Smart Water Fund

Final Report

Melbourne Residential Water End Uses Winter 2010 / Summer 2012

10TR5–001

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City West Water | South East Water | Yarra Valley Water

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Definitions

11/6 Dual Flush	A dual flush toilet capable of using 11 litres per full flush and 6 litres per half flush
ABS	Australian Bureau of Statistics
ASUPS	Appliance Stock and Usage Patterns Survey, tracks the trends in appliance ownership and usage patterns of water using appliances. It is a companion volume to this document. It reports on the results of surveys undertaken by City West Water, South East Water and Yarra Valley Water of water using appliances in the home and customers' use of them.
Cycle	A series of events used in 1 operating cycle of a property appliance
CWW	City West Water
Daily Maximum Temperature	Maximum temperature in the 24 hours from 9am on the date documented
Duration	The length of time of an event
Event	A flow of water that logs an entry with the database
End-use	A method in which water can be used on a property
Flow rate	Unit of quantity per time, usually litres per minute
Frequency	The number of times an appliance is used
L/Cap/Day	Litres per capita per day
L/min	Litres per minute
LGA	Local Government Area
Logger	A device that attaches directly to the household's water supply and records its flow properties (duration, time of day, flow rate etc).
Operational Hour	Unit of time for which household appliance is left switched on (differs from time spent consuming water)
REUMS	Residential End-Use Management Study
SEIFA	Socio-Economic Index for Areas (ABS)
SEW	South East Water
Trace Wizard©	A computer program used to disaggregate the packets of information sent by the logger into recognisable end-uses.
YVW	Yarra Valley Water

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Executive Summary 1

1.1 Background

In 2010, Melbourne's three retail water authorities (City West Water, South East Water, Yarra Valley Water) in conjunction with Western Water and Barwon Water installed high resolution meters and data loggers, capable of measuring water at the end use level, in 337 homes across their service areas. This included 100 homes for each Melbourne water retailer. Data was selected for analysis from the best two weeks in both July/August 2010 and January 2012, during which conditions were judged to be typical for the time of year. The results have been separately reported by each of the Melbourne water retailers (Quilliam, 2012) (Siriwardene & Nelson, 2012) (Roberts, Athuraliya, & Brown, 2012).

The end use level data collected formed a key element in establishing and updating an end-use model, with the dual benefit of forecasting demand and informing customers about the efficient use of water. Study findings also help guide decisions regarding investments for water efficiency programs.

This study presents analysis of the data at a Melbourne wide level, as well as the breakdown for each of the three water retailers in the Melbourne region in both the summer of 2012 and the Winter of 2010. The study reports on end uses as identified by Trace Wizard© Analysis including daily profiles as well as revealing relationships between end uses and household characteristics through basic regression analysis.

This report should be read in conjunction with The 2012 Melbourne Appliance Stock and Usage Patterns Survey Report, to gain a more complete picture of residential water use in Melbourne.

1.2 Average Daily Usage per Capita

Over the analysis period, average daily 2012 summer water use per household for the Melbourne region totalled 442 litres, which corresponds to a daily usage of 145 litres per capita. Between the winter and summer logging periods examined there is a 25% increase in daily household consumption in the summer and a 27% increase in daily per capita use. The break down is shown in Table 1.1.

		CWW	SEW	YVW	Melbourne
Summer 2012	Fortnightly Volume (L)	526,540	553,311	505,395	1,585,247
	L / Household / Day	470	499	371	442
	L / Cap / Day	149	166	121	145
Winter 2010	Fortnightly Volume (L)	478,088	443,817	437,966	1,359,871
	L / Household / Day	369	347	340	352
	L / Cap / Day	117	98	109	114

Table 1.1: Water Usage across all end uses for Melbourne and by region.

Figure 1.1 shows daily average water use per capita for the entire Melbourne region. As expected, the shower is the largest end use, regardless of season. Other figures to note are the 6 litres consumed by the evaporative cooler and the 21 litres used by irrigation recorded per person per summer's day. The summer values for these appliances were used as the winter figures were much lower and not indicative of their typical use.

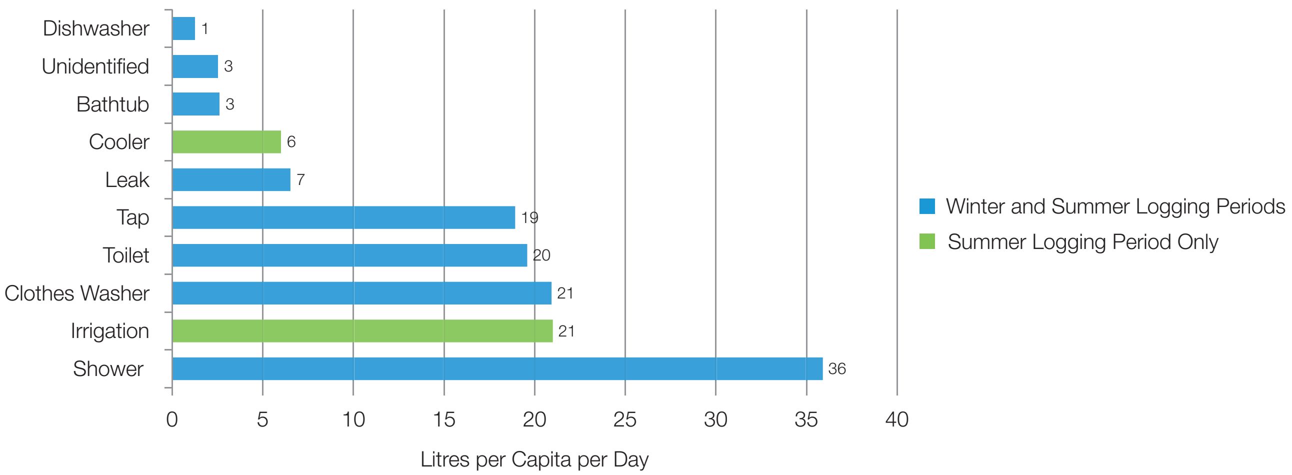


Figure 1.1: Daily average litres per person (combined winter and summer logging periods, summer only for cooler and irrigation).

Figure 1.2 below depicts end-use in summer by percentage share. As expected, the shower accounts for the largest share (26%), followed by irrigation (18%), tap (16%), clothes washer and toilet (13% each).

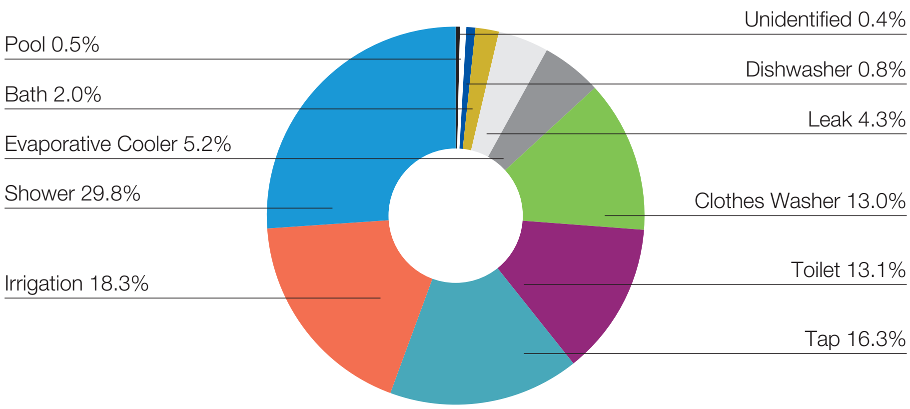


Figure 1.2: End use percentage share by volume (summer).

In contrast the winter period, although still dominated by shower use, ranks clothes washer and toilet as the second and third largest end uses (Figure 1.3), whilst irrigation and evaporative cooler make up 3.3% and 0.6% respectively. Leaks in winter constitute almost 6% of all water used, which corresponds to 6.5 litres per person per day, marginally higher than the 5 litres per person per day recorded in summer.

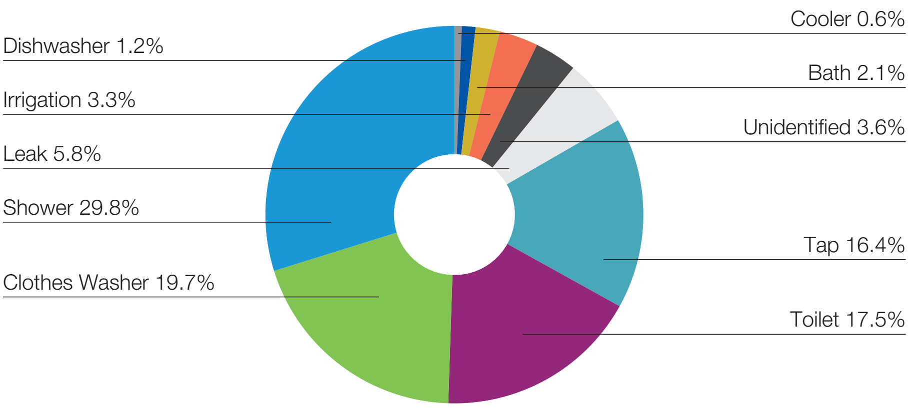


Figure 1.3 End use percentage share by volume (winter).

The proportion of each end use displayed in Figures Figure 1.2 and Figure 1.3 represents the breakdown of water use in Melbourne at an aggregate level. The divisions within each water company are shown in Figure 1.4.

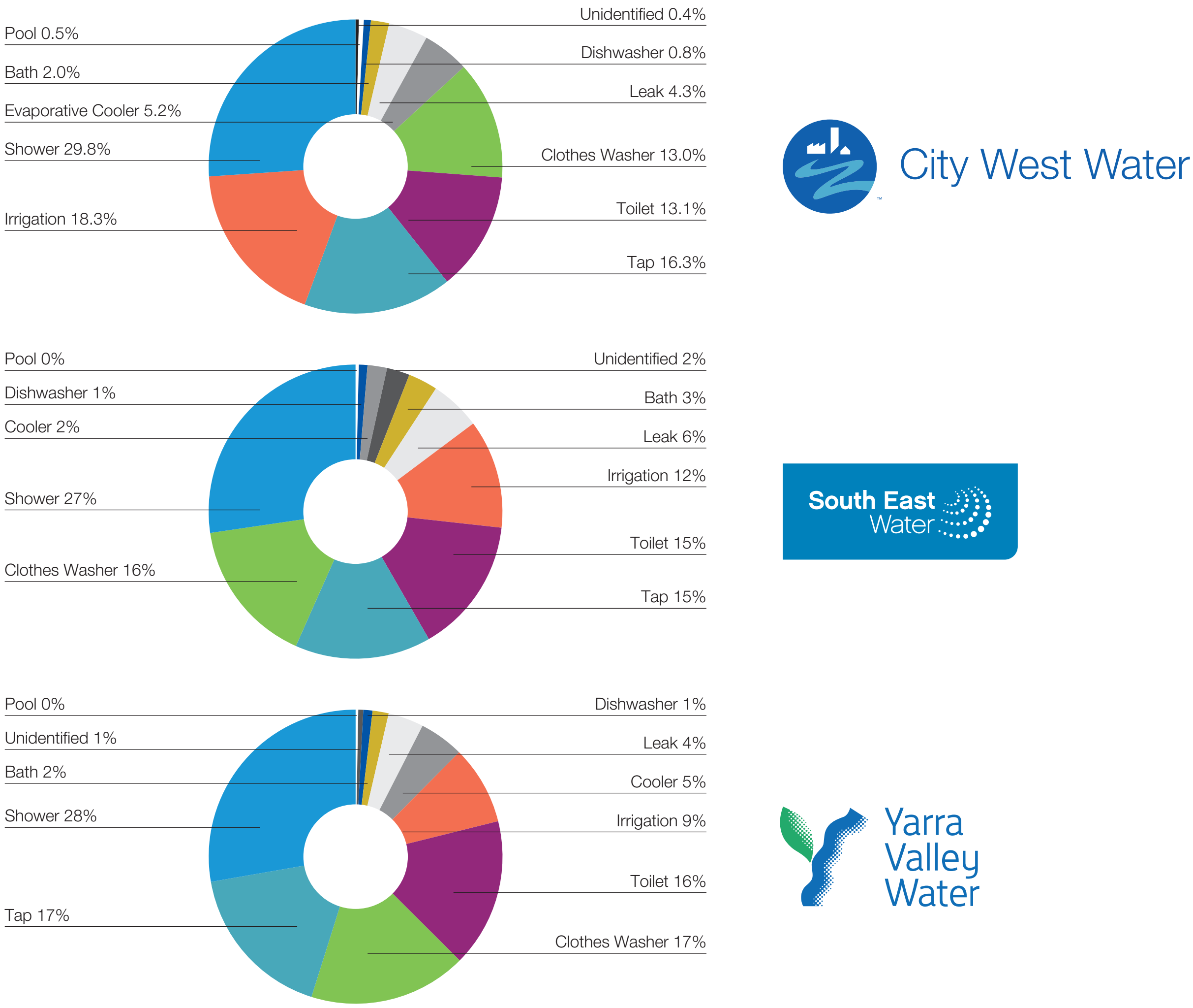


Figure 1.4: End use percentage share by volume for each retailer (combined summer and winter).

End use by volume remains constant in proportion across each retailer. Exceptions lie in the larger proportion of water devoted to evaporative coolers in the Yarra Valley Water customer base, the varying proportions of bath tub use and the random nature of leaks and drips. As can be seen in Figure 1.2 and Figure 1.3, indoor usage typically accounts for 76% in summer and 96% in winter.

Showers

Showering accounted for 33% of all indoor use on average, which equates to 36 litres/capita/day. The average flow rate was recorded at 7.2 litres/minute, with an average duration of 6.5 mins and average frequency of 0.8 showers per person per day.

Average flow rate for efficient showers capacity flow rate is 6.9 litres/minute. Efficient showers by definition have a capacity flow rate of less than 9 litres/minute.

Toilets

The toilet represented 18% of indoor water used on average, or 20 litres per capita per day. People flushed on average 3.8 times a day, exhibiting a 55:45 half to full flush ratio.

Average flush volume was logged at 5.9 litres, which exceeds the average quantities flushed by 4.5/3 dual flush and 6/3 dual flush toilets which flushed 5.2 and 5.4 litres respectively. The inefficiency of 4.5/3 toilets is addressed in Section 7.2.2.

Clothes Washers

The clothes washer appliance used 21 litres per capita per day, corresponding to a seasonal average of 19% of indoor use. Average load volume across all machine types and seasons was 88 litres, with 53 litres for an average front loader cycle and 123 litres for a top loader.

Dishwashers

The dishwasher was the smallest indoor use, using 1 litre per capita per day across the sample on average. Average load volume was found to be 14.9 litres, with a modelled weekly usage of 2.8 cycles. Note that these amounts refer only to the water used by the dishwashing machine.

Tap Use

Miscellaneous indoor tap use refers to kitchen taps, laundry troughs and hand basins, typically recording high frequency, low volume usage events. These values were measured at 1.3 litres per use and 19.6 uses per person per day. Average flow rate was recorded as 2.7 litres per minute.

Bath Use

The bath was the least common indoor end use, using 3 litres per capita per day, for those who use the bath. This appliance logged a weekly usage of 0.74 times per capita in households with a bath, and 0.84 times per capita in households with children under 10. Average bath volume was 125 litres.

Leakage

Generally considered to be of little importance, leaks and drips accounted for 6% of total use. Thirty-nine out of 294 households were responsible for approximately 80% of this figure. The bulk of leaks and drips lasted for less than 5 seconds. There was a slight correlation found between number of people in the home and average daily volume.

Introduction

2

The primary objectives of the combined 2010–12 Melbourne Residential End Use Study (REUMS 2010–12) are:

- To collect actual usage data in such a way that it can be disaggregated into individual end uses.
- To collect end use data that enables critical evaluation and revision of previous estimates of end-use model parameters.
- To report these end-use model parameters on a Melbourne wide scale.

Since 2004, residential water use in Melbourne has changed significantly. Usage in 2009/10 was estimated at 150 litres per capita per day compared to 202 litres in 2004/05. This substantial change in water usage behaviour coupled with the increasing efficiency of appliance stocks warrants further investigation.

The REUMS 2010–12 is the first major end use measurement project undertaken on a Melbourne wide scale. Not only are the aggregate Melbourne consumption figures reported, but the findings across individual water retailers are also provided.

Methodology 3

3.1 Sample Representation and Demography

Previous studies have demonstrated that water consumption is influenced by socio-economic factors such as household income, household occupancy and household size (Renwick & Archibald, 1998). An indicator of Melbourne's socio-economic characteristics is presented by the Australian Bureau of Statistics' Socio-Economic Indexes for Areas (SEIFA) taken from the 2006 census and released in 2008. This index is portrayed in Figure 3.1 and shows larger proportions of more disadvantaged districts in the north-western and south eastern regions, serviced by City West and South East Water respectively. Similarly, the lighter regions representing the least disadvantaged are found firstly in Yarra Valley Water's and South East Water's service areas.

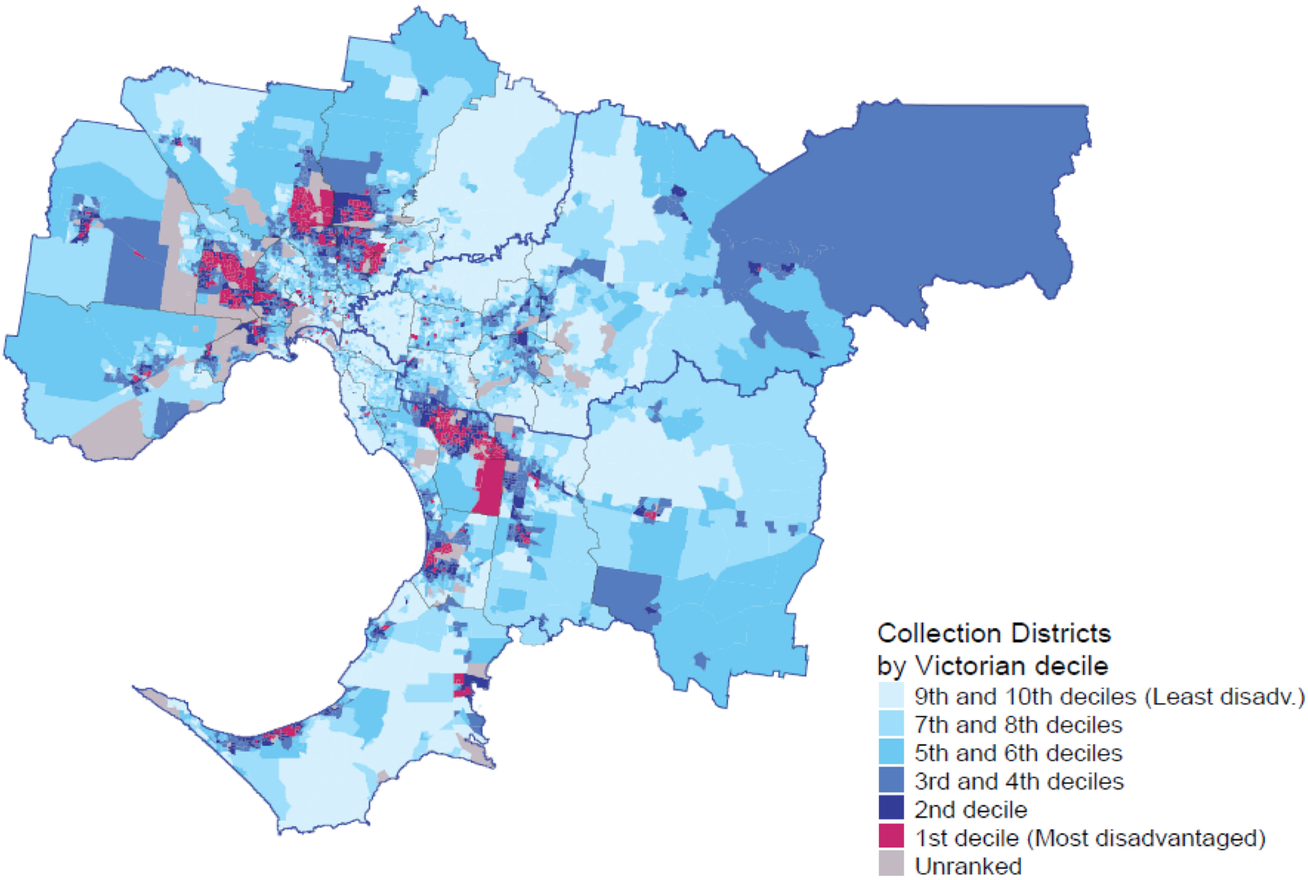


Figure 3.1: Areas of relative socio-economic disadvantage, 2006 (ABS, 2008)

Four of the 10 most disadvantaged Local Government Area's (LGA) in Melbourne are in each of City West Water or South East Water whilst Yarra Valley Water contains seven of the 10 most advantaged LGA's. That is, Yarra Valley Water appears to support a more affluent customer base, from which we generally expect greater outdoor water use. The same can be said for Bayside LGA within South East Water which ranks highly on the SEIFA index. Also characteristic to Bayside are the more sandy soils which require more irrigation due to less water retention. Table 3.1 contains information pertaining to the 10 most advantaged and 10 most disadvantaged LGAs and the percentage of Melbourne's population serviced by those LGAs.

	10 Most Disadvantaged		10 Most Advantaged	
	No. LGA's	Population 000's (% Melbourne)	No. LGA's	Population 000's (% Melbourne)
CWW	4	229.0 (5.5%)	2	48.6 (1.2%)
SEW	4	194.7 (4.7%)	1	35.4 (0.8%)
YVW	2	73.5 (1.8%)	7	241.6 (5.8%)

(ABS, 2033.0.55.001 – Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia – Data only, 2006, 2008)

Table 3.1: Number of Local Government Areas and their combined population serviced by each water retailer.

Of the sample chosen for the study, just over 8% of households lie in the 8th most disadvantaged LGA and just less than 8% are found in the 3rd most advantaged LGA. However households were selected to reflect the population characteristics of the metropolitan region. The selection process for these properties is outlined in Section 3.2. Table 3.2 contains the average rankings for economic resources, education and occupation and relative economic advantage and disadvantage, weighted by population. The objective of Table 3.2 is to demonstrate how each sample reflected the characteristics of the water retailer population it was drawn from.

Sample (Metropolitan Region)	Economic Resources[1]	Education and Occupation[2]	Relative economic Advantage and Disadvantage[3]
CWW	46 (47)	50 (55)	58 (64)
SEW	77 (73)	43 (60)	72 (73)
YVW	81 (75)	73 (73)	82 (79)

(ABS, 2008)

Table 3.2: Percentile in terms of Economic Resources, Education and Relative Economic Advantage and Disadvantage for each water retailer.

Also shown in Table 3.2, the Yarra Valley Water sample ranked highest in all categories of advantage which is in accordance with the most recent census data above in Figure 3.1. City West Water's ranked the lowest in both economic resource and relative economic advantage and disadvantage. The household selection from South East Water came in the 7th decile from economic resources and relative economic advantage, falling short in education and occupation, with a percentile ranking of 43. Note that the 99th percentile represents the most advantaged areas. These indices generally follow the population figures, shown in parentheses, with the exception of South East Water's lower than average Education and Occupation percentile rank for the sample.

Of the sample selected, approximately 90% of households were identified as living in a separate house within each retailer and in total, clearly exceeding the proportions recorded for the population which ranged from 68% to 77%. Although providing service to the CBD, there were no apartment or flat type properties selected within the City West Water group. Properties monitored from South East Water either lived in houses or apartments/units. There were seven households for which the property type was not recorded. See Table 3.3 for further details.

1 Focuses on census variables pertaining to housing expenditure and assets of households.
2 Such as, proportion of people with a higher qualification or those employed in a skilled occupation.
3 Derived from census values relating to advantage (high values) and disadvantage (low values)

Number of Properties	Flat, Unit or Apartment	Semi-detached, Terrace or Town House	Separate House	Total by Retailer
CWW	–	5	92	97
SEW	8	–	89	97
YVW	6	10	83	99
Sample	14 (4.8%)	15 (5.1%)	264 (90.1%)	293
All CWW	30.5%		69.5%	100%
All SEW	32%		68%	100%
All YVW	23.5%		76.5%	100%

Table 3.3: Number of properties by retailer and property type.

Thirty one per cent of the sample chosen are aged between 36 and 54, whilst 25% are over 55. Almost half of the sample is under 36, which represents a similar cross section to the general population, according to the ABS population data for Victoria released in 2010 (ABS, 2010). The number of people is evenly split between the three retailers. Note that Yarra Valley Water study data has a household of 2 people that did not disclose their ages. The full breakdown is shown in Table 3.4.

Number of Persons	Aged 55+	Aged 36–54	Aged 19–35	Aged 11–18	Aged 0–10	All Persons
CWW	62	112	51	35	54	314
SEW	89	93	52	33	35	302
YVW	82	85	42	46	55	312
Sample	233 (25%)	290 (31%)	145 (16%)	114 (12%)	144 (16%)	928
Population	26%	27%	25%	10%	12%	–

Table 3.4: Number of people by retailer and age compared to population data from ABS.

According to the 2011 Census data, the average number of people per household was found to be 2.6 for Australia and the greater Melbourne City statistical area. The average number of children was recorded at 1.9 per household (ABS, 2012). This is lower than the representation in the sample, which reported 3.1 people per household but compares well with the 1.7 children contained in the average sample home.

3.2 Sample Size and Selection

Upon reviewing the statistical benefits and costs of various sample sizes, it was decided that 100 households per retailer would be sufficient to provide some useful data at a reasonable expense. Suburbs were stratified into “low”, “medium” and “high” average consumption areas, from which a subset was selected at random. Once selected, customers were requested to register their interest in participating via phone, at which stage a preliminary screening was conducted. Of the customers who passed the screening, 100 households were selected. A list of questions used at the call centre is provided in Appendix 3 – Customer Information used for Selection.

From Table 3.5 we can see that, of the sample chosen, the most common household size is 2 people. Of the homes with seven people living together, two of them are found in Yarra Valley Water’s customer base. There are no homes in City West Water that contain only one person. South East water has the lowest average occupancy, with 3.0 people living in one household on average.

Households	1	2	3	4	5	6	7	Total
CWW	0	38	24	27	8	3	0	100
SEW	11	35	19	18	11	5	1	100
YVW	12	33	16	18	14	5	2	100
Melbourne	23 (8%)	106 (35%)	59 (20%)	63 (21%)	33 (11%)	13 (4%)	3 (1%)	300

Table 3.5: Distribution of household size by retailer and on average

3.3 Measurement Technology

Water is measured at its end use through the implementation of high resolution data loggers attached to the residential meters. Data is uploaded via wireless transmission and analysed using Trace Wizard©, an end use analysis tool.

Actaris CT5 standard residential water meters were modified to operate at 72 pulses per litre, which represents a significantly higher resolution than their normal 2 pulses per litre. As a result, the smallest measurable volume is 0.014 litres. For more detail regarding the specifications of the modified meters, see Appendix 2 – Measuring Equipment.

Data was captured via the use of Aegis R series data loggers. As high memory capability was necessary to accommodate the rapid collection of data, loggers that experienced difficulties due to network congestion were upgraded to RTX series loggers. Loggers uploaded data on a daily basis, initially recording at five second intervals in the winter season then set back to 10 second intervals in the summer period, in order to preserve battery life.

3.4 Trace Wizard© Analysis

The raw data was disaggregated within the Trace Wizard© program. The program functions by breaking down the flow at each interval into certain component events and assigning each to an appliance, based on expected flow characteristics and calibration at the time of data logger and water meter installation.

Through calibration, the analyst develops a set of appliance properties for each flow trace, to which the program can automatically assign events. Ideally, each device is tested individually and given reasonable bounds within which it could operate. In reality, it was often impractical to obtain signatures for devices such as dishwashers and clothes washers at the time of installation. The appliances that could be tested include:

- All toilets and their half and full flush capabilities
- Both typical and peak flow rates for all showers
- Both typical and peak flow rate for all taps, indoor and outdoor

Often, it is left up to the analyst to recognise patterns and make reasonable judgements, as Trace Wizard© analysis is not an exact science. Figure 3.2 shows a screen shot of the program, with flow rates of the colour coded events plotted along the time line.

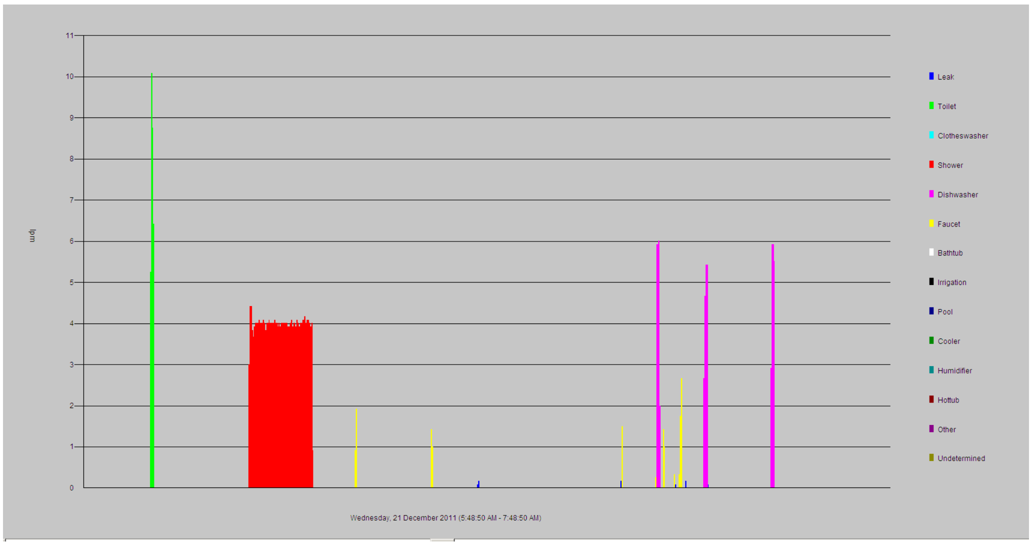


Figure 3.2: Screenshot from TraceWizard© showing the disaggregation of events.

3.5 Data Selection and Analysis

Trace Wizard© identifies end-use by flow pattern. Consequently, it is possible for devices with similar flow rates to be classified incorrectly. Analysts involved in creating the database from the raw data had various pieces of information available to them to assist the disaggregation of data. This information included frequency of use, pattern of use and knowledge of household characteristics such as how many people are normally resident in the household.

The shower data was generally clean, with some flow rates less than 1 litre per minute excluded from the detailed analysis in section 7.1.

Toilet data also included some events that were labelled as possible toilet events or toilet leakage. These uncertain events were excluded from the detailed analysis in section 7.2.

The clothes washer operates in cycles, with usually at least two intakes of water. Thus the data had to be combined into cycles, necessitating some judgement. The most accurate result was found by limiting each cycle by time, as per their respective idiosyncrasies[4]. There were some problems when splitting up various flows when cycles were run back to back, however these were dealt with on an ad hoc basis at the discretion of the analysts.

Similarly, dishwashers tend to use water in numerous intakes per cycle. However their less frequent usage, when compared to clothes washers, made it easier to segregate the loads appropriately.

The tap data contained a large range of events, with various flow rates and durations. Selective judgement was occasionally made to exclude abnormal events.

Bath events were fairly infrequent when compared to other end-use appliances. Flows recorded by the same logger that were within an hour of each other were combined and assumed to be part of one bath.

Irrigation posed a few difficulties, simply due to the variety of irrigating devices that were recorded under the one heading. Trace Wizard© analysis does not discern between irrigation types; that is, an irrigation event could refer to a hand held hose or dripper system, which have a wide range of flow rates[5]. Use of hand held hose with trigger nozzles results in a series of stop start events rather than one clearly discernible continuous event. Dripper systems tended to log hundreds of short events with low duration and volume and generally lasted for a few hours. Other events varied in duration but exhibited patterns in the time between use and higher flow rates, typical of hand held hoses. Combining events occurring within 3 hours of each other seemed to group the cycles most efficiently. This allowed for morning and evening irrigation to be counted as two separate cycles, rather than one entire day spent irrigating with a large, dry portion in between cycles.

Evaporative Coolers vary in their water consumption behaviour, depending on the type of cooler[6]. Cycles were designated to consist of water usage that occurred within 5 hours of each other. Similar to the clothes washer analysis, this discerned between various cycles on the same day.

Flows that are not characteristic to calibrated devices are usually identified as leak events. However, leaks generally refer to unintended continuous water use that lasts for long periods of time, unlike drips which usually occur for short periods straight after the appliance is used. Thus a leak event shall refer to either a drip or a leak, with the former referring to shorter events and the latter pertaining to longer events.

4 Time taken for front loaders is usually longer than that required for top loaders
5 Dripper systems are usually in the range of 2–4 L/hour; hand held hoses can allow flow rates of 20 L/min.
6 Cooler can either 'leak' small amounts of water over long periods or 'dump' larger amounts over shorter periods.

Despite occurring randomly and constituting on average 5% of total use, leaks were analysed for completeness of the report. Only the winter data was selected for the duration analysis for two reasons. Firstly, the winter data use 5 second intervals instead of 10 seconds as in summer. This allows us to demonstrate that of the leaks lasting less than 10 seconds, there is a clear majority lasting for 5 seconds or less. Secondly, combining the leak data would have severely complicated the analysis due to the number of data entries to work with and, consequently, file size. The winter data was judged to be a good representation of normal leakage occurrences.

Analysis was also undertaken based on whether the household has children younger than 10. Such a characteristic lead to different behavioural patterns, as reported in the shower and bath sections. Table 3.5 shows the breakdown of households with children under 10. On average there are 0.48 children under 10 per household. For households with a child less than 10 years of age, the average number of children in this age bracket is 1.71.

	Number of Children < 10	Number of Households
	0	216
	1	42
	2	27
	3	12
	4	3
All Households	0.48	300
Households with a Child Under 10	1.71	84

Table 3.6: Number of households containing children under 10.

Evaporative cooler usage is modelled against maximum daily temperature for the 2 week period during summer. Such analysis facilitates estimation of usage based on the maximum temperature. This data was taken from the Bureau of Meteorology, Melbourne Regional Office (Bureau of Meteorology, 2013).

Data Analysis 4

The selected two week summer period[7] exhibited warm dry weather with an average maximum temperature of 28.7 degrees Celsius and no rain. This represents a relatively harsh summer period, with the long term January average temperature being 25.9, typically with 47.3 mm of rainfall. A few homes recorded little or no consumption, possibly due to people being away on holiday. These households were omitted from the analysis of the summer period.

Stage 1 water restrictions were in force over this period. These regulations state that lawn and garden watering can be done at any time with hand held hose but only within specific times when using an automated watering system. See Appendix 1 – Water Restrictions Explained for more details.

The average daily use of 243[8] homes across the Melbourne region was 442 litres per household, with a median of 387 and standard deviation of 310. Retailer data is shown individually below in Table 4.1.

Litres per Household per Day (Summer)	CWW	SEW	YVW	Melbourne
Average	470	499	371	442
Median	395	442	324	387
Standard Deviation	382	332	221	310

Table 4.1: Litres per household per day for individual retailers and on aggregate for summer logged period.

The period in winter, taken from the 29th July to the 10th August 2010, was shortened to 13 days due to irregularities in the received data. During this period, average daily rainfall was 2.05 mm and average maximum temperature was 14.98 degrees Celsius[9]. Such a temperature is typical of this time of year, however the long term average rainfall is 1.62 mm per day for the month of August.

Stage 3 water restrictions were enforced during this time as well as Target 155, a voluntary residential water conservation program. These conditions are assumed to have contributed to the low level of recorded usage during this period. Referring to Figure 4.1, a large proportion of the winter range of use is clearly at the lower end of the distribution compared to the summer usage.

A total of eight homes were excluded due to logger data transmission failure. Average daily use was 353 litres per household per day with a median value of 311 and a standard deviation of 249. Retailer data is displayed in Table 4.2.

Litres per Household per Day (Winter)	CWW	SEW	YVW	Melbourne
Average	369	347	344	353
Median	319	280	302	311
Standard Deviation	298	236	205	249

Table 4.2: Litres per household per day for individual retailers and on aggregate for winter logged period.

7 Taken from January 16th to January 29th for CWW and SEW, 14th Jan to 29th January for YVW.
8 Data was not analysed for 57 out of 300 homes due to defective data loggers or low recorded volume.
9 Data taken from the Melbourne Regional Office

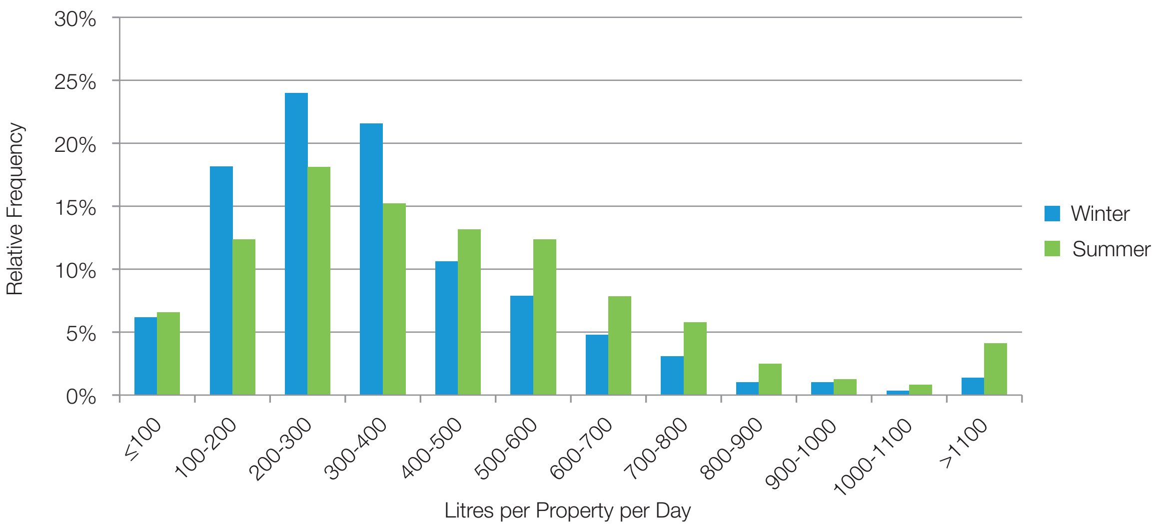


Figure 4.1: Distribution of daily water use for winter and summer.

4.1 Daily per Capita Usage

Daily per person usage for the 2012 summer logging period was 145 litres per capita per day, with a median of 117 and a high variability as indicated by a standard deviation of 1.3 times its mean. The box plots[10] for each water retailer for water consumption per capita on a daily basis is depicted in Figure 4.2. The first and third quartiles and the median are labelled. The average is marked by a cross. South Eastern Water's customers that partook in the study ranked highest on average, with 25% using up to 78 litres per person per day and 75% using 214 litres per day or less, whilst those of Yarra Valley Water used 121 litres per person per day on average with 25% using 62 litres or less and 75% using up to 164 litres. Households within the South Eastern Water boundary were observed to have the greatest range in daily per capita consumption, with a maximum of 418, excluding the extreme values.

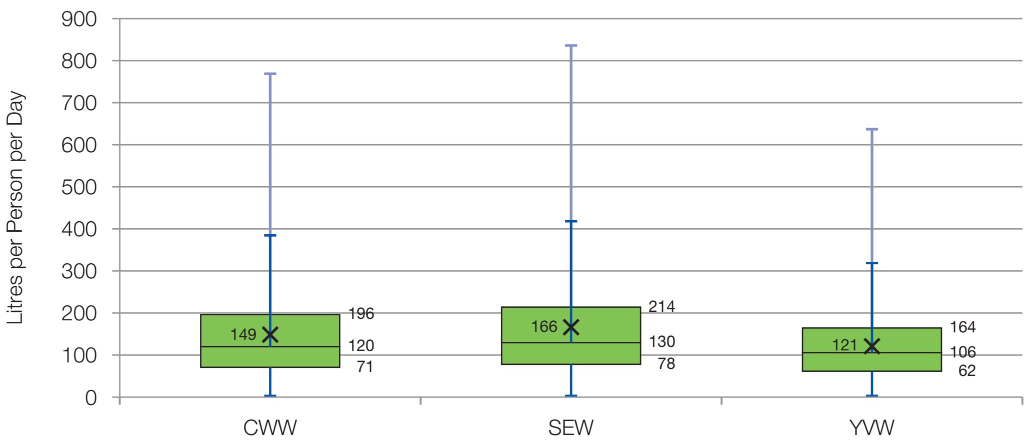


Figure 4.2: Box plot for daily usage per person by water retailer (summer).

10 A box plot provides a diagrammatic representation of variation in a data set. Within the box lie the median value and the interquartile range. The outlier range is marked by the emboldened whiskers that stem from the top and bottom of each box, representing 1.5 times the interquartile range. The extreme values are represented by the fainter whiskers, spanning a distance equal to 3 times the interquartile range.

In winter, City West Water's customers were seen to use the most water, with a daily average of 117 litres per capita. This was due to an extremely high volume event, possibly a leak, on 9th August in one household. Yarra Valley Water customers logged an average value of 109 litres per person per day, with three quarters using just less than 138 litres. These values are summarised in Figure 4.3.

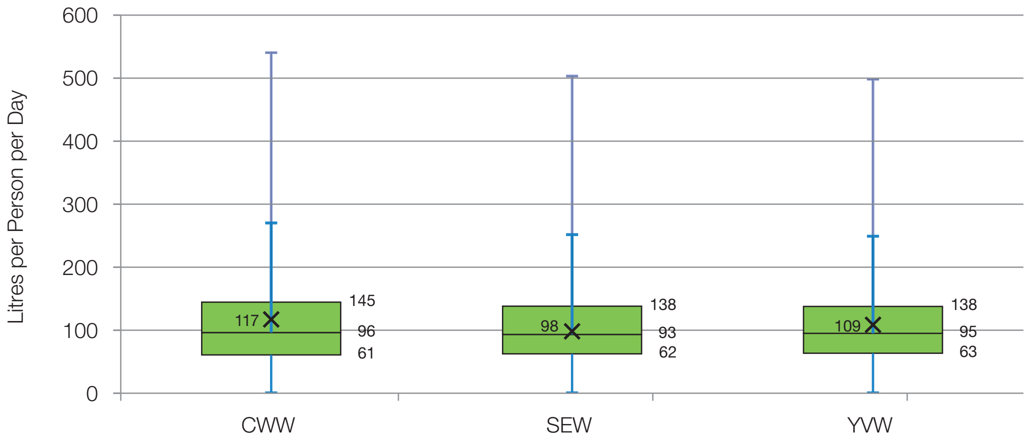


Figure 4.3: Box plot for daily usage per person by water retailer (winter).

4.2 Relationship of Water Usage to Household Size

Data for the 2010 and 2012 periods is combined and presented in Table 4.3. As one would expect, there is a positive relationship between the average amount of water used per household and the number of people per household. In addition, there is a negative relationship between average water consumption per person and the number of people in the household. Note that there were only three households studied that reported having seven people, one of which recorded very high usage in the winter period.

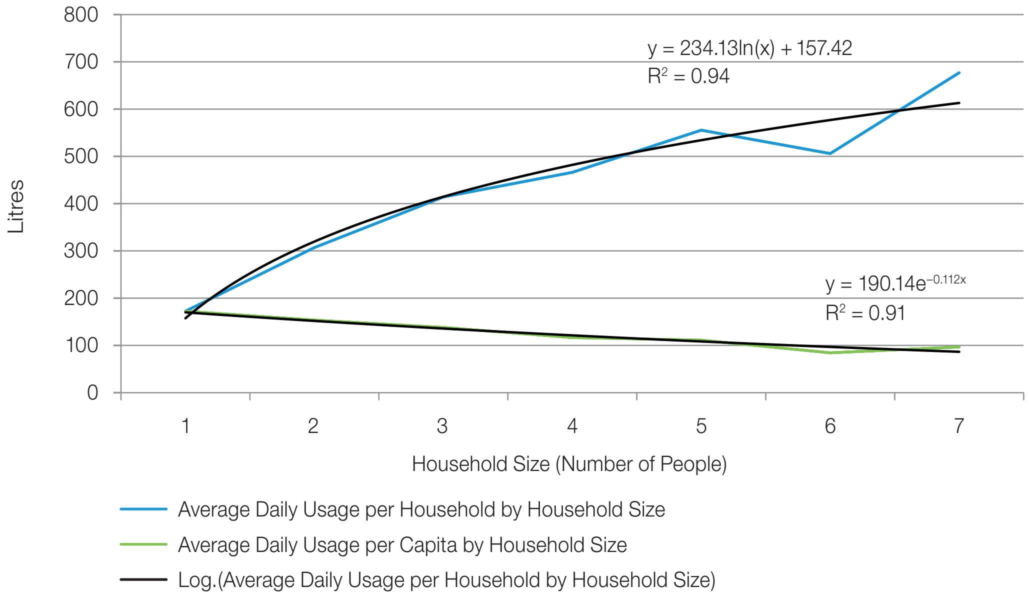


Figure 4.4: Combined 2012 and 2010 daily usage by household size.

We can see that as the number of people in the household increases, the water usage per person falls. This underlines the notion of economies of scale, noted in previous reports (Roberts, Athuraliya, & Brown, 2012). This implies that more people living together are increasingly water efficient, on an individual basis, resulting from common use being spread across more people.

The actual data is tabulated with the data predicted by the fitted lines, shown below in Table 4.3. The model follows the daily usage per capita extremely closely and predicts the average daily household use well. There was only one household that recorded no usage in either summer or winter period[11].

Number of People	Number of Households	Average Daily Use per Household	Predicted Daily Use per Household	Average Daily Use per Capita	Predicted Daily Use per Capita
1	23	172	157	172	170
2	106	307	320	154	152
3	59	414	415	138	136
4	63	466	482	117	122
5	32	555	534	111	109
6	13	506	577	84	97
7	3	677	613	97	87
Total	299	390	414	136	136

Table 4.3: Actual and modelled daily usage by household for combined logging period. An average household size of 3 people was used.

11 Possibly due to data transmission error or logger malfunction.

Sample Characteristics 5

The sample of households that took part in the study can be compared to a separate sample surveyed in the Appliance Stock and Usage Pattern Survey (ASUPS). This study tracks in detail the trends in appliance ownership and modifications made to usage patterns of water using appliances, through a series of house visits and online surveys (Ghobadi, 2013).

Recent findings from the combined ASUPS 2010–12 report reveal certain 'behind the scenes' activities which can improve the understanding gained from the REUMS, which measures only the water which is taken from the water main. Note that the findings can only be used as a guide, as the households that were surveyed are not the same households that were monitored. Both samples can be seen as relatively conservative households on a Melbourne wide scale, as indicated by their lower than average usage evident in the billing data.

Of the Melburnians surveyed,

- 75% do all washing with a clothes washer, with 96% doing 90% of laundry by machine. Consequently, the information in section 7.3 should be a good representation of the water that is actually used to wash clothes.
- 29% own a rainwater tank, which is significantly less than the 37%, 52% and 50% of homes with tanks in the City West Water, South East Water and Yarra Valley Water regions. Rainwater tank use could not be measured by the data loggers installed. Consequently, irrigation and other rainwater tank uses may be underestimated in this report.
- The dishes were washed 7 times a week by hand and 49% of people rinse their food under the tap. This behaviour is captured under the Tap event name.
- 90% had a bathtub, which is significantly higher than the number of households that used the bath in the end use study (34%)
- For irrigation purposes, 59% use hand held hoses, 8% use automatic sprinkler systems, 4% use manual sprinkler systems, 29% use a bucket, watering can or some other method.
- Almost 20% of homes had an evaporative cooler, slightly less than the 28% in the end use study sample.

High Level Summary of End Use Parameters

6

Table 6.1: High level summary of end-use parameters (summer and winter).

End-Use	Parameter / Variable	Summer 2012	Winter 2010	Units
Overview	Total	147	114	L/Cap/Day
	Shower	38	34	L/Cap/Day
	Tap	24	19	L/Cap/Day
	Irrigation	27	N/A	L/Cap/Day
	Toilet	19	20	L/Cap/Day
	Clothes washer	19	22	L/Cap/Day
	Evaporative Cooler	8	N/A	L/Cap/Day
Shower	Flow rate	7.2	7.1	L/min
	Average Duration	6.4	6.8	Minutes
	Frequency	0.9	0.7	/Capita/Day
	Efficient Showerhead Flow Rate**	6.9		L/min
	Standard Showerhead Flow Rate**	11.4		L/min
	Poor Showerhead Flow Rate**	21.1		L/min
Toilet	Flush Frequency	3.9	3.8	/Capita/Day
	Average Flush Volume	5.8	6.0	Litres
	Half to Full Flush Ratio	60:40	52:48	–
Clothes Washer	Average Volume per Load	84	96	Litres
	Average Volume per Load – Front Loader	51	54	Litres
	Average Volume per Load – Top Loader	117	130	Litres
	Average Loads per Week (measured)	4.9	4.9	/Week
	Average Loads per Week (Modelled)*	5.4		/Week
Dishwasher	Average Volume per Load	14.4	15.7	Litres
	Average Loads per Week (measured)	3.3	3.1	/Week
	Average Loads per Week (Modelled)*	2.8		/Week
Tap Use	Average Flow Rate	2.6	3.0	L/min
	Average Volume per Event	1.5	1.2	Litres
	Average Volume per Person per Day	28	20	L/Cap/Day
	Volume per Person per Day (Modelled)*	21.0		L/Cap/Day
Bath	Frequency of Use	2.8	2.1	/Week
	Volume per Bath	143	118	Litres
Irrigation	Frequency	2.0		Days/Week
	Duration	61		Minutes/Day
	Flow Rate	6.3		L/min
Evaporative Cooler	Frequency	4.1		Days/Week
	Duration	3.8		Hours/Day
	Flow Rate	17.1		Litres/Operational Hour

** Modelled values calculated using 3.1 people per household.*

*** As of 2010 when loggers were first installed, measured at capacity. For YVW and SEW.*

End Use Modelling – Parameters

7

7.1 Shower

The Shower represents the most significant and consistent residential end use. Parameters of interest that will be examined are duration, flow rate and frequency of showering.

7.1.1 Duration

Shower duration for the summer period averaged 6.4 mins for the Melbourne region, a median value of 5.3 and a standard deviation of 4.5. South East Water households shower the longest on average with an average of 6.8 minutes whilst City West Water logged the shortest times, with an average 6 minutes. Generally, shower duration was higher in winter than summer, with the exception of South East Water, recording a low of 6.6 minutes on average in winter. These results are summarized in Table 7.1.

Minutes		CWW	SEW	YVW	Melbourne
Summer	Mean	6.0	6.8	6.5	6.4
	Median	5.2	5.5	5.5	5.3
	Standard Deviation	3.8	5.6	3.8	4.5
Winter	Mean	6.7	6.6	7.1	6.8
	Median	6.0	6.0	5.8	6.0
	Standard Deviation	4.1	3.7	4.9	4.3

Table 7.1: Descriptive statistics for shower duration across each water retailer and on aggregate (summer and winter).

The distribution of duration of shower events for the Melbourne region as a whole is depicted in Figure 7.1. Typically, the distribution is skewed to the right, generally peaking just below the seasonal average value with a few extreme events at the upper end.

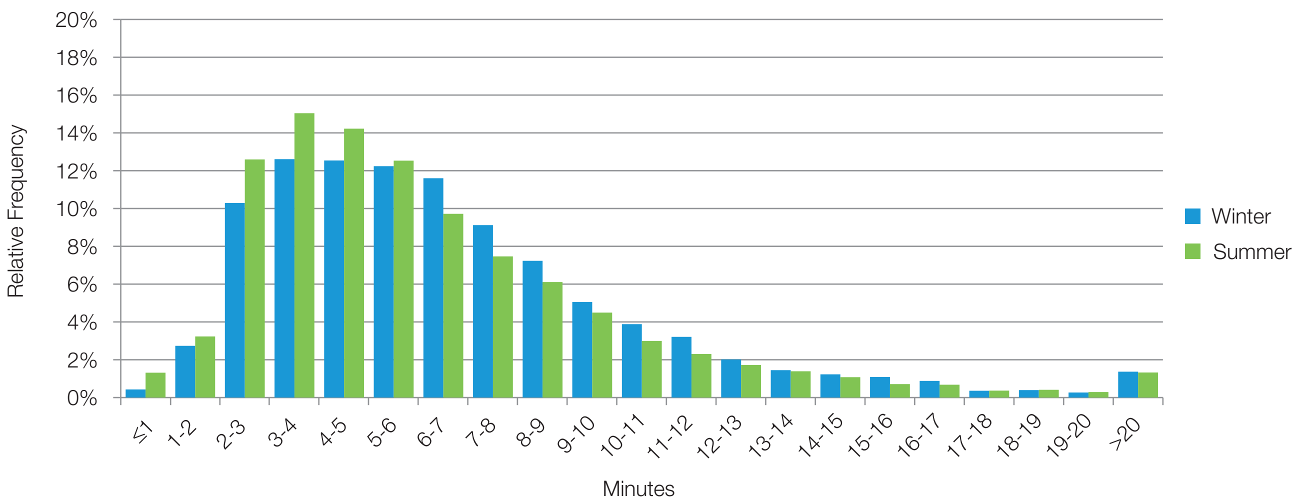


Figure 7.1: Distribution of shower duration (summer and winter).

From Figure 7.1, we can see that around 70% of showers were for 7 minutes or less in summer, whilst the same proportion shower for 8 minutes or less in winter. In both seasons, 95% of showers were of 14 minutes or less.

7.1.2 Flow Rate

Water used in the shower for the Melbourne region during the summer of 2012 flowed at 7.2 litres per minute on average, equal to that of South East Water and closely bounded by City West Water and Yarra Valley Water. The median flow rate was 6.4 litres per minute with a standard deviation of 3.9. These values differ only marginally to those in winter, which suggests people generally did not change their showering habits over the 18 months between samples. Details can be found in Table 7.2.

Litres per Minute		CWW	SEW	YVW	Melbourne
Summer	Mean	7.1	7.2	7.3	7.2
	Median	6.1	6.3	6.8	6.4
	Standard Deviation	4.4	4.0	2.9	3.9
Winter	Mean	7.3	6.8	7.2	7.1
	Median	7.0	6.2	6.7	6.6
	Standard Deviation	3.2	3.3	3.5	3.3

Table 7.2: Descriptive statistics for shower flow rate across each water retailer and on aggregate (summer and winter).

A distribution of flow rates for the Melbourne metropolitan region is shown in Figure 7.2. As seen in previous end use studies, the distribution is skewed to the right, slightly less so than the distribution of duration, peaking close to but just below its mean.

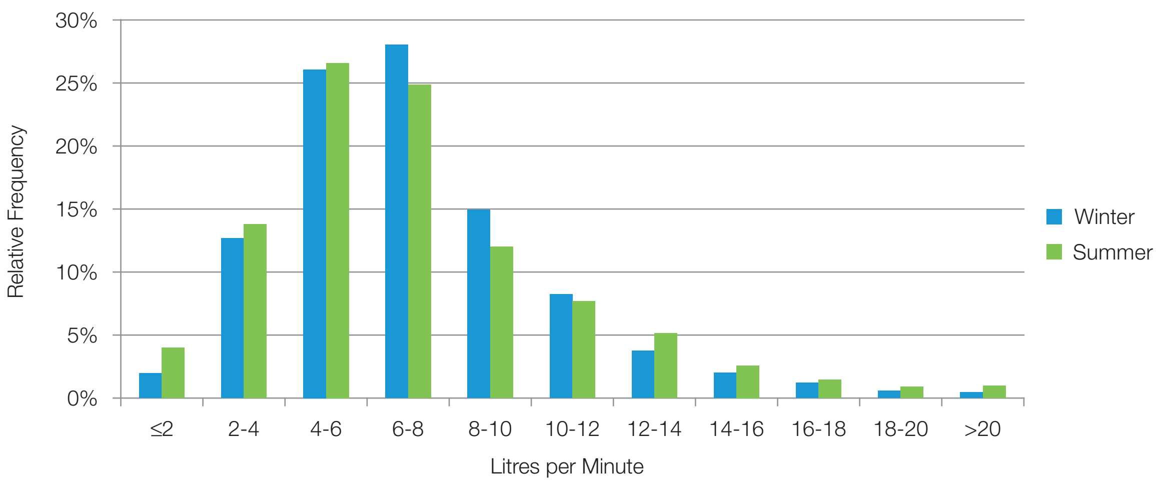


Figure 7.2: Distribution of shower flow rates (summer and winter).

According to Figure 7.2, 90% of customers shower at a flow rate of 12 litres per minute of less. In summer, 45% shower at 6 litres per minute whilst 41% do so in winter. No more than 3% shower at 16 litres per minute in either season.

Maximum shower flow rate in the monitored households were tested at the time of data logger installation. Showerheads be categorised into poor, medium or high efficiency clusters. Efficient showers by definition have a flow rate of less than 9 litres per minute. Showerheads with a poor efficiency include 9 old style shower heads, with an average flow rate of 23.9 litres per minute. Such showerheads are capable of releasing water at 21 or more litres per minute. See Table 7.3.

Showerhead Efficiency Rating	Number	Average Flow Rate (L/min)
High ≤9	69	6.9
Medium >9 and ≤15	28	11.4
Poor >15	20	21.1
Mixed	45	11.3
All Households	162	10.6

Table 7.3: Average capacity flow rate by shower head type (Yarra Valley Water and South East Water).

Across the summer and winter periods, the average flow rate was found to be 7.2 litres per minute, with 251 households having a high average efficiency rating.

7.1.3 Frequency

In the summer of 2012, Melburnians showered on average 0.9 times a day, with a median value of 0.8 and standard deviation of 0.5. City West Water and South East Water logged at 1 shower per person per day on average, while Yarra Valley Water recorded a mean of 0.7, a figure that is inexplicably low[12]. Across the city, people shower more often in summer than in winter for which a mean frequency of 0.7 per day was recorded across all retailers. Table 7.4 summarizes the statistics for the individual retailers.

Showers per Person per Day		CWW	SEW	YVW	Melbourne
Summer	Mean	1.0	1.0	0.7	0.9
	Median	0.9	0.9	0.6	0.8
	Standard Deviation	0.5	0.5	0.3	0.5
Winter	Mean	0.7	0.7	0.7	0.7
	Median	0.6	0.7	0.7	0.6
	Standard Deviation	0.4	0.4	0.3	0.4

Table 7.4: Descriptive statistics for shower frequency across each water retailer and on aggregate (summer and winter).

Figure 7.3 contains the distribution of shower frequency across the Melbourne region. As suggested by the results shown in Table 7.4, the winter season distribution is markedly lower than that for the summer season.

12 This difference is assumed to be an outcome of the relatively short periods of time over which data is analysed. If in fact there is a real difference across Melbourne in the frequency of showering it is reasonable to conclude that it is unlikely to be this marked.

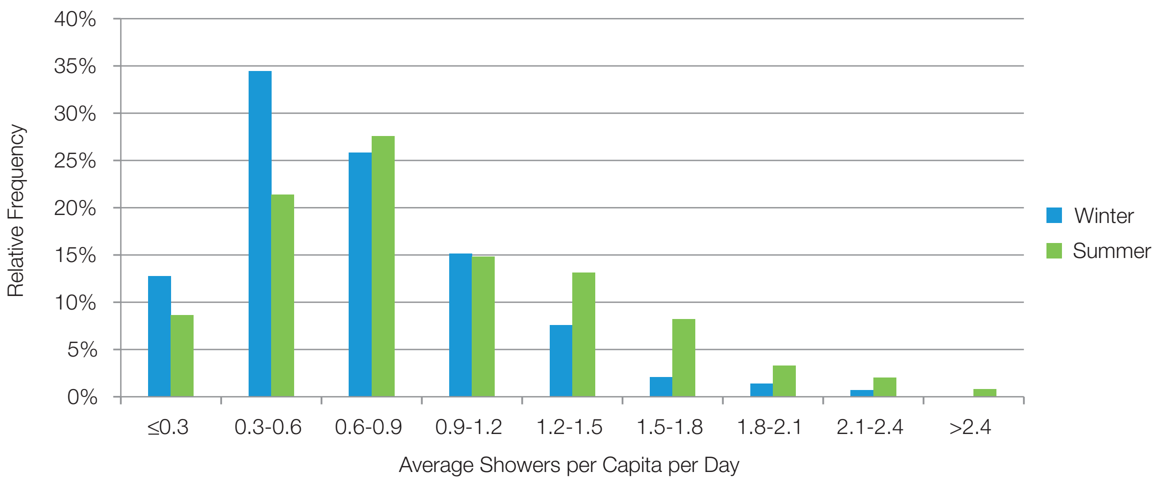


Figure 7.3: Distribution of shower frequency (summer and winter).

We can observe that 42% of people shower at least 0.9 times a day per capita in summer whilst only 27% do so in winter. On average, 3% of households shower more than 2.1 times a day per capita in summer whereas only 1% does this in winter.

7.1.4 Analysis: Effect of Number of Children on per Capita Shower Volume (in Households with Baths)

It is reasonable to assume that children at a young age will be less likely to shower if having a bath is an option. Analysis of the impact of the number of children aged 10 years or less on the shower volume and frequency bear this up.

Table 7.5 lists the average daily volume per capita used in the shower for the summer logging period. Of the 29% of households with young children, the average frequency and volume of showering on a per capita basis are both more than 20% lower than in households without young children.

Children Under 10	Number (%) Households	Shower Frequency / Capita / Day	Shower Volume / Capita / Day
No	172 (71%)	0.97	41.6
Yes	71 (29%)	0.71	32.1
All Households	243	0.89	38.8

Table 7.5: Daily shower volume per capita in households with children under 10 years of age.

7.2 Toilet

The Toilet is the third highest end use on average, requiring 20 litres per person per day. Parameters of interest are flush volume, on average and by toilet type and frequency of use. Analysis could also be done on a half or full flush basis.

7.2.1 Average Flush Volume

Average toilet flush volume for the metropolitan area is 5.8 litres per flush, with a median of 5.6 and shows relatively low variability indicated by a standard deviation of 1.6. Yarra Valley Water and City West Water customers were flushing slightly lower volumes than South East Water during this period. In winter, City West Water's higher mean brought the metropolitan average up to 6.0 litres per flush, whilst the other companies remained fairly constant. Details can be found in Table 7.6.

Litres per Flush		CWW	SEW	YVW	Melbourne
Summer	Mean	5.7	5.9	5.6	5.8
	Median	5.4	5.7	5.1	5.6
	Standard Deviation	1.6	1.7	1.7	1.6
Winter	Mean	6.4	5.8	5.7	6.0
	Median	6.2	5.6	5.5	5.7
	Standard Deviation	2.3	1.9	1.5	1.9

Table 7.6: Descriptive statistics for toilet flush volume across each water retailer and on aggregate (summer and winter).

The distribution of flush volumes can be seen in Figure 7.4. The major difference is in the 4 to 5 litres range which is significantly more frequent in summer.

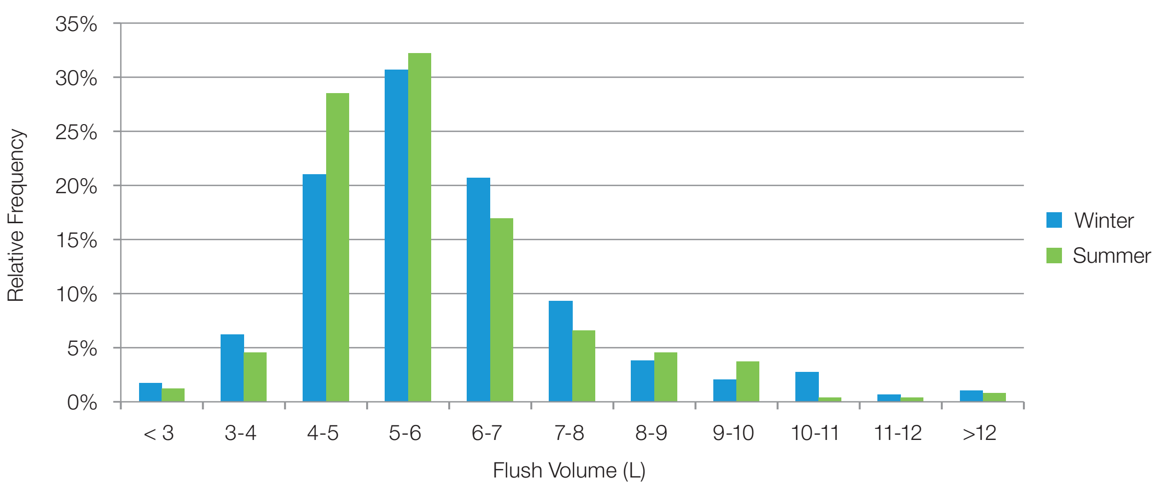


Figure 7.4: Distribution of toilet flush volume (summer and winter).

7.2.2 Flush Volume by Toilet Type

Data available from the Appliance Stock Survey allows household toilets to be classified by their flush capacities. Due to the nature of the Trace Wizard© analysis classification is done at the household level and homes with toilets of more than one type have to be classified as mixed dual/single flush, as the software cannot always discern which toilet was used. For example, in the 11/6 dual flush category households containing only these toilets appear next to this heading

Table 7.7 reports the average flush volume for each toilet type. The average volumes suggest 11/6 dual flush toilets seem to be mostly used for half flushes, while the 6/3 dual flush toilet seems to be mostly used for full flushes. It is possible that for the older (larger) dual flush toilets the half flush is usually sufficient. The 9 or 11 single flush toilets were measured at somewhat different average volumes in summer and winter. Errors in TraceWizard© analysis could have contributed to these results as the identification of full and half flushes is not exact. Some anomalies may be observed. For instance, the average flush volume of 5.2 litres for the 4.5/3 dual flush toilet appears inconsistent with the rated capacity, indicating a tendency for multiple flushes to occur.

Toilet Category	Number of Toilets		Litres / Flush		L / Cap / Day	
	Summer	Winter	Summer	Winter	Summer	Winter
11/6 Dual Flush	8	17	6.6	7.0	34.6	28.1
4.5/3 Dual Flush	28	26	5.2	5.2	19.7	19.9
6/3 Dual Flush	85	71	5.2	5.5	19.8	18.0
9 or 11 Single Flush	12	18	8.1	7.2	19.9	23.2
9/4.5 Dual Flush	47	35	5.9	6.0	23.7	21.0
Mixed Dual/Single Flush	55	8	6.1	6.1	23.4	27.0
Not Sure	7	115	5.4	6.0	21.0	21.6
All Households	242	290	5.8	6.0	21.9	21.1

Table 7.7: Average volume per flush and litres per capita per day by toilet type (summer and winter).

One anomaly is the 5.2 litres per flush used by 4.5/3 dual flush toilets. On closer examination of the data, it was found that most households tend to use the full flush function nearly always, with some households using 5 or 6 litres per flush on average. This could either be due to toilet leakage, multiple flushes or the installation of a different toilet that was not documented.

Also reported in Table 7.7 is the flush volume per person per day. The winter average of 21.1 litres was slightly lower than the summer average of 21.9 litres per person per day, but the seasonal differences were inconsistent with regard to toilet type.

7.2.3 Frequency of Use

Toilet use per person per day averaged 3.9 flushes in the summer of 2012, with a median of 3.2 and standard deviation of 2.5. Frequency of use was generally the same in both seasons within retailers, with South East Water exhibiting the highest mean in both seasons. This difference could easily result from an idiosyncrasy of the sample for example a higher proportion of residents being at home during the day. Table 7.8 presents the results for all retailers.

Flushes per Person per Day		CWW	SEW	YVW	Melbourne
Summer	Mean	3.5	4.3	3.8	3.9
	Median	3.0	3.6	3.3	3.2
	Standard Deviation	2.1	3.2	2.1	2.5
Winter	Mean	3.4	4.1	3.9	3.8
	Median	3.1	3.6	3.8	3.5
	Standard Deviation	1.6	2.4	1.8	2.0

Table 7.8: Descriptive statistics for toilet frequency across each water retailer and on aggregate (summer and winter).

From Figure 7.5, average daily toilet use in the summer appears to be more varied than in winter, which was centred more around its mean.

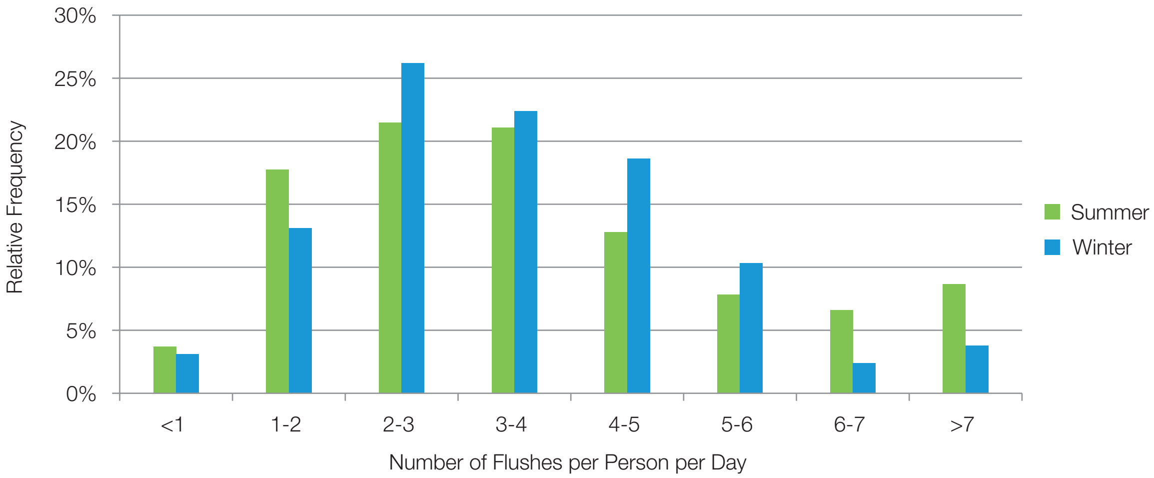


Figure 7.5: Distribution of toilet frequency (summer and winter).

7.2.4 Full Flush and Half Flush Breakdown

Table 7.9 shows the breakdown between full flushes and half flush for households with applicable toilets. The Trace Wizard© analysis for most toilet data was labelled as either half or full flush which facilitated simple categorisation. Half flushes were more frequent in summer whereas in winter there was no real discernible dominance.

	Toilet Category	Number of Households	Half Flush Ratio	Full Flush Ratio
Summer	4.5/3 Dual	28	0.66	0.34
	6/3 Dual	85	0.61	0.39
	9/4.5 Dual	47	0.58	0.42
	Mixed Dual	55	0.58	0.42
Total		215	0.60	0.40
Winter	11/6 Dual	17	0.47	0.53
	4.5/3 Dual	26	0.52	0.48
	6/3 Dual	71	0.55	0.45
	9/4.5 Dual	35	0.47	0.53
	Mixed Dual	8	0.51	0.49
Total		157	0.52	0.48

Table 7.9: Breakdown of toilet flushes into half or full flush by toilet type and season.

For the combined period, the average volume per full flush and half flush are 7.3 and 4.7 litres per flush respectively. The median values for these respective uses are 7.0 and 4.5 litres per flush. The full flush distribution has more variation in all instances, with a standard deviation of 2.1 for the Melbourne region. Details can be found in Table 7.10.

Full / Half Flush (Litres)	Melbourne		CWW		SEW		YVW	
Mean	7.3	4.7	7.5	5.5	7.4	4.6	7.1	4.0
Median	7.0	4.5	7.1	5.2	7.1	4.5	6.7	3.9
Standard Deviation	2.1	1.6	2.9	2.0	1.7	1.3	1.5	1.0

Table 7.10: Flush volume by half or full flush (combined summer and winter).

Table 7.10 splits up the data in Table 7.6 into half and full flushes. Shown is the volume per full or half flush. Generally, one half flush ranges from half to two-thirds the volume of one full flush.

Figure 7.6 superimposes the distribution of half flushes and full flushes, showing a clear separation of means. We can clearly see quasi-normal overlapping distributions. Note the full flush peak at approximately 7.3 litres per flush and half flush peak at 4.5 litres per flush.

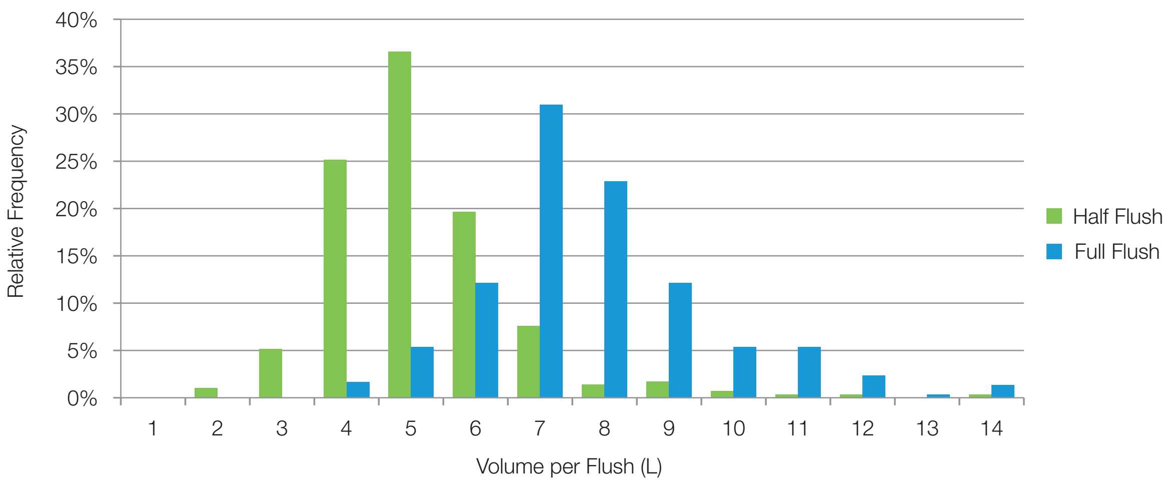


Figure 7.6: Distribution of flush volume per half and full flush (summer and winter).

7.3 Clothes Washers

7.3.1 Average Volume per Load

A total of 5017 clothes washer loads were recorded during the combined period across the Melbourne region. Across the board, the average volume per load of 85 litres in the summer period was less than that of the winter period, equating to a drop of 14%. The largest drop (25%) was seen in City West Water's data whilst South East Water's data saw a drop of 6%. See Table 7.11 for details on the individual retailers.

Litres per Load		CWW	SEW	YVW	Melbourne
Summer	Mean	78	85	93	85
	Median	54	60	76	62
	Standard Deviation	59	64	56	60
	Number of Loads	771	775	784	2330
Winter	Mean	94	88	108	96
	Median	84	70	100	84
	Standard Deviation	58	65	61	62
	Number of Loads	928	955	801	2684

Table 7.11: Descriptive statistics for clothes washer volume per load across each water retailer and on aggregate (summer and winter).

Figure 7.7 shows the distribution of clothes washer load volumes for the Melbourne region in both the summer and winter periods. The distribution is bi-modal, with local peaks either side of the means reported in Table 7.11. This is indicative of the differing water usage requirements of top and front loaders, the latter being markedly more water efficient. One notable feature is the spike in the lower end of the summer distribution, indicating more front loader use. Although this effect could be purely seasonal, the suggestion that relatively more front loader cycles are being used in 2012 than in 2010 instead of less water efficient top loader cycles is in accordance with recent trends, as seen in the market share data provided by GfK (Gan, 2010).

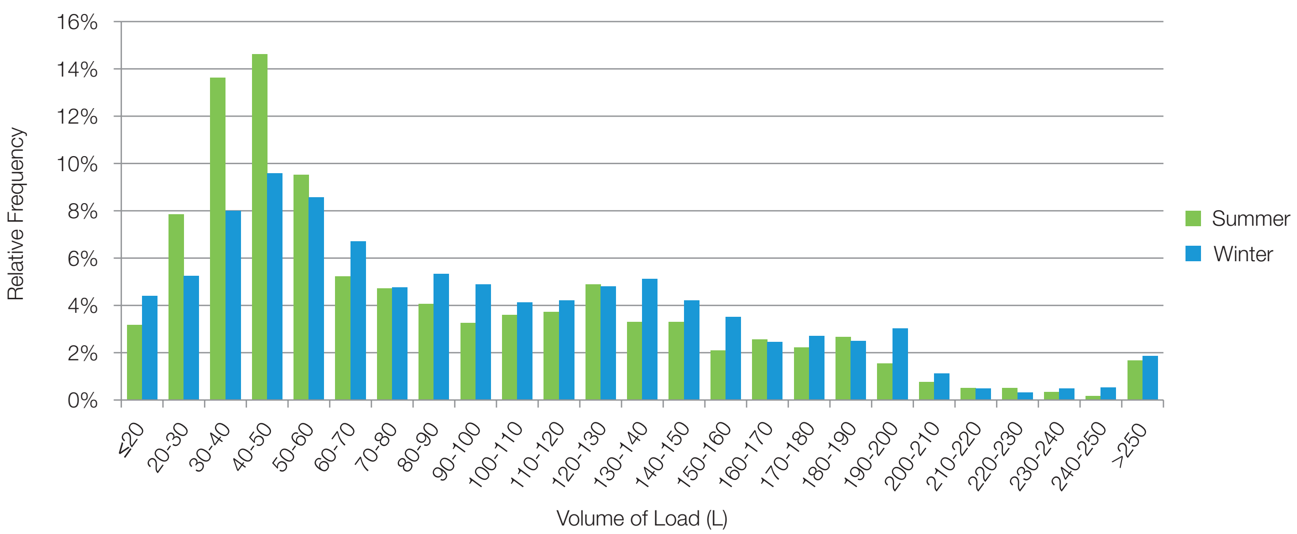


Figure 7.7: Distribution of volume per load for all machine types (summer and winter).

Examining the data in terms of machine type, we can clearly see the reduced water consumption per front loader cycle. Table 7.12 breaks down the drop in volume used occurring over winter 2010 to summer 2012.

Volume per Load	Winter 2010	Summer 2012	% change
Front Loader	54.5	50.5	-8%
Top Loader	129.6	116.6	-11%
Total [13]	96.2	84.0	-14%

Table 7.12: Change in average volume per load by machine type (summer and winter).

Table 7.13 shows the difference in water use between front and top loaders across all metropolitan areas. Note that the specifics of the washer drier combination machines were not documented and exhibited erratic behaviour. The washer drier combination data could not be further analysed and have been included for completeness.

Average Volume per Load (L)		CWW	SEW	YVW	Melbourne
Summer	Front	45	47	58	51
	Top	103	116	132	117
	Washer / Drier Combination	110	186	–	141
	Total	75	83	93	85
Winter	Front	49	48	68	54
	Top	126	123	141	130
	Washer / Drier Combination	71	13	–	33
	Total	94	88	108	96

Table 7.13: Average volume per load by machine type (summer and winter).

From Figure 7.8, it is evident that there are 2 distributions that underlie the original in Figure 7.7, one quasi normal and another skewed to the right. Almost 60% of front loading machines can complete a cycle with 50 litres or less. In contrast, 60% of top loaders require 140 litres or less for a load, with 65% using more than 100 litres. The combined period front and top loader distributions are seen to peak around their means, indicated by the bounds provided in Table 7.13. It is possible that some front loading machines logging volumes of over 150 litres per load correlate to two loads in reality. Similarly some top loading volumes of less than 50 litres per load could either represent users stopping the cycle mid spin in order to soak the contents for a better wash or machine defects. Similar conclusions can also be made for the low front loader volumes.

13 Includes Washer/Drier Combos.

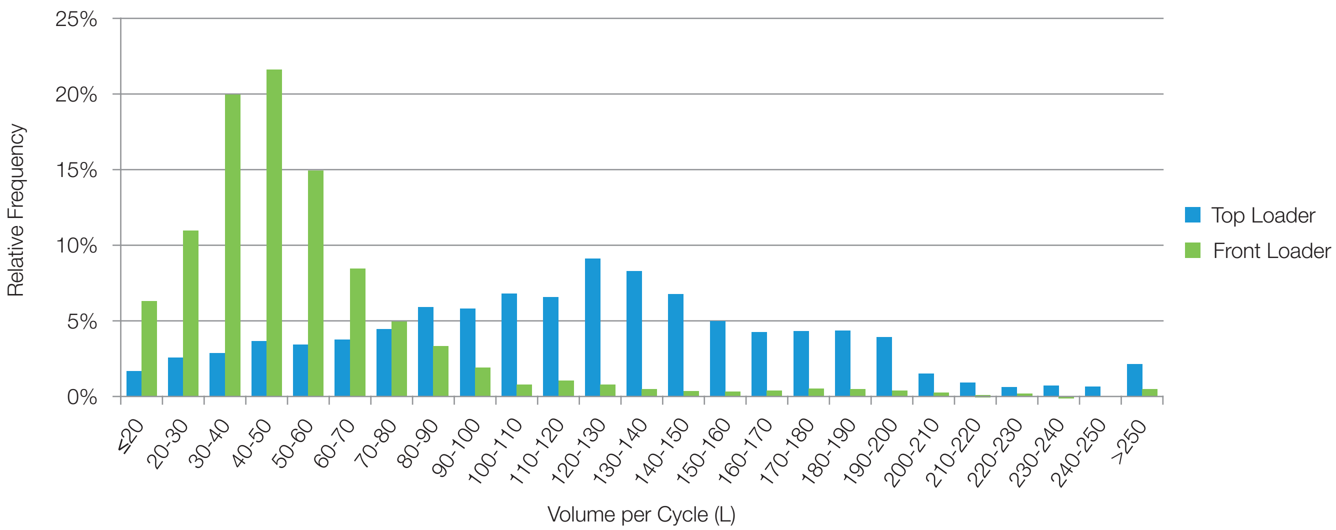


Figure 7.8: Distribution of volume per load by machine type (summer and winter).

7.3.2 Average Loads per Week

Melburnians washed their clothes on average 4.9 times per week in both logging periods. Selected households within the City West Water, South East Water and Yarra Valley Water customer groups tended to wash similar amounts each week in summer. Mean number of loads per week is significantly lower in winter for Yarra Valley Water compared to the other retailers. Unlike other retailers, Yarra Valley Water's winter figure is lower than in summer.

Loads per week		CWW	SEW	YVW	Melbourne
Summer	Mean	4.8	5.0	4.8	4.9
	Median	3.8	4.0	4.5	4.0
	Standard deviation	3.6	3.3	2.6	3.2
Winter	Mean	5.0	5.3	4.2	4.9
	Median	3.5	4.0	3.5	4.0
	Standard deviation	3.8	4.1	2.7	3.7

Table 7.14: Descriptive statistics for clothes washer loads per week across each water retailer and on aggregate (summer and winter).

The distribution for the weekly number of loads for the Melbourne region is shown in Figure 7.9. There appears to be some difference in washing habits across the sampling periods with 4 and 5 loads per week being more frequent in summer and 3 loads per week being more frequent in winter. Roughly 65% of people washed their clothes 5 times or less and 90% of people washed their clothes 9 times or less in both seasons. At the upper end of the distribution, a small proportion of customers across Melbourne did more than 13 loads a week in either season.

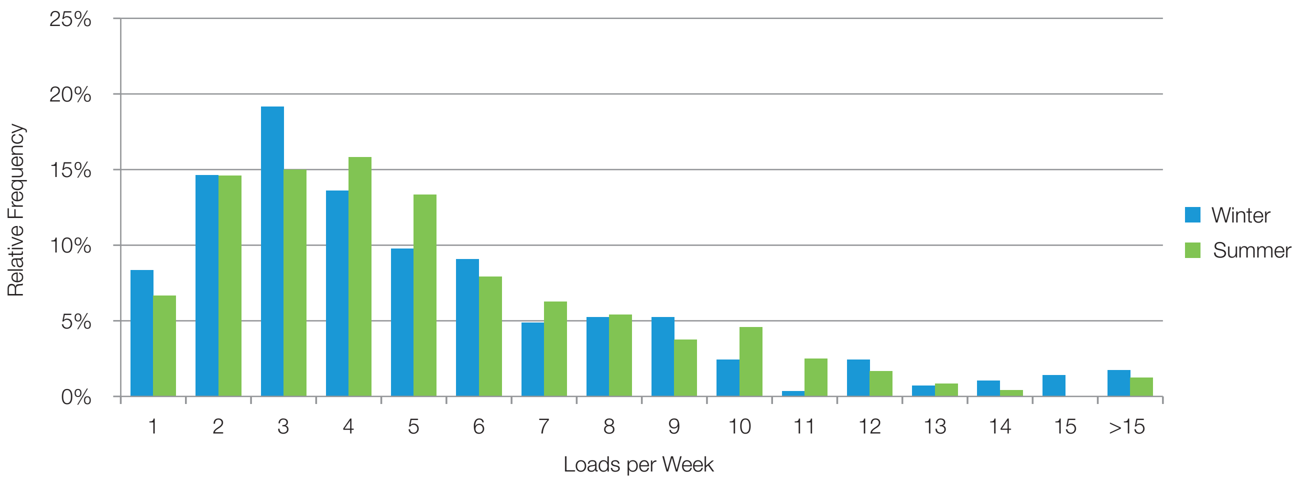


Figure 7.9: Distribution of weekly number of loads (summer and winter).

There was found to be minimal difference between households with children under 10 and households without children under 10.

7.3.3 Analysis: Impact of Household Size on the Number of Loads per Week

As one would expect, the greater the number of people in a given household, the greater the number of loads per week there are likely to be. As shown in Figure 7.10, there is a positive relationship evident in the data between the average number of loads per week and the number of people in the household, with Yarra Valley Water on a slightly lower curve compared to the other retailers for the larger household sizes. The sharp increase in average loads for large households in City West Water and South East Water is not observed for Yarra Valley Water and could result from the small sample sizes. The combined curve for Melbourne, however, appears quite smooth.

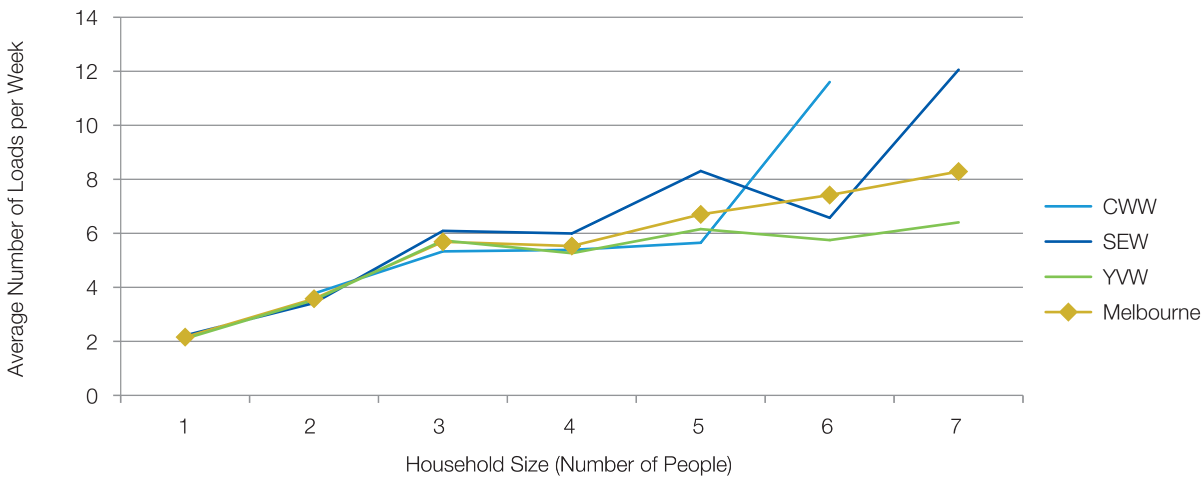


Figure 7.10: Relationship between the average number of clothes washer loads conducted per week and the number of people per household by water retailer and on aggregate (combined summer and winter).

Turning now to the combined data for all retailers in Figure 7.11, we obtain a relationship of extremely good fit. The average number of loads we can expect for households of 1 to 7 people to undertake is modelled by:

Number Weekly Loads = 3.08 ∗ ln(household size) + 1.87

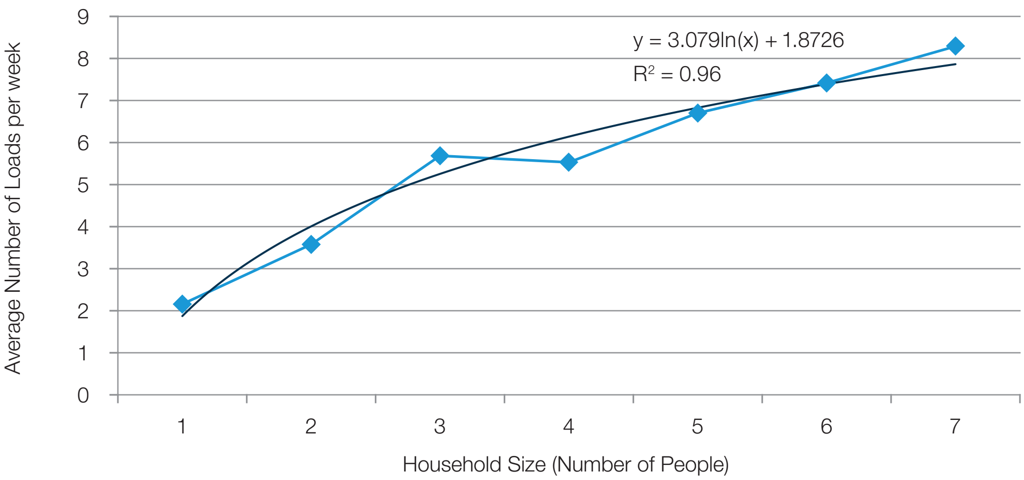


Figure 7.11: Relationship between the average number of clothes washer loads conducted per week and the number of people per household on aggregate (combined summer and winter).

7.4 Dishwashers

7.4.1 Volume per Load

During the summer period, households with dishwashers consumed between 14 to 15 litres per load across Melbourne, with an average of 14.4, a median of 13.3 and a standard deviation of 6.1. In winter, average volume per load hovered around 15.7 litres per load with a median value of 15.1.

Litres per Load		CWW	SEW	YVW	Melbourne
Summer	Mean	13.9	15.0	14.4	14.4
	Median	12.2	14.8	13.5	13.3
	Standard Deviation	7.2	6.0	4.9	6.1
Winter	Mean	15.2	14.8	17.0	15.7
	Median	15.0	13.2	15.7	15.1
	Standard Deviation	5.5	6.0	6.8	6.1

Table 7.15: Descriptive statistics for dishwasher volume per load across each water retailer and on aggregate (summer and winter).

In summer, 60% of loads used 15 litres or less, whereas 48% did so in winter. There were more loads using over 21 litres in winter. See Figure 7.12. There appears to be a tendency towards smaller sized volumes per load in summer compared to winter, possibly be due to different cycle choice or changed appliances.

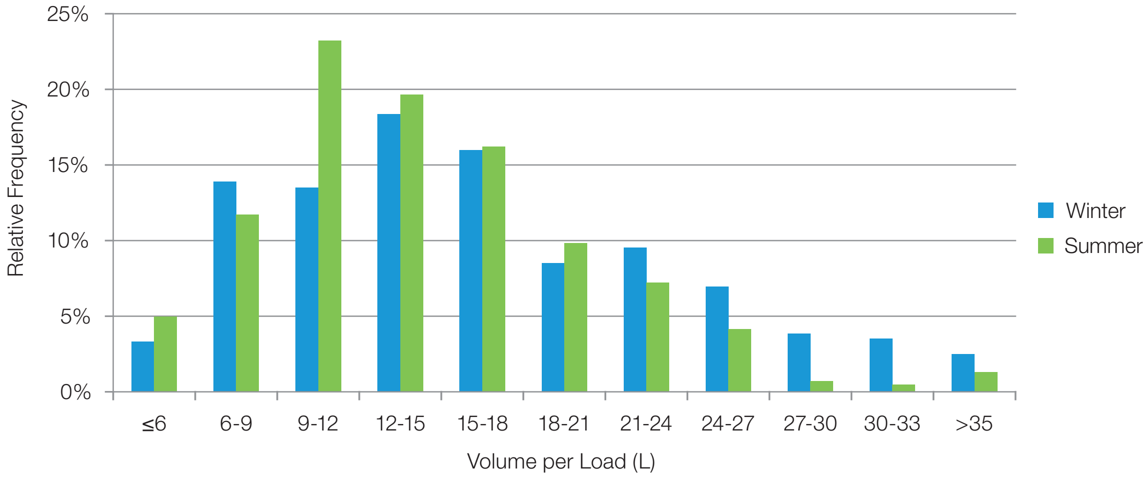


Figure 7.12: Distribution of volume per load (summer and winter).

7.4.2 Loads per Week

A total of 1908 loads were carried out during the combined logging period, 52% of which occurred in the winter period[14]. Dishwashing occurred slightly less often in winter, with customers using the dishwasher 3.1 times a week on average compared to 3.3 times in summer. Table 7.16 contains the breakdown for the metropolitan area.

Loads per Week		CWW	SEW	YVW	Melbourne
Summer	Mean	3.2	3.3	3.4	3.3
	Median	3.0	2.0	3.0	3.0
	Standard Deviation	2.0	3.1	2.5	2.5
Winter	Mean	2.9	3.0	3.4	3.1
	Median	2.7	2.9	3.2	2.7
	Standard Deviation	1.4	2.0	1.9	1.8

Table 7.16: Descriptive statistics for dishwasher weekly loads across each water retailer and on aggregate (summer and winter).

Figure 7.13 shows the distribution of loads per week. Just over 50% of people with dishwashers used them 3 or less times per week in both seasons. In summer, single weekly loads occurred most frequently and were more than twice as common as in winter, suggesting that people tend to eat in more in winter. Using the dishwasher more than once a day on average was observed in 2% of the sample in winter and 4% of the sample in summer.

14 The total numbers of summer and winter loads were 913 and 995 respectively.

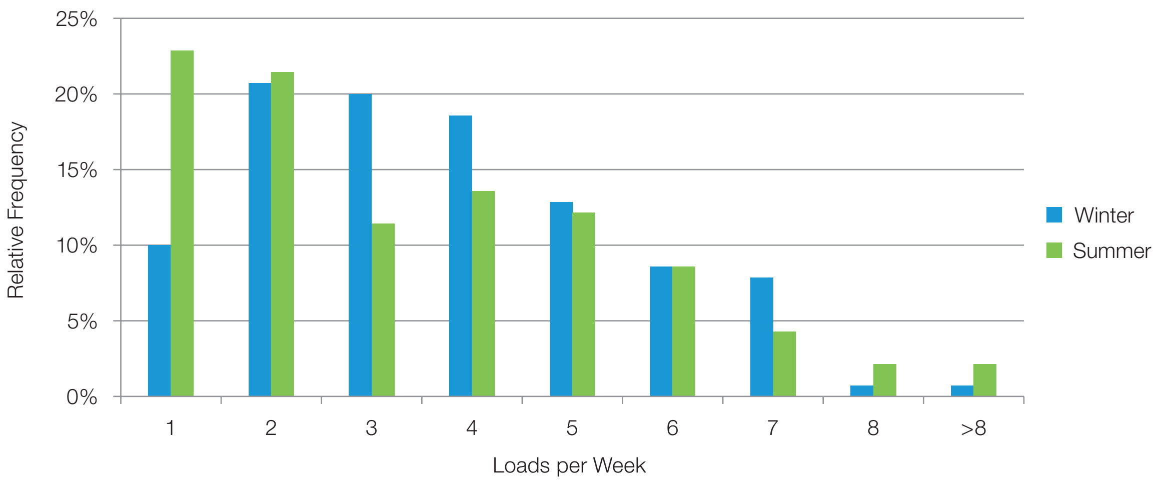


Figure 7.13: Distribution of weekly loads (summer and winter).

7.4.3 Analysis: Effect of Household Size on the Number of Dishwasher Loads per Week

As in Section 7.1.4, the number of dishwasher loads can be expected to vary with the size of the household. The data for both the summer and winter seasons were combined. Households that logged in one period but not the other were dealt with accordingly[15]. As in Figure 7.14, there is a clear increase in the number of loads for every extra person in the household. Dishwashing habits seem to be fairly uniform across the metropolitan region.

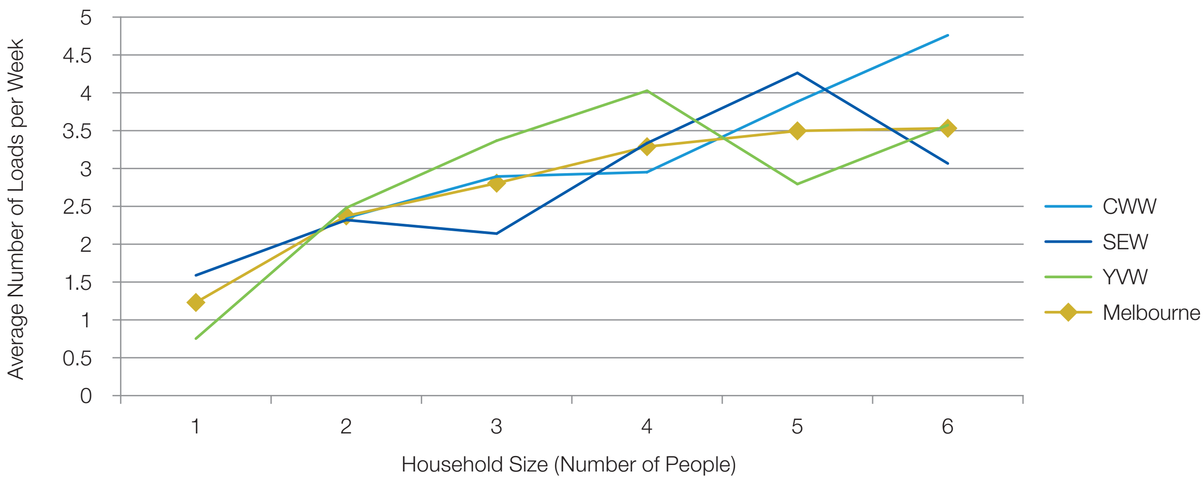


Figure 7.14: Relationship between the average number of dishwasher loads conducted per week and the number of people per household by water retailer and on aggregate (combined summer and winter).

Referring now to Figure 7.15, we can see a strong relationship between the Melbourne average number of weekly dishwashing events and the number of people. This is given by:

$$\text{Number of Weekly Loads} = 1.32 * \ln(\text{household size}) + 1.34$$

15 That is, the average number of weeks applied to the household logger varied depending on whether and when they logged.

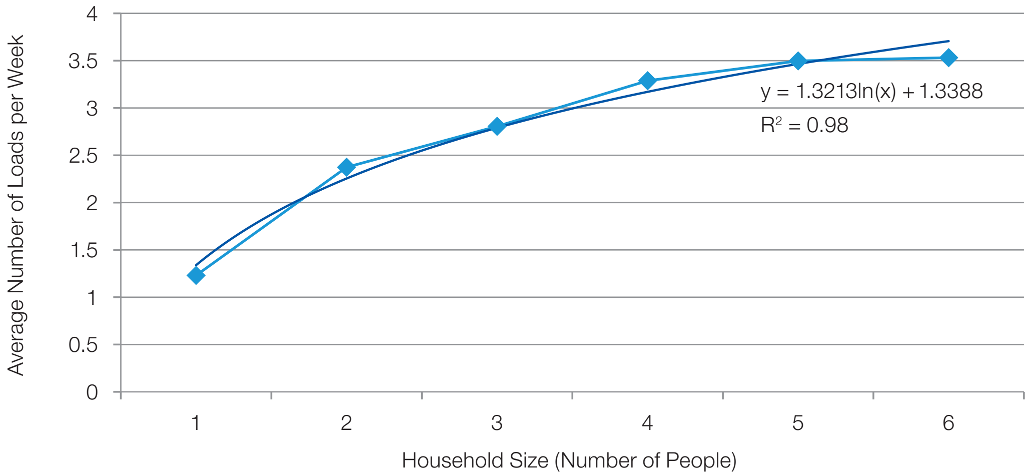


Figure 7.15: Relationship between the average number of clothes washer loads conducted per week and the number of people per household on aggregate (summer and winter).

7.5 Tap (Indoor)

Over the combined logging period, a total of 356,449 tap events occurred[16], equating to a daily average of 54 events in summer and 56 events in winter per household. A full summary is provided in Table 7.17. People used slightly more water per tap use in summer relative to winter but flow rates were generally lower in summer. On a per household per day basis, this translated to much greater volumetric use in summer than in winter.

	Summer		Winter	
	per Household	per Person	per Household	per Person
Average Volume / Day (L)	76.7	27.6	56.7	19.7
Average Uses / Day	55.8	20.5	53.8	18.9
Average Volume / Use (L)	1.5		1.2	
Average Flow Rate (L/min)	2.6		3.0	

Table 7.17: Tap use summary (summer and winter).

7.5.1 Duration

Taps were generally used for longer periods in summer, averaging 26 seconds per event, compared to the winter average of 18 seconds over Melbourne. The median summer value across the metropolitan area was 20 seconds, with a large proportion of events lasting less than 10 seconds. The winter period displayed less variability in event duration, shown by a standard deviation of almost half that of summer, a pattern which the median value also followed.

16 148687 (42%) occurring in summer and 207762 (58%) occurring in winter.

Seconds		CWW	SEW	YVW	Melbourne
Summer	Mean	30.2	27.8	22.3	26.2
	Median	20.0	20.0	20.0	20.0
	Standard Deviation	172.6	63.2	28.2	100.8
Winter	Mean	17.0	19.2	18.4	18.2
	Median	10.0	10.0	10.0	10.0
	standard deviation	35.1	67.3	60.5	56.8

Table 7.18: Descriptive statistics for tap duration across each water retailer and on aggregate (summer and winter).

Considering Melbourne as a whole, we can see that in winter, taps were used at shorter intervals, with almost 60% of events logging at under 10 seconds. Nearly 90 % of tap use was less than 30 seconds during the winter period and less than 40 seconds during the summer period. This would have been affected by the decision to increase logging intervals from 5 to 10 seconds[17]. Both seasons had a small proportion of events lasting more the 90 seconds.

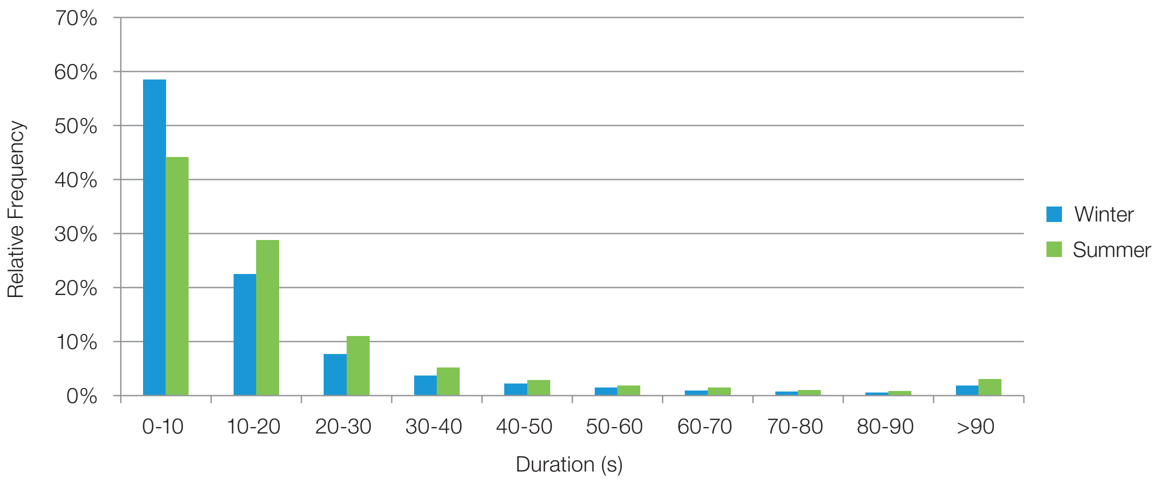


Figure 7.16: Distribution of tap duration (summer and winter).

7.5.2 Flow Rate

Standard tap flow rate for the Melbourne area was 2.6 litres per minute in the summer of 2012, just below the winter season, during which the average was 3 litres per minute. City West Water customers logged the greatest average flow rate, 3.1 litres per minute, in contrast to taps in the Yarra Valley Water region running at 2.2 litres per minute on average. Table 7.19 provides a comparison against all retailers in both seasons.

17 That is, an event lasting for 2 seconds would be recorded as 5 seconds in winter and 10 seconds in summer; an event that actually lasted for 22 seconds would be recorded at 25 in winter and 30 in summer, etc.

Litres per Minute		CWW	SEW	YVW	Melbourne
Summer	Mean	3.1	2.8	2.2	2.6
	Median	2.3	2.1	1.7	2.0
	Standard Deviation	2.5	2.3	2.0	2.3
Winter	Mean	2.9	2.9	3.2	3.0
	Median	2.5	2.3	2.5	2.5
	Standard Deviation	2.1	2.3	2.5	2.3

Table 7.19: Descriptive statistics for tap flow rate across each water retailer and on aggregate (summer and winter).

The distribution of flow rates for the Melbourne region is found in Figure 7.17. The distributions are similar, differing only by lower flow rate events occurring in the summer data. Approximately 50% of summer tap events had flow rates of 2 litres per minute or less whereas 40% of winter events shared this characteristic. For both distributions, less than 10% of events were found to have flow rates greater than 7 litres per minute.

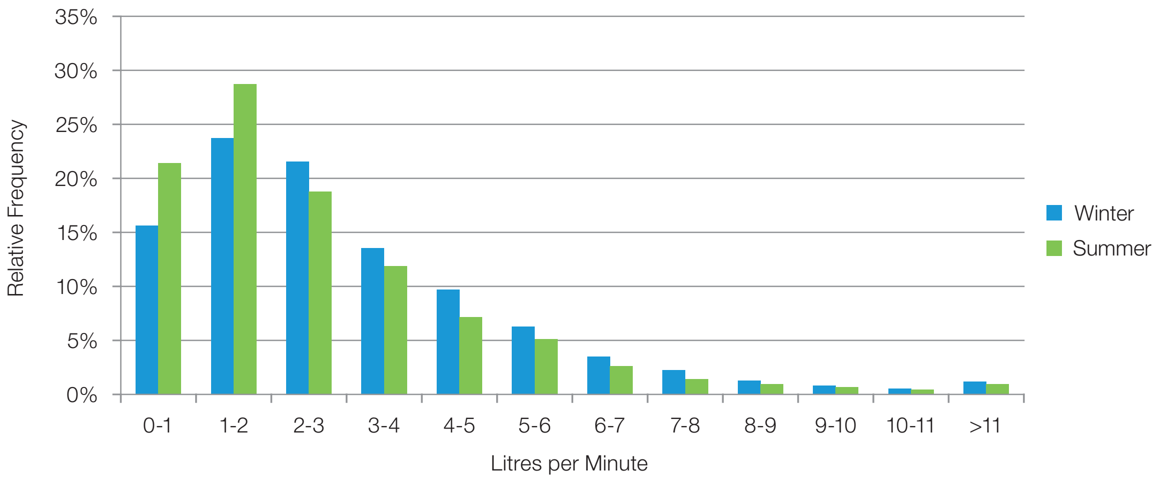


Figure 7.17: Distribution of tap flow rates (summer and winter).

7.5.3 Analysis: Effect of Household Size on Total and per Capita Use

Tap use can also be examined in terms of household size. From Figure 7.18 we can clearly see the expected negative relationship between daily tap volume per capita and the number of people per household. South East Water customers tended to log lower than the others whilst Yarra Valley Water's were generally higher than the others.

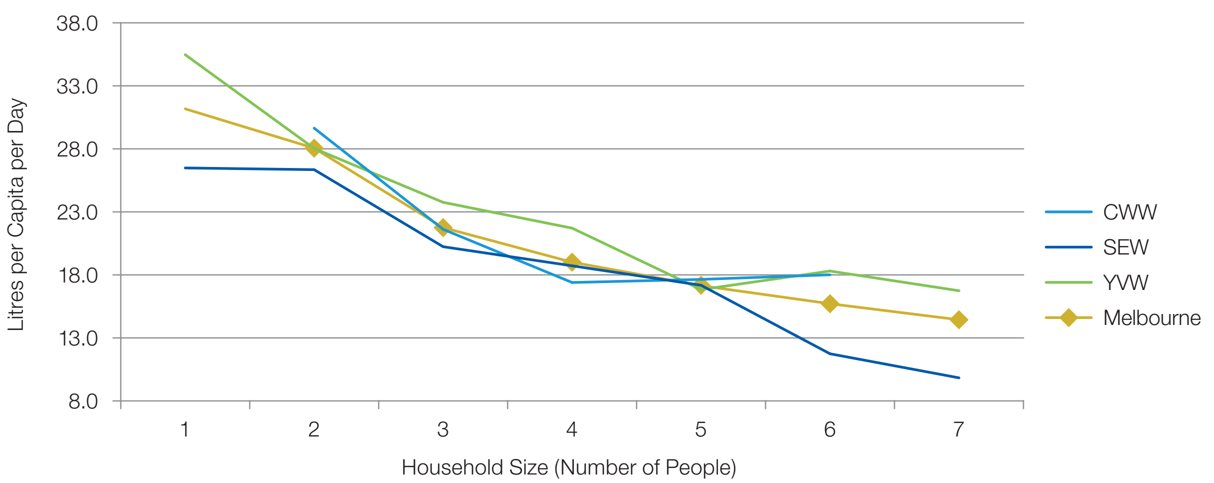


Figure 7.18: Relationship between the average tap volume per capita per day conducted per week and the number of people per household by water retailer and on aggregate (summer and winter).

Turning now to Figure 7.19, we can derive a relationship between per capita volume and household size, which can be predicted as:

Daily Per Capita Tap Volume = 33.67 ∗ household size$^{-0.42}$

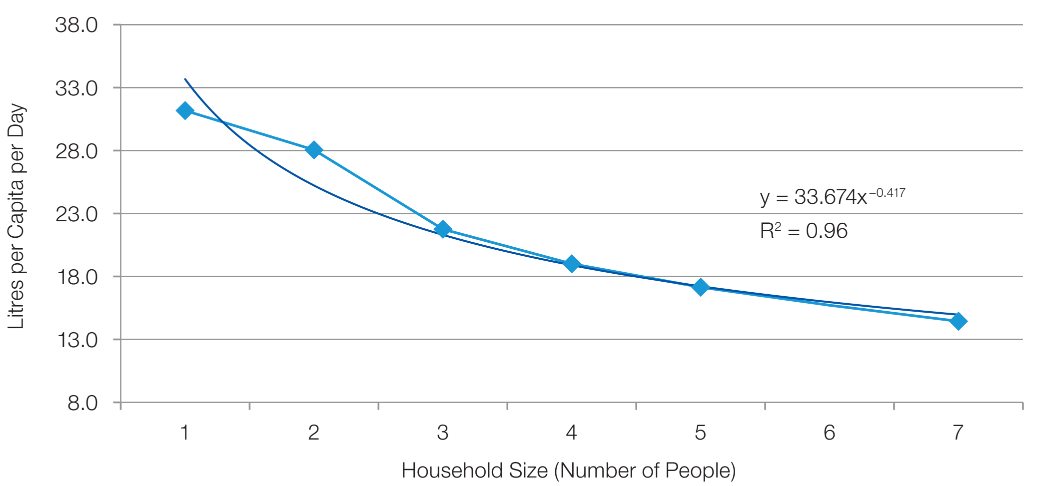


Figure 7.19: Relationship between the average tap volume per capita per day conducted per week and the number of people per household on aggregate (summer and winter).

Similarly, a relation for total average household consumption as a function of household size can be fitted, describing the relation as:

Daily Household Volume = 35.14 ∗ ln(household size)$^{30.01}$

The curve is fitted in Figure 7.20. Initially, there is a steep increase, which then softens. In both Figures Figure 7.19 and Figure 7.20, we can see greater water efficiency for each extra person, demonstrating economies of scale.

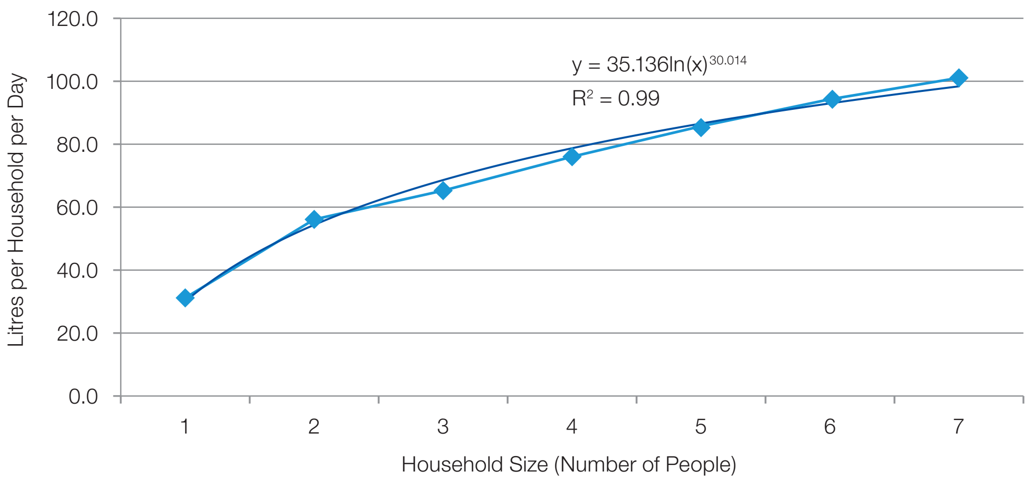


Figure 7.20: Relationship between the average tap volume per day conducted per week and the number of people per household on aggregate (summer and winter).

7.6 Bath

A total of 83 out of 243 households were recognised as having baths at least once over the combined summer and winter logging period. Nineteen households recorded having baths in both seasons, 57 households logged bath use in winter and 45 in summer.

7.6.1 Frequency

A total of 332 baths were experienced over the combined logging period[18], averaging 2.8 baths per week in summer and 2.1 in winter in households that have a bathtub. Residents in Yarra Valley Water and City West Water customer groups sat on or below the metropolitan average in both seasons while South East Water was higher. Table 7.20 contains all additional information.

Baths per Week		CWW	SEW	YVW	Melbourne
Summer	Mean	1.4	3.9	2.4	2.8
	Median	1.5	3.5	1.8	2.5
	Standard Deviation	0.7	2.2	2.1	2.2
Winter	Mean	1.9	2.3	2.1	2.1
	Median	1.3	2.0	1.8	1.5
	Standard Deviation	1.7	1.9	1.4	1.7

Table 7.20: Descriptive statistics for weekly bath frequency across each water retailer and on aggregate (summer and winter).

From the metropolitan wide distribution, the heavy skew to the right reveals that most people tend to bath once a week. The distribution for the summer data is slightly more spread out over the intervals. See Figure 7.21.

18 88 (39%) occuring in winter, 224 (61%) in summer

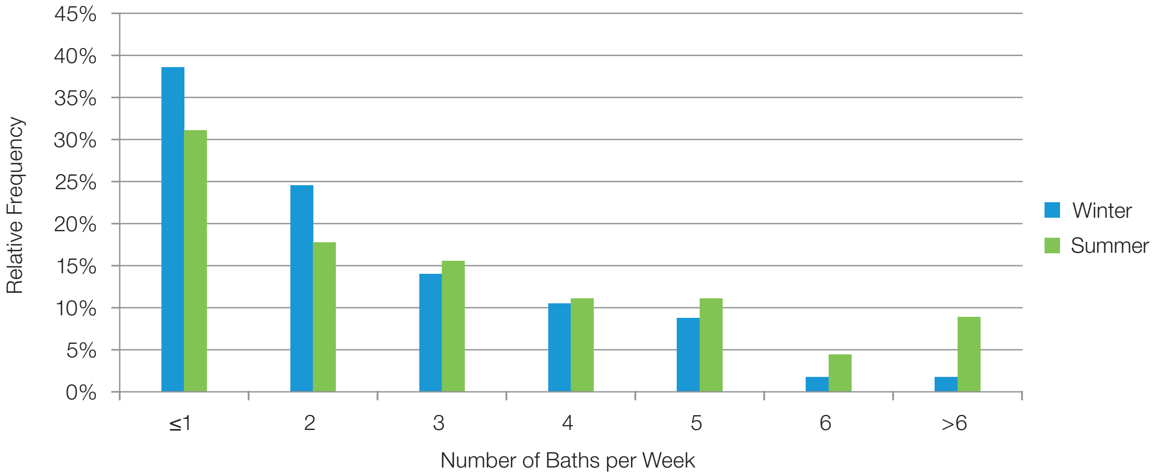


Figure 7.21: Distribution of weekly bath frequency (summer and winter).

7.6.2 Volume

Bath volume was higher in summer with the average bath using 143 litres, compared to the winter average of 118 litres. Bath volumes varied greatly within each retailer group too, probably due to the variety of bath tubs available to domestic use. In addition, there were significantly less baths taken than for any other end use event.

Litres per Bath		CWW	SEW	YVW	Melbourne
Summer	Mean	252.0	184.6	70.5	142.6
	Median	92.5	102.9	65.2	80.1
	Standard Deviation	269.0	191.0	38.5	169.4
Winter	Mean	82.3	140.3	126.1	117.6
	Median	55.9	99.6	102.6	94.3
	Standard Deviation	68.8	98.1	65.1	83.3

Table 7.21: Descriptive statistics for bath volume across each water retailer and on aggregate (summer and winter).

Figure 7.22 plots the distribution of bath volume for the Melbourne region, with a large spike around 30 to 90 litres and some volumes reaching 500 litres. The winter data also exhibits a secondary peak around the 150 to 180 litres mark. This occurred in 6 households, 4 of which have no children and took such a bath only once or twice over the winter season[19]. In summer, 70% of baths were less than 120 litres.

19 Of the two remaining households, having a bath of this volume undertaken 4 times in one household with 2 children. As a result, the peak is of little significance

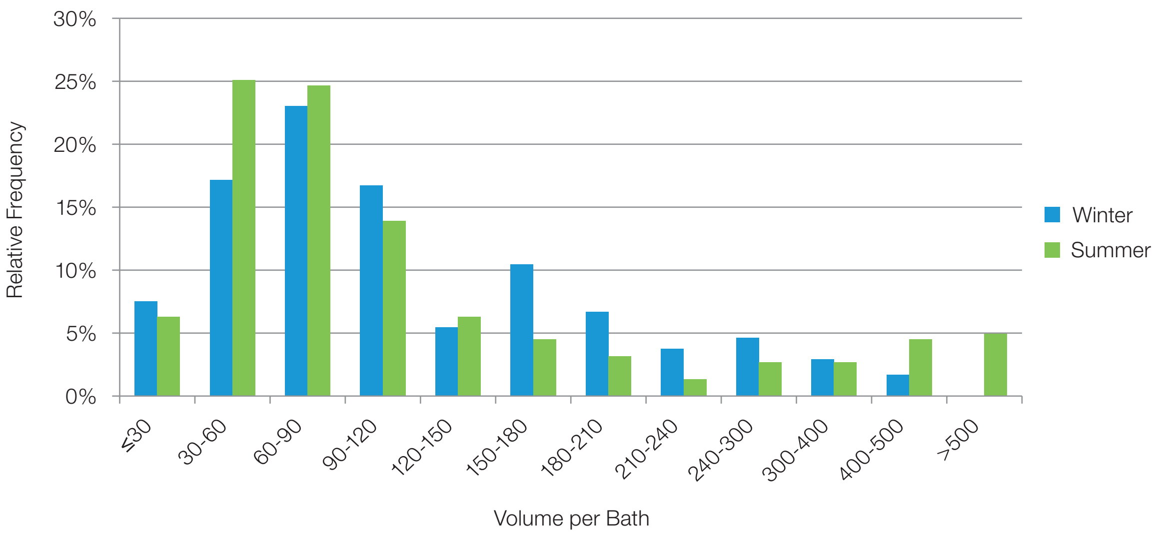


Figure 7.22: Distribution of bath volume (summer and winter).

7.6.3 Analysis: Effect of the Number of Children Under 10 on the Tendency to Use Baths

We will now compare the bath characteristics of household with children under 10 to those without. Households without young children, deemed less than 10 years old, bathe approximately 25% less per week. This translates to 0.61 baths per person per week in households that have no children under 10 and 0.81 baths per person per week in households that have. Moreover, baths in households without young children are filled to a level almost double that of those that do.

Children <10	Number of Household	Weekly Baths per Capita	Volume per Bath
No	35	0.61	57.7
Yes	48	0.84	32.5
Total	83	0.74	43.1

Table 7.22: Comparison of bathing characteristics in households with and without small children.

In addition from Figure 7.23, we can see that for every extra child in the home, the volume per small child per bath is a decreasing function of the number of small children, most likely resulting from small children having baths together[20]. The following formula expresses this:

$$\text{Bathing Volume per Child} = 66.239\ e^{-0.663\,(\text{number of children})}$$

20 Note that we cannot actually tell if the small children are actually using the bath, we can only report how and when the water is used in such households.

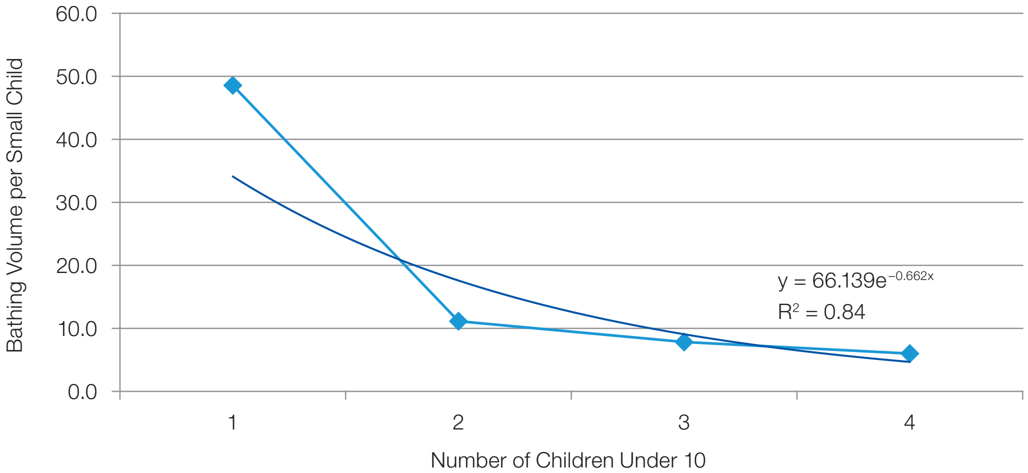


Figure 7.23: Relationship between the average bath volume per small child and the number of small children per household for the Melbourne region (summer and winter).

7.7 Irrigation

In the summer of 2012 logging period, stage 1 water restrictions were in place. The average daily maximum temperature was 28.7 degrees Celsius and there was no rain. A total of 204 out of 243 (84%) households irrigated at least once during the two week summer logging period. For the winter 18 months previously, 156 out of the 292 (53%) households logged an irrigation event during the Stage 3 plus Target 155 restrictions. As irrigation is generally of interest in during summer periods, winter will not be included in the bulk of the following analysis[21].

The average share of irrigation across all households included in the study was 9% for the summer period. The proportion of households with no irrigation totalled 16% whilst 44% of irrigating households used up to 10% of their total water on this end use. See Figure 7.24.

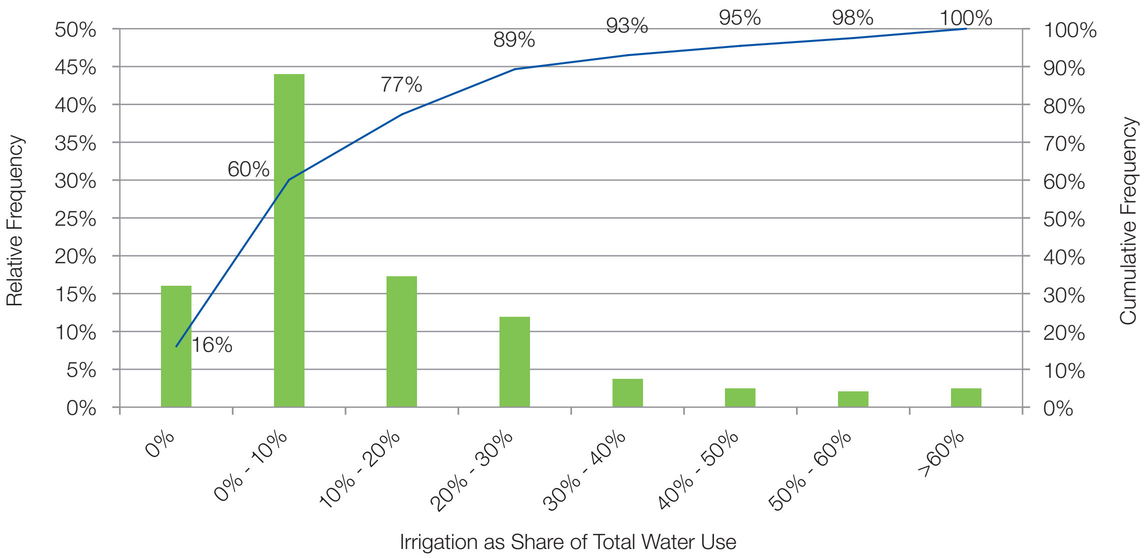


Figure 7.24: Distribution of irrigation as a proportion of total water usage by household (summer).

21 Winter will however be included in the frequency analysis.

Once again, it should be noted that these figures report only the potable water used and not the water used from rainwater tanks. Approximately 46% of the houses monitored have rainwater tanks installed.

7.7.1 Volume per Day

Daily irrigation volume varied over a vast range, with standard deviations of roughly twice the mean value in most cases. Average volume varied from 208 litres in the Yarra Valley Water region to 439 litres in the City West Water Region, placing the Melbourne average at 334 litres per day. These details are summarised in Table 7.23.

Litres per Day	CWW	SEW	YVW	Melbourne
Mean	439	379	208	334
Median	128	97	76	98
Standard Deviation	918	725	400	705

Table 7.23: Descriptive statistics for irrigation volume (summer).

The data is plotted over the range of 0 to 550 litres in Figure 7.25, with the average duration of irrigation cycles shown on the labels. With a few exceptions, the lower daily volumes tend to coincide with shorter average durations. The data appears to cluster at the tails of the distribution, due to the nature of events that are labelled irrigation. An explanation can be found in section 3.5.

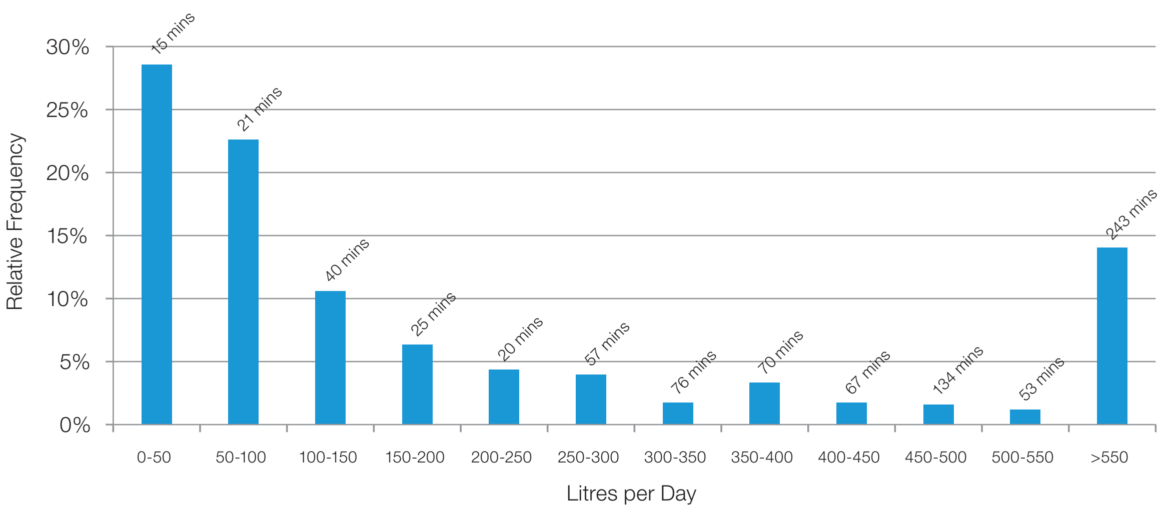


Figure 7.25: Distribution of irrigation volume (summer).

7.7.2 Flow Rate

Average irrigation flow rate for the Melbourne region was 6.3 litres per minute with a median value of 7.4 and substantial variability as indicated by a standard deviation larger than the mean. Table 7.24 contains the regional and aggregate data. Mean and median flow rates were higher in Yarra Valley Water compared to the other retailers.

Litres per Minute		CWW	SEW	YVW	Melbourne
Summer	Mean	6.0	5.1	9.9	6.3
	Median	6.2	4.6	9.5	7.4
	Standard Deviation	7.9	7.2	5.7	6.9

Table 7.24: Descriptive statistics for irrigation flow rate (summer).

The distribution for the Melbourne metropolitan region is shown in Figure 7.26. The incidence of low flow rate events occurring is due to the larger number of dripper systems used. Approximately 70% of irrigation events exhibited a flow rate of 12 litres per minute or less. In summer, 41% of irrigation events were carried out at a flow rate of between 4 to 8 litres per minute.

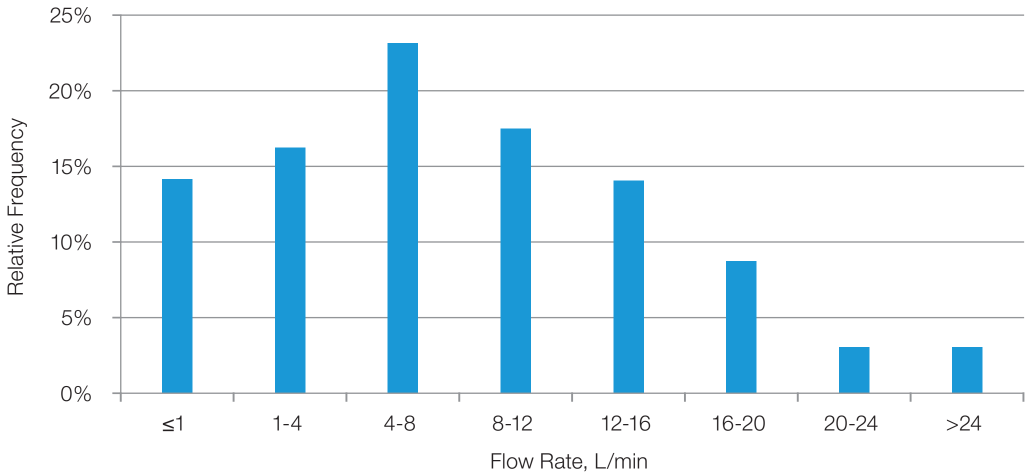


Figure 7.26: Distribution of irrigation flow rates (summer).

7.7.3 Duration per Day

Melburnians were observed to irrigate for approximately 61 minutes on average in summer, with a median of 16 minutes. South East Water logged the longest of the three retailers with an average of 101 minutes per day. As shown in Table 7.25, there was a large range in the values recorded were extremely variable, the standard deviation for the Melbourne equating to roughly three times the mean, with the exception of Yarra Valley Water, whose irrigation events were more consistent. The Yarra Valley Water area has predominately clay soil which reduces the need for irrigation in contrast to mainly sandy soils in South East Water area.

Minutes per Day		CWW	SEW	YVW	Melbourne
Summer	Mean	68	101	20	61
	Median	23	24	10	16
	Standard Deviation	138	317	34	198

Table 7.25: Descriptive statistics for irrigation duration (summer).

From Figure 7.27, it is evident that most irrigation occurrences were less than 15 minutes, with some extremely long events, displaying patterns typical of dripper or automated systems. During the summer period, durations for daily irrigation summed to an hour or less in 80% of the time.

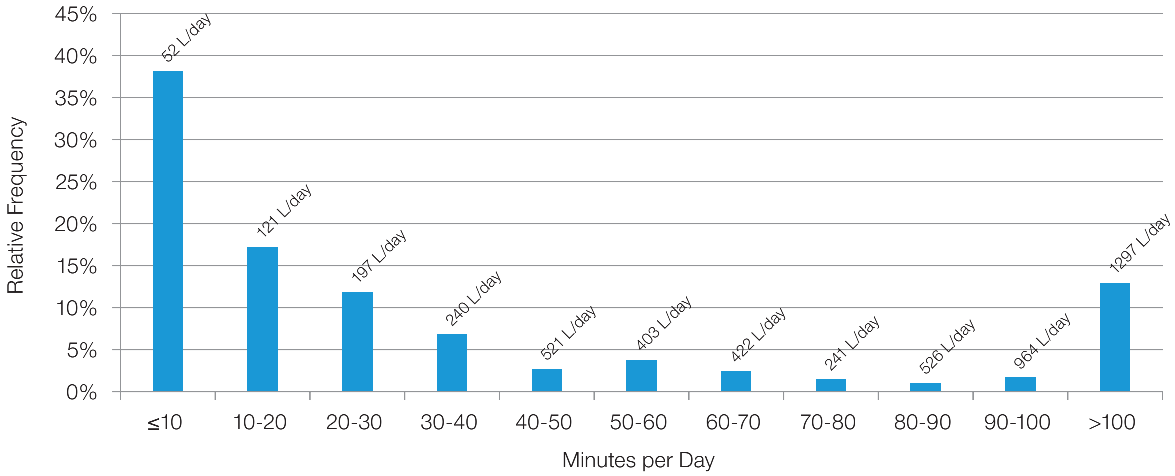


Figure 7.27: Distribution of daily irrigation duration (summer).

7.7.4 Frequency

For homes that irrigated their garden, the metropolitan average is 2.0 days per week, with a median of 1.5[22]. These households were also seen to irrigate in winter and did so less frequently, as expected. Table 7.26 shows the breakdown between water retailers.

Days per Week		CWW	SEW	YVW	Melbourne
Summer	Mean	1.9	1.8	2.3	2.0
	Median	1.5	1.5	2.0	1.5
	Standard Deviation	1.3	1.2	1.6	1.4
Winter	Mean	1.2	1.3	1.8	1.4
	Median	1.0	1.0	1.5	1.0
	Standard Deviation	1.0	1.0	1.4	1.2

Table 7.26: Descriptive statistics for irrigation frequency, for homes that irrigate (summer and winter).

Figure 7.28 graphicaly displays the data for the Melbourne region and includes homes in which irrigation could have been possible but was not recorded[23]. Also congruent with previous reports and expectations is the large proportion of households that did not irrigate during winter. With the extra households included, the Melbourne average is 1.4 days per week with a median of 1.0 in summer, and repective winter values being 0.8 and 0.5.

22 One day of irrigation simply means that an irrigation event was recorded at some stage during the day, independent of duration.
23 81 households in summer and 123 in winter did not water their garden.

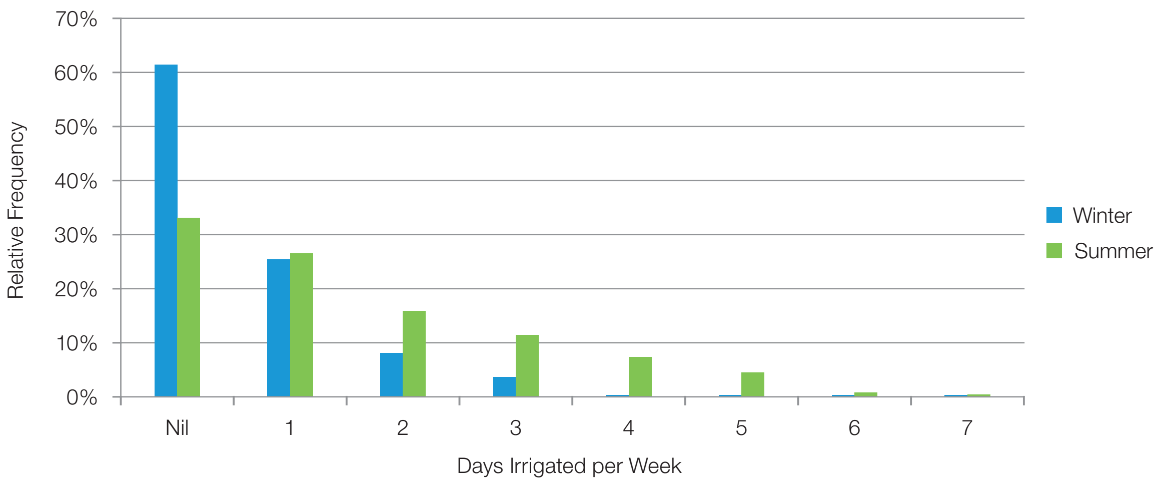


Figure 7.28: Distribution for irrigation frequency, for homes with a garden (summer and winter).

7.8 Evaporative Cooler

Evaporative cooler use was logged by 68 homes out of 243 (28%) in the sample during the summer period, representing 5.2% of total use across Melbourne during this warmer than average summer period[24].

7.8.1 Frequency

Of the households that used their evaporative cooler, usage was recorded on average around 4 days per week, with City West Water lying below the metropolitan average. Contrary to the other retailers, South East Water's sample households logged a median value of 5 days a week, which lies above its average[25]. See Table 7.27.

Days per Week	CWW	SEW	YVW	Melbourne
Mean	3.4	4.4	4.2	4.1
Median	3.3	5.0	4.0	4.0
Standard Deviation	1.9	2.1	2.1	2.1

Table 7.27: Descriptive statistics for evaporative cooler frequency of use (summer).

Figure 7.29 demonstrates how the frequency of use is distributed over the week. Approximately 18% of events occur around the mean (4.1) while a similar percentage uses evaporative coolers seven days a week.

24 The long term January average is 25.9 degrees Celsius.
25 This implies the distribution is skewed to the left, which is not usually the case when observing water end use distributions.

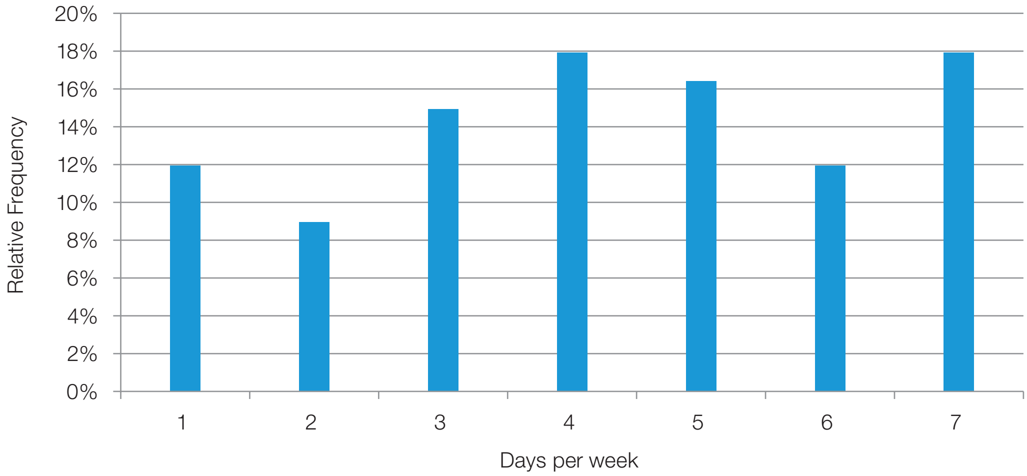


Figure 7.29: Distribution of evaporative cooler frequency of use (summer).

7.8.2 Operational Duration

The average time for which a cooler was used was found to be 3.8 hours per day, for the Melbourne metropolitan region. This is significantly above the average of City West Water average of 1.1 daily hours due to the higher times logged by South East Water and Yarra Valley Water's customers. Four homes in total, representing 1% of the sample, were recorded as operating for a full day operation at least once[26]. See Table 7.28 for more detail.

Hours per Day	CWW	SEW	YVW	Melbourne
Mean	1.1	3.4	5.1	3.8
Median	0.2	0.5	3.2	1.0
Standard Deviation	1.9	5.3	5.6	5.2

Table 7.28: Descriptive statistics for evaporative cooler duration (summer).

Figure 7.30 reveals how long the coolers were used for and their relative proportions. Approximately 65% used their coolers for 8 hours or less. Thirteen per cent used coolers for 12 hours of more.

26 1 from South East Water, 3 from Yarra Valley Water.

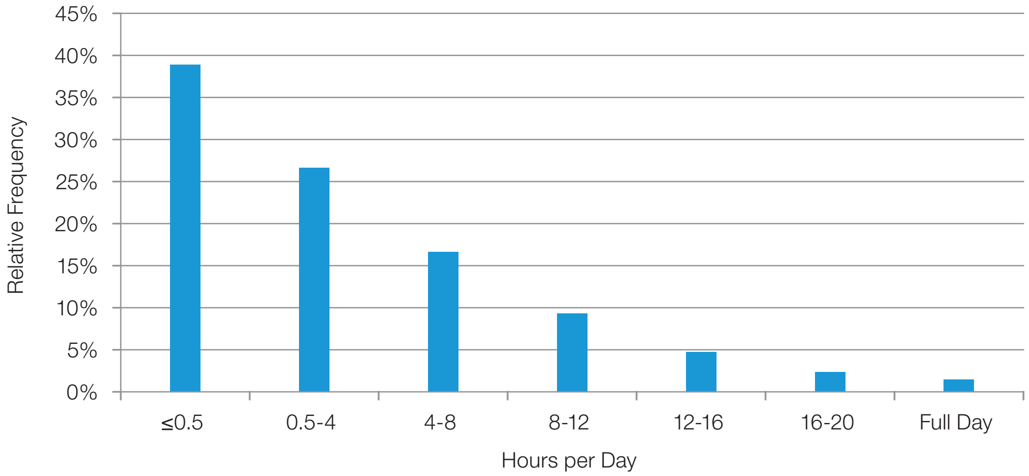


Figure 7.30: Distribution of evaporative cooler duration (summer).

7.8.3 Litres per Operational Hour

As evaporative coolers tend to consume water intermittently for short periods of time during operation, we can calculate litres per operational hour as the water consumed over the course of the cooler being turned on. Over Melbourne, the average water used by a cooler per hour of operation is 19 litres, inflated slightly by some inefficient coolers in the City West Water customer base. See Table 7.29.

Litres per Operational Hour	CWW	SEW	YVW	Melbourne
Mean	25.3	13.4	18.1	17.1
Median	31.1	18.5	22.6	22.1
Standard Deviation	54.1	31.9	10.5	32.4

Table 7.29: Descriptive statistics for evaporative coolers (summer).

From the distribution in Figure 7.31, we can see a tendency for coolers to operate mainly in the 10–30 litres per hour range, and this represents more than 60% of the evaporative coolers in the sample. Six of 11 coolers representing the 16% with an operational water consumption of 50 litres of greater belong to customers of City West Water.

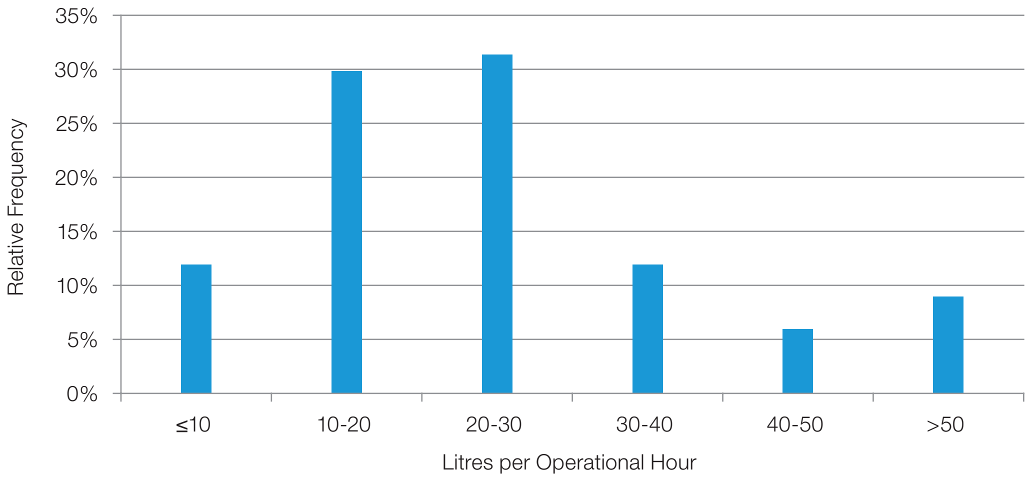


Figure 7.31: Distribution of litres per operational hour for evaporative coolers (summer).

7.8.4 Analysis: Effect of Daily Maximum Temperature on Cooler Usage

As one would expect, there is a clear correlation between cooler use and daily maximum temperature[27]. Figure 7.37 plots the number of coolers running against the daily maximum temperature for the sampling period. We can see that up to 27 (40%) of all coolers that registered during the logging period were used between 20 and 30 degrees Celsius. Note the marked increase in the number of coolers running once the temperature rises above 30 degrees, with 65% to 80% of coolers being used on the hottest days.

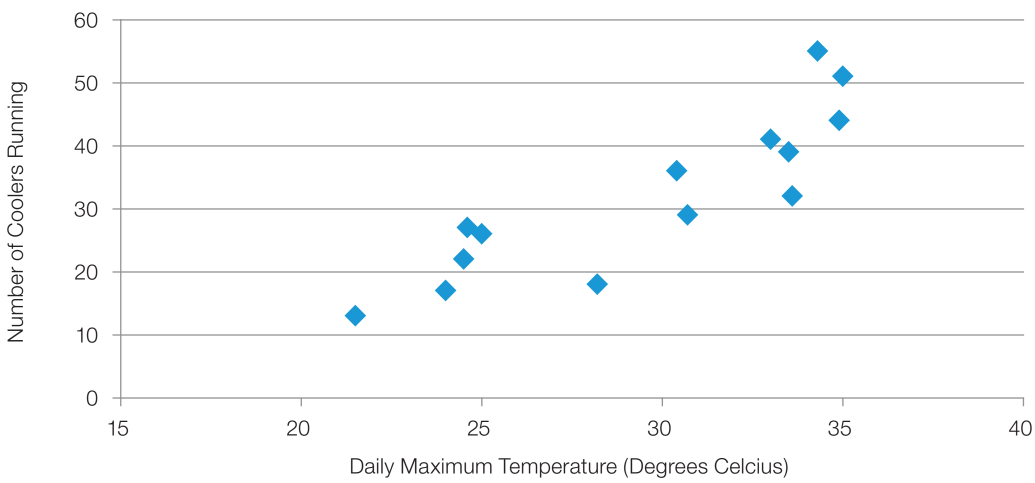


Figure 7.32: Daily maximum temperature versus number of cooler running (January 16 to 29, 2012).

Figure 7.33 models the water usage of coolers per usage as a function of maximum daily temperature, x, which is explained by the quadratic function:

Daily Water Use (L) = $0.36x^2 - 4.11x - 50.12$ if $x>19$, 0 Otherwise

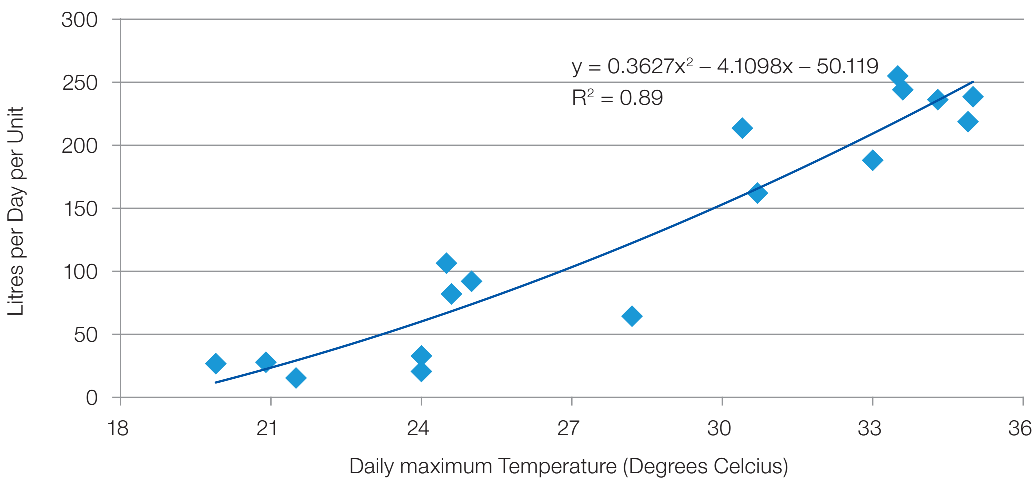


Figure 7.33: Litre per day per unit versus daily maximum temperature (January 16 to 29, 2012).

27 Data used was taken from the Melbourne Regional Office.

Again, we can see moderate water consumption for temperatures between 20 and 30 degrees, and a noticeable increase for temperatures over 30. As shown in Table 7.30, there is almost 2.5 times the number of coolers running when the temperature exceeds 30 degrees. Similarly, water usage almost quadruples, suggesting substantially longer duration of use.

	Average Number of Coolers	Average Litres per Unit (L)
Over 30	41	220
Under 30	17	59

Table 7.30: Average number of coolers and water usage per cooler for temperatures above and below 30 degrees celsius (summer).

7.9 Leaks and Drips

Overall, leaks and drips accounted for roughly 5% of the sampled residential water usage in Melbourne. All homes displayed leakage at some stage over the two week period. However these amounts were generally small as a proportion of total water use.

7.9.1 Volume

From the combined summer and winter leak data, we can see that 80% of all leaks that occurred during the logging periods emanated from just 34 (12%) households. The bulk of the sample demonstrated minimal leakage, with 78% of households accounting for only 10% of all recorded leaks. See Figure 7.34.

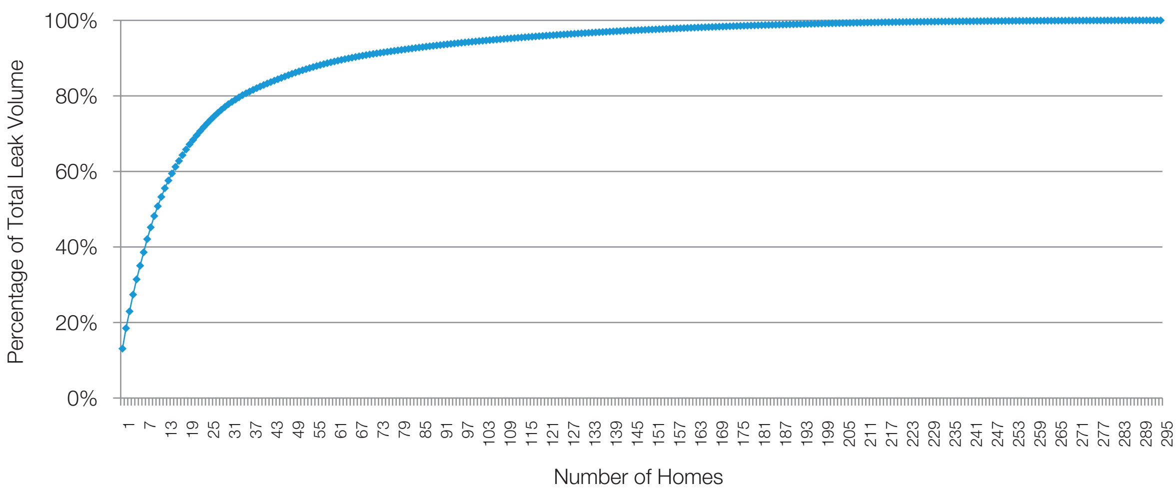


Figure 7.34: Number of homes and their relative share of total leaks and drips (summer and winter).

Similarly from Figure 7.35, we can see that 90% of leaks that occur account for only 11% of that household's total volume or less. Also note that leaks accounting for greater than 20% of total volume used in the home occur at random intervals and infrequently. The final bar on the chart represents leaks that are more than 40% of total use, which occurred in 2% of households.

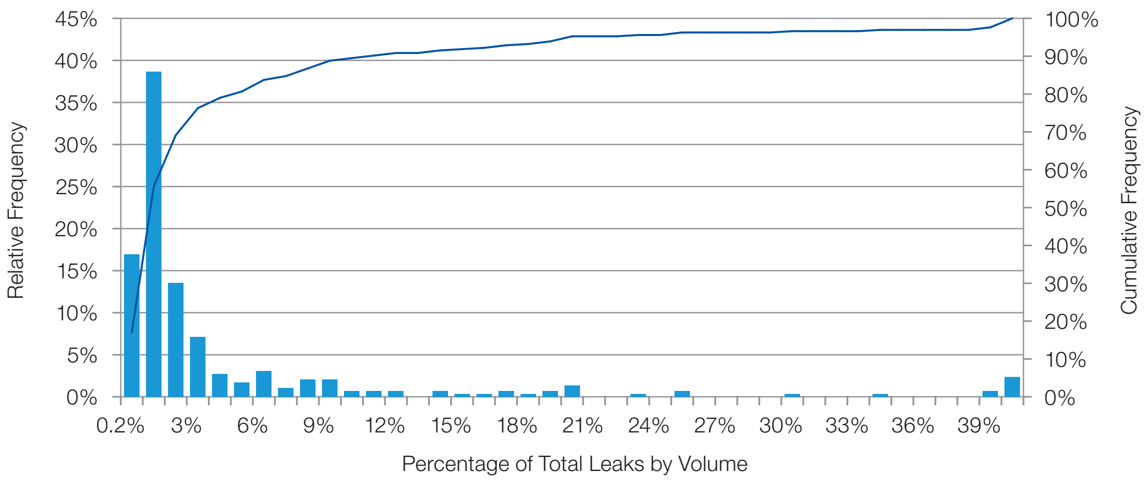


Figure 7.35: Distribution of leaks and drips volume as a share of total (summer and winter).

7.9.2 Duration[28]

From Figure 7.37, we can see that there are more events lasting for 5 seconds or less than any other interval[29]. Figure 7.37 shows the distribution of events lasting for 40 seconds or less. This represents 2.7 million events recorded. The share of leak volume is shown on the data labels on the histograms.

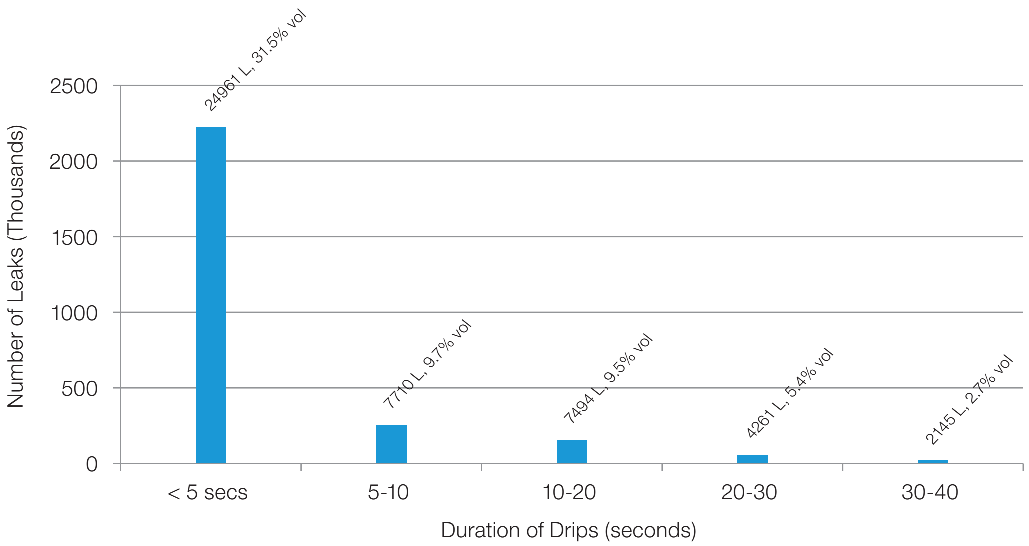


Figure 7.36: Distribution of drips lasting for 40 seconds or less (winter).

Extending the time horizon to include all leaks lasting for 40 seconds of more, we see a distribution heavily skewed to the right, shown in Figure 7.37. Leaks accounting for .3% of total household volume or more last less than 4 minutes.

28 Winter data only, see section 3.5

29 5 seconds is the smallest measurable time gap and was used when recording the winter data.

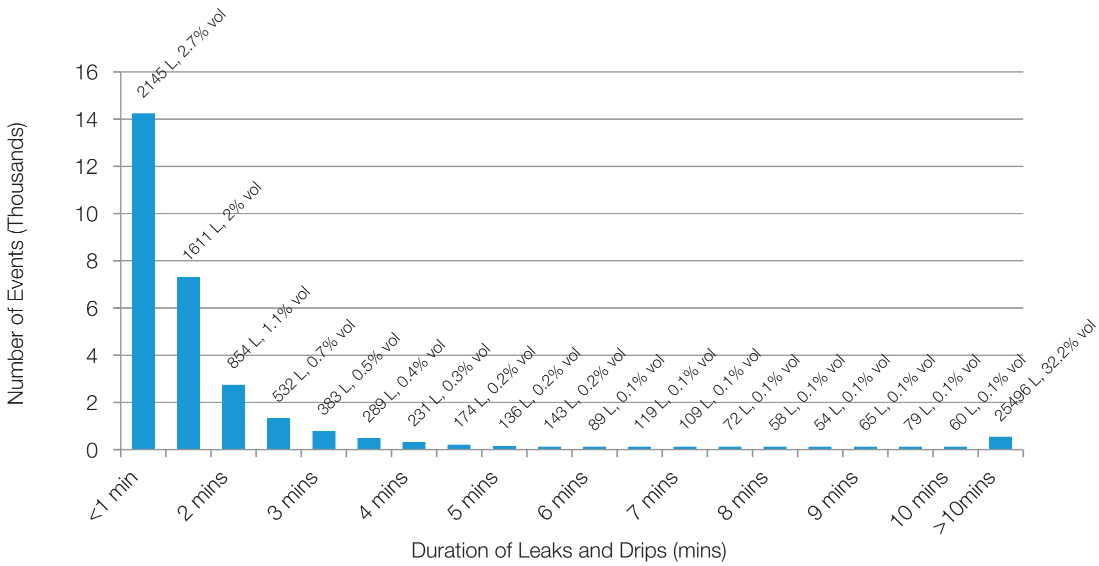


Figure 7.37: Distribution of leaks and drips lasting for 40 seconds or longer (winter).

From Figure 7.38, we can see that leaks lasting for 20 minutes or less account for the bulk of leak events. There are a small proportion of continuous leaks that last for more than 3 hours.

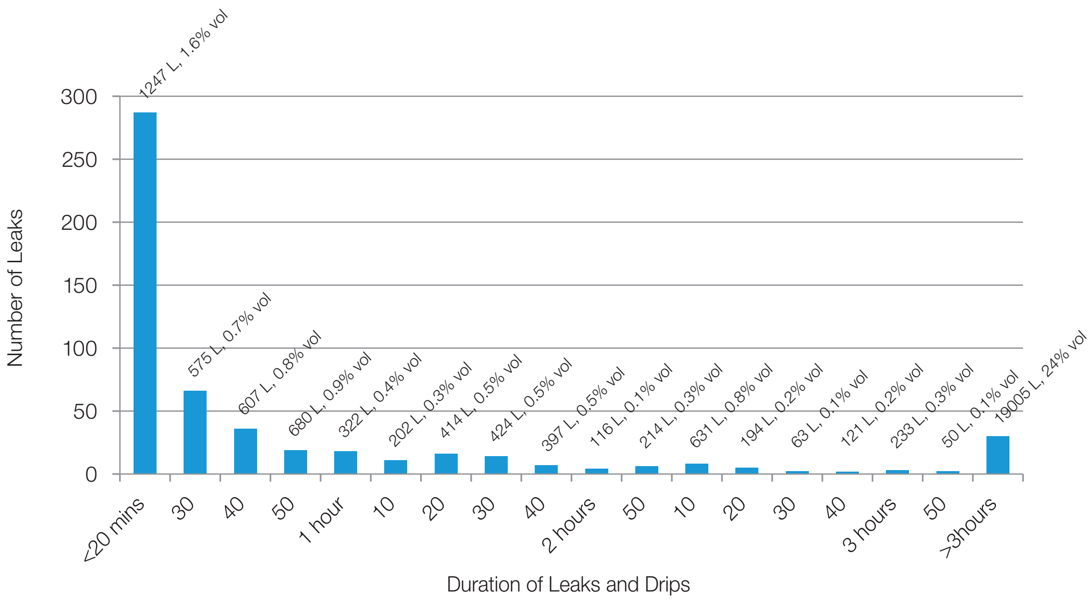


Figure 7.38: Distribution of leaks and drips lasting for longer than 10 minutes (winter).

7.9.3 Analysis: Does the Number of People in the House Influence the Likeliness of a Leak or Drip?

Pooling the data for the summer and winter periods, we can determine which households are more likely to have leaks at their end use appliances. Figure 7.39 shows the relation between the number of people in the household versus the average daily leak volume. As we can see there is generally an increase in the daily volume leaked for each extra person in the household. There are a couple of possible explanations for this occurrence. Firstly, the larger households tend to have more children, who are far more likely to leave taps not completely turned off. Secondly, the more people there are using an end appliance, the more readily it may break down and leak water at a flow rate below that which can reasonably be used by a person[30]. Finally, there are more toilets in large households, thus permitting more leaks through the toilet.

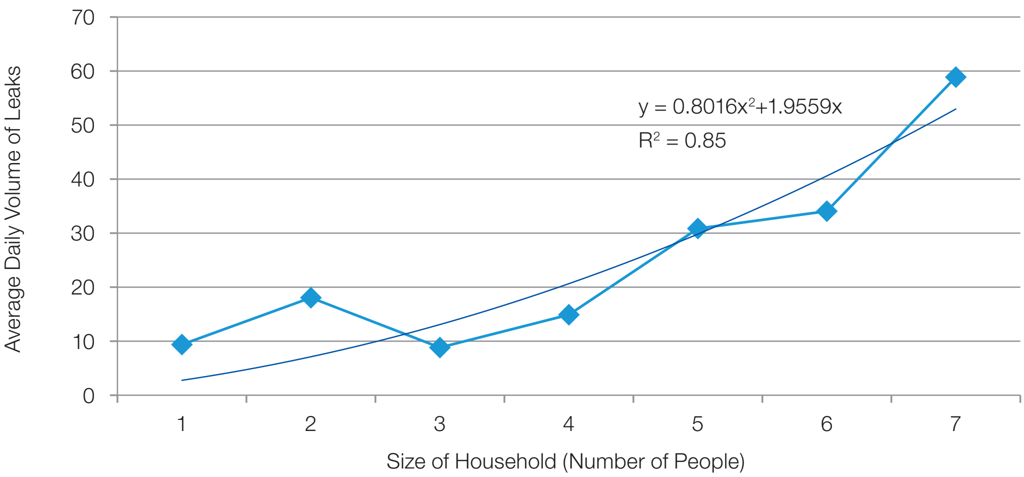


Figure 7.39: Average daily volume of leaks versus number of people per household (summer and winter).

The number of people per household tends to correlate weakly with the number of daily leaks, shown in Figure 7.40. For household sizes of between two to four people, the distribution is flat, indicating no relation whatsoever. There were only three households with seven people, and these were omitted due to small sample size.

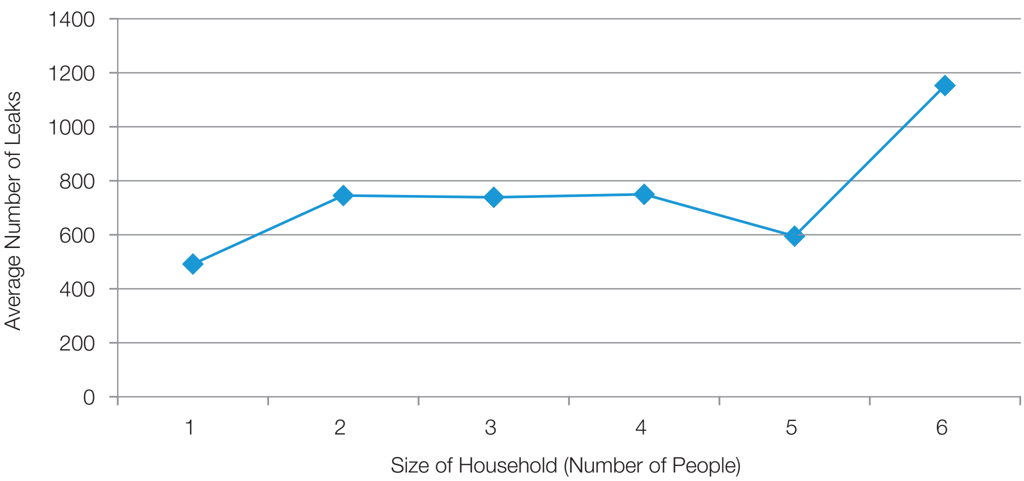


Figure 7.40: Daily average number of leaks and drips versus household size (summer and winter).

30 For example, seals wearing out in taps, toilet flush mechanisms etc.

Other variables were also examined. There was virtually no correlation found between the property size and daily number of leaks. The scatter was found to be random in nature, although some larger properties logged a higher number of leaks. The correlation between daily volume of leaks and property size is almost non-existent. In both instances, we can see an increase in variation of leakage volume and occurrence.

7.10 Hourly Use

The composite diurnal profile for total water use for each of the two weeks in summer 2012 and winter 2010 is shown in Figure 7.41[31]. These curves represent the stacking of each appliance's average use, taken only over the properties that used it. The difference in peaks is mainly driven by the inclusion of irrigation and evaporative cooler usage in summer.

7.10.1 Total Use

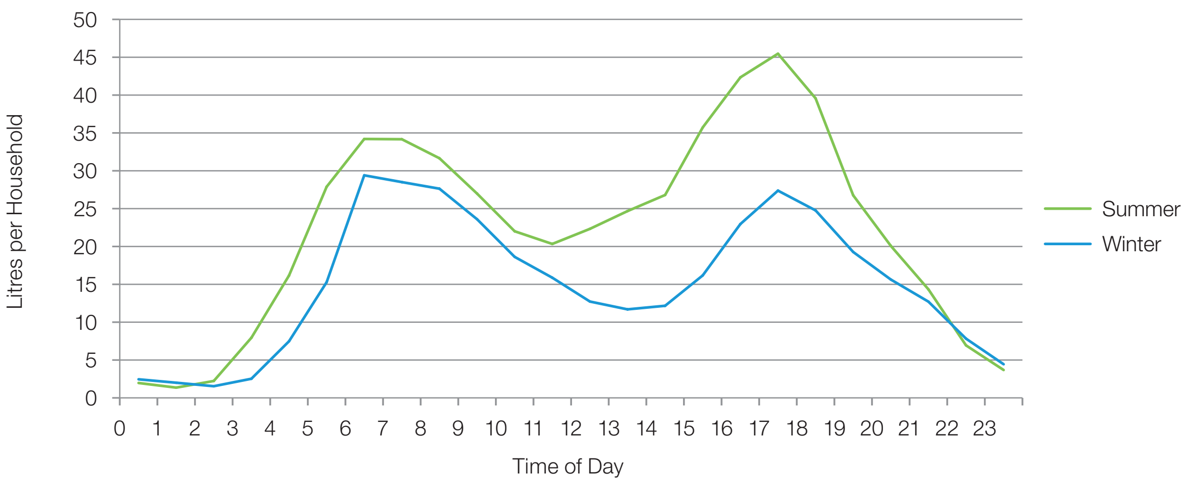


Figure 7.41: Average hourly profile for total use, adjusted for DST (summer and winter).

Comparing the core appliances[32], common in usage to both seasons, we can see the distributions are closer together. The afternoon peak in the summer data is now below the morning's, chiefly due to the exclusion of evaporative coolers during the warmer part of the day. The differential apparent in the middle part of the day is due to sustained and increased shower use and generally higher tap use[33]. See Figure 7.42.

31 Winter data adjusted for daylight savings.
32 Appliances whose usage patterns are common to both seasons exclude evaporative coolers and irrigation.
33 As measured in litres per capita per day.

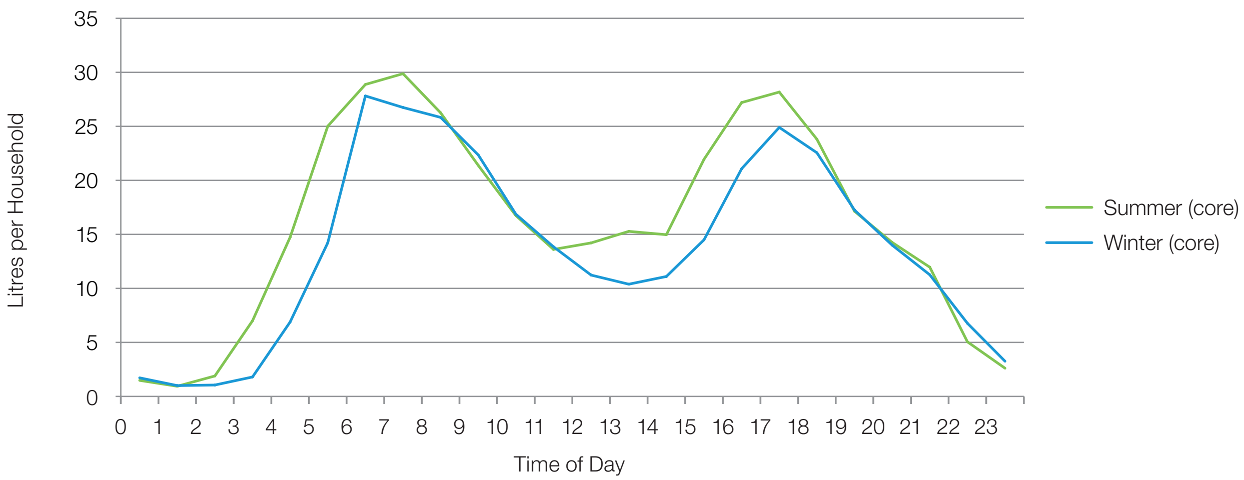


Figure 7.42: Average hourly profile for core appliances' indoor use, adjusted for DST (summer and winter).

7.10.2 Use by Appliance

Average hourly water consumption per property that used the appliance for the summer logging period is shown in Figure 7.43, broken down by appliances. Under Stage 1 Water Restrictions that were in place at the time, watering systems are allowed between 6am–10am and 6pm–10pm. These points are highlighted by the increase in irrigation volume at these times. Hand held watering devices can be used at any time and are evidenced by irrigation occurring throughout the day. Evaporative coolers come into significance around midday, and continue through the hottest portion of the day. Showers then clothes washers tend to dominate morning usage, whilst tap and toilet use is fairly constant throughout the day. Water consumption reaches a daily minimum around 2am.

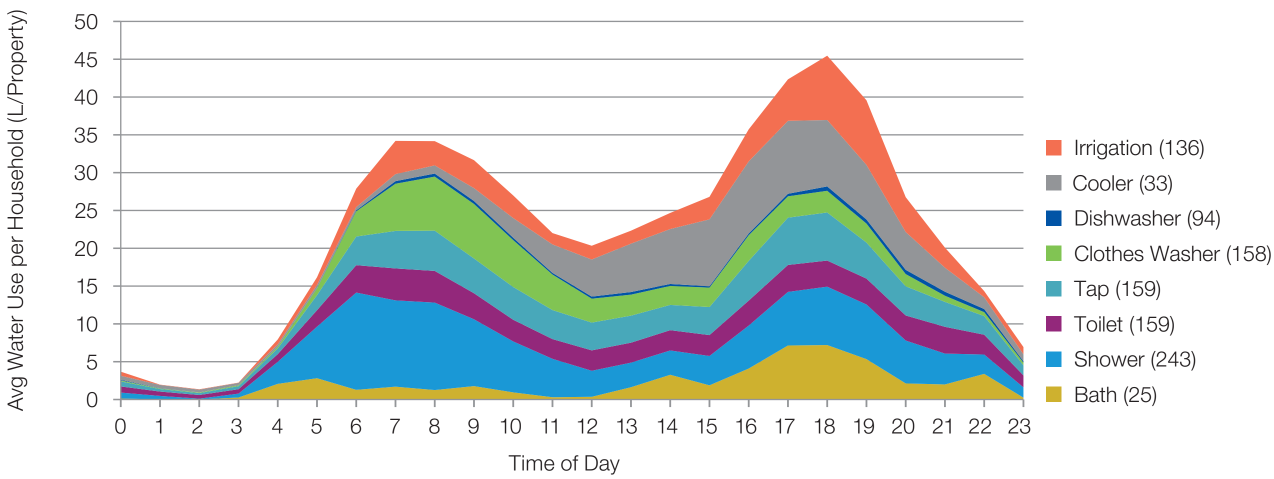


Figure 7.43: Composite diurnal profile for the summer logging period.
Figures in parentheses are the number of households included in the calculation.

In winter, we see large amounts of shower and clothes washer and shower usage throughout the day. Low amounts of irrigation and cooler events are typical of the winter period. In addition, Stage 3 water restrictions mean watering could only be conducted between 6am and 8am. See Figure 7.44.

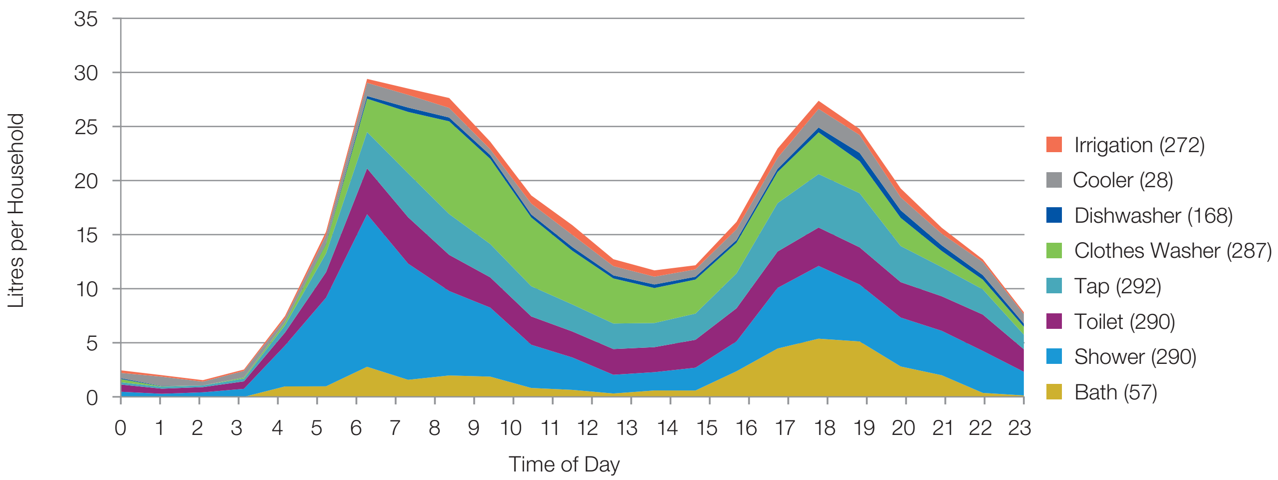


Figure 7.44: Composite diurnal profile for the winter logging period (adjusted for daylight savings).

Figures in parentheses are the number of households included in the calculation.

Note that the averages were calculated over the households that used each device, stated in parentheses in the figures, not the entire sample. That is, the composite diurnal curve states the hourly use per lot, which is representative of how a household with such an appliance would use it. These values should be weighted with appropriate values in order to generate a population wide average. Referring to the Appliance Stock Survey and Usage Report that is counterpart of this study may be useful in determining these weightings. Table7.31 summarises these values.

Appliance	Penetration as per ASUPS Sample
Shower	100%
Bath	30%
Toilet	100%
Clothes Washer	100%
Dishwasher	67%
Tap	100%
Evaporative Cooler	30%
Irrigation	100%

Table 7.31: Selected figures from the Appliance Stock Survey Report (Ghobadi, 2013).

7.10.3 Similarities between Seasons

In both summer and winter periods, some appliances exhibit similar usage patterns. This is generally seen in staple appliances, whose use is necessitated regardless of season.

Bath usage appears in the morning, dies down around midday then peaks around 6pm. The maximum reached is slightly higher in summer, but qualitatively the pattern is constant.

Dishwasher use appears slightly between 7am and 9am, early and late afternoon and is also quantitatively similar in both seasons. As found in sections 7.4.1 and 7.4.2, dishwasher volume was slightly higher in winter, but the frequency was slightly higher in summer. Consequently, the effects offset each other, with a daily total of 6.9 litres per property in winter and 6.3 litres per property in summer.

Toilet usage remained constant both qualitatively and quantitatively across seasons, averaging 59.3 litres per property per day in winter and 62 litres per property per day in summer. Usage is low but steady after midnight, picking up around 5am and hovers around 3 litres per property per hour for the rest of the day. This is also highlighted in sections 7.2.1 and 7.2.3.

Clothes washers were seen to be used at the same frequency in both periods, as concluded in Section 7.3. Usage is seen to increase between 8am and 9am then gradually thins throughout the rest of the day, picking back up a little around 6pm. Daily summer use averaged 62 litres per property, just behind the winter average of 67.5.

7.10.4 Differences between Weekends and Weekdays

Weekend and weekday water usage can vary both quantitatively and temporally. People tend to get up later on the weekends, as demonstrated by the peak in the data occurring at 8am. A similar peak is seen in the weekday data, although it occurs two hours earlier. Also due to more stringent time commitments on weekdays, the afternoon peak occurs later when people arrive home from work. Also note the far greater water use on weekends, with all households across the sample using a maximum volume of almost 11 kilolitres used between 8 and 9am on average compared to the 8.5 kilolitres between 6 and 7am on weekdays. Peak afternoon water use is approximately equal. Such behaviour is exhibited in Figure 7.45.

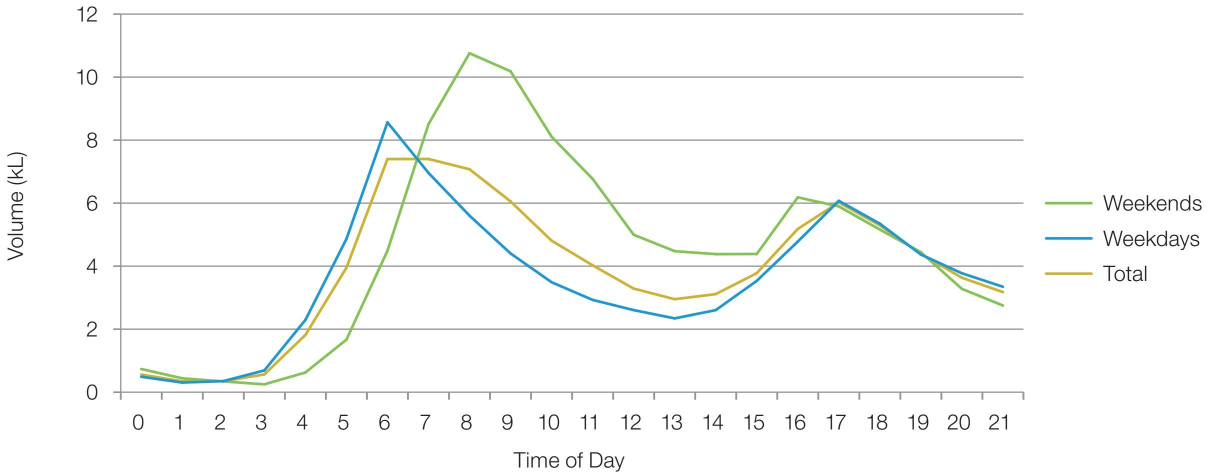


Figure 7.45: Daily consumption of the sample on weekends, weekdays and for the two week period.

From Table 7.31, we can see there is a clear increase in daily consumption on the weekends, with a 25% increase across the sample and 39% increase on a per household basis. Note that only the households that logged an event were included in the litres/household figure. These households were also found to have used certain appliances either only on weekends or only on weekdays.

	Kilolitres per Day	Litres / Hour / Household
Daily weekday consumption	82.4	14.9
Daily weekend consumption	102.6	20.8
Average daily consumption (weekends and week days)	88.2	15.1

Table 7.32: Daily consumption of the sample on weekends, weekdays and for the two week period.

Figure 7.46 and Figure 7.47 show the appliance breakdown for weekend and weekday use as a proportion of total daily use for the applicable timeframe. The large morning spike in weekend use in Figure 7.46 is primarily due to clothes washer, toilet and tap use across all households. Shower use is more protracted, due to more variable showering times when compared to Figure 7.47. Note there is similar usage in terms of volume in the afternoons from approximately 5–6pm onwards, but is a larger proportion of total volume on weekdays. The analysis was made dimensionless instead of per household, so as to clarify the relative water consumption per device. Consumption on a households basis tended to exaggerate some devices' usage, as usage of certain devices tended to be localised to either the weekends or weekdays.

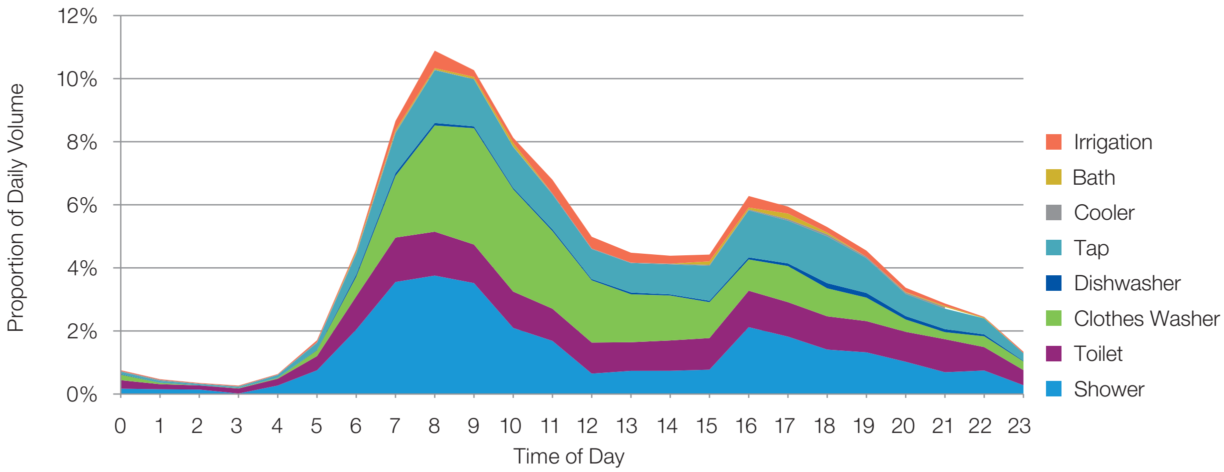


Figure 7.46: Diurnal profile of a typical winter weekend day.

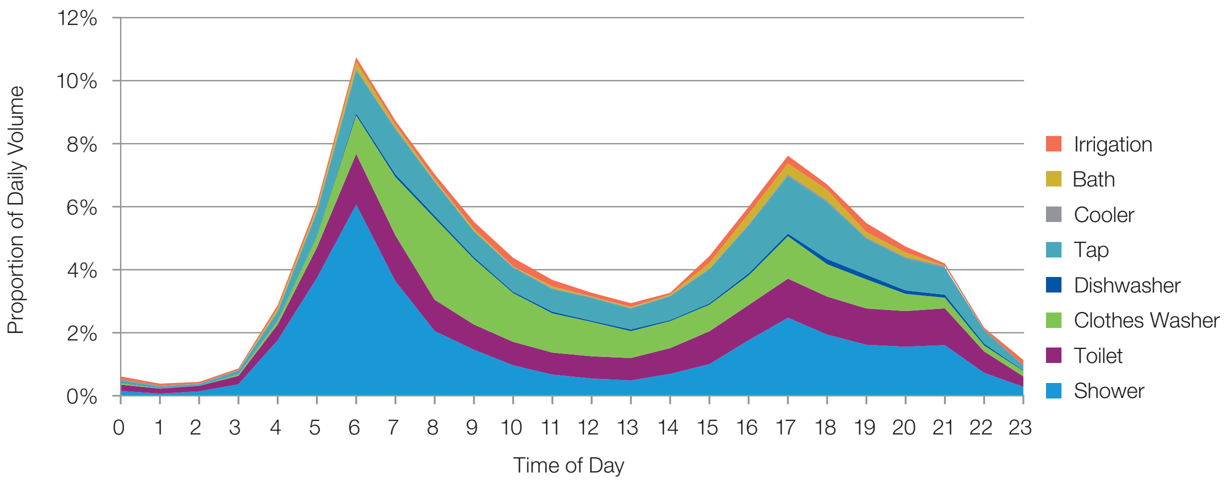


Figure 7.47: Diurnal profile of a typical winter weekday.

As mentioned above, the peaks in the weekday data are sharper, due to the fact that people are working. Note that in Figure 7.46 the later peak in the weekend data can still be observed. Interestingly, it is evident that although weekend use is greater in volume, the maximum represents a proportion of daily use equal to that of a weekday, equivalent to approximately 10.5%.

8 Conclusion

The Melbourne REUM project was technically complex and costly but has provided useful data and information regarding water use at the end use level that are difficult to obtain by any other methods.

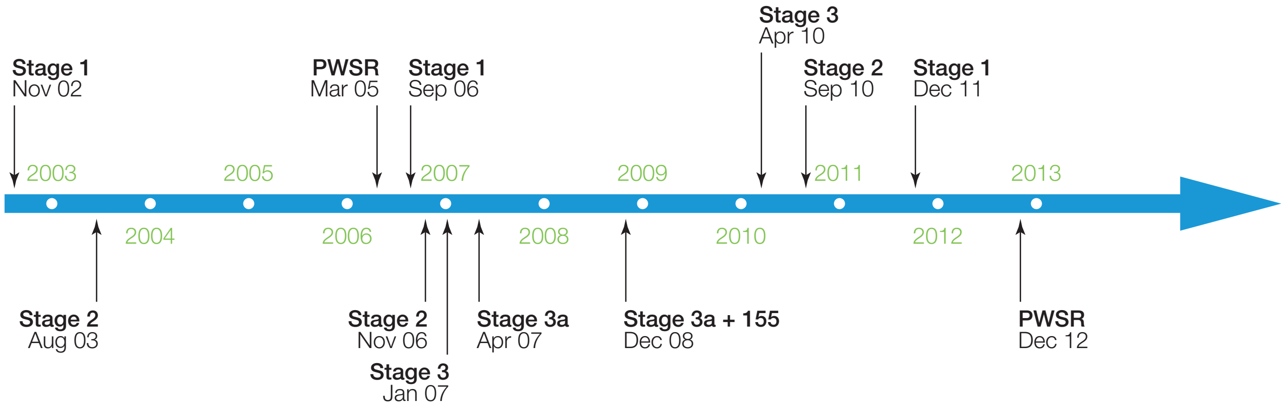
The presentation in this report of detailed results by retail area for both summer and winter demonstrates the considerable variation that can occur around many end use parameters with the standard deviation often being greater than the mean.

Data from high resolution loggers measuring the flows were disaggregated using the Trace Wizard© software, which requires some user judgement. When such judgement is required, the possibility for human error exists. Consequently, results should be viewed with caution. When considered in conjunction with the Appliance Stock Survey, a better understanding of appliance water use could be gained (Ghobadi, 2013).

The results presented in this document will be of use to water planners, researchers, consultants and students. It is planned to repeat the study every four years.

Appendix 9

9.1 Appendix 1 – Water Restrictions Explained



Permanent Water Saving Rules

Residential and commercial gardens can be watered on any day by means of a watering system (between 6pm–10am) or hand held hoses (any time), which must be fitted with a trigger nozzle and leak free.

Stage 1

Watering system allowed from: 6am–10am and 6pm–10pm.
Even and no-numbered properties may water on even dates (e.g. 2nd, 4th, 6th, etc.), odd numbered properties may water on odd dates; all properties may water on the 31st of any month or the 29th of February.

Stage 2

Watering system allowed from: 6am–8am and 6pm–8pm.
Even and no-numbered properties may water on even dates (e.g. 2nd, 4th, 6th, etc.), odd numbered properties may water on odd dates; all properties may water on the 31st of any month or the 29th of February.

Stage 3

Watering system allowed from: 6am–8am.
Even and no-numbered properties may water on even dates (e.g. 2nd, 4th, 6th, etc.), odd numbered properties may water on odd dates; all properties may water on the 31st of any month or the 29th of February.

Stage 3a,

Watering Days: Tuesday, Wednesday, Saturday, Sunday.
Manual dripper systems, a hand-held hose fitted with a trigger nozzle, watering cans and buckets can be used to water gardens as required on specified watering days between 6am–8am. Households with at least one resident aged 70 years or over may water their gardens manually on specified watering days between 6am–8am or 8am–10am.

Stage 3a + Target 155,

Watering Days: Tuesday, Wednesday, Saturday, Sunday,
Automatic dripper systems can be used to water gardens as required on specified watering days between midnight–2am.

For more information, please see http://www.water.vic.gov.au/saving/restrictions/

9.2 Appendix 2 – Measuring Equipment

CT5-S — **20mm totaliser positive displacement flowmeter with high rate 72.5 pulses/Litre pulse output**

FEATURES

- Volumetric rotary piston principle, measures accurately in any position.
- Mechanical totaliser.
- 72.5 pulses/Litre Reed Switch contact closure output for precision data collection and flowrate readings
- Designed to meet AS3565.1-1998
- Accuracy ±2% (Qt to Qs)
  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.

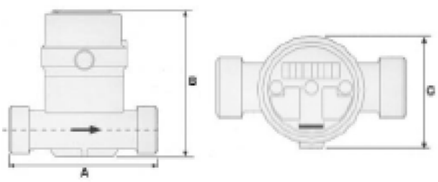
The mechanical counter register is positioned for easy reading and displays from 0.02 to 9,999,999 Litres. The precision engineered rotary piston measuring chamber ensures accurate measurement even at very low starting flow rates. Meters can be installed in any position without affecting accuracy and 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 flowmeter provides the best pulse output rate for domestic water meters, with 72.5 pulses/Litre.

SPECIFICATIONS

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



Other Specifications

Headloss @ Qn <25kPa. Max. pressure rating: 1500kPa. Max water temperature: 50°C,
Reed Switch pulse: V. max: 24V, I. max: 50mA, with anti-bounce and current-limiting resistor fitted.
Cable: 2-core, 1.5 metres long.

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

DIMENSIONS

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

ORDER CODES

Part	Size (mm)	Description of coupling set
CT5-S	20	Gasket seat ¾" BSP (male)
CT5-S-B	20	Ball seat ¾" BSP (female)

ManuFlo ® ™
Flow Measurement & Control Products

a division of

MANU ELECTRONICS PTY LTD
41 Carter Rd, Brookvale
Sydney NSW 2100 Australia
Ph: + 61 2 9905-4324, 9938-1425
Fax: + 61 2 9938-5852

Web: www.manuelectronics.com.au
Email: sales@manuelectronics.com.au

0710/1

9.3 Appendix 3 – Customer Information used for Selection

The following information was asked from candidates upon calling the call centre:

Caller_number
Retailer
Customer_number
Segment[34]
FT_Occupants
PT_Occupants
Permanent_residence
Ages_0–10
Ages_11–18
Ages_19–35
Ages_36–54
Ages_55+
Income
FT_Work
PT_Work
Casual_work
Unemployed
FT_Student
PT_Student
Planned_Changes[35]
Change_type
Owner_Occupier
Birth_Country
Language_at_home
Dwelling_Type
Time_At_Address
Panning_Move
Planning_Rennovate
Rennovate_type
Number_Bedrooms
Evap_AC
Tan_Grey_Water
Contact_Phone
Call_Centre_Notes

34 Low, Medium or High water use area, depends on address
35 Changes to familial environment and living arrangements, such as pregnancy, extra people

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10

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Smart Water Fund

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www.smartwater.com.au

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GPO Box 2203
Melbourne, Victoria 3001

City West Water

South East Water

Yarra Valley Water