Costs and Benefits of Reducing Wastewater Flows Through Improving the Efficiency of Water Using Appliances

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EXECUTIVE SUMMARY

Reducing the production of wastewater by improving the efficiency of water use in houses, shops, offices and factories can reduce the cost of wastewater service provision by deferring the augmentation of sewage treatment infrastructure. In areas served by on-site systems, the reduction in wastewater flows can improve the performance of septic systems and reduce environmental impact. This paper is a report on the preliminary results of two innovative studies being undertaken on the north coast of NSW, studies that provide a quantitative analysis of the potential costs and benefits of this approach. This work has been initiated by Rous County Council, the bulk water supply authority in the region, and its constituent councils which provide retail water and sewerage services.

In the first study, the costs and benefits of reducing indoor demand for water in a coastal town are being investigated. Byron Bay, on the north coast of NSW has a rapidly increasing residential population and a large tourist demand that has resulted in an overloading of the existing sewerage system. Options to upgrade the system have been limited due to cost and adverse community response. The current combined capacity of the two sewage treatment plants (STPs) servicing Byron Bay is 8,700 e.p. The average dry weather flow equivalent in 1996 for the total system was 9,750 e.p., rising to 14,600 e.p. in the tourist season, and 19,000 e.p. on peak days. A proposed 8,000 e.p. upgrade to increase hydraulic capacity is estimated to cost $5.5 million.

The potential impact of a major water efficiency program has been modelled, including the retrofitting of water efficient toilets, showerheads and tap flow regulators in all residential and non-residential premises. Such a program, based on a successful example developed by one of the authors in Kalgoorlie-Boulder in Western Australia, would cost approximately $3 million and would reduce inflow by 1,000 kL/day, reducing hydraulic load by 4,200 e.p., bringing it close to the design capacity. During peak days the reduction would be even greater at 1,425 kL/day, a reduction in hydraulic load of 5,940 e.p. The exact benefits of improving efficiency to reduce inflow are made difficult to determine by the role of concentration of BOD, SS and nutrients, and wet weather flow. However, it appears that the STP is primarily hydraulically constrained, and reductions in inflow following an indoor water efficiency program may provide a cost effective solution to the problem when the combined benefits of deferring or downsizing water supply and sewerage system augmentation are considered.

The second study involves a real time demand monitoring exercise in a sample of 12 houses in the village of Clunes on the north coast of NSW. Clunes is an unsewered village community of 450 people and the study was undertaken in conjunction with a Lismore City Council wastewater management strategy. The objective of the demand monitoring study is to provide more accurate information about the demand and usage patterns for different water using appliances, including toilets, showers and taps. This study will enable improvements in the estimates of the impact of installing water efficient showerheads and other water efficient appliances. Preliminary results indicate that previous estimates of demand reduction following installation of an efficient showerhead of 25 kL per household per year may be conservative. The next stage of this project is to determine whether wastewater reduction allows for cost saving wastewater management options to be pursued, including improved on-site management systems.

These studies indicate that the sewerage system must be considered in estimating the financial and other benefits of water efficiency improvements. A comprehensive approach should also include analysis of the energy benefits arising from decreased hot water use.

KEYWORDS

Demand management, wastewater reduction, water conservation, water efficiency

INTRODUCTION

Rous County Council (RCC) is a bulk water supply authority in northern NSW. In 1996 the Council implemented a comprehensive demand management strategy, aimed at deferring the need for capital investment in new water supplies and sewage treatment plant augmentation. This was to be achieved by reducing the demand for water in the region through RCC investing in improving the efficiency of water use by customers. This involved the design and implementation of a number of programs, including offering low cost household water efficiency assessments by trained plumbers, and fitting of water efficient appliances at no cost to the customer. The initial phase of the program proved successful in the community and it became clear that improving customer efficiency through demand management had benefits that included not only reduced water and energy costs to the customer and reduced environmental impact, but that it could also lead to reduction or deferral of capital costs for both water supply and wastewater treatment infrastructure.

Following this, two different studies have commenced in an attempt to quantify the benefits of demand management using a least cost planning methodology. In the first study, an attempt was made to model the costs and benefits arising from reduced sewage flows in Byron Bay, a coastal town where expansion of sewage treatment plants has been planned to cope with population growth. As there are likely to be financial benefits arising from deferral of STP augmentation, the reduction in average dry weather flow due to a program to improve indoor water efficiency constituted part of this assessment. The program which was modelled includes water audits and the supply and installation of water efficient showerheads, toilets and taps in residential and commercial premises at no cost to the customer.

The second study consists of a real time water demand monitoring over two weeks in 12 houses in the village of Clunes, an unsewered village outside of Lismore. Although the sample size is small, both inefficient and efficient showerheads and single flush and 9 L/4.5 L dual flush toilets were represented in the mix of appliances used by the householders. The monitoring program was then followed by an assessment of the patterns of water use, a comparison of volumes required by householders with efficient and inefficient appliances and thus the respective volume and type of wastewater discharged into septic tanks. This research helps to provide an improved understanding of the real end uses of water by consumers and thus greater confidence in the assumptions that are built into the modelling of water efficiency initiatives. This in turn facilitates increased opportunities for the development of water efficiency programs and reduction in wastewater production and achieving the financial, environmental and social benefits that arise from this.

Demand management and least cost planning have been used in the design of many water efficiency programs, particularly in the U.S.A. (Beecher, 1996). Programs that have been developed include retrofitting of water efficient toilets, free water audits and financial rebates for non-residential customers, sub-metering programs and showerhead retrofitting programs. New York City Council has implemented these types of water efficiency program from the 1980s onwards, to help avoid the capital costs associated with expanding water supply and wastewater treatment infrastructure. For example from March 1994 through April 1997, $US285 million was spent in rebates for property owners replacing old toilets and showerheads with water efficient models. Water savings were estimated at 265–300 ML/d, and 1.3 million old toilets have been replaced (Miele, 1997). A study conducted in California showed that water use and wastewater flow can be reduced by 10% following a program of retrofitting low flush toilets, showers and taps in existing homes (Maddaus, 1983). A similar example exists in Western Australia, in Kalgoorlie-Boulder, where a water efficiency retrofitting and customer education program was carried out in 1995 (Botica and White, 1996).

BYRON BAY WASTEWATER REDUCTION STRATEGY

In this study, an attempt is being made to model the costs and benefits arising from reduced sewage flows which could be achieved following the implementation of a comprehensive indoor water efficiency program in the northern NSW coastal town of Byron Bay. Increasing residential and visitor populations in Byron Bay have placed growing pressure on the town's existing wastewater treatment infrastructure. The two sewage treatment plants servicing the town have a combined hydraulic capacity of approximately 2,100 kL/d. However, for some time now the plants have been operating well beyond their design capacities, with flows consistently over 3,800 kL/d and over 4,500 kL/d on holiday peaks. Previous studies of the problem (SKM, 1995a) have recommended various programs of expansion of plant capacity. As there are likely to be financial benefits arising from either deferral of STP augmentation or a reduction in the plant capacity required, the potential for improved indoor water efficiency to reduce average and peak dry weather flow has also constituted part of this assessment. The program that was modelled includes conducting water audits and the supply and installation of water efficient showerheads, toilets and taps in residential and commercial premises where these do not already exist, at no cost to the customer.

Modelling a Water Efficiency Program

Potential savings in kilolitres of water following a retrofit program were calculated by modelling an indoor water efficiency program which included converting all toilets and showers to efficient models, and fitting all bathroom and kitchen taps with flow regulators. The model uses data relating to: population, housing and tourist statistics, the number of residential and commercial premises, the number and type of indoor water using appliances, and per capita water demand based on average requirements for indoor water using appliances.

Estimated costs of the retrofitting/conversion program were calculated based on a cost of $270 for each toilet conversion, $40 for conversion of each showerhead, $20 for the fitting of flow regulators to each pair of taps, and an additional $50 for a water efficiency assessment for each residence. The results are also based on conversion of 90% of total toilets and 70% of total showerheads as previous survey results estimate that 10% of toilets are already 6 L/3 L dual flush and that 30% of showerheads are already efficient (White, 1997). The high cost per unit of toilet conversion stems from the fact that all toilets converted to 6 L/3 L dual flush units, including the existing stock of 9 L/4.5 L dual flush units, require replacement of both pan and cistern for efficient functioning.

Preliminary Results

Substantial reductions in the volume of wastewater flowing into the sewerage system can be achieved by implementing an indoor water efficiency program. Based on estimates of average daily population and housing figures for 1997, retrofitting water efficient appliances (including showerheads, toilets and taps) in all residential and commercial premises in Byron Bay township and the adjoining localities would reduce sewage volumes by an average of 1,000 kL/d as illustrated in Figure 1. This would bring the average hydraulic load down to 2,140 kL/d, which is under design capacity, though load to the plants would still be slightly over capacity at peak dry weather flow. During holiday periods the decrease in hydraulic load would be even greater. For example, based on the 26 January 1997 actual peak sewage inflow of 4,693 kL/d a reduction of 1,425 kL/d would be achieved following retrofitting. On the absolute holiday peak the load to the plants would be approximately 1,200 kL/day over capacity, this peak lasts for a short period only and excess could possibly be contained in equalisation ponds or by minor amplification works.

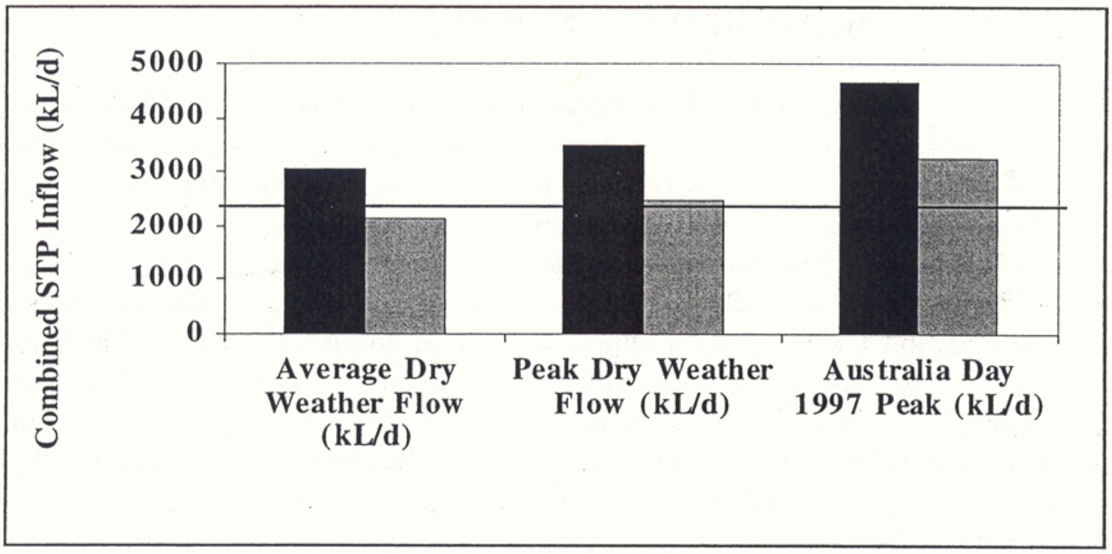

Figure 1: Combined STP inflow without (dark) and with (light) a water efficiency program. The line shows the current combined STP capacity.

The estimated cost of such a retrofitting program would be approximately $3 million. The cost of augmenting the STPs to 16,700 ep (4,600 kL/d) capacity is estimated at more than $5 million in present value terms (SKM, 1995b). This figure does not include any costs that may be associated with the possible decommissioning of one of the current plants. The estimated benefits of deferring augmentation of the STPs are at least $0.92 million for each year deferred, which results in a $1,250 saving for each 1 ML/a of wastewater reduction (White, 1997).

Associated with this reduction in inflow to the STPs are the benefits that accrue from deferring the need to develop new sources of water and new supply infrastructure, including dams, pipelines, and treatment plant capacity. The Rous Regional Demand Management Strategy (White, 1997) results indicate that a one year deferral of the proposed water supply augmentation results in a $1.4 million financial benefit to Rous County Council. Based on growth rates assumed in the supply strategy, this means that a demand reduction of 1 ML/a results in an additional financial benefit of more than $3,500. The possibility therefore exists for cost sharing between agencies for implementing such a water efficiency program.

Increasing the efficiency of water use will increase the concentration suspended solids (SS), biochemical oxygen demand (BOD) and nutrients in the STP influent. These parameters do not currently constrain operations at either plant, and there are possible efficiency gains to be made in treating higher concentrations. However, further analysis of the relationship between increases in the concentration of SS, BOD and nutrients, and the effectiveness of treatment is required to determine an optimal treatment regime. Further analysis of the impact of wet weather sewer flows is also required. There is minimal data available relating to the sewer flows during rain events. Attempts to correlate STP recorded inflows with daily rainfall data have not provided useful information, but there does not appear to be a significant peak wet weather flow problem, possibly due to the permeable coastal soils. The retrofitting of water efficient equipment in residential and non-residential premises offers an opportunity to simultaneously undertake an inspection of these premises for cross connections between the stormwater and sewage systems, at minor additional cost. In many areas, such cross connections represent a third of the volume of wet weather inflow.

CLUNES DEMAND MONITORING STUDY

The second study consisted of real time water demand monitoring of 12 houses in the village of Clunes, an unsewered village outside of Lismore on the north coast of NSW with a population of about 450. A proposal to build an STP to service the village at an estimated cost of $3 million (Geolink, 1996) is under consideration and there is interest in the potential for water efficiency measures to improve the performance of on-site sewage treatment systems. The sample size is small and not statistically significant. However, the methodology is worth developing to determine whether it can be used on a wider scale, and by other water service providers. The monitoring program was followed by an assessment of the patterns of water use, a comparison of volumes required by householders with efficient and inefficient appliances and thus the respective volume and type of wastewater discharged into septic tanks and the stormwater system. This research provides an improved understanding of the real end uses of water by customers, and thus greater confidence in the assumptions that are built into the modelling of water efficiency initiatives.

Methodology

Following householder agreement to participate in the study, water demand in 12 selected houses in the village of Clunes was monitored at ten second intervals over a period of seven to 14 days. To obtain the best possible estimate of the end use of water a number of steps were followed.

- A Hall probe was attached to a temporary water meter at each house and connected to a central datalogger. By logging flow rate at ten second intervals the probe was able to trace the characteristic flow rate or signature of an event such as the use of a toilet, shower or washing machine;
- A survey of each test household was undertaken to determine water use patterns and type of appliance (e.g. water efficient or inefficient showerheads, dual flush or single toilets) and to provide background information and assist in the identification of end uses of water;
- Selected water using fixtures in each house were tested and monitored to provide a calibration record;
- Data monitoring commenced and the data was downloaded for analysis every second day;

- Data was copied into a spreadsheet for each house for each day. Over 100 house/day records were created;
- Histograms detailing flow rates in litres per minute and length of time in ten second periods were generated for each half hour for each house/day period. Approximately 5,000 charts were generated and of these approximately 2,500 (a seven day period for each house) were analysed for water using events and grouped and printed on a houses/day basis for each half hour period where an event occurred;
- Each data grouping (i.e. each water use event) was then compared to its corresponding histogram signature and checked against the calibration record and background information for individual identification;
- Each event was then classified and recorded by type. Volume in litres for each event was then calculated from the data;
- Summaries of the data, detailing number, type, total volume and average volume of events from each house/day were created;
- Summaries of shower, toilet flushing and kitchen and bathroom tap usage events were created for each house for a seven day period; and
- Particular comparisons were then made between inefficient and efficient showerheads, dual flush and single flush toilets and preliminary analyses undertaken of the flow rates of kitchen and bathroom taps to determine if attaching flow regulators to the taps would assist in decreasing water demand.

Preliminary Results

A number of conclusions can be drawn from this study. However it must be noted that these results are preliminary and arise from a small sample of households. In the seven days of data analysed for eight test houses, approximately 85 water use events were identified as likely to be shower events. Table 1 provides a comparison between the average flow rate for the confirmed shower events in households with efficient showerheads and households with inefficient showerheads. Preliminary results are consistent with the efficient showerheads (AAA rated) reducing by half the average volume of water used per shower event.

Type of showerheads	Number of identified shower events	Average flow rate (l/min)	Average shower duration (min)	Average shower volume (L)
Efficient	27	5.5	6.0	33.5
Inefficient	26	11.7	5.7	66.6
Difference		6.2	-0.3	33.1

Table 1: Comparison of average flow, duration and volume for efficient and inefficient showerheads arising from the data comparing houses with efficient showerheads and houses with inefficient showerheads.

Note that these results indicate that householders ‘throttle back’ the showerhead from the maximum potential flow rate for both the efficient and inefficient showerheads. This data does not provide evidence that inefficient (universal 3”) showerheads that have a flow regulator will experience the same throttle back. This issue could be the subject of further investigation. These results suggest an average 33 L saving for each shower event. Energy savings and greenhouse gas reductions arising from decreased hot water usage will also be associated with this. At one shower per person per day for an average 2.8 person household, this suggests a saving of 34 kL/annum per single residential dwelling. This compares favourably with the assumed value of 25 kL/annum used in all cost effectiveness calculations. Note that the levelised cost of water saved from water efficient showerheads is approximately 15-20¢/kL, assuming a 9% discount rate over 30 years, or as a capacity cost, approximately $1,600/ML/a. Typical water supply augmentation costs are 75¢/kL to $1/kL. The difference in shower duration shown in the results is not considered significant. Figures 2 and 3 show a comparison between shower events, using efficient and inefficient showerheads from real time data monitoring.

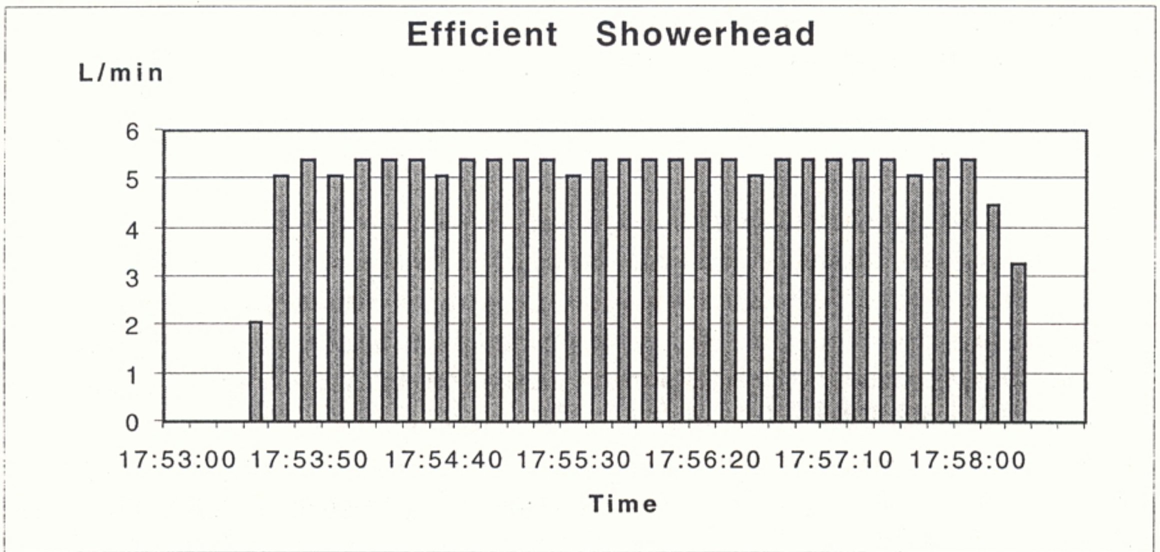

Figure 2: Use of water during a shower event using a water efficient showerhead with an average flow rate of 5.5 litres per minute, recorded from real time data monitoring.

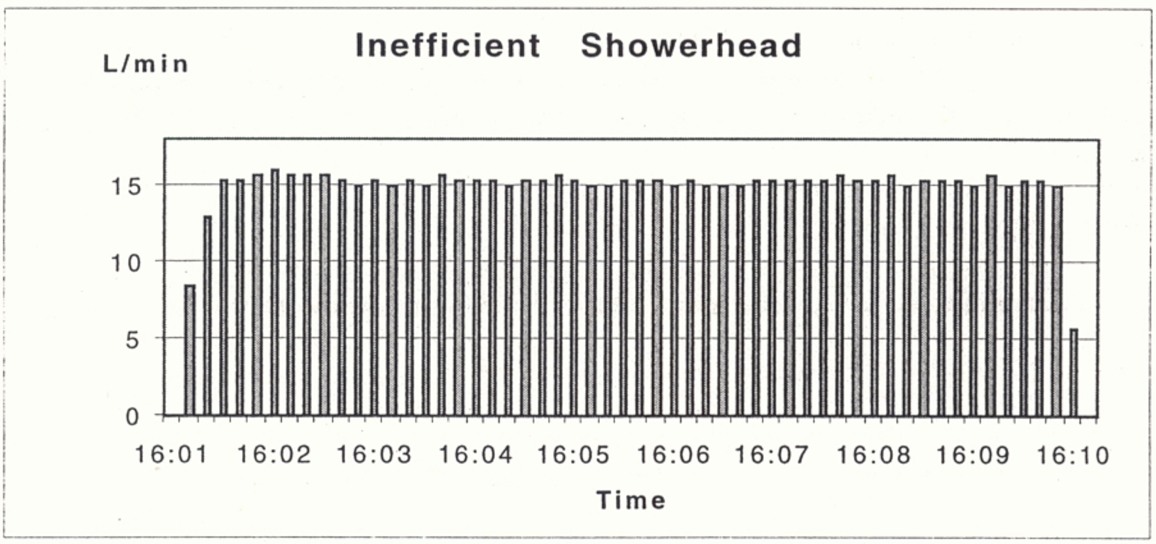

Figure 3: Use of water during a shower event using an inefficient showerhead with an average flow rate of 15 litres per minute, recorded from real time data monitoring.

There were no 6 L/3 L dual flush toilets present in the sample houses and so a preliminary comparison was possible between single flush and 9 L/4.5 L dual flush toilets only. Results indicate an average difference of only 1.2 L per flush between the single flush and 9 L/4.5 L dual flush toilets, about half that expected. However it is apparent that in some households with single flush toilets, householders are not causing a full capacity flush to occur at each use. Further work is required to determine whether this is due to mechanical intervention arresting the arm of the flush mechanism, cistern displacement devices or whether people are not completely depressing the flush mechanism. In addition, other water uses, particularly hand basin use, frequently overlap with toilet cistern filling, making interpretation difficult.

The next stage of this study will be to model the potential for improvement to the performance of on-site sewage treatment systems arising from the installation of water efficient devices and the reuse of greywater for irrigation and toilet flushing. Examination of the 'throttle back' effect among users of efficient showerheads, and the extent to which users of single flush toilets arrest the cistern flush, are matters which may be worthy of further investigation.

CONCLUSIONS

These studies have been undertaken in order to analyse the potential of water efficiency programs to reliably and permanently reduce customer demand for water and thereby reduce constraints on water supply and sewage treatment infrastructure, and to determine if real time water demand monitoring can be a useful tool for better understanding water use, and help in the design and cost benefit analysis of programs. The preliminary results suggest that a program designed for using currently available water efficient equipment can significantly reduce sewage flows and potentially reduce the cost of STP augmentation. A low cost real time water demand monitoring method has been successfully trialed, and results from efficient and inefficient showerheads indicate that estimates of household savings of 25 kL/a for retrofitting water efficient showerheads in other programs may be conservative.

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