

GOLD COAST DOMESTIC WATER END USE STUDY

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Abstract

This paper presents the preliminary findings of the Gold Coast Watersaver End Use Project which was conducted in winter 2008, for 151 homes on the Gold Coast, Australia. Specifically, the paper includes a break down of water end use consumption data, compares this with results of previous national studies, and explores the degree of influence of household socioeconomic regions on end use. Two highly variable water end use distributions, namely shower and irrigation, were examined in detail, clustered and are discussed herein. The paper concludes with a brief description of the greater ongoing research program.

Introduction

Following a long-standing drought, many regions in south east Queensland are experiencing strict water restrictions and have seen the introduction of a portfolio of other demand management and supply initiatives to ensure the provision

of a secure water supply. Residential water consumption is often dependent on the fixtures or device stock within a house, household makeup (e.g. family structure, household income), region location and psychosocial influences. A study of end use water consumption aids water planners and users to identify where and when water is used in a household hence assisting to drive proactive reductions in consumption (Loh and Coghlan, 2003).

In Australia, two major end use studies have been undertaken in Perth (Loh and Coghlan, 2003) and in Melbourne (Roberts, 2005). Internationally, several studies have been conducted in the United States of America (Mayer and DeOreo, 1999; Mayer *et al.*, 2004) and

recently in New Zealand (Heinrich, 2007). However, the end use models determined by these studies differ depending on a range of factors including the year conducted, climate, restriction regime, yard size, water using devices or fixtures and the household makeup (Roberts, 2005).

In addition, it has been acknowledged that community attitudes and behaviours can also influence the effectiveness of water savings resulting from water demand management strategies (Corral-Verdugo *et al.*, 2002). In the USA, Mayer and DeOreo (1999) explored certain relationships between water consumption and demographic variables at the end use level. Their research suggested that demographic variables such as family size and age distribution, wealth or income, ownership status, and household attitudes towards using and conserving water, influence household water consumption (Mayer and DeOreo, 1999; Kenney *et al.*, 2008; Turner *et al.*, 2005;

The average winter consumption was 157 L/pc/d.

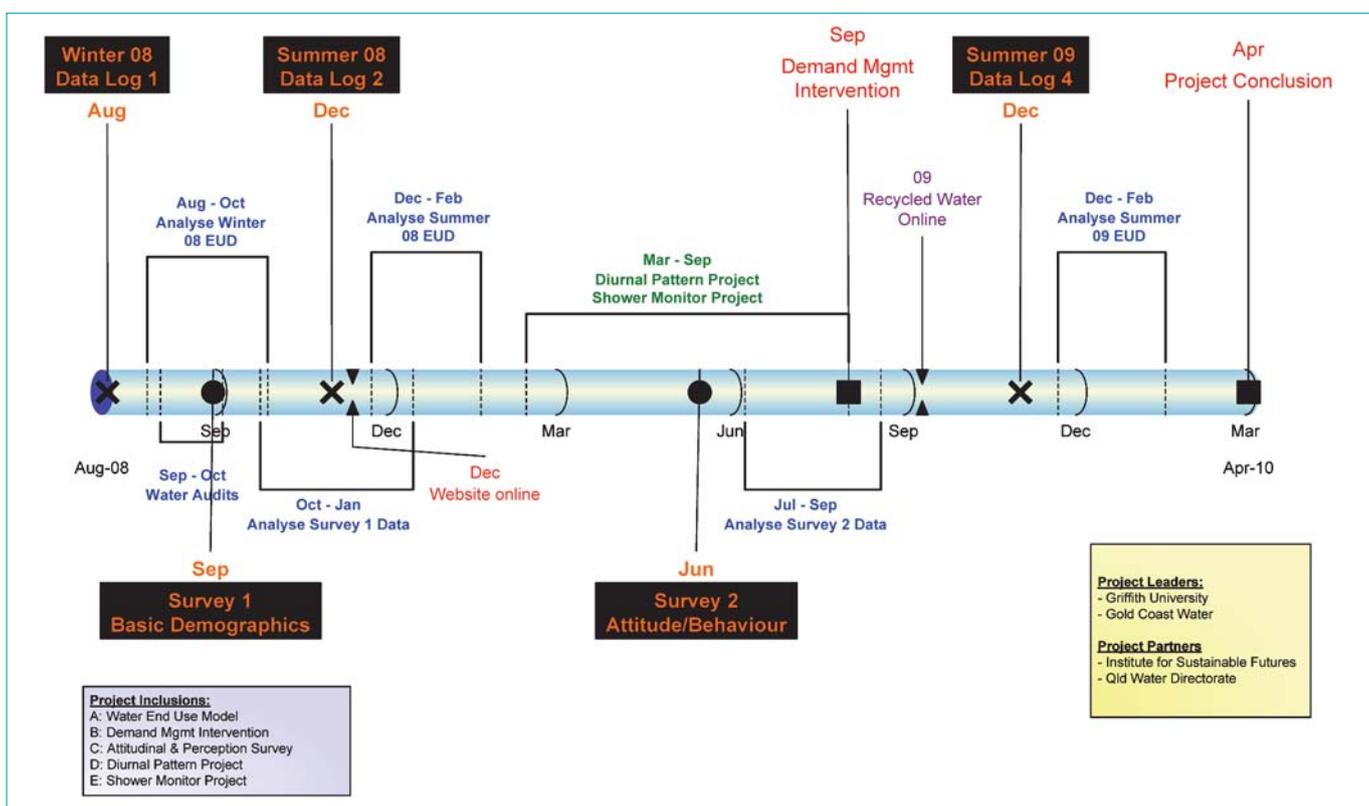


Figure 1. Gold Coast Watersaver End Use Project Schedule.

Taverner Research, 2005). However, in Australia, minimal research has been undertaken on investigating end use water consumption with relation to demographic variables within monitored homes.

The Gold Coast Watersaver End Use Study

There are no end use water consumption models currently available for South East Queensland. This region has a sub-tropical climate and has recently experienced severe drought conditions which forced both State and Local Governments to develop numerous strategies to reduce water usage. Griffith University and Gold Coast Water have collaborated under an Australian Research Council (ARC) grant to conduct an investigation of end use water consumption in the Gold Coast area. Other primary objectives of the research are to examine the effectiveness of dual reticulation and education as potable water saving mechanisms. The research will result in datasets of end use water consumption, demographic information and attitudinal data, diurnal patterns for potable and recycled supplies, and data on the effective potable water savings attributed to dual reticulation and developed education initiatives. As stated by Kenney *et al.* (2008, pp. 196), the collection and integration of such datasets especially 'household level consumption data with demographic data about the people and house', rarely occurs. Figure 1 presents the schedule and key deliverables for the Gold Coast Watersaver End Use research project. This paper only reports findings from the pre-intervention phase of the study, which includes the winter 2008 end use data recorded before the supply of recycled water to Pimpama Coomera.

Research Method

The selected dual-reticulated region was segregated into three socioeconomic categories to assist in obtaining a reliable overview of the population. A single-reticulated region was selected for comparison. The date of estate development of the single-reticulated region was similar to that of the dual-reticulated region (i.e. 5-10 years) to ensure higher efficiency fixtures were present in both regions and leakage within households was comparable.

Data was collected in winter 2008 during which time there were **no water restrictions** in place due to the Gold Coast's primary water source, the Hinze

End use analysis process in brief

The reed switch on traditional volumetric water meters is modified to collect a high resolution record of water use (i.e. from the traditional 2 to 72 pulses per litre or 0.014 litres per pulse) which can then be disaggregated into individual water use events using a flow trace analysis software tool (e.g. Trace Wizard[®]). The high resolution water measurement information from the meter is then captured by attached high data capacity loggers (i.e. 2 million readings) recording information at a pre-set time intervals (e.g. 10 seconds). Time scaled flow recording information is then collected *in-situ* through infrared cables or wirelessly through a mobile phone network. Once a representative sample of data is collected the flow trace analysis software tool is applied to disaggregate flow traces into a list of component events assigned to a specific end use appliance or fixture (e.g. shower, toilet, washing machine, etc). Stock and behaviour surveys are typically utilised to help the analyst develop templates which encapsulate the appliance properties of end use events and ensure accurate end use categorisation. Once trace analysis is completed and confirmed, a database registry of all end use events occurring during the sampled period is established and subsequently utilised for water planning and management research as demonstrated herein. Readers should refer to the *Residential End Use Measurement Guidebook* for further information (Giurco *et al.*, 2008).

Dam, being greater than 95% capacity. In total, 151 houses were monitored which included 38 single reticulated and 113 dual reticulated households. No recycled water (Class A+ is Queensland's highest quality for recycled water, not intended for drinking purposes) was being supplied as the Pimpama recycled water treatment plant had not yet been commissioned. Moreover, no awareness campaign had been launched to encourage the uptake of recycled water in the dual reticulated region. Thus, the **two datasets were treated as one sample** for the purpose of this **present** study (Willis *et al.*, 2009). Once recycled water is commissioned (3rd quarter of 2009), it is expected that a clear distinction will be present between single and dual reticulated households, predominately due to higher irrigation use within the latter sample. The Future Work section details consideration of this change.

Participants were recruited through a multi-staged process of letters and door knocking. Selection of participants was based on criteria which included: household ownership status (renting/owning); household makeup; willingness to be involved in research for two years; acceptance of multiple water consumption monitoring periods and surveys with potential interventions and; involvement in a water fixture/appliance stock audit. It should also be noted that historical household volumetric readings were analysed for the consenting sample to ensure that they were representative of the region and the broader Gold Coast.

Upon recruitment completion, existing standard residential water meters were replaced with high resolution water

meters and data loggers to enable obtainment of end use water consumption data. The modified Actaris CTS-5 water meters pulse at a rate of 72 counts per litre of water consumed, this equates to an individual recording every 0.014L of water use. Aegis DataCell D-CZ21020 data loggers were connected to water meters to record water consumption. Data loggers were set to record information every ten seconds over a two week period which resulted in fourteen days of end use data for each household. Figure 2 demonstrates the equipment configuration and BOX 1 outlines the water end use trace analysis process.

Basic surveys focusing primarily on demographic information were distributed to sample households. Surveys were conducted to solicit household demographic information, including: (1) household address and region; (2) resident numbers, gender, age, employment, weekly income, education status and relationship of people within the house; and (3) household ownership status. This paper focuses on analysing the relationship between water consumption patterns within the following socioeconomic regions of the Gold Coast: (a) Cassia Park: low socioeconomic group; (b) Mudgeeraba: low to middle socioeconomic group; (c) Crystal Creek: middle socioeconomic group; and (d) Coomera Waters: middle to high socioeconomic group. The water end use information for the listed socioeconomic groups was clustered to enable comparative analysis to determine whether relationships between demographic groupings and water consumption exist.



Figure 2. Data Loggers and Collection.

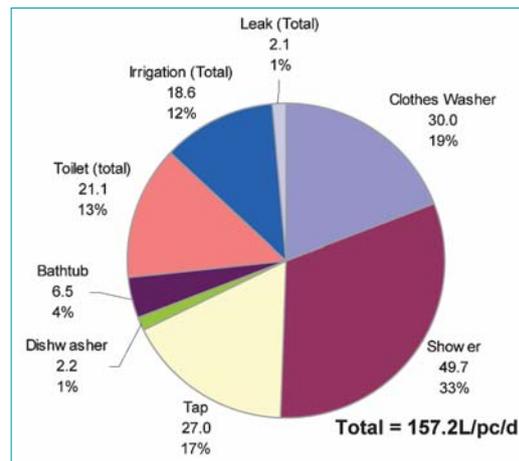


Figure 3. Average Gold Coast Daily Per Capita Consumption (L/pc/d): Combined Sample (n=151).

Results and Discussion

Water end use on the Gold Coast

The break down of water end use consumption, on a per capita basis, for the sampled households in the Gold Coast (n=151) is presented in Figure 3. The average consumption for sampled Gold Coast households is 157.2 litres per capita per day (L/pc/day). The highest end use is showering with each person consuming almost 50 litres of water a day equating to 33% of total use. Clothes washing follows equating for 19% of total consumption or 30L/pc/d. Tap use, toilet flushing and irrigation account for end use percentages of 17%, 13% and 12%, respectively. Bath use, dishwashing and leaks make up a small component of water end use with percentages ranging from 1% to 4%.

End use comparison with previous studies

Table 1 shows a comparative summary of Australian and Pacific end use studies including the Gold Coast results.

Table 1 demonstrates that total consumption and certain end use percentages vary between regions. Gold Coast consumption is the lowest recorded consumption of all studies being 157.2L/pc/d. The general trend is a reduction in total water consumption over time (i.e. 2003 to 2008). This reduction is probably due to the mounting intensity of water restrictions and increasingly frequent exposure to information on sustainable water consumption. This paradigm shift of societal water values has influenced water consumption, though elasticity will tighten in the future.

Irrigation end use percentages and volume vary significantly between each study. Perth recorded the highest irrigation volumes of up to 54% or 180L/pc/d. Auckland recorded the lowest irrigation consumption due to winter data collection, followed by the Gold Coast. Gold Coast irrigation is low as data was recorded during a winter with unseasonably high rainfall; recording and analysis of summer data will assist in verifying this deduction. Evidently, irrigation volumes play a key role in altering end use percentages.

Generally, leakage makes up a very small component of water end use. Melbourne recorded the highest leakage factor of 6% (15.9L/pc/d), whilst leakage at the Gold Coast only made up 1% (1.4L/pc/d). This should be due to the fact that monitored Gold Coast households were all constructed in the last five years, whereas Melbourne's housing stock is much older.

Table 1. Comparison between National and Pacific Water End Use Consumption Studies.

	Perth (2003)		Previous studies Melbourne (2005)		Auckland (2007)		Present study Gold Coast (2008)	
	L/pc/d	Per cent	L/pc/d	Per cent	L/pc/d	Per cent	L/pc/d	Per cent
Clothes washer	42.0	13%	40.4	19%	39.9	24%	30.0	19%
Shower	51.0	15%	49.1	22%	44.9	27%	49.7	33%
Tap	24.0	7%	27.0	12%	22.7	14%	27.0	17%
Dishwasher	NA	NA	2.7	1%	2.1	1%	2.2	1%
Bathtub	NA	NA	3.2	2%	5.5	3%	6.5	4%
Toilet (total)	33.0	10%	30.4	13%	31.3	19%	21.1	13%
Irrigation (total)	180†	54%	57.4†	25%	13.9	8%	18.6	12%
Leak (total)	5.0	1%	15.9	6%	7.0	4%	2.1	1%
Other	NA	NA	0.0	0%	0.8	0%	0.0	0%
Total Consumption	335.0	100%	226.2	100%	168.1	100%	157.2	100%

†Note: Irrigation volume per person calculated from provided volumes per household and end use break downs.

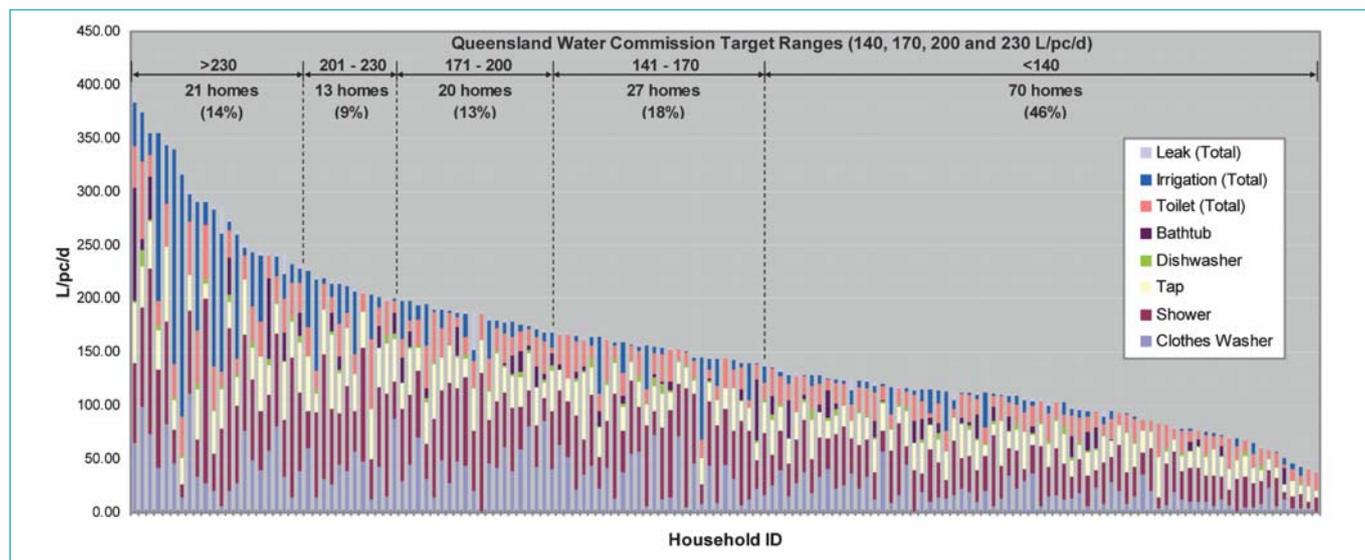


Figure 4. Household Daily Per Capita Consumption: Activity Break Down.

End use comparison: percentage or volume?

On first inspection of Table 1, with the exception of Perth (due to high irrigation volumes), the percentage break down for end uses appear relatively similar for clothes washing, tap use, dishwashers and toilets whilst variation of end use percentages are evident for showers, irrigation and leakage. Recorded shower consumption was the highest in the Gold Coast (2008) at 33% and the lowest in Perth (2003) at 15%. However, on closer inspection, shower volumetric consumption was relatively equal being 51.0L/pc/d in Perth and 49.7L/pc/d in the Gold Coast. This raises contention of simply using percentage figures for comparison. The variability between volumetric and percentage consumption observed for showers is repeated for clothes washing which, makes up 13 to 19% of end use in Perth, Melbourne and the Gold Coast. On closer examination, the actual volume of consumption for clothes washing is quite varied. A similar trend exists for toilet flushing with end use percentages being relatively comparable ranging between 10 to 14% of end use but when comparing volumetric rates, the Perth study recorded 33L/pc/d and the Gold Coast study found toilet consumption at 21.1L/pc/d. Again this reinforces the concept that volumetric consumption should be utilised as a basis of comparison rather than end use percentages.

The key contributor to the reduction in volumes evident in the more recent Gold Coast study would be the installation of

modern efficient toilets and washing machines, largely driven by recently ceased State and local government rebate schemes for efficient fixtures and appliances. As a final note, tap and dishwasher percentages and volumetric consumption were relatively comparable across the studies.

End use comparison for individual households

Figure 4 demonstrates the end use water consumption break down for each of the measured 151 households. It also illustrates the proportion of sampled households within each of the Queensland Water Commission (QWC) restriction regime categories, upon which the Gold Coast Local Government Area must conform (i.e. Target 140: Extreme Level; Target 170: High Level; Target 200: Medium Level; and Target 230: Permanent Water Conservation Measures).

While there were no restrictions during data collection on the Gold Coast, Figure 4 demonstrates that almost half of the research population (46%) consumed less than 140.0L/pc/d. Water consumption is highly varied between individual households with the highest per capita use equating to 390.0L/pc/d whilst the lowest use was as little as 38.4L/pc/d. The substantial difference between the highest and lowest per capita consumption volumes demonstrates that a range of water users are present in the research sample. Considerable variation between individual end use is also demonstrated in Figure 4.

The variation in clothes washer use

between individual households seen in Figure 4 is largely due to the diversity of clothes washing machines within homes, as established through stock surveys. The water volume consumed by a single load of clothes washing can vary from 42L/wash to 176L/wash (Commonwealth of Australia, 2008b) this obviously has a significant impact on resulting consumption. Water use for bathtubs appears to be minimal and scattered across the sample. Generally, baths were taken in houses with young children whereas older children and adults typically showered. Toilet and tap consumption varies and does not seem to be dependent on other end uses. Dishwasher use varies between individual households, as it is highly dependent on residential behaviours. No visible reduction in tap use is present in households that have dishwashers although this is a trend to investigate further. Figure 4 illustrates that the more discretionary shower and irrigation end uses can be core contributors to the total consumption level of households. The water use patterns of these two activities are further explored in Figures 5 and 6, respectively.

Figure 5 shows that 13% of households consumed 30% of the total water utilised for showering. This highlighted sub-sample (13%) constitutes a non-linear shower use pattern as opposed to the remaining research population (87%) which shows a relatively linear rate of change in consumption. The distribution of shower use, as illustrated in the Figure 5 insert, demonstrates that half of the population used less than 40L/pc/d of water for

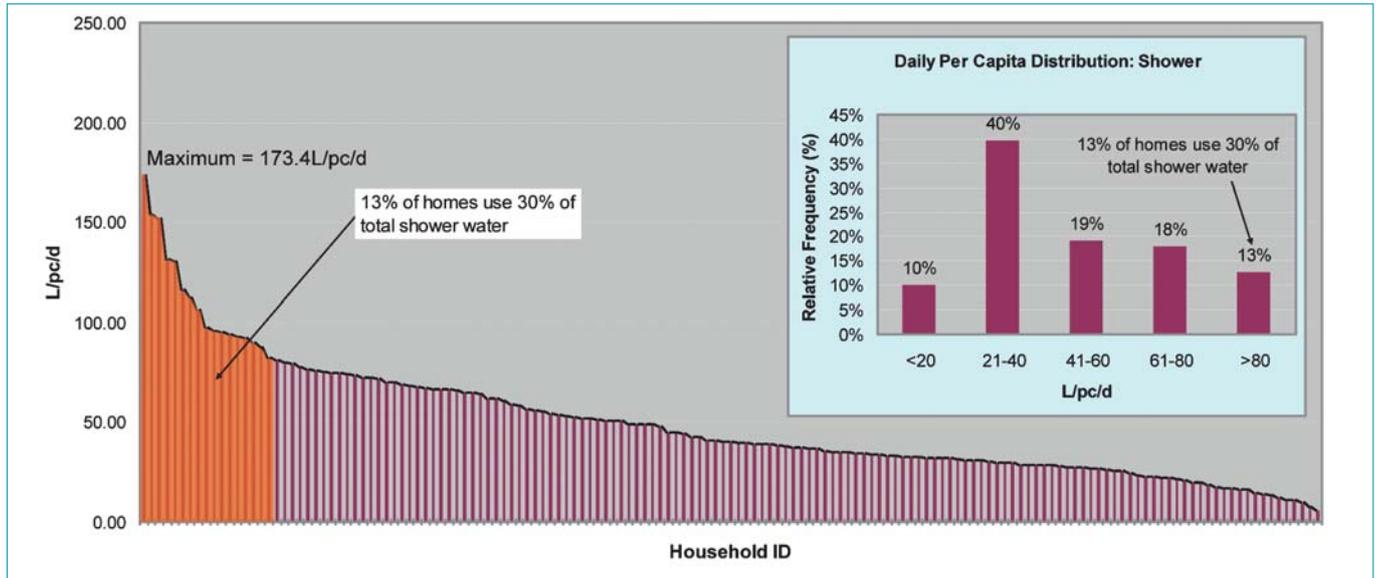


Figure 5. Household Daily Per Capita Consumption: Shower Only.

showering which is equivalent to a 5 minute shower at 8L/min. For the remaining categories, 37% of households use between 41 to 80L/pc/d with the high user group (13%) consuming more than 80L/pc/d in the shower.

Figure 6 demonstrates that 24% of the sampled households contribute to an exponential rate of change in water consumption for irrigation. This represents a group of high users consuming 80% of the total irrigation water of the entire sample, with the maximum consumption level as high as 225.9L/pc/d. In addition, the per capita distribution presented in the inset of Figure 6 shows that the majority of households (76%) used less than 20L/pc/d of water for irrigation.

End use comparison: households from different socioeconomic regions

For the purpose of this study, four socioeconomic regions were selected and compared, namely: (a) low (Cassia Park: n=42); (b) low to middle (Mudgeeraba: n=36); (c) middle (Crystal Creek: n=38); and (d) middle to high (Coomera Waters: n=35). Figure 7 displays the end use values for these four socioeconomic regions.

Previous studies have suggested that high volume water consumers are wealthier, older and live in new and larger homes (Kim *et al.*, 2007; Kenney *et al.*, 2008). Residents in Coomera Waters (higher socioeconomic region) were the largest consumers per capita, using

165.8L/pc/d with Crystal Creek residents (middle socioeconomic region) following consuming 156.2L/pc/d. Water consumption of Mudgeeraba residents (low to middle socioeconomic region) was 155.6L/pc/d while Cassia Park residents (lower socioeconomic region) consumed the least being 152.2L/pc/d. While these differences are not significant, they support previous research.

The volume of water used for clothes washing is lowest in Coomera Waters and Mudgeeraba being 28.5L/pc/d and 27.3L/pc/d respectively. Cassia Park recorded the highest clothes washing consumption at 32.2L/pc/d whilst Crystal Creek residents consumed 31.4L/pc/d for clothes washing. It is suggested that households with higher income levels are

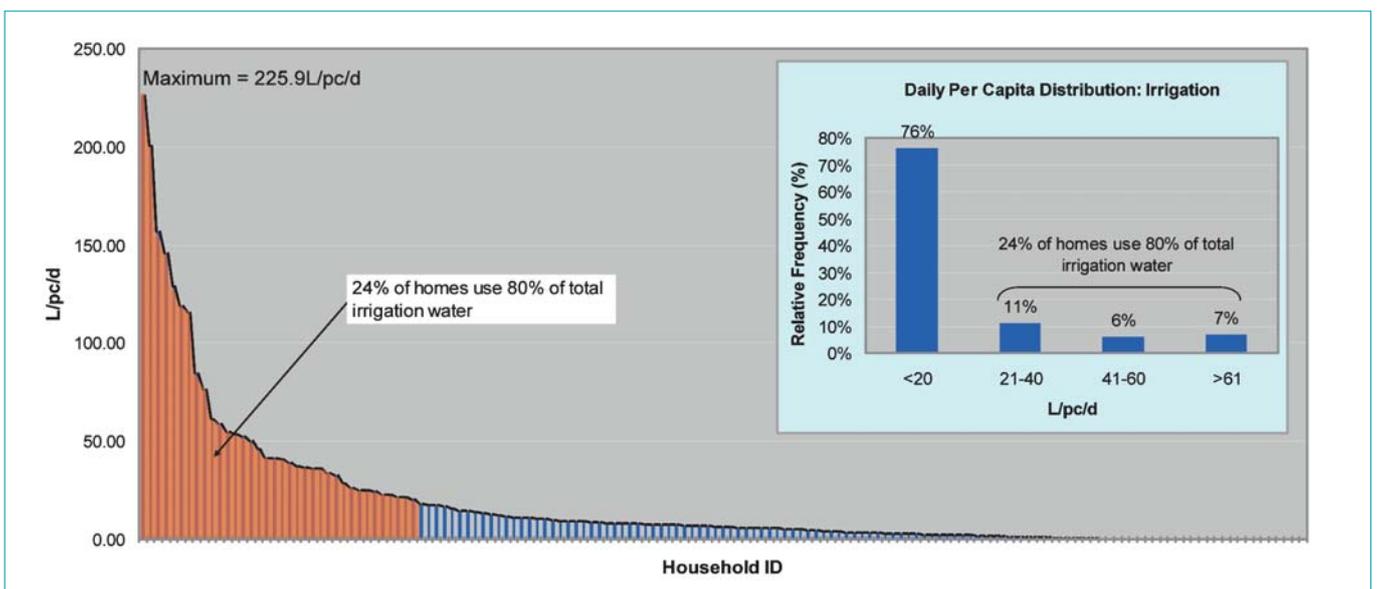


Figure 6. Household Daily Per Capita Consumption: Irrigation Only.

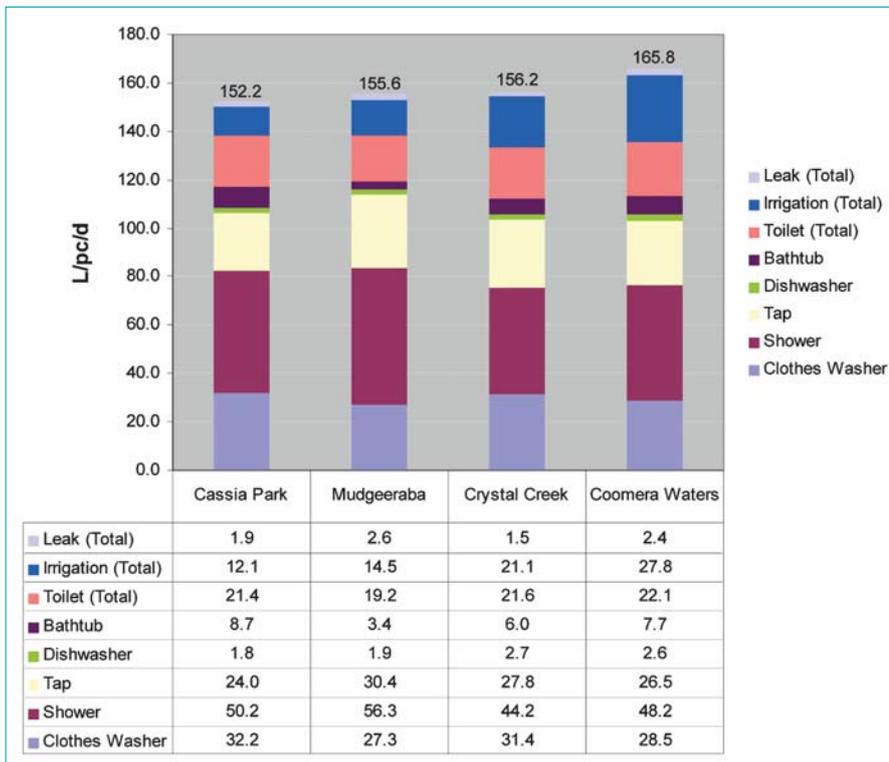


Figure 7. Average Daily Per Capita Water Consumption: Socioeconomic Regions.

more likely to purchase higher efficiency washing machines hence the differences in consumption.

Shower consumption seems to oppose this trend, although not significantly. The lower socioeconomic regions (Cassia Park and Mudgeeraba) showed higher consumption. This trend may be attributed to lower efficiency of shower roses or variations in shower behaviour. The trend of lower shower consumption volumes with more efficient devices has previously been established (Mayer *et al.*, 2004).

Irrigation usage is notably lower in Cassia Park with only 12.1L/pc/d being consumed compared with 14.5L/pc/d in Mudgeeraba, 21.1L/pc/d in Crystal Creek, and 27.8L/pc/d in Coomera Waters. This could be attributed to the fact that lower socioeconomic groups tend to have smaller lot and garden sizes and minimal ownership of pools. Finally, there is no significant difference in bath and toilet consumption among the four suburbs, suggesting no relationship between this particular water use activity and the change in socioeconomic regions.

Conclusion

This paper presented initial findings from the Gold Coast Watersaver End Use Study based on data collected in winter 2008. It was established that end use water consumption varies significantly

between individual households and noticeably between socioeconomic regions. The data demonstrates the lowest recorded end use water consumption per person in comparison to previous national and pacific end use studies. Future data collection periods over summer aim to capture increased consumption attributed to seasonal use. Overall, the data provided confirmation that high socioeconomic regions consume more water per capita than lower socioeconomic regions. Details of ongoing and planned research activities are briefly discussed below.

Future Work

Figure 1 detailed the numerous components of the Gold Coast Watersaver End Use Study to be undertaken over the coming year. Recycled water (Class A+ is Queensland’s highest quality for recycled water, not intended for drinking purposes) will be supplied to the Pimpama Coomera region in 2009. Summer end use data collection will be completed to ascertain the end use uptake of recycled water. This data will assist in verifying end use assumptions made in the planning phases of the Pimpama Coomera development. Moreover, a world first dual reticulation end use model including diurnal patterns in both the potable and recycled water supply pipelines will be completed. Variation in diurnal patterns between

single and dual (i.e. recycled water also supplied) reticulated homes will also be explored. This data will provide a comprehensive understanding of water consumption at a given time providing greater understanding on the individual end uses affecting peak loads.

The impact of a range of education or awareness demand management interventions will also be tested. One such intervention program includes the evaluation of an alarming visual display monitor device on shower event durations, flow rates and volumes, thus providing quantitative evidence on the influence of this initiative on shower water conservation behaviours. Other programs will involve the provision of detailed end use information to users and the effect this has on consumption.

The above stated components of the end use study will culminate in the development of a comprehensive domestic end use model for the Gold Coast as well as evidence that supports, or otherwise, the effect of water demand management measures, principally dual reticulation and awareness/education programs, for conserving precious potable water supplies.

For further information on the Gold Coast Watersaver End Use Study please visit either: <http://www.griffith.edu.au/engineering-information-technology/centre-infrastructure-engineering-management/gold-coast-watersaver-end-use-project> or http://www.goldcoastwater.com.au/t_gcw.asp?PID=7591

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