Understanding and Predicting Household Water Use for Adelaide

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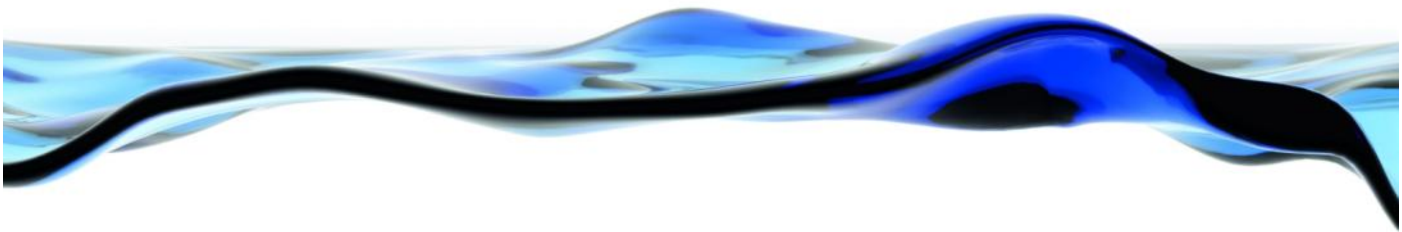

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Executive summary

This study improved the understanding of household water use in a South Australian context by measuring, surveying, analysing and predicting the water use for a representative group of 150 households in metropolitan Adelaide.

The first stage of the study selected representative households and installed high resolution meters (10- sec). The second stage undertook household surveys of demographics (age/income), attitudes, household and appliance characteristics. The third stage undertook flow trace analysis of a two week period to identify behavioural (frequency and duration of use) and appliance (flows/volumes) characteristics of indoor end-uses (shower/bath, toilet, washing machine, dishwasher, tap). The fourth stage undertook an analysis of water use drivers by combining behavioural and appliance water use characteristics with survey information on demographics, attitudes and household attributes, including water-using appliances, roof size, tank size, garden size and type of irrigation.

A preliminary analysis of drivers of seasonal water use was also undertaken. The fifth predictive modelling stage evaluated the ability of the Behavioural End-use Stochastic (BESS) model to predict end-uses by explicitly considering appliance and behavioural drivers of urban water use. BESS was then used to estimate previous changes in water use due to the recent 2007-2009 drought and predict future changes in usage by including demand management as an element in the water supply simulation and optimisation component of the Goyder Optimal Water Resource Mix Project.

Key results are summarized as follows (implications/recommendations in bold):

General trends in household water use

- Study households represented approximately 60-65% of the households in metropolitan Adelaide based on demographics (income/age) and dwelling structure (owner occupied established detached households). Under-represented households included low income, single parent family and non-family households. Units, townhouses and renters were excluded.
- Study households had an average water use of 245 L/p/day for 2012/2013, 14% higher than the SA Water average for metropolitan Adelaide. Household water use was a high 289 L/p/day during the monitoring period (March 2013-February 2014) due to a hot summer in 2013/14.
- Seasonal impact was strong, with a 2013 winter mean of 153 L/p/day increasing to 498 L/p/day in the summer of 2013/14. A significant shift in the diurnal pattern also occurred, with an afternoon peak more prominent during summer.
- On peak demand days, 20% of households contributed to 50% of the total demand.
- **Developing approaches that target these 'high peak' households represents a significant opportunity to reduce peak demand and therefore reduce infrastructure design and operational costs.**
- High resolution meters enabled fast and efficient identification of leaks within a household. The overall leakage volume was estimated to be 5-8% of the study household mean water use, but was deemed an unreliable estimate due to a small number of houses having very large leaks.
- **Household leakage reduction could potentially produce water savings of 5-8%, but a wider range of households needs to be analysed to improve the reliability of the leakage estimate**

Indoor end-use analysis

- Total indoor use was 135L/p/day, with the water split between showers (48 L/p/day), toilets (28L/p/day), washing machines (25L/p/day), taps (29/L/p/day) baths and dishwashers (5 L/p/day). Winter use also included 7% outdoor use and 8% leakage (approx.).
- Total indoor water use by the study households was 5% less than presented in 'Water for Good' [*Government of South Australia*, 2010]. The biggest differences occurring in shower/bath and washing machine usage.
- The proportion of total indoor use of the individual end-uses varied considerably between households. Householder perceptions of their use of water per end-use proved very unreliable.
- **Households need greater information and guidance (e.g. monitoring) in relation to their indoor water use so that they can identify cost-effective water savings opportunities.**
- Comparison of indoor end-use volumes to observations from previous interstate studies found that the key differences were the result of efficient appliance uptake and individual behaviours, such as the frequency or the duration of water events. The result indicates that efficient appliance uptake and behaviour need to be included to enable transferability of the knowledge from interstate studies to local areas.

Drivers of indoor water use

- *Impact of water efficient appliances*
  - Appliance efficiency, rather than behaviour, was the primary driver for reductions in indoor water use; e.g. shower duration did not change when the showerhead was more efficient.
  - Efficient appliance uptake was approximately 50%.
  - Savings of 19 L/p/day (15% of total indoor) are possible if all households change to efficient appliances.
  - Washing machines offer the greatest potential water savings (9 L/p/day).
  - As householders have a choice in terms of different washing machine efficiency, schemes that encourage the uptake of efficient washing machines should be encouraged.
- *Analysis of the household demographics (income/age) and composition (number of children) indicated the presence of distinct household usage types that selected and used appliances differently, significantly influencing water usage and water saving opportunities.*
  - Households with Adults 55+ only
    - recorded lower shower use, but higher washing machine and toilet use than the mean
    - were more likely to perceive themselves as water conservers and have water saving behaviour (shorter showers)
    - recorded indoor use higher than the mean because they have inefficient washing machines (<30% uptake of water efficient appliances) and higher toilet frequency
    - could achieve water savings from the uptake of efficient washing machines.
  - Households with children/high income
    - recorded very high shower use, but lower toilet and washing machine use than the mean
    - were less likely to think of themselves as water conservers and took longer showers
    - recorded lower indoor use than the mean, because of lower toilet frequency and more efficient washing machines (~75% uptake front loaders)
    - could achieve water savings by changing shower behaviour.
- **Different household usage types require targeted demand management programs to identify water saving opportunities.**

Predictive modelling

- The behavioural end-use stochastic (BESS) model was able to provide predictions of household end-uses using information on household occupancy, appliance uptake/flows and behaviour. Information can be sourced from interstate or local end-use studies (such as collected in this project).
- **BESS provided reliable predictions of mean end-uses volumes** (predictive errors <1-15%) using local Adelaide information. Household end-use variability was under-estimated.
- Using readily available local Adelaide information on occupancy and appliance uptake and interstate information on appliance flows and household behaviour, total household water use predictive errors <10%, but individual end-uses predictive errors were up to 40%.
- **It is recommended that BESS be further developed to include the behaviour of different household types. This would improve predictions of variability and increase the transferability of the predictions to more locations.**
- During the 2007-2009 drought, household water use decreased by 15% with approximately 50% of the reduction attributed to the uptake of water efficient appliances and the remaining 50% most likely due to reductions in outdoor use.
- There has been no major increase in household water use since the drought ended.
- **It is recommended that monitoring continue in order to determine if water use continues at post drought levels.**

Demand management

- Demand management (DM) is the use of strategies that encourage reductions in water demand and wastewater volumes. An example would be encouraging the uptake of water efficient appliances and/or behavioural changes such as shorter showers.
- BESS predicted the DM impact mid-project for the simulation/optimisation component of Optimal Water Resource Mix project using readily available data that was a mixture of interstate and local information.
- Predictions related to DM modelled changes in household occupancy and the increased uptake of water efficient appliances, but assumed no change in behaviour or technology.
- **For 2013, DM was predicted to reduce residential water demand by 7% and wastewater 11%.**
- **For the 2025/2050 baseline residential demand was predicted to decrease by 4% and wastewater by 5% due to the future uptake of water efficient appliances. DM is therefore predicted to reduce water demand by a further 4% and wastewater by a further 6% in the future, commonly referred to as 'demand hardening'.**
- Post-project, the reliability of the mid-project prediction using all the local information from the Adelaide study found the relative reductions in total use were robust, but the relative proportions of potable and non-potable residential use changed.
- Predictions of DM impacts did not include behaviour changes, but significant differences in behaviour were found for the identified different household usage types.
- **It is recommended that future work evaluate the opportunities for behaviour change to reduce water use.**

Preliminary seasonal water use drivers

- Seasonal water use is classified as water use that changes due to season, including outdoor uses such as garden watering and indoor use such as evaporative air conditioners. Results are preliminary because they are based on the analysis of a single summer (2013/2014) of quarterly billing data.
- Seasonal water use was approximately 40% of total household water use.
- Seasonal water use was higher for households with larger property or garden areas (26-30% higher than the mean seasonal use).
- Seasonal water use was lower for lower income households (20% lower than the mean), and higher for households with older residents (Adults 55+ only) (12% higher than mean).
- Householders underestimated the proportion of outdoor water used by an average of 40%.
- Similar to indoor use, **households require greater information and guidance (e.g. monitoring) on how outdoor water is used to help them identify cost-effective water saving opportunities.**
- There was a clear preference for rainwater/roof water over other sources of supply (groundwater, surface water, River Murray, desalination) for outdoor use, regardless of the demographic. However, the survey did not include information on the relative costs of the water supply options which could change the results.
- **It is recommended that further analysis of the drivers of seasonal water use be conducted using more summer data from high resolution monitoring.**

Future research

The goals of future research should be to:

- **identify drivers of reductions in seasonal and peak water use** by extending the high resolution monitoring and analysis to include more summer data for the study households. As these two types of water use are the major drivers for the design and operations of water infrastructure this will identify opportunities for cost savings.
- **identify the drivers of under-represented households** by extending the high resolution monitoring and analysis to include households under-represented or excluded in this study, which will likely be the major driver of future growth in Adelaide's water use, and provide reliable estimates of leakage volumes.
- **identify the drivers of behavioural change**, which can increase the potential water savings of demand management.
- **enable more reliable predictions of water use for a wider range of locations and end-uses** by incorporating household usage types and seasonal usage drivers into the BESS framework.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Background and motivation

Integrated urban water management (IUWM) emphasises household and cluster scale water management solutions to reduce reliance on mains water supplies and reduce environmental impacts. As these solutions are often implemented at the household scale, knowledge of the dynamics of water end-use (outdoor, shower, washing machine etc.) is required. However, there is limited data and even fewer models available to predict demand at the household scale. Thus there is a clear research and practical need to have an understanding of, and an ability to provide reliable predictions, of water use at the individual household scale at short time steps. This research project will utilise the Behavioural Stochastic End-Use Simulator (BESS) [*Thyer et al.*, 2011] developed by the eWater CRC to provide predictions of household water use at the end-use scale. BESS stochastically simulates individual end-uses (outdoor, shower, washing machine, toilet, tap etc.) at the household scale at sub-daily time steps. The model was calibrated using water use data from cities on the east coast of Australia [*Thyer et al.*, 2011] and requires adaptation for use in a South Australian context.

The challenge is that very limited data is available in South Australia at the household scale with a suitably high temporal resolution (sub-daily to daily) for end-use analysis. This project aimed to fill this knowledge gap by undertaking high resolution monitoring of household water use and combine this with end-use analysis and survey information to evaluate the key drivers (demographics, weather, appliance usage and attitude) of urban water use variability in a South Australian context.

The study was conducted in 2012-13 as part of the research program of the Goyder Institute for Water Research's Optimal Water Resources Mix (OWRM) for Greater Adelaide project (October 2012-March 2014).The metropolitan region of Adelaide has multiple sources of water – surface water, groundwater, desalinated water, stormwater, roof or rain water, recycled water and the River Murray – that can be utilised and managed for supplying the city's water needs. Determining the 'optimal mix' of these sources is necessary to underpin an efficient and sustainable solution for Adelaide. To achieve this, consideration must first be given to the trade-offs between a range of important objectives, from supply security and economic costs to social preferences and environmental impacts. The Optimal Water Resources Mix project was designed to build a strong information base to inform these discussions and planning initiatives through:

- engaging with stakeholders to provide an effective communication pathway and an agreed basis for evaluating alternative water supply mixes
- providing a model that simulates the Adelaide water supply system
- developing a multi-objective optimisation methodology to assess trade-offs
- monitoring household water use to better predict demand
- performing legal and governance analysis in delivering water solutions
- conducting economic analysis of the direct and in-direct costs of supplying water from the multiple sources
- improving understanding of social values and preferences regarding water solutions.

The role of the current study in the larger OWRM project was to monitor and analyse household water usage to provide better predictions of water demand, which can then be used to inform the optimal water resource mix decision framework.

1.2 Aims and objectives

The specific aims of this study were to:

1. Evaluate the key behavioural drivers of household water use variability through the following objectives:
    (a) Undertake high resolution water use monitoring and attitudinal/behavioural surveys of a set of households representative of metropolitan Adelaide.
    (b) Evaluate general water use characteristics including seasonal/diurnal water use variation, flow rate distribution and leakage.
    (c) Determine statistical characteristics (frequency/duration/flow rates) for each household indoor end-use (e.g., shower, washing machine, toilet).
    (d) Evaluate the impact of appliance efficiency and socio-demographics on indoor water usage and behaviour.
    (e) Evaluate the differences between perceived and actual indoor water use and attitudes to conservation.
    (f) Conduct a preliminary analysis of seasonal water use.
    (g) Evaluate the changes in household water use that were made in response to recent drought conditions.
2. Provide reliable predictions of end-uses at the individual household scale at sub-daily time steps for a range of households in a South Australian context by:
    (a) using the information from Aim 1 to evaluate the ability of the BESS framework to provide reliable predictions in a South Australian context.
    (b) evaluating the previous changes in demand caused by the 2007-2009 drought
    (c) estimating the impact of demand management on future households water use.

1.3 Scope

This project represents the most comprehensive analysis of household water use undertaken in a South Australian context. However, the project duration, timeframe and available resources necessarily limited the scope of analysis that could be undertaken. This section summarises the major points of the project’s scope and the potential impacts on the project results.

Detailed end-use analysis on indoor end-use only, preliminary analysis on seasonal water use

The project timeframe and duration limited detailed end-use analysis to indoor end-uses only. The project duration was for 15 months, October 2012 to March 2014. The household selection and meter installation were finalised in February/March 2013 and the monitoring period available for data to be included in the report ended in February 2014. This meant that only a portion of water use data from the summers of 2012/13 and 2013/14 was available for analysis during the project. Hence, detailed end-use analysis was undertaken on indoor end-uses only, using data collected during June through August 2013. For seasonal water use, a preliminary analysis was undertaken using a combination of high resolution data (where available) and available quarterly consumption data (see Section 6 for further details). As a complete summer of high resolution data was not continuously monitored, these results are regarded as preliminary. A future research opportunity is to extend this analysis to include more data from summer to provide more reliable estimates of the influences of the drivers of seasonal water use.

End-use statistics based on 150 representative households

The available resources limited the number of households analysed to 150. Given this restriction, compromises were required in deciding how to select 150 households that would be representative of metropolitan Adelaide. Households were selected based on how representative they were of households in metropolitan Adelaide (e.g., detached homes on established blocks). Significant effort was made during the household selection stage to ensure that the households were as representative as possible, using a variety of diagnostics. Despite this effort, inevitably, some household types were not included or were under-represented, such as units and flats and rental homes. (The implications of the selection process are further discussed in subsection 7.1). A future research opportunity would be to extend this analysis to include more households that were under-represented in this project (see subsection 7.6).

Predictive modelling based on indoor end-use (excluding leaks) and demand management predictions includes only appliance changes

Predictive modelling is based on indoor water use as detailed end-use and driver analysis was restricted to indoor usage. The impact of leakage was not included in the predictive modelling due to the unreliability of the data, which is a record of a very small number of events with high sampling variability. Leakage is further discussed in subsection 3.7. Demand management was limited to changes in appliance stock. The resources and timeframe meant there was no scope to monitor or evaluate the potential of behavioural interventions, such as encouraging shorter showers through the use of shower timers). These issues are further discussed in Section 7.

1.4 Approach

The project was achieved by undertaking the work in the following stages.

- **Stage 1** - Household selection

  Selecting a suitable cross-section of 150 households, in consultation with SA Water, and installing high-resolution meters (Objective 1a).

- **Stage 2** - Household surveys

  Undertaken in the households to gain an understanding of water-use, demographics, attitudes and household characteristics (water-using appliances, roof size, tank size, garden size/ irrigation type) (Objective 1a).

- **Stage 3** - Flow-trace analysis

  Undertaking a single end-use analysis of two continuous weeks of the monitoring data to determine the statistics of indoor end-uses, for example, composition of various end-uses, including showers, washing machines, dishwashers, toilets and taps for each household (Objective 1c).

- **Stage 4** - Analysis of water use drivers

  Analysis of the general use trends from continuous monitoring of total flows, including seasonal and diurnal variation, usage at different flow rates, and peak flows. Analysis of drivers of household indoor water use variability, including efficiency of appliances, household composition, demographics and perceived water conservation level. There was a preliminary analysis of seasonal drivers, for example, property area and outdoor water use preferences (Objectives 1b, 1d, 1e, 1f).

- **Stage 5** - Predictive modelling of water use

  Using the information from Stage 4 to evaluate the reliability of the BESS modelling framework to provide predictions of water use in a South Australian context. Estimation of the impact of the previous drought and future demand management on household water use (Objectives 2a, 2b, 2c) using the BESS modelling framework.

1.5 Outline of the report

This technical report summarises the major findings from Task 4 'Understanding and predicting household water use' of the U2.2. Optimal Water Mix for Metropolitan Adelaide Project.

- Section 2 of this report summarises the overall research approach and provides details on the components of the project stages. Section 2 includes a summary of the outcomes from Stages 1-3, the details of which are provided in previous technical reports [*Arbon et al.*, 2014; *Arbon et al.*, 2013a; *Beverley et al.*, 2013] (Objective 1a).
- Section 3 of this report outlines the general trends in water use and drivers from the study, including seasonal and diurnal variation, usage at different flow rates, peak flows and mean end-use volumes (Objectives 1b, 1c).
- Section 4 of this report provides the outcomes of Stage 4: Analysis of the Water Use Driver (Objectives 1c, 1d, 1e, 1f).
- Section 5 outlines the key results from Stage 5: Predictive modelling, and includes BESS modelling of indoor water use for the study households, predicting changes in water use due to the drought, and predicting the impact of demand management currently and into the future (Objectives 2a, 2b,2c).
- Section 6 provides preliminary analysis on non-indoor water use drivers and includes outdoor water source preferences.

1.6 Ethics approval

The study was reviewed and approved by the University of Adelaide Human Research Ethics Committee:

- Project title: Household Water Use Study
- Approval Number: H-2012-170

See *Beverley et al.* [2013] for further details of ethics approval.

1.7 Acknowledgments

This research project was a multi-disciplinary endeavour requiring significant input from a wide range of individuals to be successful. The contribution of the following individuals is gratefully acknowledged:

- SA Water, who provided financial contribution for the purchase of the 150 high resolution Aquiba meters.
- Thomas Ryan and Laurie McGing from SA Water's Asset Management and Metering team provided in-kind contribution for the installation and maintenance of the meters.
- Significant in-kind contribution and support from Steve Kotz and Nick Thomas from SA Water's Water Supply & Security team during the household selection phase, including extraction and analysis of the SA Water customer database for the initial survey, planning and advice regarding confidentially and privacy issues and customer relations to ensure the household selection phase and the entire project ran smoothly.
- Thanks also go to Glen O'Hara for his insightful review comments.
- In the initial planning phases, thanks go to Rodney Stewart (Griffith University) and Anthony Brown (Yarra Valley Water) for participating in a workshop that provided invaluable project planning advice.
- Lisa Stewart (Griffith University) for advice on flow trace analysis. Rodney Stewart and Cara Beal (Griffith University) for the valuable review comments.
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- The team of research assistants from the University of Adelaide who were diligent, professional and effective in representing the University during the household visits to undertake the surveys and completing the flow trace analysis. Assistants included: Kah Chia, Erika Crowley, Vanessa De Chellis, Jingxuan Du, Jingzhe Gong, Susannah Hardy, Joseph Ji, Nadja Klafke, Dongxu Li, Danica Liu, Paolo Mercorella, Graeme Riddell, Claire Settre and Michael Waskiel
- Thanks for the lab staff, particularly Terry Cox, from the School of Civil, Environmental and Mining Engineering, University of Adelaide for their help with metering downloads in all types of weather.
- Finally, to the 150 householders who volunteered to participate in the study. Though you will remain anonymous, the research team is thankful for your time and effort and your generosity in allowing us to enter your home for the household surveys. Without your assistance this project would not have been possible.

2 Research approach

The framework of the research approach is illustrated in Figure 2.1 .

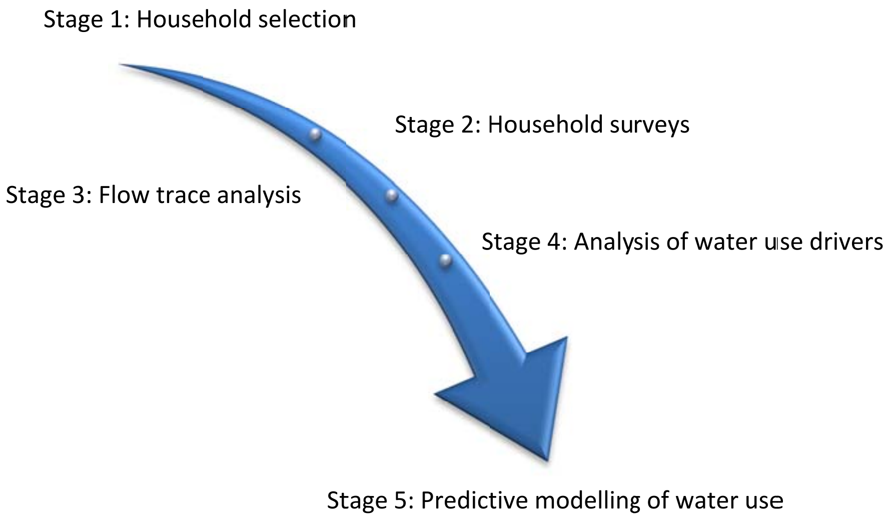

Figure 2.1: Framework of research approach

The framework for the research consisted of five stages, which will be detailed in the next sections, followed by key definitions of terms used in the report. The key aspects of each stage were as follows:

- **Stage 1 - Household selection**
  - selection of representative households
  - installation of appropriate meters
- **Stage 2 - Household surveys**
  - surveys for demographics, attitudes and household characteristics
- **Stage 3 - Flow-trace analysis**
  - end-use analysis of two week winter period
- **Stage 4 - Analysis of water use drivers**
  - general use trends from continuous monitoring
  - indoor water use variability and drivers
  - preliminary analysis of seasonal drivers
- **Stage 5 - Predictive modelling of water use**
  - current: stochastic modelling of water use
  - previous: differences in water use and actions by comparison between the 2007-2009 drought period to the current 2013 period
  - future: assessing the impact of demand management

2.1 Research stages

2.1.1 Stage 1: Household selection

The household selection process included:

- identification of target suburbs based on income levels
- initial mail out to households in target suburbs inviting householders to take part in the study and to complete a preliminary survey to identify suitability based on sample selection criteria
- based on results of the preliminary survey, 150 study households selected as representative of households located in metropolitan Adelaide
- installation of high resolution water use meters able to record at 10 second intervals at study households.

Suburbs were targeted based on geographic proximity and likely income levels. The initial mail out was stratified by suburb and income group to represent equally high, medium and low income levels based an Australian Bureau of Statistics data of average incomes for various suburbs. The initial mail out was sent to 10,000 households randomly selected from the SA Water customer database from within the target suburbs. The documents included in the initial mail out are provided in Appendix A.1. The mail out invited householders to complete a preliminary survey, either online or by return mail (Appendix A.1). From the 1,654 responses (approx. 900 online), 150 study households meeting the following criteria were selected:

- households were representative of the demographics of metropolitan Adelaide (see subsection 3.1 for comparison)
- owner-occupied (no rentals) due to confidentiality and ethics issues and to ensure consistency/stability of the households included in the project
- dwelling type specified as detached house i.e. not a flat/unit
- no internally plumbed rainwater tank as all usage was required to be metered for accurate analysis
- no gravity fed hot water system due to issues with flow trace analysis identification
- ease of access to the water meter due to manual download of data and to minimise disruption to the householder
- located in geographical clusters in established suburbs to reduce travel time
- area not located in areas with known extremes (high/low) of water pressure to avoid the influences of extremes of water pressure on water use
- mean water use that is close to mean water use of metropolitan Adelaide (see subsection 3.3 for comparison) with care taken to ensure that low, medium and high users were equally represented based on water use ranking
- not replacing an older meter type to ensure consistency of reported water use between billing and monitoring meters

The impact of the selection process in achieving a representative collection of households is discussed in Section 7. The selected households were sent the Stage 2 mail out which included a letter of congratulations, participation information sheet, complaints procedure and participant consent form to be signed by the householder (Appendix A.2).

The suburbs from which the selected households were drawn are shown in Figure 2.2. Table B.1 in Appendix B – Data and Comparison Tables provides a list of the suburbs and the number of households per suburb. For further details refer to *Beverley et al.* [2013].

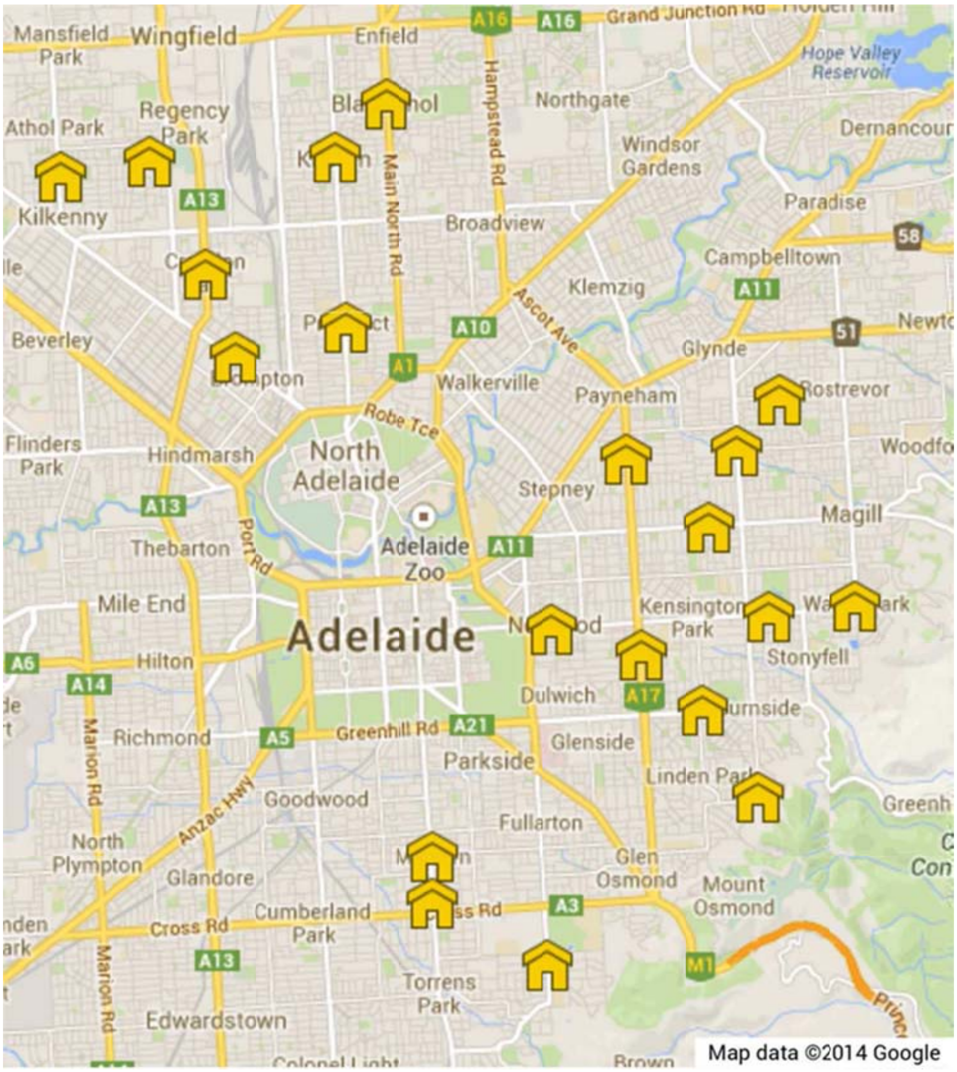

Figure 2.2: Locations of suburbs containing study households. Note, the location of the house icon represents the geographical centre of the suburb, not the location of the representative households within that suburb.

Installation and testing of the 150 high resolution Aquiba A200 meters began in January 2013 and was completed in March 2013. Aquiba A200 meters were selected in consultation with SA Water, because they were compliant with NMI-R49 and AS3561.1, and unlike other meters, met the flow and time resolution requirements while providing sufficient storage capacity for the high resolution data to be collected. For further details refer to *Beverley et al.* [2013]. The installation configuration is shown in Figure 2.3. The meters recorded high resolution (0.014 L/pulse) water flow at 10 second intervals over the monitoring period. The data from the meters was manually downloaded approximately every three months with additional downloads at crucial periods such as the household visits.

Figure 2.3: Installation of Aquiba A200 meter (left with optical sensor for manual download attached) in series with existing SA Water meter (right)

2.1.2 Stage 2: Household surveys

The key steps in the preparation of the household visit stage of the study were:

- developing survey documents for the visits
    - end-use survey – water use attitudes and perceived behaviour (Appendix A.3.1)
    - water appliance audit – appliance signatures and property characteristics (Appendix A.3.2)
    - water use diary – typical household behaviour and usage patterns over a one week period (Appendix A.3.3)
- ethics approval of the survey documents
- recruitment of a sufficient number of research assistants to undertake the visits
- determining appropriate OH&S protocols and procedures for the visits
- training the research assistants.

150 household visits were completed (143 between June and August 2013, seven in late November/early December as the households became available and meter replacement occurred). For further details of the approach and results of the household visits, end-use survey, water appliance audit and water use diary refer to *Arbon et al.* [2013b].

2.1.3 Stage 3: Flow trace analysis

Key steps of the flow trace analysis stage of the study were:

- recruitment and training of research assistants to undertake the flow trace analysis
- preparation of the household data and templates
- flow trace analysis of the two week period
- quality assurance and verification of the results from the flow trace.

Flow trace analysis was completed on 140 of the 150 study households. Eleven households were excluded from the flow trace analysis due to the following factors that had not been identified during the household selection Stage 1. Eight households had plumbed in rainwater tanks; one household had a gravity fed hot water system; one household had significant commercial water usage which became apparent during the Stage 2 visits; and one household withdrew from the study prior to the household visit. The mean water end-use results for the flow trace households during the flow trace period are provided in subsection 3.4 and detailed flow trace analysis was undertaken in Stage 4. For further details of the flow trace analysis procedure refer to *Arbon et al.* [2014].

2.1.4 Stage 4: Analysis of key drivers of water use

Presented in this report are the results of Stage 4, the analysis of the water use and key drivers of water use for the study households, including:

- general trends of total household water use from continuous monitoring, including monthly variation, usage at different flow rates, mean diurnal patterns and peak flows (see subsection 3.3)
- analysis of drivers of household indoor water use variability, including efficiency of appliances, household composition, demographics and perceived water conservation level (see Section 4)
- preliminary analysis of seasonal drivers and outdoor water use preferences (see Section 6).

2.1.5 Stage 5: Predictive water use modelling

The Behavioural End-use Stochastic Simulator (BESS) was used to model the study households to evaluate the capability of stochastic models to model water use behaviours and hence provide reliable predictions of end-uses at the individual household scale at sub-daily time steps. BESS stochastically simulates individual end-uses (outdoor, shower, washing machine, toilet, tap etc.), at the household scale at sub-daily time steps [*Thyer et al.*, 2011]. BESS was developed through the eWater CRC and calibrated using water use data from cities on the east coast of Australia. The aim of the current study was to use the data and information collected in Stages 1-4 to evaluate the ability of BESS to provide predictions of water use in a South Australian context. Further details related to the BESS framework are in subsection 5.1.

Past usage was evaluated in subsection 5.3 through by investigating the differences in water use, behaviour and actions during the height of the drought (2007 – 2009) compared to pre and post drought water usage and water saving behaviour and actions during the monitoring period in 2013. Future usage was assessed by investigating the impact of demand management. Demand management scenarios were applied to current and predicted future appliance stocks and the results are outlined in subsection 5.4.

2.2 Definitions

2.2.1 Study periods

There were two main periods of monitoring in the study:

1 <u>Monitoring period</u>, from installation of the meters (began in January 2013 and finalised in March 2013) to the last download of data (February 2014)

2 <u>Flow trace analysis period</u>, two week winter period analysed for the separate end-uses (June 15th to 28th 2013 for 92% of surveyed households)

2.2.2 Data sets

Several different data sets were used for the analysis of the households:

1 Study households, refers to all 150 households included the study

2 Flow trace households, refers to the 140 applicable households for which flow trace was completed for the two week period

3 Continuous data households, refers to the 121 households for which data was available for the majority of the monitoring period (generally March 2013 to Feb 2014)

4 Preliminary survey, completed by 1,654 respondents in the target suburbs, either online or on paper

5 End-use survey respondents, those participants who responded to the end-use survey (one per household)

6 Household billing data, the billing data for 125 households for the period mid 2002 to 2013 (or the relevant period for which the householders were residents at the property). Prior to mid 2008 this data was collected every six months; after mid 2008, it was collected quarterly.

***Unless otherwise noted, all results that refer to end-uses utilise the flow trace households data set.**

2.2.3 Testing for statistical significance in end-use statistics between household groups

Comparison of end-use statistics between household groups was considered statistically significant if the p-value of an independent two group t-test was less than 0.05. A strong statistical significance refers to a p-value of less than 0.01.

The t-tests were, in general, undertaken using the data from all events for a specified event type for households within a particular group. The primary exception is the frequency of events where a single average frequency for each household within a particular group was used.

3 General trends in total household water use

3.1 Household occupancy, age, income, composition and dwelling structure

What were the demographic differences between the study households and the greater Adelaide community?

The demographics of the study households were representative of the Greater Adelaide population, within the limitations of the scope of household selection, as shown by analysis of the mean household size, household size distribution and occupant age distribution as illustrated in Figure 3.1 to Figure 3.3, respectively. Note that in all of the following graphs the data sets refer to:

- Adelaide ABS: Greater Adelaide statistics [*ABS*, 2011a; b]
- Flow trace households: as defined in subsection 2.2.2. Note that these results are consistent with the results for the 150 study households.

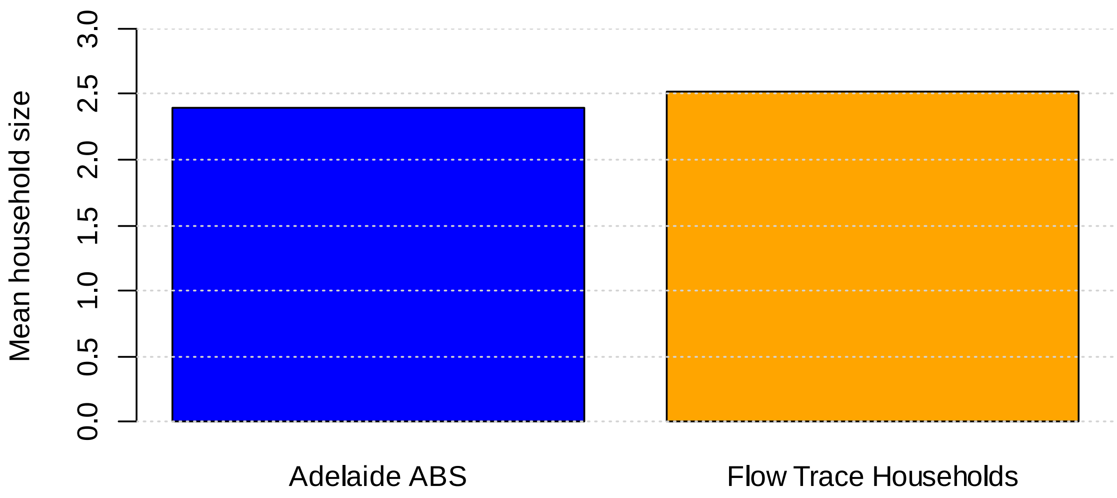

Figure 3.1: Comparison of mean household size

Figure 3.2: Comparison of household occupancy distribution

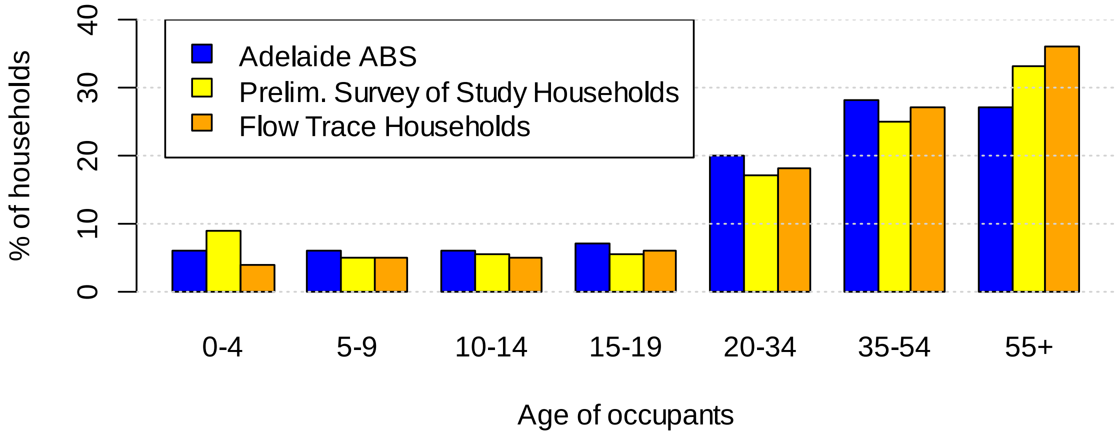

Figure 3.3: **Comparison of age distributions within households. (Flow trace household data for ages >20 was split between the three categories according to the proportions indicated in the preliminary survey since adult age was not surveyed during the household visit stage.)**

There was variation in the household size and occupancy distribution between the preliminary survey and the household surveys due to incorrectly filled out preliminary surveys, as well as changes in some households that occurred between the surveys. The full comparison tables which include the results of the 1,654 respondents of the preliminary survey are presented in Table B.2 in Appendix B – Data and Comparison Tables. The variation between the preliminary survey and the household surveys was also evident in the data relating to the distribution of ages within the households as provided in Figure 3.3. During the household visits, it was found that the preliminary survey was inaccurately completed with 5% of respondents, who wrongly identified the household's occupants as aged 0-4 instead of as adults.

The range of incomes used for the gross household annual income levels of high, medium and low was based on the Adelaide ABS statistics and was chosen to provide equal proportions of households in each income range. The variation is shown in Figure 3.4 and in Appendix B – Data and Comparison Tables. The flow trace households had a higher proportion of the high income group and a lower proportion of the low income group, compared to the Adelaide ABS statistics. This was a natural outcome of the greater number of high income households responding to the preliminary survey, and the ownership of property being nominated as a selection criterion, thus making bias difficult to avoid. The effect of the income bias will be discussed in subsection 4.4.

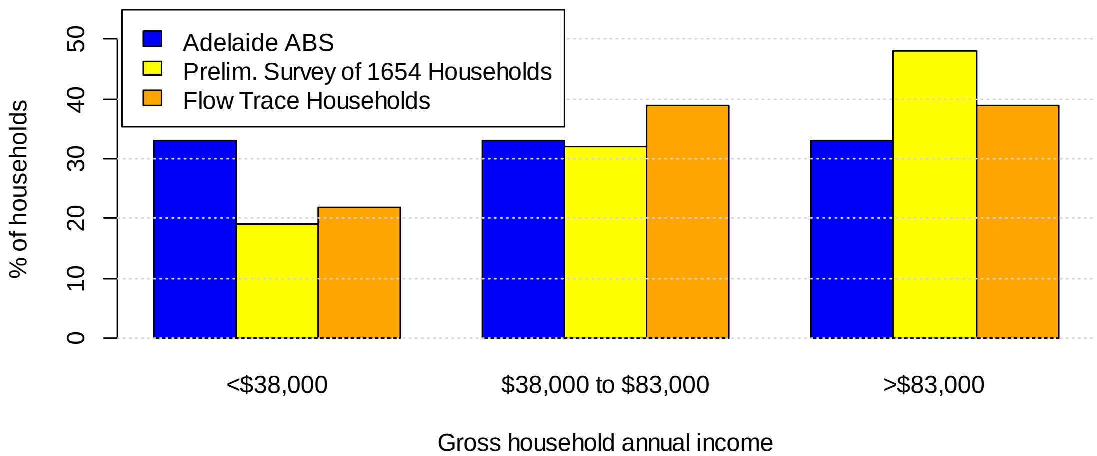

Figure 3.4: **Comparison of gross household annual income levels**

Table 3.1 presents the distribution of gross household annual income by family composition for the flow trace households, where income level is as recorded in the end-use survey. Survey data were compared to the Adelaide ABS statistics to determine whether any group was significantly over or under-represented. The participants in the study were not asked to specify family relationships, thus family households with adult children could not be separately identified. Where sub-adult children were recorded along with two or more adults, the household was classified as a couple with children. Any household with more than two adults with no sub-adult children was classified as a group household. This classification could explain the over-representation of group households (more than two adults with no children), which might have also been influenced by the location of the study households as they were close to universities and the CBD.

Table 3.1: Gross household annual income and family composition for flow trace households, Adelaide statistics in brackets [*ABS*, 2011a]. Red shading indicates groups with greater than 3% difference.

		Family composition				Total for income level
		Couple no children	Couple with children (2+ adults)	One parent with children	Non family households (Lone occupants and Group)	
Income Level	Low	7.4% (7.3%)	0.9% (2.1%)	0.0% (4.7%)	14 % (19%)	22% (33%)
	Medium	19% (10%)	7.0% (9.1%)	2.2% (4.5%)	11 % (10%)	39% (33%)
	High	11% (10%)	21% (18%)	0.7% (1.7%)	7.1 % (3.5%)	39% (33%)
Total for family composition		37% (27%)	29% (29%)	2.9% (11%)	**Lone 20% (28%)** Group 11% (4%)	100%

*Note: percentage presented is the percentage of total households

Overall, there was a satisfactory match between the flow trace households and the Greater Adelaide ABS statistics for the majority of family composition/income groups, with 63% of household groupings exhibiting less than 3% difference from the ABS statistics. The groups with larger than 3% differences were the medium income couples with no children and high income non family households no who were both over-represented, the low income one parent with children families and low income non-family households were both under-represented. However, when the limitations of sampling only 150 households are considered, the overall success of the demographic mix in matching the statistics for the Greater Adelaide area can be viewed very positively. The impact that over- or under-representation had on the results of the project is discussed in Section 7.

The study households were required to be owner-occupied detached dwellings, which excluded units, flats, townhouses, semi-detached houses and renters. The impact this had on the representativeness of the study households was evaluated by comparing ABS statistics with the proportions of different dwelling structures in the study (Table 3.2). The comparison showed that owner-occupied detached houses are the majority dwelling structure in Greater Adelaide, representing 60% of households. The impact of not including some dwelling structure types on the results of the project is discussed in subsection 7.1.

Table 3.2: Percentage of dwelling structure in Greater Adelaide [*ABS*, 2011a]

Dwelling structure	% of total households	% of persons
Separate house	77	83
Semi-detached, row or terrace house, townhouse etc.	12	9
Flat, unit or apartment	10	7
Other dwelling or unspecified	<1	<1
Own/mortgage dwellings	68	-
Rent dwelling	28	-
Own/mortgage and separate house	60	-

3.2 Appliance proportions

What were the differences between the appliance stock of the study households and the greater Adelaide community?

South Australian ABS statistics [*ABS*, 2013] were used to represent the Greater Adelaide community as the specific statistics for the Greater Adelaide region were unavailable. The flow trace households had similar proportions of efficient appliances as shown in Figure 3.5 to Figure 3.8 (see Appendix B for tables). The survey responses were split between efficient and non-efficient or single and dual flush, whereas the flow trace households' results were from the measurements taken during the household visits. Key findings were:

- Data based on phone and online surveys tended to over-estimate the proportion of water efficient (3 star) showerheads when compared to the measured values (Figure 3.5). This was not surprising as the flow rate/star rating is not clearly marked on the majority of shower heads, unlike dishwashers or washing machines.

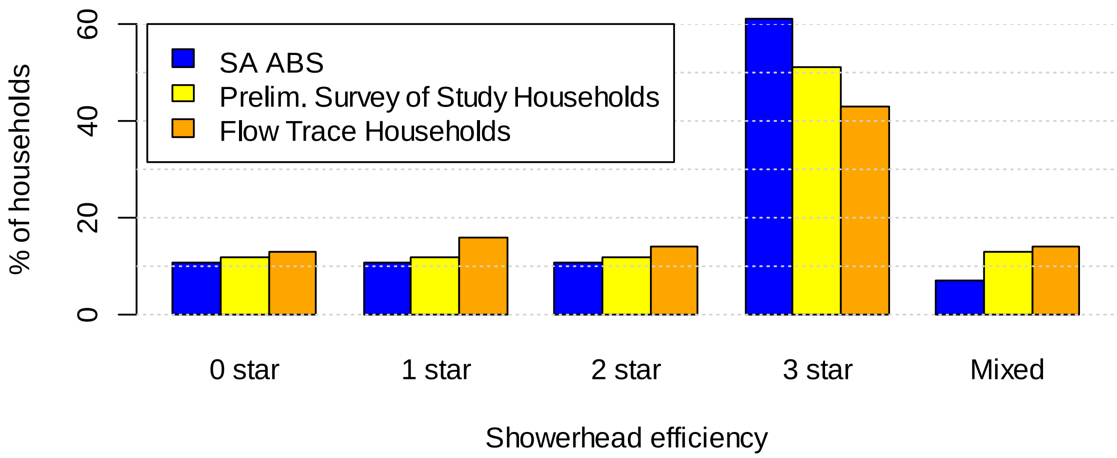

Figure 3.5: Proportions of showerhead efficiencies (Note that SA ABS and preliminary survey responses of non-efficient appliances were equally split between 0-2 star efficiency.)

- Distinguishing between dual or single flush toilets failed to differentiate household appliance stock as the majority of households had dual flush toilets (Figure 3.6). For the flow trace households, the distribution of dual flush toilets tended toward efficient types (4.5L/3L or 6L/3L), possible because inefficient types are unavailable for purchase in South Australia. As the SA ABS statistics do not collect information on the types of dual flush toilets, it proved difficult to ascertain the representativeness of toilet proportions. The flow trace households had a high proportion of the mixed toilet category as mixed was recorded for households with multiple dual flush toilets of different efficiencies.

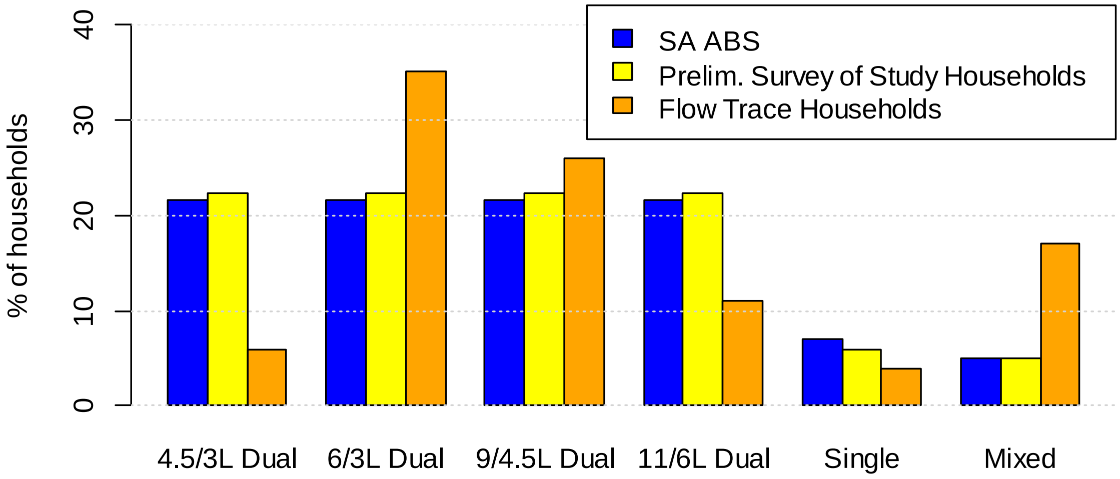

Figure 3.6: Proportions of toilet categories (Note that SA and preliminary survey responses of dual flush have been equally split between categories.)

- The proportion of top loaders in the study households (Figure 3.7) was lower than the proportion recorded by the ABS statistics for South Australia. This is partially due to the lower proportion of low income families participating in the study, and the demographics of the Greater Adelaide region compared with the whole of South Australia. As shown in subsection 4.4, low income households are more likely to own older machines that are typically top loaders. The impact this has on water usage estimates will be discussed in Section 7 and the effect of this on water usage will be investigated in subsection 4.4.

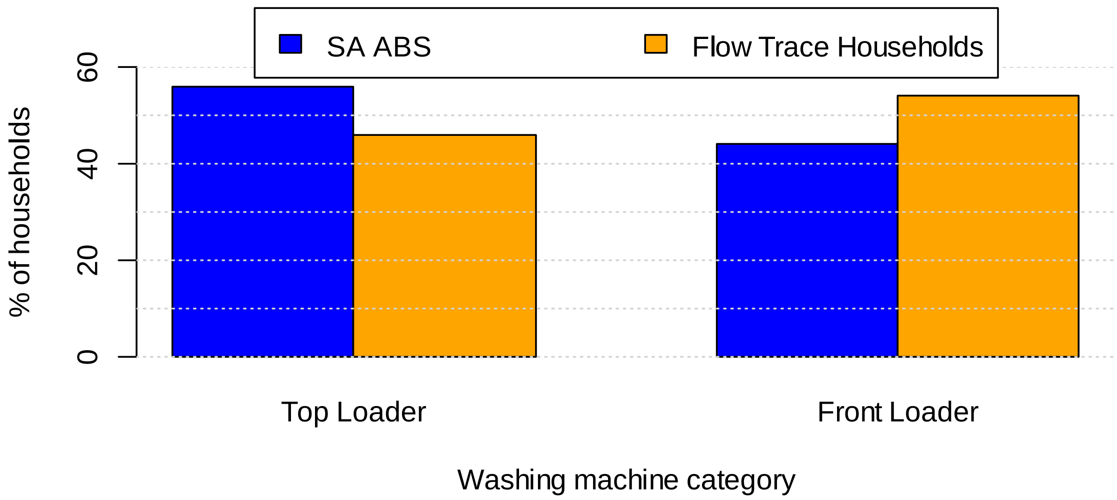

Figure 3.7: Proportions of washing machine types

The proportions of other water using appliances and rainwater tanks are shown in Figure 3.8. The proportion of rainwater tanks owned by the participating households was slightly higher than for Greater Adelaide as shown by the Adelaide ABS statistics. The use of rainwater could possibly result in a reduction in mains outdoor water use for the study households seasonally (Section 6). Seven percent (7%) of respondents incorrectly reported that they did not have a rainwater tank plumbed into the household in the preliminary survey. Their error was identified during the household survey.

It is also possible that conversion to rainwater took place between the surveys. These households were excluded from the flow trace analysis as an end-use (typically washing machine) was removed from the mains water supply and thus was not metered.

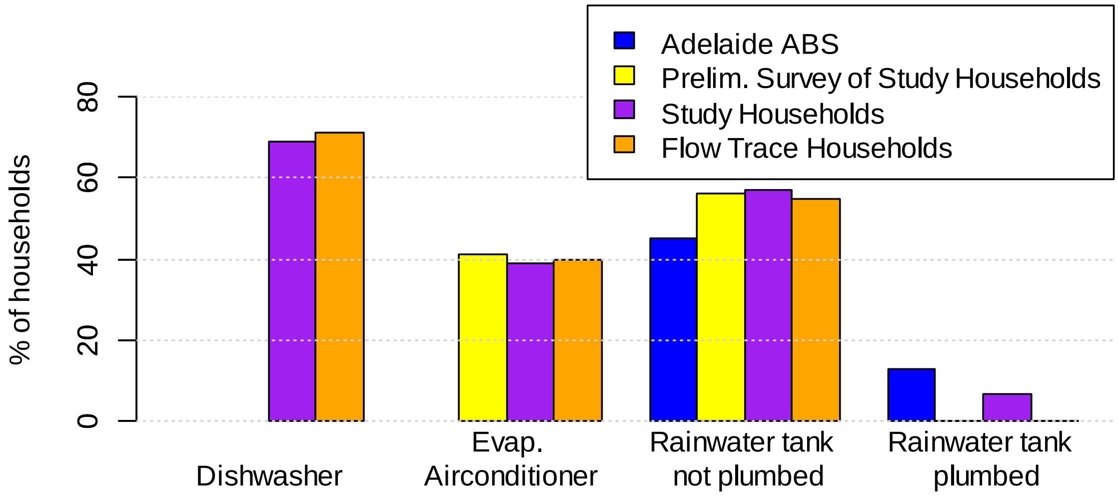

Figure 3.8: Proportions of other water using appliances and tanks

3.3 Water use for the monitoring period

3.3.1 Average household water use

Was the households' water use representative of Adelaide?

Table 3.3 shows the mean daily household usage for the study households based on two different periods: (a) Monitoring period (March 2013-February 2014) and (b) Annual figures for the 2012-2013 financial year (July 2012-June 2013) based on the quarterly billing data.

Table 3.3: Yearly water usage during the monitoring period for continuous data households

	Continuous data households during monitoring period (March 2013 – Feb 2014)	Study households during 2012-2013 (based on quarterly billing data)	Metropolitan Adelaide 2012-2013 SA Water annual report [*SA Water*, 2013]
Mean daily total usage per household	618 L	588 L	526 L*
Mean daily usage per person	289 L	245 L	219 L**
Winter (Jun-Aug) mean daily usage per person	153 L	-	-
Summer (Dec-Feb) mean daily usage per person	498 L	-	-

*192 kL per year **Assuming an mean occupancy of 2.4 [*ABS*, 2011b]

When the annual figures for the study households during 2012-2013 were compared with the mean household water use recorded in the 2012/13 SA Water Annual Report for Adelaide [*SA Water*, 2013], it emerged that study household water use was 10% higher than that for mean Adelaide household use. Given the limitations of the small study sample of only 150 households, a difference of 10% in mean water use was considered an reasonable result. This outcome may be the result of the household selection process since a range of high, medium and low water users was sought based on relative rankings only, rather than absolute values.

Interestingly, mean water use from the monitoring period was 15% higher than the 2012/2013 annual figures, possibly because during the summer of 2012/2013 Adelaide experienced the hottest January in 13 years. This relatively hot period may have had the effect of increasing seasonal water demand for outdoor use and evaporative air conditioning. The variation in mean water use for the study households from 2002-2013 is further investigated in subsection 5.3 and preliminary analysis of seasonal drivers is given in Section 6.1.

3.3.2 Seasonal variation in daily household water use

The last two rows in Table 3.3 show seasonal mean daily water use in 2013/14, which is further discretised to monthly time steps in Figure 3.9 where the width of the boxplot is proportional to the number of households included for that month. The mean daily usage and variability increased in the summer months due to seasonal usage, as shown by the greater bounds of the boxplots in the summer months.

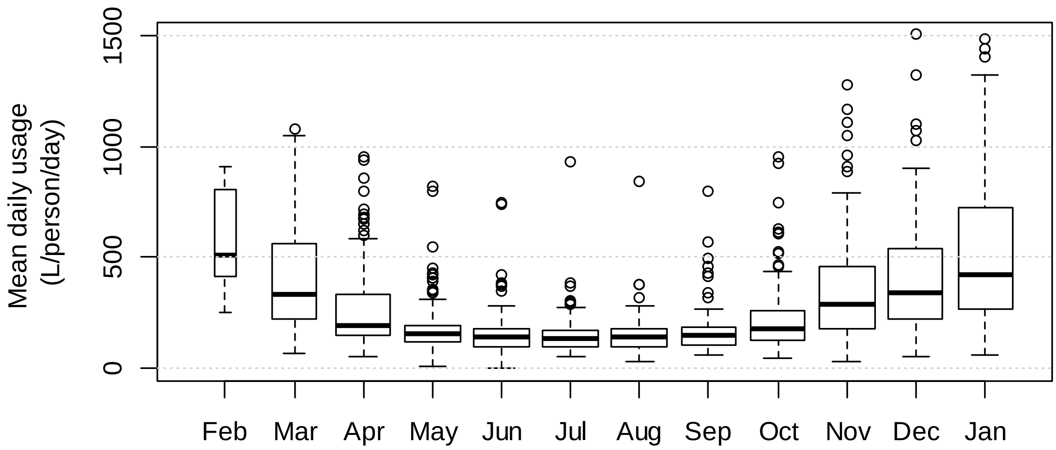

Figure 3.9: Mean daily usage (L/person/day) by month for study households Feb 2013- Jan 2014. In the boxplots the thick line is the median (50th percentile), the box edges represent the upper quartile (25% percentile) and lower quartile (75% percentile), the 'whiskers' (dashed lines) are 1.5 times the interquartile range, which represents approx. 99% of the data (assuming data is Gaussian), circles show 'outliers' outside the range of the whiskers. See further information [here](#).

Figure 3.10. shows the distribution of daily usage per person for all households for all days. 64% of the daily per person usage < 200 L/person/day and 84% < 400L/person/day.

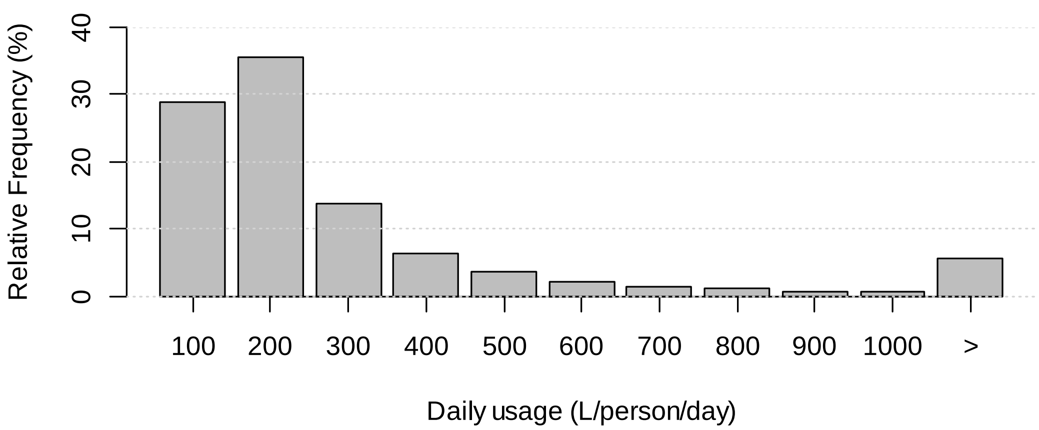

Figure 3.10: Distribution of daily usage per household for all days in the monitoring period

3.3.3 Analysis of the peak daily water use

The variation in the total daily usage (on a per household basis) was estimated by combining the data from all the study households into a single time series during the monitoring period as shown in Figure 3.11. The variation was smaller during the winter months. The total daily usage increased in the summer months due to seasonal use. The maximum peaking factor for peak day (peak total daily usage/average total daily usage) was 2.8. A peaking factor of greater than 1 was found for 40% of the days in the monitoring period as shown by the days greater than the mean value in Figure 3.11.

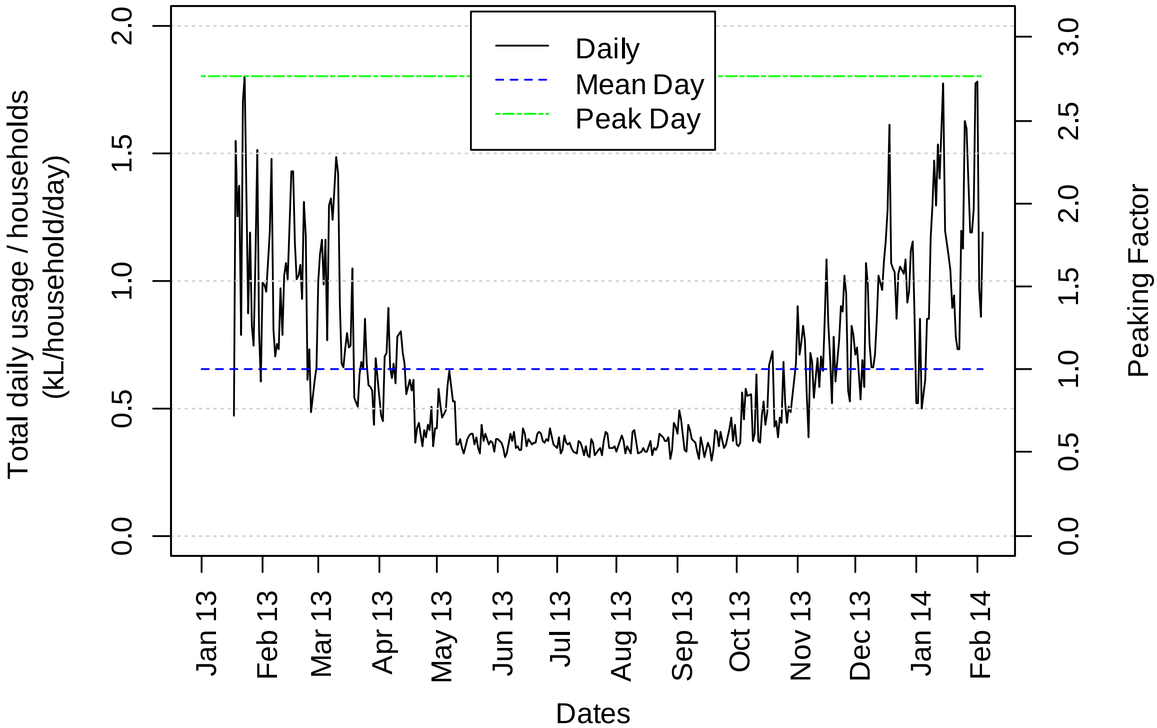

Figure 3.11: Time series of daily by household usage

To evaluate the contribution of each household to the peak total daily usage, the percentage contribution of each household to the top 10 peak usage days is shown in Figure 3.12. Of interest is that only a small number of 'high-usage' households contributed substantially to the peak daily usage; that is, approximately 20% of households used 50% of the water on peak days, while only 5% of the households used 20% of the water. These figures suggest that to reduce peak daily demand only a small number of households would need to be targeted. Awareness of this fact offers a significant opportunity to reduce peak flows, which are a major driver of design and operation of water distribution systems. One of the key advantages of high resolution smart metering is the ability to understand the drivers of peak demands[*Beal and Stewart*, 2013; *Gurung et al.*, 2014].

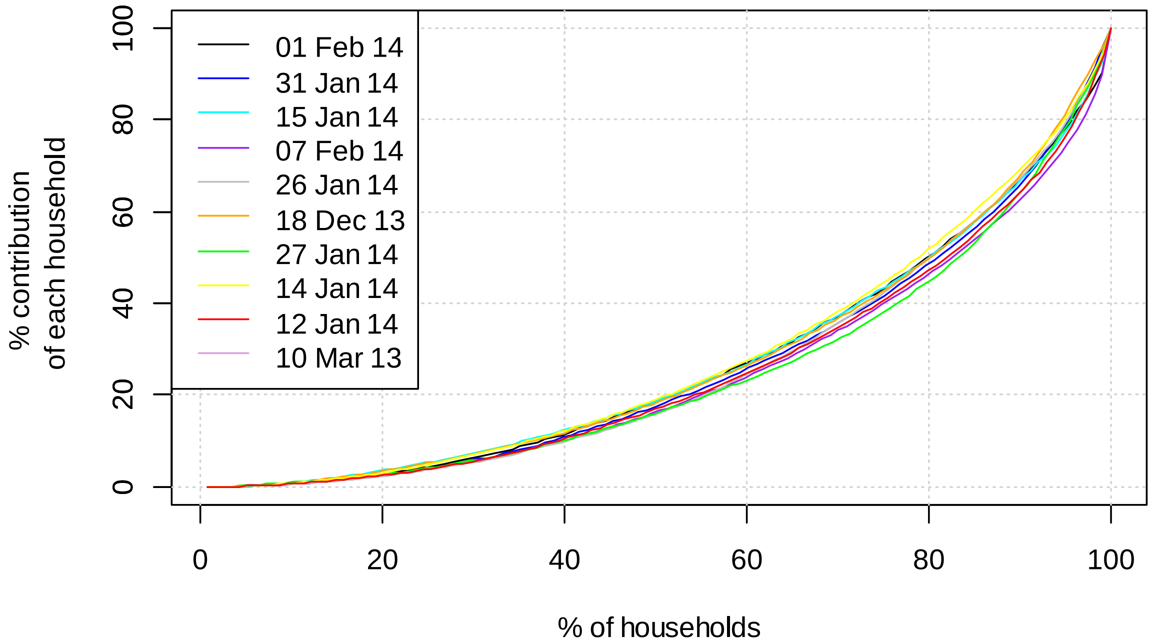

Figure 3.12: Percentage contribution of each household to the top 10 peak usage day. Each colour represents one of the top 10 peak usage days

The minimum and maximum total household daily use for an individual household on any given day is shown in Figure 3.13. There are several large events greater than 15 kL/day which might have been due to a pipe break, filling of a swimming pool or irrigation mistakenly left on for the majority of the day. The peak use by a household was 23 kL on 4/2/2014, and investigation showed a constant use of 980 L/hour for the entire day. The peaks around the 9/3/2013 and 7/12/2013 represent constant high usage over several days. The impact of these unusual large events on the predictions of water use is further discussed in Section 7. Note that an individual household can have a very high daily peaking factor.

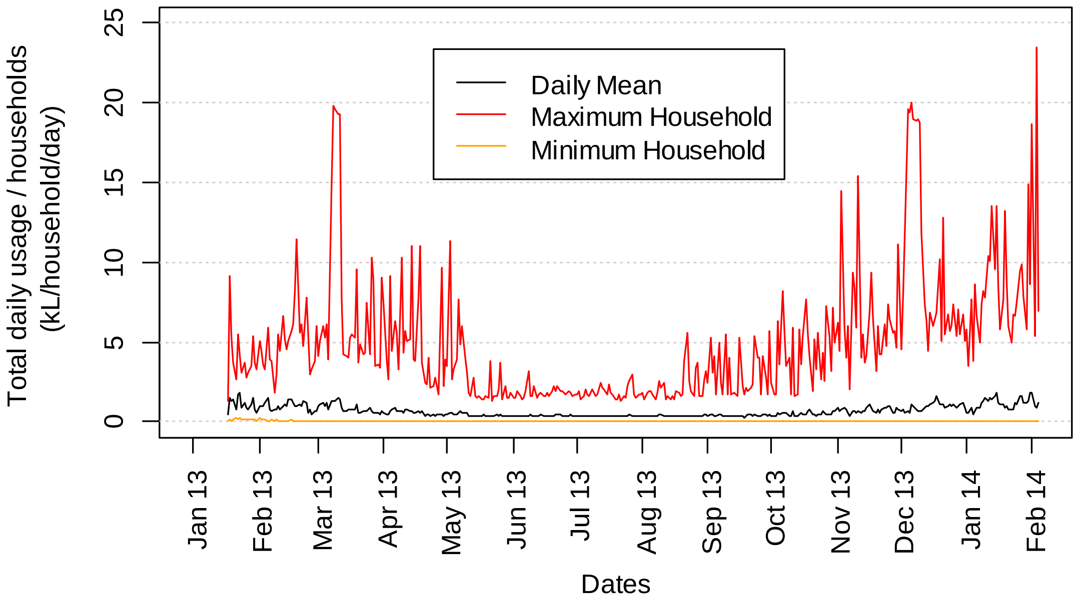

Figure 3.13: Time series of daily by household usage showing maximum and minimum usage household

3.3.4 Diurnal variation in water use

The diurnal pattern of total water usage for all the study households is shown in Figure 3.14. The graph shows that the peak morning usage was between 6am and 8am and afternoon between 5pm and 7pm. The large differences in peak height on the graph are between the winter and 'preliminary summer'. In winter the morning peak is higher whilst in summer the afternoon peak is higher, which can be assumed to be due to outdoor use, such as irrigation. The variation between houses is shown by the error bars in Figure 3.14. The contribution of the indoor end-uses to the diurnal pattern is outlined in subsection 3.5.

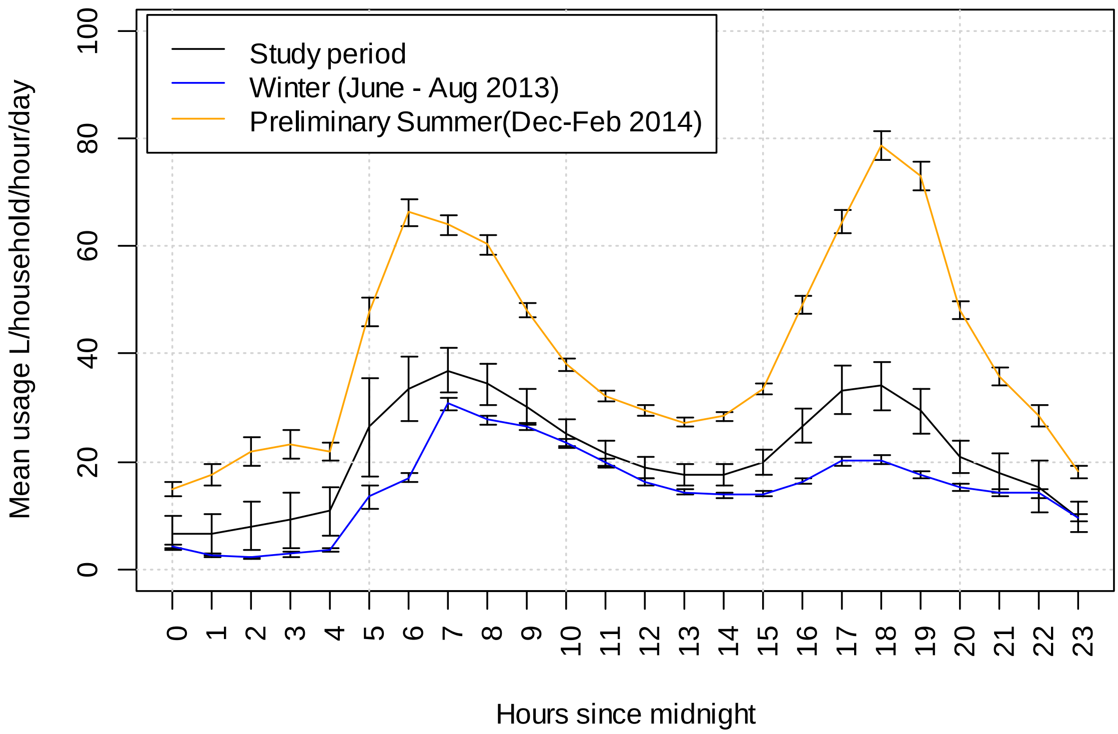

Figure 3.14: Diurnal total water usage pattern during the monitoring period. The solid line is the mean, and the errors bars show the 95% confidence limits that represent the variation between houses.

3.3.5 Flow rate distribution

The distribution of the usage by flow rate is shown Figure 3.15. Each line represents the contribution of a different meter. 18% of the usage has a flow rate less than 300 L/hr. As shown on the left of the graph, the contribution of one meter accounted for a high proportion of the 10-50 L/hr flow rate usage which investigation indicated was due to a significant leak (leakage is further discussed in subsection 3.7). Four percent (4%) of the usage was at flow rates greater than 1800 L/hr which would most likely result from concurrent events that include irrigation. As noted previously (subsection 1.3), a complete summer was not recorded for all meters, thus this flow distribution may not be representative of longer-term flow rate distribution.

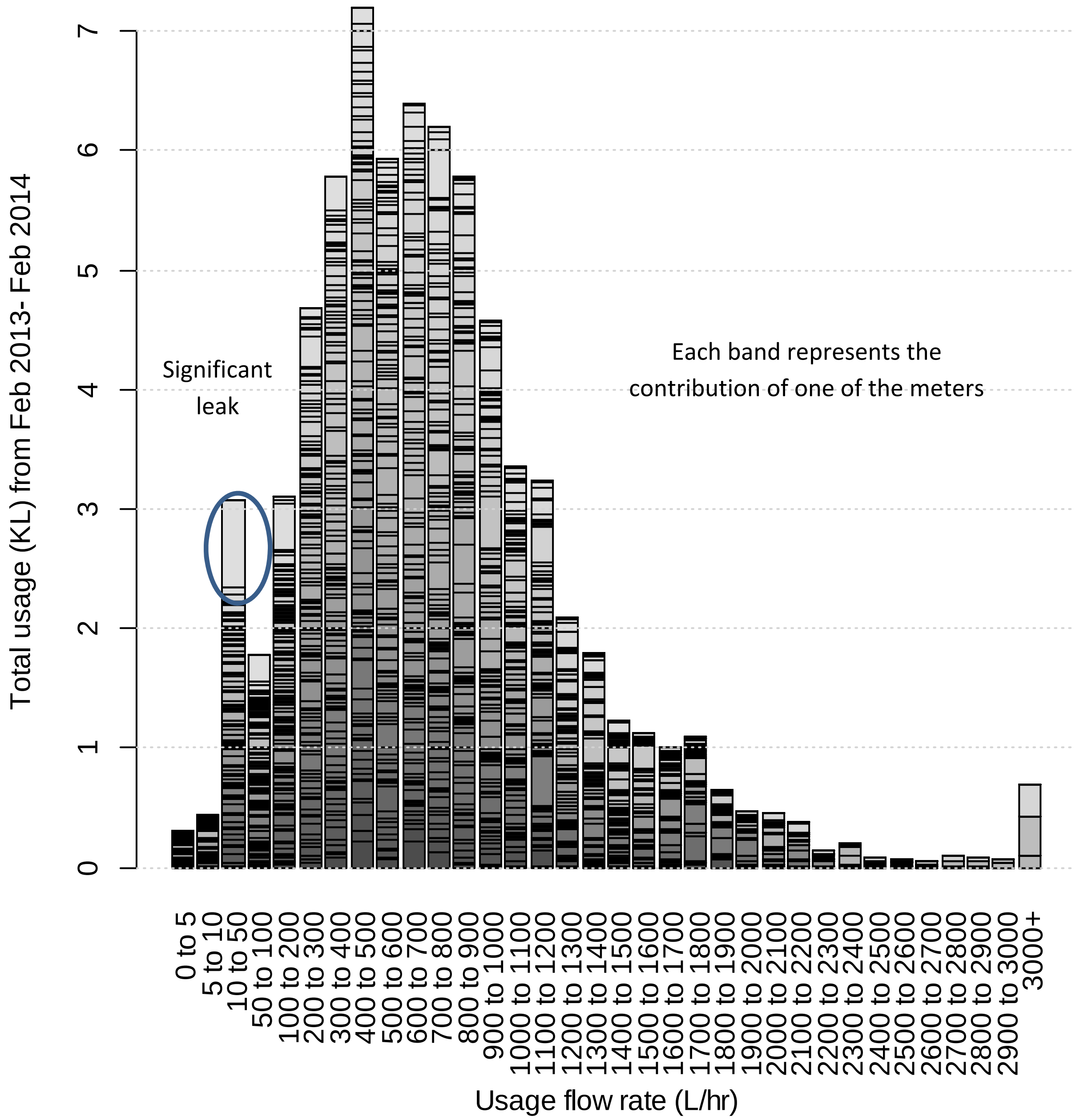

Figure 3.15: Total usage at flow rate ranges within the monitoring period showing the contribution of each meter

3.4 Water use in flow trace analysis period

What was the measured water use for the two week flow trace analysis period?

The results for the 140 flow trace households for which flow trace analysis was completed are presented in this section. The results represent a two week snapshot of continuous monitoring of the typical winter behaviour of the households and thus focus on indoor usage. The mean daily usage per household and per person are recorded in Table 3.4. Outdoor usage accounted for 7% and leakage for 8% of the usage. Leakage will be further examined in subsection 3.7.

The variations in the mean daily usage per household and per person are shown in Figure 3.16 and Figure 3.17 respectively. The total usage value includes minimal outdoor usage as the flow trace analysis period was during the South Australian wet season. The leakage value was due to the presence of a few significant leaks (see subsection 3.7).

Table 3.4: Water usage in flow trace analysis period for flow trace households

	Total kL	Mean household (L/household/day)	Mean per person (L/person/day)
Total usage	752	382	163
Indoor usage	642	327	135
Outdoor usage	50	25	17
Leakage	60	30	11

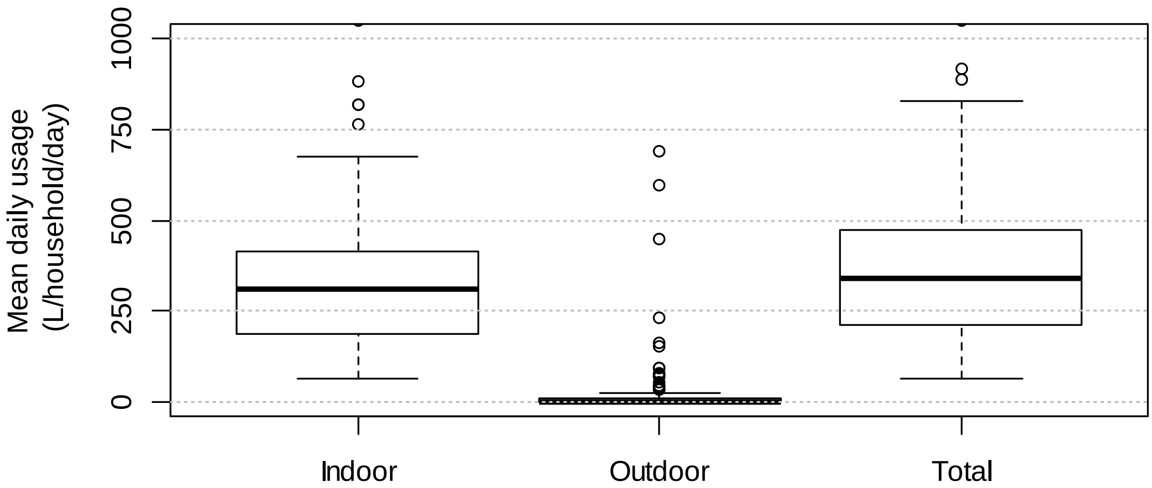

Figure 3.16: Mean daily usage (L/household/day) by category during flow trace analysis period

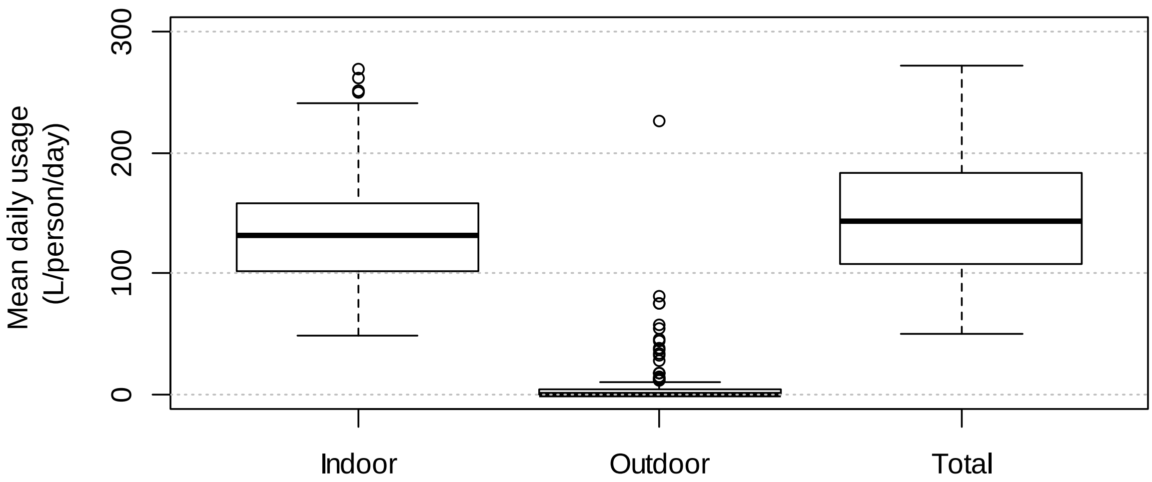

Figure 3.17: Mean daily usage (L/person/day) by category during flow trace analysis period

To verify that the two week period used for the flow trace analysis was representative of the winter period, the diurnal pattern of the flow trace period was compared to the winter period (June - August) (Figure 3.18) as recorded by the high-resolution meters. The results were very similar. The breakdown by end-use is discussed in subsection 3.5.

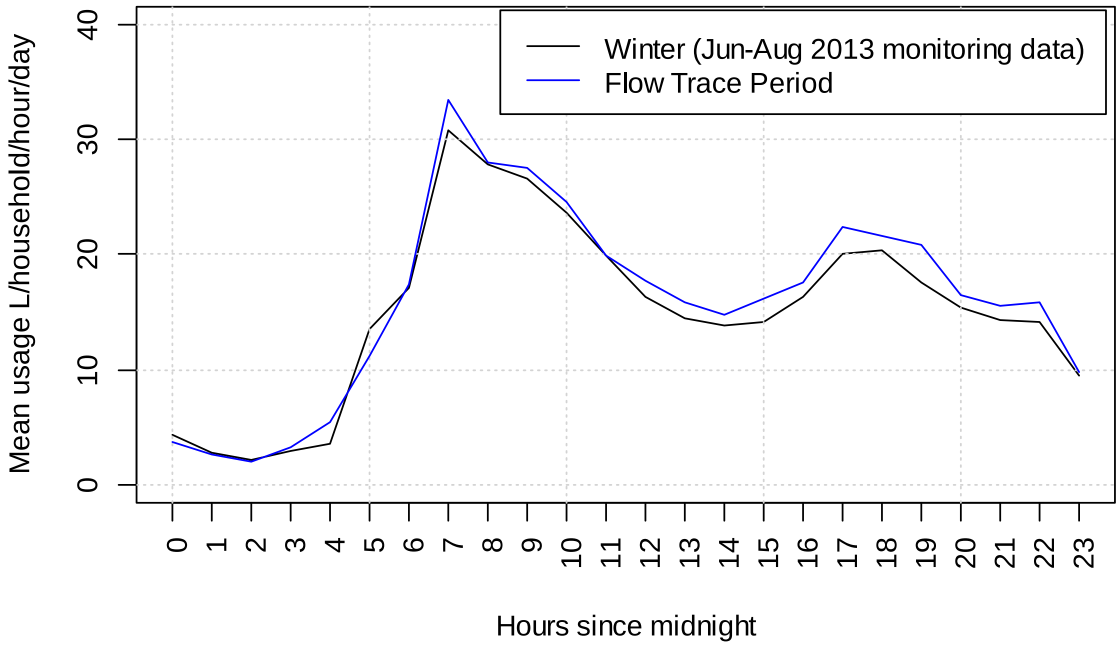

Figure 3.18: Mean diurnal water usage pattern during flow trace analysis period

To investigate whether the quarterly billing data could be used to estimate the indoor usage, the mean winter water use for the study households was estimated based on the quarterly data billing period that captured the majority of the winter period (June - August) and compared to the high resolution monitoring data in the two week flow trace period. It was found that quarterly billing data could provide a good estimate of winter usage; however, winter usage could not be used to estimate indoor usage, as a 20% over-prediction occurred due to winter irrigation and leakage. The full analysis is shown in Appendix C – Implications of the Use of Gross Demand Estimates.

3.5 Indoor end-uses for flow trace analysis period

How does the water use data for each indoor end-use in the household (toilet, shower/bath, washing machine, dishwasher, tap) compare to 'Water for Good'?

Indoor usage can be split into the component end-uses by appliance type. The variation and median of the daily usage for each component are shown in Figure 3.19.

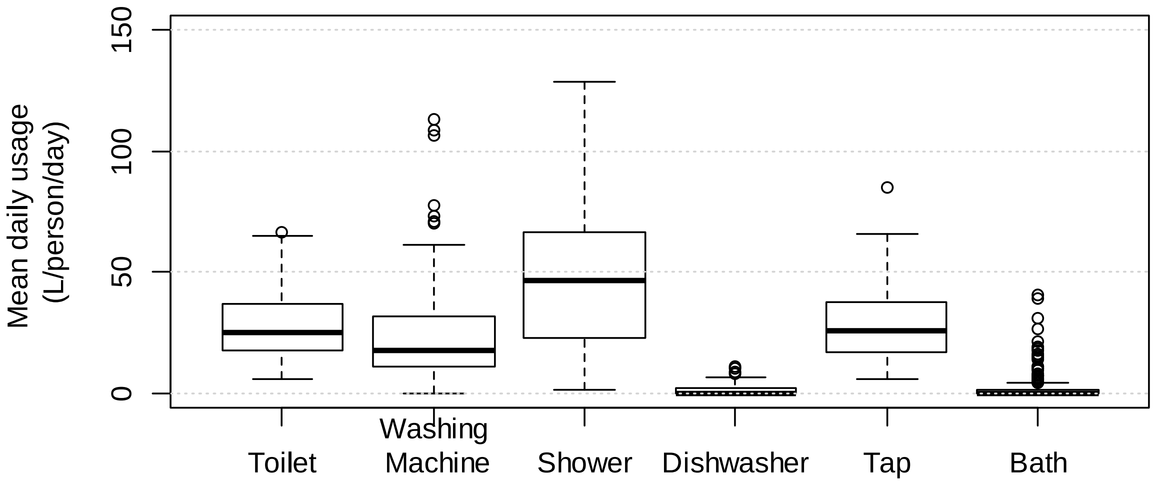

Figure 3.19: Mean daily usage (L/person/day) by indoor end-use

The share of the mean daily indoor use for each component is shown in Figure 3.20. The impact of leakage was not included due to the unreliability of the data as the leakage was caused by a low number of events with high sampling variability. Further analysis is provided in subsection 3.7.

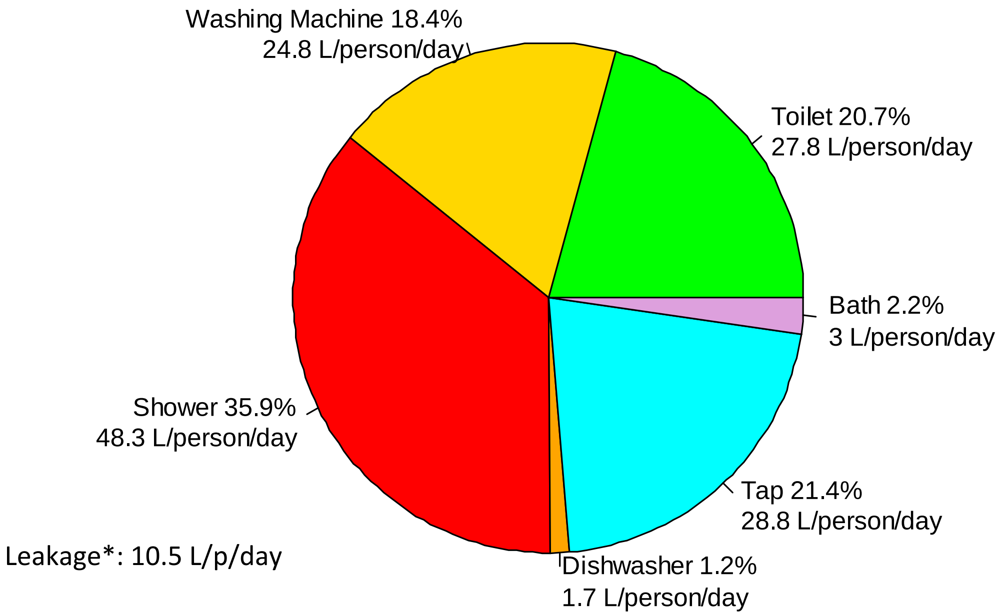

Figure 3.20: Percentage of mean daily usage (L/person/day) by indoor end-use

In Figure 3.21, and Table B.4 in Appendix B – Data and Comparison Tables, the mean daily values are compared to the estimates based on 'Water for Good' [*Government of South Australia*, 2010] .The 'Water for Good' estimates are included because they represent that best available estimate of the end-use percentages prior to this study. The total indoor usage from the flow trace analysis is 5% lower than the 'Water for Good' estimates and the main differences in the individual end-uses were:

- shower and bath: 5 L L/person/day, 2% lower from 'Water for Good'
- washing machine: 7 L/person/day decrease, 5% lower than usage noted in 'Water for Good'.

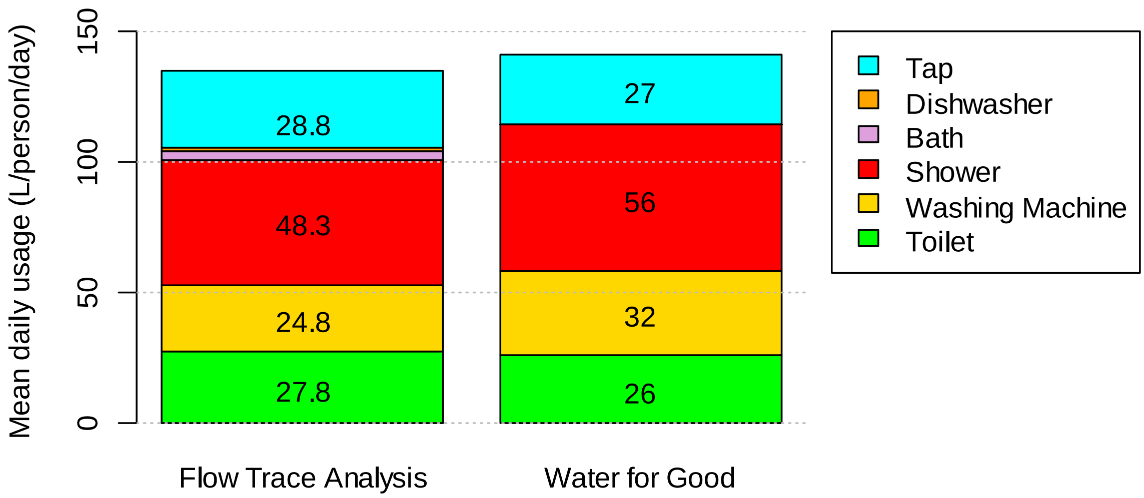

Figure 3.21: Comparison of mean daily indoor usage (L/person/day). (Note that 'Water for Good' combines bath and shower, and dishwasher and tap.)

The diurnal pattern of total household usage (Figure 3.18) is split into the separate end-uses in Figure 3.22. The variation in the amounts of water used throughout the day for the different end-uses can clearly be seen. Washing machine and toilet usage peaks in the morning, while shower usage peaks mostly in the morning, but exhibits an afternoon peak also. Tap usage is fairly constant throughout the day from 7am to 9pm.

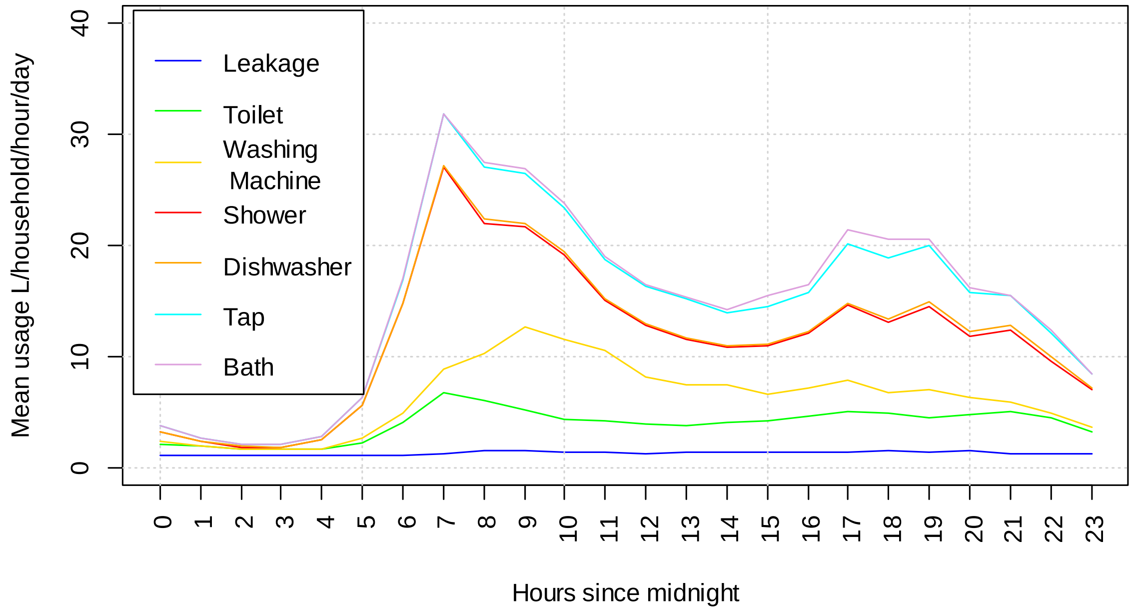

Figure 3.22: Mean diurnal water usage pattern during flow trace analysis period by end-use (stacked)

3.6 Comparison of end-uses to previous studies

Recent Australian residential indoor end-use studies utilising flow trace analysis were completed by Yarra Valley Water (YVW) in 2004 [*Roberts*, 2005] and 2010 [*Roberts et al.*, 2011] and South East Queensland (SEQ) in 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011a] with the household size and number of households given in Table 3.5. A comparison of the mean indoor daily use is provided in Figure 3.23 and Table B.5 in Appendix B – Data and Comparison Tables.

The 2010 YVW study was undertaken during a period of harsh water restrictions which appeared to influence household behaviour. The households sampled registered a per person usage 15% lower than the mean use of all YVW residential customers [*Roberts et al.*, 2011]. The result made it difficult to undertake a robust comparison against the Adelaide study. Therefore the focus was on comparing the Adelaide data to data from the YVW 2004 and SEQ 2010-2011 studies. To understand the differences in the end-uses between the various studies the appliance characteristics (proportion of efficient appliances and mean flow rate/volume) and the users' behaviour (duration and frequency) are compared in the following sections.

Table 3.5: Comparison of usage to recent studies

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Number of Households	140	100	100	252
Mean occupants per household	2.5	3.1	3.2	2.6

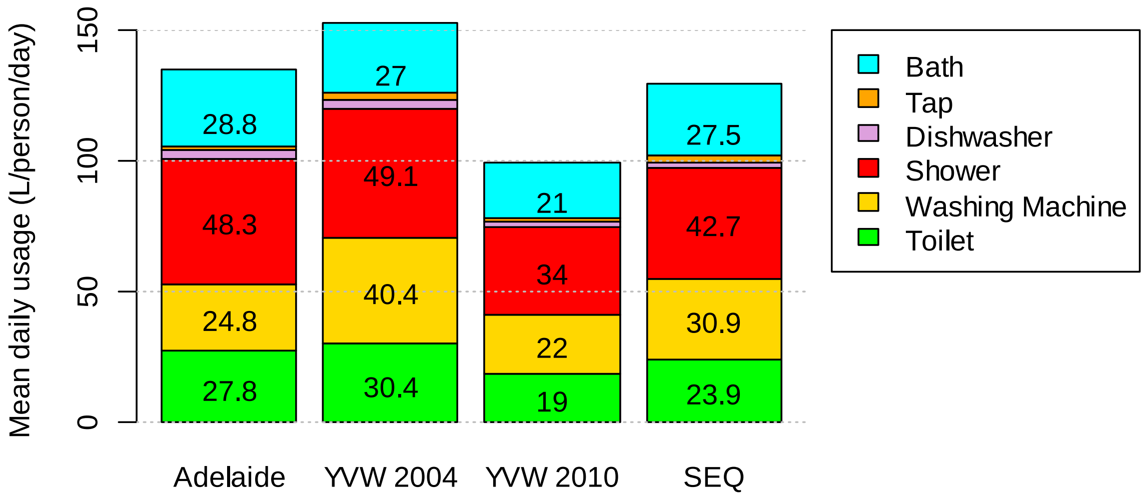

Figure 3.23: Comparison of end usage results from recent studies

3.6.1 Washing machine end-use

The difference in washing machine end-use was primarily due to the differences in load volume (Table 3.6). The 2004 YVW study had the highest usage and the highest load volume of all the recent Australian water usage studies. This can partly be explained by the fact that participants in the YVW study owned the highest proportion of top loaders (Figure 3.24 and Table B.6), which have typically larger load volumes than front loaders. The difference in load volume might also be due to the increased efficiency of both top and front loaders since 2004. The SEQ study also included a higher proportion of top loaders than the Adelaide study, and hence an associated higher usage. The weekly loads per household were greater for the 2004 YVW study due to the higher mean occupancy which increased loads per household. (Occupancy effects on washing loads per household will be explained in subsection 4.3).

Table 3.6: Comparison of mean washing machine event statistics

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Usage (L/person/day)	24.8	40.4	22	30.9
Load Volume (L)	81.8	143	110	104.6
Frequency (/household/week)	5.1	6.4	4.5	4.4

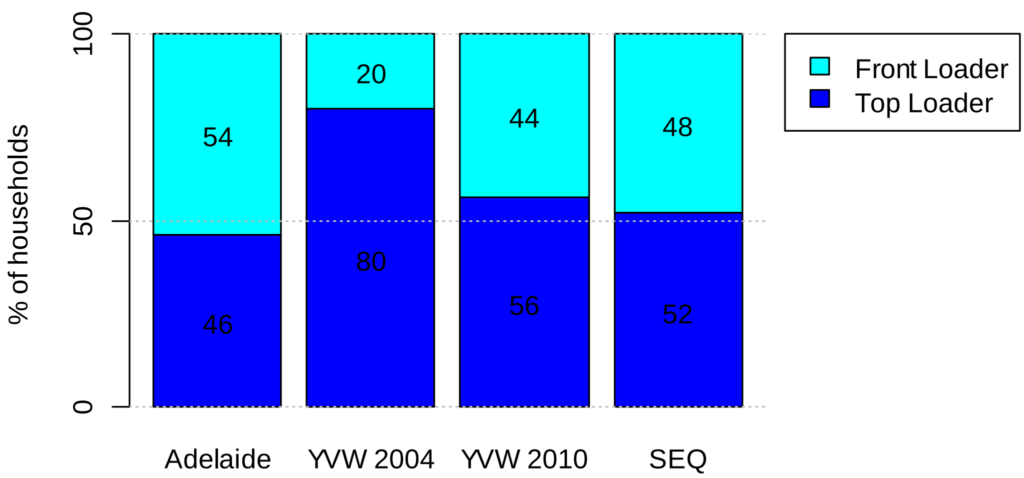

Figure 3.24: Comparison of washing machine types in recent studies

3.6.2 Toilet end-use

Comparing toilet usage across the studies (Table 3.7), the Adelaide study recorded the second highest usage, with only the 2004 YVW study having a higher average. The flush volume for the Adelaide 2013 and SEQ studies was similar, because the proportion of efficient toilets was also similar according to the data (Figure 3.25). All the more recent studies recorded far higher proportions of toilet efficiencies than the YVW 2004 study, reflecting the impact of rebates for efficient toilets and the fact that inefficient toilets have largely disappeared from the marketplace.

Toilet usage recorded in the Adelaide study is high compared to usage recorded in the SEQ study due largely to the much greater frequency of flushing (Table 3.7). Variation in the toilet usage could be the result of differences in the demographics of the households. For example, houses with small children may have lower toilet use while older occupants may spend more time at home leading to higher frequencies. The effect of demographics on toilet use is investigated in subsection 4.3.

Table 3.7: Comparison of mean toilet event statistics

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Usage (L/person/day)	27.9	30.4	19	23.9
Flush Volume (L)	5.8	7.6	5.6	5.8
Frequency (/person/day)	4.8	4.2	3.9	3.7
Half: Full Flush ratio	58:42	43:57	52:48	56:44

*SEQ values not explicitly given in report, values for different regions combined.

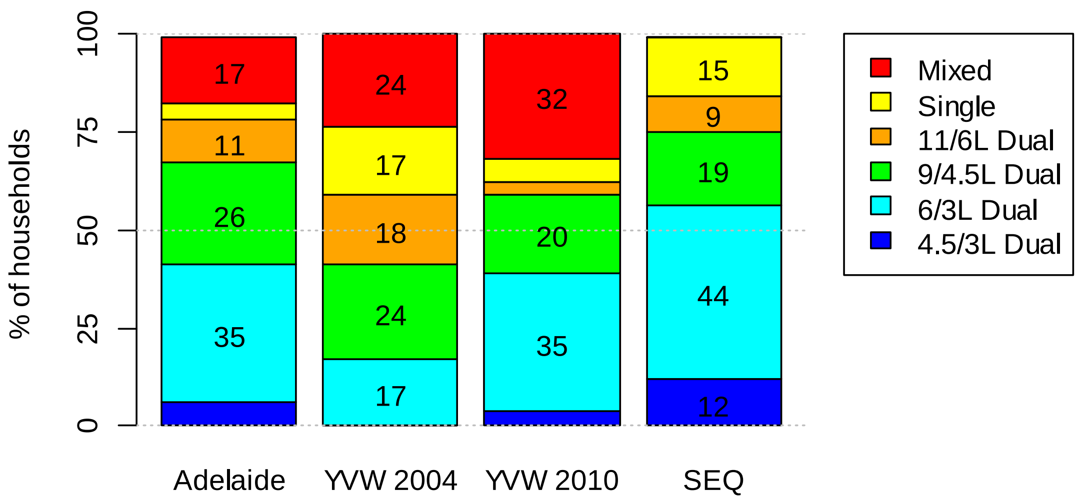

Figure 3.25: Comparison of toilet types in recent studies

3.6.3 Shower end-use

The Adelaide study recorded shower use similar to the YVW 2004 study and higher than the SEQ study (Table 3.8). Given the proportion of efficient showers (Figure 3.26) reported in the Adelaide study, this was unexpected. Adelaide, however, recorded a greater frequency of shower use (25% higher) than the SEQ study. SEQ's lower shower use might be attributed to the shorter duration and frequency of showers when compared to Adelaide (Table 3.8). The differences in shower use frequency may be attributed to the demographics, and the effect of demographics on shower use is investigated in subsection 4.3.

Table 3.8: Comparison of mean shower event statistics

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Usage (L/person/day)	48.3	49.1	34	42.7
Flow rate (L/min)	7.9	9.5	7.3	8.0
Duration (min)	6.3	7.1	7.1	5.9
Frequency (/person/day)	1.0	0.8	0.7	0.8

*SEQ values not explicitly given in report, values for different regions combined.

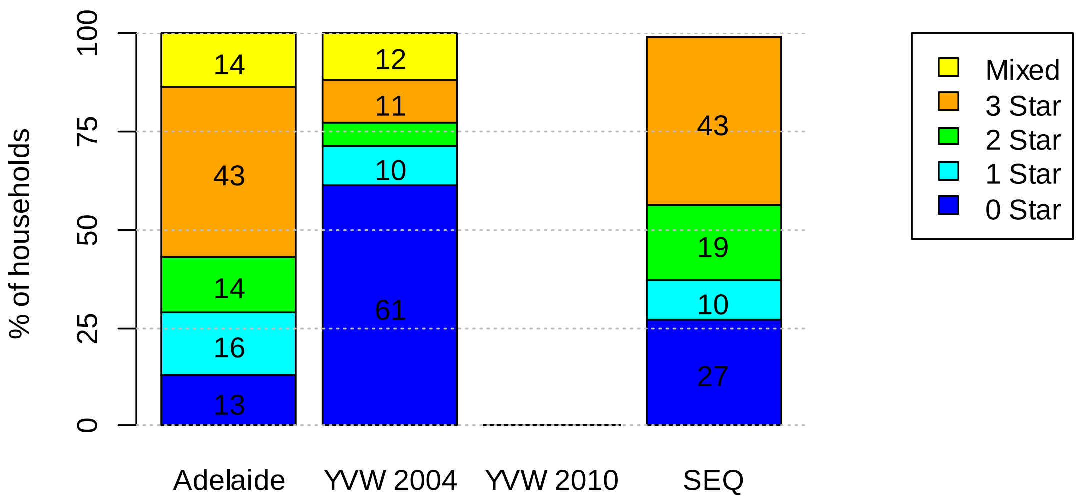

Figure 3.26: Comparison of shower efficiencies in recent studies

3.6.4 Other end-use

The mean event statistics for dishwasher, tap and bath usage are shown in Table 3.9. Bath and dishwasher use are both a small proportion of overall use for all studies. Dishwasher efficiency appears to have increased over time due to the reduction in load volume and the frequency is similar for all studies. Tap usage was relatively consistent between studies, aside from YVW 2010.

Table 3.9: Comparison of mean event statistics

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Dishwasher				
Usage (L/person/day)	1.7	2.7	1	2.5
Load volume (L)	15.7	23.9	16	22
Frequency (/household/week)	3.8	3.4	3.5	3.6
Tap				
Usage (L/person/day)	28.8	27.0	21	27.5
Flow rate (L/min)	2.1	3.3	3.0	-
Frequency (/person/day)	28	29	24	20
Bath				
Usage (L/person/day)	3.0	3.2	2	1.8
Volume	60.0	123	128	-
Frequency (/household that use bathtub /week)	3.2	2.6	2.2	-

*SEQ values not explicitly given in report, values for different regions combined.

Differences in demographics and attitudes to water use may also have an influence on the individual end-uses. Detailed analysis of the impacts of the demographics, attitudes and behaviours on water use is further examined in Section 4.

3.7 The impact of leakage on overall usage

What water is lost through leakage? Does a small proportion of households account for the majority of the leakage?

The flow trace analysis splits the usage into the end-uses, including leakage, and is the most accurate way of assessing leakage. However, it represents only a short snap shot of the system during the winter months. The findings on leakage for the two week period are as follows:

- Eight percent (8%) of the total winter usage could be assigned to leakage (60kL).
- The leakage proportion of total water use is likely to be lower because winter measurements do not include the higher summer usage.
- Nine (9) homes (6%) contributed 68% to the total leakage volumes. Two homes had very large leaks of 14kL and 12kL in total over the recording period, averaging 40 L/h and 37 L/h respectively, which contributed 44% of leakage overall. Another seven homes had leakage averaging over 4L/h totalling 20KL (34%) of the overall leakage recorded during the study.
- The remaining 20 homes with leaks had leakage averaging over 0.5L/h.
- The homeowners with significant leakage were not notified, by SA water or the study team, of the leakage prior to the analysis period. However, the analysis period was changed for some of the homes with major leaks due to the complications of undertaking flow trace analysis with the presence of leaks.

A preliminary assessment of the impact of leaks over a longer period was undertaken using the meter data from March 2013 to July 2013. After July, the home owners were notified of the leaks in their home and thus new data were no longer representative of the leakage in the system and were not analysed.

- The analysis involved the visualisation of the time series for each meter to determine the presence of leaks.
- Identification was complicated by evaporative air conditioners and dripper systems as these exhibit flow trace characteristics similar to one another.
- Leakage rates were calculated by averaging the water use in the early morning (typically 1-4am) for a particular day as minimum nightly flows where expected in this period.
- Approximate volumes were based on a constant leakage rate from:
  - meter install date to last read, or where appropriate
  - start date to last read, or
  - meter install date to leak being fixed
- Five percent (5% of usage was determined to be due to leakage (425 kL).
- 35 households were found to have leaks.
- Three (2%) houses contributed 56% of the leakage volume. (One house contributed 40% of the leakage, one 11%, one 6%, the rest were less than 3% each.)

Based on the two sets of analysis above, the leakage volume was of the order of 5-8% of total winter usage. However, the observation that a very small number of households (2% -6%) contributed a large proportion of the leakage volume (56-68%) posed a challenge to the analysis. If we removed two or three high leakage households, the leakage estimate dropped by at least 50%. The estimate of leakage volume based on the data available was considered too unreliable to be representative of metropolitan Adelaide. For these reasons leakage was excluded from the end-use analysis (subsection 3.5) results and modelling (Section 5). Further monitoring is required to provide a more reliable estimate of the leakage volume for metropolitan Adelaide.

The data collected from the high resolution meters provided a unique opportunity to enable easy identification of leakage within a home, and the method of data measurement could be used to notify home owners of leaking appliances and/or pipe break events. Additional analysis is required to determine the influence of different types of leakage events, such as leaking appliances and pipe break events. A longer data set (more than year) and more houses are required to provide a more reliable estimate of the leakage volume for metropolitan Adelaide.

3.8 Summary of general water use

The evaluation of the representativeness of the study households with Greater Adelaide ABS statistics resulted in the following findings:

- Household occupancy composition and age range were reasonably representative, but with a tendency for older adults to be over-represented.
- Household income and family type were similar for 63% of income/family groups. Medium income couples with no children and high income non-family households were over-represented, while low income, one parent with children families and low income non-family households were under-represented.
- Dwelling structure (owner occupied, established, detached households) represented 60% of households in Greater Adelaide.
- The proportion of efficient showerheads and dual flush toilets was similar to the SA ABS statistics, while the proportion of front loading washing machines was over-represented. This may have led to an under-estimate of water use as front loaders are generally more efficient than top loaders.
- Household visits were required to identify the efficiency of showers and toilets. Householder surveys (phone or online) proved inadequate as householders were unable to easily calculate toilet volumes accurately or identify showerhead efficiency.

3.8.1 General trends in water use

- Total annual water usage of the study households was 588 L/household/day, based 2012-2013 billing data. This is 10% higher than the average household from metropolitan Adelaide based on the 2012/13 SA Water Annual Report [*SA Water*, 2013].
- For the monitoring period (March 2013-Feb 2014), water usage was 618L/household/day. This higher usage is possibly due to the unusually hot 2013/14 summer.

- During winter (June-Aug) the mean daily per person usage was 153 L/person/day, which increased to 498 L/p/day (Dec-Feb) during summer due to outdoor usage and other seasonal changes, such as the use of evaporative air conditioners.
- 64% of the recorded daily per person usage was less than 200 L/person/day. However, some households recorded usage of greater than 1000 L/person/day on particular days during summer.
- Analysis of the peak demand days found that a small number of households made large contributions to the peak daily demand. The top 20% of households contributed to 50% of demand on peak days. Targeting these households has the potential to lead to reductions in peak demand.
- Diurnal use pattern in winter displayed a morning peak, which changes to an afternoon peak in summer.
- The two week flow trace analysis period was representative of winter water use for the flow trace analysis households in terms of overall usage and diurnal pattern.
- Using winter water usage values over-estimated indoor usage as 7% of use was due to irrigation and 5-8% due to leakage.
- Leakage volume was estimated to be 5-8% of winter usage for study households. As a small number of households (2-6%) contributed to over 50% of the leakage volume, it is unclear how representative the figures for leakage would be for the whole of metropolitan Adelaide.

3.8.2 Flow trace analysis on indoor end-use

Total indoor usage was 134.5 L/person/day, 5% lower than the estimate based on 'Water for Good' [*Government of South Australia*, 2010]. The main differences in the individual end-uses were the result of reductions in shower/bath usage and washing machine usage.

- Shower usage was 36% of indoor usage (48 L/person/day). The end-use with the highest per person daily usage and variation was showering, with peak usage occurring in the morning.
- Toilet usage was 21% of indoor usage (28 L/person/day). There was a slight peak in usage in the morning.
- Washing machine usage was 18% of indoor usage (25 L/person/day). Peak usage of washing machines usage occurred mid-morning.
- Tap usage was 21% of indoor usage (29 L/person/day). Tap usage remained relatively constant throughout the day.
- Dishwasher and bath usage was small and distributed throughout the day.

3.8.3 Comparison with other studies

The Adelaide study was compared to three interstate end-use studies, Yarra Valley Water 2004, Yarra Valley Water 2010 and SEQ 2010-2011, with the following findings:

- The YVW 2010 study reported substantially lower indoor water use compared with the other studies, possibly due to substantial water restrictions in place at the time of the study.
- Differences in total usage can in general be attributed to variation in household size, appliance stock changes and behavioural differences.

- The overall efficiency of appliance stock is increasing over time as demonstrated by the results of the YVW 2004 study in which the performance of significantly less efficient stock was measured.
- The Adelaide study had the lowest daily usage per person for washing machine use as the study had the highest percentage of front loaders, which generally have a lower load volume.
- Toilet flush frequency was higher for the Adelaide study, possibly due to differences in the demographics of the study participants.
- Behaviour (frequency and duration) had a significant influence on the amount of water used when showering. The demographics of the study households may be the reason for the differences. The Adelaide study reported high shower usage due to increased frequency and duration, although the efficiency of the appliance stock was high.

4 Analysis of key drivers of indoor water use

4.1 Comparison between actual and perceived variation in indoor end-uses between households

How does indoor water use vary between households?

The breakdown of the end-uses for each household during the flow trace period is shown in Figure 4.1. Households with similar total usage varied considerably in the ways they used water as evident by the different end-use proportions. Both the appliance efficiencies and household behaviours were idiosyncratic with the result that individual households exhibited end-use variations which were considerably different to the mean end-use split.

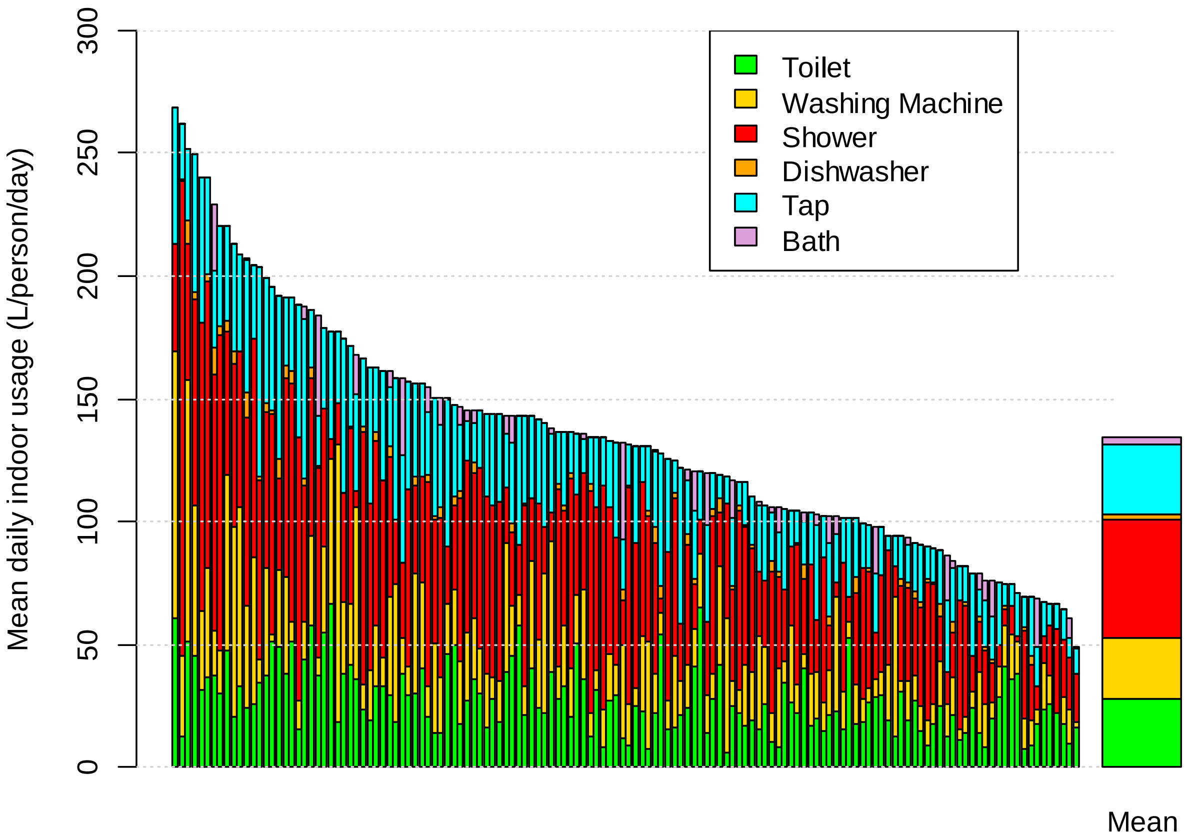

Figure 4.1: Indoor daily per person end-use for each household ordered

How accurate was self-reporting of proportion of household water end-use?

The respondents of the end-use survey were asked to specify what proportion of their water use could be assigned to which appliances during winter. The categorisation of tap/dishwasher and shower/bath from 'Water for Good' [*Government of South Australia*, 2010] was used when surveying the respondents. The comparison of the perceived proportions with the actual proportions from the flow trace analysis is shown in Table 4.1. The mean of the estimates of the outdoor and taps/dishwater use was not significantly different from the actual usage ($p>0.05$). However, the ability of the individual respondent to identify their individual household end-usage percentages was poor (negative NSE) as seen by the variance from the line of best fit in Figure 4.2(a). On average, respondents overestimated laundry use and underestimated toilet and shower/bath use. The underestimate of toilet use can be seen in Figure 4.2(b).

Table 4.1: Perceived versus actual usage from flow trace analysis

	Mean measured % by person daily usage	Mean winter % usage estimate for flow trace households	Statistically significant difference	NSE (Nash-Sutcliffe efficiency)
Outdoor	6	8	No	-0.12
Taps/Dishwasher	21	21	No	-1.62
Laundry	17	23	Yes	-0.96
Toilets	20	17	Yes	-0.15
Showers/baths	36	31	Yes	-0.28
Total	100	100		

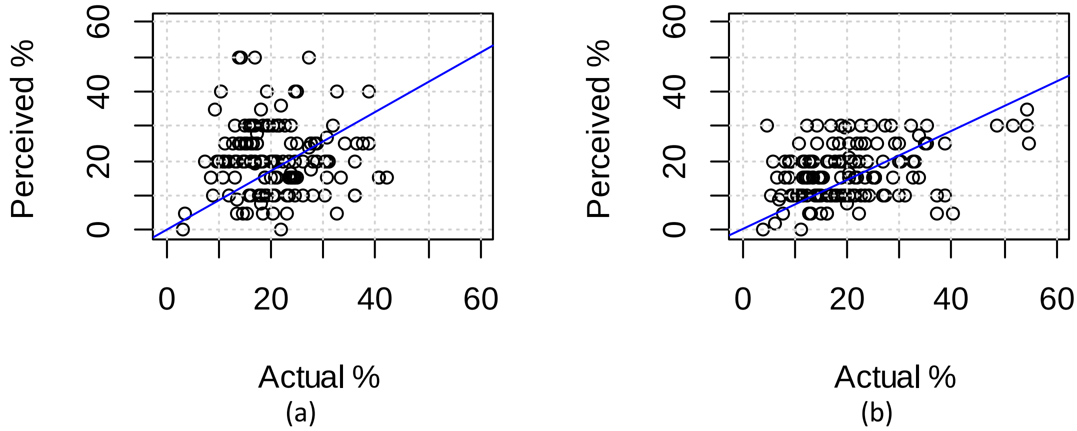

Figure 4.2: Perceived versus actual end-use proportions for (a) taps/dishwasher and (b) toilets

4.1.1 Comparison to previous studies

The variation of usage by end-use in households with similar total usage was also found in the 2011 SEQ study [*Beal and Stewart*, 2011]. In addition, the householders were unable to accurately categorise themselves as high, med or low water users [*Beal and Stewart*, 2011; *Beal et al.*, 2011a]. The results of the SEQ study are further discussed in subsection 4.5.1. The participants were not asked to specify the proportion for each end-use. However, it was found that the self-reporting low and medium users had higher taps, shower and laundry use than those that identified as high users.

4.1.2 Summary and practical implications

The differences in the perceived and actual use indicate that surveying households is not sufficient when attempting to determine the proportions of each end-use. In general:

- End-use proportions vary considerably between households, and are often quite different to the mean end-use proportions from all households.
- While a household is aware of their total water use through their billing accounts, the proportions associated with each end-use appear not to be well known.
- Practical implications are that water saving opportunities will vary significantly between households and that households need greater education, including self- and institutional monitoring, to ensure they understand what water usage occurs to enable them to identify water saving opportunities.

Overall, the research demonstrated that households vary considerably in individual end-use from the mean measured usage. Different groups of households with different appliance stocks and behaviour exist. The impact of efficient appliances and different demographics are investigated in more detail in the next subsections.

4.2 The impact of water efficient appliances

4.2.1 Summary of potential savings

How does the efficiency of the appliances affect water use? Which water use appliances should be targeted to reduce water use?

The differences between the efficient and non-efficient water appliance households in terms of mean daily water use per person per end-use are shown in Table 4.2. The data indicate that a 19.3 L/person/day reduction in water use to 115.2 L/person/day is possible from a change to all efficient appliances (shower, toilet, laundry). All differences were found to be statistically significant. The reasoning behind these values is discussed below.

Table 4.2: Potential savings in mean daily indoor use through efficient appliances

	Shower	Toilet	Washing Machine	Total
Efficient refers to	< 9L/min flow rate	6/3L Dual flush	Front Loader	-
% of households with efficient appliance	43%	35%	55%	-
Efficient households (L/person/day)	42.8*	22.8*	16.1*	-
Non-efficient households (L/person/day)	52.5	30.6	35.1	-
All households (L/person/day)	48.3	27.9	24.8	-
Potential Savings(L/person/day)	5.5	5.1	8.7	19.3

*Differences in water use between efficient and non-efficient households is statistically significant ($p<0.05$) for all end-uses

Differences in appliance efficiency were found to be the governing factor for all three appliance types as a change in appliance efficiency resulted in a higher statistical significance than any of the behavioural changes.

4.2.2 Changes in shower usage

Shower usage, flow rate and behaviour related to efficient and non-efficient shower heads are compared in Table 4.3. The difference in mean duration is statistically significant; however the mean flow rate was found to have a greater significance and percentage difference (29%). It can therefore be inferred that the efficiency of the showerhead is the main influence in the reduction of water usage. The efficiency of the shower was estimated based on the maximum flow rate recorded during the water appliance audit. Efficient shower heads refer to nominal flow rates < 9 L/min (3 star) and non-efficient nominal flow rates > 9 L/min (0 -2 stars). Star ratings are based on the Water Efficiency Labelling Standards (WELS) scheme.

Table 4.3: Comparison of efficient and non-efficient showers

	Nominal flow rate (L/min)	Number of households	Mean daily shower usage (L/person/day)	Mean flow rate (L/min)	Mean duration (minutes)	Frequency (showers/ day)
Efficient	< 9	60	42.8	6.8	6.5	1.0
Non efficient	> 9	80	52.5* (23% increase)	8.8* (29 % increase)	6.2* (5% decrease)	1.0
All	-	140	48.3	7.9	6.3	1.0

* Significant difference ($p<0.05$) from efficient household events

4.2.3 Changes in toilet usage

The variation in toilet water usage and behaviour of the efficient and non-efficient toilet households is shown in Table 4.4. The difference in the mean daily flushes per person was not statistically significant, indicating toilet volume was the governing factor in the reduction in per person toilet water usage. It was also noted that the mean flush volume for efficient dual flush toilets was closer to the full flush volume than for the inefficient toilets. The ratio of half to full flushes confirmed a higher proportion of full flushes for the efficient dual flush toilets.

Table 4.4: Comparison of toilet types

Toilet category	Number of households	Mean daily toilet usage (L/person/day)	Mean volume per flush (L)	Mean daily flushes per person
Efficient (6L/3L dual)	49	22.8	5.0	4.6
Non-efficient	91	30.6*	6.2*	4.8
All	140	27.9	5.8	4.8

* Significant difference ($p<0.05$) from efficient household events

4.2.4 Changes in washing machine usage

The significant variation in washing machine types between the mean volume per load for top and front loading washing machines resulted in a distinct variation in the water used by households in each category (Table 4.5).

Table 4.5: Comparison of top loaders and front loaders

	Number of households	Mean volume per load (L)	Mean daily per household washing machine usage (L /day)	Mean daily per person washing machine usage (L/person/day)
Top Loaders	64	117.1	70.9	35.1
Front Loaders	76	52.5*	42.2*	16.1*
All	140	81.8	55.6	24.8

* Significant difference ($p<0.05$) from top loader household events

As shown in Table 4.6, top loaders recorded a lower mean number of loads per week; however this was due to the proportion of smaller household sizes, as the mean number of loads per person was the same. It can thus be inferred that washing machine usage per person is governed primarily by washing machine load volume, and changing all washing machines to front loaders would result in a possible 8.7 L/person/day reduction in laundry water use.

Table 4.6: Comparison of top loaders and front loaders loads per week

	Number of households	Mean household size	Mean no of loads per week	Mean no of loads per week /person
Top Loaders	64	2.2	4.3	2.2
Front Loaders	76	2.8*	5.8*	2.2
All	140	2.5	5.1	2.2

* Significant difference ($p<0.05$) from top loader household events

4.2.5 Comparison to previous studies

The effect of efficiencies on end-use was considered by the previously cited end-use studies for YVW 2004 [*Roberts*, 2005] and YVW 2010 [*Roberts et al.*, 2011] and SEQ [*Beal and Stewart*, 2011]. The differences in shower usage for different efficiencies are shown in Table 4.7. The key results compared to Adelaide were:

- In terms of efficient shower heads, the YVW studies found similar flow rates as the research in Adelaide; while for non-efficient shower heads, the flow rates in Adelaide were lower than the 2004 YVW study due to the lower proportion of 1-2 star shower heads found in the Adelaide study households.
- Nevertheless, the volume of water used for showering in the Adelaide study was similar to that used in the 2004 YVW study due to an increased frequency of showering in the Adelaide study.
- The increased frequency and duration of showering observed in the Adelaide study meant that Adelaide recorded higher shower usage than the SEQ study.
- The SEQ study reported greater water savings than were recorded in Adelaide because of the different behaviour compared to Adelaide (shorter duration and lower frequency).
- The YVW studies did not differentiate usage by efficiency type; thus savings could not be estimated.

Table 4.7: Comparison of showers (efficient refers to <9L/min nominal flow rate)

	Adelaide	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Proportion of households with efficient appliance	0.42	0.11	-	0.43
Efficient households (L/person/day)	42.8	-	-	35.8
Non-efficient households (L/person/day)	52.5	-	-	-
All households (L/person/day)	48.3	49.1	34	42.7
Potential savings(L/person/day)	5.5	-	-	6.9
Efficient showers mean flow rate (L/min)	6.8	6.7	6.3	-
Non-efficient showers flow rate (L/min)	8.8	9.9	8.7	-
All showers flow rate (L/min)	7.9	9.5	7.3	8.0
Duration (min)	6.3	7.1	7.1	5.9
Frequency (showers/person/day)	1.0	0.8	0.7	0.8

The differences in toilet usage for different cistern volumes are shown in Table 4.8. The key results compared to Adelaide were that:

- The volume of water used in the toilet was similar to that in the 2004 YVW study, despite the higher proportion of efficient toilets in Adelaide. An increase in frequency is likely responsible.
- The volume of water used in the toilet was higher than in the SEQ study. The SEQ study included a higher proportion of efficient appliances (possibly due to newer housing stock). However, the mean flush volume was the same as the Adelaide study. Again, increased flush frequency was the likely cause of increased usage of water in the toilet.

Table 4.8: Comparison of toilets (efficient refers to 6L/3L dual)

	Adelaide	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Households with efficient appliance	0.36	0.17	0.35	0.44
Efficient households (L/person/day)	22.8	19.3	17.5	-
Non-efficient households (L/person/day)	30.6	33.6	20.7	-
All households (L/person/day)	27.9	30.4	19.5	23.9
Possible savings(L/person/day)	5.1	11.1	2.0	-
Efficient flush volume (L)	5.0	5.8	5.2	-
Non-efficient flush volume (L)	6.2	7.8	5.8	-
Mean flush volume (L)	5.8	7.6	5.6	5.8
Frequency (/person/day)	4.8	4.2	3.9	3.7
Half: full flush ratio	58:42	43:57	52:48	56:44

The differences in washing machine usage for top and front loaders is shown in Table 4.9. When compared to the Adelaide study, the key results were that:

- Across all studies there was significant variation in washing machine usage for both top and front loaders.
- Recent studies (Adelaide, YVW 2010, SEQ 2011) all show the potential for more than 8 L/person/day savings if all washing machines were switched to front loaders.
- The Adelaide study produced the lowest front loader volume/load volume of all the studies.
- Water use by front loaders in the Adelaide study was lower than water use in the SEQ study because the volume of water per load was lower, which counteracted the increased frequency.
- Front loader usage was higher in the Adelaide study than in the YWV 2010 study. The higher frequency of usage counteracted the lower volume of water required per load.
- As the WELS star ratings of front loaders and top loaders can be different (and change through time), future studies should compare star ratings of washing machines, rather than top and front loader.

Table 4.9: Comparison of washing machines

	Adelaide	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Proportion with front loaders	0.54	0.2	0.44	0.48
Front loader households (L/person/day)	16.1	-	13	22.5
Top Loader Households (L/person/day)	35.1	-	30	33.8
All households (L/person/day)	24.8	40.4	22	30.9
Possible savings (L/person/day)	8.7		9	8.4
Front loader (L/Load)	52.5	75	64	64.8
Top loader(L/Load)	117.1	152	147	91.9
Mean load volume (L)	81.8	143	110	81
Frequency (/household/week)	5.1	6.4	4.5	4.4
Frequency (/person/week)	2.0	2.1	1.3	1.7

4.2.6 Summary and practical implications

Key results from the analysis of the difference between efficient and non-efficient water appliances were that:

- Reductions in per person water use were primarily influenced by appliance characteristics and not by differences in behaviour, as behaviours (frequency/duration) were not found to significantly vary between efficient and non-efficient households in the Adelaide study.
- In practical terms a change of appliance stock would result in a reduction in water use and thus schemes/projects that encourage appliance changes are recommended, with consideration of barriers to uptake (see discussion in subsection 7.3).
- Washing machines represent the appliance for which the greatest potential water savings can be made. However, they also represent an appliance for which consumers have a choice between different efficiency options, unlike showers and toilets for which only high efficiency options are available. Thus, schemes that encourage switching to front loaders or efficient top loaders are recommended. The potential barriers to the uptake of front loaders, such as length of the washing cycle, not being able to add clothing once the cycle has started, and the need to bend down when loading or unloading the machine need to be considered for these schemes.
- Comparison with previous studies showed differences in water usage for different appliances was due to a combination of differences in appliance efficiency and behaviour. Hence, schemes that encourage changes in behaviour should also be considered. Note that it was outside the scope of this study to understand drivers of behaviour change. This is further discussed in subsection 7.3.
- Differences in showering behaviour (duration and frequency) were found between recent studies, which influences variation of water usage in the shower. The efficiency of water using appliances is steadily increasing and for areas experiencing growth only efficient showerheads and toilets are currently on the market. The uptake of these appliances will therefore increase over time as households replenish their appliance stock. The efficiency of dishwashers, taps and washing machines is also increasing.
- Star rating based comparisons of washing machines may yield more information, as an inefficient front loader may use more water than an efficient top loader.

4.3 The impact of household occupancy and age composition

How does increased household occupancy affect water use?

The mean daily indoor household usage was influenced by household size as shown in Figure 4.3 to Figure 4.5. Figure 4.3 shows the increasing trend as household size increases for the flow trace households. Note that there was only one household with six occupants. Figure 4.4 shows the mean proportions of each indoor per person end-use for the different household sizes and that in general the usage scales with household size for the higher volume end-uses (toilet, washing machine, shower, tap). The indoor usage per person for each household size, as shown in Figure 4.5, provides a clearer indication of the influence of household size on individual end-uses. It shows that toilet and washing machine per person usage decreases with increasing household size, while the shower per person usage increases with increasing household size. The reasons for this will be explained below.

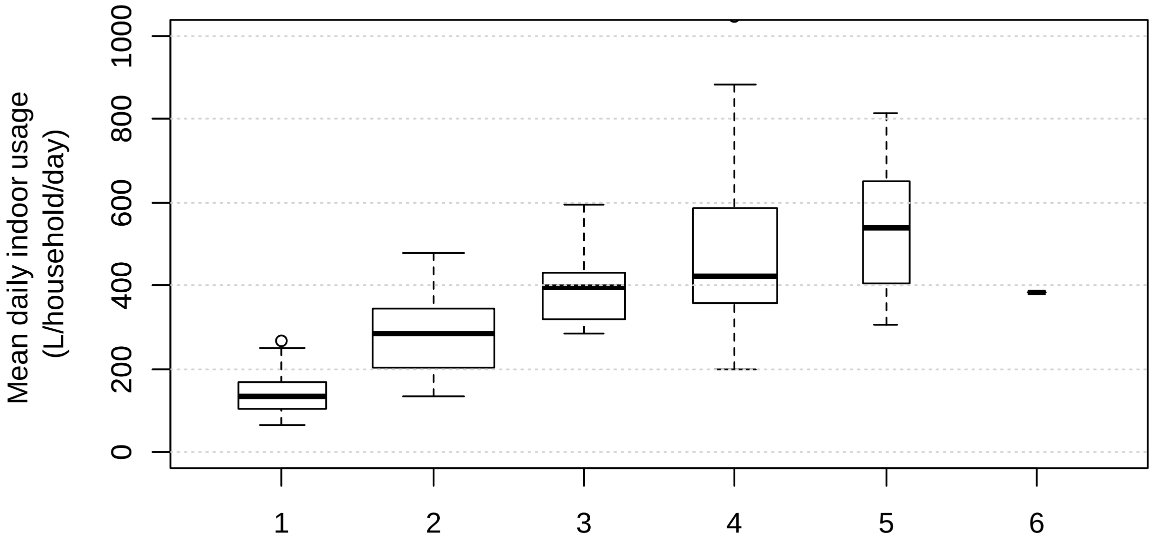

Figure 4.3: **Mean daily indoor usage (L/household/day) by household size (width of boxplot indicates number of households in each category)**

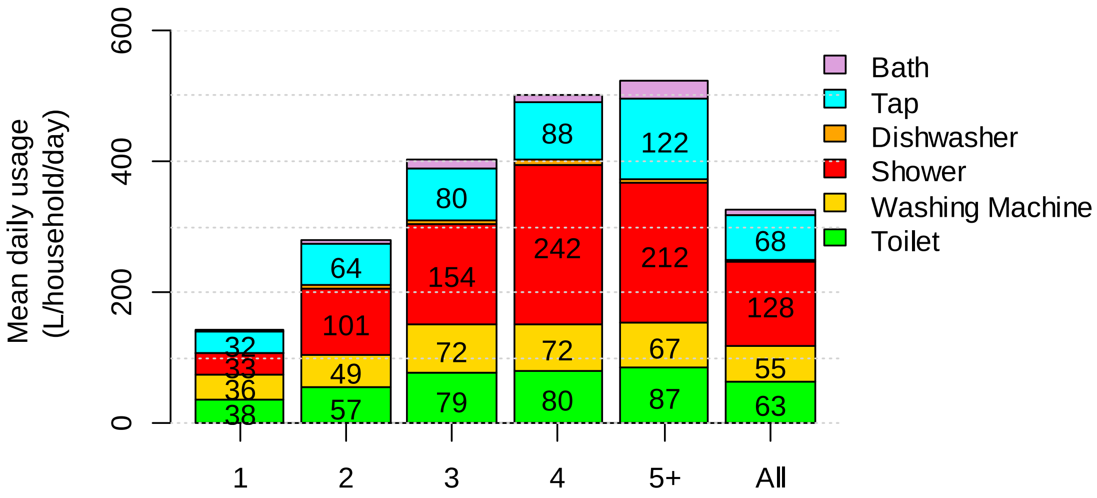

Figure 4.4: **Mean usage for each indoor end-use (L/household/day) by household size**

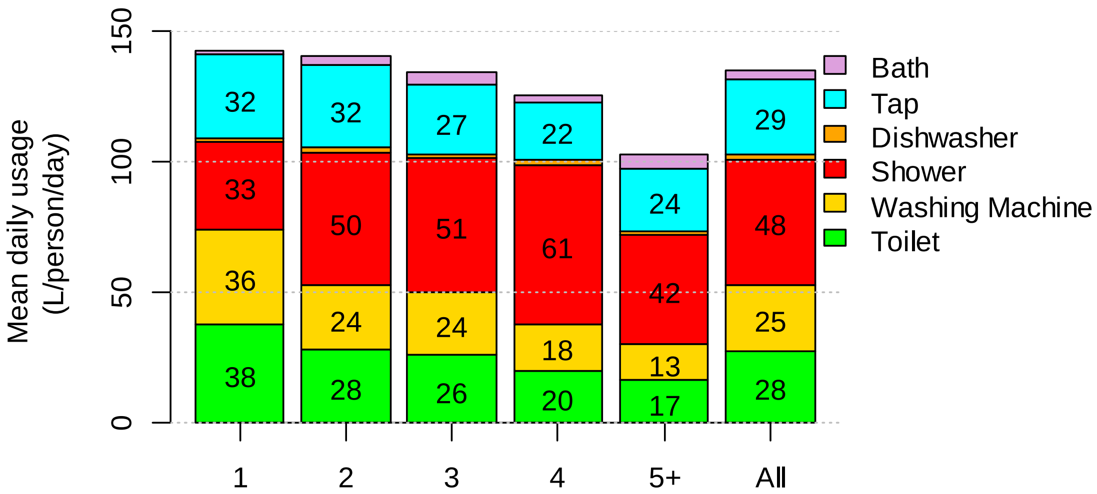

Figure 4.5: **Mean usage for each indoor end-use (L/person/day) by household size**

For shower usage, as the household size increased, the daily per person household shower use increased (neglecting 5+ households due to the small sample size). The composition of the households might influence showering behaviour, as children were only present in households with three or more occupants in this study, and the mean age of the occupants in the one occupant households was 70.1 (respondents to the end-use survey). This is further explored later in this section.

The mean age of 70.1 years for the one occupant households might account for the 35% increase in daily per person toilet usage for these households when compared to the two person households (Figure 4.5) as the occupants, being above retirement age, were more likely to be home. The reduction in frequency of toilet flushing as household size increased from three to five might be due to the presence of children under five who are not toilet trained and older children attending school. Retirement age and the presence of children are investigated later in the report.

For washing machine usage, as household size increased the daily per person washing machine use decreased. The frequency and volume of washing machine loads were responsible for the changes in washing machine water usage. As shown in Table 4.10, as household occupants increased, the number of washing machine loads increased, while the loads per person decreased (neglecting the 5+ occupant households due to the small sample size). The trend in the mean volume per load is fairly consistent for the two washing machine types. Household size must be taken into account when projecting future washing machine use.

Table 4.10: Washing machine volume and load frequency with household size

Household size	Number of households	Mean volume per load – Top Loader (L)	Mean volume per load – Front Loader(L)	Mean volume per load – All (L)	Mean no of loads per week	Mean no of loads per week /person
1	29	103.0	55.7	89.9	2.6	2.6
2	53	121.8	52.0	82.8	4.4	2.2
3	24	122.1	49.8	73.9	7.1	2.4
4	25	128.6	54.5	78.2	6.6	1.7
5	8	109.6	52.5	66.8	7.8	1.6
6	1	190.4	-	190.4	2.5	0.4
All	140	117.1	52.5	81.8	5.1	2.2

How does the presence of children and pensioners affect water use?

Figure 4.7 shows the mean proportions of each indoor end-use for various age ranges compared to households with children (19 and under) and the overall study. The difference in total indoor use between households with adults 20-54 only and adults 55+ only was not significant; however there were significant differences in individual end-uses. Some households were excluded from this analysis due to unknown adult ages as changes in household size occurred between the preliminary survey and the household surveys, which did not have an adult age breakdown. The ages from the preliminary survey were used for all households that did not have a change in occupancy or number of adults.

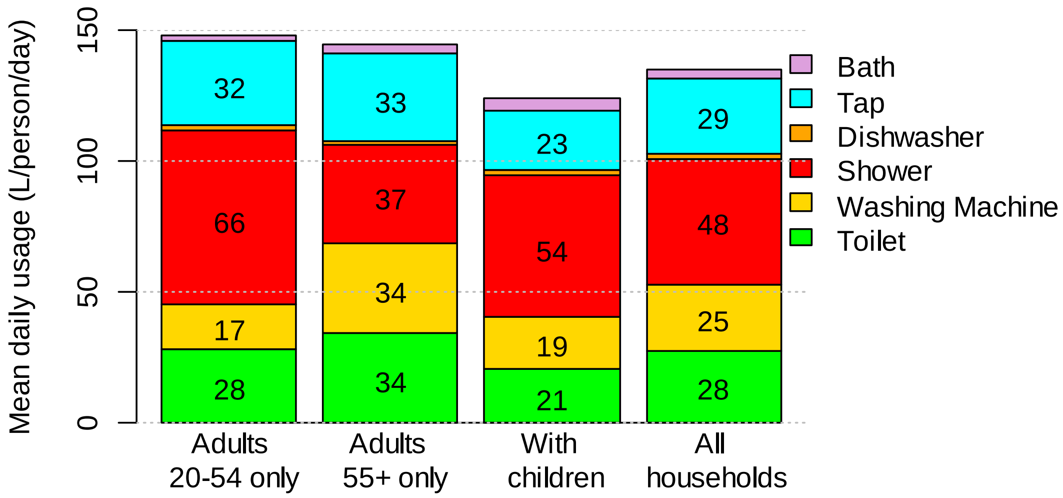

Figure 4.6: Mean usage for each end indoor use (L/household/day) for various age groups

Households identified as representing ‘adults 55+ only’ had significantly lower shower water usage than households with adults 20-54, as well as households with children, which recorded similar results. The lower water usage in the adults 55+ only households was due to a behavioural difference. Adults in this age group in this study took shorter showers and recorded a lower mean flow rate (Table 4.11).The lower mean flow rate cannot be clearly explained by the differences in the proportion of efficient showers. Therefore, it is likely that the major driver for this difference was the decreased shower duration in households with adults 55+only.

Table 4.11: Comparison of shower usage for households with various age groups

	Number of households	% efficient	Mean daily shower usage (L/ person/day)	Mean flow rate (L/min)	Mean duration (minutes)	Mean frequency (showers/ person/day)
Adults 20-54 years old	20	35	66.0*	8.3*	6.7*	1.2
Adults 55+ only	53	42	37.2	7.6	5.3	1.0
Households with children	43	40	54.4*	8.1*	6.5*	1.1
All households	140**	43	48.3	7.9	6.3	1.0

* Significant difference ($p<0.05$) from houses with adults 55+ only. ** Note the ages of the adults in some homes were mixed or unknown

Households with children recorded a statistically significant reduction in toilet usage compared to households with adults 55+ only and households with adults 20-54 only (Table 4.12).Households with children had a reduced flush frequency compared to households with adults 55+. This is likely because 76% of occupants in the households with adults 55+ only were home more than 50% of the time according to the responses to the end-use survey, whilst children were most likely at school or below toilet training age. There was no statistically significant difference in toilet use between households with adults 55+ and households with adults 20-54 due to a combination of a significantly increased volume per flush and a significant decrease in flushes per day for the adults 20-54 years.

Table 4.12: Toilet usage and age range

	Number of households	% efficient (6L/3L and 4.5L/3L)	Mean daily per person toilet usage (L/person/day)	Volume per flush (L)	Frequency (flushes/ person/day)
Adults 20-54 years old only	20	45	28.3	6.2*	4.6*
Adults 55+ only	53	42	34.5	5.7	5.8
Households with children	43	35	21.1*	5.8	3.6*
All households	140	41	27.8	5.8	4.8

* Significant difference ($p<0.05$) from houses with Only 55+ occupants. ** Note the ages of the adults in some homes were mixed or unknown

The households with adults 55+ only recorded significantly increased washing machine water usage per person (Table 4.13). This is partially due to a decrease in the percentage of top loaders, which results in a significant increase in mean volume of load as detailed in subsection 4.2.

Table 4.13: Washing machine volume and load frequency for various age ranges

	Number of households	% Front loaders	Mean daily per person washing machine usage (L/person/day)	Mean volume per load (L)	Mean no of loads per week /person
Adults 20-54 years old	20	80	17.4*	68.6*	2.0
Adults 55+ Only	53	28	34.3	96.2	2.5
Households with Children	43	70	19.2*	74.3*	2.0*
All	140	54	24.7	81.8	2.2

* Significant difference ($p<0.05$) from houses with Only 55+ occupants. ** Note the ages of the adults in some homes were mixed or unknown

Does the age of the children effect water use?

Figure 4.7 shows the mean indoor water usage per person for each end-use for households with children. The presence of children under nine significantly reduced the per capita indoor water use. However, the reduction was not significant compared to the households with children between 10 and 19. The age of the children does have a significant impact on individual end-uses.

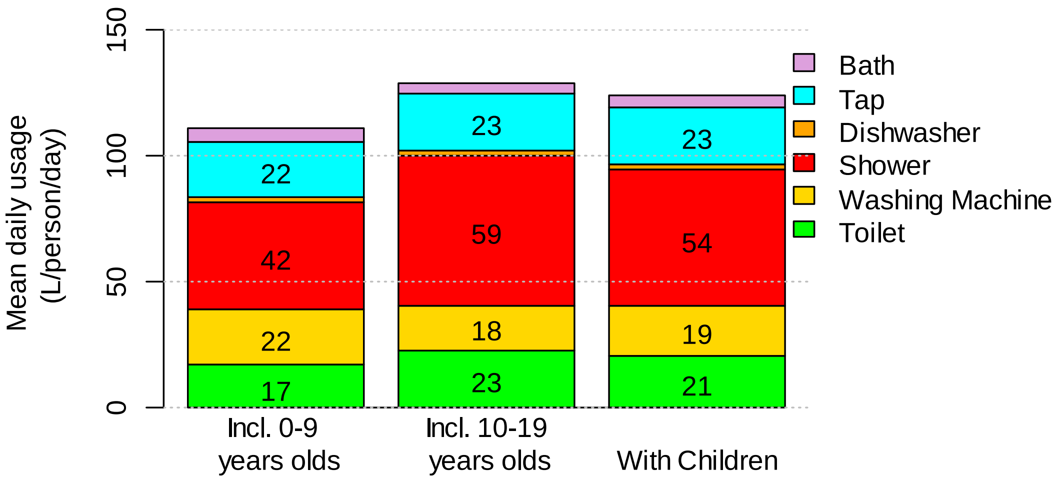

Figure 4.7: Mean usage for each indoor end-use (L/household/day) for households with children

The differences in shower usage for homes with children of different ages are shown in Table 4.14. There was a considerable difference in the mean daily usage, but it was not statistically significant, likely because of the low number of houses. However, the individual factors that contributed to water use in the shower all show significant variation. Households with children 10-19 recorded an increased duration and frequency of showering, although the flow rate was lower. The reasons for the higher mean flow rate for households with children 0-9 years old are unclear as these households had a higher proportion of 3 star showerheads installed, so there may be behavioural differences which were not considered during the study.

Table 4.14: Comparison of shower usage for households with children

	Number of households	% efficient	Mean daily shower usage (L/person/day)	Mean flow rate (L/min)	Mean duration (minutes)	Mean frequency (showers/ person/day)
Households with children 0 - 9	20	45	42.2	8.6	6.2	0.8
Households with children 10 - 19	27	37	59.2	7.7*	6.6*	1.2*
All households with children	43**	40	54.4	8.1	6.5	1.1

* Significant difference ($p<0.05$) from Includes 0-4 year olds households.** Note four households contain both children 0-9 and 10-19 years old

Toilet usage volume was affected by having young children in the household. Their presence resulted in a significant decrease in toilet flush frequency, as seen in Table 4.15. This may be due to non-toilet trained 0-4 year olds not using the toilet. The volume per flush was significantly increased for households with children 0-9 due to the lower proportion of efficient toilets.

Table 4.15: Toilet usage and households with children

	Number of households	% efficient (6L/3L and 4.5L/3L)	Mean daily per person toilet usage (L/person/day)	Volume per flush (L)	Frequency (flushes/person /day)
Households with children 0 - 9	20	30	17.4	5.9	3.0
Households with children 10 - 19	27	37	23.0*	5.7*	4.0*
All households with children	43**	35	21.1	5.8	3.6

* Significant difference ($p<0.05$) from Includes 0-4 year olds households. ** Note four households contain both children 0-9 and 10-19 years old

Households with children 0-9 were found to have the highest volume and frequency of bath usage. However, the difference in usage and frequency was not significant when compared to households that did not have occupants under 20.

There was no significant difference between washing machine usage, volumes or frequencies between the two groups.

4.3.1 Comparison to previous studies

Similar to this Adelaide study, the SEQ study and the YVW 2004 and 2010 studies found similar economies of scale, where the per person water decreases as the household occupancy increases.

As was the case in the Adelaide study, the YVW and SEQ studies found that economies of scale occur with washing machine use. Household size was found to be correlated to the number of loads of washing per household per week and was assumed to be the cause of the lower mean laundry volume per person as household size increased.

The SEQ study found that tap and toilet usage per person decreased with increased household size. The proportions of the main end-uses (laundry, shower, tap, toilet) for single person households were found to be roughly even, as with the Adelaide study. *Beal and Stewart* [2011] suggest that high end-uses for larger families, such as shower and laundry, should be targeted for reducing overall water use, rather than one person occupant households.

The Adelaide study found that the overall frequency of showering in all age categories was higher than in comparison to the previous studies. Nevertheless, all studies found that the presence of pre-teen children reduced the frequency of showering per person. The Adelaide study, for example, found reduced showering for households with children 0-9. Similarly, the YVW 2004 study found that the number of children under 12 significantly affected the frequency of showering, decreasing the frequency to 0.59 showers/person/day from 0.94 showers/person/day for households without children under 12. The YVW 2010 study also showed a decrease in frequency for young children to 0.67 showers/person/day compared to 0.76 showers/person/day for households without children.

Beal and Stewart [2011] found that the presence of teenagers significantly increased the mean daily shower per person usage and suggested houses with teenagers should be targeted for reducing water use when showering. The Adelaide study found that households with children 10-19 and households with only adults aged 20 to 54 were not significantly different in terms of shower usage. However, both of these groups exhibited a noticeable difference in usage when compared to households without children or households with pensioners.

Similar to the results for households with adults 55+ only in the Adelaide study, the SEQ study found that as age increased (the age of the survey respondent was used as a proxy for all adults in the households), shower usage decreased and the toilet usage increased.

4.3.2 Summary and practical implications

Household occupancy increases led to:

- a decrease in daily indoor usage per person
- changes in the volume of water used for each end-use
  - decrease in the toilet and washing machine volume per person
  - increase in the shower volume per person per day

This may be due to the demographics of the household and the different behaviours associated with the different ages of the occupants.

- decreased shower duration and increased toilet frequency in households with adults 55+ only occupants
- decreased shower and toilet frequency and increased bath usage in households with children 0-9

The practical implications are that:

- Households consisting only of occupants over 55 years should not be targeted for reducing shower usage; however there is potential for water savings by persuading this group to buy more efficient washing machines as only 28% of these households owned a front loader.
- For estimating the demand into the future, it is expected that the numbers of individuals living as a household group will decrease as the population ages. Since occupancy rate has a significant impact on the per capita water use and the end-use breakdown, these factors should be examined when estimating future demands.

4.4 The impact of household income level

How does gross annual household income affect water use? How does gross annual household income affect uptake of efficient appliances?

Gross annual household income levels did not significantly influence mean indoor water usage. Variations were minor, suggesting that the under-representation of low income groups among the study households had little impact on total water use in the study. This issue is further discussed in subsection 7.1. However, there was a marked variation in the usage for the individual end-uses as shown in Figure 4.8. Shower usage was significantly increased and toilet usage significantly decreased for mid and high income households compared to the low income households.

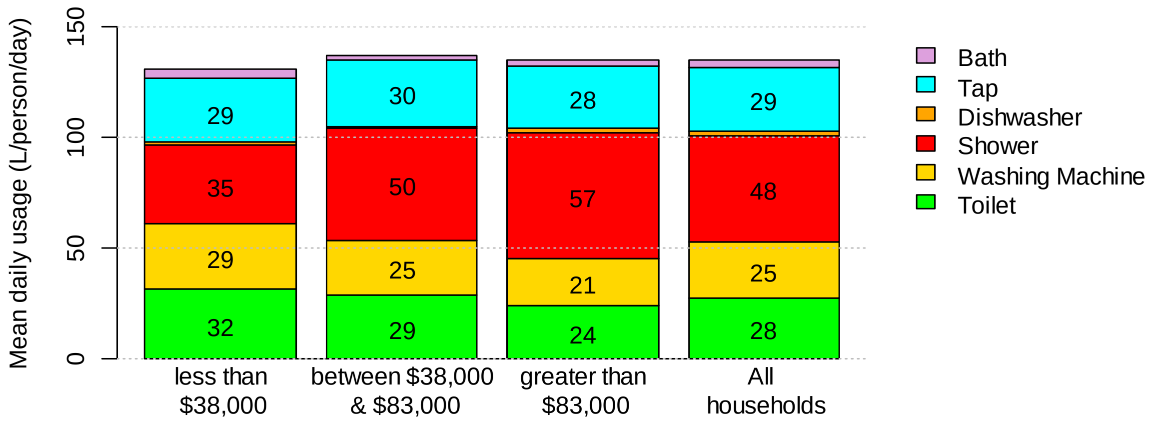

Figure 4.8: Mean usage for each indoor end-use (L/person/day) by income level

This observation may be the result of differences in household composition as shown in Table 4.16. The households with a higher gross annual household income had a higher proportion of households with children and had a larger household size. Conversely the low income households had a higher proportion of households of adults 55+ only and were less likely to contain children. This demographic characteristic in the study sample may be due to the household selection criteria, including household ownership. An increase in adults 55+ resulted in an increase per person in toilet usage and a decrease per person in shower usage among the low income households when compared with the high income households.

Table 4.16: Income level and household composition

Gross annual household income	Number of households	Mean household size	% households with children (<19)	% houses with only occupants aged 55+
Less than $38,000	40	1.9	15	68
Between $38,000 and $83,000	47	2.4	23	45
Greater than $83,000	53	3.1	49	9
All	140	2.5	31	38

The difference in toilet and shower usage was not due to a difference in the proportion of efficient devices, as the proportions were similar between groups as shown in Table 4.17. However, there is a significant variation in the proportion of front loaders, with low income homes less likely to have front loaders.

Table 4.17: Income level and efficient appliances

Gross annual household income	Number of households	Proportion efficient showers	Proportion efficient toilets	Proportion front loaders
Less than $38,000	40	0.48	0.38	0.33
Between $38,000 and $83,000	47	0.36	0.47	0.53
Greater than $83,000	53	0.45	0.40	0.72
All	140	0.43	0.41	0.54

Table 4.18 shows that for higher income households, the duration of showers was greater, likely because of the lower proportion of households with adults 55+ only and higher proportion of households with children. The mean flow rate also increased, although the proportion of efficient showers is similar. There was no significant variation in the frequency of showering, thus behaviour (duration) is the governing difference between the groups. The number of toilet flushes per day is also the dominant factor in the difference in the toilet usage between the groups and may be due to the greater proportion (74%) of occupants who are home more than 50% of the time.

Table 4.18: Income level and behaviour

Gross annual household income	Number of households	Mean duration of showers (min)	Mean flow rate of showers (L/min)	No of toilet flushes per person per day
Less than $38,000	40	5.6*	7.1*	5.3*
Between $38,000 and $83,000	47	6.3*	8.8*	5.1*
Greater than $83,000	53	6.6	7.7	4.0
All	140	6.3	7.9	4.8

* Significant difference ($p<0.05$) from houses with gross annual income greater than $83,000

4.4.1 Comparison to previous studies

The SEQ study found that increased household income was also associated with increased occupants and the associated increased water usage per household [*Beal and Stewart*, 2011]. Shower, laundry, dishwasher and bath were the end-uses that contributed most to the increase. Total usage per person was not available from the study reports and thus the studies cannot be compared with regards to this issue. Both the Adelaide and SEQ studies reported increased toilet usage for low income households. However, the Adelaide study noted an increase per person in washing machine usage for low income households in contrast to the SEQ study which found reduced water usage for washing machines.

4.4.2 Summary and practical implications

The income level of households influences water usage.

- Higher income households had greater shower usage per person, an outcome which appears to be driven by behaviour rather than by appliance characteristics. The practical implications are that these households could be targeted for education schemes on water use in showering, such as shower timer schemes which can reduce shower duration [*Willis et al.*, 2010], to reduce indoor water use.
- The majority of higher income households had already changed to front loaders, in contrast to lower income households. Although low income households might initiate water saving behaviour, the fact that they cannot or do not access to efficient appliances is negating the potential savings. The practical implications are that lower income households represent a potential target for water savings through washing machine replacement schemes.
- Toilet usage is higher in low income households, perhaps because the occupants are at home for a greater proportion of time. These circumstances may not offer an opportunity for water savings.

4.5 Comparison of actual usage to the perception of being water conservative

What was the general attitude of the end-use survey respondents towards water and the environment?

The respondents to the end-use survey (one per household) generally identified as water conservers with concern for water conservation. Broad agreement (slightly agree, agree, strongly agree) of greater than 80% was found for statements such as:

I personally think of myself as a water conserver.
I would feel guilty if I didn't save water around the house and garden.
I feel a strong personal obligation to save water around the house and garden.
I am willing to put extra effort into saving water around the house and garden.
I feel regretful if I waste water.
I think that wasting water is bad.

The respondents indicated that water conservation was important in their households. Broad agreement of greater than 80% was found for statements such as:

My household is good about conserving water.
Water conservation is important in our household
Members of my household think that engaging in everyday actions to save water around the house and garden is a good thing.
Members of my household engage in everyday actions to save water around the house and garden.
There is agreement amongst the members of my household that engaging in everyday actions to save water around the house is a good thing to do.
We think of ourselves as a water conserving household.
There is agreement amongst family members of my household that installing water efficient appliances around the house and garden is a good thing to do.

Members of my household think that installing water efficient appliances in the house and garden is a good thing.
Most individuals engage in everyday actions to save water in the house and garden.

The respondents showed concern for the environment in general. Broad agreement of greater than 80% was found for all questions in the general environment set. This could be to a bias due to the household selection process. This is further discussed in subsection 7.1.

A broad agreement of greater than 95% was found to the statement:

Having a secure water supply is important in Adelaide.

Alternative sources to desalinated water and River Murray water were sought by the respondents as indicated by broad agreement of less than 10% to the following statements:

Now that Adelaide has a seawater desalination plant, we do not need to use other water sources.
Adelaide can afford to buy River Murray water so we do not need to use other water sources.

Does a household that perceives itself to be a water conserving household use less water than a household that does not?

Survey respondents were not specifically asked if they were a high, medium or low water users. To determine if the households considered themselves a water conserving household, the mean of how strongly they agreed with the following statements on a 7 point Likert scale was used:

We think of ourselves as a water conserving household.
Most individuals engage in everyday actions to save water in the house and garden.
My household is good about conserving water.

The conservation level expressed by the respondents was compared to the mean daily indoor usage (Figure 4.9). There emerged a trend in reduced water usage, although there was no statistically significant difference between households, with a mean *corresponding to agree* (>=5) and households who are *neutral/disagree* (<5) or between those that tend toward *strongly agree* (>=6) and *those who do not* (<6).

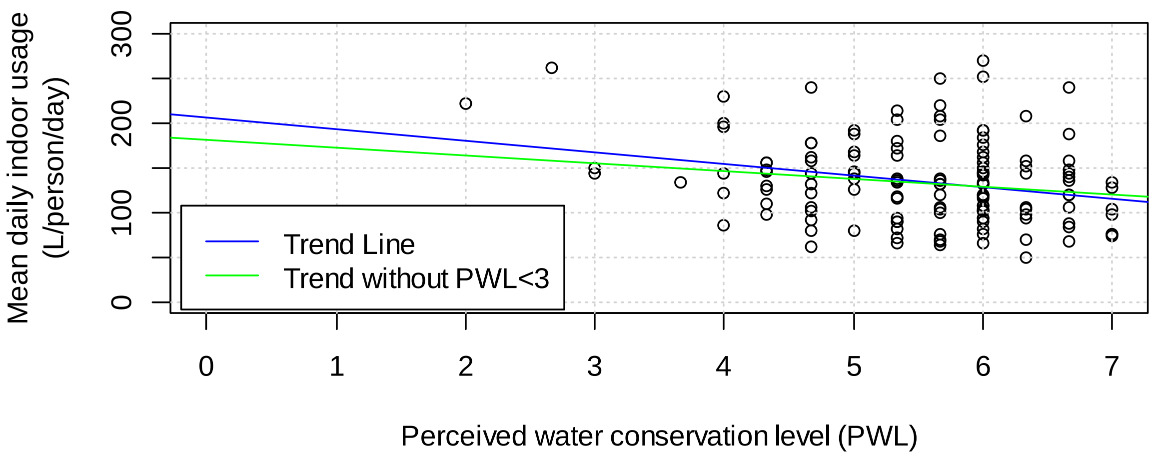

Figure 4.9: Comparison of perceived water conservation level (PWL) versus per person daily usage

Does a household that perceives itself as a water conserving household have water efficient appliances installed?

As shown in Table 4.19 the households that strongly identified as water conservers (agreement >=6) had a higher proportion of efficient shower heads and used significantly less water for showering per person. The reduction in water usage in the shower was in part due to a significant reduction in shower duration over the other categories and also due to reduced mean shower flow rate, although the frequency of showers was not significantly different.

The households that did not identify as water conservers (disagree/neutral agreement <5) had a higher proportion of efficient toilets, which might account for the lack of significant difference in total household water use between the water conservers and the non-water conservers. The toilet usage for the households that did not identify as water conserving was not significantly less than the identifying households, regardless of the higher proportion of efficient toilets. All other differences in use were not statistically significant.

Table 4.19: Efficient appliances for perceived water conservation levels

	Did not identify as water conservers	Identify as water conservers	Strongly identify as water conservers
Number of households	32	43	64
Proportion of efficient shower heads	0.38	0.37	0.48
Shower duration (min)	6.4*	6.1*	5.6
Mean shower flow rate (L/min)	8.8*	9.0*	7.5
Mean shower use (L/person/day)	59.5*	65.9*	41.0
Proportion of 4.5L/3L and 6L/3L Dual toilets	0.5	0.37	0.41
Mean toilet use (L/person/day)	26.8	23.3	28.6
Proportion of front loaders	0.56	0.56	0.52
Mean laundry use (L/person/day)	22.4	26.0	26.0
Mean tap use (L/person/day)	32.7	31.2	27.7

* Significant difference ($p<0.05$) from houses who strongly identify as water conservers

Do the demographics differ for the different conservation levels?

The houses that strongly identified with water conservation were more likely to contain only occupants that were aged greater than 55, were less likely to contain children and less likely to be in the high income group (Table 4.20). The majority of the households which were occupied by adults 55+ only and the low income households identified strongly with water conservation.

Table 4.20: Proportions of demographic groups for perceived water conservation levels

	Did not identify	Identify	Strongly identify
Number of households	32	43	64
High income (>$83,000) households	0.38	0.49	0.30
Medium income households	0.31	0.35	0.34
Low income (<$38,000) households	0.31	0.16	0.36
Households with children	0.43	0.35	0.20
Only occupants over 55+	0.28	0.26	0.52

4.5.1 Comparison to previous studies

The SEQ study [*Beal and Stewart*, 2011; *Beal et al.*, 2011a] compared the participants' perception of total water use with the measured water use. *Beal and Stewart* [2011] found a trend that participants were not able to accurately assign themselves as high, medium or low water users. The self-reporting high water users were found to have a significantly lower by person and by household daily usage than those identifying as low or medium water users. Beal and Stewart (2011) indicated the reason for the differences might be due to a lack of knowledge on the proportion of each end-use.

The self-reported low and medium water users in the SEQ study were more likely to have more efficient showerheads, likewise in the Adelaide study where the precieved water conservers had a higher proportion of efficient showers. The self-reported high water users in the SEQ study were more likely to be older, contrasting the Adelaide study where the older householders were more likely to identify as being water conservers. The self-reported high water users in the SEQ study were less likely to have children, which is similar to the Adelaide study where households with children were less likely to identify as water conservers.

4.5.2 Summary and practical implications

Households that view themselves as water conservers are:

- more likely to have efficient showerheads
- more likely to be occupied by individuals over 55 years who are not in a high income bracket.

The majority of the households which contain only householders over 55 and the households with low income identify strongly with being water conservers.

The practical implications are that:

- The self-identified water conserving households already have reduced shower duration and should not be a priority for targeting to increase water conservation behaviour.
- The overall use of water in self-identified water conserving households is not reduced due to a higher proportion of top loaders; and thus these households may respond to rebate schemes for more efficient washing machines.

4.6 Summary of drivers

Households vary considerably in individual end-uses from the mean usage and householders do not have a good understanding of the proportion of water associated with each end-use in their households. Thus there is an opportunity for the provision of better information on how households use water to enable them to better understand their water saving options.

Investigating the effects of water efficient appliances lead to the following conclusions:

- Appliance efficiency, rather than behaviour, is the primary driver for reduction in indoor water use. That is, people do not take longer showers if the showerhead is more efficient.
- Since efficient showerheads and toilets currently dominate the market, the uptake of water saving technology will occur naturally as households replenish their appliance stock.

- Washing machines offer the greatest potential water savings, but they are also available with a wide variety of options and range of efficiencies. Schemes that encourage switching to front loaders or efficient top loaders are recommended. The potential barriers to uptake of front loaders include the length of the washing cycle.

Distinct household types exhibit significantly different water usage. The study households varied in terms of efficiency, income, the presence or absence of children and the age of the adults, each of which was associated with different appliance stock and water use behaviour either on its own or in combination with other factors. For example:

- Households categorised as **adults 55+** exhibited the following characteristics:
    - water saving behaviour (shorter showers)
    - perceived themselves as water conservers
    - have inefficient washing machines (<30% uptake of water efficient appliances) and higher toilet frequency, resulting in poor overall water savings
    - should be encouraged to purchase efficient washing machines.
- Households categorised as **children / high income** exhibited the following characteristics:
    - more likely to have higher incomes and higher shower duration, lower toilet frequency and more efficient washing machines (~70% uptake), e.g., front loaders.
    - less likely to think of themselves as water conservers
    - should be encouraged to change shower behaviour.

It is important that these differences in water use for age and income be considered when taking into account future demand estimates and when transferring these results to different study areas.

5 Predictive modelling of water use

5.1 Overview of BESS framework

The Behavioural End-use Stochastic Simulator (BESS) uses a three level framework, as shown in Figure 5.1 (next page), to stochastically model water use at the individual household level and sub-daily time step. The hierarchical framework consists of the following three levels:

Level 1. The first level of the BESS represents the commonly known drivers of water use, including climate (rainfall, temperature), attitude to water use, policy (restrictions, legislation) and demographics (race, age, income). This level has yet to be incorporated into the BESS model. One of the goals of this study was to identify these key drivers to be included in future model developments.

Level 2. The second level predicts the spatial variability between households through probability distributions of household size and appliance uptake for different levels of appliance efficiency. Household type is a future component for incorporating the variation in behaviour in different households through the different drivers as discussed in Section 4.

Level 3. The third level predicts the temporal variability in individual households. This includes the variation in event dynamics that are the result of:

- behaviour

  including frequency of events such as toilet flushes, washing machine loads, showering. Incorporates economies of scale for events such as washing machine loads

- appliance characteristics

  flow rates of showers, volumes of toilet flushes and washing machine loads

- outdoor water use event dynamics

  can be incorporated [*Micevski et al.*, 2009]. Data collection related to outdoor water use was not within the scope of this study.

The BESS framework is capable of stochastically modelling sub-daily end-uses for multiple households (up to 1000s) and multiple replicates to increase confidence in the model outputs. The practical benefits of BESS include:

- flexible approach that can adapt to changes in water use behaviour
- utilise new data sets as they become available
- reliably predict current and future scenarios (e.g. demand management).

BESS was originally developed using data from the end-use statistics for the 2004 Yarra Valley Water end-use measurement study [*Roberts*, 2005]. *Thyer et al.* [2011] found that the BESS model gave excellent predictions for the mean daily per person water use in each of the end-use categories as illustrated in Figure 5.2.

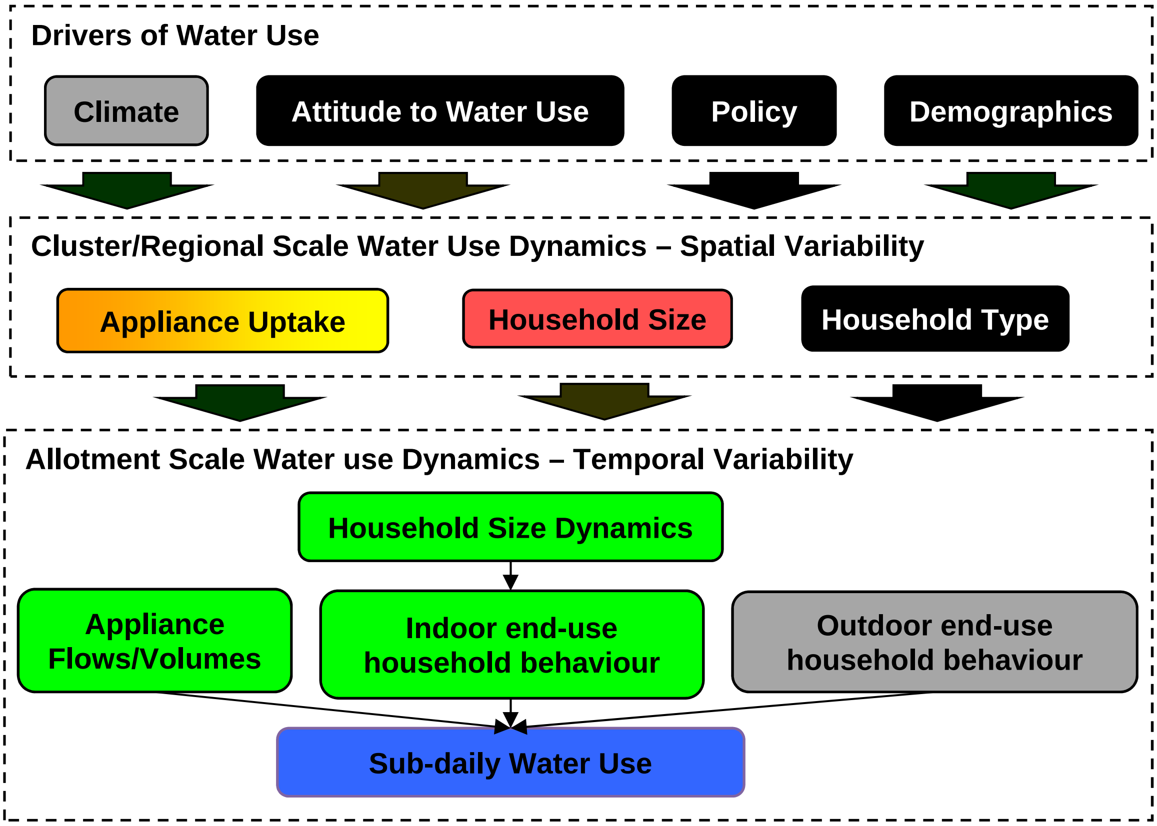

Figure 5.1: **Behavioural end-use stochastic simulator hierarchal framework (BESS)**

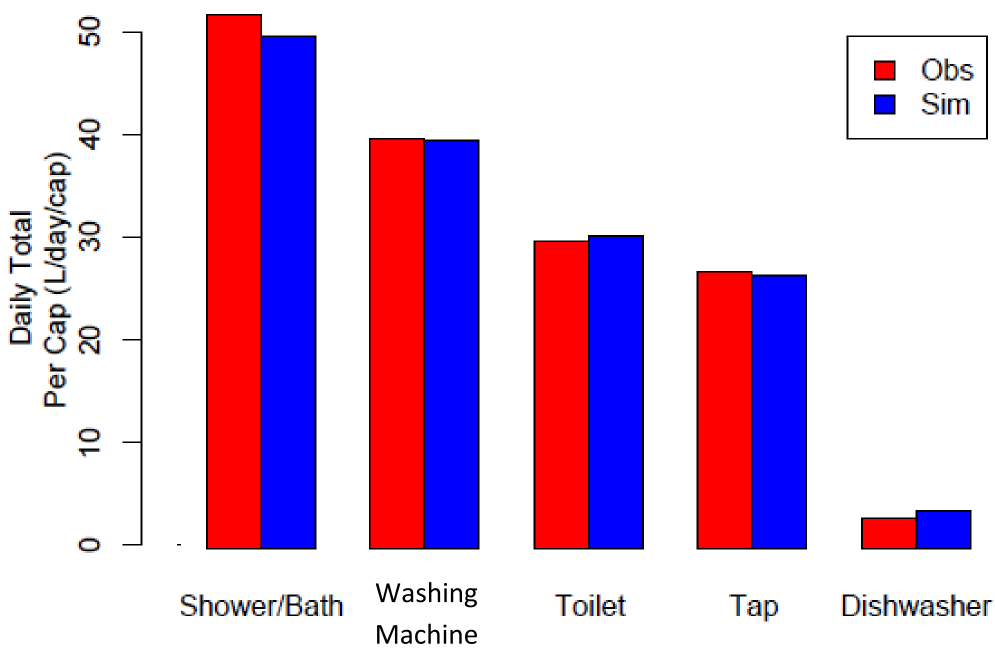

Figure 5.2: **BESS prediction for YVW 2004 data (taken from *Thyer et al.* [2011])**

5.2 Assessing the level of local information required by BESS to provide reliable predictions of end-use at the local scale

Can the flow trace results from the Adelaide study be reproduced using BESS? What type of local information is required to provide reliable predictions of end-uses?

BESS requires the following types of information as inputs to provide predictions of end-uses:

- **Appliance uptake**: the proportion of efficient appliances adopted by households
- **Appliance Flows/Volumes**: the characteristic water flows or volumes for the appliances as determined from flow trace analysis
- **Household Behaviour**: the characteristics of household behaviour as determined from flow trace analysis, including particularly the duration and frequency of the water use events.

These types of information can come from different sources, with the appliance flows and volumes, as well as household behaviour requiring flow trace analysis. This is currently a resource intensive and expensive exercise, although work is on-going to develop more efficient automated techniques [*Nguyen et al.*, 2014]. Hence the question about what resources could effectively be used was: ***Can we use interstate information about appliances and behaviour with flow trace analysis to provide good predictions of local end-uses?***

To evaluate the types of local information required to provide reliable predictions of end-uses, information from two different sources was included:

- **interstate data**: 2004 Yarra Valley Water end-use measurement study [*Roberts*, 2005]
- **local data**: 140 flow trace analysis households from the Adelaide 2013 study

For appliance uptake there were two further options for acquiring data:

- **estimated** values based on preliminary surveys of study households. Note that the proportions from the ABS statistics for South Australia [*ABS*, 2013] and the SEQ study [*Beal et al.*, 2011b] were consistent with these values
- **actual** values based on a water appliance audit for flow trace households.

The aim was to address the two related questions:

- ***Can BESS use interstate information to provide reliable predictions of end-use in another state?***
- ***What type of local information is required by BESS to provide reliable predictions of end-use?***

To undertake this evaluation, a series of predictive scenarios was developed (see Table 5.1) which used different mixes of local and interstate information. The first scenario, ‘interstate only’ has the lowest cost since it uses information from interstate only. The second scenario ‘local uptake-est’ uses local estimates of appliance uptake based on phone surveys, and hence is the next lowest cost. As phone surveys do not provide the most reliable information on appliances because households generally do not know the ‘star-rating’ of their appliances, the third scenario ‘local uptake-act‘ involves visiting the household to determine the actual appliances types, and hence is the next more expensive option. The fourth scenario ‘local only’ is the most expensive as it requires local information on appliance flows and volumes, as well as behaviour using flow trace analysis. In all scenarios, the ABS census data on household occupancy [*ABS*, 2011c] was used.

Table 5.1: Types of data used for each predicative scenario

Predictive scenario	Appliance uptake	Appliance flows/volumes	Household behaviour
interstate only	interstate	interstate	interstate
local uptake – est.	local – estimated	interstate	interstate
local uptake – act	local – actual	interstate	interstate
local only	local	local	local

To undertake this evaluation, the BESS model was used to predict the 140 flow trace analysis households with 100 replicates of each scenario undertaken. The model outputs were compared to the observed local end-use statistics from the flow trace analysis. The parameters for each predictive scenario can be found inTable D.1 and Table D.2 of Appendix D – BESS Parameters and Results.

An encouraging result was that BESS provided reliable predictions (mean % errors ~ 2%) of water use incorporating the local data from flow trace analysis without the need for calibration or changes to the model framework (Figure 5.3). Incorporating different levels of local data improved the predictions of total indoor usage (Values in Table D.3 of Appendix D – BESS Parameters and Results).

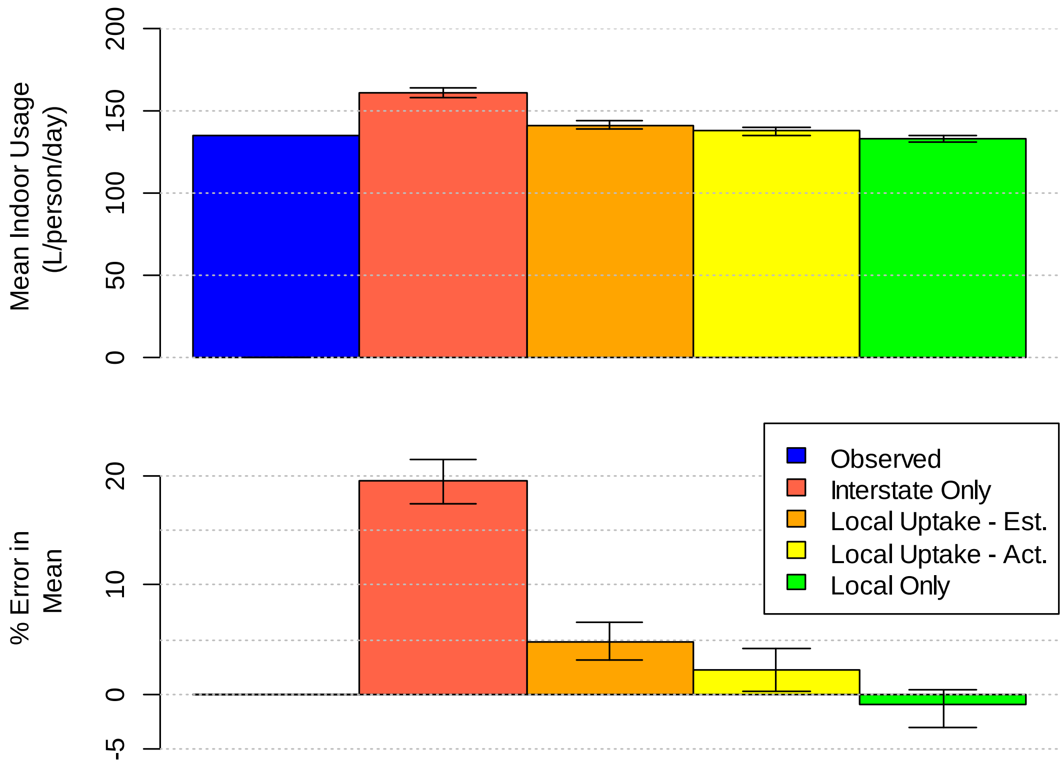

Figure 5.3: BESS results for indoor water use for predictive scenarios

In summary:

- Interstate data resulted in an over prediction of water use due to an increase in efficient appliances over time which resulted in differences in appliance characteristics.
- Local data on appliance uptake reduced total errors to <10%. However, there were significant differences in the behaviour and appliance characteristics between the studies as detailed in subsection 3.6. This led to poor predictions of individual end-use volumes (see Figure 5.4).
- Local data on appliance characteristics and household behaviour reduced errors to <1%.

The reliability of the predictions based on the total indoor usage can be misleading. Evaluating the predictions of the end-uses (Figure 5.4) shows that although the local uptake data resulted in a good prediction for total indoor use, it was actually the result of an under-prediction of shower usage and an over prediction of washing machine usage due to both behavioural and appliance characteristics changes. In summary:

- The addition of interstate data led to an under-prediction of shower usage since, although the duration of showers is longer, the frequency of showering is significantly lower than the local data, as detailed in subsection 3.6. This observation may be the result of the impact of the differences demographics, such as age, for different households as highlighted in Section 4.
- Interstate data on the volume and frequency in the use of washing machines resulted in an over prediction of usage due to the higher load volumes and greater proportion of top loaders, as detailed in subsection 3.6.
- Local data on appliance characteristics and behaviour reduced these errors to <5% for all end-uses.

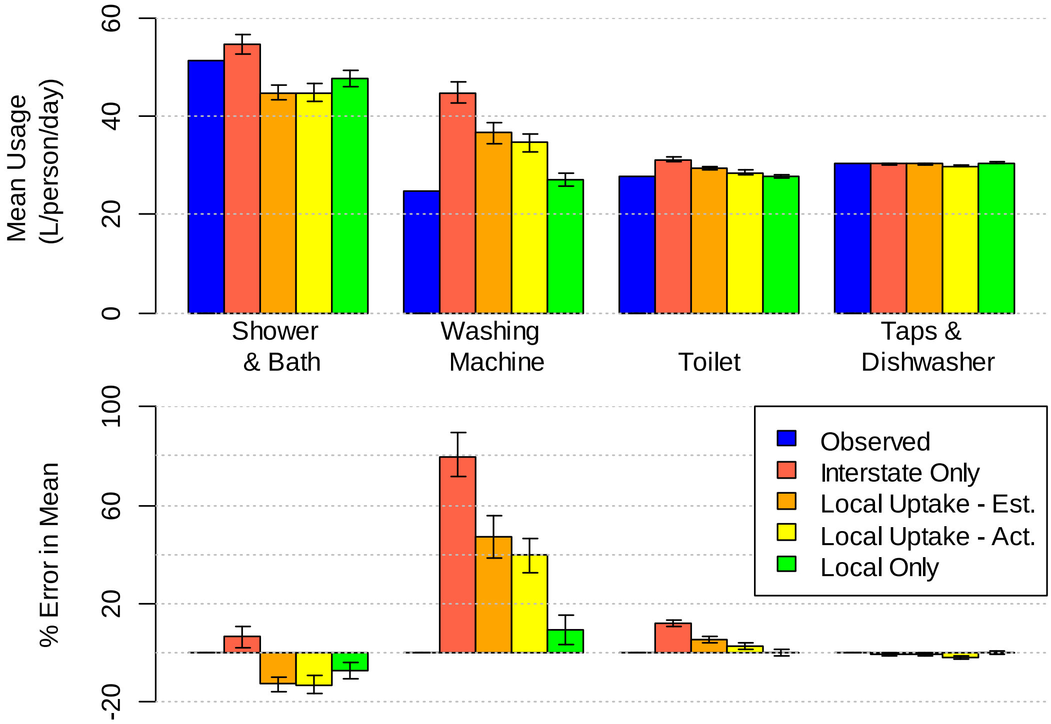

Figure 5.4: **BESS results for range of indoor end-uses for predictive scenarios**

The stochastic modelling underestimated the variability in household water use by 30-50% as shown in Figure 5.5 and 5.6. This is likely due in part to the variation of usage for different household types as discussed in Section 4, as well as the modelling approach used for each end-use. The variability of each end-use is illustrated in Figure 5.6 and further work on incorporating variability for different household types and refining the approaches used to model the end-use variability is required.

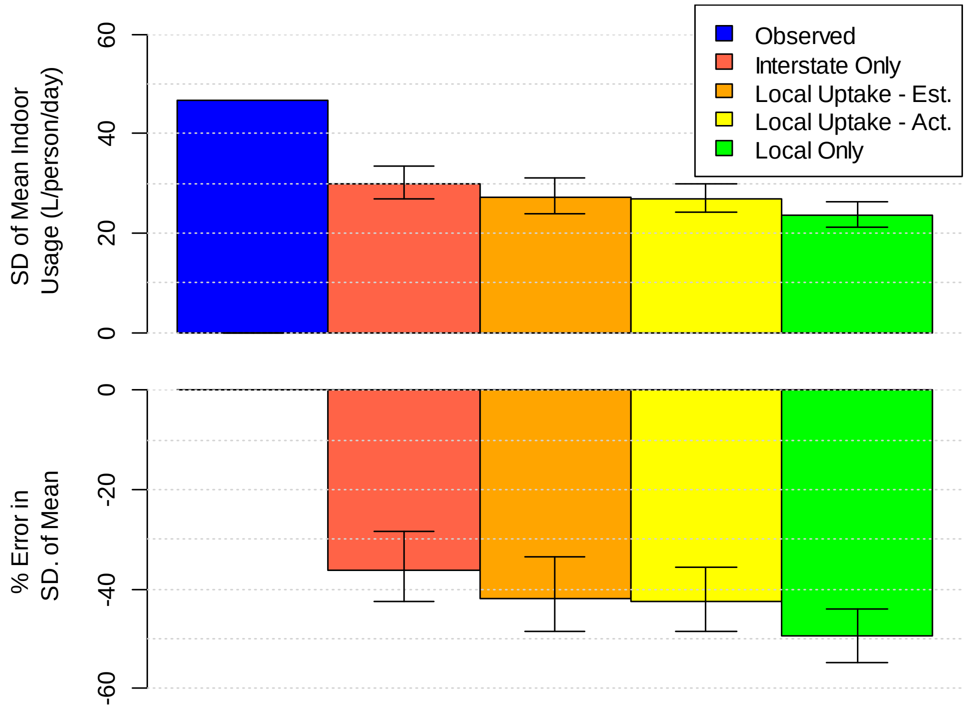

Figure 5.5: Variability of BESS results for indoor water use for predictive scenarios

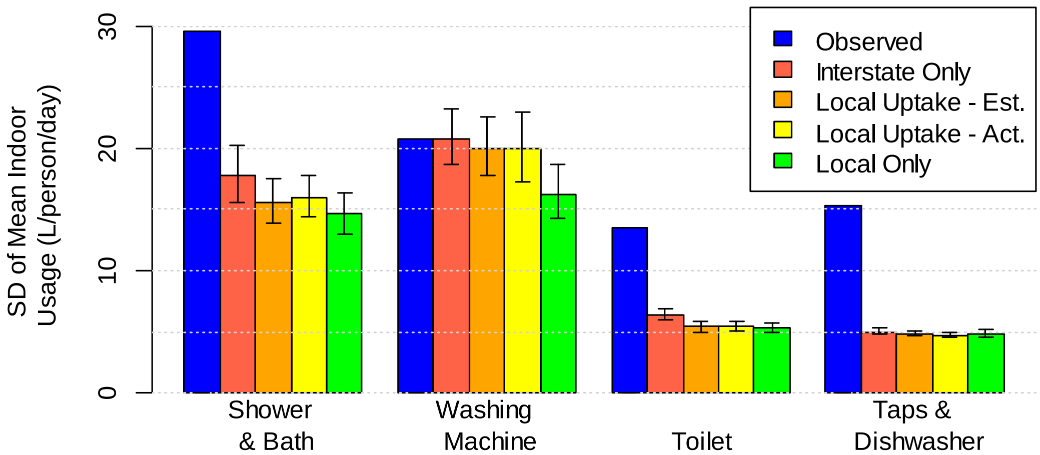

Figure 5.6: Variability of BESS results of end-uses for predictive scenarios

5.2.1 Summary and practical implications

BESS was capable of reliably predicting the mean indoor water use of the study households (1% errors) without any major changes to the model framework. As the model can explicitly predict the effect of changes in appliance uptake and appliance flows and volumes, as well as behaviour, it can provide reliable predictions of the impact of changes in efficient appliance uptake for purposes such as demand management as detailed in subsection 5.4. On the other hand, it was found that BESS under-predicted the variability of household water use.

Further work is needed to increase the transferability of BESS, because the current framework requires the detailed end-use statistics from flow trace analysis. Inclusion of the different behavioural characteristics for different household types will be a key step towards reducing reliance on local end-use data and enable BESS to provide reliable predictions of end-uses, including variability, at a wider range of locations.

5.3 Changes between 2013 and the height of the drought 2007-2009

5.3.1 Perceived changes in behaviour during drought

What were the perceived/reported changes in behaviour?

The respondents to the end-use survey were asked to recall how often they performed each of the actions presented in Table 5.2 during the summer of 2013 and during the height of the drought from 2007-2009. A 5-point Likert scale where 1 = Never and 5 = Always was used. As shown in Table 5.2, a significant change in behaviour was found for washing dishes, with respondents more likely to use minimal water in the kitchen and wait for the sink to be full before washing dishes during the drought. There was also an increase during the drought in the collection of water from the laundry or bath water for the lawn or garden, although this behaviour was still less likely to be undertaken than the other actions. Respondents were also more likely to have shorter showers during the drought.

Table 5.2: Differences in water use behaviour between summer 2013 and the height of the drought

Water use behaviour	Summer 2013 Mean response	Height of drought 2007-2009 Mean response	Significant ($p < 0.05$)
Ran the dishwasher only when it is full	4.76	4.86	No
Waited until the sink is full before washing dishes	3.16	3.54	Yes
Used minimal water in kitchen (e.g., for cooking, washing up, rinsing)	4.12	4.43	Yes
Ran the washing machine only if there is a full load of clothes	4.34	4.52	No
Collected or ran water from washing machine out to garden/lawn	1.70	2.46	Yes
Adjusted the water level for smaller loads	4.18	4.34	No
Used half flush or don’t flush the toilet every time	4.28	4.39	No
Had shorter showers (4 minutes or less)	3.68	3.99	Yes
Put the water from bath on the lawn/garden	1.73	2.41	Yes
Turned off taps when brushing teeth or shaving	4.46	4.59	No
Watered the lawn in the evening, night or early morning	4.37	4.45	No
Watered the garden in the evening, night or early morning	4.51	4.54	No
Washed your car at home with a bucket	3.61	3.75	No
Used water from the rainwater tank on garden	3.76	3.89	No

What were the actions undertaken during the drought i.e. water saving devices? What were the perceived/reported reasons for the changes?

During the water restrictions in the drought period, households in the study implemented measures to reduce outdoor water use. Specifically, more than 30% of the households installed efficient watering systems and planted drought resistant plants, which is a greater proportion than before or after the drought, as shown in Figure 5.7. Garden product rebates (50% back on eligible products $100-$400) were accessed by 18% of the households. The loss of garden plants by a majority of households during the drought may have initiated water saving changes.

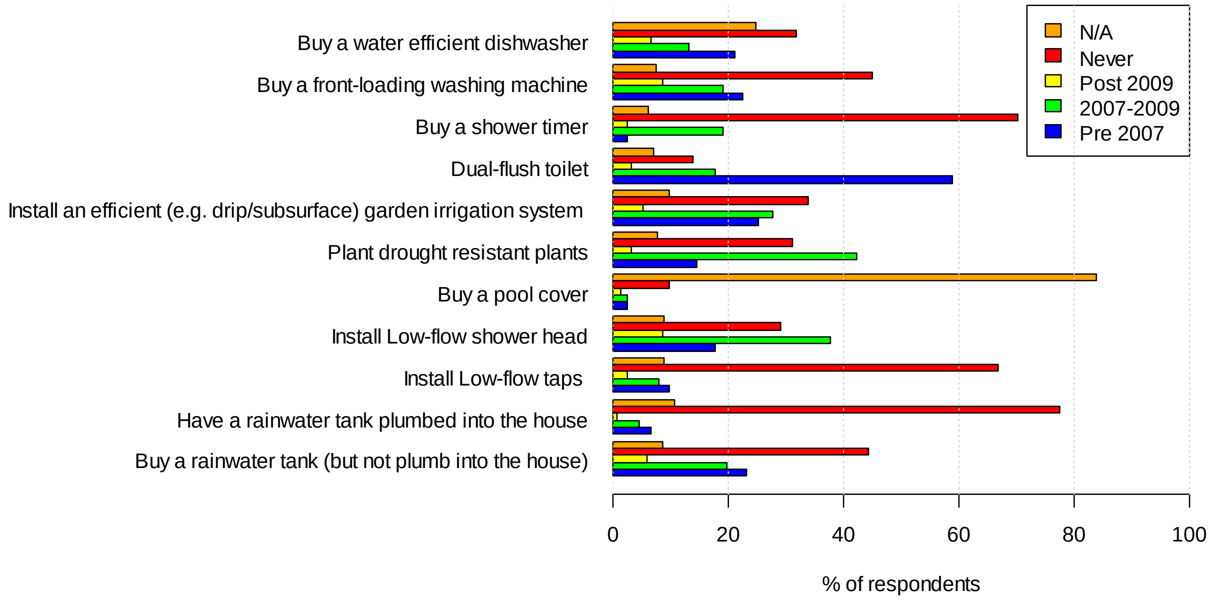

Figure 5.7: Timing of installation of water saving devices

The households also implemented low flow showerheads and shower timers at a greater rate (Figure 5.7), which may indicate that the householders recognised that shower use accounted for a large proportion of their water use. 28% of the households that changed to low flow shower heads during the height of the drought accessed the $30 rebate.

The $200 rebates for rainwater tanks (not plumbed in, greater than 1000L) and water efficient washing machines were accessed by the majority of the households implementing changes during the drought. Despite the use of the rebates, the mean importance of rebates on the implementation of water saving devices was lower than concern expressed for the River Murray or Coorong, media coverage on water restrictions, media coverage on the impact of the drought and the price of water.

Changes since the drought have been minimal compared with changes pre 2009 (Figure 5.7), largely because of the changes already made. There are, however, areas for which uptake could be improved. Installing low flow taps and plumbing rainwater tanks into the house represent areas where indoor water use could be reduced since the majority of households did not implement these measures before, during or after the drought.

5.3.2 Actual water use changes during drought

What were the changes in water use?

The variation in mean daily usage from 2002 to mid-2013 is shown in Figure 5.8 for the study households and for metropolitan Adelaide from the ABS based on SA Water annual reports [ABS, 2011c]. Billing consumption data, which was recorded half yearly from 2002 to late 2008 and since then quarterly, was used for the applicable study households based on consent from the householders for previous data and length of residence at the address. Level 3 enhanced water restrictions were in place from January 2007 to December 2010 [ABS, 2011c], and a reduction in water usage can be seen from the 2006-2007 summer to the 2007-2008 summer. The study households followed the same trend as the ABS data, indicating that the reductions were representative of the mean reductions for metropolitan Adelaide during the same periods.

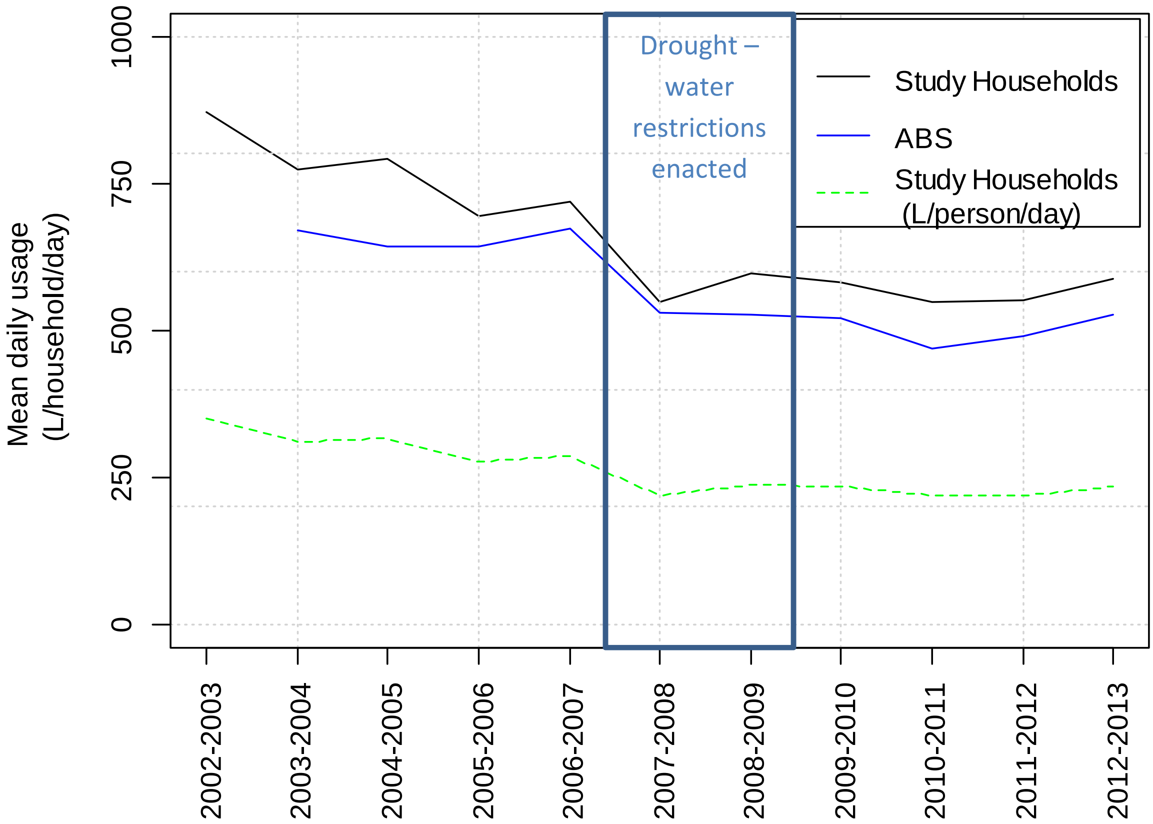

Figure 5.8: Mean water use per household from 2002 to 2013

Combining the data into pre, during and post drought in Figure 5.9, the significant reduction in water use can be seen. (Note that the width of boxplots is representative of the households included.) Before water restrictions were put in place, the mean household usage was 736 L/household/day which dropped to 569 L/household/day. Water usage since restrictions ended has not increased, with the mean usage from mid-2009 to mid-2013 being 565 L/household/day.

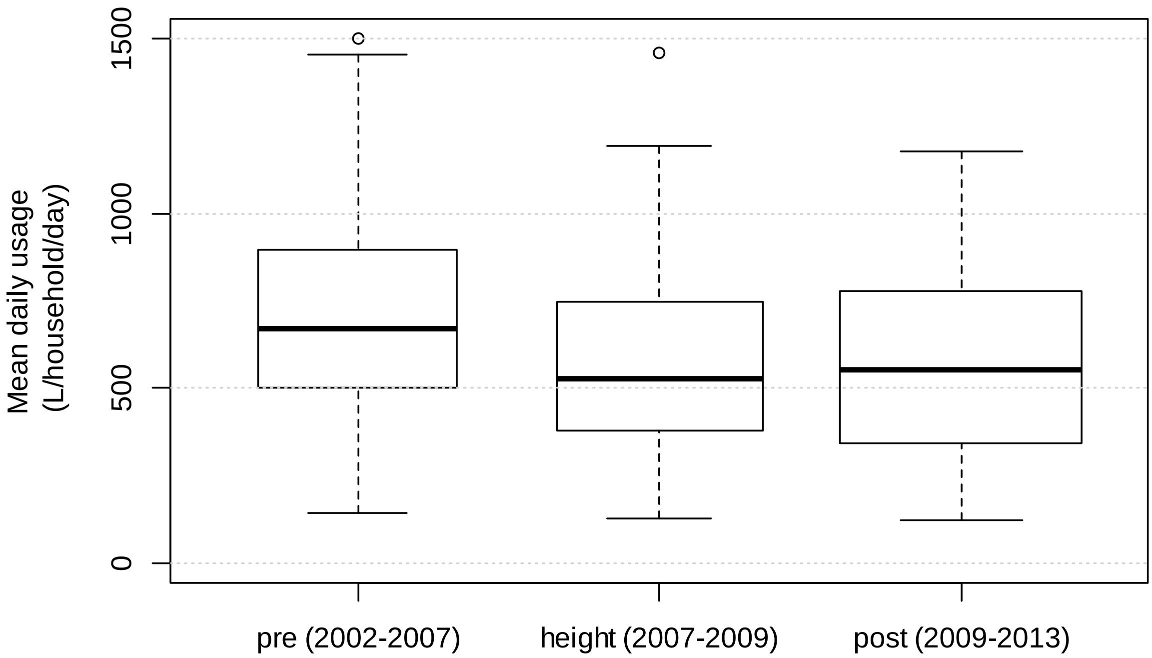

Figure 5.9: Mean water use pre and post water restrictions/height of drought

5.3.3 Understanding the reasons for water use changes during drought

This subsection uses the survey information, BESS predictions and other sources of data in order to understand the reasons for the water use changes during the drought. The end-use survey provided information on the changes in appliances between the three time periods. As detailed above, the majority of the changes to the water saving appliances occurred during the height of the drought (2007 – 2009) and the proportions of appliances adopted at different times are shown in Table 5.3. The changes in devices combined with the level 3 water restrictions account for the reduction from pre summer 2007 to the height of the drought. The proportions of water saving devices have not significantly changed since the end of restrictions, nor has the mean water use increased. This indicates that the behaviour in outside water use has not changed significantly since the drought period, as inside water use should have remained relatively constant due to the proportions of water efficient devices.

Table 5.3: Differences in water saving devices at different time periods

	2007	2009	2013
Efficient shower heads*	19%	60%	69%
Dual flush toilets*	63%	82%	85%
Front loaders	24%	44%	53%
Rainwater tank (not plumbed)	25%	46%	52%
Rainwater tank (plumbed)	7%	13%	13%
Efficient irrigation system	27%	58%	63%
Drought resistant plants	16%	62%	66%

* Note: Will include households with mixture of efficient and inefficient

There was no significant difference between the mean usage of households between the height of the drought and the last summer. The mean occupancy and household composition of the households did not vary significantly between the time periods (details in Table B.7), although there was variation in individual households. Comparison of the winter usage for 2009 (first winter with quarterly data) indicates a reduction in winter water use since 2009, although the difference in the mean is not significant. The composition of the households in the winter of 2009 was not known; therefore, the reductions due to changes in water saving devices (Table 5.3) could not be determined.

The winter usage could not be directly compared to the usage during the drought as quarterly billing did not begin until late 2008. Thus the BESS model developed in subsection 5.2 was used to predict the indoor usage. The following data were used:

- Local data on appliance characteristics and behaviour were incorporated as per 'local only' (subsection 5.2), except for washing machine characteristics (volumes) which were taken as per YVW 2004 [*Roberts*, 2005] as the efficiency of top and front loaders has significantly changed over time.
- Proportions of appliances from 2007 (Table 5.3). The proportions within the categories for non-efficient showers (0 to 2 star) and dual cistern toilets were distributed based on the relative proportions for YVW 2004 [*Roberts*, 2005] as this information was not available for Adelaide.
- Household occupancy was assumed to be the same as that specified in the end-use survey for December 2006 (Mean 2.5).

The pre drought estimates of indoor and outdoor use are shown in Table 5.4. Indoor changes were responsible for 49% of the reduction in overall water use, and outdoor changes were responsible for 51%. Reductions in indoor water use of 16% were calculated to be the result of the appliance changes. The influence on each end-use is shown in Figure 5.10. Washing machine usage accounted for 16 L/person/day due to load size and proportion changes. A 23% reduction in outdoor water use was most likely due to changes in the use of rainwater tanks, more efficient irrigation systems, and the cultivation of drought resistant plants as well as due to climate differences.

Table 5.4: Prediction of pre-drought indoor and outdoor usage

	Pre drought restrictions prediction (L/person/day)	2013 observed results (L/person/day)	% reduction of end-use (% total reduction)
Mean	289	245*	18%
Indoor	156.0	134.5	16% (49%)
Leakage**	10.5	10.5	-
Outdoor	122.5	100	23% (51%)

*2012-2013 daily usage (Table 3.3) **2007 Leakage rate assumed to be similar to flow trace period (Table 3.4)

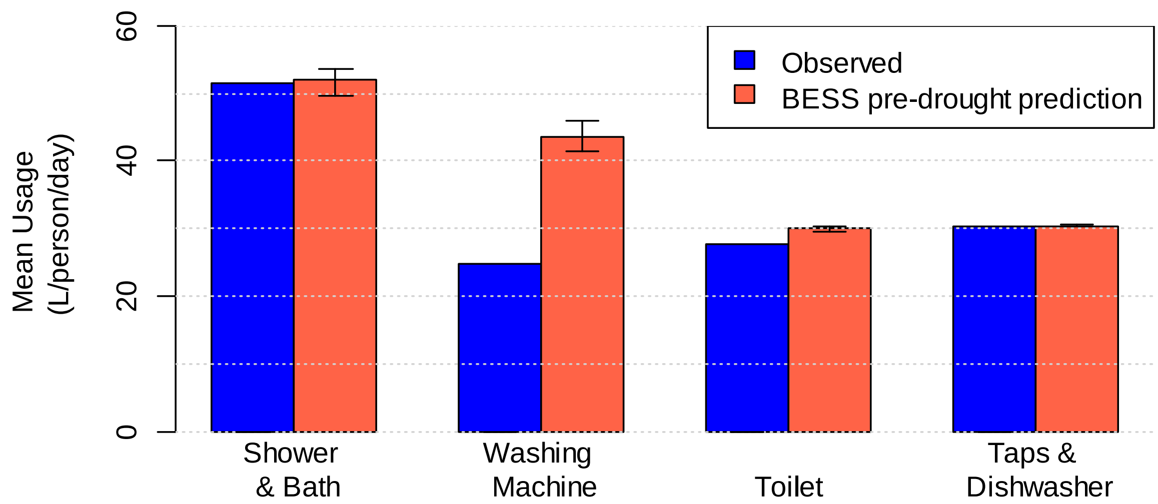

Figure 5.10: BESS prediction for pre-drought indoor usage compared to 2013 flow trace analysis

5.3.4 Summary and practical implications

- Householders indicated that they changed their behaviour (such as having shorter showers) and installed water saving devices during the drought. The garden and shower were the areas where the majority of homes introduced water saving devices. Rebates were accessed, yet they were not ranked as the most important reason for which the changes were made.
- During the height of the drought, the mean household water use decreased by approximately 170 L/household/day.
- Using the end-use survey information and BESS modelling, it was estimated that 50% of this decrease was due to changes in appliances, with the remaining savings attributed to either outdoor changes or behavioural changes in the houses.
- Since the ending of severe level 3 water restrictions in 2009 to mid 2013, the mean water use has not increased significantly. Indicating changes made during the drought (behavioural/appliances) are still having an impact. Further monitoring to capture more years of climate variation is required in order to determine if summer water use remains at pre-drought levels.

5.4 Demand management

Can BESS be used to determine the impact of demand management? What would be the impacts of demand management now and in 2025/2050?

The Behavioural End-use Stochastic Simulator (BESS) was used to determine the effect of different demand management (DM) scenarios. Demand management through changes in appliance stock only was considered, as behavioural change was not investigated in this project (see discussion in subsection 7.3).

The estimates of the impact of demand management were required for OWRM Task 2 [*Maheepala et al.*, 2014] at an early stage of the OWRM project prior to the completion of the flow trace analysis. Therefore, the approach taken was to first develop the inputs for BESS based on the best available information from local and interstate sources, hereafter referred to as Source A. After the flow trace analysis was completed, the predictions of the impact of demand management were repeated using the flow trace analysis results, hereafter referred to as Source B. This provided an opportunity to evaluate the impact of the assumptions using interstate data on the predictions of demand management.

In detail, the two sources of information were:

- **Source A**
    - interstate data on behaviour and appliance characteristics as used for the 'local uptake-est' predictive scenario in subsection 5.2
    - local data on appliance uptake from the preliminary survey completed by 1654 respondents from the Adelaide metropolitan area
    - proportion of dual flush toilets from recent YVW study [*Roberts et al.*, 2011]
    - the assumptions for each event type are detailed in Appendix E – Demand Management Parameters and the proportions used are summarised in Table E.1.
- **Source B**
    - corresponds to the 'local only' predictive scenario in subsection 5.2. Local behaviour, appliance characteristics and appliance uptake.

5.4.1 Source A: Estimated local appliance uptake, interstate appliance volumes and behaviour

A year of indoor usage was simulated for 400 households with the occurrence, flow rate/volume for each event sampled from the probability distributions for the event type. The underlying probability distribution for individual water use events, such as occurrence rate, were not yet available for the Adelaide study households and are based on the previous studies [*Roberts*, 2005; *Roberts et al.*, 2011] from Yarra Valley Water (YVW).

Four demand management scenarios were modelled:

Scenario 1: 2013 No DM (current stock)

Scenario 2: 2013 DM (100% efficient toilets, 84% efficient showers and 84% front loaders)

Scenario 3: 2025/2050 No DM (current proportion of front loaders, 100% efficient toilets and 84% efficient showers)

Scenario 4: 2025/2050 DM (100% efficient toilets, 84% efficient showers and 84% front loaders)

These scenarios assume that by 2025 all homes will move to efficient toilets, as these are the only options available for purchase and have been mandated as the only option that can be installed. For 3 star showerheads and front loaders, an 84% maximum uptake rate has been assumed based on the diffusion of innovation theory [*Rogers*, 2003] that states approximately 16% of people are 'laggards' who only adopt innovation when forced. This accounts for those people who choose to use a less efficient product.

These DM scenarios assume the following:

- Reductions in indoor usage due to DM are due to increased uptake of water efficient appliances (see above for list of scenarios).
- No behavioural changes (e.g. shorter showers) occur over time. Estimating behavioural changes is an ongoing research challenge (see further discussion in subsection 7.3).
- Reducing leaks has not been included as a demand management option as the estimate of leakage volume is unreliable (see further discussion in subsection 7.2).
- No changes in outdoor water use (see further discussion in subsection 7.3). Prior to the flow trace analysis being undertaken, no estimate of outdoor water use was available. Therefore, the assumptions of 62 L/per capita per annum, as provided by SA Water based on 'Water for Good' with a reduction factor, has been used (see further discussion in subsection 7.4).

The estimated reduction in volume due to DM in this study can be considered the lower bound of the potential reductions through DM. In addition to the above assumptions that relate to the reduction, some additional assumptions were made to translate the per household reductions from BESS to the system demand reductions in residential potable and non-potable water use.

- Non-potable water use refers to garden, laundry (washing machine), toilet.
- Potable water use refers to bathroom (bath and shower), kitchen (tap and dishwasher), other.
- A 2.4 person per household mean in Adelaide (ABS, 2011a) was used to convert from per dwelling for comparison.
- All areas (north, central, south) have the same split of mains water usage of 68% residential and 32% non-residential as provided by SA Water, leading to 95.6 L/capita/day non-residential use based on the 204 L/capita/day modified 'Water for Good' residential use.
- Non-residential use is further split into 54% non-potable and 46% potable water as provided by SA Water, leading to 44.0 L/capita/day potable non-residential use, 51.6 L/capita/day non-potable, non-residential use.

The assumptions for each event type are detailed in Appendix E – Demand Management Parameters and the proportions used are summarised in Table E.1.

Table 5.5 summarises the usage per person per day for each of the end-uses for the four scenarios and the reduction factor from the 2013 current modelled usage (Scenario 1) for the residential potable usage and the total potable usage, (including non-residential usage. Table5.6 and Table 5.7 present the monthly reduction factors for the non-potable usage for residential and total usage respectively.

Table 5.5: Usage (L/person/day) for each end-use and demand management scenario

	Modified 'Water for Good'	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Bathroom	56	40.7	37.8	37.8	37.8
Toilet	26	28.3	24.0	24.0	24.0
Laundry	32	34.1	27.2	34.1	27.2
Kitchen	27	29.4	29.4	29.4	29.4
Indoor	141	132.5	118.4	125.3	118.4
Outdoor	62	61.6	61.6	61.6	61.6
Total	203	194.1	180.0	186.9	180.0
Potable -residential	83	70.1	67.2	67.2	67.2
non-potable - residential	120	124.0	112.8	119.7	112.8
Proportion potable -residential	41%	36%	37%	36%	37%
Proportion of non-potable - residential	59%	64%	63%	64%	63%
Reduction from potable -residential			4%	4%	4%
Reduction from potable -total			2%	2%	2%
Reduction from non-potable -residential				See Table 5.6	
Reduction from non-potable total				See Table 5.7	

Table 5.6: Reduction from Scenario 1 of non-potable residential usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4:2025/2050 DM
January	5%	2%	5%
February	6%	2%	6%
March	7%	3%	7%
April	10%	4%	10%
May	13%	5%	13%
June	18%	7%	18%
July	18%	7%	18%
August	17%	6%	17%
Sept	15%	6%	15%
October	11%	4%	11%
November	8%	3%	8%
December	6%	2%	6%
Annual	9%	3%	9%

Table 5.7: Reduction from Scenario 1 of total non-potable usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
January	4%	2%	4%
February	4%	2%	4%
March	5%	2%	5%
April	7%	3%	7%
May	8%	3%	8%
June	10%	4%	10%
July	10%	4%	10%
August	9%	4%	9%
Sept	9%	3%	9%
October	7%	3%	7%
November	6%	2%	6%
December	5%	2%	5%
Annual	7%	3%	7%

What is the effect of demand management on waste water flows?

Adoption of demand management options has the potential to reduce wastewater flows. The reduction in wastewater flow was computed using the following assumptions:

- All bathroom, laundry, kitchen and toilet water use is converted to wastewater
- Outdoor water use does not become wastewater
- Indoor use that is supplied by rainwater tanks results in wastewater
- Rainfall and stormwater that enters the wastewater system are not taken into account in the reduction factors
- Solids within the wastewater are not included as they make up 0.1% of the wastewater from homes and businesses
- Mains water usage of 77.8% residential and 22.2% non-residential
- No reduction in wastewater from non-residential main water use.
- No water reuse inside the home. According to the ABS (2011b), 14% of households collect wastewater from the laundry for reuse and 12% of households collect wastewater from the bathroom for reuse. However the proportion of the water reused is not known and thus wastewater reuse within the home was not incorporated into the calculations.

Table 5.8 presents the usage for the four demand scenarios modelled with BESS and the associated wastewater totals and percentage reductions from the current expected volumes (Scenario 1).

Table 5.8: Wastewater reductions for each end-use and scenario (L/person/ day)

	Modified 'Water for Good'	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Indoor (Table 5.5)	141	132.5	118.4	125.3	118.4
Non-residential wastewater	95.6	95.6	95.6	95.6	95.6
Residential wastewater		132.5	118.4	125.3	118.4
Total wastewater		228.1	214.0	220.9	214.0
Reduction of wastewater – residential only			11%	5%	11%
Reduction of wastewater – incl. residential and non-residential			**6%**	**3%**	**6%**

5.4.2 Source B: Local appliance uptake, appliance volumes/behaviour

What is the impact of the updated BESS model incorporating local appliance characteristics and behaviours?

The analysis was repeated using the BESS model incorporating local data on appliance uptake, appliances flows/volumes and behaviour, and the results are shown in Table 5.9. The proportions used are in Table E.3 of Appendix E – Demand Management Parameters.

The biggest differences in the estimates between the sources of information was in the breakdown of end-use volumes. The 'Water for Good' estimates, over-estimate the bathroom and laundry use and underestimate kitchen and outdoor use. For this source of information, the outdoor water use was estimated at 100 L/person/day based on using summer 2012/2013 data and the indoor use from flow trace analysis. This was nearly double the previous estimate of 62 L/person/day.

The overall impact of the different sources of information was a very small change in the % reductions of the individual end-uses. However, there was a big difference in the relative proportions, which influenced the ratio of potable and non-potable usage. The proportion of residential potable usage based on flow trace analysis (Scenario 1) was 18%, reduced from the 'Water for Good' estimate of 41%, and the 12% proportion of non-potable water usage is increased. This has implications for the simulation/optimisation as non-potable and potable water are supplied from different sources and have different levels of reliability.

Table 5.9: Source B usage (L/ person/day) for each end-use and demand management scenario

	Modified 'Water for Good'	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Bathroom	56	47.7	43.9	43.9	43.9
Toilet	26	27.8	23.1	23.1	23.1
Laundry	32	27.2	21.2	27.2	21.2
Kitchen	27	30.5	30.5	30.5	30.5
Indoor	141	133.2	118.7	124.7	118.7
Outdoor	61.6	100.0	100.0	100.0	100.0
Total	203	233.2	218.7	224.7	218.7
Potable -residential	83	78.2	74.4	74.4	74.4
Non-potable - residential	120	155.0	144.3	150.3	144.3
Proportion potable -residential	41%	34%	34%	33%	34%
Proportion of non-potable - residential	59%	66%	66%	67%	66%
Reduction from potable -residential			**5%**	**5%**	**5%**
Reduction from potable -total			**3%**	**3%**	**3%**
Reduction from non-potable -residential			See Table 5.10		
Reduction from non-potable total			See Table 5.11		

Table 5.10: Source B updated reduction from Scenario 1 of non-potable residential usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 no DM	Scenario 4:2025/2050 DM
January	5%	2%	5%
February	6%	2%	6%
March	7%	3%	7%
April	10%	5%	10%
May	14%	6%	14%
June	19%	9%	19%
July	19%	8%	19%
August	18%	8%	18%
Sept	16%	7%	16%
October	12%	5%	12%
November	8%	4%	8%
December	6%	3%	6%
Annual	7%	3%	3%

Table 5.11: Source B updated reduction from Scenario 1 of total non-potable usage per month

	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
January	4%	2%	4%
February	4%	2%	4%
March	5%	2%	5%
April	7%	3%	7%
May	8%	4%	8%
June	10%	4%	10%
July	10%	4%	10%
August	10%	4%	10%
Sept	9%	4%	9%
October	7%	3%	7%
November	6%	3%	6%
December	5%	2%	5%
Annual	7%	3%	7%

5.4.3 Summary and practical implications

The BESS framework provided the predictions of demand management, taking into account appliance uptake and appliance flows and volumes. The key results from the scenarios modelled indicated that demand management can potentially lead to:

- 5% reductions in residential potable usage
- 5 – 20% reductions in monthly non-potable residential usage water usage
- 11% reduction in residential waste water flows

These estimates of the impact of DM did not include any behavioural changes in indoor use, changes in outdoor use or leakage reduction. Thus, they represent a lower bound on the potential reductions for demand management.

In the future scenarios, the potential impact of DM is reduced, due to the natural uptake of water efficient appliances.

Comparison of the BESS predictions pre- and post-flow trace analysis, showed that relative reductions in total water use due to demand management were consistent.

The biggest difference engendered by including the flow trace analysis was that the proportions assigned to the potable and non-potable components of demand were substantially different. Based on the flow trace analysis, the proportion of residential potable usage was reduced by 18% from the 'Water for Good' estimate and the proportion of non-potable water increased by 12%.

5.5 Summary of predictive modelling

Behavioural end-use stochastic (BESS) model provides predictions of household end-uses using information on household occupancy, appliance uptake, appliance flows and household behaviour. This information can be sourced from interstate end-use studies or local end-use studies (such as collected in this Adelaide study)

- Using all local Adelaide information, BESS produced predictive errors <1-5% for both total household and individual end-uses.
- Using local Adelaide information on occupancy and appliance uptake (readily available, does not require full end-use study) and interstate information on appliance flows and household

behaviour, total household water use predictive errors <10%, but individual end-uses predictive error were up to 40%.

- Variability in end-uses volumes between households was underestimated using BESS.

Future development of BESS to include the behaviour of different household types would improve predictions at a wider range of locations without the reliance on local end-use studies and also improve the ability to capture the variability in end-uses between households.

The 2007-2006 drought produced a 15% prediction in household water use. Using the BESS framework and survey information, it was estimated 50% of this reduction in household water could be attributed to an increased uptake of water efficient appliances, with the remaining 50% likely due to reductions in outdoor use. Since the ending of the drought, the household water use has not increased substantially.

The impact of demand management required for the water source modelling (Task 3) and optimisation (Task 2) of the Adelaide water supply system was estimated using the BESS framework, with the following results:

- For the current scenario (2013), DM was predicted to reduce residential water demand by 7% and residential wastewater volumes by 11%.
- For the future scenario (2025/2050), after incorporating population projections, baseline residential demand was predicted to decrease by 4% and wastewater by 5%. This is reduced in the future due to the natural uptake of water efficient appliances over time. Hence DM is predicted to have further additional reductions of water demand of 4% and wastewater by 6% – commonly referred to as demand hardening.
- Reliability of those predictions using readily available local and interstate data was evaluated using the local information collected from the Adelaide end-use study and it was found that the reductions in total water use were robust.
- However, the end-use proportions were quite different, with non-potable water (outdoor, laundry and toilet) increasing by 12%, while the potable water component (shower, tap) decreased by 18%. The key driver of these observations were changes in outdoor water use.

6 Preliminary analysis of drivers of seasonal use

6.1 Preliminary drivers of seasonal water use

What is the estimated seasonal water use based on the quarterly data and measured indoor usage?

For the purposes of this report, seasonal water usage was defined as the increase in water use during the summer period. This could include outdoor water use, such as garden watering and car washing and seasonally influenced indoor usage, such as evaporative air conditioners, and any other potential changes to usage that occur due to climate variation.

Due to Adelaide's hot, dry summer climate, seasonal usage is a significant component of total household usage. 'Water for Good' estimated seasonal usage was approximately 30% of total household usage (Table 5.5). Due to the scope and timing of this study (see subsection 1.3) an entire summer of water usage data from the high resolution meters was not available for analysis. Seasonal water usage was therefore estimated by using the quarterly billing data from 2012 to mid-2013 and subtracting the indoor usage from the winter flow trace analysis. As this was an estimate and not actually measured, some errors were unavoidably introduced. For example, a small number of households (11) recorded a mean daily usage for the year that was less than the calculated indoor use. Unintentional errors such as this were excluded from this analysis.

In addition, the seasonal usage was based only a single summer (2012/13). As seasonal usage is likely to have significant variations from year-to-year associated with climate variability, it is unknown whether this single year was representative of the long-term average. For these reasons, this analysis of the drivers of seasonal water usage has been classified as preliminary. Further research is needed to better identify the drivers of seasonal water use (see subsection 7.4).

Based on the assumptions outlined above the mean daily seasonal usage was estimated to be 307 L/person/day. This results in an annual average seasonal use of 100 L/p/day, which is 43% of the total household water use. Figure 6.1 shows the significant variation between households with the upper 25% of households using 8.6 times more water than the lower 25%,while for indoor use, the same ratio is only 3.9%.

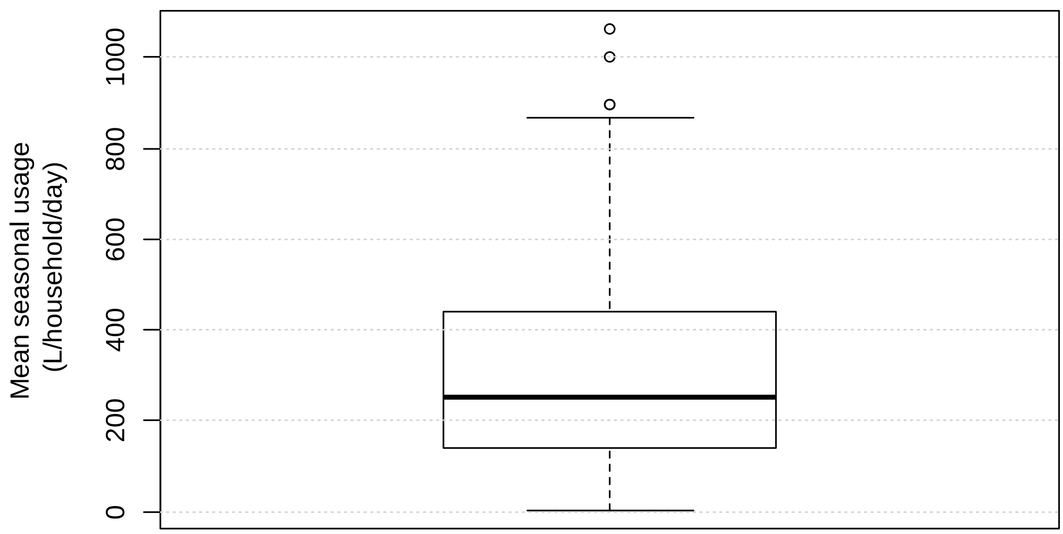

Figure 6.1: Variation of estimated seasonal usage between households

What are the drivers of seasonal water use based on the seasonal estimates?

Preliminary analysis of the impact of water use drivers was undertaken based on the seasonal estimate and characteristics of the households from the water appliance audit and end-use survey. The household characteristics measured for each household were:

- the type of watering system (sprinkler/dripper/both/none)
- the garden area
- watered garden area
- property area
- household demographics (see Section 4).

The results are shown in Table 6.1. The presence of a watering system had the largest impact on water usage, with households without a watering system recording a 30% reduction in seasonal usage. Larger properties with larger gardens and watered areas were found to have 19-26% higher seasonal usage, which is assumed to be due to greater irrigation. Income level was also found to have an effect in that lower income households recorded lower seasonal usage, which might be influenced by the smaller watered garden areas. Pensioners in this study were found to have significantly higher seasonal usage, perhaps due to the greater proportions of these households with large watered gardens as shown in Table 6.2

Table 6.1: Preliminary analysis of seasonal water use drivers

Driver	Category	Impact Volume (L/household/day) (% Difference from mean)
Watering system	With sprinkler or dripper (n=105)	334 (+9%)
	Without sprinkler or dripper (n=43)	218 (-30%)
Garden area	Large (>400 m^2) (n=42)	388 (+26%)
	Medium or small (< 400 m^2) (n=98)	263 (-14%)
Property area	Large (>750 m^2) (n=45)	381 (+24%)
	Medium or small (< 750 m^2) (n=99)	271 (-12%)
Income (Gross yearly household)	Low (<$38,000) (n=40)	243 (-21%)
	Mid/High (>$38,000) (n=100)	333 (+8%)
Watered garden area	Large (>200 m^2) (n=48)	364 (+19%)
	Medium or small (<200 m^2) (n=86)	270 (-12%)
Pensioner households (Adults 55+ only) *	Pensioner (n=53)	345 (+12%)
	Non-Pensioner (n=65)	254 (-17%)
Occupancy	None found	
Children	None found	
Rainwater tank (not plumbed)	None found	
Perceived water conservation level	None found	

Only significant ($p<0.05$) results presented, * Adult age of some householders unknown

Table 6.2: Proportions of watered garden areas

	Large (>200 m^2)	Medium (100 -200)	Small (<100 m^2)
Low Income	30%	32%	38%
Adults 55+ only	43%	33%	24%
All	35%	35%	30%

6.2 Comparison between actual and perceived proportion of seasonal water use

Can households predict the proportion of water used outside the home?

The respondents of the end-use survey in Stage 2 (Appendix A.3.1) were asked to specify the proportion of water they thought they used for different end-uses in summer, including the proportion of water used outside the house. The seasonal estimate of usage was compared to these summer proportions to determine if households were able to predict their seasonal water use. Table 6.3 and Figure 6.2 show the variation between household perception and seasonal estimate with the line of best fit (y=0.63x). Householders underestimated the proportion of water used outside the home, and the ability of the individual respondent to identify their individual household outdoor percentages was poor (negative NSE). These results are similar to the results which compared the actual and perceived proportion of indoor use (subsection 4.1). In general, households appear to be poor at estimating the proportions of total water used for different end-uses.

Table 6.3: Perceived seasonal usage versus actual usage

	Estimated % household seasonal usage	Mean perceived summer % usage in survey	Statistically significant difference	NSE (Nash-Sutcliffe efficiency)
Outside the home	46%	30%	Yes	-0.4

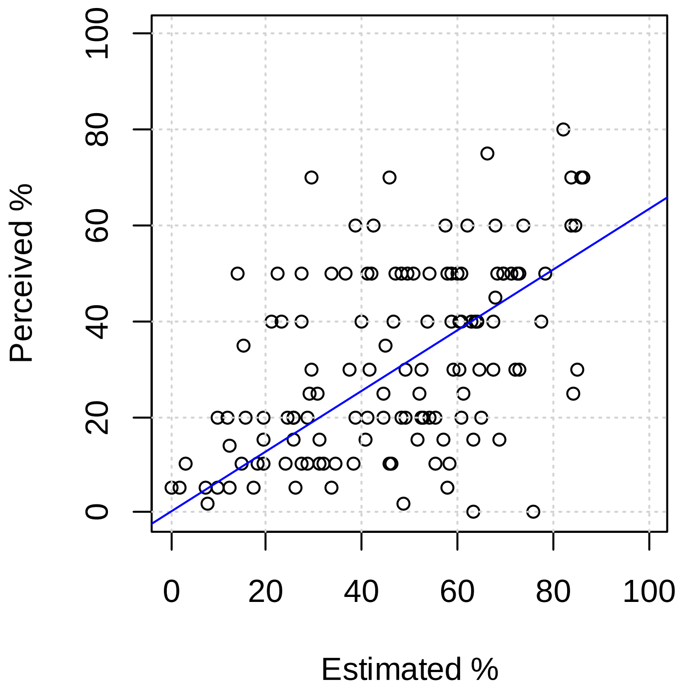

Figure 6.2: Perceived versus estimated seasonal usage percentage

6.3 Outdoor water source preference

Which water source is preferred for use on lawn, garden and outdoor areas?

Outdoor water use typically comprises the highest proportion of seasonal usage. It is highly variable between households and not typically used for potable purposes. Understanding what water source the households preferred for their outdoor water use was therefore a point of interest. During the end-use survey (Appendix A.3.1) in Stage 2 the respondents were queried on the preferred water source for use on their lawn, garden and outdoor areas of their homes. The householders were given seven sets of three choices for sourcing water used outside the dwelling. For each set they were asked to choose a best and worst option as shown in Table 6.4. The respondents were not given any information on the relative costing of the various sources and hence their responses did not incorporate willingness to pay factors.

Table 6.4: Example of best\worst choice set from end-use survey

BEST (TICK ONE BEST water source for outdoor use)		WORST (TICK ONE WORST water source for outdoor use)
	rainwater/roof water	
	recycled wastewater	
	demand management	

As shown in Figure 6.3, the end-use survey respondents had a clear preference for the use of rainwater/roof water as the outdoor water source with a Best/ Worst score of 2.0 out of a possible 3 (if it had been chosen in all cases by all respondents). The least preferred options were water from the River Murray and desalinated seawater. Figure 6.3 compares the result of the end-use survey to the results of 'Improving coastal water: a survey of Adelaide households' a survey with 1067 respondents that was conducted from Dec 2013 to Jan 2014 and funded by the Goyder Institute for Water Research. The results are similar, indicating that the preference is similar within the greater community. The improving costal water survey had a mean respondent age of 46 years, compared with 56 years for the end-use survey, and was completed online rather than in person.

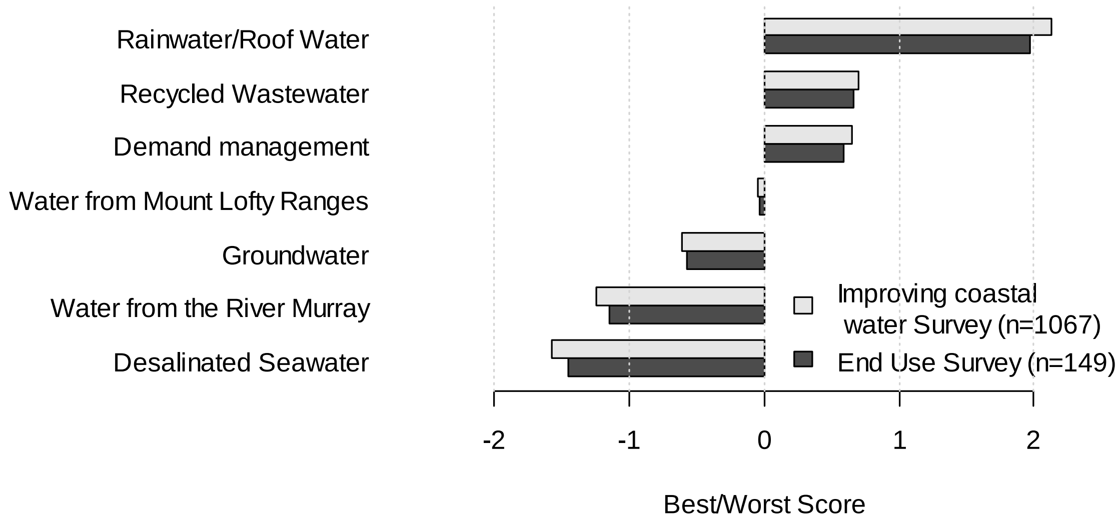

Figure 6.3: Best/worst analysis for outdoor water source

The preferred option does not reflect the actual water source used by the households as answered in the end-use survey. 78% of study participants specified tap water as the main source of water actually used outdoors; 20% specified rainwater tanks; and 2% did not use water outside the dwelling. The *ABS* [2011c] states that the main source for outdoor use for Adelaide households in 2010 was mains water (66%). The latest SA Water Annual Report[*SA Water*, 2013] identifies the sources of water being combined into mains water as 55% River Murray, 23% surface water, 16% sea water and 6% groundwater. Therefore, 77% of mains water is obtained from sources that are viewed negatively (Figure 6.3).

Does preference change with demographics?

Outdoor water source preferences did not significantly vary in relation to age, education or income. There was a clear preference for rainwater/roof water for outdoor water for the households in this study. However, this survey did not include any information on the relative costs/convenience associated with each option, which may change the preferences. Nonetheless, it is recommended that these preferences be taken into consideration for future water resource planning.

6.4 Influence of rainwater tanks on winter and seasonal usage

What is the effect of a non-plumbed in rainwater tank on overall water use and indoor water use?

There was no significant difference between the overall use of water in houses with non-plumbed rainwater tanks (n=79) and households without tanks in any month of the study. The flow trace analysis also showed there was no significant difference recorded for indoor water use during the two week period. Neither mean indoor water use nor mean total water use varied significantly between the households with and without non-plumbed in rainwater tanks. This is an interesting result, because a non-plumbed in tank would typically be used for outdoor use. The lack of use of rainwater could relate to the size of the tank or the roof area or other factors. In general, however, the result suggests that non-plumbed tanks provide little benefit in terms of reduction in household water use.

What is the effect of a plumbed in rainwater tank on overall water use and winter water use?

Eight households were excluded from the flow trace analysis because the rainwater tank was plumbed into the home. The usage for each end-use was therefore unmonitored, although the overall water use was recorded by the high resolution meters. The households with plumbed rainwater tanks had an overall mean daily water usage over the study period of 196 L/person/day compared to 289 L/person/day for the remainder of the households.

The reduction in winter usage (July-August) was statistically significant, averaging 115 L/person/day compared to 153 L/person/day for the other participant households. This reduction of 38 L/person/day in indoor usage is approximately double the potential savings of 19.3 L/person/day from switching to all water efficient appliances (Table 4.2). The households with plumbed tanks all had the tank plumbed into the laundry but not the toilets. Based on the typical per person end-use for washing machines (Figure 3.20) of 25 L/person/day, this additional reduction of 19L/day is reasonable.

This suggests that internally plumbed rainwater tanks can provide significant water savings, i.e. double the reduction of indoor usage compared with water efficient appliances. However, these results are based on a very small sample of only eight households, and there are numerous other factors that need to be taken into account, such as rainfall, roof/tank area and differences in households due to household occupancy and appliances. For example, the households with plumbed-in rainwater tanks had a lower mean household size than the remaining households. A smaller tank or roof might struggle to supply water for larger household sizes. Furthermore, the comparison of the water savings from installing an internally plumbed rainwater tank versus water efficient appliance needs to consider the relative costs of each option.

Further modelling and research on the implications of water use and wastewater flows due to rainwater tanks and reuse by the household are required. See also task 2/3 report for further information on rainwater tank modelling [*Maheepala et al.*, 2014].

6.5 Summary of preliminary analysis of drivers of seasonal use

This preliminary analysis of the drivers of seasonal water use (based on estimated values from a single summer of quarterly billing data) has led to the following observations:

- Seasonal water use, including outdoor watering, ponds and pools, evaporative air conditioners or car washing, comprised approximately 43% of total household water use, with significant variation between households – approximately two times more variation than indoor use.
- Seasonal water use is strongly influenced by the presence of a watering system, property size, garden size and watered garden area, with changes of the order of 19-30%.
- Pensioners (age 55+) recorded a higher seasonal water use (increase of 12% from mean) than other households, which might be due to their property characteristics.
- Lower income households had reduced seasonal water usage (decrease of 21% from mean).
- Householders estimated the proportions of seasonal water usage very poorly, typically underestimating it by approximately 40%. This represents a potential for reduction in water use through education into the amount of water used outdoors.
- There was a clear preference for the use of rainwater/roof water for outdoor, regardless of demographic indicators. However, this result did not include any information on relative costs of the different water sources.
- Households with rainwater tanks that were not internally plumbed did not show a significant change in indoor or total water use.
- Households with internally plumbed rainwater tanks (for laundry) showed an additional reduction in winter water use which was consistent with the washing machine end-use being supplied by the tank. This reduction in indoor use was double the potential water savings from switching to all water efficient appliances. However, this estimate is based on a small sample, and further modelling is required incorporating a wider range of household characteristics and the relative costs of rainwater tanks versus water efficient appliances to provide a reliable evaluation.
- As seasonal water use is strongly impacted by climate variation, further research and monitoring over a longer time is recommended to provide a more reliable estimate of the drivers of this significant proportion of household water use.

7 Discussion and future research

This section discusses some of the key assumptions and study limitations and identifies areas for future research.

7.1 Are the study households representative of Adelaide households?

The scope of the study was limited to sampling 150 households. Due to the relative small sample size, a relevant question is whether the households are representative of the households of Greater Adelaide. Furthermore, the household selection process included selection criteria that could have affected whether the participant households were representative of Greater Adelaide. Subsection 2.1.1 provides the full list of criteria. The key ones required that only owner-occupied, established, detached houses, located in close graphical proximity, with no renters, townhouses, units or semi-detached houses be included. These conditions were evaluated in terms of their impact on participant selection (subsection 3.1) and showed that owner-occupied detached houses represent the major dwelling structure (60%) for Greater Adelaide.

The dwelling structures that were excluded from the study included newer dwellings in outer suburban areas, units, townhouses, semi-detached homes and houses with renters, as well as houses with plumbed-in rainwater tanks. The difference in the water use between the households that were excluded and those that were included is that newer dwellings and units or townhouses are likely on smaller blocks and have smaller gardens, which would normally result in lower seasonal usage. Furthermore newer dwellings are likely to have a greater proportion of water efficient appliances. It would therefore be expected that the overall total water usage would be lower.

As the majority of future growth in Adelaide's housing will be in newer dwellings and also in units or townhouses due to urban renewal, understanding the differences between the water use in newer dwellings will be important for providing improved predictions of water use in the future. It is recommended that a future study be conducted that focusses on understanding the drivers of water use in dwellings structures that were excluded from this study.

Subsection 3.1 compared the demographic groupings of the study households with the Greater Adelaide statistics based on age, income and type of family. The comparison demonstrated that the study households provided a good representation of approximately 63% of the income/family type groups in Greater Adelaide. Some types of households were over-represented, while others were under-represented, however. Medium income couple with no children households, for example, were over-represented, while low income, one-parent with children and non-family households were under-represented.

It is difficult to predict the effect over- or under-representation of certain groups would have on the estimate of total water use, but the selection criteria for the study participants automatically excluded some demographic groups and included others who could have added further insight to the research. It was estimated, for example, that the households participating in the study had a higher representation of older people (adults 55+) and an under-representation of young adults (20-34) (subsection 3.1). Due to the differences in water use due to age composition (section 4.3), this may impact on the proportion of different end uses. Further research is needed on a wider range of households to ensure estimates of total water use reflect demographics more comprehensively.

Subsection 3.2 compared the proportions of water saving appliances in the study households with the statistics from households in Greater Adelaide. The major difference was the study households' proportion of front loaders was higher than for Greater Adelaide. As front loaders are generally more efficient than top loaders, this would mean the study households have lower mean household water use than Greater Adelaide. However, in subsection 3.3.1 it was noted that the study households recorded a mean water use that was approximately 10-15% higher than the estimate of mean household water use from Metropolitan Adelaide. So this higher proportion of front loaders does not appear to have adversely biased the average water use of the study households.

One circumstance about the study that could have introduced bias and reduced representativeness was the fact that the preliminary survey, which was made available randomly, may have attracted individuals who had an interest in water conservation. It is difficult to see how this issue could be avoided – as it was necessary for people to volunteer to participate. The impact of this is reflected in the results described in subsection 4.5, which showed there was greater than 80% broad agreement for survey questions related to water conservation.

However, despite this interest in water conservation, it was not reflected in the measured water use, with the study households having an average household use that was approximately 10-15% higher than the estimated of average household water use from metropolitan Adelaide (subsection 3.3.1). The water use despite the perceived conservation could be because households are not very good at estimating the proportion of the various end-uses (subsection 4.1 and subsection 6.2), and hence do not have a reliable indication of where they use in their households.

This represents an opportunity for future research to use monitoring and modelling to better educate and inform households of their water saving opportunities. Also, further research could be undertaken to survey a wider range of households to determine if the water conservation attitude of the study households is representative of Greater Adelaide.

7.2 Challenges in estimating representative leakage volume

The results in subsection 3.7 showed that the leakage volume from the study households was estimated to be the order of 5-8% of total winter usage. This percentage was not considered comparable to the leakage in metropolitan Adelaide as a whole because:

- A very small number of households and leaks (2% -6%) contributed a large proportion of the leakage volume (56-68%). If we removed two or three households, the leak estimate would drop to 2-4%. It is unclear if 2-6% of households with leaks are representative of Greater Adelaide.
- The percentage estimate for leakage was made during winter and did not include any seasonal water use, which is 40% of the total annual usage. The leakage volume may be over-estimated.

The advantage of high resolution monitoring is that it enables an easy approach to be developed to detect leaks, and identifying and removing leaks could potentially be effective method of reducing water use. However, as the leakage volume is unreliable in this instance, it is unclear whether the repair of leaks would provide a significant source of water savings throughout metropolitan Adelaide. Further research on more households, over a longer time is required to provide a better estimate of leakage volume representative of Greater Adelaide.

7.3 Potential savings in household water use: appliances or behaviour?

The two major mechanisms for potentially saving water in households through the use of demand management are either by using more efficient appliances or by changing behaviour, for example, taking shorter showers. In this report the demand management predictions only include changes in water efficient appliances. The advantages and disadvantages of this approach are outlined below.

- When comparing households with efficient and non-efficient appliances, changes in household water use were due to differences in appliance efficiency and not due to changes in behaviour. For example households with efficient showers did not have a different mean shower duration.
- However, the comparison with previous studies in different states showed that differences in the usage for individual end-uses was due to a combination of appliance efficiency and behaviour. Similarly, the different water use for households with different age composition was driven by a combination of appliance efficiency and behaviour. Thus behaviour does influence water use.
- Quantifying the impact of changes in behaviour was difficult, as it was outside the scope of this study to investigate the drivers of changes in behaviour (see subsection 1.3). Behaviour change has the potential to increase the impact of demand management on water savings. For example previous studies [*Willis et al.*, 2010] have shown that the use of shower timers can decrease shower duration. It is recommended that future research investigate the drivers of changes in behaviour.
- Note that for effective implementation of demand management due to increased uptake of water efficient appliances, it is necessary to consider the barriers to uptake. For example, the uptake for water efficient washing machines among adults 55+ was relatively low in this study, which could be because of cost alone or other factors, such as concern about the length of the washing cycle, not being able to add clothing once the cycle has started or problems bending down to load and unload. Further research is recommended to understand the barriers to uptake of washing machines or other water conserving appliances.

Overall, since the estimates of demand management provided in this report only include changes in appliance efficiency, they represent a lower boundary of the potential for demand management. Demand management via behaviour change could potentially increase the available water savings via demand management. Further research is required to estimate the potential for water savings through behavioural change. In addition to understanding the drivers of behavioural change, the associated cost and likely success of implementing a suitable scheme must also be considered.

7.4 Analysis of drivers of seasonal and peak daily water use

Due to the scope of the project, the analysis of seasonal water use was classified as preliminary as it was limited to a single summer based on only quarterly billing data. Nonetheless the outcomes of the analysis were as follows.

- Seasonal water use (outdoor, evaporative air conditioning and potential indoor changes) comprises over 40% of household water use.
- There is significant variation in the seasonal water use between households between households with garden area, income and watering systems having a major impact (15-26%).

- Given that seasonal water use is a significant component of total household water use and little information is available to estimate the key drivers, it is recommended that further research be undertaken to extend the period of monitoring and analysis. For example, extending the monitoring till July 2015 would provide two complete summers of data for analysis. This would enable improved understanding of the drivers of seasonal water use and better inform the impact of climate variation on seasonal water use.
- Peak demands are a key design parameter of water distribution systems. They govern the design of major hydraulic infrastructure (pipes/tanks and pumps) that ensure a reliable water supply. Similar to the seasonal water use analysis, the analysis of peak daily water use in this study was only preliminary due to the relatively short record (not even one complete summer). It was beyond the scope of this project to analyse the drivers of peak demand. However, during the monitoring period it was found that 50% of the water use on peak flow days came from only 20% of households.

As only a small proportion of households contributed to the peak demand, this represents a significant opportunity for future research to investigate approaches to reduce the peak and reduce infrastructure design and operations costs. One of the advantages of high-resolution smart metering is the ability to understand the drivers of peak demands as demonstrated in past studies [*Beal and Stewart*, 2013; *Gurung et al.*, 2014].

It is recommended that in future:

- data collection for the study household be extended for another year, until July 2015, to record two complete summers of peak data
- further analysis be undertaken to determine not just the drivers of peak water use but how they interact with household characteristics and behaviours.

7.5 Enhancements to model predictions

The evaluation of the data required by the BESS model found that all local data was required to provide reliable model predictions of mean end-uses, and the BESS model underestimated the standard deviation. It is recommended that BESS be further developed to enhance the model predictions. Modifications should include:

- the ability to model the differences in household types (adults only 55+ and children/high income households). This modification will improve the ability of BESS to provide reliable predictions without the need for local end-use information from flow-trace analysis. This would enable BESS to be used on a wider variety of locations across South Australia.
- enabling BESS to predict the entire range of household water use, including peaks, by incorporating the drivers of seasonal water use and peak water use
- improvements in future demand forecasts by including future changes in household sizes and changing population demographics (for example, increase in pensioners). Further research is needed to ascertain the relative importance of these factors on future demand.
- Development of BESS into a usable software tool. For use by stakeholders, BESS needs to be extended to include an easy to use interface. This would enable stakeholders to make the best use of the data collected as part of this project.

7.6 Summary of future research

The key areas for future research and their advantages can be summarized as follows:

- **Identify drivers of reductions in seasonal and peak water use.**
  - Extend the monitoring for the current study households to collect more summer data, e.g. summers 2013/2014 and 2014/2015. This would address the limitations of the current study where the drivers of seasonal water use, which is one of the biggest end-uses, could not be investigated.
  - Undertake analysis to understand the key drivers of seasonal and peak water use. As these two types of water use are the major drivers for the design and operations of water infrastructure this will identify opportunities for cost savings.
  - Determine if household water use remains stable at post-drought levels through extended monitoring.
- **Identify drivers of water use in under-represented households.**
  - The 150 study households used for this study were representative of approximately 60-65% of the demographic groups and existing dwelling structures in Greater Adelaide. The demographic groups that were under-represented were low income, one parent families and non-family households, young adults aged 20-54 and renters. The dwelling structures that were under-represented were newer households, units, flats, townhouses and semi-detached dwellings.
  - These dwelling structures and demographics are likely to be a major source of growth in Adelaide's future housing stock. It will be important to understand and evaluate the drivers of water use for these dwelling structures to enable reliable predictions of future demand.
  - The wider range of households would also increase the reliability of estimates of the leakage volume, which was deemed too unreliable in this study due to high sampling variability.
  - Future research should extend the analysis undertaken in this study to identify the drivers of those households that were under-represented (e.g. low income, one parent families, and newer housing stock). Comparison with the drivers identified in this study, will identify key differences.
- **Identify the drivers of behavioural change.**
  - The scope of this study did not include evaluating the drivers of behavioural change.
  - Results showed there were significant behavioural differences between different household classifications. Adults 55+ and high income families had statistically measurable differences in behavioural parameters, including the frequency and duration of events.
  - Future research should evaluate the drivers of these behavioural differences to better understand how behavioural change can be used to reduce demand.
- **Enable more reliable predictions of water use for a wider range of locations and end-uses.**
  - BESS should be extended to model differences in different household types.
  - BESS should be extended to model change drivers of seasonal and peak water use.
  - BESS should be extended to model predicted changes in household size and demographics.
  - Development of interface for BESS will enhance its use as a software tool for stakeholders.

8 Data management

A description of the data collected through this project has been registered as a research data collection with DataConnect, the University of Adelaide's data management system, which is connected to Research Data Australia as part of the Goyder Institute for Water Research collection. The link to the collection is

http://researchdata.ands.org.au/household-water-use-study-2013/454021

In the short-term de-identified summary statistics for the study households will be readily available upon inquiry through DataConnect. The summary statistics will include end-use means and standard deviations (totals, volumes, flow rates) and household demographics. In the longer term, this data will be made publicly accessible to enable researchers to re-use the data.

9 Conclusion and recommendations

Using surveys and high resolution monitoring, including flow trace analysis, this study has improved the understanding of household water use in a South Australia context. Data relating to household characteristics, behaviour, attitudes and water use were collected for a representative group of 150 study households in Greater Adelaide. Water use data was measured over an 11 month monitoring period (Mar 2013 to February 2014), with a two-week period in winter analysed using flow trace analysis to evaluate individual end-uses. Key results have been categorised and recommendations and practical implications are provided below. Key findings are highlighted in bold.

General trends in household water use

- Study households were representative of approximately 60-65% of the households of Greater Adelaide based on analysis of demographics (age/income, household occupancy), dwelling structure (unit/flats/ detached house), appliance uptake and mean household water use. Under-represented households included low income single parent family and non-family households, units/flats/townhouses/semi-detached houses and houses with renters.
- Mean water use was 289 L/p/day, higher than the 2012/13 SA Water estimates of 219 L/p/day most likely due to relatively hot summer of 2013/2014.
- Seasonal impact increased mean water use from 153 L/p/day in winter to 498 L/p/day in summer 2013/14, and changed the diurnal pattern, with an afternoon peak more prominent during summer.
- High variability in daily household use was observed, with some households recording > 1000 L/p/day during summer, while 64% of the recorded usage was less than 200 L/p/day.
- Analysis of the top 10 peak demand days showed only 20% of households contributed to 50% of the peak demand. **This represents a significant future opportunity to target a small proportion of households in order to reduce peak demand and limit the need for water infrastructure design and operation costs.**
- High resolution meters enabled fast and efficient identification of leaks within a household. The overall leakage volume was estimated to be 5-8% of the study household mean water use, but is deemed an unreliable estimate of the leakage volume of metropolitan Adelaide due to a small number of houses having very large leaks. **Household leakage reduction could potentially produce water savings of 5-8%, but a wider range of households needs to be analysed to improve the reliability of the leakage proportion.**

Indoor end-use analysis

- Individual end-use proportions varied considerable between households. Householders' perceptions of their individual end-use proportions proved very unreliable. **Households need greater information and guidance, for example, through monitoring, to appreciate how water is used in their own homes so that can identify cost-effective water savings opportunities.**
- Total indoor usage from flow trace analysis was 5% lower than estimate based on 'Water for Good' [*Government of South Australia*, 2010]. Individual end-use values that differed from 'Water for Good' [*Government of South Australia*, 2010] included reductions in shower or bath usage and washing machine usage.

- Mean indoor end-use based on the flow trace analysis periods was recorded as follows:
  - total Indoor: 135 L/p/day
  - shower usage: 48 L/p/day
  - toilet usage: 28 L/p/day
  - washing machine usage: 25 L/p/day
  - tap usage: 29 L/p/day
  - dishwasher: 2 L/p/day
  - bath: 3 L/p/day
- The flow trace analysis period also included and outdoor usage of 7% and 8% leakage.
- Comparison of indoor end-use volumes to past interstate studies found that the key differences were due to a mixture of differences in appliance uptake and behavioural (freq/durations of events) changes. This result indicates that differences in appliance uptake and behaviour need to be included to enable transferability of interstate studies to local areas**.**

Analysis of drivers for indoor water use

- Impact of water efficient appliances:
  - Water efficient appliance uptake was approximately 50% - with 43% with 3 star showerheads, 42% with 6/3 L or 4.5/3 L dual flush toilets and 54% with front loading washing machines.
  - There was potential water savings of 19 L/p/day if all households moved to efficient appliances (washing machine 8.7 L/p/day, showers 5.5 L/p/day, toilets 5.1 L/p/day).
  - For this study, appliance efficiency (rather than behaviour) was the primary driver for reductions in indoor water use. (That is, an individual's way of using water did not change when the appliance changed. For example, when efficient shower heads were installed, the duration of the shower didn't change, but water was saved.)
  - Washing machines represent the appliance for which the greatest potential savings can be made, and where householders still have a choice between efficient and non-efficient. **Development of schemes that encourage the continued uptake of water efficient washing machines are recommended to reduce water use**.
- Even from the small sample, distinct household usage types emerged with significantly different water usage and different water saving opportunities. Households could be demarcated by age, income, family type, appliance stocks and behaviour. The households and salient features are outlined below.
  - Households with **Adults 55+ only**
    - lower shower use, but higher proportion of washing machine and toilet use than the mean
    - more likely to perceive themselves as water conservers
    - demonstrate water saving behaviour (shorter showers)
    - own inefficient washing machines (<30% uptake of water efficient appliances) and exhibited higher toilet frequency
    - water saving opportunity are from uptake of efficient washing machines
  - Households with **children /high income**
    - very high shower use, but lower toilet and washing machine use than mean
    - higher shower duration

- lower toilet frequency
- more efficient washing machines (~70% uptake of front loaders)
- less likely to think of themselves as water conservers
- water saving opportunities should target changing shower behaviour.

- **Different household usage types require development of targeted demand management programs that focus on differences in water savings opportunities (changing behaviour/appliance uptake) between types.**
- The results indicate that household usage types need to be taken into account for future planning and when expanding the results of this study to different areas.

Predictive modelling of water use

- The behavioural end-use stochastic (BESS) model provided reliable predictions of mean end-use using local Adelaide end-use information (predictive errors <1.5%).
- BESS can be used to provide reliable predictions of mean end-uses for households that are represented in this study.
- Using local Adelaide information on occupancy and appliance uptake (readily available, does not require full end-use study) and interstate information on appliance flows and household behaviour, total household water use predictive errors were <10%, but individual end-uses predictive error were up to 40%.
- Variability in end-use volumes was significantly underestimated using BESS.
- The future development of BESS should include behaviour of different household usage types in order to improve predictions of end-use variability and transferability to more locations**.**
- Analysis of water use reductions during the 2007-2009 drought found there was approximately a 15% reduction in household water use. Approximately 50% of the reduction during drought was estimated to be due to the uptake of water efficient appliances, with the remaining 50% was likely due to reductions in outdoor use.
- There has been no major increase in household water use since the drought ended. **Continued monitoring is recommended to determine if the water use continues at post drought levels into the future.**

Impact of demand management

- Demand management (DM) is the use of strategies that encourage reductions in water demand and waste water volumes. An example would be encouraging the uptake of water efficient appliances and/or behavioural changes.
- BESS was used to provide predictions of the impact of DM for the water source modelling (Task 3) and optimisation (Task 2) of the Adelaide water supply system.
- Predictions included changes in household occupancy and water efficient appliances, but no change in behaviour or technology. This represents a lower bound of the estimate of the potential water use reductions due to DM.
- **For 2013 DM reduced residential water demand by 7% and wastewater volumes by 11%.**

- **For 2025/2050 scenario, baseline residential demand is predicted to decrease by 4% and wastewater by 5%** due to the natural uptake of water efficient appliances over time. **Impact of DM will be reduced with additional reductions of water demand of 4% and wastewater by 6% – commonly referred to as 'demand hardening'.**
- **As DM impacts did not include behaviour changes, but significant differences in behaviour were found for different household usage types, it is recommended that future work evaluate the opportunities for behavioural change to reduce water use.**
- Due to project timing, these predictions were based on using data readily available mid-project (mix of interstate and local information).
- Post-project these predictions were evaluated using the local Adelaide information only and it was found that the relative reductions in total water use were robust. However, the end-use proportions were quite different, with non-potable water (outdoor, laundry and toilet) increasing by 12%, while the potable water component (shower, tap) decreased by 18%. The key drivers of this were the changes in outdoor water use.

Preliminary analysis of drivers of seasonal water

- Results are classified as preliminary because they are based on an analysis of a single summer (2013/2014) of quarterly billing data.
- Seasonal water use is approximately 40% of total household water use.
- Seasonal water use is affected by increasing property size, garden size and watered garden area (26-30% higher than mean).
- Lower income households have reduced seasonal water usage (20% lower than mean).
- Households with adults 55+ only were found to have higher seasonal water use (12% higher than mean). Householders underestimated the proportion of water used outside the house by an average 40%. Similar to indoor use, **households need greater information/guidance (e.g. monitoring) on how water is used in their own homes so that can identify cost-effective water savings opportunities.**
- There was a clear preference by the respondents for the use of rainwater/roof water over other sources of supply (groundwater, surface water, River Murray, desalination) for outdoor use, regardless of demographic. However, this survey did not include information on the relative costs of the water supply options, which could change the results.
- As seasonal water use is the major proportion of household water use, it is recommend that further analysis of the drivers of seasonal water use be conducted based on high resolution monitoring using more summer data.

Future research

Future research opportunities can be summarised as follows:

- **Identify drivers of reductions in seasonal and peak water use** by extending the high resolution monitoring and analysis to include more summer data for the study households. As these two types of water use are the major drivers for the design and operations of water infrastructure, this will identify opportunities for cost savings.

- **Identify the drivers of under-represented households** by extending the high resolution monitoring and analysis to include households under-represented in this study which are likely the major driver of future growth in Adelaide's water use and to provide reliable estimates of leakage volumes.
- **Identify the drivers of behavioural change**, which can increase the potential water savings provided by demand management.
- **Enable more reliable predictions of water use for a wider range of locations and end-uses** by incorporating household usage types and seasonal usage drivers into the BESS framework.

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Appendix A – Mail out and Survey Documents

A.1 Initial Mail Out Documents

A.1.1 Cover Letter

SA Water
SOUTH AUSTRALIAN
WATER CORPORATION

SA Water House
250 Victoria Square
Adelaide SA 5000

Phone 1300 650 950

ABN 69 336 525 019

[Date]

Account No: [AccountNo]

[CustName1]
[CustAddress1]
[CustAddress2]

Invitation to participate in a Household Water Use Study

Dear [Customer Name]

The University of Adelaide and CSIRO through the Goyder Institute are carrying out a Household Water Use Study to further understand community attitudes towards water use in Adelaide and to determine the way water is used by different households.

The results of the study will contribute to research to assist in the planning of Adelaide's future water supply options. You are invited to participate in this study.

Participation is voluntary and anonymous - your household has been randomly selected by SA Water to be invited to participate. Your details have not been provided to The University of Adelaide or CSIRO.

To ensure participants represent our diverse customer base, only some of the invited homes will be selected as final participants. If you choose to participate and are selected:

- An electronic water meter that can record water usage at short time intervals will be installed at the location of your existing water meter.
- A University of Adelaide representative will visit your home to undertake an audit of your water using appliances and conduct a community attitudes survey with you.
- You will be asked to complete a water diary for a period of one week, and
- You will receive a **$50 Coles-Myer gift card** from The University of Adelaide.

The enclosed fact sheet provides further details on the study.

If you would like to be considered for this study please complete a short initial survey, available online via: **https://www.research.net/s/CKFTF8B.** Alternatively, you may complete the enclosed survey and return it using the reply paid envelope.

If you complete the survey online within 5 days you will go into a draw to win a $300 Coles-Myer gift card from The University of Adelaide.

If you require further information please call the SA Water Customer Service Centre on 1300 650 950.

Yours sincerely

Roger Perry

Roger Perry
Head of Strategy Planning & Regulation
SA Water

Government
of South Australia

A.1.2 Fact Sheet

Fact Sheet - Household Water Use Study

Who will undertake the study?

This work is being undertaken by the University of Adelaide and CSIRO as partners in the Goyder Institute for Water Research (www.goyderinstitute.org). SA Water is providing support by inviting households to participate and installing electronic meters at selected participant households.

What is the study?

The project will involve monitoring water use at 150 households across Adelaide. An electronic water meter that can record water usage at short time intervals will be installed alongside your existing water meter outside your home. A University of Adelaide representative will visit your home to undertake an audit of your water using appliances and conduct a community attitudes survey with you.

What is the aim of the study?

To provide an improved understanding of community attitudes in Adelaide towards water use and to determine the way water is used by different households. The results of the study will contribute to research to assist in the planning of Adelaide's future water supply options.

How will the study be conducted?

Electronic water meters will continuously collect water usage data for a period of approximately 15 months. The data will be downloaded periodically and analysed by University of Adelaide and CSIRO researchers – this requires water meter locations to be readily accessible.

When will the study take place?

The equipment will be installed between December 2012 and February 2013 and the study will take place between January 2013 and March 2014.

What is required of me? How much of my time will be needed?

A University of Adelaide representative will visit your home in the first half of 2013 to undertake an audit of your water using appliances and conduct a community attitudes survey with you. This will take between 1-2 hours of your time. At some time during the study you will be asked to complete a water use diary for a period of one week.

How and when will the gift cards be distributed?

Households who complete the initial survey online within 5 days of receiving this letter will go into the draw to win a $300 Coles-Myer gift card. Households will be notified during December 2012 if they have been selected to participate in the study. Participating households will receive a $50 Coles-Myer gift card upon the completion of the in-home survey. All gift cards are provided by The University of Adelaide.

How will my privacy be protected?

Personal information collected for this study will only be used by The University of Adelaide, CSIRO and SA Water for the purpose of collecting water use and attitude information. For the purposes of analysis, all data will be treated anonymously, with all personal information removed. Your privacy will be protected at all times and personal information will not be disclosed to any third parties.

Will this affect my water bill?

No, the electronic metering will not impact on your water use or water bill.

GOYDER INSTITUTE FOR WATER RESEARCH   THE UNIVERSITY of ADELAIDE   CSIRO   Government of South Australia   SA Water

A.1.3 Screening Survey – Online Version

Personal Details

This survey should be completed by an adult.

***1. What is your name?**

Title:

First Name:

Surname:

***2. What is your street address?**

Number and Street

Suburb

Postcode

***3. What is the most convenient phone number that can be used to contact you?**

4. At what email address would you like to be contacted?
This is the preferred method of contact.

***5. SA Water Account number (10 digits without spaces)?**
This is found as the reference on the letter of invitation or on the front of your water account.

Housing Details

***6. Which of the following best describes your occupancy status?**

- ◯ Owner
- ◯ Rental/Lease

***7. In which type of housing do you currently live?**

- ◯ Detached House
- ◯ Semi-detached house, terrace or townhouse
- ◯ Flat / Unit (with shared water meter)
- ◯ Flat / Unit (with individual water meter)

8. Age of dwelling in years (approx.)?

9. Number of years lived at residence?

Water Appliances

*10. What type of hot water heater do you have?**

- ◯ Mains Pressure
- ◯ Gravity Fed (ie tank in ceiling)
- ◯ Unsure

***11. Do you have an evaporative air conditoner?**

- ◯ Yes
- ◯ No
- ◯ Unsure

***12. What type of washing machine to you have installed?**

- ◯ Top Loader
- ◯ Front Loader
- ◯ Unsure

***13. What type of showerhead(s) do you have?**

- ◯ Water efficient
- ◯ Standard
- ◯ Both
- ◯ Unsure

Water Appliances

***14. What type of toilet(s) do you have?**

- ◯ Single Flush
- ◯ Dual Flush
- ◯ Both
- ◯ Unsure

***15. Do you have a swimming pool or spa?**

- ◯ No
- ◯ Swimming pool
- ◯ Spa
- ◯ Both swimming pool and spa

***16. Do you have a rainwater tank(s)?**

- ◯ Yes
- ◯ No

Plumbed Rainwater Tank

17. How many rainwater tanks to do have?

- 1
- 2
- 3
- 4+

Estimate the combined volume of your tanks in thousands of litres - if unsure leave blank.

***18. Is at least one rainwater tank internally plumbed (eg connected to toilet or other internal appliance)?**

- Yes. A rainwater tank is internally plumbed
- No.
- Unsure

Property Changes

*19. Do you plan to move or undertake major renovations or building work to your residence over the next 15 months?**

- ◯ Yes
- ◯ No

If yes, briefly describe timing (and extent of any work)

Accessibility

***20. Is your water meter accessible and able to be read if there is no one home?**

- ◯ Accesible
- ◯ Not Accesible

Comment (optional)

Household Details

***21. What is the number of people currently living in your household?**

Please enter the number of people in each age bracket

0 - 4

5 - 9

10 - 19

20 - 34

35 - 54

55+

Total

***22. What is the employment status of the people in the household?**

Please enter the number of people in each category.

Full time

Part time

Home duties

Unemployed

Student / Pre-school

Retired

***23. What is the gross annual household income?**

- less than $38,000
- between $38,000 & $83,000
- greater than $83,000

A.1.4 Screening Survey – Hardcopy Version

THE UNIVERSITY of ADELAIDE

Invitation Survey – Household Water Use Study

(This survey should be completed by an adult)

You have the chance to win a $300 gift card if you complete this survey ONLINE
(visit https://www.research.net/s/CKFTF8B)

Title: ____ First Name: ____________ Surname: ____________
Street Address: ______________________________
Suburb: ____________________ Postcode: ________
Phone number (most convenient): ____________
Email address: ______________________________

SA Water Account Number (this is at the top of the invitation letter): ____________

Occupancy status: ☐ Owner ☐ Rental / Lease

Dwelling type: ☐ Detached house ☐ Semi-detached, terrace, townhouse ☐ Flat/Unit (with shared water meter) ☐ Flat/Unit (with individual water meter)

Age of dwelling (approx): ______
Number of years there? ______

Type of hot water heater: ☐ Mains pressure ☐ Gravity fed (ie tank in ceiling) ☐ Unsure

Do you have an evaporative air conditioner? ☐ Yes ☐ No ☐ Unsure

Type of washing machine? ☐ Top loader ☐ Front loader ☐ Unsure

What type of showerhead(s) do you have? ☐ Water efficient ☐ Standard ☐ Both ☐ Unsure

Types of toilet(s) ☐ Single flush ☐ Dual flush ☐ Both ☐ Unsure

Do you have a swimming pool / spa? ☐ Swimming pool ☐ Spa ☐ Both ☐ Neither

Do you plan to move or make any major renovations in the next 15 months? If yes, please describe: ______________ ☐ Yes ☐ No ☐ Unsure

Is your water meter accessible and able to be read if there is no one is home? ☐ Yes ☐No ☐ Unsure

Do you have a rainwater tank? ☐ Yes ☐ No
If so, is it internally plumbed (eg; connected to the toilet)? ☐ Yes ☐ No ☐ Unsure

Age of people living in the house:		Number	Employment status of people living in the house:	Number
Age range (years)	0-4	______	Full time	______
	5-9	______	Part time	______
	10-19	______	Home duties	______
	20-34	______	Unemployed	______
	35-54	______	Student / Pre-school	______
	55+	______	Retired	______
Total number in household:		______		

Gross annual household income:
☐ less than $38,000 ☐ between $38,000 & $83,000 ☐ greater than $83,000

If selected, I am willing to participate in the study. SA Water will provide my water consumption data for the previous 2 years to the University of Adelaide & the University will collect & use water use data from my household for this study. Personal data collected on this page will only be used to select a range of suitable households and to contact you regarding selection for the study – all data will be kept strictly confidential.
I have read the fact sheet and understand what is required of me. ☐Yes ☐No

Please place the completed survey in the reply paid envelope and post within five days

A.2 Stage 2 Mail Out Documents

A.2.1 Congratulations Letter

THE UNIVERSITY of ADELAIDE

SCHOOL OF CIVIL, ENVIRONMENTAL AND MINING ENGINEERING

Dr Mark Thyer
Senior Lecturer

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mark.thyer@adelaide.edu.au
CRICOS Provider Number 00123M

Reference: «SAW_Acc»

«Title» «Firstname» «Surname»
«Address_1»
«Address_2» SA «Postcode»

Dear «Firstname»

Congratulations on being selected to participate in the Household Water Use Study

Thank you for registering your interest in our water usage study. We would like to advise you that your home has been selected to participate! We received replies from over 1000 homes and have selected a sample of 150 homes that best represent a cross section of households within metropolitan Adelaide.

We are planning to install the electronic water meters between December 2012 and February 2013. The electronic water meter will be fitted next to your existing meter.

The equipment will be installed by SA Water's contractor. Unfortunately, not all meter locations are suitable for our equipment - we will advise you if your meter situation is not suited to this study.

In January / February 2013 you will be contacted by University of Adelaide researchers to make an appointment to visit your home to record detailed information about your water using appliances and how you use them. This is when you will receive a $50 Coles Myer gift card as thanks for your participation in this study.

Please find enclosed:

- Participant Information Sheet, which provides additional information about this study,
- Independent Complaints Sheet.
- Consent Form (2 copies) and reply paid envelope

Please complete and sign both copies of the consent form - return one to the University of Adelaide using the reply paid envelope and keep the other for your records.

If you have any concerns or questions please feel free to call the University of Adelaide research team on 0498633452. Once again thank you for your interest in taking part in the Household Water Use Study.

Yours sincerely,

DR MARK THYER
Task Leader Household Water Use Study

A.2.2 Participation Information Sheet

Household Water Use Study

Participant information sheet

THE UNIVERSITY of ADELAIDE

What is the purpose of the study?

The study will help to provide an improved understanding of community attitudes in Adelaide towards water use and to determine the way water is used by different households. The results of the study will contribute to research to assist in the planning of Adelaide's future water supply options. The Household Water Use Study is part of a larger project funded by the Goyder Institute for Water Research – "Optimal Water Resource Mix for Metropolitan Adelaide"

Who will undertake the study?

This work is being undertaken by the University of Adelaide and CSIRO as partners in the Goyder Institute for Water Research (www.goyderinstitute.org). SA Water is providing support by inviting households to participate and installing electronic meters at selected participant households.

How will the study be conducted?

The study will involve monitoring water use at 150 households across Adelaide. An electronic water meter that can record water usage at short time intervals will be installed alongside your existing water meter outside your home. This meter will continuously collect water usage data for a period of approximately 15 months. The data will be downloaded periodically and analysed by University of Adelaide and CSIRO researchers – this requires water meter locations to be readily accessible. A University of Adelaide representative will also visit your home to undertake an audit of your water using appliances and conduct a community attitudes survey with you.

When will the study take place?

The electronic water meter will be installed at the water meter location outside the home by a representative of SA Water between December 2012 and February 2013. The study will take place between January 2013 and March 2014.

What is required of me? How much of my time will be needed?

To take part in the study please complete and sign the consent form and return in the reply-paid envelope (enclosed).

A University of Adelaide representative will visit your home in the first half of 2013 to undertake an audit of your water using appliances and conduct a community attitudes survey with you. This will take between 1-2 hours of your time. At some time during the study you will be asked to complete a water use diary for a period of one week. You will be contacted sometime during February-May 2013 to organise a time that is convenient for you for this visit.

GOYDER INSTITUTE

THE UNIVERSITY of ADELAIDE

CSIRO

Government of South Australia

SA Water

Household Water Use Study

Participant information sheet

How and when will the gift cards be distributed?

Participating households will receive a $50 gift card upon the completion of the in-home survey.

How will my privacy be protected?

Personal information collected for this study will only be used by The University of Adelaide, CSIRO and SA Water for the purpose of collecting water use and attitude information. For the purposes of analysis, all data will be treated anonymously, with all personal information removed. Your privacy will be protected at all times and personal information will not be disclosed to any third parties.

Will this affect my water bill?

No, the electronic metering will not impact on your water use or water account.

What if I want to withdraw from the study?

You can withdraw from the study at any time. To withdraw please call the University of Adelaide research team on 0498633452. The gift card is provided as compensation for your time involved in taking part in the in-home survey of your water using appliances and community attitudes – if you withdraw from the study prior to the in-home surveys then you will not receive the gift card.

How will information collected be used and how will results be reported and publicised?

The information collected will be used as part of the Household Water Use research project. Results will be presented at national / international conferences, published in scientific journals and on the Goyder Institute website (www.goyderinstitute.org). If participants are interested in the publications they may request copies.

Contact Details for the Research Team:

Kym Beverley
Household Water Use Study Research Team
Mobile: 0498 633 452
Email: wateruse@civeng.adelaide.edu.au

A.2.3 Complaints Procedure

THE UNIVERSITY *of* ADELAIDE

The University of Adelaide
Human Research Ethics Committee (HREC)

This document is for people who are participants in a research project.

CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The following study has been reviewed and approved by the University of Adelaide Human Research Ethics Committee:

Project Title:	**Household Water Use Study**
Approval Number:	**H-2012-170**

The Human Research Ethics Committee monitors all the research projects which it has approved. The committee considers it important that people participating in approved projects have an independent and confidential reporting mechanism which they can use if they have any worries or complaints about that research.

This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research (see http://www.nhmrc.gov.au/publications/synopses/e72syn.htm)

1. If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the project co-ordinator:

Name:	**Dr Mark Thyer, Senior Lecturer, School of Civil, Environmental & Mining Engineering**
Phone:	**8313 0770**

2. If you wish to discuss with an independent person matters related to:
   - making a complaint, or
   - raising concerns on the conduct of the project, or
   - the University policy on research involving human participants, or
   - your rights as a participant,

   contact the Human Research Ethics Committee's Secretariat on phone (08) 8313 6028 or by email to hrec@adelaide.edu.au

A.2.4 Participant Consent Form

Human Research Ethics Committee (HREC)

THE UNIVERSITY of ADELAIDE

CONSENT FORM

Reference: «SAW_Acc»

«Title» «Firstname» «Surname»
«Address_1»
«Address_2» SA «Postcode»

1. I have read the attached Participant Information Sheet and agree to take part in the following research study:

Title:	**Household Water Use Study**
Ethics Approval Number:	**H-2012-170**

2. I understand that the study involves the following components (explained in more detail on the attached information sheet):
   a. An electronic water meter that can record water usage at short time intervals will be installed alongside my existing water meter by SA Water.
   b. A University of Adelaide representative will visit my home to undertake an audit of my water using appliances and conduct a community attitudes survey with me – this will take 1 to 2 hours of my time.
   c. I will be asked to complete a water use diary for a period of one week.
   d. I will receive a $50 Coles-Myer gift card from The University of Adelaide on completion of the audit of water using appliances and community attitudes survey in my home.
   e. SA Water will provide my water consumption data for the previous 2 years to the University of Adelaide and that the University will collect & analyse water use data from my household for this study.
   f. The electronic water meter will be used to monitor my water usage for a period of approximately 15 months. SA Water reserves the right to remove the electronic meter after the completion of the study.
3. I have contacted The University of Adelaide Research team to obtain clarification about any concerns or questions I have about any aspect of the study.
4. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.
5. I understand that I am free to withdraw from the study at any time.
6. I am an SA Water account holder for the supply of water to the address set out at the top of this consent form and agree for myself and on behalf of the other account holder(s) (if any) that SA Water may carry out the activities described in this consent form and the attached Participant Information Sheet.

Participant to complete (by a person named on the SA Water account)**:**

Name: ____________________ Signature: ______________________ Date: __________

Please complete & sign both copies of this form:
- place one copy in the reply paid envelope and post to The University of Adelaide,
- keep one copy with the attached information sheet for your records.

A.3 Household Visit Documents

A.3.1 End-use survey

Water End Use Study

Household Survey

Household ID: 2370277549

GOYDER INSTITUTE FOR WATER RESEARCH
THE UNIVERSITY of ADELAIDE
CSIRO
Government of South Australia
SA Water

Purpose of the Survey

The purpose of this survey is to help the research team at Adelaide University and the CSIRO understand household water use and attitudes in the community.

What's required of you?

This survey along with the water appliance audit will take approximately 1.5 hours to complete.

Some of the questions may seem similar, but there are important differences. This survey will provide important information for the research team.

PLEASE ANSWER EVERY QUESTION.

Different types of water for outdoor use

In the future there could be different sources of water that you might be able to use on your lawn, garden and **outdoor areas of your home**. There is a definition sheet for you to use. We would like you to think about which types of water you would like to use for these areas. For each group of three, please tick the statement you like the BEST for **OUTDOOR USE** and which type of water would you consider to be the WORST for **OUTDOOR USE**.

Please make sure that you select:

- ***only one water source as the BEST and***
- ***only one as the WORST.***

You will see different statements repeated in different combinations – we have found this is the easiest way to compare statements.

Here is an example using food that will show what to do. Your questions will involve different water sources.

EXAMPLE:

BEST (TICK the BEST chocolate)		WORST (TICK the WORST chocolate)
	Milk chocolate	✓
✓	Dark chocolate	
	White chocolate	

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BEST (TICK ONE BEST water source for outdoor use)		WORST (TICK ONE WORST water source for outdoor use)
	Rainwater/Roof Water	
	Recycled Wastewater	
	Demand management	

BEST (TICK ONE BEST water source for outdoor use)		WORST (TICK ONE WORST water source for outdoor use)
	Water from Mount Lofty Ranges	
	Desalinated Seawater	
	Rainwater/Roof Water	

BEST (TICK ONE BEST water source for outdoor use)		WORST (TICK ONE WORST water source for outdoor use)
	Rainwater/Roof Water	
	Water from the River Murray	
	Groundwater	

BEST (TICK ONE BEST water source for outdoor use)		WORST (TICK ONE WORST water source for outdoor use)
	Water from Mount Lofty Ranges	
	Water from the River Murray	
	Demand management	

BEST (TICK ONE BEST water source for outdoor use)		**WORST (TICK ONE WORST water source for outdoor use)**
	Desalinated Seawater	
	Recycled Wastewater	
	Water from the River Murray	

BEST (TICK ONE BEST water source for outdoor use)		**WORST (TICK ONE WORST water source for outdoor use)**
	Demand management	
	Groundwater	
	Desalinated Seawater	

BEST (TICK ONE BEST water source for outdoor use)		**WORST (TICK ONE WORST water source for outdoor use)**
	Water from Mount Lofty Ranges	
	Recycled Wastewater	
	Groundwater	

Now we are going to ask some questions about how you feel about water use.

INSTRUCTIONS

In the following questions we are interested in your opinion on a variety of statements. To answer these, simply circle the number that best corresponds to how much you agree or disagree with the statement – see below. **IT'S THAT EASY!**

EXAMPLE QUESTION

Dark chocolate tastes better than white chocolate

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Please circle the number that corresponds to how you feel RIGHT NOW about a statement

People who are important to me want me to save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Whether I save water around the house and garden or not is entirely up to me

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

I personally think of myself as a water conserver

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

The decision to save water around the house and garden is beyond my control

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

I am confident that I could save water around the house and garden if I wanted to

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

My household is good about conserving water

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Please circle the number that corresponds to how you feel RIGHT NOW about a statement.

I would feel guilty if I didn't save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

I feel a strong personal obligation to save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

People who are important to me want me to save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

I am willing to put extra effort into saving water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

It is expected of me that I save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

I feel like there is social pressure to save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Thinking about indoor and outdoor water use in the **SUMMER 2013,** try to recall what you were using water for around the house. How often did you do each of the following?

Never	Rarely	Sometimes	Almost Always	Always	Not Applicable
1	2	3	4	5	N/A

Circle the number that corresponds to how often you

In the kitchen:						
Ran the dishwasher only when it is full	1	2	3	4	5	N/A
Waited until the sink is full before washing dishes	1	2	3	4	5	N/A
Used minimal water in kitchen (e.g., for cooking, washing up, rinsing)	1	2	3	4	5	N/A
In the laundry:						
Ran the washing machine only if there is a full load of clothes	1	2	3	4	5	N/A
Collected or ran water from washing machine out to garden/lawn	1	2	3	4	5	N/A
Adjusted the water level for smaller loads	1	2	3	4	5	N/A
In the bathroom:						
Used half flush or don't flush the toilet every time	1	2	3	4	5	N/A
Had shorter showers (4 minutes or less)	1	2	3	4	5	N/A
Put the water from bath on the lawn/garden	1	2	3	4	5	N/A
Turned off taps when brushing teeth or shaving	1	2	3	4	5	N/A
Outside the house:						
Watered the lawn in the evening, night or early morning	1	2	3	4	5	N/A
Watered the garden in the evening, night or early morning	1	2	3	4	5	N/A
Washed your car at home with a bucket	1	2	3	4	5	N/A
Used water from the rainwater tank on garden	1	2	3	4	5	N/A
Other? ___________________________						

What was the reason for undertaking the actions listed above in the **SUMMER 2013**? For each reason, please give a ranking from ‘not important at all’ to ‘most important’, using the following scale:

Not important at all 1	Little importance 2	Neither important or unimportant 3	Very Important 4	Most Important 5	Not Applicable

Discussions with neighbours, family, friends	1	2	3	4	5	N/A
Concern about the River Murray or the Coorong	1	2	3	4	5	N/A
Price of water	1	2	3	4	5	N/A
Other:	1	2	3	4	5	N/A

What is the main source of water you used for outdoor water use in summer:

Now (summer of 2013):

- ☐ Tap water
- ☐ Rainwater tank
- ☐ Greywater (laundry or bath)
- ☐ Don’t water/ rely on rain
- ☐ Other

Thinking about how you use water now and how you used water during **<u>the height of the drought in 2007- 2009.</u>**

Never	Rarely	Sometimes	Almost Always	Always	Not Applicable
1	2	3	4	5	N/A

Circle the number that corresponds to how **<u>often</u>** you, took the actions listed below:

In the kitchen:						
Ran the dishwasher only when it is full	1	2	3	4	5	N/A
Waited until the sink is full before washing dishes	1	2	3	4	5	N/A
Used minimal water in kitchen (e.g., for cooking, washing up, rinsing)	1	2	3	4	5	N/A
In the laundry:						
Only ran the washing machine if there is a full load of clothes	1	2	3	4	5	N/A
Collected or ran water from washing machine out onto garden/lawn	1	2	3	4	5	N/A
Adjusted the water level for smaller loads	1	2	3	4	5	N/A
In the bathroom:						
Used half flush or didn't flush the toilet every time	1	2	3	4	5	N/A
Had shorter showers (4 minutes or less)	1	2	3	4	5	N/A
Put the water from bath on the lawn/garden	1	2	3	4	5	N/A
Turned off taps when brushing teeth or shaving	1	2	3	4	5	N/A
Outside the house:						
Watered the lawn in the evening, night or early morning	1	2	3	4	5	N/A
Watered the garden in the evening, night or early morning	1	2	3	4	5	N/A
Washed your car at home with a bucket	1	2	3	4	5	N/A
Used water from the rainwater tank on garden	1	2	3	4	5	N/A
Other? ____________________________	1	2	3	4	5	N/A

What was the reason for undertaking the actions listed above during **<u>the height of the drought in 2007- 2009</u>**? For each reason, please give a ranking from 'not important at all' to 'most important', using the following scale:

Not important at all 1	Little importance 2	Neither important or unimportant 3	Very Important 4	Most Important 5	Not Applicable

Discussions with neighbours, family, friends	1	2	3	4	5	N/A
Concern about the River Murray or the Coorong	1	2	3	4	5	N/A
Media coverage on impact of drought	1	2	3	4	5	N/A
Price of water	1	2	3	4	5	N/A
Media coverage on water restrictions	1	2	3	4	5	N/A
Other:	1	2	3	4	5	N/A

What is the main source of water you used for outdoor water use in summer:

During the height of the drought 2007-2009:

- ☐ Tap water
- ☐ Rainwater tank
- ☐ Greywater (laundry or bath)
- ☐ Don't water/ rely on rain
- ☐ Other

Thinking back to **<u>the height of the drought in 2007- 2009</u>**, did your household undertake any of the following actions:

Install Low-flow taps	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Install Low-flow shower head	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Buy a pool cover	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Plant drought resistant plants	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Install an efficient (e.g. drip/subsurface) garden irrigation system	Yes	No	don't know	N/A	Installed Pre-2007	Installed Post-2009
Dual-flush toilet	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Buy a shower timer	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Buy a front-loading washing machine	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Buy a water efficient dishwasher	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Buy a rainwater tank (but not plumb into the house)	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Have a rainwater tank plumbed into the house	yes	no	don't know	N/A	Installed Pre-2007	Installed Post-2009
Other? ___________________________	yes	no			Installed Pre-2007	Installed Post-2009

Thinking back to **the height of the drought in 2007- 2009**, what was the reason for undertaking the actions listed above? For each reason, please give a ranking from 'not important at all' to 'most important', using the following scale:

Not important at all 1	Little importance 2	Neither important or unimportant 3	Very Important 4	Most Important 5	Not Applicable

Rebates offered by SA Water	1	2	3	4	5	N/A
Media coverage on water restrictions	1	2	3	4	5	N/A
Media coverage on impact of drought	1	2	3	4	5	N/A
Needed to change appliance anyway (old one broke down/house renovations)	1	2	3	4	5	N/A
Price of Water	1	2	3	4	5	N/A
Discussions with neighbours, family, friends	1	2	3	4	5	N/A
Concern about the River Murray or the Coorong	1	2	3	4	5	N/A
Other:	1	2	3	4	5	N/A

Thinking back to **<u>the height of the drought in 2007- 2009</u>**, did you access any of the following rebates?

Rainwater tank (not plumbed in), $200 rebate for a tank greater than 1000L	yes	no
Rainwater tank (plumbed into toilet), $600 rebate for plumbing services	yes	no
Plumbing services, $600 rebate for tank connection	yes	no
Low flow showerhead, $30 rebate for 3 Star product	yes	no
Garden products, 50% back on eligible products ($100-$400)	yes	no
Dual-flush toilet, $150 rebate on 3 star product	yes	no
Washing Machine, $200 rebate on a water efficient model	yes	no
Water Audit, $100 rebate	yes	no
Pool Cover, $200 rebate	yes	no

Did your household experience any of the following as a result of the **2007-2009 drought**:

☐	Property damage e.g. cracks in the walls of my house
☐	Tree(s) dying in the yard
☐	Tree(s) dying on the street where you live
☐	Plants dying in garden
☐	Other (please write)

In the last **SUMMER** where do you think water was used by your household?

NEEDS TO ADD UP TO 100%

%	Outside the house
%	Taps/Dishwasher
%	Laundry
%	Toilets
%	Showers/Baths

In the current **WINTER**, where do you think water is used by your household?

NEEDS TO ADD UP TO 100%

%	Outside the house
%	Taps/Dishwasher
%	Laundry
%	Toilets
%	Showers/Baths

We will be analysing the water metering data and it would be useful to know over the next few months, will your household install any the following devices?

Definitely will not install	May not install	Unsure	Might install	Definitely will install	Not Applicable
1	2	3	4	5	N/A

Front-loading washing machine	1	2	3	4	5	N/A
Water efficient dishwasher	1	2	3	4	5	N/A
Low-flow taps	1	2	3	4	5	N/A
Low-flow shower head	1	2	3	4	5	N/A
Pool cover	1	2	3	4	5	N/A
Dual-flush toilet	1	2	3	4	5	N/A
Shower timer	1	2	3	4	5	N/A
Hose with trigger or a timed sprinkler	1	2	3	4	5	N/A
Water-wise plants and/or gardens	1	2	3	4	5	N/A
Install an efficient (e.g. drip/subsurface) garden irrigation system	1	2	3	4	5	N/A
A rainwater tank plumbed into the house	1	2	3	4	5	N/A
A rainwater tank not plumbed into the house	1	2	3	4	5	N/A
Other?___________________________________	1	2	3	4	5	

We will be analysing the water metering data and it would be useful to know if in the next few months, you are planning to renovate, or if the number of people staying in the house will vary, as this can change how you use water.

Having friends/family stay	yes	no	N/A
Being away for more than 2 weeks	yes	no	N/A
Renovating the Kitchen	yes	no	N/A
Renovating the Bathroom	yes	no	N/A
Renovating the Laundry	yes	no	N/A
Adding more rooms onto the house	yes	no	N/A

There are many everyday actions that save water around the house and garden

- Check and fix leaking taps
- Collect rainwater to use on garden
- Only run dishwasher when it is full
- Have shorter showers (4 minutes or less)
- Turn off taps when brushing teeth
- Run washing machine only when it is full
- Use minimal water in the kitchen
- Being water-wise in the garden by watering at night
- Planting drought resistant plants

Please circle the number that corresponds to how you feel about a statement.

Water conservation is important in our household

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Members of my household think that engaging in everyday actions to save water around the house and garden is a good thing

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

Members of my household engage in everyday actions to save water around the house and garden

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

There is agreement amongst the members of my household that engaging in everyday actions to save water around the house is a good thing to do

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

We think of ourselves as a water conserving household

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

There is agreement amongst family members of my household that installing water efficient appliances around the house and garden is a good thing to do						
Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Members of my household think that installing water efficient appliances in the house and garden is a good thing						
Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Most individuals engage in everyday actions to save water in the house and garden						
Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Next we have some general questions about your attitudes towards the environment more generally.

Tropical rain forests are essential to maintain a healthy planet earth

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

The effects of pollution on public health are worse than we realise

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

Environmental protection benefits everyone

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

A clean environment provides me with better opportunities for recreation

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Over the next several decades, thousands of species will become extinct

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Pollution generated here harms people all over the earth

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Environmental protection will provide a better world for me and my children

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Environmental protection is beneficial to my health

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

Environmental protection will help people have a better quality of life

Strongly Disagree	Disagree	Slightly Disagree	Neither agree or disagree	Slightly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**	**7**

To answer this group of statements, simply circle the number that best corresponds to how much you agree or disagree with these general statement about water. These are designed to be answered quickly.

IT'S THAT EASY!

I feel regretful if I waste water				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Water is an unlimited resource				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Water is a precious resource				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Water is important to my way of life				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
I think that wasting water is bad				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Conserving water is part of the Australian lifestyle				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Without water we cannot survive				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
We, as a community, should cherish water				

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Having a secure water supply is important in Adelaide				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Adelaide can afford to buy River Murray water, so we don’t need to use other water sources				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**
Now that Adelaide has a seawater desalination plant, we don’t need to use other water sources				
Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**

NOW WE WOULD LIKE TO ASK A FEW QUESTIONS TO MAKE SURE THAT THE PEOPLE WE ARE SURVEYING ARE FROM A WIDE RANGE OF BACKGROUNDS. THESE QUESTIONS WILL ALSO HELP US UNDERSTAND MORE ABOUT WATER USE

What is your age? _________
How long have you lived in this house? ________________
How many people are living full-time in your household today? ____________

How many children 0-4 years of age? _________

How many children 5 - 9 years of age? _________

How many children 10 - 15 years of age? ________

How many 16 - 19 years of age? ________

How many adults? ________

How many people were living full-time in your house in December 2006? ____________
(enter 0 if you moved in after December 2006).

How many children 0-4 years of age? _________

How many children 5 - 9 years of age? _________

How many children 10 - 15 years of age? ________

How many 16 - 19 years of age? ________

How many adults? ________

With the next question, we are trying to understand how many people are likely to be home using water through a week with the school, work and at home schedules that people may have.

How many members of the household, adults and children, are at home 50% of the time? These include pre-school children not in childcare, adults who work at home, work outside part-time

Household members at home more than 50% of the time: ________

Household members at home less than 50% of the time: ________

Are you:

☐ Male ☐ Female

QUESTION x: What is the highest level of education you have obtained? *Please tick one*

☐ Year 9 or below

☐ Year 10

☐ Year 12

☐ Diploma

☐ Trade qualification

☐ Bachelor degree or equivalent

☐ Graduate diploma or graduate certificate from university or equivalent

☐ Postgraduate degree or equivalent

To the best of your knowledge, please indicate your total income before tax. If you have shared household responsibilities with a spouse or partner, please indicate the total combined income for both you and your partner. *Please tick one box.*

	Annual income	Weekly income
☐	$1 to $20,749	$1 to $399 a week
☐	$20,750 to $31,149	$400 to $599 a week
☐	$20,750 to $31,149	$400 to $599 a week
☐	$31,150 to $41,549	$600 to $799 a week
☐	$41,550 to $51,949	$800 to $999 a week
☐	$51,950 to $64,949	$1,000 to $1,249 a week
☐	$64,950 to $77,949	$1,250 to $1,499 a week
☐	$77,950 to $103,949	$1,500 to $1,999 a week
☐	$103,950 to $129,949	$2,000 to $2,499 a week
☐	$129,950 to $155,949	$2,500 to $2,999 a week
☐	$155,950 to $181,949	$3,000 to $3,499 a week
☐	$181,950 to $207,949	$3,500 or $3,999 a week
☐	$207,950 to $259,999	$4,000 to $4,999 a week
☐	over $260,000	$5000 or more a week

Thank you for your time and consideration in taking part, your answers are vital to our research.

Thank you on behalf of all the study team.

A.3.2 Water Appliance Audit

Household Water Use Study

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Water Appliance Survey - Instructions for Researchers

Household ID: «Household_ID»

Purpose of the Water Appliance Survey

The Water Appliance Survey is intended to produce a "signature" for each water using appliance / item in the home. The signature is captured on the electronic water meter installed alongside the "regular" SA Water meter at the front of the house.

The electronic water meter is configured to record at 10 second increments, so to make sure we can differentiate between appliances you will need to make sure there is at least a one minute gap between each appliance test.

The water appliance survey should take place when **no water using appliance / item is being used** (eg no dishwasher running, no load of washing on, no watering system, no shower, etc,). **Make sure the householder and anyone else in the house is aware of this**. (If they need to wash hands etc, it's okay, they just need to let you know).

The Water Appliance Survey form

The Start Time column needs to be accurately recorded (use the time on your mobile phone). The Duration is how long you ran the tap for / how long the toilet cistern took to fully recharge.

When testing the toilet flushes, allow plenty of time for the cistern to recharge fully before doing the next flush or moving on to the next appliance.

Do not test the dishwasher or washing machine, but do record any available details as to make & model.

Do not test the garden watering systems but do record the types of systems the householder uses.

Do NOT ask the householder about leaks – identify them yourself & tick the appropriate box (small or large).

Tick the appropriate box if an Aerator, Flow Controller or Leak is present.

Contact Details for any questions:

Kym Beverley
Household Water Use Study Research Team
Mobile: 0498 633 452
Email: wateruse@civeng.adelaide.edu.au

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Household Water Use Study

Water Appliance Survey

Household ID: «Household_ID»

Date: ____________________

			Start Time	Duration (seconds)	
Kitchen	Tap - typical flow:	Cold			☐ flow controller
		Hot			
	Tap - maximum flow:	Cold			☐ aerator
		Hot			
	Filter tap				
	Other (eg ice making fridge)		☐	☐	
	Leak?		☐ small	☐ large	
	Dishwasher: Make		☐		
	Model		☐		Water star rating
	Date and Time last used?		☐	☐	

Laundry	Tap - typical flow:	Cold			☐ flow controller
		Hot			
	Tap - maximum flow:	Cold			☐ aerator
		Hot			
	Other		☐	☐	
	Leak?		☐ small	☐ large	
	Washing Machine: Make		☐ ☐		
	Model		☐		Water star rating
	Date and Time last used?		☐	☐	

Evaporative Air Conditioner	Yes / No	Approximate age:	
	Make & Model:		

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Household Water Use Study

Water Appliance Survey

Household ID: «Household_ID»

<table>
<tr><th colspan="3"></th><th>Start Time</th><th>Duration (seconds)</th><th></th></tr>
<tr><td rowspan="16">Bathroom 1

(main)</td><td rowspan="2">Basin Tap - typical flow</td><td>Cold</td><td></td><td></td><td rowspan="4">☐ flow controller

☐ aerator</td></tr>
<tr><td>Hot</td><td></td><td></td></tr>
<tr><td rowspan="2">Basin Tap - maximum flow</td><td>Cold</td><td></td><td></td></tr>
<tr><td>Hot</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">Basin Tap leak?</td><td>☐ small</td><td>☐ large</td><td rowspan="4"></td></tr>
<tr><td colspan="2">Shower - maximum flow</td><td></td><td></td></tr>
<tr><td colspan="2">Shower - typical flow</td><td></td><td></td></tr>
<tr><td colspan="2">Shower Leak?</td><td>☐ small</td><td>☐ large</td></tr>
<tr><td colspan="2">Bath - typical flow</td><td></td><td></td><td rowspan="2">☐ flow controller

☐ aerator</td></tr>
<tr><td colspan="2">Bath size (WxLxH):</td><td colspan="2"></td></tr>
<tr><td colspan="2">Bath Leak?</td><td>☐ small</td><td>☐ large</td><td></td></tr>
<tr><td colspan="2">Toilet 1/2 flush</td><td></td><td></td><td rowspan="3">Cistern volume if known (eg 9/4.5 L):</td></tr>
<tr><td colspan="2">Toilet full flush</td><td></td><td></td></tr>
<tr><td colspan="2">Toilet Leak?</td><td>☐ small</td><td>☐ large</td></tr>
<tr><td colspan="2">Other</td><td>☐</td><td>☐</td><td></td></tr>
<tr><td colspan="2">Notes:</td><td>☐</td><td colspan="2">☐</td></tr>
</table>

Household Water Use Study

Water Appliance Survey

Household ID: «Household_ID»

			Start Time	Duration (seconds)	
Bathroom 2 **(ensuite)**	Basin Tap - typical flow	Cold			☐ flow controller ☐ aerator
		Hot			
	Basin Tap - maximum flow	Cold			
		Hot	☐	☐	
	Basin Tap leak?		☐ small	☐ large	
	Shower - maximum flow				
	Shower - typical flow				
	Shower Leak?		☐ small	☐ large	
	Bath - typical flow				☐ flow controller ☐ aerator
	Bath size (WxLxH):				
	Bath Leak?		☐ small	☐ large	
	Toilet 1/2 flush				Cistern volume if known (eg 9/4.5 L):
	Toilet full flush				
	Toilet Leak?		☐ small	☐ large	
	Other		☐	☐	
	Notes:		☐	☐	

(if more than 2 bathrooms use additional sheets - make sure you record the Household ID)

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Household Water Use Study

Water Appliance Survey

Household ID: «Household_ID»

			Start Time	Duration (seconds)	
Garden	Front tap - typical flow				☐ flow controller
	Front tap - maximum flow				☐ aerator
	Front Tap Leak?		☐ small	☐ large	
	Rear tap - typical flow				☐ flow controller
	Rear tap - maximum flow				☐ aerator
	Rear Tap Leak?		☐ small	☐ large	
	Other tap - typical flow				☐ flow controller
	Other tap - maximum flow				☐ aerator
	Other Tap Leak?		☐ small	☐ large	
	Garden area (m^2)*		☐	☐	☐
	Watered Garden area (m^2)*		☐	☐	
Watering system	Sprinkler	Y / N	Auto / Manual	Hours run / week:	
	Dripper	Y / N	Auto / Manual	Hours run / week:	
	Other _____________	Y / N	Auto / Manual	Hours run / week:	
	Date and Time last used?				
	Notes:				

* Use measuring wheel

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Household Water Use Study

Water Appliance Survey

Household ID: «Household_ID»

Rainwater tank	Yes / No	Y / N	Connected to: (circle) Laundry
	Number of tanks		Toilet
	Roof area connected (m^2)*		Kitchen
	Total capacity		Other ____________
	If you were going to install a rainwater tank where would you put it?		
	Connectable area (m^2)*? Research Assistant to estimate.		

Property area (m^2)*		Sketch:
House area (m^2)*		
Total roof area (m^2)*		

* Use measuring wheel

Researcher: ______________________________

Signature: ______________________________

Date: ______________________________

A.3.3 Water Use Diary

THE UNIVERSITY of ADELAIDE

Household Water Use Study
Water Use Diary

Household ID: <<mailmerge field>>

Day:_______________ Date: _______________

	Category (tick)										
Time	Inside tap	Toilet flush	Shower	Bath	Dishwasher	Washing machine	Outside tap	Air conditioner (evaporative)	Watering system	Other	Details

Appendix B – Data and Comparison Tables

A list of the suburbs and the number of households per suburb that participated in the study is shown in Table B.1.

Table B.1: Participating suburbs and household number

Suburb	Households
Beaumont	6
Blair Athol	22
Croydon Park	6
Erindale	8
Evandale	1
Ferryden Park	5
Firle	3
Heathpool	3
Kilburn	12
Malvern	2
Netherby	5
Prospect	28
Renown Park	3
Rose Park	5
St Morris	7
Tranmere	16
Tusmore	8
Unley Park	1
Wattle Park	7
Woodville Gardens	2

Note in all the following comparison tables the acronyms refer to:

- Adelaide: Greater Adelaide statistics [*ABS*, 2011a; b]
- Prelim: Preliminary Survey (1654 respondents). The preliminary surveys were not always fully completed, hence percentages may not sum to 100. A high proportion of the surveys were inaccurately filled out with 0-4 instead of adults
- SH Prelim: Study households data taken from preliminary survey (150)
- SH Visit: Study household data taken from visit surveys (150)
- FT Visit: Study households that were flow trace analysed (140) data taken from visit surveys

Table B.2: Comparison of demographics of study households

	Adelaide	Prelim*	SH Prelim	SH Visits	FT Visits
Mean number of occupants	2.4	2.64	2.45	2.48	2.52
Number of Occupants					
0	0%	1%	0%	0%	0%
1	28%	18%	23%	22%	21%
2	34%	39%	37%	38%	38%
3	16%	15%	19%	17%	17%
4	15%	18%	15%	17%	18%
5	5%	8%	5%	5%	6%
6	2%	1%	1%	1%	1%
7+	1%	1%	0%	0%	0%
Age (% of total householders)					
0-4 years	6%	10%**	9%**	3%	4%
5-9 years	6%	5%	5%	5%	5%
10-14 years	6%	13%	11%	5%	5%
15-19 years	7%			6%	6%
20-34 years	20%	12%	17%	80%	80%
35-54 years	28%	25%	25%		
+55 years	27%	34%	33%		
Gross Household Weekly Income					
Less than $600	26%	N/A	N/A	27%	26%
Greater than $3000	8%	N/A	N/A	26%	17%
Gross Household Annual Income**					
Low (<$38,000)	33%	19%	29%	23%	22%
Medium	33%	32%	35%	39%	39%
High (>$83,000)	33%	48%	36%	38%	39%

** Note: Income is interpolated for *ABS* [2011a] and visit survey due to different categorisation, 4 respondents chose not to respond.

Table B.3: Comparison of proportion of efficient appliances

	South Australia [*ABS*, 2013]	Prelim*	SH Prelim	SH Visits	FT Visits
Showers					
0 star	0.32	0.37	0.36	0.13	0.13
1 star				0.15	0.16
2 star				0.14	0.14
3 star	0.61*	0.48	0.51	0.43	0.43
Mixed	0.07	0.15	0.13	0.14	0.14
Toilets					
4.5/3 Dual	0.86*	0.85	0.89	0.06	0.06
6/3 Dual				0.34	0.35
9/4.5 Dual				0.27	0.26
11/6 Dual				0.11	0.11
Single Flush	0.09	0.07	0.06	0.04	0.04
Mixed	0.05	0.08	0.05	0.18	0.17
Washing Machines					
Top loader	0.56	0.45	0.47	0.47	0.46
Front loader	0.44	0.54	0.53	0.53	0.54
Dishwasher	N/A	N/A	N/A	0.69	0.71 (0.52 used during 2 week period)
Rainwater Tanks	0.45*	0.58	0.56	0.57	0.55
Rainwater Tanks internally plumbed	0.13	0.17	0.00	0.07	0.00
Evaporative Air Conditioner	N/A	0.30	0.41	0.39	0.40
Swimming Pool	N/A	0.13	0.10	N/A	N/A
Spa	N/A	0.06	0.05	N/A	N/A
Both Swimming Pool and Spa	N/A	0.02	0.01	N/A	N/A

*Note: The shower statistic was for presence of efficient shower head (68%), not exclusively efficient showerhead. Australia wide was reported 10% of the households containing water efficient shower heads had a mixture of showerheads, hence 6.8% was assigned to mixed. Likewise 5% of households had a combination of dual and single flush toilets.**Note: Rainwater tanks are for Adelaide, not SA, and includes only properties suitable for a tank

Table B.4: Comparison of Mean daily indoor usage (L/p/day)

	Flow trace analysis	'Water for Good' [*Government of South Australia*, 2010]
Toilet	27.9	26
Washing Machine	24.8	32
Shower	48.3	56
Bath	3.0	
Dishwasher	1.7	27
Tap	28.8	
Total Indoor	134.5	141

Table B.5: Comparison of usage to recent studies

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Number of Households	140	100	100	252
Mean occupants per household	2.5	3.1	3.2	2.6
End-use Usage (L/person/day)				
Toilet	27.9	30.4	19	23.9
Washing Machine	24.8	40.4	22	30.9
Shower	48.3	49.1	34	42.7
Bath	3.0	3.2	2	1.8
Dishwasher	1.7	2.7	1	2.5
Tap	28.8	27.0	21	27.5
Total Indoor	134.5	152.8	99	129.3

Table B.6: Comparison of proportion of efficient appliances

	Adelaide 2013	YVW 2004 [*Roberts*, 2005]	YVW 2010 [*Roberts et al.*, 2011]	SEQ 2010-2011 [*Beal and Stewart*, 2011; *Beal et al.*, 2011b]
Showers*				
0 star	0.13	0.61	-	0.27
1 star	0.16	0.10	-	0.10
2 star	0.14	0.06	-	0.19
3 star	0.43	0.11	-	0.43
Mixed	0.14	0.12	-	-
Toilets*				
4.5/3 Dual	0.06	-	0.04	0.12
6/3 Dual	0.35	0.17	0.35	0.44
9/4.5 Dual	0.26	0.24	0.20	0.19
11/6 Dual	0.11	0.18	0.03	0.09
Single Flush	0.04	0.17	0.06	0.15
Mixed	0.17	0.24	0.32	-
Washing Machines				
Top loader	0.46	0.80	0.56	0.52
Front loader	0.54	0.20	0.44	0.48

* Note SEQ proportions are based on total showers/toilets whilst the other studies are by household

Table B.7: Occupancy Changes between height of drought and now

	December 2006	Household visit mid 2013	Change
Mean number of occupants	2.54	2.48	-2%
Number of Occupants			
1	19%	22%	+3%
2	34%	38%	+4%
3	26%	16%	-10%
4	15%	18%	+3%
5	3%	5%	+2%
6	1%	1%	-
7+	1%	0%	-1%
Age			
0-4 years	4%	3%	-1%
5-9 years	5%	5%	-
10-14 years	6%	5%	+1%
15-19 years	6%	6%	-
Adult	80%	80%	-

Appendix C – Implications of the Use of Gross Demand Estimates

Can the quarterly data be used to estimate winter water use?

The mean winter water use for the study households was estimated based on the quarterly data billing period that captured the majority of the winter period (June to August). The comparison of the quarterly data estimate to the measured usage in the two week period is shown in Figure C.1 for the 121 households with continuous data (quarterly read for winter not available and was estimated based on high resolution meter data). The estimate was generally good (line of best fit (y=0.998x) shown with R^2=0.95, standard error 0.02) and there was no significant difference in the mean, thus the quarterly data can be used to estimate mean winter usage.

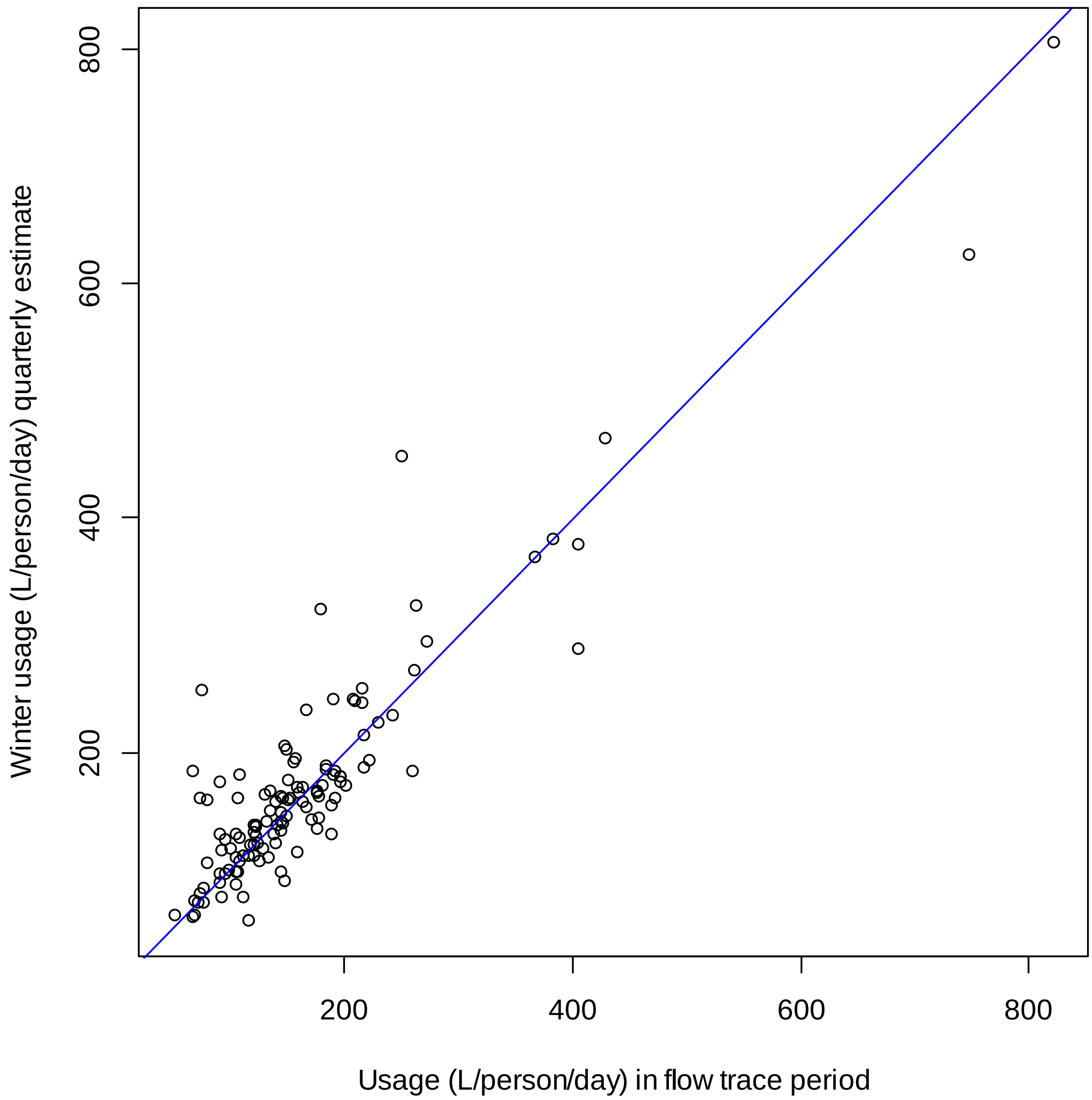

Figure C.1: Comparison of usage in flow trace period and winter estimate from quarterly billing data

Can the quarterly data be used to estimate indoor water use? What are the errors introduced by using quarterly data

The mean winter usage contains data on outdoor usage and leakage and is thus an overestimate of the indoor usage. The comparison of winter and indoor usage for the flow trace period is shown in Figure C.2. The R^2 value of the line of best fit (y=1.21x) is 0.78 with Standard error 0.059 and there is a significant difference in the mean. For the continuous data households the indoor usage averaged 135 L/person/day whilst the total winter usage was 166L/person/day, a 22% over prediction of indoor use would therefore result if the winter usage was used to estimate indoor usage.

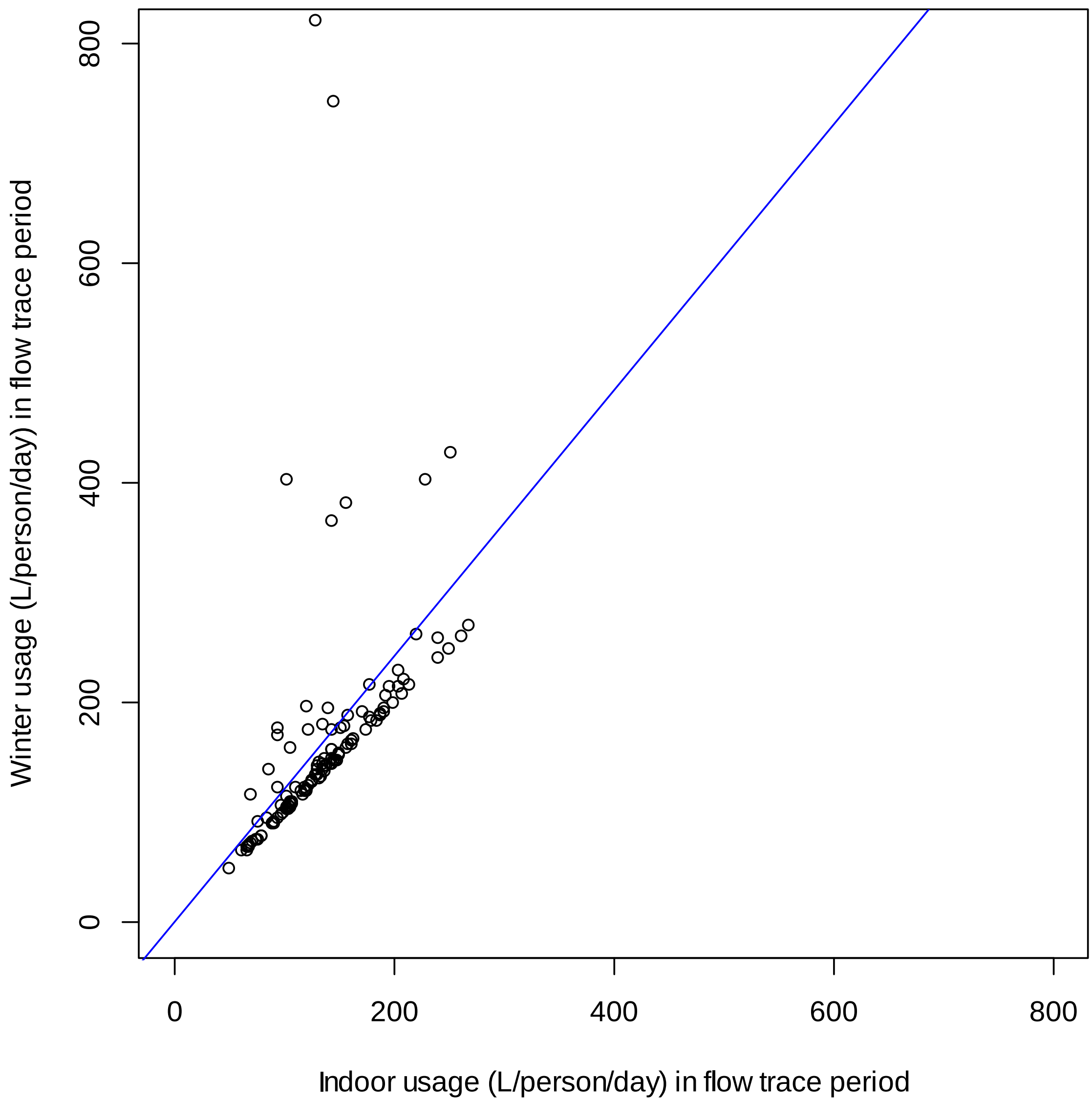

Figure C.2: Comparison of total winter usage and indoor usage in flow trace period

When this error is combined with the errors between winter quarter and measured winter usage (Figure C.3) the line of best fit has equation y= 1.26x, R^2=0.80, Standard error=0.058. The means are significantly different, 135 L/person/day compared with 173L/person/day based on the winter quarterly estimate.

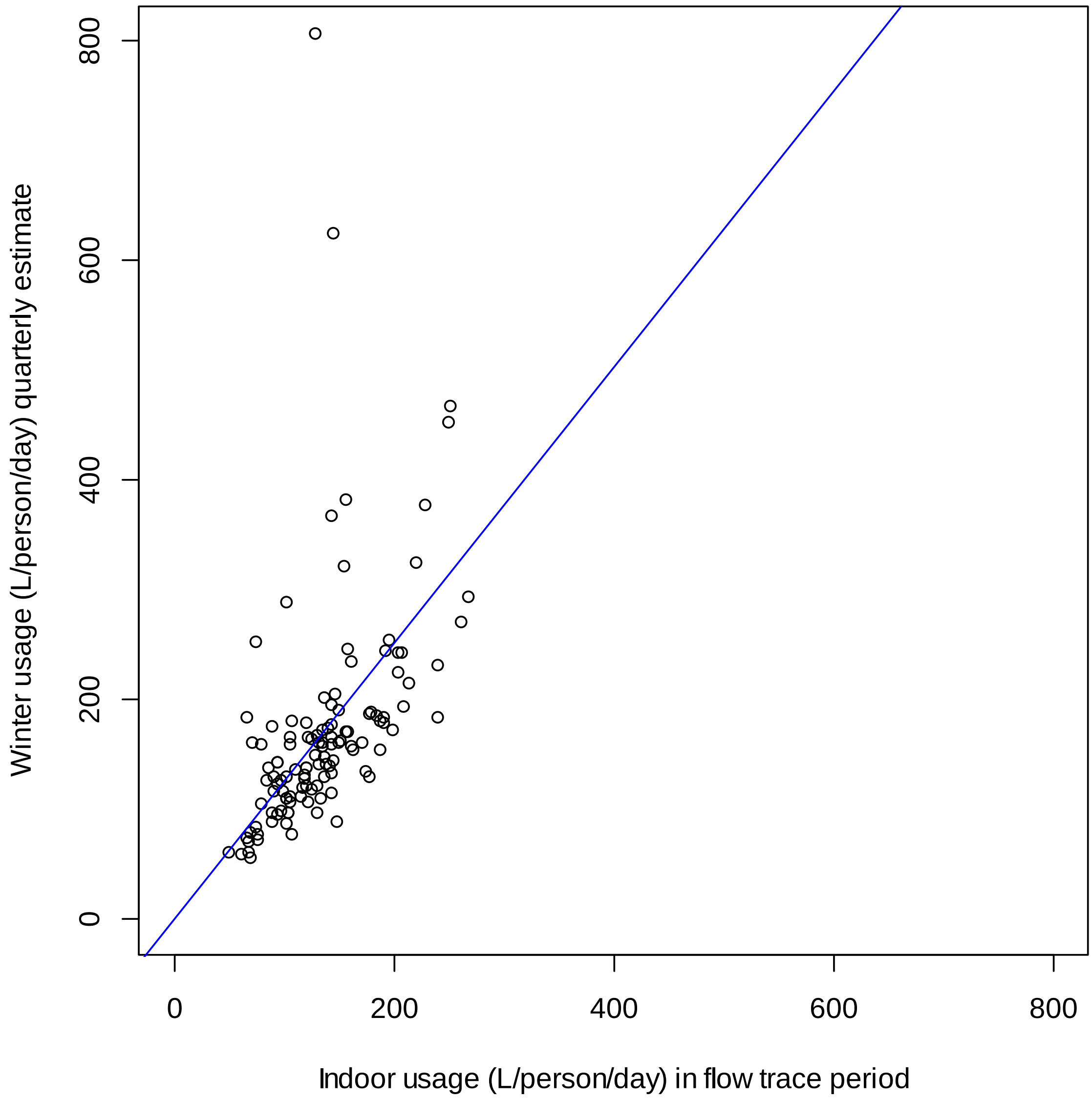

Figure C.3: **Comparison of indoor usage in flow trace period and winter estimate from quarterly billing data**

Summary and Practical Impacts

The winter quarter that covers the majority of the winter time period may be used to estimate winter use. However 20% of winter use is due to irrigation and leakage and thus quarterly estimates will lead to over prediction of indoor use.

Appendix D – BESS Parameters and Results

Table D.1: Appliance uptake proportions for BESS scenarios

Event ID	Interstate Only	Local Uptake – Est**	Local Uptake – Act/ Local Only
SHOWER-0star	0.69	0.16	0.165
SHOWER-1star	0.16	0.16	0.195
SHOWER-2star	0.07	0.16	0.175
SHOWER-3star	0.09	0.52	0.465
WM-Front	0.2	0.53	0.54
WM-TopLoader	0.8	0.47	0.46
HANDTAP	1	1	1
DISHWASHER	0.72	0.72	0.71
BATH	0.27	0.27	0.27
TOILET-STD-FULL	0.22	0.07	0.074
TOILET-STD-HALF	0	0	0
TOILET_11_6_DUAL-FULL	0.24	0.31	0.144
TOILET_11_6_DUAL-HALF	0	0	0
TOILET_9_4.5_DUAL-FULL	0.32	0.31	0.294
TOILET_9_4.5_DUAL-HALF	0	0	0
TOILET_6_3_DUAL-FULL	0.22	0.31	0.478
TOILET_6_3_DUAL-HALF	0	0	0

*Note: Mixed and unknown values were spread evenly between other categories. ** Even split between inefficient shower categories and dual flush toilets

Table D.2: Comparison of appliance characteristic and behavioural parameters for BESS scenarios

	Interstate Only/ Local Uptake – Est/ Local Uptake – Act	Local Only
Shower occurrence rates (0-3 star)	0.76	1.0
Shower Flow rate means	10.5,8.0,7.7,6.7	9.1,9.5,8.0,6.8
Shower Flow rate SD	4.1,3.2,3.0,2.6	4.2,4.0,3.0,2.4
Shower duration mean	7.1	6.3
Shower duration SD	3.8	4.4
WM Occurrence (per household per week)	1.02 x HS + 1.72	1.34 x HS + 1.66
WM Load Volume (Front, top) mean	73.3,152	52.5,117.1
WM Load Volume (Front, top) SD	40.9,48	15.7,37.9
Tap Occurrence (per household per day)	11.4 x HS + 15.9	12.9*HS+19.4
Tap volume	1.3	1.05
DW Occurrence (per household per week)	1.17 X HS + 0.62	0.82 X HS + 1.40
DW Volume mean	8	15.7
Bath Occurrence (per person per day)	0.12	0.16
Bath Volume mean	120	60
Toilet Occurrence Full flush (STD, 11/6, 9/4.5, 6/3)	4.2,1.9,2.3,3.1	3.4,1.8,1.7,2.2
Toilet Occurrence half	0,2.3,1.9,1.1	0,2.5,3.4,2.4
Toilet Volume full	9.4,10.5,9.2,6.5	9.4,10.9,8.4,6.8
Toilet volume half	0,5.5,9.2,4.7,3.5	0,6.0,4.5,6.8,3.4

- *Note: Log normal distributions used for all variables for which mean and SD is included in table*
- *Note: Means are based on all events not household means*

Table D.3: BESS Scenarios comparison of mean daily indoor usage (L/person/day)

	Flow trace analysis	Interstate Only	Local Uptake – Est	Local Uptake – Act	Local Only
Toilet	27.9	31.2	29.3	28.5	27.8
Washing Machine	24.8	44.5	36.5	34.6	27.2
Shower	48.3	54.7	44.7	44.6	47.7
Bath	3.0				
Dishwasher	1.7	30.3	30.3	29.8	30.5
Tap	28.8				
Total Indoor	134.5	160.7	140.8	137.5	133.2

Appendix E – Demand Management Parameters

Table E.1: Proportions of appliances used for each DM scenario

	Task 3 [*Marchi et al.*, 2013]	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Shower 0 star	0.35	0.15	0.053	0.053	0.053
Shower 1 star		0.15	0.053	0.053	0.053
Shower 2 star		0.15	0.053	0.053	0.053
Shower 3 star	0.65	0.55	0.84	0.84	0.84
Front Loaders	0.75	0.54	0.84	0.54	0.84
Top Loaders	0.25	0.46	0.16	0.46	0.16
Dishwashers	-	0.72	0.72	0.72	0.72
Bath	-	0.05	0.05	0.05	0.05
Toilets					
Single Flush (10 L)	0.11	0.07	0	0	0
Dual 11/6L	0.89	0.15	0	0	0
Dual 9/4.5L		0.32	0	0	0
Dual 6/3L		0.46	1	1	1

Household occupancy:

- Based on ABS (2011a) for Adelaide
  - 1: 25%, 2: 35%, 3: 16%, 4: 16%, 5: 5%, 6: 1%, 7+: 1%

Showers:

- Based on the Preliminary survey 37% of houses identified as having non efficient showers, 48% as having efficient showers and 15% as mixed or unsure
- Efficient was assumed to refer to 3 star efficiency (max flow rate <9 L/min)
- Non efficient was split evenly between 0 star (>16 L/min), 1 star (12 – 16 L/min)and 2 star (9 – 12 L/min) efficiency
- Mixed/unsure was split evenly between efficient and non-efficient
- For demand management and future scenaios a 84% uptake rate is used based on the diffusion of innovation theory [*Rogers*, 2003] and the remaining split evenly between the 0 to 2 star efficiencies
- Proportions used:
  - Scenario 1: 0 star 15%, 1 star 15%, 2 star 15%, 3 star 55%
  - Scenario 2,3,4: : 0 star 5.3%, 1 star 5.3%, 2 star 5.3%, 3 star84%

Washing Machine:

- Based on the Preliminary survey 54% of houses identified as having front loaders, 46% as having top loaders
- For demand management a 84% uptake rate is used based on the diffusion of innovation theory [*Rogers*, 2003]
- Proportions used:
    - Scenario 1 and 3: Front Loaders 54%, Top Loaders 46%
    - Scenario 2 and 4: Front Loaders 84% , Top Loaders 16%

Dishwashers:

- Preliminary survey did not include a question on dishwasher ownership
- 72% ownership used for all scenarios based on the YVW study [*Roberts*, 2005]

Baths:

- Preliminary survey did not include a question on bath frequency
- 5% chance of the household having a bath event was used based on the YVW study [*Roberts*, 2005]

Toilet:

- Based on the Preliminary survey 7% of houses identified as having single flush toilets, 85% as having dual flush and 8% as mixed or unsure
- Single flush was assumed to refer to a standard efficiency single flush toilet (flush volume 10 L)
- Dual and mixed responses were split between the three modelled dual flush options, based on the proportional split of the 2010 YWV study [*Roberts et al.*, 2011] as this was assumed to most accurately reflect the current stock in Adelaide
- For demand management a 100% uptake rate is used as the installation of this option is mandated
- Proportions used:
    - Scenario 1: Single 7%, Dual 11/6L 14.5%, Dual 9/4.5L 32.3%, Dual 6/3L 46.2%
    - Scenario 2,3 and 4: Dual 6/3L 100%

Garden Use:

- Mean use of 62 L/person/day as provided SA Water based on 'Water for Good' with a reduction factor
- Garden use is assumed to be constant over time, i.e. garden size and water habits will not change
- Monthly usage factors, and consequently non-potable usage factors have been taken from *Barton and Argue* [2005]which was generated from the outputs from the six water treatment plants
- It was assumed that the usage pattern remains the same, but the mean usage has been reduced from the mean of 136kL/dwelling
- Table E.2 shows the assumed season proportions and factors for garden use for each month. A 2.4 person per household mean in Adelaide (ABS, 2011a) has been used to convert from per dwelling for comparison

Table E.2: Assumed Seasonal proportions and factors for Garden use

	Usage (kL) per dwelling from *Barton and Argue* [2005]	Usage (L) per /person/day adapted from *Barton and Argue* [2005]	Outdoor seasonal proportion	Outdoor seasonal factor (mean = 1)	Assumed outdoor usage (L/person/day)
January	31130	418	0.229	2.75	169
February	25610	318	0.188	2.26	139
March	19240	259	0.141	1.70	105
April	8720	121	0.064	0.77	47
May	4040	54	0.030	0.36	22
June	0	0	0.000	0.00	0
July	130	2	0.001	0.01	1
August	890	12	0.007	0.08	5
Sept	1900	26	0.014	0.17	10
October	6710	90	0.049	0.59	36
November	14520	202	0.107	1.28	79
December	23110	311	0.170	2.04	126

Table E.3: Proportions of appliances used for each DM scenario updated model

	Scenario 1: 2013 No DM	Scenario 2: 2013 DM	Scenario 3: 2025/2050 No DM	Scenario 4: 2025/2050 DM
Shower 0 star	0.165	0.053	0.053	0.053
Shower 1 star	0.195	0.053	0.053	0.053
Shower 2 star	0.175	0.053	0.053	0.053
Shower 3 star	0.465	0.84	0.84	0.84
Front Loaders	0.54	0.84	0.54	0.84
Top Loaders	0.46	0.16	0.46	0.16
Dishwashers	0.72	0.72	0.72	0.72
Bath	0.27	0.27	0.27	0.27
Toilets				
Single Flush (10 L)	0.074	0	0	0
Dual 11/6L	0.144	0	0	0
Dual 9/4.5L	0.294	0	0	0
Dual 6/3L	0.478	1	1	1

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