Performance of Rainwater Tanks at an Inner City House in Carrington NSW During a Drought

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Abstract:

Two small rainwater tanks and a 4A rated water efficient washing machine have been installed at a typically small house in Carrington an inner city suburb of Newcastle in New South Wales. Monitoring of the performance of the dual water supply scheme (rainwater and mains water) during a drought has revealed a 43% reduction in mains water demand. Analysis based on the monitoring results predicted that the combination of the rainwater tanks and 4A rated washing machine will reduce average annual mains water demand by 62% (104 kL). The cost of rainwater supply was calculated to be $0.28/kL and the benefits of the combined water management strategy were $3.24/kL of mains water saved. The microbial and chemical quality of rainwater was observed to improve throughout the rainwater treatment train. In addition the design and installation of the dual water supply scheme is presented.

1.0 INTRODUCTION

The ongoing research program at the University of Newcastle into the performance of rainwater tanks continues with the installation of two rainwater tanks at a typically small house in Carrington an inner city suburb of Newcastle in New South Wales. Previous studies by Coombes et al. [2000; 2003] analysed the performance of rainwater tanks at Figtree Place and the Maryville house. Figtree Place is a water sensitive urban redevelopment consisting of 27 residential units located in Hamilton, an inner suburb of Newcastle. The site uses underground rainwater tanks to supply hot water and toilet uses in the units. The prototype water sensitive urban design (WSUD) redevelopment was subject to many design and construction faults. Nevertheless the microbial and chemical quality of rainfall runoff from roofs was found to improve in the rainwater tanks and tank water used in storage hot water systems set at temperatures ranging from 50°C to 65°C was compliant with Australian Drinking Water Guidelines. In addition, mains water use was reduced by around 45% and small cost savings were experienced.

Using the lessons learnt from the Figtree Place redevelopment, an old house in Maryville, an inner city suburb of Newcastle was fitted with a large above ground 9,060 Litre Aquaplate rainwater tank to supply hot water, toilet and outdoor uses. The improved rainwater tank design cost $1,851 to install and resulted in mains water savings of 52% (62 kL/annum) in the three person household. Rainwater supply at the Maryville house was estimated to cost $0.30/kL. Similar to the Figtree Place redevelopment, the microbial and chemical quality of rainfall runoff from roofs was found to improve in the rainwater tanks and tank water passing through the instantaneous hot water service set at 55°C was compliant with Australian drinking water guidelines.

This paper describes the performance of a third installation at an old miner's cottage at Carrington with a roof area 95 m^2 on an allotment with an area of 178 m^2. Two small rainwater tanks with capacities of 2.2 kL were installed during July of 2003 and a water efficient (4A rated) washing machine was installed during January of 2004. Rainwater is used to supply all household water uses. Prior to installation of the WSUD measures the average annual water use in the two person household was165 kL. A monitoring program has been installed to analyse water use and rainwater quality in the rainwater tank and at various end uses in the house. This paper discusses the design, monitoring results and economic performance of the dual water supply system.

2.0 DESIGN OF THE DUAL WATER SUPPLY SYSTEM

The dual water supply system and locations of the water meters used to monitor water use are shown in Figure 1. Rainfall from 84% of the roof area (80 m^2) discharges to two rainwater tanks and supplied to the household via a water filter using a Davy XP350 pump.

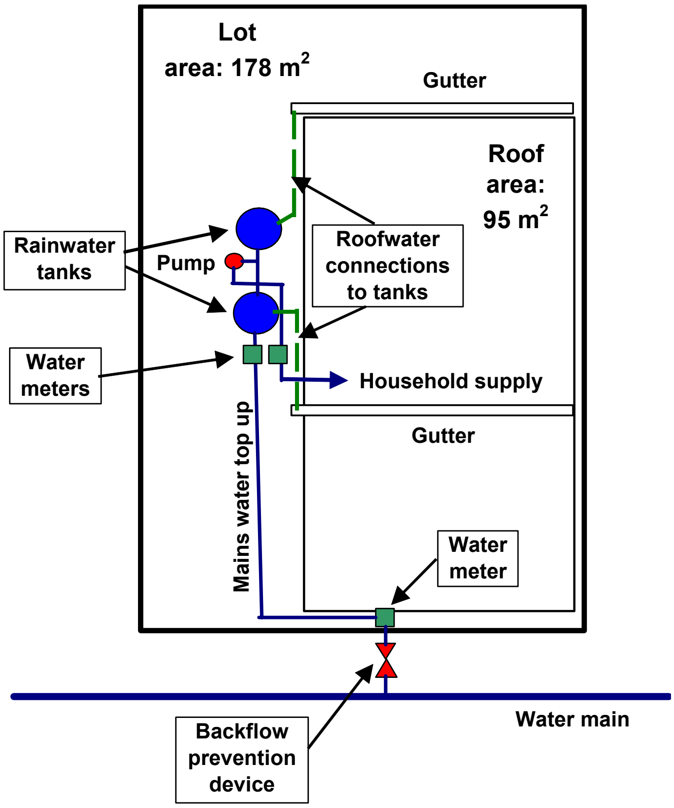

Figure 1: Plan view of the dual water supply solution at Carrington

The configuration of the rainwater tanks in the dual water supply system is shown in Figures 2 and 3. A mechanical system is used to top up the rainwater tanks when tank water levels are drawn down to a depth below 0.4 m. In the event of a pump or power failure the rainwater supply system can be bypassed. Design of the rainwater supply scheme provides a minimum storage volume of 0.72 m^3, a rainwater storage volume, airspace between the mains water inlet and the tank overflow to prevent backflow of rainwater into the mains water system, and rainwater supply drawn from above the anaerobic or sludge zone. A dual check valve for backflow prevention was placed at the water meter.

Figure 2: Picture of rainwater tanks

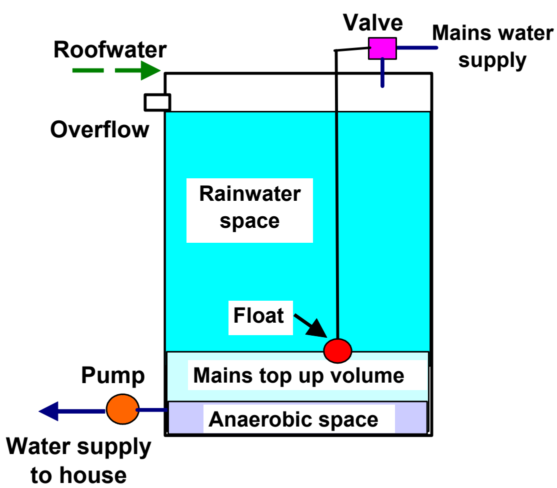

Figure 3: Rainwater tank details

If the volume of stored water in the rainwater tanks falls below 0.72 m^3, the shortfall is overcome by the mains water trickle top up system. The mechanical trickle top up system includes a diaphragm valve connected to a stiff arm and a float. Vertical movement of the float allows trickle top up at a variable rate governed by the depth of water in the tanks. A low water depth will trigger a greater top up flow rate than a small drawn down of the storage volume.

The two tanks were interconnected to the pump using a three way plumbing connection. This allows the water levels in the tanks to equalise and for water supply to be drawn from both tanks. Rainwater is drawn from the tanks at a point 0.1 m above the base to avoid entraining sediment into the water supply from the base of the tank. The tanks were placed on a 100 mm thick reinforced concrete slab. After the concrete had set the tank manufacturer delivered the tanks and placed them on the concrete slab with outlets and inlets orientated in the required directions. A plumber was then commissioned to install the pump, connect the tanks to the household plumbing and roof water connections from downpipes to the tanks. Half of the available roof catchment was connected to each rainwater tank. The plumber also installed the mains water trickle top up and float system. An electrician was used to install a power point close to the pump.

2.1 The Approval Process

State Environmental Planning Policy 4 (SEPP4) in New South Wales allows the installation of above ground rainwater tanks that have storage capacities of 10 kL or less without a development approval from local government. However the use of a mains water top up scheme requires approval from the local water authority. A sketch of the dual water supply scheme was provided to Hunter Water Corporation.

2.2 Costs

There has been considerable debate about the cost of rainwater supply to a house. The cost and performance of the rainwater supply system at Carrington were monitored closely in an attempt to understand the true costs and benefits of the system. The total cost to install the rainwater supply system was $2,350 and the itemised costs are shown in Table 1.

Table 1: Costs to install the rainwater supply system in 2002 (Australian $)

Item	Cost ($)
Aquaplate tanks	756
Pump	389
Plumber + electrician	600
Fittings	455
Concrete slab	150
Total	**2,350**

One of the common assumptions is that rainwater tanks occupy a large area and therefore must be installed underground at considerable cost. However the two 2,200 Litre capacity rainwater tanks at the Carrington house were chosen to occupy a minimum area of about 2 m^2. This is approximately 2% of the small land area occupied by the allotment.

3.0 RESULTS AND DISCUSSION

The dual water supply system was installed during July 2003. Additional water meters were installed in the rainwater supply pipe on the downstream side of the pump and in the mains water top up pipe (Figure 1). In combination with the existing water meter at the property boundary, the meters were used to determine mains and rainwater use at the house. Daily climate data from the nearby Maryville weather station operated by the Hunter Valley Research Foundation was incorporated with the meter readings, water billing records from the Hunter Water Corporation and a diary study of household water use to understand the water balance at the house.

A manual monitoring programme to collect and analyse water samples from the rainwater tank and household taps commenced in July 2003. In addition the site is also being used in the ongoing rainwater quality research program at the University of Newcastle to further understand the action of biofilms in the rainwater tanks, water quality processes in roof runoff, rainwater tanks and hot water services, and atmospheric deposition. The preliminary results from a 260 day period that represents stage 1 of the research site development are presented in the following section. Stage 2 of the research site development will be discussed later in this paper.

3.1 Water quantity

The dual water supply scheme at Carrington has been operating during a period of drought that has affected most of NSW. Little or no rainfall has been experienced in the majority of water supply catchments whilst rainfall depths have decreased in the urbanised coastal regions. Rainfall records from the Maryville weather station show that 620 mm of rainfall has been experienced during the 260 day monitoring period that represents a 24% reduction in rainfall at that site. In addition, 30% of the entire rainfall depth during the monitoring period occurred during two rainfall events. A time series of daily rainfall is shown in Figure 4.

During the monitoring period, analysis of readings from the water meters revealed that the total water use at the site was 97.74 kL. This water use was supplied by 55.52 kL of mains water and 42.22 kL of rainwater. The use of the rainwater tanks resulted in a 43% reduction in mains water use. Comparison to the water billing records for the previous year from the Hunter Water Corporation revealed that a 53% reduction in mains water use was experienced. A time series of total and rainwater use during the monitoring period is shown in Figure 5.

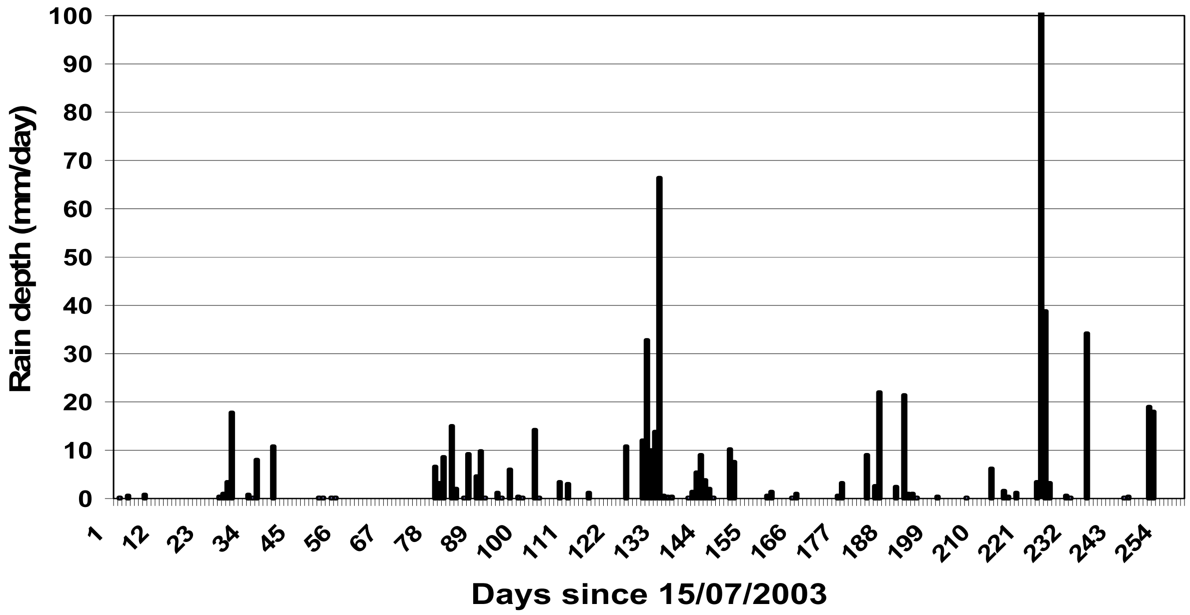

Figure 4: A time series of daily rainfall

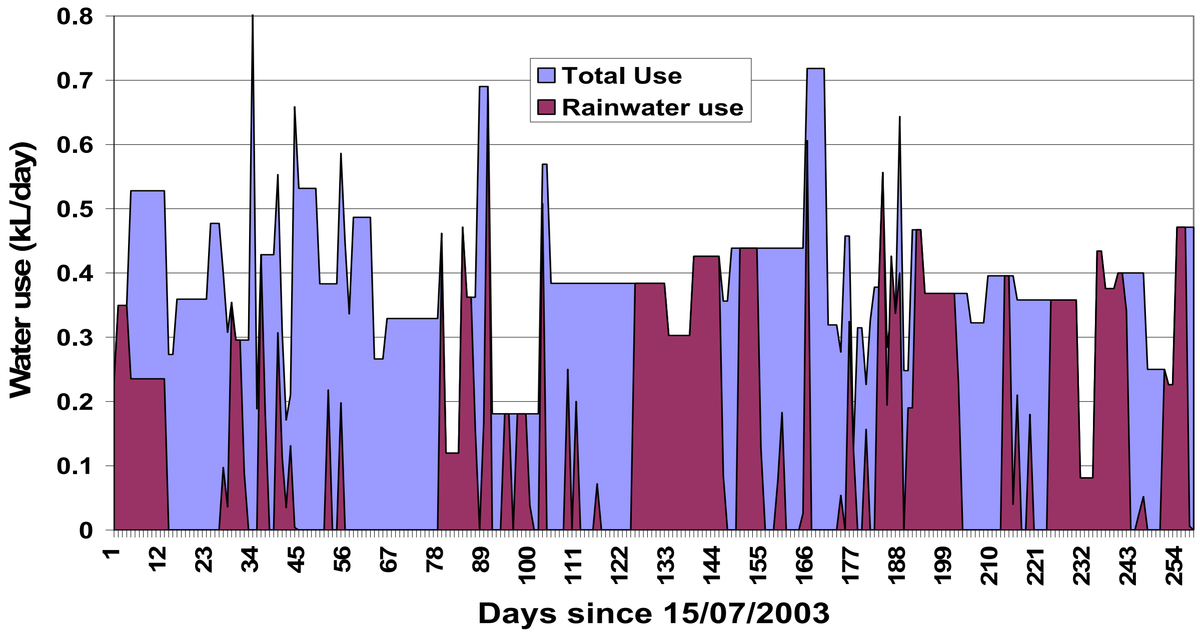

Figure 5: A time series of daily total and rainwater use

Figures 4 and 5 reveal that the house was supplied with rainwater during and after rainfall events. After the stored rainwater is exhausted, household water demand is met with mains water from the trickle top scheme. Average daily water demand in the house during the monitoring period was 0.376 kL/day indicating that the full rainwater tanks can supply total water demand for about 11 days. Analysis of rainfall also revealed that 42.2 kL of the 49.6 kL of roof runoff during the monitoring period was utilised for household water use. This is a yield of about 85% from the rainwater catchment. Only 15% (7.4 kL) of roof runoff from the rainwater supply catchment has overflowed from the rainwater tank.

The combination of small rainwater tanks and a mains water trickle top up system has created an efficient dual water supply scheme. This is due to the drawdown of the rainwater storages between rainfall events. A design philosophy for rainwater tanks used in a dual water supply scheme is highlighted here: the designer should aim to maximise drawdown of the rainwater tank between storm events whilst maximising yield from the roof catchment.

Water use patterns at the house in Carrington were determined from tri-annual billing records from the Hunter Water Corporation and are shown in Figure 6. Figure 6 shows that average daily water use has declined from over 0.5 kL/day to about 0.43 kL/day in the period prior to installation of the rainwater tanks. The decline in water use is due to the residents' regular absences from the Carrington house on weekends during the last two years. It is also shown that an 4A rated washing machine was installed in January 2004. It is clear from Figure 6 that the monitoring program and Hunter Water Billing records have not yet reflected the full impact on water use created by the rainwater tanks and the 4A rated washing machine.

Installation of the rainwater tanks has resulted in a 43% reduction in water use but comparison to water use in the year prior to installation reveals a 53% reduction in water use. Replacement of the 4.5 kg capacity top loading washing machine with the 4A rated front loading washing machine with a 7 kg capacity has resulted in reducing water use per washing load from 114 litres to 58 litres. This is a 14% reduction in total water use in the house. However the 4A rated washing machine was installed in January 2004 therefore the impact of the washing machine on the reduction in average water use during the monitoring period is a 4% reduction in water use. The remaining 6% additional reduction in water use is due to the pump suppling water at a lower flow rate and pressure to the house.

The 4A rated washing machine cost $940 to purchase. In addition to reducing water use replacing the old top loading washing with the 4A rated washing machine reduced the frequency of clothes washing and minimised use of washing powder. This reduced the expense of purchasing washing powders from $23.45/week to $3.66/week.

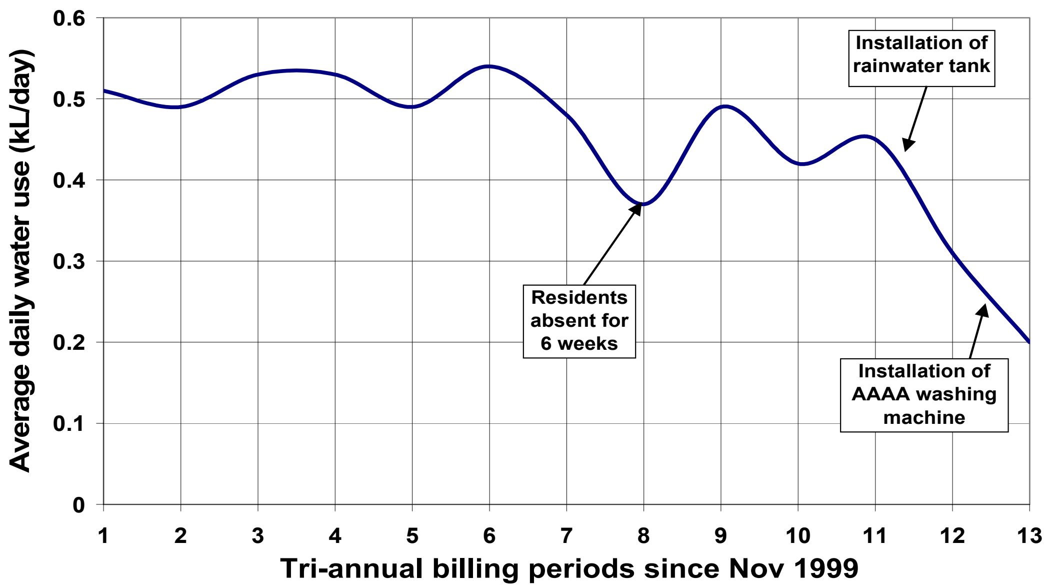

Figure 6: Previous water use patterns derived from Hunter Water Corporation accounts

A diary study of water use was combined with the meter readings to determine the water use categories in the household for the period following the installation of the 4A rated washing machine. The results are shown in Figure 7.

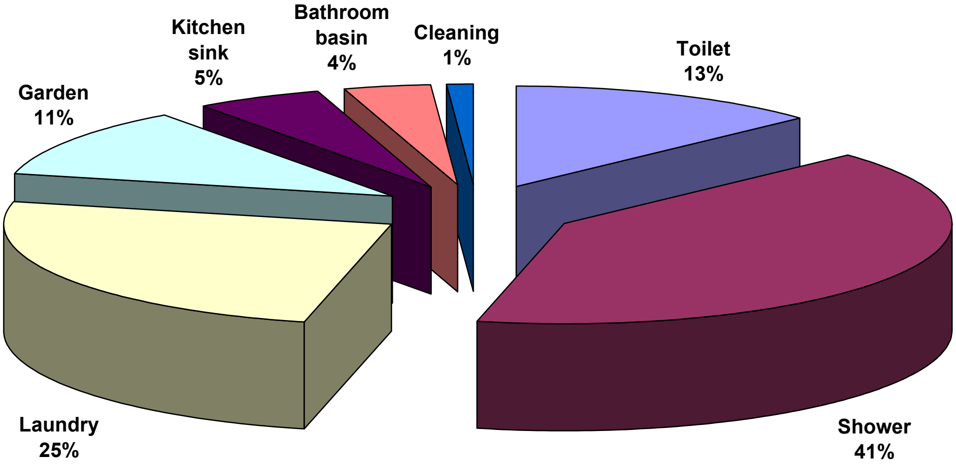

Figure 7: Categorisation of water use at the Carrington house

Figure 7 reveals that the highest water use category in the house is for showering (41%) and the lowest water use is at the kitchen sink (5%). The combined water use of laundry, toilet, garden, cleaning and shower is 91% of total water use in the inner city house.

4.2 Water quality

Carrington is an inner city suburb located in a dockland area within the industrial area of Newcastle. The house is situated close to roads with high traffic loads and trees containing birds overhang the house roof. Roof runoff at the site was expected to contain a variety of contaminants. A first flush device has not been installed and a small 125 litre capacity storage hot water service set at a temperature of 60°C operates in the house.

Previous studies conducted by the Coombes et al., [2000; 2000a; 2003] and Spinks et al., [2003; 2003a] have established that the rainwater treatment train, including the roof, tanks, pump and hot water service can remove the majority of contaminants from rainwater. A number of processes are believed to improve the quality of stored rainwater including flocculation, settlement and bio-reaction processes. In addition both instantaneous and storage hot water services have observed to remove bacteria from rainwater.

The water quality monitoring programme at the Carrington house includes sampling and analysis of water from three different locations in the tank water column (top, middle and bottom), at the cold water tap and at the hot water tap in the kitchen. The microbial quality of tank water was analysed using membrane filtration in accordance with AHPA standard methods. This involves filtering of a specified amount of water through a 0.45 μm filter that is placed on a selective growth medium and incubated for a specified length of time. Preliminary average water quality results from 6 samples are compared to the results from roofs at Figtree Place and from the rainwater tank at Maryville in Table 2.

Table 2 compares the preliminary average water quality results from the Carrington to roof runoff results from Figtree Place [Coombes et al., 2000], water quality from the rainwater tank at Maryville [Coombes et al., 2003], Australian Drinking Water Guidelines [NHMRC, 1998] and the American Drinking Water Guidelines [Fujiwara et al., 1992]. A treatment train effect is evident in the preliminary results. The microbial quality of hot water at the site was compliant with the Australian and American Drinking Water Guidelines with the exception of the Total Coliform. Interestingly further analysis of the hot water samples that apparently contained Total Coliforms using PCR methods revealed that the bacteria found was actually *Bacillus Sp.* Note that the average temperature of the hot water was about 65°C.

Cold water quality at the tap exceeded the guidelines for Faecal and Total Coliforms. Water quality in the rainwater tank, cold and hot water taps was also found to be compliant will the drinking water guidelines for metal, physical and chemical parameters including lead, iron, zinc, ammonia, nitrates, dissolved and suspended solids from a single sample.

The significance of exceeding drinking water guidelines for Coliform bacteria in rainwater supplies is unknown. Total Coliforms are no longer recognised as being a suitable indicator of faecal contamination of water or as having any relevance to health [Cunliffe, 2004]. Even though many studies have found Coliform bacteria in rainwater tanks and 3 million Australians rely on rainwater for drinking water supply there are no health epidemics attributed to rainwater tanks. Indeed only a small number of reported health concerns have been attributed to rainwater tanks in Australia. Notably the epidemiological study by Heyworth [2001] found that drinking rainwater posed a lesser health risk than drinking mains water in Adelaide.

Table 2: Preliminary microbial water quality results at various locations

Location	**E. Coli** (CFU/100 ml)	**Total Coliform** (CFU/100 ml)	**Pseudomonas Sp.** (CFU/100 ml)	**Heterotrophic Plate Count** (CFU/ml)
Roof runoff at Figtree Place	135	359	59,604	1,362
Maryville rainwater tank	0	18	1673	784
Water surface in tank	**108**	**1050**	**3100**	**1,050**
Medium depth in the tank	**34**	**900**	**780**	**427**
Bottom of the tank	**55**	**862**	**4060**	**1,252**
Cold water tap	**<1**	**200**	**412**	**76**
Hot water tap	**0**	**2**	**<1**	**<1**
Australian Drinking Water Guidelines	0	0	-	-
American Drinking Water Guidelines	0	0	-	200

A parallel scoping study into biofilm development at the University of Newcastle by Pigott [2003] established that the dominant bacteria present in biofilms found in rainwater tanks was *Bacillus Sp.* and *Coliform Sp.* that mostly originate from soils. This study also found evidence that biofilms may extract metals from the water column. It should be recognised that Coliform bacteria are common to soils and are also used to indicate faecal contamination of drinking water that may result in the presence of human pathogens. The majority of human pathogens are found in human sewage. It is unlikely that significant pathways exist for contamination of above ground rainwater tanks with human sewage. Note that Cunliffe [1998; 2004] concedes that the detection of human pathogens in rainwater tanks is uncommon.

Ongoing research at the University of Newcastle is determining the pathways for contamination of rainwater and the likelihood of the presence of pathogens in rainwater tanks. Importantly there has been some early progress in determining appropriate indicators for contamination of rainwater supplies at various end user locations in households. Clearly the risk of human illness from consuming rainwater trends to negligible when rainwater is not used for drinking water supply and the rainwater tank system is correctly installed. Note that kitchen water use (including drinking) is an insignificant portion (5%) of household water demand. The exclusion of drinking water from a dual water supply strategy will have little or no impact on the efficacy of a dual water supply strategy.

The use of rainwater in hot water systems will have a significant impact on the viability of a dual water supply strategy that utilises rainwater [Coombes et al., 2003b]. Continuing research by Spinks et al. [2003; 2003a] has extended the finding that hot water services can eliminate bacteria by Coombes et al., [2000] to analysis of the heat death behaviour of selected pathogens. The time to eliminate 90% of a bacterial population at a given water temperature (D-value) is shown for selected bacteria are shown in Table 3.

Table 3: Preliminary heat death results for selected bacteria (after Spinks et al. [2003])

Bacteria	**D-value (seconds)**		
	55°C	**60°C**	**65°C**
E. coli	1,493	66	3
Shigella sonnei	586	54	3
Pseuodomonas aeruginosa	304	49	5
Salmonella typhimurium	77	4	<2
Klebsiella pneumoniae	35	<2	<2

Table 3 shows that potentially pathogenic bacteria (note that *E. coli* is not usually pathogenic) are eliminated rapidly from rainwater at temperatures of 60°C or greater. This is consistent with the requirement in Australian Standard 3500.4.2 for hot water services to be set at temperatures greater than 60°C to eliminate *Legionella Sp.* from mains water. These results suggest that rainwater supplied to hot water services maintained at 60°C will provide water of adequate hygienic quality. A mixing valve should be used to deliver hot water to household taps at non scalding temperatures. The Carrington house site will be used to continue investigations into pathways for contamination of rainwater and the effectiveness of hot water services in the elimination of bacteria.

4.3 Energy

Electricity use at the Carrington house was extracted from quarterly billing records provided by Energy Australia to determine the impact of using rainwater supplied by a pump and are shown in Figure 7.

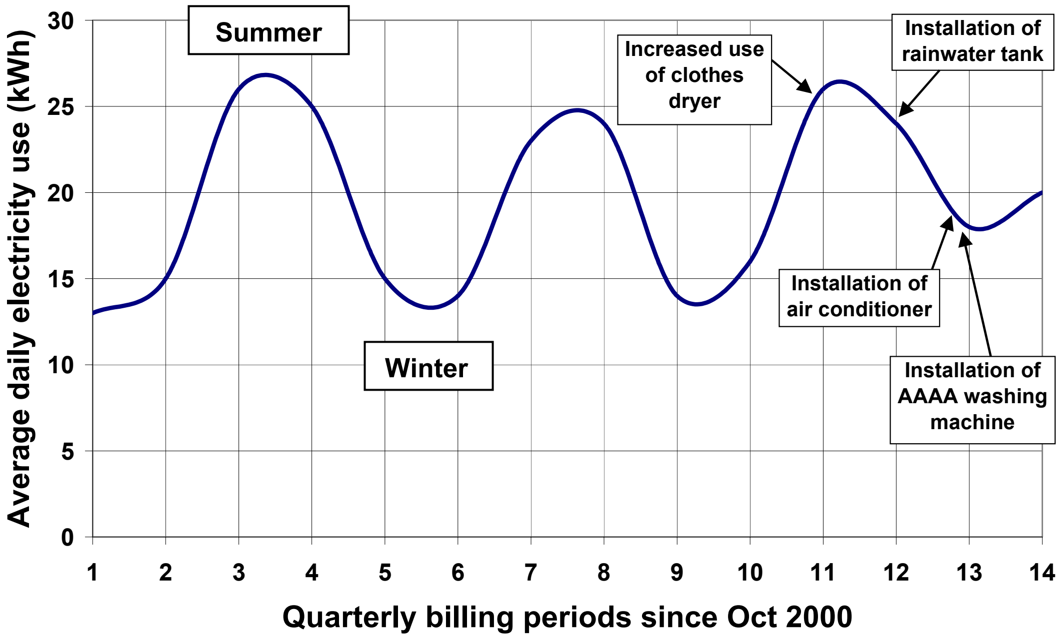

Figure 8: Daily average electricity use from quarterly billing periods

Figure 7 shows the cyclic nature of electricity use at the Carrington house that includes higher use in the winter for heating and lower use in the summer. Unfortunately the increased use of a clothes dryer, installation of an air conditioner and the 4A rated washing machine has obfuscated the impact of the rainwater pump on electricity use. Nevertheless it is revealed that the installation of the air conditioner has significantly increased the use of electricity during the summer period.

Using information provided by the pump manufacturer it is estimated that 0.24 kWh of electricity is used to supply 1 kL of rainwater to the house. The expected increase in annual electricity usage is 33 kWh at an annual cost of $3.92.

5.0 LONG TERM PERFORMANCE OF THE RAINWATER TANKS AND 4A WASHING MACHINE

The performance of the rainwater tanks and the 4A rated washing machine was continuously simulated using the PURRS water balance model developed by Coombes and Kuczera [2001] to understand the average annual impact on the household water balance. Synthetic pluviograph rainfall developed using the methods outlined in Coombes [2004] was used in the analysis. The synthetic pluviograph rainfall with a length of 100 years was generated using daily rainfall from Newcastle (Nobby's) and pluviograph rainfall from Maryville and Patterson.

Monthly average daily indoor and outdoor water demand (L/day), and water use categories shown in Figure 7 were used in the PURRS model. In addition it was estimated from the monitoring data that the 4A rated washing machine will reduce indoor water demand by 14% and the lower water pressure/flow rates supplied by the pump will reduce indoor water demand by about 6%. Climate data from the Maryville and Newcastle weather stations was also used in the analysis. The rainwater tanks were modelled as two tanks that are topped up to a water level of 0.3 m with mains water when the tanks are depleted. Results from the continuous simulation are shown in Table 4.

Table 4: Water balance results from continuous simulation of the Carrington dual water supply scheme

Category	Total	Mains water	Rainwater	Demand management
Water supply (kL/annum)	167	63	75	29
Proportion of water demand (%)	100	38	45	17

Table 4 shows that the use of the rainwater tank produced a 45% reduction (75kL/annum) in mains water demand and demand management processes resulted in a 17% reduction in mains water demand. The demand management response was achieved by the low pressure/flow rate delivered by the pump and the 4A rated washing machine that delivered mains water savings of 5% (8 kL/annum) and 12% (20 kL/annum) respectively. The use of the rainwater tank scheme was therefore responsible for a 50% (84 kL/annum) reduction in mains water use. The long term performance of the rainwater tank and the 4A rated washing machine revealed a 62% reduction in mains water demand (104 kL/annum).

6.0 ECONOMIC RESULTS

The long term performance of the rainwater tanks and the 4A rated washing machine were included in an economic analysis to determine the lifecycle costs of the integrated water management system. Economic performance was analysed using the whole of water cycle investment methodology that employs a community perspective developed by Coombes [2002]. The methodology is fully described by Coombes and Kuczera [2003]. The whole of water cycle investment methodology includes an initial investment, construction, operating and replacement costs for various alternatives, benefits from avoided costs of purchasing water and other cost savings. The following assumptions have been made in the analysis:

- The real interest rate is 5%. Note that the real interest rate is the reserve bank interest rate less the consumer price index.
- The installation costs of the rainwater supply scheme and the 4A rated washing machine were $2,350 and $940 respectively.
- The expected useful life of the rainwater tanks, pump and 4A rated washing machine was 25 years, 10 years and 10 years respectively
- The expected replacement costs of the rainwater tanks, pump and 4A rated washing machine were $756, $389 and $940 respectively
- The operating cost of the rainwater tank scheme was assumed to be $0.05/kL of rainwater supply
- Use of the 4A rated washing machine created a saving in use of detergents of $19.80/week
- The rainwater supply scheme and the 4A rated washing machine produced mains water savings of 100 kL/annum and 20 kL/annum respectively
- The price of mains water in Newcastle is currently $0.98/kL and the price of sewage disposal as a function of water demand is $0.22/kL.

The present values and cost of water supply (in year 2003 dollars) from the rainwater supply scheme, the 4A rated washing machine and the combined strategy was derived using a 50 year planning horizon and is shown in Table 5.

Table 5: economic analysis of the dual water supply scenarios

Scenario	Present value ($)	Cost of supply ($/kL)
Rainwater tanks	1,160 (cost)	0.28 (cost)
4A washing machine	17,917 (benefit)	17.91 (benefit)
Combined system	16,855 (benefit)	3.24 (benefit)

Table 5 shows that an initial investment of $1,160 is required to ensure that the rainwater supply investment strategy had a positive balance at the end of the planning horizon. This translated to a cost to supply rainwater of $0.28/kL. The avoided cost of purchasing mains water has created the low cost of rainwater supply. This result is similar to the finding that the cost of rainwater supply at the Maryville house was $0.30/kL [Coombes et al., 2003].

The economic results from the 4A rated washing machine produced an astounding insight: the present value benefit was $17,917 which equates to benefit of $17.91/kL of water saved by the washing machine. The considerable lifecycle benefits of installing the 4A rated washing machine were attributed to the large reduction in washing powder use created by replacing the small and inefficient washing machine with the 4A rated washing machine. This result cannot be generalised to other households because it is dependent on the washing and purchasing habits of the household.

The present benefit of the use of the rainwater tanks and the 4A rated washing machine was $16,855 which translates to benefit of $3.24/kL for rainwater supply and demand management. This result is worthy of reflection: the high cost of installing the rainwater tanks and the 4A rated washing machine of $3,290 has resulted in considerable lifecycle benefits of up to $17.91/kL of mains water saved and an average annual mains water saving of 62% (104 kL).

The high installation costs of the scenarios would ensure that the rainwater tanks and the 4A rated washing machine would not survive a least cost planning process [see White et al., 1998] even though a strategy to use both measures produces considerable lifecycle benefits and water savings. Note that the three strategies considered in the analysis were less expensive than purchasing mains water. Another planning consideration is also obvious: one may be tempted to select the 4A rated washing machine in preference to the rainwater strategy because of the higher lifecycle benefits and lower installation costs. The resulting small annual mains water saving of only 20 kL/annum from that choice highlights the need to mindful of primary objectives such as reducing mains water consumption in selection of strategies. The most important finding is that the combination of the rainwater tanks and the 4A rated washing machine creates considerable lifecycle benefits and mains water savings in spite of the installation costs.

Note that this economic analysis has under-estimated the benefits of installing the rainwater tanks and the 4A rated washing machine by not considering the benefits derived from reducing water demand on water supply infrastructure and reducing the requirement for stormwater infrastructure.

7.0 Reflections on the Installation Process

Instructing a plumber to install a rainwater tank can be a difficult and expensive task. Many city plumbers are not familiar with efficient methods for connecting rainwater tanks to houses and have perceptions about regulatory requirements that are not consistent with current guidelines. Plumbers were also found to significantly over-charge for installation of a rainwater tank.

Similar to previous research sites, including Figtree Place and the Maryville House, some difficulties were experienced with the installation of plumbing at the Carrington house [see Coombes, 2002; Coombes et al., 2003; Coombes et al., 2003a]. From past research and industry experience, it has been established that a cost effective approach to a rainwater tank installation was to independently order the pump(s), rainwater tank(s) and fittings prior to commissioning the plumber. Following the development of a design sketch for the rainwater tank installation the plumber should be employed on an hourly rate or a fixed price contract to install the plumbing specified in the design sketch.

This approach was taken for the installation at the Carrington house. Nonetheless some difficulties were experienced. The plumber was instructed to install non-metallic plumbing at the connection to the tanks to avoid the creation of a corrosion circuit between the copper water pipe and the galvanised iron in the rainwater tank. In addition, the plumber was asked to install flexible plumbing between the tanks, pump and the water meter in the rainwater supply pipe. These instructions were not followed and the pump was installed incorrectly. Although the plumber was employed on an hourly rate arrangement, the account for plumbing did not reflect the actual time spent on the project, indeed the time spent on the project in the account was triple the actual time spent on the project.

The supply of rainwater via a pump to a hot water service can lead to variable flow rate in a shower unless the installer understands that the pressure rating of the pump will need to be adjusted to ensure that a constant flow rate is available to the shower. This simple task is often overlooked. Residents wishing to install rainwater tanks are often given conflicting and misleading advice from water authorities, local councils and plumbers. This problem was highlighted by the large number of rainwater tanks purchased in the Sydney region (>20,000) and the low number of applicants (<2,000 for the Sydney Water Rebate Scheme during 2003. Indeed a large number of Sydney people sought advice from the author after losing patience with the Sydney rainwater tank rebate process.

To ensure that rainwater tanks become an important element in the WSUD treatment train for stormwater management and a fundamental source control measure in an integrated water management strategy a clear set of guidelines for installation will need to be developed. Ideally this will include clear instructions and sketches for installation of various rainwater supply strategies, independent advice on guidelines, installation and operation, and a register of plumbers who are trained to install rainwater tanks.

8.0 CONCLUSIONS

The installation of the dual water supply scheme (rainwater and mains water) at Carrington has highlighted the need for clear instructions and sketches for installation of various rainwater supply strategies, independent advice on guidelines, installation and operation, and a register of plumbers who are trained to install rainwater tanks. Installation of two small rainwater tanks with capacities of 2.2 kL each and a mains water trickle top up system to supply all household water uses resulted in a 45% (75 kL/annum) reduction in mains water use during a drought. The lower pressures and flow rates provided by the pump in the dual water supply scheme resulted in an additional 5% (9 kL/annum) reduction in mains water use. The use of the rainwater tanks resulted in a 50% (84 kL/annum) average annual reduction in mains water use. It is notable that the use of the rainwater tanks during a drought period produced a 50% reduction in mains water use.

Replacement of an old front loading washing machine with an 4A rated washing machine produced a mains water savings of 12% (20 kL/annum). The combined strategy of the rainwater tanks and the 4A rated washing machine will provide a 62% (104 kL/annum) mains water saving. Even though the installation costs of the rainwater tanks and 4A rated washing machine was $2,350 and $940 respectively, considerable mains water savings and lifecycle benefits were experienced. Importantly the cost of rainwater supply was only $0.28/kL which verified the cost of rainwater supply of $0.30/kL experienced at the Maryville house. Therefore rainwater supply is an affordable supplement for mains water supplies or competitive to mains water supplies. Addition of the 4A rated washing machine to the dual water supply strategy improved the cost of reducing mains water use to a benefit of $3.24/kL. Nevertheless this promising result is conservative because the systems benefits of reducing mains water demand and stormwater runoff have not been considered.

A treatment train effect was evident for the rainwater supply. The quality of rainwater was observed to improve throughout the rainwater supply system of roof, tank and end uses. Preliminary results indicate that the quality of rainwater supplied by the hot water system was mostly compliant with the Australian Drinking Water Guidelines. The results of this study add weight to the body of evidence that leads the water industry to the inevitable conclusion that the source control measures such as rainwater tanks and 4A rated washing machines are essential to the success of integrated water management and water sensitive urban design strategies. Importantly it can also be concluded that the use of “least cost” planning methodologies can exclude the use of high impact demand management measures such as rainwater tanks and 4A rated washing machines.

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