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A Sensitivity Analysis of an Investment Model Used to Determine the Economic Benefits of Rainwater Tanks

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Abstract:
The community-based investment model created by Coombes et al. [2000a; 2002] that allows economic comparisons between a traditional base scenario for urban water cycle services and alternative scenarios that include rainwater tanks is examined. The economic benefits derived from the use of rainwater tanks vary with the price of mains water and the cost to augment mains water supply headworks systems. The magnitude of the economic benefits accruing to the community from widespread installation of rainwater tanks was dependent on real interest rates, the value of stormwater savings that result from the use of rainwater tanks and the installation costs of rainwater tank systems. Nonetheless it was shown that the use of rainwater tanks provided greater economic benefits to the community than the traditional water supply and stormwater management options in the majority of cases considered.

Keywords: Economics, investment, price, costs, rainwater tanks, headworks, stormwater

1. INTRODUCTION

Rainwater collected from roofs and stored in tanks to supplement mains water supplies for domestic consumption was shown by Coombes et al. [2000; 2002] and Mitchell et al. [1997] to significantly reduce household mains water use. The householder installing a rainwater tank will gain economic benefit from purchasing a reduced volume of mains water. Coombes et al. [2000a; 2000] established that the widespread introduction of rainwater tanks with a 10 kL capacity to supplement mains water supplies for domestic hot water, toilet and outdoor uses will result in a substantial reduction in regional mains water use leading to deferral of the requirement for new water supply dams. The economic benefit of deferring the construction of new dams accrues to the community.

Domestic above ground rainwater tanks were also shown by Coombes [2002] and Coombes et al. [2003; 2000] to reduce the requirement for stormwater infrastructure resulting in construction, depreciation and maintenance cost savings. The benefits from a reduced requirement for stormwater infrastructure will accrue to the householder and the community. The householder pays the cost to install, operate and maintain rainwater tanks on domestic allotments but benefits from installing the tanks accrue to householders and the wider community. Indeed benefits that accrue to the householder may be small in comparison to benefits accruing to the community that are derived from the deferral of the requirement for new dams and water distribution infrastructure, reduced requirement for stormwater infrastructure and improved environmental impacts.

In spite of this currently accepted analysis of the costs and benefits of domestic rainwater tanks typically ignore the majority of benefits that accrue to the community focusing only on the economic savings from reductions in domestic water use and installation costs for the tank. For example analysis of the economic efficiency of rainwater tanks by ACTEW [1994] and White et al. [1998] do not account for the impact of the tanks on water supply and stormwater infrastructure.

In addition the currently accepted methodology for comparing alternatives to traditional water supply approaches such as the least cost planning approach described by White et al. [1998] uses an assumed short run marginal cost of $0.15/kL for mains water in short term planning horizons and large discount rates. The discounting of future benefits of saving water is inconsistent with the requirement for future water resource security and the price the community pays for water is not the assumed short run marginal cost. Importantly the use of short run marginal cost of water in the comparison of alternatives is misleading for a regulated monopoly required to provide long term security of supply [Dixon and Norman, 1989]. Moreover the determination of short run marginal costs varies with volume of supply [Hirshleifer, 1988]. As volume of supply increases the short run marginal cost approaches the average and long run marginal costs. Dixon and Norman [1989] explain that the average cost and the marginal costs of water are similar. These costs are slightly less than the price of water as expected for a regulated monopoly [Hirshleifer, 1988].

The currently accepted economic approach has created an illusion that many alternatives to current water supply practices are not viable. A new approach is required to compare alternatives for water supply that include whole of water cycle costs and benefits, a community perspective and values future water security.

The installation of rainwater tanks is a potential alternative augmentation strategy for water supply and stormwater infrastructure. A method is therefore required to compare the economic benefits of augmentation strategies for traditional infrastructure provision to the benefits of augmentation strategies that include rainwater tanks. This study examines the community-based whole of water cycle investment model developed by Coombes et al. [2000a; 2002] used to determine the economic benefits accruing to the community from the installation of rainwater tanks in the Lower Hunter and Central Coast regions of New South Wales. The assumptions in the investment model are subjected to a sensitivity analysis.

The investment model allows an economic comparison between strategies to install rainwater tanks and the provision of traditional urban water cycle infrastructure. The investment model combines regional water use results with the coincident deferral of new dams, stormwater infrastructure savings and costs of rainwater systems to determine the economic benefits accruing to the community from the installation of rainwater tanks.

2. A COMMUNITY BASED INVESTMENT MODEL

Coombes et al. [2000a; 2002] adapted the methods of annual and present equivalence by Smith [1979] to create an investment model that compares economic benefits accruing to the community from a traditional Base scenario to alternative scenarios that include installation of rainwater tanks. The Base scenario considers the status quo: provision of traditional stormwater systems to areas undergoing urbanisation and provision of additional mains water supply by further regulation of river systems. It is important to note that each scenario provides water supply and stormwater services to a minimum standard that ensures public safety and drought security. Each scenario starts with enough funds to ensure economic viability of the strategy. Each year expenses are deducted, income is added and interest is earned on the balance. The analysis considers comparative costs and benefits using the Base scenario as the reference. A schematic of the Base scenario is shown in Figure 1.

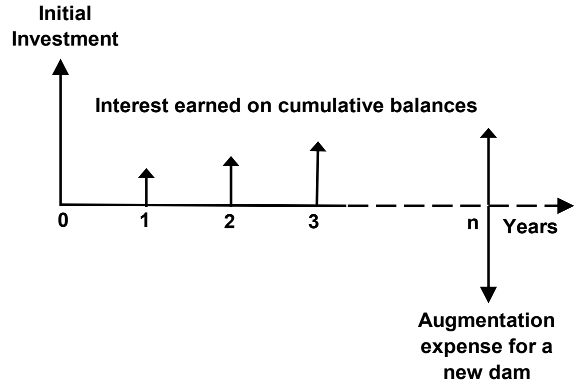

Figure 1: Schematic of the Base investment scenario

Figure 1 shows that analysis of the Base scenario begins with an initial investment and accumulative interest is earned on the initial investment in each year. In year n the water supply system requires augmentation thus the cost to construct a new dam is deducted from the balance of the initial investment in year n. For the Base scenario, the balance of the initial investment carried forward from year t, Bal_{t+1}, is:

$$Bal_{t+1} = (1 + Rint)(Bal_t - augCost_t) \quad (1)$$

where Rint is the real interest rate and $augCost_t$ is the augmentation cost of the traditional water supply (if any) in year t.

Costs and benefits for provision of mains water and disposal of stormwater considered common to the base and alternative scenarios were not included in the analysis. Construction of a new dam is included in the Base and alternative scenarios because these costs are incurred by the community with significant impact on the balance of a scenario and may occur in different years in the various scenarios. The costs and benefits that differ from the base scenario are considered in analysis of alternative scenarios. A schematic of the alternative scenarios is shown in Figure 2.

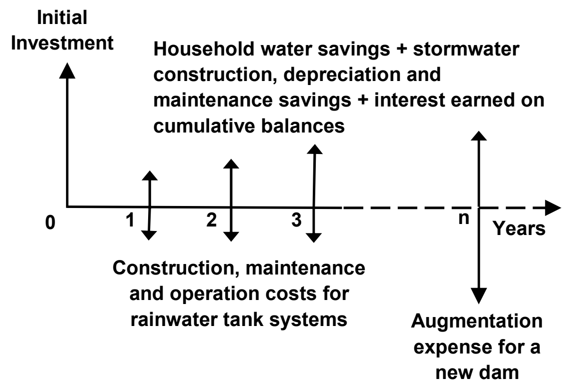

Figure 2: Schematic of the alternative investment scenarios

In the alternative investment scenario (Figure 2) it is assumed that a household can purchase water from a water utility and use rainwater tanks for water supply. In this model the water utility is a service provider that no longer has a monopoly. The utility charges for the provision of mains water so that it makes a fair return. The community pays the cost of installing, operating, maintaining and replacing rainwater tank systems whilst gaining benefits from reductions in mains water consumption and the requirement for stormwater infrastructure that results in decreased depreciation and maintenance costs. For the alternative investment scenarios, the balance in year t is:

$$\mathrm{Bal}_{t+1} = (1+\mathrm{Rint})\begin{pmatrix} \mathrm{Bal}_t - \mathrm{augCost}_t - \mathrm{Trep}_t \\ - \mathrm{Prep}_t - \mathrm{conCost}_t \\ - \mathrm{maintCost}_t - \mathrm{opCost}_t \\ + \mathrm{savWat}_t + \mathrm{savDev}_t \\ + \mathrm{savDep}_t + \mathrm{savMaint}_t \end{pmatrix} \quad (2)$$

where at year t $\mathrm{conCost}_t$, $\mathrm{mainCost}_t$ and opCost_t are construction, maintenance and operation costs for rainwater tank systems, Trep_t are replacement costs of rainwater tanks, Prep_t are replacement costs of pumps in the rainwater tank systems, savWat_t are savings in foregone mains water consumption, savDev_t are savings in new stormwater infrastructure, savDep_t are depreciation savings and $\mathrm{savMaint}_t$ are maintenance savings derived from a reduced requirement for stormwater infrastructure.

Alternative scenarios that include rainwater tanks are evaluated using Equation 2 and the Base scenario is evaluated using Equation 1. The annual equivalence analysis compares the balance of the initial investment in the base and alternative scenarios in any year. The present equivalence analysis compares the initial investment required to achieve a surplus of funds at the end of the investment period for each scenario.

3. ECONOMIC ANALYSIS FOR THE LOWER HUNTER AND CENTRAL COAST REGIONS

The investment model was employed by Coombes et al. [2000a; 2002] to evaluate benefits accruing to communities in the Lower Hunter and Central Coast regions from the widespread installation of rainwater tanks. It was assumed that rainwater tanks with a capacity of 10 kL will supplement mains water supply for domestic hot water, toilet and outdoor uses. The economic efficiency of the rainwater tank scenarios was evaluated using the following data. A real interest rate of 5% was used that was defined as the difference between the interest rate set by the Reserve Bank and the inflation rate in the year 2000. Maintenance and operation of rainwater tank systems was conservatively assumed to cost $0.05 per kL of rainwater use. Note that Coombes et al. [2000, 2002a] found the operation and maintenance costs for rainwater tank systems at the Figtree Place and Maryville experiments to be negligible.

The installation of rainwater tanks in new developments or redevelopments was considered to reduce the requirement for stormwater infrastructure resulting in a saving, conservatively set at $959 per dwelling from the Figtree Place site [Coombes et al., 2000]. Analysis of a development in the Lower Hunter region revealed construction cost savings of $210 to $511 per dwelling were possible [Coombes, 2002]. However the analysis only evaluated the impact of rainwater tanks on stormwater pipes and gross pollutant traps. A full Water Sensitive Urban Design (WSUD) approach was not evaluated, although Coombes et al. [2003] and Coombes and Kuczera [2000] report that greater savings can be achieved by a full WSUD approach. The Figtree Place savings were used because the savings were the result of a full WSUD approach to water supply and stormwater management.

Coombes [2002] showed that annual replacement and maintenance costs for stormwater infrastructure in subdivisions could be reduced by $10.65 to $23.45 per dwelling by installing a 10 kL rainwater tanks. An annual stormwater maintenance and replacement saving of $23.45 per dwelling was used in the investment analysis.

The redevelopment rate for dwellings in the Lower Hunter and Central Coast regions was about 0.9% per year [ABS, 1999]. Rainwater tanks were estimated to have useful lives of 50 years with replacement costs of $840. Pumps used in rainwater tank systems were assumed to have useful lives of 10 years with replacement costs of $200. Costs to install rainwater tank systems were estimated to be $2185 per dwelling and the price of a kilolitre (kL) of mains water was $0.94 in Lower Hunter region and $0.65 in Central Coast region during the year 2000.

The augmentation strategy for the water supply headworks system in the Lower Hunter region was considered to be construction of Tillegra Reservoir at a cost of $103.7M. The augmentation strategy for the Central Coast region was construction of the Wyong River to Mangrove Dam transfer system at a cost of $76.4M. A second phase augmentation scheme included construction of a McDonald River to Mangrove Dam transfer scheme and increasing the capacity of Mangrove Dam at a cost of $194.5M. Security of the water supply systems was analysed using the WATHNET network linear program for headworks simulation and regional water demand was determined using a non-parametric regional demand model (see Coombes et al., 2000a; 2002 for details).

3.1 Comparative economics for the installation of rainwater tanks in the Lower Hunter Region

Coombes et al. [2000a; 2002] evaluated time series of annual and present equivalent economic position Bal_{t+1} (Equations 1 and 2) for the different scenarios in the Lower Hunter region. Each alternative scenario began in year 2000 with enough funds to ensure economic viability of the base scenario at the completion of an investment period of 100 years.

A number of investment scenarios were considered for the Lower Hunter region. The Base scenario considers the status quo. This involves provision of traditional stormwater systems to areas undergoing urbanisation and provision of additional mains water supply by further regulation of river systems. Alternative scenarios consider the use of rainwater tanks. A number of alternative scenarios are considered: In the Growth scenario (denoted as G), rainwater tanks are installed for all new housing. In the other scenarios (denoted as G+0.25% to G+3%), rainwater tanks are installed for all new housing and existing housing is retrofitted with rainwater tanks at rates varying from 0.25% to 3% per year until 90% of dwellings have a rainwater tank. The present equivalence analysis for the Lower Hunter region presented in Table 1 shows the initial investment, the comparative present benefit and the augmentation requirement for each scenario determined by Coombes et al. [2002].

Table 1: Results of the present equivalence analysis for the Lower Hunter region

Scenario	Initial investment ($M)	Present benefit ($M)	Augment in year
Base	15	0	2041
Growth	-44	59	2049
G+0.25%	-45	60	2050
G+0.5%	-52	67	2055
G+0.75%	-59	74	2064
G+0.9%	-63	78	2067
G+2%	-22	37	2075
G+3%	27	-12	2075

Table 1 reports the comparative benefits that are the present value to the community of an investment in a particular scenario in comparison to the traditional Base scenario. For the Base and G+3% scenarios capital investment is required to ensure viability of the strategy. However for the other scenarios an initial capital investment is not required. For example the G+0.9% scenario required an initial investment in the first year of -$63 million, indicating that the community can spend $63 million on other activities in the first year, and still finance the provision of water supply and stormwater services. Moreover the community does not need to set aside $15 million to finance the Base scenario. Thus investment in the G+0.9% scenario provides a $78 million present worth benefit to the community. In Table 1 it is shown that the G+0.9% scenario has the greatest comparative present worth benefit of $78 million. Comparative present worth benefits of the growth to G+2% scenarios range from $37 million to $78 million. The G+3% scenario shows a comparative present cost of $12 million.

3.2 Comparative Economics for the Installation of Rainwater Tanks in the Central Coast region

Coombes et al. [2000a; 2002] also evaluated time series of the annual and present equivalent economic position Bal_{t+1} (Equations 1 and 2) for different scenarios in the Central Coast region. The present equivalence analysis presented in Table 2 shows the initial investment, the comparative present benefit and the augmentation requirement for each scenario. Note that the Base scenario will require augmentation in the years 2026 and 2062.

Table 2: Results of the present equivalence analysis for the Central Coast region

Scenario	Initial investment ($M)	Present benefit ($M)	Augment in year
Base	33	0	2026, 2062
Growth	-3	36	2054
G+0.25%	-5	38	2058
G+0.5%	-7	40	2062
G+0.75%	-13	46	>2100
G+0.9%	-14	47	>2100
G+2%	22	11	>2100

The Base and G+2% scenarios require capital investment to ensure viability of the strategy. Table 2 shows that the G+0.9% scenario had the greatest comparative present worth benefit of $47 million. Comparative present worth benefits of the Growth to G+2% scenarios range from $11 million to $47 million. The Growth to G+2% scenarios are shown to be more economically efficient than the traditional

Base scenario. This result is similar to the findings for the Lower Hunter region. The comparative present worth benefits of alternative scenarios in the Central Coast region were less than the comparative present worth benefits found in the Lower Hunter region. The difference in the magnitude of benefits is due to lower price of mains water and lower first stage augmentation cost for the water supply headworks system in the Central Coast region. A lower price for mains water reduces the economic savings that results from saving mains water and a lower augmentation cost will result in reduced interest savings from the deferral of augmentation.

4. A SENSITIVITY ANALYSIS

It was shown in Section 3 that widespread installation of rainwater tanks for water supply and stormwater management can produce considerable economic benefits for the community. However economic benefits derived from widespread installation of rainwater tanks may alter significantly with variations in installation costs, stormwater infrastructure savings, real interest rates and the price of mains water. This section explores the economic impacts of different assumptions used in the investment model.

Inappropriate use of discount rates in the evaluation of alternative solutions can introduce considerable bias into an analysis. The use of excessive discount rates will create an illusion that alternatives with high initial investment costs are not economically competitive. Smith [1979] and de Neufville and Stafford [1971] argue that discount rates should be applied using the opportunity cost (OC) of capital from private investment described as:

$$OC = \frac{i - s}{1 - t} \qquad (3)$$

where i is the interest rate on government bonds, s is the inflation rate and t is the company tax rate. Note that i – s is the real interest rate.

There is considerable uncertainty about investment returns therefore the opportunity cost of capital for investments should be comparable to risk free constant capital returns currently available, such as from government bonds. It is also important to properly account for the reduction in returns from government bonds due to the effects of inflation. During May 2003 the reserve bank interest rate was 4.75%, the inflation rate was 3.2% and the company tax rate was 30%. Thus the opportunity cost of capital was 2.2%. This considerably less than the real interest rate used in Section 3 and by White et al. [1998] to analyse alternative scenarios. It can be argued that in a managed economy real interest rates or opportunity costs of capital will not be sustained at high levels.

One can also argue that if sustainable solutions are to be found we should not penalise solutions that provide future benefits or favour solutions that create environmental impacts in a discounted future. For example de Neufville and Stafford [1971] explain that the choice of discount rate must be appropriate for the benefit under consideration. The benefits of flood protection and security of water supply do not diminish with time and therefore should not be subject to a discount rate.

4.1 Variation in Real Interest Rates

The analysis in Section 3 assumed a real interest rate of 5%. Real interest rates are dependant on the economic status of a country or region and can vary widely. For example during 1999 the real interest rate in Australia was about 5%, whilst thereafter real interest rates plunged to 2%. Changes in interest and inflation rates may significantly alter the results of the investment analysis for the installation of rainwater tanks. The investment cases for the Lower Hunter (Table 3) and Central Coast (Table 4) regions was evaluated using real interest rates of 2% and 8% respectively to determine impacts on the economic benefits derived from the installation of rainwater tanks. Tables 3 and 4 show the initial investment required in year 2000 to ensure the economic viability of a strategy.

Table 3: Results of the present equivalence analysis for the Lower Hunter region subject to variation in real interest rate.

Scenario	Initial investment ($M) by real interest rate		
	2%	**5%**	**8%**
Base	47	15	5
Growth	-141	-44	-21
G+0.25%	-162	-45	-19
G+0.5%	-194	-52	-20
G+0.75%	-228	-59	-21
G+0.9%	-247	-63	-22
G+2%	-161	-22	9
G+3%	-43	27	41

Tables 3 and 4 show that variation in real interest rates significantly alter the magnitude of community benefits from installation of rainwater tanks. Lower real interest rates increase the magnitude of benefits and higher real interest rates decrease benefits. In the case with a real interest rate of 2% all alternative scenarios in the Lower Hunter and Central Coast regions show greater economic benefits to the community than the traditional Base scenario.

The greater economic benefits derived from a lower real interest rate are due to increased funds required to maintain viability of the Base scenario in a low interest rate environment. Thus the comparative benefit is greater. In the case with a real interest rate of 8% the scenarios Growth to G+0.9% provide greater economic benefits to the community than the traditional Base scenario in both regions although the magnitude of benefits are decreased due to the lower investment required to maintain viability of the traditional Base scenario. However the use of high interest rates is considered inappropriate given the time invariant benefit of a secure water supply.

Table 4: Results of the present equivalence analysis for the Central Coast region subject to variation in real interest rate.

Scenario	Initial investment ($M) by real interest rate		
	2%	5%	8%
Base	105	33	13
Growth	-29	-3	4
G+0.25%	-46	-5	5
G+0.5%	-61	-7	5
G+0.75%	-97	-13	5
G+0.9%	-105	-14	5
G+2%	-25	22	30

4.2 No Stormwater Infrastructure Savings for Redevelopment

In Section 3 it was assumed that installation of rainwater tanks in redevelopment of dwellings would reduce the requirement for stormwater infrastructure thereby decreasing construction, maintenance and replacement costs of stormwater infrastructure. Use of rainwater tanks in redeveloped dwellings (scenarios G+0.25% to G+3%) may not produce stormwater infrastructure savings, though this is considered unlikely given the infrastructure savings reported by Coombes et al. [2000; 2003] and Coombes and Kuczera [2000]. Note that many Local Government Authorities require the installation of site detention facilities at redevelopment sites. The investment case was evaluated using the assumption that installation of rainwater tanks in redevelopment of buildings will not result in stormwater infrastructure savings. Results for the Lower Hunter and Central Coast regions are shown in Table 5.

When it was assumed that installation of rainwater tanks in redevelopment of dwellings will not produce stormwater infrastructure savings the economic benefits of the G+0.25% to G+3% scenarios in the Lower Hunter and Central Coast regions are reduced in comparison to the analysis in Section 3. However in the Lower Hunter region the scenarios G+0.25% to G+0.9% still produce greater economic benefits to the community than the traditional Base scenario. In the Central Coast region the Growth to G+2% scenarios produced greater economic benefits to the community than the traditional base scenario.

Table 5: Results with no stormwater infrastructure savings for redevelopment

Scenario	Initial Investment ($M)	
	Lower Hunter	Central Coast
Base	15	33
Growth	-44	-3
G+0.25%	-33	3
G+0.5%	-28	3
G+0.75%	-23	9
G+0.9%	-19	13
G+2%	22	17
G+3%	71	-

4.3 Reduced Stormwater Infrastructure Savings for All Development

In Section 3 stormwater construction cost savings of $959 per dwelling was used in all new and redeveloped dwellings (Growth to G+0.9% scenarios). Analysis of a development in the Newcastle region by Coombes [2002] found that installation of 10 kL rainwater tanks produced a minimum construction cost saving for stormwater infrastructure of $218 per allotment. The saving for replacement and depreciation costs of stormwater infrastructure of $23.45 per dwelling used in Section 3 was changed to the minimum replacement and depreciation cost saving reported by Coombes [2002] in this investment analysis. In addition to the assumption that all redeveloped housing with rainwater tanks will not provide stormwater infrastructure savings stormwater construction cost savings of $218 and replacement and maintenance cost savings of $10.87 per allotment for new developments are used in the investment model. Results of the analysis for the Lower Hunter and Central Coast regions are shown in Table 6.

Table 6: Results from reduced stormwater infrastructure savings for new development and no savings for redevelopment

Scenario	Initial Investment ($M)	
	Lower Hunter	Central Coast
Base	15	33
Growth	-22	22
G+0.25%	-14	25
G+0.5%	-13	28
G+0.75%	-12	29
G+0.9%	-11	32
G+2%	30	67
G+3%	79	-

Table 6 shows that reduced cost savings for stormwater infrastructure resulting from the use of rainwater tanks has decreased the benefits of the alternative scenarios in the Lower Hunter and Central Coast regions although the Growth to G+0.9% scenarios still provide greater economic benefits to the community than the traditional base scenario.

4.4 Variation in Installation Costs and Price of Mains Water

This section investigates the impact of increased installation and replacement costs and variation in the price of mains water on the economic efficiency of the rainwater tank scenarios. It is assumed that installation costs for rainwater tank systems increase to $2700 per dwelling and replacement costs of tanks and pumps increase to $1200 and $350 per dwelling respectively. The price of mains water in the Lower Hunter and Central Coast regions was also varied by ± 10%. It is also assumed that the redevelopment of dwellings will not result in stormwater infrastructure savings. Tables 7 and 8 shows the initial investment required in year 2000 to ensure economic viability of the strategies.

Table 7: Results for the Lower Hunter region with increased installation costs and variation in the price of mains water

Scenario	Initial investment ($M) by price of mains water		
	$0.85/kL	$0.94/kL	$1.03/kL
Base	15	15	15
Growth	-9	-16	-24
G+0.25%	7	-1	-9
G+0.5%	19	9	-1
G+0.75%	29	19	7
G+0.9%	37	25	13
G+2%	119	103	87
G+3%	205	186	167

Tables 7 and 8 show that increased installation and replacement costs for rainwater tank systems reduced the magnitude of benefits resulting from alternative scenarios in the Lower Hunter and Central Coast regions. However the Growth to G+0.5% scenarios in the Lower Hunter region provided greater benefits than the Base scenario. A reduction in the price of mains water to $0.85/kL further decreased benefits although the Growth and G+0.25% scenarios still provided greater benefits than the Base scenario. An increase in the price of mains water to $1.03/kL produced greater benefits with the Growth to G+0.9% scenarios providing greater benefits than the Base scenario.

Increases in installation and replacement costs for rainwater tank systems in the Central Coast region also reduce the magnitude of benefits (Table 8). A reduction in the price of mains water to $0.58/kL will also decrease the benefits of the alternative scenarios. In both cases the Growth scenario shows greater economic efficiency that the Base scenario. Increasing the price of mains water to $0.72/kL improves the benefits with the Growth and G+0.25% scenarios providing greater benefits than the Base scenario.

Table 8: Results for the Central Coast region with increased installation costs and variation in the price of mains water

Scenario	Initial Investment ($M) by price of mains water		
	$0.58/kL	$0.65/kL	$0.72/kL
Base	33	33	33
Growth	32	27	24
G+0.25%	42	37	32
G+0.5%	52	47	42
G+0.75%	59	53	47
G+0.9%	66	60	53
G+2%	129	121	112

Even with high installation costs and the exclusion of stormwater infrastructure benefits from installation of rainwater tanks at redeveloped dwellings the scenarios with rainwater tanks provide greater benefits to the community. Increases in the price of mains water for demand management purposes will also increase the benefits accruing from installation of rainwater tanks.

CONCLUSIONS

This study described the development of the community-based investment model created by Coombes et al. [2000a; 2002] that allows economic comparisons between a traditional base scenario for urban water cycle services and alternative scenarios that include rainwater tanks. The traditional base scenario assumes further exploitation of rivers to meet growth in urban water demand and additional pipe drainage systems to manage increasing stormwater runoff.

The economic benefits derived from the use of rainwater tanks vary with the price of mains water and the cost to augment mains water supply headworks systems. The magnitude of the economic benefits accruing to the community from widespread installation of rainwater tanks was dependent on real interest rates, the value of stormwater savings that result from the use of rainwater tanks and the installation costs of rainwater tank systems. Nonetheless it was shown that the use of 10 kL rainwater tanks provided greater economic benefits to the community than the traditional water supply and stormwater management options in the majority of cases considered.

This study also did not attempt to establish the optimum sized tank for water supply and stormwater management. Importantly Coombes and Kuczera [2003] have established that rainwater tanks with capacities of 1 kL to 5 kL provide considerable reductions in mains water demand and stormwater runoff. These smaller tanks will have reduced installation costs that may lead to greater community benefits.

Even though this study suggests that the economic performance of rainwater tanks is robust, it in fact was biased against rainwater tanks. This study has not valued the environmental benefit associated with delaying the construction of dams to augment water supply and from reduced stormwater discharges to the receiving environment, and the cost savings from a reduced requirement for water distribution and treatment infrastructure. Moreover, the construction and lifecycle costs of alternative scenarios have only been assessed, albeit conservatively, using data from a small number of case studies and demonstration sites. Therefore, the benefits of the alternative approaches that include rainwater tanks have most likely been understated for the Lower Hunter and Central Coast regions.

Importantly the community-based analysis allows for multiple providers of water and accounts for costs and benefits regardless to whom they accrue. Future research into community investment models should seek to determine optimal regional urban water cycle solutions for the community and ecosystems. There is a pressing need to develop and demonstrate a methodology for decision making that favours sustainable use of ecosystem services. The significance of this future research is that it would provide a rational framework for the community to assess its water cycle management requirements at all scales and also provide an effective tool for government to set policy objectives.

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