UNIVERSITY OF SOUTHERN QUEENSLAND
FACULTY OF ENGINEERING AND SURVEYING

DARWIN RESIDENTIAL END USE PILOT STUDY

A dissertation submitted by

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In the fulfilment of the requirements of

Bachelor of Engineering

27 October 2011

ABSTRACT

Rapid urban development and climate change are contributing to an increased risk and security of supply to the Darwin Water Supply System. Annual water consumption in Darwin is well above the national average. End-use measurement is an essential input into the development and assessment of supply side strategies and demand management initiatives.

The Darwin Residential End Use Pilot Study seeks to provide an insight into where, when and how much water is used in residential households in Darwin. High resolution water meters and data loggers were installed on a sample of 10 households. Data loggers recorded water consumption every 10 seconds over a 6 week logging interval. Special purpose Trace Wizard software was used to disaggregate consumption in end uses such as showers, clothes washing, irrigation etc. The study commences during the dry (summer) period which coincides with peak water consumption.

Average daily household consumption across 8 households was 1878.1 L/hh/d with an average per capita consumption of 747.2 L/c/d. Two of the households were omitted from the study due to data logger failures and statistical relevance. Approximately 77 % of overall consumption was directed to outdoor uses and 23 % to indoor uses. Water consumption was highly skewed towards the highest water users.

Average per capita indoor consumption was disagreggrated into showers (36.5 %), clothes washing (20.6 %), leakage (15.9 %), toilets (13.5 %), faucets (12.5 %) and dishwasher (1 %). Indoor consumption showed minimal variation from studies in other regions. The study supports the use AMR systems to identify leakage during night time flows.

Irrigated areas for each household were calculated and demonstrated a close correlation to overall consumption. This study supports evidence from the DeOreo (2011) study that an outdoor model can be generated to relate lot size to irrigated area and to overall consumption for broader catchment areas. Targeted demand management programs towards the highest water users can be optimised with consideration to the theoretical irrigation requirements and degree of excess irrigation. Demand management initiatives need to be targeted to excess irrigators without encouraging deficit irrigators to irrigate.

The study indicates that the use of historical planning estimates to forecast water supply is significantly overestimating water consumption with the increasing trend towards higher housing densities, smaller lot sizes and reduced irrigated areas.

Outdoor water use contributed to an average 93.5 % of peak hour demand between 6pm to 7pm. Cumulative sporadic irrigation events at peak hour had a significant influence on the peaking factor coinciding with optimum and convenient irrigation times.

The annual variations in climatic and transient population cycles suggest that annual consumption alone is a poor indicator of annual performance and in the assessment of demand management initiatives. Darwin's distinct climate cycle presents opportunities to track demand management initiatives, identify excessive irrigators and households with high level leakage.

A pilot study provides the opportunity to understand the underlying variables that influences both indoor and outdoor end uses in tropical climates and outlines recommendations for future targeted research. The study forms the first phase of an extended project to analyse seasonal variations of water use in tropical climates.

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111 Research Project Part 1 &
ENG4112 Research Project Part 2

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ACKNOWLEDGMENTS

First and foremost, I would like to thank Ella Patterson for making this project possible and ensuring continued advancement and assistance through all phases of the project.

A huge thankyou to the team at PWC, Kevin O'Brien and Sue Collins for meter registry and installation, Nick Frew for assistance with data logger programming, Kerry Moran for bracket design and Russell Jennings for ongoing support and assistance.

A special thankyou to Dr Andrew Huang (Griffith University) for making a seemingly impossible raw data conversion into a lesser impossible task.

Finally, thankyou to the nine households for participating in the study and advancing the science of end use analysis into the high extremities of water consumption. This project would not have been possible without you continued commitment.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The Darwin Residential End-Use Pilot Study seeks to provide an insight into where, when and how much water is used in residential households in Darwin. The study provides highly detailed water consumption information and is capable of disaggregating overall water consumption in individual end uses such as showers, clothes washing, dishwashing, irrigation etc.

A pilot study provides the opportunity to understand the underlying variables that influences both indoor and outdoor end uses in tropical climates and outlines recommendations for future targeted research. The study commences during the dry (summer) period and forms part of an extended project to analyse seasonal variations of water use in tropical climates.

1.2 Objectives and Scope

The specific objectives of this project will seek to:

- Analyse the distribution and variability of water consumption end uses in residential households in Darwin and in tropical climates.
- Evaluate and outline the role smart metering can provide in meeting water reduction targets in reducing residential water consumption in Darwin.
- Experiment with and evaluate the optimum data collection, transfer and analysis of water consumption data using smart metering systems in Darwin
- Analyse the effects of temperature and rainfall on water consumption patterns and compare to existing end use studies.
- Calculate household and per capita water use, diurnal flow patterns and peak hour factors for the study sample.
- Review the use of water and wastewater network planning guidelines for single dwelling, medium density residential and high density residential and outline methodologies to revise these guidelines.
- Provide recommendations for future research.
- Improve understanding of conservation potential associated with various end uses.

The study takes a holistic approach in the analysis of individual end uses due to the limited sample selection and the sample bias. The study will not seek to analyse the water efficiencies of household appliances nor the penetration of water efficient appliances in Darwin.

The pilot project focuses on single dwelling residential developments and does not record or analyse information relating to medium-density, high-density, commercial or industrial sectors.

1.3 Background

The Darwin Region's water supply system sources its water from both surface water and groundwater sources. Approximately 90 % of water is supplied from Darwin River Dam and the remaining 10 % is supplemented from McMinns and Howard East Borefields.

Power and Water Corporation (PWC) is responsible for the supply of potable water to a permanent population of 114,000 people and approximately 50,000 properties including commercial, industrial and government properties, as highlighted in Figure 1-1. The total bulk water consumption in 2009/2010 was 41367 ML and 43,138 ML in 2008/2009. Growth is forecasted to grow at 2-3 % per annum.

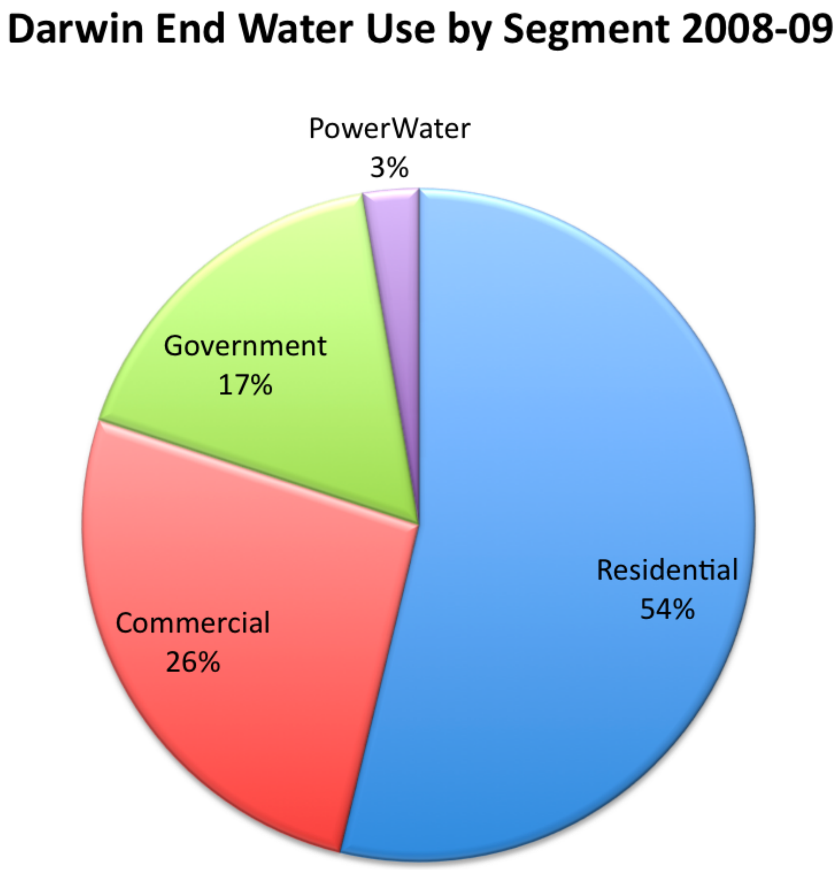

Figure 1-1 –Water Consumption by Customer Type (PWC, 2011)

Whilst most cities in Australia have witnessed a sustained reduction in residential water consumption as a direct result of water security threats and ongoing water restrictions, water consumption in Darwin remains well above the national average. In response to this, PWC are currently in the process of developing a Darwin Region Water Supply Strategy. A major focus of this strategy is to review and develop demand management initiatives for the Darwin region. The strategy is supported by the commitment in the Territory 2030 Strategic Plan to reduce water consumption by 20 % by 2015 and a further 10 % by 2025 compared to 2009 consumption levels. (NTG, 2009)

Water demand is highly seasonal and fluctuates between a lower water use in the wet (winter) season and a higher water use in the dry (summer) season. The monsoonal wet season generally last for 4-5 months followed by a period of almost zero rainfall during the dry season for an average of 7-8 months. Yearly fluctuations can be up to 10 % and largely depend upon the length of the dry season, transient population cycles and industry cycles. The effects of rainfall and temperature on bulk water consumption for the preceding 5 years are shown in Figure 2-1.

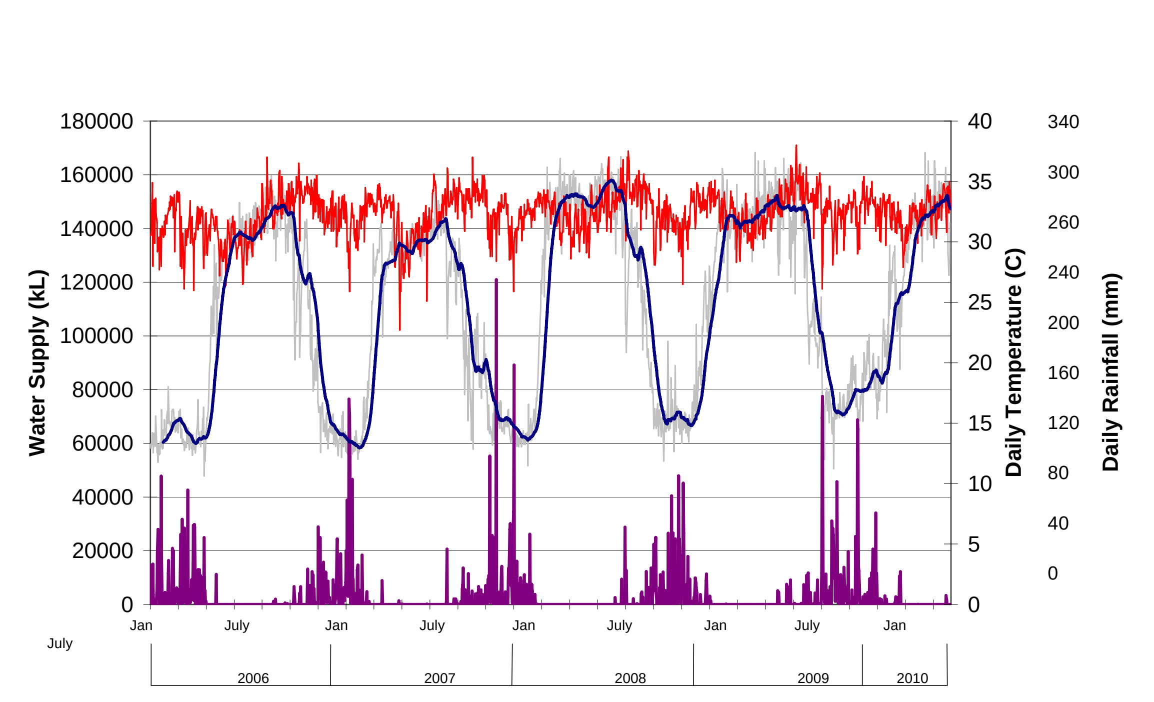

Figure 2-1 - Daily Water Production vs. Climate (PWC, 2011)

Residential consumers direct the bulk of water consumption to outdoor uses. Indoor use is also high within the residential sector suggesting that that discretionary garden use is but one factor in explaining the very high rates of consumption in Darwin.

A direct comparison to regions located in similar climate regions such as Cairns and Mackay still shows residential water consumption well above these regions as shown in Figure 3-1. It is important to keep in mind that these two regions have previously been subject to imminent water security or water supply threats within the past 10 years which Darwin has not been exposed to. However, they do provide an indication as to the potential savings that can be achieved in a similar climatic region.

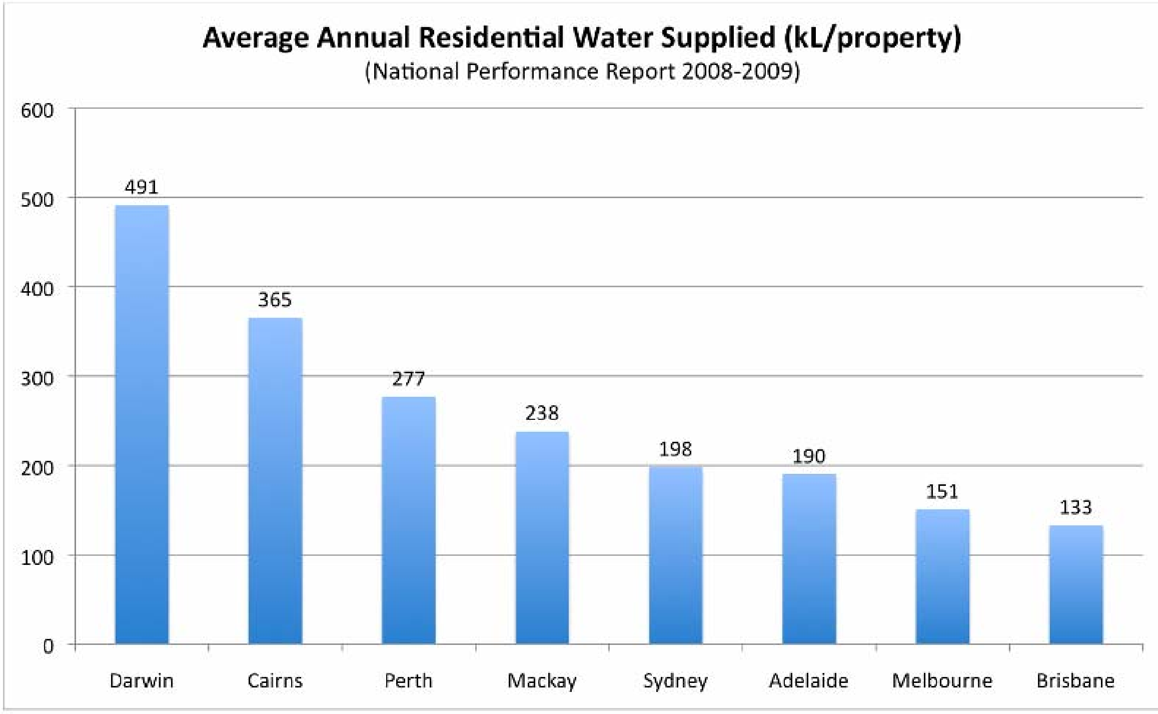

Figure 3-1 – National Annual Residential Water Consumption Comparison (PWC, 2011)

1.4 Justification

Rapid urban and industrial development in Darwin in combination with climate change is contributing to an increased risk and security of supply to the Darwin Water Supply System. While there is a need to secure future water supplies, measures need to be put in place to manage water demand. As demand grows further and annual extraction is increased the available headroom is decreased.

A key component of a future regional water strategy is to implement demand management initiatives to reduce residential water consumption. Reducing water consumption has the potential to defer major capital expenditure on water and wastewater infrastructure. Preliminary forecasting using northern territory water reduction targets in residential households illustrate that the need for the next major water source can be delayed from 2017 to 2024 and beyond if these targets are met.

Integrated Supply-Demand Planning (iSDP) is emerging both nationally and internationally as best practice in the development and analysis of supply and demand options, and PWC are seeking to adopt this framework. End-use measurement is an essential input into the development and assessment of supply side strategies and demand management initiatives.

There is limited information about residential end-uses in Darwin and cities situated in tropical climates. Application of historical end-use models or end use models from other Australian cities cannot be justified without consideration to differences in per-capita demand, demographics, climate and behavioural attitudes to water use.

The disaggregation of residential household water consumption should be considered as the critical first step in the development of demand management initiatives for residential households. For demand management instruments to be effective, efficient and equitable, their design needs to based on an understanding of how water is used by whom and in what way water savings can be achieved. (Jorgensen et al. 2009)

Diurnal patterns in high irrigating environments are subject to extreme morning and afternoon peaks coinciding with optimum irrigation periods. An understanding of the timing and behavioural influences of end use consumption at peak hour flows, in particular sporadic and automatic irrigation systems, can inform network planning in developing strategies to reduce peak hour flows and therefore reducing water and wastewater capital network infrastructure.

The accuracy of forecasting water use using historical planning estimates for single dwelling residential, medium and high density residential has come under continued scrutiny. The flow on effects from on a under conservative or over-conservative approach to water and wastewater planning can lead to ineffective capital works programs and poor design leading to operational and environmental issues such water quality during non-seasonal flows, increased wastewater retention times, pumping inefficiencies etc.

A pilot study is useful for the testing of new technologies and can identify issues associated with data capture, transfer, analysis and storage i.e. meter installation, logger failures etc. This will allow a more effective and efficient implementation of broader scale projects.

An end use study undertaken in a tropical climate can highlight extreme trends and variables that may not be evident in studies undertaken in other climatic conditions. A micro-level analysis of end uses over limited number households with ongoing direct contact with the participants can provide insights that may be overlooked from broader analyses.

1.5 Overview of Dissertation

Chapter 2 undertakes a literature review on previous end uses studies and provides case studies for the use smart metering systems to reduce residential consumption. The review focuses on end-uses studies using Trace Wizard software and studies undertaken with significant outdoor use components.

Chapter 3 outlines the methodology undertaken to investigate water consumption in 10 households in Darwin. The chapter defines the technical requirements of the project relating to data capture, transfer, analysis and storage. It develops a model for assessing both indoor and outdoor water uses separately.

Chapter 4 discusses the issues encountered throughout the project and outlines recommendations for future study methodologies.

Chapter 5 provides a summary of overall water use for the 6 week logging period.

Chapter 6 investigates indoor consumption and discusses the Trace Wizard process for indoor uses, generates overall indoor use summaries and compares indoor consumption to other studies.

Chapter 7 presents an overview of outdoor water consumption by discussing the methodology of Trace Wizard analysis and investigates the variables that influence outdoor consumption.

Chapter 8 and 9 summarize the key conclusions from the pilot study and provide recommendations for future study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The importance of understanding the distribution and variability of end uses of water has evolved with increasing focus to demand management. Water conservation presents a way to economically reduce urban water demands and reduce the need to source future water supplies which are increasing becoming harder to source and considerably more expensive. The shift towards more sustainable and environmental planning has further encouraged the need for water conservation.

Over the past 20 years, advanced end use studies have been undertaken in the United States, Australia, New Zealand, Canada, Spain, Jordan and many other countries. The technological development of data capture, transfer, storage and analysis in recent times have allowed for the ability for water utilities to undertake end use studies in a less intrusive, cost effective and timely manner.

2.2 End Use Measurement

There are a variety of methods used in the collection, transfer and analysis of end use information and usually combine some form of technology with household surveys and/or statistical information. End use measurement can range from manual measurement from house inspections, log books and questionaries to technological measurement using smart meters and data loggers. Data can be transferred for further analysis using manual or automated techniques.

Blokker et al (2010) used a stochastic end use model to estimate residential end-uses in Sydney. The study combined statistical information from census, household surveys and stock appliance manufacturers. Results showed a good correlation to existing end use studies but the approach can lead to inaccuracies, particularly in end uses such as showers and taps. These errors were further highlighted in a study by Mead and Aravinthan (2009) whom undertook a pilot study in Toowoomba and found that estimated manufactured flow rates were different to actual flow rates in household appliances.

Regardless of the level of technology or resolution used in the analysis, surveys and logbooks recording demographic and behavioural data provide an essential link to end-use analysis.

Wide bay water was one of the first utilities to employ smart metering on a broader scale in Australia. The smart meters provided an enhanced understanding of customer water use patterns capable of discerning between overall indoor and outdoor water use and detecting household leakage during off-peak periods. A review by SMEC highlighted the limitations of recording at 1 hour intervals and an inability to disaggregate indoor water use and monitor the effectiveness of end-use scale demand management initiatives. The report recommended for more advanced metering to be applied on a selection of households to understand water at an end-use scale to allow for the development of an overall demand forecasting and options model. (Turner, 2010)

An internal smart metering trial was undertaken on 10 employees from Power and Water using Halytech Wireless Window equipment to monitor water use during the dry (winter) and in the wet (winter) season in 2010. The instruments recorded consumption over a 1 hour period and each household was to record water events with a log audit spreadsheet. The analyst was required to remotely download the data and estimate water consumption using the water diaries and manufactured flow rates. Results of this study are shown in Figure 1-2. Several of the households could not be disaggregated due the incompletion of water diaries or logger failures. Therefore a key consideration for future studies was to have an independent process that could automatically disaggregate water use events, minimise household participation and improve data storage and transfer capabilities.

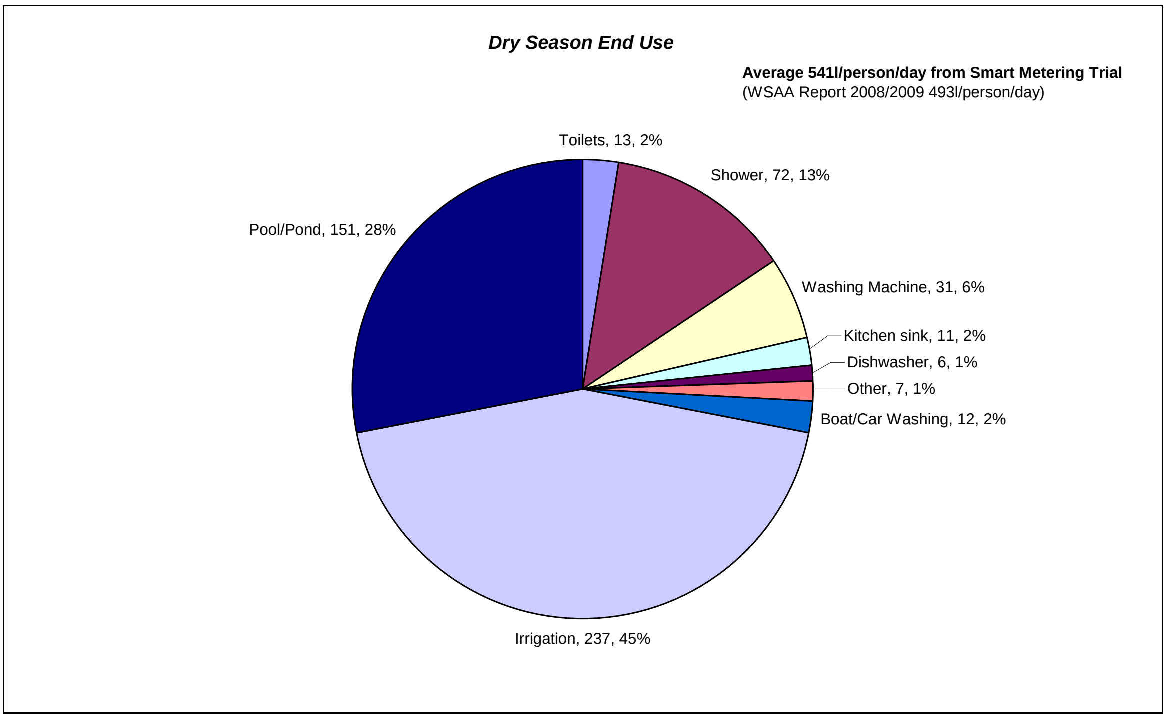

Figure 1-2 – Previous Internal Smart Metering Trial - Dry Season End Use Summary (PWC, 2010)

2.3 Advanced End Use Measurement

The first version of Trace Wizard software was developed to measure the impacts of a conservation retrofit program in Boulder Colorado and capable of disaggregating end uses from a single water meter (DeOreo et. al 1996). Whilst the system significantly increased the speed and accuracy of flow trace analysis, simultaneous events still required manual manipulation of the database. A further improvement to the software has enabled simultaneous events to be identified within the program and has provided a key link between measured data and end use disaggregation. (DeOreo, 2011).

A summary of results for several advanced end-use studies that have utilised Trace Wizard software in recent years is shown in Figure 2-2 (Beal, 2010). The results emphasise the variability in water consumption and that each region has a specific end use profile relating to local demographics and climates.

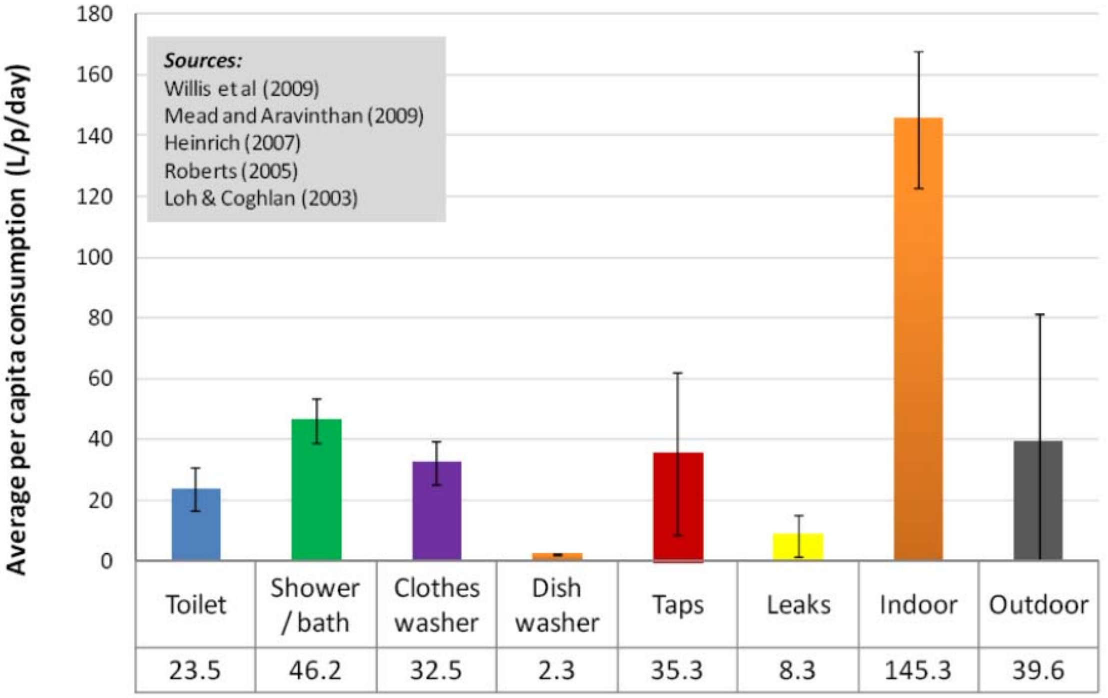

Figure 1: Average water consumption for common residential end uses sourced from recent Australian studies.

Figure 2-2 - Summary of Recent End Use Studies (Beal, 2010)

The majority of indoor water use is directed to showers, clothes washing, toilets and faucet use. Household appliances with distinct volumes and cycles such as clothes washers, dishwashers and toilets show little variance between studies. Faucet use can considerably vary between studies and dependent upon the methodology utilised and the amount of information provided from surveys and water audits. Outdoor water use can considerably vary between regions and the parameters that influence outdoor water use are discussed later.

Several end-use studies have been undertaken in Perth using a variety of approaches to disaggregate end uses. These studies have highlighted the importance of capturing detailed water consumption information in combination to water diaries and surveys; stating that for outdoor irrigation use the respondents could correctly identify the number of irrigation events, however the duration of irrigation events can be underestimated by as much as 30 % to 50% (Loh & Coghlan, 2003). As Darwin has a high outdoor usage during the dry season, it is imperative that a higher level of accuracy is achieved than capable in a survey-only based approach.

A study was undertaken on 735 single family homes across ten water agencies throughout the State of California from 2005 to 2010 and used Trace wizard software for flow trace analysis. Annual water consumption was divided into 53 % for outdoor uses and 47 % to indoor uses. The study developed an model to predict outdoor water use with the major variables affecting outdoor water use being evapotranspiration, irrigated area, household income, landscape ratio, the presence of a pool, whether the customer was over-irrigating and the presence of an in ground sprinkler system. The study found that the three most effective parameters to reduce outdoor consumption were to reduce irrigated areas, use of more xeric plant material and the elimination of over-irrigation. It also highlighted that the distribution of water savings is skewed as this is the distribution for water use and excess irrigation and that this distribution is a key component to designing targeted demand management approaches. . For indoor consumption, the only statistically significant variable was the number of residents in the home and all other variables were random in predicted indoor water use. The study also found that household income was a much better predictor of water consumption than the marginal prices of water. (DeOreo, 2011)

2.4 Diurnal Flow Patterns

Water consumption varies throughout the day and directly relates with the daily cycles of residents and their interaction with end uses. A typical residential curve applied to a network model is shown in Figure 3-2. A demand multiplier is used to convert average peak day flow to peak hour flows during a peak day scenario. A peak is usually experienced in the morning and a further peak in the evening and this is when indoor and outdoor consumption is at the maximum. In high irrigating environments, the peak hour factor can considerably increase coinciding with irrigation cycles.

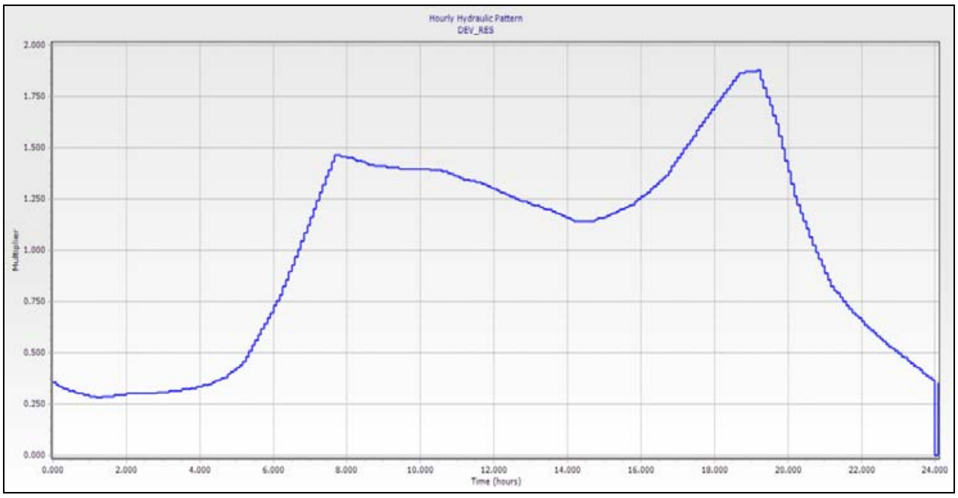

Figure 3-2 - Typical Residential Diurnal Pattern (PWC, 2011)

The diurnal pattern can vary significantly throughout the course of the year with the cyclic nature of climates, tourism and industry. Residential water consumption is generally higher on weekends and during holidays.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The methodology for this project is based on methodologies used in previous end use studies. Equipment and software were selected based on similar studies, so in the event of troubleshooting previous or current studies could be contacted for assistance.

The key focus of the methodology was to minimise the reliance of participant involvement in the study where possible and still be able to achieve outcomes where poor participation arises. Water conservation awareness is lower in Darwin than other regions and therefore the desire to participate in water consumption studies is perhaps lower without the higher exposure to water conservation messages seen in other regions. The methodology also seeks to be as non-intrusive as possible with the aim of observing behaviour without influencing behaviour.

3.2 Sample Selection Process

As a pilot study, a statistically relevant population is not required. However, stratified sampling is essential to providing a realistic sample of the broader population. Specifications of the acceptable level of error and required confidence limits are not achievable as pilot study.

Selection processes in existing studies generally target higher water users and they are responsible for a higher proportion of water use and where the maximum savings can be achieved. Therefore having a sample above the mean water use of the population is desirable to understand the end use factors that are contributing to higher water use.

The study focuses on owner-occupied households as rental households are generally transient and seasonal comparisons become invalid.

A general email combined with a fact sheet was submitted to Water Services personnel to generate volunteers for the study. Due to a limited number of respondents, individual staff was approached to participate in the study. Respondents seemed to be more eager to participate in the study after directly describing the capabilities of the project. Where this was perceived pressure or not is difficult to determine. This also implies that the email was not the most effective approach to generating volunteers; a more effective approach would have been to have a general presentation prior to seeking volunteers.

The distribution of households is shown in Figure 1-3.

Figure 1-3 - Household Locations

3.3 End Use Equipment

The study required the purchase of 10 new water meters and data loggers for the study. The specifications for each are described below.

3.3.1 Meters

A high resolution of recording is required for flow trace analysis in Trace Wizard. The most common meters used in previous studies is the Actaris CT5-S water meter and are readily available from Australian suppliers. This meter was selected as suitable for this study. Existing water meters in Darwin are generally 20 mm diameter Elster Meters, and therefore a direct switch to the 20 mm diameter Actaris meters was possible without the need for additional accessories. The meter has a long battery life that is suitable for the duration of this study and for the expansion for future studies. The meters are provided with a high resolution reed switch contact closure output.

The meter was modified from its normal 2 pulses / litre to record at 72.5 pulses/Litre at the manufacturing stage. This is currently the highest amount of pulses per litre that can be achieved from a domestic water meter. At the time of ordering these meters have a unit cost of $339.00/unit. The meters were tested during the manufacturing stage.

Contractors were sourced to install plugs onto the reed switches.

The specification for the Actaris CT5-S water meters are shown in Appendix D.

3.3.2 Data Loggers

Aegis Datacell Rtx data loggers were selected to satisfy the requirements of this study. The logger has a capacity to store up to 2 million records with a battery life of 10 years which combined make it suitable for the duration of this project. The loggers are capable of recording up to 100 Hz which is required for this project. The data loggers are provided and tested with inserted SIM cards and the setting of all communication and typical operation parameters. SIM cards were purchased locally and sent to Aegis for installation and testing.

The logger was set to record consumption every 10 seconds and to transmit weekly profiles. The logger has remote interrogation and programming capabilities but this could not be achieved with consideration to the sample size and the complexity of IT systems required. Two email addresses were created to ensure a backup of data. Each logger was attached with household abbreviations to ensure transmitted emails could be identified. The emails were staggered in time to ensure identification and minimise traffic.

A software suite was downloaded from the Aegis website to convert the raw data transmitted from the data logger via email to a format suitable for input into Trace Wizard. However, the conversion from the latest version of the software suite could not be achieved and an older version of the software suite was sourced to achieve the conversion. This software was downloaded from the Aegis website.

The loggers were purchased at $900 per unit.

The specification for the Actaris CT5-S water meters are shown in Appendix E.

3.3.3 Pressure Loggers

Pressure loggers were installed at each of the sites and recoded residual pressures over a 5 day period. An average pressure profile was developed for each of the sites. High end irrigation flows were compared against pressures at time of the day. This was necessary as several sites due to the variable nature of pressures throughout the day. One of the pressure loggers recorded erroneous results and pressure for this allotment was compared with nearby pressures and network models.

3.4 Testing and Installation

Data loggers were synchronised to local time. An installation report was generated from each logger to verify correct SIM card installation and signal strength. The data loggers were programmed to transmit an email to check logger settings were correct and operating as expected. Each meter and data logger was labelled externally and serial number recorded to ensure loggers were installed at the correct addresses.

A 5 litre flow was passed through each water meter and compared to the data logger readings. Where inconsistencies existed the connection points and logger settings were checked and logger inputs were switched if required.

A bracket was developed from Power and Water Personnel to connect the meter to the data logger. The logger is designed to operate in an upright position and this was considered in the bracket design.

The meters and data loggers were installed by qualified Power and Water personnel and contractors over a 4 hour period on 16th August 2011.

Water meters in Darwin are located above ground and therefore careful consideration to operational issues such as environmental damage and security was paramount without affecting the GSM signal strength of the data logger. Most of the water meters were located behind fences or security gates and provided adequate protection.

The bracket orientation needed to be modified in several houses due to proximity near fences. Where meter access was not possible due to plant overgrowth, alternative houses were selected for the study.

3.5 Household Audit and Water Diaries

After the meters and data loggers were in place, a household audit was undertaken on each property over the course of two weeks to provide signature traces of individual water events. The type and rating of each household fixture was noted. Each fixture units was applied for 10 seconds to allow a Trace Wizard profile to be developed for each fixture. This is important as indoor fixtures such as bath taps can be higher than external fixtures and outdoor fixtures during outdoor use can be lower than indoor fixtures. Photographs were taken of each appliance for future reference.

The boundaries of irrigated areas were also determined at the household audit.

A household questionnaire was also developed to determine household demographics, water appliances and water use behaviours. This was supplemented with a log book for the first 4-5 days assist in the flow trace analysis in determining dish washer and clothes washer cycles that cannot be determined at the household audit. The log sheets proved to be extremely valuable for complex flow trace analyses particularly on weekends and in identifying common events from the daily cycles of participants.

3.6 Trace Wizard

Trace Wizard is special purpose software used to disaggregate overall water consumption into individual water uses such as showers, toilets, leaks etc. The program is capable of automatically disaggregating up to two simultaneous events.

Analysis in Trace Wizard is a two part process. The first is to the task of resolving the raw flow trace data from the converted output data logger file into individual water use events. At this stage, the leakage parameters and simultaneous event properties are calibrated. Parameters can be changed to increase the minimum leak tolerance or to adjust properties for the recognition of simultaneous events.

The second process is to identify and apply fixtures to each water use event. Initial calibration is achieved from using the signatures traces from the household audit.

Dishwasher and washing machine cycles can be determined from the household survey. The program provides a fixture library which the analyser uses to select the total number and type of fixtures to cater for each household. The analyser modifies the parameters (e.g. volume, peak, duration and mode) for each fixture to match the individual household. This is achieved by setting a range of criterion for each parameter i.e. a maximum volume and a minimum volume etc. The order of fixture units in the fixtures library is important as each flow event is matched against the fixture list and assigns a fixture type if the event rests between the maximum and minimum range for all parameters of the fixture type.

Multiple fixtures can be applied for each end use. For example if a clothes washing machine has three cycles of different volumes, peak flow and volumes then each cycle can be matched separately as Clothes Washing 1, Clothes Washing 2, Clothes Washing 3 and the template parameters are set to each cycle. The variation can be minimal and the parameter range can be increased to match all cycles, as long as other household fixtures will not fall within the parameter ranges.

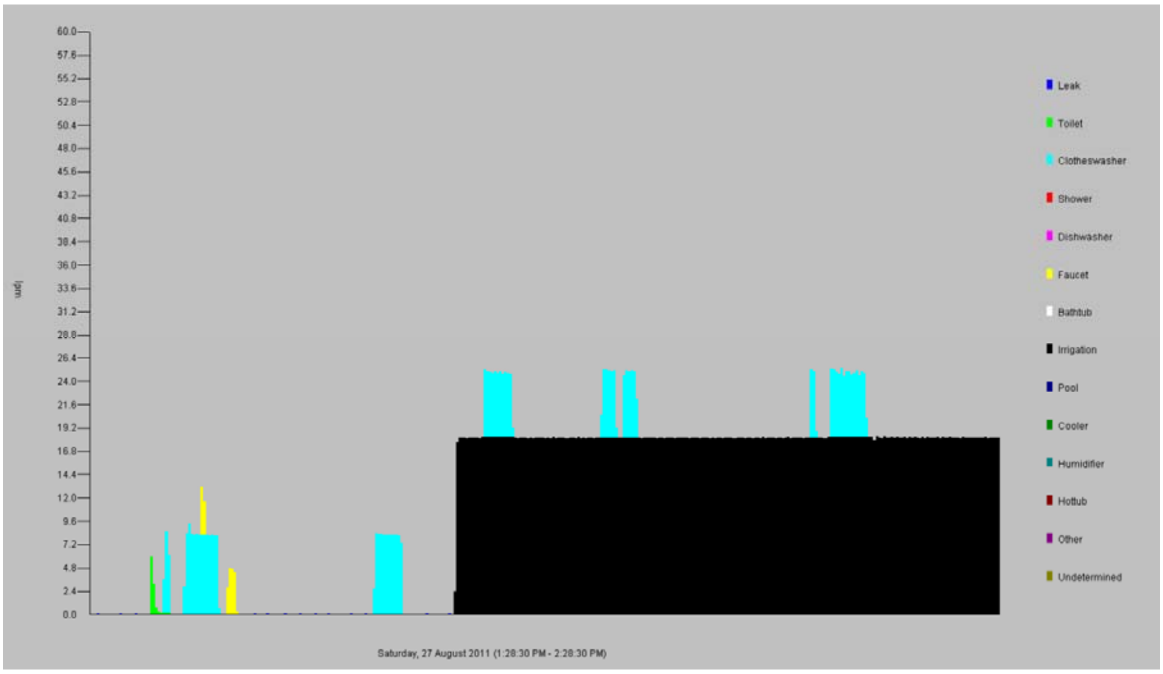

Figure 2-3 - Example Trace Wizard Flow Trace

All water profiles can be viewed in the primary user interface Events Graph. All calculated fixtures are assigned an individual colour for each end use. An example trace wizard flow trace over a 1 hour interval is shown in Figure 3-3. The trace shows two clothes washing cycles, a toilet flush and a simultaneous irrigation event.

Trace wizard calculates three types of events known as base events, trickle event and super events. Trickle events can be automatically incorporated into the previous water event. The interface also allows for water events to be merged or split manually if the water profile does not match the intended water use.

Trace wizard is capable of disaggregating two simultaneous events. Any water event that does not meet any listed parameters, then the event will be labelled as undefined and the analyser must manually assign the water event to the corresponding water use by visual inspection. The analyser can then decide whether to modify the existing parameters.

Trace Wizard 4.1 Software had a unit cost of $1495 (US dollars) at the time of purchase.

3.7 Microsoft Excel Database

The template file created as an output from the flow analysis in Trace Wizard is formatted into a Microsoft Access file. The analysed flow traces can be viewed in Microsoft Access and has several in-built summary queries that summarize the results of the flow trace analysis.

Each weekly flow trace file was exported to Microsoft Excel for increasing graphing and data analysis capabilities. Relevant summaries and queries were generated in the excel files.

Trace Wizard rounds volumes to the nearest 10ml for flow trace analysis and a leakage adjustor script was generated from the raw data to account for differences in low level leakage. Although each event may seem small, the cumulative error from rounding is significant to influence the overall leakage consumption and end use profiles.

3.8 Irrigated Area

The irrigated area boundaries for each property were determined from the household audit. Google Earth (NT Visualiser) was used to determine the irrigated area from the recorded boundaries using the polygon area tool, as illustrated in Figure 3-3. Almost all of the properties have tropical gardens with a high level of overgrowth. Several of these areas are not irrigated and determining areas which are irrigated would not have been possible without the onsite inspection, particularly on the rural property. Furthermore, the degree of accuracy independent of on-site inspection can also depend on the age of GIS imagery. At the time of the image was taken, one of the allotments was under construction and another allotment did not have a carport addition which would have led to an incorrect estimation of irrigated area. The degree of accuracy also depends upon the time of year the image was taken. Irrigated areas can be identified in the dry season from green patches but this would not have been possible if the image was taken in the wet season.

Figure 3-3 - Irrigated Area Calculation

CHAPTER 4: PROJECT ISSUES

4.1 Introduction

Only seven of the originally targeted 10 households were successfully used for the result summaries. One of the households was replaced with another household and therefore 8 households were successfully used to generate summaries of results. This chapter presents some of the issues encountered throughout the course of the project and suggests how these issues can be resolved in future studies.

4.2 Project Issues

- Meter Access

One household had overgrown plant growth and meter access was not possible without significant clearing to gain access and this would endanger the meter installer. It is the responsibility of the homeowner to ensure water meter inspectors can be accessed and read. An additional household was selected to replace this household. This would not have been possible if the target population was random and statistically relevant.

- Logger Site Failures

All ten of the data loggers were successfully calibrated, tested and installed in the field.

A tampering error message was generated from a data logger on the evening after installation. The data loggers transmitted in excess of 500 emails over the course of a weekend and subsequently drained the battery life of the data logger. The data logger was removed from the household but will likely form part of a future expansion of this study.

- Logger Transmission failures

Data transmission issues were prevalent in the weekly transmission of emails. Only 6 of the 9 data loggers completed successful transmissions over the entire 6 week logger period. The 3 remaining data loggers transmitted 4 emails out of a possible 21 emails. Two of these households are located within a 100 m radius and the 3rd household was located in a rural area. This indicates that the transmission problems were likely due to poor transmission strength rather than issues with the data loggers. This is an area that will need further consideration in the use of wireless data loggers in future studies. Significant time and resources is required to manually download the data. Two of the data loggers were located inside automatic gates and therefore data recovery needed to be organised outside of working hours. This suggests that sample selection should also consider area transmission strength if possible; however caution needs to be addressed to prevent any bias in water consumers.

- Household Omission

Although the study is statistically irrelevant, a household was omitted from the flow trace analysis as it was not representative of the general population and would provide an unrealistic skew on certain end uses.

- Missing Data

Data entries are missing in several households over the 6 week logging period primarily due to logger failures and an inability to recover the information with an on-site manual download. Therefore some statistical summaries could only be generated from complete data sets depending on the type of summary. The variability between weekdays and weekends requires at least weekly cycles to be used and often this could not be reasonably satisfied.

- Resource Expertise

The project required a significant amount of technical requirements and relevant expertise was often difficult to source internally on several occasions. This should be a key consideration for future studies or other water authorities seeking to undertake a smart metering or flow trace analysis. The raw data conservation in particular needed significant external assistance to be achieved.

- Intrusive Nature

The flow trace analysis is extremely intrusive if the analyser personally knows the participants. An effective flow trace analysis requires the analyser to establish daily patterns to correctly identify water events. The more engrossed the analyser becomes in understanding the underlying behaviours of each household end use the more accurate the overall flow trace will be. Simply put, the analyser can understand the daily habits of households better than they know them themselves. For instance, a water diary indicated that a household had three showers in an evening yet the flow trace only showed two showers events. After querying the householder it was determined that a householder was using the pool as a substitute for the shower and therefore did not appear within the flow traces. These type of insights were numerous.

Future studies should require the analyser to remain anonymous from the participants.

- Complexity of Flow Trace Analysis

Due to time constraints, only 2 weeks were used in the flow trace analysis using Trace Wizard. However it was decided that 2 weeks would provide an adequate reflection of water end uses with consideration to the statistically relevance of the sample size. Furthermore, several of the flow traces were complicated due the combined use of outdoor and indoor uses thus requiring a high degree of manual separation where the Trace Wizard template was often unable to correctly identify water events. There were multiple events in each weekly flow trace where water diaries and surveys were used to estimate the event. The accuracy of the flow traces should be reviewed when the wet season comparison is undertaken. A direct comparison in the wet season would require this analysis to be extended over a longer period and more meaningful statistical summaries can be generated such as shower durations, number of clothes washing cycles etc.

The outdoor water use component can provide enough complexity to make it impossible to distinguish individual events. An example flow event is shown in Figure 1-4 which contains several toilet flushes, two showers, bath, faucet use and outdoor irrigation with a continuous leak within the main event.

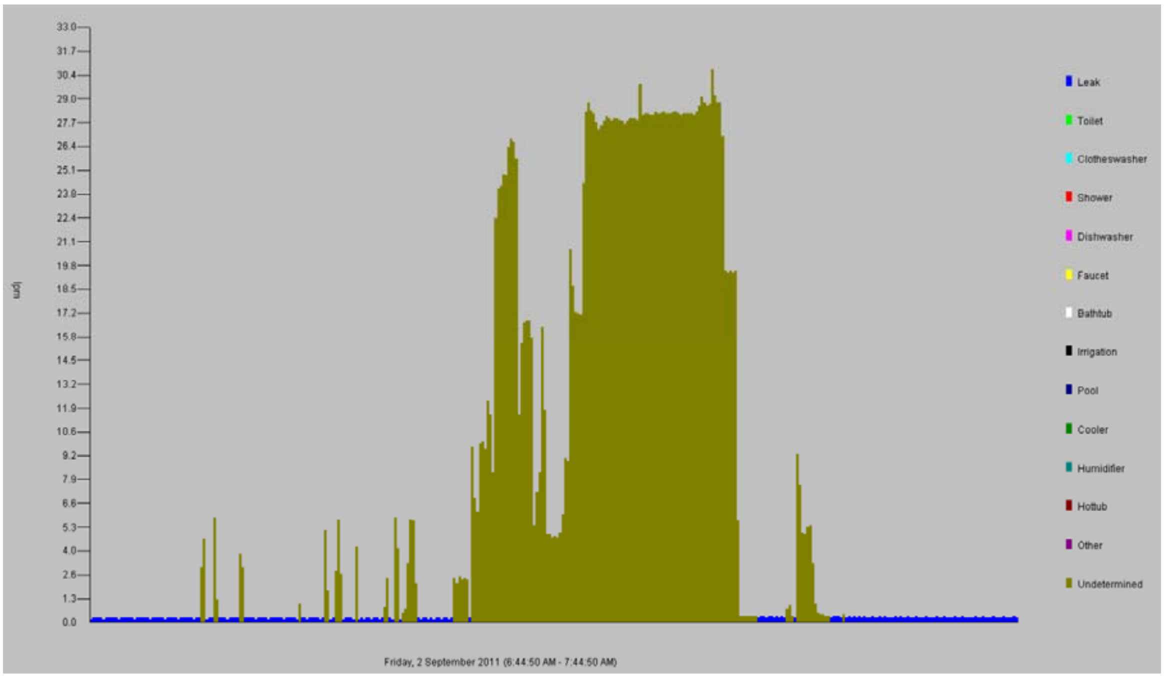

Figure 1-4 - Complex Flow Trace

- Demographic Bias

The study sample are all water service employees of PWC and therefore would exhibit similar weekly patterns and would be expected to possess a higher awareness of water conservation. It is difficult to extend some of the insights shown in this report to the broader population.

- Further considerations

The following results need to be viewed with caution and should be viewed as an insight only. Although the consumption figures and trends seem realistic for a tropical region, the results may not be relevant to the general population given the statistical bias.

There are several considerations to make when interpreting the following results:

- The analyser has not undertaken training in Trace Wizard software and the use of the program is self taught using program in-built tutorials.
- The analyser had limited understanding of end uses and end use profiles prior to undertaking this assessment.
- Most existing studies have at least two people analysing the data to eliminate bias in the results where possible.
- Most studies undertake an indoor end use model in the winter (wet) season and use a simplified indoor / outdoor model for summer (dry) season analysis.
- Darwin has a much higher water use than most previous studies and may increase the complexity of flow trace analysis particularly on weekends.

CHAPTER 5: OVERALL CONSUMPTION

5.1 Introduction

This chapter provides a summary of the results relating to overall consumption over the 6 week logging period. A range of data periods has been used to generate statistical summaries and the data period is indicated for each of the summaries and calculations. There are different variables that influence indoor and outdoor consumption and these summaries are presented separately in Chapter 5 and 6.

5.2 Discussion

The data was collected over a 6 week period from 19th August 2011 to 30th September 2011 for 9 households. One household was omitted from the analysis leaving 8 households available for analysis as discussed in Chapter 4. Overall per capita consumption estimates were calculated using complete weekly data sets over the 6 week period. Weekly data sets were omitted in several households where data entries were missing and averaged across the remaining weeks, ensuring that an equivalent ratio between weekends and weekdays was maintained. Although not ideal, this methodology was deemed adequate as the variation in consumption between August and September would be minimal and with respect the statistical relevance of the sample population. There were two minor rainfall events witnessed over this period that would likely have a limited affect on water consumption. Statistical summaries were generated from complete data sets only over the 6 week duration.

The results are presented in average daily water consumption per household measured in terms of litres per household per day (lphh). Average per capita consumption estimates were generated by averaging all individual per capita estimates measured in litres/capita/day (lpcd) to allow for a direct comparison to other studies. This is necessary to account for vary degrees of occupancy ratios between regions. Alternatively the results can be expressed in litres per person per day by adding the total consumption for all individual households and dividing by the number of participants in the study. It is important to keep in mind that two methods will produce different values as certain end uses such as leakage and irrigation are not normally distributed.

Statistical summaries for overall consumption were generated from the raw data and the overall indoor / outdoor relationship was developed from the Trace Wizard flow trace analysis.

5.3 Overall Consumption

The overall average daily water consumption recorded over the six week logging period was 1878.1 litres per household per day. The average per capita water use was 747.2 litres per capita per day. The average occupancy ratio for the study was 2.75 which is above the 2.5 average occupancy ratio for Darwin.

The only reported figures that can be used as a comparison are annual consumption figures and previous smart metering trials. The variance between overall per capita estimates between wet and dry seasons has been calculated; however the breakdown into leakage, residential, commercial and industrial components is less understood between wet and dry seasons with the variance in climate, transient and industrial cycles.

Average annual residential water consumption for Darwin was 491 KL/household (1345 L/hh/d) from 2008-2009 and 458 (1255 L/hh/d) from 2009-2010. (WSAA, 2011) The average consumption of 1878.1 L/hh/d for the study is higher than these figures which is expected as the study is during the peak consumption period. The variance in wet to dry season for residential properties from the bulk metered data needs further investigation.

The overall water consumption divided by the number of participants was found to be 682.9 litres/person/day. This is higher than the previous internal smart metering trail of 541 L/p/d, however the differences in occupancy ratios could not be established.

Three complete weeks of data over the six week logging period without missing entries was used to generate statistical summaries shown in Table 1-5. The calculated mean over the three week interval was 1847.3 L which is less than 1878.1 L overall. The 3 week interval is still expected to provide a good indication as to the degree of statistical variance between and within the sample population.

Table 1-5 – Sample Overall Consumption Statistical Summary

Parameter	Overall Consumption (L)
Mean	1847.3 ± 1177
Median	1821.8
Maximum	8093.5

The peak daily water consumption for the 3 week statistical analysis for all households was 2650 L/household occurring on Saturday 18th September (n=8). The absolute maximum consumption for a single property over the logging period occurred on the same day with 8093.5 L. This further illustrates the degree to which individual houses can skew the overall data set and the need for larger data sample than other regions to account for increased variability.

Figure 1-5 illustrates the distribution of overall consumption across the eight households. The figure shows that water consumption is not normally distributed and higher water users skew overall consumption figures. The two highest consuming lots account for 40 % of the total consumption and the two lowest consuming lots account for just 12 % of the overall consumption. The end use contributions to the skewness of water consumption are further discussed in Chapter 5 and 6.

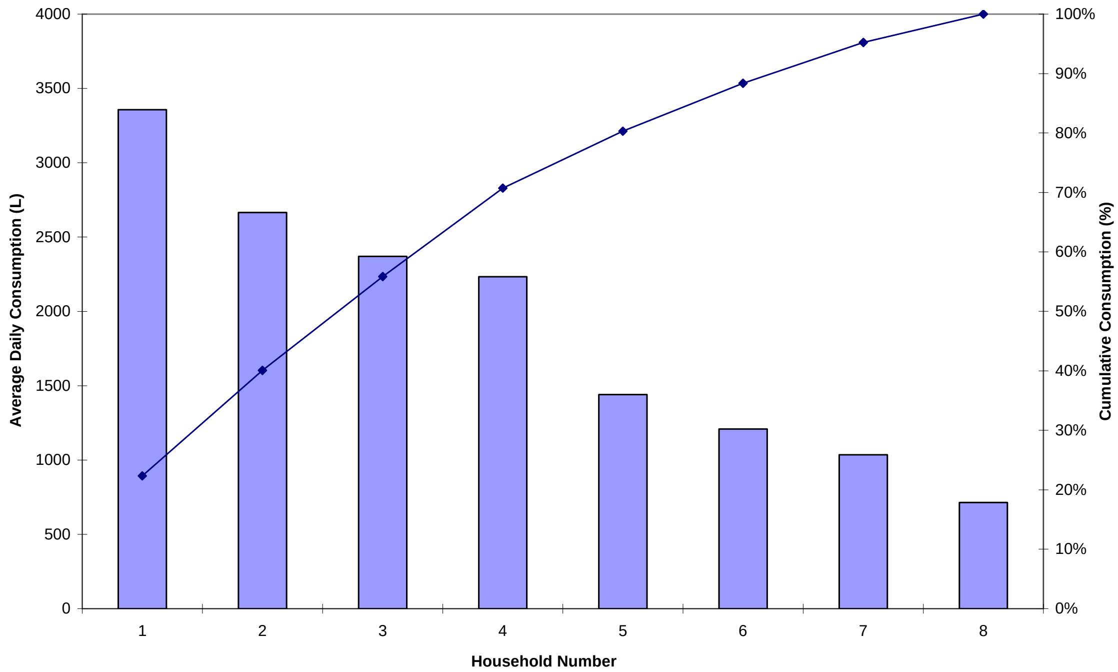

Figure 1-5 - Household Consumption Distribution

Figure 2-5 illustrates the frequency of daily usage for each consumption interval. Figure 3-5 shows the percentage contribution from each consumption interval to the overall consumption. A direct comparison between Figures 2-5 to 3-5 indicates that although the frequency of daily water consumption is higher for lower consumptions the percentage contribution to the overall consumption increases with increasing consumption. For instance, although 80 % of the number of overall consumption days are below 2500 L/day this accounts for 60 % of the overall consumption.

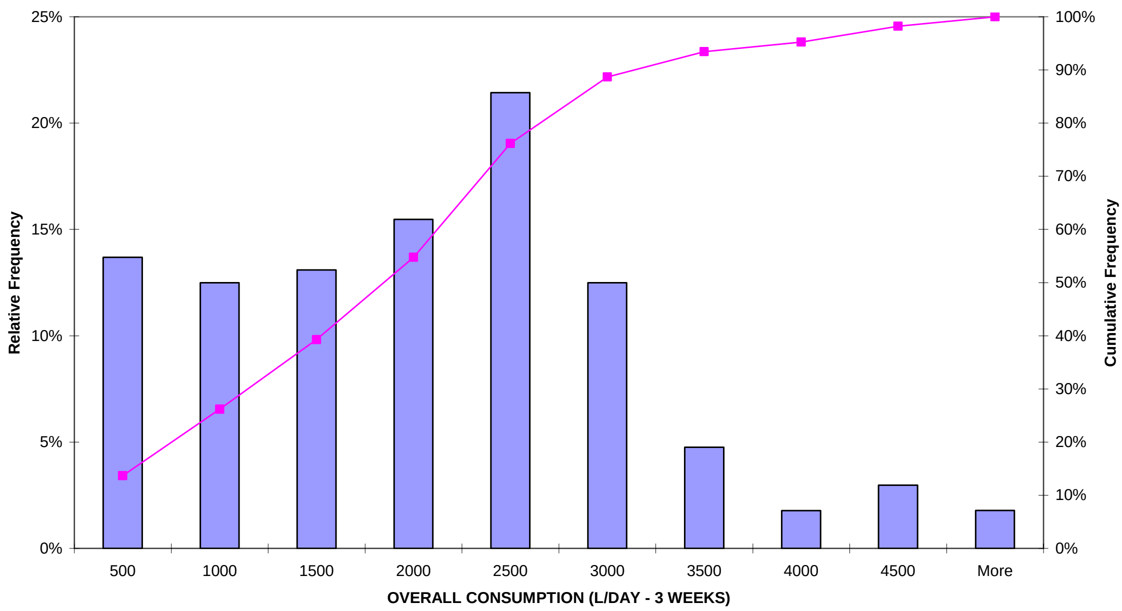

Figure 2-5 – Overall Water Consumption Statistical Summary

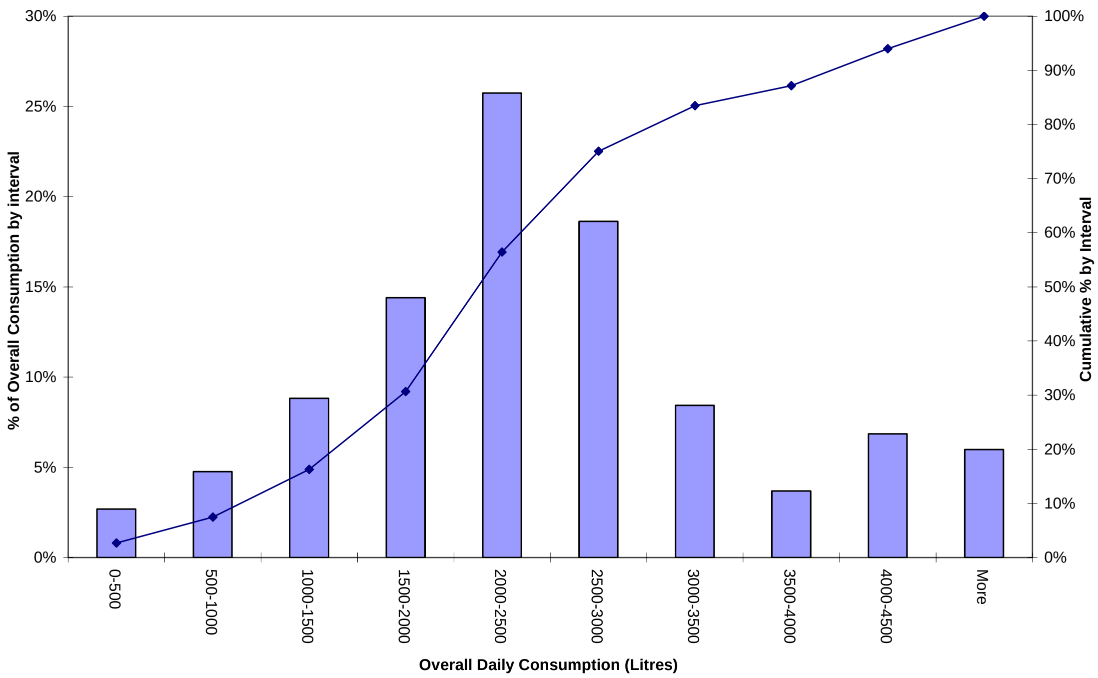

Figure 3-5 – Percentage Contribution to Overall Consumption per Interval

A higher proportion of water use is used on weekends than on weekdays coinciding with increased indoor and outdoor consumption. The mean water consumption on weekends was 2248 l/hh/d over the 6 week logging period which is higher than the average weekday consumption of 1736 L/hh/d. The end use contribution to weekends and weekdays are shown in Chapter 5 and Chapter 6.

5.4 Trace Wizard Analysis – Overall Consumption

A flow trace analysis was undertaken for two of the six weeks to provide a highly detailed end use breakdown for each of the 8 households. The average household consumption was determined to be 1881 L/hh/d which is slightly greater than the overall mean of 1871 L/hh/d.

As previously mentioned, the selection methodology for two average weeks were not continuous and therefore the results for each indoor and outdoor end uses will contain bias. It can be observed that the pool filling events significantly increase daily consumption and selection of two average weeks were generally outside of observed pool filling events. However, for the purpose of providing an insight into water consumption this methodology is adequate. An extended flow trace analysis is required to account for the variability of pool filling events on overall consumption and increase confidence in the results.

The bulk of the water consumption is directed to outdoor uses with 1447 lphd (77 %) of the total water consumption and 434 lphd (23 %) is directed to indoor uses as shown in figure 4-5. It is important to keep in mind that indoor uses accounts for overall leakage which may be directly attributed to irrigation systems.

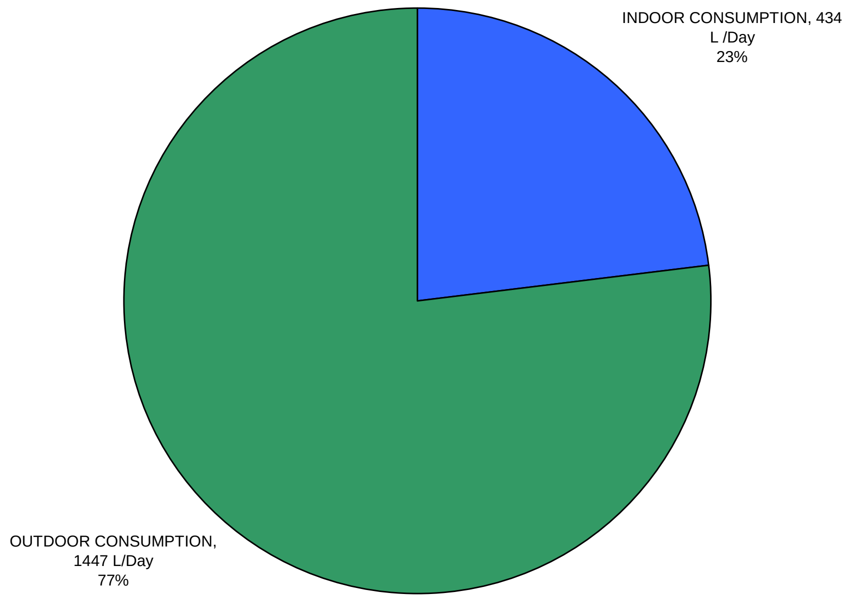

Figure 4-5 – Overall Indoor / Outdoor Consumption per household.

Indoor consumption follows a closer correlation to the number of residents within each household whilst outdoor consumption has a stronger correlation to lot size or irrigated area. For this reason, two separate chapters are presented for both indoor and outdoor consumption and relevant statistical summaries are considered independent from this point forth.

CHAPTER 6: INDOOR CONSUMPTION

6.1 Introduction

Indoor use comprises 23 % of the total consumption for the eight households. This chapter discusses the approaches and limitations of the Trace Wizard analysis, overall indoor use summaries and compares indoor use to other end use studies

6.2 Trace Wizard Summary- Indoor Water Use

6.2.1 Clothes Washing

Clothes washing events have a distinct number of cycles, volumes, flow rates and durations and can be easily identified within a flow trace. Often, simultaneous events prevent the template from identifying the trace however a least one cycle is usually identified. The remaining cycles can be identified with consideration to the peak flow rate, volume and duration of other cycles. Six out of the eight households possessed top loading washing machines with only two of the households with front loader washing machines. Front loader washer machines are considered to be more water efficient than top loading machines and use approximately half the total water use per cycle than top loaders. An example clothes washing flow trace is shown in Figure 1-6.

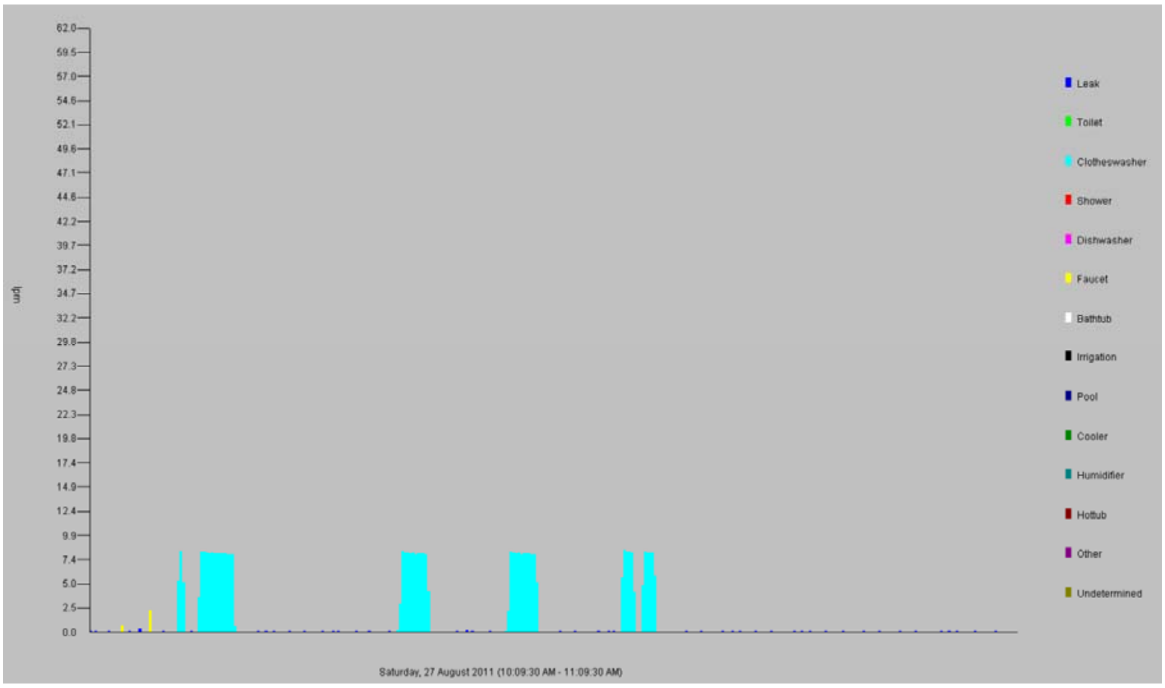

Figure 1-6 – Front Loader Clothes Washing Cycle

6.2.2 Dish Washing

An example dishwashing flow trace is shown in Figure 2-6. Dishwasher cycles have very distinct profiles and therefore the template parameters can be set to be specific volumes, flow rates and durations. The number of simultaneous events present during this study can make dishwashing events hard to identify, however usually the flow trace identifies a least one cycle and the other cycles can be determined from the durations between cycles. Five of the eight households had dishwashers. Two of these households never used the dishwasher during the two week flow trace analysis.

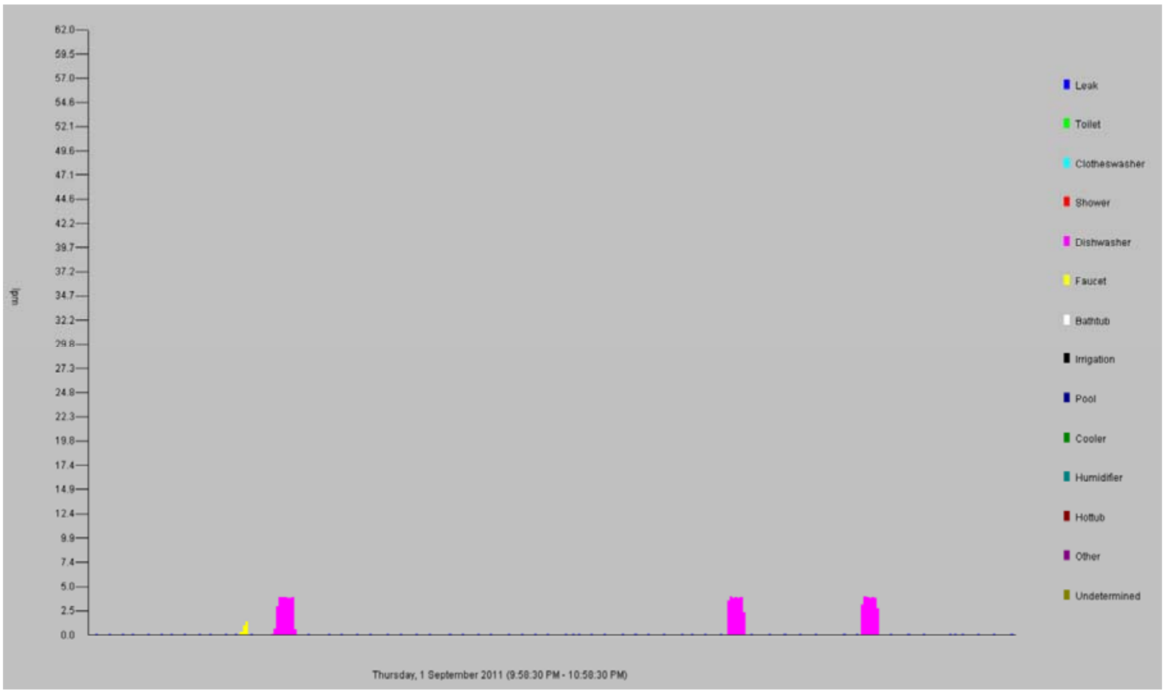

Figure 2-6 - Dishwasher Flow Trace

6.2.3 Showers

An example shower flow trace is shown in Figure 3-6. This particular household had a long duration for hot water to reach the showerhead. It can be seen that the hot water tap is turned on until hot water comes through and the flow rate is increased with the cold water adjustment.

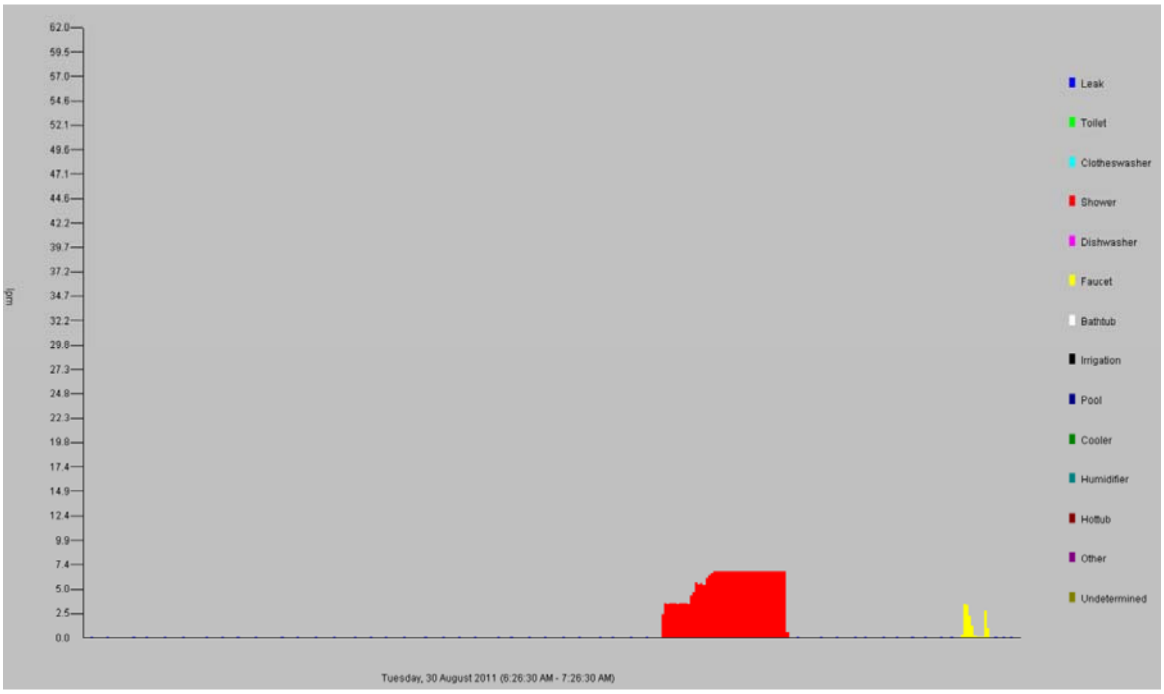

Figure 3-6 – Shower Flow Trace

6.2.4 Toilets

Two different toilet profiles can be observed within Trace Wizard. Toilets with a long tail can be easily determined and generally have a high initial flow rate and reduces as the cistern fills up. Figure 4-6 shows an example toilet flow trace, and shows several leakage events following the toilet event. Depending on the household, two separate fixtures can be allocated to account for half flush and full flush events.

Toilets with cisterns that close abruptly after a specific duration are harder to identify and can easily be mistaken for faucet events. These toilets are calibrated from the water audit to determine the volume, flow rate and duration for each toilet in the household. Toilet use is often followed by simultaneous faucet use and therefore a degree of conservatism needs to be applied to peak flow and volume to determine toilet events. Often the faucet event cannot be separated from the toilet event and is considered part of the toilet volume.

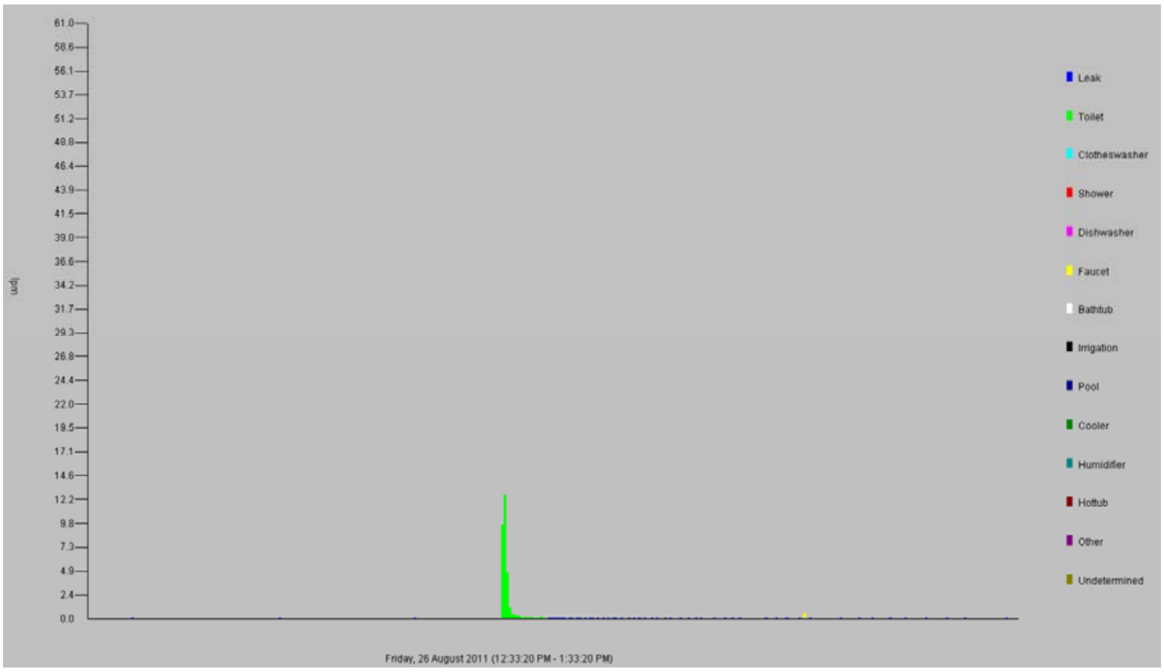

Figure 4-6 – Toilet Flow Trace

6.2.5 Leakage

Leakage can be divided in two categories consisting of continuous and discrete leakage. Parameters in Trace Wizard need to be altered to separate continuous leakage from other events; otherwise all events will be classified as simultaneous events. For example, a simultaneous shower and toilet leakage will assign the entire event as shower. The two events cannot be separated as the cause of the leak maybe directly related to simultaneous end use or the leak may reduce due to a reduction in pressure.

Figure 5-6 shows a leak directly related to the automatic irrigation system and depended upon the user of the system. The leak commenced at the previous irrigation cycle and continued to the next irrigation cycle over an eight hour period.

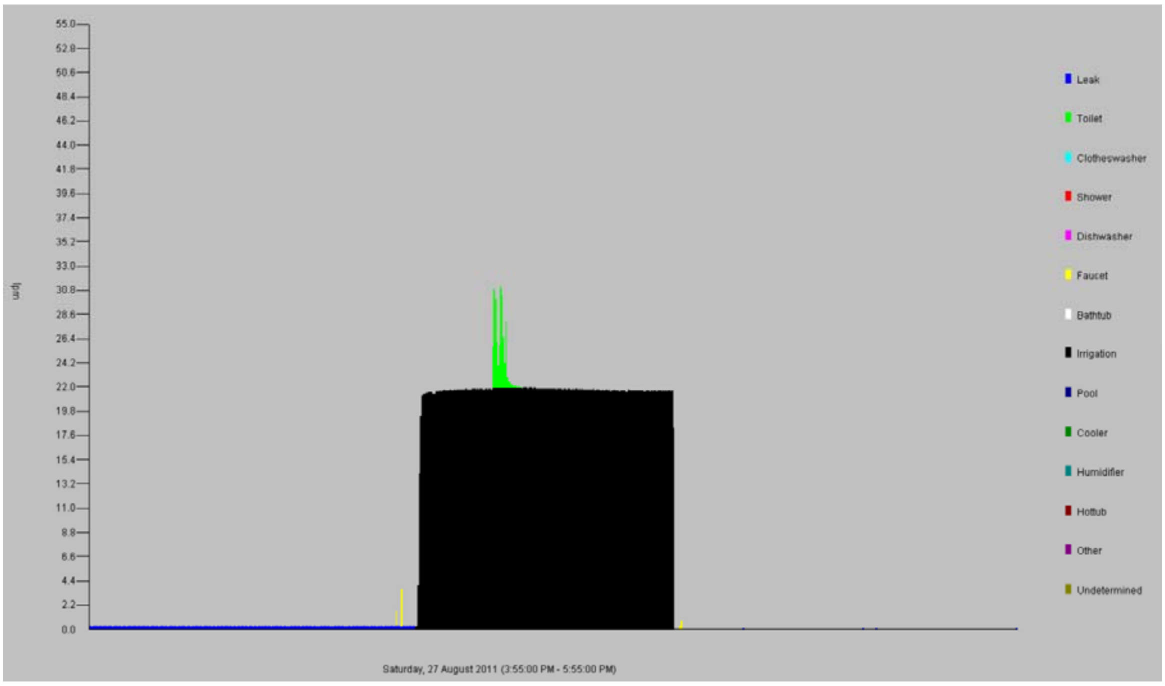

Figure 5-6 – Leakage Flow Trace

6.3 Discussion

A flow trace analysis was undertaken on 2 average weeks of the 6 week data set. The limitations and bias of this method were previously explored in Chapter 4 and 5. It is expected a more accurate assessment can be undertaken in the wet (winter) season where the bulk of water consumption will be indoor consumption. The results presented in this chapter provide an insight into indoor water consumption and statistical summaries focus on overall volumes from each end use.

Statistical summaries are expressed in terms of average per household use (L/hh/d) by taking the average of individual indoor household consumption and averaging across the eight households. Average per capita estimates (L/p/d) were calculated by taking the average of each individual per capita estimate across the eight households.

Average per capita estimates is the preferred method to compare to other regions to account for varying degrees of occupancy ratios between regions. There are several factors that need to be considered when interpreting these results. The number of visitors and guests residing at infrequent intervals at several of the households was impossible to track. This is typical of the dry season as this is the ideal time to visit. Therefore per capita consumptions would be expected to be higher in the dry season that the wet season to account for the increased number of visitors assuming internal usage from the participants is the same. In addition, the frequency of each end use would increase to account for the increased number of visitors.

For these reasons, the statistical summaries have been generated for average per capita estimates and overall households' consumption to allow for future comparisons in the wet season.

6.4 Overall Indoor Summary

The average indoor use over the two week flow trace analysis for each household was 432.9 L/hh/d. This equates an average indoor per capita consumption of 165.1 l/p/d. The average occupancy ratio in the study is 2.75 which is slightly higher than the 2.5 occupancy ratio for Darwin. (ABS, 2010). The highest average per capita consumption was 627.9 lpcd on a Saturday with 72 % of the daily consumption directed to clothes washing. This matched the highest peak day from a household with 1256 L in a single day. The 95 % confidence level for indoor litres/capita day is 17.1 L over the two week period.

Table 1-6- Average per Capita Indoor Statistics

Parameter	Litres / Capita / Day (lpcd)
Mean	165.1 ± 91.5
Median	145
Maximum	627.9

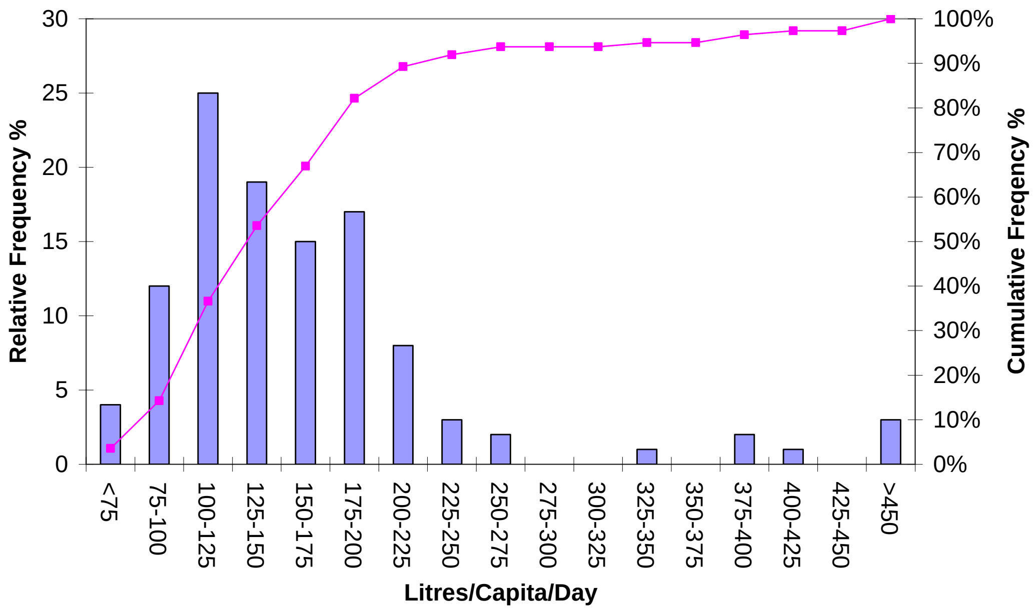

Figure 7-6 - Frequency distribution of indoor daily per capita water use

The frequency distribution of indoor daily per capita water use is shown in Figure 7-6. The most frequency indoor consumption was between 100 – 125 L/p/d. A standard variation of 91.5 lpcd or 55 % indicates an extremely high variation in indoor water consumption and a high positive skew of 2.73. The skew is primarily a result of a much higher indoor water use on weekends.

Seven of the highest per capita consumptions above 275 L/p/d occurred from two houses. This was directly related to the clothes washing machine events in each house. Both households contained top loading machines which have higher water consumption per cycle. One of these households had a significant increase in guests every weekend that would contribute to a much higher per capita consumption.

Table 2-6- Average Household Use

Parameter	Litres / Household / day
Mean	432.9 ± 219.5
Median	363.1
Maximum	1255.8

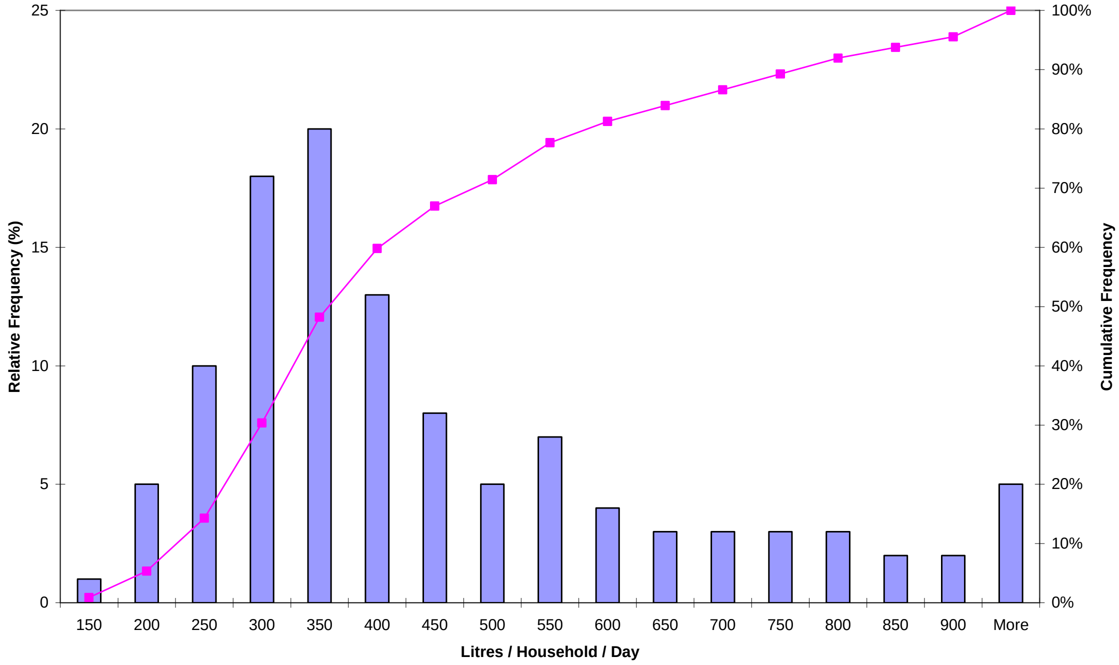

Figure 8-6 - Indoor Household Consumption Distribution

6.5 Disaggregated Household Use

Indoor water consumption can be broken down into leaks, showers, toilets, clothes washing, dishwashing and faucet use. An ice maker was present on one of the households but this was considered as part of faucet use for the analysis. The disaggregated average overall consumption is shown in Figure 9-6.

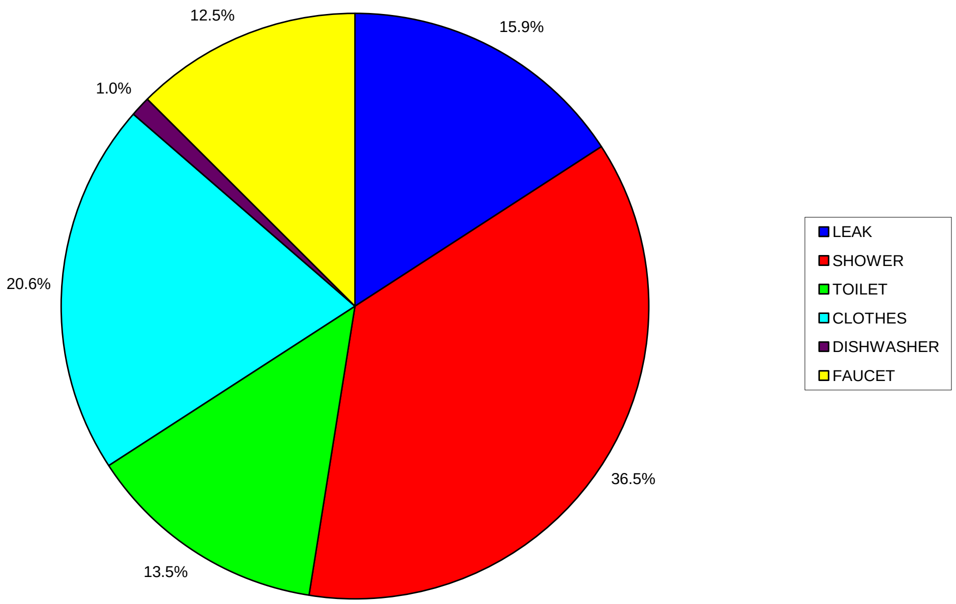

Figure 9-6 – Percentage overall indoor end use volumes.

Shower use contributes to a highest percentage with 36.5 % of the overall consumption followed by 20.6 % for clothes washing. Leakage is high with 15.9 % of the total consumption. Toilet use contributes to 13.5 % and faucet with 12.5 %. Dishwashing consumption was minimal with 1 % of total indoor use.

Although not included in the study, the ninth household had a major leak which would have further increased the leakage percentage if included.

The statistical summaries for average per capita end use consumption are shown in Table 3-6. Note that the overall household percentages for each end use are different that than calculate average per capita percentages. This is because water consumption does not follow a normal distribution. End uses such as irrigation, leaks, dishwashing generally have a high variation where else end uses such as showers, clothes washing, toilets and faucets are common end uses and subject to less variability.

Table 3-6 – Average per Capita Statistical Summary

Parameter	Leak (L/p/d)	Toilet (L/p/d)	Clothes Washing (L/p/d)	Shower (L/p/d)	Dish Washer (L/p/d)	Faucet (L/p/d)
Mean	28.9	23.4	35.5	53.7	1.9	21.0
Median	7.7	18.4	20.3	52.8	1.1	22.4
Standard Deviation	34.6	16.6	16.6	19.5	2.3	8.3
Maximum	78.0	55.7	114.9	78.7	5.5	31.7

The distribution and variability of end uses throughout the eight households is better represented in Figure 10-6.

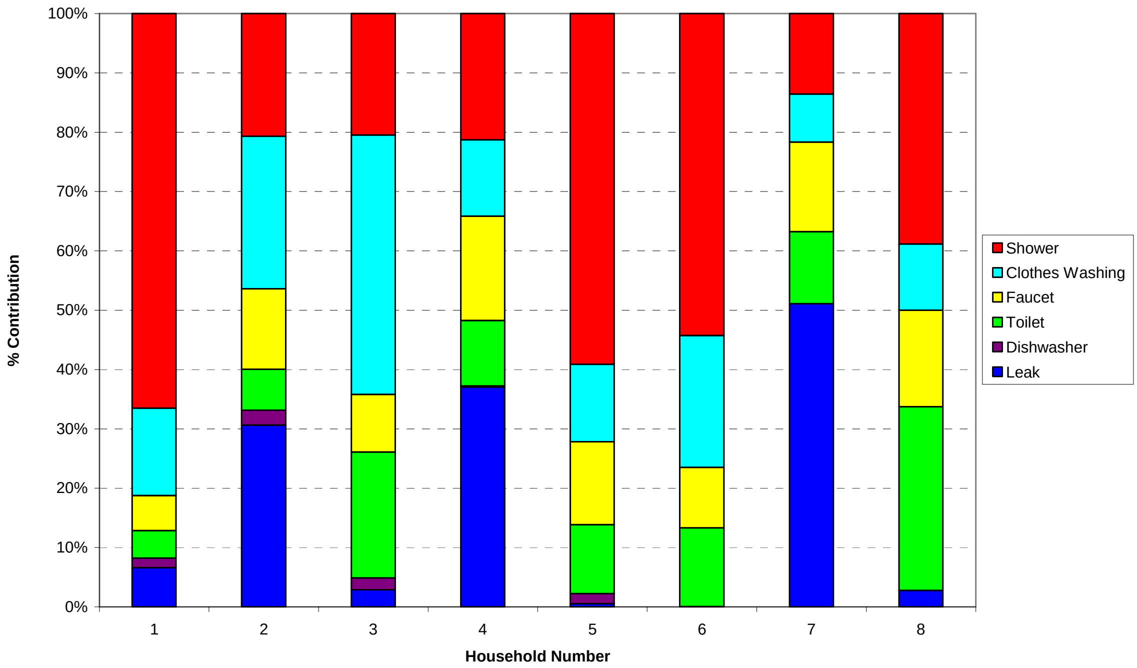

Figure 10-6 - Indoor Water Consumption Profiles for Individual Households

Figure 10-6 shows that the majority of leakage is occurring within three households and exceeds 50 % of the total indoor consumption for one household. Two of the three leakage events were related to outdoor irrigation systems and the other significant leak was attributed to a toilet. Two of these households participated in a previous smart metering trial last year and were notified of the leak during the previous trial. One of these households did not fix the leak during that time, but when shown the percentage contribution of leakage to overall consumption the participant was more willing to fix the leak. This supports the use of visual pie charts as an effective tool in motivating individuals to reduce leakage. The other household rectified the leak during the previous smart metering trail; however this study indicates that a further leak has developed during the past year. The sample size is too small to extrapolate to the broader population, but given that the ninth household also possessed a major leak the results indicate that household leakage could be a widespread issue.

Shower use is also skewed towards several households as demonstrated in Figure 10-6. It can be observed that the influence of previous exposure to water restrictions had an effect on percentage shower consumption for each of the households. Interstate residents with previous exposure to water restrictions used less than residents who have never been exposed to water restrictions. It could also be observed in the flow trace analysis that interstate residents are more likely to exhibit water efficient practices such as reduced shower durations and faucet use. This can not be conclusively illustrated due to the sample size.

6.6 Comparison to other studies

Most end use studies have disaggregated indoor consumption during winter periods and are located in milder climatic regions. To date, no studies have been undertaken in tropical climates in a first world country and therefore a direct comparison that can compare typical end use consumption and trends in a similar climate is not possible.

In Australia, most of cities analysed have previously faced water security threats and the populous have been subject to water conservation programs and water restrictions. The majority of residents, in particular Darwin locals, have generally not been exposed to water restrictions or been subject to significant water conservation initiatives.

Table 4-6 and 5-6 compares the average per capita consumption and average percentage consumption for indoor uses to other regions in Australia. The results highlight that there is limited variability in indoor water consumption from this study to most other end use studies even with the range of climate and behavioural variables. The sample limits extrapolation and may not be indicative of the broader population.

Leakage is high with comparison to other studies and potentially influenced by the age of the properties in the analysis. However given that most of the houses have been part of previous in-house smart metering trials and leakage is still high, this suggests it is possibly a widespread occurrence.

*Table 4-6 – Average per capita consumption for each end use (L/p/d)***

Region	Leak (L/p/d)	Toilet (L/p/d)	Clothes Washing (L/p/d)	Shower (L/p/d)	Dish Washer (L/p/d)	Faucet (L/p/d)
Darwin (n=8)	28.9	23.4	35.5	53.7	1.9	21.0
South East Queensland (n=252)	6.0	16.5	31.0	44.5	2.5	27.5
Toowoomba (n=10)	0.5	14.2	25.4	48.7	2	16.8
Melbourne (n=100)	15.9	30	40	49	2.7	27
Perth (n=120)		21	27	33		83
Auckland (n=50)	7.0	31.3	39.9	50.4	2.1	22.7

*Table 5-6 Average percentage of total consumption***

Region	Leak	Toilet	Clothes Washing	Shower	Dish Washer	Faucet
Darwin (n=8)	15.9	13.5	20.6	36.5	1.0	12.5
South East Queensland (n=252)	6.0	16.5	21.0	30.5	2.0	19.0
Toowoomba (n=10)	0.4	12.3	22.7	45.2	2.1	16.8
Melbourne (n=100)	6.0	13.0	19.5	23.0	1.0	12.0
Perth (n=120)		10.0	13.0	16.0		7.0
Auckland (n=50)	4.0	19.0	24.0	30.0	1.0	14.0

** Sources: Mead and Aravinthan (2009), Roberts (2005), Loh & Coghlan (2003), Heinrich, M. (2007), Beal (2010)

CHAPTER 7: OUTDOOR CONSUMPTION

7.1 Introduction

Outdoor use contributes 77 % of the overall consumption for the eight households and therefore an increased focus has been placed on understanding the variables that influence outdoor water use than indoor water uses. This chapter presents an overview of the Trace Wizard analysis for outdoor uses, generates statistical summaries and discussion for outdoor water use and investigates the relationship between lot size, irrigated area and outdoor consumption.

From the household surveys and flow trace analysis it is clear that the mentality and activities surrounding irrigation events is closely correlated to the dry vs. wet season interaction. It is not a question of *if* it will rain, but a question of *when* it will rain.

7.2 Trace Wizard Summary – Outdoor Water Use

7.2.1 Irrigation

Irrigation can be separated into automatic or sporadic irrigation events. Automatic events are controlled by a timer and can have several cycles up to 10-15 minute duration per cycle over multiple cycles. Figure 1-7 shows an automatic irrigation event with 9 cycles over a 1 hour duration with varying durations. This corresponds to 9 separate irrigation zones on the property and each volume and flow rate of each cycle is dependent on head losses, amount of irrigated area and the required application ratio for each zone. These events are easy to recognise and simultaneous events can be identified through changes to the irrigation profile.

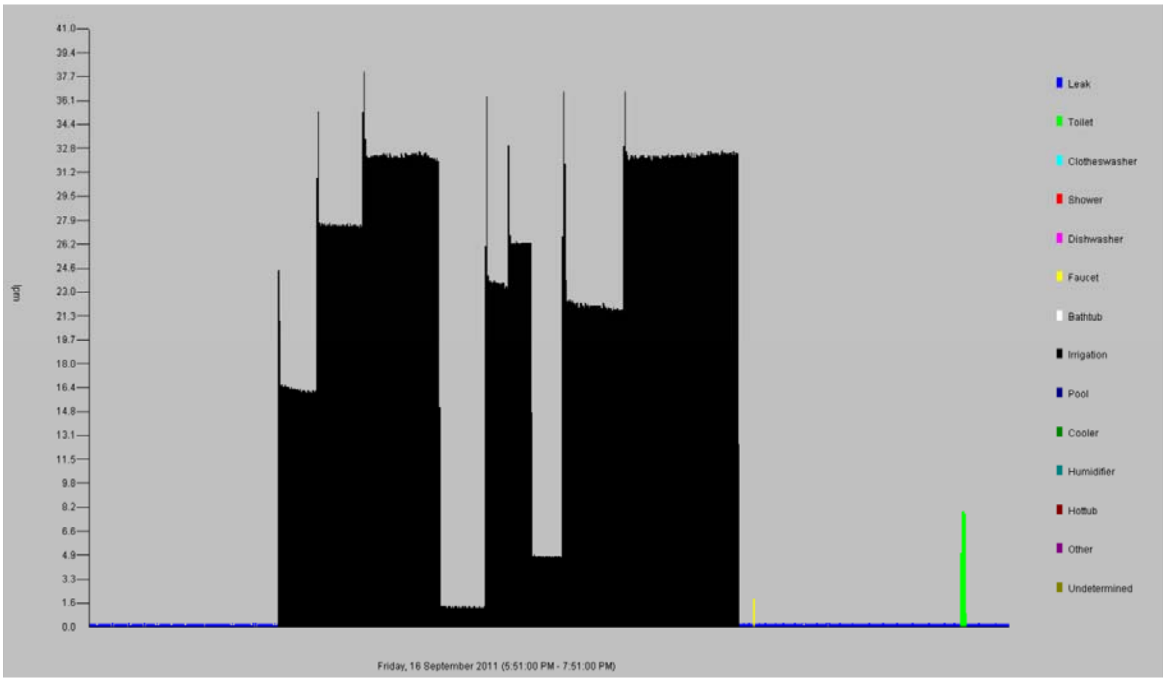

Figure 1-7 - Automatic Irrigation Flow Trace

Sporadic irrigation events are extremely variable in nature and can vary between long sustained flow rates from rose head sprinklers to relatively short events such as car washing. A boat washing event can be seen in Figure 2-7. Consideration to the time of the day, the peak flow rate, frequency of event, water diaries and surveys provide sufficient information to assess sporadic irrigation events. Indoor events such as rinsing dishes can easily be mistaken with outdoor events and vice versa for fixtures with similar flow rates. Therefore there will a degree of error related to faucet use and outdoor use for these properties.

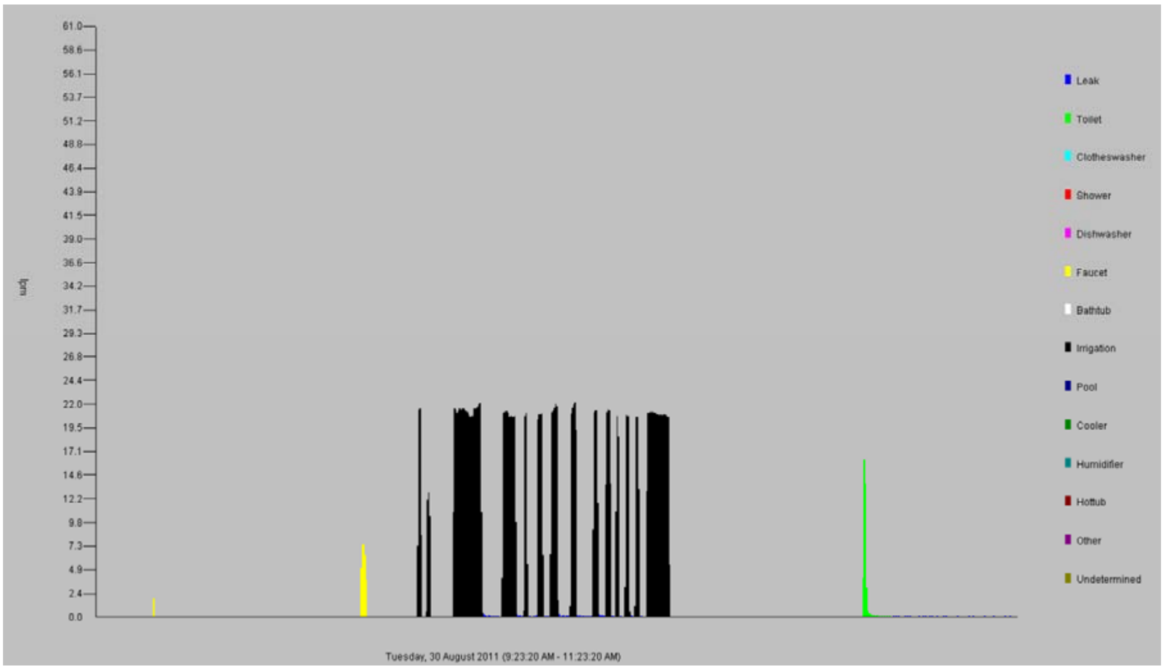

Figure 2-7 – Example Outdoor Boat Washing Event Flow Trace

7.2.2 Pools

Outdoor use has not been divided into irrigation and pool events due to the selection methodology and the limited sample period for flow trace analysis as highlighted in Chapter 4. There are however a number of observations that can be noted and are discussed here.

Pool events can usually be identified from extremely long events over several hours, however often sporadic irrigation events can reach similar durations and posses a similar flow rate. There are a number of ways these events can be separated. For instance, excessive daily consumptions usually indicate that a pool event has occurred in conjunction with an irrigation event. Pool events in one household could be separated from sporadic irrigation events from the same outdoor tap from a slight increase in flow rate; however this could only be determined after discussing irrigation behaviours with the participant. An example pool flow trace is shown in Figure 3-7.

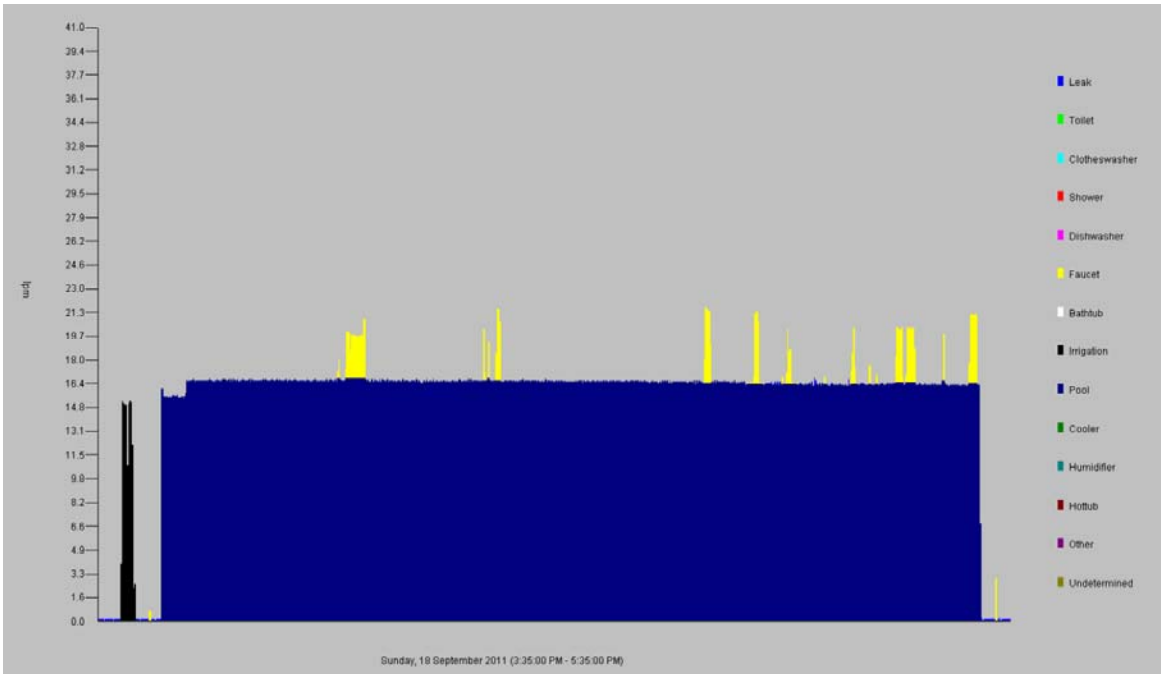

Figure 3-7 – Example Pool Event Flow Trace

A reduced number of pooling filling events were observed in the raw data where pool covers, sails and tree cover were present on the property.

7.3 Overall Outdoor Summary

Outdoor water consumption has a closer correlation to lot size or irrigated area than number of residents per household. Therefore the results for outdoor use are expressed using these parameters only. All the participants in the study were irrigating over the 2 week flow trace analysis.

Table 1-7 – Lot Size Statistics

Parameter	Lot size (m^2)
Mean	4519 ± 10338
Median	817
Maximum	30100

The average lot size in the sample population is 4519 m^2 with a median of 817 m^2. The rural property in the data set is contributing to an extremely high skew with a maximum of 30100 m^2. The lot size on seven of the eight properties is well below the calculated mean and this scenario would not be demographically relevant to the broader population. Therefore a relationship between lot size and overall consumption cannot be adequately represented. The lot sizes were determined from Facility Information Systems and were modified to include front road verges.

The average outdoor water consumption over the two week flow trace analysis was 1477 L/hh. The maximum outdoor use of 7340 L accounted for 91 % of the daily consumption with several clothes washing events occurring on the same day.

Table 2-7 – Outdoor Water Use Statistics

Parameter	Daily Outdoor Water Use (L/hh)
Average	1447 ± 1169
Median	1419
Maximum	7340

Figure 4-7 illustrates how higher water users use a much higher percentage of outdoor water use than lower water users. The highest water user accounts for over 26 % of total outdoor water use across the eight households.

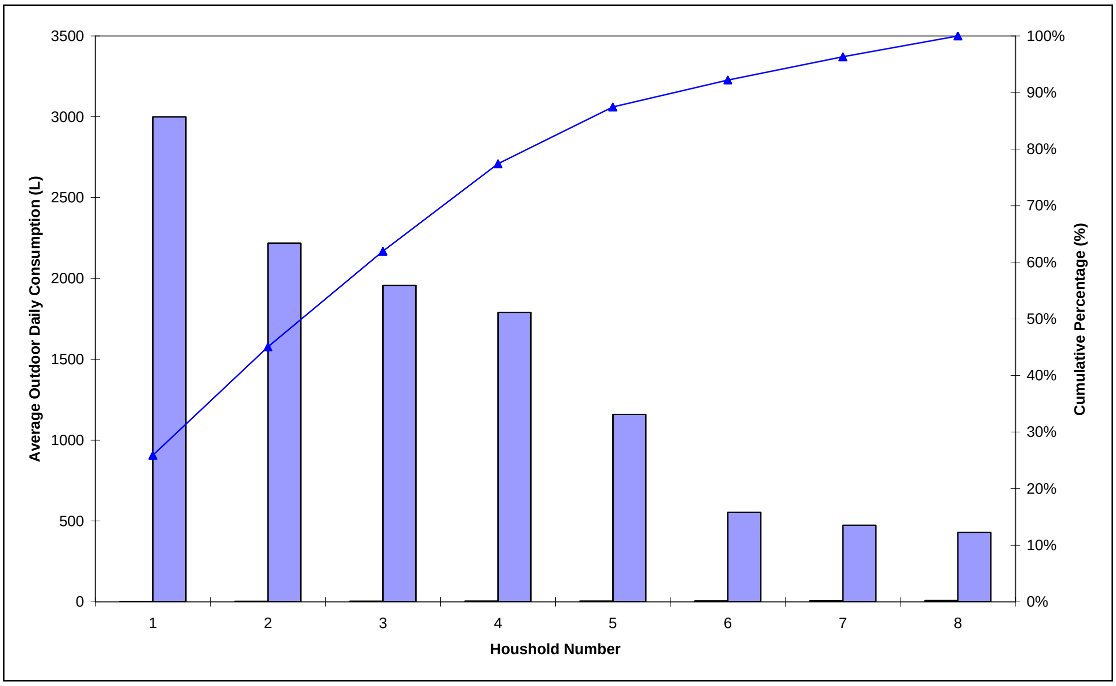

Figure 4-7 – Relative and Cumulative Outdoor Consumption per household.

Figure 5-7 illustrates the number of daily outdoor consumption over a range of consumption intervals. The percentage contribution from each consumption interval is shown is Figure 6-7. A direct comparison indicates that the frequency of higher water use events is low however the percentage contribution from these events increases over each consumption interval. Only 1.7 % of daily water events exceeded 4500 L yet this accounted for 8 % of the total consumption. It was observed that several of the excessive daily consumptions coincide with pool filling events; however this cannot be conclusively shown as it was not broken down in the flow trace analysis.

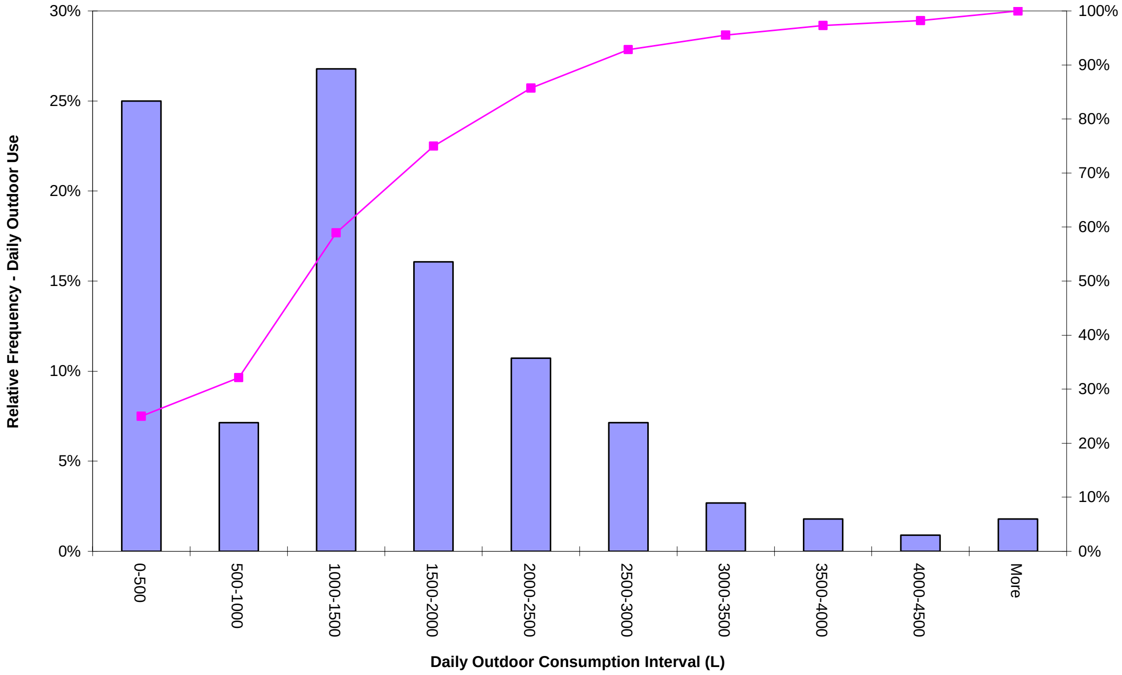

Figure 5-7 - Relative Frequency of Daily Outdoor Use

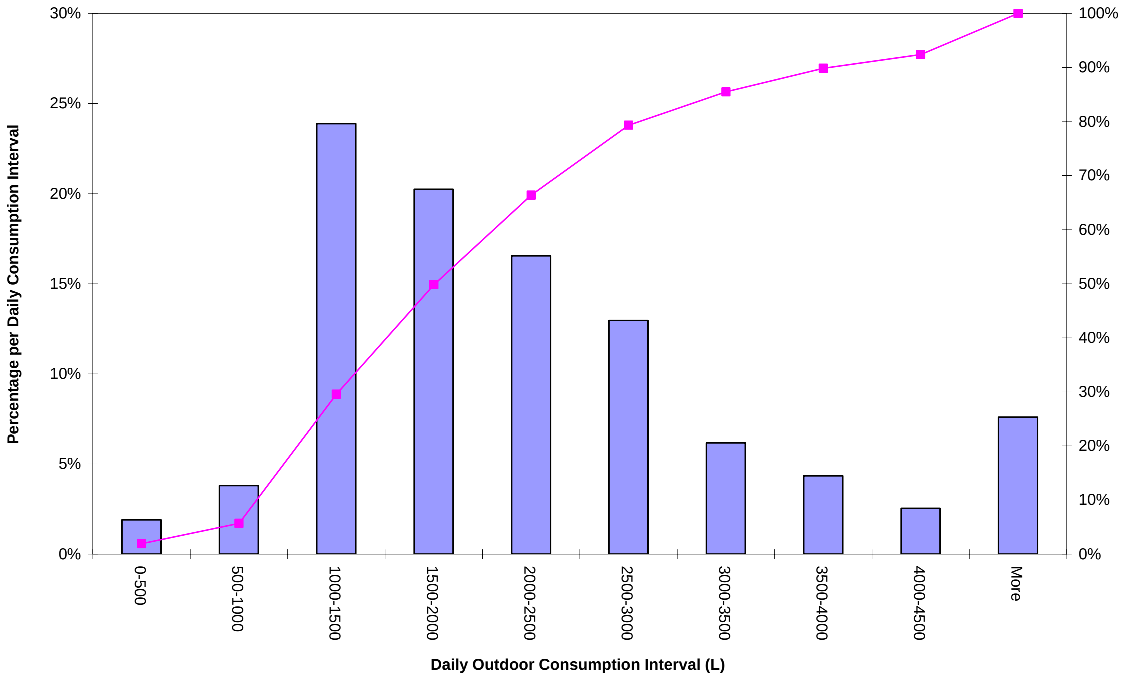

Figure 6-7 - Percentage Contribution to Overall Consumption per Interval

7.4 Irrigated Area vs. Outdoor Consumption

De Oreo (2011) demonstrated the link between lot size, irrigated area and outdoor consumption in a study of 734 single dwelling residential developments across the state of California. This relationship was investigated for the 8 households over the 2 week flow trace analysis. The process for estimating the irrigated area was explained in Chapter 4.

Table 3-7 –Irrigated Area Statistics

Parameter	Irrigated Area
Average	546 ± 191
Median	542
Maximum	838

The average irrigated area was calculated to be 546 m^2 with a maximum of 838 m^2. The actual irrigated area for the rural property was 700 m^2 which was significantly less than the actual lot size of 30100 m^2. The rural property was only irrigating 2.3 % of the total lot size. The irrigated area and outdoor consumption for the rural development was less than the irrigated area and outdoor consumption than the largest single dwelling lot.

The relationship between irrigated area and outdoor consumption is demonstrated in Figure 7-7. A linear trend was applied onto the data set and illustrates that as the irrigated area increases the outdoor consumption also increases, as expected. Although this study suggests a linear relationship between outdoor water use and irrigated area, De Oreo (2011) indicates the relationship is not linear and increases in irrigated area will have a diminishing impact on outdoor water use in a non-linear fashion.

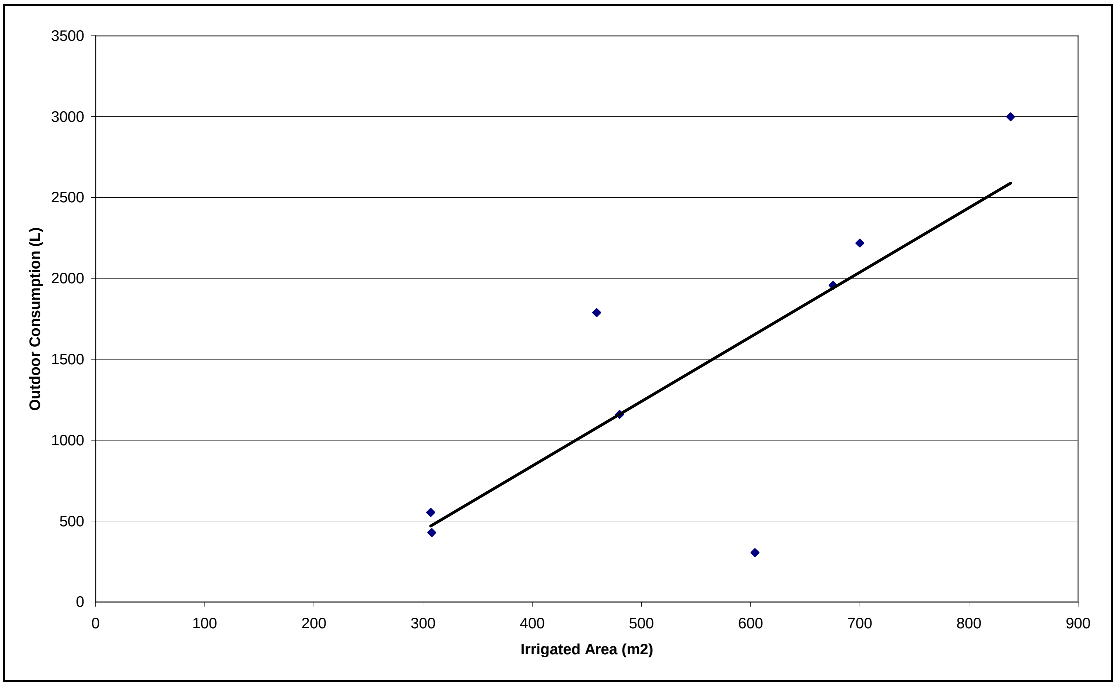

Figure 7-7 -Outdoor Consumption per Irrigated Area 7-6

The data points with the highest deviation from the linear curve in Figure 7-7 were further investigated. It became apparent that the allotment with the lowest consumption to irrigated area ratio stopped irrigating shortly after the data logging commenced. The participant felt that with the proximity of the wet season approaching it was not worthwhile irrigating given that significant percentage of the lawn and vegetation had become already become parched. Therefore, it was easier to wait for the guarantee of rainfall rather than to re-invigorate the lawn. This further illustrates the influence that the interaction between the wet and dry season cycles has on the mentality of the population towards irrigation practices. If we apply the actual irrigation practices over the first week of the raw flow data assuming an indoor / outdoor percentage from the 2 week flow trace analysis we can see a closer correlation to the linear curve as shown in Figure 7-8.

Further investigation on the property with the highest outdoor consumption to irrigated area indicated that several pool filling events occurred within this period. The pool filling events on this property over the 2 week flow trace analysis accounted for 15 % of the household consumption and 1.7 % of the total consumption. This data point is labelled in Figure 8-7. An additional factor can be applied to account for the presence of pools if developing a regression outdoor model.

There would be multiple influences on each data point that have not been considered in Figures 8-7 and 7-7, however the two outliers considered provide an indication some of the variables that influence outdoor water use.

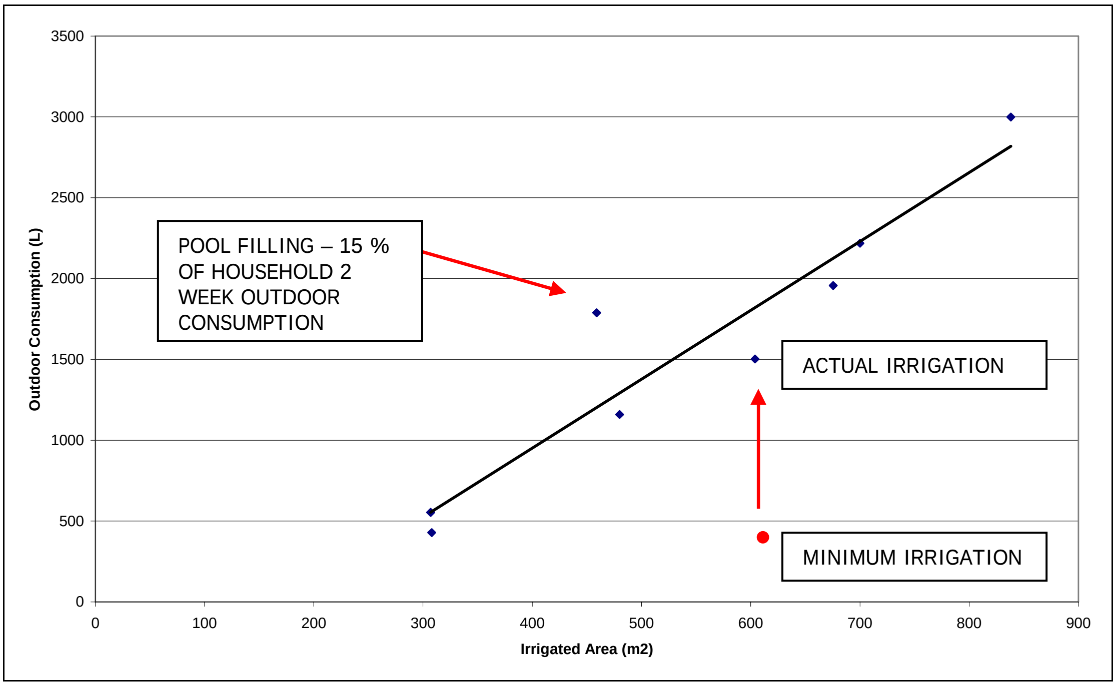

Figure 8-7 - Outdoor Consumption per Irrigated Area – Hypothetical

7.5 Irrigated Area Applications

The concept of relating lot size to irrigated area to overall consumption would be extremely valuable for planning purposes and in developing targeted demand management strategies. These applications are discussed further.

- Planning

De Oreo (2011) demonstrated a correlation between lot size and irrigated area. The study found for the percentage of homes with larger areas, the irrigated area would drop off geometrically as the lot size increases. As demonstrated in this study regarding the rural development, a formula can be developed to account for a reduced irrigated area on a large rural property. This is useful because it is much easier to obtain lot size information than irrigated area information, and having this relationship to predict irrigated area makes it possible to do projections for populations more easily. It is not possible to analyse this relationship in this study due to the sample size and selection.

The increasing trend for increased housing density, affordable housing and a reduction in lot size / irrigated area is requiring a substantially reduced consumption. The lowest outdoor consumption to irrigated area ratio from figure 7-6 is located within a new suburb in Darwin with a reduced lot size and therefore reduced irrigated area. The application of historical planning estimates for forecasting water supply for single dwelling residential using average mean per capita or lot size estimates could significantly overestimate actual demands for these suburbs.

Whilst this relationship may be a good predictor of broader catchment sizes, De Oreo et al (2011) indicates that there is enough variability in the scatter plot of irrigated area to water consumption to be a poor predictor for individual lots or small groups of lots. Therefore there needs to be a degree of conservation if planning estimates are to be revised.

Older properties in Darwin generally have a higher lot size / irrigated area ratio than newer subdivisions which have a much lower lot size / irrigated area ratio and these could be split into 'like' suburbs for planning purposes.

- California Single Family Residential Water Efficiency Study

De Oreo (2011) further develops the concept of irrigated area into theoretical and excess irrigation for single dwelling residential allotments. The key parameters that determine the theoretical requirement is related to the evapotranspiration, the irrigated area, and the crop coefficients of the plantings and the irrigation efficiencies. If the actual application rate is higher than the theoretical demand then excess irrigation is occurring.

The study found that although 87 % of the demographic were irrigating less than 46 % of the population were still under irrigating. This indicates that excessive irrigation is not a city wide problem and demand management programs need to be targeted to consumers who are over irrigating without encouraging the under-irrigators how to irrigate. De Oreo (2011) found that if the all the households irrigating were brought to a theoretical irrigation requirement the overall savings from excessive irrigation would be balanced by increasing irrigation requirements from the under irrigators.

De Oreo (2011) also indicated that 18 % of all lots irrigating or 15 % overall were accounting for 62 % of the total excess volume. Therefore targeting the highest excessive water users would be the most cost effective approach in reducing water consumption.

- Darwin - Identifying excessive consumers.

Although the concept of theoretical irrigation vs. excess irrigation should be part of further research, Darwin's unique climate cycle presents opportunities to identifying excessive irrigation and the ability to track demand management initiatives directly from metered data.

Residential water consumption is low in the wet season and high in the dry season and there exists little variance in residential consumption in the mid-wet season (January-February) and in the mid to late-dry season (August / September) in each annual cycle. If metered consumption is related to lot size, then it would be possible to compare and determine the excessive irrigators for each lot range and where the potential savings exist. If the metered consumption is high in both the wet and dry season then it would indicate that either the allotment has high level leakage or continued irrigation into the wet season.

Comparing annual data is still a useful tool is analysing climatic influences spanning years or even decades; however there is too much variation in climatic and transient population cycles within each annual cycle to effectively track any demand management initiatives.

- Seasonal Comparison

Further logging is required to determine the amount of outside water use and in particular the activities that drive outdoor water use in the wet season. Also to determine the influences of turning off irrigation systems in the 'build up' and that maintain irrigation in the wet season such as pest control.

7.5 PWC Planning Estimates - Water

- Water

Single Dwelling Residential – 1100L/c/d @ 3.5 EP = 3850 L/hh/peak day (PWC, 2011)

The use a single equivalent population in high irrigating environments to forecast water supply for residential lots is inherently flawed. Water consumption does not follow a normal distribution and is skewed by higher water users. This study has illustrated that peak water consumption has a closer correlation to lot size than the number of residents over the eight households. The trend towards smaller lot sizes and increased housing density is limiting the amount of irrigated areas and therefore reducing consumption.

The highest average peak day water use across the 8 households was 2650 L which is below the 3850 L peak day estimate. Although this value also accounts for network losses, the smaller lot sizes in this study plus additional network leakage would rest well below this planning value.

A much more effective approach to account for a range of variable lots size is to stagger planning estimates of a range of lots sizes i.e. water consumption for 700-1000m2, 1000-1500m2. The average water consumption for each range can be calculated from metered data. The revision of peak hour and peak day factors is discussed in Chapter 8.

Whilst it is plausible that suburbs with higher household income, larger lot sizes and therefore larger irrigated areas are consuming more than the 3850 L estimate on average, staggering the water consumption over a range of lot sizes may account for these variations.

Overestimating water demand leads to increased costs for capital infrastructure and inefficient capital works programs. This increases the likelihood of operational issues such as reduced water quality, inefficient pumping efficiencies and therefore increased operational costs. With demand management targeted to reduce water consumption by 25 % in residential households by 2030, these issues would be further compounded.

Planning estimates for rural developments are based on the number of hectares. Rural water use can vary widely and further consideration is required, but given that the rural property in this study is only irrigating 2 % of the allotment, estimating on a per hectare basis over the entire allotment can significantly overestimate demand. Metered data can be used over peak month periods to evaluate the skew in the data and determine average consumptions.

CHAPTER 8: DIURNAL PATTERNS

8.1 Introduction

This chapter will seek to provide an insight into the underlying end uses that influences consumption in a peak day scenario. The chapter also investigates weekday to weekend variations and further breaks down diurnal patterns into indoor and outdoor diurnals. The sample size and bias limit extrapolation to the broader population.

8.2 Overall Diurnal Pattern

The overall daily diurnal pattern was calculated over the entire 6 week logging period using complete weekly data sets for each household and averaged across the eight households. The diurnal curve is illustrated in Figure 1-8. The diurnal interval was kept in 30 minute intervals to due to the significant fluctuations between each interval. It is clear that irrigation events are the dominant influence on each of the peaks.

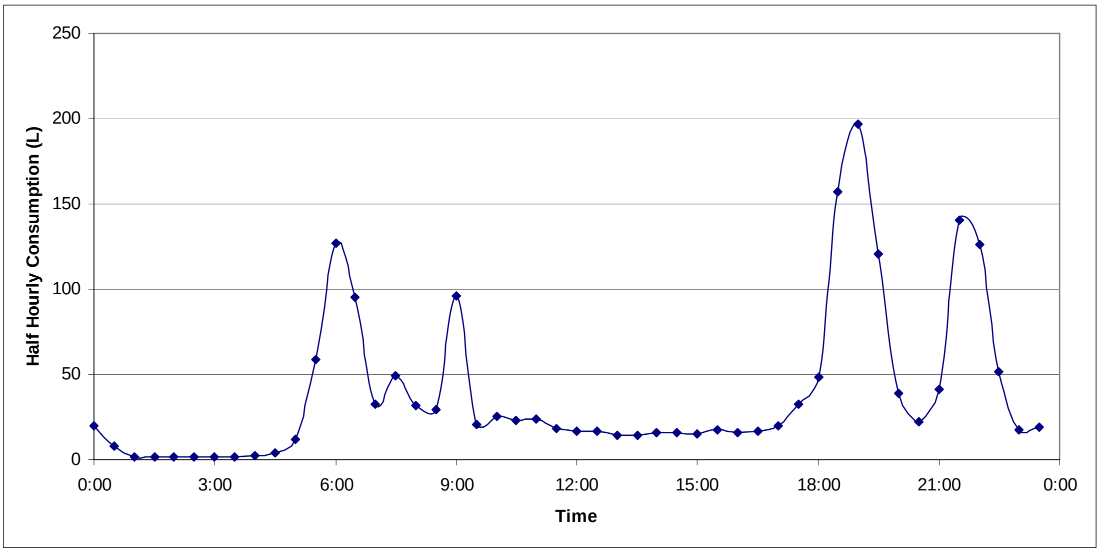

Figure 1-8 – Overall Daily Diurnal Pattern

The highest average peak hour flow during the logging period was 587 L between 6:30pm to 7:30pm on Wednesday 21st September and the highest 30 minute peak flow was 317 L on Thursday 8th September. The highest peak day flow occurred on Saturday 18th September with 2650 L/hh.

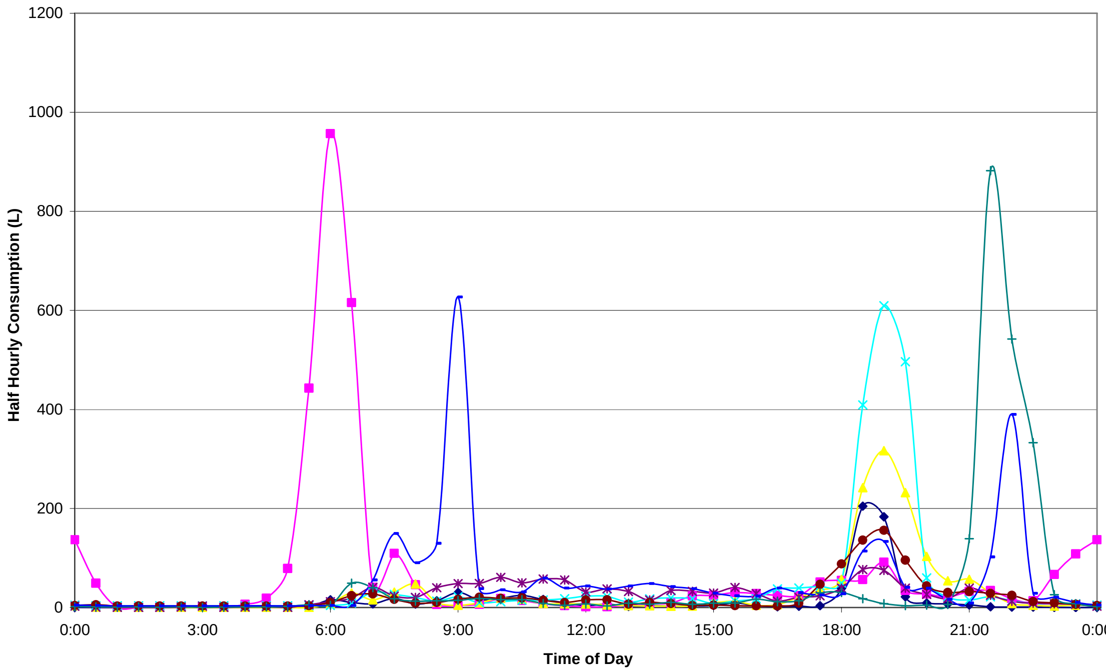

Figure 2-8 Diurnal Patterns by Household

Figure 2-8 demonstrates the influence that each household contributes to the overall diurnal curve. The highest water consumer in the study is represented by the pink curve which also possesses the highest ½ hourly consumption. The peak of this curve coincides with the timing of an automatic irrigation system with an average consumption of 2333 L over a one hour interval. This irrigation cycle contributes to 15.5 % of the *total* consumption over the 8 households and exceeds the average daily consumption for 5 of the other 7 households in the study. It may seem obvious that this household should be targeted to reduce consumption; however figure 8-7 suggests that the outdoor consumption to irrigated area is appropriate for this household. Therefore in this case targeting the highest water consumer in this study would not maximise potential water savings and further consideration to the irrigated area and the degree of excess irrigation is required for an effective demand management approach.

Interestingly, four of the highest individual peaks occur outside the overall peak hour and coincide with automatic sprinkler systems. Only one of the households has an automatic sprinkler system occurring at the overall peak hour. This indicates that the cumulative influence of sporadic irrigation is contributing to a higher overall peaking factor than each of the automatic systems. This suggests that controlling the afternoon peak hour is a little more complex than simply encouraging residents to adjust the timings on automatic systems to non-peak hour periods.

Comparing Figure 1-8 to Figure 2-8 also indicates that the cumulative consumption from each household increases during non-peak hour flows in the overall diurnal curve, effectively reducing the overall peaking factor or smoothing out the peaks. Increasing the sample size would like further reduce the peaking factor, depending upon the timing and contribution of irrigation to the evening and morning peaking cycles. Therefore a direct comparison to current standards is not possible with consideration to the selected sample size and variability in irrigation timings.

A comparison between the average daily consumption on weekdays and weekends across the 6 week logging period is shown in Figure 3-8. Total per capita weekend consumption over the seven week logging period was 2248 L/hh/d which was higher than weekday average per capita consumption of 1736 L/hh/d. This is represented in the diurnal curve, where consumption significantly increases during the weekend when people are at home; and reduces during weekdays when most people are at work.

It can also be noted that the peak half hourly consumption at 6:30pm is higher during weekdays than on weekends. The end use contribution to this peak is discussed in the outdoor diurnal breakdown. If the graph was plotted in one hour intervals then the peaks would have matched and this insight would likely have been overlooked.

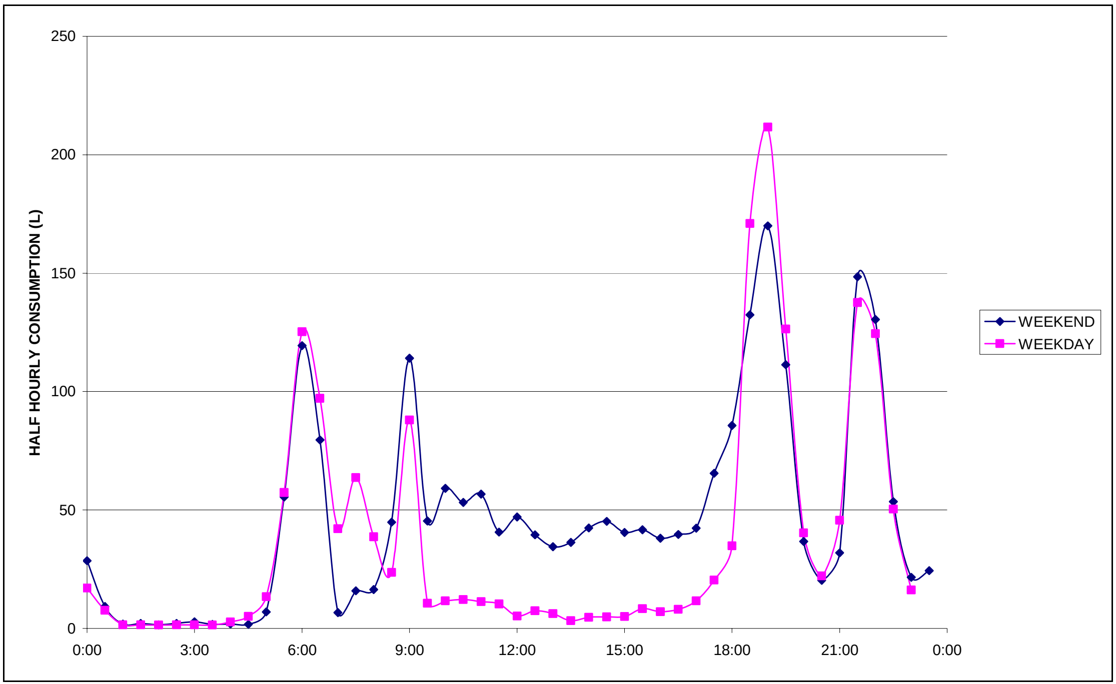

Figure 3-8 - Weekday vs. Weekend Consumption

The weekend comparison confirms the importance of using extended period simulation in designing water systems. If this relationship is indicative of the broader population, then the use of a single absolute peak day would not be able to satisfy all of the design requirements for a water system.

8.3 Trace Wizard – Diurnal Patterns

The diurnal patterns for indoor and outdoor water use were developed from the 2 week flow trace analysis in Trace Wizard. The overall diurnal pattern highlights the variability associated with diurnal patterns, and therefore the following discussion should be viewed as an insight rather than to provide conclusive results.

Figure 4-8 shows the average percentage distribution of each end use on an average peak day scenario. The percentage distribution for each end use for each hourly consumption in presented in Table 1-8. Leakage will vary throughout the day from simultaneous indoor and outdoor water uses and from variable mains pressures but has been averaged across the day for simplicity.

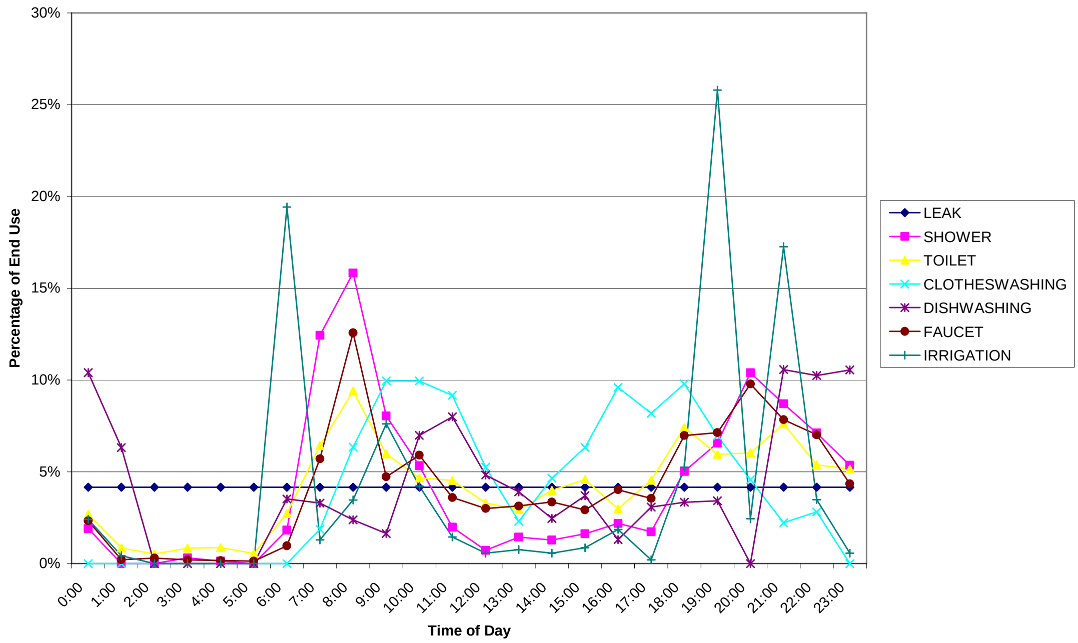

Figure 4-8 - Percentage of end use at time of day

The distribution of outdoor use is similar to the overall diurnal pattern indicating the influence that irrigation cycles has on each peak shown in Figure 1-8. Shower, faucet, and toilet events peak in the morning and afternoon coinciding with daily cycles. Clothes washing in primarily undertaken on weekends and possesses a higher distribution during the course of the day. The number of dishwashing events is too small to conclusively show any trends, but there is a tendency for dishwashing peaks to occur just after peak indoor cycles suggesting the start of the dishwashing cycles commence towards the end of indoor peak hours.

Table 1-8 – Percentage of end use at time of day

TIME	LEAK	SHOWER	TOILET	CLOTHES WASHING	DISH WASHING	FAUCET	OUTDOOR
0:00	4.2%	1.9%	2.7%	0.0%	10.4%	2.3%	2.4%
1:00	4.2%	0.0%	0.9%	0.0%	6.3%	0.2%	0.4%
2:00	4.2%	0.0%	0.5%	0.0%	0.0%	0.3%	0.0%
3:00	4.2%	0.3%	0.8%	0.0%	0.0%	0.2%	0.0%
4:00	4.2%	0.1%	0.9%	0.0%	0.0%	0.2%	0.0%
5:00	4.2%	0.0%	0.6%	0.0%	0.0%	0.1%	0.0%
6:00	4.2%	1.8%	2.7%	0.0%	3.5%	1.0%	19.4%
7:00	4.2%	12.4%	6.4%	1.9%	3.3%	5.7%	1.3%
8:00	4.2%	15.8%	9.4%	6.4%	2.4%	12.6%	3.5%
9:00	4.2%	8.0%	6.0%	10.0%	1.6%	4.7%	7.6%
10:00	4.2%	5.3%	4.7%	10.0%	7.0%	5.9%	4.2%
11:00	4.2%	2.0%	4.5%	9.2%	8.0%	3.6%	1.5%
12:00	4.2%	0.7%	3.3%	5.3%	4.8%	3.0%	0.6%
13:00	4.2%	1.4%	3.0%	2.3%	3.9%	3.1%	0.8%
14:00	4.2%	1.3%	4.0%	4.7%	2.5%	3.4%	0.6%
15:00	4.2%	1.6%	4.6%	6.3%	3.7%	2.9%	0.9%
16:00	4.2%	2.2%	3.0%	9.6%	1.3%	4.0%	1.9%
17:00	4.2%	1.7%	4.5%	8.2%	3.1%	3.6%	0.2%

18:00	4.2%	5.0%	7.4%	9.8%	3.3%	7.0%	5.3%
19:00	4.2%	6.6%	6.0%	7.0%	3.4%	7.1%	25.8%
20:00	4.2%	10.4%	6.0%	4.6%	0.0%	9.8%	2.4%
21:00	4.2%	8.7%	7.6%	2.2%	10.6%	7.8%	17.3%
22:00	4.2%	7.1%	5.4%	2.8%	10.2%	7.0%	3.5%
23:00	4.2%	5.4%	5.2%	0.0%	10.6%	4.4%	0.6%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The cumulative contribution from each end use is illustrated in Figure 5-8.

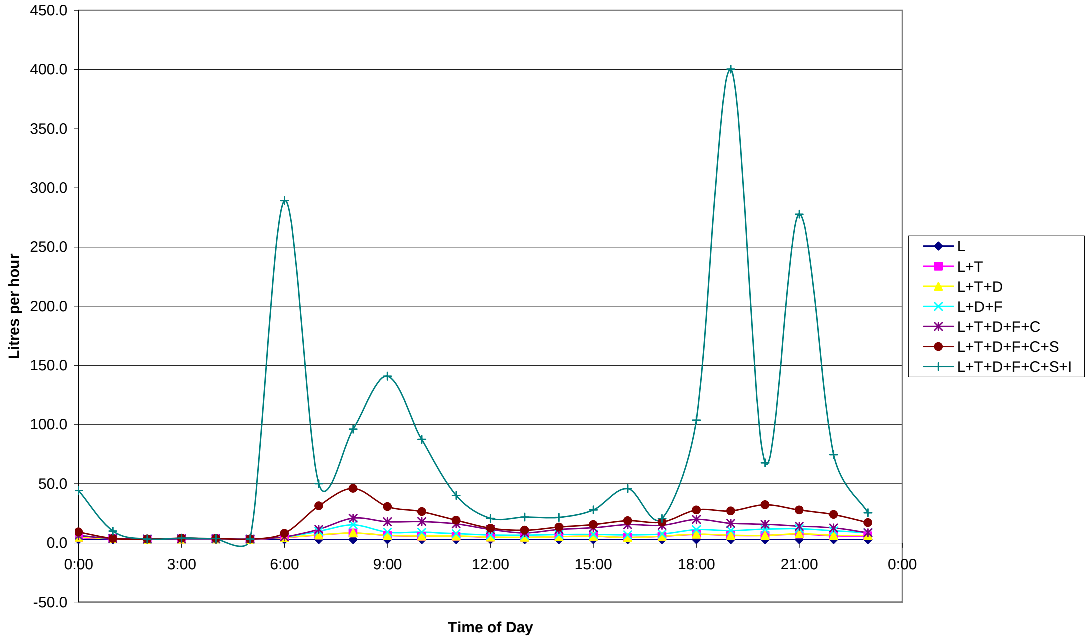

Figure 5-8 - Cumulative diurnal curve with outdoor uses.

Table 2-8 shows the percentage contribution of each end use for each time interval. At peak hour between 6pm to 7pm, outdoor use is contributing to 93.3 % of the peak hour curve. The maximum contribution of outdoor use occurs at 6am to 7am with 97.2 % of overall consumption coinciding with a single irrigation cycle from the highest water user.

The table also supports the use of night-time flow recording to identify leakage. Leakage contributes to a high proportion of overall flow between 1 am to 5 am in the morning when most people are asleep reaching a maximum 87.8 % of consumption at 2am to 3am. AMR systems with real time monitoring and feedback provide the optimal means of identify household leakage during these hours.

Table 2-8– Percentage of end use at each time interval.

TIME	LEAK	SHOWER	TOILET	CLOTHES WASHING	DISH WASHING	FAUCET	OUTDOOR
0:00	6.5%	6.8%	3.6%	0.0%	1.0%	2.9%	79.2%
1:00	28.8%	0.0%	5.0%	0.0%	2.7%	1.2%	62.3%
2:00	85.8%	0.0%	9.2%	0.0%	0.0%	4.9%	0.0%
3:00	72.2%	12.6%	12.5%	0.0%	0.0%	2.8%	0.0%
4:00	78.0%	5.7%	13.8%	0.0%	0.0%	2.4%	0.0%
5:00	87.8%	0.0%	9.9%	0.0%	0.0%	2.3%	0.0%
6:00	1.0%	1.0%	0.6%	0.0%	0.1%	0.2%	97.2%
7:00	5.7%	39.4%	7.5%	3.4%	0.3%	6.2%	37.4%
8:00	3.0%	26.1%	5.7%	5.9%	0.1%	7.1%	52.1%
9:00	2.0%	9.0%	2.5%	6.3%	0.0%	1.8%	78.2%
10:00	3.3%	9.6%	3.1%	10.2%	0.3%	3.7%	69.8%
11:00	7.1%	7.8%	6.6%	20.4%	0.8%	4.9%	52.4%
12:00	13.8%	5.6%	9.3%	22.6%	1.0%	7.8%	39.9%
13:00	13.1%	10.5%	7.9%	9.4%	0.8%	7.8%	50.5%
14:00	13.3%	9.5%	10.8%	19.3%	0.5%	8.5%	38.2%
15:00	10.2%	9.2%	9.6%	20.2%	0.6%	5.7%	44.6%
16:00	6.3%	7.5%	3.8%	18.7%	0.1%	4.8%	58.8%
17:00	13.9%	13.3%	12.9%	35.3%	0.6%	9.3%	14.7%
18:00	2.8%	7.7%	4.2%	8.4%	0.1%	3.6%	73.2%
19:00	0.7%	2.6%	0.9%	1.6%	0.0%	1.0%	93.3%
20:00	4.2%	24.4%	5.2%	6.0%	0.0%	7.9%	52.3%
21:00	1.0%	5.0%	1.6%	0.7%	0.2%	1.5%	90.0%
22:00	3.8%	15.1%	4.2%	3.4%	0.6%	5.1%	67.7%
23:00	11.3%	33.3%	11.8%	0.0%	1.8%	9.3%	32.6%

8.3.1 Indoor Diurnal Patterns

The cumulative indoor consumption over a daily period provides an indication of indoor peaking factors and the end-uses that contribute to peak hour flows. The morning and afternoon peak hour factors are directly related to typical movement patterns, with a concentrated morning peak relating to a common working starting time and an extended afternoon peak for a more distribution of indoor use over of the course of the evening. The indoor diurnal pattern is shown in Figure 6-8.

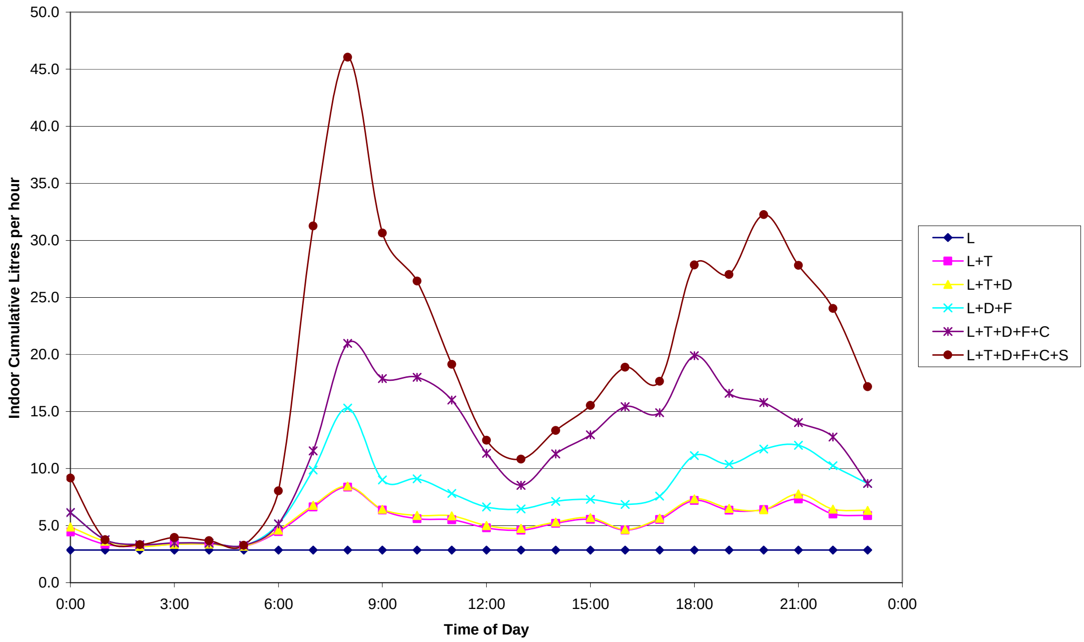

Figure 6-8 - Cumulative Indoor Daily Curve

Shower use is the highest contributor to each peak with 54.5 % of the morning peak hour between 7am to 8am and 51 % of the afternoon peak hour 7pm to 8pm. Clothes washing contributes to a higher percentage between the peak hours with a maximum of 45.8 % between 3-4pm.

Leakage contributes to a significant percentage of the indoor consumption of the course of the day; however it is important to keep in mind that leakage may be attributed to outdoor fixtures such as sprinkler systems.

Table 3-8 – Percentage of indoor end use at each time interval

TIME	LEAK	SHOWER	TOILET	CLOTHES WASHING	DISH WASHING	FAUCET
0:00	31.3%	32.9%	17.1%	0.0%	4.8%	13.8%
1:00	76.4%	0.0%	13.3%	0.0%	7.2%	3.2%
2:00	85.8%	0.0%	9.2%	0.0%	0.0%	4.9%
3:00	72.2%	12.6%	12.5%	0.0%	0.0%	2.8%
4:00	78.0%	5.7%	13.8%	0.0%	0.0%	2.4%
5:00	87.8%	0.0%	9.9%	0.0%	0.0%	2.3%
6:00	35.7%	36.0%	19.9%	0.0%	1.9%	6.6%
7:00	9.2%	63.0%	12.0%	5.4%	0.4%	9.9%
8:00	6.2%	54.5%	11.9%	12.3%	0.2%	14.8%
9:00	9.4%	41.6%	11.4%	29.0%	0.2%	8.4%
10:00	10.8%	31.9%	10.3%	33.6%	1.1%	12.1%
11:00	15.0%	16.4%	13.9%	42.8%	1.8%	10.2%
12:00	23.0%	9.2%	15.5%	37.6%	1.6%	13.1%
13:00	26.5%	21.2%	16.0%	19.1%	1.5%	15.7%
14:00	21.5%	15.3%	17.5%	31.2%	0.8%	13.7%
15:00	18.5%	16.6%	17.3%	36.4%	1.0%	10.2%
16:00	15.2%	18.3%	9.2%	45.4%	0.3%	11.6%
17:00	16.2%	15.6%	15.1%	41.4%	0.7%	10.9%

18:00	10.3%	28.6%	15.6%	31.4%	0.5%	13.6%
19:00	10.6%	38.5%	12.9%	23.0%	0.5%	14.3%
20:00	8.9%	51.1%	10.9%	12.7%	0.0%	16.5%
21:00	10.3%	49.6%	16.0%	7.2%	1.6%	15.3%
22:00	11.9%	46.9%	13.1%	10.5%	1.8%	15.8%
23:00	16.7%	49.4%	17.6%	0.0%	2.6%	13.7%

Figure 7-8 and Figure 8-8 illustrate the difference in indoor diurnal curves between weekdays to weekends. The morning peak hour is sharper on weekdays directly related to a common working starting time. The morning peak on weekends is shifted to later in the morning and longer in duration. The morning peak is also higher on weekends from the contribution of clothes washing in the mornings.

Clothes washing is the major contributor to indoor use on weekends during the day in addition to increased faucet and toilet use as residents are likely to be home and using more indoor uses.

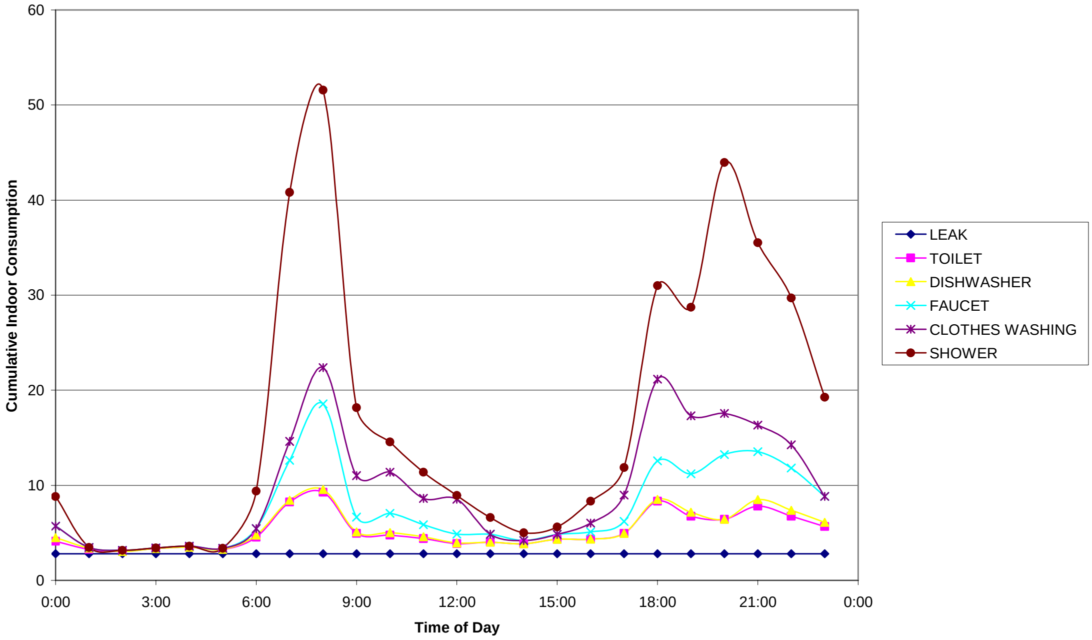

Figure 7-8 - Cumulative Weekday Indoor Consumption

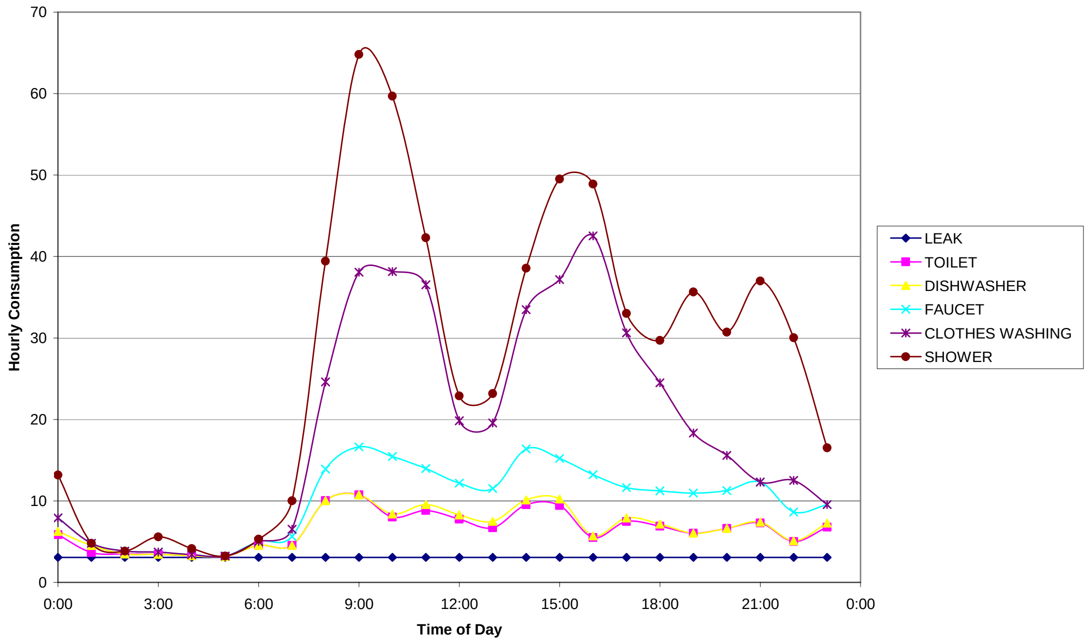

Figure 8-8 - Cumulative Weekend Indoor Consumption

8.3.2 Outdoor Diurnal Patterns

Figure 9-8 compares weekend to weekday outdoor use and confirms that sporadic outdoor events have a much higher contribution to the increase in peak hour during weekdays than the peak indoor use at this hour. Whether this is indicative of the broader population requires further investigation as it could potentially be related to the irrigation habits of the households under study. In addition the flow trace analysis was only undertaken over a two week period and therefore several pools filling or significant irrigation events can skew results.

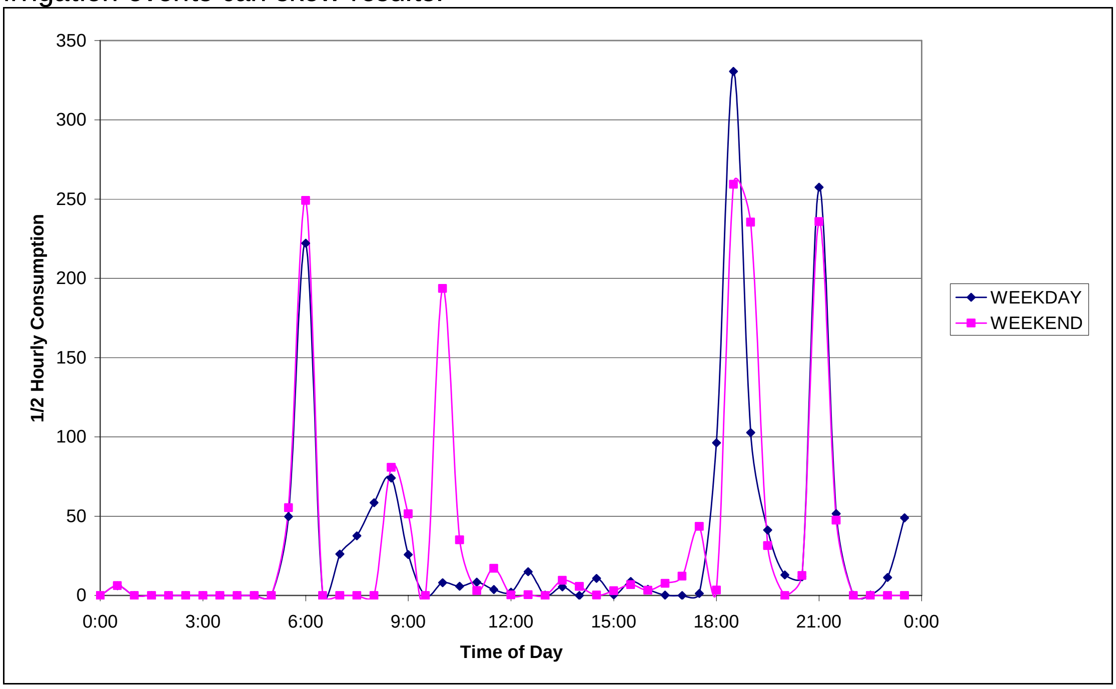

Figure 9-8 – Weekend and Weekday Diurnal Curve

The results highlight the variable nature of irrigation use and that the use of an hourly diurnal curve may not adequate reflect actual peaking factors on a ½ hourly basis, particularly in smaller catchment areas.

8.4 Darwin Water Story Survey Results

The Darwin Water story was released in 2006 with the aim of educating the public about water conservation and water resource issues in the northern territory. A follow up survey was undertaken with 610 surveys completed comprising 602 residents and 8 businesses. (PWC, 2011)

The survey showed that most residents (4 out 5) water their garden into the afternoon and evening (4pm to midnight). Those that watered in the afternoon do so to ensure lower evaporation as this is the optimum time to irrigate. Equally, convenience was also a major influence on afternoon irrigation. Those that watered in the afternoon were significantly less likely to have automatic timers. Most of the premises surveyed had sprinklers with 81 % of using timed sprinklers and 74 % of have automatic sprinklers. (PWC, 2011)

This study has shown that cumulative influence of outdoor sporadic events is a significant contributor to afternoon peak hour. Therefore controlling afternoon peak hour is difficult as one of the primary reasons for irrigating was convenience, and the only way to achieve this is to implement water restrictions. The survey overwhelming illustrated that residents are not open to water restrictions. Also this is optimum and preferred time to irrigate for automatic systems. Therefore further investigation should evaluate the morning and afternoon peak hours, and encourage afternoon automatic systems to use irrigation systems in the morning. Furthermore, reducing excess irrigation on automatic systems would significantly lower the overall peak hour factors.
(PWC, 2011)

CHAPTER 9: CONCLUSIONS

The Darwin Residential End Use Pilot Study has provided an insight into the underlying variables that influence the high rates of water consumption experienced in Darwin households. With urban development and climate change increasing the risk and security of supply to Darwin's water supply network, demand management will form an important component in the development of a regional strategy. This study has highlighted some of the variables and possible strategies that need to be considered in the development of this strategy.

The sample size and bias present in this study limit extrapolation to the broader population and would certainly not satisfy the full range of socio-economic and cultural variables present in the northern territory.

The following provides key summaries relating to each chapter presented throughout the paper.

- Overall Consumption

The study confirms that water consumption in Darwin is much higher than the national average with average household consumption of 1878.1 L/hh and an average per capita consumption of 747.2 l/c/d. Outdoor consumption is higher than other Australian cities with 77 % of the total consumption across the 8 households. Although indoor usage still forms an important component with 23 % and would likely increase from the wet season, increased attention needs to be placed towards outdoor consumption. Demand management strategies that are effective in other parts of Australia can still be applied, but they might not be the most effective way and strategies need to be specific to the location.

The annual variations in climatic and transient population cycles suggest that annual consumption alone is a poor indicator of annual performance and in the assessment of demand management initiatives. Darwin's distinct climate cycle presents opportunities to track demand management initiatives, identify excessive irrigators and households with high level leakage. Comparisons between wet season recordings and dry season recordings would be a much better indicator.

- Indoor Consumption

Average per capita indoor consumption was disagreggrated into showers (33 %), clothes washing (22 %), leakage (18 %), toilets (14 %), faucets (13 %) and dishwasher (1%). The study supports the use AMR systems to identify leakage during night time flows with a maximum 87.5 % contribution to total flow between 1am to 5am.

The need for a detailed end use breakdown for indoor consumption is perhaps less critical than other regions in Australia. Although the sample size limits extrapolation to the broader population, the similarities between this study and other regions of Australia indicate that successful demand management initiatives such as water efficient appliances would have a similar impact here but to a lower degree with outdoor use forming a significant component of overall water consumption.

- Outdoor Consumption

DeOreo (2011) presents an excellent case study in developing an outdoor model and developing targeted demand management approaches for outdoor consumption. The relationship between irrigated area and overall consumption is demonstrated from this study. Relating lot size to irrigated area to overall consumption would be useful for forecasting future water supply with varying degrees of lot sizes, housing densities and irrigated areas.

This study also demonstrates that targeting the highest water users is not necessary the optimal strategy to reduce consumption. The highest water user in this study had a similar outdoor consumption to irrigated area ratio to other properties and therefore potential water savings might be negligible. Further consideration is required to the theoretical irrigation requirements on the allotment and degree of excess irrigation. DeOreo (2011) found that the three most effective parameters to reduce outdoor consumption were to reduce irrigated areas, use of more xeric plant material and the elimination of over-irrigation. Demand management initiatives need to be targeted to excessive irrigators without encouraging deficit irrigators to irrigate relative to the theoretical irrigation requirements.

- End Use Equipment and Analysis

The project has experimented with high resolution data collection, storage, transfer and analysis and has highlighted the potential issues that need to be addressed in future studies. Future studies need to account for the possibility of data logger failures or unforeseen events to ensure that the targeted sample size is achieved and that the sample size is statistically relevant. Sample sizes would likely need to be higher than studies from other regions to account for the variability in outdoor use. The study has highlighted that resource expertise needs to be fully evaluated prior to undertaking a study. Future participants in Trace Wizard studies should remain anonymous from the analyser with respect to the intrusive nature of the analysis.

Whilst high resolution data analysis and recording is effective in understanding the underlying influences and behaviours on water consumption, the need for a high level of resolution on a broader catchment scale is not apparent. The effectiveness of demand management programs that target outdoor use can easily be evaluated through a lower level of resolution. Given that outdoor water consumption can reach up to 95 % of outdoor consumption at peak hour and for short intervals, changes to irrigation profiles from a lower level resolution can easily be assessed. A selection of households using high resolution data analysis as part of the broader catchment can however confirm insights that could be overlooked using a lower resolution as evident throughout this study.

- Planning estimates

The study indicates that the use of historical planning estimates to forecast water supply is significantly overestimating water consumption with the increasing trend towards higher housing densities, smaller lot sizes and reduced irrigated areas. The households with the lowest lot sizes in this study are using much less water than current planning estimates. The costs and operational risks associated with conservative design were discussed and with demand management targeted to reduce residential water consumption by 25 % in residential households by 2030, these issues would be further compounded.

The variability of indoor and outdoor use between weekdays and weekends illustrate the importance of using an extended period for water and wastewater assessment. For each case, there was no single day present in this study that could account for the full range of design criterion required in a network analysis.

- Diurnal Patterns

Irrigation is the major contributor to peak hour demand. The study illustrated that 93.5 % of peak hour demand between 6pm to 7pm was outdoor consumption. Sporadic irrigation was a major influence on the peak hour demand during the afternoon and evening. This supports previous research undertaken regarding automatic and sporadic irrigation habits, with sporadic irrigation preferred in the afternoon due to convenience and also coincides with optimum irrigation periods.

CHAPTER 10: RECOMMENDATIONS

- Metered Data

The metered data recordings for monthly intervals form the basis for further investigation and monitoring. The metered data can be used to revise baseline planning estimates, evaluate the distribution and level of skew in the data, assess consumption vs. lot size, evaluate the excessive water users, where the water savings exists and the ability to track demand management initiatives through wet season and dry season recordings. Data cleansing will form an important component of this process and there needs to be a degree of confidence in the data to achieve the aforementioned processes.

- Revise Planning Estimates & Diurnal Curves

Baseline consumption for single dwelling residential can be determined from the metered data during peak hour periods. SCADA systems and zone flow recorders are the best means to revising residential curves. Actual peaking factors can be determined from SCADA and this will advise the optimum approach to encouraging customers when to irrigate.

Diurnal curves and network analysis should be extended to account for the variability in water and wastewater systems and be specific to each network model, if possible.

- Smart Metering on Excessive Consumers

Smart metering with real time feedback can be used to educate water consumers and identify high level leakage and excessive irrigation. The study has indicated the use of a pie chart and percentage comparisons to show leakage or irrigation is the optimum approach to motivating change.

- Outdoor Model: Theoretical vs. Excessive water use

Irrigation forms the major component of overall consumption and therefore further research should target irrigation practices. DeOreo 2011 presents an outdoor model that is extremely relevant and should be the focus of further research. With climate change forecasted to increase rainfall in the wet season but an extended dry season, the use of this model can be applied to evaluate changes over a range of variables.

- Wet season vs. dry season comparison

The research project can be extended into the dry / wet season for seasonal comparisons. The Trace Wizard template will be more effective in the wet season in analysing indoor uses without the outdoor use component and will reduce the analysis time. It is recommended that a revision should be undertaken for this analysis and extended over several weeks for increased confidence. A simple outdoor / indoor model can be generated and divide outdoor use into sporadic, automatic and pool events. This extension can also potentially evaluate the use of non-seasonal metered data as a proxy to evaluate outdoor consumption in the dry season.

- Further discussion

The author / analyser is a water and wastewater planning engineer and the breadth of issues discussed in this dissertation cannot be fully realised from a single individual. The focus of this dissertation is to understand the variables that influence water consumption in tropical regions and present several possible strategies to reduce water consumption. A multi-disciplined and combined approach is required to develop a suitable demand management strategy for Darwin.

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APPENDIX A – Project Specification

University of Southern Queensland
FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Christopher Shane SECCULL**

TOPIC: DARWIN RESIDENTIAL END USE PILOT STUDY

SUPERVISORS: Dr Vasantha Aravinthan

MAIN
Ella Patterson
Senior Services Development Engineer
Power and Water Corporation

ALTERNATE
Russell Jennings
Senior Engineer Asset Management
Power and Water Corporation

SPONSORSHIP: Power and Water Corporation – Supply of meters, loggers and computer software.

PROJECT AIM: This project will seek to investigate residential water consumption in Darwin and determine potential demand management strategies to meet Power and Water Corporation water reduction targets.

PROGRAMME:

1. Conduct a literature review on methodologies for procedures on estimation of residential demand focusing on smart metering technology.

2. Develop an appropriate methodology for a pilot study to estimate residential water use in 10 households in Darwin.

3. Implement methodology and install smart metering systems in 10 households in Darwin and develop a suitable database to analyse and store the information.

4. Disaggregate end uses for flow based and volume based indoor appliances and fixtures along with outdoor uses using the special purpose software ” Trace Wizard”.

5. Analyse the distribution and variability of itemized water consumption end use and calculate household and per capita water use, diurnal flow patterns and peak hour factors.

6. Determine potential demand management initiatives to assist in meeting Power and Water Corporation's commitment to reducing residential water consumption.

7. Review and evaluate the use of existing hydraulic modelling input parameters for forecasting water use for standard dwelling residential.

8. Provide recommendations to Power and Water Corporation for future research using smart metering.

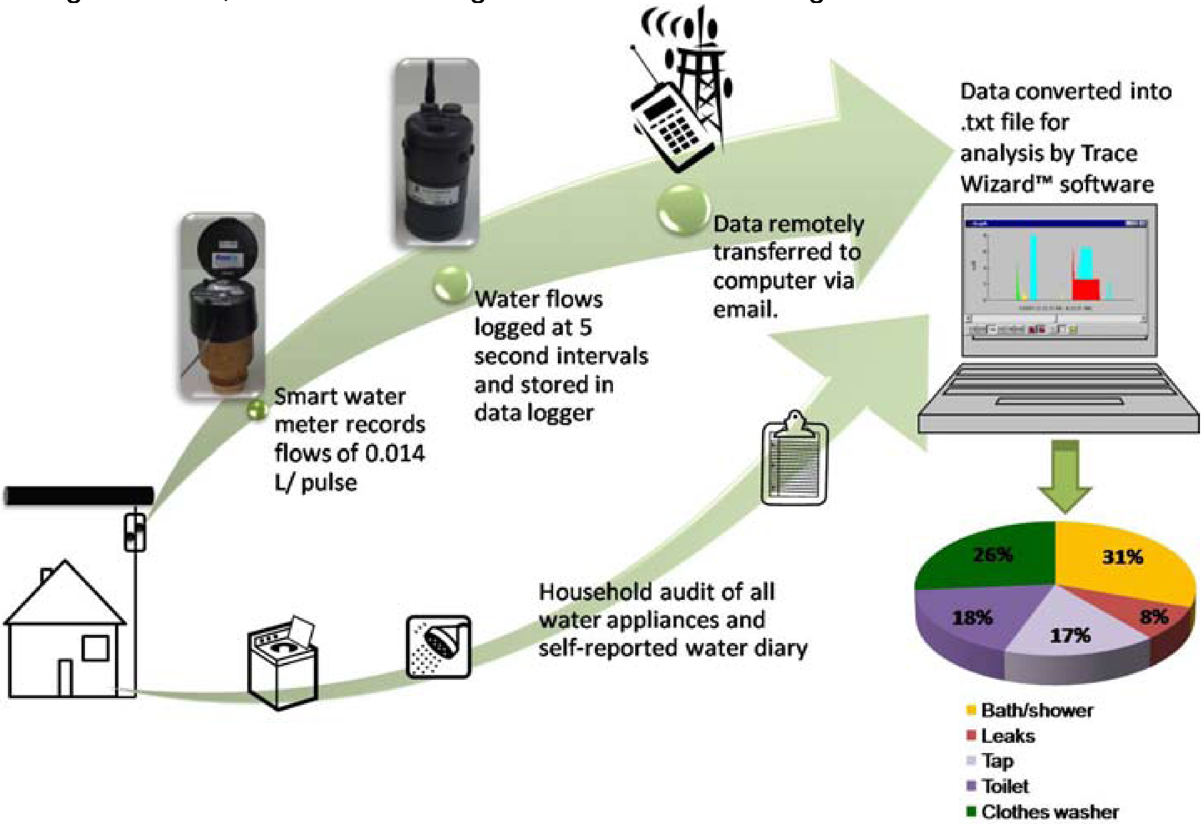
9. Submit an academic dissertation on the research.

APPENDIX B – Information Fact Sheet

RESIDENTIAL WATER USE PILOT STUDY - FACT SHEET

What is this study?

The residential water use pilot study will seek to analyse where, when and how much water in used in residential households in Darwin. Using high resolution smart water meters and data loggers, data will be analysed by specialized software called 'Trace Wizard' to isolate, quantify and identify individual water use events. Once calibrated, the data will be precise enough to distinguish between simultaneous events such as filling up a glass of water, taking a shower, household leakage etc. Please refer to figure below.



NOTE: Self reported water diary is needed for first 4-5 days only to determine events such as washing machine and dishwasher cycles etc. to assist in flow analysis in Trace Wizard.

Why is the study needed?

Darwin has much higher water consumption than other Australian capital cities due to our unique culture, tropical climate, behavioural attitudes and lack of exposure to water restrictions. This project will provide a valuable insight into water consumption patterns for both indoor and outdoor water uses in Darwin households.

This study will inform the development of water conservation initiatives for residential properties to meet PWC ongoing reduction targets. Achieving these targets has potential to defer major capital works such as Warrai Dam.

How will the study be conducted?
Existing water meters will be replaced with high resolution water meters capable of recording up to 0.014 L/pulse. Wireless data loggers will record information every 5-10 seconds and transmit data remotely to a central office computer on a weekly basis. The raw data files will be converted and analysed using Trace Wizard software to disaggregate consumption into individual water use events. The initial household audit and self-reported diary will gather information about fixtures/appliance with the household and water use habits, which will assist in the flow analysis.

Who are we looking for?
Water Services employees living in ground level or elevated houses with established gardens. The household will need to be connected to reticulated water. The participant should be based in Darwin for the majority of the study period.
We are seeking a broad range of demographics (e.g. lot sizes, number of occupants, swimming pools etc.) that is representative of the Darwin region.

How much of my time will be needed?
Approximately *1 hour* of your time will be needed for the entire duration of the project. The homeowner / tenant will need to be present during the initial household audit, during which a brief questionnaire will be undertaken regarding water use habits.

Who will carry out the study?
Chris Seccull from the Planning and Infrastructure Division of Water Services will carry out the study with mentoring by Ella Patterson. The dry season phase of the project will form part of a final year research project with collaboration with the University of Southern Queensland.

When will the study take place?
The study is expected to commence in early to mid August 2011 and will continue into the wet season to analyse seasonal variations in water use.

Is there any feedback during the study?
A general email will be sent to each participate on a weekly / monthly basis that summarizes water consumption patterns for the 10 households. These results will remain anonymous; however individual profiles will be available upon request.

For more information please contact:

Chris Seccull
# # # # # # #
# # # # # # #

APPENDIX C – Audit Questionnaire

Audit Questionnaire – Water Consumption Study

Date: ______________ Time: ______________

Demographics

How many years have you lived at this address? ________yrs

Is it rented or owned?

If rented: excess water charge? ______

Number of fulltime residents (2011):

	Male	Female
TOTAL	_________	_________
(0-2)	_________	_________
(3-14)	_________	_________
(15-24)	_________	_________
(25-44)	_________	_________
(45-65)	_________	_________
(65+)	_________	_________

How many occupants remain at home during the weekday? ____
the weekend? ____

Time spent away from home/day:

Person	Av. Hours
________	_________
________	_________
________	_________
________	_________
________	_________

Do you have regular visitors? Give details e.g. regular/occasional, meals, all day,
overnight….

____

Frequency: _______________
Duration: _______________
Time of Day: _______________

What type of property? E.g bungalow, double storey etc.

____

Age of property: ____yrs Number of bedrooms_____
Number of bathrooms____ Rainwater Tank (Y/N)
Shed_____ (outside sink (Y/N))

Income:
How would you rate your household's water consumption?

Low: 1 2 3 4 5 High

Kitchen

Dishwasher: Make ____________
Model ____________
Cycle used ____________

Do you rinse before placing in Dishwasher? (Y/N)

Do pots& pans get put in dishwasher? (Y/N)

How often does the dishwasher get used? _____/day

What time of day would the dishwasher normally be run? _________

Sink:

Volume of sink ___________ L
Volume of second sink ___________ L

Start: ________

Tap: Make ____________
Model ____________
Aerator? (Y/N)
Flowrate ____________ L/sec

How many times do you hand-wash dishes? ____ per day/____per week

Do you rinse food (e.g vegies & fruit)? (Y/N)

Do you use the plug when rinsing? (Y/N)

How full do you fill the sink (%)? ______

How many meals are eaten in the house during the week? _______ /day
on the weekend? _______/day

Icemaker on Fridge? Make/Model _________
How often used? _________

Start: ________

Garbage Disposal? Make/Model _________
How often used? _________

Laundry

Washing Machine: Make _______________
Model _______________
Size _______________

Top load/Front Load
Cycle used ________________
Water Temp ________________

How many loads of washing would you do per week? ________

What size would they be? Small _____/week
Medium _____/week
Large _____/week

What time of day would they normally occur? ______

Do you send clothes to the dry cleaner? (Y/N) Frequency? _______/month

Do you use a launderette? (Y/N) Frequency? ______/month

Laundry Tub: Volume ____________L
(length__, width ___, depth___)

Start: ________

Faucet: Make ____________
Model ____________
Aerator? (Y/N)
Flowrate ____________ L/sec

How often is this tub used? ______/week

Time taken for hot water? ___________

Bathrooms

How many bathrooms do you have? _________
How many toilets? _________
Estimated shower duration: Person Time

_______ ______
_______ ______
_______ ______
_______ ______
_______ ______
_______ ______

What time of day would showers normally occur? ________

Are any showers taken away from the home? E.g. gym, school, work (Y/N)
Frequency? ________/week

Is any shower water harvested? (Y/N)

How often do people in the home take baths? ______

Bathroom 1: Description (main, guest, kids)__________

Showerhead: Type ___________
Flow-rate ___________

Start: _________

How often does this shower get used? __________/week

Time taken for hot water? _________mins

Sink Tap: Make _____________
Model _____________
Aerator (Y/N)
Flow rate _____________ L/sec
Main use (e.g. hand, face, teeth, baby) __________

Start: _________

Bath Tap: Make _____________
Model _____________
Aerator (Y/N)
Flow rate _____________ L/sec
Volume of Tub Length _____________
Width ______________
Depth ______________
Fill level (%) __________

Start: _________

Frequency of use? _________/week

Toilet: Make __________
Model __________
Dual Flush (Y/N)
Volume (Full-flush) __________
Volume (Half-flush) __________

Half Start: _________

Full Start: _________

Bathroom 2: Description (main, guest, kids)__________

Showerhead: Type ___________
Flow-rate ___________

Start: _________

How often does this shower get used? __________/week

Time taken for hot water? _________mins

Sink Tap: Make _____________
Model _____________
Aerator (Y/N)
Flow rate _____________ L/sec
Main use (e.g. hand, face, teeth, baby) __________

Start: _________

Bath Tap: Make _____________
Model _____________
Aerator (Y/N)
Flow rate _____________ L/sec
Volume of Tub Length _____________
Width ______________
Depth ______________
Fill level (%) __________

Start: _________

Frequency of use? _________/week

Toilet: Make __________
Model __________
Dual Flush (Y/N)
Volume (Full-flush) __________
Volume (Half-flush) __________

Half Start: _________

Full Start: _________

Outdoor:

What is the number of external taps? __________

Do you have a sprinkler system in place? (Y/N)

Start Time: _____________

Stop Time: ____________

Cycle Description: __________

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

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

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

What is the area of the garden?

Other:

Air-conditioner 1: Make _____________
Model _____________
Hours of use _____________
Time of use _____________
Temp set at _____________

Air-conditioner 2: Make _____________
Model _____________
Hours of use _____________
Time of use _____________
Temp set at _____________

Air-conditioner 3: Make _____________
Model _____________
Hours of use _____________
Time of use _____________
Temp set at _____________

Hot Water System: Make _____________
Model _____________
Volume _____________
Type (Gas/Electric/Solar/Other_____)
Location _____________

Distance to remotest point ______

Rain Water Tank: Volume _____________
Connections: Toilets
Washing machine
Outside tap
Drinking water

Pets: How many dogs? ______
How often do they get washed? _____/month
Do the kennels get washed down? (Y/N) ______/week

Pool: Size: ______
How often is it refilled? _____
Pool Cover? ________

Do you have any known leaks? (Y/N)

APPENDIX D – Meter Specifications

CT5-S20 20mm totaliser positive displacement flowmeter with high rate 72 pulses/Litre pulse output

FEATURES

- Volumetric rotary piston principle, measures accurately in any position.
- Mechanical totaliser.
- 72 counts/Litre Reed Switch contact closure output for precision data collection and flowrate readings.
- Designed to meet AS3565.1-1998.
- Accuracy (Qt to Qs): ±2%, Repeatability: ±0.15%

The CT5-S20 20mm water meter is suitable for measurement of cold water upto 50 °C with a working pressure upto 1500 kPa. The meter offers great accuracy and a long operating life for domestic drinking water applications.

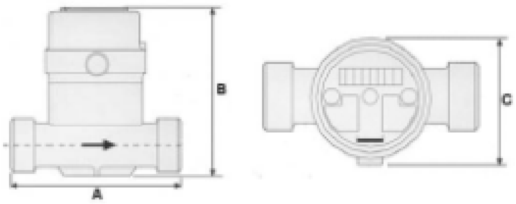
The mechanical counter register is positioned for easy reading and displays from 0.02 to 9,999,999 Litres. The precision engineered rotary piston measuring chamber ensures accurate measurement even at very low starting flow rates. Meters can be installed in any position without affecting accuracy and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

CT5-S20 flowmeters are fitted with a high resolution reed switch contact closure output. At the request of various water authorities, with Manuflo technology, 72 pulses per Litre (ppL) output signal is achieved, which is the highest amount of pulses per Litre for a domestic water meter of this size (whilst retaining the mechanical register). This allows capture of precision water measurement information to data-loggers and to other data collection devices. Very accurate data can then be obtained for water usage totals and flowrate habits of consumers. Electrical connection is via a 1.5 metre 2-core shielded cable.

All meters are supplied with a gasket seat coupling connection kit (optional ball seat available). CT5-S20 flowmeters are manufactured from high quality materials to meet Australian specification requirements.
The CT5-S20 20mm provides the best pulse output rate for domestic water meters, with 72 pulses/Litre.

SPECIFICATIONS

Size (mm)		20
Pulse output rate	Pulses/Litre	72
Mechanical register	Minimum Litres	0.02
	Maximum KL	9999.9999
Starting flow rate		0.033
Min. registration	Qr ±5% Litres/min	0.05
Min. transitional flow	Qt ±2% Litres/min	0.41
Nom. continuous flow	Qn ±2% Litres/min	41.6
Max. intermittent flow	Qs ±2% Litres/min	83.3
Weight with couplings	kg	1.9



Other Specifications
Headloss @ Qn <25 kPa; Maximum pressure rating 1500 kPa; Maximum water temperature 50°C.
Accuracy Qt to Qs: ±2%; Repeatability: ±0.15%.
Reed switch pulse Vmax: 24V; I max: 50mA, with anti-bounce and current-limiting resistor fitted.
Cable: 2-core, 1.5 metre length (with some input devices, to avoid bounce install a 450pF capacitor across input).

Other pulse data: Typically 50% duty cycle pulse (equal on/off state), largest difference 46% on / 54% off state.
At Qs flowrate (83.3 Litres/min), pulserate maximum frequency is 100Hz (1.388 Litres/sec x 72 pulses/Litre).

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

DIMENSION (see diagram)	
Length A	152 mm
Height B	145 mm
Width C	92 mm

Order Code	Description
CT5-S20	20mm flowmeter, with Gasket Seat ¾" BSP (male) coupling set

Options	(add suffix to flowmeter Order Code)
-BS20	Ball seat ¾" BSP (female) coupling set for NSW, instead of Gasket Seat
-DCV	Dual Check Valve

Thread connections available to suit different states.
Also available as manifold flowmeter for Brisbane Water.
Also available : 15mm CT5-S15 and 25mm CT5-S25 (see separate data sheets).

ManuFlo ®TM
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Rev: 1005/1

http://www.manuelectronics.com.au/pdfs/CT5-S20.pdf

APPENDIX E – Data Logger Specifications

DataCell

Rtx

Advanced monitoring and reporting.

Applications:

- Key account metering
- Event monitoring
- Air conditioning monitoring
- Refrigeration monitoring
- Environmental monitoring
- Process monitoring

Features:

- Two-way Communications
- Four programmable inputs
- Waterproof to 1 metre
- SMS and e-mail reporting
- Stores 2 Million Records
- 10 year battery life*

AEGIS

DataCell

Rtx
Data logger

Product Overview

The DataCell Rtx advanced data logger has been designed to give you complete control of your data logging fleet without leaving your office. However, the Rtx is not just a data logger, it also is a highly capable alarm device providing condition warnings for the water, refrigeration and air conditioning industries to name just a few.

Equipped with two-way communications capability, the unit can be remotely interrogated and reprogrammed allowing full access to all of the Rtx features and the ability to correct any installation programming errors without an expensive field visit.

In addition to the two-way communications, the Rtx has a number of advanced features including:- programmable SNTP time update, low battery warning, local communications activity notification via LED's, easy to understand SMS message format and improved communications retry logic.

These features along with its 10 year battery life, storage capacity of 2 million records and field proven, waterproof case make the DataCell Rtx a must for your measurement and monitoring needs.

Specifications

Inputs

Up to 4 unpowered floating Voltage free inputs.

Short cable mode:-	Max input cable length 4 metres
Long cable mode:-	Max input cable length 10 metres

Communications

Serial:	Infrared interface
Wireless:	GSM/GPRS modem File Transfer Protocol (FTP)

Logging

Memory	2 million records
Alarms	Low or Zero usage in a period High usage in a period Return of state Tamper detection
Clock	Real time with time and date stamp Remote SNTP time update
*Battery life	Typically 10 years at one call per day

Physical

Dimensions	88mmØ x 170mm
Weight	470 grams
Environmental	IP68

Operating Temperature -20°C to +75°C for all logger functions
-20°C to +55°C for GSM functions

Part Number CZ21040

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CZ21040-01-02