Independent research and consulting

Submission to the Senate Standing Committees on Environment and Communications inquiry into the quantum of stormwater resource in Australia and impact and potential of optimal management practices in areas of flooding, environmental impacts, waterway management and water resource planning.

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Submission from

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About the author

Dr Peter Coombes is the managing director of Urban Water Cycle Solutions that operates as an independent research and consulting think tank. He is currently developing a discussion paper for Engineers Australia on integrating urban drainage components of Australian Rainfall and Runoff into modern water cycle management and contributing to the authorship of urban chapters of Australian Rainfall and Runoff. He was most recently a Chief Scientist in the Victorian Government.

Peter was formerly the Managing Director of Bonacci Water, a conjoint Associate Professor of Integrated Water Cycle Management at the University of Newcastle, an Associate Professor of Chemistry and Biomolecular Engineering at Melbourne University and former chairman of the Stormwater Industry Association.

He was one of the architects of the previous Victorian government water policy Living Melbourne, Living Victoria; the recent report on water reform in the Greater Sydney region and led the investigation into restoration of Al Asfar Lake system near the historical city of Al Hasa in Saudi Arabia.

Peter has served as a member of advisory group to the Prime Ministers Science, Engineering and Innovation Council, a member the advisory council on alternative water sources for the Victoria Government's Our Water Our Future policy, a member of the advisory panel on urban water resources to the National Water Commission, an advisor on alternative water policy to the United Nations and a national research leader of innovative WSUD strategies in the eWater CRC.

His research interests include Integrated Water Cycle Management, Water Sensitive Urban design, hydrology, analysis of complex systems and molecular sciences including water quality. He has generated over 150 scientific publications and designed more than 120 sustainable projects including settlements that generate all of their water resources. Dr Coombes was also a co-author of Australian Runoff Quality. Further details about Dr Coombes or Urban Water Cycle Solutions can be found at http://urbanwatercyclesolutions.com.

Summary

This submission discusses the key insights from initiation of water cycle reform and policy development for water cycle management in the jurisdictions of the New South Wales, Victorian and Australian Capital Territory governments.

Policies and strategies for stormwater management are needed in the context of water cycle and planning systems. It is essential to frame evidence based policy from the "bottom up" using all available data and integrating all available spatial and temporal scales of behavior.

New policy frameworks are required to integrate rainwater and stormwater harvesting, soil profiles, vegetation, land uses and waterways in town planning processes.

It is a key insight that waterways, land uses and stormwater management are inexorably linked to water cycle and town planning systems and are the foundations of successful water cycle management.

The value of waterway and stormwater management policies and actions are only fully realized from a systems perspective. Analysis of biophysical systems reveals that the behaviors of water cycle systems are cumulative rather than static.

This insight indicates the potential exponential impacts of missed opportunities and a need for ongoing diligence to avoid transferring substantial problems to surrounding communities and future generations. A summary of our submission is:

- Stormwater must be evaluated and managed from the perspective of the entire water cycle to meet whole of society objectives
- Stormwater runoff generated by urban areas is similar or greater than water demands from cities.
- Urban catchments are more efficient than water supply catchments for generating runoff – especially during droughts.
- Stormwater is responsible for significant costs and potential economic savings.
- Traditional "centralized scale" management of stormwater at the bottom of catchments results in cumulative risks within urban catchments.
- Retention of urban stormwater near the source of runoff will improve the livability and amenity of urban settlements. This includes avoidance of damage to property and protection of environments.
- Optimizing the benefits of urban stormwater will require solutions at multiple scales, multiple objective planning and integrated governance.
- There is a requirement for open access to data, expanded monitoring efforts, new science and national standards for the provision of infrastructure to foster innovation.

Introduction

The Senate of the Australian Parliament has initiated an inquiry into the stormwater resource in Australia. This submission responds to this important issue from the necessary context of the entire water cycle.

Our response to the inquiry is shaped by the contribution of Dr Peter Coombes and Urban Water Cycle Solutions to significant analysis and policy processes during the last decade.

In particular, our submission provides brief extracts from our involvement in analysis and policy processes for Melbourne, Sydney, Ballarat and Canberra to outline issues that should be addressed by this inquiry. Whilst our discussion is relatively brief in the discussion of a selection of key issues, we are willing to contribute further to the inquiry. Additional detail about these issues can also be sourced from our website http://urbanwatercyclesolutions.com.

Quantum of the stormwater resource

Urban water management has continued to evolve since the establishment of centralised and separate water supply, stormwater drainage and wastewater disposal in the 1800s. Most of water supplied to Australian cities has, until been recently, been sourced from rainfall runoff collected from inland catchments. Australia experiences a highly variable climate that has required the construction of large dams and long pipelines to provide secure water supply to cities.

The future amenity, affordability and water security of urban areas is challenged by the combined pressures of population growth, a highly variable climate and the potential for climate change. Recent drought was a catalyst for diversification of our water solutions.

It is recognised that multiple sources of water from centralised and decentralised locations in combination with a diverse range of water conservation strategies can increase the resilience and reliability of a city's water supply.[1] Nevertheless, the water available in our cities from rainwater, stormwater and wastewater sources is not fully exploited. To illustrate this, Figure 1 presents the average annual water balances from households in a range of Australia cities.

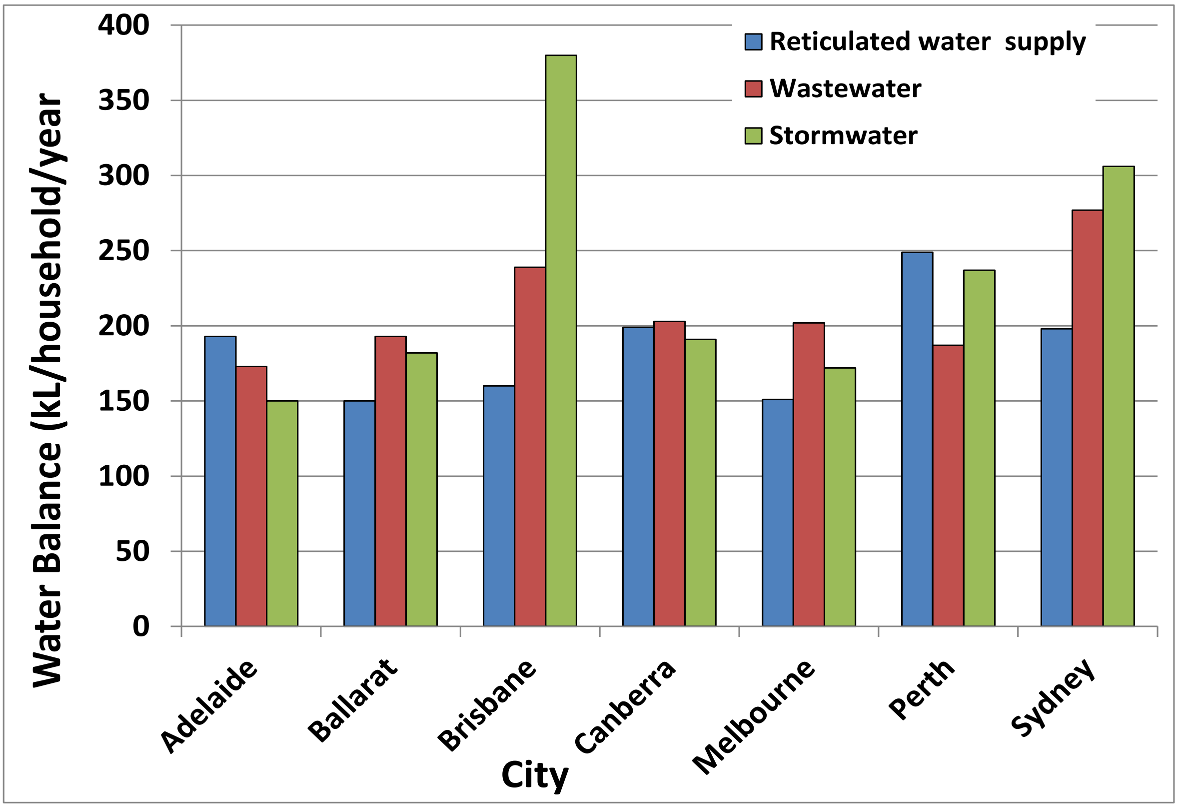

Figure 1: Average annual water balances from households in Adelaide, Ballarat, Brisbane, Canberra, Melbourne, Perth and Sydney

[1] PMSEIC. 2007. Water for Our Cities: building resilience in a climate of uncertainty. A report of the Prime Minister's Science, Engineering and Innovation Council working group. Australian Government. Canberra.

Figure 1 reveals that the combined volumes of stormwater runoff and wastewater discharging from households (and their properties) in each of the cities are greater than the volume of water demands at each location. Indeed the average annual volumes of stormwater runoff from residential properties are similar or greater than average water demands from each property in most cities.

The efficiency of urban catchments (roofs and paved surfaces) is also considerably greater than inland water supply catchments for the generation of stormwater runoff.[2]

It has also been shown that in dry years (rainfall < 500 mm) the annual runoff in water supply catchments is insignificant. In these years water losses to the soil and atmosphere balances most of the rainfall and, as a result, water supplies to cities are almost totally dependent on water stored in dams from more bountiful years and from aquifers.

In contrast urban catchments, being mostly impervious, only experience small losses during rain events and generate substantial stormwater runoff.

As a result, urban areas can provide beneficial volumes of water even during drought years. This result suggests that rainwater and stormwater harvesting in cities can supplement the performance water supply strategies providing an overall improvement in the resilience of urban water supplies. The concept of relative catchment efficiency is presented in Figure 2.

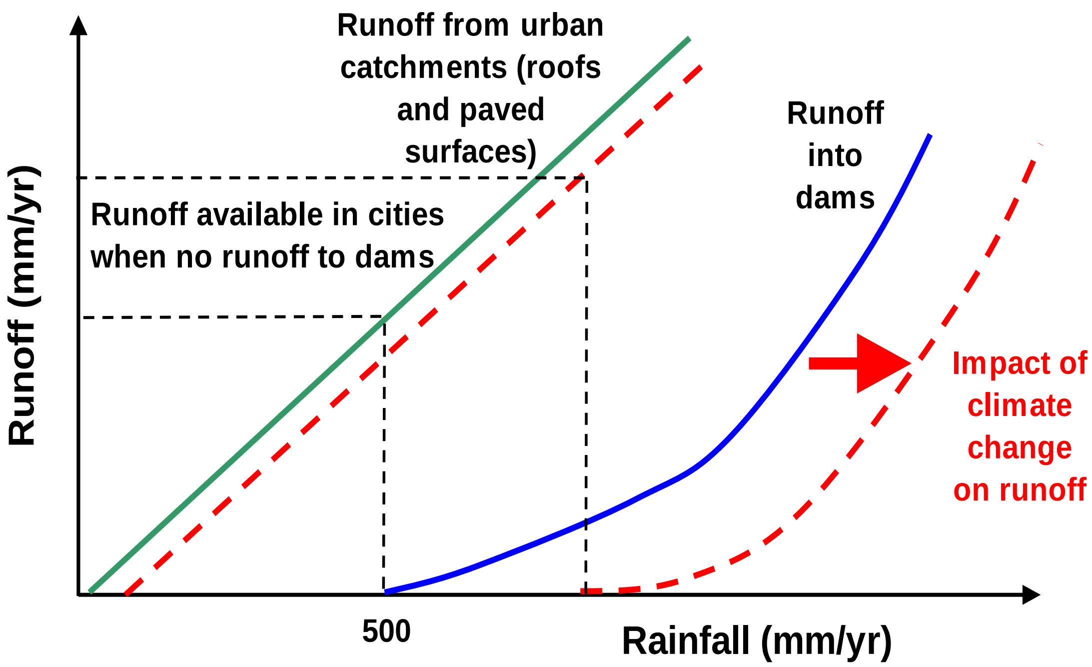

Figure 2: Relative catchment efficiency for urban areas and inland water supply catchments

Figure 2 shows that during years of limited runoff into dams a significant volume

[2] Coombes P.J. and M.E. Barry, 2008. The relative efficiency of water supply catchments and rainwater tanks in cities subject to variable climate and the potential for climate change. Australian Journal of Water Resources. Vol. 12. No. 2. pp. 85 – 100.

of rainwater and stormwater can be harvested from urban areas. Droughts and expected climate change decrease the efficiency of inland water supply catchments relative to catchments within cities.

Consideration of the entire water cycle reveals linked whole of system benefits of rainwater and stormwater harvesting. Rainwater or stormwater is harvesting in urban areas which allows regional reservoirs to fill. This additional "banked" water in reservoirs can utilized during periods of lower rainfall in urban areas or to restore environmental flows in waterways.[3] Rainwater and stormwater harvesting, and stormwater retention measures within urban catchments also reduce the volumes of stormwater runoff with associated pollutant loads.[4] This mitigates flood risks, the regimes of stormwater volumes in urban waterways and the risks of wastewater surcharges.

The estimated volume of additional stormwater runoff from urban areas for the Australian Capital Territory, City of Ballarat, Greater Melbourne and Greater Sydney regions is provided in Table 1.

Table 1: Stormwater runoff from urban areas

Region	**Additional stormwater runoff from urban areas (GL/year)**	
	2010	**2050**
Australian Capital Territory	72	124
City of Ballarat	11	18
Greater Melbourne	414	527
Greater Sydney	547	795

Note that Table 1 only presents the additional stormwater runoff generated by urban development which does not include runoff from parks, open space and non-urban areas.

Table 1 highlights that the volumes of stormwater runoff generated by urban surfaces are substantial and increasing with the population of each region. The magnitude of this distributed water resource increases with population growth.

The Water Cycle includes Stormwater

The dynamics of stormwater management are driven by dependencies on the entire water cycle (water supply, wastewater disposal, waterways and the environment) and urban development. Urbanisation alters the natural water cycle. Impervious surfaces and directly connected drainage infrastructure decrease

[3] Coombes P. J., (2005). Integrated Water Cycle Management: Analysis of Resource Security, Water, 32: 21-26.

[4] Coombes P.J and M.E. Barry., (2014). Key insights from development of policies for integrated water cycle management that include stormwater in Systems Frameworks for Big Data analysis. 3rd National Conference on Urban Water Management. Stormwater Australia. Adelaide.

evapotranspiration and infiltration to soil profiles. This increases the volume and frequency of stormwater runoff and reduces baseflows; which can result in flooding and diminished waterway health.

Approaches to stormwater management that are solely reliant on drainage strategies can transfer additional stormwater runoff and pollutant loads generated by urban areas to other locations.

There is emerging understanding that stormwater management challenges can be mitigated by considering urban stormwater as an opportunity to supplement urban water supplies, to enhance the amenity of urban areas and protect the health of waterways. Water cycle management is also subject to jurisdictional and institutional boundary conditions that limit the opportunities for catchment based solutions that are consistent with whole of society objectives.

The timing of water balances in the Ballarat water district[5] during the recent drought are provided in Figure 3 as an example of water cycle processes.

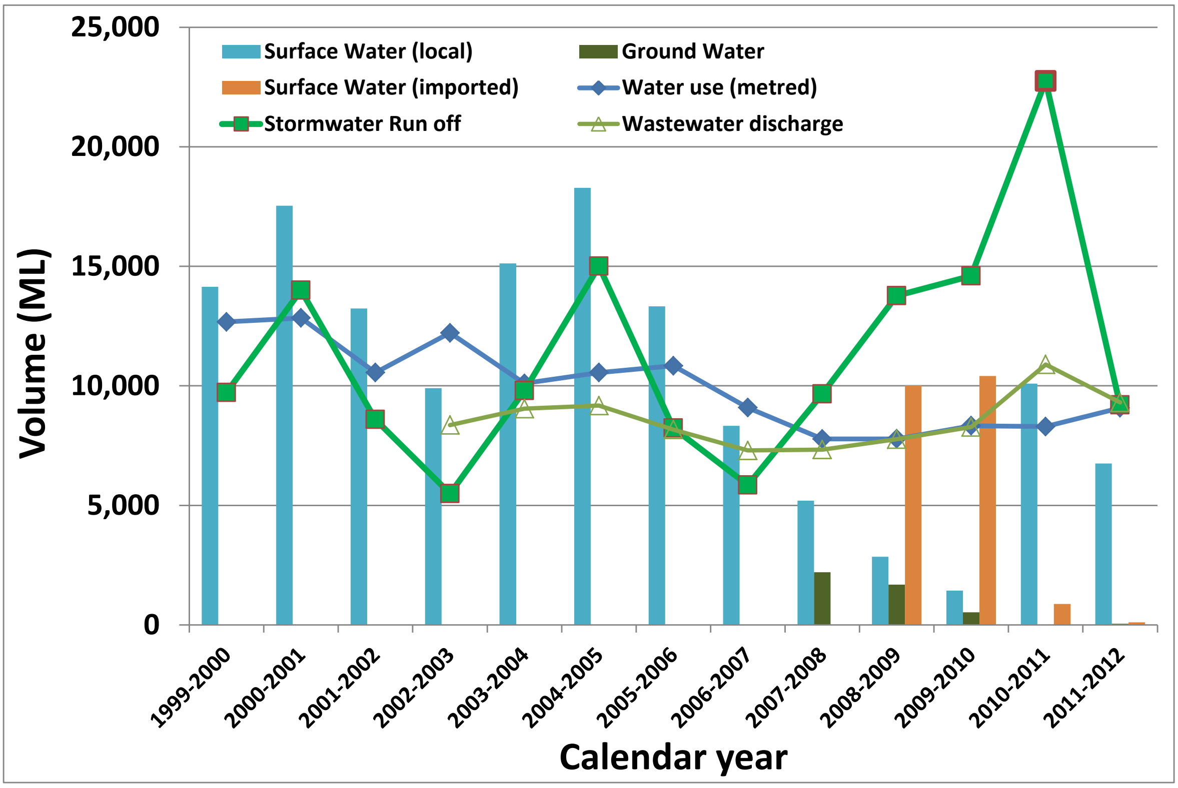

Figure 3: Water cycle processes in the Ballarat Water District from 1999 to 2012

Figure 3 shows that the Ballarat Water District was dependent on surface water from nearby dams on local waterways until the worst of the drought in 2006. Then reduced flows into local dams were supplemented using ground water and surface water imported from the distant Goulburn River.

The actions of citizens to reduce water use in response to water restrictions,

[5] Coombes P. J. and M.E. Barry (2014). Systems Analysis of water cycle systems – analysis of base case scenarios for the Living Ballarat project. Report by the OLV Chief Scientist. Urban Water Cycle Solutions.

installation of water efficient appliances and rainwater harvesting also halved the water demands of the Ballarat Water District. The Council and the Water Authority also implemented stormwater harvesting and wastewater reuse facilities. In combination with the timely availability of ground water and imported surface water from the Goulburn River, these actions ensured that the City of Ballarat did not exhaust water supplies during the drought.

The integrated action across the water cycle and the entire Ballarat community is a success story of the recent drought from a water supply perspective.

Drought and concerns about water security motivated a wide range of solutions that would otherwise be dismissed during periods of more plentiful water supply. Similar processes were experienced for Greater Melbourne, Greater Sydney and the Australian Capital Territory.

Cities and towns are characterised by multiple linked interactions with waterways throughout river basins that produce cumulative impacts. For example, the Ballarat Water district is dependent on the Moorabool, Campaspe, Goulburn, Loddon and Yarrowee River catchments.

Regional water resources are often shared with adjacent communities and ecosystems. These waterways can be subject to increasing cumulative impacts including loads of contaminants and diminishing fresh water flows that impact downstream communities. In addition, properties within urban catchment can be subject to risks of stormwater damage and flooding. For example, up to 8,000 properties may be subject to flooding in the City of Ballarat jurisdiction.

In contrast, Figure 3 reveals that substantial volumes of local stormwater runoff from urban surfaces were available throughout the drought. Similar volumes of wastewater were also available during the drought. The local management and use of these resources can reduce impacts on surrounding communities and ecosystems whilst meeting multiple local objectives (such as a secure water supply, reduced flood risk, increased urban amenity and improved waterway health).

Nevertheless, the Ballarat region was dependent on surface water from distant communities and irrigation districts (including the Murray-Darling Basin) that were experiencing dryer conditions during the drought. This solution also involves a transfer distance from Warranga Basin of 200 km and a lift of 500 m to White Swan Reservoir as shown in Figure 4.

Use of local resources may also avoid the high cost and energy impacts of importing water across regions whilst avoiding local challenges. The consideration of the entire water cycle and solutions at multiple scales from the perspective of all stakeholders is needed.

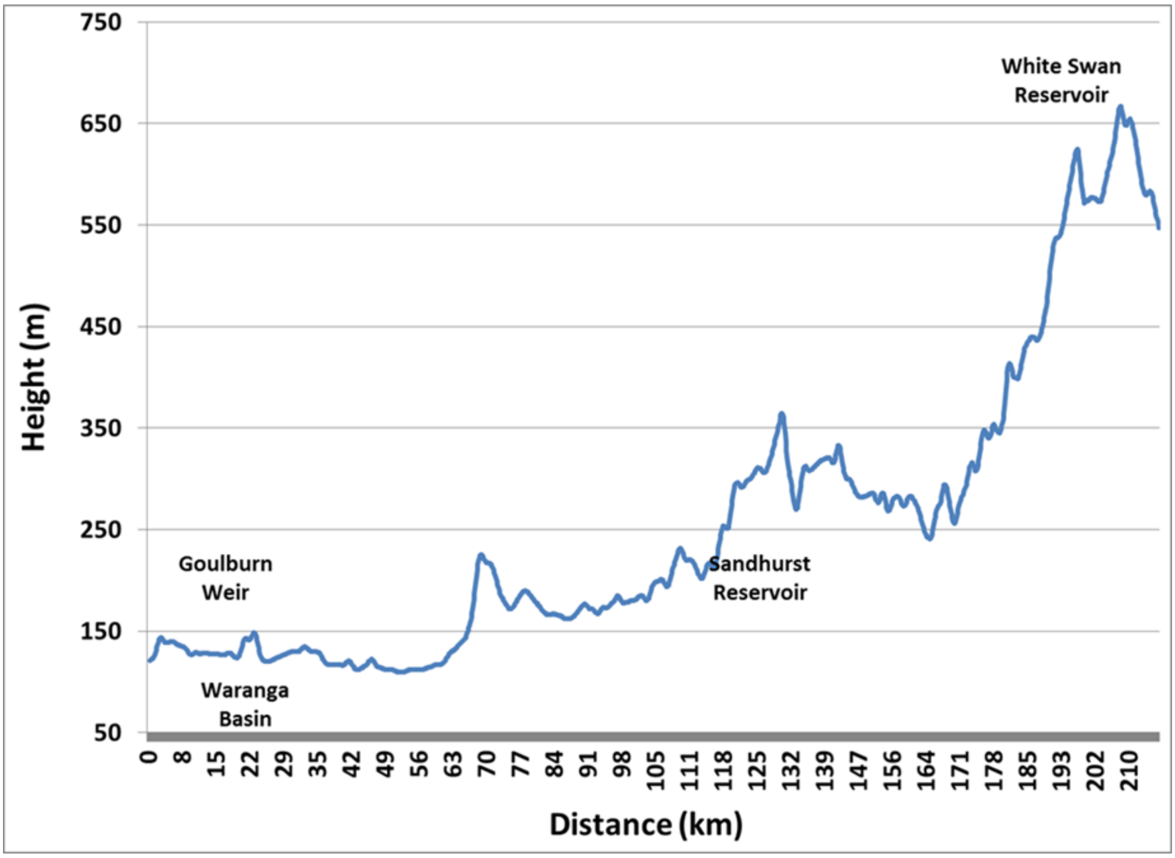

Figure 4: The distance and height of transferring water from Goulburn River to Ballarat

The issue of scale

The dynamics of stormwater management is dependent on the many interacting elements of the water cycle and urban development. Management of the water cycle and provision of infrastructure is often dominated by "top down" assumptions at the centralised scale. In contrast, water is demanded, stormwater and wastewater are generated, and hydrology is altered from the smallest distributed "bottom up" or decentralised scale. The traditional definition of stormwater catchments and solutions is shown in Figure 1.

Figure 1 shows the different regional scale responses within a river basin and a linked urban catchment. The impervious surfaces and hydraulically efficient infrastructure associated with urban catchments increases the magnitude and frequency of stormwater runoff whilst reducing the infiltration to soil profiles and subsequent baseflows in waterways.

The first response at A is the (undisturbed) ecosystem upstream from urban impacts, the second response at B includes the impact of water extraction to supply the urban area (changed flow regime in rivers created by water supply) and the third response at C includes water discharges from the urban catchment (changed flow and water quality regime from both stormwater runoff and wastewater discharges) into the river basin.

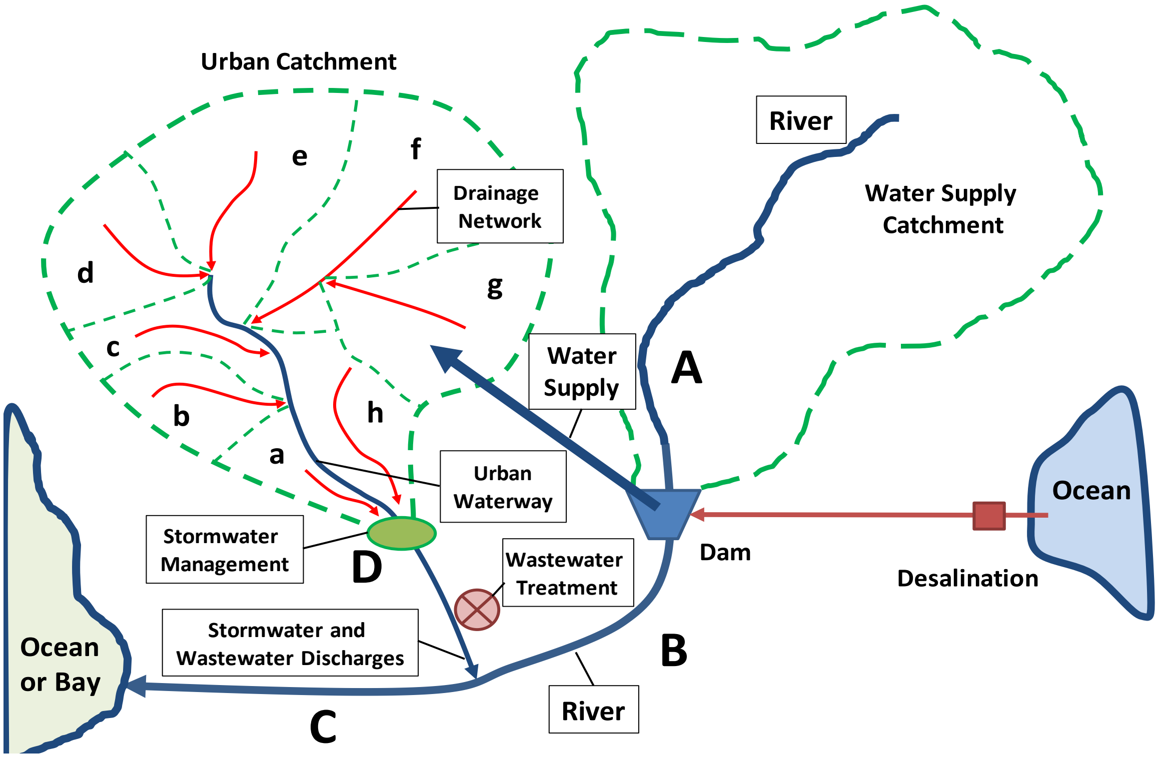

Figure 5: Traditional definition of stormwater catchments for centralized solutions

Analysis and solutions at point D as "end of pipe" management also excludes understanding of impacts within the urban catchment (sub-catchments a-h) and external impacts to the river basin at B and C.

Traditional analysis of the performance of the urban catchment is from the perspective of rapid discharge of stormwater via drainage networks (in sub-catchments a-h) with management of flows and water quality at the bottom of the urban catchment (D) using retarding basins, constructed wetlands and stormwater harvesting. However, the benefits for flood protection, improved stormwater quality and protection of the health of waterways from this approach do not occur within the urban catchment upstream of point D.

Current approaches stormwater management involve minor and major drainage methods where the minor approach is a pipe and inlet pit drainage network provided for a given rainfall frequency and the major approach conveys excess stormwater runoff along road profiles and overland flow paths towards point D. It is noteworthy that roads and open space are also key elements of traditional drainage infrastructure.

Simply put, urban drainage is reliant on rapid discharges and accumulation of stormwater volumes to locations at the bottom of catchments where large storages and land area is then required to slow and hold the volumes of stormwater.

Increasing urban density, diminished capacity of aging drainage infrastructure, blocked inlet pits to the pipe network, climate change and the changed characteristics of rainfall runoff generate the potential for unexpected flooding and stormwater damage within urban catchments. These impacts are likely to occur upstream of the management of stormwater flows and volumes at point D.

Real rainfall generates runoff volumes and timing that may not be captured by peak design assumptions underpinning national practice for design of drainage infrastructure.[6] Stormwater peak discharges from urban areas are also highly sensitive to variations in the biophysical (including town planning) and climate systems.

Engineers Australia is addressing some of these issues in the revision of the national guideline Australian Rainfall and Runoff. This revision is supported by the Australian government. This modernisation of Australian practice requires enhanced scientific capability, and broad support from Australian institutions and agencies.

There are multiple ecosystem and biophysical responses associated with urban catchments. Figure 6 shows that urban catchments incorporate multiple linked scales including regional, urban catchment and distributed sub-catchments that contain local scale processes.

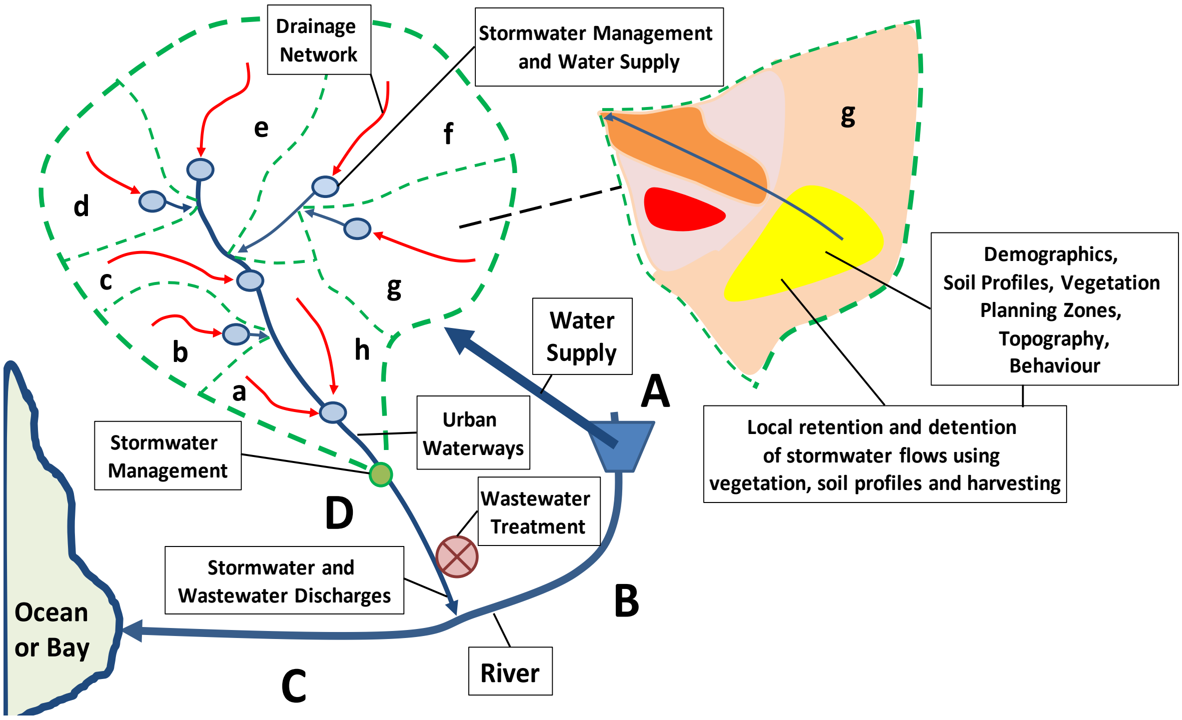

Figure 6: Definition of catchments and land uses for integrated solutions

The local scale drivers of behaviour within urban catchments include demographics, soil profiles, planning zones, topography, vegetation, human behaviour and urban infrastructure. Consideration of the urban catchment at multiple scales allows understanding of the potential to change impacts on

[6] Kuczera G. A., and P. J. Coombes, (2002) Towards Continuous Simulation: A Comparative Assessment Of Flood Performance Of Volume-Sensitive Systems, *Exploding The Myths: Stormwater Driving The Water Cycle Balance*, Orange, New South Wales.

surrounding areas. This is the philosophy that underpins water sensitive urban design (WSUD) and integrated water cycle (IWCM) management approaches.

These benefits result from local scale management by using excess stormwater generated by urban surfaces to supplement water supplies, utilizing vegetation to slow flows and retaining stormwater in soil profiles. The impacts of these local integrated solutions includes improved urban amenity, increased liveability and decreased urban heat island effects.

The responses of urban catchments are cumulative rather than static or average and are dependent on spatial and temporal characteristics throughout the catchment. This insight indicates that the impacts of hidden or missed challenges or opportunities within catchments are not linear processes and are exponential in nature.

Emerging approaches to stormwater management utilise multiple solutions that cascade across scales to mitigate these cumulative impacts – for example; household rainwater harvesting overflowing to streetscape measures such as rain gardens, infiltration and vegetation that discharge to sub-catchment scale bio-retention and stormwater harvesting - is a treatment train that can restore the natural regimes of flow volumes.

Traditional "end of pipe" analysis relies on "engineering judgement" to assess the benefits or impacts of distributed solutions within catchments. Consideration of the actual behaviours within catchments using enhanced methods may reveal substantial benefits or impacts. Analyses that is limited to stormwater management (both ecological and infrastructure related) at the "end of pipe" scale are unlikely to account for the true complexity within urban catchments and can only provide "net effect" information. This type of information cannot be deconstructed to the necessary detail to provide information about waterway processes and usually precludes the effectiveness of decentralized or within catchment solutions. How can decisions about IWCM and WSUD be made if there is only non-responsive data from traditional analysis to infer decisions from?

New science, design standards and governance structures are required to understand and transform the distributed stormwater challenges facing our nation into opportunities.

Analysis of opportunities must link actions at any scale or location within the entire system. For example, stormwater runoff generates peak discharges and surcharges in wastewater infrastructure, and harvesting rainwater and stormwater can reduce impacts on waterways including flooding, stormwater pollution, erosion and flow regimes.

Cumulative actions at the smallest scale (source control), such as retaining stormwater in the soil profile can produce significant responses throughout urban systems and to surrounding systems. Changing land uses within an urban catchment has the potential to change the regimes of stormwater runoff volumes and quality throughout an urban catchment and in surrounding river basins.

The impact of traditional evaluation of stormwater management upstream of location D (Figure 5) is shown in Figure 7 and analysis of integrated solutions for stormwater management using details of the entire system (Figure 6) is presented in Figure 8.

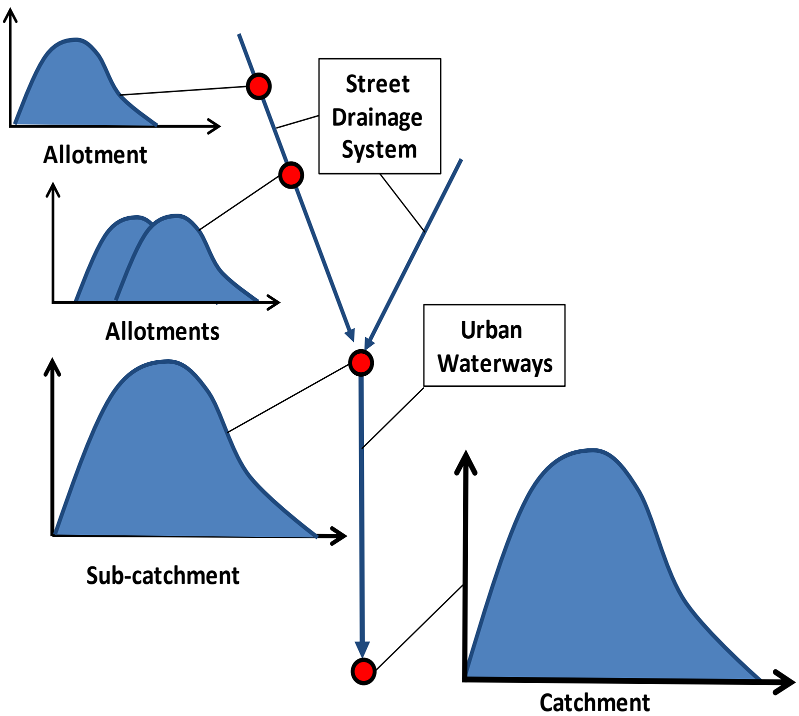

Figure 7: Traditional evaluation of stormwater management at end of pipe

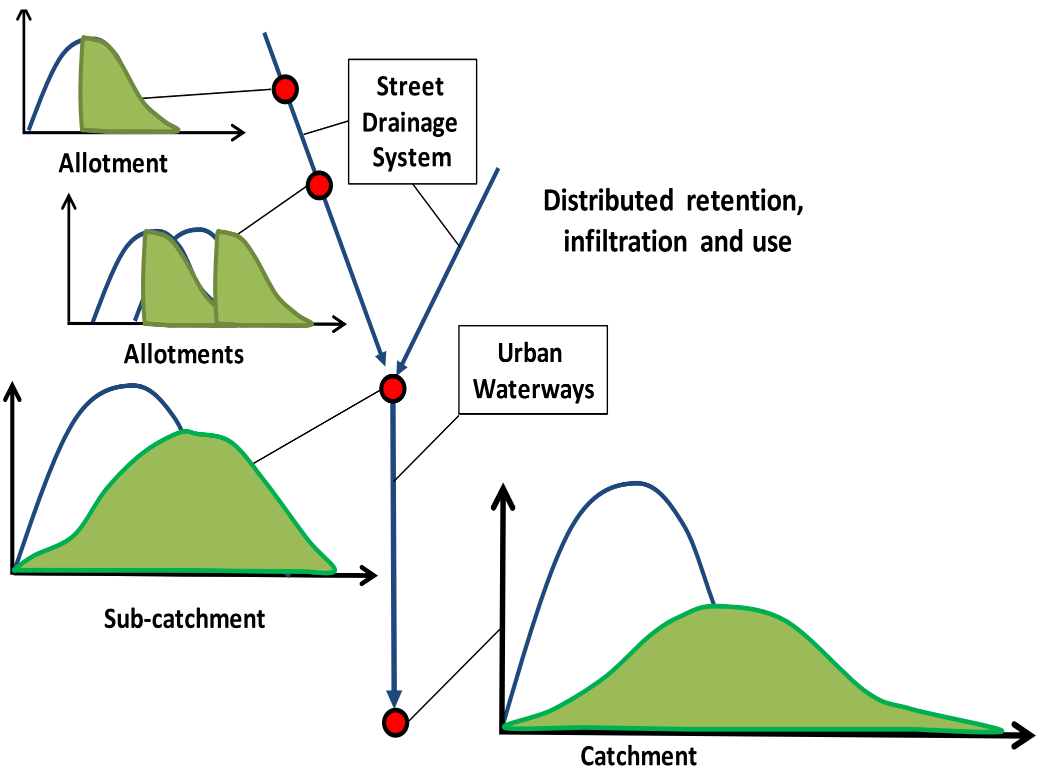

Figure 8: Integrated evaluation of stormwater management in the Systems Framework consistent with natural processes

Figure 7 shows traditional stormwater management where individual land uses (allotments or properties) produce hydrographs of stormwater runoff into the street drainage system. The street drainage system accumulates stormwater runoff from multiple inputs that creates progressively larger volumes of stormwater runoff that ultimately flows into urban waterways or adjoining catchments. This process results in dramatic changes in the volume and timing of stormwater discharging to downstream environments.

Figure 8 demonstrates that impacts of distributed stormwater retention (for example; retaining stormwater in soil profiles to maintain soil moisture, landscaping and vegetation, and rainwater harvesting) throughout urban catchments to point D. This approach can restore the natural flow regimes in urban catchments and manage risks within and at the bottom of urban catchments.

Even if distributed retention strategies do not reduce peak discharges from individual land uses (as shown in Figure 8), the reduced volumes and timing of stormwater runoff inputs to drainage networks changes the characteristics of accumulated stormwater runoff as stormwater travels downstream. This example shows the importance of stormwater management interventions within the headwaters of urban catchments and the need for integrated solutions at multiple scales.

Advances in science including continuous simulation, use of multiple climate sequences and linked processes across the entire water cycle (including water demands) allows understanding of the retention status and the probability of responses throughout urban catchments. Our national standards, regulations and research institutions need to embrace and advances in science.

Spatial considerations

Our solutions, assessment and governance processes for water cycle management are often based on a single centralised scale.

However, water efficient buildings and use of local water sources such as rainwater and wastewater can reduce dependence on centralised water and wastewater services. This can result in a diminished requirement to transport water, stormwater and wastewater across cities can reduce the costs of extension, renewal and operation of infrastructure. In addition, a reduced requirement for regional augmentation of water security creates long run economic benefits.

For example, traditional water supply can involve transport of across large distances as shown for Melton in the Greater Melbourne region is presented in Figure 9.

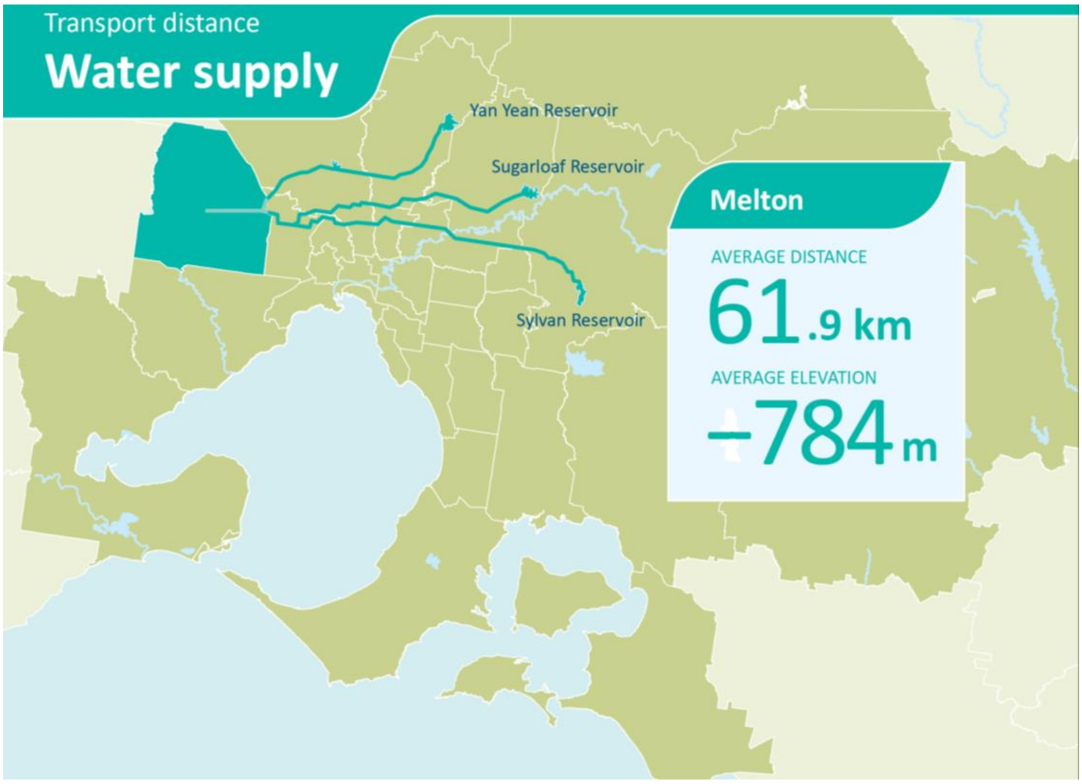

Figure 9: Average distances to supply water to Melton in the Greater Melbourne region

Figure 9 shows that water is transferred from a range of reservoirs to Melton over an average distance of 61.9 km. The inclusion of the Wonthaggi desalination plant as an additional water source as shown in Figure 10 results in a substantial increase in the distance of water transport to Melton.

Figure 10: Average distances to supply water to Melton in the Greater Melbourne region with the inclusion of desalination

Figure 10 highlights the cumulative nature of water supply networks. The addition of the desalination to the water supply network for Melbourne increases the transport distances and pumping for water supply by 84 km and 500 m, respectively. This adds to spatial variation of costs and energy use of regional water supplies throughout the Greater Melbourne region.[7]

The different transport distances for water supply throughout the Greater Melbourne area (not including desalination) are shown in Figure 11.

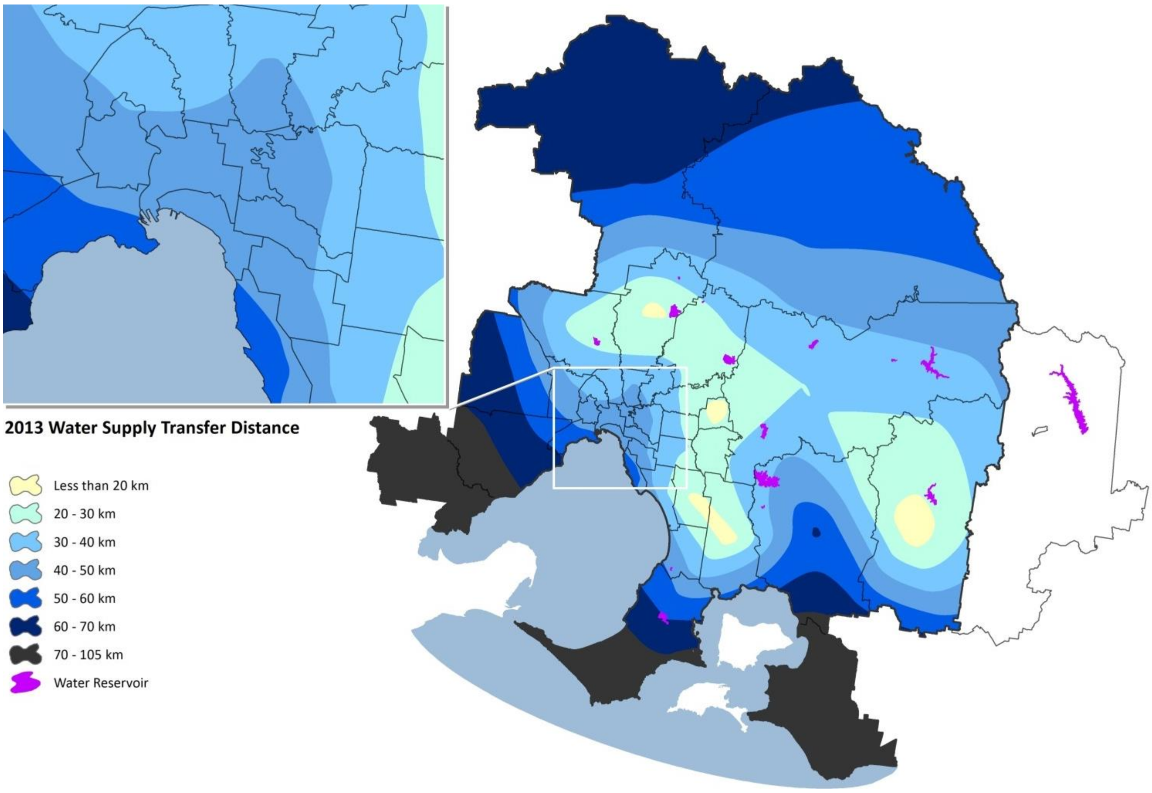

Figure 11: Transfer distances for water supply across Greater Melbourne (not including desalination)

Figure 11 reveals that the longest transfer distances for water supply are to inland and western areas that are distant from traditional water sources located east of Melbourne. The transfer distances for disposal of wastewater throughout Greater Melbourne are presented in Figure 12. The longest transfer distances for wastewater are from the current urban growth areas and inner city regions.

A key insight from these investigations was that reducing the size and connectivity of wastewater catchments reduces the transport of stormwater in traditional sewage networks. Management of stormwater runoff volumes and peak discharges from urban area reduces risks associated with flooding, environmental damage created by higher frequency events and nutrient loads impacting on waterways.

The expected annual greenhouse gas emissions of traditional water, sewage and

[7] Coombes P.J., A systems framework of big data driving policy making – Melbourne's water future. OzWater14 Conference. Australian Water Association. Brisbane. (2014).

stormwater management by 2050 throughout Greater Melbourne is presented in Figure 13.

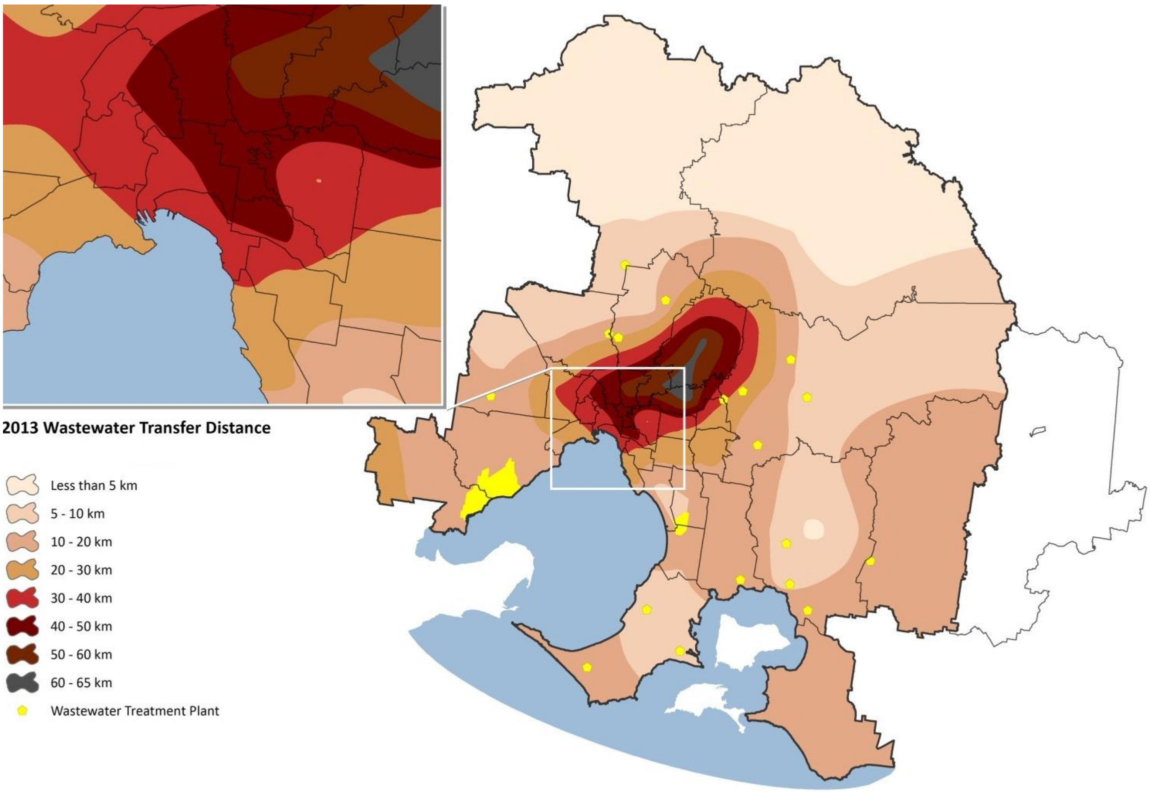

Figure 12: Transfer distance of disposal of wastewater across Greater Melbourne

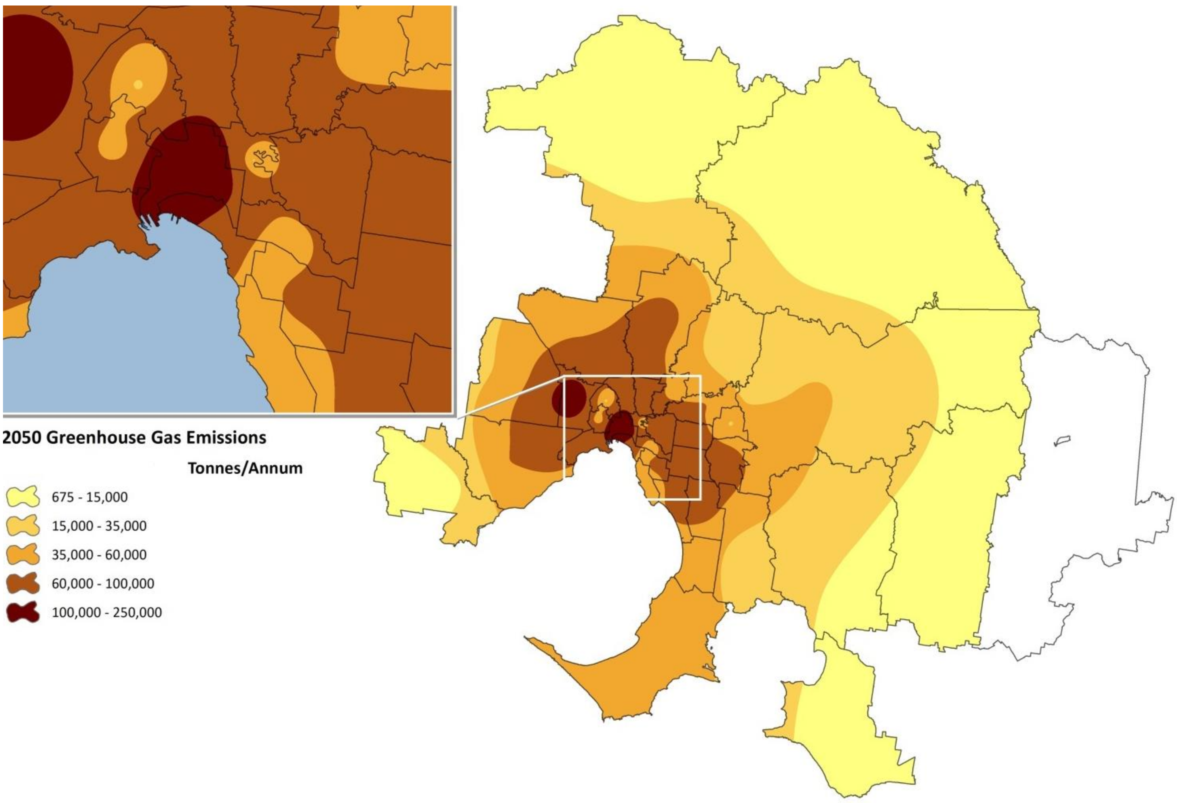

Figure 13: Spatial distribution of Greenhouse Gas emissions for traditional water and sewage services in 2050

The transport distances and energy use in traditional water, sewage and stormwater networks generate strong spatial variation in costs throughout a region. This spatial variation in traditional costs of water cycle management is estimated for the Greater Melbourne region to 2050 in Figure 2050.

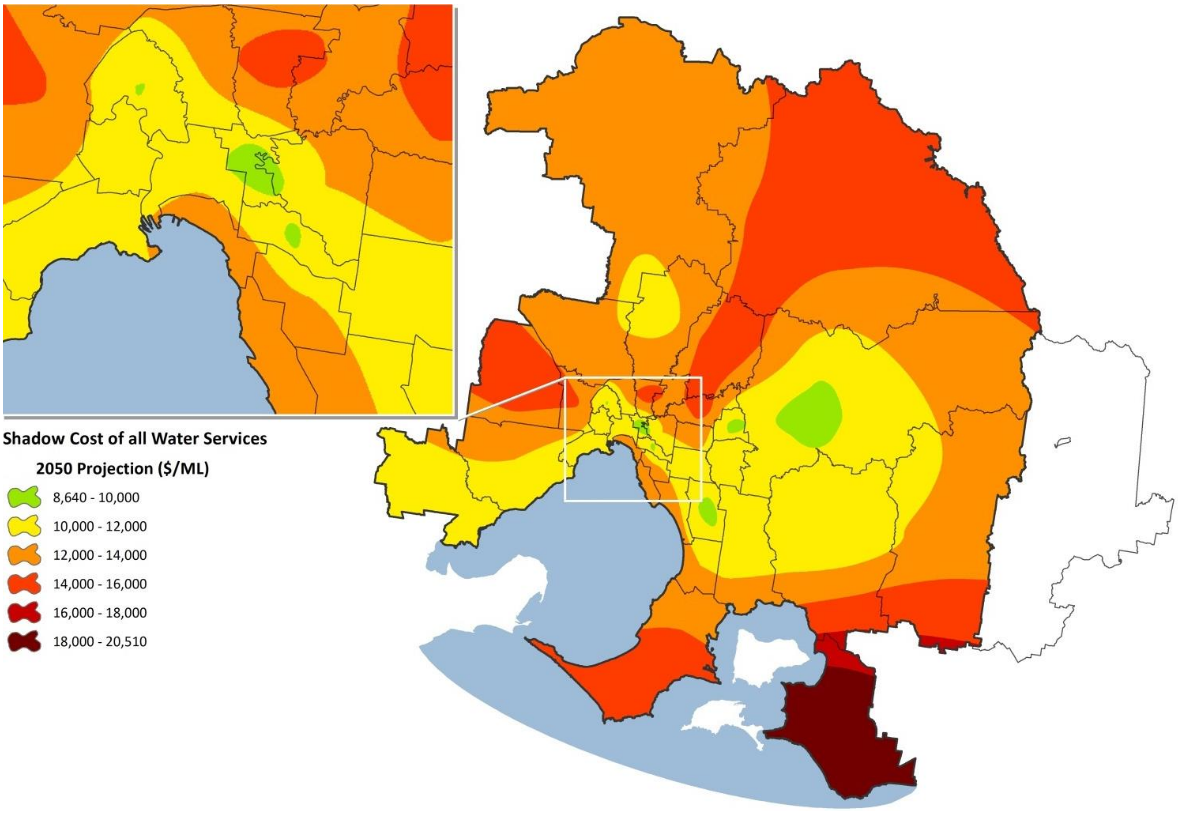

Figure 14: Spatial distribution of the costs of traditional water, sewage and stormwater costs to 2050

It is common practice to compare the costs of alternative water projects (such stormwater harvesting) to the assumed treatment costs of desalination or similar centralised solution (for example in Victoria). This is known as a fixed "shadow cost".

However, this discussion demonstrates that traditional water cycle costs are accumulative and strongly variable throughout a city as demonstrated by the estimated shadow costs for Greater Melbourne in Figure 14. It is, therefore, important to recognise that the viability of alternative solutions must be evaluated against the equivalent traditional services to the location of a proposed project.

We should also be mindful that solutions within urban areas generate multiple benefits across the water cycle and society – our assessment methods must account for these multiple benefits.

The value or cost of the resource

A summary of the results from systems analysis of the Greater Melbourne region and Ballarat Water district are presented in this Section to highlight the cost or value of the stormwater resource. Three options are presented to allow understanding of the magnitude of the challenges and opportunities. The Options are:

Business as Usual (BAU): Management of water, wastewater and stormwater using centralised infrastructure. Future water security and wastewater treatment is provided by regional infrastructure (such as desalination). Population growth requires expansion of existing networks.

Building Scale: Water efficient appliances (Green Star 6 standard) and water efficient gardens installed at all new and redeveloped buildings. Rainwater harvesting used for toilet, laundry and outdoor uses replacing requirement for On-Site Detention for stormwater management.

IWCM: Wastewater treatment and reuse for toilet and outdoor uses implemented at a sub-catchment scale. Stormwater harvesting for potable water supply installed at a sub-catchment scale. Stormwater is treated and injected into the water supply network. Rainwater harvesting for laundry and hot water uses, water efficient appliances and gardens installed at all new and redeveloped dwellings.

A summary of the net present costs for water supply, wastewater and stormwater management to 2050 for the Greater Melbourne region is provided in Table 2. This analysis uses a real discount rate of 5%.

Table 2: Net present costs to 2050 for Greater Melbourne using a 5% discount rate

Option	NPC ($B)				
	Water	Wastewater	Stormwater	Total	Difference
BAU	36.5	24.4	11.5	72	
Building scale	32.5	22.6	10.8	66	6
IWCM	34.2	19.8	8.4	62	10

Table 2 demonstrates that the building scale strategy will reduce the net present costs of water cycle management to 2050 by $6 billion which is 8% of expected discounted future costs. Similarly, an IWCM strategy will diminish the net present costs of water cycle management by $10 billion which is 14% of expected discounted future costs. Results for the Ballarat Water district are provided in Table 3.

Table 3: Net present costs to 2050 for the Ballarat Water District using a 5% discount rate

Option	NPC ($M)				
	Water	Wastewater	Stormwater	Total	Difference
BAU	734	707	315	1756	
Building scale	694	668	305	1667	89
IWCM	627	652	307	1586	170

Table 3 shows that the building scale strategy will reduce the net present costs of water cycle management to 2050 by $89 million which is 5% of expected discounted future costs. Similarly, an IWCM strategy will diminish the net present costs of water cycle management by $170 million which is 10% of expected discounted future costs.

An analysis using a real discount rate of 0% was also conducted to understand the cumulative benefits for the Greater Melbourne region and the Ballarat Water District as shown in Tables 4 and 5.

Table 4: Cumulative costs for Greater Melbourne to 2050

Option	Cumulative costs ($B)				
	Water	Wastewater	Stormwater	Total	Difference
BAU	78.4	52	29.3	134.5	-
Building scale	68.4	47.5	3.4	119.4	15.1
IWCM	71.5	40.3	3.4	115.2	19.3

Table 4 reveals that the building scale and IWCM options can reduce cumulative costs to Victorians of $15.3 billion to $19.3 billion over the planning horizon to 2050. These savings also equate to an average annual saving of up to 14% of long term annual water cycle costs.

Table 5: Cumulative costs to 2050 for the Ballarat Water District

Option	NPC ($m)				
	Water	Wastewater	Stormwater	Total	Difference
BAU	1,787	1,524	768	4,079	
Source control	1,636	1,473	737	3,846	233
IWCM	1,426	1,367	787	3,580	499

Table 5 shows that the building scale and IWCM options can reduce cumulative costs for Ballarat of $233 million to $499 million over the planning horizon to 2050. These savings also equate to an average annual saving of up to 12% of long term annual water cycle costs.

These results indicate the substantial costs and benefits of managing stormwater accrue throughout the water cycle. It is important that our understanding of stormwater management is linked to the entire water cycle, and counts all of the potential costs and benefits.

For example, the design of our sewage infrastructure is driven by wet weather factors (typically 2 to 12 times dry weather sewage flows) that account for inflows of stormwater into sewage network.

The net present costs of stormwater inflowing to wastewater infrastructure in the Greater Melbourne region are estimated to be $8.5 billion (discount rate of 5%) or cumulative costs of $24 billion to 2050.

Similarly, the net present costs of nitrogen pollution in the Greater Melbourne region are estimated to be $50 billion (discount rate of 5%) or a cumulative cost of $123 billion to 2050.

Finally, there have been increases of insurance premiums for stormwater damage and flooding throughout Australia of up to $2 billion/annum since 2007.

Key insights

The different policy development processes for Sydney, Melbourne, the Australian Capital Territory and regional Victoria motivated the key insights provided in this submission. Analysis that includes the entire water cycle, environment and waterway processes are required to frame evidence based policy using all available data. Integrating all of the spatial and temporal scales of behaviour in analysis and design is needed for a detailed understanding of trade-offs in benefits and costs throughout society.

The analysis underpinning these policy processes revealed that the increasing accumulation of stormwater and wastewater throughout expanding and aging water cycle networks is a substantial physical and economic challenge or opportunity for governments. Similar results were found for all jurisdictions.

Population growth drives the dynamic links between water cycle and town planning systems to present strong challenges and opportunities. A variable climate and potential for increased rates of climate change is an additional challenge that will force greater variability of behaviours with associated uncertainty about urban futures.

Almost all parameters that describe the performance of urban settlements are subject to strong spatial and temporal variability which drives spatially variable responses to policy measures. A combination of spatially variable responses and non-linear translation of behaviours across scales also reveals opportunities and challenges that are not apparent in average assessments. Systems analysis has revealed "hidden" opportunities.

The rate of urban development and associated town planning processes are a serious challenge in all jurisdictions for flooding, the health of waterways, urban amenity and the liveability of urban settlements. A rush to solutions that maximize land yield for each new development whilst stormwater management is moved increasingly downstream of urban areas may be an exponential driver of substantial future problems. These processes defer increasing cumulative costs and declining liveability to future generations and governments.

Stormwater inflows to wastewater networks drive the design, management and regulatory costs of wastewater infrastructure. Indeed, about 10% to 30% of current and future wastewater capital and operating costs were attributed to stormwater runoff. In addition, the risks of flooding of existing urban areas are substantial and increasing as a consequence of increased urban density, aging infrastructure and management at the "end of pipe".

The value of stormwater infrastructure and the costs of stormwater management are a significant proportion of total water cycle values and costs for an urban area.

The future volumes of stormwater runoff with associated costs are seen to increase for urban settlements in all jurisdictions as a response to population growth.

Stormwater management strategies also need to focus on the changing characteristics of urban catchments upstream of traditional management approaches. There is a pressing requirement to retain stormwater within the drying urban soil profiles beneath our cities to maintain the health of urban vegetation and to restore base flow in urban waterways which will improve amenity and liveability outcomes. Simply put, our remnant urban vegetation, forests and waterways may not survive ongoing urbanization unless stormwater management practices emerge to meet the challenges.

Population growth also increases the volumes of stormwater and wastewater that are discharged to waterways. Substantial future increases in the loads of pollutants accumulating in waterways and bays are expected for all jurisdictions. These impacts are even higher for inland areas such as the Australian Capital Territory and regional Victoria where waterways are subject to declining fresh water flows and increasing pollutant loads.

This analysis has also revealed that alternative water cycle management strategies provide substantial opportunities to mitigate emerging challenges to urban settlements in all jurisdictions. The analysis process includes trade-offs across society and counts all available costs and benefits – stormwater management is a significant cost and water cycle alternatives can provide substantial benefits. The entire system displays accumulative and volume sensitive behaviours. It will be important to implement volume based targets (not just harvesting) for stormwater management and to minimize transfer distances for water, wastewater and stormwater.

Urban catchments that include impervious services are substantially more efficient than water supply catchments in translating rainfall into runoff. However, analysis further reveals linked whole of system benefits of rainwater and stormwater harvesting. Rainwater or stormwater can be harvested in urban areas which allow regional reservoirs to fill. This additional "banked" water in reservoirs is utilized during periods of lower rainfall in urban areas.

Importantly, rainwater and stormwater harvesting, and vegetated measures within urban areas also reduce the volumes of stormwater runoff with associated pollutant loads. This mitigates flood risks as previously demonstrated, the regimes of stormwater flows in urban waterways and risks of wastewater surcharges. Similarly, a policy of increased water efficiency in buildings reduces wastewater discharges and decreases pollutant loads to waterways.