Yarra Valley Water

2004 Residential End Use Measurement Study

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1 Executive Summary

The Residential End Use Measurement Study (REUMS) is the second stage of a comprehensive two part research project into how and where water is used in the residential sector.

The first stage was the Appliance Stock and Usage Patterns Survey (ASUPS) which involved household visits to 840 Yarra Valley Water residential customers. This survey identified in detail all water using appliances, measured flow rates and flush volumes and ascertained usage behaviours for all water use. ASUPS was the subject of a separate report published in November 2004.

The REUMS used high resolution meters and data loggers to collect water usage data at five second intervals for two weeks in February 2004 (summer) and two weeks in August 2004 (winter). The usage data was subsequently disaggregated into specific end uses using an end use water analysis tool, Trace Wizard©.

One hundred separate homes were selected from the 840 ASUP homes and fitted with the special measurement equipment. The end use measurement phase was deliberately restricted to “separate” homes to maximise the collection of garden irrigation data since this is known to be a significant component of residential water use in Melbourne. Consequently the findings of the REUMS cannot always be interpreted as being representative of the complete residential customer base because flats, apartments and any other non separate dwellings have inherent differences to detached houses.

Per capita consumption estimates are derived from the reported number of people in the household at the time that the survey was undertaken. In most cases this was shortly before the first logging period. It is assumed that the number of people in the household remained at this level throughout both the summer and winter logging periods.

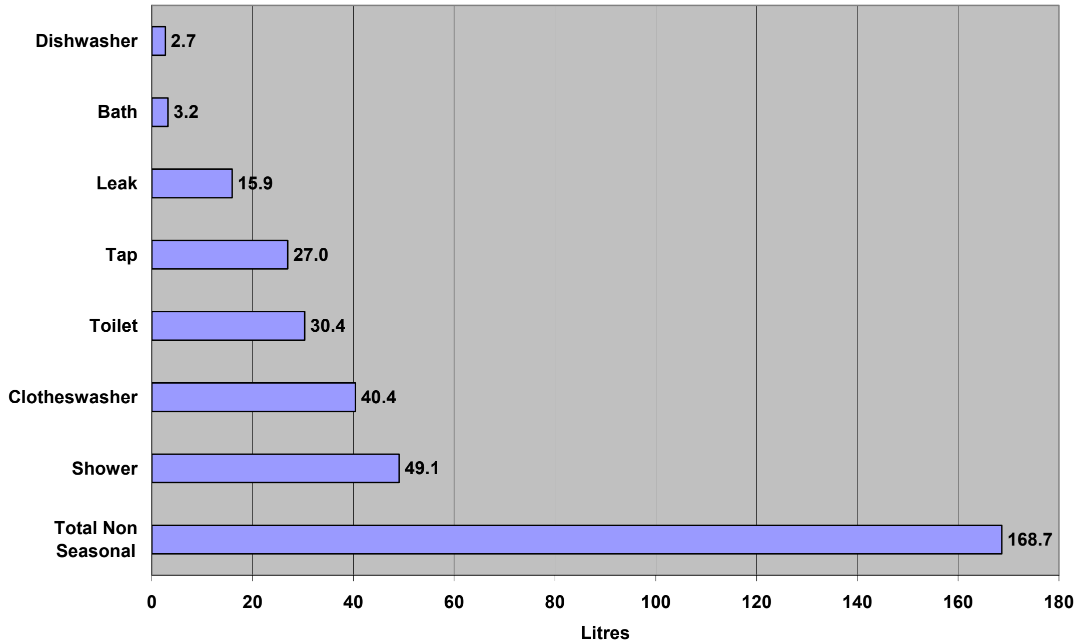
This report presents the findings of the REUMS as well as compares where possible the results of actual measurement with survey based estimates. The findings from REUMS have enabled Yarra Valley Water to establish a robust end use modelling capability. In addition the end use measurement has also enabled more informed design and assessment of various demand management programs and provided a valuable data set from which to provide customers with informative usage data via their quarterly account statement.

- ***Average Daily Indoor[1] Per Capita Usage***

Average daily indoor use per household was measured at 523 litres which equates to an average daily per capita indoor usage (LpCpD) of 169 litres. Figure 1 below shows the measured average daily volumes for each non seasonal[2] end use.

The largest indoor use is shower at 49 LpCpD, followed by clothes washer 40 litres and toilet 30 litres. These three end uses account for 71% of total non seasonal use.

Figure 1: Average Litres per Capita per Day – Non Seasonal Use (Indoor)



Note that the average daily per capita toilet volume is understated slightly as a result of the retrofit of Caroma smartflush® 4.5/3L dual flush toilets in about one quarter of the logged homes between the summer and winter logging periods. This retrofit trial is a joint project undertaken with Caroma to assess this new 4A rated toilet. Without the impact of these toilets daily per capita toilet use increases by about 3% to an average of just over 31 LpCpD.

The next biggest user of water was tap usage and this averaged 27 LpCpD. This refers to the combined usage from bathroom basins, kitchen sinks and laundry troughs.

The volume of water identified as leakage was surprisingly high at just under 16 LpCpD. However care needs to be taken with the interpretation of this finding. Firstly the high per capita result was due to very high leakage in a relatively small proportion of homes. Secondly it is difficult to translate this result into a general finding on leakage because, unlike the other non seasonal uses, it cannot be assumed that what

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[1] Indoor or more correctly “non seasonal” usage is considered on an average daily per capita basis because it is assumed to occur in a similar pattern across the year. It is of little value to include seasonal use (irrigation, evaporative cooler, pool etc) in the per capita daily average analysis. It makes more sense to consider seasonal usage on the basis of its contribution to annual usage.

[2] Non seasonal use is similar to “Indoor” Use but excludes evaporative air conditioner use which is seasonal. This distinction is necessary in order to extrapolate from a short measurement period to the typical usage on an annual basis.

has occurred over a short measurement period will necessarily continue for the full year.

The 169 LpCpD shown in Figure 1 applies to just separate homes. In order to estimate what the equivalent usage is for all customers the survey data is used together with the end use measurement to model the relationship between household size and usage. The resultant estimated average usage across the whole residential customer base is 178 LpCpD. This equates to an average annual non seasonal usage of 166 KL for the average household[3].

- ***Seasonal Use***

The seasonal uses are dominated by garden irrigation but also include evaporative air conditioner, pool and outdoor spa use. These collectively made up 32% of the volume used during the summer logging period. None of these uses were identified during the winter logging period.

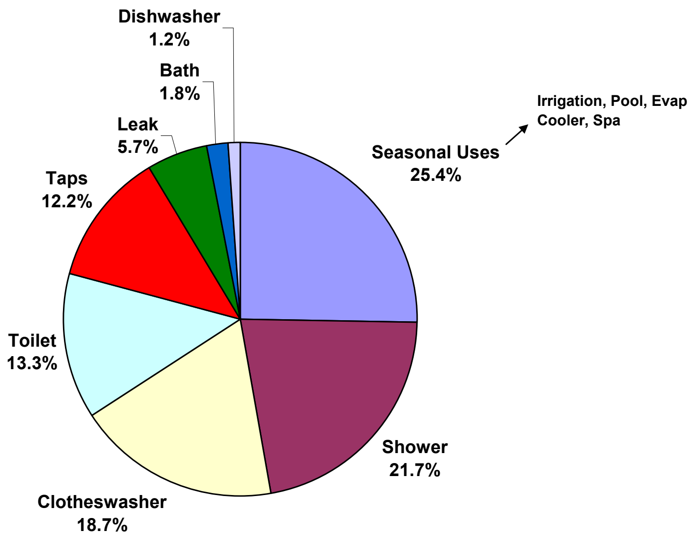
For two reasons this share in itself is of little consequence. Firstly seasonal use varies with the climatic conditions so measurement over a short duration cannot be considered indicative of usage over longer periods. Secondly the use of water for garden irrigation was significantly curtailed during the logging period by Stage 2 drought restrictions.

Because of these factors, estimation of the contribution of seasonal usage to total residential usage is determined from billing data rather than on the basis of end use measurement. In total seasonal use is estimated to account for 25.4% of total annual residential use and of this irrigation accounts for 22% based on the relative shares of each of the seasonal uses during the logging period.

The estimated contribution of each end use is show in Figure 2 below. The top four uses of Irrigation, Shower, Clotheswasher and Toilet collectively account for 79% of total usage. The fifth largest use is the combined bathroom, kitchen and laundry taps accounting for around 12% of usage.

[3] The average household size for Yarra Valley Water is estimated at 2.55 persons.

Figure 2: End Use Shares – Estimated Annual Contribution



- ***Showers (section 5.1)***

Average usage is 49 LpCpD but variation around the mean is large with standard deviation of about 40 litres.

On average people shower for 7.1 minutes (Std Dev 3.8) and the average flow rate was measured at 9.5 litres per minute (LpM).

The average flow rate for the more efficient showers (ie A, AA and AAA) was 7.6 LpM compared to 10.5 LpM for the standard showers. This differential flow rate would result in a saving of around 16 KL pa in an average size household.

The observed average frequency of showering was lower than expected at only 0.76 showers per capita per day. This parameter should be viewed with some conservatism because of the uncertainty around the number of people in the household throughout both logging periods.

- ***Toilets (section 5.2)***

Average per capita use is 31 LpCpD with standard deviation of 20 litres. Per capita use ranged from 19.3 litres for households with 6/3 dual flush toilets to over 42 litres for households with 11 or 12 litre single flush toilets.

Average flush volume overall was 7.6 litres but for the 6/3 dual flush toilet the average was 5.8 litres indicating a higher than expected ratio of full flush to half flush use.

Average frequency of toilet use was measured at 4.2 flushes per person per day.

- **Clothes Washers (section 5.3)**

Average per capita use is just over 40 litres but there is very wide variation around the average with a standard deviation of 61 litres.

The average household will do about five and a half loads of washing per week. Observed average volume per load across all types of washer was 143 litres. Significantly the average volume of front loading machines was just 75 litres compared to the average for top loaders of 152 litres. On the basis of these findings the average household with a top loader would save around 22 KL pa by changing to an efficient front loading washing machine.

There is a very strong relationship between the volume used for clothes washing and the household size with economies of scale occurring for this end use as households get larger (and diseconomies as household size decreases).

- **Dishwashers (section 5.4)**

Dish washing is only considered in relation to automatic dishwasher use because tap use specific to dish washing cannot be identified with the adopted measurement technology.

The dishwasher is a relatively minor user of water. The average measured volume per load was around 24 litres and on average the dishwasher is only used around 3 times per week.

- **Evaporative Air Conditioners (section 5.5)**

Around one fifth of the logged homes had an evaporative air conditioner and for these homes water used by this appliance can be significant during summer. No use of this appliance was recorded during the winter logging period

Usage is fairly negligible up to a maximum daily temperature of around 25^{o} but thereafter rises rapidly with the temperature.

Average measured use on the days that the appliance was utilised was 155 litres with usage being significantly higher on weekend days than on week days.

- **Tap Use (section 5.6)**

Miscellaneous tap use (bathroom basins, kitchen sink, laundry trough) is a high frequency, low volume end use.

On average tap usage amounts to 27 LpCpD with standard deviation of 21 litres. Each person uses a tap an average of 20 times per day with an average use of just 1.3 litres.

The measured average flow rate of tap use was 3.3 litres and a vast majority of events occur at less than 7 LpM.

The findings confirm the previously held belief that there is little or no demand management benefit derived from restricting the capacity flow rate of taps in the residential setting.

- **Bath Use (section 5.7)**

This is a relatively minor end use in volume terms even for those households that regularly use a bath. For households using the bath this end use accounted for just under 7% of their non seasonal indoor usage.

On average the households that utilise the bath do so less than 3 times per week and the average fill volume was measured at 123 litres.

- **Irrigation (section 5.8)**

As stated previously Stage 2 drought restrictions prohibiting the watering of residential lawns were in place during the summer logging period (Feb 2004). As a result it is problematic to extrapolate from the end use measurement data to what might be typical usage in an unrestricted environment. Consequently the findings relating to frequency and duration of garden irrigation need to be considered in this context.

The share of total use accounted for by garden irrigation varied considerably during the summer logging period. For around 10% of homes garden irrigation share was zero whilst at the other end of the scale it accounted for 73% of total use for one household. Overall irrigation accounted for 28% of the total summer logged volume.

Average frequency of irrigation was 2.8 times per week or 3.1 times for just those homes that irrigate. The average flow of irrigation was 16.3 LpM and the average duration was around 46 minutes per irrigation event.

The average duration of irrigation differed significantly with the method[4] of irrigation used. The duration of events with the hand held hose averaged 37 minutes compared to 66 minutes for the manual and automatic sprinkler system households collectively.

The hand held hose method appears to have higher relative efficiency, used by 57% of homes as the main method of irrigation but accounting for just 43% of irrigation volume. By contrast manual and automatic sprinkler systems were the main irrigation methods used by 29% of homes but accounted for 52% of total irrigation volume.

- **Swimming Pool (section 5.9)**

Overall pool use accounted for only 1.5% of the total summer logged volume. However for the nine homes that registered pool usage this use on average accounted for 12% of their total summer logged volume.

[4] Note that the method of irrigation (hand held hose, manual sprinkler, automatic sprinkler) is not identified from the analysis but rather from the survey. Many homes use multiple methods of irrigation so from the survey information an assessment is made of the “main” methodology utilised. Consequently the analyses around irrigation methodology are not exact and so findings can only be considered indicative.

2 Introduction

The Residential End Use Measurement (REUM) Study was the second element of a three stage project designed to enhance understanding of residential water use in the Yarra Valley Water service area.

Stage 1: Appliance Stock and Usage Patterns (ASUP) Survey
The first element was the 2003 Appliance Stock and Usage Patterns (ASUP) Survey[5] which had the following objectives:

i. assess current levels of penetration of water efficient and standard efficiency appliances,
ii. assess trends in the adoption of efficient appliances by comparison of appliance penetration data to a previous survey,
iii. collect data on usage behaviours and patterns to contribute to the establishment of an enhanced end use modelling/forecasting capability, and
iv. improve the level of detail and reliability of end use data collected.

Through household visits to 840 customers the ASUP survey was able to accurately identify the water using appliance profile within those households. However with regard to usage behaviour the accuracy of the ASUP survey is subject to a number of limitations such as

i. how well the respondent can recall or estimate usage behaviour,
ii. how well the respondent can represent the usage patterns for all members of the household,
iii. the potential for respondents to either deliberately or inadvertently underestimate their usage patterns, eg in order to appear to be more environmentally conscious.

Because of the uncertainties resulting from these limitations it is essential to undertake end use measurement in order to assess the quality of survey estimates and provide more rigour around usage parameters that ultimately will be critical to the end use model's reliability. With actual end use measurement it is therefore possible to compare survey estimates for parameters such as average shower duration, number of toilet flushes per person per day etc with actual behaviour.

Stage 2: Residential End Use Measurement (REUM) Study
The primary objectives of the REUM study were

a) to collect actual usage data in such a way that it can be disaggregated into individual end uses
b) to collect end use data that enables estimates of parameters required for an end use model to be formulated
c) to enable an assessment to be made of the quality of parameter estimates based entirely on survey responses.

[5] Yarra Valley Water Appliance Stock and Usage Patterns Survey, Peter Roberts, Nov 2004 (ASUP Survey)

Customers living in one hundred detached houses were selected for end use measurement and subsequently installed with special meters and data loggers about the same time as the ASUP survey of the household. By using ASUP households a complete understanding of all appliances within each house was established around the time that the first period of logging occurred. End use data was collected for two weeks in February 2004 (summer) and two weeks in August 2004 (winter)[6].
.
Stage 3: Peak Flow Design Standards Study
The dataloggers that record water usage data at very high frequency for end use measurement (EUM) purposes (5 second intervals in the REUM study) can also be utilised to collect continuous flow data at longer intervals (such as 5 minute intervals) suitable for analysis of seasonal and peak customer flows. The equipment was reset to record at five minute intervals after the summer EUM, subsequently reset to 5 second intervals for the winter EUM and then reset again to 5 minute intervals. The five minute data is to be collected continuously over 3 to 4 years in order to capture the impact of different weather conditions.

Additional Aspects to the REUM Study

A) Caroma 4A Toilet Retrofit
At the time the REUM study was being planned Yarra Valley Water was approached by toilet manufacturer Caroma who were looking for an opportunity to field test their new smartflush® toilet. This 4A rated toilet has a 4.5/3L dual flush cistern.

Consequently it was decided that some of the same homes that were fitted with end use measurement equipment could be retrofitted with the smartflush® toilet thereby establishing a capability to determine whether the theoretical savings were actually delivered.

B) Evaporative Air Conditioner Usage
Evaporative air conditioners have been increasing their market penetration in recent times[7] and the Water Services Association of Australia (WSAA) has expressed concern at the reportedly high water usage associated with this appliance.

The data logging that took place in February 2004 for end use measurement purposes appeared to accurately identify the usage by these appliances and so an additional measurement period just for those households with evaporative coolers was planned for the summer of 2005. This additional phase of the project was a joint exercise between WSAA and Yarra Valley Water and will be the subject of a separate report.

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[6] The two week duration was only nominal and in fact for a number of homes data was collected for over 20 days and for a few, data was collected for about 11 or 12 days. The summer logging period had an average duration of 14.5 days between the 10th February and the 4th March 2004 and the winter logging period averaged 13.0 days between 1st and 20th August 2004.
[7] ABS publication 4602.0 Environmental Issues, People's Views and Practices March 2002 shows the share of evaporative air conditioners in Victoria has increased from 16.8% of dwellings with air conditioning in June 1994 to 29.7% in March 2002 (refer Table 4.17).

3 Methodology

3.1 Sample Size

In order for end use modelling to deliver an accurate estimation of the real world the model parameters clearly need to be identified as precisely as possible. However the population being modelled is known to exhibit wide variation and so the parameters measured using a sample of the population will often be subject to large confidence intervals. The choice of how many properties to include in the sample is often a compromise between the cost and the required level of statistical significance and of the required narrowness of the confidence intervals.

For example if the average shower duration is measured at 7.6 minutes we might specify something like a requirement that there be a 95% chance that the real average is within ±5% of the sample average. Because the variance of this parameter is large (sample standard deviation is 4.8 minutes) we would need a sample of over 600 households to meet the above requirement.

Reducing the confidence level from 95% to 90% still requires a sample size of around 430 for the above example. However the collection of end use data is expensive with total per property costs around $1500 so precision of estimates needs to be traded off against project cost.

The American Water Works Association Research Foundation (AWWARF) in its residential end use study[8] logged 100 homes in each of 12 water utility service areas in the US and Canada. It was therefore decided to sample 100 households in Yarra Valley Water's area with a view that in the near future the other Melbourne water retailers would also undertake measurement for around 100 households each. Consequently there would ultimately be a sample of around 300 households for the whole of Melbourne.

3.2 Sample Selection

High-use customers are responsible for a higher proportion of peak demand use, outdoor use and possibly other less well understood end uses such as evaporative air conditioners, spas and swimming pools. It is important to allocate research resources to some extent in proportion to total use of customers. On this basis, the actions of high use customers are more important than those of low use customers.

Therefore it was decided to deliberately sample a higher proportion of high use customers and a lower proportion of low use customers. The sample target was to get around one quarter of the sample to be in the bottom third of users (based on annual consumption), one quarter in the middle third and one half in the top third.

It was also decided that all the dwellings in the final sample should be owner occupied rather than tenanted properties. This was because the special logging equipment would be in the field for a number of years and owner occupied homes

[8] Residential End Uses of Water, AWWA Research Foundation, 1999

tend to have a more stable population over time. All the homes in the sample were houses (ie separate dwellings as opposed to flats or townhouses).

From an initial larger random sample selected from the customer billing system a smaller sample of 1226 customers was chosen from suburbs that reflected the income and household size distributions across Yarra Valley Water's service area[9] and also the sampling frame described above. An initial letter and fact sheet (shown in Appendix A – Customer Letters) was sent to all households explaining what the survey was about and what would be required of participants and also offering a $50 gift voucher as an incentive for their participation. One hundred and ninety six households responded from which the final sample of 100 was chosen on the basis of several criteria including household size, usage and Caroma[10] retrofit suitability.

In accordance with the above sample design the sample was split into three parts as shown in Table 1. Because of this design the average consumption of the sample is higher than that for the Yarra Valley Water customer base in general. Figure 3 demonstrates the over sampling of those customers with annual consumption greater than 200 KL pa.

Table 1: Sampling Frame

KL pa	YVW % of Customers	No. Cust Mailed	No. in REUM Sample	No. Summer Log Period	No. Winter Log Period
< 150	32%	297	23	22	22
150 to 249	31%	327	34	32	24
=250	37%	602	42	39	35
Total	100%	1226	99	93	81

It was necessary to replace six of the chosen properties because residents had changed their minds after initially agreeing to participate. Also it was found that one property was part of a dual occupancy development that was not separately metered. This property also had to be replaced in the final sample. Replacements were chosen from the original 196 customers who had expressed interest in participating in the study.

Due to equipment failure it was not possible to download flow data from all the sample properties in both logging periods. Table 1 also shows the number of properties for which usable log data was achieved in the summer and winter periods.

One of the properties selected as for the sample was inexplicably vacated after equipment was installed so effectively the sample was reduced to 99. The final sample by postcode is shown in Table 2.

[9] The 2003 Appliance Stock and Usage Patterns Survey report, section 1.3 detailed the sampling frame of suburbs

[10] Caroma identified approximately 40 of the preferred sites that best matched their requirements for pilot testing of the 4.5/3 dual flush toilet. In particular Caroma were interested in the position of the toilets on the sewer line in relation to other appliances.

Figure 3: Distribution of Final Sample and Population Annual Usage

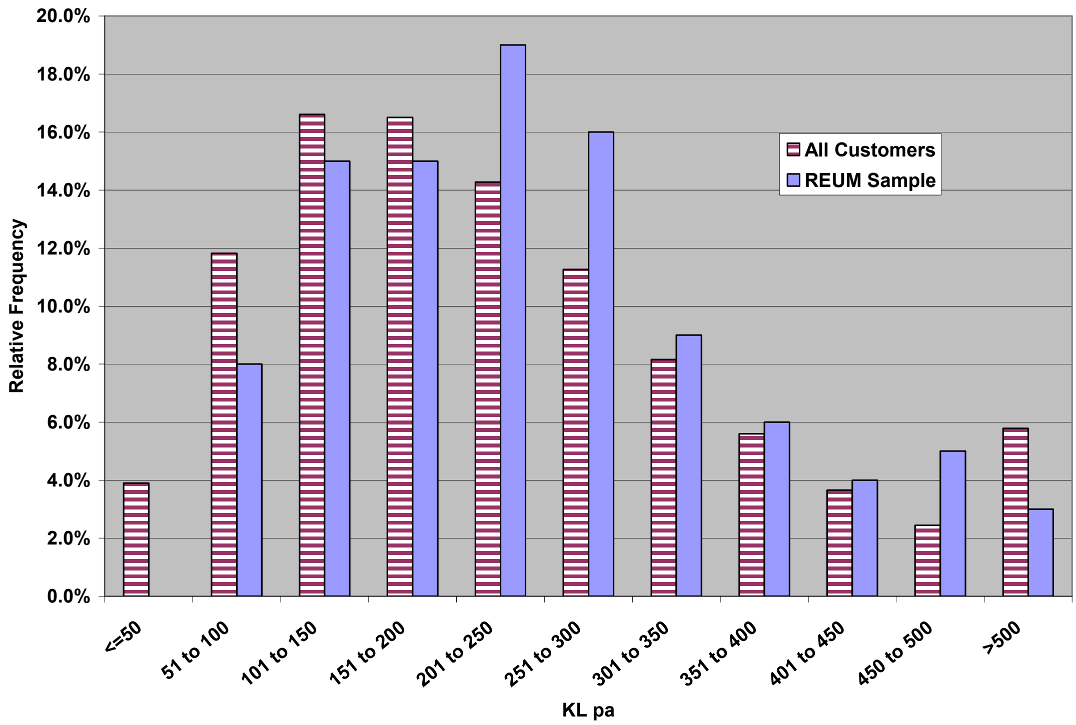


Table 2: Final Sample by Postcode

Postcode	Suburb	No. Customers Mailed	No. in Sample
3044	Pascoe Vale	65	7
3056	Brunswick	42	6
3073	Reservoir	108	7
3074	Thomastown	62	4
3082	Mill Park	133	2
3083	Bundoora	83	4
3089	Diamond Creek	38	2
3095	Eltham	56	5
3106	Templestowe	61	8
3122	Hawthorn	41	4
3124	Camberwell	60	5
3136	Croydon	146	16
3146	Glen Iris	43	5
3149	Mount Waverley	90	7
3150	Glen Waverley	165	17
3153	Bayswater	33	0
	Total	1226	99

3.3 Representativeness of Sample

Because of the factors discussed in 3.2 above the sample is clearly not representative of the entire Yarra Valley Water residential customer base. However the average annual consumption[11] of the sample at 246 KL is close to the average consumption for all houses which was 251 KL, as shown in Table 3 below.

Table 3: Average Annual Consumption in Population and Sample

Group	Number Customers (000)	Population Consumption (KL pa)	Sample Consumption (KL pa)
Detached Houses	466	251	246
Flats/Units	120	142	na
All Residential Cust	580	228	na

So whilst care needs to be taken with some results, many of the findings will be representative of customers whose dwelling is a house, a group making up around 80% of Yarra Valley Water's residential customer base.

It is reasonable to propose that the two major points of distinction between flats and houses are the average household size (ie number of people living in the home) and the size of the garden. It is also reasonable to assume for the personal end uses such as shower, toilet and bathroom basin that per capita use will not differ significantly between flats and houses.

Therefore many of the findings of the study (eg no. showers per capita per day, no. toilet flushes per capita per day etc) are assumed to be representative of all residential customers. Where it is considered necessary the findings for some end use parameters will be adjusted to be representative of all residential customers.

[11] Annual consumption referred to is the sum of billed volumes for the 4 quarters from December quarter 2002 to the September quarter 2003.

3.4 Measurement Technology

The adopted approach to end use measurement was to collect a high resolution record of water use which could then subsequently be disaggregated into individual water use events using Trace Wizard© [12] water use analysis tool.

Actaris CT5 standard residential water meters were modified from their normal 2 pulses per litre to operate at 72 pulses per litre. Consequently meters are capable of reading volumes as small as .014 litres. The specifications of the modified meters are shown in Appendix B – Measuring Equipment.

The high resolution water measurement information from the meter was captured by Monatec Data Monita XT dataloggers with a storage capacity of 2 million readings. The high memory requirement was necessary to accommodate the collection of data at 5 second intervals for up to 3 weeks at a time. During the project some of the loggers that had been found to have failed were substituted with the Monita XT's replacement which was the Monita D Series logger which had similar specifications.

The loggers were set to record at 5 second intervals for 2 weeks in summer and then again for 2 weeks in winter of 2004. For the rest of the time the loggers were reprogrammed to record at 5 minute intervals continuously over the whole year and this additional data will be analysed to understand how hourly and daily usage patterns vary across seasons and years.

3.5 Trace Wizard© Analysis

The output files from the loggers were loaded into a separate access database for each property and sent to Aquacraft for analysis into individual end uses. It was felt that it would be better to utilise Aquacraft's considerable experience in the use of Trace Wizard© rather than develop the analytical expertise in-house.

Trace Wizard© works by disaggregating the flow trace into a list of component events, and then assigning each of these events to a specific appliance.

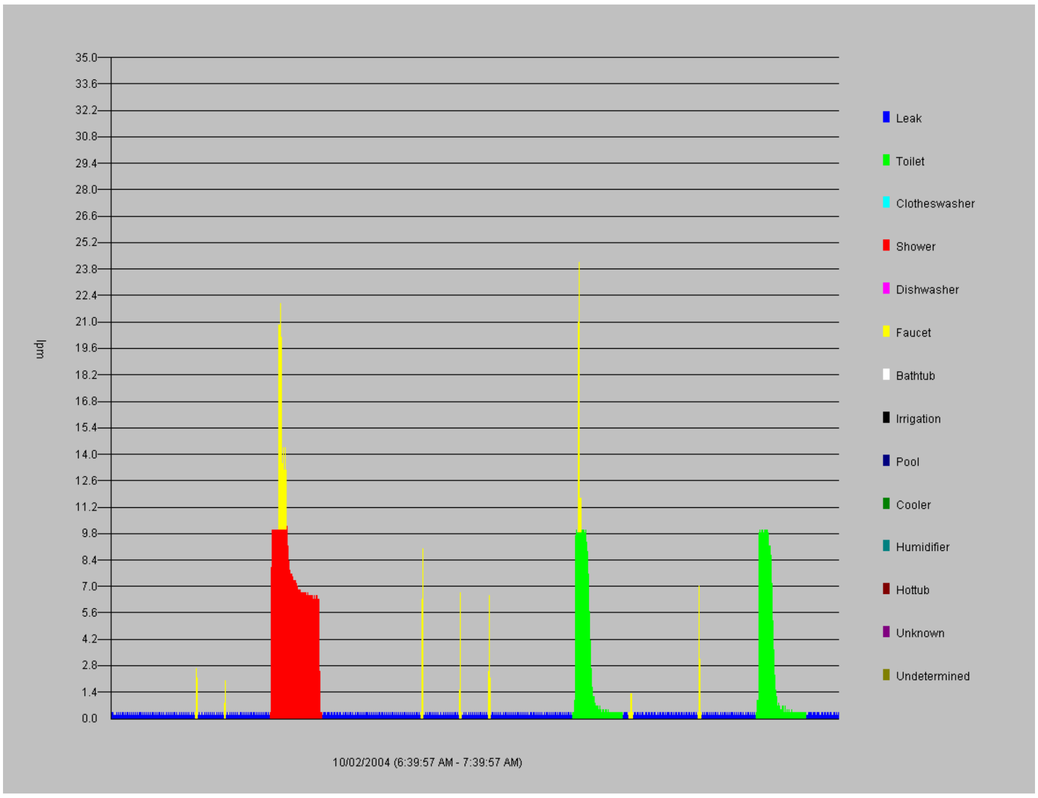
The analyst develops a set of appliance properties for each flow trace which informs the program how to distinguish the various events, such as a tap event and a toilet event and an irrigation event. Ideally when the dataloggers are first installed each appliance is triggered in a predetermined sequence so that its "signature" can be readily identified. In this study however all participating homes underwent the ASUP survey which accurately identified all appliances as well as measured flow rates and flush volumes. Consequently the triggering of appliances was not considered necessary in this study.

Figure 4 below demonstrates a typical output from Trace Wizard© where the separate end uses are identified by different colours. Note that it is possible only to identify total tap use (faucet on the diagram) as opposed to identifying bathroom basin,

[12] Trace Wizard© is a water use analysis tool developed by Aquacraft Inc. Water Engineering and Management to automate analysis of flow traces from water meters with pulse output. Aquacraft Inc is in Boulder, Colorado (see www.aquacraft.com.au).

kitchen tap and laundry taps separately. This is a limitation of the selected measurement technology.

Figure 4: Example of Trace Wizard© Analysis



Appendix C – Data Examples demonstrates what the logger data looks like and the other types of reporting available in Trace Wizard© .

4 Data Analysis

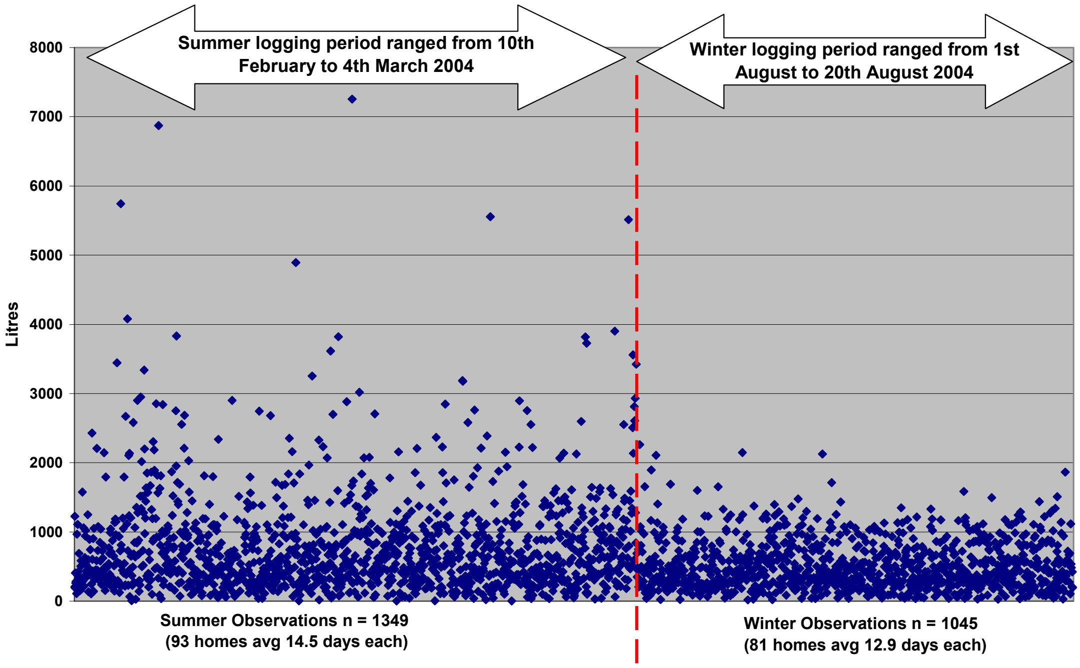
4.1 *Total Daily Use*

A total of 2394 full days of end use data was collected across the sample homes. Due to equipment failure data was not collected from the full sample of homes. In the summer logging period data was collected from 93 homes whilst in the winter period useful data was gathered from just 81 homes[13].

Note that in both logging periods Stage 2 drought restrictions were in place. This will predominantly have impacted the summer usage because the restriction includes a total ban on lawn watering and curtailed hours of use for sprinkler systems used on the garden. However, analysis of the impact of drought restrictions also indicated that even winter usage was reduced by around 5%, believed to be the result of voluntary reduction over and above the specific restrictions.

The average daily usage was both substantially higher and more variable in summer as Figure 5 below demonstrates. The average daily usage per house in the summer period was 784 litres compared to 511 litres in the winter period.

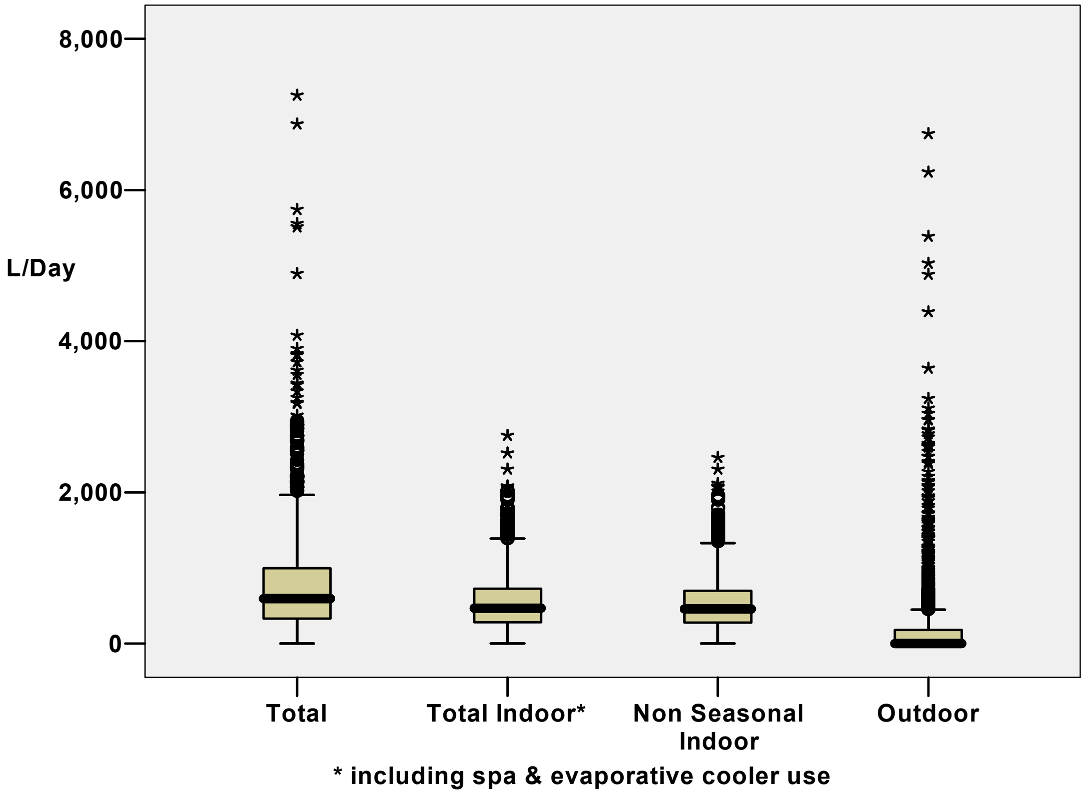
Figure 5: Daily Use Over Time, All Logged Properties



[13] Both the modified meters and the dataloggers appeared to be subject to the effects of corrosion which was not evident until downloading of data was attempted.

Figure 6 below is a boxplot showing the range of values for total daily usage, indoor, non seasonal and outdoor usage for the summer logging period only. The end uses within each category are defined in Table 4 below and it should be noted that in some cases there is some discretion as to what uses are labelled indoor and what are outdoor. For example Spa usage could be considered either but has been classified as indoor here. Similarly leakage strictly speaking cannot be labelled indoor or outdoor usage but has been classified as indoor usage here.

Figure 6[14]: Average Daily Use (L) by End Use Category – Summer Logging Period



Note that both spa and evaporative cooler usage has been classified as **indoor** usage but that a category called **"non seasonal indoor"** usage has been defined to exclude these two end uses. This is an important distinction to make when end use measurement is undertaken for short periods of time because it is only the non seasonal uses (as opposed to all indoor uses) that can be assumed to occur across the whole year.

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[14] A Box Plot gives a diagrammatic representation of the variation in a series of numbers. The median volume is shown as a line within a box that represents the interquartile range (or range of values from the 25th to the 75th percentile). The single bars above and below the box represent 1.5 box lengths above and below the IQ range or the lowest and highest values if they are within 1.5 box lenths. The circles represent **Outliers** which are between 1.5 and 3 box lengths from the upper or lower edge of the box. **Extreme** points represented by the "✳" are more than 3 box lengths from the upper or lower edge of the box.

Figure 6 clearly shows that there is considerable variation in all types of usage with frequent outliers and extreme observations. To avoid the loss of detail Figure 6 has been replicated in Figure 7 but with a reduced scale that excludes some of the outliers. The median total daily use is 598 litres and the median indoor daily usage is 468 litres. The median non seasonal use is only slightly lower than this at 458 litres per day which is equivalent to 167 KL per year.

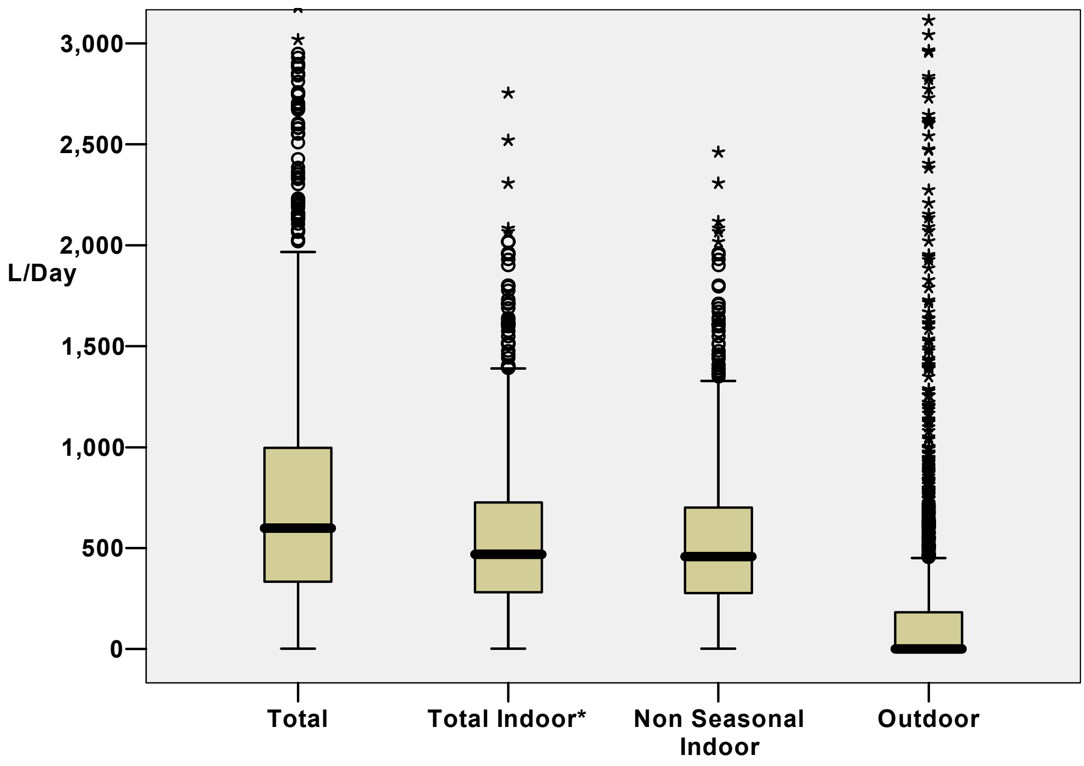
Table 4: End Uses in Each Category of Use

Use Type	Total	Total Indoor	Indoor Non Seasonal	Outdoor
Bath	✓	✓	✓	
Clotheswasher	✓	✓	✓	
Cooler	✓	✓		
Dishwasher	✓	✓	✓	
Tap	✓	✓	✓	
Irrigation	✓			✓
Leak	✓	✓	✓	
Outdoor	✓			✓
Pool	✓			✓
Shower	✓	✓	✓	
Spa	✓	✓		
Toilet	✓	✓	✓	
Unknown	✓	✓	✓	

It is evident from Figure 7 that even non seasonal usage can demonstrate considerable variation with the interquartile range being some 423 litres. The large variation is also evidenced by the ***mean*** daily non seasonal usage of 532 litres being 16% higher than the ***median*** usage of 458 litres. That is, the average is significantly influenced by the outliers and extreme points shown in Figure 7.

Note also that the median outdoor usage is zero because less than half of the observations recorded any usage. In fact of the 1349 daily usage observations in the summer logging period only 512 or 38% recorded outdoor usage.

Figure 7: Average Daily Use (L) by End Use Category extremes removed for more detail



4.2 Winter versus Summer Indoor(Non Seasonal)[15] Use

In order to show the relative contribution of indoor and outdoor use the above analysis of daily usage referred to the data collected in the summer logging period only. However for indoor usage a comparison of summer and winter usage can be made to determine whether this usage varies across seasons.

Such a comparison has been made in Table 5 below. Note that these daily averages apply only to the 75 homes that provided usable traces for both the summer and winter logging periods. The winter average of 523 litres is 3% lower than the summer average of 538 litres. However this difference is not significant (using a statistical test for the difference between means at the 1% level of significance) and so for indoor usage we can analyse combined average daily usage across the two seasons.

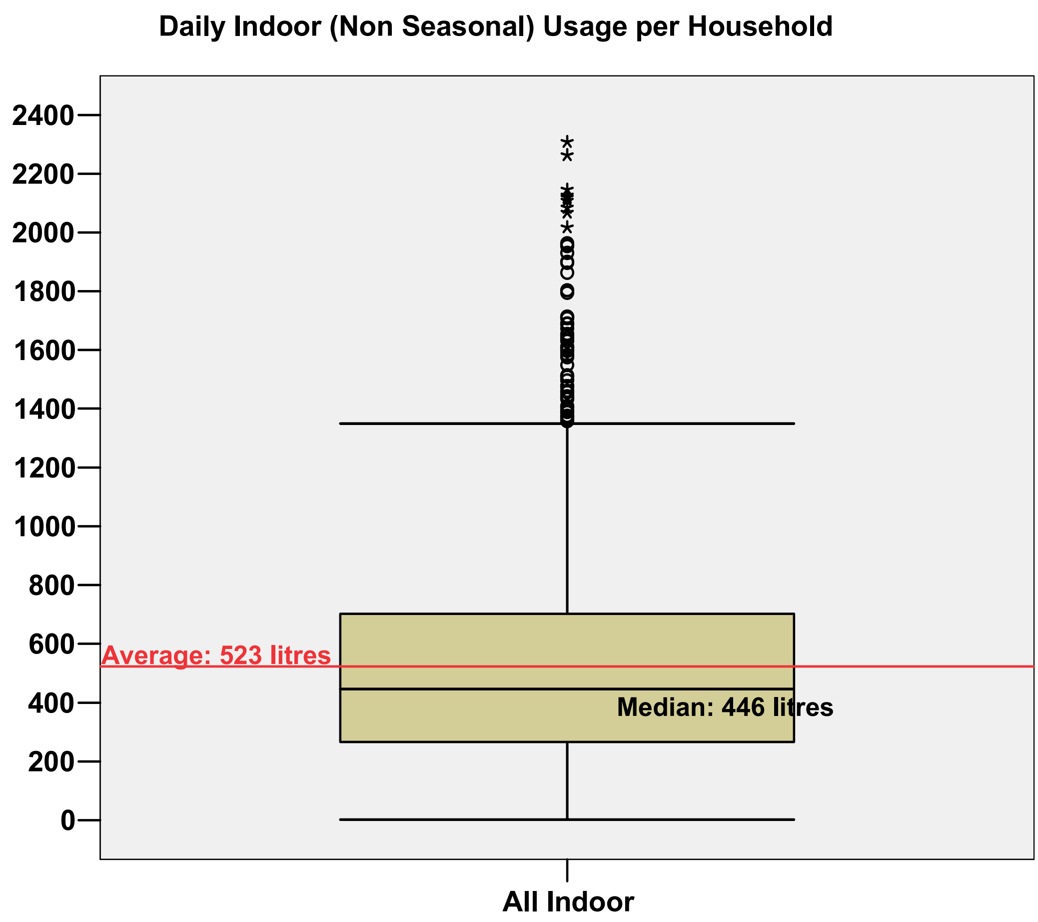
[15] For reasons of convenience indoor (non seasonal) use will from now on be referred to as indoor use but it should be remembered that evaporative air conditioner and spa use is excluded because of their seasonal nature.

Table 5: Daily Indoor (Non Seasonal) Usage Summer & Winter

Household Daily Indoor Usage	Summer	Winter	% Difference
Mean	538	523	-3%
Median	461	435	-6%
Standard Deviation	366	347	-5%

This combined usage is shown in Figure 8 below. The comparison above was made just for the 75 homes that were common to both logging periods, in order to determine if the indoor usage data from both periods can be combined. Given that this appears to be the case, the data represented in Figure 8 is the combination of all 93 summer and 81 winter homes. Average daily usage is 523 litres which is equivalent to 191 KL[16] per year, whilst median daily usage of 446 litres equates to 163 KL per year.

Figure 8: Daily Indoor Household Usage Summer & Winter



[16] This annual indoor usage should be considered in the context that the average total consumption of these households for the 4 quarters ending the September quarter 2003 was 246 KL and that Stage 1 restrictions were introduced in November 2002 and Stage 2 restrictions in August 2003.

4.3 Daily Per Capita Usage – Total Indoor

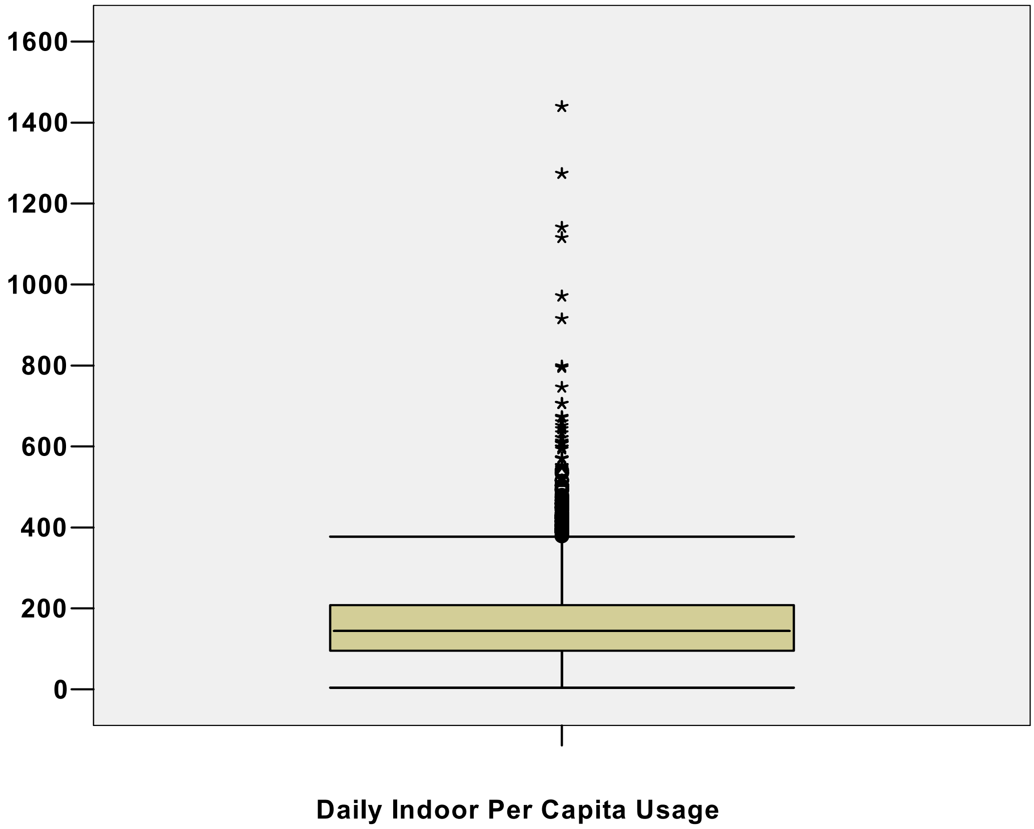
Total daily indoor use per capita is shown in Table 6 and Figure 9 below. Like the litres per household data, the per capita usage is skewed by high users with the mean of 169 LpCpD[17] some 17% higher than the median of 144 LpCpD.

Table 6: Average Indoor Per Capita Usage

Per Capita Daily Indoor Usage	Litres
Mean	169
Median	144
Standard Deviation	117

The interquartile range shown in Figure 9 ranges from around 100 to 200 LpCpD.

Figure 9: Total Indoor Per Capita Usage in Litres



[17] LpCpD is the abbreviation for Litres per Capita per Day

Estimated Indoor Usage for Average Size Household

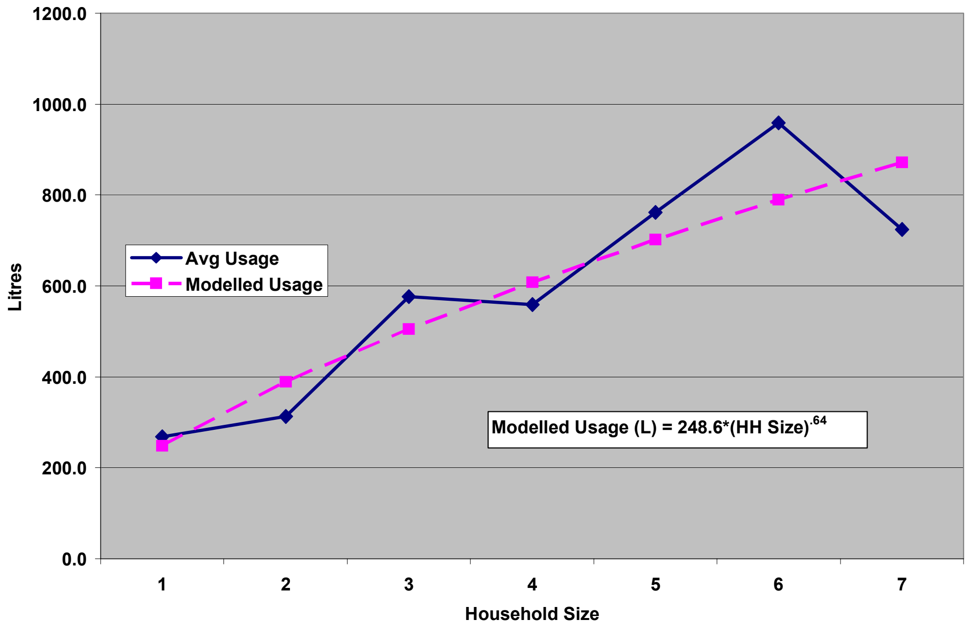
The average household size in Yarra Valley Water's service area is 2.55 persons whereas the average measured LpCpD of 169 litres applies to the sample households which have an average household size of 3.24.

An estimate of the impact on indoor usage of changes in household size can be formulated from the measured daily household usage and the household size data. Such a model is demonstrated in Figure 10 below (power function, $R^2 = 0.88$).

Using this model it is possible to estimate the indoor use for an ***average residential property*** within Yarra Valley Water. For an average household size of 2.55 people the model suggests the following:

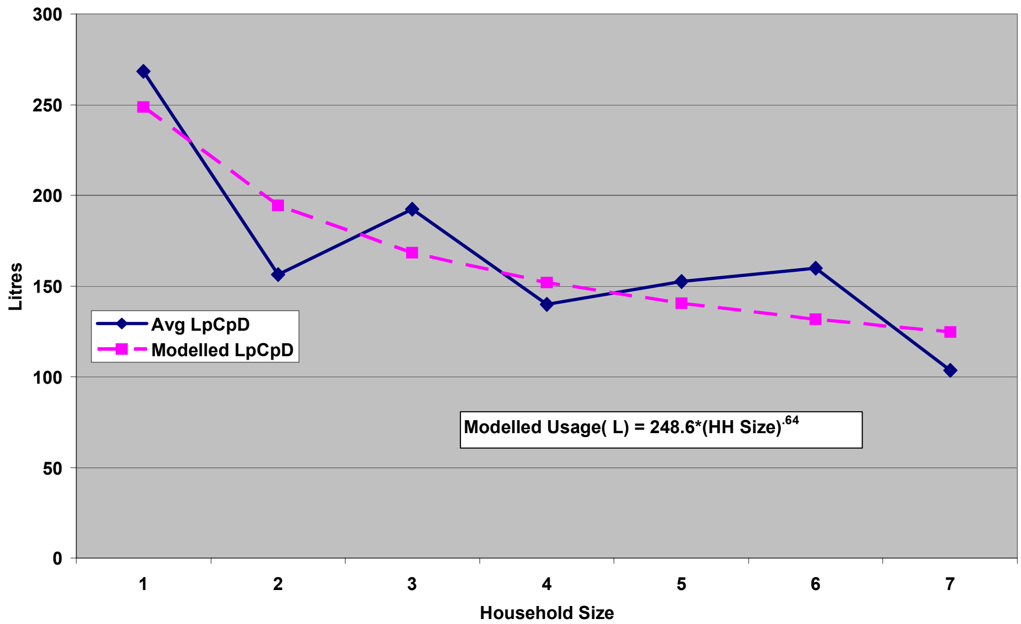
Average Indoor Use per Capita per Day:	**178 litres**
Average Indoor Use per Household per Day:	**455 litres**
Average Indoor Use per Year:	**166 KL**

Figure 10: Average Daily Indoor Use per Household by Household Size



The same indoor per capita usage data shown in Figure 10 above can be viewed on a per capita basis to demonstrate the clear economies of scale associated with increased household size. This can be seen in Figure 11 below and results from household uses of water (as opposed to personal uses) such as clothes washing and dish washing which are more efficient on a per capita basis in larger households.

Figure 11: Average Daily Indoor Use per Capita by Household Size

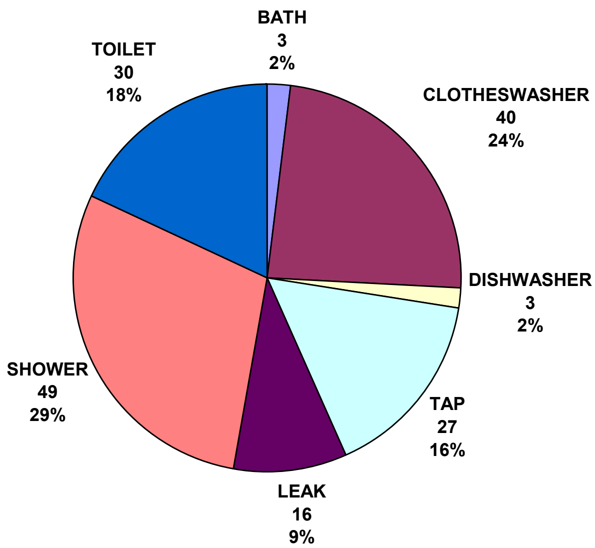


4.4 Indoor End Uses Daily per Capita Usage

As discussed above the average measured indoor usage was 169 LpCpD. This can be disaggregated into its component end uses as shown in Figure 12 below.

Approximately 2% or 3 litres of the 169 LpCpD was in the "unknown" category which means that the flow trace analysis could not assign this usage to a specific end use. Consequently In Figure 12, this usage has been allocated proportionally across the known categories.

Figure 12: Share of Household Indoor Daily Water Uses per Capita (Litres)



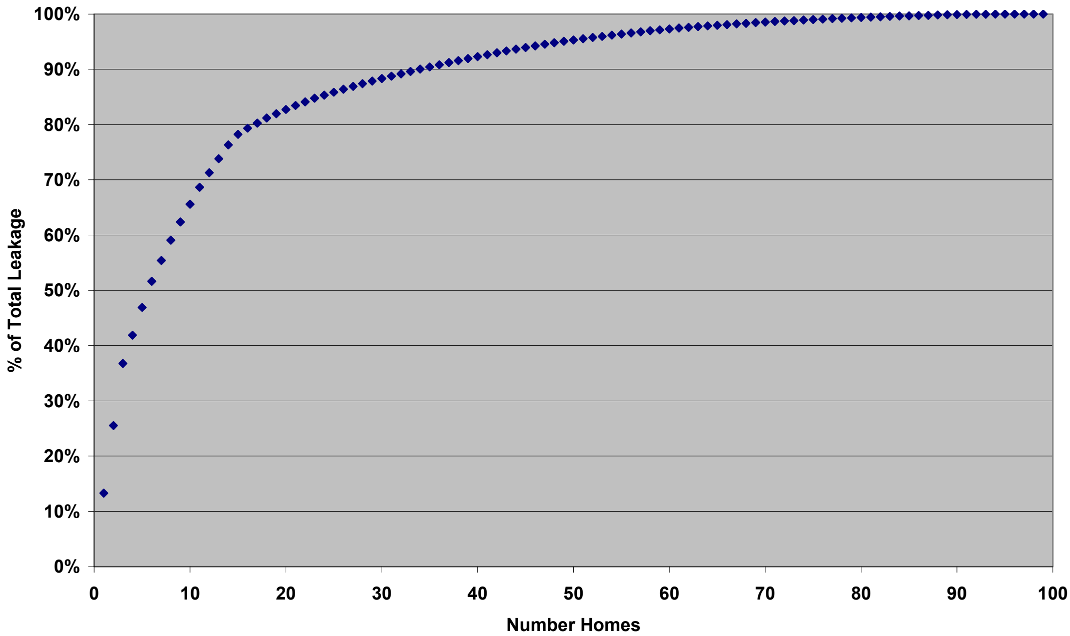
Note that the usage figures shown in Figure 12 are averages over all measured households. So for instance the bath usage of 3 LpCpD is the average usage across all the households NOT the average usage of just the houses that utilise the bath which is more like 12 LpCpD for the 31 homes that registered bath usage.

Showers, clothes washing and toilet use collectively account for 71% of indoor usage. The largest single indoor end use is ***showering which uses 49 LpCpD or 29%***; ***clothes washers were the second highest indoor use accounting for 24% of usage or 40 LpCpD; toilet usage makes up 18% of indoor use or 30 LpCpD[18].***

Tap use averages 27 LpCpD and includes bathroom basins, kitchen sink and laundry trough but specific locations cannot be identified individually.

A surprising outcome is the high level of leakage which accounted for 7.5% of total indoor use or 39 litres per day. However this finding should be handled with care given the small sample size and that the leakage was found to be concentrated in a relatively small proportion of the homes. Around three quarters of the homes had only between zero and 20 litres per day and six homes accounted for more than half of all leakage. The concentration of leakage in a small number of homes is evident from Figure 13 below.

Figure 13: Number of Homes & Share of Total Leakage



The danger in the interpretation of the leakage volume is that it may not occur on a consistent basis throughout the year as would the genuine indoor uses such as shower, toilet and clothes washing.

[18] Note that the average of 30 litres pcpd for toilet use is slightly lower than the volume of 31 litres reported later in the detail section on toilets (section 5.2). This is due to the inclusion above of the flush volumes from the households that were retrofitted with the Caroma 4.5/3 litre dual flush toilets.

The majority of the observed leakage comes from a small number of homes with high leakage. As can be seen in Figure 13 above only about 14 homes had substantial leakage and of these nine households had substantial leakage in only one of the two logging periods.

Consequently, because of the small sample, there is considerable risk in concluding that the measured level of leakage is indicative of the level that might occur on an extended basis.

As mentioned in section 3.4, there is a 5 minute interval data series also being collected and although end use analysis normally requires usage data to be collected in very short intervals (5 or 10 seconds) it is sometimes possible to identify the incidence of leakage in the 5 minute series due to its continuous nature. It is intended to undertake additional analysis over time utilising the 5 minute interval data in order to assess the incidence of leakage over an extended period.

4.5 Outdoor End Uses[19]

4.5.1 Seasonal Use – Proportion of Total Usage

The outdoor or seasonal end uses are garden irrigation, swimming pool/spa filling and top up, evaporative air conditioner use and other. There is a blurring of the distinction between “outdoor” and “seasonal use for some miscellaneous outdoor uses such as car washing or hosing down windows or buildings which are certainly outdoor uses but are arguably not seasonal.

With any type of measurement technology it is problematic to separate different end uses that emanate from the same appliance. So even if a separate metering approach was adopted for every tap it would normally still not be possible to distinguish between car washing and garden irrigation except in the unlikely event that there is a devoted tap for each of these uses. Consequently with the Trace Wizard approach to end use measurement there are possibly some outdoor end uses that will be incorporated in with other categories.

It is likely that miscellaneous outdoor uses will be counted in with either irrigation or miscellaneous tap use. Any high flow rate uses would most likely be in the irrigation category since the indoor taps are typically not capable of high flow rates.

For the two week summer logging period itself the outdoor end uses accounted for 32% of total volume as shown in Table 7 below. **Note that the Stage 2 drought restrictions that were in place at the time would have substantially reduced the garden irrigation component of usage. Normally at this time of the year billing data analysis indicates that garden irrigation would account for around half of the usage of separate houses.**

[19] It is not practical to consider seasonal uses on a **per capita** basis so analysis is based around the proportion of total usage that seasonal use accounts for over a year.

Table 7: Seasonal Uses Share during Summer Logging Period

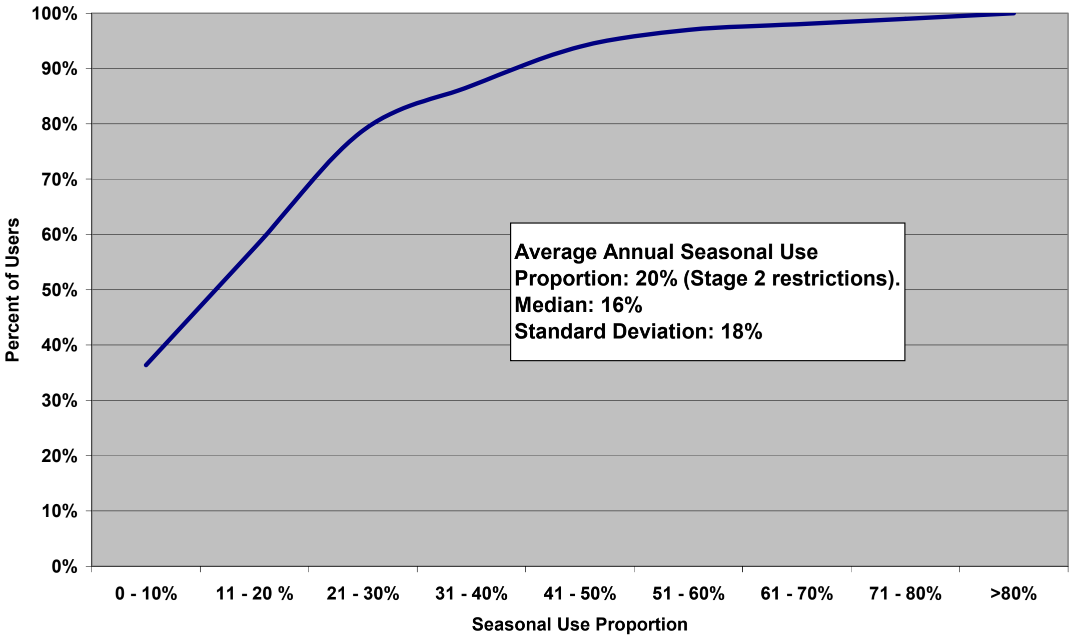
Seasonal Uses	% of Seasonal Volume	% of Total Volume
Evap Air Conditioner	7.9%	2.5%
Irrigation	87.3%	28.0%
Outdoor	0.1%	0.0%
Pool	4.7%	1.5%
Spa	0.1%	0.0%
All	100.0%	32.1%

When end use measurement is collected for a relatively short period of time it is not practical to extrapolate seasonal uses across the whole year. Therefore the average daily non seasonal uses are pro-rated to an annual volume which is then differenced from annual total consumption (using quarterly billing data) to establish an annual seasonal use estimate.

In order to best align the indoor use measured in the two logging periods with the indoor use captured in the billing data, the total annual volume used to establish the seasonal use estimate is the sum of the 4 quarterly bills from the December quarter 2003 to the September quarter 2004. This timing is unfortunate because Stage 2 drought restrictions ran from August 2003 through February 2005 so the estimate of seasonal uses will be considerably less than it would have been without the restrictions in place (see section 4.5.2 below).

Using the above methodology the average proportion of total usage accounted for by seasonal uses over a year was 20%. There is substantial variation around this proportion with the standard deviation being almost as big as the mean at 18%. The median proportion was 16% and for four out of every five households this proportion was less than 30%. The cumulative frequency distribution of the seasonal use proportion is shown in Figure 14 below.

Figure 14: Seasonal Use as a Proportion of Total Usage



There is no way of determining how seasonal use splits into its component parts over the whole year. It is however possible to apply the relative shares as measured during the summer logging period (shown in Table 7 above) to the estimated annual seasonal proportion of 20%. This is presented in Table 8 below.

Table 8: Seasonal Uses Components – Annual

Seasonal Uses Detached Houses	% of Total Volume	% of Customers*
Evap Air Cond	1.6%	20.0%
Irrigation	17.5%	93.0%
Outdoor	0.0%	na
Pool	0.9%	10.0%
Spa	0.0%	4.0%
All	20.1%	na

* Source 2003 ASUP survey. Note 93% of households have a garden but only around 85% undertake irrigation

4.5.2 Adjustment for Impact of Drought Restrictions

As previously stated the estimate of seasonal uses formulated above is underestimated due to the impact of Stage 2 drought restrictions. The billing data from earlier years prior to the introduction of drought restrictions can be compared to the pro-rated non seasonal uses to determine the contribution of seasonal uses under "normal" conditions.

However such an approach is unreliable because of two shortcomings. Firstly the household situation in previous years may have been different from when the end use measurement was undertaken. For example there may have been different appliances or a different number of people living in the house.

Secondly the choice of which year of billing data to use is itself problematic. For example the most recent drought restriction-free year was 2001/02 which had an extremely cold summer in which consumption was actually less than the following summer when drought restrictions were in place. Consequently use of billing data from this year would also understate the "normal" level of seasonal usage.

Consequently it is considered more reliable to base an estimate for the normal seasonal use proportion on historical billing data for a large subset of customers. This is done by comparing the winter quarter bills to the total bills for the year. In particular those customers whose quarterly bill falls in the month of August are unlikely to have any seasonal use in this bill[20]. Using billing data also enables separate estimates to be formulated for "houses" and "other[21]" dwellings.

Billing data was used for the five years from 1997/98 to 2001/02 to determine the ***average*** seasonal usage proportion. The data from 2002/03 and 2003/04 has to be excluded because it is impacted by restrictions. Note also that the 2001/02 data was weighted lower than the other years because of its extremely cold summer.

The analysis described above results in the estimate of average seasonal use for houses of 26.3% of annual usage (compared to the 20.1% formulated in section 4.5.1 above). Using the shares as measured during the summer logging period, the components shown in Table 8 can now be adjusted to reflect this higher seasonal use proportion. These component shares are shown in Table 9 below.

Table 9: Adjusted Seasonal Uses Components – Normal Annual

Seasonal Uses - Detached Houses	% of Total Volume
Evap Air Conditioner	2.1%
Irrigation	22.9%
Outdoor	0.0%
Pool	1.2%
Spa	0.0%
All	26.3%

For **other** dwellings the average seasonal use proportion is **17.2%.** For **all residential** dwellings seasonal use is estimated at **25.4%** of annual volume.

[20] The quarterly bills of customers billed in August will contain three months of usage within the 4 month band from May to August. August is the second month of the billing cycle and YVW bills approximately one quarter of a million residential customers in this month.
[21] "Other" dwellings include all property types other than separate houses.

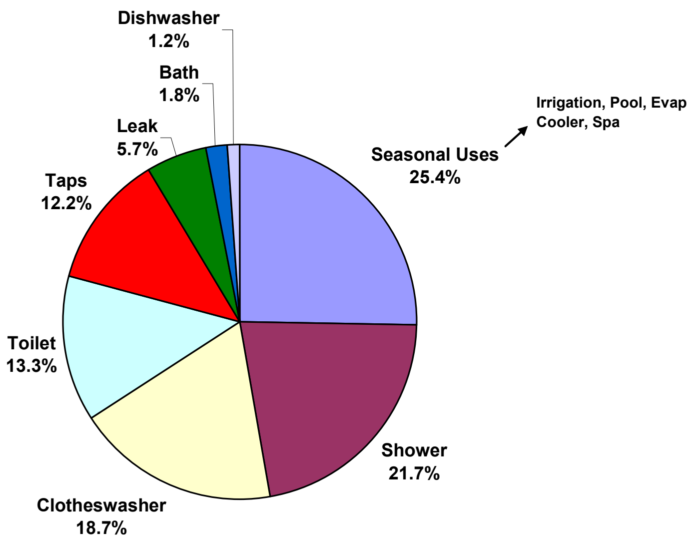
4.6 Final End Use Shares

Using the seasonal use proportion of 25.4% for all residential customers the end use shares[22] of total use can be formulated as shown in Figure 15 below.

The top four uses of Irrigation, Shower, Clotheswasher and Toilet collectively account for 79% of total usage. The fifth largest use is the combined bathroom, kitchen and laundry taps accounting for around 12% of usage.

There is some uncertainty as to whether the contribution of 5.7% from leakage can be relied upon given the short duration of the measurement period. This is a distinction from the other indoor uses which can be assumed to be reasonably uniform across the year.

Figure 15: Annual Residential End Use Shares



[22] Once again it should be remembered that these shares represent the contribution of each end use to total usage and NOT the average usage for residential households with that use. A good example of this distinction is swimming pools which account for only 1.2% of total residential consumption but substantially more for those 10% of households that have a pool, etc.

5 End Use Modelling - Parameters.

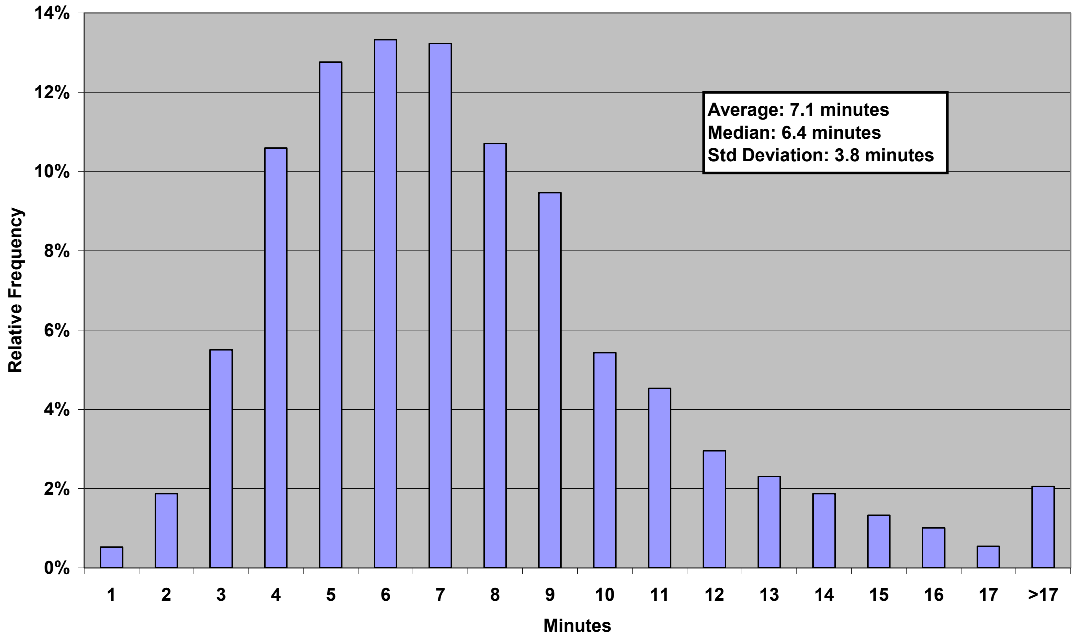
5.1 Showers

The three parameters of interest are the duration (minutes), the average flow rate (litres per minute) and the frequency of showering.

Duration[23]

The average duration of showering was the same in both the summer and the winter logging periods. ***Average duration was 7.1 minutes*** but as Figure 16 below demonstrates there is considerable variation around this average. Seventy percent of showers are between 3 and 9 minutes long whilst over one fifth of showers are 10 minutes or longer.

Figure 16: Distribution of Shower Duration



The 2003 ASUP survey[24] asked respondents to estimate the average shower duration for their household. For the same households that subsequently underwent end use measurement, the ***survey based estimated average duration was 6.2 minutes***. This means that on average, respondents underestimated the shower duration by 0.9 minutes or 13%.

[23] Note that for the analysis of both duration and flow rate the data from seven households with gravity fed hot water services had to be excluded. For an explanation refer to Appendix D – Gravity Fed Hot Water Services

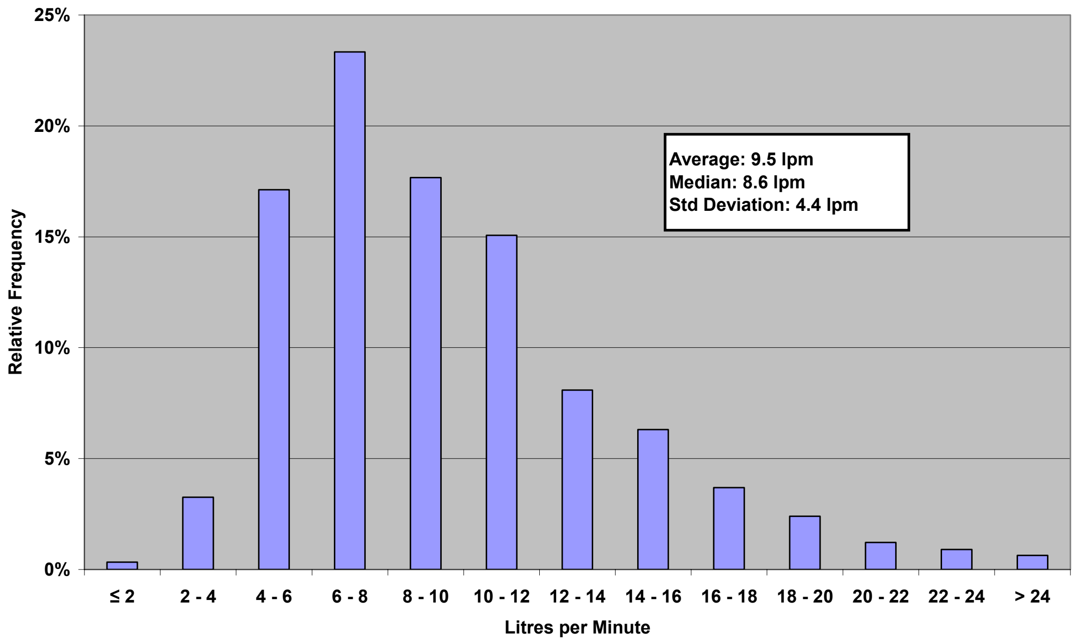
[24] Roberts, op cit

Flow Rate

The ***average flow rate across all showers was 9.5 litres per minute (LpM)*** whilst the median flow rate was only 8.6 LpM. The distribution of shower flow rate is shown in Figure 17 below. Seventy-seven percent of showers had a flow rate of 12 LpM or less.

In the ASUP survey respondents were asked to turn their showers to the typical flow rate and this was measured in addition to the capacity flow rates of the showers. The ***average typical flow rate for the end use measurement homes was 10.2 LpM*** so the respondents were reasonably capable of approximating how the shower was run in their households.

Figure 17: Distribution of Shower Flow Rate (LpM)



There is a strong relationship between the type of shower and the average flow rate with the more efficient showers clearly having lower average flow rates than the standard showers. This can be seen in Table 10 below, where showers are categorized into efficiency ratings by the “capacity” flow rates measured in the ASUP Study.

The weighted average flow rate of the efficient showers (ie A, AA & AAA) was 7.6 LpM compared to 10.5 LpM for the standard showers, a saving of 2.9 LpM on average.

Table 10: Average Flow Rate by Shower Type

Shower "Capacity" Flow Rate	Efficiency Rating	Number of Showers	Number Shower Events	Flow Rate lpm
<=9 litres/min	AAA	14	417	6.7
9.1 - 12 litres/min	AA	8	302	7.7
12.1 - 15 litres/min	A	13	745	8.0
15.1 - 18 litres/min	Std	2	112	13.5
18.1 - 21 litres/min	Std	7	161	11.7
> 21 litres/min	Std	70	2784	10.3
Mixed	na	16	788	9.5
All	na	130	5309	9.5

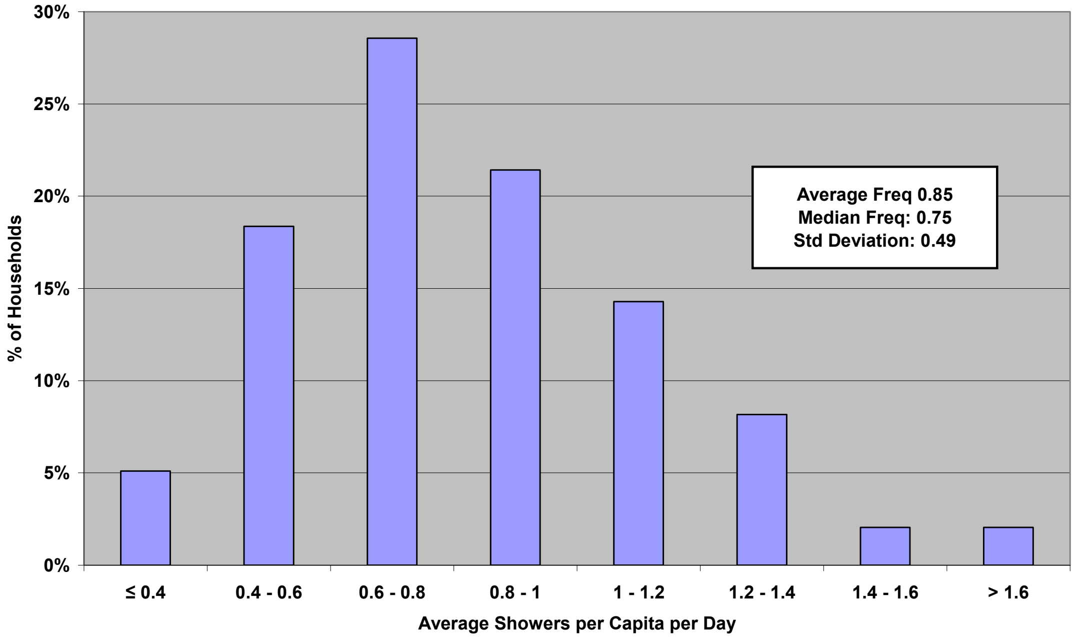
Frequency

On average the ***frequency of showering was 0.76 showers per capita per day (pCpD)*** which is lower than expected based on previous studies undertaken. If baths are combined with showers the average frequency for either rises to 0.8 pCpD.

The relatively low showering frequency arises because shower use was recorded on only 2144 or around 90% of the total possible logged days of 2394. Taken over just those days when shower use was recorded the average frequency rose to 0.85 showers pCpD.

The distribution shown in Figure 18 is taken over just the days when shower use was recorded in each property. The most common average frequency is 0.6 to 0.8 showers pCpD with 29% of households falling in this range. Interestingly, this corresponds to about 5 showers per person per week.

Figure 18: Average Number of Showers per Capita per Day



The presence of children under twelve is a highly significant factor in the frequency with which showers are taken. As Table 11 below shows for households without children under twelve years of age the frequency of showering increases to 0.94 pCpD whereas for the households with children under twelve the average frequency is only 0.59 pCpD.

Table 11: Frequency of Showering (pCpD)

Children Under Twleve in Household	% of Households	Shower Frequency pcpd
No	73.0%	0.94
Yes	27.0%	0.59
All	100.0%	0.85

In the ASUP survey respondents were asked to estimate the number of showers taken and the average estimate for ***the end use measurement homes was 0.89 showers pCpD*** which is quite close to the measured average of 0.85. Shower frequency therefore appears to be a parameter that can be estimated via surveys.

5.2 Toilets

Daily Per Capita Volume by Toilet Type

The measurement of toilet usage is encumbered by the fact that many households have multiple toilets which can differ from each other in regard to their flush volumes. The Trace Wizard methodology for end use measurement can accurately identify toilet use but it does not identify which specific toilet was in use.

Therefore in order to compare the average toilet volume across different types of toilets it is necessary to categorise the end use measurement households on the basis of all the toilets in the household. The household groupings are shown in Table 12 below. Note that the "Mixed" households have some combination of single and dual flush toilets whilst the "Mixed Dual" households have different types of dual flush toilets.

Table 12: Average Daily Toilet Volume per Capita by Toilet Type (L)

Toilet Category	No. Households	Avg Litres pCpD
6/3 Dual	16	19.3
Mixed Dual	7	26.1
9/4.5 Dual	23	29.3
11/6 Dual	17	33.6
9 Single	8	34.8
Mixed	16	38.3
11&12 Single	8	42.3
All Toilets	95	31.2

The overall ***average flush volume was 31.2 litres pCpD*** and ranged from just under ***20 litres for the 6/3 dual flush toilets*** up to over ***42 litres for the 11 & 12 litre single flush toilets***.

Note that between the summer and the winter logging period 21 of the households had at least one toilet retrofitted with the Caroma 4.5/3 litre dual flush toilet. The post retrofit usage for these households was excluded from the daily volume analysis in Table 12 so that the average flush volume reflects the existing toilet appliance stock.

For the retrofitted homes the average daily per capita flush volume fell from 29.6 litres to 21.8. This represents a reduction of 26% or 8 litres per capita per day[25]. Eighteen of the retrofitted homes had all their toilets converted to 4.5/3 toilets and the average volume per capita per day for these homes was reduced from 26.6 to 19.2 litres pcpd, a drop of 7.4 LpCpD, or 28%.

[25] Note that 3 of the 21 homes had only one of their two existing toilets replaced. The toilets replaced covered the full range of single and dual flush toilet types.

Average Flush Volume

The average volume per flush[26] was 7.6 litres, ranging from an average of 5.8 litres for 6/3 dual flush toilets up to an average of 10.1 litres for 11& 12 litre single flush toilets.

Table 13: Average Volume per Flush by Toilet Type

Toilet Category	No. Households	Avg Vol per Flush
6/3 Dual	16	5.8
Mixed Dual	7	6.5
9/4.5 Dual	23	7.1
11/6 Dual	17	7.8
Mixed	16	8.6
9 Single	8	8.8
11&12 Single	8	10.1
All Toilets	95	7.6
4.5/3 Dual	16	4.6

Note that although 21 homes were retrofitted with Caroma 4.5/3 litre dual flush toilets, 4 of these did not record usage data post retrofit and 3 of the homes had additional different toilets so the average flush volume in retrofitted homes is based on just 16 homes from the winter logging period. Average flush volume for these toilets was 4.6 litres which is a reduction of 21% or 1.2 litres per flush on the average for 6/3 dual flush toilets. However this data can be considered as preliminary only since many of the valves used in this retrofit trial were prototypes still under development. The ultimate average flush volume may well be lower again than the 4.6 litres shown here.

The average flush volume of 5.8 litres for 6/3 toilets is higher than expectations and could result from a number of factors including a higher ratio of full to half flush use than what has previously been assumed[27] (this is discussed further in the following section).

Other possible explanations are that there is a high incidence of double or extended flushing with 6/3 toilets possibly the result of poor installation or that some of the water used for hand washing after toilet use has been included in with the toilet volume. This option is not a major problem because it results in a slight overstatement in toilet usage and a corresponding understatement in tap usage but total water usage is fully accounted for.

[26] excluding the data from the Caroma 4.5/3 dual flush toilet retrofits.
[27] The typical ratio of half to full flush has been 40% full to 60% half flush so for a 6/3 toilet operating to specification this would result in an average flush volume of 4.2 litres.

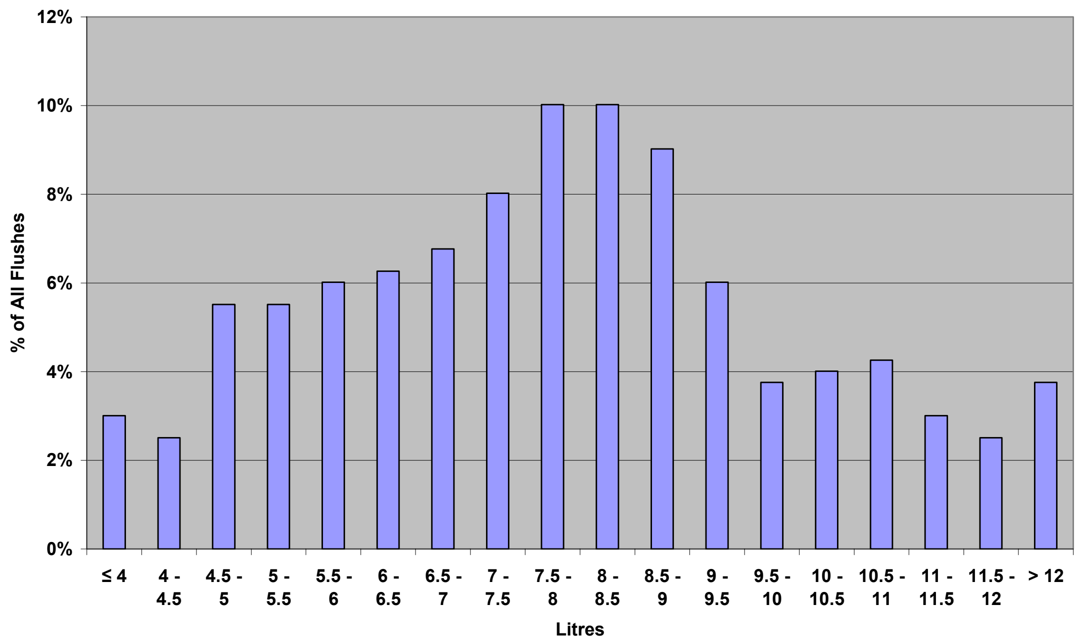
Also toilet identification is difficult so an additional possible cause of the above outcome is that some toilets were manufactured to be able to function as 6/3 models or to be set to use a higher flush volume, and these toilets may have been characterized as being 6/3 toilets (which they may have been when sold) while in fact they now were set to a higher flush volume.

Half Flush to Full Flush Ratio

An important parameter for end use modelling is the ratio of full to half flush usage. The Trace Wizard© methodology of end use analysis identifies each toilet use but not whether the half or full flush option was chosen. We are therefore left to analyse the flush volume data to gain an insight into this ratio.

However this is not as straight forward as one might expect. For example the measured data for 11/6 litre toilets is not simply a collection of 11 and 6 litre flush events but a continuum of events ranging from under 4 litres to over 12 litres. This is well demonstrated in Figure 19 below which shows the distribution of flush volumes for the 11/6 dual flush toilets. It is not clear where the half flush events stop and the full flush events start.

Figure 19: Distribution of Flush Volumes for 11/6 Dual Flush Toilets



It is therefore necessary to choose a nominal threshold volume below which the flush is more likely to be a half flush and above which it is more likely to be a full flush. Table 14 below shows the nominal threshold volumes chosen which were 2 litres above the design threshold and the ratio of half to full flush usage for each type of dual flush toilet.

Overall the ratio of half to full flush use is 43:57 and there is clearly a pattern in this ratio for each class of toilet. The ratio is progressively more weighted to full flush as the volume of the toilet decreases. So for 6/3 toilets around 3 in 4 flushes are a full flush whilst for 11/6 toilets less than half are a full flush.

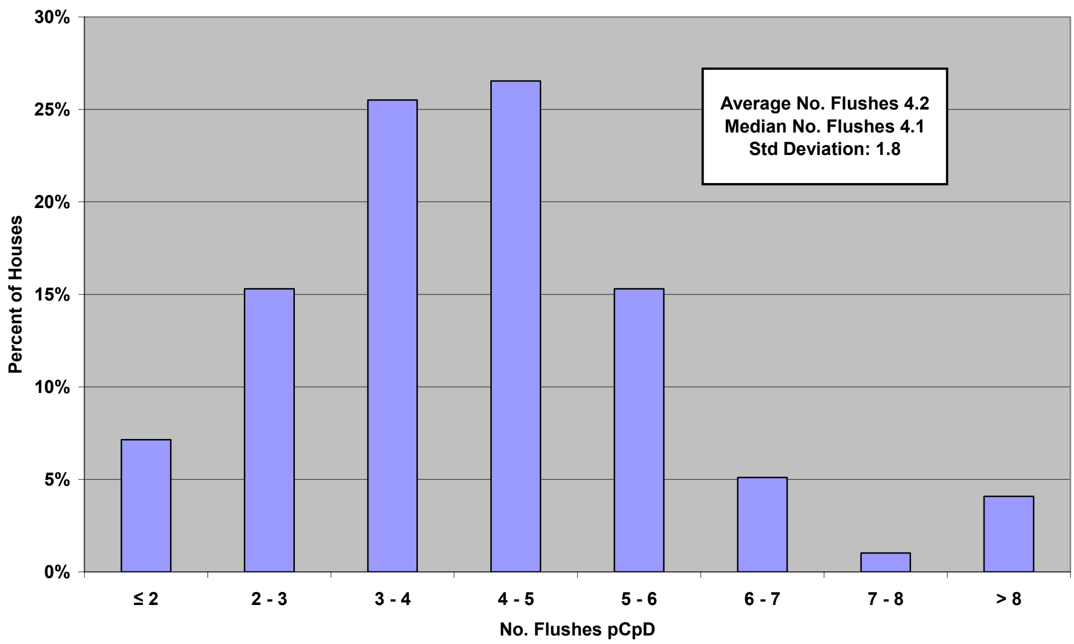
Table 14: Ratio of Half to Full Flush

Toilet Category	Nominal Half/Full Threshold	Min Flush Vol	Max Flush Vol	Half:Full Ratio
6/3 Dual	5 litres	3.0	10.2	27 : 73
9/4.5 Dual	6.5 litres	3.5	12.4	45 : 55
11/6 Dual	8 litres	3.3	13.1	54 : 46
All Dual Flush				43 : 57

Flush Frequency

The distribution of the average number of flushes per capita per day is shown in Figure 20 below. The average is 4.2 flushes pCpD although around one quarter of households averaged 5 or more flushes pCpD.

Figure 20: Average Flushes per Capita per Day



The 2003 ASUP survey[28] asked respondents to estimate the number of times each toilet in the household was used per week. For the same households that subsequently underwent end use measurement, the ***survey estimated average daily usage was 4.1 pCpD***. So respondents only slightly underestimated their toilet usage. In fact the survey average across all 840 households was 3.7 pCpD so allowing for the same degree of underestimation would suggest that ***3.8 flushes pCpD*** is a reasonable parameter to apply to the overall customer base.

[28] Roberts, op cit

5.3 Clothes Washers

Average Volume per Load

There were a total of 2148 loads of washing undertaken during the two logging periods. Of these clothes washing events 258 loads were in front loading machines in 19 homes and 1890 were in top loading machines in 78 homes.

The average total water use per load across all machines was 143 litres.
Importantly the average ***volume per load in the front loaders was 51% less than that for the top loaders***. The average volume per load for each type of washer is shown in Table 15 below which also shows how the volume varies with household size.

The last column of the table demonstrates the economies of scale around per capita volume associated with increasing household size. (Note that there were only 5 households with 6 or more people so the sample is too small to draw any conclusions for these subsets).

Table 15: Average Volume per Load by Household Size

Household Size	Avg Vol per Load - Top	Avg Vol per Load - Front	Avg Vol per Load - All	Avg Vol per Capita
1 (n=11)	126	73	117	117
2 (n=22)	136	75	118	59
3 (n=18)	150	80	142	47
4 (n=27)	150	51	147	37
5 (n=14)	169	71	159	32
6 (n=3)	152	-	152	25
7 (n=2)	156	97	127	18
All	152	75	143	-

However the observed steep increase in the number of loads performed as household size increases appears to compensate for much of the decreasing per capita volume per load shown above (see Figure 24 below).

Figure 21 below shows the distribution of the volume for all clothes washer loads and it shows that volume is reasonably normally distributed around the average of 143 litres. The chart also shows that it is not uncommon (17% of loads) to use more than 190 litres per load.

Figure 22 below compares the distributions of volume for front loaders versus top loaders and clearly demonstrates the significant relative efficiency of the front loading machines.

Figure 21: Clothes Washer - Distribution of Volume per Load

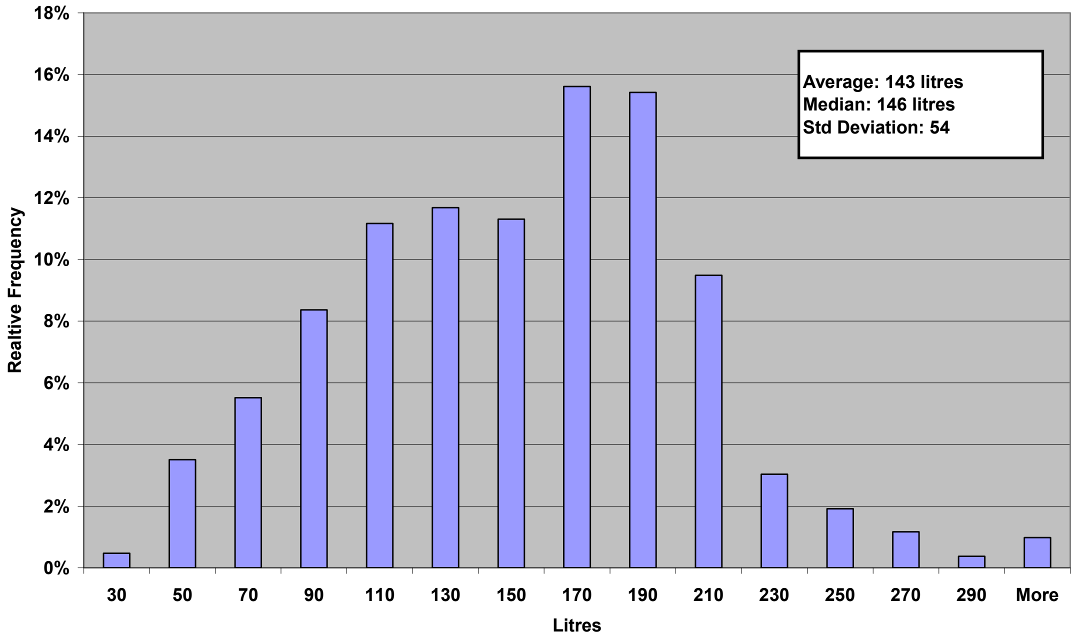
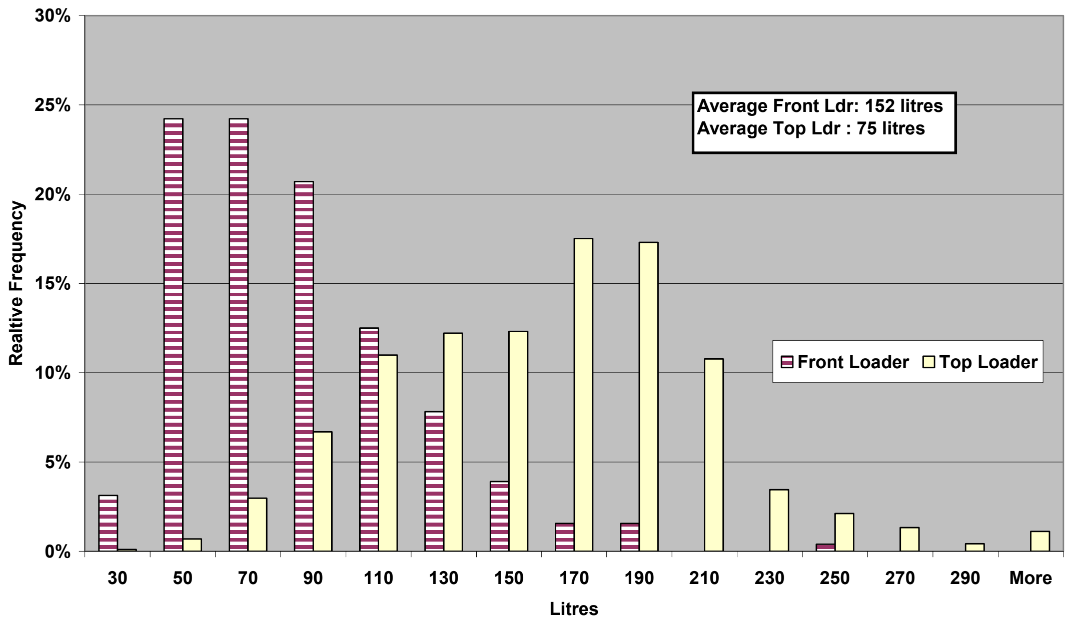


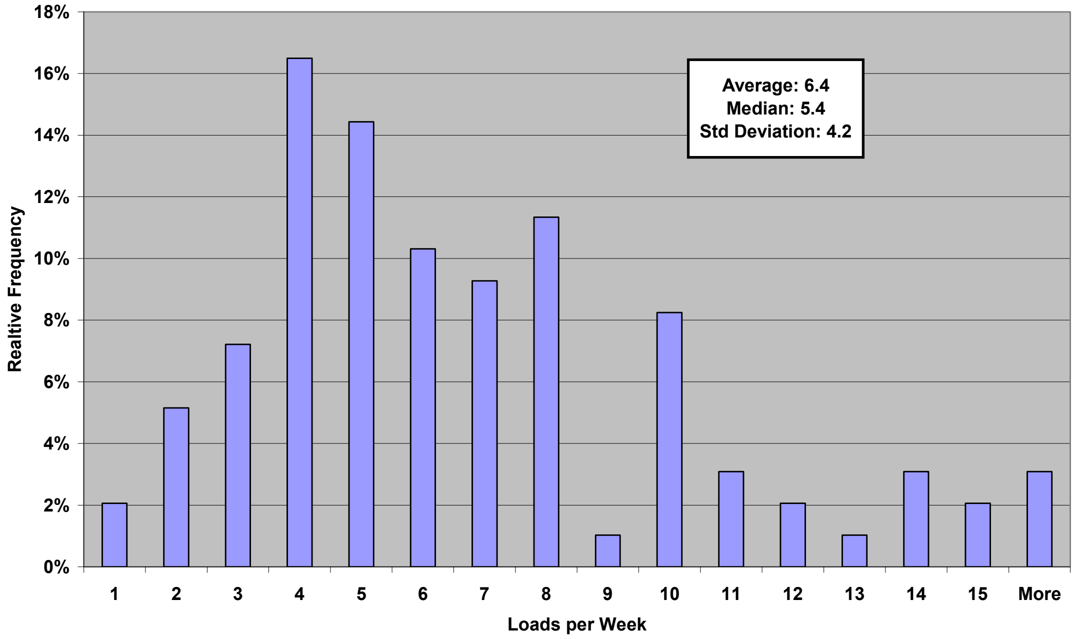
Figure 22: Distribution of Volume per Load – Top vs Front Loaders



Average Number of Loads[29]

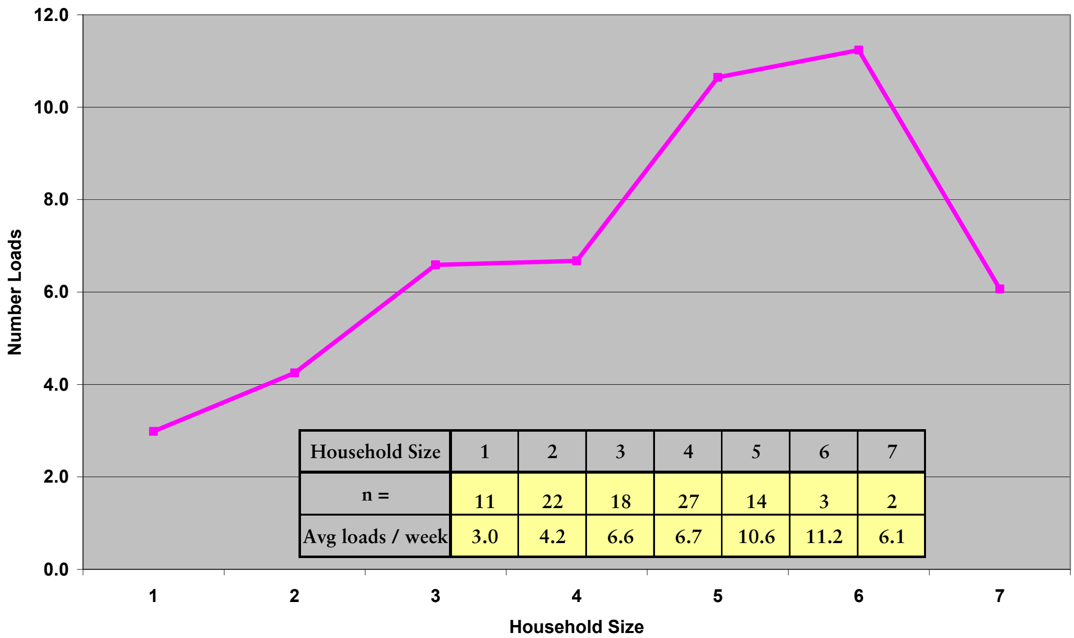
The average number of clothes washer loads per week was 6.4 with a majority of households washing between 4 and 8 times per week – see Figure 23 below.

Figure 23: Clothes Washer Loads per Week



There is naturally a very strong correlation between the household size and the number of loads of washing done and this is demonstrated in Figure 24.

Figure 24: Relationship between Household Size & Number of Loads (1)

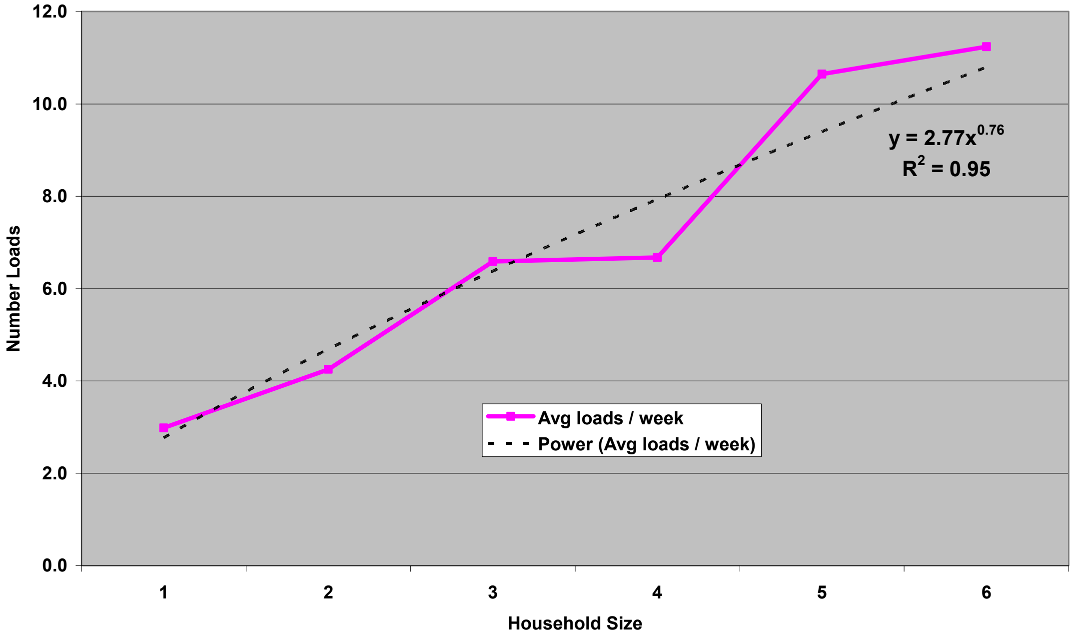


Household Size	1	2	3	4	5	6	7
n =	11	22	18	27	14	3	2
Avg loads / week	3.0	4.2	6.6	6.7	10.6	11.2	6.1

[29] Average number of loads is calculated as a "per week" rate which is equivalent to the total number of loads over the two logging periods divided by the number of logged days multiplied by 7.

Apart from the result for 7 person households the correlation between household size and washing machine use is consistent. Since there are only 2 seven person households in the sample we can remove this inconsistent data and model the remaining results as shown in Figure 25.

Figure 25: Relationship between Household Size & Number of Loads (2)



So the relationship between household size and washing machine use can be represented by the model:

$$\textbf{No. Loads/Week}_{CW} = \textbf{2.77 * (Household Size)}^{.76}$$

As discussed above the average number of loads per week was found to be 6.4. However the average household size for the end use measurement homes was 3.3 which is substantially higher than the average household size for Yarra Valley Water's entire customer base which is estimated to currently be around 2.5 people per dwelling. Using this household size and the above model, ***the average washing machine use for all customers becomes 5.5 loads per week.***

This estimate is 10% higher than the 2003 ASUP survey result which showed an average of 5.0 loads per week.

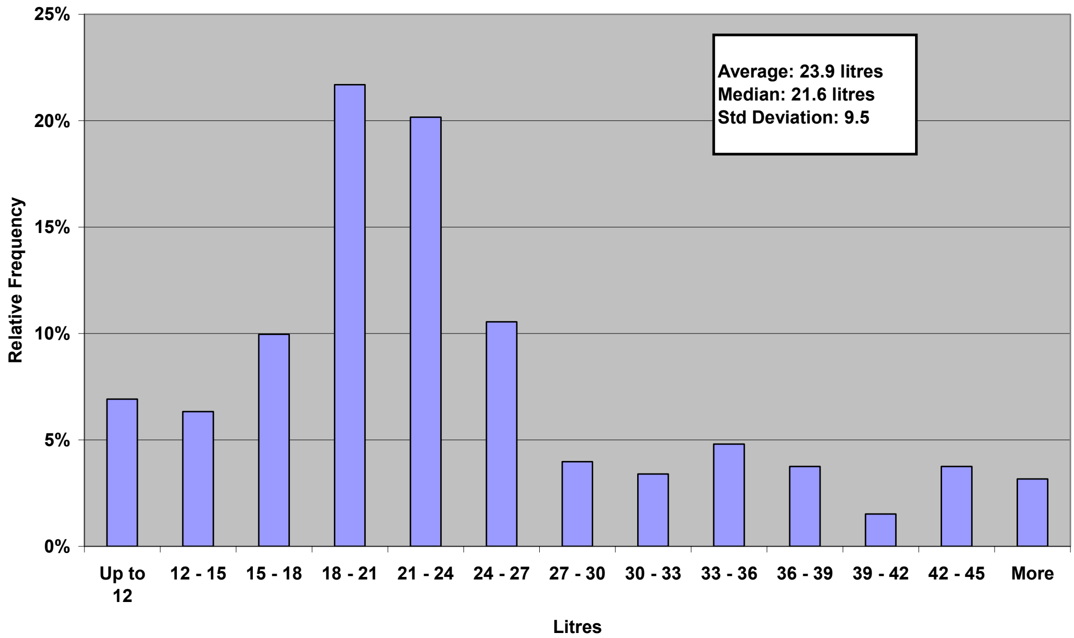
5.4 Dishwashers

Average Volume per Load

Water consumption by dishwashers is a very minor component of residential water usage. Nevertheless dishwasher use was recorded in 72 of the logged homes over both logging periods although in may homes use of the appliance was minimal[30]. In total 854 dishwasher loads were recorded.

The overall average volume per load was 23.9 litres and as Figure 26 shows the most common volume per load falls between 18 and 24 litres.

Figure 26: Clothes Washer - Distribution of Volume per Load



Average Number of Loads

The average usage across all households is 3.4 loads per week but as Figure 27 below shows there is a wide range around this average.

As was the case with clothes washers there is a strong correlation between household size and the average number of loads per week. This is shown in Figure 28 below. The relationship is consistent until household size reaches 6 and 7 where the sample size is only 3 and 2 respectively.

Therefore these values are removed in order to more accurately model the relationship up to household size of five. This model is shown in Figure 29 below.

[30] In 20 of the 72 homes the dishwasher was used only 4 times or less over the two logging periods combined.

Figure 27: Dishwasher Average Loads per Week

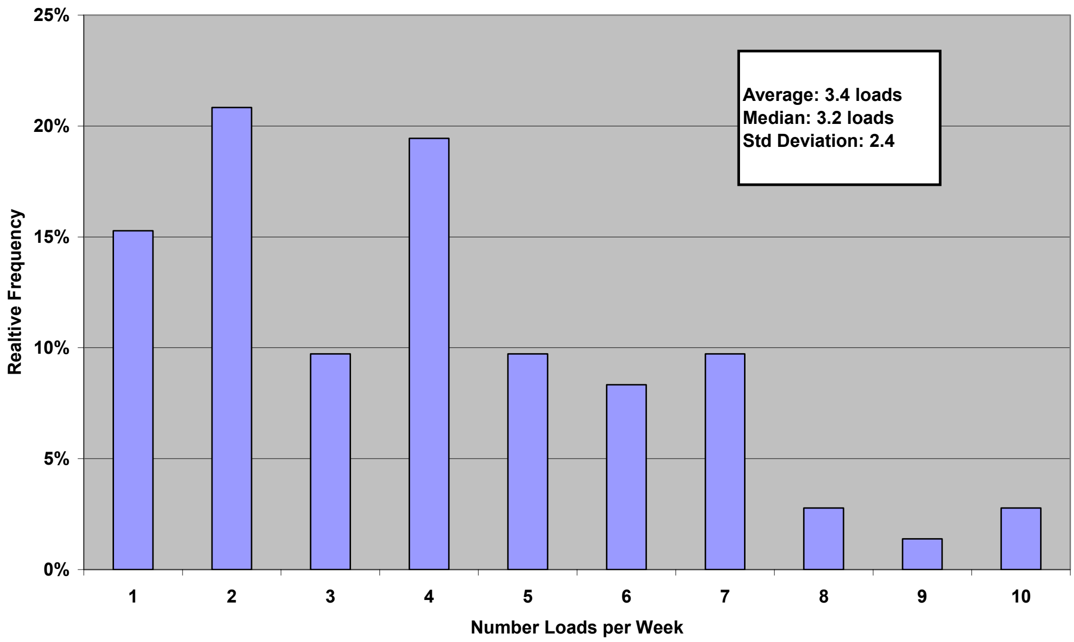
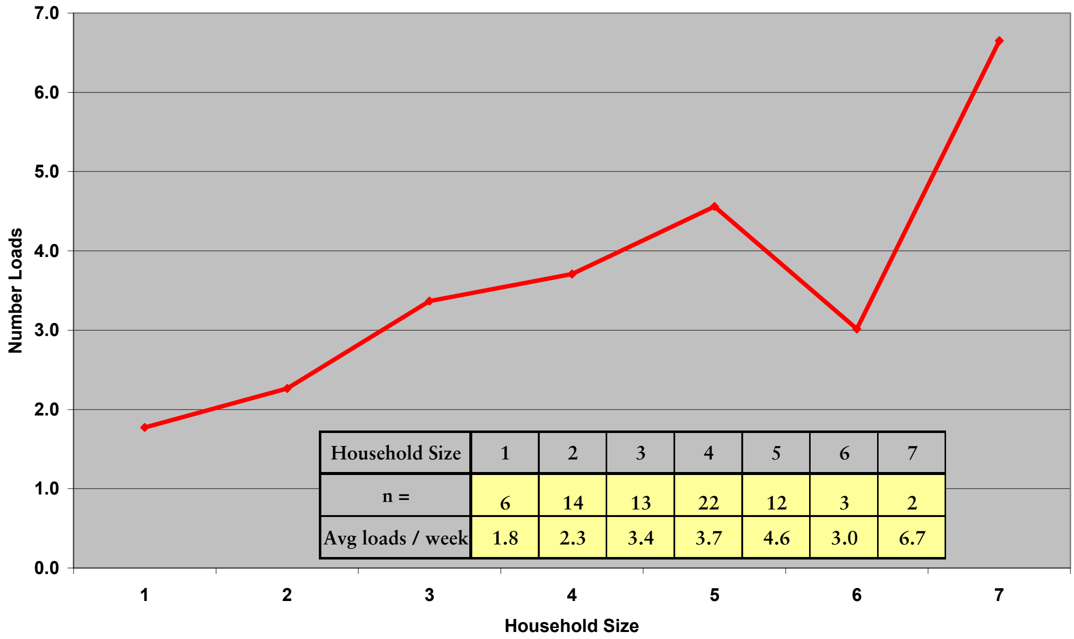
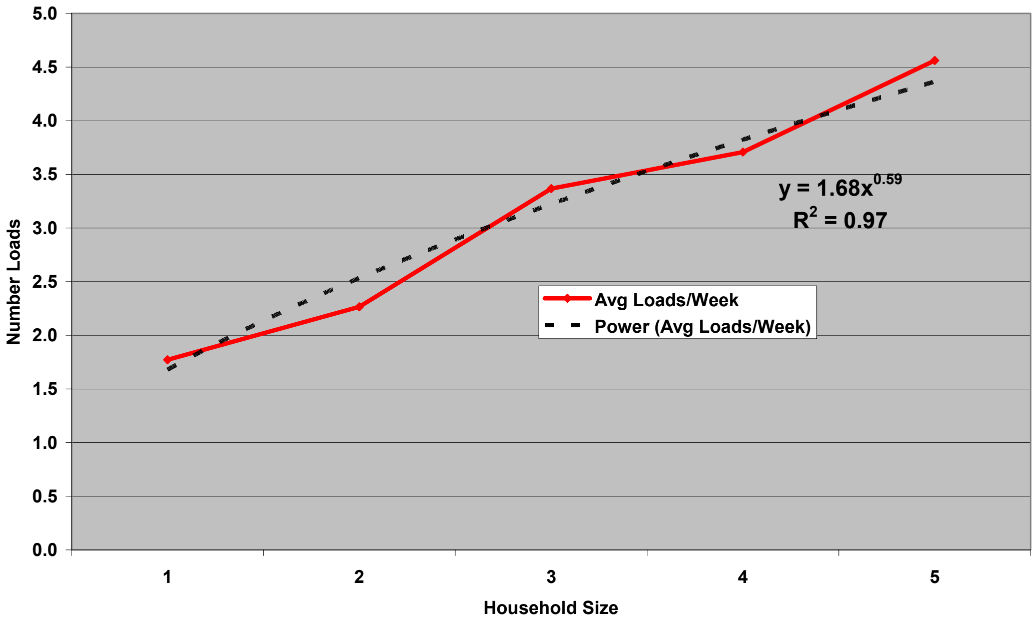


Figure 28: Relationship between Household Size & Number of Loads (1)



Household Size	1	2	3	4	5	6	7
n =	6	14	13	22	12	3	2
Avg loads / week	1.8	2.3	3.4	3.7	4.6	3.0	6.7

Figure 29: Relationship between Household Size & Number of Loads (2)



As Figure 29 shows the relationship between household size and washing machine use can be represented by the model:

$$\text{No. Loads/Week}_{DW} = 1.68 * (\text{Household Size})^{.59}$$

***For an average household size of 2.55 persons the modelled average number of dishwasher uses per week is therefore 2.9 loads*.**

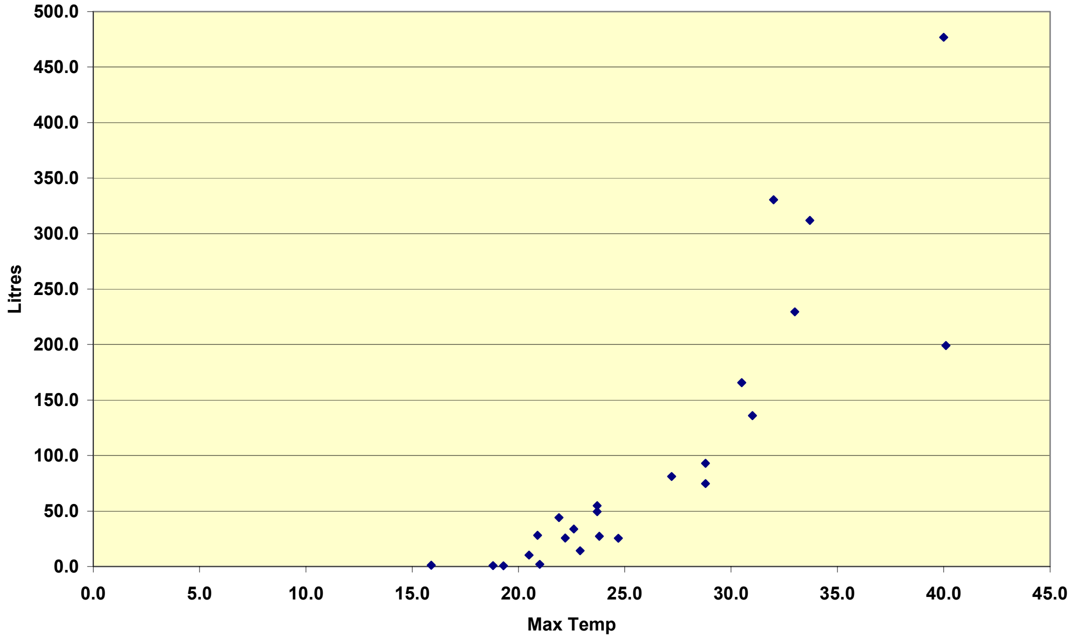
This estimate is considerably lower than the 2003 ASUP survey result which showed an average of 4.3 loads per week for the end use measurement homes and an average of 4.4 loads across all homes. With only 72 homes registering dishwasher use in the end use measurement sample it is possibly more prudent in this case to favour the ASUP survey usage estimate since this is based on about 450 homes (ie 54% of the sample of 840 households used their dishwasher at least once per week).

5.5 Evaporative Air Conditioners

Twenty one of the end use measurement homes registered some evaporative air conditioner (EAC) usage during the summer logging period. There was no usage registered during the winter logging period.

Not surprisingly there is a strong relationship between the daily maximum temperature and the average volume per air conditioner on any day. This is demonstrated in Figure 30 below.

Figure 30: Average Daily Volume per Unit vs Max Temperature



It would appear from the chart that usage generally does not occur until around 20° but is reasonably negligible up to a daily maximum of 25° with usage generally below 50 litres per day. However when the daily maximum temperature is in the high twenties or above the usage increases steeply in line with the temperature.

As the chart also demonstrates in some cases the average volume of water used by EACs is impacted by something else other than the daily maximum temperature. Two days in the summer logging period in particular had the same maximum temperature but totally different average usage. Both days reached a maximum of 40°[31] but on one day average usage was 199 litres whereas on the other average usage was 477 litres.

The relative humidity on both days was quite low and doesn't explain the vast difference in usage. The high use day was on a weekend whereas the low use day was not. This could indicate that more people were home for a larger part of the day on the weekend. The length of operation on these two days however is considerably different. Average minutes of operation were 327 on the high use day but only 117 on the low use day.

The overall average usage of EACs is shown in Table 16 below. ***Average usage per day was 155 litres*** but the range is large with one household using 964 litres on one of the 40° days.

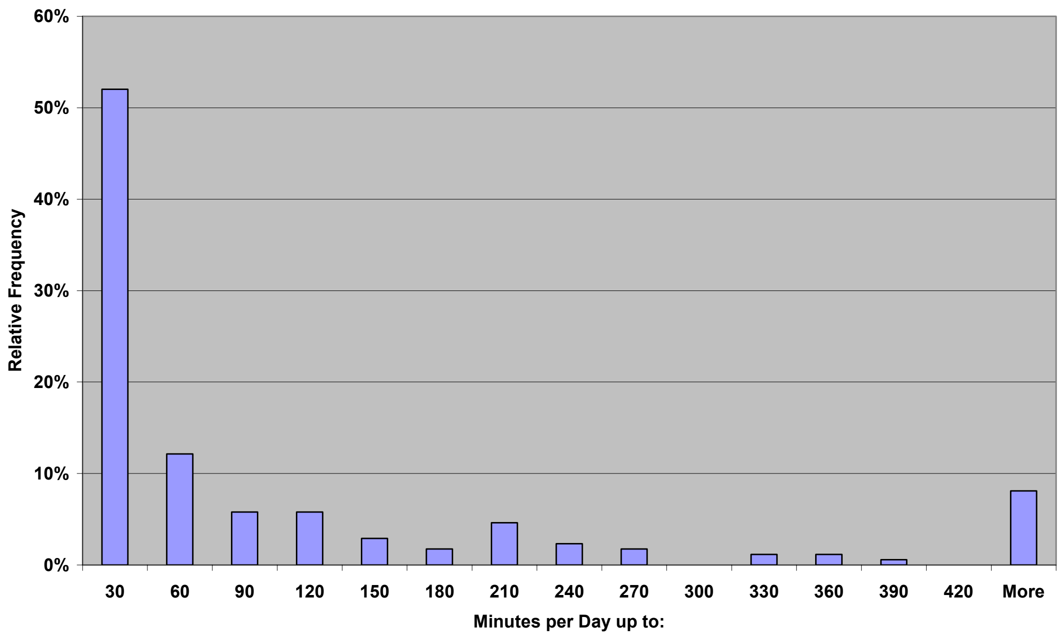
The average duration of use was 106 minutes and again the range is large with the maximum usage being 1137 minutes (approx 19 hours). This sort of extended use however is unusual with a majority of users operating their EAC for only a half an hour. The distribution of usage duration is shown in Figure 31 below.

[31] Note that daily maximum temperatures of 40° in Melbourne are quite rare with only 15 days in the last 10 years being 40° or above.

Table 16: Evaporative Air Conditioner Usage

Evaporative Air Conditioners	Average	Range
Duration/Day (mins)	106	1 - 1137
Volume/Day (litres)	155	1 - 964
Litres per Minute of Operation	1.5	0.2 - 13

Figure 31: Evaporative Air Conditioner – Duration of Use



On average EACs use 1.5 litres per minute but once again there is considerable variation with the range being 0.2 – 13 LpM.

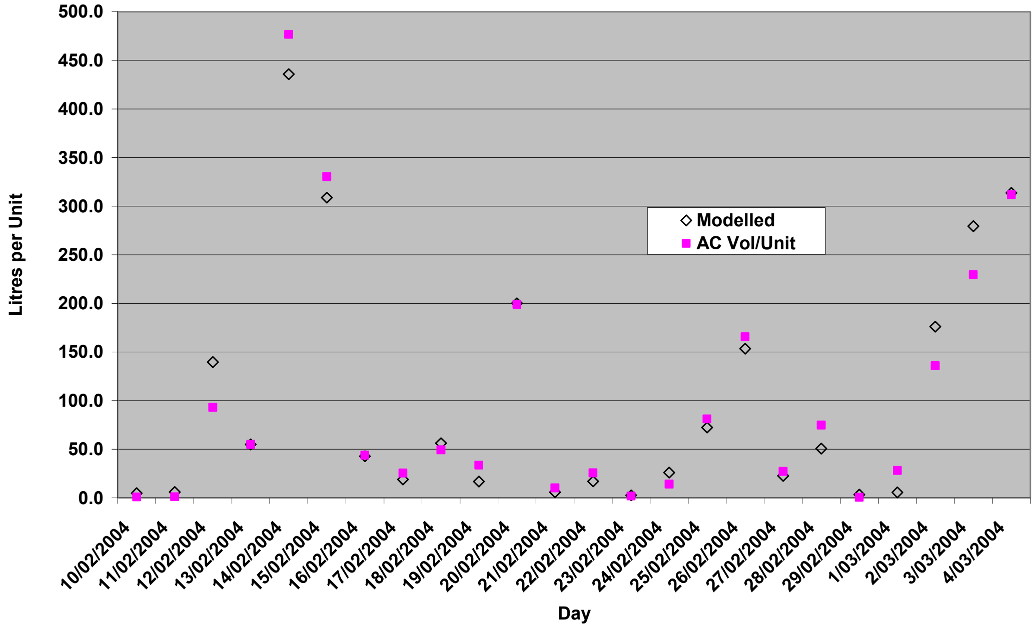
It is reasonable to speculate that EAC usage is a function of daily maximum temperature, duration of use (related to how long the day and the house remains hot) and day of the week. A simple linear model based on these variables can very effectively predict EAC usage as shown in Figure 32 below.

The model specification is:

Daily Vol/Unit = 3.58*MaxTempExcess + 1.09*Duration + 20.00*Weekend

Where Max Temp Excess = 0 if Max Temp < 21^o
= (Max Temp-21^o) otherwise,
Duration = minutes of operation
Weekend = 0 if weekday, 1 if Saturday or Sunday.

Figure 32: Modelled versus Actual EAC Average Volume/Unit



5.6 Tap Use

Tap use is considered as an indoor use but in reality could be outdoor as well. It is assumed to be predominantly bathroom basin, kitchen sink and laundry trough use.

Over the two logging periods there were just under 152,000 tap events recorded. This equates to an average of 64 tap use events per household per day – see Table 17: Tap Use Summary below. On average each person in the household uses a tap 20 times per day and the average volume of each use is just 1.3 litres. ***That is, tap usage is characterised by a high number of very low volume events.***

Table 17: Tap Use Summary

Tap Use	Per Household	Per Capita
Average Volume/Day (Litres)	85	27
Average No. Tap Uses	64	20
Average Volume/Use (Litres)	1.3	
Average Flow Rate (lpm)	3.3	

Duration

The average duration is between 20 & 25[32] seconds but this is misleading because the majority of events are of very short duration often running for only 5 or 10 seconds. Eighty six percent of tap use events occur for 30 seconds or less. The distribution of tap use duration is shown Figure 33 below.

Tap Use and Household Size

As one would expect tap usage goes up as household size increases. This is shown in the average daily usage by household size table (Table 18) below. Also shown is the average LpCpD for each household size and this shows that other than for the drop in average per capita usage from 1 to 2 person households, thereafter usage is fairly stable around the average of 27 LpCpD.

This is unlike the relationship between clotheswasher or dishwasher use and household size and suggests that a majority of tap usage relates to individual use as opposed to common use such as filling the kitchen sink for hand washing dishes or using water for cooking. Alternatively there is possibly a more direct relationship between household size and these particular common uses.

[32] The exact arithmetic average is artificial because usage was recorded at five second intervals.

Figure 33: Distribution of Tap Use Duration

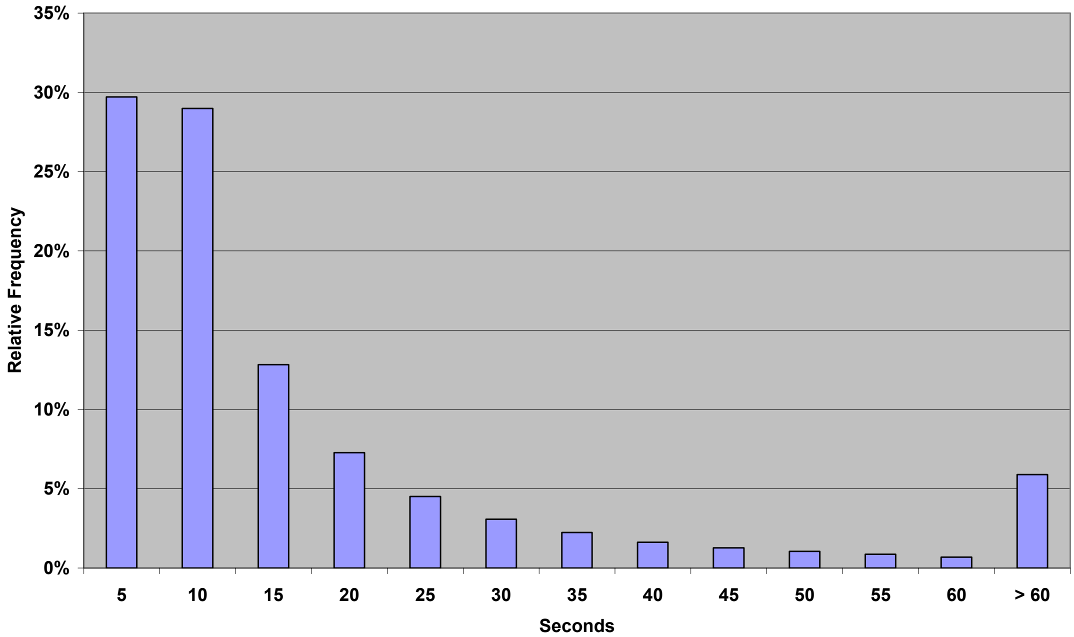


Table 18: Average Tap Usage & Household Size

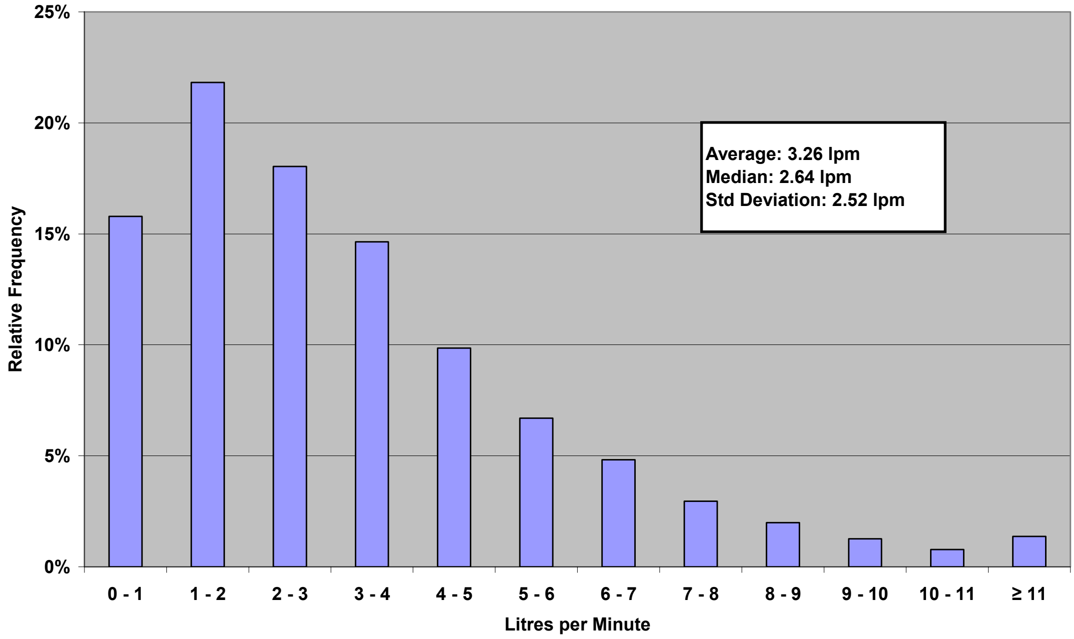
Household Size	n =	Avg Daily Litres	Avg LpCpD
1	11	41	41
2	23	52	26
3	18	81	27
4	27	87	22
5 +	19	145	27
All	98	85	27

Flow Rate

Consistent with the above finding that tap usage is a high frequency low-volume activity, the ***average flow rate of tap usage is low at just 3.3 LpM***. In fact as is evident from the distribution of flow rate shown below in Figure 34, the vast majority of events are less than 7 litres per minute.

This is an important finding in the context of demand management because it confirms that the widespread adoption of flow control valves in the residential setting is highly unlikely to result in reduced water usage since the vast majority of use is already occurring well below the maximum flow rates limited by flow control valves.

Figure 34: Distribution of Tap Usage Flow Rate



5.7 Baths

Use of the bath is a fairly minor end use for about one quarter of households at any one time and not used at all by the rest. For those households that utilised the bath on average this use accounted for just under 7% of their total non seasonal indoor usage. In the summer logging period 24 homes registered bath use whilst 23 used the bath during the winter logging period. All together 31 homes used their bath at some stage during either period.

Amongst just these homes the bath was used on average on 2.6 days per week. For over one quarter of the houses bath use occurred on only 1 day across both logging periods.

The average volume of water used for each bath was 123 litres. This translates into an average across all logged days of only 46 litres per bath using household per day.

5.8 Irrigation

As previously stated the summer end use measurement occurred in February 2004 when Stage 2 drought restrictions were in place[33]. Of the 93 homes for which measurement was undertaken 84 recorded some irrigation use during the logging period although in 5 of these homes total usage came to under 100 litres. A check of

[33] Stage 2 drought restrictions applying to residential gardens include no watering of lawns at all, watering of garden beds with automatic irrigation systems only between 11pm and 6 am, manual sprinkler systems only from 5am to 8am and 8pm to 11 pm. Hand held hose use was allowed at any time.

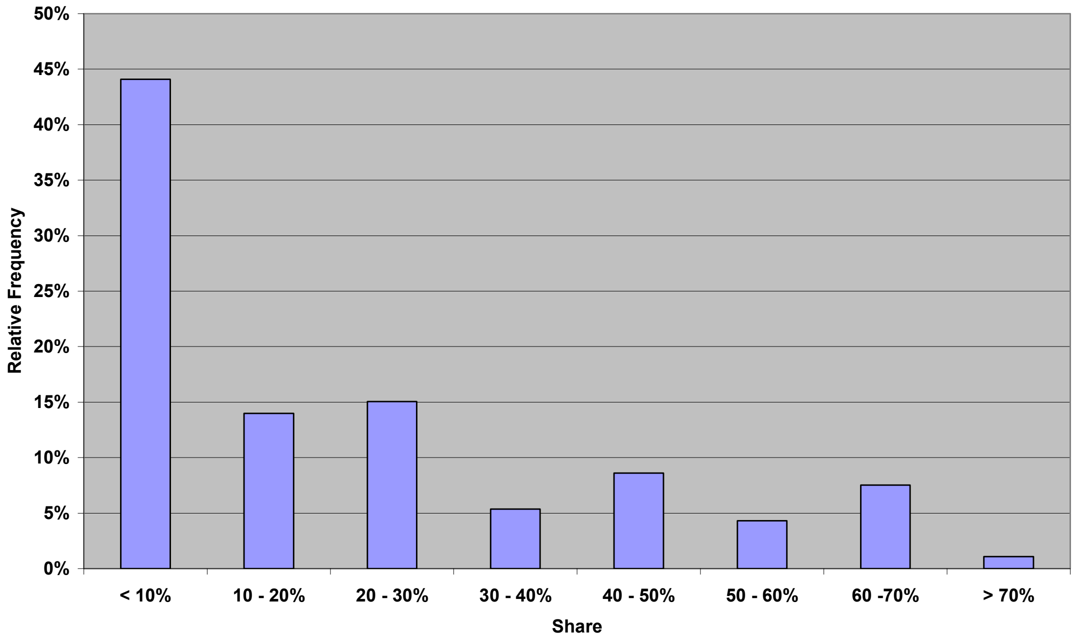
the survey responses for the remaining 9 homes confirmed that 8 of these homes indicated that they did not normally water their garden.

On average irrigation accounted for 28% of the water used during the logging period but for the 84 homes with garden usage the share was slightly higher at 30%. The share itself has little significance given the short duration of the logging period but the range of this share is meaningful. For one household irrigation use accounted for 73% of their total usage whilst as we have already seen for around 10% of homes irrigation share is zero.

Figure 35 below shows the distribution of irrigation share and in particular that the biggest group (44% of homes) is that for which irrigation accounts for 10% or less of total usage. As a result of this left skewed distribution the median share for irrigation use at 14% is well below the average of 28%.

So the measured data supports what we already know from analysis of summer quarter billing data: the average seasonal usage is skewed by large users with a majority of customers using well below “average” garden usage.

Figure 35: Irrigation Share of Total Use during Logging Period



Flow Rate

On average garden irrigation used water at the rate of 16.3 LpM. Table 19 below shows how the flow rate varied with the particular methodology[34] adopted. Manual sprinkler systems had the highest average flow rate at 18.9 LpM whilst hand held hose had the lowest average at 14.8 LpM.

Table 19: Irrigation Methodology Comparison

Main Irrigation Method	n =	% of Households	% of Irrigation Volume	Average Flow Rate lpm
Hand Held Hose	48	57%	43%	14.8
Manual Sprinkler	19	23%	41%	18.9
Automatic Sprinkler	5	6%	11%	15.4
Other/None/Unknown	12	14%	5%	15.7
Irrigation Households	84	100%	100%	16.3

Table 19 also presents the relative volume share for each of the irrigation methodologies and demonstrates that hand held hose is relatively more efficient than the use of sprinkler systems. ***Manual or automatic sprinkler systems were the main methodology for 29% of households but accounted for 52% of irrigation volume. Conversely those homes for which hand held hose is the main method make up 57% of homes but only 43% of the total irrigation volume.***

Irrigation Frequency

Because irrigation can often occur over an extended period in a stop and start fashion, the frequency and duration of irrigation are analysed on a daily basis rather than on an individual event basis. That is multiple irrigation events occurring on the same day are aggregated and analysed as one irrigation occurrence.

The average irrigation frequency per week is a pro rated number calculated as

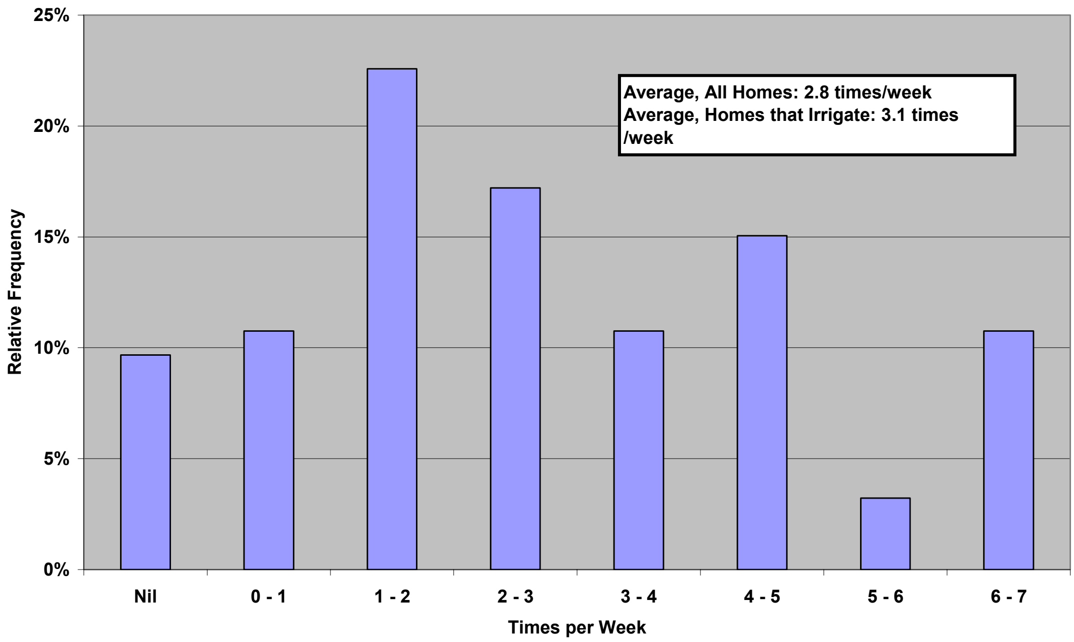
Number of days Irrigated/Total Days Logged * 7

Clearly with such a short logging period this parameter can be considered as indicative only.

Most commonly gardens are watered between 1 and 2 times (ie days) per week as shown in Figure 36 below. ***On average gardens are irrigated on 2.8 days per week or 3.1 days if just considering those homes that irrigate***. Some 29% of homes watered their gardens at a rate of 4 times or more per week.

[34] Note that a methodology comparison cannot be exact because many homes reported utilising two or more different methods of irrigation and usage identified by Trace Wizard© as "irrigation" makes no distinction between these methods. The "main" irrigation method was identified as the dominant method from the survey data on frequency and duration of each methodology. Where no one methodology was dominant these homes were counted in the "Other/None/Unknown group shown in Table 19.

Figure 36: Frequency of Garden Irrigation



The frequency of garden watering does not vary significantly across the different methods - refer to Table 20 below. The average frequency of use for automatic systems at 3.9 times per week appears to be higher than the other methods but with only five households in the group this conclusion cannot be made.

Table 20: Irrigation Frequency & Duration

Main Irrigation Method	n =	Days per Week	Average Duration (minutes)
Hand Held Hose	48	3.2	37
Manual Sprinkler	19	3.3	68
Automatic Sprinkler	5	3.9	57
Other/None/Unknown	12	2.1	28
Irrigation Households	84	3.1	46

Average Duration

Table 20 also shows the average daily duration of garden irrigation. ***Overall, homes that water their garden irrigate for an average of 46 minutes. However this differs significantly depending on the method used.*** Collectively automatic and manual sprinkler systems average 66 minutes and this is significantly[35] higher than the average duration for irrigation by hand held hose which on average lasts for 37 minutes.

[35] One tailed test for the difference between means at the 95% level of significance.

However analysis of the distribution of garden watering duration brings the average duration of 46 minutes above into question. Figure 37 below shows that a majority of irrigation is of short duration, in fact 61% lasts for 30 minutes or less. The median duration is just 18 minutes and the standard deviation at 93 minutes is more than double the mean. It is clear therefore that the average is skewed by some very large events.

This distribution results from particularly large single irrigation events for 3 homes as shown in the following table.

Table 21: Unusually Large Irrigation Events

	Irrigation Methodologies	Duration Hours	Avg Flow Rate lpm
Home 1	Hose Only	19	3.5
Home 2	Hose & Manual Sprinkler	14	1.0
Home 3	Hose Only	13	1.9

It is tempting to exclude these 3 events from the analysis which would reduce the average duration significantly from 46 to 40 minutes. However the question is whether these events are legitimate cases of how garden irrigation can occur.

Figure 37: Duration of Garden Irrigation

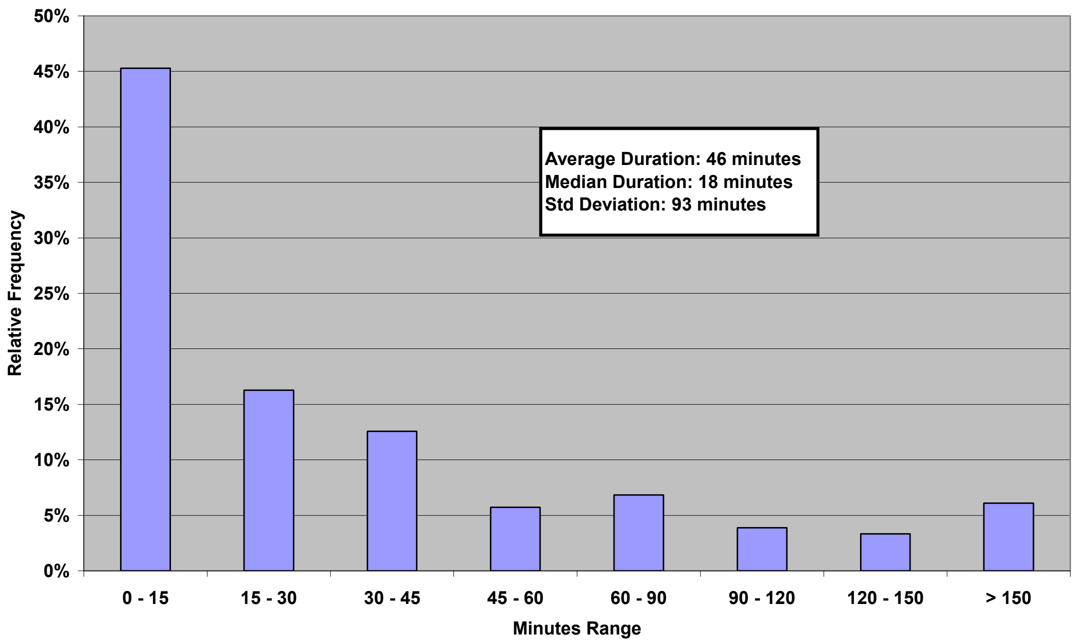


Table 21 also shows the average flow rate for these large events and they are all quite low ranging from 1 to 3.5 LpM. So the events could be either deliberate attempts at slow saturation irrigation or inadvertent occurrences such as forgetting that a tap was on or not turning the tap off completely. Either way, although unusually long, these appear to be events that could potentially occur on an ongoing basis so should be left in the analysis rather than excluded as outliers.

Survey versus Measurement

The 2003 ASUP[36] survey asked respondents to estimate for each irrigation methodology the number of times they watered their garden each week and for how long.

Table 22 shows the comparison of the ASUP and REUM studies for the frequency of irrigation and it can be seen that respondents appear to be reasonably adept at reflecting the frequency of their irrigation practices.

Table 22: Irrigation Frequency ASUP vs. REUM

Main Irrigation Method	Days per Week ASUP	Days per Week REUM
Hand Held Hose	3.3	3.2
Manual Sprinkler	3.1	3.3
Automatic Sprinkler	4.0	3.9

However the same cannot be said for the duration of irrigation, shown in Table 23 below. For the three major irrigation methodologies, respondents on average underestimated their actual duration by between 33 and 40 percent.

Table 23: Irrigation Duration ASUP vs. REUM

Main Irrigation Method	Avg Duration ASUP (minutes)	Avg Duration REUM (minutes)	% Under Estimation
Hand Held Hose	25	37	-33%
Manual Sprinkler	42	68	-38%
Automatic Sprinkler	34	57	-40%

5.9 Swimming Pools

The incidence of swimming pool use was too low to warrant analysis, with only 15 occurrences of pool use from just 9 households in the summer logging period only.

Overall pool use accounted for only 1.5% of the total summer logged volume. However for the nine homes that registered pool usage this use on average accounted for 12% of their total summer logged volume and ranged from 1% to 28%.

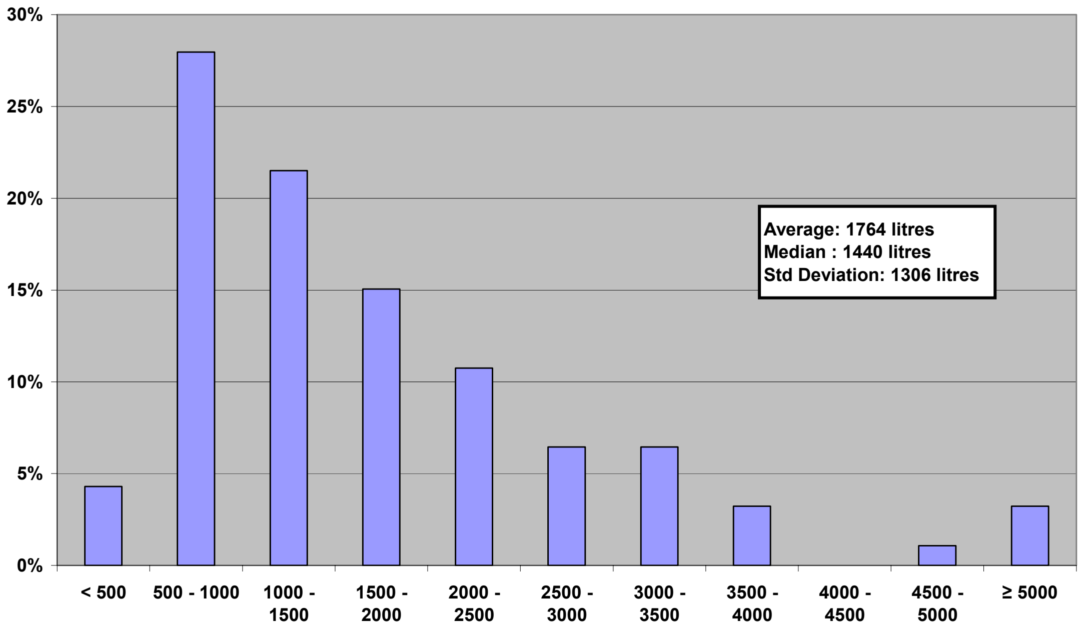
[36] Roberts, op cit

5.10 Peak Day & Hourly Use

Peak Day

The peak day demand was calculated for each of the 93 properties with logged data during the summer period. The frequency distribution for these peak demands is shown in Figure 38. The average peak day was 1764 litres and the median was 1440 litres. The highest one-day use by a study participant was 7254 litres which occurred on the hottest day during the logging period (maximum temperature 40.1^{o}) and on this day irrigation accounted for 93% of the total volume used at this property. In fact that property recorded total irrigation duration of 9 hours on the day.

Figure 38: Distribution of Peak Day Demands



However that highest household peak day was relatively unusual and for the majority of homes (75%) the peak day fell within the range 500 to 2500 litres.

Hourly Use

Analysis of the average hourly profile of usage for the logged homes revealed the typical diurnal profile but the end use measurement also revealed the contribution of each end use to the various peaks. The two logging periods also enables a comparison from summer to winter.

Figure 39: Average Hourly Profile - Summer & Winter Logging Periods

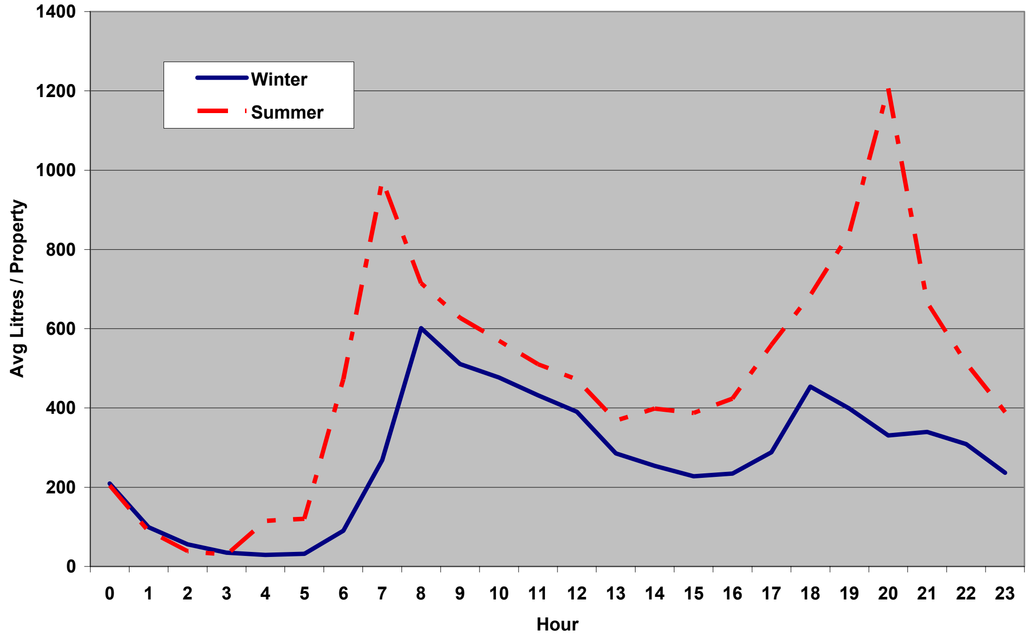


Figure 39 shows the average hourly profile of total usage for each of the logging periods. Note the additional morning peak in summer between 5 and 8 am which corresponds with the Stage 2 drought restrictions in place at the time.

The average contribution of each end use to each hour of the day during winter can be seen in Figure 40 below. In winter both the morning and afternoon peak appear to be driven by the shower end use.

Conversely in the summer the morning peak is the result of shower use whilst the evening peak is dominated by irrigation – refer to Figure 41 below. Once again Stage 2 drought restrictions will have impacted on the evening peak through the restriction of manual sprinkler systems to the hours of 8 pm to 11 pm.

Figure 40 and Figure 41 show the ***relative contribution*** of each end use throughout the day. To enable comparison of summer and winter quantities the same charts are repeated with ***volumes*** on the y-axis (refer to Figure 42 & Figure 43 below).

Figure 40: Average Hourly Profile by End Use - Winter Logging Period (%)

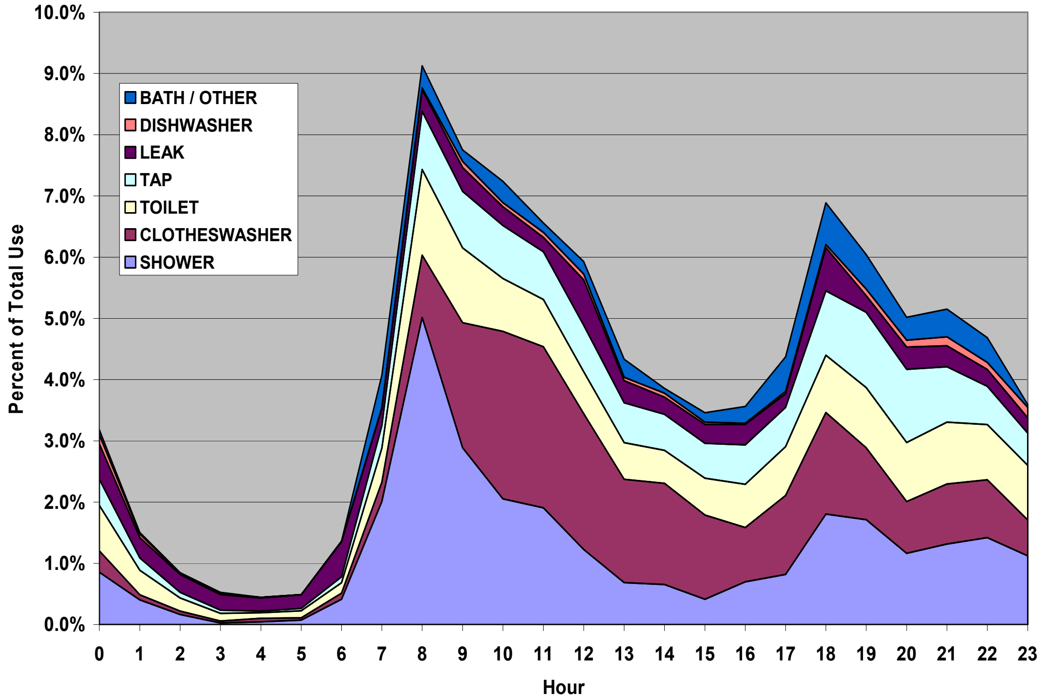


Figure 41: Average Hourly Profile by End Use - Summer Logging Period (%)

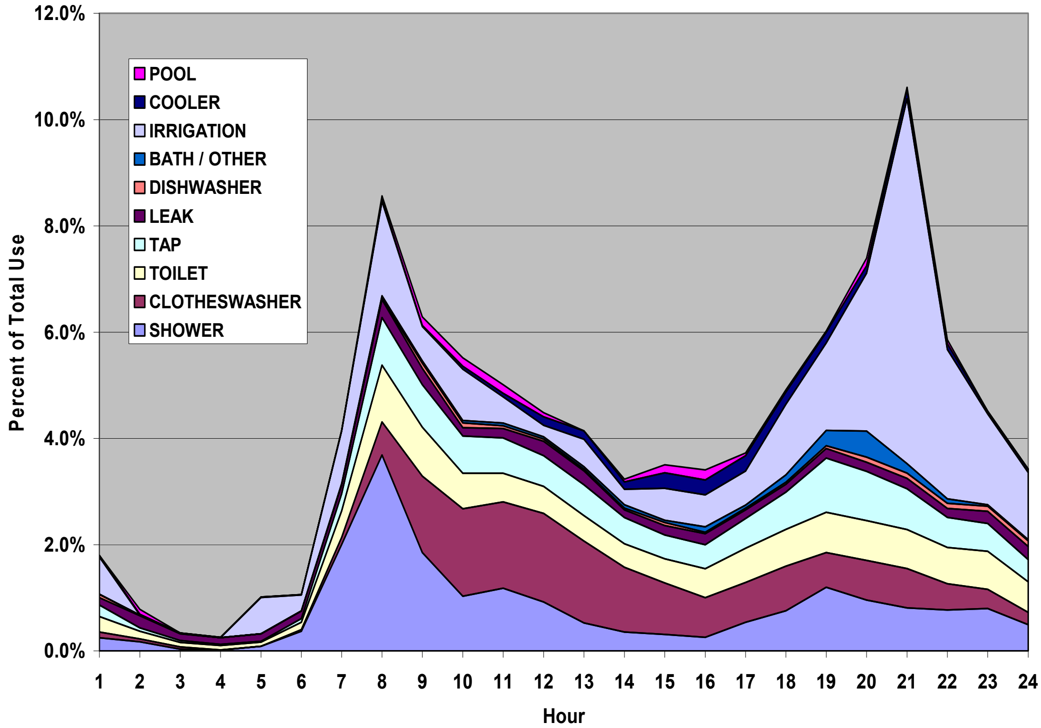


Figure 42: Average Hourly Profile by End Use - Winter Logging Period (Average Litres per Property)

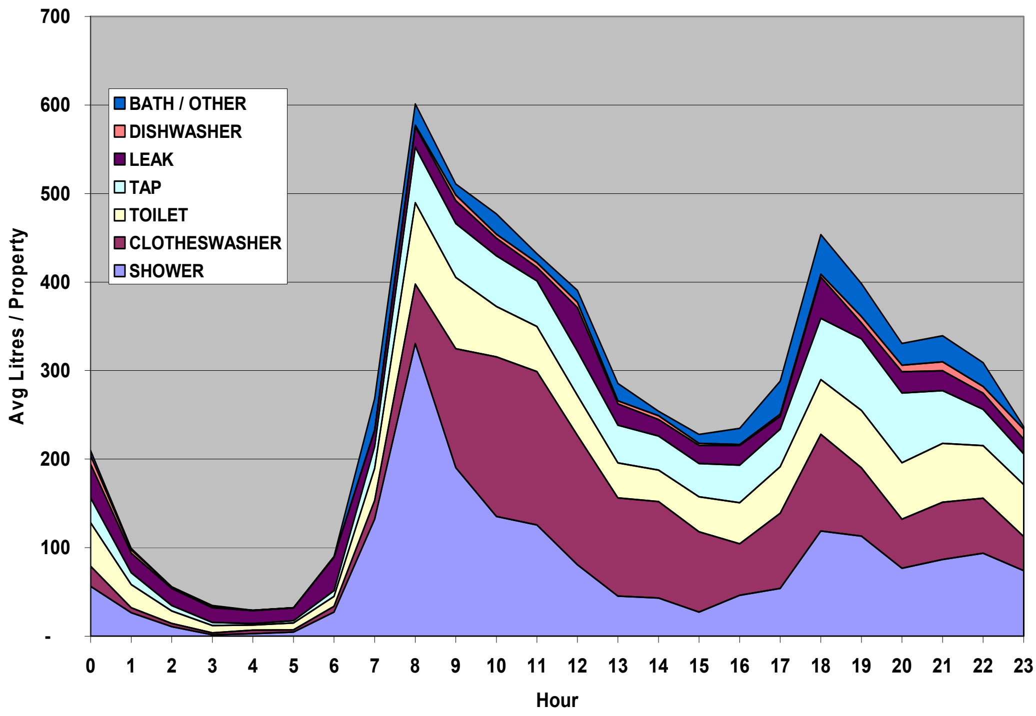
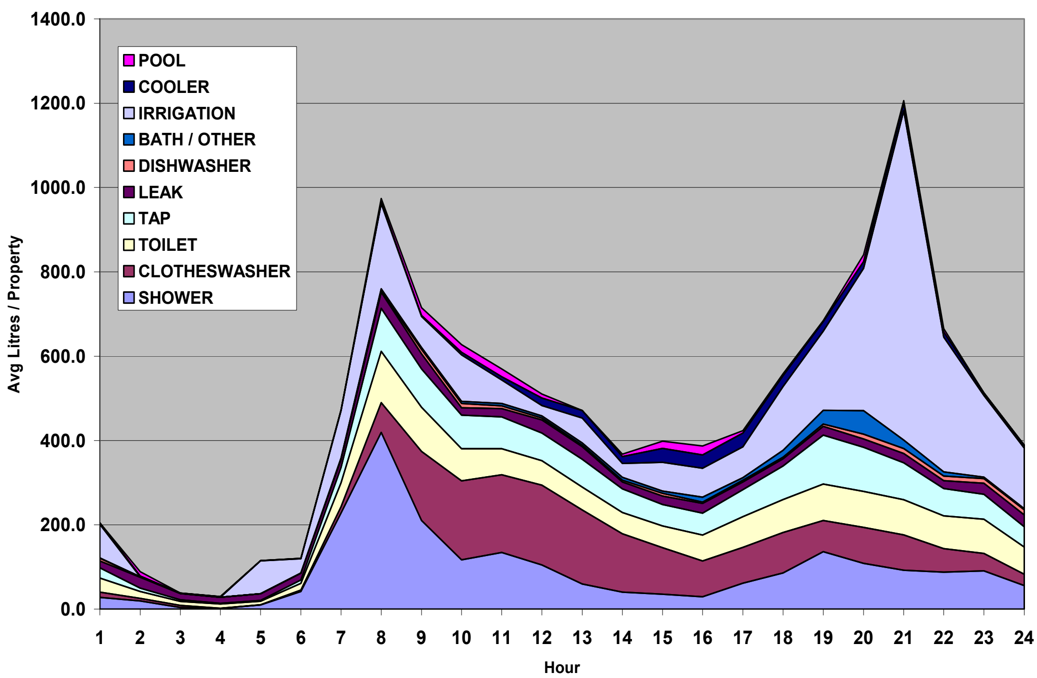


Figure 43: Average Hourly Profile by End Use - Summer Logging Period (Average Litres per Property)



6 Appendix A – Customer Letters

Initial Letter

<ADDRESS>

Dear <NAME>

You are invited to participate in a special Water Usage Study being undertaken by Yarra Valley Water. The attached Fact Sheet explains what the survey is and how it will be undertaken. Your household has been randomly selected as one of a sample of residential customers.

In return for your participation you will be offered your choice of a gift voucher or a rebate off your water bill to the value of $50.

Some of the participants may also be offered the choice to trial some water efficient toilets, although this is not an essential part of the study. If yours is one of the homes selected to trial these toilets, and you are happy with the product it will be yours to keep!

To ensure the sample is representative of our customers only some of the invited homes will be selected as final participants. If you are selected, specially modified water measuring equipment will be installed at your existing water meter's location. You will also be required to participate in a survey of your water using appliances and usage behaviour.

Yarra Valley Water will use the results of the Water Usage Study to forecast the future requirements for water and sewerage services and also to assist in the design of new water and sewer systems.

If you would like to be considered for participation in this study we ask that you please complete the short survey form on the back of the enclosed postage paid envelope and return it by mail.

Sincerely

PETER ROBERTS
Demand Forecasting Manager
Yarra Valley Water

WATER USAGE STUDY FACT SHEET

WHAT IS THE STUDY?
The project will involve studying the water use at 100 homes within Yarra Valley Water's service area. Daily water use data will be collected and analysed over a period of several years. Data loggers (devices that can register water usage at pre-set time intervals) will be installed on the water meter outside the home. This data will be analysed by a team of YVW staff and professional consultants.

WHY CONDUCT THE STUDY?
There are two main purposes of the study. The first is to determine the amount of water used by different household appliances and fixtures. This data will assist with long term water resources planning. The second is to measure how flows vary throughout the day and over the various seasons. This data will contribute directly to the design of new water infrastructure.

WHO WILL ADMINISTER THE STUDY?
YVW staff will administer the study together with our plumbing contractor Schultz Plumbing who will install the equipment and collect the data.

HOW WILL THE STUDY BE CONDUCTED?
Data loggers connected to specially modified water meters will continuously collect water usage data at 5 minute intervals for a period of at least 3 years. The data will be downloaded every six months. In the first year only, for each of two 2 week periods in summer and winter, the data logger will be reset to collect data at 5 second intervals. This data will be downloaded at the end of each two week period. The data can be downloaded directly from the water meter without the need for residents to be at home.

WHEN WILL THE STUDY TAKE PLACE?
It is anticipated that the equipment will be installed by December 2003 and remain in place until June 2007.

HOW MUCH OF MY TIME WILL BE NEEDED?
The study requires an initial interview to record what types of appliances are in the home and how they are used. This will take about one and a half hours of your time. At the same time the data logger and special meter will be installed. Each year you will be asked to complete a small survey to determine if any changes have occurred in the household such as appliance replacement or changes in the number of people in the household. Other than this the data collection process will continue without the need for your involvement.

WHAT IS REQUIRED OF ME?
If eligible and selected for the study you will be asked to sign an agreement to provide the survey data needed. Your water meter's location will need to be readily accessible. You should also be planning on staying in your home for the foreseeable future. That is, if you have an intention to move house within the next few years we would ask that you do not nominate for participation in this survey.

Appendix A

EMPTY ENVELOP, PLEASE DO NOT OPEN.

<table>
<tr><td colspan="2">Yes, I would like to participate in the Residential Water Usage Study.</td></tr>
<tr><td colspan="2">Name:</td></tr>
<tr><td colspan="2">Address:</td></tr>
<tr><td>Home Phone:</td><td>Work Phone:</td></tr>
<tr><td>No. of people living in house:</td><td>Age of House (approx):</td></tr>
<tr><td>No. of Toilets in house:</td><td>No. Years lived in this house:</td></tr>
<tr><td colspan="2">Would you be interested in a trial that replaces the toilets in your house with more efficient toilets? □Yes □No</td></tr>
<tr><td colspan="2">Does the most used toilet in your house have an outlet to the floor or to the wall? □Floor □Wall</td></tr>
</table>

Appendix A

Follow Up Letter One – All registers of interest

Date

Address 1
Address 2
Address 3

Dear

Water Usage Study

Thank you for your recent response to register your interest in participating in our water usage study. We received replies from nearly 200 homes and are now going through the process of selecting the 100 homes that represents the best cross section of our customer base.

It is useful to have spare homes in case site visits of the 100 selected homes should indicate that the site is not suitable for some reason. Consequently I would like to keep all names on the list at this stage until the final 100 homes are successfully up and running with the special measuring equipment. In the meantime I would ask for your patience and assure you that all those who have registered interest will be notified of the outcome as soon as possible.

We are planning to install the special measuring equipment in a pilot group of 10 homes in December and the remaining homes will be done in January 2004. If selected, your property will be in this latter group. Providing your meter is readily accessible the equipment can be installed without the need to bother you at the time.

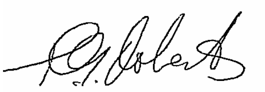
The equipment will be installed by Yarra Valley Water's plumbing contractor, Schultz Plumbing. In addition to providing data for the study, this equipment will also be used for billing purposes. If the installer considers the equipment is exposed to potential vandalism he will encase the meter in a locked container.

Within two weeks of the installation you will be contacted by our licensed consultants to make an appointment at your home to record detailed information about your water using appliances and how you use them.

continued over…..

If you have any concerns or questions please feel free to call me on **9872 1648.** Once again thank you very much for your interest in helping us to plan for the future water resources for Melbourne.

Sincerely



PETER ROBERTS
Demand Forecasting Manager
Yarra Valley Water

Appendix A

Follow Up Letter Two – Pilot Group

Address 1
Address 2
Address 3

Dear

Water Usage Study

Thank you for your recent response to register your interest in participating in our Water Usage Study. We received replies from nearly 200 homes and are now partially through the process of selecting the 100 homes that represents the best cross section of our customer base.

We intend to start installing the special measuring equipment in December. Your home is one of a small number of properties that has been selected as a pilot group to check that the equipment delivers data as expected. Providing your meter is readily accessible the equipment can be installed without the need to bother you at the time.

The equipment will be installed by Yarra Valley Water’s plumbing contractor, Schultz Plumbing. In addition to providing data for the study, this equipment will also be used for billing purposes. If the installer considers the equipment is exposed to potential vandalism he will encase the meter in a locked container.

Within two weeks of the installation you will be contacted by our licensed consultants to make an appointment at your home to record detailed information about your water using appliances and how you use them.

If you have any concerns or questions please feel free to call me on **9872 1648.** Once again thank you very much for your interest in helping us to plan for the future water resources for Melbourne.

Sincerely

PETER ROBERTS
Demand Forecasting Manager
Yarra Valley Water

Appendix A

Follow Up Letter Three – Balance of Sample

18 July 2005

Address 1
Address 2
Address 3

Dear

Water Usage Study

Your home has been selected as part of the final sample of 100 homes to participate in Yarra Valley Water's water usage study.

The special measuring equipment will be installed within the next two weeks and as previously advised in most cases this can be undertaken without the need to bother you at the time.

The equipment will be installed by Yarra Valley Water's plumbing contractor, Schultz Plumbing. Within two weeks of the installation you will be contacted by our licensed consultants to make an appointment at your home to record detailed information about your water using appliances and how you use them.

Additionally if your home is subsequently selected as one of a smaller sample suitable for possible retrofit of a low flush toilet, you may be contacted within the next month to pursue this option. As stated previously this is an entirely voluntary aspect of the study.

If you have any concerns or questions please feel free to call me on **9872 1648.** Once again thank you very much for your interest in helping us to plan for the future water resources for Melbourne.

Sincerely

PETER ROBERTS
Demand Forecasting Manager
Yarra Valley Water

Appendix A

Follow Up Letter Four – Not Required for Sample

Date

Address 1
Address 2
Address 3

Dear

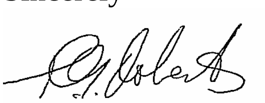
Water Usage Study

Thank you for your recent response to register your interest in participating in our water usage study. We received replies from nearly 200 households and have selected a sample of 100 homes that represent a cross section of our customer base.

At this stage your home has not been included as part of the final sample for this study. However I intend to keep your name on the list in case some of the participating households should decide to withdraw from the study or if future studies eventuate.

Once again thank you for your interest in helping us to plan for the future water resources for Melbourne.

Sincerely



PETER ROBERTS
Demand Forecasting Manager
Yarra Valley Water

7 Appendix B – Measuring Equipment

CT5-S 20mm totaliser positive displacement flowmeter with high rate 72.5/litre pulse output

FEATURES

- Volumetric rotary piston principle, measures accurately in any position.
- Mechanical totaliser.
- 72 counts/litre reed switch contact closure output for precision data collection and flowrate readings
- Designed to meet AS3565.1-1998
- Accuracy ± 2 % (q-min to q-max) Repeatability ±0.15%

The CT5-S 20mm water meter is suitable for measurement of cold water upto 50°C with a working pressure upto 1500 kPa. The meter offers great accuracy and a long operating life for domestic drinking water applications.

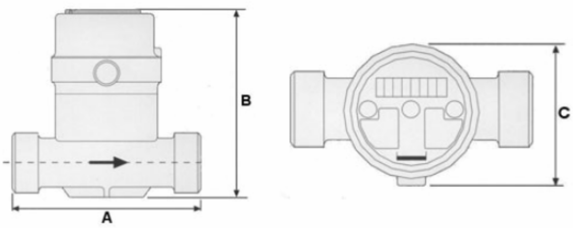
The mechanical counter register is positioned for easy reading and displays from 0.02 to 9,999,999 Litres. The precision engineered rotary piston measuring chamber ensures accurate measurement even at very low starting flow rates. Meters can be installed in any position without affecting accuracy and require no onsite calibration. An inline filter element prevents blockages and an internal check valve stops backflows (can optionally have dual check-valves).

CT5-S flowmeters are fitted with a high resolution reed switch contact closure output. At the request of various water authorities, with Manuflo technology, 72.5 pulses per Litre output signal is achieved, which is the highest amount of pulses per Litre for a domestic water meter (whilst retaining the mechanical register). This allows capture of precision water measurement information to data-loggers and to other data collection devices. Very accurate data can then be obtained for water usage totals and flowrate habits of consumers. Electrical connection is via a 1.5 metre 2-core shielded cable.

All meters are supplied with a gasket seat coupling connection kit (optional ball seat available). CT5-S flowmeters are manufactured from high quality materials to meet Australian specification requirements.
The CT5-S 20mm provides the best pulse output rate for domestic water meters, with 72.5 pulses/litre.

SPECIFICATIONS

Size (mm)		20
Pulse output rate	Litres/pulse	72.5
Mechanical register	Minimum Litres	0.02
	Maximum KL	9999.9999
Starting flow rate		0.033
Min. registration	Qr ±5% LPM	0.05
Min. trans. flow	Qt ±2% LPM	0.41
Nom. continuous flow	Qn ±2% LPM	41.6
Max. intermittent flow	Qs ±2% LPM	83.3
Weight with couplings	Kg	1.9



Other Specifications
Headloss @ Qn <25kPa., Max. pressure rating 1500kPa, Max water temperature 50°C,
Accuracy Qt to Qs +/-2%, Repeatability +/-0.15%.
Reed switch pulse V.max:24V, I.max:50mA, with anti-bounce and current-limiting resistor fitted.
Cable 2-core, 1.5 metre length.

Pipeline must be full at all times for correct measurement. Suitable for clean water only. Purge the pipeline prior to install. Once installed, to avoid damage to measuring chamber, bleed the liquid into the pipeline and flowmeter.

DIMENSIONS mm

Model No:	CT5-S
Length A mm	152
Height B mm	145
Width C mm	92

ORDERING CODES

Part	Size (mm)	Description of coupling set
CT5-S	20	Gasket seat ¾"Bsp(m)
CT5-S-G	20	Ball seat ¾"Bsp(f)

ManuFlo®™
Flow Measurement Products
a division of
MANU ELECTRONICS PTY LTD
Rev: 03/04
41 Carter Rd., Brookvale NSW 2100
Sydney, Australia
Ph: +61 2 9938-1425 Fax: +61 2 9938-5852
www.manuelectronics.com.au

Appendix B

Modified Actaris CT5 meter with initial logger Monatec Data Monita XT

Modified Actaris CT5 with replacement logger Monatec Monita D Series

8 Appendix C – Data Examples

Example of datalogger output

Date Time	Logger ID	Counts	Interval (sec)	Cumulative Counts	Litres	Cumulative Litres	Litres per second	UoM
11/08/2004 5:38:34	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:38:39	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:38:44	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:38:49	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:38:54	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:38:59	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:04	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:09	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:14	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:19	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:24	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:29	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:34	1806	0	5	106413	0	1477.9583	0	Litres
11/08/2004 5:39:39	1806	51	5	106464	0.708333	1478.6667	0.14	Litres
11/08/2004 5:39:44	1806	59	5	106523	0.819444	1479.4861	0.16	Litres
11/08/2004 5:39:49	1806	55	5	106578	0.763889	1480.25	0.15	Litres
11/08/2004 5:39:54	1806	45	5	106623	0.625	1480.875	0.12	Litres
11/08/2004 5:39:59	1806	33	5	106656	0.458333	1481.3333	0.09	Litres
11/08/2004 5:40:04	1806	21	5	106677	0.291667	1481.625	0.06	Litres
11/08/2004 5:40:09	1806	9	5	106686	0.125	1481.75	0.03	Litres
11/08/2004 5:40:14	1806	4	5	106690	0.055556	1481.8056	0.01	Litres
11/08/2004 5:40:19	1806	4	5	106694	0.055556	1481.8611	0.01	Litres
11/08/2004 5:40:24	1806	2	5	106696	0.027778	1481.8889	0.01	Litres
11/08/2004 5:40:29	1806	2	5	106698	0.027778	1481.9167	0.01	Litres
11/08/2004 5:40:34	1806	1	5	106699	0.013889	1481.9306	0	Litres
11/08/2004 5:40:39	1806	1	5	106700	0.013889	1481.9444	0	Litres
11/08/2004 5:40:44	1806	1	5	106701	0.013889	1481.9583	0	Litres
11/08/2004 5:40:49	1806	1	5	106702	0.013889	1481.9722	0	Litres
11/08/2004 5:40:54	1806	1	5	106703	0.013889	1481.9861	0	Litres
11/08/2004 5:40:59	1806	1	5	106704	0.013889	1482	0	Litres
11/08/2004 5:41:04	1806	0	5	106704	0	1482	0	Litres
11/08/2004 5:41:09	1806	2	5	106706	0.027778	1482.0278	0.01	Litres
11/08/2004 5:41:14	1806	0	5	106706	0	1482.0278	0	Litres
11/08/2004 5:41:19	1806	0	5	106706	0	1482.0278	0	Litres
11/08/2004 5:41:24	1806	1	5	106707	0.013889	1482.0417	0	Litres
11/08/2004 5:41:29	1806	0	5	106707	0	1482.0417	0	Litres
11/08/2004 5:41:34	1806	0	5	106707	0	1482.0417	0	Litres
11/08/2004 5:41:39	1806	1	5	106708	0.013889	1482.0556	0	Litres
11/08/2004 5:41:44	1806	0	5	106708	0	1482.0556	0	Litres
11/08/2004 5:41:49	1806	0	5	106708	0	1482.0556	0	Litres
11/08/2004 5:41:54	1806	0	5	106708	0	1482.0556	0	Litres
11/08/2004 5:41:59	1806	2	5	106710	0.027778	1482.0833	0.01	Litres
11/08/2004 5:42:04	1806	0	5	106710	0	1482.0833	0	Litres
11/08/2004 5:42:09	1806	0	5	106710	0	1482.0833	0	Litres
11/08/2004 5:42:14	1806	0	5	106710	0	1482.0833	0	Litres
11/08/2004 5:42:19	1806	0	5	106710	0	1482.0833	0	Litres

For analysis by Trace Wizard© this data is used to create an access database for each property containing the date time field and the usage for each interval as litres per minute flow rate.

Appendix C cont'd

Example Trace Wizard Summary Report

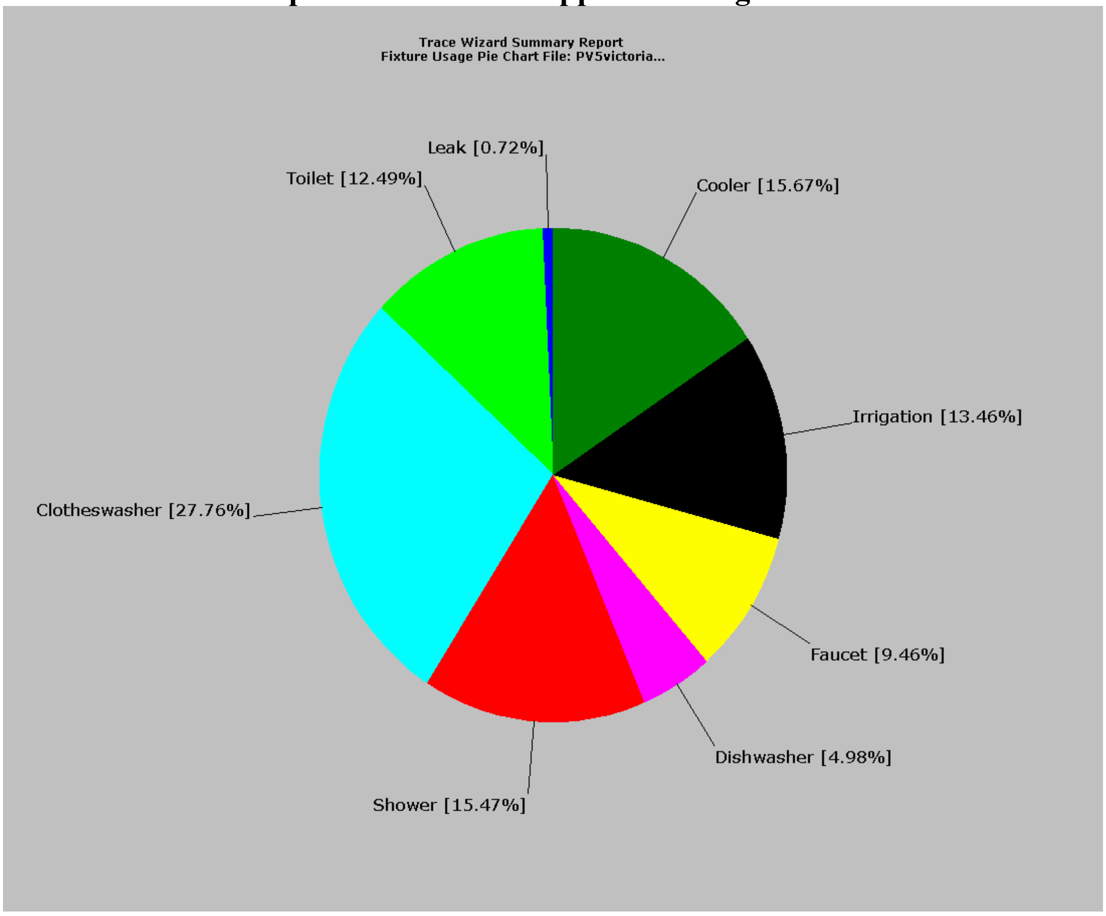
Total Volume By Fixture

Site: PV5victoria

Start Date: 13/02/2004 9:24:45 AM
End Date: 27/02/2004 8:27:45 AM

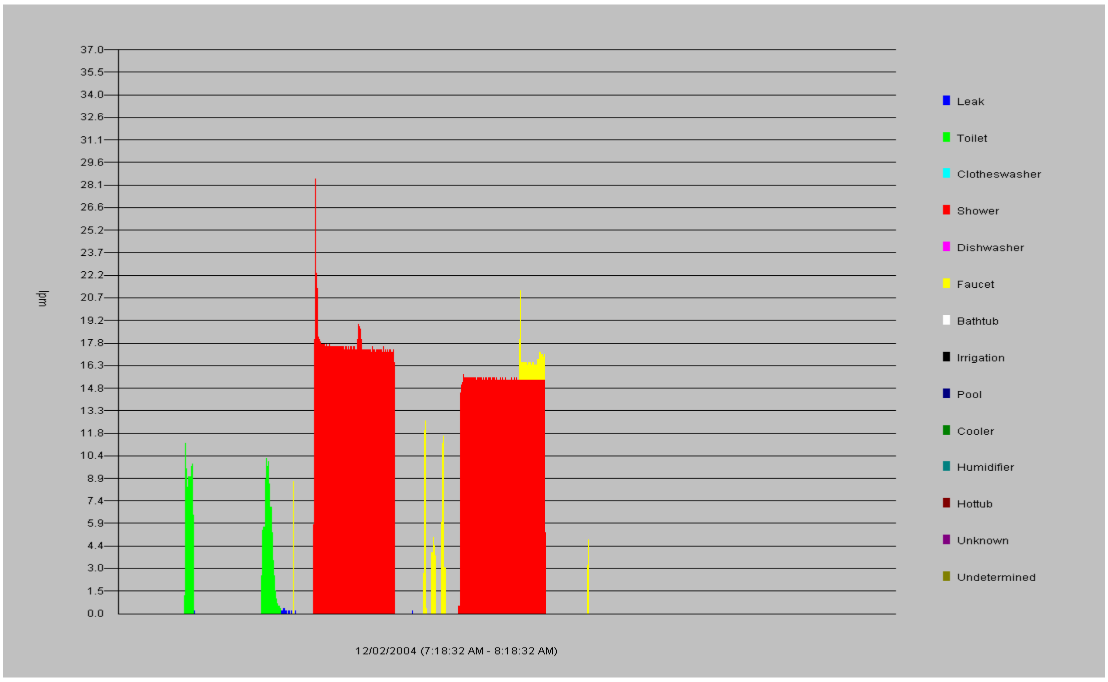
CATEGORY	VOLUME
Leak	38.41
Toilet	662.19
Clotheswasher	1472.05
Shower	820.18
Dishwasher	264.23
Faucet	501.45
Irrigation	713.71
Cooler	831.07
TOTAL:	5303.29

Example Trace Wizard Appliance Usage Pie Chart

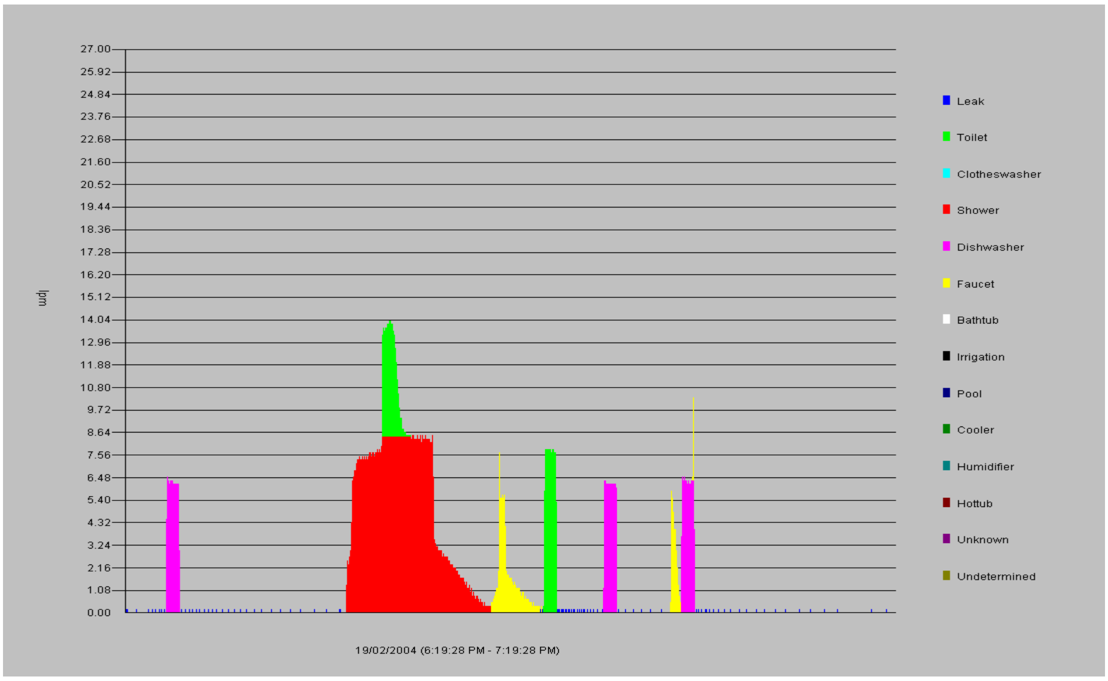


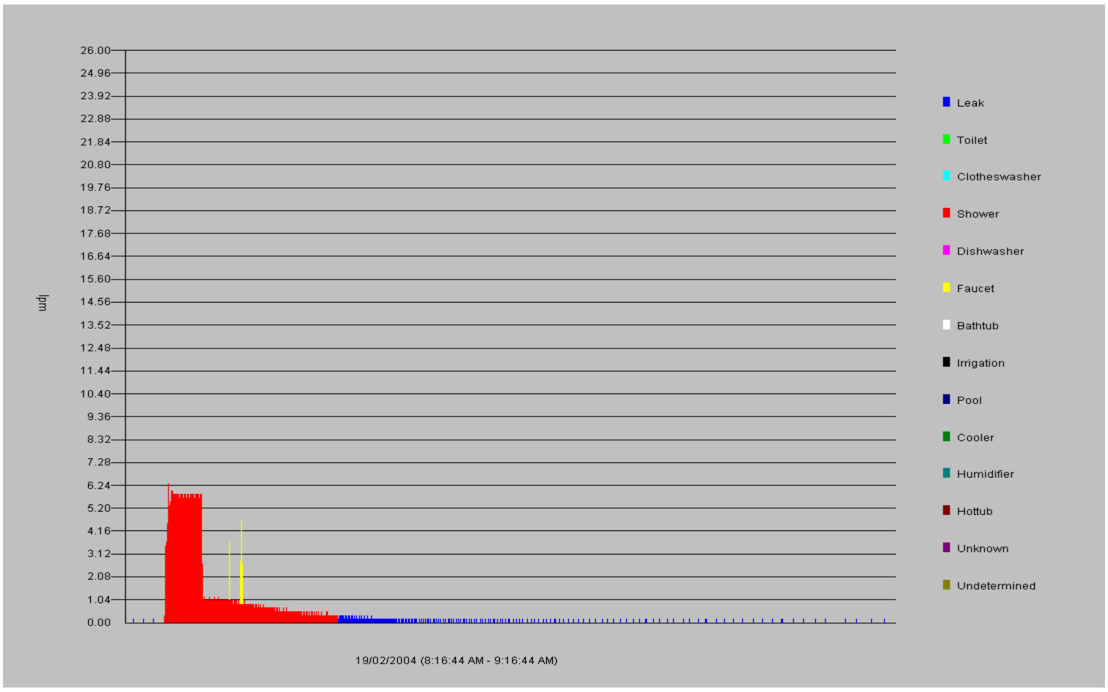
9 Appendix D – Gravity Fed Hot Water Services

For the majority of households with non gravity fed hot water services shower usage (red coloured sections) is typically portrayed in Trace Wizard as shown below:



The chart above reflects a fairly uniform flow rate other than for an initial spike when the shower is turned on. However because of the nature of gravity feed hot water services the shower signature in Trace Wizard are quite different as the examples shown in the next two diagrams demonstrate:





As the examples show there is an elongated period of usage at a very low flow rate in the later part of the shower events. This is because gravity fed hot water services operate at low pressure and refill very slowly, controlled by a floating arm & ball valve mechanism.

It appears that Trace Wizard has reasonably accurately identified the total volume of water involved in the shower event but that the durations are overstated by the extended hot water service refill period. Since flow rate is calculated from the volume and duration, the average flow rates will be correspondingly understated. For this reason data from the seven households with gravity fed hot water services was excluded from the shower duration and flow rate analysis.

While they could have been assessed manually, the numbers of households with gravity-feed hot water systems are insufficient either to affect the statistical inferences in a major way, or to collect useful data on households with gravity-fed hot water service and how their water use differs from water use in households with pressurized hot water services.

In a small number of instances the effect described above for shower use was also evident in tap use but this was not considered a problem due to the typically small duration and small volume events associated with tap use. The low incidence of elongated durations for tap use could also indicate the relative low contribution of hot water in this end-use.