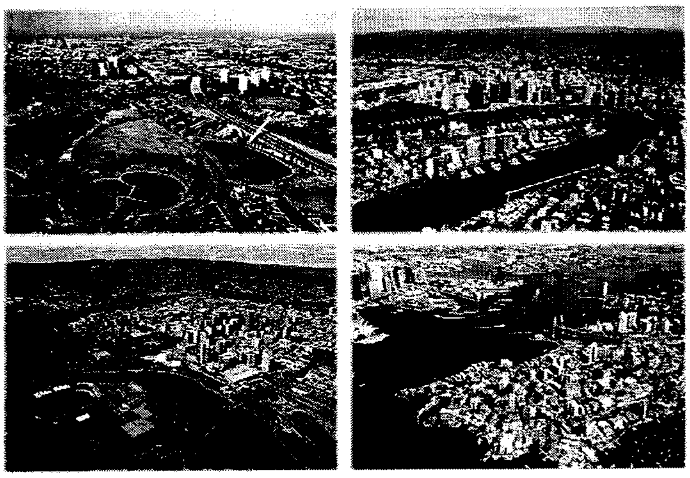
centre for water sensitive cities



Inquiry by the Productivity Commission

Australia's Urban Water Sector

January 2011

centre for water sensitive cities

About the Centre for Water Sensitive Cities

The Centre for Water Sensitive Cities at Monash University (www.watersensitivecities.org.au) was established in February 2010 under the auspices of the Monash Sustainability Institute. The Centre consolidates all of Monash University's research and development efforts in advancing water sensitive cities.

The Centre hosts a number of cross-faculty interdisciplinary research projects with a core vision to advance sustainable urban water practices through research excellence, engagement with practitioners, supporting the development of government policies, and the translation of research into practice.

The mission of the Centre is to undertake inter-disciplinary research to provide social and technical evidence for guiding the formulation of an overall policy blueprint for Water Sensitive Australian Cities.

Areas of research include Water Sensitive Urban Design and Planning Strategies for:

- Resilience to droughts and climate change through a diversity of water sources and enabling infrastructure
- Resilience to floods and sea level rise
- Climate adaptation through improved micro-climate, reduced urban heat island, associated health impacts
- Water conservation and behavioural change initiatives
- Liveable & affordable urban renewal/greenfield developments
- Industrial and commercial precincts around an urban metabolism framework of resource flow
- Nexus between local water recycling/stormwater harvesting and low carbon energy production
- Delivering Ecological Landscapes – healthy streams, flora and fauna bio-diversity, productive landscapes, carbon sink, micro-climate etc
- Building connected and sustainable communities
- Governance and socio-political arrangements for a water sensitive city

Contemporary research in integrated urban water cycle management has highlighted that a Water Sensitive City will involve significant departures from conventional urban water management approaches and that the transformation of cities will require a major socio-technical overhaul of conventional approaches. Three key principles set the foundation (pillars) for our blueprint for a Water Sensitive City:

- Cities as Water Supply Catchments: meaning access to water through a diversity of sources at a diversity of supply scales
- Cities Providing Ecosystem Services: meaning the built environment functions to supplement and support the function of the natural environment
- Cities Comprising Water Sensitive Communities: meaning socio-political capital for sustainability exists and citizens' decision-making and behaviour are water sensitive.

Led by foundation directors Professors Tony Wong, Ana Deletic, and Rebekah Brown, the Centre involves 45 researchers and PhD students from across a number of faculties in the University.

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Introduction

This submission to the Productivity Commission is in response to the Commission's invitation to all interested organisation to participate in the public inquiry into the case for microeconomic reform in Australia's urban water sector requested by the Australian Government. Over the past few decades, Monash University has established itself as a centre of excellence for research into the sustainable management of water resources and urban sustainability. The Centre for Water Sensitive Cities at Monash University consolidates all of Monash University's research and development efforts in advancing water sensitive cities. It is from this perspective that we believe we can make salient, informed comments on delivering urban water services options that will offer the most sustainable and effective outcomes, including improving the long term resiliency and liveability of Australian cities, towns and regional centres/villages.

The Productivity Commission Issues Paper defines the Urban Water Sector as covering *the supply and consumption of water in cities, towns and regional centres that have reticulated water supply provided by a water supplier, as well as the treatment and disposal of wastewater.* The inquiry terms of reference nevertheless require the Commission to have regard to emerging water management practices, particularly in relation to Integrated Water Cycle Management (IWCM) and the notion of '*water sensitive cities*'.

It is Centre's view that there are benefits from providing urban water services from a whole-of-water cycle basis that integrates the three basic urban water services of water supply, sewerage and drainage. Many of these benefits are either intangibles, cut across sectoral and institutional boundaries, or have not been identified and monetised within the current economic efficiency assessment framework, and therefore remain as externalities to current decision framework for investment in Australia's urban water sector.

Challenges facing Cities of the Future

Urban environments have become a critical focal point for Ecologically Sustainable Development (ESD) practices with the world's urban population having now surpassed the population living in rural environments. Future visions for urbanisation and urban renewal encompassing land uses, population densities, mobility, urban composition and built form must be put forward in terms of good health, social equity and inclusion, lower energy consumption and production, water efficiency and, adaption and flexibility of all aspects of our environment.

Successful urban communities are extremely complex socio-physical systems that are interactive and constantly evolving. The quality of the built, social and natural environments within a city is the result of complex interactions between the quality of the natural and built environments, the social and institutional capital, and the natural resources that support a city. The ability of a city to meet current and emerging challenges in relation to achieving a harmonious interplay of the built, social and natural environments is closely linked to the resulting strength of the urban economy.

Fundamental to the economy of the city is the people, the ingredient and engine of growth and productivity. The 'creative capital theory' (Florida, 2005)[1] postulates that economic growth is determined by the locational choices of the 'holders' of creative capital. Lifestyle options are also cited as a driving force in location choice.

Designing cities[2] for resilience to the impacts of climate change, particularly ensuring secure water supplies and the protection of water environments, is an emerging challenge as growing urban communities seek to minimise their impact on already stressed water resources.

The way we manage urban water influences almost every aspect of our urban environment and quality of life. Beyond the apparent water economy of water demands and consumption, there is a 'hidden' water economy that is inextricably linked to the economy of the city in areas as diverse as public health and wellbeing, productive urban landscapes, climate responsive urban design, carbon footprints and energy efficiencies.

[1] Florida, R (2005), Cities and the Creative Class, Routledge, ISBN 0-415-94886-8, 2005
[2] The term 'cities' used here to encompass cities, towns and regional centres/villages

Water Sensitive Urban Design: An emerging urban water management practice

The term Water Sensitive Urban Design (WSUD) is commonly used to reflect a new paradigm in the planning and design of urban environments that is 'sensitive' to the issues of water sustainability and environment protection. WSUD, ESD and IWCM are intrinsically linked.

The Australian governmental agreement of the National Water Initiative (COAG, 2004)[3] defines WSUD as "*the integration of urban planning with the management, protection and conservation of the urban water cycle that ensures that urban water management is sensitive to natural hydrological and ecological processes*".

Wong and Ashley (2006)[4] consider WSUD as comprising two parts, i.e. 'Water Sensitive' and 'Urban Design'. Urban Design is a well recognised field associated with the planning and architectural design of urban environments and is the integrative discipline that brings 'sensitivity to water' and ensures that water is given due prominence within the urban design processes. The words "Water Sensitive" define a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of urban water services including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore urban water management practices. Collectively WSUD integrates the social and physical sciences.

> Best-practice urban water management, is widely acknowledged as complex, because it requires urban water planning to protect, maintain and enhance the multiple benefits and services of the total urban water cycle that are highly valued by society. The practice of Water Sensitive Urban Design is the integrative process and Water Sensitive Cities are the outcome.

Part of the complexity of realising best-practice in urban water management is the need for identifying and employing approaches that protect and enhance the multiple and interdependent benefits and services. In the past, water managers have often reduced this complexity by focussing on optimising singular parts of the water cycle such as 'supply security' in isolation and/or in absence of reliable consideration to the other dimensions of the urban water cycle. This often results in outcomes that compromise a significant proportion of the multiple objectives of best-practice urban water management, including the numerous well known social, ecological and economic costs, which overall increases the vulnerability of Australian cities.

> Water supply solutions that best protect and enhance full suite of values and benefits from a total water cycle perspective are likely to result in more resilient solutions over the long-term.

Contemporary research in integrated urban water cycle management has highlighted that establishing and supporting a Water Sensitive City will involve significant departures from conventional urban water management approaches and that the transformation of cities will require a major socio-technical overhaul of conventional approaches.

> A major focus is attaining a future water sensitive city is to commence the transition towards integrated water management systems that are substantially different to the water management regimes that are employed by Australian cities.

[3] Council of Australian Governments (COAG) (2004). Intergovernmental Agreement on a National Water Initiative. Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the Australian Capital Territory and the Northern Territory, signed 25 June 2004. Available at: http://www.coag.gov.au/meetings/250604/iga_national_water_initiative.pdf.

[4] Wong, T.H.F and Ashley, R. (2006). International Working Group on Water Sensitive Urban Design, submission to the IWA/IAHR Joint Committee on Urban Drainage, March 2006

Linking Liveability to Urban Water Management

Beyond the basics of water supply and sewerage, water is an essential element of place making, both from maintaining/enhancing the environmental values of surrounding waterways to the amenity and cultural connection of places. There are at least three frameworks[5] is assessing the liveability of cities and each one of them include as criteria (i) the environmental and recreational eco-ranking based on water availability and drinkability; (ii) waste removal; (iii) the quality of sewage systems; (iv) air pollution; (v) the quality of architecture; (vi) access to nature; and (vii) urban design.

The nexus between sustainable urban water management and the vitality and prosperity of urban environments is only beginning to be recognised and they include:-

(i) Access to secured and clean water supply – the Intergovernmental Panel on Climate Change (IPCC) reports have clearly highlighted through the comparison of climatic predictions of a number of global climate change models that, with the exception of temperature, predictions of future trends in climatic conditions remains highly uncertain. This is particularly the case with seasonal rainfall predictions. With future climatic uncertainties, it is imperative that future liveable cities would secure its water supply through investment in a diversity of water sources underpinned by a range of centralised and decentralised infrastructure. A strategy is required to provide cities with the flexibility to access a 'portfolio' of water sources at optimal value and with least impact on rural and environmental water needs.

(ii) Clean water environment – the value of healthy and functioning environments to communities is reflected in the efforts taken to protect these qualities. The ecological health of Port Phillip Bay in Melbourne was a key driver for policies and action plans directed at nutrient reduction in sewage treatment plant effluent and urban stormwater discharge to the bay. Similar actions for the protection of Moreton Bay in Brisbane were also instigated. Urban waterways in a water sensitive city are valued as an integral part of a city, and its ecological integrity actively protected with the underpinning knowledge that healthy ecosystems and waterways provide important ecosystem services that mitigate the impact of the city on environmental values of aquatic systems within and downstream of the city, and in many aspects also make a city more liveable.

(iii) Flood protection – in addition to increased flood vulnerability of future coastal cities associated with rising sea levels, future climatic scenarios predicts higher climate variability including more intense storms. Future cities would incorporate into its planning and design appropriate land uses in accordance to the three-tiered approach of retreat, adapt and defend against future flood vulnerability. In addition to increased flood risk associated with sea level rises, conventional urban development and associated drainage design can often cause its own increase in downstream flooding risk. A water sensitive city would establish a network of open spaces and green corridors with the capacity to serve as an integral element of the city's drainage infrastructure and floodway for flood conveyance during rare (low probability) storm occurrences. These floodway and designated flood inundation spaces could also serve as terrestrial and aquatic wildlife corridors to promote flora and fauna diversity, and/or productive landscapes as described in (vi) and (vii).

(iv) Green infrastructure – urban design approaches that strive to describe parklands, green waterways, structures and buildings as 'green infrastructure' to emphasise the important role that vegetation plays in urban environments. Access to alternative fit-for-purpose water sources provides an additional and abundant source of water to support the greening of cities. Green infrastructure supported by such design principles of keeping water in the landscapes and promoting lush and well-irrigated vegetation can provide microclimate benefits by reducing excess urban heating (through shading, and cooling by evapotranspiration) as described in (v).

(v) Climate-responsive designs – mitigating urban heat will have a positive effect on human health. Such designs would place particular emphasis on the strategic implementation of WSUD technologies and green infrastructure. Heat-health outcomes (e.g. mortality and morbidity) result from the combined effects of exposure, adaptability, and vulnerability. Use of well-irrigated green landscapes that are spatially distributed, and also vertically in buildings,

[5] (i) the Mercer Quality of Living Survey; (ii) the Economist's World's Most Liveable Cities (using data from Mercer as well); and (iii) the lifestyle magazine Monocle annual list of liveable cities

has the potential to limit human exposure to extreme heat. These green landscapes may also be productive landscapes as discussed in (vi).

(vi) Productive landscapes – one of the emerging global challenges is that of preserving productive landscapes and improving food productivity. In offsetting loss of arable land to urbanisation, there are emerging design concepts that exploits the nexus between water recycling/stormwater harvesting and local food production. The concept of urban green landscapes that are also productive (e.g. orchards, community gardens etc.) and supported by local recycling of wastewater and/or stormwater is now emerging as an integral element of sustainable urban design concepts for future cities.

(vii) The quality of public spaces – urban water systems could be designed in urban environments to incorporate means of enhancing social engagement and cultural expression. This may include the celebration of water in urban environments with art features that respond to water availability and seasonality, and the establishment of biodiversity terrestrial and aquatic corridors.

Water plays many critical roles in supporting a range of features of cities that can contribute to liveability and, consequently, to the economy of cities. Many of these valuable roles of water are outside of current water management systems.

An illustration of the many water sensitive urban design elements in redeveloping a flood affected allotment. [Source: Brisbane City Council]

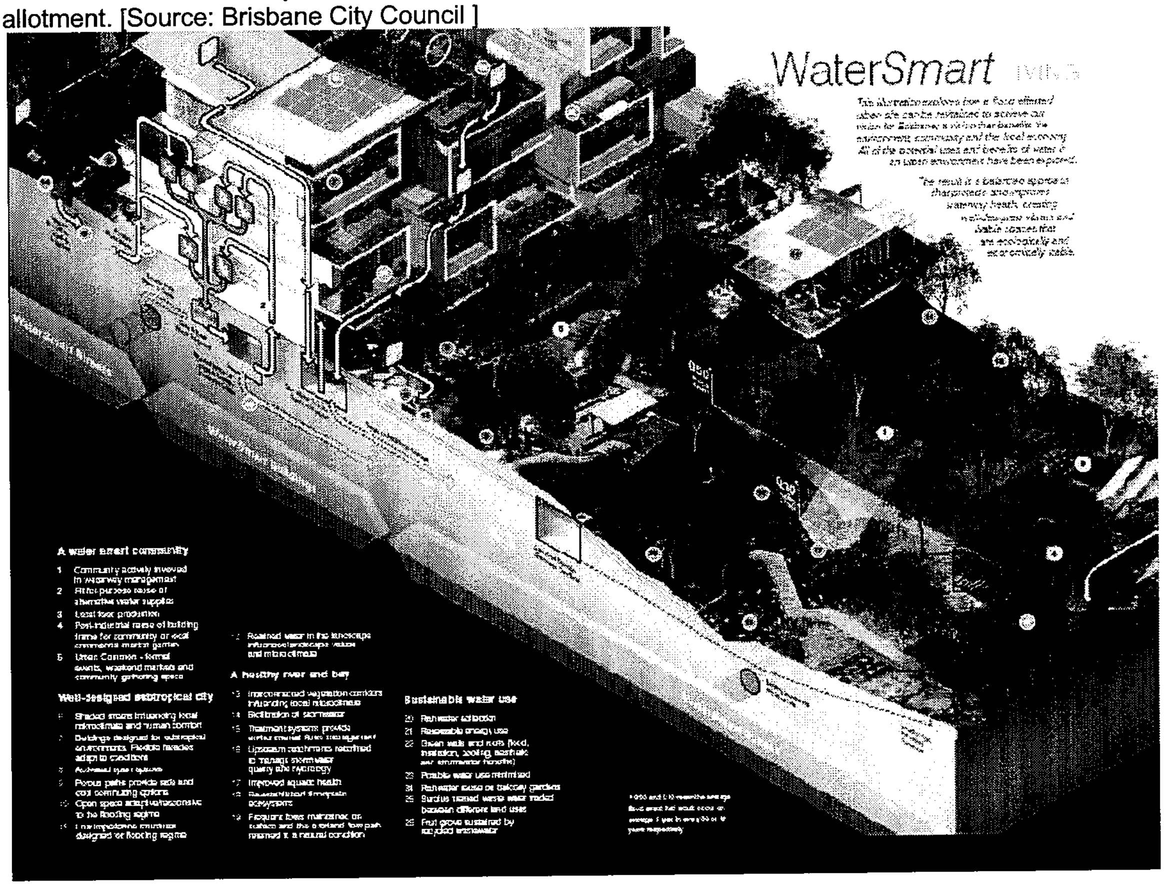

Figure 1. An illustration of the many water sensitive urban design elements in redeveloping a flood affected allotment. [Source: Brisbane City Council[6]]

[6] Brisbane City Council (2010), Watersmart City Strategy.

Achieving long term water security: A portfolio approach to a diversity of water sources

Like many cities worldwide, the majority of Australian cities are almost exclusively dependent on water resources derived from capture of rainfall-runoff from largely rural or forested catchments. Communities are increasingly susceptible to the impacts of increasing temperatures and soil moisture deficit in water supply catchments, climate variability, drought and climate change. Continuing the conventional approach of 'building another dam' is often not the most effective option. Although in many regions of Australia, the effect of climate change on rainfall is very uncertain and may not necessarily lead to any consistent trend of reduced rainfall, there is a higher certainty that climate change will increase global temperature and its corresponding effect on soil moisture deficit in water supply catchments (i.e. a drier catchment). This would consequently reduce catchment runoff during storm events and thus the water yield of the catchment.

Future cities should reduce its vulnerability to favourable soil moisture conditions to secure its water supply through accessing a range of alternative water sources.

Australian cities can have access to a diverse range of water sources in addition to capturing rainfall-runoff from rural and forested catchments. These alternative water sources for cities include groundwater, urban stormwater (urban catchment runoff), rainwater (roof runoff), recycled wastewater and desalinated water. Many of these sources are within city boundaries.

As highlighted by the Prime Minister's Science and Engineering and Innovation Council Working Group in Australia (PMSEIC, 2007)[7]:

> *"Water supplies to Australia's cities need to move from reliance of traditional sources to an efficient portfolio of water sources which can provide security through diversity. Like a share portfolio, flexible and cost effective access will be underpinned by diversity, including centralised and decentralised infrastructure. Like a share portfolio, the composition of water source portfolios also needs to reassessed as new information on costs, prices, climate, environmental objectives and impacts, and risks becomes available".*

A strategy built around a diversity of water sources and a diversity of water infrastructure will allow cities the flexibility to access a 'portfolio' of water sources at optimal value and with least impact on rural and environmental water needs.

A clear distinction is made in referring to optimal value rather than adopting the conventional approach of least cost. As outlined in the report by PMSEIC (2007)[7], "*there is a wide range of costs and impacts for any individual option and these overlap across the options*" as shown in Figure 2. However, the inherent values of accessing many of the water sources are not well documented.

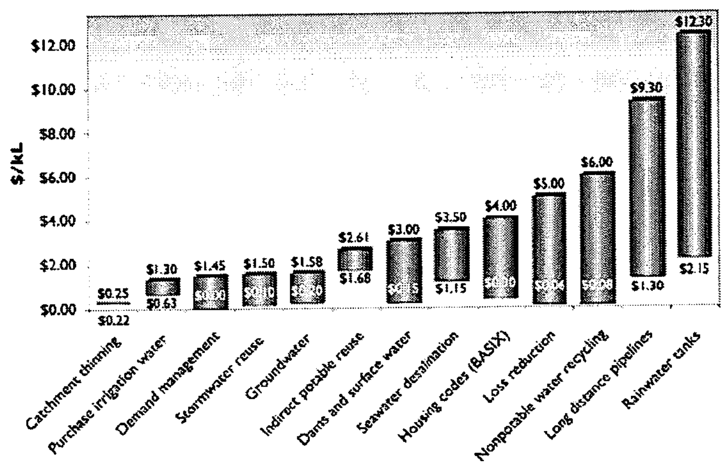

Figure 2. Direct cost of water supply/demand management options[8] (source: PMSEIC, 2007)

[7] Prime Minister Science Engineering and Innovation Council Working Group (PMSEIC) (2007), Water for Our Cities: building resilience in a climate of uncertainty, a Report of the PMSEIC Working Group, June 2007. [http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/water_for_our_cities.htm]

Each of the alternative water sources shown in Figure 2 have unique reliability, environmental risk and cost profiles which are site specific, with the tendency for sources of high reliability to also have associated high cost and environmental risk profiles and vice versa. In a future water sensitive city, access to these alternative sources will be optimised dynamically (even on a short term basis) through the availability of diverse centralised and decentralised infrastructures associated with the collection, treatment, storage and delivery of the water sources. The diverse schemes would include elements, ranging from the simple rainwater tank for non-potable use to city-scale indirect potable reuse schemes and the 'pipeline grid' linking regional reservoirs. Optimisation will ensure preferential access of sources of high value, low cost and environmental risk ahead of options with higher cost and environmental risk.

An important component underpinning a diversity of infrastructure is the secondary supply pipeline for non-potable water (sometimes referred to as the third pipe system or dual supply). Water delivered via a secondary supply system provides a sound basis for promoting a 'fit-for-purpose' approach to water use. Non-potable water from a variety of local sources (e.g. stormwater, groundwater, recycled wastewater) can replace the use of potable water for such uses as toilet flushing, laundry, garden watering and open space irrigation. Figure 3 shows alternative sources of water with their uses guided by a "fit-for-purpose" approach to the use of different water sources and associated quality.

At a building scale or precinct scale, the nexus of local greywater/blackwater treatment, recycled water for non-potable uses and productive landscapes are emerging sustainable urban design concepts.

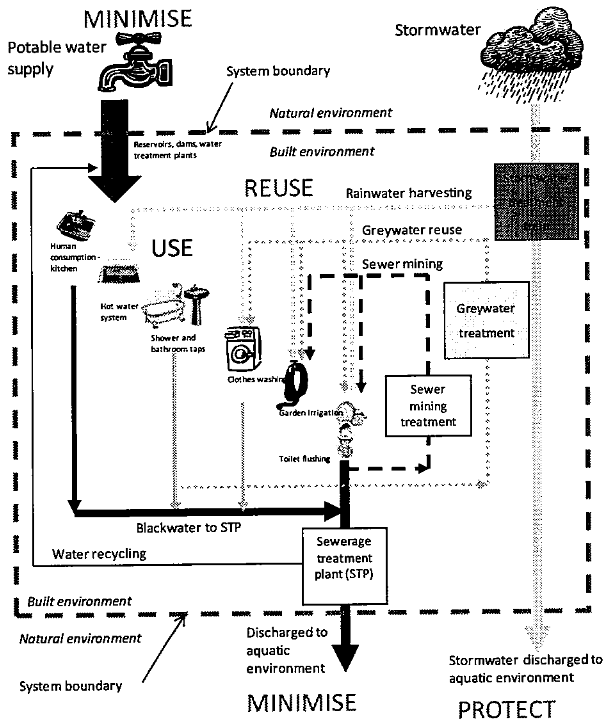

Figure 3. Schematic illustration of alternative sources of water with an emphasis of minimising import of potable (mains) water to, and export of wastewater and stormwater from, the built environment [adapted from Ecological Engineering, 2005[9]]

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[8] Data based on Marsden Jacob Associates analysis of water supply plans for Sydney, Adelaide, Perth, Newcastle (Originally produced for Marsden Jacob Associates, 2006, Securing Australia's Urban Water Supplies: Opportunities and Impediments, paper prepared for Department of the Prime Minister and Cabinet, and recent NSW Treasury cost estimates. Lower bound of indirect potable reuse estimate based on Toowoomba. Figures for rainwater tanks based on Marsden Jacob Associates (2007). The cost-effectiveness of rainwater tanks in urban Australia, paper prepared for National Water Commission, 22 February 2007) Note: Comparable costings for Melbourne are not available and no costings are available for Queensland.

[9] Ecological Engineering (2005). Wastewater Reuse in the Urban Environment: Selection of Technologies, report prepared for Landcom, NSW, Australia.

Recent studies examining the opportunities presented through increased urban densities for cost-effective decentralised fit-for-purpose provision of urban water services have highlighted a number of economic advantages. These are derived from (i) deferred augmentation of existing centralised water infrastructure (e.g. desalination plants); and (ii) significant reduction in the carbon footprints associated with water supply, hot water and sewerage services, and their nexus with precinct-scale electricity generation.

Building a diversity of infrastructure throughout a built-up area takes time and therefore does not address the immediate short-term water crises facing many Australian cities prior to the recent wet conditions. Governments have focussed on large centralised infrastructure such as desalination plants, indirect potable substitution scheme (i.e. treated recycled water returned to water supply storages) to address the short-term requirement. These schemes are important elements of a diverse water portfolio but governments should not overlook the importance of building the diversity of sources in concert with the centralised schemes being implemented.

Notwithstanding the many advantages of rainfall-independent water sources attained through desalination plants, there remain a number of concerns about the environmental, social and economic costs of water desalination and efforts need to be directed at ensuring that they are not adopted as 'silver-bullets' that would eliminate the need to further investigate and develop other options of higher value, and of lower economic and environmental costs as part of a portfolio approach to enhance supply resilience into the future.

Stormwater as a Valuable Resource

Stormwater is a large but almost entirely untapped water source and is considered a highly valuable resource beyond that of simply an undifferentiated commodity. It has the highest potential for achieving the many benefits associated with improved liveability of cities outlined earlier in this submission.

Measuring the full impact of any investment option in harnessing the potential of urban stormwater in any given context requires a shift to value-based decision making across both space and time so that the full spectrum of costs and benefits, including the flexibility and resilience of systems, can be taken into account.

Stormwater runoff is generated across distributed areas and therefore distributed stormwater infrastructure typically provide the best opportunities to capture and use urban stormwater, and to establishment ecological landscapes that provide a range of ecosystem services to the built and natural environment and to improve the liveability of a city. Innovative built form and open space design incorporating ecological landscapes provides green infrastructure to support future cities.

Stormwater as a precious resource at a diversity of supply scales

The policies and principles delineated in the *National Water Quality Management Strategy* (NWQMS)[10] provide the reference in Australia for recycling water from different sources, i.e. sewage, grey water and stormwater. However, the goals outlined in national guidelines relate to best practice and are not enforced by the Australian Government.

Stormwater is at present mainly used for non-potable end uses, with irrigation being the most widely practiced. However, there are now examples of stormwater being used for potable water augmentation; the stormwater harvesting scheme of Orange, NSW, is the only operating system in Australia that is using stormwater for potable uses in indirect ways. There are no high profile international best-practice examples for stormwater harvesting, except in Singapore. Other nations have not considered stormwater for substituting or augmenting drinking water sources within their regulatory framework so far.

Costs of stormwater harvesting systems, based on analysing 15 Australian systems undertaken by the Centre[11], are found to be as follows:

- Production costs based on traditional Life Cycle Costing vary from 0.26 to 7.05 $/kL, with a median of 2.17 $/kL. Almost 50% of all examined schemes were delivering water under the current price of the local mains water;
- The larger the schemes, the lower the production costs (this finding may be highly influenced by projects associated with the use of Aquifer and Storage & Recovery as the storage method in large systems);
- Community costs based on incorporation of potable water savings and nitrogen removal savings vary between -1.06 to 5.2 $/kL with a median of 1.04 $/kL. The negative costs, found for 1/3 of all systems, mean that stormwater harvesting schemes are making a profit for the community by achieving two objectives at the same time.

[10] NRMMC (2009) Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse. Canberra, Australia. National Resource Management Ministerial Council, Environment Protection and Heritage Council, and National Health and Medical Research Council - National Water Quality Management Strategy, Document 23.
NRMMC-EPHC-AHMC (2007) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks. Phase 2A. Augmentation of Drinking Water Supplies. Draft for Public Comment July 2007
NRMMC-EPHC-AHMC (2008) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2): Stormwater Harvesting and Reuse. Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, National Health and Medical Research Council.
NHMRC and NRMMC (National Health and Medical Research Council and Natural Resource Management Ministerial Council) (2004) Australian Drinking Water Guidelines, NHRMC and NRMMC, Canberra. http://www.nhmrc.giv.au/publications/_files/adwg_11_06.pdf
NRMMC, NHMRC, EPHC (2008) Draft Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse Canberra, Australia. National Resource Management Ministerial Council, Environment Protection and Heritage Council, and National Health and Medical Research Council - National Water Quality Management Strategy.
[11] Cities as Water Supply Catchment Research Program (2010), Literature and Practice Review, Centre for Water Sensitive Cities.

Currently, uncertainty on health risks is serving as a barrier to development of stormwater systems as health regulators take a risk-adverse approach to their approval. There are a number of immediate research needs to aid in better formulating regulations for stormwater harvesting for non-potable and potable uses. In the first instance it is necessary to enhance the available database on the characterisation of stormwater as a source, focusing on chemicals and pathogens, to enable accurate health risk assessments and narrow the gap between perceived and measured risks. In particular, health-based regulations addressing chemical risks are required.

A research priority is the identification of chemical risks, how to relate them to 'catchment risk factors' (potential hazards) and the establishment of screening tools that can enable identifying groups of chemical contaminants. At the same time it is necessary to identify individual or groups of chemical contaminants of concern for stormwater, taking into account available dose-response data and observed concentrations, and ultimately quantifying the human health risk for different exposure scenarios.

Stormwater harvesting to protect urban streams

The hydrology of urban waterways is substantially different from that of rural waterways. Many of Australian rural waterways are significantly degraded by excessive upstream water extractions. Significant changes to the hydrology of rural waterways often occur, especially when these waterways are being used to convey irrigation water, leading to high flow conditions during the dry season (where water is released from storages for irrigation) and the reverse in the wet season (where catchment rainfall-runoff is stored).

Urban stormwater is the runoff that comes from impervious areas (roads, roofs, footpaths, carparks, etc.) and is the main source of water in urban waterways. This water flows rapidly into urban waterways, causing erosion, pollution and potentially flooding. Prior to urbanisation, most rainfall would infiltrate into the soil, with the vast majority (typically 80-95%) being evapotranspired back into the atmosphere. However, with reduced evapotranspiration and infiltration in developed urban areas, the resulting annual runoff volumes are therefore typically 5 to 10 times the pre-development runoff volumes. In this way, urban streams have an environmental flow problem which is the inverse of rural streams; they suffer from total flow volumes that are far greater than natural. For example, Figure 4 shows that the excess runoff, which is a result of building Melbourne metropolitan area, exceeds the total annual water demand of the city. The same pattern exists for virtually every city – large and small – in Australia.

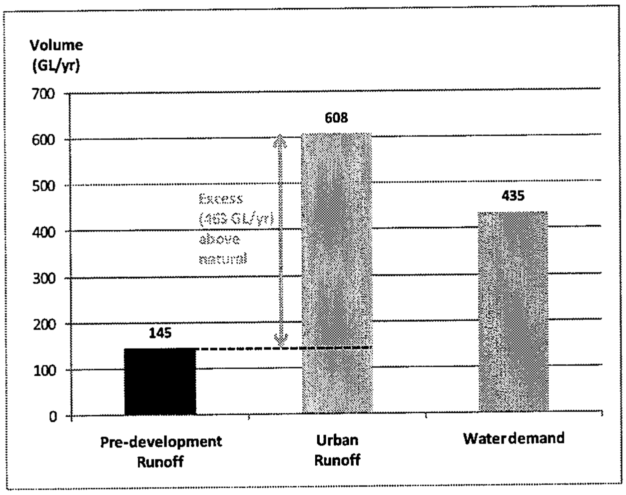

Figure 4. Comparison of runoff volumes from the Melbourne metropolitan area prior to and after urbanisation. The excess stormwater runoff of 463 GL damages waterways, but represents a major alternative water resource (adapted from www.urbanstreams.net/Rpad/melbrunoff.html).

So, whilst Australian cities have suffered severe shortages of drinking water over the last decade, there is actually a substantial excess of stormwater flowing through our cities every year, causing environmental damage. It is the excess that should be kept out of creeks and streams if their important ecological values are to be maintained as it is well documented that uncontrolled stormwater runoff from urban areas degrades creeks and waterways (e.g. Walsh *et al*, 2004)[12].

Improved urban waterway health

Treatment and harvesting of urban stormwater leads to positive management of the water quality and natural hydrology of urban creeks and waterways to improve waterway ecosystem health (Fletcher *et al.*, 2007)[13]. Stormwater treatment through WSUD elements for improved water quality is becoming mainstreamed in many cities in Australia through development conditions imposed as part of the planning approval process (e.g. the Victorian Planning Provisions, Clause 56). It has been estimated that in the next 5 years, WSUD will deliver a community water quality benefit of over $56M by reduction of pollution to the receiving waters (e.g. Port Phillip Bay).

However, stormwater harvesting remains optional and urban streams continue suffer from too much flow, with almost all of it delivered in short, sharp pulses. It has been estimated that stormwater harvesting schemes and associated stormwater detention and treatment elements, if applied to greenfield developments in Melbourne, would protect 6.5 km of waterways over the next 5 years, amounting to approximately $120M of avoided maintenance costs on these waterways.

Urban stormwater harvesting therefore represents a rare opportunity to provide a major new water source for use by cities, while helping to protect valuable waterways from excessive pollution and ecosystem degradation.

Improving liveability through green infrastructure

Harvesting urban stormwater can do more for cities than protect its waterways and provide inhabitants with a new water resource.

Stormwater harvesting provides an additional and abundant source of water to support the greening of cities. These green infrastructure and productive landscape provide benefits in creating more liveable and resilient urban environments. For effective realisation of the above multiple beneficial outcomes, it is critical that the green infrastructure be distributed throughout the urban area; end-of-pipe systems will have only local impacts.

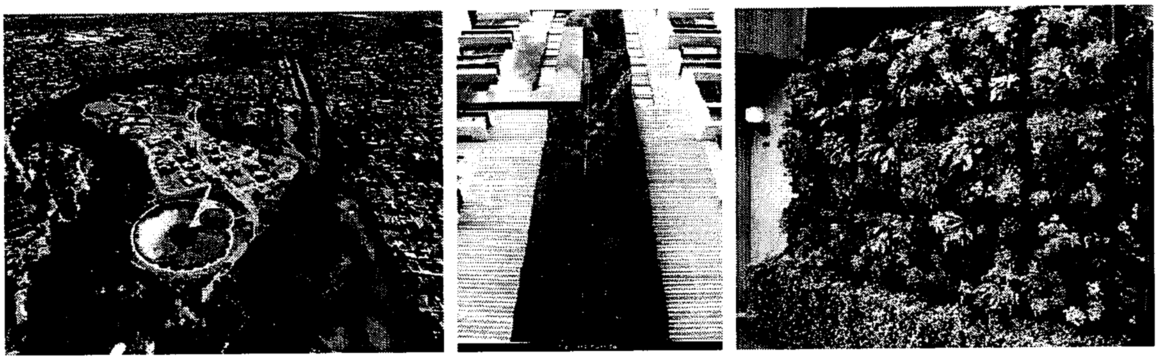

Figure 5. Green urban landscapes: important features of a Water Sensitive City, serving the needs of humans and ecosystems. *left:* Lochiel Park, Adelaide, Australia (Source: LMC, 2009)[14] - *middle:* Trio building, Sydney, Australia (Source: Blanc, 2010)[15] - *right:* ACROS Fukuoka Prefectural International Hall, Fukuoka, Japan (Source: Balzano, 2010)[16]

[12] Walsh, C. J., Leonard, A., Fletcher, T. D. & Ladson, A. R. (2004) Decision-support framework for urban stormwater management to protect the ecological health of receiving waters. Sydney, Australia, Water Studies Centre, CRC for Freshwater Ecology, Institute for Sustainable Water Resources (Dept. of Civil Engineering) and CRC for Catchment Hydrology, for the NSW Environment Protection Authority.
[13] Fletcher, T. D., Mitchell, G., Deletic, A., Ladson, A. & Seven, A. (2007) Is stormwater harvesting beneficial to urban waterway environmental flows? Water Science and Technology, 55, 265-272.
[14] Land Management Corporation of South Australia (2009) Lochiel Park Urban Design Guidelines. Land Management Corporation.
[15] Blanc, P. (2010). Vertical Garden - From Nature to Cities [Online]. Murvegetalpatrickblack.com. Available: http://www.murvegetalpatrickblanc.com/#/en/resources [Accessed 26.09.2010].
[16] Balzano A. (2010) Images sourced from Internet Resource: www.flickr.com/photos/andreabalzano/, accessed 6th September 2010.

Improved climate-responsive urban design

By retaining water in the urban landscape, filtering it through technologies such as biofiltration (swales, 'rain-gardens' and wetlands) and using it for irrigation, it is possible to substantially reduce summer peak temperatures in urban environments.

Stormwater is one of a suite of tools used to combat the *Urban Heat Island (UHI) effect* and can help to provide cities with attractive, *green landscapes* (Figure 5), and in some cases contributing to urban food production. Combined with the protection/restoration of urban waterways and their riparian zones, retaining stormwater in the landscapes is a specific and valuable use of water that contributes to the liveability and economic wellbeing of urban environments.

Improved quality of urban spaces

Stormwater harvesting using green infrastructure enhances social amenity and opportunities for public recreation in addition to its potential for influencing micro-climates in urban areas. WSUD increases property values by effective use of green spaces and water features. Anecdotal evidences have indicated increased property values and/or market advantage associated with the implementation of WSUD elements for stormwater treatment such as constructed wetlands, raingardens and ponds although these are usually highly varied and not well quantified. Brisbane City Council's survey (unpublished) found that for every dollar invested into WSUD there is a 90% return on increased property value.

Urban micro-climate and public health

Current urban design and stormwater management practices give little or no consideration to the urban micro-climate. The significance of keeping water within the landscape, combined with the role of vegetation and orientation of building elements, are urban design issues that will be critically influence the urban micro-climate (Endreny, 2008)[17];

Recent work on mortality and extreme temperature shows a marked threshold temperature beyond which significant increases in mortality occur (Nicholls *et al.*, 2007)[18], so even relatively slight ameliorations of extreme temperature through improved urban design can have the potential to save lives and reduce hospital cost. By way of example, the January 2009 heat wave in Melbourne led to 374 excess deaths over expected, 37% increase in emergency department attendances by people that are over 75 years of age (source: Victorian Chief Health Officer Assessment).

Effective drainage and flood mitigation

A network of green/blue corridors that serves as open spaces and productive landscapes is also effective in detaining flood water for flood protection of downstream communities. Studies undertaken by Melbourne Water have highlighted the contribution of WSUD elements in deferring the need for drainage infrastructure augmentation to accommodate increased catchment impervious area coverage attributed to urban consolidation.

The advert of future technology for real-time control that links advancements in weather forecasting to operation of stormwater harvesting infrastructure that would serve as flood mitigation systems during imminent occurrence of high intensity storm events. In Seoul, South Korea, new buildings are designed with large rainwater tanks for harvesting rainwater for non-potable use within these buildings. The outlet controls of these tanks are linked to a central drainage control agency responsible for flood forecasting and management. Through a sophisticated system of weather forecasting and real time control, the Seoul City network of rainwater tanks can be purged in anticipation of an imminent storm event so as to serve as flood detention system to protect the city from flooding. These tanks thus serve the dual functions of harvesting rainwater as an alternative source of water supply and flood protection for the city of Seoul.

The traditional finance models predicated on discounted cash flows (DCF) and standard net present value (NPV) structures fail to adequately capture the broader values and benefits of investment into WSUD outlined above.

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[17] Endreny, T. (2008), Naturalizing urban watershed hydrology to mitigate urban heat-island effects, invited commentary, Hydrological Processes, Vol 22, pp 461–463, 2008.
[18] Nicholls, N., Skinner, C., Loughnan, M. and N Tapper (2008), A simple heat alert system for Melbourne, Australia. Int. J. Biometeorology (pre-published online) doi:10.1007/s00484-007-0132-5

Building Social and Institutional Capital for Integrated Urban Water Management

There are profound social and institutional barriers to the pursuance of new and alternative urban water technologies, which can be summarised as "insufficient practitioner skills and knowledge, organisational resistance, lack of political will, limited regulatory incentives and unsuitable institutional capacity" (Brown *et al.*, 2009)[19].

Within the water sector there is an increasing recognition in both theory and practice of the importance of expanding current economic valuation methods to incorporate those elements of value that normally sit outside the domain of the decision-maker, and that such values may affect the rank ordering of different investment options and interventions in the water landscape.

The calculus of value and risk in the appraisal of water infrastructure investments is being challenged by both an alteration of the underlying entitlements in water and our understanding of the inherent value of resilience in an uncertain realm. The specifics of alternative water sources as an investment option need to be considered relative to other investments and in the context of these changing valuation metrics, in a changing climate, and appropriate to the dynamics of the business landscape in which they will be situated.

Achieving a city comprising water sensitive communities requires institutional reform that is flexible and sympathetic to a new, water-sensitive agenda. There is co-dependence between socio-political capital for sustainability and water sensitive decision-making and behaviour. A new "hydro-social contract" would need to evolve that puts communities at the forefront of policy decision-making.

The current hydro-social contract underwrites governments in Australia largely making decisions on behalf of citizens and the private sector about design, management and operation of the urban water system. Opportunities for community input are generally limited to formal processes of consultation. These are framed by the historical precedents of hierarchical, centralised governance with a culture of governmental control during the post-war period through to market governance with its culture of efficiency during the 1980s and 1990s.

Ultimately, evolving into a Water Sensitive City relies on the ability of its institutions to transform. The literature reveals that community norms vary across cities according to culture and geographic setting and need to be accounted for in planning water sensitive communities. Achieving Water Sensitive Cities will also rely on management of networks and the changes in practice afforded by both interdisciplinarity and the practical engagement of water users and technology recipients.

The consideration and adoption of urban water alternatives within the prevailing hydro-social contract are determined by the degrees of confidence in their viability and efficacy to perform under various scenarios. Confidence in certain alternatives, such as less conventional and decentralised options, can be undermined by a "fear of failure" and dread associated with perceived consequences of failure. Such perceptions can be tied to the public health risks of decentralised systems, real and presumed financial costs, potential damage to personal and organisational reputations, the political and legal liabilities for negative public health effects, and any lost opportunities for future experimentation.

There are a number of things that need further understanding in order to achieve water sensitive communities. The receptivity of urban water professionals to alternative water sources and technologies, especially through the lens of risk perception is not adequately understood. There are also uncertainties about the receptivity and willingness of communities to commit to different water alternatives. This is partially a function of the prevailing institutions and the limited ability to reliably and relatively value the options presented, both at spatial (externalities) and temporal (real options) scales. While decision-makers have intuitively understood the value of flexibility and options, their understanding of analytically rigorous methodologies that provide a sound basis for decision rules around investment and other strategic options is however, relatively new and limited.

[19] Brown, R., Farrelly, M. and Keath, N. (2009). Practitioner perceptions of social and institutional barriers to advancing a diverse water source approach in Australia. International Journal of Water Resources Development 25(1): 15-28.

The traditional finance models predicated on DCF (discounted cash flows) and standard NPV (net present value) structures fail to adequately capture benefits accrued from adopting the principles of flexibility and resilience in the provision of urban water services. The underlying risk structures, information and game theoretic considerations essential to analysis of future investments, are largely unknown in the urban water sector.