STUDY REPORT

No. 159 (2007)

Water End Use and Efficiency Project (WEEP) – Final Report

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Preface

This report summarises the findings from eight months of water end use monitoring, conducted in a sample of residential homes on the Kapiti Coast, and the findings from the initial pilot and testing phase.

Acknowledgements

This work was funded by the Building Research Levy.

I would also like to acknowledge the help and support of the Kapiti Coast District Council (KCDC), especially Ben Thompson and Alan Smith in installing the water meters and assisting with the downloads, and to thank the homeowners for participating in this study.

Note

This report is intended primarily for councils, government agencies, water suppliers and others researching and wanting to measure end use consumption of water in residential buildings or introducing water efficiency measures.

Water End Use and Efficiency Project (WEEP) – Final Report

BRANZ Study Report SR 159 (2007)
Matthias Heinrich

REFERENCE

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ABSTRACT

Twelve homes on the Kapiti Coast are being monitored to find out where the water is used. This report includes monitoring data and analysis of the winter and summer period, as well as a summary of the methods and tests that have been conducted in order to derive an end use monitoring technique. By analysing water use at an end use level, it is possible to identify the areas which would yield the greatest results when conducting a retrofit. The largest water savings could be achieved by installing low flow shower heads and water efficient washing machines. High savings in mains water use can be accomplished by installing a greywater system or rain tank.

KEYWORDS

Water, end uses, demand management, efficiency, WEEP, rainwater, greywater, environment.

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1. INTRODUCTION

Water is a significant issue at present in many parts of New Zealand and indeed the world. 'Water Shortages Threaten to Spread, Say Forecasters' quoted a recent headline of the *NZ Herald* (Ihaka 2007), which addresses water shortages caused by drought conditions in parts of New Zealand, especially the South Island.

1.1 Project background

The aim of this pilot study is to develop a robust and tested methodology for monitoring the end uses of water in residential homes, in order to find out how water is used in New Zealand homes.

The main part (Stage 3) of this pilot study was the monitoring of 12 residential homes on the Kapiti Coast using the techniques and equipment developed and tested in Stages 1 and 2 of the project. The homes have been continuously monitored for a period of eight months. The winter monitoring period started in mid-July and finished in mid-October 2006. The summer period started in mid-November and finished at the end of February. It was monitored over two separate periods to capture the seasonal variations. This report discusses the testing undergone in Stage 2, and the analysed water use data for the winter and summer monitoring periods which formed Stage 3 of the project.

International research and development of the flow trace analysis process are not provided (these can be read in BRANZ *Study Report 149* (Heinrich 2006) which was the output from Stage 1 of the project). The stages of the WEEP project are shown in Figure 1.

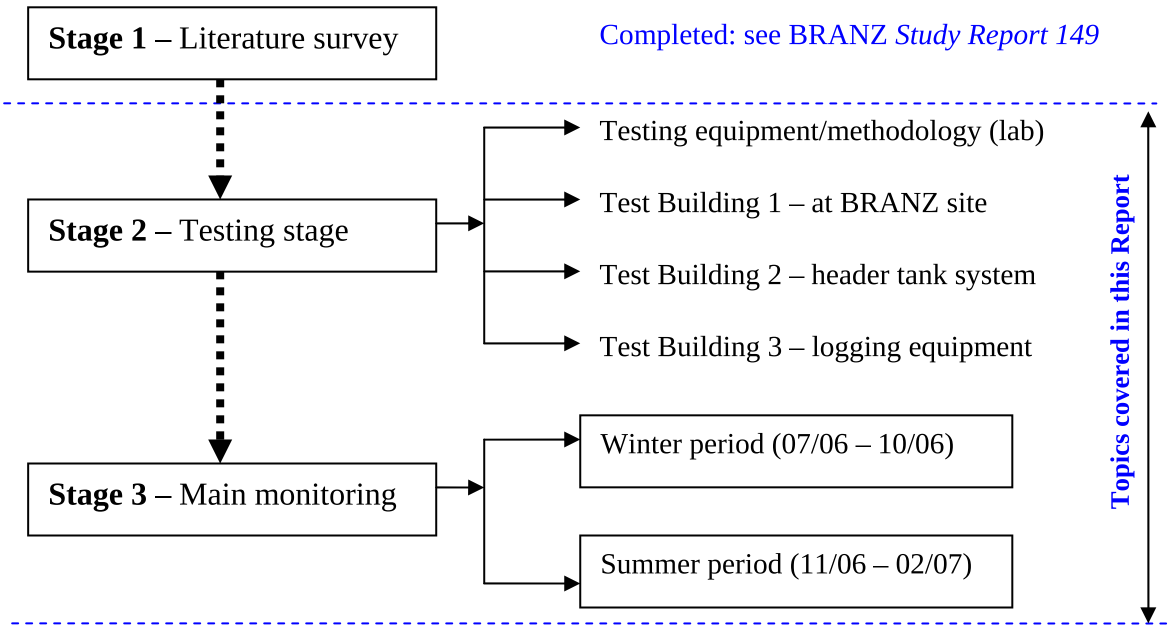

Figure 1: Stages of WEEP project

Litres (L) is used throughout the report; for volumes of 1000 L or above m^3 is used ($1\ m^3 = 1000\ L$).

2. STAGE 2 – INITIAL TESTING PHASE

The aim of the initial testing phase was to decide on the methodology and equipment to be used. Various monitoring options were considered and evaluated. After completing the literature survey at the end of 2005, it was decided to adopt an end use disaggregation method using a software package and BRANZ logging equipment, and this methodology will be explained further in the text.

For the first trial, different water meters were tested in the lab. The aim was to find a suitable meter which fulfilled the requirements for disaggregating water flow traces, as well as having a minimal pressure drop. After successfully completing the lab test, the equipment was installed on a residential home on our site in Judgeford in April 2006.

2.1 Lab measurements

We set up our equipment in the lab prior to installing it on the house. The set-up is shown in Figure 2. This test was not only to check the water meter and the interaction with the logger at known flow rates and volumes, but also to measure the pressure drop across the meter. The water was pumped in a loop. Three meters were tested in total.

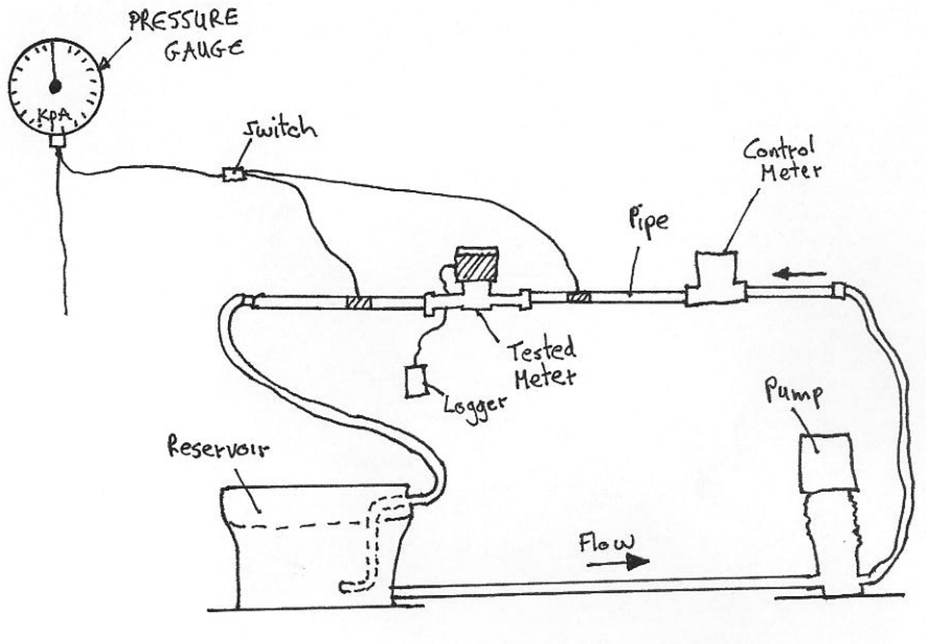

Figure 2: Experimental set-up

2.2 Water meters

The first meter we tested was a standard **Kent PSM** (20 mm) meter with two pulses per litre (ppL). The main problem with this meter was that it caused a noticeable pressure drop for the inhabitants, so we had to remove it. Another problem was that the meter's resolution was too low for performing a disaggregation from a flow trace.

The second meter was a nutating disk meter from **Badger** (Model: M25 20 mm) with a pulse output of 52.4 ppL. This meter provided useful output for disaggregation and caused no noticeable pressure reduction.

The third meter was a positive displacement meter from **ManuFlo** (Model: CT-5S 20 mm) with a pulse output of 72.5 ppL. A divider chip was added to the meter's output to give us a pulse rate of 36.25 ppL, which was still enough for disaggregating the flow traces into its end use components.

The fourth meter was another nutating disk meter from **Neptune**, modified by ManuFlo (Model: MES-25 25 mm) with a pulse output of 34.2 ppL. The 25 mm model was chosen, due to the fact it has a lower pulse rate than the 20 mm model, but still provided adequate resolution.

The turbine flow meter from **GPI** had a pressure drop close to 0 for all flow rates. However, the properties of the turbine flow meter were not suitable for our application, due to the high pulse output (2500 ppL) and the inaccuracy of the meter at low flow rates (<2 litres per minute (Lpm)).

The following graph (Figure 3) shows the pressure loss curves from lab measurements for both the Badger M25 and the Kent PSM meter. As can be seen from the graph, there is a substantial difference between the standard Kent PSM meter and the nutating disk meter M25 from Badger (especially above a flow rate of over 40 Lpm where the pressure drop doubles for the Kent meter).

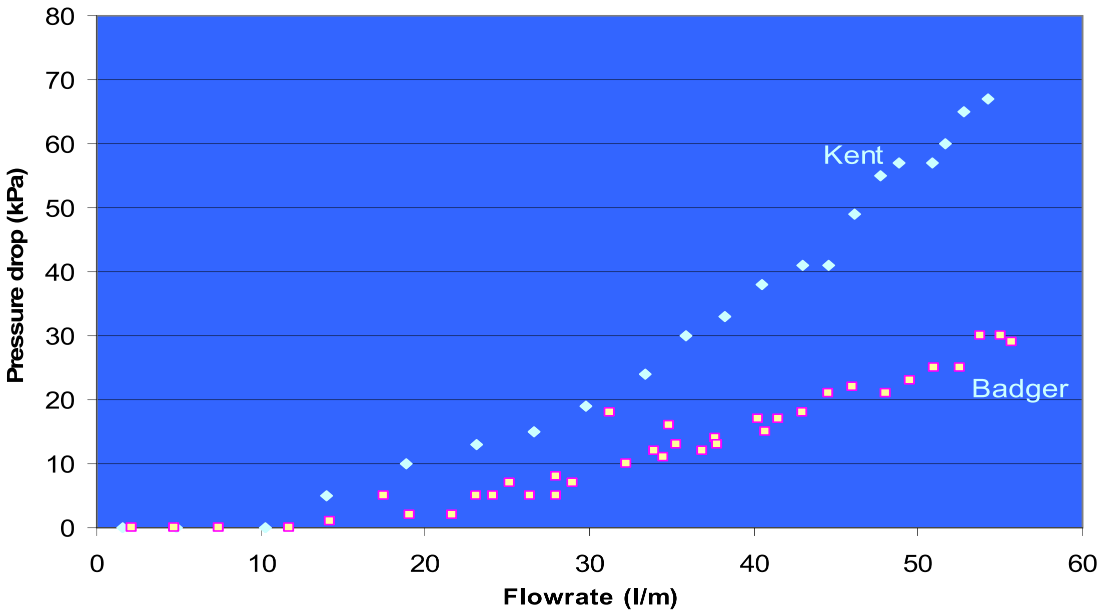

Figure 3: Pressure loss curves of water meters

2.3 Test Building 1 – initial trials

As a first test we installed our equipment on the caretaker's cottage on the BRANZ site in Judgeford. This was a suitable place, since data could be downloaded and changes to the equipment made quickly. Also since people inhabited the house, this would provide useful test data. Due to the location of our site the house was on tank water with a low pressure of around 200 kPa (20 m head) – this is also a reason why different water meters were used in the initial testing stage.

A water meter, used in the lab tests, was attached to the feed line of the house as shown in Figure 6. The modified BRANZ logger, which is capable of logging at a 10 second interval, was attached to the reed switch output of the water meter to collect the data. The logger was kept in a weathertight container to keep moisture away from the electronic components.

Various weathertightness options were considered and tested to keep any direct moisture and condensation away from the electrical components and to reduce the possibilities of corroding parts. These will be explained later in the text.

2.3.1 Description of home

Figure 4: Picture of Test Building 1

The one storey three bedroom house (Figure 4) has the following water using fixtures:

- toilet
- shower (hot and cold)
- bath (hot and cold)
- washing machine
- bathroom tap (hot and cold)
- kitchen tap (hot and cold)
- laundry tap (hot and cold)
- outside tap (cold).

The following diagram shows a floor plan of the house, and the locations of the fixtures and our equipment. The house is presently occupied by two people.

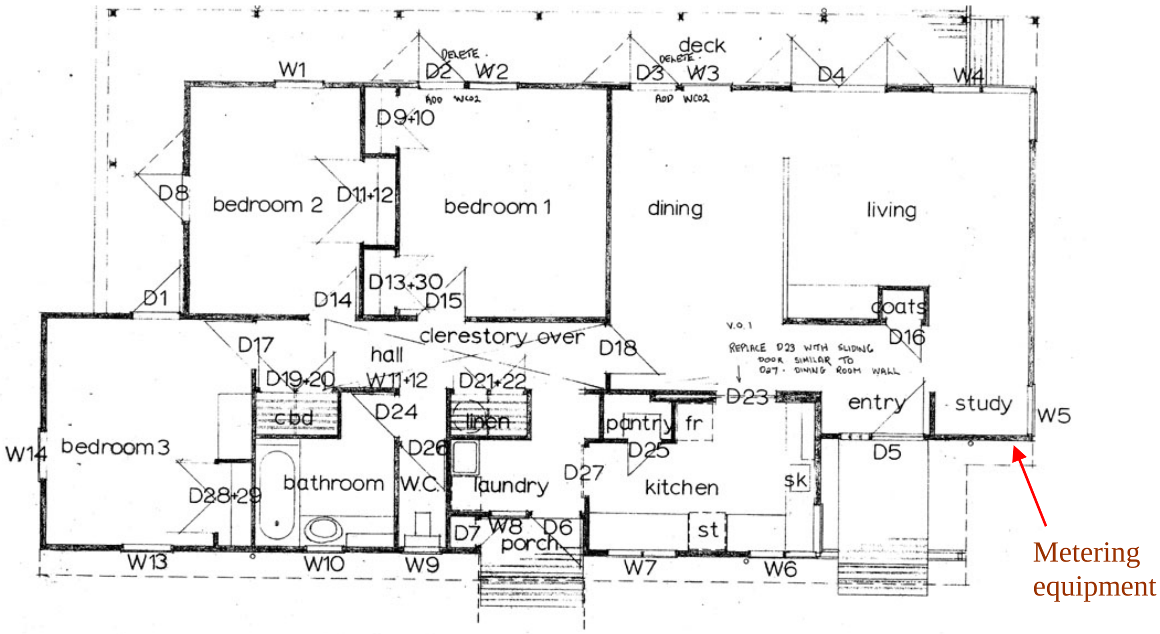

Figure 5: Floor plan

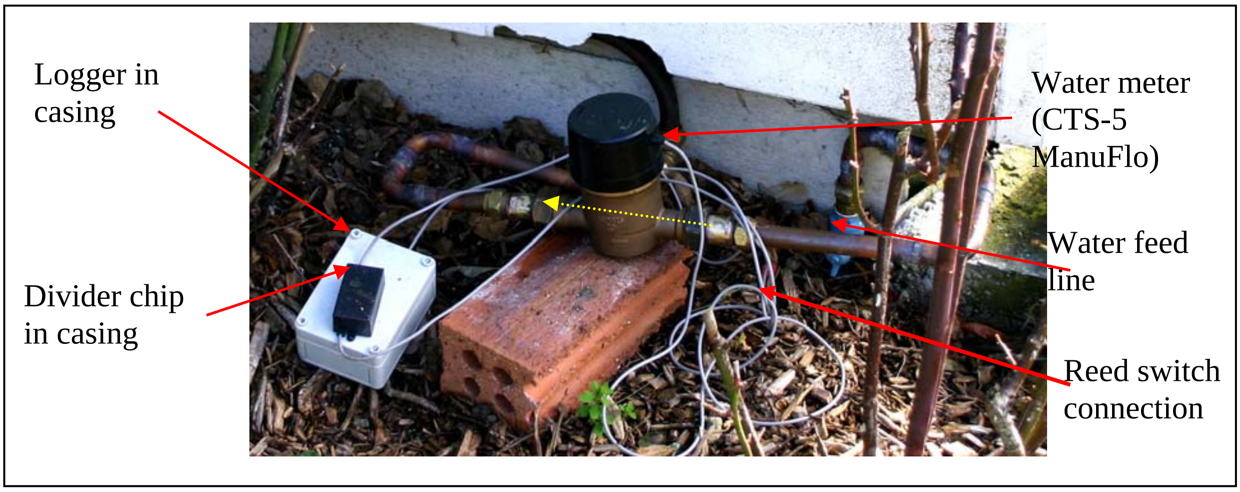

Figure 6: Monitoring arrangement of equipment

The picture in Figure 6 shows the installed measuring equipment. The location is marked on the plan.

2.3.2 Flow measurements

After the water meter and our data logger were in place a signature trace was performed. This involved operating each appliance for at least 1 minute (min) and recording the time the fixture was operated (this is useful when it comes to analysing the data at a later stage). We also measured the maximum flow rates of each of the taps using a conventional bucket and stop watch technique. The latter is, however, not necessary since the maximum flow rates can be identified from the flow traces. The following graph (Figure 7) shows the sample signature trace from the test house.

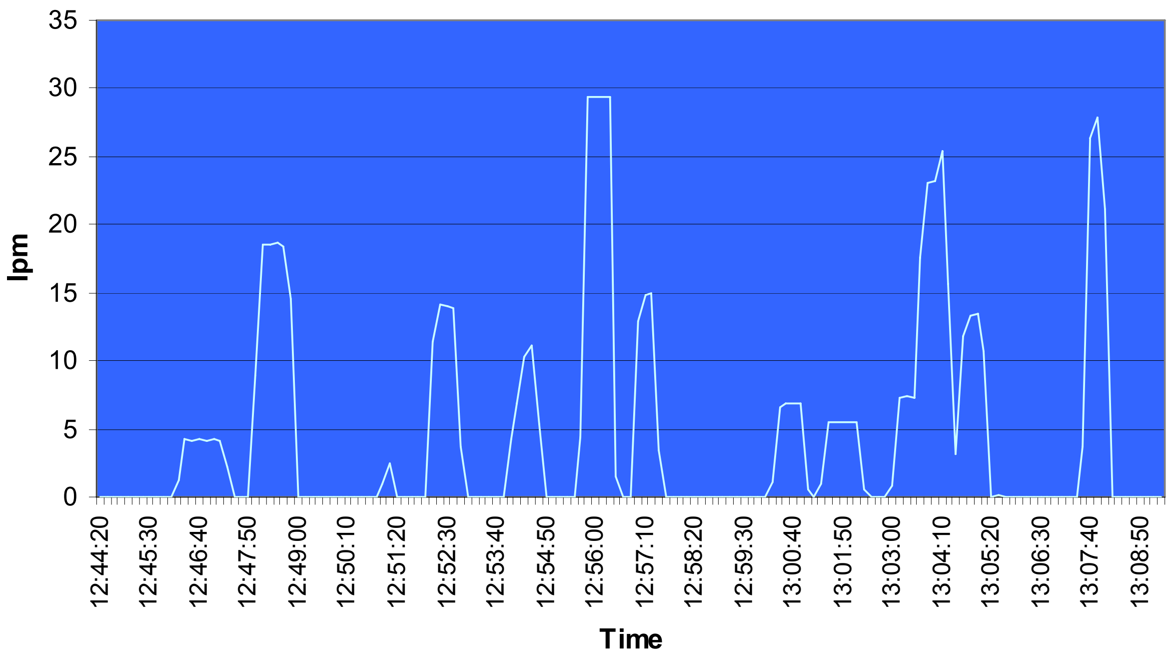

Figure 7: Signature trace from test building

Table 1: Signature trace

Order	Fixture	Notes
1	Kitchen tap (hot)	
2	Kitchen tap (cold)	
3	Unidentified	Leak (<0.5 L)
4	Bathroom sink (cold)	
5	Bathroom sink (hot)	
6	Bathtub (cold)	
7	Bathtub (hot)	
8	Shower (cold)	
9	Shower (hot)	
10	Laundry tap (cold)	Includes toilet refilling
11	Laundry tap (hot)	
12	Outside	

Table 1 shows the corresponding water end uses, which are represented in Figure 7 (starting with the kitchen hot water tap at the left of the graph).

2.3.3 Data analysis and disaggregation

When plotting the flow profiles (output of 10 second data from our logger), the profiles for each fixture became apparent, and after time it was possible to visually disaggregate the data.

2.3.4 Toilet

The following graph (Figure 8) shows a typical flow profile of the toilet, which in this case has an average flush volume of 9.56 L.

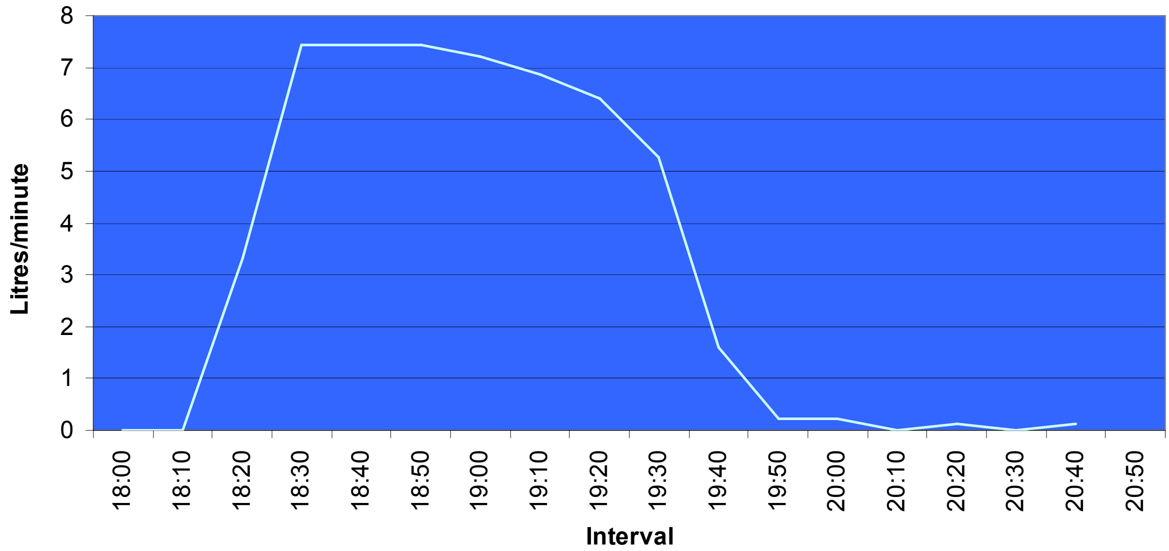

Figure 8: Flow profile of toilet flush

When looking at the average peak flow of 7.44 Lpm, and the duration for the refilling of the cistern (about 1 min 40 seconds), it is possible to identify the toilet flush using those figures. The following graph (Figure 9) shows the flow profile of 35 toilet flushes superimposed. This is useful because it shows that each flush from the same toilet has a similar profile and it is therefore possible to identify this end use. This is also the basis on which Trace Wizard operates.

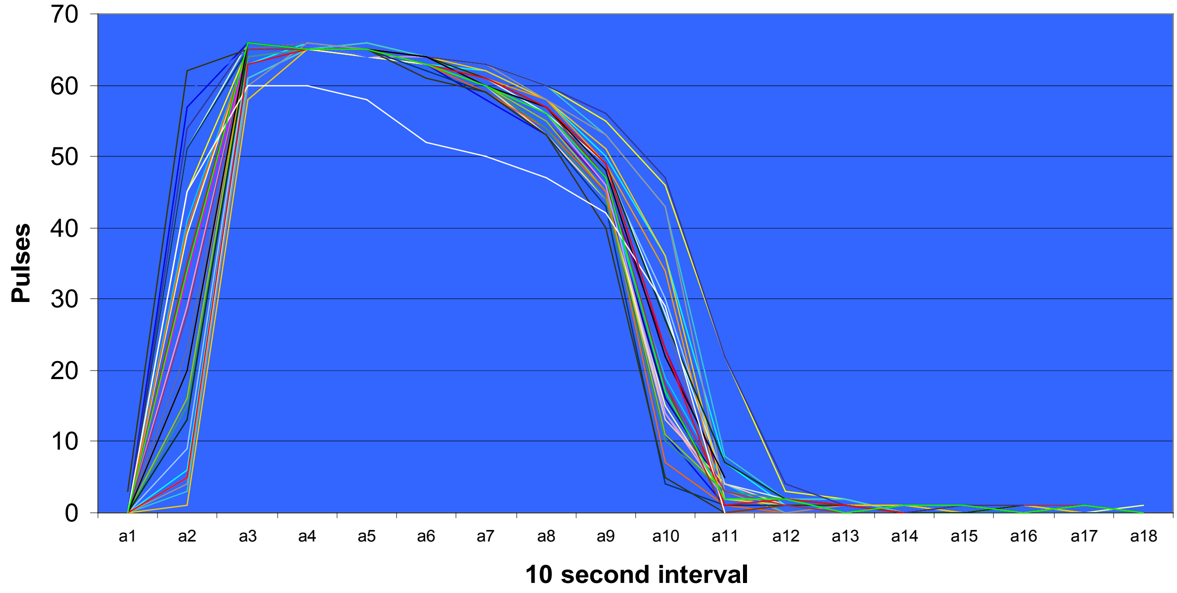

Figure 9: Multiple toilet flushes superimposed

2.3.5 Washing machine

The washing machine in our test home had two different settings – normal wash and heavy wash. Each load had three separate cycles, which are evenly spaced. The following graph shows the flow profile for this particular washer (heavy wash), and shows the associated volumes, duration of cycle and time between the cycles.

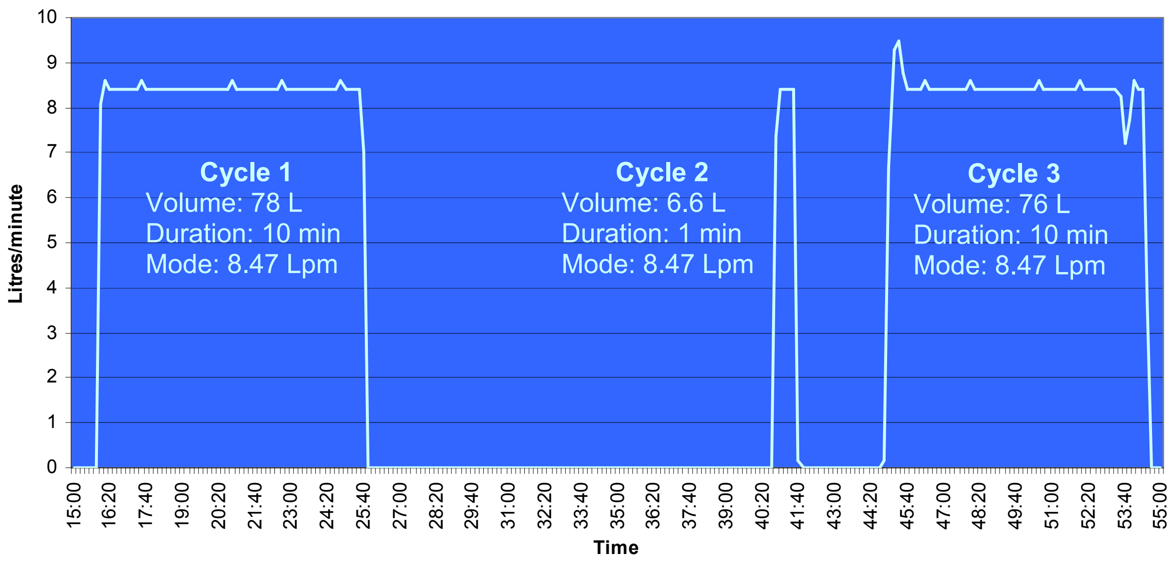

Figure 10: Sample flow of top loading washing machine

A washing machine can easily be identified, since it always has a similar flow profile and parameters as shown in the above table when the same settings on the machine are used. There are many different models and settings available, which all have different flow profiles. Front loading washing machines have a different flow profile altogether. A signature trace helps to identify the profiles of the different machines.

2.3.6 Shower

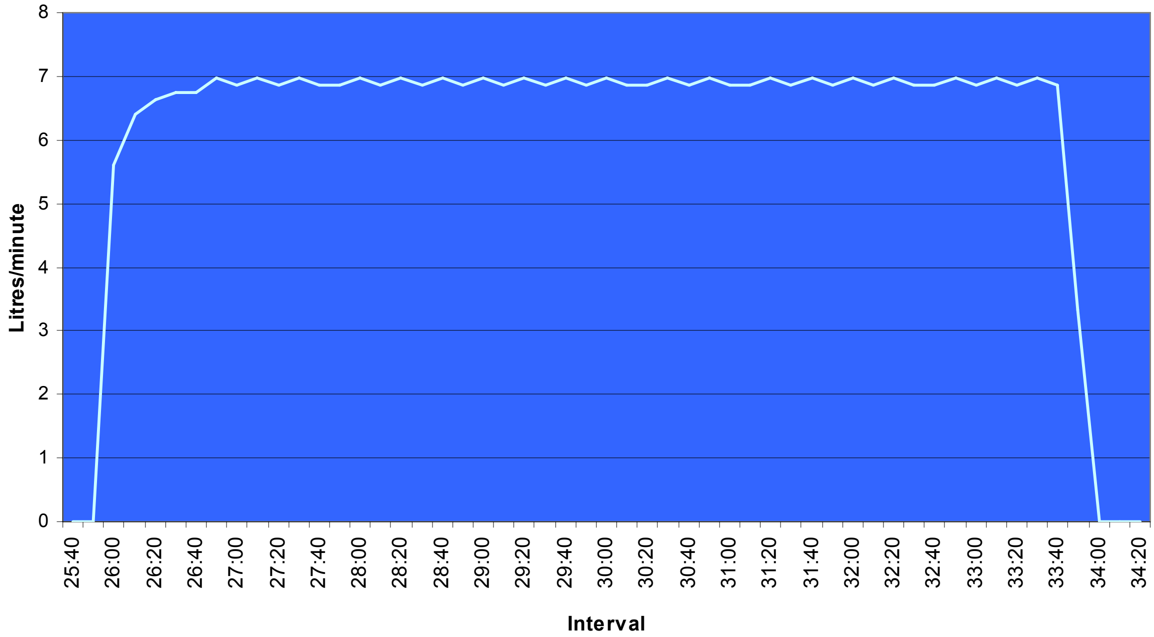

Figure 11: Shower profile

As shown in Figure 11, the mode flow for this particular shower head is 6.87 Lpm. Again the profiles for other showers taken in this home show a similar profile. As a shower is user defined (i.e. the user decides on the time and in some cases on the flow rate), the volume varies accordingly. The average shower time over the study period of our test home was around 7.5 min. When multiplying this by the mode flow, this gives about 50 L per shower event.

2.3.7 Bath

Bathing is another event that is completely human determined and it has a wide range of flow properties. It is not always easy to identify the event. Usually the taps on the bath have a very high flow rate (25 Lpm in the test home). The bath volume was around 100 L per bath. However, the outside tap has a similar flow rate and it becomes hard to distinguish between the two. The main time for baths in this case was in the morning between 05:00 and 07:00 and in the evening after 18:00. Because of the signature trace that was conducted, and talking to the occupants (knowing habits), the bathing events can be identified satisfactorily in the case of this home.

2.3.8 Tap

Generally the tap usage had a fairly low volume and duration, so it was easy to distinguish. It is not possible to say which tap was used, but tap usage can be identified satisfactorily.

2.3.9 Outside tap

It is not always easy to distinguish between outside tap uses and other events, particularly when filling the bathtub. This is because of the large range in flow rates of this particular appliance, which is anywhere between 0.1 to 29 Lpm. It is therefore helpful to know the habits of the residents and what sort of hose or sprinkler system they are using. The answers to the survey questions and information from the residents can help in identifying these events.

2.3.10 General profiles

The following graph (Figure 12) shows a typical flow profile with multiple events.

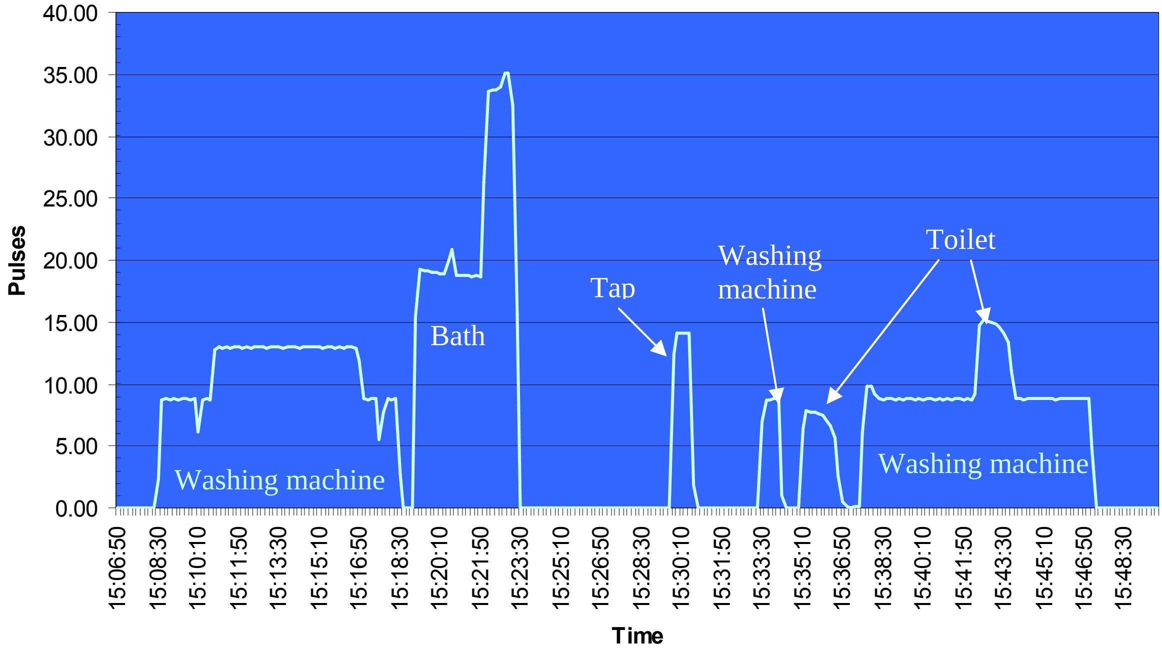

Figure 12: General flow profile

Table 2: Flow profiles from Figure 12

Start time	Appliance	Stop time	Comments
15:08:20	Washing machine (cycle 1)	15:18:30	
15:10:50	Shower	15:16:50	
15:19:10	Bath	15:23:20	96 L
15:29:50	Tap	15:30:40	11.3 L
15:33:30	Washing machine (cycle 2)	15:34:20	
15:35:10	Toilet flush	15:37:10	
15:37:40	Washing machine (cycle 3)	15:47:10	
15:42:30	Toilet flush	15:43:50	

2.3.11 Trace Wizard output

The following picture (Figure 13) shows an output file by Trace Wizard.

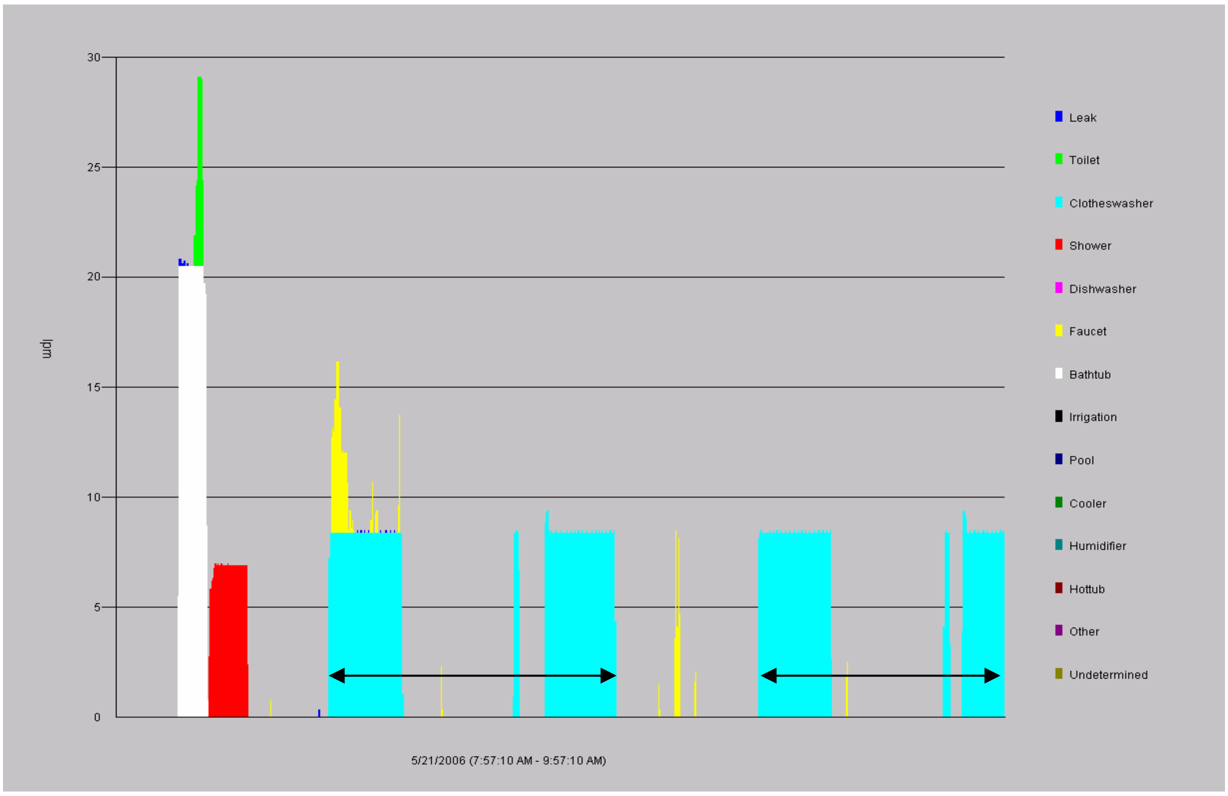

Figure 13: Trace Wizard output screen

The turquoise section shows the three cycles of the clothes washer. Two separate loads are being washed within this frame. The white bar shows a bath which was drawn. The green section represents a toilet flush, which was performed when the bath was being filled. The yellow bars represent individual tap usage events. The red section shows a shower which was taken after the bath has been filled.

The output file gives an overview of the appliances (end uses) that were being used during the specified period. When the output file is opened in MS Access, the built-in queries can summarise the end use data even further. Information about each separate event can be displayed which shows the times, duration, volumes, peak flows and other relevant information. Sample output files are shown in Appendix C.

2.3.12 Conclusions from Test Building 1

At first not many people believed it was possible to disaggregate the water use data into its end use components, but the pilot proved that we can use available technology with our equipment to achieve meaningful results. The logger's storage capacity was increased from 7 to 35 days by our electronics technician to capture more data without having to replace the logger as frequently. Other modifications to the logger improved the overall performance of the equipment (this is further described in Appendix B). The flow trace analysis method provided valuable and accurate results on the end uses, which were confirmed by talking to the homeowners.

As a build-up from the initial test building, the pilot was extended by installing equipment on both our electronics technician's home and a header tank. This allowed us to look at different systems and sort out any issues that would still need to be resolved with the logging equipment before the final study (Stage 3) was to commence.

3. TEST BUILDING 2 – HEADER TANKS AND LOW PRESSURE SYSTEMS

At the start of the project header tanks were considered a major problem in monitoring the end uses using the flow traces obtained from a single meter, since a header tank refills at a certain rate not corresponding to the actual usage rate. It was thought that an additional meter and logger needs to be placed at the outlet of the header tank. From this the discussion on pressure drop arose, which caused unnecessary complications.

After setting up our first trial home with a header tank system, it became apparent that these systems would cause no problem in being monitored using flow traces from a single high resolution water meter attached to the feed line of the home. However, the total amount of time an appliance was used (i.e. shower duration) would be harder to identify, although the total volume of the event was identified accurately.

The following graph (Figure 14) shows an x-y plot of a gravity feed shower. The hot water cylinder is fed by the header tank, which is fed from the mains water supply. As can be seen from the graph, the shower profile (data obtained from the data logger) does not show a constant flow rate, as would be the case for a shower fed directly from mains pressure. This is shown by the superimposed actual perceived flow profile (light blue) measured at the shower head.

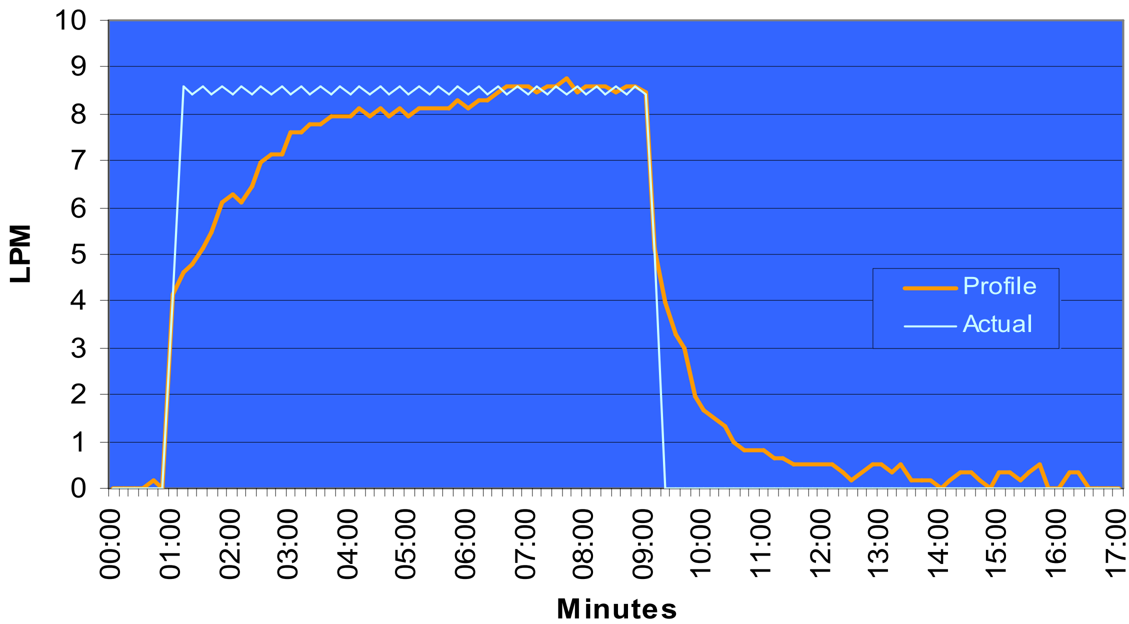

Figure 14: Gravity fed shower (header tank)

The total volume of water represented by the flow profile (Figure 14) is equal to the volume used in the actual shower, and is represented by the area under the graph. The profile is gradually increased until the mode flow rate is reached at about 07:00 min. When the shower is turned off at around 10:00 min, the header tank is still refilling until 12:30 min. This is followed by a trickle event until 16:30 min. Trace Wizard shows the similar profile (Figure 15), which overestimates the actual length of the shower, but the volume of water used is still identified correctly. In this particular case, the actual shower time is around 9 min, and the shower time perceived by Trace Wizard through the actual flow measurements is 12.5 min.

Other end uses, which are connected to the header tank, have a similar type of profile e.g. hot water tap.

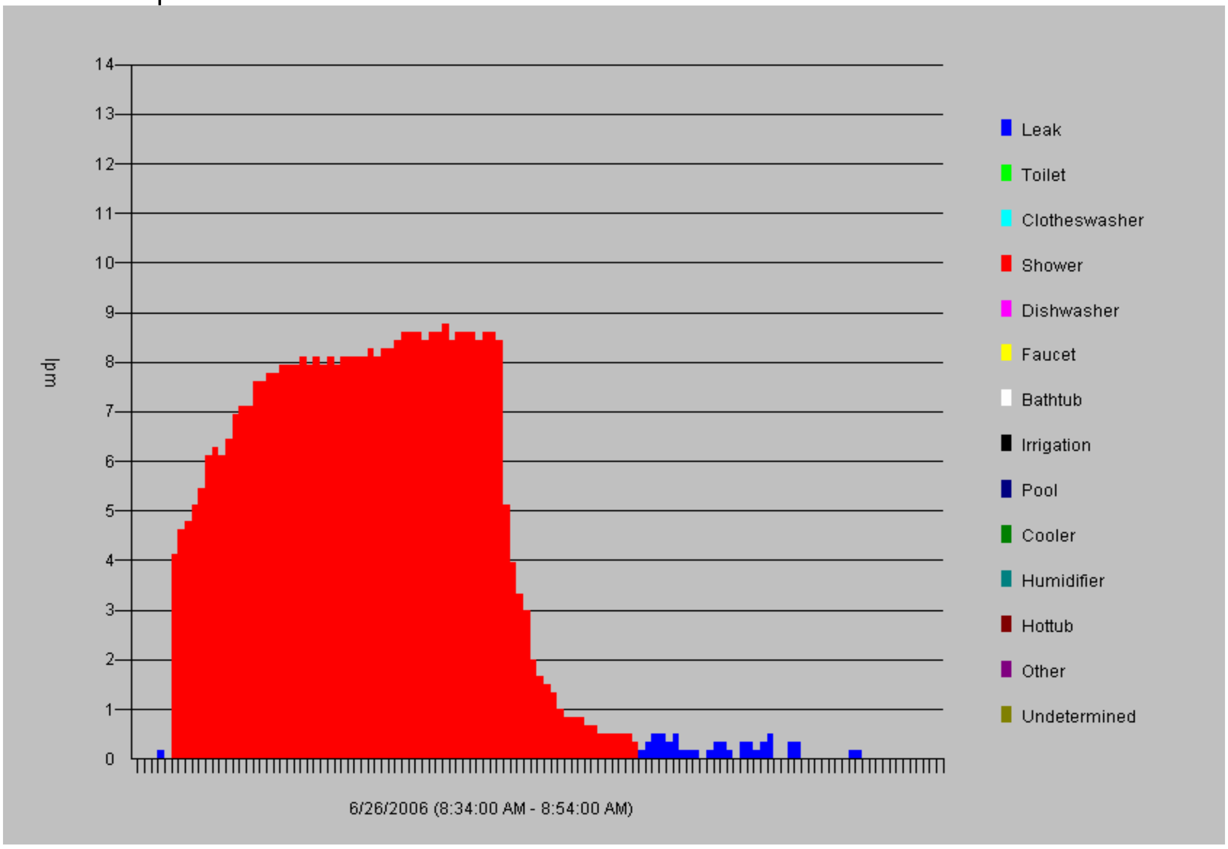

Figure 15: Trace Wizard output screen of gravity fed shower

By changing the temperature of the shower different flow profiles were observed, since the cold water came directly from the mains and the hot water was gravity fed into the hot water cylinder. It is hence possible to identify the approximate shower temperature when analysing the various flow traces from the showers that were taken. This is, however, beyond the scope of the project and is not discussed further in this text.

4. TEST BUILDING 3 – EQUIPMENT TESTS

For additional tests in the field for our data loggers, a high resolution water meter was installed at our electronics technician's home (who was responsible for improving and upgrading the original logger design).

The main reason why we had to improve the in-house data loggers, which have been successfully used in previous projects for years, was that the storage capacity was not adequate for our needs. For end use disaggregation, data needed to be collected at a 10 second interval from a high resolution water meter (≈ 30 ppL). This would produce large amounts of data, which would have filled the logger's storage after approximately seven days. After the major design changes, it was possible to store 35 days worth of 10 second data. A detailed description of these design changes is beyond the scope of this report. The specification sheet of the BRANZ data logger is shown in Appendix B. Tests that were conducted included battery lifetime, storage capacity and field use.

5. MAIN MONITORING STUDY

The main stage of the project was to monitor the end use consumption in a sample of 12 homes in the Kapiti Coast area over a period of eight months. The results represented in this section conclude the winter monitoring period, which started in mid-July and finished in mid-October 2006, and the summer monitoring period which started in mid-November 2006 and went through to the end of February 2007.

5.1 Methodology

5.1.1 Sample selection

The main aim of the pilot study was to develop a methodology which could be used to monitor the water end uses. For this reason, and because we only monitored a small number of homes, it was not necessary to have a special selection process. Company-wide emails were sent out at both BRANZ and the KCDC to advertise the study and look for volunteers. Two page questionnaires were then sent out to the volunteers to capture demographics and water using appliances. Potential homes were then visited to check for the suitability of installing water meters after the toby. The homes in the district have no water meters in place, so it was necessary to install a metering box which contained the water meter.

Houses that had their toby (which was the proposed place for our equipment installation) on a concrete driveway, for example, were unsuitable for monitoring since we wanted to cause minimal disruptions and not conduct major engineering works.

5.1.2 Equipment installation

After the participants were confirmed, KCDC installed the metering boxes and the high resolution water meters on the water pipe feeding the house. Appointments were then made with the occupants to perform a water audit and the signature trace (see Section 2.3.2 of this report) for simplifying the identification of the appliances when it comes to analysing the data within Trace Wizard. More detailed questionnaires were conducted at the site visit, while the audit and signature trace were performed, to collect more data on demographics and behaviour. A sample questionnaire can be seen in Appendix A. In addition to the audits, the roof areas were measured to calculate the potential rainwater harvesting capacity.

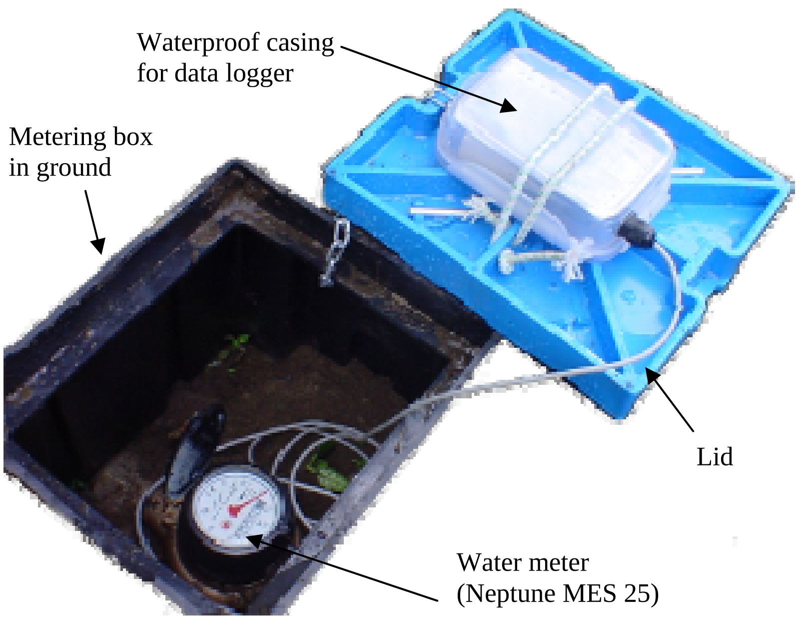

Figure 16: Monitoring set-up

Before entering the house, the logging equipment was installed in the metering box (see Figure 16) and the logger started to capture the flow data. After the audit was complete, the logger was removed to download the signature trace data and replaced with an empty logger, which would collect data for the next month.

To keep moisture away from the data loggers, vacuum sealed boxes that contained the loggers were attached under the lid of the metering pit using shock cord. Desiccant was added to reduce the condensation induced moisture within the box, due to the temperature fluctuations.

5.1.3 Measurement technology

The approach which was adopted for the final study group included a modified high resolution nutating disk meter from Neptune MES25, with a pulse output of 34.2 ppL. A BRANZ data logger was used to collect the pulse outputs from the water meter at a 10 second interval.

Each month the loggers from each of the houses were downloaded by KCDC and replaced with an empty logger to obtain continuous flow traces. The data from the data loggers was then analysed using the software package Trace Wizard to disaggregate the flow traces into its end use components. For a detailed description of the data collection method, see BRANZ *Study Report 149* (Heinrich).[1]

5.1.4 Waterproofing

The waterproofing of the installation was an important issue which was addressed. The loggers have relatively high costs and loss should be kept to a minimum (and if possible completely avoided). In the beginning we used standard weatherproofing boxes for electrical installations which had a screw-on lid. After some time the screws wore out and it was always an effort to unscrew the lid. This was not only time-consuming, but became a hassle. Then watertight lunch boxes with a clip-on lid were used (Figure 16). A hole was drilled to fit the gland for the cable which connected to the logger. To reduce the amount of condensation a large amount of desiccant was added to the box, which contained the logger, and this reduced the moisture content within the box. When the logger was downloaded, the desiccant was then replaced by a dry one. To ensure the desiccant was as dry as possible, it was kept in a sealed container until it was placed in the box that contained the logger.

The logger would sit in the metering box together with the water meter, which is a wet and damp environment. Considerable thought was put into where the logging equipment should be placed. The logger would be installed as high as possible in case the metering box filled up with water. Even though the box containing the logger was sealed, water needs to be kept away as much as possible. One way to ensure this is to have the logger placed directly under the lid of the metering box, kept in place by a type of harness (shock cord).

In installations where the water meter was not put into a metering box underground, but under or next to the house, there was always a relatively dry place to put the logging equipment. We only had three installations of this kind, which were used in the pilot phase of the project.

5.1.5 Demographics

For our study group, we obtained a good demographic mix of households in different parts of the Kapiti Coast area. However, patterns in demographics and water use became apparent, and we have concluded that the study group is too small to make generalisations. For example, the finding that homes with small children have a higher proportional use of baths needs to be validated by a larger sample number of study homes.

5.2 Kapiti Coast description

The Kapiti Coast is located about 50 km north of Wellington. With a population of 46,200 (March 2006) and a population increase of 10% from 2001 to 2006 (Wellington 5.9%, New Zealand 7.8%), it is one of the fastest growing population areas in New Zealand. The Kapiti Coast has less winds, more sunshine and slightly higher temperatures than Wellington.

6. DATA ANALYSIS – WINTER MONITORING PERIOD

This section shows the result of the winter monitoring period from the 12 study homes on the Kapiti Coast.

6.1 Total daily use

Data was collected on average over 72.6 days from the 12 sample homes across the winter period. House 13 was not included in the analysis, since it was the initial test building which was used to test our equipment and was not part of the Kapiti Coast area.

Table 3: Monitoring duration of study homes – winter period

House	Start	End	Duration (days)	Data lost (days)	Initial testing duration (days)
	Main study (winter period)				
1	26/07/2006	11/10/2006	77	0	
2	4/08/2006	3/10/2006	60	0	
3	4/08/2006	3/10/2006	60	0	
4	26/07/2006	11/10/2006	77	4	
5	4/08/2006	4/10/2006	61	0	
6	26/07/2006	3/10/2006	69	0	
7	26/07/2006	3/10/2006	69	0	
8	21/07/2006	11/10/2006	83	0	
9	21/07/2006	11/10/2006	83	0	
10	26/07/2006	4/10/2006	70	0	
11	21/07/2006	19/10/2006	91	0	120*
12	10/07/2006	29/09/2009	71	0	82*
13	22/04/2006	29/08/2006	Data not included in main study		130
		Total	**871**		
		Average	**72.6**		

* Total duration of monitoring (including main study period)

The average daily use per household (Figure 17) during the winter period was 439 L, with an average of 2.7 people living in each home. Towards the end of the monitoring period, high daily usages can be observed in some of the homes. These are mainly due to garden irrigation. The graph also shows the daily average, minimum and maximum values that have been recorded.

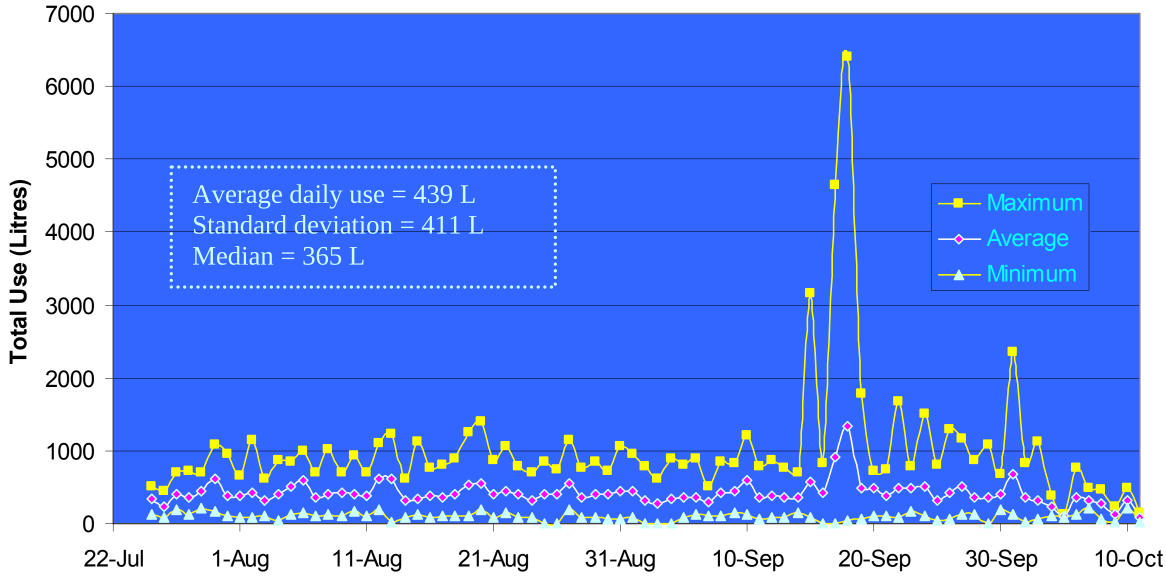

Figure 17: Daily household use – winter period

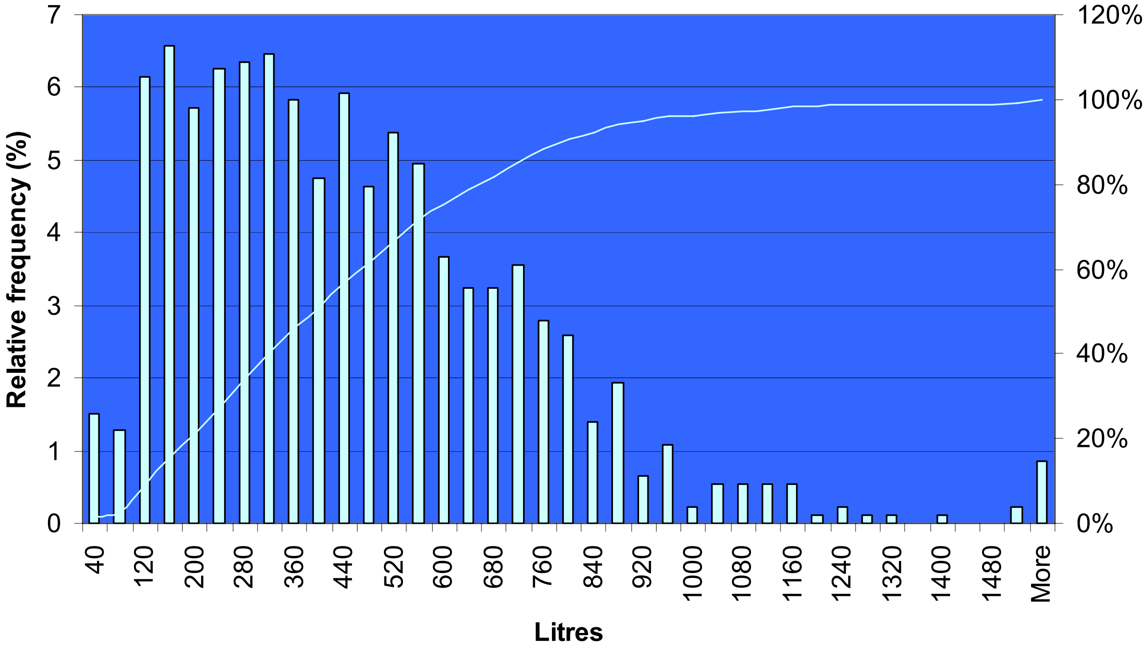

Figure 18: Distribution of litres per household per day

From the distribution graph (Figure 18) it can be seen that 83% of the daily household water use is between 120–720 L.

6.2 Daily per capita use

The total daily per capita use was calculated daily for each of the study homes using the data collected by the data loggers. The average daily per capita use for the winter monitoring period was 168.1 L. As can be seen from the distribution in Figure 19, 80% of the water uses are between 60–260 litres per person per day (l/p/d). The 2.2% of uses which are 500 L or more are mainly due to garden irrigation or other outside uses.

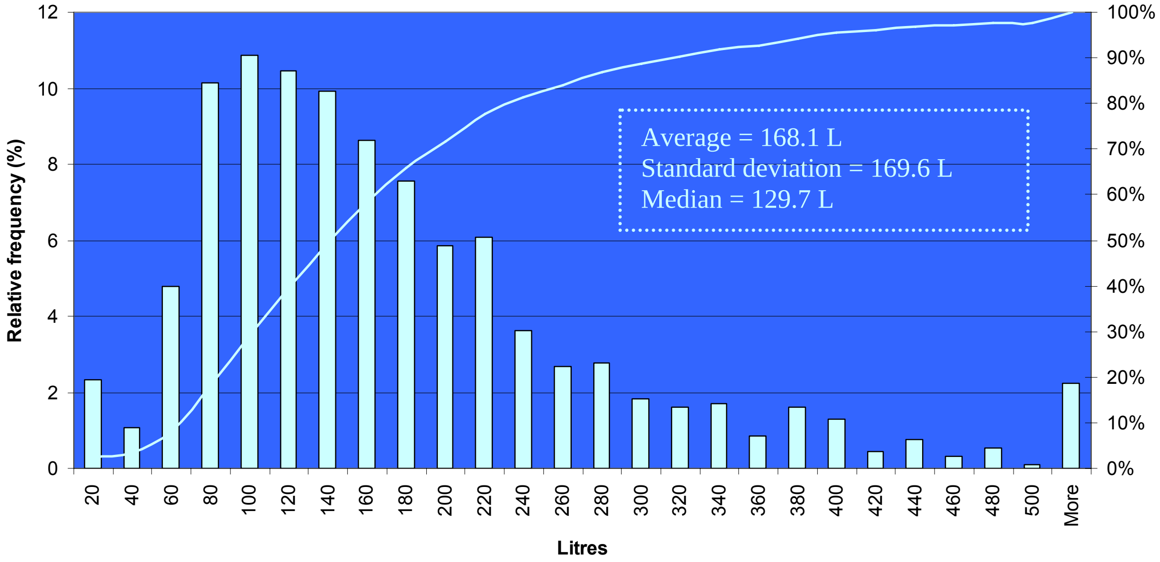

Figure 19: Distribution of litres per person per day

6.3 End uses

Table 4 shows the average daily volumes per capita for each of the end uses. The indoor demand per person per day across the study homes was 147.1 L.

Table 4: Average volumes per end use

	Percent	Average (l/p/d)
Tap	13.5	22.7
Shower	26.7	44.9
Washing machine	23.7	39.9
Toilet	18.6	31.3
Dishwasher	1.2	2.1
Bathtub	3.3	5.5
Miscellaneous	0.4	0.8
TOTAL INDOOR	**87.5**	**147.1**
Outdoor	8.3	13.9
Leaks	4.2	7.0
TOTAL USE	**100.0**	**168.1**

The following pie graphs (Figure 20 and Figure 21) show the distribution of total end uses and indoor end uses over the winter monitoring period. These are average values across all of the study homes. Not every home has a bath or dishwasher.

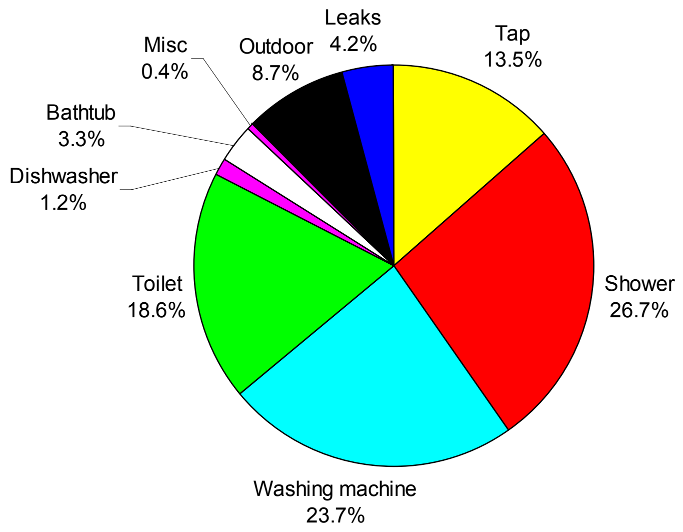

Figure 20: Total end uses – winter period

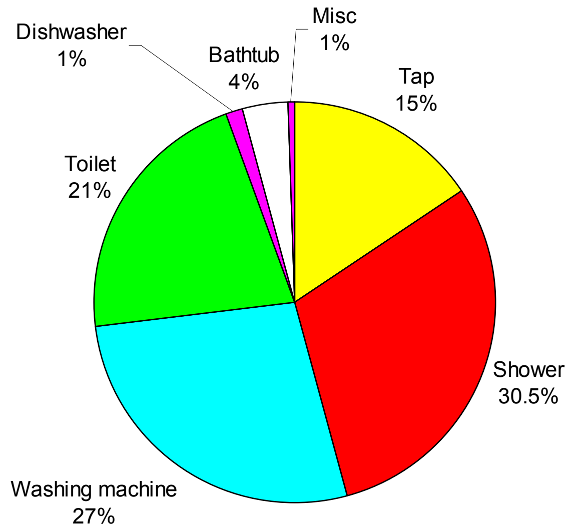

Figure 21: Indoor end uses – winter period

The largest measured indoor event was the shower, accounting for 30.5% of all indoor uses, followed by the washing machine and the toilet with 27% and 21% respectively.

6.3.1 Shower

The shower accounted for 26.7% of the total uses (30.5% of indoor uses) during the winter monitoring period (and was therefore the end use with the highest proportion of total use). A total of 920 shower events were recorded for the main study group within the winter monitoring period. The average shower time for the mains pressure houses was 7.7 min at an average flow rate of 11.8 Lpm. The average volume for each shower event was 82 L. The three homes in the study group with header tanks were not included in the shower time analysis, because the times are overestimated since the tank still refills after the shower has been turned off (also see Section 3 of this report).

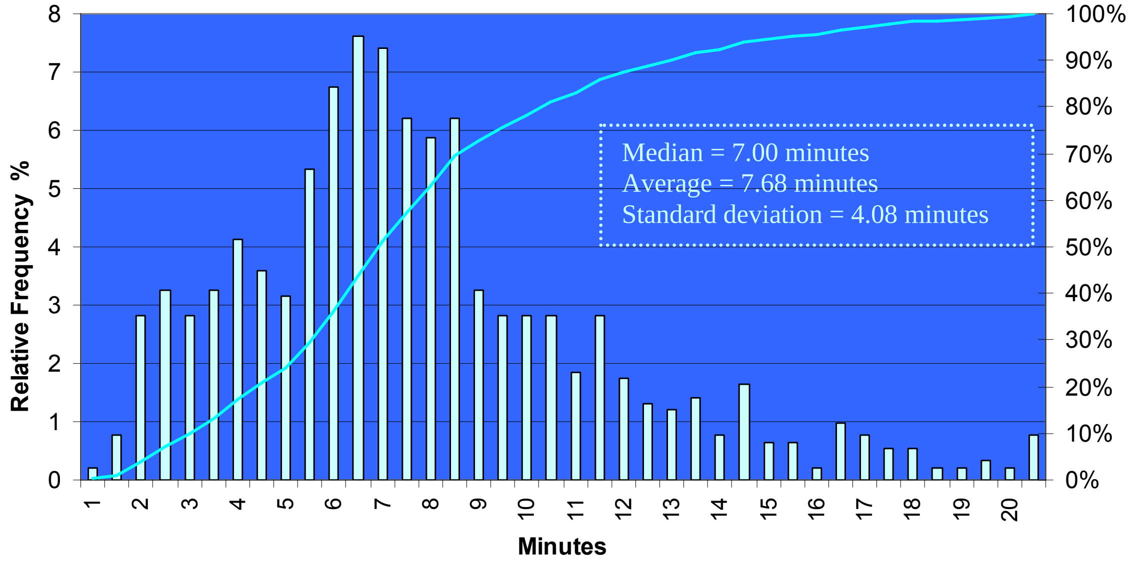

Figure 22: Shower duration

From the graph in Figure 22 it can be seen that 80% of showers have a duration of 3–12 min. Only 3% of showers are longer than 17 min and only 4% are 2 min or less. The median was 7 min, with the average being 7.7 min and a standard deviation of 4.1 min.

Figure 23 shows the distribution of shower volumes. Eighty-three percent of showers used a total of 40–150 L of water per event. The median was 71.6 L, the average volume was 82 L, and the standard deviation was calculated to be 45.8 L.

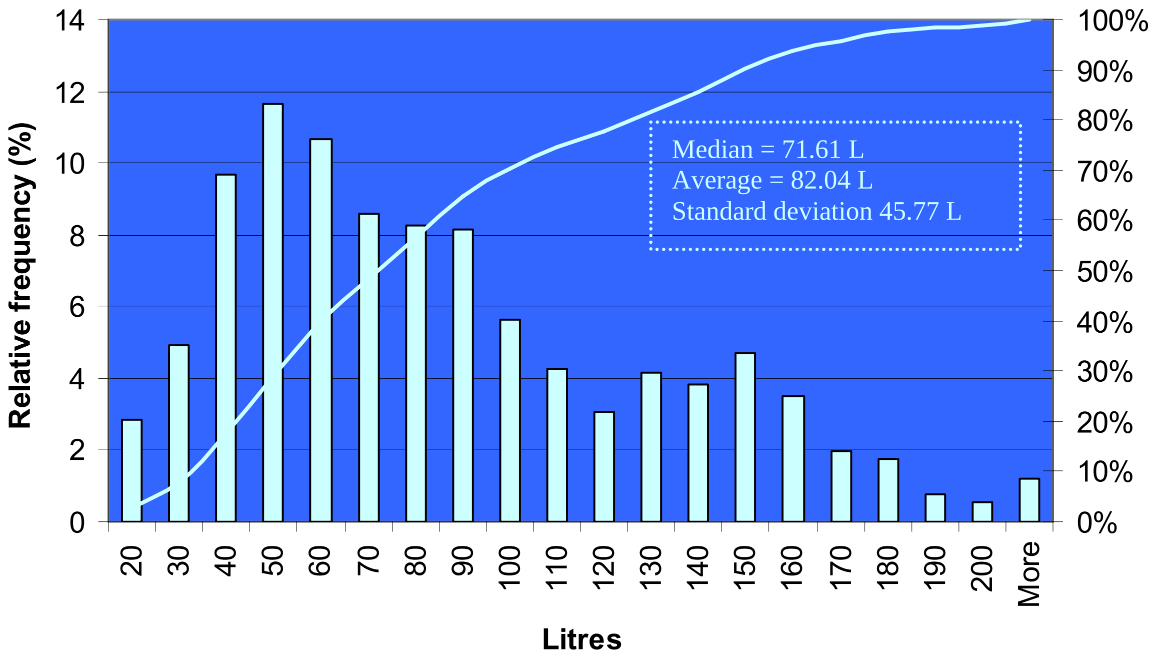

Figure 23: Shower volume distribution

The shower flow rates have a median of 12.5 Lpm, an average of 11.8 Lpm, and a standard deviation of 5.5 Lpm. The distribution in Figure 24 shows that 81% of all shower events had a flow rate of between 6–16 Lpm. The reason for the pattern shown in this distribution is that some of the shower heads in the homes only supported one flow rate.

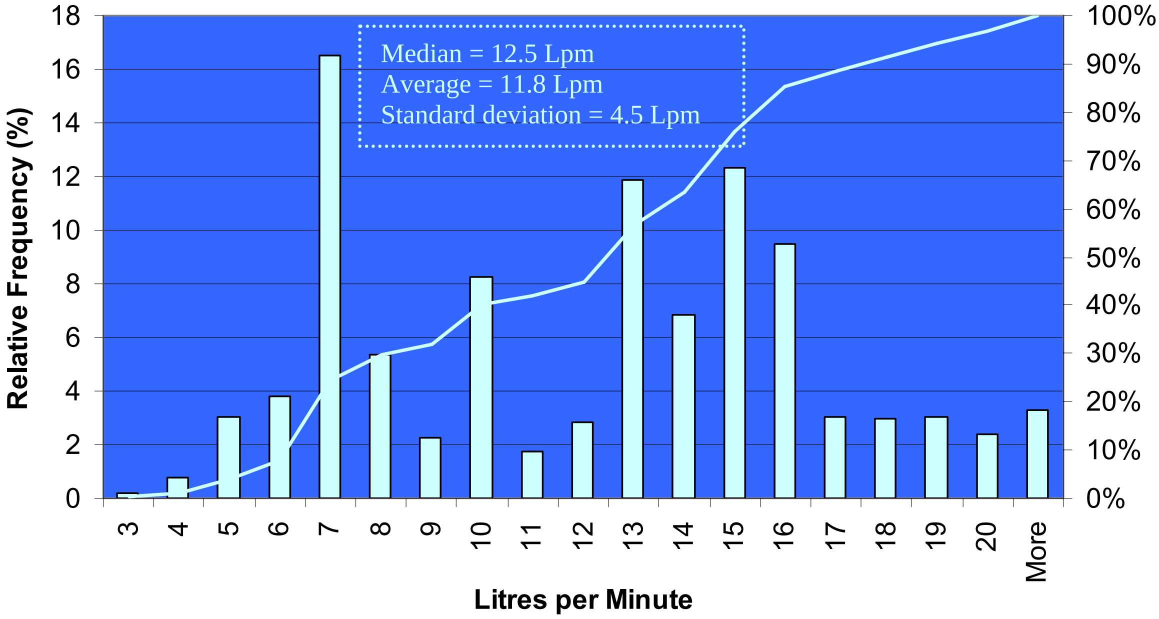

Figure 24: Shower flow rates

Water use in some of the homes could be reduced by installing a low flow shower head to reduce the flow rate to 8 Lpm. Seventy percent of showers in the study group have a flow rate of more than 8 Lpm. A large proportion of water could be saved by retrofitting this end use.

6.3.2 Washing machines

The washing machine accounts for 23.7% of the total uses (27% of indoor uses). In all of the study homes, except for one, top loading machines are used (they use up to 180 L of water per load). When looking at the data for individual homes, the home with a front loading machine only used 8% of its water for this purpose, with an average of 0.75 washes per house per day and an average volume of 50.7 L per wash. The loads washed with a top loading machine used an average of 134.8 L, which is 2.7 times as much water per load as for front loading machines. Table 5 summarises results for washing machine use.

Table 5: Summary of results for washing machine use

	Average	Standard deviation
Load top loader (L)	134.8	17.5
Load front loader (L)	50.7	N/A
Loads per home per day (#)	0.75	0.5
Loads per person per day (#)	0.3	0.1
Litres per house per day	104.1	74.4
Litres per person per day	39.9	20.5

Over the whole winter period, 652 loads of washing were undertaken in the study homes using a total of 85 m^3 of potable water. On average a house from the study group would use 38 m^3 of water annually for laundry use alone, not taking into account the seasonal variations. This potable water could easily have been supplemented by collected rainwater which would have reduced the environmental impact (see case study in Section 6.4 of this report).

By retrofitting a top loader to a more water efficient front loading machine an average annual water saving of 23.5 m^3 per house could be achieved. Front loaders use considerably less water than top loading machines, but the majority of machines used in New Zealand homes are still top loaders.

6.3.3 Indoor taps

Indoor tap use (includes hot, cold and mixed taps) accounts for 13.5% of the total uses (15% of indoor uses). A total of 28,400 individual tap uses were registered during the winter monitoring period (average of 11.9 uses per person per day). The distribution in Figure 25 shows that 82% of tap use is 30 seconds or less. Since our data was collected at a 10 second interval, a further breakdown in data would require a shorter logging interval (e.g. 5 seconds). This would halve the memory of the data loggers and double the volume of the data. The average tap use time is 27.8 seconds, with a median of 20 seconds, and a standard deviation of 37.7 seconds.

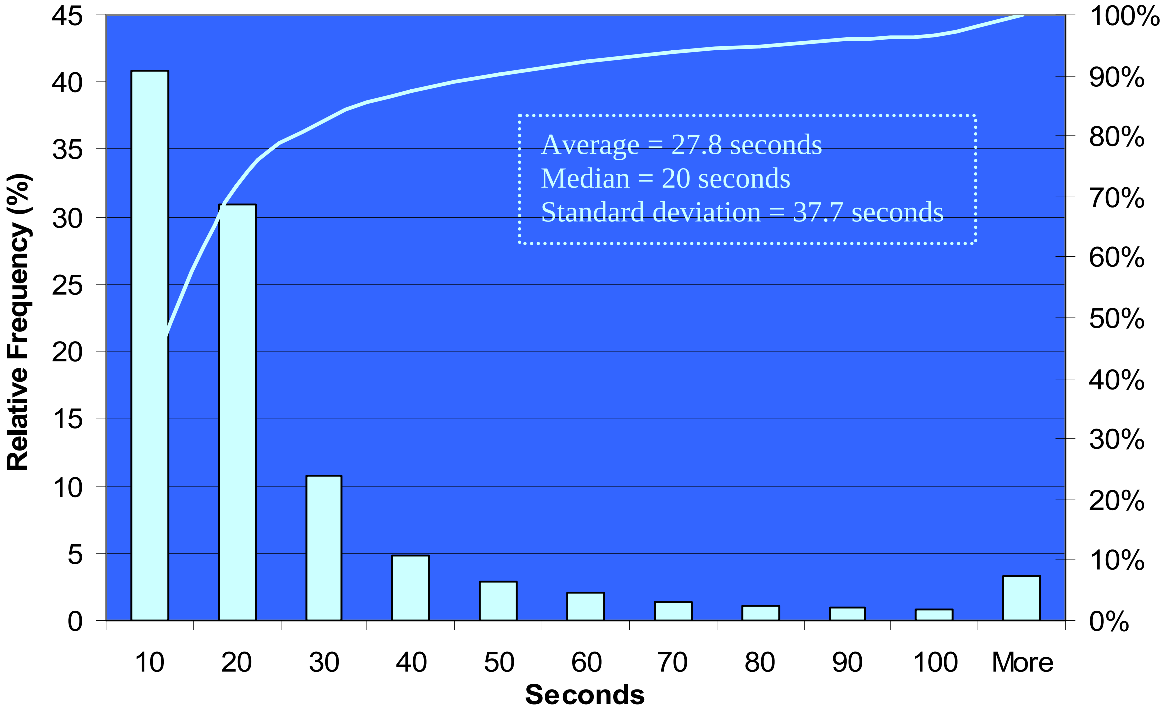

Figure 25: Tap use duration

The following distribution in Figure 26 shows the total volumes used in each tap event. Eighty percent of tap use events use 2 L or less and only 4.6% use more than 6.5 L per event. The average volume of each event is 1.57 L, the median 0.7 L, and the standard deviation 2.57 L.

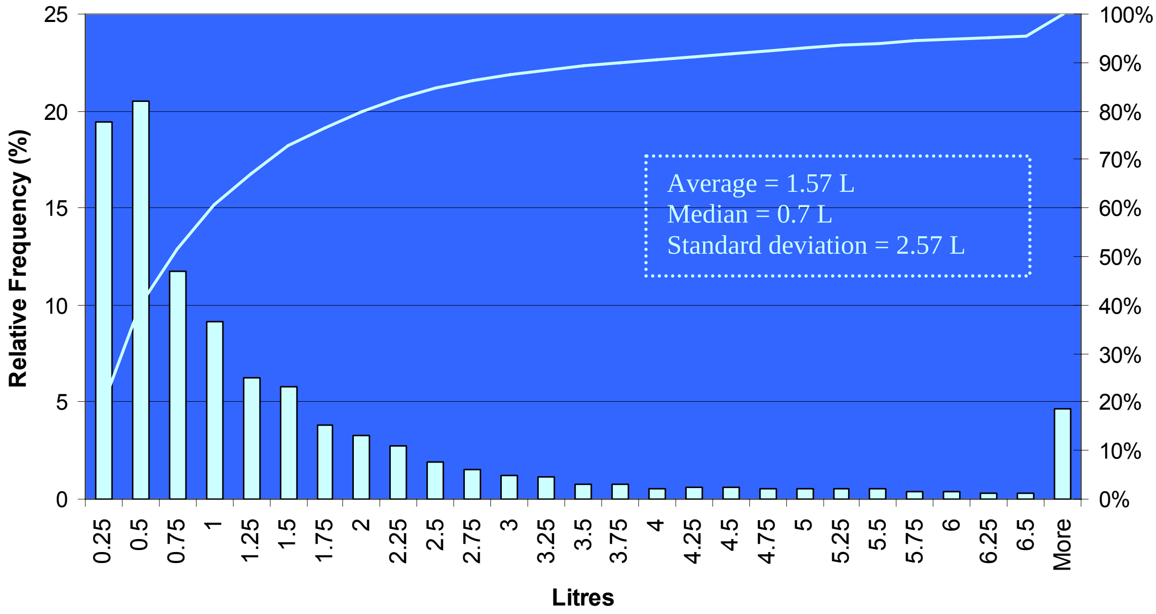

Figure 26: Tap use volumes

The distribution of tap flow rates is shown in Figure 27. Eighty percent of tap usage has a flow of 0.5–6 L. The average flow rate of a tap event is 3.79 L, the median 2.81 L, and the standard deviation 3.23 L. From these results, retrofitting taps with aerators or other low flow devices will not reduce water consumption significantly for the homes in the study group, since the flow rates are already fairly low.

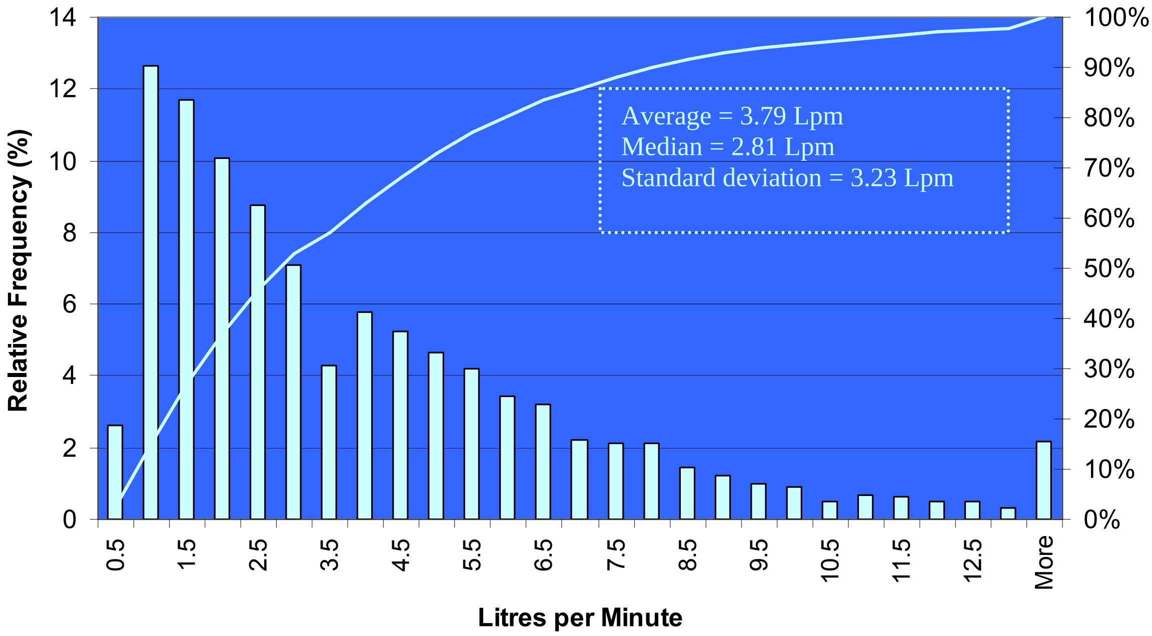

Figure 27: Tap flow rate distribution

6.3.4 Toilet

The toilet accounted for 18.6% of the total uses (21% of indoor uses). A total of 9621 toilet flushes were recorded from all the homes in the winter monitoring period. On average 12.9

toilet flushes per home per day were recorded, with an average of 4.7 flushes per person per day. The average flush volume across the study homes was 6.2 L. However, by retrofitting homes with 6/3 dual flush toilets, or lower volume cisterns, the water consumption could be reduced significantly in a number of homes who still have larger than standardised volume cisterns. Water-less toilets, such as composting toilets, would reduce the water consumption even further.

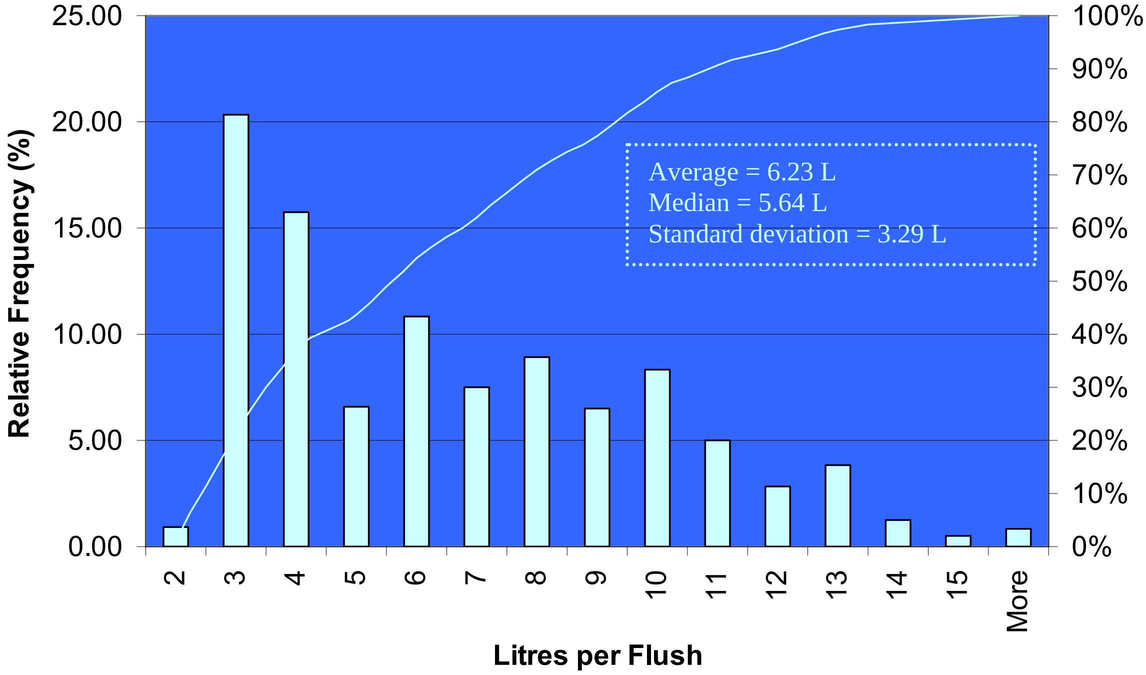

Figure 28: Toilet flush volumes

6.3.5 Leaks

Leaks represent 4.2% of the total water usage across all the study homes. However, a small number of houses were responsible for the majority of leaks. On one occasion 56% of a single home's end uses were due to leaks, which equalled almost 200 L per day. The council was notified, who then fixed this major leak after our first week of monitoring. The reason for this leak was a malfunctioning toilet cistern, which could be seen in the flow trace. The average amount of leakage was found to be 7 l/p/d (major leak not included) over the whole study group. The main source of leakage was identified as the toilet cistern not stopping to refill.

As a first step for water efficiency it is essential to eliminate the sources of leakage, since 4% is very high proportion of water which does not find a use.

6.3.6 Irrigation and outdoor use

During the winter monitoring period, a small number of homes were responsible for the majority of irrigation. On one occasion a sprinkler system irrigated nearly 8 m^3 of fresh water in a single day. The explanation for this was that the lawn has just been fertilised and required this intense amount of water.

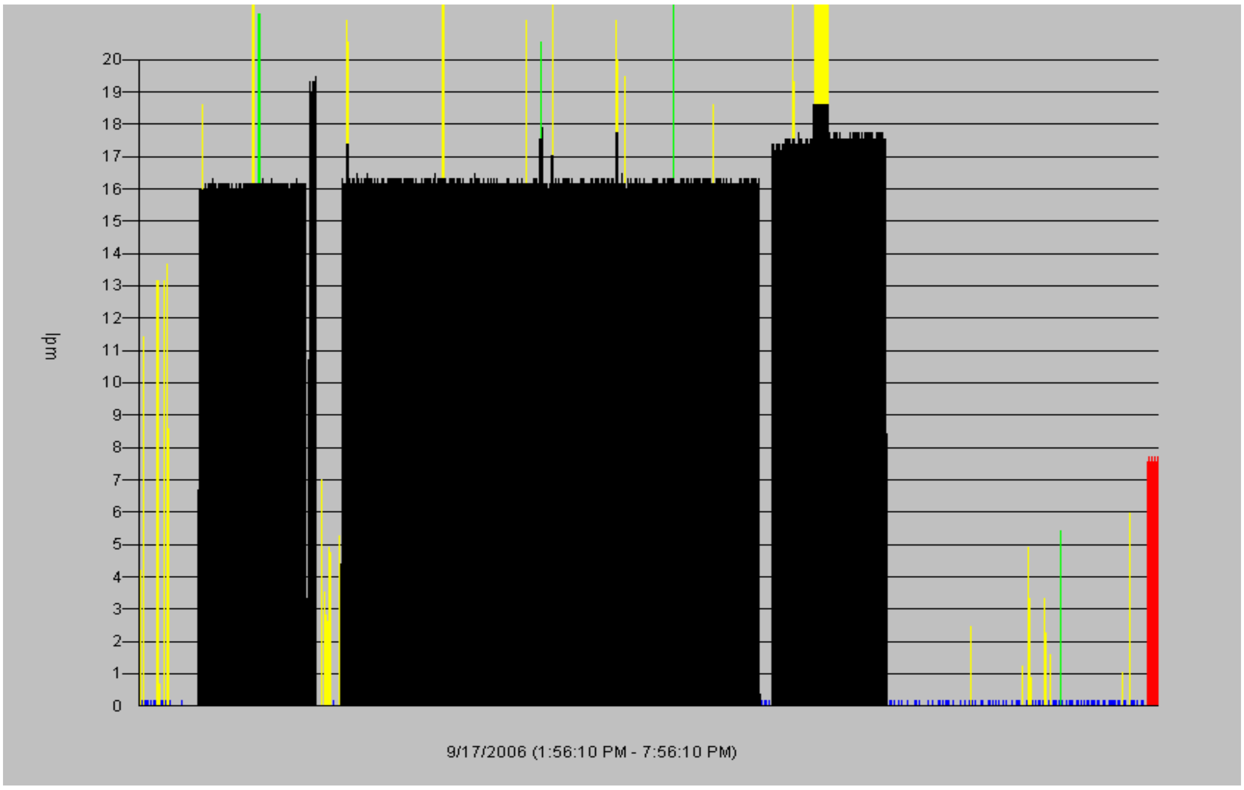

Figure 29: Sample screen of irrigation period (six hour period)

Figure 29 shows a six hour frame of an extensive irrigation event. To reduce the amount of potable water used for irrigation, rainwater or greywater could be used as a supplement.

7. DATA ANALYSIS – SUMMER MONITORING PERIOD

This section shows the result of the summer monitoring period from the 12 study homes on the Kapiti Coast.

7.1 Total daily use

Data was collected on average over 89 days from the 11 sample homes across the summer period. Data for house 3 was lost due to a faulty water meter. After the meter had been replaced at the end of January, data continued to be collected. However, due to the hospitalisation of the download person at the end of the project the file for this period went missing. The water meter for house 10 had a leaking seal, which caused the electronics to malfunction. After this has been replaced the meter provided unreliable data, hence reliable data was only collected until 09/12/2006. This is summarised in Table 6.

Table 6: Monitoring duration of study homes – summer period

	Main study (summer period)			
House	**Start**	**End**	**Duration (days)**	**Data lost (days)**
1	16/11/2006	27/02/2007	104	0
2	16/11/2006	27/02/2007	104	0
3				(104)[1]
4	16/11/2006	27/02/2007	104	0
5	16/11/2006	27/02/2007	104	0
6	16/11/2006	27/02/2007	104	0
7	16/11/2006	27/02/2007	104	0
8	16/11/2006	27/02/2007	104	0
9	16/11/2006	27/02/2007	104	0
10	03/11/2006	09/12/2006	36	(68)[2]
11	16/11/2006	23/02/2007	100	0
12	16/11/2006	23/02/2007	100	0
14 - Rainwater	03/10/2006	ongoing	Data not included in main study	
		Total	**1068**	
		Average	**89**	

[1] – Data lost through faulty water meter/hospitalisation of download person.
[2] – Data lost through faulty water meter.

The average daily use per household (Figure 30) during the summer period was 525 L, with an average of 2.7 people living in each home. The graph also shows the daily average, minimum and maximum values that have been recorded.

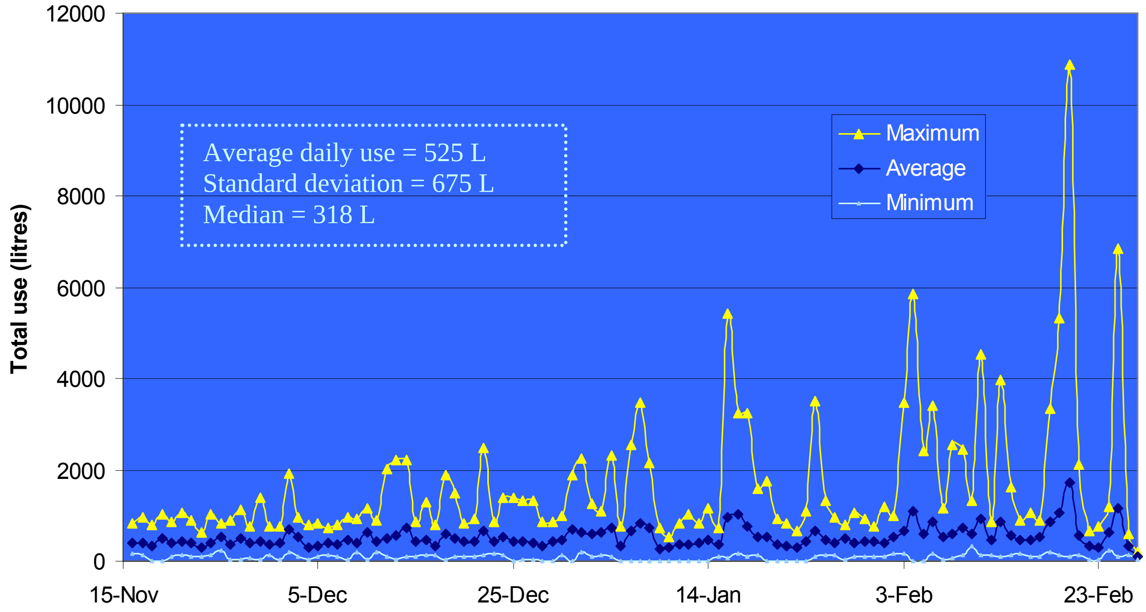

Figure 30: Daily household use – summer period

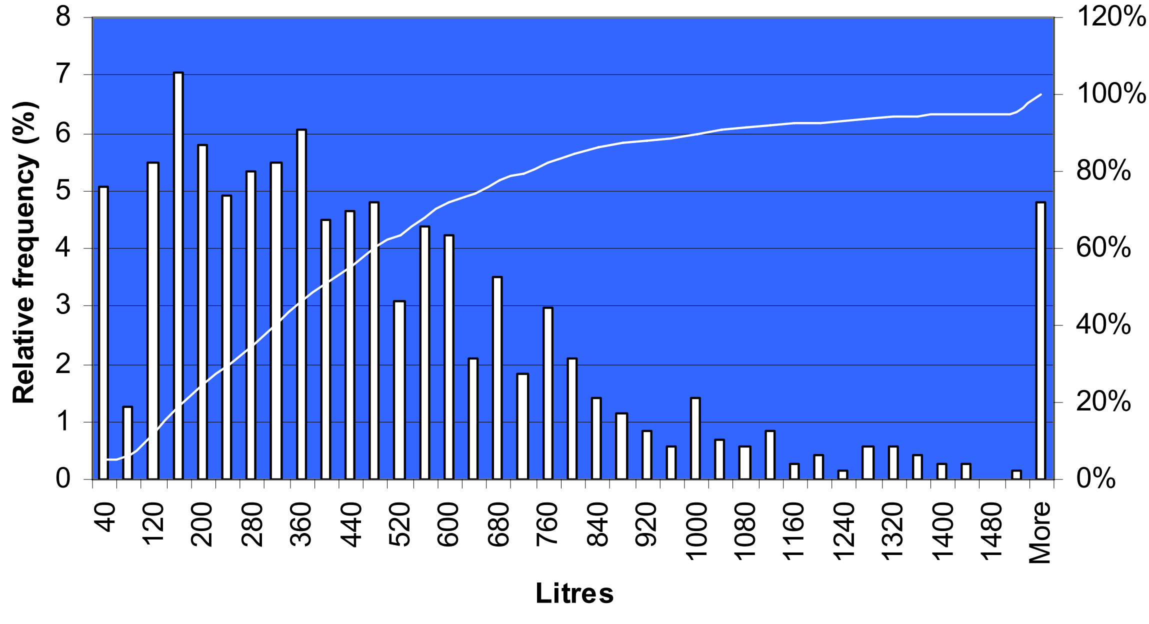

Figure 31: Distribution of litres per household per day

From the distribution graph (Figure 31) it can be seen that 81% of the daily household water use in summer is between 120–880 L. Five percent of the uses were 1500 L per day and above. The maximum recorded daily usage was 10,891 L per house (10.9 m^3).

7.2 Daily per capita use

The average daily per capita use for the summer monitoring period was 203.9 L. As can be seen from the distribution in Figure 32, 81% of the water uses are between 60–300 l/p/d. The 5% of uses which are 500 L or more are mainly due to outside uses and irrigation.

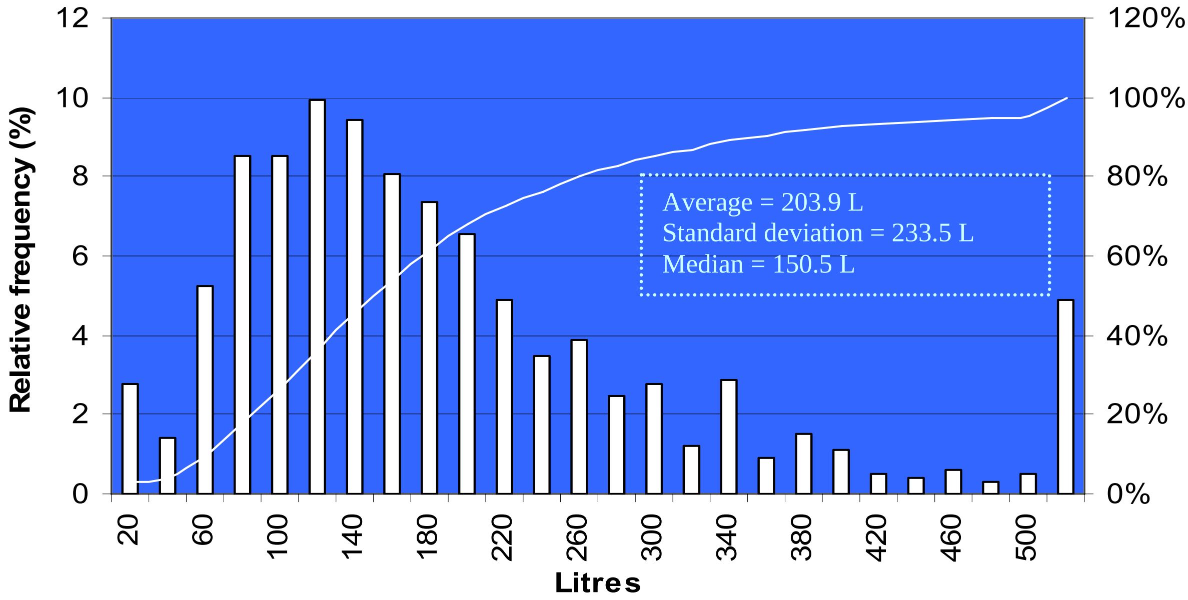

Figure 32: Distribution of litres per person per day

7.3 End uses

Table 7 shows the average daily volumes per person for each of the end uses. The indoor demand per person per day across the study homes was 151.3 L. The percentage use of each end use is discussed in the following Section 7.3.

Table 7: Average volumes per end use

	Percent	Average (l/p/d)
Tap	11.7	23.9
Shower	22.2	45.3
Washing machine	20.4	41.6
Toilet	17	34.7
Dishwasher	1.3	2.7
Bathtub	1.5	3.1
Miscellaneous	0	0.0
TOTAL INDOOR	**74.22**	**151.3**
Outdoor	21.8	44.5
Leaks	3.3	6.7
TOTAL USE	**100.0**	**203.9**

The following pie graphs (Figure 33 and Figure 34) show the distribution of total end uses and indoor end uses over the winter monitoring period. These are average values across all of the study homes. Not every home has a bath or dishwasher.

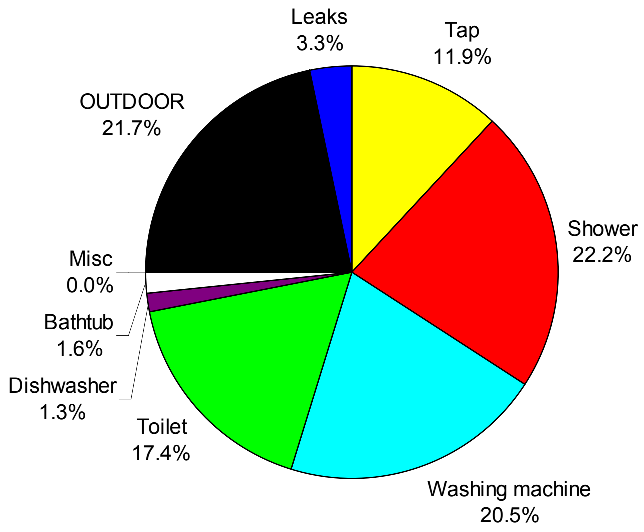

Figure 33: Total end uses – summer period

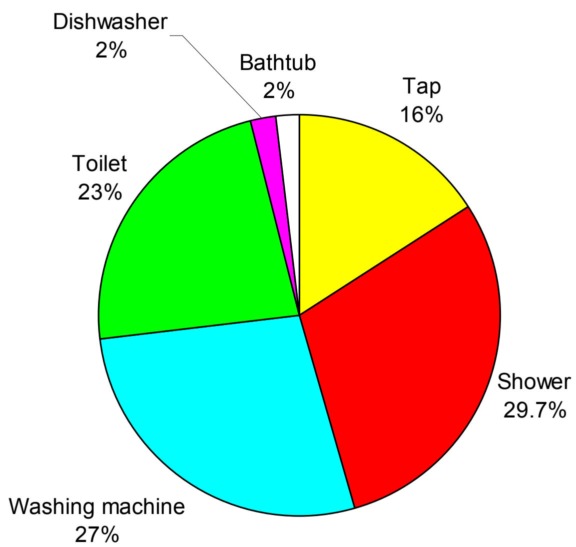

Figure 34: Indoor end uses – summer period

The largest measured indoor event was the shower, accounting for 30% of all indoor uses, followed by the washing machine and the toilet with 27% and 23% respectively.

7.3.1 Shower

The shower accounted for 22% of the total uses (30% of indoor uses) during the summer monitoring period (and was therefore the end use with the highest proportion of total use). A total of 1030 shower events were recorded for the main study group within the summer monitoring period. The average shower time was 7.5 min at an average flow rate of 10.7

Lpm. The average volume for each shower event was 76.3 L. The three homes in the study group with header tanks were not included in the shower time analysis, because the times are overestimated since the tank continues to refill after the shower has been turned off (also see Section 3 of this report).

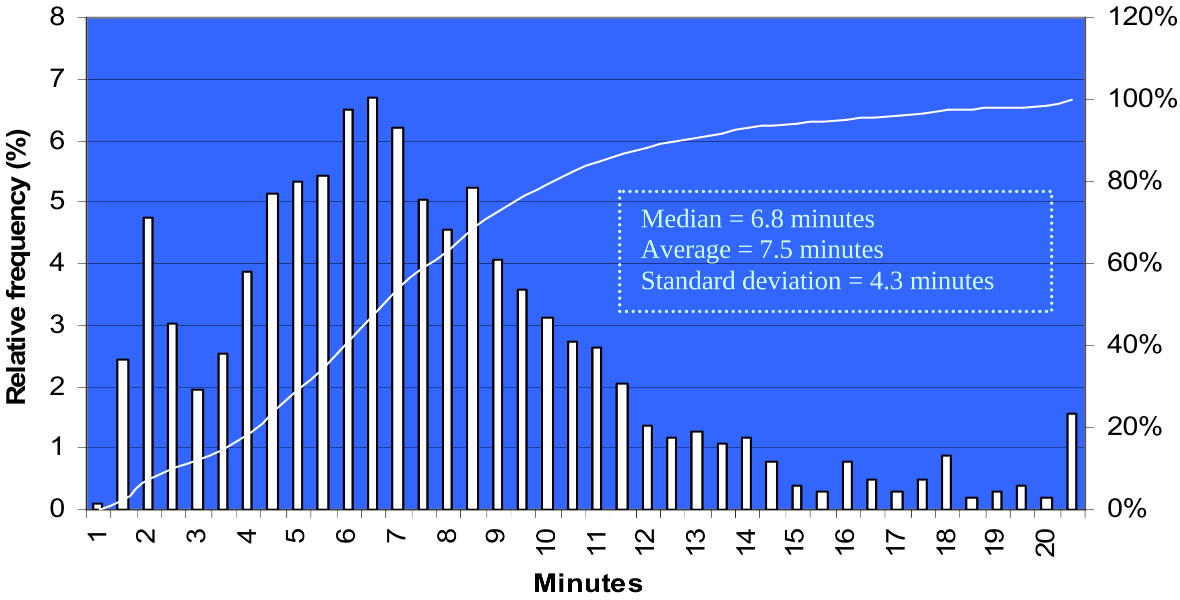

Figure 35: Shower duration

From the graph in Figure 35 it can be seen that 80% of showers have a duration of 2–11 min. Only 6% of showers are longer than 15 min and only 7% are 2 min or less. The median was 7 min, with the average being 7.7 min, and a standard deviation of 4.1 min.

Figure 36 shows the distribution of shower volumes. Eighty-three percent of showers used a total of 30–160 L of water per event. The median was 62.8 L, the average volume was 76.3 L, and the standard deviation was calculated to be 51.4 L.

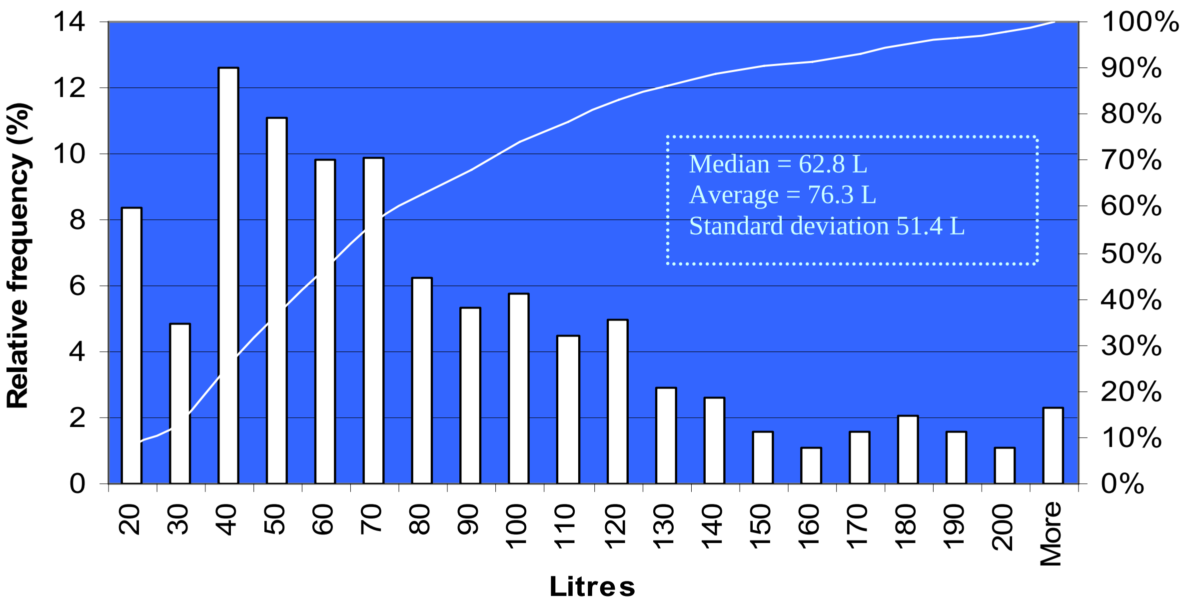

Figure 36: Shower volume distribution

The shower flow rates have a median of 9.2 Lpm, an average of 10.7 Lpm, and a standard deviation of 4.6 Lpm. The distribution in Figure 37 shows that 81% of all shower events had a flow rate of between 6–16 Lpm. The reason for the pattern shown in this distribution is that some of the shower heads in the homes only supported one flow rate.

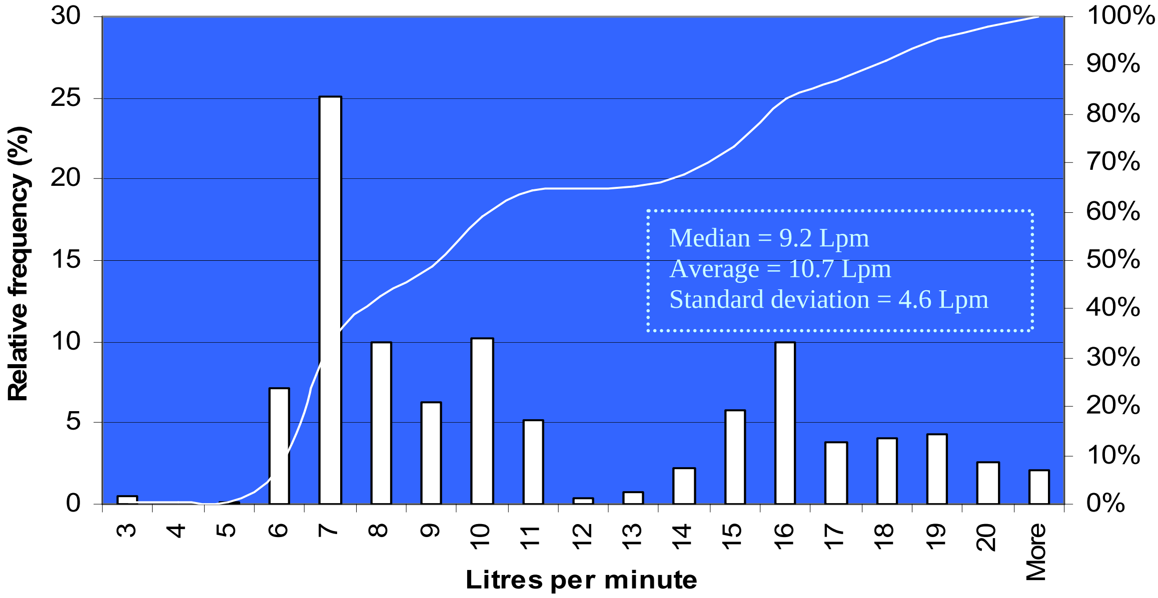

Figure 37: Shower flow rates

7.3.2 Washing machines

The washing machine accounts for 20.5% of the total uses (27% of indoor uses). In all of the study homes, except for one, top loading machines are used (they use up to 180 L of water per load). When looking at the data for individual homes, the home with a front loading machine only used 8.5% of its water for this purpose, with an average of 0.8 loads per house per day and an average volume of 59.1 L per load. The loads washed with a top loading machine used an average of 130.1 L, which is 2.2 times as much water per load as for front loading machines. Table 8 summarises results for washing machine use.

Table 8: Summary of results for washing machine use

	Average	Standard deviation
Load top loader (L)	130.1	18.6
Load front loader (L)	59.1	N/A
Loads per home per day (#)	0.80	0.54
Loads per person per day (#)	0.32	0.14
Litres per house per day	102.7	77.7
Litres per person per day	41.8	20.7

Over the whole summer period, 812 loads of washing were undertaken in the study homes using a total of 103 m^3 of potable water. On average a house from the study group would use 38 m^3 of water annually for laundry use alone, not taking into account the seasonal variations. This potable water could easily have been supplemented by collected rainwater which would have reduced the environmental impact (see case study in Section 9.1 of this report).

7.3.3 Indoor taps

Indoor tap use (hot, cold and mixed) accounts for 12% of the total uses (16% of indoor uses). A total of 30,781 individual tap uses were registered during the summer monitoring period

(11.6 uses per person per day). The distribution in Figure 38 shows that 82% of tap use is 30 seconds or less. Since our data was collected at a 10 second interval, a further breakdown in data would require a shorter logging interval (e.g. 5 seconds). The average tap use time is 27.3 seconds, with a median of 20 seconds, and a standard deviation of 29.9 seconds.

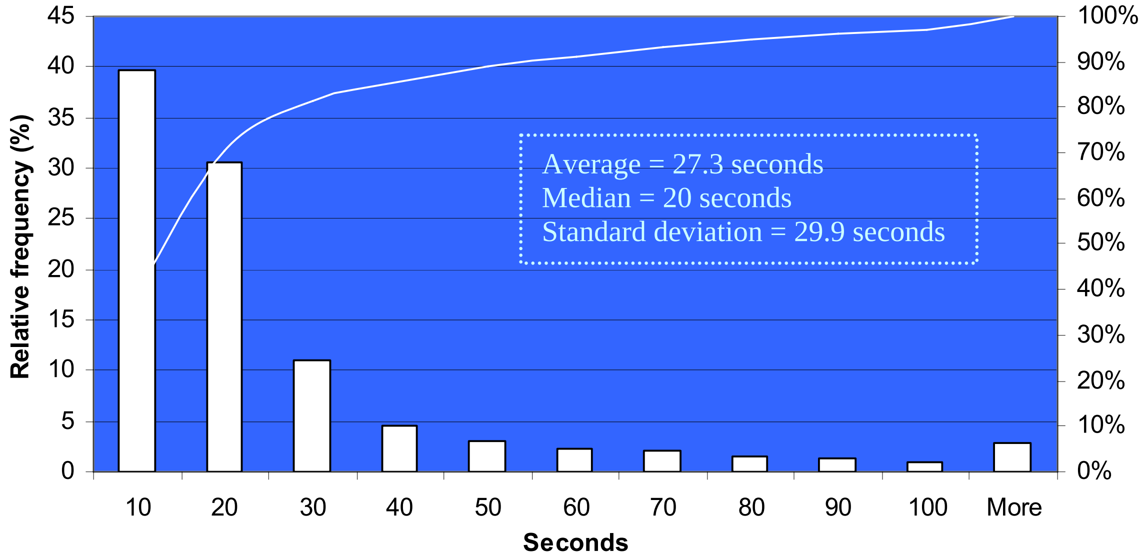

Figure 38: Tap use duration

The following distribution in Figure 39 shows the total volumes used in each tap event. Eighty percent of tap use events use 2 L or less and only 4.7% use more than 6.5 L per event. The average volume of each event is 1.64 L, the median 0.7 L, and the standard deviation 2.77 L.

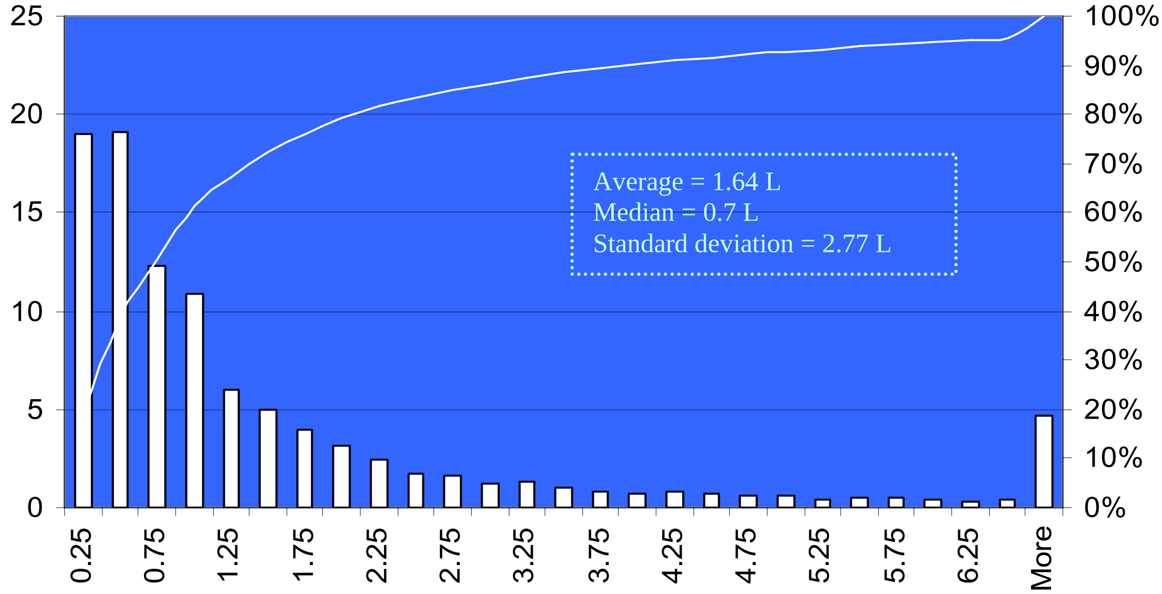

Figure 39: Tap use volumes

The distribution of tap flow rates is shown in Figure 40. Eighty percent of tap usage has a flow of 0.5–6 L. The average flow rate of a tap event is 3.85 L, the median 2.86 L, and the standard deviation 3.37 L.

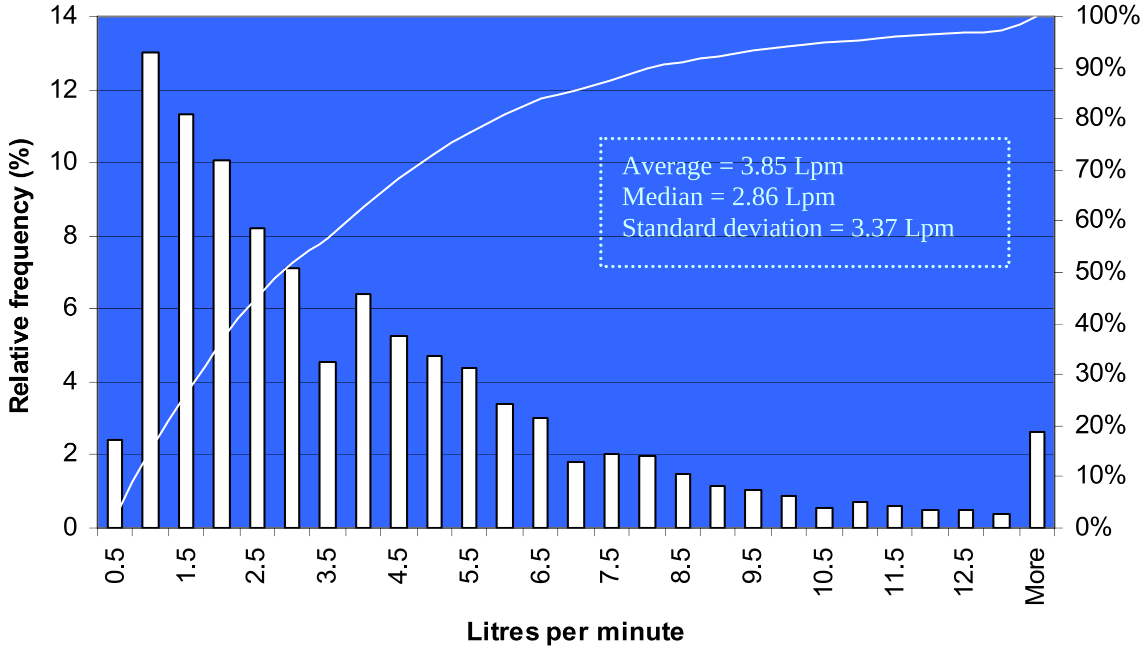

Figure 40: Tap flow rate distribution

7.3.4 Toilet

The toilet accounted for 17.4% of the total uses (23% of indoor uses). A total of 13,279 toilet flushes were recorded from all the homes in the summer monitoring period. On average 13.1 toilet flushes per home per day were recorded, with an average of 5.2 flushes per person per day. The average flush volume across the study homes was 6.2 L. However, by retrofitting homes with 6/3 dual flush toilets, or lower volume cisterns, the water consumption could be reduced significantly in a number of homes who still have larger than standardised volume cisterns. Water-less toilets, such as composting toilets, would reduce the water consumption even further.

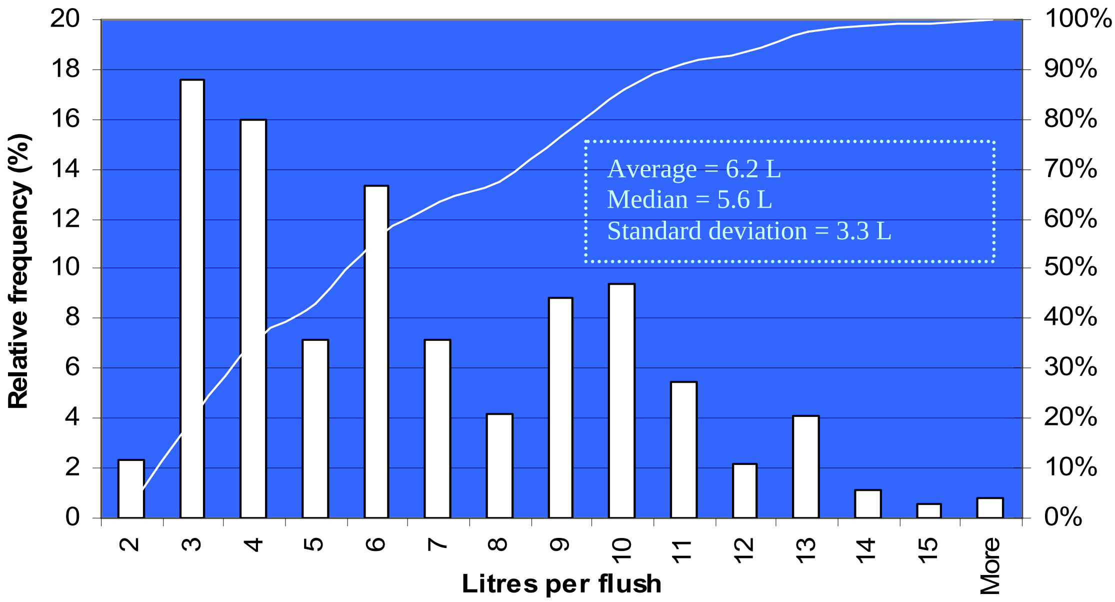

Figure 41: Toilet flush volumes

7.3.5 Leaks

Leaks represent 3.3% of the total water usage across all the study homes through the summer period. The largest leakage represented 12.5% of the total usage of one particular home, consuming 45 litres per day (16.4 m^3 annually). The average amount of leakage was found to be 7 l/p/d (2.6 m^3 annually) over the whole study group. The main source of leakage was identified as the toilet cistern.

7.3.6 Irrigation and outdoor use

During the summer monitoring period, a small number of homes were responsible for the majority of irrigation and outdoor uses. The largest share for an individual house was 57% of the total uses. This equates to about 640 L per day on average. The largest observed irrigation event was over 11 hours and used about 12 m^3 of fresh water. Together with the shower, outdoor use accounts as the highest use at 22% of the total uses. On average, 44.5 l/p/d (16.2 m^3 annually) are used outdoors.

8. SUMMER/WINTER COMPARISON

This section analyses the variations between the summer and the winter monitoring period, and the variations throughout the year. Due to data loss from two premises, data was also analysed on a per house basis.

8.1 Daily per capita use

During summer the average daily use per person was 203.9 L and during winter 168.1 L. The average per person use over the whole monitoring period was 184.2 l/p/d, which is comparable to figures measured in the Auckland region (metered supply – domestic consumption of 185 l/p/d).[10]

The water usage pattern per person per day over the whole monitoring period (July to March) is shown in Figure 42. In the summer months the maximum water use per person is higher than the maximum use in winter. This is mainly due to irrigation and outside uses in a small number of houses. On average 36 L are used additionally in summer by each person. The house which had the highest outdoor use during winter also had the highest outdoor use during summer.

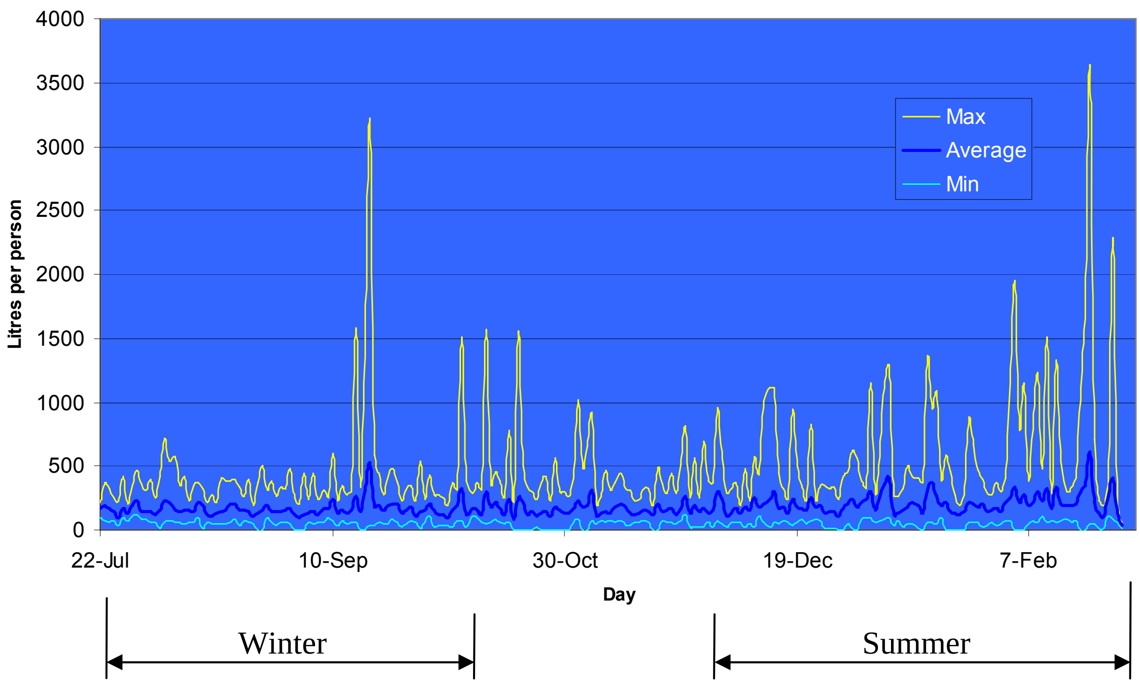

Figure 42: Daily water usage pattern (per person)

Figure 43 compares directly between the summer and the winter period. The reason for a higher frequency of uses of 20 L and less during summer is that people are away from their home more than during winter (e.g. holidays). Higher frequency uses of 550 l/p/d are found, which are mainly due to outside uses. The highest per person use was found to be 3630 L (10,891 L/house) during the summer and 2167 l/p/d (6414 L/house) during winter. This was the same house in both cases.

During winter daily uses over 1000 L per house only occurred for 4% of the time, whereas during summer it was 10%.

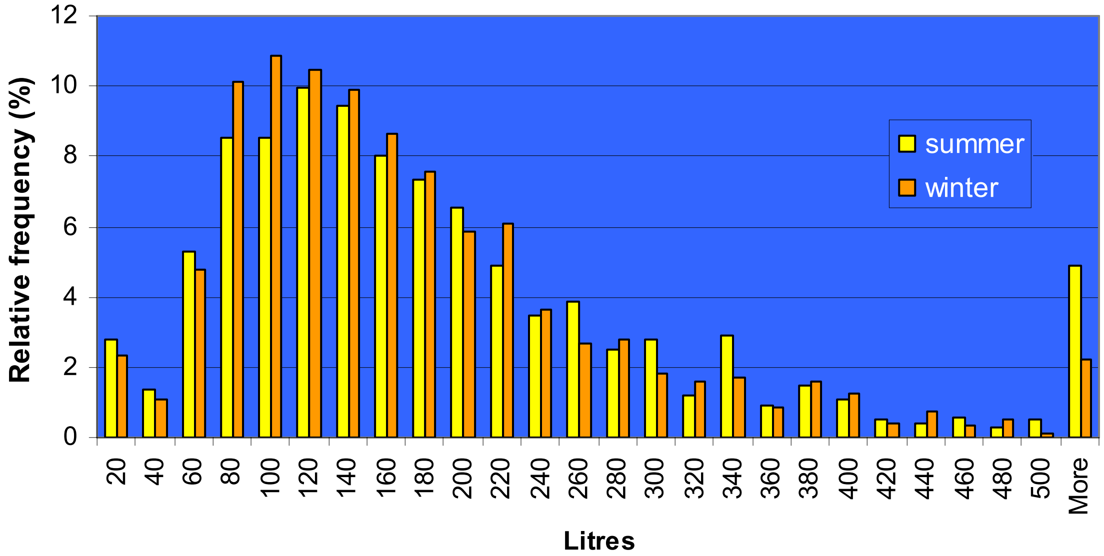

Figure 43: Daily use comparison (litres/person/day)

8.2 End uses

Table 9 shows a summary of the share of end uses and the average volumes used per person during the two separate periods. The indoor use for summer is nearly identical with the winter indoor use, suggesting that indoor use keeps constant throughout the year, with a few exceptions. In the winter bathtub usage is double to summer usage. This seems logical, as the outside temperatures are lower during winter. However, bathtub usage is only a small proportion of indoor use.

Table 9: Summer/winter end uses comparison

	Total use (%)		**Indoor use (%)**		**Average (l/p/d)**	
	Summer	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**
Tap	11.9	13.5	15.6	15.5	24.3	22.7
Shower	22.2	26.7	29.8	30.5	45.3	44.9
Washing machine	20.5	23.7	27.4	27.1	41.8	39.9
Toilet	17.4	18.6	22.9	21.3	35.5	31.3
Dishwasher	1.3	1.2	1.8	1.4	2.7	2.1
Bathtub	1.5	3.3	2.0	3.8	3.1	5.5
Miscellaneous	0	0.4	0.0	0.5	0	0.8
TOTAL INDOOR	**74.22**	**87.5**	**100**	**100**	**151.3**	**147.1**
Outdoor	21.7	8.3			44.2	13.9
Leaks	3.3	4.2			6.7	7
TOTAL USE	**100**	**100**			**203.9**	**168.1**

The main difference as expected between summer and winter is the outside usage. During summer outside usage accounted for 22% of the total usage, which is three times the amount used during winter. The majority of outside usage is for irrigation. On average 36 l/p/d of water was additionally used during summer.

8.3 Shower

Table 10 shows a detailed shower comparison of the individual homes across the two monitoring periods (note houses 8, 9 and 11 are not represented in this table due to low pressure systems – see Section 3 of this report). This data shows that even between the different houses there is little variation in shower time, average flow rates and number of showers per person per day, between the summer and winter season. The average values, including the data for house 3 and 10, are given in the brackets.

Table 10: Shower comparison

	Average shower Time (min)			Average flow rate (Lpm)			Showers/person/ day		
House	**Summer**	**Winter**	**Δ**	**Summer**	**Winter**	**Δ**	**Summer**	**Winter**	**Δ**
1	11.0	13.2	120%	5.9	4.9	84%	0.9	0.9	100%
2	4.7	6.5	139%	6.7	6.8	102%	0.9	0.6	60%
3		<8.3>			<15.6>			<0.5>	
4	6.4	7.2	112%	9.7	9.6	100%	0.9	0.8	94%
5	6.8	5.1	75%	17.9	17.9	100%	0.4	0.5	116%
6	10.2	9.3	91%	7.2	6.9	96%	0.6	0.7	117%
7	6.3	6.6	105%	14.3	14.0	98%	0.2	0.3	133%
10		<6.3>			<12.5>			<0.4>	
12	8.4	7.7	92%	15.2	14.3	94%	0.6	0.8	131%
Average	**7.7**	**7.9**	**103%**	**11.0**	**10.6**	**97%**	**0.7**	**0.7**	**100%**
<Average>		<7.7>			<11.8>			<0.7>	

For all monitored showers, the average shower time was 7.8 min throughout the year with an average of 0.7 showers per person per day. The amount of water used in the shower can be reduced substantially in a number of homes by installing a low flow shower head (LFSH). Low pressure systems, which have not been included in the shower analysis, already have a relatively low flow rate and it is not recommended to install an LFSH in these premises. The homes with small children have a lower shower usage than homes without, but the bath usage tends to be higher.

8.3.1 Shower retrofit

By retrofitting the shower in the following houses to more water efficient shower heads as specified in the Water Efficiency Labelling and Standards Scheme (WELS), the following savings can be achieved in each of the specific cases (Table 11).

Table 11: Potential shower retrofit savings by adopting WELS scheme

House 3

WELS Rating	Flow* (Lpm)	Usage (L/house/day) Present	Post retrofit	Average savings (L/house/day)	(%)	Annual (m^3)
*	12 to 16	291.3	261.5	29.9	10%	10.9
**	9 to 12	291.3	196.1	95.2	33%	34.8
***	7.5 to 9	291.3	154.1	137.2	47%	50.1

House 5

WELS Rating	Flow* (Lpm)	Usage (L/house/day) Present	Post retrofit	Average savings (L/house/day)	(%)	Annual (m^3)
*	12 to 16	213.0	166.6	46.4	22%	16.9
**	9 to 12	213.0	124.95	88.1	41%	32.1
***	7.5 to 9	213.0	98.175	114.8	54%	41.9

House 7

WELS Rating	Flow* (Lpm)	Usage (L/house/day) Present	Post retrofit	Average savings (L/house/day)	(%)	Annual (m^3)
*	12 to 16	92.3	91.0	1.3	1%	0.5
**	9 to 12	92.3	68.3	24.1	26%	8.8
***	7.5 to 9	92.3	53.6	38.7	42%	14.1

House 12

WELS Rating	Flow* (Lpm)	Usage (L/house/day) Present	Post retrofit	Average savings (L/house/day)	(%)	Annual (m^3)
*	12 to 16	167.8	158.8	9.0	5%	3.3
**	9 to 12	167.8	119.1	48.7	29%	17.8
***	7.5 to 9	167.8	93.6	74.2	44%	27.1

*Flows as specified by WELS (median value used for calculation)

By installing the maximum efficient shower head (three star***) in houses 3 and 5, an annual water saving of 50 m^3 and 42 m^3 respectively could be achieved. This equates to 47% and 54% savings in water used for showers alone. Even when installing a one or two star shower head, the savings would still make an impact on total consumption.

The estimated annual consumption of house 3 is 219 m^3. By installing a three star shower head, the consumption would be reduced to 169 m^3 (23% savings). For house 5 the estimated annual consumption would be reduced by 13%. House 7 would save 10% of its annual consumption and house 12 would achieve savings of 13%.

8.4 Washing machine

Table 12 shows a breakdown of the amount of loads washed per person per day. The data is based on 1464 loads of washing from all households over the whole two monitoring periods. The average annual volume of water used per person was 14.5 m^3 when a top loader was used and 6 m^3 with a front loading machine.

Table 12: Washing machine comparison

	Loads/person/day		
House	**Summer**	**Winter**	**Difference**
1	0.28	0.35	126%
2	0.40	0.29	73%
3		<0.26>	
4	0.22	0.14	65%
5	0.55	0.54	98%
6	0.16	0.14	90%
7	0.13	0.12	93%
8	0.39	0.35	90%
9	0.30	0.21	71%
10		<0.31>	
11	0.23	0.15	68%
12	0.54	0.54	100%
Average	**0.32**	**0.28**	**89%**

When comparing the washing behaviour of houses in Table 12 and Table 13, data shows that there is no significant difference between the summer and the winter period. The majority of houses have even washed the same number of loads per day in both periods (e.g. house 12 and house 5).

In the Yarra Valley water study of 2004 (Roberts) a formula (equation 1) was derived to analyse the number of loads washed. The value obtained from the formula is compared to the actual measured value in Table 13.

$$\text{No. loads week} = 2.77 \times (\text{household size})^{0.76} \qquad \textbf{(Equation 1)}$$

Table 13: Washing machine comparison (loads/home/day)

House	Actual usage: Summer	Actual usage: Winter	Actual usage: Average	Formula	Difference	Difference (%)
1	0.28	0.35	0.31	0.40	0.08	26
2	0.80	0.58	0.69	0.63	-0.06	-9
3	-	0.78	0.78	0.83	0.04	5
4	0.44	0.29	0.36	0.63	0.27	73
5	2.20	2.16	2.18	1.00	-1.18	-54
6	0.48	0.43	0.46	0.83	0.37	80
7	0.53	0.49	0.51	1.00	0.49	97
8	0.78	0.70	0.74	0.63	-0.11	-15
9	0.60	0.42	0.51	0.63	0.12	24
10	-	1.24	1.24	1.00	-0.24	-19
11	0.90	0.62	0.76	1.00	0.24	32
12	1.08	1.07	1.08	0.63	-0.45	-41
Average	**0.81**	**0.79**	**0.80**	**0.74**	-0.06	-8

(All figures in: **#/loads/day** unless otherwise stated)

In the case of the measured data, the formula represents an inaccurate picture of the number of loads actually washed in a home, but overall gives a reasonable estimate when a group of houses is considered, slightly underestimating actual use by 8%. When looking at individual homes, the variations were up to ± 100%.

8.4.1 Effect of household size on washing machine use

There were five four person households participating in the study, consisting of two adults and two children, as well as five two person households. There were substantial differences in the amount of loads washed and the amount of water used.

Four person households:

- Extreme case – one house washing 2.2 loads per house day on average using 296.8 L per house per day (74.19 l/p/d) using a top loading machine. When talking to the occupant it was found that only half loads are being washed. Hence the increased number of loads as the washing machine is not used in its most efficient way.
- Medium case – 0.9 loads per day using a front loader (33 l/p/d).
- Low case – 0.5 loads per day using a front loading machine at 60 L per load (8 l/p/d). An interview with the occupants confirmed the speculation that only lull loads are washed in the house (most efficient use of washing machine).

During the same time period of 104 days, the family using the front loading machine used about a 10th of the water than the extreme case (3.3 m^3 and 30.9 m^3 respectively).

Two people households:

- on average 0.74 loads per house per day (min: 0.4 max: 1.1).

There is little variation between the amount of loads washed between the summer and winter period across the whole study group, but when looking at the individual houses differences can be seen. Even if the house has similar demographics there is a difference in how many loads are washed on average. This could be due to different behaviours e.g. people only washing full loads, as opposed to smaller loads more frequently.

8.5 Indoor taps

Table 14 shows a breakdown of the tap usage over the two monitoring periods. The data is based on 59,181 individual indoor tap usages (30,781 in summer and 28,400 in winter). On average a person from the study group used a tap 11.6 times per day during the summer and 11.9 times during winter.

Table 14: Tap use comparison (event basis)

	Summer	Winter	Δ
Duration (seconds)			
Average	27.3	27.8	102%
Median	20	20	100%
Standard deviation	29.9	37.7	126%
Volumes (L)			
Average	1.64	1.57	96%
Median	0.7	0.7	100%
Standard deviation	2.77	2.57	93%
Flow rates (Lpm)			
Average	3.85	3.79	98%
Median	2.86	2.81	98%
Standard deviation	3.37	3.23	96%

There is no major variation between the data measured in the two separate periods. Only 1.4 L of water was used additionally by each person per day during the summer. The average duration, volume and flow rates of the separate events stayed the same. The average flow rate of 3.83 Lpm is well below a six star WELS rating, which specifies flows of less than 4 Lpm. Hence by retrofitting water efficient tapware to the case study homes no significant water reduction would be achieved.

8.6 Toilets

Table 15 shows a comparison between the summer and winter toilet usage. When comparing the number of toilet flushes per person on a house level there is only 4% variation between summer and winter. The daily per capita uses were found to be 35.5 L and 31.3 L for summer and winter respectively. As an approximation the toilet is flushed about five times per person per day throughout the year, using an average volume of 11.3 m^3 per person annually (6.2 L/flush).

Table 15: Toilet comparison

House	Summer	Winter	Difference
1	3.44	3.90	113%
2	6.54	4.37	67%
3		<3.11>	
4	5.15	4.86	94%
5	5.57	5.63	101%
6	4.48	4.40	98%
7	4.78	4.71	99%
8	4.21	3.49	83%
9	8.23	7.09	86%
10		<3.90>	
11	3.01	3.08	102%
12	6.26	7.89	126%
Average	**5.17**	**4.94**[1]	**96%**

[1] 4.7 l/p/d including figures in <brackets>

8.6.1 Toilet retrofit

The majority of houses in the study group already had dual flush toilets installed. The average flush volume over the whole study group was 7.9 L per full flush and 4.1 L per half flush. Two homes had 12 L single flush toilets. The flush volumes might sometimes be misleading as these toilets do not always use exactly the same amount of water for each flush.

By substituting the 12 L toilet for a 4.5/3 L (four star∗∗∗∗ rating) one, approximately two-thirds of the water used in the toilet could be saved. A particular house (with a 12 L toilet) used on average 124.8 l/p/d with toilet flushing (45.5 m^3 annually). Potentially 85.8 L/day could be saved, which translates to an annual saving of 31.3 m^3 of water. A three star 6/3 L toilet could achieve a saving of 28.5 m^3 annually in this particular case.

Toilet retrofit programmes in New York, Los Angeles and Seattle have helped to minimise water use, despite a growing population. The following extract was taken from an article in the *Plumbing Connection* magazine:

> *Between March 1994 and April 1997 approximately 1.3 million new 6 L toilets were installed in the city at a cost of $290 million in rebates, or about two-thirds of overall fixture and installation costs. Water use fell by an average 29% in participating buildings. In 2004 New York City consumed 4.64 GL (4.64 billion L) of water per day, which is 25% less than it did in 1991.*

8.7 Irrigation and outdoor use

Outdoor irrigation is the major factor for differences in water use between the different seasons. During the winter outdoor use accounted for 8.3% of the total uses and during the summer it was 21.7% (13.9 and 44.4 l/p/d respectively). The majority of outdoor uses were found in a small number of homes throughout both periods. These tended to be the same houses. The majority of outdoor uses were for irrigation. Some houses used no water for irrigation and let nature take its course. The largest irrigation event recorded had a duration of 11 hours and used nearly 12 m^3 of mains water. In the summer period there were a relatively high proportion of irrigation events using more than 2 m^3.

It is not entirely possible to determine for what exact purpose the water is used outside. Irrigation events tend to have a higher duration and flow rate. When a hand-held hose is used, as opposed to a sprinkler system, the water can be used for other purposes like washing the car or footpath, filling a paddling pool or other outdoor related uses.

A rainwater or greywater system would be the most water wise investment for high irrigation users to cut down on their water use and reduce their environmental footprint (see Sections 9 and 10 of this report).

8.8 Daily variations

When looking at the hourly profile in Figure 44 and Figure 45, which has been derived from the water usage of all the homes, a peak in water use can be seen from 06:00 to 08:30. This is the time when people get up, take a shower and use the toilet. After 17:00 there is another peak which lasts until 20:30.

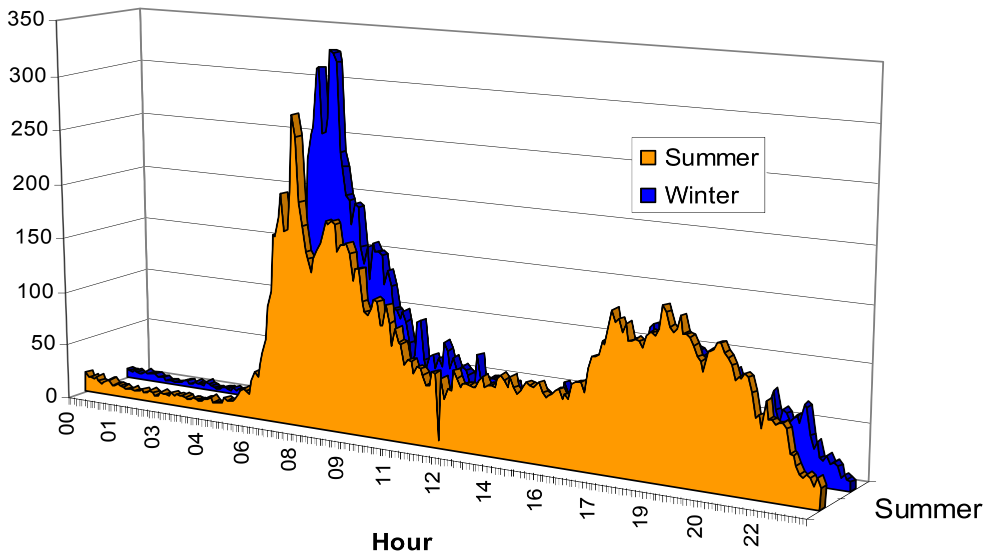

Figure 44: Daily variations 1

During summer this peak extends to 21:00. The higher afternoon use during summer is due to an increased irrigation demand. The morning peak could be reduced by installing low flow shower heads and upgrading older model toilets with more water efficient models.

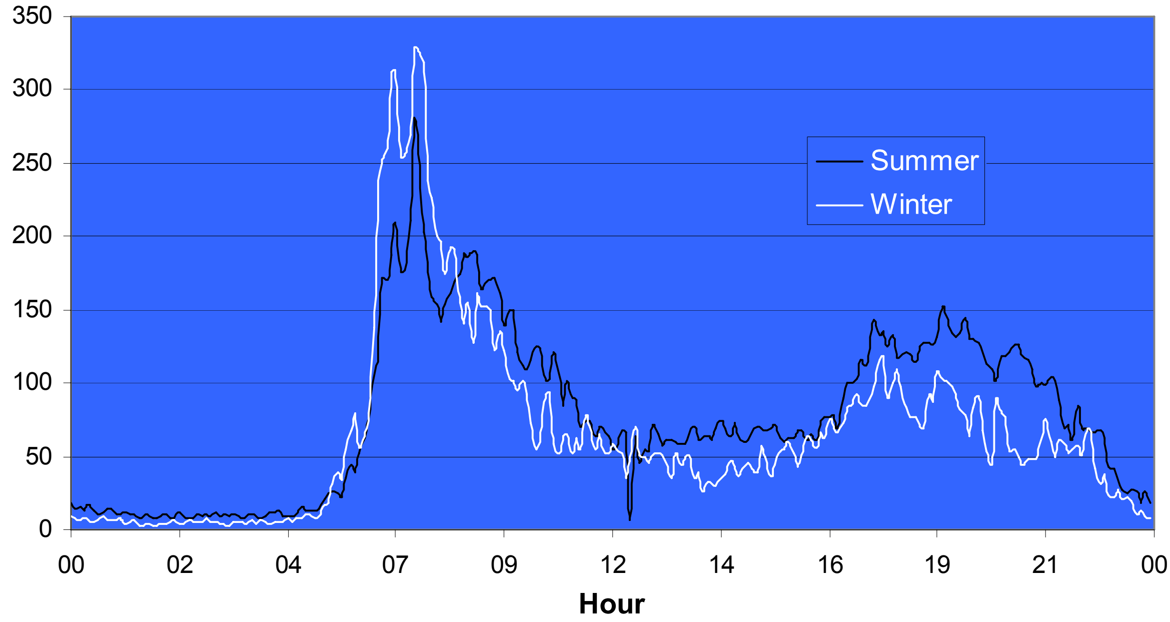

Figure 45: Daily variations 2

8.9 Weekly variations

Figure 46 shows the weekly variation in water use. During the week days (Monday to Friday), water use remains fairly constant, with a slight drop on Thursdays.

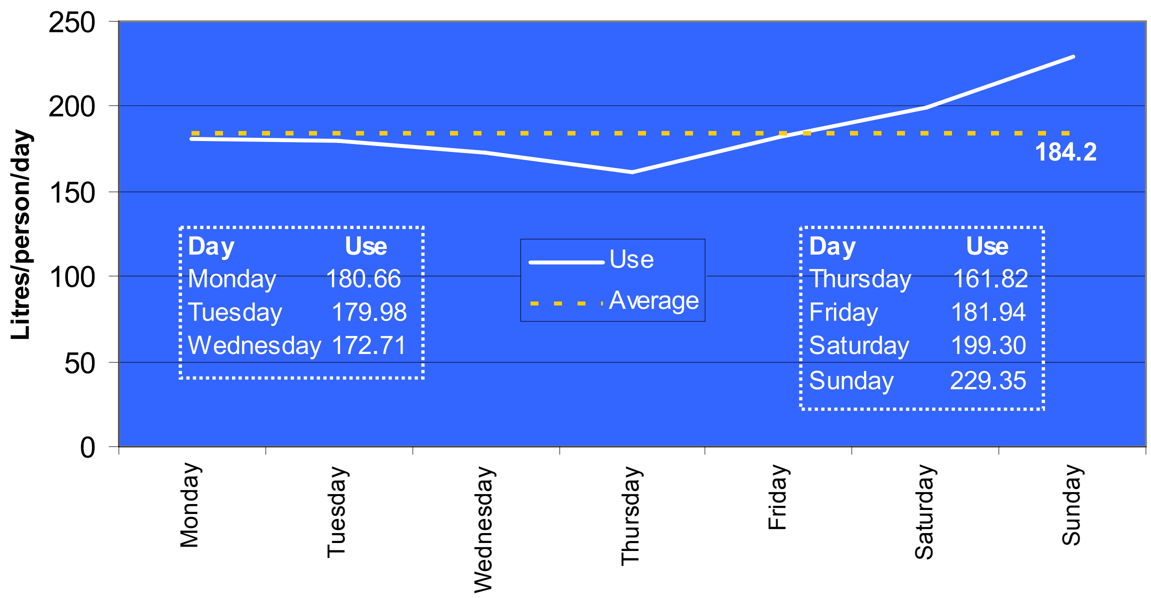

Figure 46: Weekly variations (litres/person/day)

On the weekend water use increases, being highest on Sundays. This is because people tend to be home for longer parts of the day and hence use more water. When all occupants are working during the week, irrigation demand and outdoor use is higher on the weekends and the use of the washing machine also increases.

8.10 Monthly variations

Figure 47 shows the monthly water use variation. Water use tends to be fairly constant from July to December, and increases from January. The highest per person usage was in February, when there was increased irrigation and outdoor use and usage increased to 254 l/p/d on average.

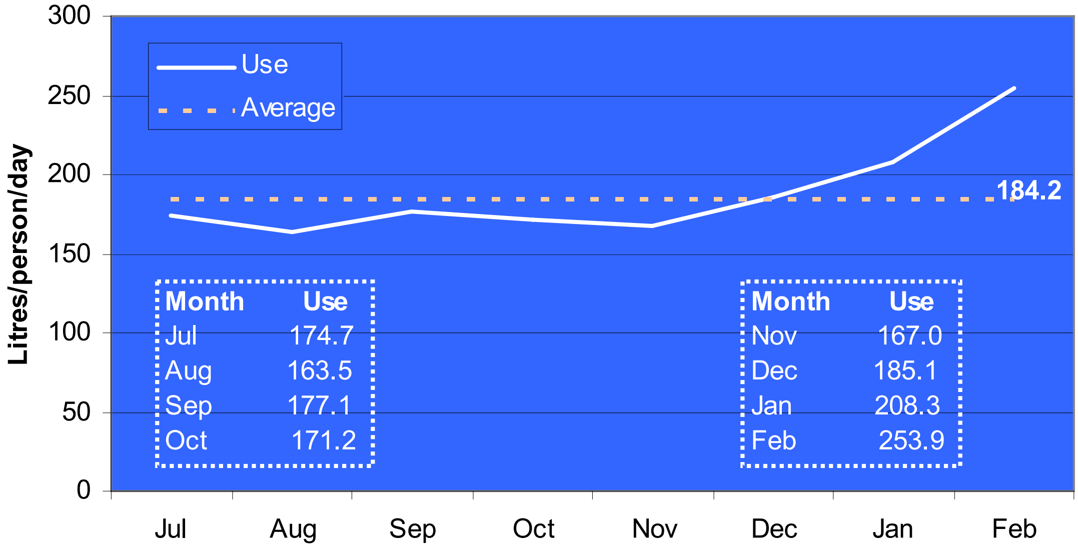

Figure 47: Monthly variation (litres/person/day)

8.11 Yearly usage

Table 16 shows the projected yearly volumes of water used on average by each house and by each person. These are projected values, since the homes were not monitored for the full year. On average a household would use 177 m^3 per year. This equates to about 67 m^3 per person per year. The highest users were households with the largest number of occupants (four people). The lowest household usage figure was from the home with only one occupant. However, when looking at the yearly consumption on a per person basis, the lowest users were the large households (four people). This was not surprising, since larger households 'share' water that is used for the washing machine, cleaning, irrigation etc, between them.

Table 16: Yearly usage

	m^3/year	Household size	m^3/person/year	Household size
Max	309	4	103.9	2
Average	176.4	2.7	67.6	2.7
Min	58.6	1	34.1	4
St dev.	77.3	-	23.8	-

When looking at the projected yearly consumptions from similar size household in Table 17, it can be seen that there is a wide range of volumes used. The average use for a four person household (two adults, two children) was 210 m^3, with a maximum of 304 m^3 and a minimum of 137 m^3. The maximum is more than twice the minimum value. A main reason for the difference in this particular case was that the home with the minimum volume used about a 10th of the water for washing machine use than the house with the maximum volume. Only full loads were being washed in a water efficient front loader, as opposed to smaller loads in a top loading machine. Considering the fact that 96% of washing machines in New Zealand are top loaders, and many people do not always wash full loads of washing, large volumes of water get wasted unnecessarily. By adopting different habits and technology the amount of water wasted can be reduced substantially.

Table 17: Yearly usage for similar size household

	Volume year (m^3)	
	4 people	**2 people**
Max	309.3	207.8
Average	210	145
Min	136.5	83.4
St dev.	72	53.8

9. RAINWATER AND STORMWATER

NIWA estimates a 3% increase in annual rainfall on the Kapiti Coast by 2030 and 13% by 2080 (Saxena 2005). The increased rainfall will also have an impact on the stormwater run-off.

According to Ben Thompson, the water use coordinator of the KCDC, the Kapiti Coast area has three issues surrounding stormwater:

1. the flat sandy coastal typology
2. the urbanised catchments discharging water to council networks with little attenuation
3. impacts from climate change.

The Kapiti Coast has a historical duneland and wetland profile. Rain falling on the coastal plains moves through the sandy soils into the shallow ground water. During wet years the high water table can pond at the surface, making it difficult for drainage.

The relatively flat profile of the coastal areas also makes it difficult for stormwater to drain away to sea level; particularly in urban catchments with reduced permeability. Therefore the stormwater is directed straight to the stormwater infrastructure.

Due to the flat profile, the stormwater network takes time to transport the stormwater to the receiving environment. With a high water table and high stormwater loadings, stormwater can pond and become an issue. The figures below also show that climate change may increase the intensity of the storms and further test the capacity of the stormwater networks.

The council is investigating options for attenuating peak flows during stormwater events for identified areas with ponding. In new developments the council requires sites to be hydrologically neutral and encourages individual lots to attenuate stormwater.

The NIWA report (NIWA 2005) produced for the KCDC states the following:

The rainfall predictions by 2030:

- Summer -4% to +10%
- Autumn -6% to +6%
- Winter -6% to +28%
- Spring -10% to +10%
- Annually -8 to +2%

The rainfall predictions by 2080:

- Summer -2% to +46%
- Autumn -8% to +11%
- Winter -6% to +62%
- Spring -23% to +21%
- Annually +1 to +26%

Other parts of new Zealand may experience the opposite effect, where a decrease in potential rainfall can increase the risk of drought, causing further water shortages.

9.1 Rainwater collection case study home

Three years ago a Paekakariki (Kapiti Coast) family started building their new house in a sustainable manner. From passive solar design, to solar water heating, to rainwater collection they covered a wide spectrum of sustainable building techniques. The focus of this section will be on their rainwater collection and reuse systems.

Two 4,500 litre tanks were buried in the ground during the building's construction. The rainwater is collected from a total roof area of 174 m². Figure 48 shows a plan view of the house. The collected rainwater finds a number of uses within the home. The tanks feed the toilet cistern, the laundry and the outside taps, which are mainly used for irrigation proposes.

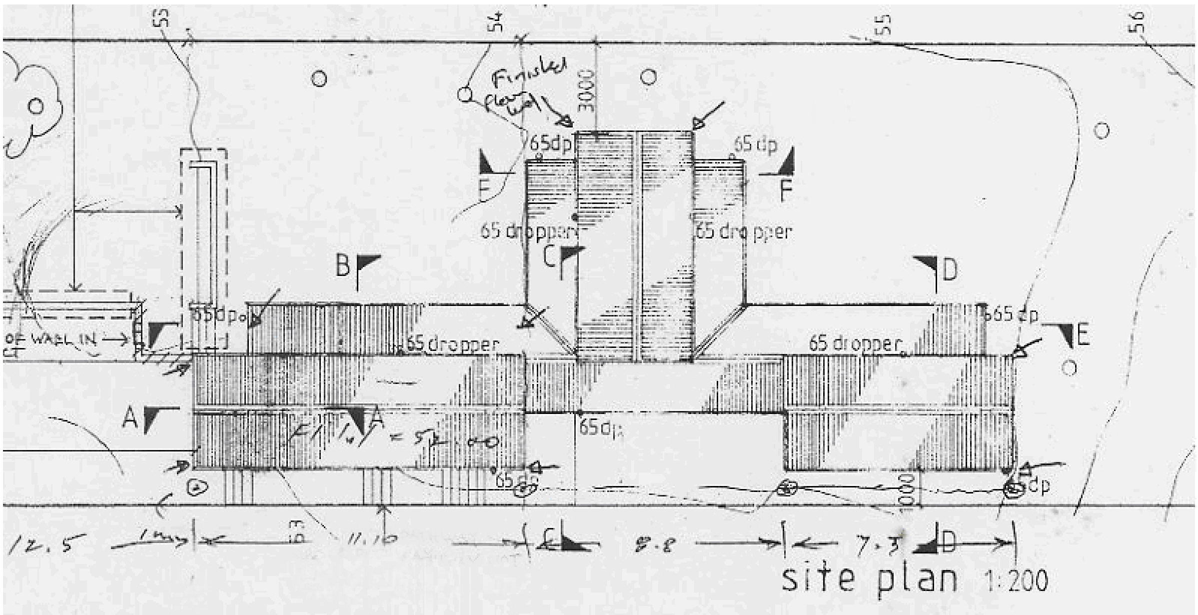

Figure 48: Plan view

The owners monitored their water use over two years with two standard water meters, one on the tank and one on the mains supply, by taking a daily reading. This made it possible to quantify the volumes and shares of their consumption. Nearly 50% of their water use is covered by the rainwater they are collecting and, according to the owners, they have never run out of rainwater. With the rainfall data that has been collected in the area, it is possible to calculate the amount of rainwater that can be collected. This is given by multiplying the roof area by the amount of rainfall and a factor of 90% (around 10% lost through evaporation, spillage, first flush diverters) (equation 2).

Amount of rainwater captured (m^3)	=	90% efficiency	x	Roof area (m^2)	x	Annual rainfall (m)

Equation 2: Rainwater harvesting formula

Rainwater captured = 0.9 x 174 m^2 x 1040 mm = **163 m^3** annually (446 L per day)

This home is currently being monitored by BRANZ and KCDC (started in October 2006) using two sets of equipment, one on the tank and one on the mains supply, for disaggregation into its end use components from the two supply sources. Only recently a mains top-up system has been installed to ensure a water supply if the tank has emptied during times of no or low rainfall.

9.2 Rainwater collection in study homes

Of the main study group there was just one house collecting rainwater from the roof (for irrigation purposes); all other homes solely rely on mains water for their water supply. This sections outlines the potential savings that could be achieved by the study homes by adopting a rainwater collection approach and supplementing their mains supply.

Table 18: Annual rainfall data for Kapiti Coast (GWC 2007)

Year	Annual rainfall total (mm)	Maximum daily rainfall (mm)
2006	1566	100.5
2005	826.5	99.5
2004	1735	110.5
2003	952	68.5
2002	1090.5	57
2001	834	57.5
2000	1079.1	63
1999	967	52.4
1998	1551.5	104.1
1997	993.1	76.2
1996	1503.1	60.7
1995	1395.8	74.6

Not all end uses necessarily require mains water. Rainwater can be used for toilet flushing, irrigation and the washing machine without major concerns or health issues. When the right techniques and equipment are used for rainwater collection all uses can be supplied by rainwater. This is, however, beyond the scope of the project.

Table 18 shows a rainfall summary of the Kapiti Coast, measured at the Waikanae treatment plant. The average annual rainfall taken from the table is 1200 mm. Table 19 and Table 20 outline the amount of rainwater that could potentially be harvested by each of the homes in a year with both lower and above average rainfall. These values were taken as 825 mm and 1500 mm of rain annually respectively.

The 12 homes have a combined roof area of 2085 m^2 (average 173 m^2) and could potentially harvest 1462 m^3 of rainwater annually (4 m^3 daily) in a lower than average rainfall year and 2658 m^3 (7.2 m^3 daily) in an above average rainfall year. If the study homes would install a rainwater system, as in the case study house outlined in Section 9.1 of this report (i.e. using rainwater for washing machine, outside uses and flushing toilets), high mains water savings could be achieved. This particular house achieves a mains water supplementation of nearly 50% by using rainwater. Software tools are available which can calculate the required tank size which is needed for optimum rainwater collection.

During the winter period, captured rainfall would cover for all those needs in all the homes and no mains top-up supply would be required during a year with above average rainfall, but two homes would require back-up in a year with low rainfall. During the summer mains top-up would be required in 40% of the homes during a low rainfall year and in 10% of the homes in a high rainfall year. However, as rainfall intensities at the Kapiti Coast are likely to increase (NIWA) in the coming years due to climate change, more rainwater can potentially be harvested and more stormwater run-off diverted from the stormwater system if a system is installed. In areas where a decrease in rainfall is predicted for the future, the benefit for a rainwater system would be a reduction of pressure on the water supply system.

Table 19: Potential rainwater capture and usage in low rainfall year (825 mm)

			Litres						
				Daily usage**		Excess rainwater		Top-up required	
House	Catchment area* (m^2)	Volume annual (m^3)	Daily volume	Summer	Winter	Summer	Winter	Summer	Winter
1	160	112.2	307	59	65	248	242	N	N
2	120	84.2	231	169	132	62	99	N	N
3	160	112.2	307	-	237		70		N
4	120	84.2	231	142	112	89	119	N	N
5	240	168.3	461	608	444	-147	17	Y	N
6	230	161.3	442	812	297	-370	145	Y	N
7	320	224.4	615	157	128	458	487	N	N
8	130	91.2	250	448	300	-198	-50	Y	Y
9	145	101.7	279	166	106	113	172	N	N
10	220	154.3	423	-	308		115		N
11	140	98.2	269	256	215	13	54	N	N
12	100	70.1	192	236	264	-44	-72	Y	Y
Σ	**2085**	**1462.1**	**4006**	**3053**	**2608**	**223**	**3043**		

* Approximate area measured using aerial photographs.
**Water used for irrigation, toilet, washing machine.

Table 20: Potential rainwater capture and usage in high rainfall year (1500 mm)

			Litres						
				Daily usage**		Excess rainwater		Top-up required	
House	Catchment area* (m^2)	Volume annual (m^3)	Daily harvest	Summer	Winter	Summer	Winter	Summer	Winter
1	160	204.0	559	59	65	500	494	N	N
2	120	153.0	419	169	132	250	287	N	N
3	160	204.0	559	-	237		322		N
4	120	153.0	419	142	112	277	307	N	N
5	240	306.0	838	608	444	230	349	N	N
6	230	293.3	803	812	297	-9	506	Y	N
7	320	408.0	1118	157	128	961	990	N	N
8	130	165.8	454	448	300	6	154	N	N
9	145	184.9	507	166	107	341	400	N	N
10	220	280.5	768	-	308		460		N
11	140	178.5	489	256	215	233	274	N	N
12	100	127.5	349	236	264	113	85	N	N
Σ	**2085**	**2658.4**	**7283**	**3053**	**2609**	**2903**	**4674**		

* Approximate area measured using aerial photographs.
**Water used for irrigation, toilet, washing machine.

Rainwater has been harvested for thousands of years. However, in the urban environment where a mains water connection is available the trend of using rainwater (even for irrigation) has declined. It is convenient to have your water supplied by the council, or regional retailer, especially if there is no direct cost involved for the end consumer. As Kapiti is not metered, the incentive to save water is not very high, as there are no financial benefits for the consumer.

Methods of collection can range from a simple rain drum put underneath the down pipe to a sophisticated dual supply system running the toilet and the washing machine. Even a rain drum can have an impact and reduce irrigation demand.

10. GREYWATER

Greywater is the wastewater from the kitchen (varies) and bathroom sinks, baths, showers and laundry. Greywater can be reused for toilet flushing, gardening and, in some circumstances, for washing machines (check with local councils). When looking at the proportion of end uses, it is possible to identify the amount of greywater produced by each of the homes.

Only one of the study homes had a greywater system installed. Greywater from the shower, bath, bathroom sinks and the washing machine was distributed through a series of pods, which were buried in the garden. On average 125 L of greywater was produced by the house per day during the monitoring period. As it is not possible to distinguish between the share of water used from the different taps, it is assumed that 50% of the total tap usage occurred in the bathroom and 50% in the kitchen. This equates to about 46 m^3 of greywater annually, which is watering the garden and does not need to be treated. This reduces the cost and associated energy use for wastewater disposal and the irrigation demand. There are no financial benefits for the owner at present, since the water supply is not metered. This home also had a very low per capita consumption of 110 L per day (in winter), considering they had the most vegetated and greenest garden of the whole study group. In addition to their greywater system, a 2700 L rain tank was in place to harvest rainwater for irrigation from a total roof area of 140 m^2.

Table 21: Greywater produced

	Daily (L)		Annual (m^3)		
House	**Summer**	**Winter**	**Summer**	**Winter**	**Average**
1	96	105	35.0	38.3	36.7
2	179	152	65.3	55.5	60.4
3	-	363	-	132.5	132.5
4	236	234	86.1	85.4	85.8
5	624	585	227.8	213.5	220.6
6	316	290	115.3	105.9	110.6
7	185	226	67.5	82.5	75.0
8	210	187	76.7	68.3	72.5
9	124	125	45.3	45.6	45.4
10	-	362	-	132.1	132.1
11	400	425	146.0	155.1	150.6
12	376	423	137.2	154.4	145.8
Σ	**2746**	**3477**	**1002.3**	**1269.1**	**1268.7**
Average	**275**	**290**	**100.2**	**105.8**	**105.7**

Table 21 shows the amount of greywater produced per house on a daily and annual scale. On average 105.7 m^3 of greywater is produced annually from each of the homes. The greywater requires treatment at a cost of $0.90 per m^3 (WaterCare 2006). The total cost would be around $95 per house per year on average. A detailed description of water and wastewater costs in the Auckland region is given in Appendix D. Auckland figures were used as figures from Kapiti are not publicly available.

House 5 produced about 604 L of greywater daily (220.5 m^3 annually) at an annual treatment cost of $198. Considering the irrigation demand for this house is about 200 L per day, the installation of a greywater system is likely to be worth the investment should water and wastewater be charged on a consumption basis.

Retrofitting a house with a greywater system can be problematic, especially if the house does not have a suspended floor and access to pipes is limited. It is therefore wise to think about this type of system in the design stage of a new building. The same applies to a dual supply system using rainwater. There are still issues (e.g. health) with greywater being used within the house (i.e. flushing toilets). This is beyond the scope of this report.

11. EMISSION AND POLLUTANTS

Treatment, supply and distribution of water and wastewater require both sophisticated infrastructure and ongoing supply of consumables, including chemicals (chlorine, fluoride etc.) and energy. Hence for some regions the water and wastewater sector produces a substantial part of the local area's greenhouse gas emissions. For example, the Kapiti Coast District Councils water and sewage treatment produced 57.3 percent (CO_2 equivalent) of their total greenhouse gas emissions in 2001, which corresponds to 2,318 tonnes of CO_2 equivalent (1,030 tonnes, 40.1% in 2006) (Parsons 2001). Table 22 shows an emission summary of each of the sectors.

Table 22: Water and sewage equivalent CO2 emissions 2001 (Parsons 2001)

	CO_2 Equivalent	
Sector	**(Tonnes)**	**(% of total emissions)**
Mzgb. Rd Treatment Plant	66	1.6
Sewage Collection	329	8.1
Sewage Disposal	29	0.7
Sewage Treatment	752	18.6
Water Collection	509	12.6
Water Distribution	518	12.8
Water Treatment	116	2.9
TOTAL	**2319**	**57.3**

In 2001, 4.8 million m^3 of water was supplied in the Kapiti Coast district in total, which equates to greenhouse gas emissions of 0.23 kg of CO_2/m^3 for mains water supply (collection, distribution and treatment) alone. In the same year 1.83 million m^3 of sewage was treated, which equates to 0.64 kg of CO_2/m^3 of sewage (collection, disposal and treatment). These emission values differ from region to region, as the methods (collection, distribution, treatment), fuel types used and other factors differ. In comparison with other councils, the greenhouse gas emissions from the water and sewage sector for Kaikoura District Council represented 40% of their total emissions of 2001 (emissions of CO_2 equivalent expected to triple by 2011)(CCP-NZ 2005a). For Rodney District Council this sector represented 35% of total emissions for 2002 (CCP-NZ 2005b).

Reducing the amount of mains water used and the amount of wastewater (sewage) produced, reduces the amount of greenhouse gases released into the atmosphere. Greywater systems can be one way of reducing the amount of wastewater from individual properties, as the water used in the washing machine, shower and bath is directly used for irrigation or other purposes.

12. CONCLUSION

The results from the pilot study provide a useful insight into the ways water is used in the KCDC homes and ways to measure end use consumption. By obtaining accurate end use information, areas in which water can be used more efficiently are able to be identified. The most impact could be achieved by installing LFSHs, front loading washing machines and dual flush toilets. The installation of a rain tank or greywater system could reduce mains water consumption even further. In addition, the reduction in the amount of hot water used reduces the energy required to heat it and hence the direct costs involved. Water and wastewater treatments are energy intensive processes and a reduction in water demand translates into electricity savings. A reduction in energy use reduces the amount of greenhouse gases, especially CO_2, which contribute to global warming.

The key findings from the study which have the greatest impact on water consumption and conservation include the following:

1. reducing leakage
2. retrofitting opportunities (including WELS)
3. on-site rainwater
4. on-site greywater.

12.1 Water efficiency and retrofit

As a first step in water efficiency it is necessary to eliminate the sources of leakage. The homes in the study group leaked an average of 7 l/p/d. In the first weeks of monitoring one house was found to leak at a rate of nearly 200 L per day, which made up 56% of its uses.

By reducing the shower flow rates a large reduction in water efficiency could be achieved. This is outlined in the example in Table 23, where the installation of a three star LFSH would yield water savings of 50 m^3 per year (47% reduction in water used for showering).

Table 23: Potential water savings by adopting WELS scheme

		Usage (L/house/day)		Average savings		
Rating	**Flow* (Lpm)**	**Present**	**Post retrofit**	**(L/house/day)**	**(%)**	**Annual (m^3)**
*	12 to 16	291.3	261.5	29.9	10%	10.9
**	9 to 12	291.3	196.1	95.2	33%	34.8
***	7.5 to 9	291.3	154.1	137.2	47%	50.1

On average a house from the study group would use 39 m^3 of water annually (14.5 m^3 per person) for laundry use alone. This potable water could easily have been supplemented by collected rainwater and then be reused as greywater. This would have reduced the environmental impact substantially. By replacing a top loader with a front loading machine, an average annual water saving of 23 m^3 per house could be achieved. Front loaders use considerably less water than top loading machines, but still 96% of washing machines used in New Zealand homes are top loaders.

By just making changes to some water using appliances without having to change behaviour, substantial water savings can be achieved. By installing a WELS *** LFSH and a front loading washing machine 33% of the total water used in house 5 (Table 24) could be saved. Even just a modern LFSH, which requires modest investment, can reduce total consumption by 19% in this particular case.

Table 24: Potential retrofit savings (house 5)

Present annual consumption (m^3)			Potential annual savings after retrofit (m^3)				
			Shower head				
Total	Shower	Washing machine	*	**	***	Front loader	Front loader & ***SH
309.2	70.6	109.2	16.9	32.1	41.9	60.1	102
		Consumption after retrofit	**292.3**	**277.1**	**267.3**	**249.1**	**207.2**
		% saving of total	**6%**	**10%**	**14%**	**19%**	**33%**

Table 25: Potential retrofit savings (house 12)

Present consumption (m^3)			Savings (m^3)				
			Shower head				
Total	Shower	Washing machine	*	**	***	Front loader	Front loader & ***SH
207.7	59.8	53.4	3.3	17.8	27.1	21.681	48.8
		Consumption after retrofit	**204.4**	**189.9**	**180.6**	**186.0**	**158.9**
		% saving of total	**2%**	**9%**	**13%**	**10%**	**24%**

Water efficiency is a topic that will not go away, and will have an even higher priority in the future, even in New Zealand where some councils (Kapiti Coast, Christchurch) already have water restrictions in place at certain times of the year.

12.2 Alternative supplies

Even in the urban environment it is possible to use rainwater or greywater as a source of supplementing mains water supply. Many different systems are available, from small range rain drums (for irrigation purposes) to dual supply systems, which supply rainwater to flush the toilet and for the washing machine and outdoor uses. These systems can reduce mains water consumption by 50%. Using collected rainwater not only decreases the amount of mains water required, but also reduces the amount of stormwater run-off, especially in New Zealand which (on a global scale) has a higher than average amount of annual rainfall.

On average 106 m^3 of greywater was produced by each of the homes annually (39 m^3 per person). 'Disposing' of greywater through irrigating the garden reduces the amount of wastewater, which needs to be treated, hence reducing the costs and the amount of greenhouse gases released into the atmosphere. As an additional effect, the irrigation demand is decreased, saving additional volumes of mains water.

At present different councils have different perceptions of how greywater or rainwater can be used in the home. By standardising these requirements throughout New Zealand, a difference can be made about how these potable water supplements can be used.

12.3 Direct and indirect costs

Water costs money. Water also travels a long way from its source until it comes out of the tap. After it goes into the drain its journey continues to return to its natural source. Energy and capital intensive treatment is required at many stages of its journey. The cost of supplying 1 m^3 of water is about $0.45 to $0.50 (WaterCare 2006). The cost for treating the same amount is almost double. A large amount of money can be saved by reducing water consumption and using alternative supplies.

Using less water also has an impact on the amount of energy used for heating, treating and pumping the water along its path. Especially since the problem of climate change and global warming increases, additional CO_2 is pumped into the atmosphere by an increasing water demand. Demand is not likely to decrease, as the population continuously grows. However, the rate at which the demand for water increases can be slowed down if water is used more wisely and efficiently.

By increasing demand, it gets to a point when the infrastructure to supply and treat the water and stormwater has reached a saturation point. Additional infrastructure (treatment plants, pipes, reservoirs, dams etc) and water sources are required. In most cases this is a very costly and sometimes multi-million dollar undertaking. By reducing demand the future investment costs can be reduced and delayed. This principle is illustrated in Figure 49.

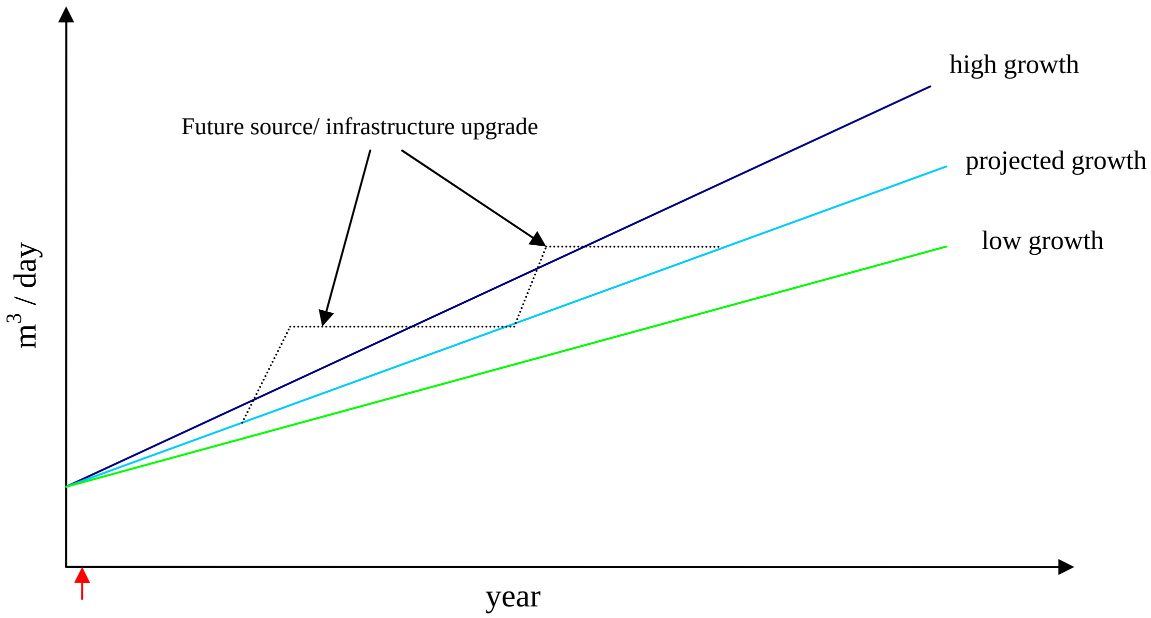

Figure 49: Demand management

12.4 Recommendations

By conducting the pilot, areas of improving the way the data was collected arose. The improvements from Stages 1 and 2 of the project were incorporated into the main study of Stage 3, and can be incorporated into future ventures. Potential improvements include:

- The use of remote downloading systems could be employed (i.e. mobile phone chip technology or radio frequency). This would make it possible to get real time data, avoid downloading, and minimise data loss, and would be feasible for an extended study i.e. 100 houses or more.
- Increasing the download speed of the data loggers even further. The download units of our loggers were modified to a higher download speed (9800 baud), which halved the time for downloading.
- Weatherproofing should be an important issue, especially in the winter months where large temperature fluctuations are the norm. This issue was resolved in Stage 2 of the project and incorporated into the main study. Using a relatively simple and low cost

method, moisture was kept away from our equipment and logger failure or corrosion issues did not arise at all.

- After monitoring for several months, it became apparent that water usage patterns repeat themselves within the same season e.g. data collected in August showed similar results to that collected in September. Since we wanted to capture the seasonal variations, data was collected for the whole period as the equipment was already in place. If less time is available, the monitoring period could be reduced to one month periods (this yielded representable results). When analysing the data for two separate two week periods within the same months, variations in data were quite substantial at times. In some cases end use proportions differed by as much as 6% (Figure 50). This might have to do with different end use proportions of water being used during the week and the weekend. Variations can depend on the start and stop date of monitoring.

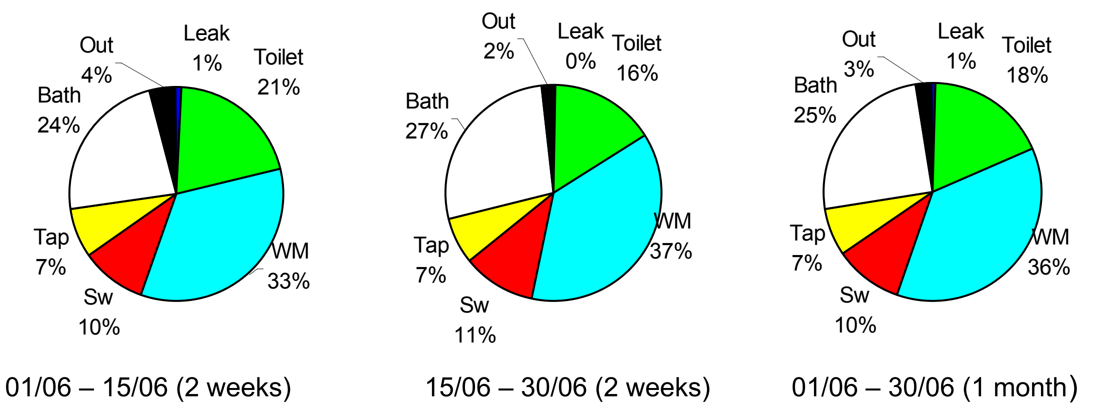

Figure 50: Variation in end use distribution

- Data loss from houses 3 and 10 could have been reduced by downloading data more frequently (every two weeks). This, however, would have required additional resources for downloading and introduced additional sources of error when it comes to importing the data into a common database. Having access to replacement meters and people who can conduct the replacement at short notice would be desirable. Remote downloading as mentioned before would also reduce data loss.

12.5 Next steps

There are a lot of opportunities to build upon WEEP. The study could be rolled out nation-wide to obtain a larger and hence more statistically valid sample. Looking at the potential of rainwater and greywater to supplement the use of potable water in residential houses is another way to build upon the study. By conducting a retrofit program on the monitored homes, the potential savings and areas where water use can be reduced could validate some of the issues addressed in this document i.e. impact of installing LFSHs, greywater systems etc.

The construction of a mathematical model, which can calculate potential savings by changing parameters such as shower head or washing machine, would be another opportunity to build upon the work.

A large barrier to the efficient use of water is that many areas throughout New Zealand are not metered and pay a fixed rate. This does not encourage people to use water more efficiently, since there are no direct savings for the consumer. By increasing the sample size and surveying different areas a comparison between the water using behaviour of metered and unmetered areas can be made.

12.6 Last words

From questionnaire data and discussions with the occupants it became apparent that the incentive to save water is not very high, since there are no direct costs involved for the occupant in most residential homes. If metering were to be introduced by the councils, this perception might change and water might be used more efficiently. Most people have no idea about how much water they are using and they generally tend to underestimate their use.

Only when there is a price and the individual knows their consumption are there incentives to save water and use it more efficiently. This can be compared to filling a car with petrol. If a fixed rate would be paid at the gas station, regardless of what is used, there is no incentive to use petrol wisely, and the amount of journeys and amount of petrol wasted will certainly increase. As the pressure on water resources continues to grow, the likelihood of universal metering being introduced by the regional authorities continues to grow.

Water might not have a price for the end consumer, but it does for the people who supply and treat it and for our environment. Using water more efficiently and reducing the amount wasted can have a large impact on improving our environment and way of life.

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APPENDIX A – QUESTIONNAIRES

HOUSEHOLD WATER USE QUESTIONAIRE

Address …………………………………………….   (Street)

……………………………………………   (Suburb)

……………………………………………   (Town/City)

Phone (Day)…………….. (Evening)………………

Name of interviewee(s) ………………………………. ……………………………

When an occupant is unable to answer please put "don't know" (D/K)

OCCUPANT DETAILS

1. **Could you tell me who is living in this household at present?**

Person	Name (first name ok)	Male/female	Age	Relationship to person 1
1				
2				
3				
4				
5				
6				

2. **How many years have you occupied this dwelling?** ☐
   (less than one = 0)
3. **Typically how many adults (i.e. 15 and over) and children are usually at home (i.e. not at work, school or elsewhere):**

	adults	children
during week day		
week night		

(if no children in house code as N/A)

3. ***How many baths in this dwelling?*** ☐
4. ***How many showers in this dwelling?*** ☐
5. ***How many toilets in this dwelling?*** ☐
6. ***Do you have a rain tank (with pump)?*** **YES** **NO**
7. ***Do you have a rain drum (no pump)?*** **YES** **NO**
8. ***Do you have a washing machine?*** **YES** **NO**
9. ***Do you have a dishwasher?*** **YES** **NO**

10. Do you have a spa pool/hot tub? **YES** **NO**

11. Do you have a swimming pool? **YES** **NO**

12. What is the number of external taps? [ ]

13. Do you have a sprinkler system in place? **YES** **NO**

14. What pressure is your hot water cylinder on? **High** **Medium** **Low**

15. Do you have a header tank? **YES** **NO**

16. Do you have a private bore? **YES** **NO**

17. Do you have a greywater system? **YES** **NO**

18. What is the approximate area of your dwelling (m^2)? (circle one)

1. 50 – 99	**2. 100 – 149**	**3. 150 – 199**
4. 200 – 249	**5. 250 – 300**	**6. 300 +**

19. What is the approximate area of your section (m^2)? (circle one)

1. Below 100	**2. 100 – 299**	**3. 300 – 499**
4. 500 – 699	**5. 700 – 899**	**6. 900 – 1099**
7. 1100 – 1299	**8. 1300 – 1499**	**9. 1500 +**

20. Are you directly connected to mains water supply?

YES **NO**

22. How would you rate your household's water consumption? (circle one)

LOW **1** **2** **3** **4** **5** **HIGH**

23. What made you participate in this study?

THANK YOU FOR YOUR TIME

HOUSEHOLD WATER USE QUESTIONAIRE

Date…………………… Time………………..

Address …………………………………………….   (Street)

……………………………………………   (Suburb)

……………………………………………   (Town/City)

Phone (Day)…………….. (Evening)……………….

Name of Interviewee(s) ………………………………….   ……………………………

Name of Correspondence (Full name + title) ……………………………………………

A CHARACTERISTICS OF THE HOUSEHOLD

When an occupant is unable to answer please put “don’t know” (D/K) rather than leaving the answer box empty.

A.1a OCCUPANT DETAILS

A.1a.1 Could you tell me who is living in this household at present?

Person	Name (first name ok)	Male/female	Age	Relationship to person 1
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

If the occupants change please inform the download person.

Type of tenure:

Which of the following best describes the ownership situation of this dwelling?

1 = occupants own dwelling with mortgage
2 = occupants own dwelling without mortgage
3 = occupants rent/lease dwelling
4 = other

How many years have you occupied this dwelling?

(less than one = 0)

WATER USE AND LIVING PATTERN

Occupancy hours

Typically how many adults (i.e. 15 and over) and children are usually at home (i.e. not at work, school or elsewhere):

	adults	*children*
during week day		
week night		

(if no children in house code as N/A)

What time do the members of this household usually get up and go to bed during the week?

Put name in the space – start with main interviewee (check back to page 1 question on household membership)

	get up time	bed time
Person 1:		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Water heating

What systems are used to heat water? (use ONE code for ONE system)

1 = electric cylinder 2 = gas cylinder 3 = zip heater 4 = solid fuel cylinder 6 = elec & solar 7 = heat pump (i.e. Quantum) 8 = instant gas 9 = other 10 = night rate elec 11 = instant electric 15 = elec & wetback
16 = elec, solar & wetback 25 = gas & wetback

Note: Ask explicitly about wetback and solar collector!

1	
2	
3	
4	

What pressure is your hot water cylinder on? (for each system)

1 = mains 2 = medium 3 = low pressure -9 = don't know -999 = n.a.

(Use same umbers as in question B.2.1)

1	
2	
3	
4	

If low pressure, does the cylinder have a pressure reducing valve or a header tank?
1 = pressure reducing valve 2 = header tank -9 = don't know -999 = n.a.

1	
2	
3	
4	

Do you have a tempering valve?
1 = yes 2 = no -9 = don't know

1	
2	
3	
4	

Water-using appliance

How many baths in this dwelling?

How many showers?

Do you have a rain tank (with pump)?
1 = yes 2 = no -999 = n.a

What is the approximate volume of the tank? L

Do you have a rain drum (no pump)?
1 = yes 2 = no -999 = n.a

What is the approximate volume of the drum? L

Do you have a pump for water pressure?
1 = yes 2 = no -9 = don't know

For each person what are their usual (weekday) bathing habits: (fill in each box with a number, D/K or N/A)

Person (as per previous question)	**Showers/week** (number or D/K)		**Baths/ week**	**How much water (bath)?** 1 = 1/3 full 2 = ½ full 3 = ¾ full 4 = full	**Usual time of day** **1 = morning 5 = morn & eve 2 = afternoon 6 = after & eve 3 = evening 7 = m & a & e 4 = morn & after**		**Preferred temp** 5 = very hot 4 = hot 3 = warm 2 =cool 1 = cold	**If shower - how long?** (mins)
	1	**2**			**Shower**	**Bath**		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Total bath-fills/week?								

Is your shower(s) fitted with a low pressure or low flow shower head?
1 = yes 2 = no -9 = don't know

shower 1
shower 2
shower 3
shower 4

Do you sometimes run out of hot water ?
1 = never 2 = rarely 3 = sometimes 4 = often -9 = don't know

Laundry and dishwasher

Do you have a washing machine – what sort?
1 = top loader 2 = front loader 3 = semi-automatic
4 = manual 5 = twin tub 6 = none

Does your household mainly do its own washing?
(Tick 'no' if you send it out instead or it is done somewhere else.)
1 = yes 2 = no 3 = N/A

On average how many loads of washing are done in this household per week?

When in the day is the laundry usually done
Weekday (1 = morning 2 = afternoon 3 = evening)
Weekend (1 = morning 2 = afternoon 3 = evening)

Usual type of wash:
1 = cold 2 = warm 3 = hot

Do you use a dishwashing machine for washing up?
1 = yes 2 = no

What is the connection type of the dishwashing machine?
1 = hot 2 = cold 3 = dual 4 = don't know

Pools and spas

Do you have a spa pool/hot tub?
1 = yes 2 = no

What is the approximate volume of the spa pool/hot tub?
m^3

How often is the spa pool/hot tub refilled?

Do you have a heated swimming pool?
1 = yes 2 = no
means of heating:...…………………

Do you have an unheated swimming pool?
1 = yes 2 = no

What is the approximate volume of the swimming pool?
1 = yes 2 = no
m^3

How often is the swimming pool refilled?

If you have a spa and/or a heated swimming pool do you use a thermal pool cover when the spa/pool is not in use?
1 = yes 2 = no 3 = sometimes -999 = N/A

If spa pool/tub **how many times a week is it used on average?**
-999 = N/A

Outdoor water use

What is the number of external taps?

Do you have a sprinkler system in place?
1 = yes 2 = no

How often do you water your garden per week by hand?

How often do you water your garden per week by sprinkler system?

How often do you wash your car per week using the taps on your premises?

What is the area of your section? m^3

What is the area of your house? m^3

What is the area of your garden? m^3

Bathroom

How many toilets do you have?

Do you have an ensuite bathroom?
1 = yes 2 = no

How many of these toilets are dual flush?
1 = dual flush 2 = single flush

1		
2		
3		
4		
5		

How many times a day is the half-flush option used?

How many times a day is the full flush option used?

Does anyone in your household sometimes multiply flush toilets?
1 = yes 2 = no

What is the volume (litres) of your cistern?

-9 = don't know

#	Single flush	Double flush	
1			
2			
3			
4			
5			

What 'type' of water is used for toilet flushing?

1 = mains water 2 = rainwater 3 = grey water

General

Do you have an existing water meter installed?

1 = yes 2 = no

How are you billed for the use of water?

1 = fixed rate 2 = metered (i.e. pay what you use)

Are you directly connected to mains pressure?

1 = yes 2 = no -9 = don't know

Do you have any known leaks?

1 = yes 2 = no -9 = don't know

If yes – what are the leak(s)?

……………………………………………………………………………………..

Do you have any dripping taps?

1 = yes 2 = no -9 = don't know

Have you ever made home improvements to improve water efficiency?

1 = yes 2 = no

If yes – what has been done?

……………………………………………………………………………………………….

How do you rate your water usage?

1 = high 2 = medium 3 = low -9 = don't know

Using the scale on card 1, how would you rate your household's water consumption (litres per person per day)?

Card 1 – Water consumption (litres per person per day)

1 = 0 – 50 L	2 = 51 – 100 L
3 = 101 – 200 L	4 = 201 – 300 L
5 = 301 – 400 L	6 = 401 – 500 L
7 = 501 – 600 L	8 = 601 – 700 L
9 = 701 – 800 L	10 = 801 – 900 L
11 = 901 – 1000 L	12 = more than 1000 L

BACKGROUND DETAILS ON OCCUPANTS

Ethnicity and education

For each occupant what is their ethnic background, employment situation and education?

Person no. & name (note keep same order as earlier questions A1.1 and B1.2)		Ethnic background (card 2)	Employment situation (card 3)	Occupation (write it & code later 4)	Highest qualification (card 5)
			All under 15 year olds should be coded to N/A for these three questions		
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

Ethnic codes (card 2)
1 = NZ European or Pakeha
2 = NZ Maori
6 = Other European
7 = Samoan
8 = Cook Island Maori
5 = Other
9 = Tongan
10 = Niuean
11 = Chinese
12 = Indian
13 = Other Asian

Employment status codes: (card 3)
1 = currently in full-time paid employment
2 = currently in part-time paid employment
3 = self-employed
4 = unemployed / not working
5 = home duties (housewife/house husband)
6 = retired
7 = student
N/A = under 15 years old

Occupation codes: (card 4)
1 = legislators, administrators, managers
2 = professionals (science, health, teaching, law etc)
3 = technicians and associate professionals
4 = clerks
5 = service & sales workers
6 = agriculture & fishery workers
7 = trades workers
8 = plant & machinery operators & assemblers
9 = elementary occup (labourers etc)
11 = armed services
10 = other
N/A = retired/student/home duties or under 15 years old

Education codes: (card 5) Note: code only "attained qualifications" i.e. if currently in 6th form studying for 6th Form Certificate the code would be 2 if they have achieved School Certificate in one or more subjects or code 1 if they do not have School Certificate in one or more subjects.
1 = no school qualification
2 = School Cert in one or more subjects
3 = 6th Form Cert or UE in 1 or more subject
4 = University Bursary or scholarship
5 = overseas qualification
6 = Trade Certificate
7 = nursing/NZ cert/technician's/teacher's certificate or diploma
8 = University degree
9 = other tertiary qualification
N/A = under 15 years old

Household income

How many occupants regularly contribute to the income of the household?

What is your household's main sources of income (and which are the most important)?
1 = most important etc 2 = second most important (tick sources)

	Source	1 = most important
wages/salary		
investments /dividends		
national super		
benefit/allowance		
ACC/insurance		
other		

And lastly:

From card 6 please indicate what is the approximate total income of this household before taxes etc are taken out?

Income (card 6):

	per year	*per week*
1 =	up to $5,000 per year	(on average less than $96 per week before tax)
2 =	$5,001 – $10,000	($96 – $191 per week)
3 =	$10,001 – $15,000	($192 – $287 per week)
4 =	$15,001 – $20,000	($288 – $384 per week)
5 =	$20,001 – $25,000	($385 – $480 per week)
6 =	$25,001 – $30,000	($481 – $576 per week)
7 =	$30,001 – $40,000	($577 – $768 per week)
8 =	$40,001 – $50,000	($769 – $961 per week)
9 =	$50,001 – $60,000	($962 – $1,153 per week)
10 =	$60,001 – $80,000	($1,154 – $1,538 per week)
11 =	$80,001 – $100,000	($1,539 – $1,923 per week)
12 =	over $100,000	($1,924 per week or over)
13 =	wouldn't say	
-9 =	don't know	

Thank you for your time and patience

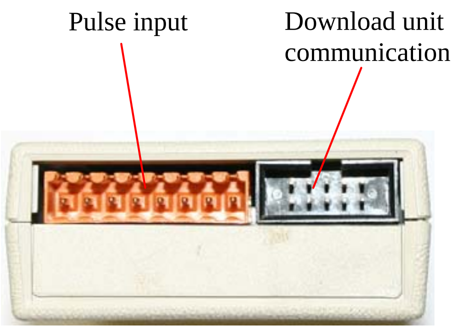
APPENDIX B – EQUIPMENT

BRANZ Pulse Logger 512k

The BRANZ pulse logger has been designed as a large capacity data logging solution for the collection and storage of meter count intervals. The original use of the logger was in the Household Energy and Efficiency Project (HEEP). It has successfully been used for nearly eight years in various monitoring applications.

For our water monitoring project this logger has been modified to suit the pulse output from high resolution water meters (e.g. 50 ppL) at a 10 second interval.

When connected to a pulse output (e.g. water meter), the logger counts and stores the pulse total for each logging interval. Different intervals can be selected, ranging from 10 seconds to 6 min.



The logger can be set up, downloaded and erased with our download unit connected to the serial output of a PC. The Windows standard Hyper Terminal software is used for communication with the logger.

The logger is powered by an Alkaline 9V battery, which lasts more than three months when 10 second data is collected.

Specs:

Memory:	326,700 records including daily timestamps at 10 second intervals
Dimensions:	95 x 60 x 25 (mm)
Number of channels:	1 channel
Recording intervals:	10 seconds, 1, 2, 3, 4, 5, 6 min*
Power supply:	9V Alkaline (PP3)
Weight (incl. battery):	120 g
Weight (without batteries):	65 g
Logging:	max. count rate 40 Hz (max. 4095 counts/interval)

Download unit – provides a simple indication of logger functions. Interface between logger and the RS232 port of the PC. The download speed is 9800 baud.

MES-MR Mechanical register totaliser flowmeter

Sizes 20, 25, 32 and 40 mm

- Nutating disc measurement
- High rate of pulses for precision data logging
- Mechanical toatliser register
- Low head pressure loss
- Passes impurities without jamming
- Accuracy +/-1.5%, with 0.1% repeatability

25mm size shown

The MESM series nutating disc positive displacement flowmeters are fitted with a non-resetable mechanical totaliser sealed counter c/w a reed switch contact closure output. The pulse output delivers a high rate of pulses per volume making these meters ideal for precision data logging and batching applications. The volt free contact allows use in remote areas where no power source is available.

These meters are ideal for economical totalising applications, for water consumption and a range of other water based liquids can be used.
The nutating disc principle allows the meter to be used in applications where the water is not pure and can pass small impurities without blockage.

The body and measurement chambers of the 20, 25, & 32mm size meters are common to the complete MES range of flowmeters (MES, MESLCD5, MESM & MESR series). Therefore for example the MES20M mechanical totaliser meter can be upgraded to a digital LCD resetable unit (MES20LCD4) or to a transistor pulse output unit (MES20) by simply changing the capsule head.

SPECIFICATIONS

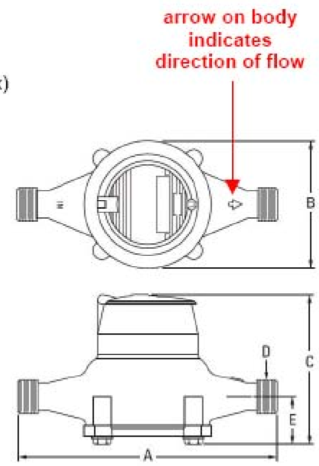
Sizes mm	20	25	32	40
Start flow @ 5%	0.6	1.1	1.5	3.0
Min. flow litres/min @ +/-1.5%	1.5	2.7	3.8	7.5
Nom. flow litres/min.	45	65	125	200
Max. flow litres/min.	80	110	180	340
Min. register reading	1 ltr	1 ltr	1 ltr	1 ltr
Max. register reading	99999 m3	99999 m3	99999 m3	99999 m3
Pulse output value / Ltr	61.5	34.2	16	7.1
Connection Type	¾" BSP(m)	1" BSP(m)	1 ¼" BSP(m)	1 ½" BSP(f)
Weight Kgs	1.8	2.6	6.0	12.1

Other Data:-

Accuracy minimum to maximum flowrange curve	± 1.5 %
Repeatability of set flowrate	± 0.1 %
Headloss at maximum continuous flow	25Kpa (3 metres)
Maximum continuous working pressure	1160 Kpa
Maximum temperature	50 C°

Pulse Output Data:-

2 wire connection (shielded) with 270 omh internal current limiting resistor.
Max.Current Switching:- 5Vdc = 18mA, 12Vdc = 44mA, 24Vdc = 88mA. (100mA max)



Dimensions in millilitres	size mm	20	25	32	40
Length of threaded end meter	A	191	229	273	330
Overall height of meter	C	158	178	200	252
Height from under face to centreline	E	041	048	054	065
Overall width	B	092	111	165	205

MATERIAL SPECIFICATIONS (MESM)

Register window	Perspex lens
Register body & lid	Synthetic polymer
Register internals	Hermatically sealed
Dry gearing	Plastic
Magnet	Polymer barium ferrite
Meter body	Gunmetal AS 1565 C83810
Filter	Polyolefin
Measuring chamber & disc	Polyphenylene
Nutating disc peg	Stainless steel AS1444-316
Roller pin & drive shaft	Nylon 11, glass fibre, graphite
Chamber O ring & Base seal	Ethylene propylene & Neoprene
Base plate	20, 25, 32mm Cast Iron
Base bolts	Stainless steel 304

ORDERING CODES:-

Item number	Size
MES20-MR	20mm (3/4")
MES25-MR	25mm (1")
MES32-MR	32mm (1 ¼")
MES40-MR	40mm (1 ½")

Options for 20mm size:-

-S Ryton chamber for petroluem based products
-S-T Ryton chamber and teflon coated body for corrosive chemicals

ManuFlo ®™
Flow Measurement Products

A Division of:
MANU ELECTRONICS PTY LTD

41 Carter Road, Brookvale
Sydney NSW 2100 Australia
Ph: + 61 2 9938 1425, 9905 4324
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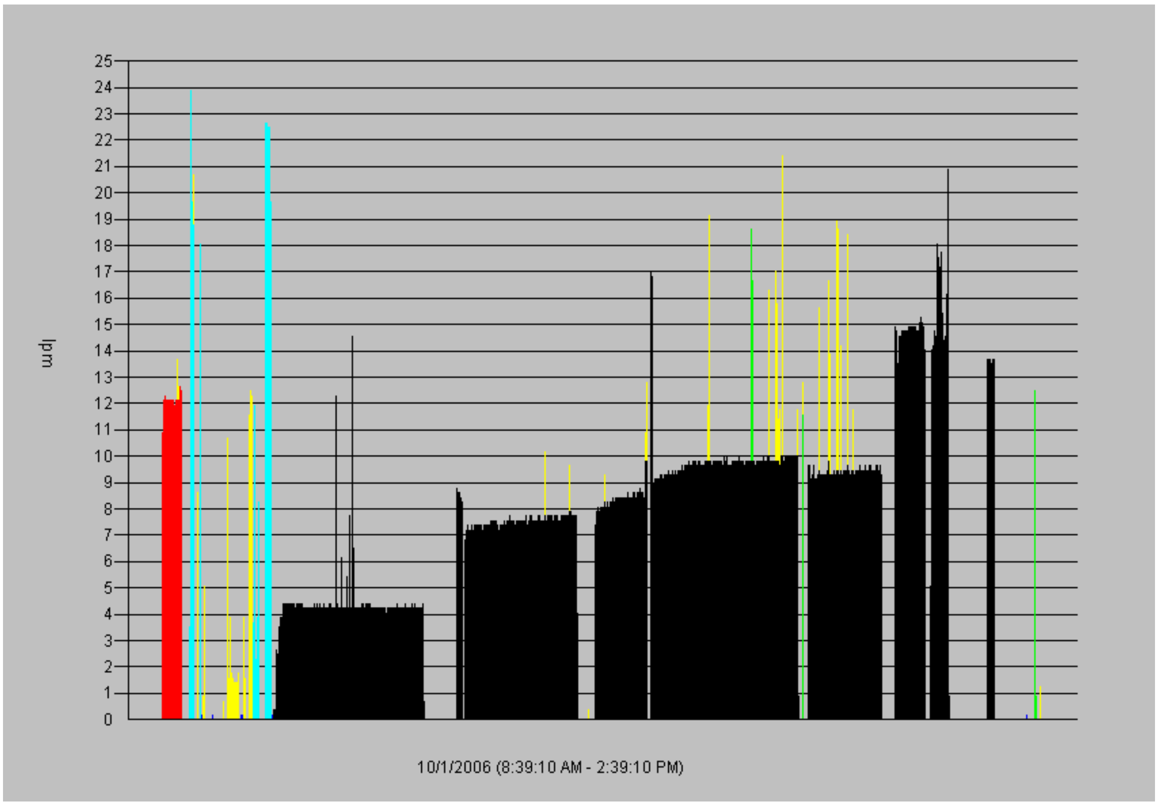
APPENDIX C – SAMPLE OUTPUT FILES



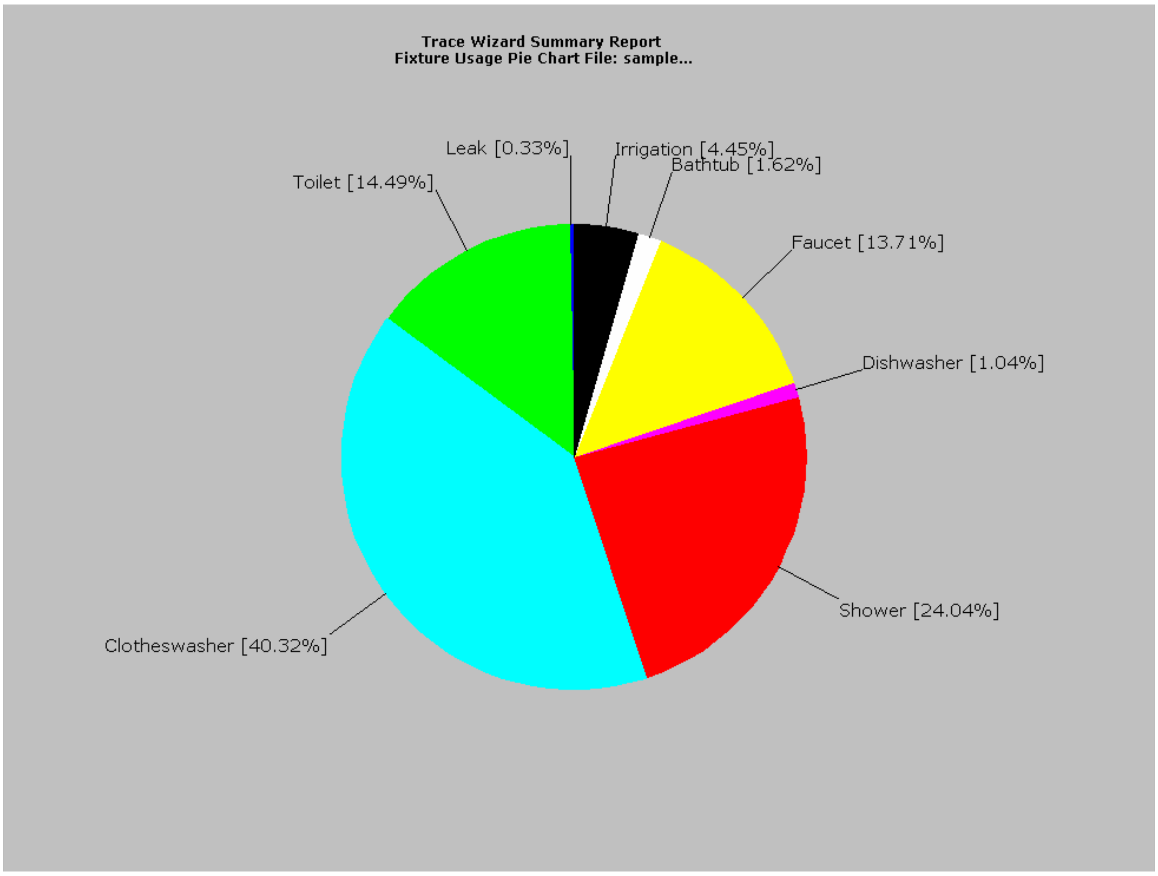
Example Trace Wizard Summary Report

Trace Wizard Summary Report
Total Volume By Fixture

Site:	sample
Start date:	4/08/2006 1:33:20 pm
End date:	4/10/2006 9:17:50 am

CATEGORY	VOLUME
Leak	151.90
Toilet	6616.82
Clothes washer	18409.88
Shower	10975.48
Dishwasher	473.29
Faucet	6258.95
Bathtub	741.82
Irrigation	2029.84
TOTAL:	45657.98

Example Trace Wizard Appliance Usage Pie Chart



APPENDIX D – THE COST OF WATER

A large and complex infrastructure is required to deliver mains water to the user, and take waste and stormwater away from them. Vast amounts of energy are used annually by the water suppliers to provide this service. The following diagram shows the annual average cost per household in the Auckland region for water supply and wastewater removal.

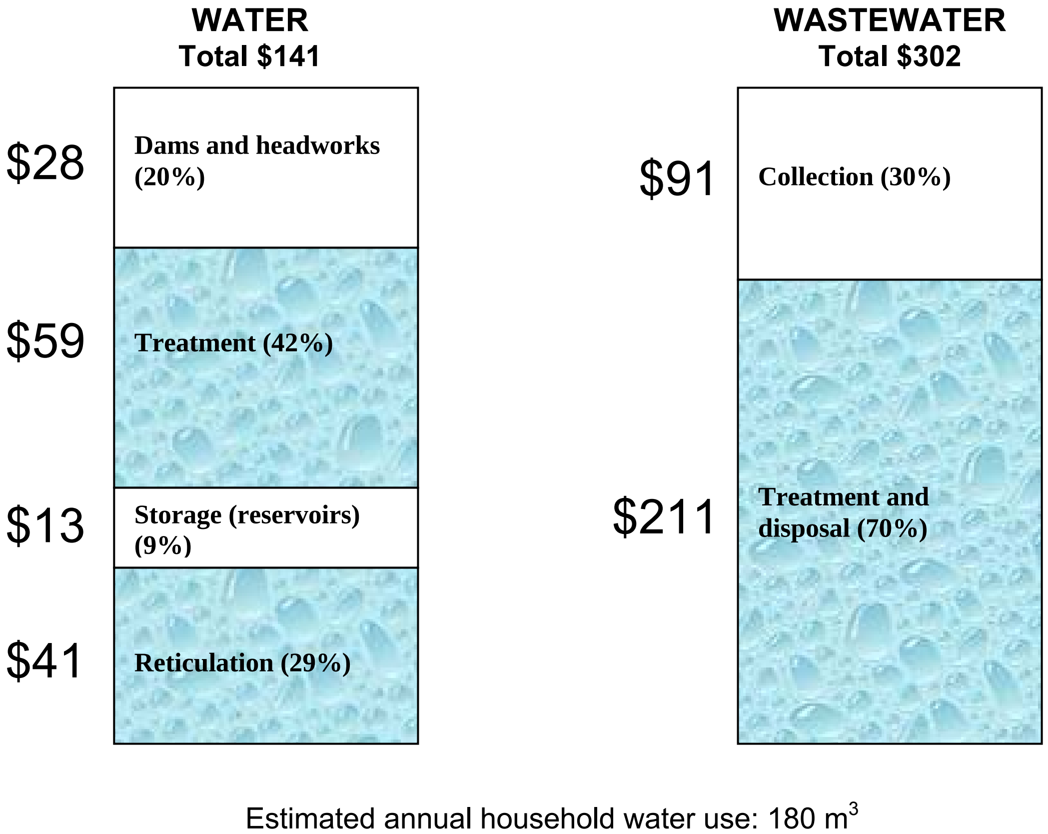


Figure 51: Annual average household costs for Auckland (Watercare 2007)

The energy used for treatment, pumping, disposal, heating etc, releases greenhouse gases, especially CO_2. The amount of CO_2 released depends on the treatment method and the amount and type of energy used. By using water more efficiently and reducing unnecessary waste a positive contribution can be made towards the effects of climate change.