits of WSUD that focus solely on these water-related outcomes are incomplete. Through the principles of working with nature and employing green technologies, WSUD has the potential to deliver a wide range of additional co-benefits, over and above those relating to water. Some of these are other (non-water) environmental benefits: for instance, the preservation of natural soils, microclimate moderation and terrestrial habitat for native biodiversity provision. Others can be framed as social benefits, both water and non-water related. Water-related social benefits include the provision of supplementary water supplies and enhancement of opportunities for contact recreation. Non-water social benefits include public safety, property values and improved health and wellbeing deriving from the use of GI.

A number of tools developed overseas provide for assessments of the benefits of WSUD. Spreadsheet-based tools such as the UK B£ST and a benefit-cost tool under development in Australia draw on established methods from the field of resource economics to infer economic benefits associated with the GI's delivery of a wide range of water-related and co-benefits. Combined with information on infrastructure costs, these methods can be used in assessments of cost-benefit and cost-effectiveness of WSUD compared to conventional water management approaches. Both the UK B£ST and the Australian tool under development allow uncertainty in value of benefits to be assessed, while the UK tool also identifies potential beneficiaries beyond the water sector.

However, these tools are not readily applicable in New Zealand, for reasons that include uncertainty in benefit transfer from one jurisdiction to another and an aspiration to adopt assessment methods that explicitly recognise Māori values. There are also cautionary considerations around methods that generate monetized estimates of environmental values and their suitability for informing collaborative assessment and planning processes involving non-technical audiences.

Rather than focus on economic methods of benefit evaluation which remain under debate in the wider literature, and in recognition of the need to provide a 'quick win' method by which practitioners can demonstrate and communicate the wide-ranging benefits of WSUD, the Activating WSUD research team has developed a qualitative assessment method. This 'More Than Water' (MTW) assessment tool is described in a separate report available on the Activating WSUD website[79].

In conclusion, we suggest there is a need to reposition WSUD in New Zealand in a way that fully reflects its potential to deliver a wide range of water-related and non-water-related benefits. This is more than a re-branding exercise: it aims to grow WSUD's reach and appeal, resulting in an expanded community of practice and activating its uptake as an integral part of sustainability-driven future urban development in New Zealand.

We make the following recommendations for research to further develop methods for assessing the wide-ranging benefits of WSUD/GI:

[79] https://www.landcareresearch.co.nz/science/living/cities,-settlements-and-communities/water-sensitive-urban-design/more-than-water-mtw-assessment-tool

(1) The MTW tool should be promoted as part of the Activating WSUD Phase 3 dissemination workshops and its utility assessed by practitioners trialing the use of the tool in WSUD projects. Feedback from practitioners, for instance on the most challenging aspects of assessing benefits, should be considered in the setting of priorities for research to develop underlying assessment methods (including the research suggested in the following recommendations).

(2) Representatives of regional and local councils should be surveyed to investigate decision-makers' requirements and attitudes towards methods that involve the monetization of benefits.

(3) Comprehensive assessments should be made of the UK B£ST tool and the benefit-cost tool under development by the CRCWSC Australia for their potential application in New Zealand. This would involve exploring the scope of any customization needs, for instance: reviewing the availability of data from local studies (such as hedonic property price analyses) to construct NZ-specific valuation libraries; and engaging with NZ Treasury to ensure the validity of the underlying assumptions and methods adopted by these tools.

(4) Opportunities provided by WSUD projects should be taken to conduct benefits valuation studies, contributing to the development of an NZ database for use in benefits assessments (for instance by providing the customization data sought for recommendation (3)).

(5) The potential of public health economics to contribute to a more comprehensive assessment of the benefits of WSUD/GI (i.e. via its influence on the incidence of mental and chronic health conditions) should be further explored.

Appendix A – Benefits Assessment Resources

UK CIRIA B£ST tool

The home page for B£ST tool is at:

https://www.susdrain.org/resources/best.html

This contains links to several resources, including:

- a webinar video:

https://www.youtube.com/watch?v=pdDepFDusw4&list=PLinYZSz1gzVUz_W_6xkabZC_QESVbM6_t&index=4&t=0s

- a literature of GI benefits and assessment method:

https://www.susdrain.org/files/resources/ciria_guidance/ciria_rp993_literature_review_october_2013_.pdf

USEPA and CNT resources

The Green Values® national stormwater calculator is at:

http://greenvalues.cnt.org/national/calculator.php

The USEPA home page on benefits of GI is at:

https://www.epa.gov/green-infrastructure/benefits-green-infrastructure

This contains links to several resources, including:

- cost-benefit resources:

https://www.epa.gov/green-infrastructure/green-infrastructure-cost-benefit-resources

- the CNT guide for valuing GI:

http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf

- a literature review on the economics of LID:

https://s3-us-west-2.amazonaws.com/econw-publications/2007-Economics-of-Low-Impact-Development-Lit-Review.pdf

Australian CRCWSC Benefit-Cost Analysis (BCA) tool

The home page for the BCA tool is at:

https://watersensitivecities.org.au/research/our-research-focus-2016-2021/integrated-research/irp2-wp3/

A report that sets out the background to the methods used in the development of the tool is at:

https://watersensitivecities.org.au/wp-content/uploads/2016/06/TMR_A1-2_Ranking-Projects-for-WSC_web.pdf

A webinar video is at:

https://watersensitivecities.org.au/content/benefit-cost-analysis-of-water-sensitive-projects-and-policies-david-pannell/

Other relevant CRC documents include:

- A presentation on the economic evaluation of WSUD

https://watersensitivecities.org.au/wp-content/uploads/2016/12/IdeasforSA_EnhancingtheEconomic_WEB.pdf

- An information sheet on the economic evaluation of WSUD

https://watersensitivecities.org.au/wp-content/uploads/2016/05/FS_A1-2_ValuationEconomicSocialEcologicalCostsBenefitsWSC.pdf