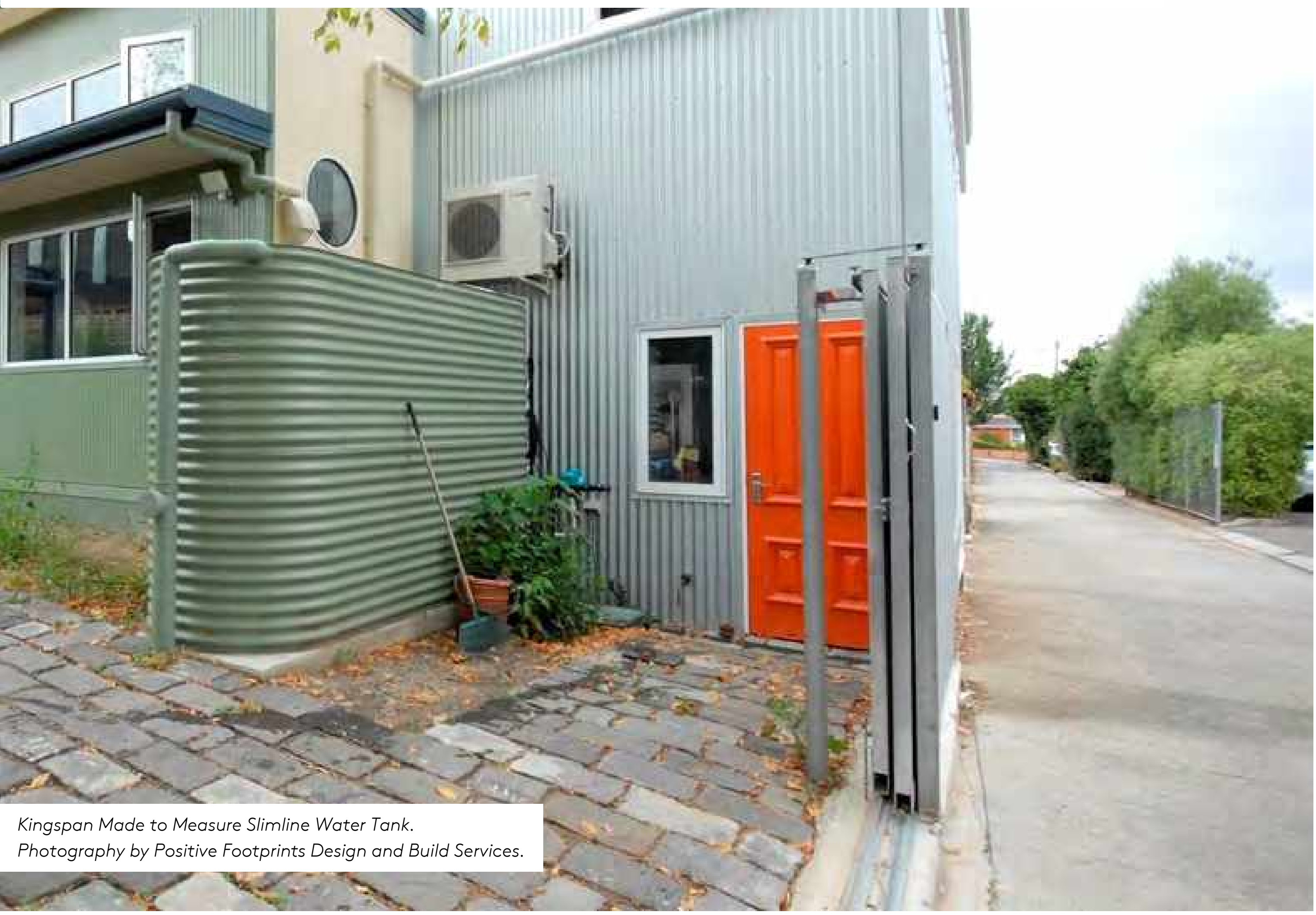
ALTERNATIVE WATER STRATEGY FOR SYDNEY



Kingspan Made to Measure Slimline Water Tank.
Photography by Positive Footprints Design and Build Services.

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Hyde Park, Sydney.

1 PRELUDE

This report was prepared in 2019 using detailed modelling for Greater Sydney and the findings demonstrated the benefits of decentralised solutions for urban water management were greater than the costs. Further modelling has been carried out for the NSW government in 2020, including the latest industry and government data, which has demonstrated even more significant benefits however this material has not yet been published. The authors have decided to release the current strategy and findings as version 1 and release a subsequent version with the updated research after it has been published as version 2.

2 EXECUTIVE SUMMARY

Greater Sydney is the premier Australian city and it faces profound urban water challenges. Sydney must manage its infrastructure efficiently and sustainably to compete internationally as a Global city. Sydney has a strongly performing water services sector but has a traditional approach to water service management. Significant challenges include long transfer distances for water and sewage services and inadequate urban stormwater infrastructure management. These problems appear to be intractable using traditional water analysis approaches however a Systems Framework investigation can identify efficient solutions.

The Systems Framework methodology was recognised in 2018 by Engineers Australia as leading water resource research.

This report finds that Greater Sydney, despite significant challenges, currently has the most efficient and sustainable water services in Australia. This has been achieved through the strategic alignment of water demand management, rainwater harvesting and urban development. The BASIX state environmental planning policy has built-in demand management and stormwater management in most new buildings in the Greater Sydney region since 2004 and this 'bottom up' approach has a major legacy impact on the efficiency of water services. BASIX policies have already saved the Greater Sydney region about 79 billion litres of water annually by 2019, comparable to the 90 billion litre annual capacity of the Sydney desalination plant.

The Systems Framework is used to model and then compare four future scenarios based around the current BASIX policy. Business as Usual projects continuing the current Planning Policy compared to

- not having BASIX,
- an improved BASIX to include water sensitive urban design and
- a combined improved BASIX and variable price structure for water and sewage.

Up to 2050 an improved BASIX and variable price structure would deliver benefits of $7B in community benefits compared to Business as Usual and $11B compared to not having BASIX at all.

The key insight is that a combination of supply and demand management is more efficient than relying entirely on supply solutions when considering whole of society benefits. These demand management solutions include behaviour change, water efficient appliances and rainwater harvesting. An example of these benefits is the 5 year deferral of the multi-billion dollar desalination augmentation provided by the BASIX policy. The inclusion of rainwater harvesting as a stormwater management solution has both infrastructure and demand management benefits and is an efficient decentralised infrastructure asset that improves the performance of the whole system.

This investigation has identified water and sewage transfer distances of over 50 km across Greater Sydney. Transporting a heavy liquid over these distances and significant changes in ground elevations represents high capital and operational costs and potential economic inefficiencies. In some parts of Greater Sydney, the shadow cost (medium run marginal cost) of delivering water and sewage services is greater than $16/kL, which is nearly 800% more than the household usage tariff.

As a result of the analysis the report recommends continuing the BASIX program, considering an improved version of BASIX and considering a more efficient pricing structure for water and sewage services.

The recommended reference for this work is Coombes P.J and Smit M., (2020) Alternative water strategy for Sydney v1. Kingspan Water and Energy & Urban Water Cycle Solutions

Kingspan Made to Measure Round Water Tanks at Marrickville Library and Pavilion, Sydney. Photography by Philip Noller.

3 INTRODUCTION

3.1 Why we need an Alternative Strategy

Water management should operate for the public good with an objective of overall increased benefit to the greater community. The community includes the government who funds the infrastructure, the customer paying for water services and the natural environment which absorbs the environmental impact of our cities.

Kingspan Water & Energy, who contributed to this report, believe that the strategic recommendations of this report will support more sustainable, resilient cities and create a stronger market for supplemental water technologies.

3.2 About the Authors

Professor Coombes is a Fellow of Engineers Australia and Chair of Engineering at Southern Cross University, a former Chief Water Scientist for Victoria, a former member of the Prime Ministers Science, Engineering and Innovation Council water working group, a former member of the advisory panel on urban water resources to the National Water Commission and an adviser to the United Nations.

Michael Smit is the Technical and Sustainability Manager for Kingspan Water & Energy. Michael has a background in land use planning, natural resource management and economics. Kingspan Water & Energy has an international perspective on building materials, renewable technology and commercial expertise. The manufacturing industry can provide key insights and bring different options to the water industry.

3.3 Objectives of the Report

The report applies a system framework understanding to the Greater Sydney water networks, including water, sewage and stormwater, and land uses.

The report provides key insights into the economics of water services and the costs and benefits for the greater community from an independent perspective in an industry traditionally dominated by a limited range of options.

The report provides results from models four options for water service management in Greater Sydney. The report provides recommendations for future action to protect and enhance the public good for Greater Sydney.

3.4 System Framework

The Alternative Plan is based on a Systems Approach and a whole of society perspective. Water cycle management is a system that includes human and environmental elements that can be analysed as a model to test different options. Water cycle management, environment and urban areas are complex dynamic systems and no model is perfect, however, the advantage of the digital age is that powerful computing can use billions of pieces of information, or big data, to model the real world[1]. Once a model is developed, the rules of the model, or scenarios, can be changed to achieve a better outcome. Understanding and modelling the system to test different outcomes is called a Systems Approach. A Systems Approach is a powerful tool for understanding complex dynamic systems.

The responsible and equitable social, fiscal and environmental management of water resources and ecosystem services is central to planning for a world challenged by population growth and increasingly variable climate. Development of a robust understanding of the nonlinear interactions of all water streams with our urban settings is vital to realising our visions and plans to build sustainable and resilient cities into the future. One way to come to this understanding is to construct and deploy numerical tools that consider the natural and anthropogenic water cycles and their interactions as a linked system. These human and linked earth systems generate trade-offs in response to proposed interventions that may only be revealed using systems thinking and models of system dynamics.[2]

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[1] Coombes P.J., and Barry M.E (2015), A Systems Framework Of Big Data Driving Policy Making – Melbournes Water Future", OzWater Conference. Australian Water Association. Brisbane.

A description of the concept and modelling for the Systems Framework is available in Barry and Coombes (2018)[2] 'Planning for Resilient Communities' which was the recipient of the Engineers Australia 2018 GN Alexander prize for Hydrology and Water Resources.

3.5 How the report was constructed

The basis for the report was setting up and running systems modelling for four options. This allowed a comparison of different policy options against the business as usual base case. This process took several months using high end computers.

The System Framework model of Sydney includes the simulation of water, wastewater and stormwater utility services at three hierarchical and linked levels of spatial and temporal scales:

- the local scale (individual dwellings and land uses);
- zone scale (suburbs or local government areas); and
- the whole of system scale (Greater Sydney region).

This approach ensures that the modelling system properly accounts for both the spatial and temporal behaviour-driven variability of most parameters that are well-known to characterise urban and non-urban areas. This systems approach ensures that this variability is included as it manifests in reality, from the bottom at the smallest spatial and temporal scales at the individual property or dwelling, upwards to the whole of system scale via the intermediary zone scale that includes infrastructure processes.

A description and an explanation of the key underlying assumptions is provided for each of the options. The main body of the report is a detailed description of the outcomes for each option considering

- Water Demand
- Water security
- Sewage Discharges
- Stormwater Runoff
- Greenhouse Gas Emissions
- Costs, Tariffs and Economics
- Summary of the costs and benefits of the Options
- Legacy benefits (circa 2019)
- Summary of the benefits of the options

A discussion highlights key insights and key concepts arising from the result, leading to conclusions and recommendations for future action.

4 OPTIONS

4.1 Universal Assumptions

A number of assumptions are common to all options:

[2] Barry, M. E., & Coombes, P. J. (2018). Planning resilient water resources and communities: the need for a bottom up systems approach. *Australasian Journal of Water Resources 22(2)*, 113-136

- Population projections were derived from the NSW state government[3][4][5]
- Charges for Water Services obtained from the Independent Pricing and Regulatory Tribunal (IPART) and Sydney Water annual reports.
- The operating regimes operated by Sydney Water and regulated by IPART continue into the future
- Rainwater tanks will operate for 20 years before requiring replacement
- Rainwater pumps will operate for 10 years before requiring replacement
- Rainwater harvesting yield and water efficiency savings are calculated at the lot level based on parameters outlined in the Systems Framework.

Augmentation

The analysis underpinning this report includes the following options to augment regional water security are utilised in the systems model in the following order as required.

Fitzroy Falls Reservoir to Avon Dam tunnel with 1750 ML/day capacity providing more efficient connection from Shoalhaven River catchment to Illawarra and south coast areas. The construction cost is $500 million.

Stage 2 of Sydney desalination plant with 250 ML/day capacity supplying Potts Hill demand catchment. The construction cost is $1 billion and the operating costs are $2.30/kL. Annual costs are already accounted for in phase one of this project.

New desalination plant with 500 ML/day capacity supplying Prospect Reservoir which broadens the water security effect of the augmentation (increased storage and distribution). Construction cost is $4.65 billion, annual cost is $390 million and operating cost is $2.30/kL.

New desalination plant with 100 ML/day capacity supplying the South Coast and Illawarra region. Construction cost is $2 billion, annual cost is $78 million and operating costs are $2.30/kL.

These regional water security options are implemented to ensure an acceptable level of water restrictions until 2050 for the Greater Sydney region.

4.2 Option 1: Business As Usual (BAU)

Business as Usual (BAU) is the operation of Sydney's water, sewage and stormwater services based on current practice and planned futures. The BASIX State Environmental Planning Policy continues to be applied to new buildings in greater Sydney. Our investigations to establish the BAU Option revealed higher than expected growth in population that is not spatially consistent and increased density of development. We also discovered that there is a reduced focus on water efficiency. Investigations to establish the BAU Option revealed higher than expected growth in population in some local government areas and increased density of development which was driving increasing demands for utility water supply as shown in Figure 1.

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[3] ABS. (2017). Environmental Issues: water use and conservation (Mar, 2013), Cat No. 4602.0.55.003: customised report. Australian Bureau of Statistics.

[4] ABS. (2016). *Census of Population and Housing Cat No. 2901.0; Household Income and Wealth, Cat No. 6523.0.* Australian Bureau of Statistics

[5] NSW Government. (2016). 2016 New South Wales state and Local govenment Area Population and Household Projections and Implied Dwelling Requirements. Department of Planning and Environment.

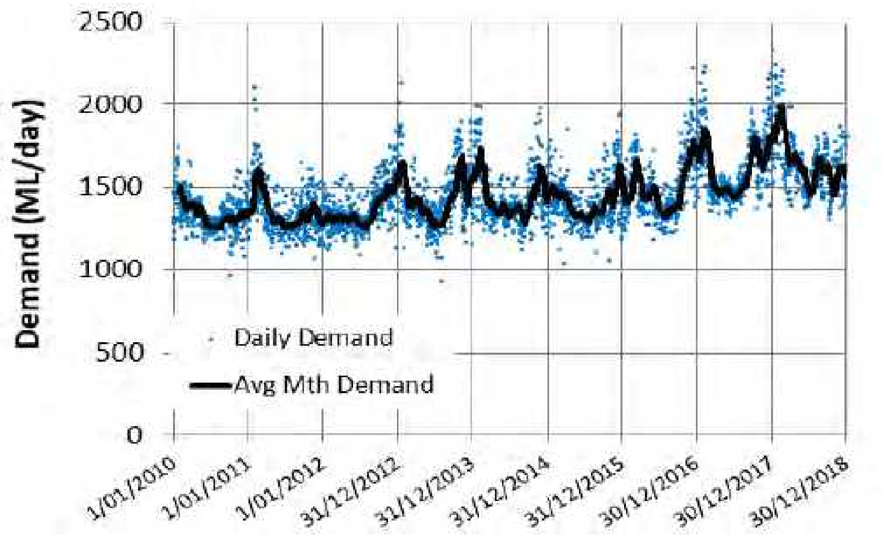

Figure 1: Observed demands for utility water supply from since 2010

We also discovered that there is a reduced focus on water efficiency which was confirmed by the NSW Auditor General.[6] These considerations were included in the systems modelling.

This option commences in 2010 with about 13.2% of dwellings with rainwater tanks and 43% of dwellings with greater than 3-star water efficient appliances. The characteristics of buildings in the BAU option are presented in Table 1.

Table 1: Characteristics of the business as usual (BAU) option for Sydney

At approximately 2010
Water efficient (6/3 dual flush) toilets in 82% of dwellings
Low flow showers in 65% of dwellings
Water efficient clothes washer in 24% of dwellings
Rainwater tanks at 18.6% of dwellings
After 2010
60% of renovated dwellings install low flow showers and water efficient clothes washers.
All new dwellings install low flow showers, 4.5/3 litre flush toilets and water efficient clothes washers
30% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank to supply toilet, laundry and outdoor uses)
80% of new (detached and semi-detached) dwellings install rainwater tanks (100 m^2 roof, 3 kL tank to supply toilet, laundry and outdoor uses)
5% of new units install rainwater tanks (2 kL/dwelling)

4.3 Option 2: Greater Sydney Without Basix (NoBASIX)

This option assumes that the BASIX policy ended in 2010 and there is no water efficiency performance requirement on new or renovated buildings throughout Greater Sydney. This option models what might have happened if the BASIX policy was not continued and provides a unique insight into the benefits of the BASIX policy. The model assumes that rainwater harvesting and

[6] NSW Audit Office, (2020), Water conservation in Greater Sydney, Report by the NSW Auditor General. Parliament of NSW, Sydney.

water efficient appliances will continue to be incorporated in dwellings at the rates shown in Table 2.

Table 2 Characteristics of the No BASIX option for Sydney

After 2010
50% of renovated dwellings install low flow showers and water efficient clothes washers.
80% of new dwellings install low flow showers, 4.5/3 litre flush toilets and water efficient clothes washers
8% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank, supply toilet, laundry and outdoor)
9% of new (detached and semi-detached) dwellings install rainwater tanks
5% of new units install rainwater tanks

4.4 Option 3: Greater Sydney With Improved BASIX (NewBASIX)

This option assumes the BASIX policy was expanded in 2019 to include stormwater volume targets based on the assumptions outlined in Table 3.

Table 3 Characteristics of the improved BASIX option for Sydney

After 2010
70% of renovated dwellings install low flow showers and water efficient clothes washers.
All new dwellings install low flow showers, 4.5/3 litre flush toilets and water efficient clothes washers
40% of renovated dwellings install rainwater tanks (100 m^2 roof, 3 kL tank to supply toilet, laundry and outdoor uses)
90% of new (detached and semi-detached) dwellings install rainwater tanks (100 m^2 roof, 3 kL tank to supply toilet, laundry and outdoor uses)
10% of new units install rainwater tanks (2 kL/dwelling)
Stormwater volume targets: 50% reduction in the annual average stormwater runoff volume created by urban development

4.5 Option 4: Greater Sydney With Improved Basix And No Fixed Tariffs on Water and Sewage services (BSXprice)

This option assumes BASIX is expanded in 2010 to include stormwater management and a modified pricing regime for water and sewage services in Greater Sydney. This option applies a single usage tariff for water and sewage services, and a single impervious area tariff for stormwater management. This option abandons fixed tariffs to provide greater incentives to utilities and citizens for efficient water use and stormwater management.

The quantity of water supply with associated wastewater discharges from each property is impacted by the price elasticity of demand (E_p) which is defined as a function of the base price (P), change in price (ΔP) and quantity (Q) demanded:

$$E_p = \frac{\Delta Q/_Q}{\Delta P/_P}, \xrightarrow{yields} \Delta Q = E_p \frac{\Delta P}{P} Q \qquad (1)$$

The price elasticity of indoor and outdoor water demand was defined as -0.10 and -0.14 respectively, and as -0.05 for units from Abrams et al (2011).[7] These values for price elasticity were consistent with published research (for example: Veck and Bill, 2000; Thomas and Syme, 1979) and were used as follows to estimate behaviour change in demands for indoor (indem), outdoor (Outdem) and non-residential (ComInd) uses at each property on each day as follows:

$$InSup = indem - 0.10\frac{\Delta P}{P}indem \quad (2)$$

$$OutSup = outdem - 0.14\frac{\Delta P}{P}outdem \quad (3)$$

$$ComSup = ComInd - 0.05\frac{\Delta P}{P}ComInd \quad (4)$$

The water supply to each property was altered by the price elasticity and change in price in comparison the Business as Usual (BAU) base price on each day to produce residential indoor (InSup) and outdoor (OutSup) supply, and non-residential (ComSup) supply. Water supply with associated sewage discharges and stormwater runoff from properties are also altered by the installation of water efficient appliances and local water sources such as rainwater harvesting.

Coombes et al (2018) examined data from ABS (2017) to estimate the numbers and installation rates of water efficient appliances and rainwater harvesting in each local government area in the business as usual (BAU) scenario. An average summary of installation rates for Greater Sydney in response to the revised pricing regime is provided in Table 4.

Table 4 Estimated installation rates for water efficient appliances and rainwater harvesting in response to the new pricing regime

After 2010
$Reno_{WEA} = 70\% + 0.10\frac{\Delta P}{P}70\%$
All new dwellings install low flow showers, 4.5/3 litre flush toilets and water efficient clothes washers
$Reno_{RWTd} = 40\% + 0.14\frac{\Delta P}{P}40\%$
$New_{RWTd} = 90\% + 0.10\frac{\Delta P}{P}90\%$
$New_{RWTu} = 10\% + 0.05\frac{\Delta P}{P}10\%$

Commencing in 2010, the water and sewage service charges are entirely variable and based on local government area. There is also an additional impervious area tariff for stormwater services that is applied to each property. The total costs to provide stormwater services is divided by the effective impervious area in each local government area to create the stormwater tariff. This changes the modelling as changes in demand iteratively modify the real service charges over the study period. This option models:

- changes in water demand,
- changes in stormwater runoff and stormwater quality
- revenue to water providers

[7] Abrams, B., Kumaradevan, S., Sarafidis, V. and Spaninks, F. (2011) The Residential Price Elasticity of Demand for Water, Joint Research Study, Sydney, February

- changes in water service charges (impact on household welfare) for each local government area
- changes in requirement for stormwater infrastructure and operations
- funds for stormwater management

Chatswood, Sydney.

5 SYSTEM BACKGROUND

5.1 Sydney Governance

Water NSW and the Land and Water Division of the Department of Industry have ultimate responsibility for urban water through the Water Management Act 2000 (NSW). The NSW Water Act 1994 provides an operating licence to Sydney Water to supply water, sewerage services, stormwater drainage and wastewater disposal.

The primary role of Sydney Water is to be a successful business. This is reflected in the IPART commentary on the regulation of Sydney Water[8]. This concept is essential to understanding the logic behind both Sydney Water management decisions and IPART regulatory role. Sydney Water must exhibit a sense of social responsibility but the requirement to remain viable and maximise its net worth appears to take precedence over social responsibility considerations. It is worth expanding on what being a successful business could include. A successful business could act to protect its monopoly status, it could seek to maximise revenue and it could seek to increase its value and influence through infrastructure investment.

5.2 Sydney Water's role

Sydney Water is a NSW government owned water utility, which serves a population of over five million in the Sydney, Illawarra and the Blue Mountains regions. It does not manage bulk water supply or the catchment areas. It sources its water from WaterNSW, and when required, from the Sydney Desalination Plant Pty Ltd.

Sydney Water is a statutory State Owned Corporation, wholly owned by the NSW Government. Its principal functions are to provide, construct, operate, manage or maintain systems or services for:

- *storing or supplying water*
- *providing sewerage services*
- *providing stormwater drainage systems, and*
- *disposing of wastewater.*

Sydney Water's principal objectives are prescribed by the State Owned Corporations Act 1989 and the Sydney Water Act 1994, and are to:

- *be a successful business, and to this end:*
  - *to operate at least as efficiently as any comparable businesses, and*
  - *to maximise the net worth of the State's investment in the Corporation, and*
  - *to exhibit a sense of social responsibility by having regard to the interests of the community in which it operates,*
  - *protect the environment by conducting its operations in compliance with the principles of ecologically sustainable development contained in section 6(2) the Protection of the Environment Administration Act 1991, and*
  - *protect public health by supplying safe drinking water to its customers and other members of the public in compliance with the requirements of any operating licence.*
- *In implementing these objectives, Sydney Water has the following special objectives:*
  - *to reduce risks to human health, and*
  - *to prevent the degradation of the environment.*[8]

5.3 The Sydney System

The population of the Greater Sydney region is expected to increase from 4.3 million in 2010 to 6.8 million in 2050. The Greater Sydney region includes 45 local government areas (white polygons) and weather stations (red markers) as presented in Figure 2.

[8] IPART. (2018). Review of the Sydney Water Corporation Operating Licence 2015-2020. Sydney: Independent Pricing and Regulatory Tribunal.

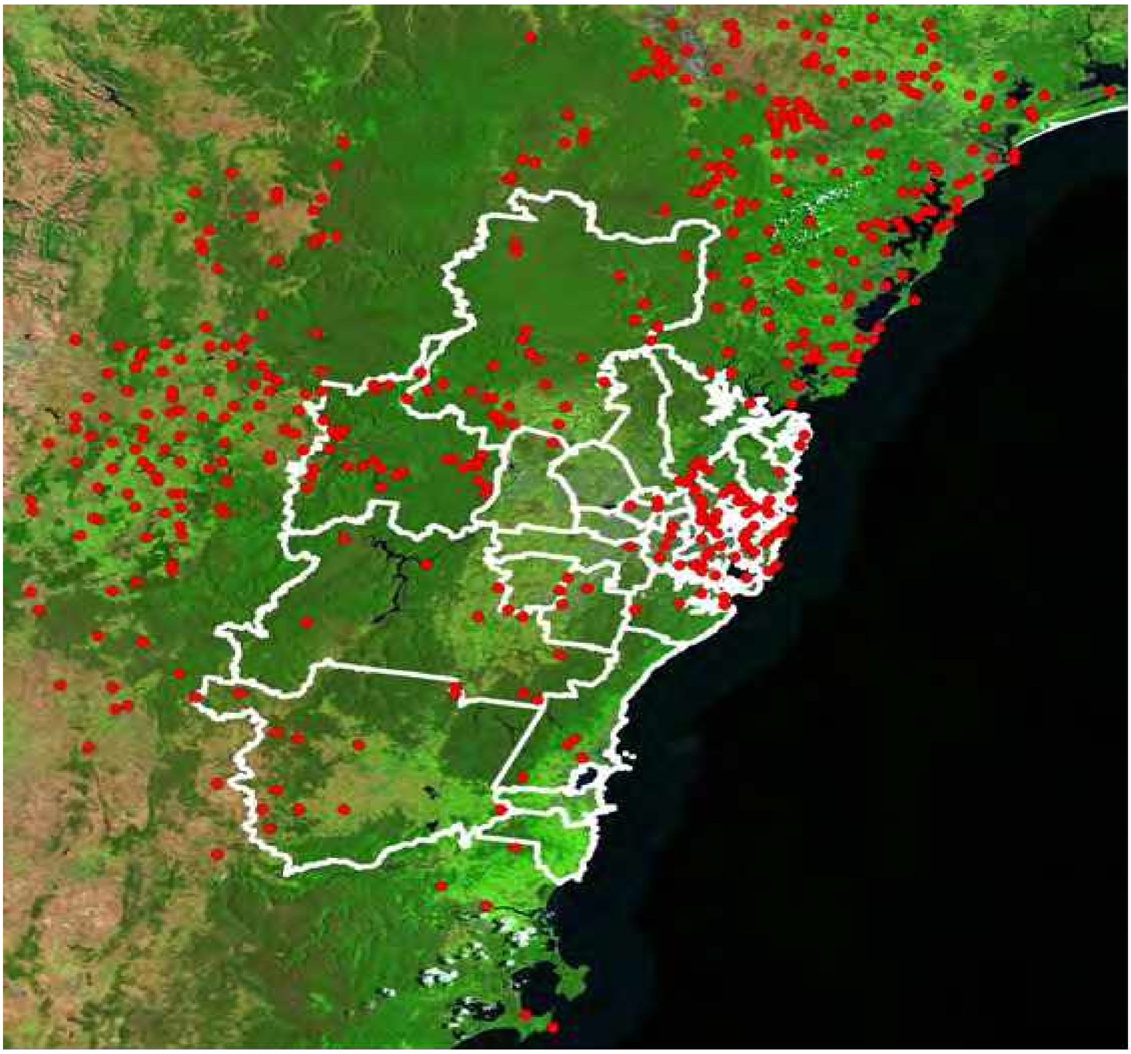

Figure 2: Sydney zones (white polygons) and weather stations (red markers) (Barry and Coombes, 2018)

Analysis of the Sydney water supply systems used daily water demands, streamflows, operational data and rules provided by Sydney Water Corporation and the NSW government. Analysis of the Sydney water supply systems used daily water demands, streamflows, operational data and rules provided by Sydney Water Corporation and the NSW government.

Water demands for the 45 local government areas were combined in the regional analysis. Observations of daily water demand from 1976 to 2010 for the 14 water supply catchments enabled verification of these water demands. The Greater Sydney region includes different demand zones that are supplied from the Warragamba, Upper Nepean, Shoalhaven and Woronora river catchments (Coombes, 2005; 2012) as shown in Figure 3.

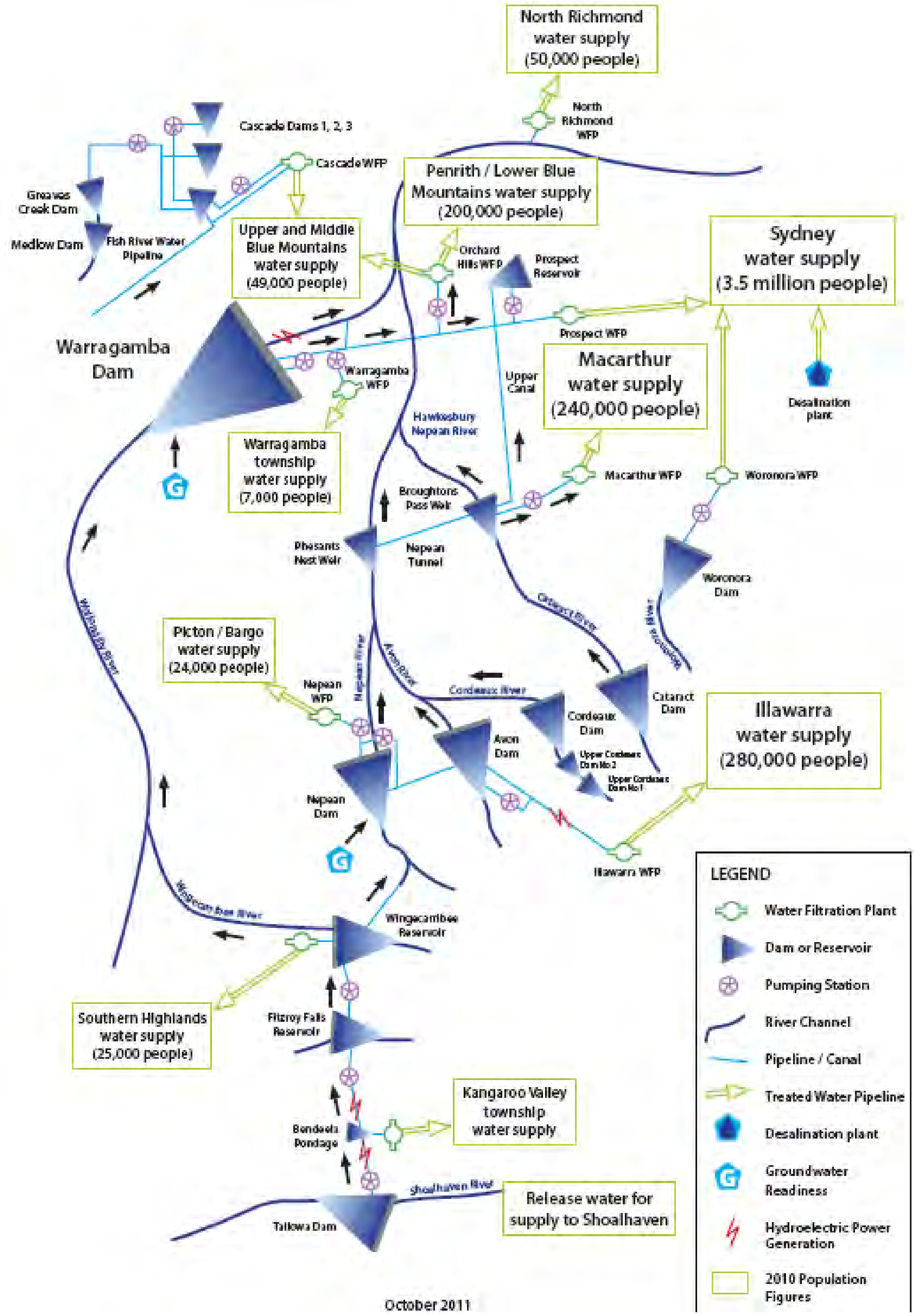

Figure 3: Schematic of the water supply system for Greater Sydney (Sydney Water, 2010).

Streamflow from the Warragamba catchment is captured at Warragamba Reservoir. Water from the Cataract, Cordeaux, Avon and Nepean Dams located in the Upper Nepean catchment is conveyed via a system of pipes, natural river channels, weirs, tunnels and aqueducts to Prospect Reservoir whilst also supplying various communities along the transfer routes.

The South Coast region is supplied with water from the Avon and Cordeaux Dams and Nepean Dam via the Nepean–Avon tunnel. Streamflow from the Shoalhaven catchment is captured in Lake Yarrunga and Tallowa Dam where water is pumped to Wingecarribee Reservoir via Fitzroy Falls Reservoir when the water storage volume in Warragamba Dam is less than 65%. Water from the Wingecarribee Reservoir is distributed to Nepean Dam and Lake Burragorang via the Wingecarribee and Wollondilly Rivers.

The townships of Mittagong and Bowral are also supplied with water from the Wingecarribee Reservoir. Desalination is used to supplement the water supply to the Potts Hill reservoir when total storages in dams are less than 80%. Restrictions on urban water demands are triggered when storage levels in Warragamba Dam or Avon Dam fall below 60%. The reported effectiveness of water restrictions in the Sydney region during the 1992–1998 drought by Deen (2000) was used to develop restriction criteria and subsequent demand reductions for domestic outdoor demand as shown in Table 5.

Table 5. Water restriction criteria for residential and non residential demands.

Storage in dams less than (%)	60	55	50	40	30	20
Reduction in residential outdoor demand (%)	33	57	75	100	100	100
Reduction in residential indoor and nonresidential demand (%)	0	0	5	10	15	20

5.4 Verification using hindcasting

The predictions of the system scale models were validated against available data, such as water treatment plant flows or reservoir levels and volumes. The 'bottom-up' process of generating local water use from dwellings and land uses in each zone was evaluated by comparison of historical observed water use to predicted water use for the entire Greater Sydney region as presented in Figure 4.

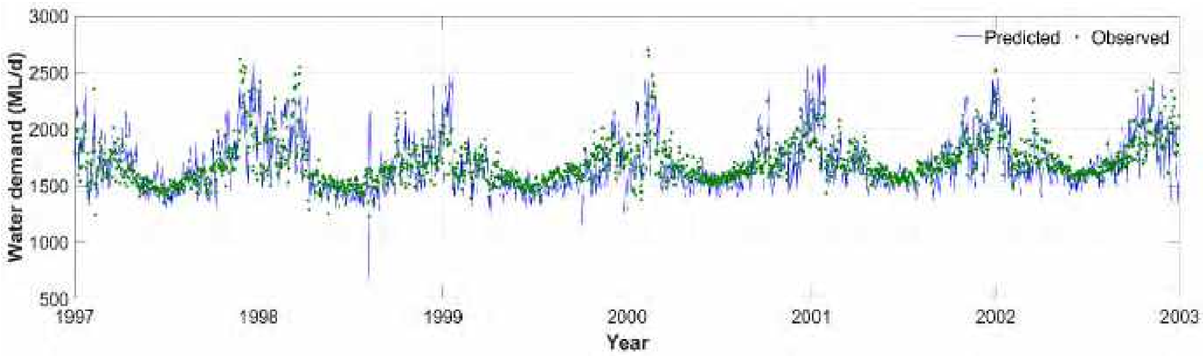

Figure 4: Observed and predicted daily water demands for Greater Sydney (1997–2005) (Barry and Coombes, 2018).

6 ASSESSMENT OF OPTIONS

The results from the systems analysis of the four options BAU, NoBasix, NewBASIX and BSX_price is summarised in this section for a range of physical, environmental and economic criteria.

6.1 Water Demand

The expected total demand of the Greater Sydney region for utility water supply is presented in Figure 5 for the period 2010 to 2050.

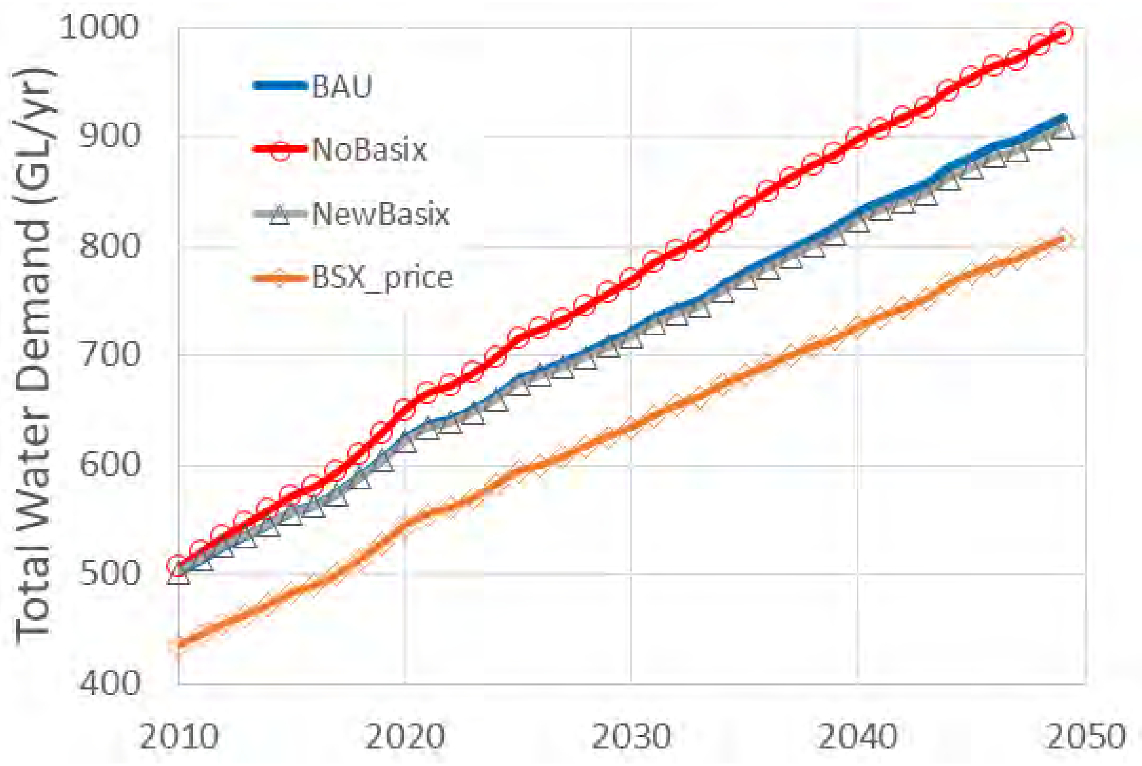

Figure 5: Total utility water supply for the Greater Sydney region for each option from 2010 to 2050.

Figure 5 shows that regional demands for utility water supply in the BAU option increases by 414 GL (82%) to 917 GL/annum in 2050.

The NoBasix option results in a 492 GL (98%) increase in utility water supply to 994 GL/annum in 2050. This is a 78 GL/annum greater water demand by 2050 than the BAU option due to reduced uptake of water efficient appliances and rainwater harvesting.

Regional demands for utility water supplies in the NewBasix option increases by 405 GL (81%) to 908 GL/annum by 2050. The 8 GL/annum decrease in utility water supply, as compared to BAU, by 2050 results from increased uptake of rainwater harvesting.

The BSX_price option experiences an increase in regional utility water supply of 304 GL (60%) to 807 GL/annum in 2050. This option results in a 110 GL/annum decrease in regional water supply from the BAU option due to behaviour change (80 GL/annum), water efficient appliances (16 GL/annum) and rainwater harvesting (14 GL/annum). Note that an adjustment period of one year to the new pricing regime is assumed for the BSX_price option as outlined by Abrams et al (2011)[9] which results in a lower regional supply in 2010.

The expected regional water savings from uptake of more efficient household appliances is provided in Figure 6.

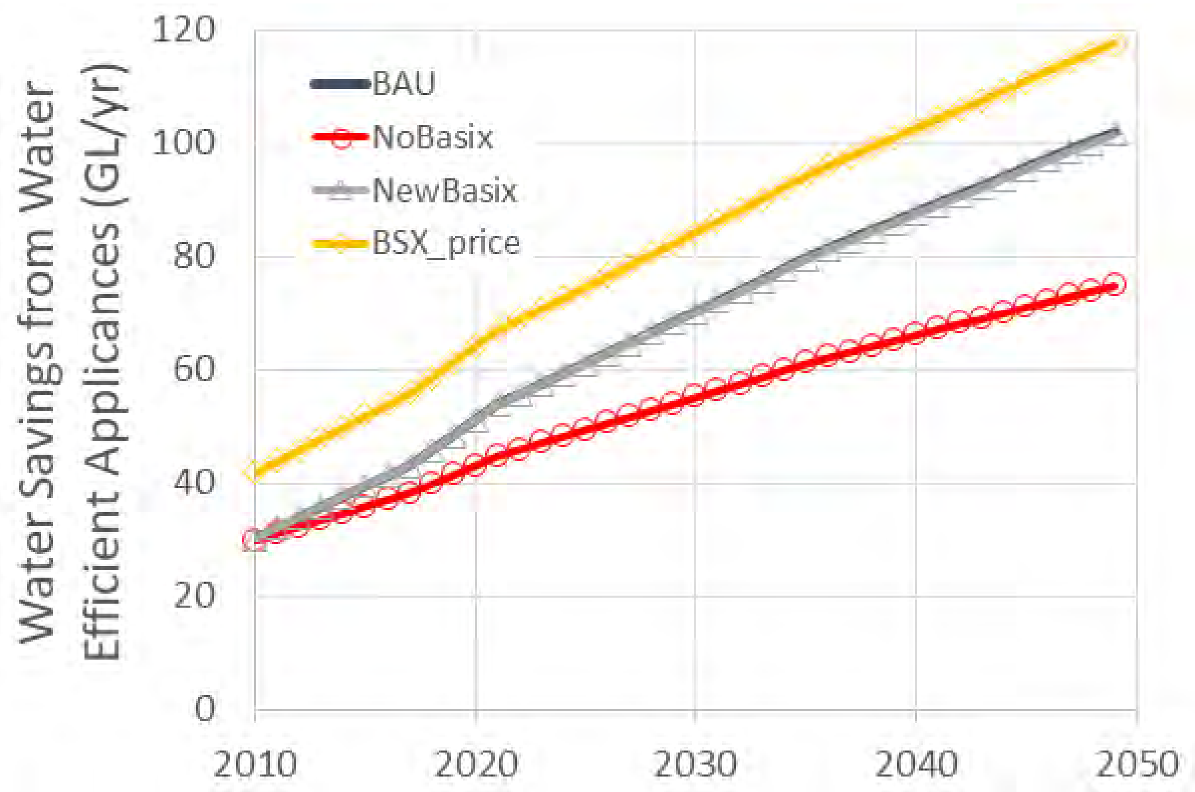

Figure 6: Regional water savings from uptake of more efficient appliances for the Greater Sydney region for each option from 2010 to 2050.

Figure 6 shows that the uptake of more efficient appliances in the BAU option provides an increase in regional water savings of 72 GL (239%) to 102 GL/annum in 2050.

Regional water savings in the NoBasix option increase by 45 GL (149%) to 75 GL/annum by 2050. This result indicates a reduction in regional water saving of 27 GL/annum by 2050 due to decreased adoption of more efficient appliances in new and renovated dwellings.

The NewBasix option provides similar regional water savings as the BAU option. Regional water savings from uptake of more water efficient appliances in the BSX_price increased by 87 GL (290%) to 117 GL/annum in 2050. The economic incentive created by full usage tariffs increased uptake of more efficient appliances to provide additional water savings of 16 GL/annum by 2050.

The expected total regional rainwater supply from rainwater harvesting from roofs at the property scale is presented in Figure 7.

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[9] Abrams, B., Kumaradevan, S., Sarafidis, V. and Spaninks, F. (2011) The Residential Price Elasticity of Demand for Water, Joint Research Study by Sydney Water and University of Sydney, Sydney.

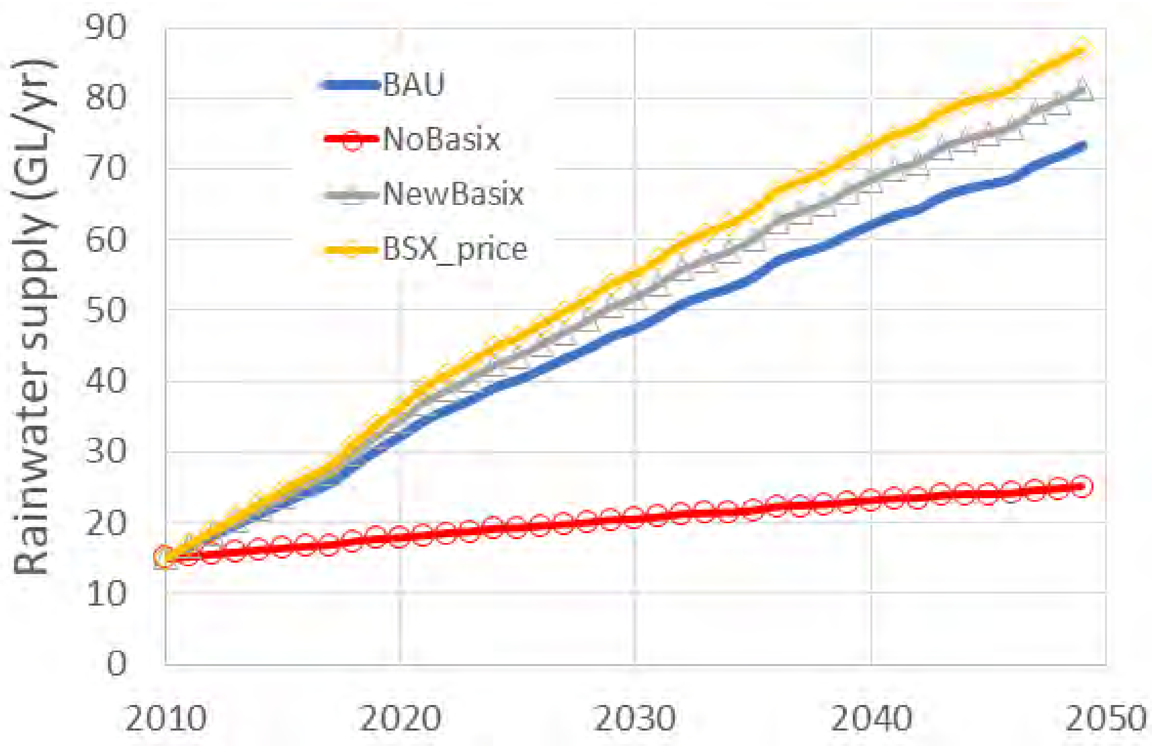


Figure 7: Regional rainwater supply from property scale rainwater harvesting for Greater Sydney from each option from 2010 to 2050.

Figure 7 reveals that rainwater supply from roofs on properties in the BAU option increased by 58 GL (390%) to 73 GL/annum in 2050.

The NoBasix option shows rainwater supply increased by 10 GL (67%) to 25 GL/annum in 2050. Eliminating government support of property scale rainwater harvesting from 2010 reduced regional rainwater supply by 48 GL/annum by 2050.

Regional rainwater supply in the NewBasix option increased by 66 GL (442%) to 81 GL/annum in 2050. The inclusion of targets for reduced stormwater runoff volumes in the BASIX policy has increased rainwater supply by 8 GL/annum by 2050.

The full usage tariffs (no fixed tariffs) in the BSX_Price option was an incentive to increase property scale rainwater harvesting which increased regional rainwater supply by 72 GL (481%) to 87 GL/annum in 2050. This is an increase in regional rainwater supply of 14 GL/annum by 2050.

6.2 Water security

The water security provided to the Greater Sydney region from each option is represented by the timing of the major augmentation of regional water supplies by the Avon Tunnel or desalination plants in Table 6.

Table 6: Water security for the Greater Sydney region from each option as defined by timing of requirement to augment with major supply sources

Option	Augmentation timing by year			
	First	Second	Third	Fourth
BAU	2034	2034	2038	2042
NoBasix	2029	2029	2034	2042
NewBasix	2034	2034	2038	2046
BSX_price	2038	2038	2042	-

Table 6 shows that the BAU option requires four major supply augmentations in the period to 2050 – these major supply options are the Fitzroy Falls to Avon tunnel and desalination plants.The NoBasix Option requires earlier implementation of the first three supply options by four years and the NewBasix option delays the fourth augmentation (desalination plant supplying the south coast) by two years.

Requirement for first three major supply augmentations is delayed by four years by the BSX_price option and the final supply augmentation is avoided.

These results are based on systems analysis that combines all behavioural demand and water resources processes using detailed spatial inputs and daily time steps. These processes are more detailed than the current analysis by WaterNSW (2018)[10] that utilises lumped catchment (larger scale) inputs and monthly time steps.

This investigation employed 100 replicates of climate and streamflow based on historical records from the period 1910 to 2010. In contrast, the current WaterNSW analysis employed 2000 replicates of historical data for the period 1909 to 2016 and reduced Shoalhaven River streamflows to indicate reduced regional water yield from 600 GL/annum to 570 GL/annum. Whilst the systems analysis in this investigation is not directly comparable to the traditional yield analysis and does not include climate change, these results provide robust assessment of the relative changes in water security provided by each option.

6.3 Sewage Discharges

The expected wastewater discharges from the Greater Sydney region for utility sewage networks is presented in Figure 8 for the period 2010 to 2050.

[10] WaterNSW (2018), Greater Sydney's water supply system yield, May 2018, Sydney.

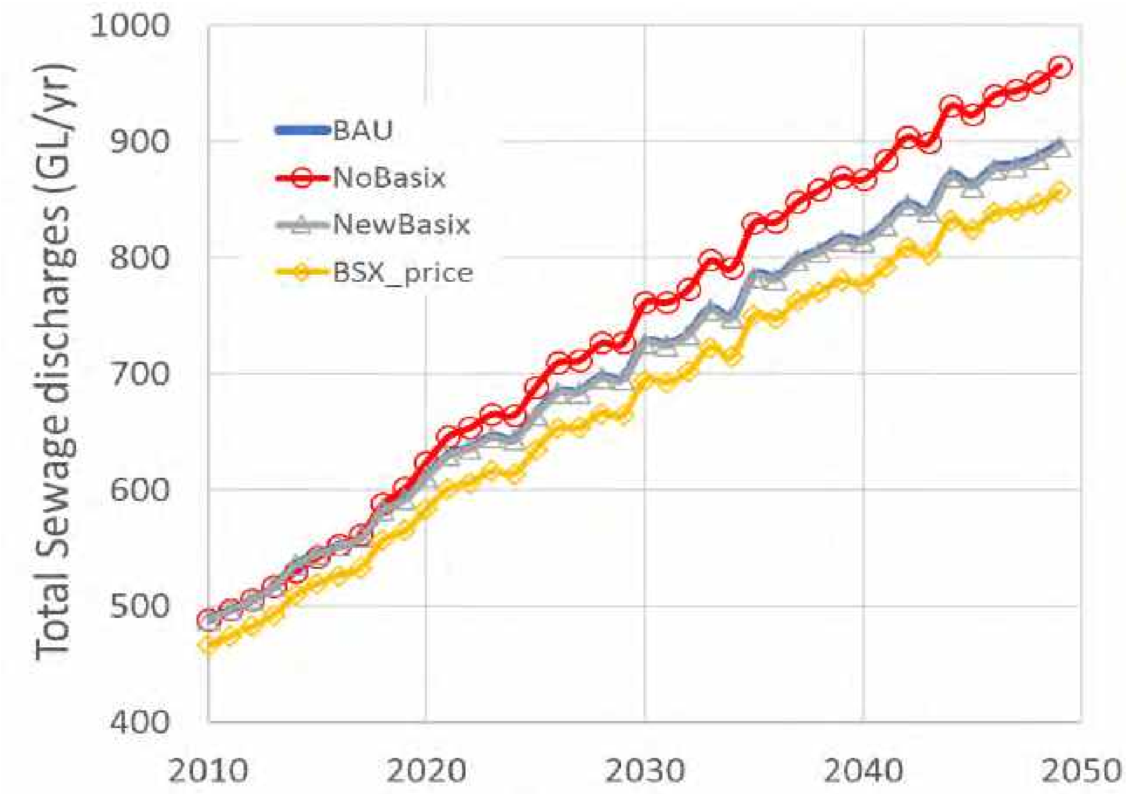


Figure 8: Regional wastewater discharges for Greater Sydney from each option from 2010 to 2050.

Figure 8 shows that wastewater discharges from the BAU option for the Greater Sydney region increase by 410 G (84%) to 965 GL/annum by 2050.

The NoBasix option is subject to 476 GL (97%) increase in wastewater discharges to 965 GL/annum by 2050. This result indicates a 67 GL/annum increase in wastewater discharges by 2050 due to decreased uptake of more efficient appliances.

Regional wastewater discharges in the NewBasix option increased by 407 GL (83%) to 896 GL/annum in 2050. The increased uptake of more efficient appliances reduces wastewater discharges by 3 GL/annum by 2050.

The BSX_Price option resulted in a 368 GL (75%) increase in regional wastewater discharges to 857 GL/annum in 2050. A pricing regime that did not include fixed tariffs incentivised changes water use behaviours and increased uptake of more efficient appliances to decrease regional wastewater discharges by 42 GL/annum by 2050.

6.4 Stormwater Runoff

The expected stormwater runoff from all urban areas across the Greater Sydney region is presented in Figure 9 for the period 2010 to 2050. Note that these values include stormwater runoff from all land uses in urban areas and does not include inflows from upstream rural areas.

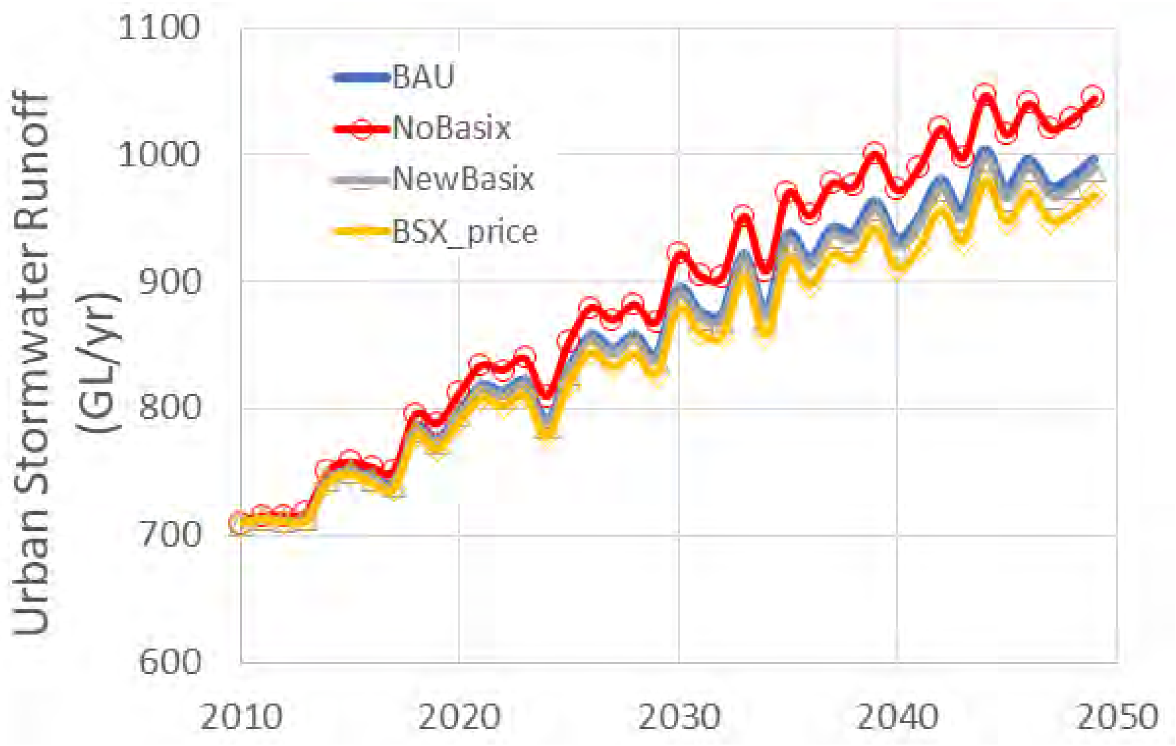


Figure 9: Regional urban stormwater runoff for Greater Sydney from each option from 2010 to 2050.

Figure 9 shows that regional urban stormwater runoff in the BAU option increased by 287 GL (49%) to 996 GL/annum by 2050. Urban stormwater runoff in the NoBasix option increases by 335 GL (47%) to 1045 GL/annum by 2050. This is an increase in regional urban stormwater runoff of 48 GL/annum by 2050.

The NewBasix option is subject to an increase in urban stormwater runoff of 279 GL (39%) to 989 GL/annum by 2050. Additional uptake of rainwater harvesting has diminished urban stormwater runoff by 8 GL/annum in 2050.

The BSX_price option that does not include fixed tariffs for water, sewage and stormwater services results in an increase in regional urban stormwater runoff of 258 GL (38%) to 968 GL/annum by 2050. The price incentives in this option increases the uptake of rainwater harvesting (additional 241,750 properties) which decreases urban stormwater runoff by 14 GL/annum in 2050. An impervious area tariff was also estimated to drive a further reduction in urban stormwater runoff of 14 GL/annum due to disconnection of impervious surfaces from street drainage networks via raingardens or similar.

The expected nitrogen loads in urban stormwater runoff across the Greater Sydney region is presented in Figure 10 for the period 2010 to 2050.

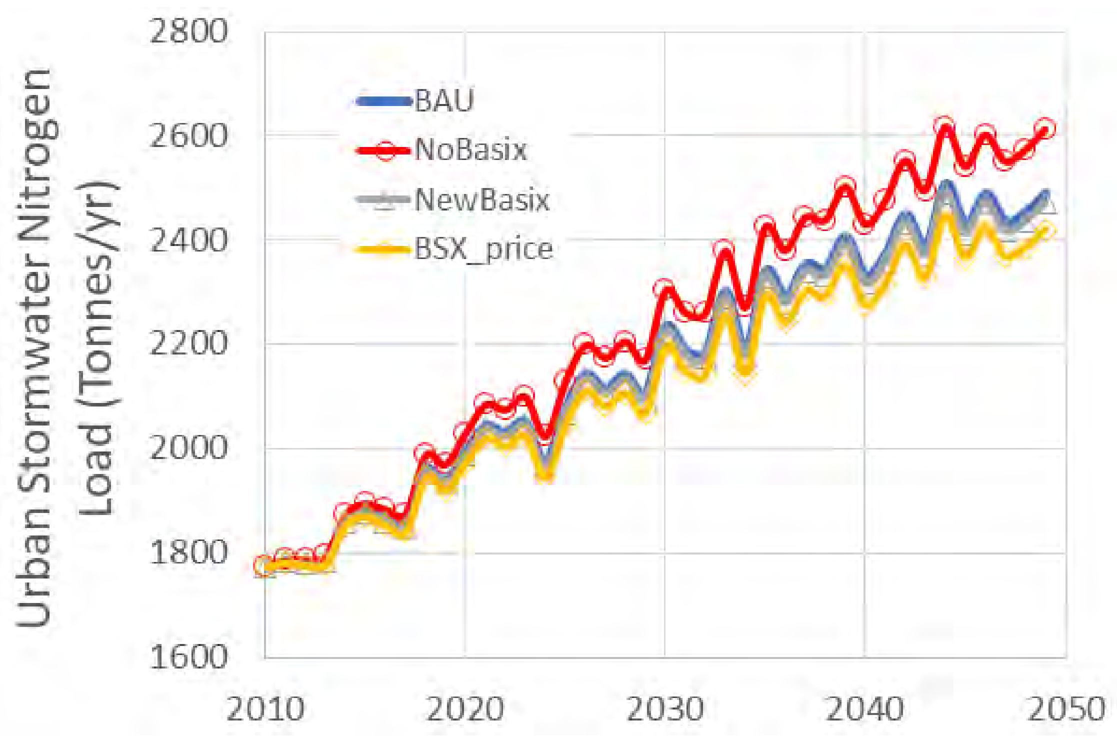


Figure 10: Regional nitrogen loads from urban stormwater runoff for Greater Sydney from each option from 2010 to 2050.

Figure 10 reveals that the BAU option increases in regional nitrogen loads in urban stormwater runoff by 717 tonnes to 2419 tonnes/annum by 2050. The nitrogen loads in urban stormwater runoff from the NoBasix option increase by 838 tonnes (47%) to 2612 tonnes/annum by 2050. A reduced uptake of rainwater harvesting results in an increase in nitrogen loads in urban stormwater by 121 tonnes/annum by 2050.

Regional nitrogen loads in urban stormwater runoff in the NewBasix option increased by 698 tonnes (39%) to 2471 tonnes/annum by 2050. Additional rainwater harvesting has reduced nitrogen loads by 19 tonnes/annum in 2050.

The BSX_price option experiences 646 tonnes increase of nitrogen loads in urban stormwater runoff to 2420 tonnes/annum in 2050. Increased uptake of rainwater harvesting and other measures that disconnect impervious surfaces from drainage networks, such as raingardens, decreases nitrogen loads by 71 tonnes/annum in 2050.

6.5 Greenhouse Gas Emissions

The greenhouse gas emissions from utility water and sewage services, water efficient appliances and rainwater harvesting across the Greater Sydney region is presented in Figure 11 for the period 2010 to 2050. Note that these values account for reductions in emissions created by water efficient appliances due to reduced hot water use and lower flowrates in household appliances as outlined by Coombes (2005).[11] This analysis also considers 20 years of monitoring as reported by Coombes (2018) that reveals reductions in household energy use after installing rainwater harvesting.

[11] Coombes P.J., (2005), Integrated water cycle management: analysis of resource security, Water, Australian Water Association, 21-26.

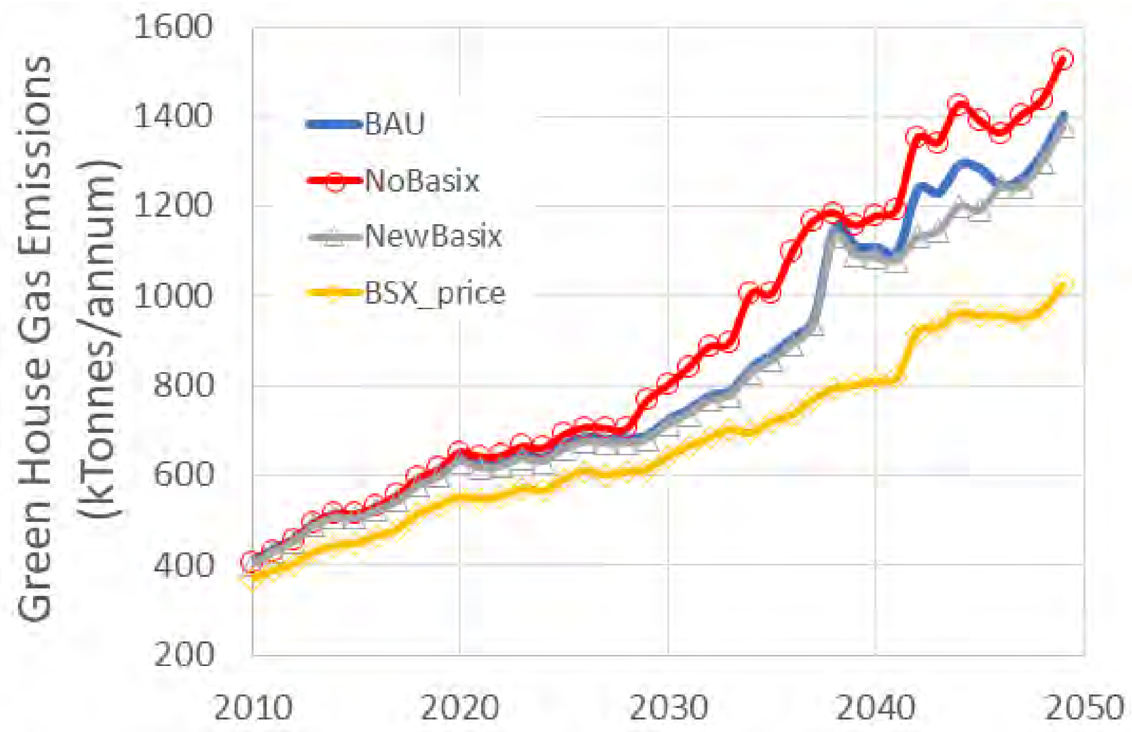


Figure 11: Greenhouse gas emissions generated by water and sewage services for Greater Sydney from each option from 2010 to 2050.

Figure 11 shows that increased dependence on desalination for utility water supply generates a step change after 2028 to higher rates of greenhouse gas emissions for the BAU, NoBasix and NewBasix options. The BAU option generates increased annual greenhouse gas emissions of 994 kTonnes (241%) to 1405 kTonnes/annum in 2050.

The greenhouse gas emissions from the NoBasix option increase by 1115 kTonnes (271%) to 1527 kTonnes/annum by 2050. A reduced uptake of water efficient appliances and rainwater harvesting increases greenhouse gas emissions relative to the BAU option by 122 kTonnes/annum in 2050. These increased emissions are caused by higher demands for utility water supply and wastewater disposal increase energy uses for desalination, water and wastewater treatment, and for transferring water and sewage across the region.

Greenhouse gas emissions in the NewBasix option increased by 973 kTonnes (236%) to 1377 kTonnes/annum by 2050. Additional water efficient appliances and rainwater harvesting has reduced greenhouse gas emissions by 21 kTonnes/annum in 2050. The BSX_price option increases greenhouse gas emissions by 657 kTonnes to 1026 KTonnes/annum in 2050. Changes in water use behaviours, increased uptake of rainwater harvesting and water efficient appliances that reduce utility water supply decreases greenhouse gas emissions by 337 kTonnes/annum in 2050.

6.6 Costs, Tariffs and Economics

6.6.1 Water and Sewage

A focus on centralised supply and disposal solutions has defined the urban water sector as a transport industry that moves water and sewage across large distances.[12] This centralised paradigm has substantial impacts on resources (Clarke and Stevie, 1981)[13] and economic outcomes (Coase, 1947).[14] The water supply transfer distances from reservoirs to local government areas are shown in Figure 11 and the wastewater disposal transfer distances from local government areas to wastewater treatment plants are presented in Figure 12.

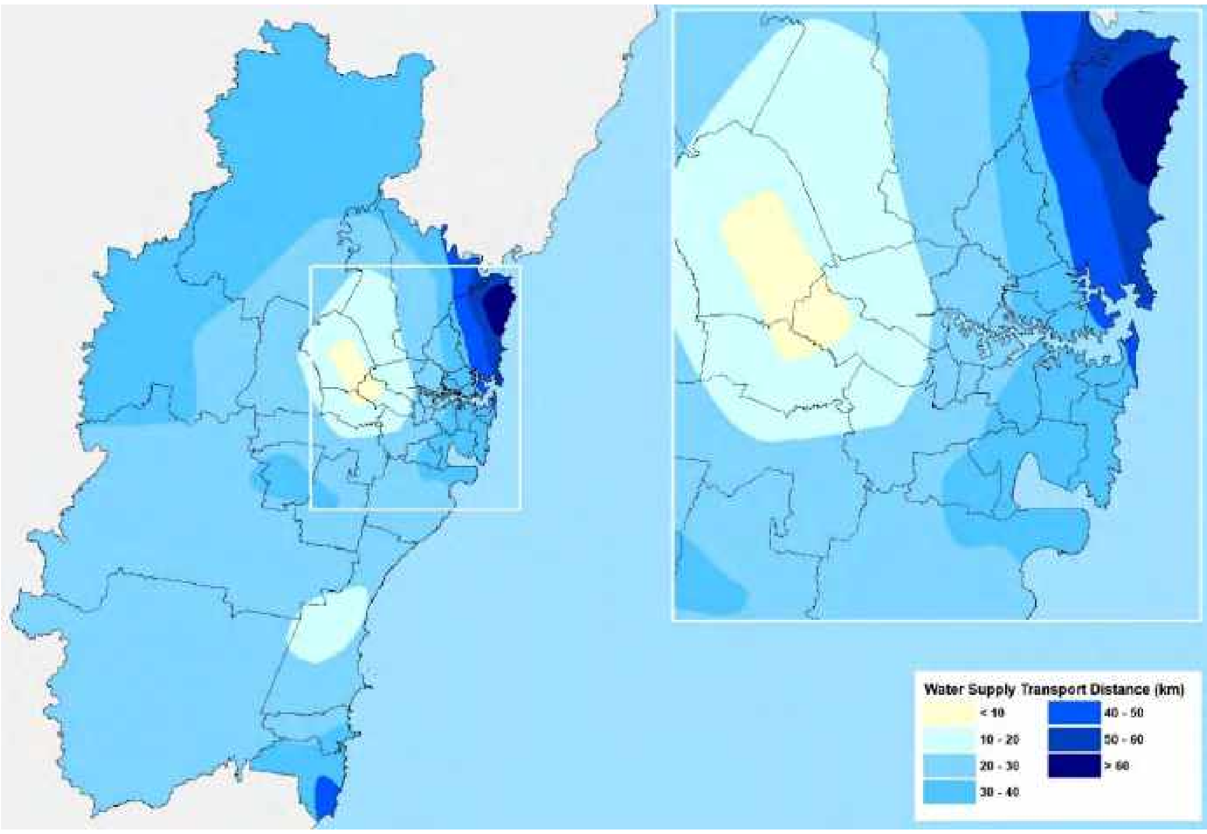


Figure 12: Water supply transfer distances across greater Sydney

[12] Coombes P.J., and Barry M.E., (2014), A systems framework of big data driving policy making for Melbourne's water future, OzWater14, Australian Water Association, Brisbane.

[13] Clarke R.M., and Stevie R.G., (1981), A water supply cost model incorporating spatial variables, Land Economics, University of Wisconsin Press, 57(2), 18-32.

[14] Coase R.H., (1947), The economics of uniform pricing systems, Manchester School of Economics and Social Studies, 139-156.

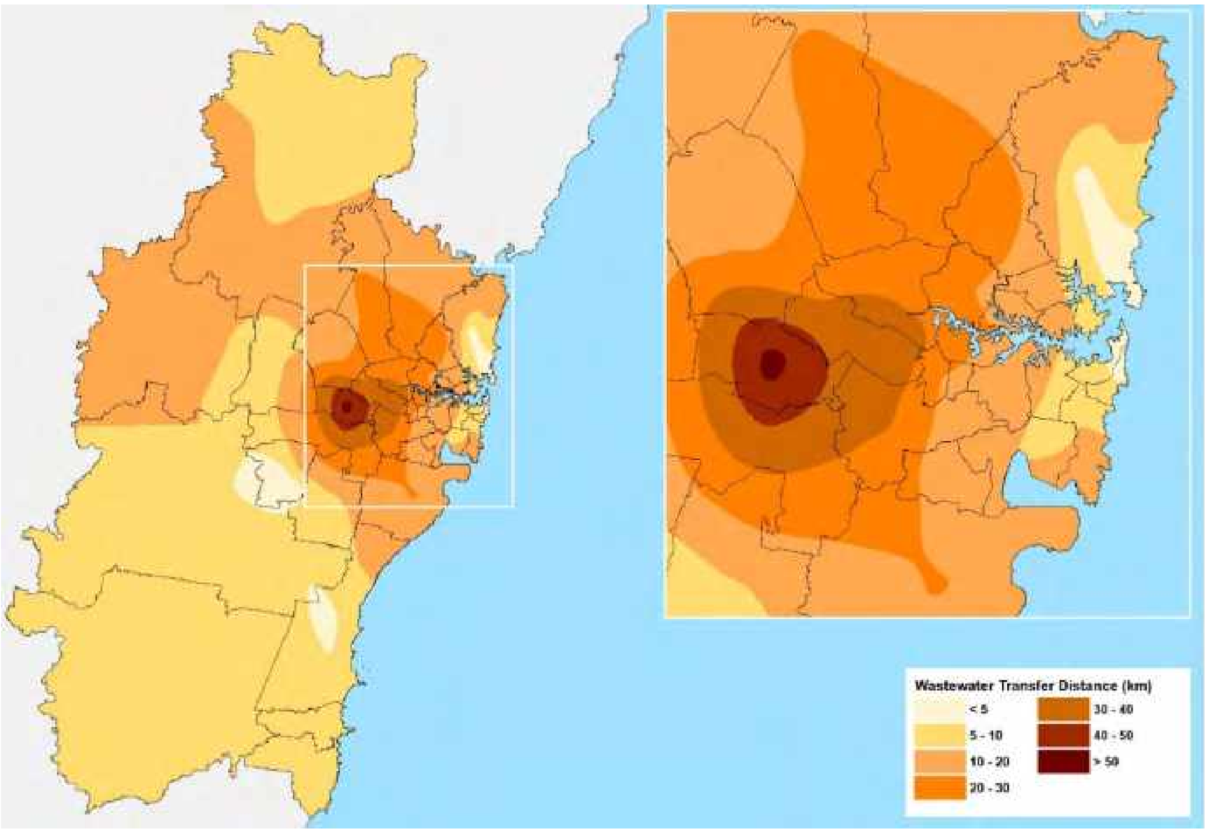


Figure 13: Wastewater disposal transfer distances across greater Sydney

The total capital and operational costs of providing water and sewage services throughout the Greater Sydney region are presented in Figure 14 for the period 2010 to 2050 for each option. Note that these costs are based on 2019 dollar values.

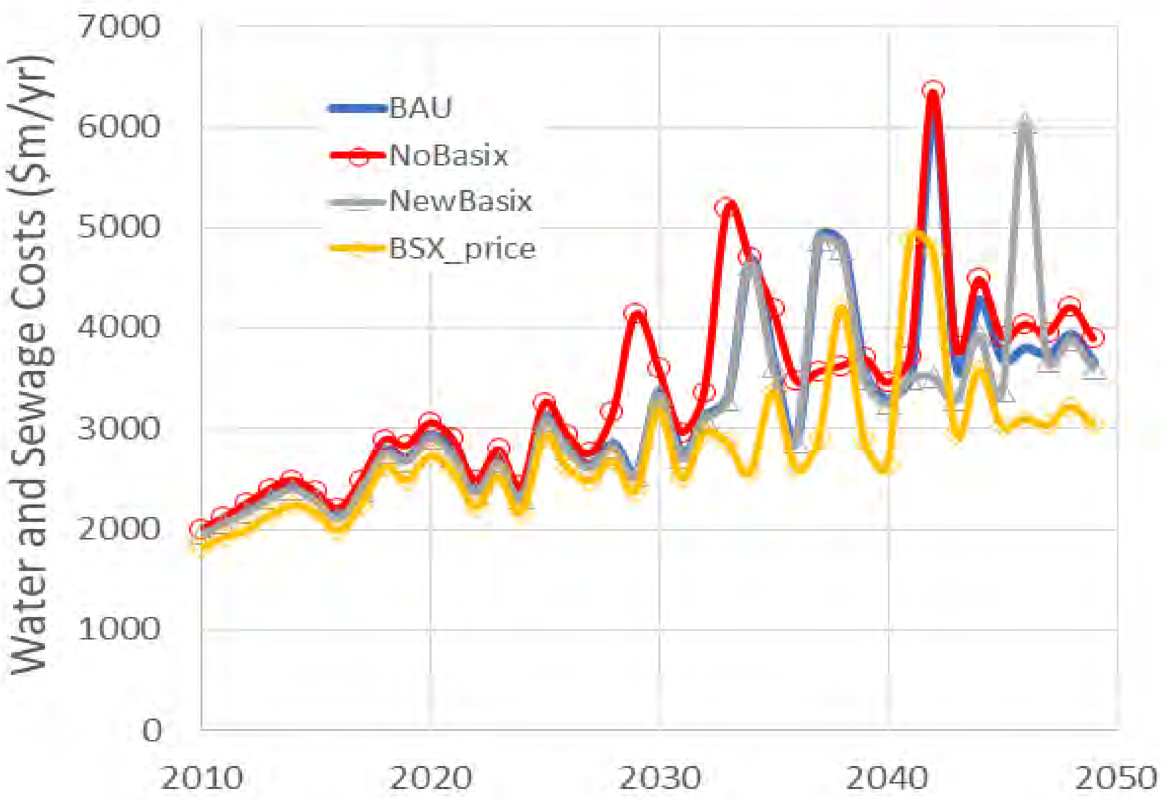


Figure 14: Total capital and operational costs (in 2019 dollar values) for Greater Sydney from each option from 2010 to 2050.

Figure 14 shows that the annual costs to provide water and sewage services in the BAU option increase by $1681 million (85%) to $3657 million/annum by 2050.

The NoBasix option is subject to increases in annual water and sewage costs by $1917 million (97%) to $3894 million/annum by 2050. A reduced uptake of water efficient appliances and rainwater harvesting results in higher annual costs of $236 million by 2050.

Annual costs to provide water and sewage services for the NewBasix option increased by $1627 million (82%) to $3603 million by 2050. Greater uptake of water efficient appliances and rainwater harvesting has lowered annual costs by $52 million in 2050.

The BSX_price option resulted in an increase in annual costs to provide water and sewage services of $1065 million (54%) to $3040 million in 2050. Increased uptake of rainwater harvesting and water efficient appliances, and changed water use behaviours decreased annual costs by $615 million in 2050.

The spatial costs of water and sewage services for the BAU option were derived for all costs in the planning horizon from 2010 to 2050 and are shown in Figure 15.

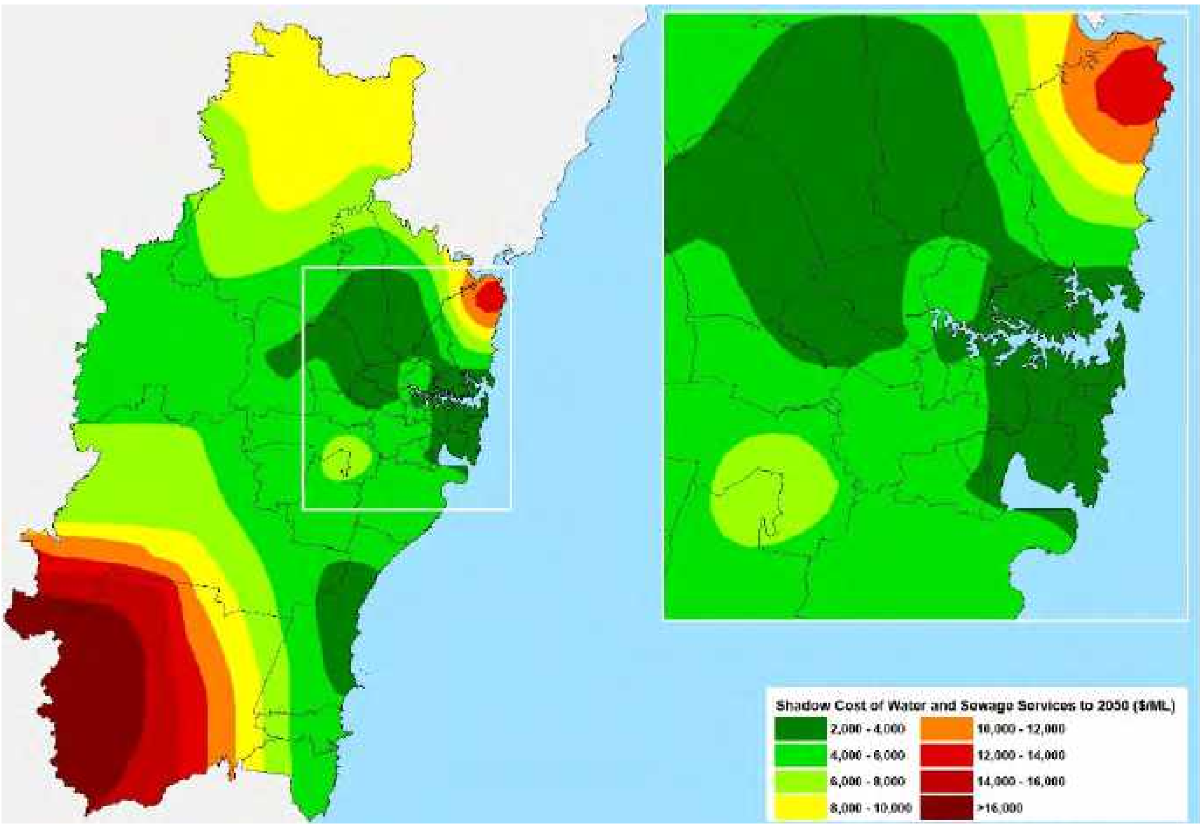


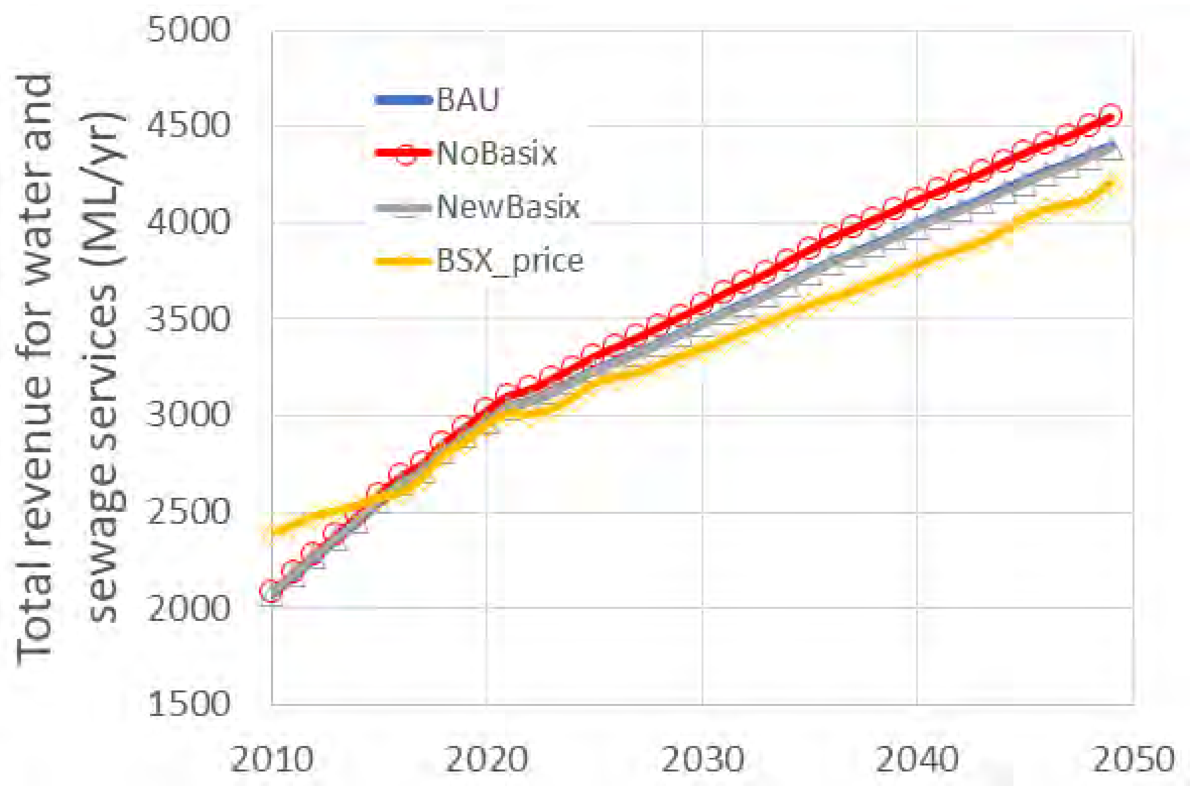
Figure 15: The spatial costs of water and sewage services to 2050 across greater Sydney for the BAU option

Figure 15 reveals that the total spatial costs of water and sewage services ranged from $2/kL to greater than $16/kL. These values represent all operation, renewal, capital and water security costs divided by the cumulative water supply volumes for the period 2010 to 2050. Given that in the long run all costs are variable, these results represent the long run spatial marginal costs of water and sewage services for Greater Sydney and can be used to evaluate the economic viability of distributed solutions.[15]

These values can be considered to be shadow cost maps for evaluation of distributed strategies such as water efficient appliances, rainwater harvesting and alternative water sources. A majority of these spatial long run marginal costs are greater than the values of $1.28/kL in the short run and $2.08 in the long run proposed by Sydney Water Corporation for assessment of water conservation strategies.[16]

The revenue earned from consumers paying for utility water and sewage services for the Greater Sydney region is presented in Figure 16 for the period 2010 to 2050. This source for revenue for the BAU, NoBasix and NewBasix options includes fixed and variable tariffs for water and sewage services as levied by IPART (2016)[17] and reported in Sydney Water Annual reports (for example; SWC, 2010).[18]

The BSX_price option does not include fixed tariffs and utilises two full usage tariffs for water and sewage, and stormwater services. This option uses a full usage tariff for water and sewage services that is levied by the water utility for each local government area. The usage tariffs are revised annually by the regulator in response to spatial costs and demands. A single impervious area tariff is also levied by local government for stormwater services to properties in each local government area. This impervious area tariff will also be revised annually by the regulator for each local government area in response to costs and environmental impacts.



[15] Coombes P.J., Barry M.E., and Smit M., (2020), Revealing the spatial long run marginal costs of water and sewage services for Australian capital Cities, In review

[16] Sydney Water (2018), Water conservation report 2017-2018, Sydney Water

[17] IPART (2016), Review of prices for Sydney Water Corporation 1 July 2016 to 30 June 2020, Water Final Report, Independent Pricing and Regulatory Tribunal.

[18] SWC (2010), Annual Report, Sydney Water Corporation.

Figure 16: Total revenue for water and sewage services (in 2019 dollar values) for Greater Sydney from each option from 2010 to 2050.

Figure 16 shows that the NoBasix option earns more revenue than the BAU and NewBasix options, and the BSX_price option earns less revenue than the other options. The total annual revenue for water and sewage services earned in the BAU option increased by $2325 million (112%) to $4402 million by 2050.

Annual revenue for water and sewage services in the NoBasix option increased by $2308 million (119%) to $4552 million/annum in 2050. The reduced uptake of water efficient appliances and rainwater harvesting results in $150 million/annum additional revenue by 2050 and the utility also incurs $236 million/annum in extra costs.

The NewBasix option experiences increased annual revenue for water and sewage services of $2308 million (111%) to $4385 million/annum in 2050. This option reduces annual revenue by $16 million and annual costs by $52 million by 2050 in comparison to the BAU option in response to lower demands for utility water and sewage services.

The BSX_price option increased revenue for water and sewage services by $2127 million (102%) to $4204 million/annum by 2050. Incentives created by the full usage tariffs for water and sewage services decreased annual revenue by $198 million and annual utility costs by $615 million by 2050.

A key insight from these results is that decreased costs overwhelm diminished revenue by a factor of three when distributed solutions reduce demand for utility water and sewage services. Increased costs also overwhelm gains in revenue by a ratio of 1.6 in the situation where policies supporting distributed water savings are abandoned in NoBasix.

The net present costs, revenues and benefits are summarised for the period 2010 to 2050 using a discount rate of 4% in Table 7.

Table 7: Summary of present economic values for water and sewage services to 2050

	Present value versus option			
Item	BAU	NoBasix	NewBasix	BSX_price
Costs ($m)	57,149	60,205	56,121	51,021
Net costs ($m)		+3056	-1028	-6128
Revenue ($m)	61,676	62,998	61,545	60,808
Net revenue ($m)		+1322	-131	-868
NPV ($m)	4,527	2,793	5,424	9,786
Net Benefit ($m)		-1734	+897	+5259

Table 7 demonstrates that the net present costs of utility water and sewage services increases for the NoBasix option by $3056 million, and decreases for the NewBasix option by $1028 million and by $6128 million for the BSX_price option.

The net present value of revenue earned from utility water and sewage tariffs increases by $1322 million for the NoBasix option and declines by $131 million for the NewBasix option and by $868 million for the BSX_price option.

A combination of these outcomes provides the net present benefit (a combination of costs and benefits) of utility water and sewage services declines by $1734 million for the NoBasix option, and increases for the NewBasix and BSX_price options by $897 million and $5259 million respectively.

These economic results show that the distributed water savings reduce utility costs more than any losses of revenue, and provide significant opportunities to reduce the impacts of utility tariffs on households and businesses.

6.6.2 Stormwater Services

The operation and capital costs of stormwater services for the Greater Sydney region is presented in Figure 17 for the period 2010 to 2050.

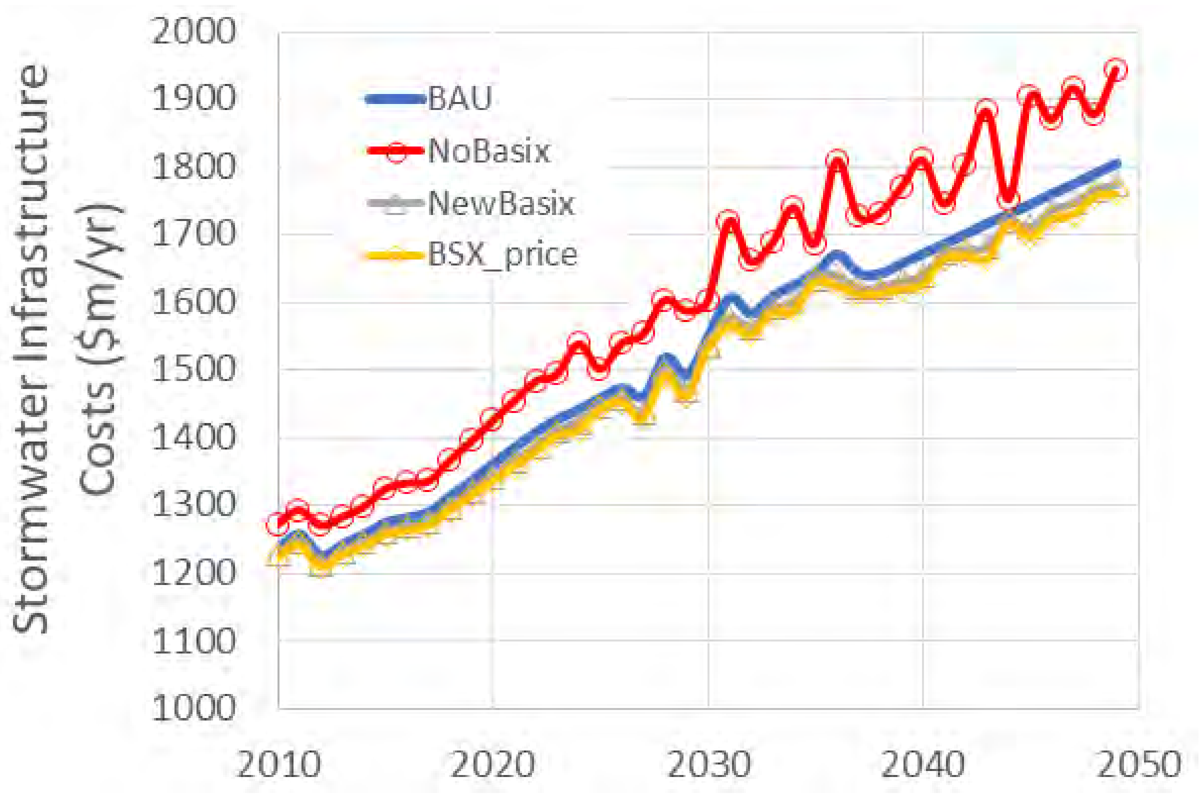


Figure 17: Operation and capital costs of stormwater services (in 2019 dollar values) for Greater Sydney from each option from 2010 to 2050.

Figure 17 shows that the regional and local government costs to provide stormwater management increases by $579 million to $1806 million/annum by 2050. These are the annual costs to operate, renew and augment stormwater quality and quantity infrastructure for the region.

The NoBasix option increases regional stormwater management costs by $706 million (57%) to $1942 million/annum by 2050. Reduced uptake of rainwater harvesting increases annual stormwater management costs by $138 million by 2050.

Regional stormwater management costs in the NewBasix option increase by $537 million to $1775 million/annum in 2050. Increased uptake of rainwater harvesting lowers annual stormwater management costs by $31 million by 2050.

The BSX_price option has increased stormwater management costs of $525 million (42%) to $1762 million/annum by 2050. A full usage tariff for water and sewage services, and an impervious area tariff for stormwater services provides incentives to reduce stormwater runoff. Increased rainwater harvesting and other methods to disconnect impervious surfaces from streets and waterways reduces annual management costs by $44 million by 2050.

Distributed management of stormwater runoff can provide a range of cumulative benefits including reduced nutrient loads to waterways and diminished risks of flooding from stormwater surface flows within urban areas (Coombes, 2018).[19] The costs of changes in nutrient loads discharging in stormwater runoff for the Greater Sydney region is provided in Figure 18 for the period 2010 to 2050. Note that discharges in total nitrogen loads to the environment have been used as an indicator for all nutrient discharges in this investigation.

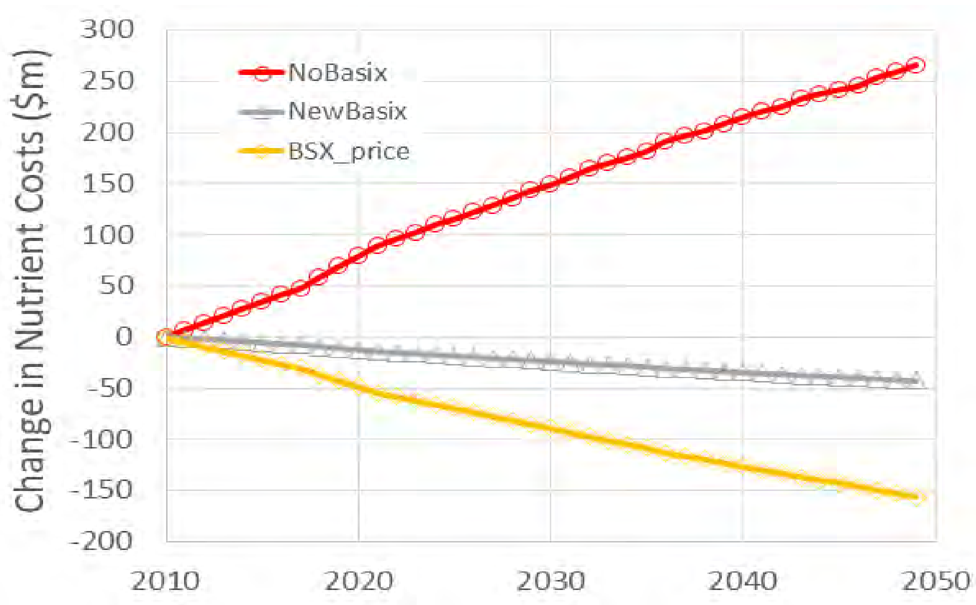


Figure 18: Changes in costs of nutrient discharges (in 2019 dollar values) for Greater Sydney from each option from 2010 to 2050.

Figure 18 shows that the NoBasix option results in higher nutrient costs of $266 million/annum by 2050, and the NewBasix and BSX_price option reduces annual costs by $43 million and $156 million respectively. Distributed management of stormwater runoff using rainwater harvesting (NewBasix), and a combination of rainwater harvesting and measure that disconnect impervious surfaces from street drainage or waterways (BSX_price) reduces nutrient loads with associated costs.

The expected changes in annual average damage costs from stormwater runoff for the Greater Sydney region is provided in Figure 19 for the period 2010 to 2050. Assessment of annual damage costs resulting from urban stormwater runoff was based on NSW Office of Environment and Heritage Guidelines (OEH, 2016)[20], and flood damage curves for the City of Sydney (Cardno, 2014)[21] and Camden Council (WorleyParsons, 2015).[22]

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[19] Coombes P.J., (2018), Status of transforming stormwater drainage to a systems approach to urban water cycle management – moving beyond green pilots, Australasian Journal of Water Resources, 22(1), 15-28.
[20] OEH (2016), Floodplain risk management guidelines, NSW Office of Environment and Heritage
[21] Cardno (2014), Alexandra Canal floodplain risk management study and Plan, City of Sydney.
[22] WorleyParsons (2015), Nepean River flood study, Camden Council.

The focus of this assessment was the changes in local damages associated with urban stormwater runoff from more frequent events (from 50% to 10% AEP) that were more clearly defined for City of Sydney. The changes in local annual average damage costs from flooding associated with more frequent urban stormwater runoff for the Greater Sydney region is provided in Figure 18 for the period 2010 to 2050.

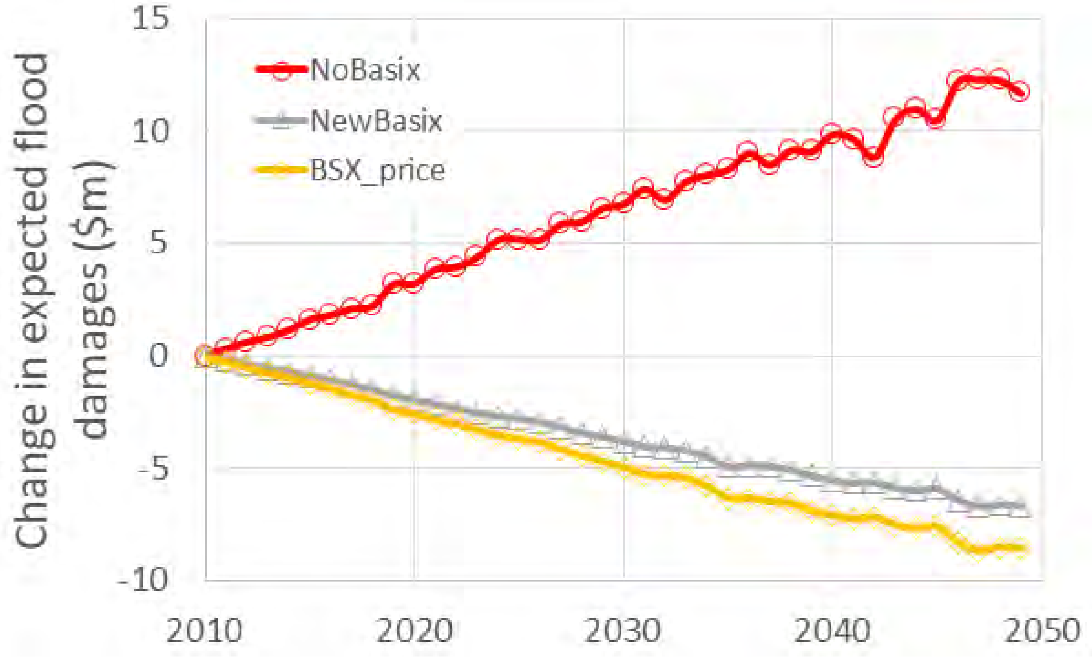

Figure 19: Changes in local annual average damage costs from flooding (2019 dollar values) in more frequent urban stormwater runoff events for Greater Sydney from each option from 2010 to 2050.

Figure 19 reveals that the NoBasix option has higher annual average damage costs from local urban flooding of $12 million by 2050. The NewBasix and BSX_price option decreases annual average damage costs by $7 million and $9 million respectively. A majority of these changes in expected annual damage costs results in changes in stormwater runoff flowing through properties at below floor level depths.

The detailed damage curves from City of Sydney were most relevant for determining the impacts of changes in overland flows in the upper reaches of urban catchments created by local stormwater management measures such as rainwater harvesting and measures that disconnect impervious surfaces from street drainage networks.

An example of the average increases in peak stormwater runoff (%) created by the NoBASIX option across all of the local government areas in Greater Sydney is shown for 1, 2, 5 and 10 year return periods is provided in Figure 20.

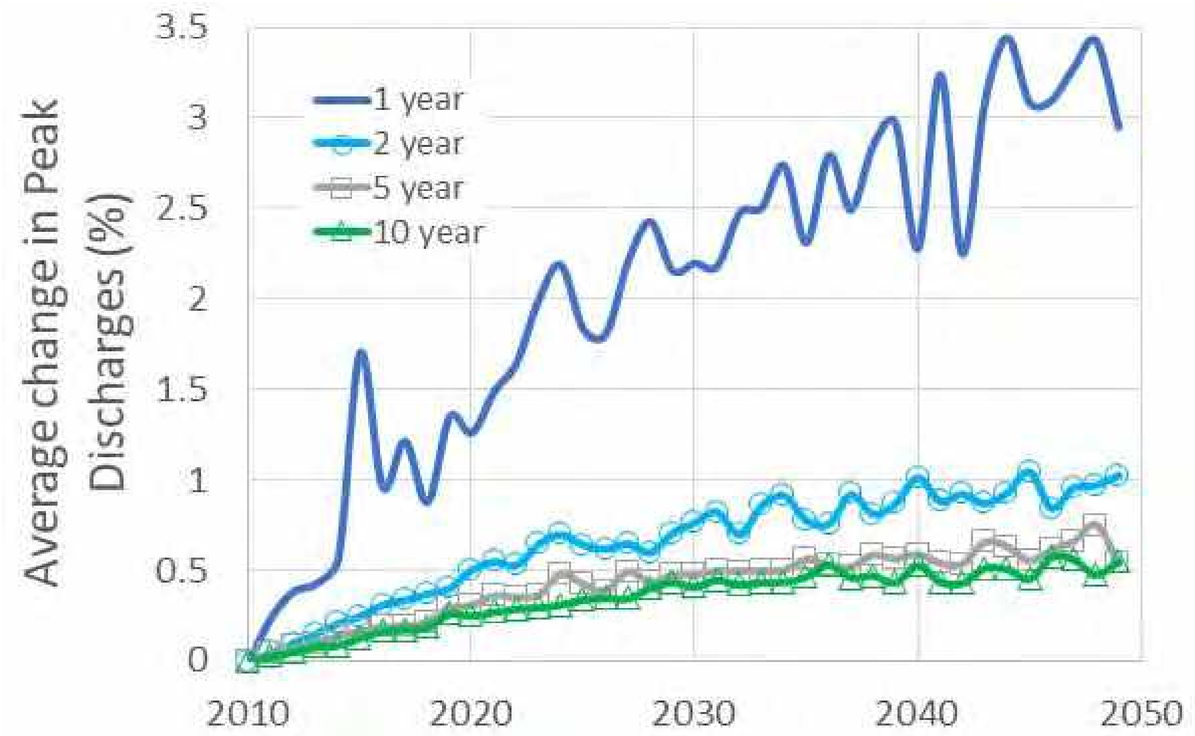

Figure 20: Average increases in peak stormwater discharges in the NoBasix option for Greater Sydney from each option from 2010 to 2050

Figure 20 demonstrates that the NoBasix option results in cumulative increases in peak discharges from more frequent stormwater runoff events across the Greater Sydney region. As expected, the increases in peak discharges from the one-year return period are greater than increases in the ten-year events. Note that the average of results across Greater Sydney does not display the strong spatial variability in these increases in peak stormwater runoff that was evident across local government areas.

These small changes in peak discharges in areas where stormwater management networks are operating at below design capacity, such as older areas or areas with increasing density, are sufficient to increase local damages as highlighted in the flood damage curves for City of Sydney.

The net present costs (NPC) and benefits (NPV) of stormwater management are summarised for the period 2010 to 2050 using a discount rate of 4% in Table 8.

Table 8: Changes in net present costs (NPC) of stormwater management for each option to 2050

Option	NPC ($m)	Change from BAU (%)	NPV ($m) from NoBasix
NoBasix	+1414	+ 6.2	-
NewBasix	-344	-1.5	1758
BSX_price	-497	-2.2	1911

Table 8 shows that the NoBasix option increased the net present costs of stormwater management by $1414 million, and the NewBasix and BSX_price options reduce net present costs by $344 million and $497 million respectively. These results indicate that the options have a significant impact on local and state government budgets to operate, renew and provide stormwater management infrastructure.

The reduction in costs of $1758 million to $1911 million between supporting and not supporting decentralised stormwater management highlights that the contribution of local solutions to stormwater management produce significant financial benefits to government.

The net present costs (NPC) and benefits (NPV) associated with nutrient loads are summarised for the period 2010 to 2050 using a discount rate of 4% in Table 9.

Table 9: Changes in net present costs (NPC) of nutrient loads for each option to 2050

Option	NPC ($m)	Change from BAU (%)	NPV ($m) from NoBasix
NoBasix	+4372	+ 6.2	-
NewBasix	-1092	-1.5	5464
BSX_price	-1562	-2.2	5934

Table 9 reveals that the NoBasix option increased the net present costs of nutrient discharges by $4372 million, and the NewBasix and BSX_price options reduce net present costs by $1092 million and $1562 million respectively. These outcomes indicate the changes in costs to protect urban waterways and regional rivers from nutrient loads in stormwater runoff that created by the different options. The distributed stormwater management approaches provide $5464 million to $5934 million in the costs to improve the health of waterways.

The net present costs (NPC), annual average damage (AAD) costs and benefits (NPV) of changes in flooding from more frequent stormwater runoff events are summarised for the period 2010 to 2050 using a discount rate of 4% in Table 10.

Table 10: Net present values of the changes in flood damages for each option to 2050

Option	NPC ($m)	AAD ($m)	NPV ($m) from NoBasix	Net annual damages ($m)
NoBasix	+93	+ 6.03	-	-
NewBasix	-53	-3.4	146.4	9.43
BSX_price	-69	-4.4	162.4	10.44

Table 10 reveals that the NoBasix option increases net present costs by $93 million. In contrast the additional rainwater harvesting and rain gardens in the NewBasix and BSX_price options reduce the net present costs of flood damages by $53 million and $69 million respectively. The reductions in average annual damages and net present values from the NoBasix options were $9.43 million to $10.44 million and $146 million to $162.4 million respectively.

The average changes in impervious area tariffs for the Greater Sydney region for each option are presented in Figure 21.

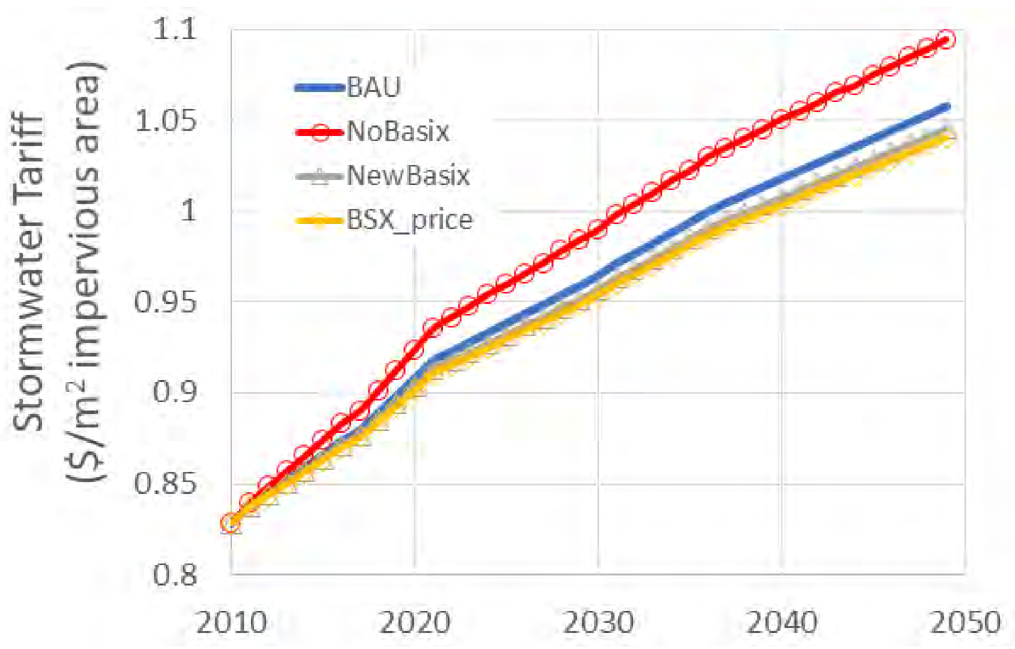

Figure 21: Average increases in stormwater impervious area tariffs for Greater Sydney from each option from 2010 to 2050.

Greater uptake of rainwater harvesting and disconnecting impervious areas on properties in the NewBasix and BSX_Price results in lower stormwater tariffs for all properties. Reduced uptake of rainwater harvesting in the NoBasix option drives increases in stormwater tariffs for all properties.

6.7 Summary of the costs and benefits of the options

This section provides the legacy benefits of existing rainwater harvesting and water efficient appliances with greater than 3 star efficiency in 2019. The Greater Sydney region benefits from these existing distributed measures but these benefits are rarely included in analysis of the water resources behaviours of cities. In addition, this section provides a summary of the alternative options that were evaluated in this study.

6.8 Legacy benefits (circa 2019)

The existing rainwater harvesting provided 30 GL/annum of water supply to the Greater Sydney region and water efficient appliances (greater than 3 star efficiency) provided 49 GL/annum water savings. This is a total contribution of 79 GL/annum (13%) to reducing demands for utility water supply in 2019. These legacy measures also reduce stormwater runoff by 30 GL/annum (4%), nutrient loads by 47 tones/annum and greenhouse gas emissions by 123 kTonnes/annum.

The total economic value of the benefits of legacy measures is $3414 million. This includes $1191 million for water and sewage services, $856 million for stormwater infrastructure services, $58 million for avoided flood damages and $1309 million for reduced nutrient loads discharges to waterways.

6.9 Summary of the performance of the options

The performance of the options to 2050 is summarised in Table 11. The total economic value (NPV) of the options indicates that ending the BASIX Policy in 2010 would cost $5334 million, improving the BASIX policy provides additional economic benefits of $1633 million, and a combination of improved basic and a revised pricing strategy provides benefits of $7081 million.

Table 11: Summary of Benefits in 2050

Description	Options			
	BAU	NoBasix	NewBasix	BSX_price
Utility water supply in 2050 (GL)	917	+78	-8	-110
Water Security (number of augmentations) Change in augment timing	4	4 5 years earlier	4 4 years delay	3 4 years delay
Utility sewage discharges (GL) in 2050	899	+64	-8	-42
Stormwater Runoff (GL) in 2050	996	+48	-8	-28
Nitrogen Loads (tonnes) in 2050	2491	+121	-19	-71
Greenhouse gas emissions (kTonnes) in 2050	1405	+122	-21	-337
Utility water and sewage NPC ($m)	57,149	+3056	-1028	-6128
Utility water and sewage net present revenue ($m)	61,676	+1322	-131	-868
Utility water and sewage NPV ($m)	-	-1734	+899	+5259
Economic multiplier (Δ costs/Δ revenue)	-	2.31	7.85	7.06
Stormwater services NPC ($m) to 2050	28,501	+1414	-344	-497
Nutrient NPC ($m) to 2050	89,679	+2092	-337	-1256
Change in flood damages NPC ($m) to 2050	-	+93	-53	-69
Total economic value NPV ($m)		-5334	+1633	+7081

7 DISCUSSION

7.1 Expected Demand

Greater Sydney will need to find 80% more water by 2050 than it currently provides. To put this in perspective Greater Sydney would need nearly 5 more desalination plants running full time to meet increased demand. Just maintaining the current BASIX policy until 2050 will save Greater Sydney the annual equivalent of a desalination plant.

In 2019 Greater Sydney commenced consideration of additional desalination capacity. This was not projected in the Business as Usual option until 2034 and reflects the unexpected severity of the 2020 drought. The current rate for desalination infrastructure is about $1 Billion for each 50 GL of additional supply. Sydney Water already has a debt level of $9 Billion. Adopting the Basix Price option would delay the next desalination plant to 2038.

7.2 The Basix Price Option

The Systems Framework has demonstrated a remarkable outcome that reflects one of the essential 'leverage points' identified by Meadows - access to information improves the efficiency of the system. In this regard implementing a pricing system that reflects the full, local cost of water and sewage services and stormwater management costs to the consumer would drive systemic change. The actual costs to businesses and households would increase in terms of unit cost, but decrease in total bills. Water businesses would experience reduced revenue but increased profitability.

The extent of these benefits are summarised in Table 11delivering a Net Present Value of over $7 Billion compared to BAU and $12 Billion compared to NoBasix.

The remarkable aspect of this option is that these benefits can be delivered without significant infrastructure investment, legislative change or regulatory enforcement. Accurate pricing information provides sufficient incentive to the market to drive benefits much greater than an estimated $8 Billion infrastructure investment in desalination.

7.3 Spatial Costs for Greater Sydney

The systems framework is based on a framework of local land uses and behaviours. It is, therefore, capable of highly resolved mapping of capital and operational costs for water and sewerage services as discussed in section 6.6 and shown in Figure 15.

This is a remarkably effective way to show spatial data in the context of a century old assumption that service costs are uniform across the Greater Sydney region. Areas with water and sewage costs up to $16/kL map out opportunities for innovation and alternative strategies that are not apparent and are not considered in the current IPART assessment paradigm.

7.4 Stormwater Management

The stormwater management benefits of rainwater harvesting were not part of the original BASIX policy in 2004. In this regard both South Australia and Victoria have made significant progress in their planning frameworks in implementing a water sensitive urban design (WSUD) approach and drafting deemed to comply rainwater harvesting provisions for WSUD.

South Australia has identified that infill development can generate more stormwater volume than local infrastructure can manage resulting in increased flood risk, polluted stormwater to receiving waters, increased council infrastructure costs and loss of opportunity to use water to cool suburbs.[23] As a result South Australia has drafted a planning code supporting rainwater harvesting as a deemed to comply solution for water sensitive urban design requirements. Victoria has identified that their current stormwater management infrastructure is not designed for increased urban densities and is not up to the challenges of population growth and more intense rain events associated with climate change[24].

Incorporating water sensitive urban design as well as water efficiency objectives into BASIX is a logical and potentially overdue step for the BASIX planning policy.

As discussed in section 6.2, BASIX will deliver 48GL/annum reduced urban stormwater runoff compared to NoBasix however there will still be a 49% increase in urban stormwater runoff across Greater Sydney. This implies an increased flooding risk at a net present cost of $93 million.

7.5 Benefits of BASIX

The objective of the NoBasix option was to measure the impact of the BASIX planning policy on the Sydney water and sewage system. Comparing the Business as Usual and NoBasix options from section 6.8 shows that BASIX has delivered the following benefits up to 2019.

- Additional local water supply of 30 GL/annum
- Water savings of 49 GL/annum
- Overall 79 GL/annum or 13% reduction in water demand. In late 2019 this would have meant an additional 8 weeks supply of water for greater Sydney.

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[23] State Planning Commission. (2019). *People and Neighbourhoods Policy and Discussion Paper*. Adelaide: Government of South Australia

[24] State of Victoria. (2018). *Improving Stormwater Management Advisory Committee Final Report*. East Melbourne: Department of Environment, Land, Water and Planning

- Stormwater runoff would also have been reduced by 30 GL, nutrient loads by 47 tonnes and greenhouse gas emissions by 123 kTonnes/annum.
- The combined economic value of benefits from savings in water and sewage services, stormwater management, avoided flood damages and reduced nutrient loads is $3414 million

7.6 Economic Level of Water Conservation

7.6.1 What is the Methodology based on?

The Sydney Water ELWC methodology is based on a marginal value framework, where investment in water conservation could increase until the cost of saving an extra volume of water is just equal to the cost of supplying an extra volume of water.[25]

7.6.2 Eliminating Geography

The methodology assumes that the whole of greater Sydney is a single point in space. The methodology does not make any allowance for distance or elevation which are two crucial engineering concepts for moving water. The cost to Sydney Water of providing water supply varies with the distance the water needs to be transported and the difference in elevation. The cost of providing a kilolitre of water to a household will vary depending on the location and elevation of the household, the reservoir and the water treatment plant. These costs also include transporting and treatment sewage because a majority of water demand is disposed of as wastewater.

As discussed in Chapter 6 the cost of water and sewage services may vary from $2/kL to more than $16/kL. However, the ELWC assumes that the short and long term cost of supply is the same for the whole of Greater Sydney. In an area where the cost of supply is more than $16/kL a range of water conservation options will be economically viable that would not be in an area where the cost of services is only $2/kL. This provides an immense opportunity for greater efficiencies. The opportunities and efficiencies of geographic variation across greater Sydney have been eliminated from the methodology in the ELWC method.

7.6.3 System Inputs and Outputs - Sewage

The methodology recognises water supply as input without recognising an output. If water is supplied to a house there will also be sewage as an output. The financial analysis focuses on the cost of supplying a volume of water without acknowledging that there is an implied cost to treating the resultant volume of sewage that is often similar to the cost of supply. As above, the cost of sewage treatment is highly variable with distance and elevation. The resultant increased costs in extra demand and increased savings from reduced demand are not considered in the ELWC methodology, underestimating costs and benefits by as much as 50%.

7.6.4 Integrated Water Management

Greater Sydney is a not a financial ledger, it is a city full of people. Geography and system dynamics show that complexity provides opportunities. Rainwater harvesting, recycling, and stormwater retention all provide opportunities both inside and outside the water management system including more vegetation to reduce urban heat island effects, improve waterway health and beach quality and which have measurable economic benefits. By only considering the cost of water supply the ELWC fails to account for most of the actual costs and benefits for the urban area. The ELWC methodology in eliminating complexity also eliminates the local opportunities.

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[25] Determining Sydney Water's Economic Level of Water Conservation Part A: The ELWC Methodology, Sydney Water 2017

7.6.5 Long Run Marginal Cost of Water (LRMC)

The essential consideration for marginal cost is that all costs have to be included – this is a key economic principle. The value of water used for the ELWC is based on a partial analysis considering only a small fraction of the actual costs of water services. Sydney Water have determined that the long run marginal cost of water for Greater Sydney is $2/kilolitre. As shown in 4.6 it is not possible to deliver water services to most of Greater Sydney at this low figure. Water infrastructure operates over very long time scales potentially measured in tens of years. This is important because over a long period of time all fixed costs become variable costs. The ELWC methodology relies on a value of water based on a short term partial operating cost and not including the long term costs of capital investment. An artificially low LRMC of water ensures that there is little or no investment in water conservation or alternative water supply options.

Our analysis is that the ELWC is a predictable product of the Sydney Water Operating licence, which requires Sydney Water to conduct a successful business, by selling water and building infrastructure. This makes selling more water a valid business objective for Sydney Water, even if it's desalinated water or expensive recycled water. Water conservation runs counter to this business objective. It reduces community water use, reduces water utility revenue and operating costs, and reduces the need for infrastructure. The current ELWC methodology appears to maximise the revenue of Sydney Water and appears to ensure that there will be long term investment in water infrastructure such as desalination plants and will delay and defer most investment in water conservation to occur only in periods of drought crisis.

Kingspan Made to Measure Slimline Water Tanks

8 CONCLUSION AND RECOMMENDATIONS

Greater Sydney is the premier Australian city and it faces profound urban water challenges. Sydney must manage its infrastructure efficiently and sustainably to compete internationally as a Global city. Sydney has a strongly performing water services sector but has a traditional approach to water service management. Significant challenges include long transfer distances for water and sewage services, inadequate sewage treatment, severe urban heat island problems in the rapidly growing west and inadequate urban stormwater infrastructure management. These problems appear to be intractable using traditional water analysis approaches however a Systems Framework investigation can identify efficient solutions.

The Systems Framework methodology was recognised in 2018 by Engineers Australia as leading water resource research.[26]

The Systems Framework is used to model and then compare four Options. The Business as Usual (BAU) Option considers current water cycle (water, sewage, stormwater and environment) management practices and BASIX policies across the Greater Sydney region. The second Option (NoBasix) examines the impacts of removing the BASIX policy in 2010 to document the benefits of the state planning policy. A third Option is a new BASIX (NewBasix) that includes stormwater volume targets and improved online tools designed to address key Greater Sydney challenges. The final Option (BSX_Price) applies a single usage tariff for water and sewage services, and a single impervious area tariff for stormwater management. This option abandons fixed tariffs to provide greater incentives to utilities and citizens for efficient water use and stormwater management.

The key insight is that a combination of supply and demand management is more efficient than relying entirely on supply solutions when considering whole of society benefits. These demand management solutions include behaviour change, water efficient appliances and rainwater harvesting. An example of these benefits is the 5 year deferral of the multi-billion dollar desalination augmentation provided by the BASIX policy. The inclusion of rainwater harvesting as a stormwater management solution has both infrastructure and demand management benefits and is an efficient decentralised infrastructure asset that improves the performance of the whole system.

This report finds that Greater Sydney, despite significant challenges, currently has the most efficient and sustainable water services in Australia.[27] This has been achieved through the strategic alignment of water demand management, rainwater harvesting and urban development. The BASIX state environmental planning policy has built-in demand management and stormwater management in most new buildings in the Greater Sydney region since 2004 and this 'bottom up' approach has a major legacy impact on the efficiency of water services. BASIX policies will save the Greater Sydney region about 100 billion litres of water annually by 2050.

This investigation has identified water and sewage transfer distances of over 50 km across Greater Sydney. Transporting a heavy liquid over these distances and significant changes in ground elevations represents high capital and operational costs and potential economic inefficiencies. In some parts of Greater Sydney, the shadow cost (medium run marginal cost) of delivering water and sewage services is greater than $16/kL, which is nearly 800% more than the household usage tariff, as shown in Figure 22.

[26] Barry M.E., and Coombes P.J., (2018), Planning resilient water resources and communities: the need for a bottom-up systems approach, Australasian Journal of Water Resources, 22(2), 113-136 - Awarded the GN Alexander Prize for Hydrology and Water Resources 2018

[27] Coombes, P.J., Barry, M., & Smit, M. (2018). Systems Analysis And Big Data Reveals Benefit Of New Economy Solutions At Multiple Scales. WSUD 2018 & Hydropolis conference, Engineers Australia, Perth.

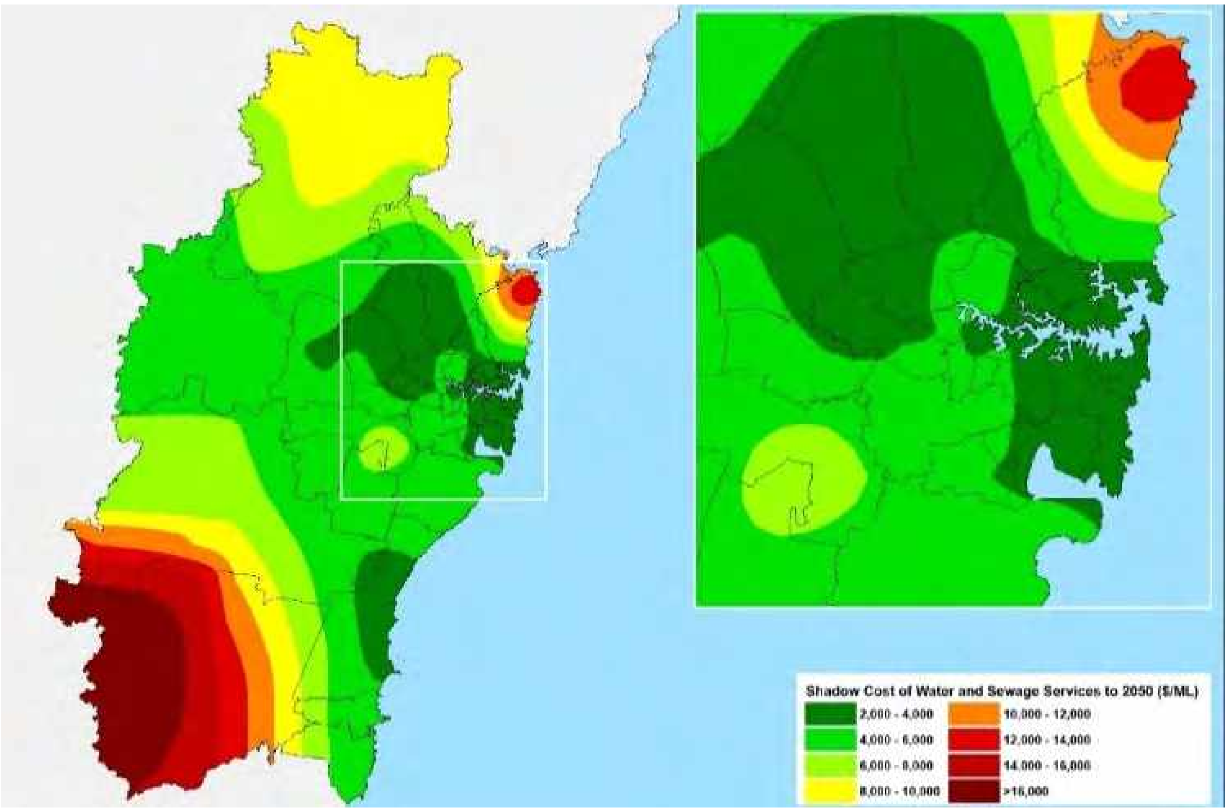

Figure 22: Medium run spatial costs of utility water and sewage services map

Stormwater management is emerging as one of the most significant urban infrastructure challenges[28]. The stormwater infrastructure established often more than 50 years ago is inadequate for modern challenges.[29,30] However, it is prohibitively expensive to retrofit traditional infrastructure into existing urban areas. Greater Sydney is experiencing a higher than expected level of urban infill development which increases impermeable surface areas and generates greater urban stormwater runoff. Climate Change predictions from the IPCC are for more intense rainfall events from summer storms that significantly increases the flooding risk.[31] Importantly the improved BASIX program to 2050 provides $4.3 Billion NPV through at source controls improving stormwater service costs, nutrients and flood risk compared to not having BASIX at all. If you include legacy benefits this increases to $6.6 Billion

The options for future water cycle management examined in this study shows reveals that an improved form of BASIX with stormwater and green infrastructure will further reduce water and sewage utility costs by over $1 Billion and provide nett benefits of over $1.6 Billion to 2050. The difference between no BASIX policy and improved BASIX policy from 2010 to 2050 is a net present benefit of $7 billion. Improved water and sewage charges to deliver accurate price signals would have even greater benefits.

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[28] Australian Senate (2015), Stormwater Management in Australia. Environment and Communications References Committee of the Australian Senate, Commonwealth Government of Australia

[29] Coombes P. J., (2018), Status of transforming stormwater drainage to a systems approach to urban water cycle management – moving beyond green pilots, Australasian Journal of Water Resources, 22:1, 15-28.

[30] State of Victoria. (2018). Improving Stormwater Management Advisory Committee Final Report. East Melbourne: Department of Environment, Land, Water and Planning.

[31] Coombes P. J., Roso S., (2018), Editors, Book 9: Runoff in Urban Areas, Australian Rainfall and Runoff, Commonwealth of Australia (Geosciences Australia), Australia

8.1 Outcomes

BASIX is one of the most successful sustainability and financial policies in Australia and continues to provide good value to the community and the NSW government. Ceasing BASIX would result in a measurable increase in water consumption, costs of infrastructure, and environmental and flooding damage.

Recommendation 1

The BASIX planning policy should be retained and reviewed to bring software and assessments up to best practice.

Modifying BASIX to recognise water sensitive urban design and green infrastructure would bring BASIX inline with community attitudes and Engineers Australia best practice stormwater management and deliver additional community benefits.

Recommendation 2

Department of Planning, Infrastructure and Environment consider modifying the BASIX policy.

Modifying BASIX and changing the cost structure to accurately reflect the real variable cost of water and sewage and stormwater management costs would deliver enormous community and environment benefit at almost no cost to government and maintain the financial viability of Sydney Water.

Recommendation 3

Department of Planning, Infrastructure and Environment and IPART consider the benefits of a revised pricing regime based on a systems framework considering all costs in a variable price scheme.

Recommendation 4

Department of Planning, Infrastructure and Environment and IPART consider the benefits of understanding spatial costs of water, sewage and stormwater based on a systems framework considering all network and local costs.

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