Using Geographic Information Systems to Explore the Determinants of Household Water Consumption and Response to the Queensland Government Demand-Side Policy Measures imposed during the drought of 2006-2008.

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ABSTRACT

During a lengthy drought, and after imposition of a suite of demand-side policies, South East Queensland (SEQ) water use dropped dramatically, by nearly 80% in a three year period. This was an unprecedented response to water demand policy. It is not well known which of the particular policies was most influential in the reduction of domestic water use. Nor is it known which determinants of household water use were most significant for the greatest reductions in water use and for high water users. Urban water use, its determinants, and the interaction of these with demand-side policy, has been extensively investigated. However, most studies have been of relatively broad scale, and few have had access to household level datasets of domestic water use.

A range of tools was used to investigate the reduction in household water use and to identify which households used more water. The water use of detached households on the Sunshine Coast (which did not have water restrictions) was compared to that of Brisbane (which did) to isolate the effect of water restrictions from the raft of demand side policy measures. Geographical Information Systems (GIS) was used to stratify households according to water use, and socio-demographic characteristics. Thereafter, a random sample of households in both LGAs was surveyed to explore how key in-depth household characteristics related to water use. Quantitative statistical analysis, including geodemographic techniques, was used to analyse patterns of water use, as well as census data. The survey design was guided by a range of commonly used psychological frameworks, particularly an extended version of Ajzen's Theory of Planned Behaviour (TPB). Although qualitative analysis was not a component of the research methodology, the questionnaire included a single open-ended question, which was used to inform and flesh out the quantitative results.

As expected and in accordance with previous research, household level structural characteristics, such as lot size and swimming pools, were the most significant drivers of higher water consumption. Higher levels of water use clustered in areas with higher incomes and education levels. During the drought, these areas reduced their water use to a proportionately greater degree than areas with lower socio-economic status. In addition, Brisbane and the Sunshine Coast had dissimilar levels of water use, with the Sunshine Coast's water use was consistently higher. However, despite having normal rainfall, Sunshine Coast water use also dropped significantly during the period.

Water use also had a temporal component, dropping most significantly during 2007, at the height of the drought. This also corresponded to the period in which the media most actively reported the drought as a "crisis". During the period of the drought, attitudes to policy also changed, with support dropping over time. Respondents strongly supported policy measures that allowed personal control over the resource, such as the water tank rebates and the Home WaterWise Scheme (a subsidised service to check and fix leaks, and replace shower heads). Attitudes to supply-side policies were mixed, and some, such as to the deferred Traveston Dam proposal, differed spatially. The TPB constructs were not significant for water use, and as in similar studies, only predicted intention, and not actual behaviour.

In conclusion, the depth of available data allowed detailed investigation of household water use. Although results of the study largely corresponded with previous research, the study allowed further insights into how responses to policy measures can be relatively rapid. Further investigation into the influence of the media, as well as means to maintain reductions in household water use post drought appear fruitful for future research. Given the widespread flooding of 2010/2011, future research on changes in attitudes might be particularly worthwhile.

GLOSSARY

- **ABS:** Australian Bureau of Statistics
- **AMOS:** Component of SPSS software to build structural equation models
- **ANOVA:** Analysis of Variance – testing the means of different groups.
- **BASIX**: Building Sustainability Index (NSW Government Policy)
- **BIC:** Bayesian Information Criterion (criterion to select the best model to fit in a Structural Equation Model. Can also use the Akaike Criterion.)
- **BoM:** Australian Bureau of Meteorology
- **CCD:** Census Collection District, smallest unit of geography used in 2006 Census.
- **CUSUM:** Cumulative Sum Chart. Often used in changepoint analysis to identify marked changes in time series or panel data.
- **Demand-Side & Supply-Side policies:** Demand-side refers to policies aimed at decreasing demand (i.e. water restrictions) and supply-side to policies aimed at increasing supply (i.e. new water infrastructure).
- **DERM:** Department of Environment and Resource Management (aka, Dept. of Natural Resources & Mines and Dept. of Natural Resources & Water).
- **Geodemographics**: the socio-economic and spatial classification of populations
- **Getis Ord Gi* Hotspot analysis**: "The local sum for a feature and its neighbours is compared proportionally to the sum of all features; when the local sum is much different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score is the result." (ESRI, 2010)
- **GFC:** Global Financial Crisis
- **GIS:** Geographic Information System (software program for spatial analysis)
- **"Greenhouse Gas":** increased levels of gasses from industrial activity, contributing to anthropogenic climate change (i.e. methane, carbon dioxide, water vapour and ozone).
- **GLM:** Generalized Linear Models
- **LCD:** Litres Capita Day
- **LGA:** Local Government Area
- **LMM:** Linear Mixed Models
- **Mahalanobis:** How much the values of a case differ from the average of all cases. The greater the Mahalanobis distance, the greater the likelihood of extreme values on one or more of the independent variables.
- **Megalitres:** 1,000 litres
- **NIMBY:** Not In My Back Yard
- **QWC:** Queensland Water Commission
- **PBC**: Perceived Behavioural Control (a construct from the Theory of Planned Behaviour). Also includes the constructs **Attitude** and **Social Norm.**
- **PCA:** Principal Components Analyses (exploratory statistical technique)

- **PFA:** Principal Factor Analysis
- **Rational Choice models:** typically based on classical economic theory, and assume reasoned decision making by individuals to maximise net benefits.
- **SEQ:** South East Queensland
- **SEM:** Structural Equation Modelling (sometimes referred to as Path Analysis). Statistical method that aims to measure the influence of non-observed (or latent) variables on a measurable dependent variable, such as household water use.
- **Southern Oscillation (El Nino and La Nina):** periodic weather and ocean temperature pattern found in the Pacific Ocean. El Nino phases are typically dry, and La Nina phases, typically wetter.
- **Target 140:** the QWC's behavioural change and water saving campaign
- **TPB:** Theory of Planned Behaviour (behavioural framework that attempts to explain intention to behave; comprises **Attitude, Social Norm** and **Perceived Behavioural Control**)
- **VIF:** Variance Inflation Factor (number to identify multicollinearity in a dataset).

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PEER-REVIEWED PUBLICATIONS ARISING FROM THIS THESIS

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  (PhD Scholar Category: A paper by a researcher who was, at the time of paper submission, a PhD student enrolled or awaiting award of a PhD at an Australian university, which is judged to make a distinctive contribution to knowledge and capacity for the sustainable development of Australian Cities and Regions. http://soac2011.com.au/awards.php)

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CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND

1.1.1 Urban Water Security

A number of factors influence urban water security. The most important of these are population growth and climate change (Birrell, Rapson, & Smith, 2005; WSAA, 2010). Population growth is a major driver of water demand, as domestic households use the majority of urban water supplies. The influence of population growth on water demand is exacerbated by demographic changes. Smaller households are becoming more common, because of the ageing population and the decline of the traditional family (ABS, 2007; Birrell et al., 2005; Troy, Holloway, & Randolph, 2005; WSAA, 2010). An increase in smaller households places increased pressure on urban water supply as, per capita, smaller households use more water (Domene & Sauri, 2006; Troy et al., 2005). Smaller households are also less able to reduce water use because of economies of scale for common uses, such as clothes washing (Troy et al., 2005).

Future impacts of human induced climate change are likely to give rise to greater extremes of climate; increasing the duration and frequency of droughts, and increased temperatures and catchment hardening further reduces supply (Cai, 2009). Australia, with its highly variable climate, is particularly vulnerable to climate change. Therefore, the combination of increased growth and urbanisation, rainfall scarcity and demographic changes means urban water demand is likely to keep rising—as more frequent droughts lower supply (Birrell et al., 2005; Clarke, Kashti, McDonald, & Williamson, 1997; Domene & Sauri, 2006; Hoffmann, Worthington, & Higgs, 2006; Troy et al., 2005).

1.1.2 Implementing Effective Policy Measures

However, in many regions limited suitable sites exist for new major bulk water supply infrastructure. Large infrastructure also depends on reliable rainfall and it can have political, social and environmental impacts. Therefore, maintaining reductions in demand is essential for future urban water security.

If well planned, and implemented as part of a targeted suite of measures, demand-side policies can effectively reduce household water consumption (Turner, White, Beatty, & Gregory, 2005). Demand-side measures are also generally more cost effective than supply-side measures, but universally implementing these can still be expensive. For example, large scale awareness raising campaigns can be costly, and their outcomes difficult to evaluate (Syme, Nancarrow, & Seligman, 2000; Turner et al., 2005).

In addition, some demand-side policy measures are implemented with little evidence base, and without comprehensive evaluation of outcomes (Head & Muir, 2007). Thus, to ensure the most cost-effective use of public funds, policy measures should be carefully developed; to strategically target those groups that use the most water, and those with the greatest capacity to change (Allon & Sofoulis, 2006; Jorgensen, Graymore, & O'Toole, 2009). Therefore, it is important that policy makers have a good understanding of the spatial and temporal extent of the determinants of household water use.

However, establishing the determinants of household water use is not necessarily straightforward. The determinants of total water use are population, climate and price, but at smaller spatial scales, urban water use is driven by a complex combination of structural (property level), socio-demographic and psychological factors (Birrell et al., 2005; Clarke et al., 1997; Durga Rao, 2005; Po et al., 2005; Troy et al., 2005; Wentz & Gober, 2007). Thus, household water demand is not homogenous across any given urban area; it often differs markedly according to factors such as income, lot area, household size, and individual attitudes and beliefs (Harlan, Yabiku, Larsen, & Brazel, 2009; Jorgensen et al., 2009; Troy et al., 2005; Wentz & Gober, 2007). However, research on the degree of influence of many of these is contested; for example, the influence of socio-demographic factors such as income and education (Harlan et al., 2009).

Furthermore, demand-side policy measures such as water restrictions or awareness campaigns are typically short-term, and largely target the psychological determinants of household water use. Short term policy measures cannot change the structural and socio-demographic determinants of water use. Lot sizes do not suddenly decrease, nor do income levels rapidly increase. However, these factors can limit the ability to change behaviour. Affluent neighbourhoods are often characterised by large expanses of lush, irrigated lawn and swimming pools. These neighbourhoods typically have a poorer response to voluntary demand-side measures, in part because such policies influence social norms (i.e. "dead" lawns), and property values (De Oliver, 1999; Harlan et al., 2009). On the other hand, lower income households and those in rented properties also have lesser ability to respond to policy, i.e. to install water tanks.

Therefore, to devise effective policy, it is essential that policy makers understand the full suite of structural, socio-demographic and psychological drivers of household water use. However, few studies have explored the determinants of household water use at smaller scales such as Census blocks or households (Clarke et al., 1997; Domene & Sauri, 2006). Even fewer studies have used disaggregate data at the household level, which is more appropriate for studying individual behaviour (Clarke et al., 1997; Kenney, Goemans, Klein, Lowrey, & Reidy, 2008).

Therefore, research using a comprehensive, longitudinal database of household water use could be of great benefit in understanding some of the major determinants of household water use. Furthermore, it could help understand why the SEQ demand-side measures were so successful in reducing household water demand. These learnings could be of great benefit to inform future policy iterations. In addition, future research investigating attitudes to household water use after the floods of 2010/2011, might be especially worthwhile.

1.1.3 Background to the South East Queensland Drought

Something rather striking took place in South East Queensland, Australia between 2005 and 2008. During a recent drought, a suite of demand-side measures was remarkably successful in reducing household water use. Over this relatively short period, residential water use plummeted from approximately 300 Litres Capita Day (LCD) to a low of 122 LCD. Despite the success of these policy measures, it is unclear which were most effective, and why. Understanding how this behavioural change happened so rapidly and on such a large scale, is potentially of great significance for the future management of household water demand.

1.1.4 Study Area

The study was set in the Local Government Areas (LGAs) of Brisbane and the Sunshine Coast (Figure 1). Both form part of South East Queensland (SEQ), a region which totals 22,420km^2, and comprises 10 LGAs. SEQ is bordered by Coolangatta to the South, Noosa to the North and Toowoomba to the west. SEQ's population is approximately 2.6 million; nearly 72% of the State population; the majority of which (>90%) live in the highly urbanised Brisbane and the Gold and Sunshine Coasts(ABS, 2010b).

As a whole, SEQ is one of the fastest growing regions in Australia (ABS, 2010b; OUM, 2005). Brisbane is the largest centre and the capital of Queensland, with a population of approximately 1.95 million (ABS, 2009). The Sunshine Coast has a population of approximately 313,000, and is approximately 100km to the north of

Brisbane, and separated from Brisbane by the Moreton Bay Regional Council. The Sunshine Coast formerly comprised three separate LGAs (Caloundra, Maroochy and Noosa), but these were merged on 15 March 2008, during a State Government initiated local government amalgamation process. Both Brisbane and the Sunshine Coast had high rates of population growth, although this has recently slowed somewhat with the "Global Financial Crisis" (GFC). For example, during the period 2007-2008, Brisbane had the largest increase in population growth for any Capital City Statistical Division, and the Sunshine Coast's annual growth rate was 2.9% (ABS, 2009).

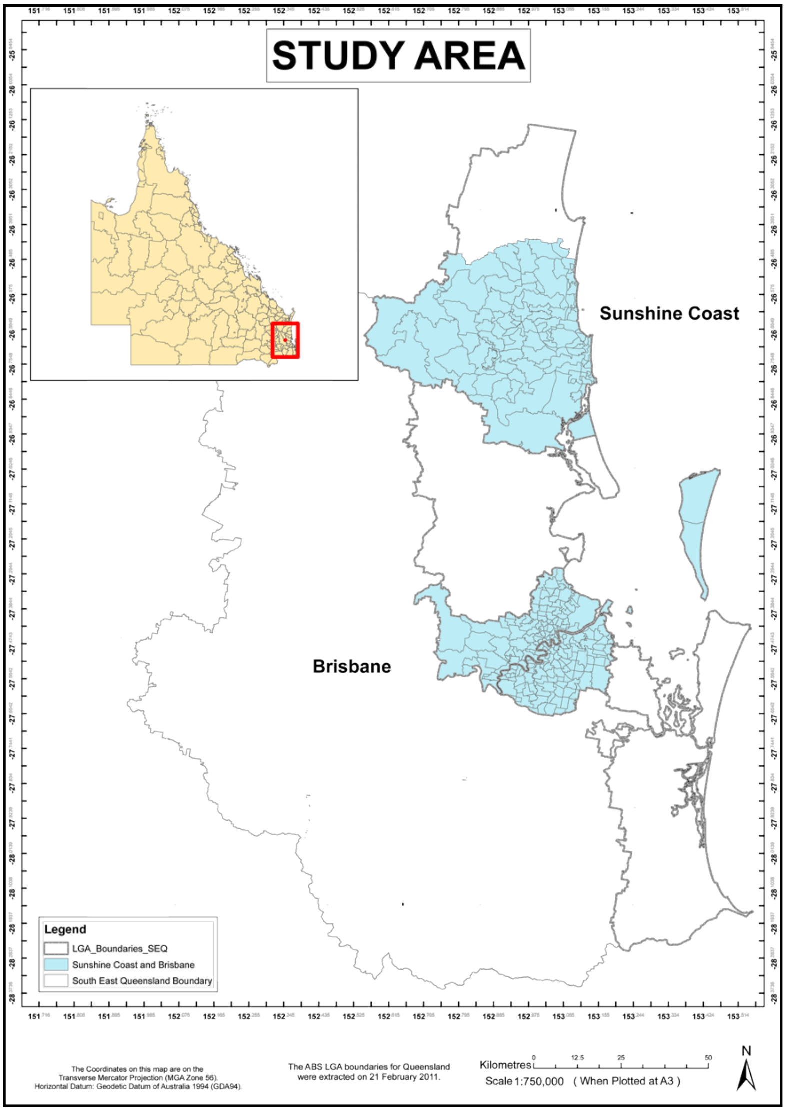

Figure 1 Study Area

SEQ has a humid sub-tropical climate influenced by the warm waters of the Coral and Tasman Seas, giving rise to warm temperate conditions along the coast. In general, rainfall increases in an eastward direction, from approximately 600mm per annum in the west of the region, to over 2000mm on the coast. The highest rainfalls are usually associated with Summer conditions, and the period from July to September tends to be driest (BOM, 2007; NRW, 2007). SEQ can experience periods of very intense rainfall, associated with tropical lows, cyclones and thunderstorms. Brisbane generally has a lower rainfall than the Sunshine Coast; very broadly, Brisbane's average rainfall is approximately 1,200mm per annum, in comparison with the Sunshine Coast's average of 1,650mm per annum (BOM, 2007).

1.1.5 Water Use in South East Queensland

In SEQ, urban areas use the majority of water, and of these, residential households are the largest water users, using 76% of urban water supplies (Figure 2). At a finer level of detail, detached houses (Single Family Residential) account for 59% of total supply (ABS, 2010c; QWC, 2008b).

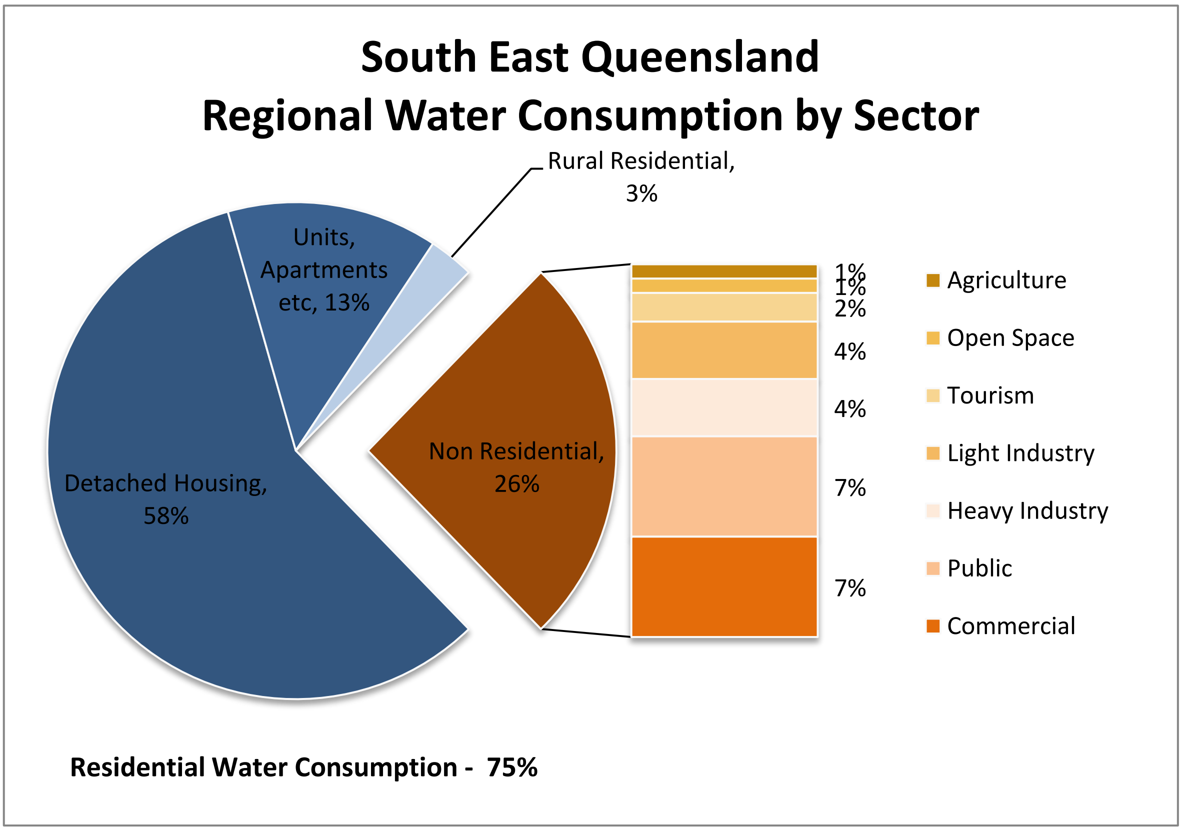

Figure 2 Breakdown of Water Consumption in SEQ – 2005 (adapted from Queensland Water Commission, South East Queensland Regional Water Supply Strategy,2005)

History of SEQ Water Policy

Prior to 2005, domestic water consumption in the Greater Brisbane area was higher than other major Australian metropolitan area, but SEQ had not previously experienced any serious water shortages (Hoffmann et al., 2006). Regular flooding rains kept the dams full and the city green, and floods were more of an issue than drought. Household water demand was not restricted, and few barriers to consumption existed. Demand-side measures, such as awareness campaigns and water restrictions, usually sprinkler bans, were rare. Indeed, the majority of Brisbane households had no water meters until 1990 (Spearritt, 2008). Unsurprisingly, Brisbane had one of the highest per capita water consumption in Australia—greater than 300 LCD.

Despite the perceptions of plentiful supply; by the late 1990s, some staff from the Department of Natural Resources and Mines predicted future water shortages from climate change, high population growth and inadequate infrastructure (Spearritt, 2008). Apparently, these warnings went unheeded; the State Government, supported by the development industry, continued to promote interstate migration without supplementing supply (Craig, 2007; Spearritt, 2008)

These predictions began to eventuate in 2004, the usual rains never fell, and even the higher rainfall areas, such as the coastal strip, began to dry out. Water levels in the main storages, Wivenhoe and Somerset Dams, began to drop. By late 2005, SEQ was experiencing an extended drought; with average rainfall 23.8% less than any similar recorded period. To respond to the drought, the Government began work on the South East Queensland Regional Water Supply Strategy (SEQRWSS) (SEQRWWS *Interim Report*, November 2005: 1).

In January 2006, the Interim Report of the SEQRWSS stated that if rain did not fall on the dam catchments, at the time less than 35% full, "…*SEQ will be in the grip of the worst drought in recorded history*" and "…*the region has about 3 years of supply* *remaining*" (SEQRWWS *Interim Report*, November 2005: 1). The SEQWRSS argued for the first time that SEQ might have to restrict domestic water consumption, to a relatively "low" 300 LCD (SEQRWWS *Interim Report*, November 2005: 1). Predictions that SEQ could actually run out of water demanded immediate action, emergency powers legislation was passed to deal with the "Water Crisis", and the then Premier, Peter Beattie, almost declared a State of Emergency (ABC, 2006; NRW, 2007).

By June 2006, the crisis deepened, and the Government had no choice but to act. Some functions and staff were split from the Department of Natural Resources, Mines and Water, to form an "independent" commission, the Queensland Water Commission (QWC, 2008b). To achieve the "blueprint for securing water supply", the QWC initiated a combination of supply and demand-side policy measures.

South East Queensland Supply Side Policies

The State Government had invested little in water supply infrastructure prior to the drought. Two major storages on the Brisbane River, Somerset and Wivenhoe Dams, provide the majority of Brisbane's water supply. The largest, Wivenhoe, is situated in a relatively dry region, and was built less for water supply than for flood retention after the 1974 floods[1]. These storages also supply water to agriculture and electricity power plants, such as Tarong Power Station (Allon & Sofoulis, 2006, p48; Barraque; Spearritt, 2008).

During the drought, the State proposed a range of supply-side measures that included new infrastructure, desalination and recycling plants, and a series of interconnected pipelines to link up existing (and new) water storages across the region (the Water Grid). The measures also included programs aimed at encouraging water

[1] Due possibly to poor management, this dam proved ineffective even for flood retention in the January 2011 floods.

reuse and recycling. The proposed major bulk water source was to be the Traveston Dam on the Mary River (NRW, 2007). This dam was controversial from the outset; the affected community believed the site, in a National Party electorate, was chosen more from political expediency than from practical considerations. Opposition to this dam was particularly strong on the Sunshine Coast, which had normal rainfall during the drought, with some residents thinking that Brisbane was taking their water[2].

The South East Queensland Water Grid is a two-way system of pipelines designed to connect major bulk water sources. The aim of the Grid is to coordinate water supply, allowing surplus water to be moved to areas with deficits. The Grid was also proposed to pipe high quality recycled water to the Wivenhoe Dam. Water recycling was initially only proposed for Toowoomba, which is prone to regular water shortages. However, after a concerted effort by the opposition Liberal National Party, and an anti-recycling group (Citizens Against Drinking Sewage), a Referendum resulted in a 62% "No" vote against recycled water, and the project was temporarily shelved.

After the cancellation of the Traveston Dam, the final SEQ Water Strategy changed focus to desalination, stating, *"…desalination facilities will underpin SEQ's future water security"* (QWC, 2010). The existing desalination plant, at Tugun (on the Gold Coast) has been beset by operational and maintenance issues, but the State Government proposed two further desalination plants (QWC, 2010). Of note, desalination is an expensive method to secure supply, typically costing over $1 billion to construct, and produces significant greenhouse gas emissions(Chong & White, 2009).

When the Final SEQ Water Strategy was released in July 2010, the construction of new supply infrastructure was linked to residential water use (QWC, 2010). According to the SEQWS, if residents maintained use under 230LCD, new supply

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[2] On November 11, 2009, the Federal Minister of the Environment used the provisions of the Environment Protection and Biodiversity Act, 1999 to reject the dam, on the grounds of severe negative impacts to endangered ecosystems and species, in particular, the Queensland lungfish (*Neoceratodus forsteri*).

infrastructure, including the unpopular desalination plants, could be delayed until 2017. Moreover, if residents maintained consumption to under 200LCD, this could be further delayed until 2022 (QWC, 2010).

South East Queensland Demand-side Measures

The demand-side measures included an awareness and information campaign (Target 140), increasing levels of water restrictions, home retrofits (Home WaterWise) and a range of incentive mechanisms, such as subsidies on water tanks (QWC, 2008a). With the exception of the water restrictions (and the mandated 140 LCD), the measures applied to all SEQ, including the Sunshine Coast.

Target 140 was the Queensland Water Commission's behavioural change and water saving campaign aimed at reducing average household water consumption to 140LCD. This highly successful campaign ran from March 2007 to July 2008. It was promoted in a range of media, and included releases praising householders for lowering consumption, and daily reports of water consumption and dam levels. The campaign was also supported at a local government level; Brisbane City Council released their own Target 140 material, including an online tool to compare personal water use with other Brisbane suburbs, water saving tips, quizzes on water use, and educational material. A key aspect of Target 140 was targeting indoor as well as outdoor water use. In the beginning, achieving Target 140 was a voluntary goal, but was later mandated as part of Level 6 water restrictions.

The water restrictions consisted of increasingly strict levels, each succeeding stage of which further limited outdoor water use. Level 6 completely banned all lawn watering, washing vehicles and filling new pools. Topping up existing pools was only permitted if three water saving devices, such as pool covers and water tanks were installed. Bucket watering of plants was permitted, but was limited to 3 days a week, at specific times. Unusually for such policy measures, the strictest Level 6 restrictions also targeted indoor water use. Level 6 restrictions set per capita quotas, that included provisions specifically aimed at higher water users who exceeded specified per capita water consumption.

Home WaterWise was a government-funded campaign that paid a licensed plumber to carry out a range of water saving initiatives for households. Householders paid a small sum ($20), for water savings advice, identification of leaks, provision of flow restrictors on taps and a "low flow" showerhead. Another subsidy mechanism was subsidised rainwater tanks. Until 31 December 2008, a paid rebate of $1500 was offered on water tanks, and subsequently increased for tanks plumbed into the main water supply. Some LGAs, such as Brisbane, matched this with additional funding.

All the demand-side measures were communicated by means of an information campaign. However, the reporting of these differed during the drought. In 2006 and 2007, the demand and supply side measures were portrayed favourably in the media, and the QWC praised for having achieved such a record drop in water consumption. However, by 2008, the general tone of the media articles changed markedly. As the drought began to ease, the media were increasingly critical of the demand-side measures (particularly the restrictions) and there was a greater emphasis on infrastructure options, such as recycled water, the water grid, various dams and desalination plants. However, this was also tied into criticism of the State Government takeover of bulk water infrastructure.

Overall, the tone of the media articles corresponded with the severity of the drought. The drier it was, the more prevalent were the themes of emergency, crisis, and collective solidarity in response. Frequent praise for lower water use was reported, as was praise for the QWC policy measures. However, once the rains began again, many people, and the LGA Local Governments, apparently resented the continuing water restrictions. Furthermore, the emphasis on supply-side instead of demand-side measures was marked.

1.2 Aim

In the Summer of 2010/11, the La Nina weather pattern returned, ending 6 years of drought, and bringing widespread flooding rains. However, these climatic influences are cyclical, and the drier El Nino phase of the Southern Oscillation will return, and with it, reduced rainfall and drought. This cycle is also forecast to increase in intensity and duration from human induced climate change. Therefore, protecting urban water security is still a major policy objective of the Queensland Government.

The outstanding success of the Queensland Government’s policy measures could potentially have far-reaching consequences for the future management of household water demand. However, it remains unclear which of the policies were the most effective, and why. Nor is it clear what determinants of household water use were most influential in higher levels of water use, and changes in water use. However, to effectively understand, and thus target, demand-side policies, it is necessary to understand these determinants at a finer scale. Most studies of household water use have been at larger scales, such as the city and suburbs; however, only a few studies have investigated aspects of this at the neighbourhood and household level (Aitken, Duncan, & McMahon, 1991; Keys, Wentz, & Redman, 2007; Troy et al., 2005).

This study aimed to obtain a richer understanding of the determinants of household water use, and the types of households that were more likely to use more water, and respond most favourably to demand-side measures. The study also aimed to identify some reasons why the South East Queensland demand-side measures were so successful in changing household water use behaviour, and identify which of the policies were the most effective. A comprehensive, academically rigorous evaluation into which determining factors are influenced by a policy can potentially be of great benefit for future policy iterations, and to the accountability of water managers (Syme et al., 2000; Turner et al., 2005).

1.3 Research Questions

Therefore, this research sought to examine the relationship between the spatial and temporal variance of household water use, and to understand the drivers of household response to the Queensland Government demand-side policies. To do so, it also compared the Sunshine Coast to Brisbane, in order to isolate the effect of the water restrictions from the other demand-side measures. The thesis asks the following questions (which are further broken down into sub questions in Table 3):

1. How did household water use vary spatially and temporally from 2006–2009, and what structural, socio-demographic and psychological factors contributed to this variance?
2. Did specific household types and regions respond differently to the South East Queensland demand-side policies?
3. Which of the policy measures were the most effective, and why?

Table 1 Research Sub Questions

Main Question	Sub Questions	Thesis Section
1. How did household water use vary spatially and temporally from 2006–2009; and what structural, socio-demographic and psychological factors contributed to this variance?	1.1. How did household water use vary spatially over the period 2006-2009?	Chapter 4, 4.1
	1.2. Were structural, socio-demographic and policy factors significantly related to the spatial extent of household water use?	Chapter 4, 4.1, 4.2, 4.3
	1.3. Did socio-demographic variables significantly influence domestic water use at the Census Collection District (CCD) scale?	Chapter 4, 4.3
	1.4. Can selected socio-demographic variables be combined into a meaningful index to predict water use at a CCD scale?	Chapter 4, 4.3
	1.5. What are key individual attitudes and beliefs about water conservation?	Chapter 5, 5.1, 5.2, 5.3
	1.6. Can an expanded Theory of Planned Behaviour (TPB) be used to predict water use at the household level?	Chapter 5, 5.2
2. Did specific household types and regions respond differently to the SEQ demand-side policies?	2.1. Did households with certain structural characteristics change their water use to a greater or lesser degree in response to demand-side policy measures?	Chapter 4, 4.1
	2.2. Did households with certain socio-demographic characteristics change their water use to a greater or lesser degree over the study period?	Chapter 4/5, 4.3, 5.1
	2.3. Do householders who have lived in rural/water-stressed areas use less water than those who have not?	Chapter 5, 5.2, 5.3
3. Which of the policy measures were the most effective, and why?	3.1. Were the prescriptive water restrictions the most significant influence on household water use?	Chapter 4/5 4.2, 5.1, 5.3
	3.2. How did household water use vary temporally in response to each level of the prescriptive water restrictions?	Chapter 4 4.1, 4.2
	3.3. What were householder's attitudes and opinions of the Queensland demand-side policies?	Chapter 5 5.1, 5.2, 5.3
	3.4. What barriers prevent further reductions in water use?	Chapter 5 5.1, 5.2, 5.3

1.4 Methods and Analysis

To plan, monitor and adapt demand-side policies, water managers need the ability to predict small area variations in water use (Clarke et al., 1997; Durga Rao, 2005; Hillier, 2007). Without adequate micro-level data, it is difficult to pinpoint where and why water use reductions occur (Domene & Sauri, 2006; Hoffmann et al., 2006; Troy et al., 2005). It is also important to understand the spatial differentiation of household water use; why some areas consistently use greater quantities of water, and respond differently to various policy measures (Aitken et al., 1991; Wentz & Gober, 2007).

Mapping can be of great value in understanding a spatially-based phenomenon such as water use. It can reveal patterns of water demand not immediately obvious with other methods of data collection (Hillier, 2007). Therefore, mapping can be an essential aid to effectively target policy measures, and policy analysis. Maps quickly and graphically indicate areas of high water use, helping policy makers effectively target conservation campaigns or initiatives (Troy et al., 2005).

Mapping can also provide important insights into the relationship between various datasets, such as aggregate socio-demographic Census data and structural variables, such as land value and lot area (Hillier, 2007). For example, by using the technique of geodemographics (the socio-economic and spatial classification of populations), it is possible to identify if household socio-demographic characteristics influence spatial variations in water demand, and their response to specific policy measures (Clarke et al., 1997; De Oliver, 1999; Domene & Sauri, 2006; Durga Rao, 2005; Hillier, 2007).

Furthermore, household water use is not a static phenomenon; it also manifests temporally. When combined with statistical techniques, such as Getis Ord Gi* Hotspot analysis, a GIS can also be used to analyse temporal phenomena, such as changes in water use in response to time-dependent policy measures, like water restrictions. Evidence of strong spatial and temporal correspondence may be of great value to monitor the outcome of demand-side policies after implementation, and analyse the effectiveness of policy (Clarke et al., 1997; Durga Rao, 2005; Hillier, 2007).

Therefore, by combining spatial analysis with geodemographics, policy makers can better identify detailed variations in water demand (Clarke et al., 1997; Domene & Sauri, 2006; Durga Rao, 2005; Hillier, 2007).

Phase One

In order to address the research questions, a Geographic Information System (GIS) was used to examine the spatial distribution of household water use over the period 2006-2009. The dependent variable, household water use, and independent structural and socio-demographic variables, were mapped at the household, Census Collection District, and Local Government Authority (LGA) scale. This spatial analysis was also combined with geodemographics to better identify detailed patterns of water demand, such as areas of high water use. Statistical techniques used included simple Bivariate Correlations, Ordinary Least Squares Regression Analyses, Analysis of Variance (ANOVA) variants such as Generalized Linear Models (GLM) and Linear Mixed Models (LMM), Principal Components Analyses (PCA), and Structural Equation Modelling.

However, GIS mapping and statistical analysis are also inadequate to describe human behaviour; for example, how household water use behaviour changed in response to the policy measures. In addition, aggregate spatial groupings are not necessarily representative of the individuals within (the Ecological Fallacy)[3]. Because of this, aggregate datasets, such as CCD-level socio-economic data, cannot be verified without detailed household surveys (Clarke et al., 1997). Thereafter, a survey approach

[3] This is known as the Ecological Fallacy, and is detailed further in the Methods Chapter.

was used to explore more in-depth household attitude to conservation of water, and response to policy measures. A GIS was used to determine the area of interest and the spatial resolution, and to select a smaller stratified subset for the survey.

Phase Two

The second phase of the study was a large scale Questionnaire Survey. Combining methodologies allowed a deeper and more complex analysis of spatial datasets. This Questionnaire included questions on household water use behaviour. To match stated with actual behaviour , the survey responses were linked with actual water use records. General descriptive analysis was also used to identify socio-demographics of the sample, indoor and outdoor water use, and attitudes to policy measures and water conservation.

In addition, a robust, well-researched behavioural model, the Theory of Planned Behaviour (TPB), was used as a framework to investigate which behaviours were most influenced by the demand-side measures. The core elements of the TPB—attitude, subjective norm and perceived behavioural control—were extended with the additional variables—affect and past behaviour, to capture some of the affective and historical antecedents of behavioural change. Analysis of the Questionnaire data also entailed calculating the means, standard deviations and correlations between the TPB, affective and past behaviour variables. Finally, the SPSS module, AMOS, was used to create a model of household water use, using a combination of regression, factor analysis and Structural Equation Modelling.

Phase Two also included a semi qualitative analysis of the final open-ended question on the survey, which sought to clarify some in-depth beliefs of householders about water use, conservation and demand-side policies. Because the qualitative component of the study was relatively small, comprehensive qualitative analytical techniques were not used. Instead, basic text coding was used to organise comments into themes, which were identified both inductively, and from the literature, and then described in the text. Selected comments were also chosen to add deeper layers of meaning to the quantitative analysis of the Questionnaire.

Therefore, by using a mix of methods; the study aimed to understand some of the reasons how and why households changed their water use behaviour in response to the Queensland Government demand-side measures.

1.5 Research Design

The research project used an explanatory mixed methods design, with a combination of qualitative and quantitative methods (Ivankova et al, 2006; Massey, 1999). Every research method has limitations, but an explanatory mixed methods design allows a deeper and more meaningful comparison of quantitative data, such as household water use and demographic data, and qualitative data, such as opinions on water policies (Ivankova et al, 2006). This research design can also lead to a more complete understanding of the multiple socio-demographic characteristics of households. For example it is difficult to accurately analyse attitudes using only quantitative data, nor can this method address the “attitude-behaviour” gap (attitudes often do not manifest in actual behaviour), a common problem in behavioural research (Carrigan & Attalla, 2001).

The Questionnaire study used systematic random sampling within a random multistage cluster design. By including participants from all socio-demographic sectors, this enabled inferences to the wider population of South East Queensland (SEQ). Clustering was based on structural and geographical factors: i.e. detached households in Brisbane and the Sunshine Coast connected to reticulated water supplies. The final study design combined methods and tools, including Geographic Information Systems (GIS) mapping and quantitative and qualitative analysis of a Questionnaire survey (Figure 3).

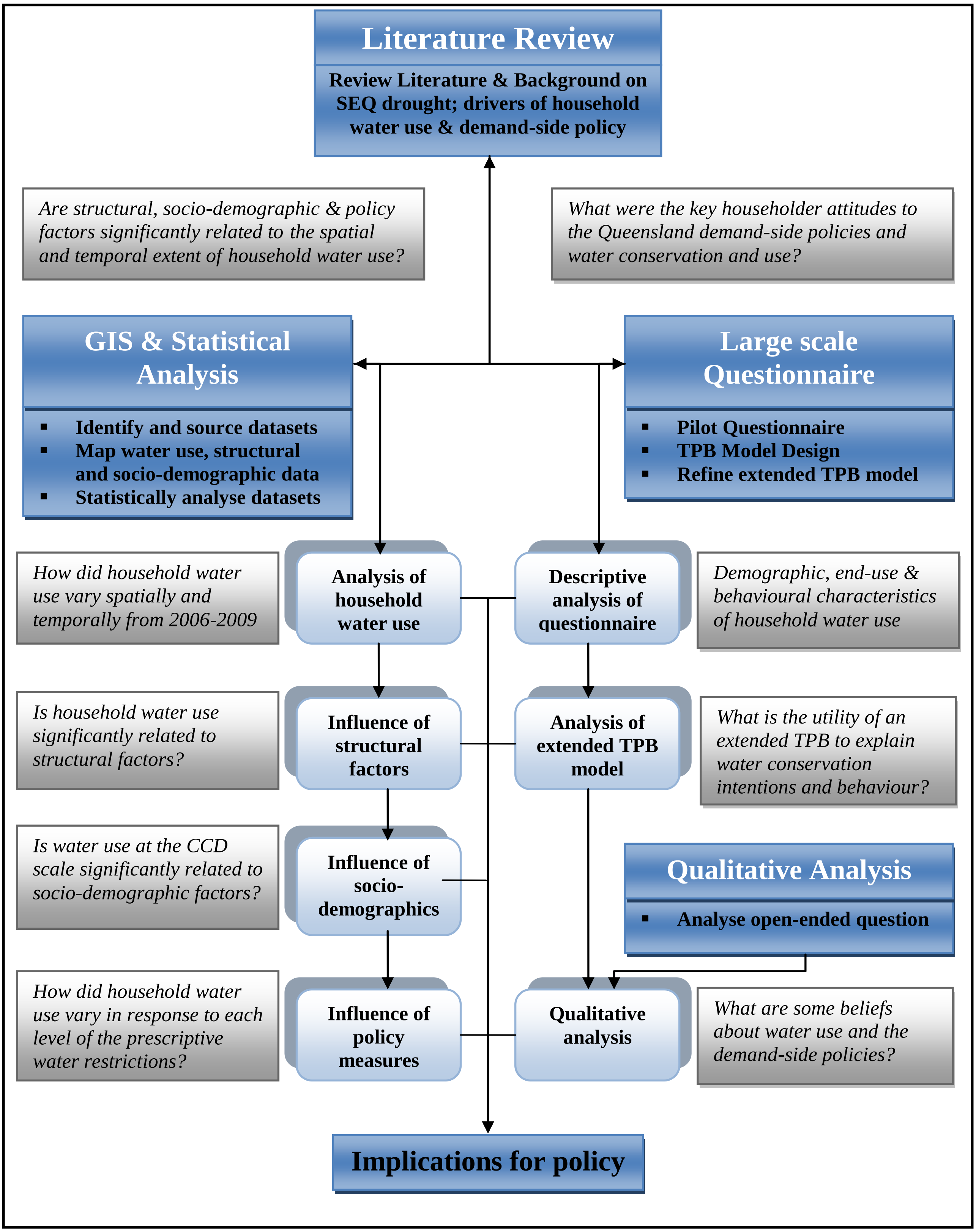

Figure 3 Research Design

1.5.1 Delimitations of scope

The study compared the urban household water use of Brisbane and the Sunshine Coast Local Government Areas (LGAs) of Maroochy and Caloundra. In 2008, the three LGAs were amalgamated into one Sunshine Coast LGA. However, during the research period (2006-2009), each LGA still collected water data separately, in a variety of formats. Because of data limitations, Noosa was excluded from this research; as was the Gold Coast, and the remaining rural LGAs in SEQ. This was not seen as a major limitation; as the Gold Coast had similar policies to Brisbane, and the other LGAs are largely rural, thus outside the scope of this investigation.

The reason for comparing the two LGAs was that the Sunshine Coast was the only LGA in SEQ *not* subject to the water restrictions. Further, Sunshine Coast residents exhibited very different water using behaviour to Brisbane residents (i.e. using reticulated water supplies to clean driveways). However, the Sunshine Coast has similar population growth and demographics to Brisbane. It is also relatively close to Brisbane, and many residents are employed, shop and entertain in Brisbane. Given that the major demand-side policy was the water restrictions, and these were not implemented on the Sunshine Coast, it was deemed a useful comparison site, especially to explore the psychological aspects of water use.

In addition, only the water consumption of detached houses was analysed; a departure from similar work where the water use of detached houses was compared with that of semi-detached units and apartments (Troy et al., 2005). This was also not considered a major limitation, as detached houses use the majority of urban water supplies. In addition, it was only possible to analyse per capita water use for the much smaller survey sample; so any extrapolations about per capita water use to the broader population should be viewed with caution.

1.6 Thesis Outline

Chapter Two reviews the literature, including a brief background on the global threats to water supply, and reasons for increased water demand. It describes common types of supply and demand-side water policy, and details how these were used during the SEQ drought. It summarises pertinent research into the drivers of household water use including structural (i.e. lot area, land value and swimming pools); socio-demographic (i.e. household size, income and education) and psychological (i.e. attitude and values). It also describes some theoretical perspectives on environmental behaviour, such as the Theory of Planned Behaviour (TPB). Finally, it gives critical examples of policy measures used to address water consumption, and how these interact with the determinants of water use.

Chapter Three outlines the research methods and tools used in the thesis. These included a Geographic Information Systems (GIS) based quantitative analysis of the spatial and temporal dimensions of household water use, a large-scale Questionnaire survey, and statistical analysis. The Chapter describes the datasets used, their custodians and the research procedures necessary to create the base GIS map for further analysis. It also describes the criteria by which participants were selected, and the sampling methodologies. The design, format and distribution of the Questionnaire are described, and some limitations to the methods are presented at the conclusion.

Chapter Four presents the results of the GIS analysis of household water data. It describes the statistical procedures used on the water and demographic data; as well as the mapping methodology. It summarises the results, and gives some limitations of the study, and justification for the methods used.

Chapter Five presents the results of the Questionnaire Survey. This analysis included descriptive statistical analysis; such as information on demographics, and a coded question linked to actual water use. It also describes the mapping and analysis of combined variables created with Principal Components Analysis. It also details the methods used in this analysis, such as Structural Equation Modelling. Finally, it presents a qualitative analysis of the final question in the Questionnaire; an open-ended question seeking opinions on demand side policy, and the “water crisis”.

Chapter Six discusses results obtained with the research, and relates this back to the research questions, and to the literature reviewed. It also concludes the thesis, discusses the contribution of the study, and concludes by giving limitations of the study, and directions for future research.

CHAPTER 2 DETERMINANTS OF HOUSEHOLD WATER USE

This Chapter summarises the areas of research relevant to the major research question posed in this thesis; "*How did urban household water use vary spatially and temporally in response to the South East Queensland demand-side policies, and what structural, socio-demographic and psychological factors contributed to this variance*?"

The chapter begins by discussing the various threats to water supply. It then discusses the determinants of water use, from the broad (total urban water use) to the specific (household water use). The determinants of household water use are discussed in order of classification, into structural, socio-demographic and psychological drivers. Some major theoretical perspectives applied to water conservation behaviour, and the links between behavioural change and socio-demographic variables are explored. The chapter then describes some of the better known theories of behaviour change, including the theoretical framework (an extended Theory of Planned Behaviour) chosen to address an aspect of the research question. Finally, the chapter gives a critique of different policy measures used to address household water demand, including those used in SEQ.

2.1 Urban Water Security

One of the most pressing natural resource management issues facing our society is maintaining security of water supplies (Darrel-Jenerette & Larsen, 2006; Pearce, 2006). Only 3% of the earth's water is fresh, and of that, only 5% is available for human use (the remainder is locked up in ice-caps and in groundwater) (Darrel-Jenerette & Larsen, 2006). Fresh water is also unevenly distributed; some more arid regions, such as Australia, have very little available freshwater.

Even in developed nations, such as Australia, agriculture is the largest consumer of fresh water (ABS, 2010c). However, the next highest use of fresh water is urban household supply. Worldwide, urbanisation is increasing; there is a continuing shift from rural areas to cities, and Australia is no exception; more than 85% of the population live in cities larger than 100,000 (ABS, 2007). These urban areas are dependent on natural resources such as water, sourced from a wide geographical area. Water sources include rivers, dams, groundwater, rainfall harvesting, desalination, interbasin transfers, and recycled wastewater. These sources are largely determined by geophysical factors; such as suitable catchments for dams, groundwater availability and climate.

However, the availability of fresh water is not just a function of physical supply and distribution; it is also a function of socio-economic and cultural factors, such as property rights, policy, economics, and historical methods of water capture (Darrel-Jenerette & Larsen, 2006). Until recently, water was seen more as common property than a market good (Barraque, 2003, p200; Vlek & Steg, 2007). This derived from the legal systems of Germany, and from Roman law; where water rights were maintained as part of the feudal system and Common Law (Barraque, 2003). However, when a resource is considered common property, it can be subject to the "tragedy of the commons" and ultimately depleted by the "innocent" action of many individuals (Hardin, 1968).

Furthermore, the lack of direct contact with the source of supply means urban end-users have relatively little concept of the quantity or quality of the resource. In rural areas without access to reticulated water, it is immediately obvious when supplies are running low. However, modern society has developed a complex, yet "invisible" system of water supply and distribution, whereby water users are almost completely removed from the source (Shove, 2003). The end users of urban water supplies are individual households, often with little or no knowledge of the level of supply (Kenney et al., 2008). The majority of households can easily access seemingly endless supplies of cheap, clean water at the turn of a tap (Allon & Sofoulis, 2006; Shove, 2003). Because of this, water has not generally been highly valued in developed nations; urban residents have grown so accustomed to high quality, cheaply priced water on demand, it is even used to flush wastes and clean streets. However, this waste does not reflect the true value of water, a finite resource, which is threatened by a range of factors.

Threats to urban water supply can be differentiated into threats to water quality, and threats to water availability. Threats to water quality include poor land management, pollution, failing river systems and aquifers, and poorly planned and ageing infrastructure (Allon & Sofoulis, 2006, p45; Birrell et al., 2005; Darrel-Jenerette & Larsen, 2006; Kolokytha & Mylopoulos, 2004, p391). Threats to water availability include climate change, increases in population and demographic change, increases in per capita water use, and allocations for conservation (Darrel-Jenerette & Larsen, 2006, p203). The major threats to water supply are discussed below.

Threats to water quality

Even before becoming available for urban use, water sources can be degraded and depleted by unsustainable land use, pollution and excess extractions. For example, constructing artificial barriers such as weirs and dams to create water storages can severely degrade downstream ecosystems, flood fertile land, and negatively impact on species habitats and breeding cycles.

Fresh water sources can also be polluted by a variety of point and non-point sources. Pollutants include agrichemicals, pesticides, industrial effluent, and sewage and stormwater runoff. Polluted waterways can be “cleaned up” and returned to relatively healthy function, but this is often a lengthy and expensive process. Water sources can also be polluted by other processes; such as clearing riparian vegetation, which can increase streambank erosion, and input sediment and land-based pollutants into waterways.

Ageing water supply infrastructure

Another threat to water quality (and water availability) is ageing water supply infrastructure. Many Australian urban areas have ageing water infrastructure; older materials and structural defects give rise to frequent leaks. For example, Brisbane can lose up to 70 Megalitres per year from leaking water pipes, burst water mains and other defective infrastructure (BCC, 2008). However, unless the leak is extremely severe, pipelines are often not replaced, as many pipes are overlaid by large buildings and other infrastructure, and replacing these is prohibitively expensive.

In addition, water supply is also subject to threats from availability from climate change, droughts and long term weather cycles, such as El Nino.

Threats to water availability

Climate Change

Possibly the most serious threat to urban water availability is climate change (Chong & White, 2009; Vlek & Steg, 2007; WSAA, 2010). Anthropogenic climate change is predicted to increase mean air temperature and rainfall variability. This is particularly relevant for Australia, the world's driest inhabited continent. Australia's climate is characterised by irregular rainfall patterns and frequent lengthy dry spells, and it is becoming drier. From 1950 to 2011, Eastern Australia was in a prolonged drying trend; SEQ recently experienced the worst recorded drought in history: from 2001-2009, rainfall trended on average 23.8% less than any other recorded period (Cai, 2009; NRW, 2007; QWC, 2008b).

Anthropogenic climate change is forecast to create further extremes, such as lengthier and stronger droughts (Cai, 2009). Water availability is likely to decrease to an even greater extent, as a reduction in rainfall can have a proportionately greater reduction in dam inflows, due to catchment drying, vegetation loss, bushfire and increased extractions from rivers (Cai, 2009; 2006; WCWA, 2005). This has serious implications for urban water supply, particularly in densely populated areas such as the east coast of Australia.

Increases in Population and Demographic Change

Increased population growth is the other major threat to water supply; some state that population growth is *the* major determinant of increases in total urban water demand (Birrell, O'Connor, & Rapson, 1999; Domene & Sauri, 2006; Troy et al., 2005). Globally, and in Australia, urban areas are growing rapidly (Darrel-Jenerette & Larsen, 2006). For example, South East Queensland, Australia, recently had growth rates exceeding that of Sydney and Melbourne. Some Local Government Areas (LGAs) in SEQ experienced growth rates of nearly 4% per annum, and by 2031, greater Brisbane was projected to grow by nearly 60% (ABS, 2006b; Birrell et al., 2005; OUM, 2005). This growth rate slowed somewhat during the Global Financial Crisis (GFC), but it is still high relative to other parts of the country.

Increases in water demand due to population growth are also exacerbated by demographic change. The ageing population and decline of the “nuclear family” (comprising two parents and their children) has resulted in an increase in singles and non-traditional families. Overall, household size is getting smaller; the Australian average is now 2.6%; and by 2026, this is projected to decrease to between 2.2 and 2.3% (ABS, 2010a). Single households are the fastest growing household type in Australia (WSAA, 2010). The sheer growth in numbers of older people alone will result in a significant proportion of the increase in households (Birrell et al., 1999; Birrell et al., 2005; Grove et al., 2006; Hoffmann et al., 2006). The increase in population, together with demographic change, means that numbers of households are increasing faster than population growth. For example, by 2026, dwelling numbers are projected to increase by 39-47%; which is greater than the projected 25% increase in population

(ABS, 2010a). In Melbourne, for example, a 33% growth in population has been accompanied by a 51% growth in households (Birrell et al., 1999, p10).

This has serious implications for water supply, as smaller households tend to use more water per capita than larger households (Troy et al., 2005). Furthermore, smaller households are less able to reduce water use, as larger households can use economies of scale to cut per capita water use (Harlan et al., 2009; Troy et al., 2005). Another complicating factor is that demographic changes are relevant more for increases in indoor water consumption, which is harder to address with policy measures than is outdoor water use.

Urban areas thus face increased pressures on water supply simply from demographic change (Birrell et al., 2005). Even if household water consumption remains consistent, urban water demand is likely to keep rising—at the same time as more frequent droughts are lowering supply (Clarke et al., 1997; Domene & Sauri, 2006; J. Stewart, Turner, & Gardner, 2005). Because of the combination of population growth and demographic change, by 2031, total urban water use in some metropolitan areas may grow by up to 37% (Birrell et al., 2005; R. Stewart, Willis, Giurco, & Capati, 2010). For example, by 2031, it is estimated that the combination of urban growth and demographic change will increase Melbourne's water consumption to 582 Gigalitres per year; which is greater than the currently available supply (Birrell et al., 1999, p13). Sydney's water supplies are more parlous; Sydney's predicted water demand is likely to exceed available supplies before 2031 (Birrell et al., 1999, p15).

Brisbane, with its high population growth rates, is just as vulnerable. Population growth alone is estimated to double Brisbane's household water demand. Considering demographic changes, estimates are, by 2031, Brisbane's water consumption will increase by 37% (Birrell et al., 1999). Brisbane also has a higher proportion of detached houses with gardens than other capital cities, and households on larger lots tend to use greater quantities of water for outdoor uses, mostly due to larger gardens.

These threats to water quality and water availability, together with increased urban growth and demographic changes means that urban water demand is likely to keep rising, increasing pressure on water supplies (Birrell et al., 2005; Clarke et al., 1997; Turner et al., 2005). Therefore, it is important to consider some of the drivers of household water demand, particularly of high water use.

2.2 Determinants of Household Water Use

At the broadest scale, total water use is a function of population, climate and price: more people use greater quantities of cheaper water on hotter days (Birrell et al., 2005; Clarke et al., 1997). However, when disaggregating demand to the micro level, such as the individual household, water use cannot be directly linked to a few overarching causes, but to a complex interaction of multiple structural, socio-demographic and psychological factors (Browne, Tucker, Johnston, & Leviston, 2007; Gilg & Barr, 2006; Kenney et al., 2008; Vlek & Steg, 2007; Zhang & Brown, 2005).

Even at the city scale, water use is not homogenous; the spatial variation of demand can differ markedly, even between small areas (Durga Rao, 2005; Troy et al., 2005; Wentz & Gober, 2007). However, little research exists on how and why water demand varies spatially across urban areas and what factors determine urban water use, particularly at the smaller scale (Hoffmann et al., 2006; Troy et al., 2005). Complicating the matter is that controlling for these makes it difficult to isolate the exact marginal effect of any one factor (Kenney et al., 2008).

At the household scale, water use can be differentiated into outdoor and indoor use. The determinants of outdoor water use are generally structural factors, such as dwelling type and urban form; which is why total water use is often higher in the outer suburbs, with large detached houses and bigger gardens (Domene & Sauri, 2006; Wentz

& Gober, 2007). On the other hand, determinants of indoor use are generally socio-demographic, and include household size, income, education and age (Harlan et al., 2009; Troy et al., 2005). Moreover, some drivers, such as income, influence both outdoor and indoor use; for example, higher income households tend to have larger houses and gardens, with more water using features, such as swimming pools.

Research into the small scale drivers of water demand has generally focussed on two major dimensions; structural and socio-demographic—i.e. climate, lot and house size, income and education; and psychological constructs—i.e. attitudes, beliefs and values (Clark & Finley, 2007b). Substantial research has been conducted on structural and socio-demographic factors, but less has been conducted on psychological constructs and how these interact with other determinants to influence behaviour (Birrell et al., 2005; Domene, Sauri, & Paracos, 2005; Syme, Shao, Po, & Campbell, 2004, p122). Socio-demographic characteristics influence behaviour by influencing attitudes. For example, attitudes to water conservation might differ between a highly educated individual, and one with no formal education (Clark & Finley, 2007b; Domene & Sauri, 2006; Zhang & Brown, 2005).

For the purposes of this thesis, artificial categories have been imposed upon the multiple determinants of household water use. These categories should not be considered exclusive, as they can have multiple synergies and overlaps, For example, income and affluence cannot be viewed in isolation from education, as both are highly intercorrelated. Bearing this in mind, this thesis classified the determinants of household water use into the following overarching categories, Structural, Socio-demographic and Psychological Constructs (summarised in Table 1):

Table 2 Main Drivers of Urban Household Water Use

Sources: (Birrell et al., 1999; Browne et al., 2007; Clarke et al., 1997; Gilg & Barr, 2006; Harlan et al., 2009; Hoffmann et al., 2006; Redman, Grove, & Kuby, 2004; Vlek & Steg, 2007; Zhang & Brown, 2005).

Determinant	**Details**
Structural • Climate • Lot area • Garden Type • Dwelling Type • Swimming pools & other water features	Households on larger lots generally have greater outdoor water use, but indoor water use is usually consistent despite the urban form. Older houses generally use more water, mostly because of older technology. Garden type can have a major impact on outdoor water use, depending on plant type, size of lawns and water features like swimming pools and spas (also related to income and education).
Socio-Demographics • Age • Gender • Income • Education • Household Size • Household Makeup	Household size is often the major socio-demographic influence on total water use; although per capita, smaller households sometimes use more water. Income is also an important influence, higher income households tend to have larger houses and gardens and more appliances, thus use greater volumes of water. Age and gender are less significant for water use.
Psychological Constructs • Attitude • Subjective norms • Perceived Behavioural Control • Affect • Past Behaviour • Identity	Attitudes can influence intention to conserve water, although not necessarily behaviour. Also mediated by subjective norms and perceived behavioural control. Other important drivers are; affect (the influence of emotional responses to resource use); past behaviour (previous experiences in water stressed areas may create water saving habits in the future); and group identity (identifying with a specific social group may influence beliefs about resource use).

Using the classification above, this section begins by describing some of the structural factors that influence water use, which are described in descending scale levels, from the broad regional level (climate) to the specific local level (swimming pools). Thereafter, the section describes the major socio-demographic and psychological drivers of household water use.

2.2.1 Structural (Property Level) Factors

In this thesis, the word 'Structural' is used to describe those physical determinants that exist prior to the interaction of the household with the resource, and are related to the wider environment, such as climate, urban form and lot area. In general, structural factors are more generally drivers of outdoor rather than indoor water consumption. Structural factors are also interrelated with socio-demographics; for example, swimming pools and larger gardens and houses reflect individual choices and socioeconomics (Harlan et al., 2009). This study investigated the major structural factors found in the literature to predict higher levels of water use; such as climate, lot size, and swimming pools (Birrell et al., 1999; Domene & Sauri, 2006; Syme, Porter, Goeft, & Kington, 2008).

Climate

Climate is interrelated with other structural factors, such as lot area and water using equipment. Houses on large lots usually use more total water, as they have larger gardens, and often swimming pools or spas, and all require more water in times of lower rainfall and high evaporation. Climate is mostly relevant only for outdoor water uses, as indoor water use generally remains consistent despite the rainfall or season (Syme et al., 2004). In general, households in arid climates are likely to use more water in the dry season for outdoor uses such as irrigating gardens, filling swimming pools or washing cars (De Oliver, 1999; Harlan et al., 2009; Jorgensen et al., 2009). Because climate can be an important confounding variable, especially for outdoor water use, this needs to be controlled for, especially in regression based analyses (Kenney et al., 2008).

Lot area

Lot area can be related to higher levels of outdoor water use; total household water use is often higher in the outer suburbs, with large lots and areas of landscaped gardens (Domene & Sauri, 2006; Troy et al., 2005). In general, outdoor water use is broadly dependent on garden size: the smaller the garden, the lower the outdoor water use. Because of this, promoting urban consolidation is a major goal of many urban settlement policies in Australia. The creators of such policies assume that increased densification will reduce outdoor water use, because gardens will be small or nonexistent, and other uses not dependent on urban form, such as washing cars, will be simpler to control with prescriptive legislation (Birrell et al., 2005; Troy et al., 2005).

However, the assumption that increased densification will lead to improved environmental outcomes remains contested. Urban densification policies, together with zoning and development controls, can influence the form of preferred settlement and individual dwelling characteristics, such as lot area. However, relatively little research has been conducted into the longer term impacts of these policies, particularly on small scale characteristics such as population density and actual resource use (Rickwood, Glazebrook, & Searle, 2008).

One attempt to model the "best" outcomes of urban consolidation policies on water use evaluated four water demand scenarios, which modelled varying trajectories of growth and urban densification for major Australian cities (Birrell et al., 1999). The scenario with the highest degree of consolidation was the most effective in reducing total water demand, primarily because of reductions in garden size[4].

However, densification outcomes differed between metropolitan areas. Although, the urban consolidation process had progressed to a greater extent in Sydney, this is due more to the spatial constraint of natural features, than to successful policy outcomes (Birrell et al., 1999). Indications are that urban consolidation has not markedly reduced water use; smaller households in high rise apartments were found to use more water per capita than households in the outer suburbs (Troy & Randolph, 2008). In other metropolitan areas, the mostly aspirational state planning schemes will likely not achieve the desired levels of urban consolidation; new land releases are constrained by economic factors, such as infrastructure charges, rather than by policy measures.

[4] Scenario D assumed current urban consolidation measures achieved the goals of increasing density and reduced detached housing growth.

The most important caveat to urban consolidation policies is the inelasticity of housing supply. Even if these policies ultimately achieve their goals, housing stock changes slowly over time, and has a slow replacement rate. For example, in Perth, the marked expansion of detached housing in the 1990s and beyond will likely influence urban resource use long into the future (Birrell et al., 1999, p21).

Finally, contrary to the assumption that detached houses with gardens use more water; detached households maintained water conservation after mandatory restrictions eased to a greater extent than other household types (De Oliver, 1999, p389). This was possibly because such householders changed gardening practices and installed water saving technology, continuing passive water conservation after the short-term crisis ended (De Oliver, 1999, p 389).

Gardens

Few accurate statistics exist on the actual water use of houses with large gardens (Birrell et al., 1999, p13). In one model, that categorised gardens into large, medium and small; medium gardens were estimated to use 60% of a large garden, and small garden to use 25% of a large garden (Birrell et al., 1999; WSAA, 2010). This is a fruitful area for further research.

Garden water use is also related to socio-demographic factors, such as housing tenure, income and affluence. Wealthier householders are likely to have larger, better maintained gardens, with swimming pools and other water using equipment, and are more likely to be homeowners than renters (Harlan et al., 2009; Syme et al., 2004, p126; Wentz & Gober, 2007, p1851). Contemporary landscaped gardens, with expanses of green turf and non-native plants, especially if on sandier soils, are also heavy water users.

However, urban consolidation policies aimed at reducing lot and thus garden size, may have unforseen repercussions. Gardens play important social roles, and can be considered as part of national cultural heritage (Aitken et al., 1991; Allon & Sofoulis, 2006; Askew & McGuirk, 2004; Browne et al., 2007; Syme et al., 2004). Gardens offer quality of life benefits not necessarily recognised by policy-makers; a sense of place, family values, property value, manifestations of affluence, and relationship with nature (Allon & Sofoulis, 2006, p51; Syme et al., 2004, p122). People also have strong affective attachments to gardens. Gardens are seen as a safe sanctuary and places for social interaction, private recreation and relaxation (Askew & McGuirk, 2004; Browne et al., 2007). Those with deep emotional attachments to their garden can be deeply distressed by plant deaths in times of drought (Browne et al., 2007).

Gardens can also motivate innovative water recycling and sustainable consumption, such as increased purchases of organic food and non-toxic herbicides (Allon & Sofoulis, 2006; Browne et al., 2007; Gilg & Barr, 2006). Restricting gardening activities impinges on the connectedness to nature, and can reduce social and neighbourhood interaction, possibly undermining social networks (Allon & Sofoulis, 2006, p52; Browne et al., 2007). Finally, gardens also have environmental values; they provide habitat, and garden trees shade houses, helping reduce energy and water use.

In conclusion, gardens provide a multitude of beneficial environmental, social and economic values. Thus, planning and demand-side policies to reduce garden size or eliminate gardens are not likely to succeed, because of deeply entrenched social and cultural meanings, as well as the overall value of gardens. Furthermore, planning against gardens raises some troubling ethical issues like decoupling man from nature.

Swimming Pools

In addition to the previous determinants of household water use, such as lot size and garden type; a significant determinant of outdoor water use is the presence of water using equipment such as swimming pools (Domene & Sauri, 2006; Troy et al., 2005; Troy & Randolph, 2008; Willis, Stewart, Talebpour, Mousavinejad, & Jones, 2009).

Indeed, the presence of a swimming pool can be the most important factor for increased levels of outdoor water use (Eardley, Parolin, & Norris, 2005; Harlan et al., 2009; IPART, 2007; Randolph & Troy, 2008; Willis et al., 2009). Residents of detached houses with swimming pools tend to use increased levels of water, ranging from 144Kl per annum more than those without pools (IPART, 2007). Other studies concur, finding that households with pools use approximately twice as much water as those without pools (Gato, 2006; Wentz & Gober, 2007).

Policy measures placing constraints on discretionary water use (such as filling swimming pools) can significantly reduce household water use (Hoffmann et al., 2006). However, evaporation is the major cause of water loss from pools, especially in Summer, and pool covers have been proven to reduce evaporation, but few householders regularly use these (Aitken et al., 1991; Troy et al., 2005).

Of note, swimming pools are also strongly intercorrelated with income; wealthier households tend to have swimming pools (Domene & Sauri, 2006; Harlan et al., 2009; Loh & Coghlan, 2003; OECD, 2008). Therefore, this highlights the importance of understanding the complex interaction of structural and socio-demographic factors when investigating household water use.

House Size

Garden and lot area are some of the primary structural determinants of outdoor water use, but an important structural determinant of indoor water use is house size. House size has a direct relationship to household water use; particularly for indoor water use, as larger houses are likely to have more water using appliances (Wentz & Gober, 2007). House size is often linked with socio-demographic factors, such as household size and affluence. Larger households tend to live in larger houses, and household size is a major determinant of water use (Browne et al., 2007`; Troy et al., 2005). Of note, although larger families generally live in larger houses, smaller families do not necessarily live in smaller houses. For example, over the last 20 years, Australian house size has increased nearly 20% (Demographia, 2009). The average Australian house, at 215m^2, is the largest in the developed world (Demographia, 2009; Martin, 2009). In general, house size is usually not as significant a determinant of water use as socio-demographic factors, such as household size, income and education (Clarke et al., 1997; De Oliver, 1999; Zhang & Brown, 2005).

2.2.2 Socio-demographic factors

Unlike outdoor water use, indoor water use is influenced more by socio-demographics than by structural factors (Troy et al., 2005). Wide differences in water use can exist between households with similar lot areas, but dissimilar socio-economic characteristics. This is a potentially fruitful area of research; at fine spatial scales, such as the household, relatively little comprehensive research exists controlling for the influence of socio-demographic factors on urban water use (Domene & Sauri, 2006; Troy et al., 2005).

However, information on the spatial distribution of socio-demographic factors is essential for targeted policy formulation. For example, if certain socio-demographic groups use more water, future information campaigns can be more finely targeted towards these groups, with overall cost savings and more effective outcomes. Therefore, understanding if and how socio-demographic groups respond to changes in policy, is potentially of great significance for future policy iterations.

Household size

The major determinant of indoor water use is the number of people living in the house (Birrell et al., 2005; Syme et al., 2000; Wentz & Gober, 2007; Zhang & Brown, 2005). However, the relationship of water use to household size is complicated. Total water use is determined by household size, but per capita water consumption is generally highest for single person households and decreases non-linearly for every additional member of the household (Domene & Sauri, 2006; Harlan et al., 2009; Turner et al., 2005). This is because indoor water consumption is driven by economies of scale. Indoor water consumption comprises general household use (i.e. washing clothes and dishes) and personal use (i.e. showering, cleaning teeth, flushing toilets). Therefore, smaller households can reduce personal use, but it is more difficult to reduce general household use (Birrell et al., 1999; Domene & Sauri, 2006; Turner et al., 2005, p6).

However, other socio-demographic factors besides household numbers also influence water use, and these include income, education, age and gender.

Income and Education

Income is a consistently important influence on water use, its influence can be negative or positive. For example, higher income households often use more water and energy because, as affluence increases, so do total numbers of appliances, size of gardens, and swimming pools (Allon & Sofoulis, 2006; Corral-Verdugo, Bechtel, & Fraijo-Sing, 2003; Gregory & Di Leo, 2003; Randolph & Troy, 2008; Syme et al., 2004). On the other hand, higher income residents can have a greater capacity to reduce water use, because they are often better educated, more environmentally aware, and can afford better quality appliances with improved water efficiency (Barr & Gilg, 2006; Hoffmann et al., 2006).

However, in a survey of 17,000 households taking up a home retrofit program indicated that healthcare/veteran cardholders (i.e. lower income residents) had proportionately higher water savings than the overall average (Turner et al., 2005, p7). Households with relatively “modest” incomes also recycled water on a regular basis, often in innovative and creative ways (Allon & Sofoulis, 2006, p49). In contrast, some high income householders said if they could afford to pay for a resource, they could use as much of it as they wished (Browne et al., 2007).

Of all socio-demographic groups, high income and high education households responded the least to voluntary water conservation measures (De Oliver, 1999). However, once mandatory policy such as water restrictions was imposed, these households responded to a greater extent than other socio-economic groups. Of note, although the degree of response was greater, the overall reduction was similar to other socio-demographic types, likely because the high-income group used proportionately more water to begin with (De Oliver, 1999). This research was based largely on correlations, but it largely concurs with other studies (Turner et al., 2005).

Income is also highly intercorrelated with education; higher income individuals tend to have higher levels of education (Clark & Finley, 2007b; De Oliver, 1999; Harlan et al.). Education is often assumed positively related to pro-environmental behaviour; the better educated the individual, the more likely that individual is to expresses positive attitudes towards, and the intention to practise pro- environmental behaviours (Clark & Finley, 2007b; De Oliver, 1999). However, the assumption that those individuals with more positive attitudes are more likely to practice pro-environmental behaviours can be subject to the “attitude-behaviour” gap, in that attitudes do not necessarily predict actual behaviour (Jackson, 2005; Lucas, Brooks, Darnton, & Jones, 2008).

Other socio-demographic factors

The influence of other socio-demographic variables, such as age, gender and ethnicity is contested. For example, increasing age is often related to positive environmental attitudes, but younger residents tend to be more environmentally aware and use less water (Clark & Finley, 2007b; Corral-Verdugo et al., 2003; Corral-Verdugo, Carrus, Bonnes, Moser, & Sinha, 2008). Conversely, young people, such as teenagers, are often assumed to use *more* water (Domene & Sauri, 2006; Troy et al., 2005; Wentz & Gober, 2007, p1851).

These apparently conflicting influences of age might result from the research methods than actual behaviour. Survey research is often biased towards older homeowners, who are also usually the bill paying member of a household (Tonglet, Phillips, & Read, 2004). Survey research can also be biased towards home owners or single family renters, and do not take into account alternate arrangements, such as the tendency for younger people to live in shared accommodation (Birrell et al., 2005, p9). In conclusion, it is unlikely that younger people are less environmentally aware. However, younger people may have less time for environmental concerns, particularly when establishing relationships and careers.

Gender is also contested, and its influence on resource use unclear. Even when significant, the influence of gender is usually weak (Davis, Phillips, Read, & Iida, 2006; Gregory & Di Leo, 2003).

Tenure is also interrelated with income, as lower income households tend to rent instead of own their properties. Some older householders have low incomes, but can still be relatively asset-rich. Tenure can influence higher levels of water use; for example, owner occupied houses tended to use more water than rented houses, mainly to maintain gardens (Syme et al., 2004, p136).

2.3 Household water use behaviour

However, both structural and socio-demographic variables influence household water use because of their effect on human behaviour (Domene & Sauri, 2006). Complicating the matter is that water is more than a natural resource used in supply and demand-based economic transactions. Water has complex cultural meanings that are deeply resistant to change, and are largely ignored (or unknown) by water managers (Allon & Sofoulis, 2006, p45). Many water uses are embedded in habit and everyday practices, with little conscious thought given to them (Allon & Sofoulis, 2006, p46; Shove, 2003).

Therefore, to fully understand the determinants of household water use, it is also important to recognise the complex cultural and social meanings of water use; how it is embedded in a complex system of technology, cultural meaning and social interaction; and how psychological factors can interact with structural and socio-demographic factors to influence water use behaviour (Allon & Sofoulis, 2006; Clarke et al., 1997; Gregory & Di Leo, 2003).

In general, the literature on household water use behaviour can be differentiated into two main categories; the influence of situational (structural) and socio-demographic factors on behaviour; and the influence of psychological factors on behaviour (Clark & Finley, 2007b). The literature on the psychological drivers of water use behaviour is relatively sparse, and includes affective concern, awareness and knowledge, environmental attitudes, beliefs about fairness and equity, perceptions of benefit, attitudes and environmental worldview (Corral-Verdugo et al., 2008; Gatersleben, Steg, & Vlek, 2002; Gilg, Barr, & Ford, 2005; Jackson, 2005; Trumbo & O'Keefe, 2005);Table 2). However, a large literature exists on the determinants of other pro-environmental behaviour, such as recycling, use of public transport, environmental activism and energy use (Gilg et al., 2005; Hinds & Sparks, 2008; Jackson, 2005).

Many broad conceptual social psychological theories have been devised to explain the determinants of resource use behaviour (Jackson, 2005). Excess water use is, fundamentally, a psychological problem (Barr & Gilg, 2006). Therefore, in order to investigate household water use, some of the better known theoretical frameworks are briefly discussed.

2.3.1 Theoretical Perspectives of Pro-Environmental Behaviour

Conceptual models are frameworks to help understand the psychological factors driving behaviour (Jackson, 2005). Models can generally be classified into Rational Choice, Values-based, Social or Combination theories (Jackson, 2005).

Rational Choice models are typically based on classical economic theory, and assume reasoned decision making by individuals to maximise net benefits (Jackson, 2005). Commonly used in policy formulation, these underpin most incentive and pricing mechanisms. Rational Choice models aim to address the psychological precursors of behaviour, such as attitudes and intentions, and include the Theory of Reasoned Action (TRA) and its later iteration, the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Ajzen & Fishbein, 1973; Armitage & Conner, 2001; Jackson, 2005).

Rational Choice models have been extensively criticised because of the limitations of cognitive deliberation, the influence of affect and the omission of moral and altruistic behaviours (Jackson, 2005). The focus on the individual also neglects the mediating influence of the social and cultural environment. Despite these criticisms, such models are used extensively in research, and are often adapted to include additional variables such as moral norms and past behaviour (Armitage & Conner, 2001; Clark & Finley, 2007b; Jackson, 2005).

In contrast, Values-based theories assume that pro-environmental behaviour results, not from a desire to maximise net benefits, but from a sense of moral values. For example, those holding a set of core biospheric values, known as the “New Environmental Paradigm” are assumed more likely to engage in pro-environmental behaviour than those holding individual, egoistic values (Clark & Finley, 2007b; Corral-Verdugo et al., 2008). Value Based theories include Schwartz’s Norm Activation Theory which assumes that behaviour change results from awareness of an issue, which activates personal norms and thus changes behaviour (Jackson, 2005).

However, Values-based theories tend to attribute behaviour to psychological factors at the expense of situational factors (known as the Fundamental Attribution Error). For example, despite a person holding strong environmental values, their behaviour can still be constrained by external factors, such as income or tenure

(Jackson, 2005; Troy et al., 2005). Both Rational Choice and Values-based Theories are also subject to the Attitude-Behaviour Gap: attitudes often do not predict actual behaviour (Gatersleben et al., 2002; McKenzie-Mohr & Smith, 1999; Troy et al., 2005).

Although both Rational Choice and Values Based models focus on the individual, Social Based models attempt to understand how behaviour is mediated by the wider societal context. These models are based on Anthropology, developmental Psychology and Evolutionary Biology. For example, Social Identity Theory is based on Group Psychology, and asserts that identifying with a group creates positive cognitive and affective feeling, and thus influences behaviour (Jackson, 2005; Tajfel, 1979).

However, it is unlikely that a single theory can explain all the variance of human behaviour; for many behaviours, it is difficult to identify psychological factors or even the direction of causality (Gilg et al., 2005; Jackson, 2005; Lucas et al., 2008). Because of these issues, psychological frameworks sometimes have low explanatory power; explaining at best, 25-33% of the variance in behaviour (Jackson, 2005). However, a robust theoretical framework can help policy makers understand the psychological determinants of environmental behaviour, thus aid effective, targeted policy formulation (Randolph & Troy, 2008). A flexible and well-researched conceptual framework such as the TPB—with proven predictive ability for intentions to behave—can potentially help understand some of the complex subtleties underlying changes in household water use behaviour (Tonglet et al., 2004).

2.3.2 Theory of Planned Behaviour

The TPB is a Rational Choice model developed from the Theory of Reasoned Action (Armitage & Conner, 2001; Jackson, 2005; Tonglet et al., 2004). In both, the immediate antecedent of behaviour is the intention to behave, and this intention is mediated by attitudes and the subjective norm (Ajzen, 1991; Clark & Finley, 2007b; Hinds & Sparks, 2008; Tonglet et al., 2004). The TPB also incorporates the concept of

Perceived Behavioural Control (PBC)—the belief in the ability to undertake a behaviour—to help explain intention to behave in the absence of full control (Ajzen, 1991; Armitage & Conner, 2001; Hinds & Sparks, 2008).

As with other Rational Choice models, the TPB has been extensively criticised, particularly as it is subject to the Attitude Behaviour Gap, which is borne out by its low explanatory power for actual behaviour (Browne et al., 2007; Gilg et al., 2005; Gregory & Di Leo, 2003; Jackson, 2005; Lucas et al., 2008). Self-reported behaviour often does not reflect real behaviour; for example, many householders falsely claim they regularly recycle (Gilg & Barr, 2006; Tonglet et al., 2004). Likewise, householders often claim to use less or similar water to others, despite meter readings to the contrary (Troy et al., 2005). Therefore, the TPB has relatively high predictability for intention to perform a behaviour, but is markedly lower for actual behaviour.

Despite these criticisms, the TPB is a flexible and robust psychological model, which can be used to understand why pro-environmental choices are made, and the determinants of those choices (Tonglet et al., 2004). The TPB been extensively used to predict intentions for resource use behaviour such as recycling (Tonglet et al., 2004); energy use (Poortinga, Steg, & Vlek, 2004); environmental activism (Fox-Cardamone, Hinkle, & Hogue, 2000); and transport choice behaviour (Bamberg & Möser, 2007).

Because of the widespread use in similar research, an extended TPB model was constructed to help understand the variance in household water use behaviour in response to the Queensland demand-side policies. The final model aimed to identify which aspects of water use behaviour were most influenced by the policy measures; for example, whether attitudes to water conservation were more influential than social norms. The final model was used to match stated intentions with actual water use. Using actual water consumption data linked to survey data eliminated some of the problems arising from self-reported behaviour.

The following section briefly describes the core components in the context of the TPB, as well as the additional variables used to create the proposed model.

Attitude

Attitude is an individual's belief and cognitive evaluation of the outcome of behaviour (Armitage & Conner, 2001; Francis et al., 2004; Hinds & Sparks, 2008). Whether the TPB measures both cognitive and affective attitudes is contested. In practice, it is often difficult to separate these; as these likely fall on a continuum rather than being discrete measures. However, many argue that many TPB studies only capture the rational aspect of attitude, and many water use behaviours can have a distinct affective component (Allon & Sofoulis, 2006; Head & Muir, 2007; Hinds & Sparks, 2008, p111; Shove, 2003; Vining & Ebreo, 2002).

Relatively few studies on the relationship between attitudes and water conservation exist, and attitudes to water use can vary markedly (Browne et al., 2007; Head & Muir, 2007). In a Taiwanese study, the strength of a "social desirability scale" influenced attitudes, but not actual water use behaviour (Lam, 1999). In another study, positive attitudes towards gardening were significant for higher levels of water use (Syme et al., 2004, p128). Earlier studies found no significant relationship between attitudes to gardening and water use; but these were possibly flawed, as they did not separate indoor from outdoor water use (Syme et al., 2004).

In many cases, positive attitudes towards water conservation do not translate to changes in actual behaviour (Aitken et al., 1991; Jorgensen et al., 2009). However, awareness of (outdoor) water use behaviours can break habits, and thus reduce water use (Gregory & Di Leo, 2003). Further, in Reno–Sparks, Nevada, the provision of information was shown to influence attitudes, and thus behaviour (Trumbo & O'Keefe, 2005). Despite this, water use is often determined more by the broader cultural context, and is often simply a function of logistics, than attitude or belief (Vlek & Steg, 2007).

Subjective Norms

The other major component of the TPB is the Subjective Norm; which is the perceived social desirability of a behaviour, and how important others, such as friends and family, feel about the behaviour (Clark & Finley, 2007b; Francis et al., 2004). Perceived social pressure to conform can be an important behavioural modifier, especially when combined with social identity; for example, the belief in a local norm for a green, landscaped garden could result in greater water use (Domene & Sauri, 2006; Gilg et al., 2005; Grove et al., 2006; Head & Muir, 2007; Jackson, 2005; Syme et al., 2004).

Subjective norms can also motivate positive behavioural change; for example, householders might emulate their neighbours pro-environmental behaviour (Gilg et al., 2005; Grove et al., 2006). This could even lead to conflict; in one area, those who viewed themselves as water conservers, expressed strong disapproval of neighbours who they viewed as water wasters (Head & Muir, 2007). Subjective norms are further influenced by context, such as economic status, technology and socio-cultural factors. For example, affluent households may use more water for garden maintenance because of a perceived loss to property values and a negative attitude towards those seen to neglect their property.

Perceived Behavioural Control

However, in reality, behavioural choice is not always fully volitional. For example, renters have a reduced control to install water saving appliances, and installing these in rented properties does not provide any personal long term economic benefit (Lucas et al., 2008; Randolph & Troy, 2008; Troy et al., 2005). Therefore, Ajzen reformulated the TRA to include another variable, Perceived Behavioural Control (PBC). If a behaviour is perceived to be effective, it is more likely to be practiced. Improving the convenience of an environmental action can also improve uptake, if it is believed that the behaviour will not mean sacrificing comfort or convenience (Allon & Sofoulis, 2006; Gilg et al., 2005; Shove, 2003). For example, in a UK recycling study, PBC added little to the variance; because recycling was seen as easy, and the community had high levels of recycling knowledge (Tonglet et al., 2004). In general, PBC is only significant when a behaviour is perceived as difficult.

The PBC is sometimes differentiated into separate constructs, such as locus of control and self-efficacy. For example, “curtailment” behaviour (i.e. reducing water use by choosing to take shorter showers) is considered completely under volitional control, but behaviour moderated by “efficiency procedures” (i.e. reducing water use because of flow restricting devices); is not under full volitional control (Lam, 1999). Like the Social Norm, PBC is a fundamental part of the dominant social culture; affluence can play a major role in response efficacy, as affluent people have greater resources to change personal surroundings and act more effectively (Allon & Sofoulis, 2006; Gilg et al., 2005; Head & Muir, 2007; Jackson, 2005; Troy et al., 2005).

Extending the TPB: Other Sources of Behavioural Influence

Although the TPB is commonly used in research, the links between intention and actual behaviour are often weak (Clark & Finley, 2007b). At best, the TPB only explains between 27% and 39% of the variance in intentions to behave, and less for actual behaviour (Armitage & Conner, 2001). Thus, if this markedly increases the predictive ability of the model, the addition of other variables is acceptable (Ajzen, 1991; Armitage & Conner, 2001; Hinds & Sparks, 2008). Additional variables included in TPB studies are identity and affect, moral obligation, and past behaviour (Allon & Sofoulis, 2006; Clark & Finley, 2007b; Hinds & Sparks, 2008; Lam, 1999; Tonglet et al., 2004; Trumbo & O'Keefe, 2005; Zhang & Brown, 2005).

For example, socio-demographics, environmental attitudes, information and concern about the future were added to a model that accounted for 27% of variance in intention to reduce water use; with TRA variables explaining 67% of that (Trumbo & O'Keefe, 2005 239). Another study attempted to differentiate between intention to reduce water use and installing water saving devices; and added additional variables to the TPB—perceived water rights and moral obligation (Clark & Finley, 2007b; Lam, 1999). This model explained a relatively large proportion of the variance in intention to reduce water use (41%), although explained a lesser variance (24%) in intention to install water saving equipment (Clark & Finley, 2007b; Lam, 1999). Finally, in Bulgaria, environmental attitudes, socio-demographics, and worry about water shortages in the future were added to the base TPB (Clark & Finley, 2007b). In this model, the variables of age, education, gardens and awareness and concern for global issues were all significant, but explained a relatively low 26.8% of the variance in intention to conserve water (Clark & Finley, 2007b).

Affect

The most persistent criticism of the TPB is that it fails to fully account for affective influences on behaviour (Ajzen, 1991, p118; Jackson, 2005; Tonglet et al., 2004). Traditional TPB questionnaires usually address this issue by ranking feelings about the behaviour on a positive to negative continuum, but some consider that affect such an important influence on behaviour, that it should be considered as a separate construct (Hinds & Sparks, 2008; Tonglet et al., 2004).

Water use is possibly more affectively driven than many other environmental behaviours, with "…*sensory, experiential, habitual and affective qualities*" (Allon & Sofoulis, 2006). Water using activities are pleasurable, providing comfort and addressing modern standards of cleanliness, It is simple to turn on a tap and have instant clean hot water for daily laundering and lengthy showers (Allon & Sofoulis, 2006, p52; Shove, 2003). Water also plays a vital role in maintaining relationships; sites of water use, such as swimming pools and the garden can be important areas of social interaction (Allon & Sofoulis, 2006, p50; Head & Muir, 2007; Shove, 2003).

Affect is apparently linked with past behaviour; for example, a past rural childhood contributed to greater affective connection to the environment (Hinds & Sparks, 2008). A rural rather than urban childhood created more positive and stronger attitudes towards the natural environment, a stronger identification with nature, intentions to engage in environmental behaviour and greater PBC (Hinds & Sparks, 2008). The more noteworthy the experience, the greater the influence of affective over cognitive attitudes.

The Role of Past Behaviour and Habit

An additional factor omitted from many behavioural models is the strength and persistence of habitual, unconscious behaviour (Jackson, 2005). Many behaviours result from rapid decision-making based on emotional cues or subconscious intuition, than from logical reasoning or cognitive attitudes (Cooke & Buckley, 2008; Gilg et al., 2005; Jackson, 2005). However, establishing the direction of causality can be difficult; habitual behaviour such as recycling might positively influence environmental attitudes, instead of vice versa (Gilg et al., 2005; Jackson, 2005).

Habit is linked to past experience; repeatedly practising a behaviour often results in habituation, a psychological shortcut that frees up cognitive processing for more important tasks (Jackson, 2005). Water use is often habitual and embedded in everyday practices; for example, water technology delivers high quality water with ease, and disposes of it after one use, without requiring conscious thought (Allon & Sofoulis, 2006; Gilg et al., 2005; Jackson, 2005; Shove, 2003).

As with affect, Ajzen considered past experience as contributing to attitude, instead of being a separate construct (Ajzen, 1991). However, past experience has been shown to directly influence intention and behaviour without prior mediation by the standard TPB variables (Hinds & Sparks, 2008). For example, past experience of the environment led to greater empathy, connectedness and nature protective behaviour, and added 8% to the variance of the TPB model (Hinds & Sparks, 2008). In a UK study, TPB variables explained 26.1% of the variance in intention to recycle, with attitude the most significant predictor. However, when past behaviour was included in the model, the predictive ability of the extended TPB increased to 33.3% (Tonglet et al., 2004).

For example, in China, Tianjin residents, habituated to the long-term unreliability of water supplies, use 60% less water per capita than Beijing residents with similar socio-demographic profiles, and despite Beijing's many water conservation campaigns (Zhang & Brown, 2005). Other studies concur, finding that levels of awareness influence habit, and thus changes in water consumption behaviour (Gregory & Di Leo, 2003, p1282). For example, residents of Western Sydney who practised water conservation behaviour, such as recycling grey water, were found more likely to have experienced water scarcity (Allon & Sofoulis, 2006, p50; Head & Muir, 2007). A relationship with past experience and ethnicity was also evident; elderly immigrant women engaged in generational water collection practices, such as collecting grey water to maintain vegetable gardens (Head & Muir, 2007). Very generally, migrants and older Australians were more frugal than younger, native born residents. Therefore, some of the influences of age on water use may be attributed to past experience conserving water (Gregory & Di Leo, 2003, p1284).

These structural, socio-demographic and psychological determinants of water use are largely beyond the control of water managers and policy makers, at least in the short term (Kenney et al., 2008). However, water managers can influence household water use by means of various policy measures, either implemented alone, or more commonly, as part of a suite of measures. As policy measures are often influenced by structural and socio-demographic factors, these can be of varying efficacy. Furthermore, the majority of policy measures are often ineffective in reducing indoor water use, and maintaining lower water use after short term crises, such as droughts. Therefore, encouraging permanent reductions in water use will likely require long-term behavioural changes, so that water conservation becomes habitual (Gilg & Barr, 2006; Jackson, 2005).

2.4 Water Policy

However, the most common method used to manage urban water use is by policy measures. Governments and water managers generally implement a range of policy measures aimed at increasing storage and supply and reducing demand. Such policies are generally discrete, but some overlap between supply and demand-side policy can occur; for example, by providing incentives to install rainwater tanks. Therefore, some common policy measures used to manage urban water use are described, with emphasis on the policies used by the Queensland State Government.

2.4.1 Supply-Side Policy

The basic definition of supply-side water policy is the treatment and distribution of potable water from the source to the domestic end-user and excluding provision for agriculture (Cairncross & Valdmanis, 2006). Standards of acceptable supply vary widely between societies, increasing with economic prosperity and degree of development.

Urban water policy typically evolves through three temporal phases that succeed one another along a generalised continuum. These stages include: 1) large scale supply-side policies and water transfers; 2) localised supply-side policies and water treatment, and 3) integrated supply and demand-side management and pollution control (Barraque, 2003).

Stage 1 is one of quantitative, supply side policies, with water transfers supplying water to urban areas, and is typically characterised by mega infrastructure projects, such as the Snowy Mountains Interbasin Transfer Scheme. Such infrastructure serves multiple purposes apart from urban supply, such as irrigation and hydroelectricity. During droughts, water managers generally focus on increasing bulk supply; if one dam dried, plentiful suitable land existed for new dams, and if these failed to fill, external catchments were targeted. This stage is still prevalent world-wide, especially in developing countries (Barraque, 2003).

However, constructing new bulk infrastructure is often unsuccessful; rainfall patterns change and new dams are often controversial for their negative environmental effects on fisheries, wetlands, and salinisation. New dams can also have economic, political and social repercussions. Therefore, with an increasing focus on the costs of bulk water supply schemes, many developed countries have progressed to State 2, qualitative supply-side strategies (Barraque, 2003, p206).

In Stage 2, water is sourced and treated locally. This reduces investment in infrastructure, but higher quality treatment standards results in greater operational costs. Although the end-user pays for water deliveries, the price of water is still relatively cheap in comparison to median incomes. Furthermore, people are increasingly accustomed to clean, fresh water “at the turn of a tap” (Allon & Sofoulis, 2006; Barraque, 2003, p207; Shove, 2003).

However, the predominantly supply-side focus of Stages 1 and 2 can have limitations, such as ageing infrastructure and the lack of funding for replacement. Full cost pricing can also lead to decreasing demand by big users, such as industry. In addition, customers become increasingly accustomed to the concept of no or minimal risk, and demand ever higher quality standards. Because of this, the price of water supply and treatment keeps increasing (Barraque, 2003, p208). Finally, local supply-side options also have negative environmental effects, and still require expensive, major infrastructure, suitable dam sites and sufficient rainfall.

Therefore, water managers in developed nations have increasingly moved to the third stage of water management; policies aimed not at increasing supply, but at reducing demand at the household level. Such policies are typically less expensive than supply side options, and have fewer environmental impacts (Clarke et al., 1997; Hoffmann et al., 2006; Kolokytha & Mylopoulos, 2004; Turner et al., 2005).

The third stage of water management includes integrated river management; pollution control at the source and demand-side management (Barraque, 2003, p206). Water managers increasingly diversify their business, using new methods to improve supply, such as protecting catchments; and seeking alternative supply, such as desalination, recycling and water buy-backs from agriculture (Barraque, 2003, p208-9). A range of demand-side policy measures exist; including prescriptive policy measures, such as price increases, and water restrictions, and voluntary policy measures, such as awareness campaigns and incentives (Kenney et al., 2008)..

2.4.2 Demand-side Policy

Demand-side policy can be defined as:

> "*The adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability."* (Vairavamoorthy & Mansoor, 2005).

<u>Benefits of Demand Side Policies</u>

Demand-side policies, such as restricting domestic water use, generally have fewer environmental impacts and lower costs than supply-side polices (Kolokytha, Mylopoulos, & Mentes, 2002, p391). These policies are also less socially contested—less land is required for resumption for water infrastructure, and less contested politically—new infrastructure such as large dams and desalination plants can lead to community dissatisfaction. Reducing household water demand also has multiple environmental benefits including reducing catchment water demand, reducing discharge to waterways and decreasing greenhouse gas emissions (CSIRO, 2006).

However, implementing universal demand-side measures can still be costly. Some demand-side measures are politically unpopular, particularly if a policy requires major behavioural changes, such as reducing indoor water use. In such cases, many apparently prefer supply-side (engineering) solutions (Kolokytha et al., 2002, p395). Mandatory policies, such as high level water restrictions, can also lead to community backlash, particularly when “normal” rainfall resumes, and the restrictions are retained. However, these issues can be successfully addressed if demand-side policies are marketed as achieving the “triple bottom line” of environmental, social and economic sustainability, are transparent, and genuinely involve consumers in water management (Barraque, 2003, p 209).

Many demand-side policies still maintain a core supply-side philosophy; viewing water consumers as a large aggregate mass and targeting entire populations at the macro scale, with blunt instruments such as restrictions or education campaigns (Allon & Sofoulis, 2006, p45/6). Few policies take account of how water use is embedded in a complex system of technology, cultural meaning and social interaction. Water also has various emotional and cultural meanings beyond practical uses; as well as complex interactions with socio-demographic characteristics (Allon & Sofoulis, 2006, p46).

Furthermore, some demand-side policies have relatively minor influence on household water use; for example, water price is largely inelastic, and price increases often do not result in reductions in use (Kenney et al., 2008; Kolokytha et al., 2002); restrictions are often only effective during droughts, and often only target outdoor water use (Browne et al., 2007; J. Stewart et al., 2005; Zhang & Brown, 2005).

In practice, it is difficult to separate the effects of individual components of policies (Kenney et al., 2008, p194). Thus, an entire suite of policy measures should be assessed as a whole, particularly when investigating attitudes to policy, as these can differ markedly depending on the type of policy and the individual concerned.

Classification of Demand-Side Policies

It is possible to classify demand-side measures in many ways; such as pricing and non-pricing policies, and mandatory and voluntary policies (Kenney et al., 2008). Mandatory policies such as water restrictions are imposed from the top, as opposed to the bottom-up approach of voluntary policies, such as incentives or rebates, which depend on individual decisions (Mankoff, Matthews, Fussell, & Johnson, 2007, p1). As this thesis focuses on the SEQ demand-side policies, which did not use pricing mechanisms, this thesis classifies demand-side measures into voluntary policy—i.e. incentive schemes, rebates and education campaigns, and mandatory regulation—i.e. restrictions, taxes and pricing (Kolokytha et al., 2002, p391; Lucas et al., 2008). Demand-side policies can also be classified by scale and time; but many permutations and sub-classifications exist. For example, the SEQ Demand Management Strategy (2007) classifies demand management into "5Es" (Table 2).

- <u>Encouragement</u> (Voluntary). Incentives, rebates and persuasive marketing aimed at purchasing water saving products and behaviour change.
- <u>Education</u> (Voluntary). Awareness-raising programs.
- <u>Economic</u> (Mostly Mandatory). Pricing, and other economic instruments, such as taxation, also includes "Encouragement" mechanisms such as rebates.
- <u>Enforcement</u> (Mandatory). Regulation, restrictions, fines and requirements to install water efficient technology.
- <u>Engineering</u> (Mandatory and Voluntary). Includes leakage control, smart metering and water sensitive urban design.

Table 3 Effectiveness of demand-side policies in reducing water use

Type	Sub-Type	Scale	Effectiveness
Mandatory	Planning policy Building Codes & Standards *Enforcement* *Engineering*	Long Term City-wide	Mostly a long term policy measure, but targets some major structural drivers of water use, i.e. lot and garden size. In rapidly growing urban areas, can influence domestic water use in relatively short time timescales. Building codes and standards can reduce water use over the long term, i.e. by mandating compulsory water tanks. Usually only effective for new construction.
	Pricing *Economic*	Long Term (or short term crisis driven) LGA level	Needs to be relatively high to be effective. Mostly targets bill-paying household member. Generally only effective for lower income groups, thus can have equity implications. Water demand is also relatively price inelastic.
	Restrictions *Enforcement*	Long & Short term (depends severity) LGA level	Effective for outdoor use, but can lead to dissatisfaction with government when crisis is over. Community also resistant to reducing "essential" indoor use, such as toilet flushing.
Voluntary	Awareness Raising & Education *Education and Encouragement*	Short & Long term Local, LGA, City wide	Awareness of an issue not necessarily related to behavioural change (attitude-behaviour gap). Difficult to isolate the actual effect of campaigns. Dependent on level of education, or access to information sources (hence income).
	Rebates & Incentives *Education, Encouragement, Economic*	Short term Local to State	Popular, but dependent on income, education and tenure. Also expensive for water managers, and not necessarily effective in reducing overall water use. Similar to technology retrofits.
	Technology retrofits *Engineering, Education*	Short & Long term Local	Number of appliances related to water use. "Easy" way to conserve water without changing behaviour. Can be costly, needs education about benefits; more suited to higher socio-economic groups; ability limited by control, (tenure).

Mandatory Measures

<u>*Planning Policy and Building Standards*</u>

Planning policy aims to influence structural factors, such as dwelling type and lot size. These can be key determinants of water use, given that total household water use is often higher in the outer suburbs, with larger, detached houses and gardens

(Birrell et al., 2005; Domene & Sauri, 2006; Troy et al.; Wentz & Gober, 2007). Planning policy uses codes that allow for denser development; which is assumed to have a flow-on effect, reducing use of environmental goods, such as water (Birrell et al., 1999). In the long term, policies aimed at increasing urban density can reduce sprawl, but not necessarily levels of household water use. However, a direct relationship between smaller lots and lower water use is not a given. On a per capita basis, those living in smaller households in the denser, more affluent inner-city suburbs, can use more water than those living in the outer suburbs (Troy et al., 2005). Furthermore, planning policy mostly addresses outdoor water use, as indoor water use is largely independent of urban form (Domene & Sauri, 2006; Hoffmann et al., 2006; Troy et al., 2005).

However, planning policy cannot influence socio-demographic determinants of water use, such as household size, which is a major driver of water use. Despite this, in the long term, the promotion of alternate housing configurations, such as higher density developments, can discourage larger households, as these may not be the preferred residential choice of families with children (Wentz & Gober, 2007, p1861).

Building and construction standards are related to planning policy. Setting standards for construction type and installation of water tanks can reduce household water use, particularly for newer houses. For example, in NSW, planning approval requires minimum BASIX standards for new dwellings (Bunker, Holloway, & Randolph; Randolph & Troy, 2008; Troy et al., 2005). The BASIX (or Building Sustainability Index) sets energy and water reduction targets for new residential dwellings (NSW, 2011). Likewise, the Queensland Development Code requires that all new houses built after 1 July 2007 must achieve water savings targets, primarily by mandating rainwater tanks with a minimum 5000L capacity for new detached houses.

However, both planning policies and construction standards are long term policy measures. Although these will likely improve future environmental outcomes, the majority of housing stock remains as existing dwellings, which have a lengthy turnover, of decades or longer. For this reason, planning policies and construction standards are unlikely to have had any impact on SEQ household water use during the drought.

Pricing Policy

Water pricing is commonly used to reduce household water demand (Hoffmann et al., 2006; Kenney et al., 2008, p194; Zhang & Brown, 2005). Pricing policy can take many forms, from simple increases to highly complex block pricing schemes. However, there is conflicting evidence on the effectiveness of price on water demand, as demand is largely price-inelastic (Kenney et al., 2008). Price increases can influence the water use of lower income groups, but are of minimal influence on higher income groups as, for this group, water bills comprise a proportionately smaller share of total household bills. Large price increases can also have serious equity implications for lower income households (Domene & Sauri, 2006; Harlan et al., 2009; Troy et al., 2005).

The relative ineffectiveness of pricing policy is supported by research findings. For example, although the majority of surveyed households in Thessalonika, Greece, thought price was an effective method to reduce water consumption, but more than 50% reported that price had little relevance to their *own* water use (Kolokytha et al., 2002). Furthermore, due to equity implications for lower income households, pricing policy, particularly in developing nations, requires complicated instruments, such as block pricing, in combination with changes in other policy, such as taxation. Price is generally also only an effective determinant for the bill-paying member of the household; higher prices only indirectly affect other household members, such as teenage children.

In addition, water use is billed usually retrospectively, and most water bills provide little useful feedback on water use, or improve awareness of unconscious or habitual water use behaviour (Hoffmann et al., 2006; Troy et al., 2005). Comparing resource use with others can effectively reduce consumption but water bills generally only provide a comparative mechanism for a single household's historical water use, and do not easily allow comparisons with other households. However, since approximately 2006, Brisbane water bills allowed spatial and temporal comparisons with past water use, and the average for households in the same suburb (Queensland Urban Utilities, 2011). However, the SEQ demand-side measures did not include any changes to pricing policy. Block pricing was raised in a parliamentary research paper in 2005, but was never implemented (Hoffmann et al., 2006).

Restrictions and Fines

Often used in concert with various water pricing regimes, restrictions can be an effective tool to reduce water use, with the key benefits of preserving scarce supply, and delaying or even preventing the need to source alternative, and often expensive supply(Chong & White, 2009).

If used alone, restrictions can be a blunt policy instrument, and only reduce consumption to a limited extent (Birrell et al., 2005; Jackson, 2005; Troy et al., 2005). Restrictions are most effective when combined with awareness-raising or media campaigns (Chong & White, 2009).

Restrictions can also influence long term behaviour; for example, Canberra residents, with long experience of permanent water restrictions, were more accepting of these than were Perth residents, who had briefer experience of water restrictions (Browne et al., 2007). Restrictions are particularly effective when accompanied by pressure to conform to subjective norms, such as publicising the names of high water users (Birrell et al., 2005; Hoffmann et al., 2006).

Restrictions are often more or less effective depending on factors such as socio-economic status, type of water users (i.e. high, medium or low) and whether the area is in drought (Kenney et al., 2008). Restrictions are often ineffective during wetter periods, and can lead to community dissatisfaction, as some consider water supply shortages result more from political mismanagement and the tardy provision of infrastructure (Browne et al., 2007; Spearritt, 2008; Troy et al., 2005). Maintaining strict, permanent restrictions also leaves fewer options for policy makers to use in short term crises, such as droughts (WSAA, 2010).

Furthermore, restrictions are mostly effective only when mandatory; voluntary restrictions can often have little effect on water consumption (Kenney et al., 2008, p195). However, restrictions can have marked impact in the short term, if accompanied by motivations to comply (i.e. fines), environmental values, or a perception that water is scarce, and that others are also conserving water(Jorgensen et al., 2009).

Water restrictions almost always target outdoor uses such as hosing driveways and washing cars. Restricting outdoor use can markedly lower water consumption levels, but in some areas indoor uses can comprise as much as 50-70% of total demand (Water Corporation, 2009). Therefore, even if all outdoor use is forbidden, this may not markedly reduce total water demand (Birrell et al., 2005; J. Stewart et al., 2005; Zhang & Brown, 2005). Projected supply shortages and increases in water demand may necessitate reducing demand to a greater degree than is possible by restricting only outdoor uses (Kenney et al., 2008, p195; Troy et al., 2005).

However, reducing indoor water use is difficult. Outdoor water use is mostly driven by structural factors, such as garden size, and climate; but indoor water use is influenced by a complex combination of demographic, socio-cultural and psychological factors (Allon & Sofoulis, 2006; Birrell et al., 2005; Shove, 2003). Using water restrictions to reduce indoor use can pose problems with monitoring and enforcement. There is also resistance to reducing some indoor uses, like toilet flushing, because of social norms of cleanliness and hygiene. Forgoing or reducing indoor use also involves sacrificing comfort and convenience; as well as reduced expectations of high quality, low priced water on demand (Allon & Sofoulis, 2006; Birrell et al., 2005, p6; Shove, 2003; Troy et al., 2005). Underlying this is an implicit assumption that water shortages can be blamed on individuals, who are expected to make personal sacrifices for the failure, unsustainability and wastefulness of the large institutional system on which they are almost totally dependent (Allon & Sofoulis, 2006 p49).

Despite some criticisms, water restrictions played a major part in the SEQ demand-side policies. From May 2005, the majority of SEQ was subject to varying levels of water restrictions (Table 3). These restrictions only targeted outdoor use, except for Level 6, which specifically included high water users. At the time of writing (September 2010) all SEQ was subject to permanent water restrictions with a target of 200 LCD[5]. Although, as a whole, the Sunshine Coast only came under the QWC water restriction regime on 1 December 2009, in July 2007, the Maroochy Shire Council implemented Level 2 water restrictions; restricting garden watering to between the hours of 4am-8am and 4pm-8pm on an odds and evens basis, with no watering permitted on Mondays (MSC, 2007).

[5] As of August 2010

Table 4 Table of Brisbane Water Restrictions (Section 360ZE of the Water Act 2000)

	Watering (per week)	Vehicles/Hard Surfaces	Pool
Level 1 13/05/05	3 days; 4-8am/pm	Vehicles – Yes Driveways – No	Hose
Level 2 03/10/05	3 days; not 7am-7pm	Vehicles – Yes Driveways – No	Hose
Level 3 13/06/06	Established – Bucket only Not 7am-7pm	No hard surfaces	3 days - top up
Level 4 01/11/06	Bucket only; 3 days; 4-8am/pm,	Vehicles – Bucket No hard surfaces	Ok if water saving devices + tank
Level 5 10/04/07	Bucket 4-7pm, 3 days. Users >800LCD-forbidden	Glass clean + boat engine flush	Ok if water saving devices + tank
Level 6 23/11/07	No lawns, gardens bucket, only; 3 days 4-7pm. restrictions for high users	Glass clean + boat engine flush	Ok if water saving devices + tank
High Level Target 170 31/07/08	Bucket only; 3 days; no lawns	Vehicles – bucket No hard surfaces	3 days - top up; Ok if water saving devices + tank
Permanent 1/12/2009	Sprinkling ok, not 10am-4pm	Vehicles permitted	Filling ok if efficient fittings

The water restrictions apparently reduced household water use. From the first date of imposition in May 2005, to December 2009, household water use dropped by nearly 80% (QWC). However, the restrictions were not the only demand-side policy used, so before attributing causality, it is important to consider the confounding effect of the other measures such as, penalties for breaching restrictions, fines for excessive water use, and specific measures aimed at high water users.

More often, in crisis situations, such as droughts, the initial policy response is voluntary, short term demand-side policy, such as education and awareness campaigns.

Voluntary Measures

Education and Awareness Campaigns

Awareness-raising is a common method used to address a multitude of environmental issues. Most environmental-based campaigns include some awareness-raising component, as awareness is generally a precursor to behavioural change

(Gregory & Di Leo, 2003). In general, awareness-raising campaigns follow a linear model, assuming that if people are aware of an issue, they will act on it (Jackson, 2005). In reality, there is often minimal relationship between levels of awareness and actual behaviour; sometimes those most aware of an issue do not practise conservation behaviour (Gregory & Di Leo, 2003; Vining & Ebreo, 2002). For example, the amount of individual Carbon Dioxide emissions often bears little relation to an individual's degree of environmental awareness (McKenzie-Mohr & Smith, 1999).

Awareness influences behaviour to a greater or lesser degree depending on the type of behaviour, ability to change and perceived importance of the issue (Gregory & Di Leo, 2003; Jackson, 2005). Awareness is also mediated by contextual factors, such as efficacy, convenience and logistics (Mankoff et al., 2007, p1). For example, many are unwilling to make major lifestyle sacrifices but if a pro-environmental behaviour is shown to be straightforward and easy; many support and participate in such actions (Allon & Sofoulis, 2006, p43; Gilg & Barr, 2006; Jackson, 2005).

Some prerequisites for awareness-based change are allowing bottom-up participation and mechanisms to compare behaviour with others (Beekman, 1998; R. Stewart et al., 2010). This may include tools such as "Smart Meters" (real time monitoring of water or energy use). Greater awareness also improves the ability to make informed choices; as well as bring everyday actions, such as habitual water use, to consciousness (Gregory & Di Leo, 2003, p1282; Mankoff et al., 2007; R. Stewart et al., 2010). For example, many householders inaccurately estimate their actual water consumption, with many claiming to use average or less water than others (Gregory & Di Leo, 2003; Kenney et al., 2008, p194; Kolokytha et al., 2002, p394; Randolph & Troy, 2008). Therefore, increasing awareness of water use can help monitor or even change behaviour (Syme et al., 2000). In general, because of a real, or perceived, lack of public knowledge and the relative cost effectiveness of such measures, awareness-raising often plays a major role in demand-side policy, usually in the form of an information campaign(Jackson, 2005 ; Syme et al., 2000).

Target 140

The Queensland Water Commission's Target 140 Campaign was a voluntary awareness-raising campaign, that later changed into a mandatory target (QWC, 2008a). On 9 March 2007, the aspirational (and later mandated) target of 140 litres per capita was announced, which became known as the Target 140 Campaign. Aspects of the Target 140 Campaign included daily reports of total water consumption (on the QWC website); regular media reports on dam levels, online information on dam levels, and tools to compare personal water use with the average use of other Brisbane suburbs.

The Target 140 Campaign was supported by television, print, outdoor and radio advertising, and included communications material on how to reduce indoor water consumption, such as taking shorter showers; only washing machines with full loads; installing dual flush toilets, and applying for Home WaterWise subsidies (described in the following section). In addition, the QWC issued regular press releases, with headings such as "*Target 140 beaten again*"; "*Three months under Target 140*" and "*SEQ achieves Target 140*" (QWC, various media releases). These detailed the week's consumption, praised residents of SEQ for achieving, and beating, Target 140, and were often reported in the mainstream media.

A Target 140 website was constructed with news on water use, and weekly water consumption and dam levels. It also included simple instructions how to reduce household water use, such as how to monitor water meters. This campaign was also supported at a local government level; the Brisbane City Council released their own Target 140 material, with water saving information, quizzes on personal water use, and educational material aimed at all members of a household.

Unusually for such measures, the Target 140 Campaign also specifically targeted indoor water use, particularly shower times. Prior to the campaign, average shower time was estimated to be 7 minutes, but the Target 140 campaign aimed to reduce the average to 4 minutes. To do so, a 4 minute shower timer and information booklets were distributed to 1.1 million SEQ households, including households on the Sunshine Coast (Spiller, 2010).

For example, in a press release, Elizabeth Nosworthy, the then Chair of the QWC stated; "*We're asking all South East Queenslanders to take* ***personal responsibility*** *for achieving 'Target 140' as a region…over two-thirds of consumption occurs in households and our water security depends on us all saving water* ***inside*** *the home "(Nosworthy, 2007)*(bold text, author).

Despite the success of voluntary demand-side measures, promoting pro-environmental behaviour, some are still more likely to comply with mandatory than voluntary initiatives (Kenney et al., 2008; Wentz & Gober, 2007). It is also difficult to quantify the actual influence of voluntary policies. As a result, many mandatory measures, such as pricing and restrictions, are often used in concert with voluntary measures, such as awareness-raising. Interestingly, the Target 140 campaign was a voluntary demand-side measure that evolved into a mandated measure.

Subsidies, Incentives and Rebates

Instead of using disincentives, subsidies and rebates use rewards to encourage householders to voluntarily reduce water use. Incentive based policies can be very popular; for example, over 350,000 residential households in Sydney, Australia, took up a retrofit program known as Every Drop Counts (or WaterFix) (Turner et al., 2005, p6). The WaterFix service involved a visit by a registered plumber, replacing showerheads (with low flow showerheads), installing flow regulators on taps and toilet cistern arrestors, checking leaks and providing information on household water savings (Turner et al., 2005, p1).

A large scale evaluation of the WaterFix program found that it was possible to determine total savings as well as savings for sub groups (not everyone participated in all aspects of the program) [6]. Participants and non-participants were matched by geographic proximity, and paired comparisons used to contrast proportional water savings (Turner et al., 2005). Overall water savings for the program equated to a total annual savings of 3,344 ± 400 Megalitres per annum for retrofitted detached houses (Turner et al., 2005, p1). In total, 22 out of the 40 Sydney suburbs had significant relative savings. Of particular note, some higher income (mostly north-east) suburbs showed large drops in consumption, on a per capita and per household basis (Turner et al., 2005, p7).

Similarly, after demand management programs were implemented in Thessalonika, Greece, “prodigal” water users had a high potential for water savings. Some 12% of surveyed householders classified themselves as “prodigal water users”, and 50% of these thought reducing water use would have no impact on them (Kolokytha et al., 2002). Similar results were apparent for higher income, higher water users in San Antonio Texas; although these only responded to mandatory and not voluntary water conservation measures (De Oliver, 1999, p390). The rate of consumption for these users in the period with mandatory restrictions was 16.8%, as opposed to the average rate of 24.8% (De Oliver, 1999, p389).

However, the larger water savings of upper income suburbs may just reflect that such suburbs used more water to begin with, thus the savings only occurred because of the greater reduction possible—i.e. a household using 300LCD is less able to reduce its water use than a similarly sized household using 700LCD (Kolokytha et al., 2002;

[6] With a sample size of 17,000 detached houses

Turner et al., 2005). The degree of advantage is directly related to higher water use, but lower income groups can still have high potential for water savings (Eardley et al., 2005, p37; Turner et al., 2005). For example, lower income suburbs in Western Sydney had a higher take up of the WaterFix program; as many householders believed the rebates and incentives would help save water, and thus money (Turner et al., 2005).

Likewise, the SEQ demand-side measures included incentives and rebates on water tanks, water efficient appliances and fixtures and fittings such as toilets and shower heads. Similar to WaterFix, Home WaterWise was a Queensland government-funded campaign that paid for a licensed plumber to carry out a range of water saving initiatives in SEQ households. Householders paid a small sum ($20), for water savings advice, identification of leaks, provision of flow restrictors on taps and one low flow showerhead.

In addition, a paid rebate of $1500 was offered on water tanks, which was raised for tanks plumbed into the main water supply. In certain LGAs, this was matched with additional funding. As of the 31 December 2008, the scheme was cancelled, although for some time afterwards, householders could still apply for $500 water tank rebates from the Federal Government.

In total, the Queensland Government paid $261 million in subsidies for approximately 508,000 water tanks, toilets, washing machines and water efficient toilets. Nearly 21% of existing households took up the water tank rebate (Spiller, 2010). According to QWC research, these effectively reduced household water use. Consumption was reduced by 31% if a rebate was paid for a water tank, 34% if a rebate paid for shower, toilet and washing machine, and 40% for all four (shower, toilet, washing machine and water tank) (Spiller, 2010).

In general, rebates and incentives are often very popular in the community. However, they can be expensive and in some cases, do not necessarily lead to large water savings in relation to their cost. For example, in Sydney, water savings for non-plumbed rainwater tanks were considerably lower than estimates, and had higher costs (Turner et al., 2005).

Improvements in Technology

Another policy measure to reduce water use is to replace old wasteful technology with modern appliances that use less water (and energy). This can reduce water use, as the number of water using appliances is directly proportionate to total water use (Aitken et al., 1991; Domene & Sauri, 2006; Gregory & Di Leo, 2003; Randolph & Troy, 2008). In addition, water efficient technology can reduce water use without undue inconvenience to householders; many modern appliances are easier to use, more efficient and faster than older technology (Domene & Sauri, 2006; Gilg & Barr, 2006; Shove, 2003; Troy et al., 2005)).

The improved technology of water efficient appliances makes it simple and convenient for households to incorporate water conservation into habitual behaviour (Troy et al., 2005). However, the same process of habituation can also result in excess water use. For example, many modern appliances are designed for ease of operation, but not to bring water use to consciousness, or encourage re-use (Allon & Sofoulis, 2006; Lawrence & McManus, 2008; Shove, 2003). For example, households with sophisticated irrigation systems tend to use more water because these are automatic and operate at set times, even if it is raining or the soil is already wet (Syme et al., 2004, p126-27). Despite this, some demand-side policies subsidise or otherwise encourage the installation of such devices. Therefore, it is often necessary to promote water efficient technology concurrently with education and awareness campaigns (Syme et al., 2004).

In addition, ability to afford and use technology is related to socio-demographic status; and varies with income, awareness, tenure and dwelling type. For example, some water efficient technology, especially dual reticulation systems and even water tanks, are more commonly installed in new housing rather than retrofitted to existing stock. In addition, some socio-demographic groups, particularly those on lower incomes and or non-English speaking, are less able to take advantage of modern water saving technology, because of lack of understanding of information material, and decisions made primarily on price (Harlan et al., 2009; Troy et al., 2005). Moreover, in economic downturns, many delay the purchase of new appliances because of financial constraints.

Moreover, householders often still expect financial and technical support for installing water saving technology, thus are still dependent on the "big business" water authorities (Allon & Sofoulis, 2006, p51). Despite this, householders are willing to try new domestic water infrastructure and technology if supported by government, and if it is shown to be cost effective, with genuine savings (Allon & Sofoulis, 2006).

Another voluntary policy method used to reduce internal water use, related to technological innovation and education, is appliance labelling, such as the Water Efficiency Labelling and Standards scheme (WELS). The WELS is a Federal legal requirement for new appliances, such as washing machines, dishwashers and toilets, to have a label featuring a star rating which gives a quick comparative assessment of the water efficiency of the appliance, as well as a water consumption figure (Patterson, 2004). However, because this was a Federal (and not State) Government policy, and due to lack of data, appliance labelling was not investigated as part of this research.

2.5 Summary

Structural, socio-demographic and psychological factors are important drivers of household water use, but their influence can be complex, inter-related and often inconsistent. Alone, socio-demographic variables are not particularly significant predictors of household water use and, at best, the variance in water consumption explained by most socio-demographic models is around 40% (De Oliver, 1999; Jorgensen et al., 2009; Kenney et al., 2008). However, structural and socio-demographic factors are better predictors of household water use than are psychological factors (Domene & Sauri, 2006; Gilg & Barr, 2006 2005; Grove et al., 2006; Jackson, 2005). Water use is often determined more by the broader cultural context, and is often simply a function of logistics, than attitude or belief (Vlek & Steg, 2007).

Nevertheless, demand-side policies effect household water use by influencing behaviour, and not by influencing structural or socio-demographic factors, but these factors can limit the ability of some householders to control or change their behaviour, even if desired. For example, housing tenure or income may constrain the ability to install water efficient appliances. Income is also relevant to pricing policies, as these can often have negative impacts on lower income households.

Therefore, to fully understand changes in household water use; it is important to understand the interaction of structural, socio-demographic and psychological factors with policy (Domene & Sauri, 2006; Troy et al., 2005; Zhang & Brown, 2005). Furthermore, householders are more inclined to change water using practices if that change does not affect comfort or convenience (Allon & Sofoulis, 2006; Birrell et al., 2005, p6; Shove, 2003; Troy et al., 2005). Policy measures such as technology retrofits are one means by which householders can make such changes, without sacrificing comfort and convenience. Changes in planning policy, building codes and incentives and rebates are also means by which such policy can influence water use. For example, changes to building codes to make rain water tanks compulsory (or rebates on their purchase) can effectively reduce outdoor water use. In addition, if households with swimming pools use more water, then policy aimed at reducing evaporation, such as pool covers or restricting pool filling to tank water only, could effectively reduce water demand.

However, a major research gap exists on the combined influences of structural, socio-demographic and psychological factors on water use behaviour (Clark & Finley, 2007a; Domene & Sauri, 2006). Another gap is the differing response of socio-demographic groups to demand-side policies; important for policy evaluation and to inform future policy iterations (Mankoff et al., 2007, p5). In addition, little is known about the response to policy of households with different structural characteristics, such as lot area. For example, in Arizona, detached households on larger lots had higher decreases in water use after mandatory restrictions were imposed, and this was maintained even after the drought was over (De Oliver, 1999, p386).

Therefore, by analysing a comprehensive, household-scale dataset of water use, the study will provide essential information on the influence of structural, socio-demographic and psychological influences on household water consumption. By understanding the spatial variations in water use, the study could enable effective policy targeting, with large potential cost savings. Mapping structural and socio-demographic factors will help identify if these influenced patterns of higher water use, and changes in response to policy. This research investigates the efficacy of the water restrictions, during the drought, and in the year following. The results of the study will also help provide further information on the determinants of water use, which may benefit policy makers.

Finally, the study investigates attitudes to the supply-side policies, such as the Traveston Dam proposal and desalination plants, and to the demand-side policies, such as the Target 140 awareness raising campaign, the water restrictions and the rain water tank rebate.

CHAPTER 3 METHODS

A two-phase mix of quantitative methods were used, with each phase building on the previous one to answer the research questions: "*How did household water use vary spatially and temporally between 2006 and 2007, and what structural, socio-demographic and psychological factors contributed to this variance?*"; "*Did specific household types respond differently to the South East Queensland demand-side policies?*"; and "*Which of the policy measures were the most effective, and why?*"

This chapter first discusses the methods of GIS mapping and statistical analysis that were used to identify the most significant structural, socio-demographic and policy determinants of household water use. Thereafter, it discusses the methods used for Phase 2, a quantitative questionnaire survey. It details how the questionnaire was used to identify some end-uses of water, and attitudes and opinions about policy and water conservation. It also describes how the final open ended survey question was used to identify some in-depth attitudes to the water policies.

3.1 Phase one: Spatial Analysis using Geographic Information Systems (GIS)

The first phase of the study used GIS and spatial analysis techniques to explore the spatial distribution of household water use, and the influence of structural and socio-demographic variables. How and why households use water is a highly complex issue. The multiple determinants of household water use are difficult to isolate only using raw data and statistical analysis. Analysis of the geographical relationship of structural and socio-demographic data can add a new dimension to conventional statistical analysis; showing the relationships between variables as well as the spatial proximity of data (De Oliver, 1999).

The most common tool used to map the spatial extent of variables is computerised mapping systems, commonly known as Geographic Information Systems

(GIS). A GIS is defined as a system that "*…integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information*" (ESRI, 2009). A GIS comprises three components; the database, a model and map views. The database has the same functionality as any other database, but includes an additional feature, that of georeferencing, which enables spatially locating the data. The model view incorporates additional modelling and scripting, to process and analyse geographically referenced information (ESRI, 2009)

The map, which is the feature most commonly associated with a GIS, is a means by which "layers" of geographically referenced data are juxtaposed, classified and analysed. With a GIS, maps can be drawn almost instantaneously, and incorporate data from other sources, such as Global Positioning Systems (GPS), digital cameras and the world wide web (ESRI, 2009).

A GIS was used to map and statistically analyse (spatially and temporally) a comprehensive household-level database of water meter readings of SEQ households, to investigate whether structural and socio-demographic factors influenced water use. In addition, the water database was used to investigate the response of households to the policy measures, such as the water restrictions.

This water data was also aggregated to CCD and LGA level, to compare the water use of different areas, and to incorporate data at other scales, such as Census data, to investigate whether socio-demographic groupings influenced household water use. The results of this helped to identify and understand some of the spatial variations in water use, and informed Phase 2 of this study.

3.1.1 GIS Data Collection

A comprehensive literature review of peer-reviewed sources identified the structural and socio-demographic variables likely to influence household water use (See Chapter Two). Appropriate datasets for the selected variables were identified and located, and access to these was negotiated. These datasets included publicly available data (i.e. aggregated Census datasets and Bureau of Meteorology rainfall data) and some government owned data sourced and appropriately licensed for research purposes, such as household water use data (Queensland Water Commission). The variables used in the GIS analysis are summarised in Table 5, and detailed in the text following.

Table 5 Variables used in GIS analysis

Name	**Description/measurement**	**Type of data**	**Scale**
Water Use	Water use per lot plan	Dependent	Household
ConsDiff	Water use 2008-2006	Dependent	Household
Rainfall	Avg monthly rainfall, mm	Independent, exogenous	Station/LGA
Temperature	Avg highest mth. Celsius	Independent, exogenous	Station/LGA
Lot area	Lot area in m^2	Independent, exogenous	Household
Land value	Average per CCD, dollars	Independent, exogenous	CCD
Sale Price	Average per CCD, dollars	Independent, exogenous	CCD
Pools	Yes/No per Lot Plan	Independent, exogenous	Household
Demographic Variables	Census Demographic Data: household size, housing type, age, education, income, etc. (Section 4.3)	Independent, endogenous	CCD

Dependent Variables

Dependent Variable: Actual Water Use

The dependent variable comprised household water use, measured at quarterly (or biannual intervals), for all detached and semi-detached houses in Brisbane and the Sunshine Coast (the former Caloundra and Maroochy LGAs). The dataset included a complete consumption history for 2006-2009: for example, the data for a Brisbane household included a property descriptor (Lot and Plan); quarterly meter reading dates, and the Kilolitres used between dates[7]. The dataset was provided by the Queensland

[7] Given the size of the dataset, encompassing over 90% of detached houses in the area, this may be enumeration rather than sample data. Although tests of inference are not statistically valid for whole of population data, this thesis reports tests of significance "…*in deference to its widespread use in social science for exploratory analysis of non-random data*" (Garson, 2002, p198)

Water Commission (QWC) in the form of a Microsoft Access database, and current from April 2006 to December 2009. It was converted for use in a GIS by joining the tables by Lot and Plan to the Digital Cadastral Database (DCDB).

The longitudinal, panel format of this dataset allowed detailed analysis of responses to policy measures, such as the water restrictions. However, this analysis provided some challenges. Because a finite number of manual meter readings are possible on any given day, individual readings can span a large temporal period. For example, for Q2 2006 (2^{nd} Quarter; roughly equivalent to the period 1 April to 30 June), meter readings in Brisbane were conducted from 12 April to 11 July 2006 (a period of approximately 3 months). If the corresponding reading for the same property in the next period was equivalent (i.e. meter readings exactly 3 months apart), this would not have posed a problem. However, the following reading ranged from one to three months, and was not consistent between reading periods. Given that the Brisbane dataset alone had 272,474 records, this added a degree of complexity to modelling the response of households to the water restrictions.

Finally, it was not possible to use Census CCD counts to calculate per capita water use for different property types, as this method required access to all water consumption records for all property types, and this dataset comprised only detached houses (Troy et al., 2005). In addition, the number of properties with a full 4 years of water data (a longitudinal database) did not correspond with the Detached Dwelling count for each CCD in the ABS Census BCP (a cross-sectional database). However, it was still possible to calculate a broad per capita water use for CCDs by dividing Average Litres per Day water use by the Average Household Size variable in the Census Basic Community Profile (BCP).

Dependent Variable: Change in Water Use (ConsDiff)

This dependent variable (ConsDiff), was created by subtracting the average daily water use for 2006 from the average daily water use for 2008. Water readings for 2009 were not used because, by 2009, the drought was largely over, and water restrictions were eased. An additional variable was calculated by subtracting ConsDiff from Total Water Use, and used to compare water use during and post drought (PostDrought).

<u>Independent Variables</u>

Independent variables analysed included Climate data (rainfall and temperature); Lot area; Swimming Pools and Property Value and Sales Data (when a property had been sold). Of note, sales data was only used in the aggregate.

Rainfall and Temperature

Rainfall and temperature data were sourced from the Australian Bureau of Meteorology. Only data from weather stations with continuous records for the entire period was used. Total rainfall was graphed per station, per month, and linked to CCDs using Voronoi/Thiessen polygons (described in detailed methods). A detailed analysis of temperature was not conducted, instead the highest mean temperature was graphed, per station and per month.

Swimming Pools

Swimming pools were manually identified by the researcher, using ortho-rectified satellite imagery, digitised in an edit session, saved as a Point Shapefile, and linked to the Lot and Plan information in the Digital Cadastral Database (see below). The swimming pool data was a large random sample of the whole dataset (81,918 properties or approximately 1/3 of total households).

Lot Area, Land Value, Sales Data

The Queensland Department of Environment and Resource Management (DERM) now Department of Natural Resources and Mines) provided the Digital Cadastral Database (DCDB), an electronic map with spatial and attribute data including lot and plan description, land parcel boundaries, coordinates of land parcel corners and natural features. The DCDB is updated monthly, and the chosen version corresponded with the date of the final water meter readings, December 2009. The Queensland Government valuations database was used for land value and sales data, which was aggregated to CCD level to protect privacy.

Data Collection: Socio-demographics

For the socio-demographic variables, the Basic Community Profile (BCP) from the 2006 Census dataset was used. The BCP provides count data for Census variables, such as detached houses, people with degrees and ethnic origin. Counts of dwellings per CCD were also added as a table to the GIS map.

3.1.2 Data Management and Analysis

<u>Creation of Base Maps</u>

Using ArcView, a map was created, with the coordinate system GCS_GDA_1994 (the most commonly used projection for the majority of the datasets). All GIS layers were added as Shapefiles or as DB IV tables, joined to Shapefiles. After all GIS iterations (such as clipping and spatial joins), the original layers were deleted from the map to speed processing. Excess fields were eliminated from the Shapefile attribute tables to reduce data file size, and to remove any confidential data.

As the primary focus was on detached, urban households, all non-urban properties were eliminated. The original intent was to use the LGA zoning schemes for this, but these were too complex and inconsistent between LGAs. Therefore, the Urban Footprint Shapefile, from the Queensland Office of Urban Management, was used as a proxy for urban zoning. The Urban Footprint is a zoning of the South East Queensland Regional Plan, which designates areas in which urban development is permitted 8.

Table 6 summarises the GIS layers used in the base map, and the methods used to create these. The name of the map layer is given, the description of the layer, and the procedure by which it was added to the map.

Table 6 Map Layers[9]

Name and Custodian	**Description**	**Procedure**
Study_Area DERM	Local Government Area boundaries	Study area LGAs (Maroochy, Caloundra and Brisbane) merged to one Shapefile
Urban_Footprint DERM	SEQ Regional Plan boundary layer	Used to clip Study_Area to identify urban households.
CCD_Only ABS	Census Collection District boundary	Queensland CCD layer, clipped by Study_Area (included State Suburb codes)
DCDB_Merge DERM	Queensland cadastre (area, tenure, sale price, value, land use)	Merged with value database on Lot/Plan field. Spatially joined to CCD_Only to link each Lot/Plan with CCD identifier code. Clipped by Study_Area.
Water_Use QWC	Water Use (Kilolitres)	Per household, per period, linked to DCDB_Merge on Lot/Plan field
Water_Use_CCD Calculated	Mean water use	Water_Use - aggregated to CCD level
ConsDiff Calculated	Water use difference	Difference in water use (2008 – 2006)
LGA_Mosaic DERM	Satellite Imagery	15cm Orthophoto, ECW image file
Pools DERM	Swimming Pools	Point Shapefile, linked to Lot Plan; edited manually from LGA_Mosaic
ABS_info ABS	Basic Community Profile Variables	Selected variables from BCP: linked to CCD (proportions and z-scores)
Rainfall BoM	Rainfall Stations	Point dataset of rainfall stations, linked to tables of monthly rainfall
Other DERM	Linear Data	Roads and other infrastructure, Waterways, Contours, Towns

[8] "*The South East Queensland Regional Plan 2009-2031 is the Queensland Government's plan to manage growth and protect the region's lifestyle and environment.*" OUM, 2010.

[9] Note Currency of Data: DERM and QWC data, current as of December 2009; ABS data, current as of 2006 Census; BoM data, current as of December 2009; and calculated data, current as of December 2010.

Analysis of Water data

The main analysis was conducted on the household water use datasets. These datasets were very large; Brisbane had quarterly records for each household from Q3_2006 (third quarter of 2006), and Caloundra and Maroochy had biannual records for each property for 2006-2009. Microsoft Access 2007 was used to merge all the datasets to a single database. Each property had a unique Lot and Plan identifier, with separate columns for water readings and dates of reading.

To compare Brisbane and the Sunshine Coast, all water data was aggregated to biannual periods (the period of measurement for the Sunshine Coast), and annually. Water use per month was also calculated, using smoothed averages. The water data tables were added to the GIS map, and joined one-to-many to DCDB_merge by the Lot and Plan field, keeping only matching properties. This was then exported and added to the map as a Shapefile (Water_Use). A random selection of properties was checked against the original dataset to ensure each property was correctly matched with consumption data.

However, it was still necessary to clean and prepare this data for analysis. To ensure only detached households using reticulated urban supplies were analysed; all properties without water consumption records were eliminated, as were those with zero readings, for any period. Tenure codes in the DCDB, and Primary Use (PLU) code in the internal database, were used to eliminate non-residential properties. For example, properties coded as RL (Railway Land) and PO (Port Authority) were deleted. Only lots with PLU codes of 2 and 5 were retained[10]. Thereafter, ortho-referenced (spatially georeferenced aerial photos) satellite imagery was added to the map, to identify

[10]Only Codes 2 & 5 are directly related to detached housing 2: Single unit dwelling; and 5: Large Home site –Dwelling.

swimming pools, and enable further ground-truthing[11]. Obvious anomalies, such as airports and industrial properties, were deleted.

To identify univariate outliers, z-scores were calculated, and all lots with mean water use >4SD were deleted[12]. Properties with exceptionally high water consumption for only one period were removed from the dataset, because anomalous readings were assumed to result from leaks or incorrect data entry. Approximately 1,235 properties (0.3% of 328,016) were highly positively skewed in this manner. Multivariate outliers were identified using the Mahalanobis D2 statistic[13]. These were retained, to compare high with low water users, and for selecting survey respondents, but were filtered for statistical analyses that require normally distributed data. A random sample of multivariate outliers were further analysed with ownership databases, and Google Earth. If non-residential or multi-residential, these were eliminated. However, most analysed in this manner appeared on visual inspection to be domestic residences.

The study area dataset now consisted of a single table with a column for each period with household water use linked by Lot and Plan, CCD Code and LGA, to enable spatial aggregation for analyses against socio-demographic data. As far as could be estimated by desktop analysis, the majority were residential households, and all had water data for the entire four-year period.

The mean water data for the entire period was calculated, and mapped using ArcMap's built in classification algorithm (Jenk's Algorithm) which was manually modified to show equal intervals. To compare water use between years, the same scale was used for each year. Water data was also mapped using Standard deviations, and Getis-Ord Gi* HotSpot Analysis.

[11] The Custodian of this imagery is the (then) Department of Environment and Resource Management (DERM), and the currency was 2009.

[12] The cut-off for univariate outliers is usually 3SD, but was raised to 4SD because of the large database.

[13] Mahalanobis D2 (or Distance) is a multivariate effect size statistic, comparing similarity of a known to unknown sample set.

The water data was statistically analysed using SPSS v19, and Microsoft Excel 2007/2010. The water data was analysed using descriptive statistics (mean, standard deviation and measures of normal distribution, such as frequency distribution).

Analysis of Structural Data

Data on structural determinants, such as rainfall, lot size, land value and swimming pools were also mapped and analysed. Monthly rainfall was mapped by measuring station, and Thiessen polygons used to link these to the centroid of each CCD. lot size, land value and sale price were georeferenced by Lot and Plan to the water data, so each property included this additional information. Mean sale price was only used in aggregate, as, obviously, only a relatively small percentage of properties were sold during the time.

To identify swimming pools, the mapped water dataset was overlaid over high resolution Orthophoto imagery (15 and 20cm Enhanced Compression Wavelet (ECW) a type of proprietary image compression), a point Shapefile created, and properties with swimming pools manually identified in an ArcGIS edit session. This was time consuming, but it enabled further filtering of the water data, by identifying additional industrial or agricultural properties. Thereafter, the lot and plans were overlaid with the CCD layer, and all households within each CCD counted. Because this was a cluster sample (households chosen with CCDs), it was not strictly random. However, it was a large sample, and included 81,918 properties (approximately 1/3 of total households).

Descriptive statistics such as mean and standard deviation were used to describe the various structural determinants, alone as independent determinants of household water use, and in combination. Correlational analysis was used to describe the strength of the associations between variables. To clarify this association, inferential statistical analysis, such as Analysis of Variance (ANOVA), Generalised Linear Model (GLM)

ANOVA, and Ordinary Least Squares (OLS) Regression were used to identify the influence, if any, of these on household water use.

Analysis of Socio-demographic Data

Before conducting data analysis, it was important to note two issues pertinent to using aggregate data such as Census Data. First, is the Ecological Fallacy, whereby inferences are incorrectly made from average, aggregated data to the individuals within (Janelle, 2009; Stimson, 2009). For example, the average income of all households within a certain CCD might be $3,000 per month, but within that CCD, a wide income range can and does occur.

Second, the Modifiable Areal Unit Problem (MAUP) is relevant for aggregate datasets of socio-demographic variables, such as the Census. The MAUP describes how man-made boundaries, such as Census Collection Districts (CCDs), can impose artificial and often arbitrary zones on urban geographies (Janelle, 2009; Stimson, 2009). The MAUP has both a scale and an aggregation dimension. For the scale dimension, standard statistical tests can give different results at various scales (i.e. CCD and suburb scale); and for the aggregation problem, changed groupings will give differing statistical results, depending on the grouping. Although the MAUP cannot be "solved" per se, awareness of it is a necessary qualification when investigating the spatial distribution of variables such as water use (Stimson, 2009).

The ABS Basic Community Profile was the main source of socio-demographic data. Place of Usual Residence was used in preference to Place of Enumeration, as it was considered that temporary residents, such as tourists, could skew the data. In addition, given the focus of the study on household water use, place of residence was a logical choice. Selected variables were identified in the literature as potentially significant socio-demographic determinants for household water use, as well as relevant to general socio-demographic and geodemographic analyses (ABS, 2006a; Baum, Van

Gellecum, & Yigitcanlar, 2004). The research methods for the socio-demographic data are summarised below (and further detailed in Appendix A, p249-250).

A combined table was created, using variables from the BCP dataset, such as household size, age of residents, education, income and industry of employment. Proportions were calculated for each variable, to enable comparison of CCDs with dissimilar populations. The combined table (ABS_info) was added to ArcMap, and filtered to remove predominantly commercial or industrial CCDs, and those with fewer than 75% detached households. CCDs with exceptionally mean high water readings were further investigated by overlaying on to satellite imagery for visual inspection, and those with predominantly non-residential uses were deleted.

With the data now cleaned and filtered, statistical tests were conducted on the water data and the ABS data (ABS_info).

Geodemographic Analysis

The geodemographic analysis was conducted at the CCD level, to investigate the influence of socio-demographic factors on household water use. First, the water data was aggregated to CCD scale, to enable comparison with the Australian Bureau of Statistics Census 2006 Basic Community Profile (BCP). Selected variables from the BCP were converted to percentages. Some variables were also combined to create composite variables. The socio-demographic data was then linked to the existing attribute table, using the Code_2000 field (unique ID code for each CCD). Thus, it could be mapped and symbolised with ArcGIS. It could also be overlaid against the water data to identify any correlations.

Multiple regression analyses were conducted to identify variables significant for water consumption at the CCD level. Thereafter, Principal Components Analysis (PCA) was used as an exploratory tool to identify a set of common Factors (or Components) in the data. The purpose of a PCA is to extract a smaller set of related variables, to identify similar spatial variation in a given area. The method used to prepare the variables for PCA is summarised below, and detailed in Appendix A (p249).

The CCD table was filtered to remove CCDs with fewer than 75% of detached houses. In a similar study, all CCDs with less than 99% of detached houses were removed, but this was considered too prescriptive, as it eliminated CCDs with high quality water data (Troy et al., 2005). Variables included were those commonly used in demographic profiling and research into household water use, such as household size; income; children at school; proportion of state housing; and industry of employment (Baum et al., 2004; Clark & Finley, 2007b; Troy et al., 2005).

The bivariate correlation matrix of all the variables was examined, to investigate the extent of association between each pair of variables (Garson, 2010). The variables were restricted to those with correlation coefficients significant at the 1% level to reduce the possible margin of error and ensure the analysis was in line with generally accepted practice for PCAs (Garson, 2010). Highly intercorrelated variables were eliminated, because these could be "double-counted" and measure the same underlying factor. However, some highly intercorrelated variables considered relevant to the analysis, for example, the correlation of *Professionals* and *Persons holding Degree Qualifications*, were retained, as these were measuring diverse factors, education and employment. Further, after each iteration of the PCA, variables that added little to the variance (i.e. scoring below 400 on the communalities table or with extremely small populations) were eliminated.

<u>Analysis of Water Restrictions</u>

Quantitative statistical analysis was conducted only on the dates of implementation of the water restrictions, as it was not possible to quantify the other policy measures. To investigate whether the water restrictions had a statistical significance on household water use, a fixed effects Linear Mixed Model (LMM) procedure was conducted. LMMs are suitable to analyse longitudinal panel data, such as the water data, where successive observations are highly intercorrelated. These models are superior to GLM because they allow the inclusion of random effects, can analyse subjects measured at various times, and cope well with unbalanced datasets (West, 2009).

To run the LMM procedure, it was first necessary to convert the data to "long" format, with each observation on a separate row, because standard "wide" format (each row represents a series of observation linked to a case) is not suitable for LMMs. The dataset was transformed by creating two long variables, Cons (KL used before each read date, i.e. Cons Q3_06) and Read (Date of Reading matched with Cons). Fixed independent variables included in the model were Land Value, Lot Area and Restrictions (dates of implementation). Mean rainfall per month was calculated for each CCD, and included as a fixed variable.

The Restrictions variable was a categorical variable numbered according to the Restriction level in place at that time. It was created by subtracting the date of implementation (i.e. Level 4 Restrictions, implemented on 10 April 2007) from the date of reading. For example, a water reading taken on 9 April 2007 was categorised as Level 3, and a reading taken on 30 April 2007 was categorised as Level 4. Thus, it was possible to identify exact periods when increasing levels of water restrictions were implemented.

3.2 Phase Two: Quantitative Questionnaire Survey

This second part of the chapter discusses the method used to investigate the contribution of behaviour to the variance in household water use. GIS mapping and statistical analysis, can be of great value in understanding a spatially based phenomenon. However, if these methods are combined with other methodologies, such as questionnaire surveys, spatial datasets can be investigated in more detail, thus providing a deeper and more complex level of analysis. Furthermore, many aggregate datasets, such as suburb or CCD-level water use and socio-economic data, cannot be verified without detailed household surveys (Clarke et al., 1997). Therefore, a questionnaire survey was used to investigate the relationship between individual water consumption, and attitudes to government policy.

This section presents the design, creation and delivery of this questionnaire survey, which aimed to identify some end-uses of water, and some attitudes, beliefs and opinions about demand-side policy and water conservation. The questionnaire also sought to explore whether an extended Theory of Planned Behaviour (TPB) could be used as a framework basis to explore water use behaviour. The planned model added past behaviour (habit) and affect to the standard TPB variables of Attitude, Social Norms and Perceived Behavioural Control. The Questionnaire also included a final, open-ended question that was qualitative in focus, which sought comments on the demand-side policies and water conservation. This question was analysed in two phases, as part of the quantitative analysis, and separately, using modified theme analysis, which was used to support and value-add to the quantitative answers.

Because the Questionnaire survey involved human subjects, Griffith University Ethics approval for human research was applied for and granted. In addition, data used in the first phase of the research was de-identified, and where potentially sensitive information, such as land value and house prices, were analysed, the data was aggregated to CCD level. Households were chosen randomly, and the questionnaire survey was anonymous, with participants not asked to provide any personal details, except postcode and suburb of residence. Informed consent was obtained through the standard process (a Questionnaire coversheet with consent indicated by the return of the completed questionnaire). Where the survey was completed online, the content of the "coversheet" was identical, and consent indicated by "clicking" on the "Agree" button.

The information sheet provided during the informed consent process included contact details of all researchers. All participants were assured of confidentiality and anonymity; as data was de-identified, any data provided by the participant would be published in a manner to ensure no third-party identification can occur (protected anonymity). If requested, participants could request a summary of the research results.

3.2.1 Sample Design and Collection

The sample was chosen from the entire population of detached households in Brisbane, Maroochy and Caloundra with four years of water consumption data, and identified with the GIS methods. The sampling frame differed slightly according to the sampling methods used (the two methods used are detailed below). Selection of households was both list-based (from an internal database that linked Lot Plans to street addresses) and area-based (selected CCDs in the three LGAs).

In Method 1 (briefly described below, and further detailed in Appendix A, p249), all households had an equal chance of being selected for sampling. However, in Method 2 (briefly described below, and further detailed in Appendix A, p251-254), households were randomly selected from the highest and lowest quintile of water users.

<u>Method 1: Random Selection (Clustered Multistage)</u>

The sampling frame was the total dataset consisting of all detached residential properties in Maroochy, Caloundra and Brisbane with four years of water data. All households identified in the initial GIS mapping exercise had an equal chance of selection. The sub-dataset used for sample selection was the aggregate CCD table. The sampling method used multistage cluster sampling, with Probability Proportionate to Size Sampling (PPS) (CDC, 2009).

"Probability Proportional to Size Sampling (PPS) is a sampling technique, commonly used in multi-stage cluster sampling, in which the probability that a particular sampling unit will be selected in the sample is proportional to some known variable (e.g., in a population survey, the population size of the sampling unit" (CDC, 2009).

Four major types of sample designs are simple random, stratified, systematic and cluster sampling (Daniel, 2012). Simple random sampling would not have suited the data, as this would have selected a larger proportion of Brisbane than Sunshine Coast households, due to different size populations. PPS sampling was used because of the nature of the datasets, and the differing numbers of households in CCDs. Data, such as water use and land value, was available on a property basis, while other data, such as household size, was only available at the CCD scale. This type of sampling allows analysis of the clusters, as well as the population (Daniel, 2012). Further, as this population was widely geographically dispersed, a cluster sampling method allowed for relative ease and cost effectiveness of data collection (Daniel, 2012);(CDC, 2009).

The commonest proportion used in PPS sampling is the '30*7' cluster survey method. However, for this study, a larger 60*14 proportion was chosen, as it was considered important to select as many primary clusters as possible (Milligan, Njie, & Bennett, 2004);(CDC, 2009). In addition, a higher sample size has less chance of sampling error than simple random sampling (Daniel, 2012). This method is detailed further in Appendix A, Section 8.1.3.

<u>Method 2: Random selection of Households by Water Use</u>

The Method selected 50% of households in the lowest 20%, and 50% in the highest 20% of water users. To ensure a proportionate sample, the same numbers of households were selected as in Method 1 (840 households). In addition, the area was stratified into two regions, Brisbane and the Sunshine Coast. This was done to prevent bias, because the higher water use (mean and variance) on the Sunshine Coast would have meant greater numbers of high water users selected in Sunshine Coast and greater numbers of low water users selected in Brisbane. Within each LGA, 420 households were chosen by simple random selection: 105 in the lowest water use group (lowest 20%) and 105 in the highest water use group (highest 20%). This method is detailed further in Appendix A, Section 8.1.3.

In both methods, some random households were "ground-truthed" to ensure they were genuinely detached households. The address was put into Google Maps, with "Street View" enabled. Street View is an application of Google Maps, which has relatively recent photographs of the "street view" of properties in many countries, including Australia. In this manner, it was possible to visually check if a property was a detached house, and not units or a business. On closer investigation, some households chosen in this tranche appeared to be agricultural properties. As all of these were larger than 2 hectares; all properties with excessively high readings *and* lot areas larger than 2ha were replaced with the "next in line" from the random selection (if not larger than 2ha).

3.2.2 Recruitment of Participants

Participants for the Questionnaire survey were selected from the population of Brisbane and the Sunshine Coast using systematic random sampling within the multistage design detailed above. This was to ensure a probabilistic survey design to enable inferences to the population of detached householders of urban SEQ. Each selected household was sent an Advance Postcard (Appendix B), giving notice of the forthcoming survey, and encouraging response. The Advance Postcard was not personally addressed to the householders, only to "The Householder". The original intention was to hand deliver these to individual houses; as this was more cost effective than posting, and did not involve any third party databases. However, because addresses were chosen randomly and not systematically, this proved extremely time-consuming as the study area covered a large geographical area, so it was eventually abandoned in favour of posting. No personal identifying information was used in the documentation (i.e. addressed to The Householder), so as to not contravene Ethical provisions.

The Questionnaire booklet was posted to the same 1680 households as the postcard. The survey was also uploaded to the internet, as the Questionnaire Booklet and Advance Postcard contained a link to a secure internet website containing an electronic copy of the survey instrument (www.heathershearer.com/survey.html). The website contained the standard information and consent forms (see Attachment B).

The Questionnaire survey was anonymous, and participants were not asked to provide any personal details. However, each questionnaire contained a unique code number (cross-referenced to an Excel spreadsheet), linked to the water database and to a unique address. No householder could be directly identified using the code number. The questionnaire could be completed by any adult member of the household. Of note, self-selection methodologies can be biased, for example, towards female members, and non-working or elderly householders, but with the limited resources available, it was not possible to remove this potential bias.

Another tranche of 250 Questionnaires was sent to non-respondents some four weeks after the initial posting; in an attempt to obtain a larger returned sample percentage. The Questionnaire survey also offered an incentive in the form of a prize (detailed below, under Survey Creation).

3.2.3 Development of Questionnaire

The Questionnaire was constructed with reference to the major determinants of household water consumption (Clark & Finley, 2007b; Troy et al., 2005). Questions included household demographics; indoor and outdoor end-use; and awareness of the Queensland demand-side policies. An optional question was asked on the amount of water used in the last billing period (not the dollar figure); to match actual water use with reported behaviour, and with actual water use. Other questions covered attitudes to the demand-side policies, water conservation beliefs and proposed future water saving behaviour.

Most questionnaire items, including the TPB items, were on a 5-point Likert scales, ranging from positive to negative (i.e. strongly disapprove to strongly approve; or strongly agree to strongly disagree). Between some questions, the direction of the scales was reversed in an attempt to prevent respondents answering all questions similarly. Question 28, "*Opinion on Queensland Government policies*" also included a sixth item, "*Never Heard Of*". This was added to investigate the awareness level of respondents to the policies. Some questionnaire items, such as "*For my household, using less than 140 litres per person was*:" and "*Some banned water uses, like hosing my driveway, are pleasurable*" also included a "N/A" column, because these were not relevant to the Sunshine Coast.

The TPB portion of the Questionnaire was constructed according to the methods of Francis et al (2004) and Ajzen (2002), and adapted by adding the extended variables of habit (past behaviour) and affect (Hinds & Sparks, 2008). Questionnaire items were constructed based on other TPB and similar water use questionnaires (Eardley et al., 2005; Troy et al., 2005). Questionnaire items for the extended variables were adapted from the methods found in Bamberg, Ajzen, & Schmidt (2003); Clark & Finley (2007b); Corral-Verdugo, et al (2003); and Hinds & Sparks (2008). The proposed model for the extended TPB is described in Figure 4, below.

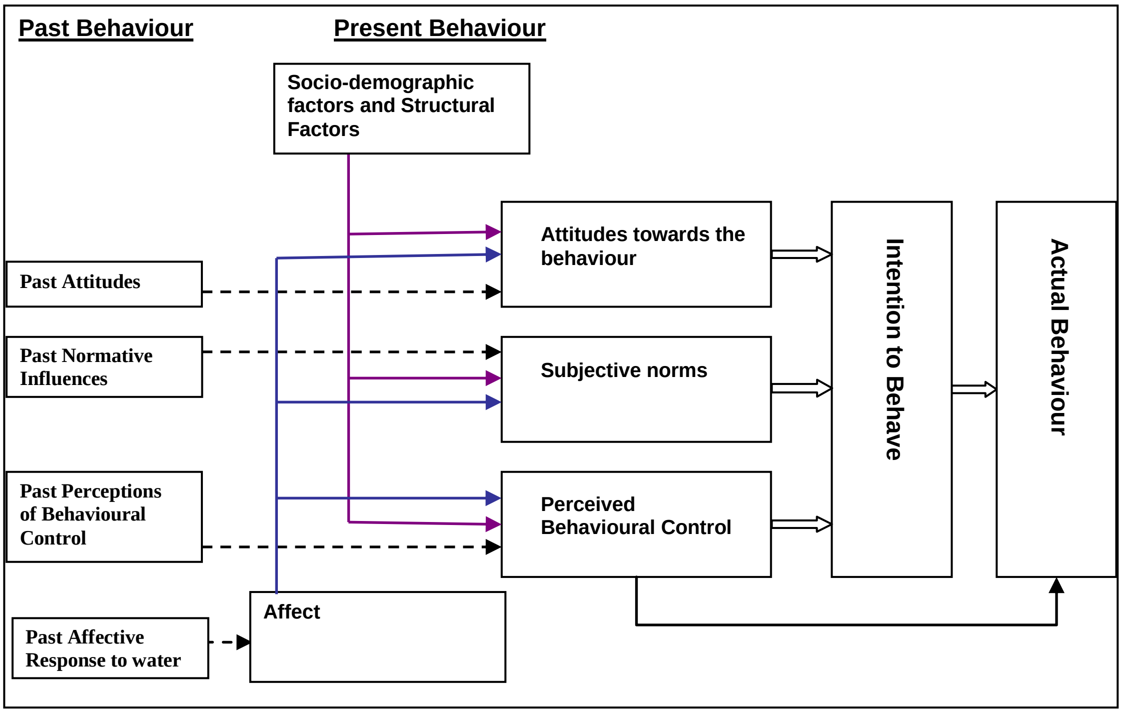

Figure 4 An Extended model of the TPB (Adapted from Coogan (2004))

Piloting and Refinement

The first drafts of this survey were pilot tested on a small population; it was sent by email to all DERM staff (approximately 70) in the Nambour office, with a request to comment on length, comprehension, clarity and confusion. This was to identify ambiguous, repetitive, lengthy, or annoying questions (Francis et al., 2004). Ten responses were received to this email pilot survey. These responses were obtained by qualitative methods (snowballing), but were not attributable to any specific person.

After piloting, some questions were rewritten or modified. A N/A column was added to some items, the meaning of some questions was clarified, and some were dropped to maintain a manageable length. Reasons for dropping questions included confusion in the pilot study and comments regarding relevance to the study. Questions on water pricing were also dropped because this was not used as a demand management policy by the Queensland Government, so it was considered not relevant to the research question. Some questionnaire questions were also amended to include the water source used, for example, in garden watering.

Format of the Questionnaire

The questionnaire was divided into 8 sections, and included a double printed front page, with information about the questionnaire, how to fill in the questions, Ethics, and Terms and Conditions of the Prize Draw. The full version of the Questionnaire is provided in Appendix B (Section 8.2.2); but in brief, the questions were organised as follows:

- Unique Code number: A compulsory question, to match the household with actual water use, cross-referenced to the water use dataset.
- Information on House: Size of house/lot, water use, and water tanks.
- Indoor water use: Indoor appliances, and habits, i.e. leaving taps running.
- Outdoor water use: Outdoor water use, and water conservation behaviour.
- Behaviour (BI): This section included the BI (Behavioural Intention) independent variable for the TPB portion of the Questionnaire. The question was phrased, "*which of the following water conservation actions did you do during the drought (from 2005-2008) and are you likely to do in the future (from now on)?*" Choices included; take shorter showers, always turn off the tap when brushing teeth, and change gardening practices to reduce water use. A scale (*did during the drought, intend to do in the future, and do not intend to do in future*) was given for each choice.
- Awareness of demand-side policies: Aimed at identifying knowledge of and attitudes to water policies. A table of the various policies was given, with a 6-point Likert scale (*Strongly Oppose to Strongly Approve, and Never Heard Of*). Questions were also asked about opinions of the State Government; concern for future water supplies; infrastructure and whether access to fresh water is a basic human right. Knowledge of the current level of water restrictions was asked, including a "*none*" choice.

- Attitudes to Water Use: All questions used five-point semantic difference scales; for example, from Very Important to Very Unimportant.
    - Attitude: Personal attitudes to conservation, keeping gardens green, and protecting the environment.
    - The Subjective Norm. The social pressure to conserve water. In similar format to the Attitude question. For example, the attitudinal statement, "*It is important to conserve water*" was rephrased as "*My family and friends think it is important to conserve water*".
    - Perceived Behavioural control. Perceived control over water conservation behaviour; water use of other family members, and ability to install water saving devices. Phrased slightly differently to the other TPB questions, because more comprehensive responses were sought.
    - Past Behaviour. Personal habits, and past water conservation experience.
    - Affective connection. Affective dimension of water use, such as hosing driveways, keeping gardens green and having long showers.
- Demographic questions: Age, gender, education, income and children.
- Question 47: Designed to elicit qualitative responses. "D*o you have any final comments on water consumption or the water policies?*"
- Question 48: "*do you want to take part in further research*?". Intended for self-selection by participants for a planned Phase 3, semi-structured qualitative interviews, but due to time constraints, this was not conducted.
- Question 49: "*Do you wish to enter our competition*?" Considered that an incentive might increase survey responses. A choice of vouchers from two retail outlets, Wow Sight and Sound (electronic goods) or BCF (camping, fishing and outdoors) was offered. The incentives were a $300 voucher first prize (the

maximum allowable under Griffith University's Ethics guidelines for a random survey of the public) and 5 prizes of $50 vouchers.

In addition to the paper based Questionnaire, an identical copy was uploaded to SurveyMonkey (http://www.surveymonkey.com) an online survey creation tool; to offer an option to reply in paper form or online, and to assist with data entry.

In brief, how the questions of the survey relate to the research questions (and the extended TPB model, is summarised in Table 7 (below). Note, not all research questions are listed, as some pertain only to Phase 1 of the research.

Table 7. Survey Questions and Research Questions

Sub Questions	**Survey Questions (Appendix B)**
1.5 What are key individual attitudes and beliefs about water conservation?	*Section 5 and Section 6* Q. 30 & 31; Q. 33-38
1.6 Can an expanded TPB be used to predict water use at the household level?	*Section 5 and Section 6* Q. 26 & 31; Q. 33-38
2.3 Do householders who have lived in rural/water-stressed areas use less water than those who have not?	*Section 6* Q. 36 & 37
3.1 Were the prescriptive water restrictions the most significant influence on household water use?	*Section 4 and Section 5* Q. 18-26; Q. 26-32
3.3 What were householder's attitudes and opinions of the Queensland demand-side policies?	*Section 5 and Section 6* Q. 26-31; Q.33-38
3.4 What barriers prevent further reductions in water use?	*Section 6* Q. 35, 36 & 38

3.2.4 Distribution of Questionnaire

The Questionnaire survey was sent to a random sample of 1680 residents in detached houses in Brisbane and the Sunshine Coast. The initial response rate was low, around 17%, but another round of reminder letters was sent, resulting in an eventual 351 responses; a response rate of 20.8%. Although this is relatively low, 47.72% of respondents provided useful qualitative responses in the final comments field, and 21% expressed willingness to partake in further study (interviews and focus groups). Of note, response rates for surveys have generally been decreasing over time, partly because of saturation of the potential surveyed audience (Holbrook et al, 2008). Another possible reason for the relatively low response rate (based on comments on returned Questionnaires) is that some renters felt the Questionnaire did not apply to them, because tenants are not generally charged for water use. It would have been better to state more clearly upfront that the questionnaire was aimed at everyone.

3.2.5 Analysis of the Questionnaire

Questionnaire Data Management

The majority of Questionnaires were received in the first month, although a few were still received up two months after the closing date. Once no more Questionnaires were received, all responses were inputted into the online SurveyMonkey database. For input of the paper based responses, an additional "collector link" was created in the SurveyMonkey web form. SurveyMonkey offers the option to create multiple collector links, enabling answers to be filtered and separately analysed. This internet form interface provided a simple method to differentiate online from mail responses.

Once downloaded, the Excel file was imported into SPSS. The first step was to ensure the Questions were numbered the same as in the Questionnaire. Second, a Codebook was created, and all questions were coded numerically according to this. Third, each question was given a unique name (i.e. Q1A, Q1B) and all possible values listed in the Values Field. For example, for Gender Q 40, this was coded as follows; 1=Male, 2=Female. Missing values were not coded because SPSS automatically codes and accounts for missing values during statistical analysis procedures. Questions were also categorised according to the type of variable, for example, Nominal, Ordinal or Scale (Ratio and Interval data are both treated the same in SPSS, and termed Scale).

Statistical Analysis

After coding and cleaning the information, basic descriptive analysis was conducted on the questionnaire; using SPSS to calculate statistics such as mean, frequencies and simple correlations. Answers to questions on age, house size, and attitudes to policy were graphed to better visualise the responses. Simple correlational analyses were conducted between variables, such as water use and age, and water use and attitudes to policy.

For the items on the Questionnaire designed to measure TPB constructs, and other attitudes, statistical methods included descriptive statistics and Principal Components Analysis (PCA). Analysis of Variance (ANOVA) was used to identify if any significant relationship existed between these constructs and household water use.

Structural Equation Modelling (SEM) was used to further analyse the relationship between water use and psychological and socio-demographic variables. SEM is commonly used in the Social Sciences because it aims to measure the influence of non-observed (or latent) variables on a measurable dependent variable, such as household water use (Syme et al., 2004, p125). SEM can be useful when fitting a framework, such as the Theory of Planned Behaviour, to survey results. It is impossible to directly measure a construct, such as attitude to water conservation, but SEM can create a latent composite variable, which can then be used in further analysis.

SEM is commonly used when variables are highly intercorrelated; for example, questionnaire items designed to measure varying aspects of similar psychological constructs. Collinearities can be desirable in such circumstances, but can cause problems in multiple linear regression models because the estimated variance is often excessively large (Syme et al., 2004, p125). Thus, it is statistically desirable to construct a lower dimension set of latent variables derived from the original regressors (Syme et al., 2004, p125). In this manner, SEM is similar to other exploratory statistical analysis, such as PCA, Factor Analysis and Cluster Analysis, which derive a smaller number of combined variables from a larger number of intercorrelated variables.

To perform the SEM procedure, a correlation analysis and a Factor Analysis, with principal axis factoring and Varimax rotation were conducted. Principal Factor

Analysis (PFA) is most often used in confirmatory research. It analyses the covariance instead of the correlation matrix, and is often used in conjunction with path analysis and SEM. PFA typically explains less variance than PCA, but is useful to identify the most parsimonious set of factors to account for the common variance shared by a set of variables (Garson, 2010).

Two combined behaviour and behavioural intent variables were created from the nine dichotomous variables comprising the question, "*Which of the following water conservation actions did you do during the drought (from 2005-2008); and are you likely to do in future (from now on)*" (Appendix B, Questionnaire). For "*Did during drought*", answers were coded as Yes (1), and No (0). These were summed to create a composite variable (*BehaviourDuring*). For *BehaviourIntent*, the two questions were combined, and as for the first, coded as Yes (1) and No (0). Blank "answers" were not used in the analysis, as a lack of response cannot be assumed as either Yes or No.

Because these new variables were created from individual items on the nominal scale, a Cochran's Q reliability test was performed. As the result was significant ($p<.01$), the combined measure did not adequately represent general behaviour. Therefore, some items with low intercorrelations were dropped and new composite measures created. The final *BehaviourDuring* combined variable comprised Shorter Showers, Use Economy Settings, Use Half Flush and Turn off Taps. The final *BehaviourIntent* variable comprised the same variables (ticked in the Future Intention column). Removing, "*Obey All Restrictions*" improved the significance, but reduced Alpha (from *.931* to *.908*). A final (reverse coded) variable *BehaviourNot*, was eventually discarded, as Alpha did not significantly increase or decrease.

Some measurement scales were in opposite dimensions, making interpretation of the already complex path analysis diagram more difficult (Syme et al., 2004, p125). Therefore, some variables used to create combined variables were recoded to ensure consistency in measurement, and for ease of interpretation. Some were also simplified; a new variable, “Swimming Pool: Yes”, was created (eliminating multiple water sources). Others, such as income, were recoded to ensure answers, such as “*prefer not to say*” were recoded as zero, and not counted in the analysis.

The PFA excluded the socio-demographic and structural variables, because the initial correlation analysis indicated these had high individual explanatory power over the dependent variable (particularly swimming pools and household size). Dichotomous categorical variables also can be tricky when conducting a PFA, as they often intercorrelate, and can generate multiple factors and multiple variable loadings on these factors. This can pose problems when attempting to identify the most parsimonious underlying data structure (Garson, 2010). Because some variables such as swimming pools, were highly significant in predicting water use, these were used instead as stand-alone predictors in the model (Syme et al., 2004).

The final PFA extracted similar factors to those derived in a previous PCA analysis. After investigation of the scree plot, and variable loadings, extraction was limited to 6 factors. Two latent variables, (‘Concern’ and ‘Infrastructure’) had no significant covariances with the other latent variables, or with water use. Concern was eliminated, but whilst Infrastructure was not a significant predictor of water use, it was retained in the model, as removing it was detrimental to the model fit.

This exercise resulted in a marked improvement to the predictive power of the final SEM model; which achieved identification, and did not require the imposition of additional constraints. Furthermore, some direct variables used in other water use studies, such as education; were removed, as these were not significantly related to the dependent variable. In the final SEM model, four latent exogenous variables were selected, and used in Amos Graphics (v.17). These were Policy, Garden, TPB Future and Water Conservation, and are described in Table 8.

Table 8. Variables used in Structural Equation Modelling

Latent Exogenous Variables	Indicator Variables (survey items)
Policy: Opinion on policies? (1 Strongly Disagree – 5 Strongly Agree)	(HWW) Home WaterWise (CS) Climate Smart (Rebate) Water Tank Rebates (Recycle) Recycling
Garden: (1 Very Unimportant to 5 Very Important); and (1 Strongly Disagree to 5 Strongly Agree)	(Sad) Sad garden suffered during water restrictions (AGrn) To me, that my garden looks green is: (SNGrn) My family and friends agree that it is important that my garden looks green
TPB Comp: (1 Very Unimportant to 5 Very Important) and (1 Strongly Disagree to 5 Strongly Agree)	(AComp) Composite of Attitude Questions TPB (e.g. I believe that conserving water is:) (SNComp) Composite of Social Norm TPB (Future) Belief not enough water in the future
Water Cons Behaviour: (1 Very Easy to 5 Very Difficult); and (1 Strongly Disagree to 5 Strongly Agree)	(HHLess) Household uses less water than similar (Changed) I've changed my water use since the water policies were implemented (During) Composite of water conservation behaviours during drought (Intent) Composite of water conservation behaviours intended to perform after drought
Direct, Observed Variables	
Water Use	Average Daily Water Use per household
Swimming Pool	Yes (1) No (2)
Household Size	Interval variable, number of people in household

3.2.6 Summary of Methods

Phase 1 explored the spatial and temporal variation of the dependent variable (household water use) and a range of independent variables such as lot size, land value and rainfall. Geographic Information Systems (ArcView v 9.3.1) and other software tools (i.e. SPSS) were used to map and categorise household water use at a range of scales. Spatial statistics, such as Getis Ord Gi*, were also used to identify hotspots. Other statistical methodology included creating Cumulative Sum (CUSUM) charts to identify trends in household water use. These methods were also used to map and analyse socio-demographic data from the ABS Census (2006). The statistical technique of Principal Components Analysis (PCA) was used to identify groupings at CCD level, and whether these extracted factors had any relationship to water use, or changes in water use over time.

Phase 2 involved the creation, distribution and analysis of a questionnaire survey. This was sent to 1680 detached, urban households in the Sunshine Coast (the previous Shires of Caloundra and Maroochy) and Brisbane. Half of these were randomly selected, and the additional half were randomly selected within a clustered research design, based on Probability Proportionate to Size methods. The questionnaire was delivered by mail, but was also available online. Questions were asked on indoor and outdoor water use, socio-demographics, attitudes to water use, and attitudes to water policy. A final, open-ended question was included to gather some more detailed comments on water conservation and the demand-side policies. The aim of this was to allow a more nuanced interpretation of some of the results.

3.2.7 Summary of Statistical Methods

A number of statistical methods were used in various phases of this research. Table 9 lists the research questions, with the major method, and the specific statistical tests used to analyse these. All statistical methodology was performed using either the Spatial Statistics module in ArcGIS 9.3.1, SPSS (PASW) Statistics, v. 19, or Microsoft Excel 2010. Texts consulted for statistical advice were (Field, 2009),(West, 2009), (Shek & Ma, 2011),(Syme et al., 2004) and the SPSS online help guides (SPSS, 2011).

Further to the standard statistical methods used (i.e. Ordinary Least Squares (OLS) Regression, Analysis of Variance (ANOVA), and Correlation), the major statistical methods used were Generalised Linear Models (GLM) Repeated Measures, Linear Mixed Models (LMM), Principal Components Analysis (PCA) and Structural Equation Modelling (SEM).

An Analysis of Variance (ANOVA) model, GLM Repeated Measures was used to analyse the influence of static structural variables on household water use. These independent variables, such as land size and swimming pools, did not vary during the period researched. Further, these models are relatively robust for equal sized datasets, with no missing data.

For the analysis of the temporal data, such as the water restrictions, a Linear Mixed Model (LMM) was created. This also analysed the influence of static, fixed variables, such as lot size and presence of swimming pools. LMMs are suitable to analyse longitudinal panel data, such as the water data, where successive observations are highly intercorrelated. These models are superior to GLM because they allow the inclusion of random effects, can analyse subjects measured at various times, and cope well with unbalanced datasets (West, 2009).

Principal Components Analysis (PCA) was used to analyse much of the Questionnaire data, particularly the questions on attitude, and water conservation behaviours. The purpose of a PCA is to extract a smaller set of related variables, to identify similar spatial variation in a given area.

Finally, Structural Equation Modelling (SEM) was used to analyse the constructs of the extended TPB model, namely Attitude, Social Norm, Perceived Behavioural Control, Affect and Habit. SEM aims to measure the influence of non-observed variables on a dependent variable, such as household water use (Syme et al., 2004, p125). SEM can be useful when fitting a framework to survey results. It is impossible to directly measure a construct such as attitude, but SEM can create a latent composite variable, which can then be used in further analysis.

Table 9. Statistical Methods Used

Research Question	Method	Statistical Tests
Q 1.1: How did household water use vary spatially over the period 2006-2009?	GIS and statistical analysis	• Mapping water use with Jenks algorithm/ Standard Deviation • Generalized Linear Models (GLM) • Getis Ord Gi*
Q 1.2: Were structural, socio-demographic and policy factors significantly related to the spatial extent of household water use?	GIS analysis	• Ordinary Least Squares (OLS) Regression • Analysis of Variance (ANOVA)
Q 1.3: Did socio-demographic variables significantly influence domestic water use at the Census Collection District (CCD) scale?	GIS and statistical analysis	• OLS Regression • Principal Components Analysis (PCA)
Q 1.4: Can selected socio-demographic variables be combined into a meaningful index to predict water use at a Census Collection District scale?	Analysis of Census Data	• PCA • Correlation
Q 1.5: What are key individual attitudes and beliefs about water conservation?	Survey	• Descriptive Statistics
Q1.6: Can an expanded Theory of Planned Behaviour (TPB) be used to predict water use at the household level?	Survey	• SEM
Q 2.1: Did households with certain structural characteristics change their water use to a greater or lesser degree in response to demand-side policy measures?	GIS and statistical analysis	• Linear Mixed Models • ANOVA
Q 2.2: Did households with certain socio-demographic characteristics change their water use to a greater or lesser degree over the study period?	GIS and statistical analysis	• PCA and OLS Regression
Q 2.3: Do householders that have previously lived in rural/water-stressed areas use less water than householders who have not lived in water-stressed areas?	Survey	• ANOVA
Q 3.1: Did the prescriptive water restrictions have the most significant influence on household water use?	Statistical analysis	• Linear Mixed Models • OLS Regression
Q 3.2: How did household water use vary temporally in response to each level of the prescriptive water restrictions?	GIS and statistical analysis	• Linear Mixed Models • Cumulative Sum Graphs • Getis Ord Gi*
Q 3.3: What were householder's attitudes and opinions of the Queensland demand-side policies?	Survey	• Descriptive Statistics • Structural Equation Modelling
Q 3.4: What barriers prevent further reductions in water use?	Survey	• Descriptive Statistics

CHAPTER 4 RESULTS PHASE 1; HOUSEHOLD LEVEL WATER USE

The overarching research question for this thesis is: "How did household water use vary spatially and temporally in response to the South East Queensland demand-side policies, and what structural, socio-demographic and psychological factors contributed to this variance?" This was further divided into four sub-sections

Section One. the spatial and temporal extent of household water use,

Section Two. the influence of structural and policy factors;

Section Three. the influence of socio-demographic factors; and,

Section Four. the influence of psychological factors.

The chapter describes Sections One, Two and Three, as above. The following Results chapter discusses Section Four.

4.1 Section One

4.1.1 The spatial variance of household water use from 2006-2009

For this analysis, the quarterly measured Brisbane dataset was aggregated to biannual periods for comparison with the Sunshine Coast[14]. The Brisbane dataset was incomplete for 2006, so it was impossible to calculate mean water use for that year. The dataset was positively skewed, with some high outliers, but this distribution is common in domestic water consumption data (De Oliver, 1999; Harlan et al., 2009; J. Stewart et al., 2005).

For every year, Brisbane had the lowest mean water use, followed by Maroochy and Caloundra (Figure 5). The lowest water use for all years was in 2008, and extreme high values were commonest in Caloundra. Water use in Brisbane and Caloundra for 2009 was similar to that of 2007.

[14] For example, P1 2007 is roughly equivalent to January 1 to June 30 2007; and P2_2007 equivalent to July 1 to December 31 2007.

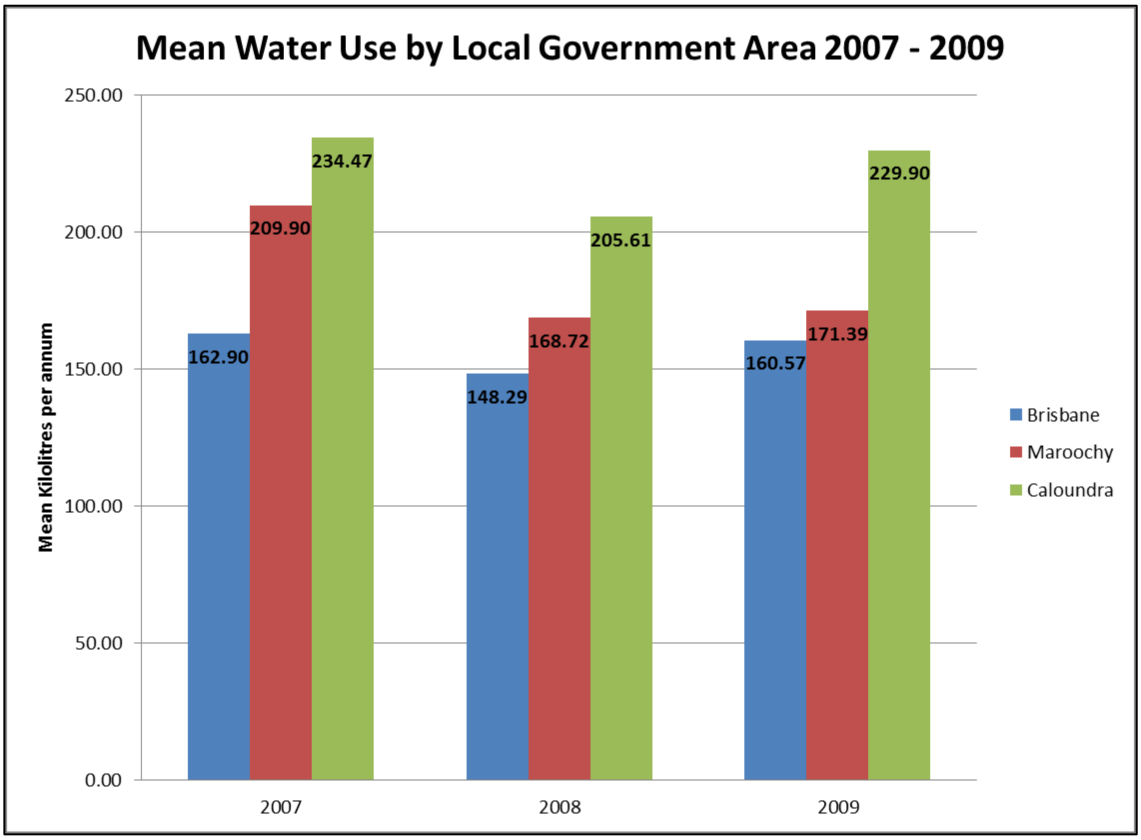

Figure 5 Mean Water Use by Local Government Area (2007-2008) (in Kl)

To enable comparison between all years, average water use (in litres per household per day) was calculated by dividing the consumption by the number of days between periods (Figure 6). For all areas, average water use per household per day dropped significantly until 2008, and began to rise again in 2009. Maroochy and Caloundra had similar water use in 2006, and mean water use in both areas increased until the beginning of 2007. After 2007, Maroochy water use reduced to a greater extent than Caloundra. Although water use for all LGAs fell until 2008; Brisbane water use was still lower than Maroochy and Caloundra. However, during 2009, the water use of all LGAs rose once again (after water restrictions in Brisbane were eased, and the drought was "broken").

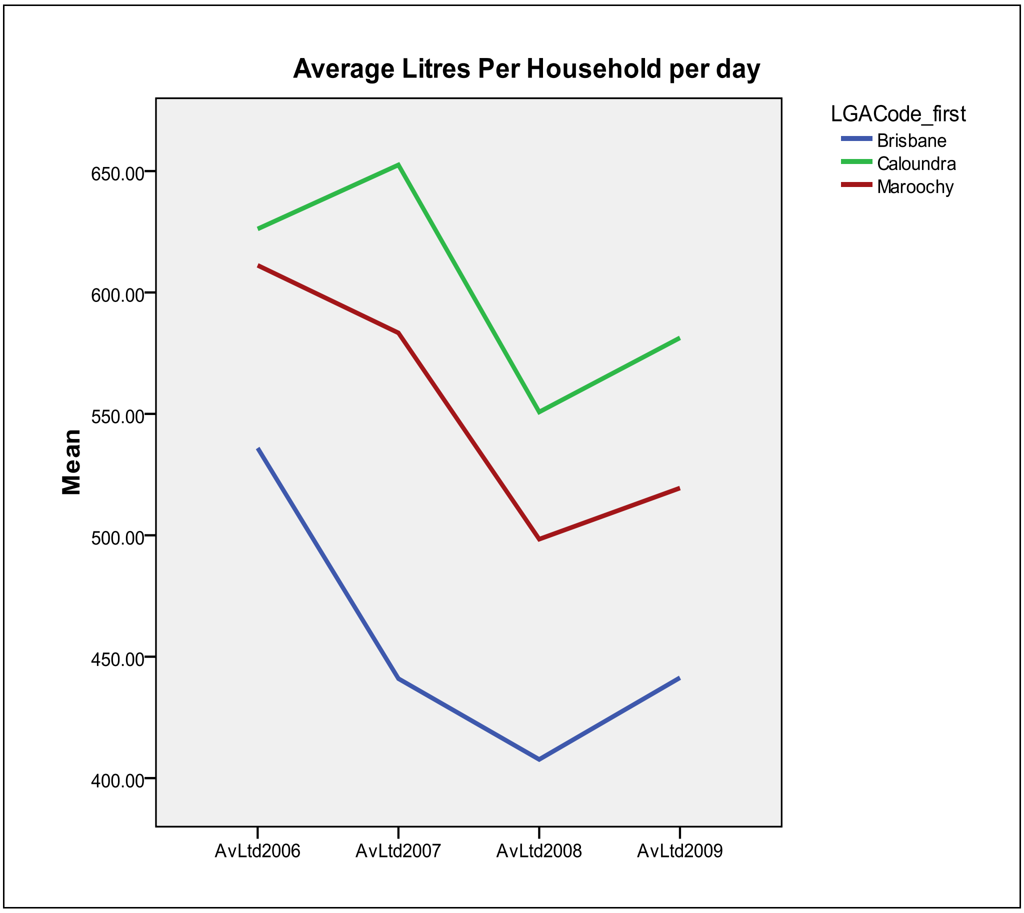

Figure 6 Average Water Use per household per day per LGA

These differences in mean water use were statistically significant between groups (LGAs) and within subjects (biannual time periods). Between groups, mean water use was higher for Caloundra and Maroochydore than for Brisbane. Within subjects (time periods); for Brisbane, the change in water use between all the periods was significant. For Caloundra, the change in water use for all periods was significant except for 2009; and for Maroochy, the change in water use for all periods was significant, except between the latter half of 2007 and the first half of 2008.

These results were tested for significance using a Generalised Linear Model (GLM) Within Subjects Repeated Measures test. Prior to running the GLM procedure, the dataset was investigated for multivariate and univariate outliers, using Cooks and Mahalanobis distances. Univariate outliers were filtered from the dataset, as it was considered that retaining them would skew the results. However, multivariate outliers were retained, as these were considered to represent “normal” water use. As a whole, the dataset was slightly positively skewed, but applying log normal and square root transformations did not substantively change the skew. This was a very large dataset, so despite significant Kolmogorov Smirnov result, visual inspection of the histograms indicated relative normality. Finally, ANOVA models such as GLM Repeated Measures are relatively robust, particularly for equal sized groups such as this. The GLM Repeated Measures analysis was conducted twice, once on the whole dataset, with LGA code as fixed Factor; and once split dataset, without Fixed Factors.

First, the water consumption per period for the entire dataset (not split by LGA) was compared. Because Mauchley's test of sphericity was significant[15], degrees of freedom were corrected using the Greenhause-Geiser estimates of sphericity ($\varepsilon = 0.712$). The change in household water use per period was significant,[16] as was the interaction between LGA and Period[17]. As shown in Table 10, Tukey post hoc tests indicated that all LGAs had significantly different water use per period ($p<.01$).

Table 10 Tukey Post Hoc Tests Water Use per LGA

(I) LGACode	(J) LGACode	Mean Diff (I-J)	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Brisbane	**Caloundra**	**-19.60***	1.03	-22.01	-17.19
	Maroochy	**-9.37***	0.87	-11.40	-7.34
Caloundra	**Brisbane**	**19.60***	1.03	17.19	22.01
	Maroochy	**10.23***	1.28	7.23	13.23
Maroochy	**Brisbane**	**9.37***	0.87	7.34	11.40
	Caloundra	**-10.23***	1.28	-13.23	-7.23

Based on observed means. The error term is Mean Square (Error) = 146.473
**. The mean difference is significant at the .05 level*

Second, the change in water use per period for the separate LGAs was analysed. For this analysis, LGA was removed as a Fixed Factor, and the dataset split by LGA Code. Mauchley's test was once again significant ($p<.01$), indicating sphericity was breached (Brisbane = ($\chi^2 = 2426.663$), Caloundra = ($\chi^2 = 153.045$) and Maroochy ($\chi^2 = 168.827$). For each LGA, degrees of freedom were corrected using Greenhause-Geiser

15 ($\chi^2=1840.131, P<.05$)

16 ($F=1344.352, p<.05$, *Partial* $\eta 2 = .395$)

17 ($F=335.015, p<.05$, *Partial* $\eta 2 = .246$)

estimates of sphericity. As shown in Table 11, changes in water use per period differed significantly between all LGAs; Brisbane (*F=3027.895, p<.05*); Caloundra: (*F=99.246, p<.05*); and Maroochy (*F=474.083 p<.05*).

Table 11 Tests of Within Subjects Contrasts

LGA	period	Type III SS	df	Mean Square	F	Sig.	Partial Eta Squared
Brisbane	**P2_06-P1_07**	19873.19	1	19873.19	346.00	**.000**	.170
	P1_07-P2_07	450983.84	1	450983.84	6995.08	**.000**	.806
	P2_07-P1_08	2376.44	1	2376.44	68.43	**.000**	.039
	P1_08-P2_08	2786.23	1	2786.23	103.61	**.000**	.058
	P2_08-P1_09	28067.80	1	28067.80	710.06	**.000**	.296
	P1_09-P2_09	11629.44	1	11629.44	271.36	**.000**	.139
Caloundra	**P2_06-P1_07**	22432.33	1	22432.33	130.16	**.000**	.465
	P1_07-P2_07	41708.01	1	41708.01	227.98	**.000**	.603
	P2_07-P1_08	825.74	1	825.74	52.17	**.024**	.033
	P1_08-P2_08	1405.70	1	1405.70	8.85	**.003**	.056
	P2_08-P1_09	18726.60	1	18726.60	147.19	**.000**	.495
	P1_09-P2_09	86.15	1	86.15	1.04	.310	.007
Maroochy	**P2_06-P1_07**	7029.98	1	7029.98	40.29	**.000**	.155
	P1_07-P2_07	102653.57	1	102653.57	496.05	**.000**	.693
	P2_07-P1_08	81.78	1	81.78	0.49	.485	.002
	P1_08-P2_08	58505.67	1	58505.67	348.50	**.000**	.613
	P2_08-P1_09	80816.06	1	80816.06	503.00	**.000**	.696
	P1_09-P2_09	93953.71	1	93953.71	787.63	**.000**	.782

These results raise the question, was Brisbane's water use always lower than the Sunshine Coast? Comprehensive data prior to 2006 was not available, but some relatively sparse data, aggregated to suburb level, existed in the form of the Draft Urban Water Use Study of South East Queensland (Stewart et al, 2005). It was thus possible to compare 2004/5 mapping with the current water data. As the 2006 dataset was incomplete, 2007 data was mapped in ArcGIS, using the same scale (Figure 7, right). As Figure 7 (left) clearly indicates, prior to the drought, Brisbane households used similar high levels of water to the Sunshine Coast. Therefore, Brisbane residents had markedly reduced water consumption in the two years prior to 2006.

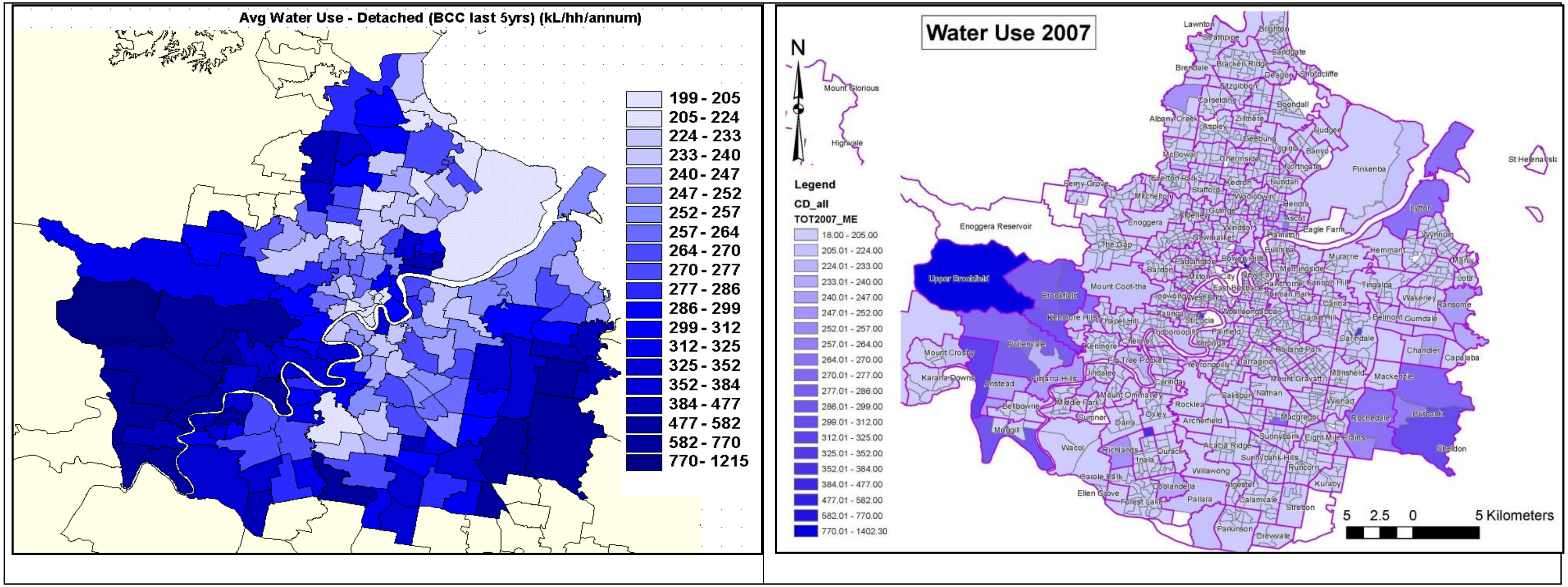

Figure 7 Average Water Use Brisbane (<2005- left) and 2007 (right)

Table 12 Average KL per selected Brisbane Suburbs (source QWC Urban Water Study)

Name	Avg KL pa 2004	% Diff 2004-2007	Avg KL pa 2007	Avg KL pa 2008	Avg KL pa 2009
Algester	319	48.93%	162.90	149.79	162.43
Calamvale	340	51.73%	164.16	149.21	162.02
Kuraby	322	51.03%	157.67	145.14	155.54
Runcorn	286	44.17%	159.68	147.07	161.40
Sunnybank Hills	336	52.95%	158.09	145.69	156.37

Mean water use for the suburbs listed in the Draft Urban Water Use Study of South East Queensland was compared with the full water dataset (Stewart et al, 2005). This study only listed those suburbs with a connection to the Karawatha reservoir, so it was not possible to detail the water use of other suburbs. Since 2004/2005, most Brisbane suburbs had reduced their water use by around 50%, and by 2008, to an even greater degree (Table 12).

Therefore, domestic water use significantly differed at the LGA and household spatial scales, and between time periods. At the LGA scale, the Sunshine Coast had higher water use than Brisbane. However, historical mapping showed that Brisbane water had previously been of similar levels to the Sunshine Coast. Differences in water use within smaller spatial scales, such as CCDs, were also apparent, with some CCDs having markedly higher or lower water use than the mean. Within LGAs and between periods, water use also differed significantly, with the most notable being in 2007, for Brisbane and Caloundra, and 2008 – 2009 for Maroochy.

4.1.2 Mapping Water Use

To visually highlight changes in household water use, the water data was aggregated to CCD, and mapped for each year. To enable comparison over time; average water use per household, per day for 2006 was used as baseline data. ArcGIS default, Jenks Algorithm was used to symbolise the data, and the resulting four classes were rounded to the nearest multiple of 10. Thereafter, the same symbolisation and intervals were used for every year. This enabled the immediate visualisation of the change in water use over time, in comparison to 2006 (Figures 8-11; see Appendix C for the full map series).

Brisbane water consumption noticeably "flattened" during the period 2006 – 2008. By 2008, the water use of the majority of CCDs fell in the lowest 2 classes. This was particularly apparent for the smaller, more central CCDs, with the larger CCDs (with correspondingly larger property sizes) showing higher water use, and less variation. However, by 2009, water consumption once again began to show more variation, similar to 2006 and 2007. Despite the overall water use for the Sunshine Coast being higher than Brisbane (the majority of CCDs mapped in the highest two classes); the same trends were also apparent.

Average Litres per day was also mapped using Standard Deviations, and the same symbolisation used for every year (Figure 10). The range of variance of Brisbane water consumption reduced from 2006 to 2008. As with the equal intervals, extreme variations occurred in the outer suburbs, with larger property sizes, such as Upper Brookfield and Chandler. The trend was similar for the Sunshine Coast. In 2006, CCDs with a greater proportion of high land value properties appeared to have higher water consumption. However, by 2008, the Sunshine Coast water use, like that of Brisbane, had flattened markedly, with no CCDs being more than 1.5SD from the mean. By 2009, this had not markedly changed, more CCDs were clustered about the mean, and fewer were greater or lesser than 1.5SD from the mean.

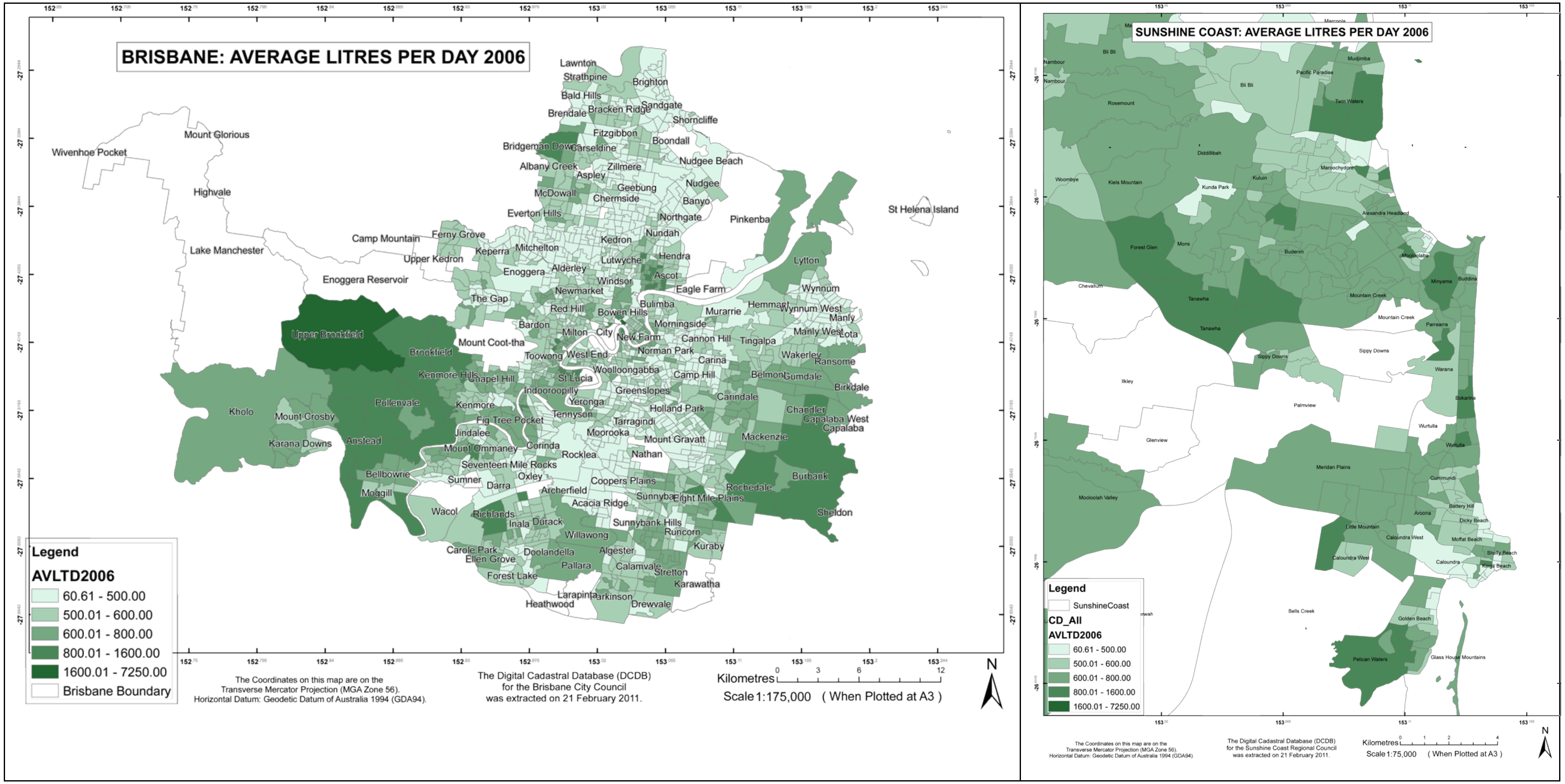

Figure 8 Average Litres per Day per CCD 2006 Brisbane and Sunshine Coast (See Appendix C for full map series)

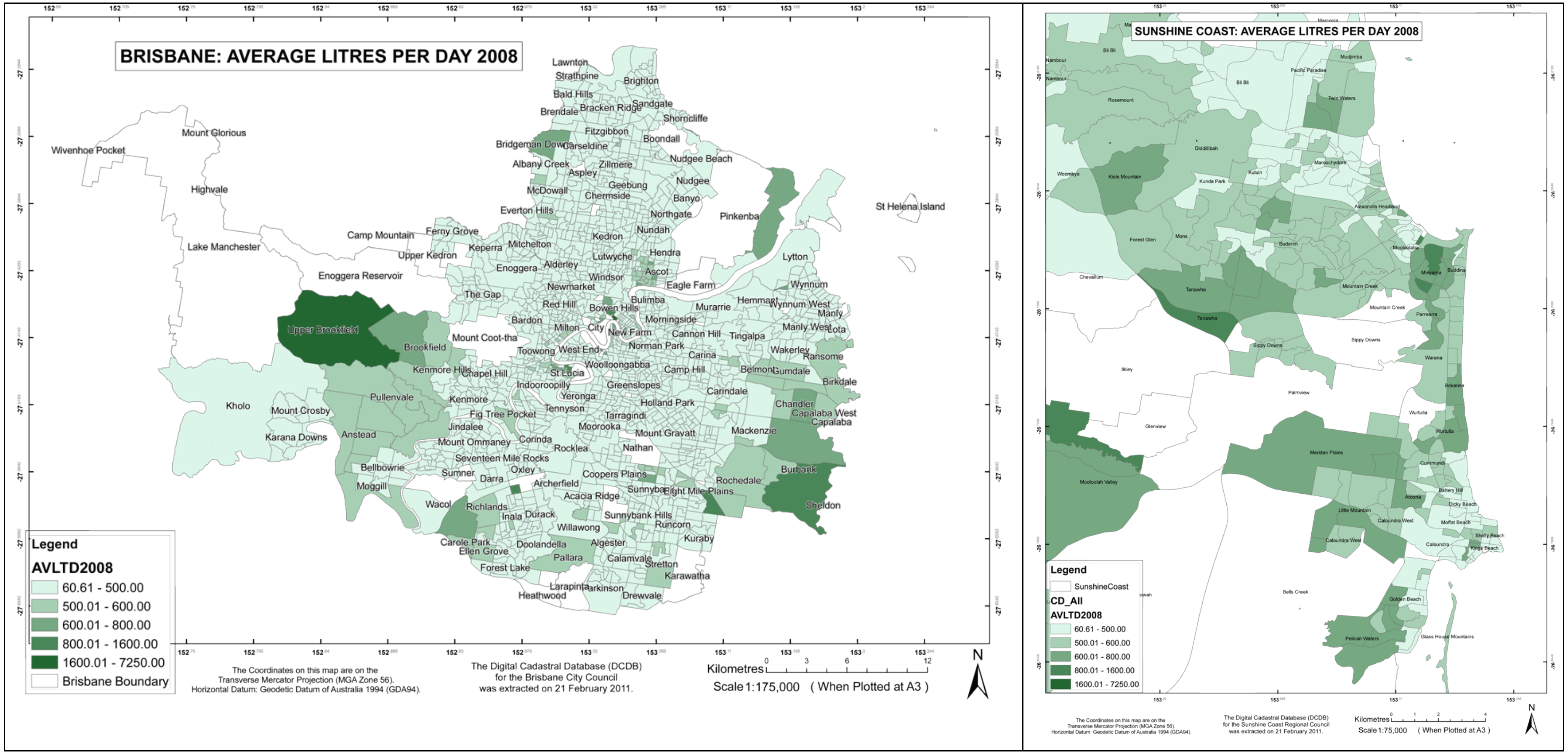

Figure 9 Average Litres per Day per CCD 2008 Brisbane and Sunshine Coast (See Appendix C for full map series)

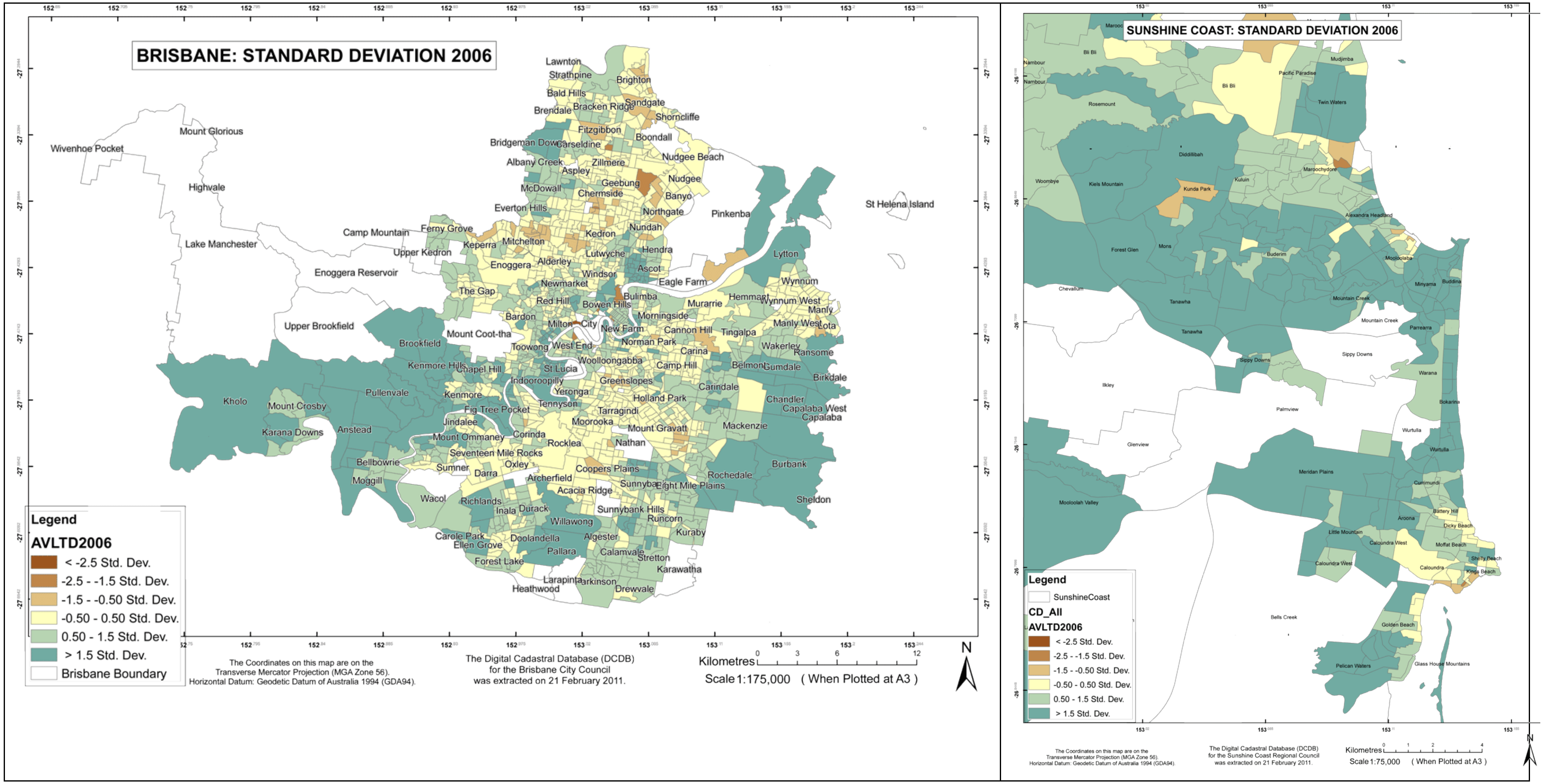

Figure 10 Standard Deviation Mean Water Use per CCD 2006 Brisbane and Sunshine Coast (See Appendix C for full map series)

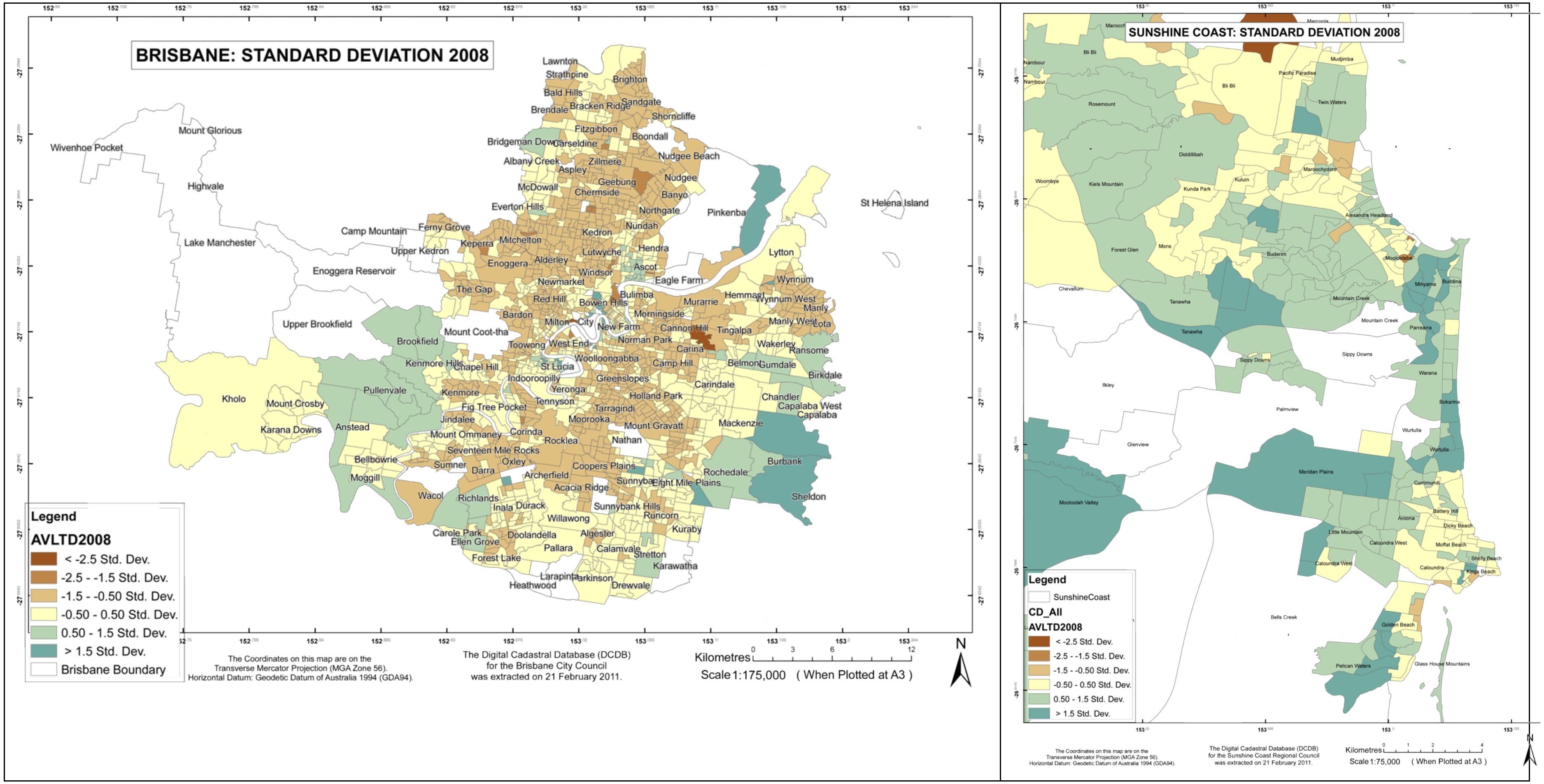

Figure 11 Standard Deviation Mean Water Use per CCD 2008 Brisbane and Sunshine Coast (See Appendix C for full map series)

To analyse if this apparent spatial clustering of household water use at the CCD level was statistically significant; the spatial statistics toolbox in ArcGIS 9.3.1 was used to calculate the Getis Ord Local Gi* “hot spot” statistic. The Gi* statistic is basically a z-score, which indicates where statistically significant z-scores cluster together; if the water use for a CCD and neighbouring CCDs is high, the process maps this as a “hot spot”, and the same applies to low scores. For both high and low scores, the larger the z-score, the more intense the clustering[18]. The degree of clustering is relevant in spatial analysis because it is a way of quantifying patterns of geographic variation (Jacquez, 2008).

For the total study area, significant clustering of both high and low water use was evident (Figure 12). In 2006, in Brisbane, water consumption in the majority of north, central and eastern CCDs was significantly lower than the mean. However, a narrow band of CCDs from The Gap in the north to Chatswood in the south, were not statistically significant or clustered, and nor were the majority of the western, inland CCDs of the Sunshine Coast. The majority of the coastal CCDs of the Sunshine Coast, and the far western suburbs of Brisbane, such as Pullenvale and Upper Brookfield, had water use that was significantly higher than the mean.

Because the Average Litres per day was higher for the Sunshine Coast than for Brisbane; the dataset was split by LGA and separate Getis Ord Gi* statistics calculated for each LGA, to enable comparison between CCDs within the same LGA. If this comparison was conducted on the whole dataset, the higher mean of the Sunshine Coast might have skewed the data, making comparisons within areas difficult. Therefore, by comparing the Getis-Ord Gi* statistic of the split dataset, it was possible to identify clusters previously obscured by the larger variance of the full dataset.

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[18] “*The local sum for a feature and its neighbours is compared proportionally to the sum of all features; when the local sum is much different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score is the result*.” (ESRI, 2010)

Brisbane

Figure 12 (2006) indicates two major clusters of significantly lower water use; the north-eastern suburbs (i.e. Chermside and Alderley); and the inner southern suburbs (i.e. Tarragindi and Holland Park). Another, less significant cluster of lower water use was apparent in the eastern suburbs (i.e. Manley and Wynnum). Clusters of significantly higher water use were apparent in the western suburbs (i.e. Pullenvale and Upper Brookfield); and the inner western suburbs (i.e. Indooroopilly and Taringa). A higher cluster was also apparent in the south east suburbs (i.e. Capalaba and Burbank).

By 2007, the northern cluster of lower water use had expanded to include the majority of northern suburbs; but the inner southern area remained relatively static. The same clusters of higher water use were evident, but the western cluster increased to include the majority of the inner city, river-side suburbs. In addition, a new cluster of higher water use was evident around Runcorn and Sunnybank Hills.

In 2008, the northern cluster of lower water use remained similar to 2007, and the inner southern area expanded to include Murarrie, Cannon Hill and Moorooka. The cluster of higher water use in the west was smaller, but was larger in the south east, and included suburbs such as Chandler, Burbank, Eight Mile Plains, Stretton and Drewvale.

By 2009, the majority of inner city riverside suburbs had significantly higher water use, as did the western suburbs of Pullenvale, Upper Brookfield and Anstead. A smaller cluster of higher water use was now apparent around Doolandella. Clusters of lower water use remained relatively similar to 2008, running in the south east from Wynnum to Rocklea, and in the north from Enoggera to Brighton.

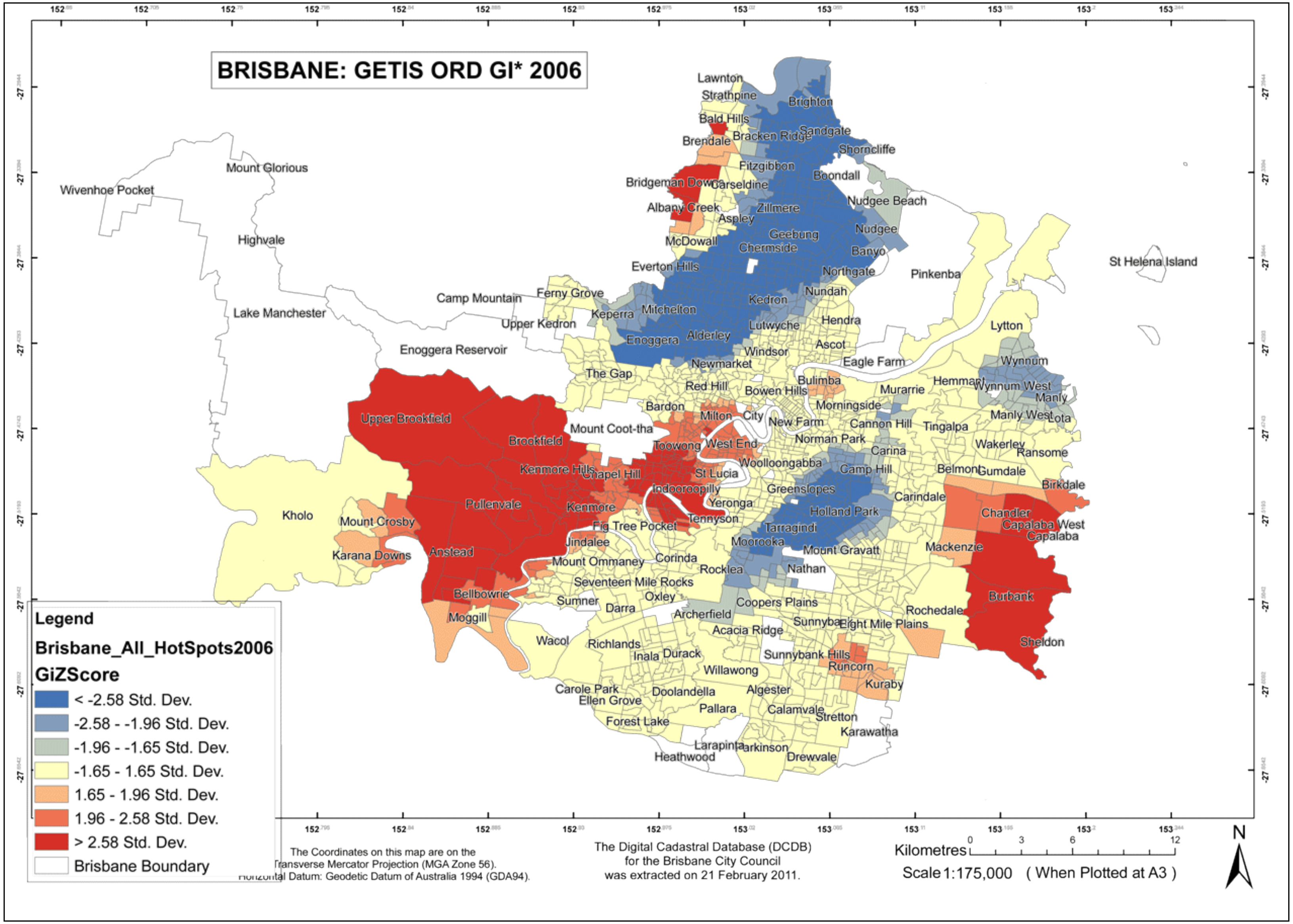


Figure 12 Getis Ord Gi Brisbane 2006 (Additional Maps in Appendix C)*

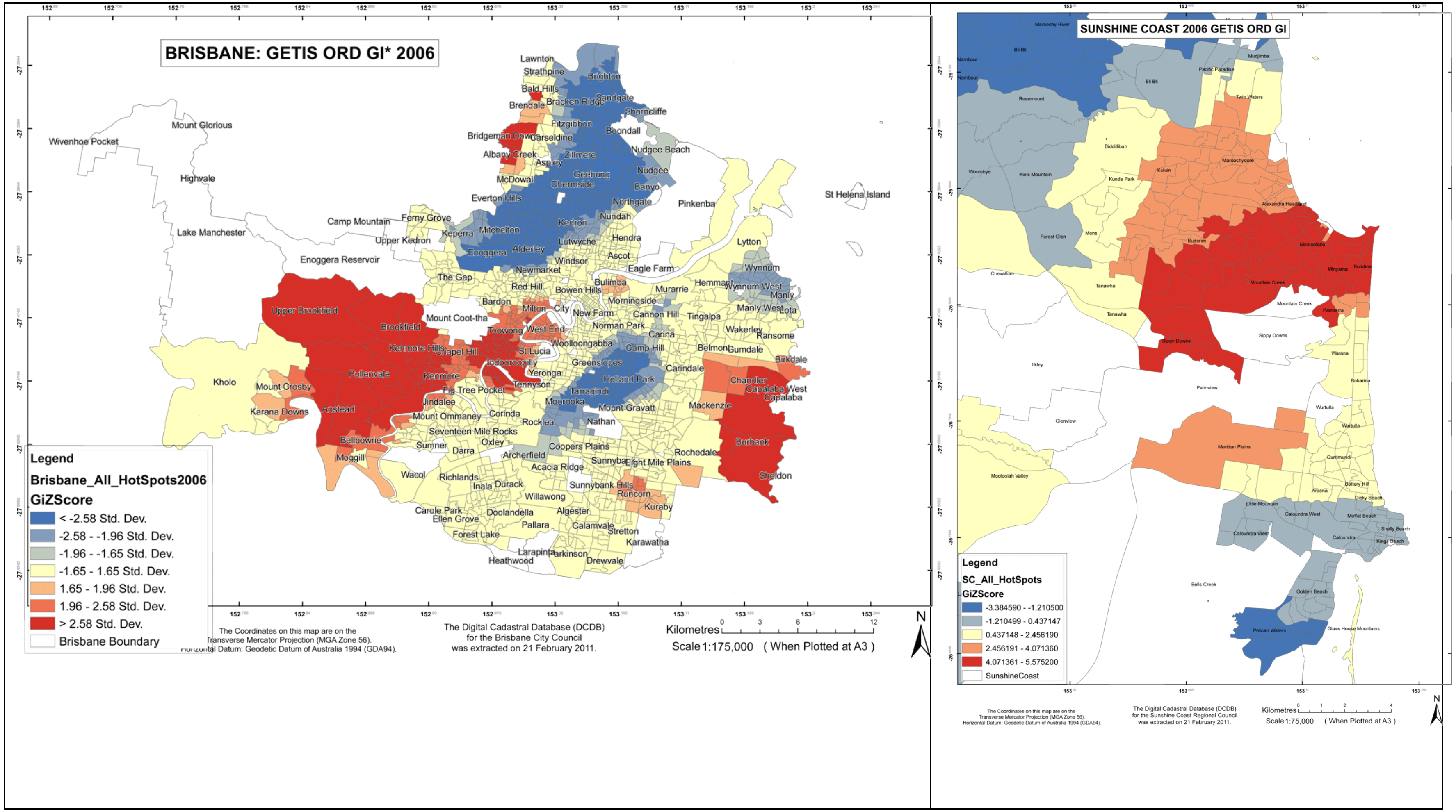


Figure 13 Comparison of the Getis-Ord Gi Scores for Brisbane and the Sunshine Coast (separate analysis)*

Sunshine Coast

Figure 13 shows that, in 2006, a cluster of significantly higher water use was evident around the central Sunshine Coast suburbs (i.e. Maroochydore, Buderim and Buddina). Clusters of lower water use were evident in the outlying, hinterland areas (i.e Maroochy River and Maleny). By 2007, all the northern and western hinterland areas had significantly lower water use. However, the cluster of higher water use had expanded, and encompassed most of coastal Sunshine Coast from Golden Beach to Alexandra Headland. All the northern Sunshine Coast suburbs of Coolum, Peregian and Marcoola had lower levels of water use.

By 2008, the water use of the southern hinterland suburbs was not statistically significant; but that of the northern areas was still significantly lower. The central Sunshine Coast suburbs (i.e. Mooloolaba and Buddina), were all significantly higher. However, the water use of the southern Sunshine Coast was lower. By 2009, all clusters of high and low water use had contracted. Fewer suburbs in the north had significantly lower water use, and clusters of higher water use had reduced to the coastal strip from Aroona to Minyama (previously the Caloundra LGA).

The graphical display of the Getis-Ord Gi* statistic over time indicated higher variability for the Sunshine Coast water use, which had similar lows to Brisbane but more extreme highs. Brisbane water use was, in general, much less variable than Sunshine Coast water use. However, a significant change in water use occurred over time, and between the LGAs. Symbolising water use proved an effective method to highlight the differences between LGAs, and between CCDs within LGAs. It also highlighted the change in water use over time, and significant clustering of high and low water use.

This mapping exercise showed that water use was apparently influenced to some extent by structural variables, such as lot size and land value. Therefore, the possible effect of these, and other spatial and temporal independent variables such as swimming pools, rainfall and the prescriptive water restrictions were further investigated.

4.1.3 Significant structural variables for household water use

A major goal of this research was to investigate the influence of structural variables on household water use. Therefore, statistical analyses were conducted on rainfall, lot area, land value, sale price, and swimming pools.

Climate, Lot Area, Land Value and Swimming Pools

Influence of Climate (Rainfall and Temperature)

In general, the Sunshine Coast receives approximately 50 to 100% greater rainfall than Brisbane. During the period 2006 – 2009, rainfall increased in a northerly direction from Brisbane to the Sunshine Coast (Figures 14 and 15). The Sunshine Coast hinterland received the highest rainfall, and western Brisbane, the lowest.

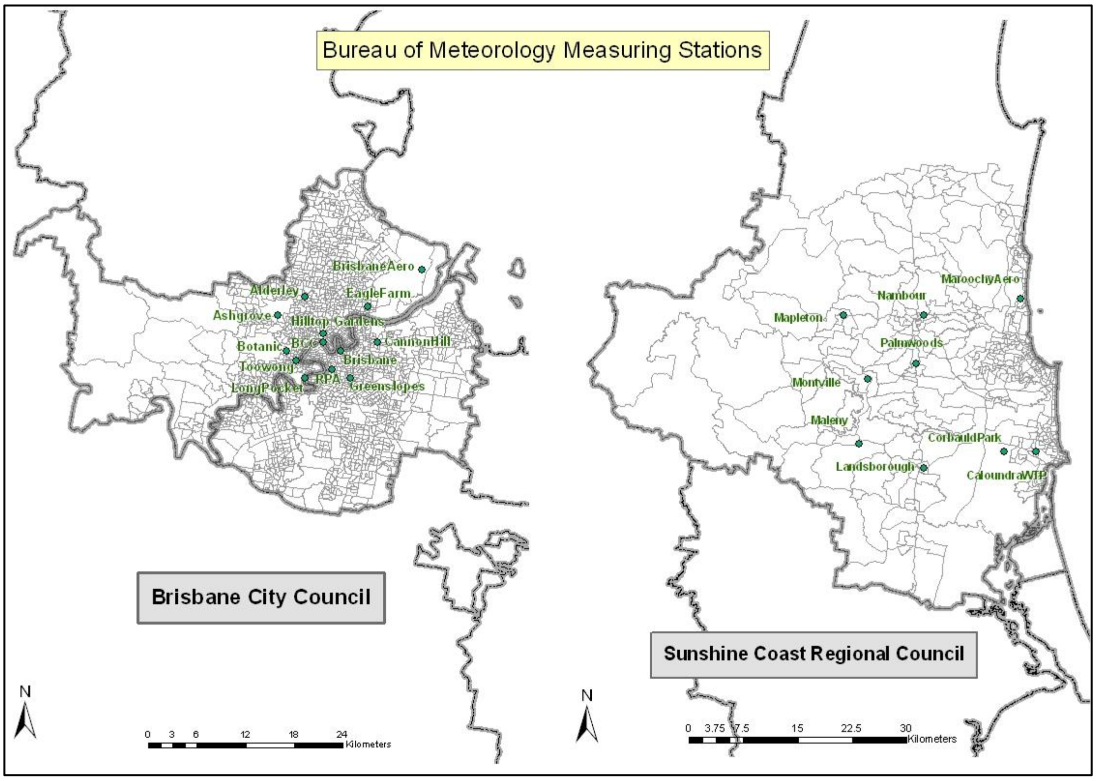


Figure 14 Rainfall Stations used in analysis (source BOM)

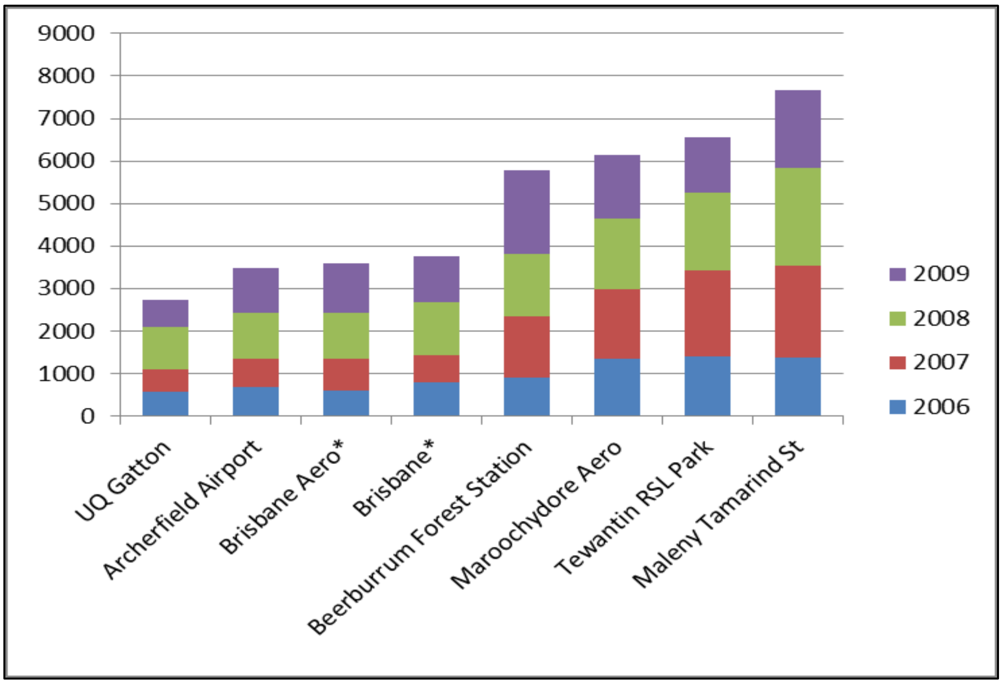


Figure 15 Annual Average Rainfall, 2006 – 2009 (ordered from lowest total to highest total (source BOM)

On a monthly average basis, rainfall was significantly bimodal in 2006 and 2008, with marked low rainfall periods in February and March, and in July, August and September. However, 2006 and 2007 differed from this pattern; with generally low rainfall most of the year after March. The years 2006 and 2007 were both much drier than usual, although in 2007, high rainfall fell in August, a traditionally dry month.

As Table 13 shows, Brisbane's mean rainfall in 2006 was extremely low, while the Sunshine Coast mean rainfall was normal. Brisbane Airport, which usually receives 1191mm per annum, only received 613mm. At the same time, Maroochy Aero received 97% of its usual rainfall of 1384mm. In 2007, rainfall tended more towards average, but was higher than normal on the Sunshine Coast. By 2008, rainfall was high to very high over the entire area. In 2009, the rainfall was more mixed, ranging from near average to very high. Of note, the analysis of rainfall data was relatively broad, and a comprehensive analysis between rainfall and water use was not undertaken. This is a fruitful area for further research.

Table 13. Rainfall per selected station, total and percentage of mean

Brisbane	**Avg.**	**2006**	**%Avg**	**2007**	**%Avg**	**2008**	**%Avg**	**2009**	**%Avg**
Archerfield	**1063**	685	64%	665	63%	1089	103%	1046	98%
Brisbane Aero	**1191**	613	51%	737	76%	1090	111%	1158	116%
Brisbane	**1149**	796	69%	652	58%	1241	110%	1072	96%
Sunshine Coast									
Beerburrum	**1393**	908	65%	1431	103%	1481	106%	1971	141%
Maleny	**1973**	1381	70%	2148	109%	2312	117%	1825	92%
Maroochy Aero	**1384**	1346	97%	1647	122%	1661	121%	1480	107%

Because of the limited number of measurement stations used, and microclimate variability from relief, vegetation cover and soil types, temperature was only broadly described, and not analysed in detail. In general, 2006 was cooler than average and 2009 was warmer. As expected, higher altitude areas, such as Maleny, were cooler than western areas, such as Archerfield. Of note, rainfall was further analysed with other variables, such as lot area, land value and the water restrictions.

Influence of Lot Area

Lot area can be a predictor of higher water consumption, particularly for outdoor water use (De Oliver, 1999; Troy et al., 2005; Wentz & Gober, 2007). As the water database had property level data on lot area, it was possible to investigate whether this was a predictor of higher water use.

Initially, to visually identify any possible correlations between lot area and water consumption, ArcGIS was used to map lot area, using the default, Jenks Algorithm. The mean water use layer was then superimposed on to this, and symbolised with proportional quantitative symbols (also using Jenks). Figure 16 shows an apparent correlation between larger lots and higher water use.

Second; given the seeming correspondence between lot area and water use, additional statistical analyses were conducted on lot area, together with land value and sale price, to identify if any of these were statistically significant for water use. Descriptive statistics for these variables are summarised in Table 14.

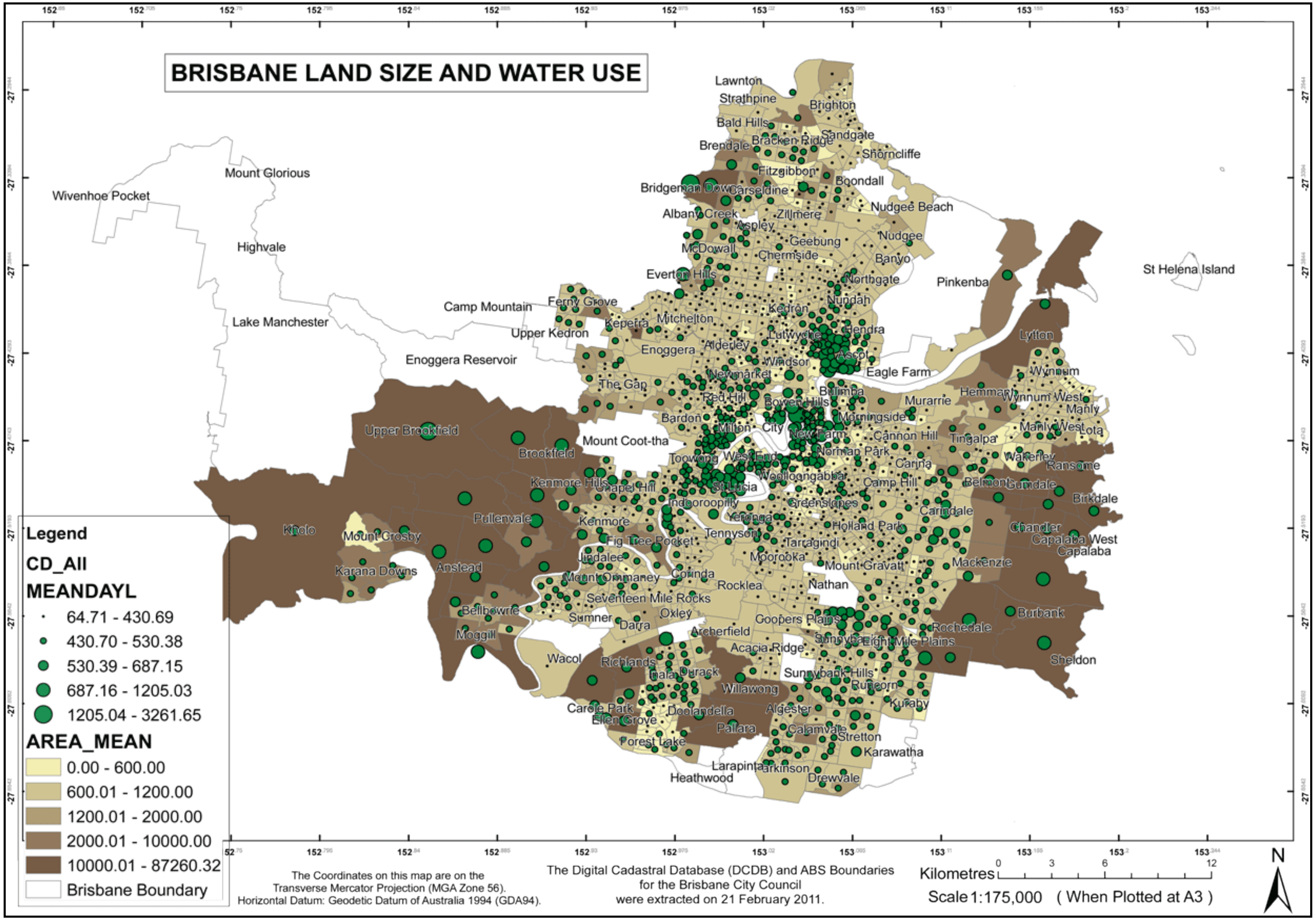


Figure 16 Mean Water Use per CCD and Lot Area

Third; a simple bivariate Pearson correlation was conducted on the water use data (per biannual period). Water use was significantly correlated with lot area for all periods and for all LGAs. In general, mean water use increased with mean lot area.

Table 14 Descriptive Statistics Area and Land Value

LGA		Lot Area	Land Value
Brisbane	N	274467	274467
	Mean	**1005.24m^2**	**$225,154.95**
	Std. Deviation	3403.75	224747.67
	Variance	1.159E7	5.069E10
Caloundra	N	22803	22803
	Mean	**1355.19 m^2**	**$279,051.09**
	Std. Deviation	6202.95	195471.04
	Variance	3.848E7	3.821E10
Maroochy	N	30738	30738
	Mean	**1566.49 m^2**	**$229,295.68**
	Std. Deviation	6900.56	179510.83
	Variance	4.762E7	3.222E10

Fourth; additional analyses were performed to identify if households on specific lot areas reduced their water use to a greater or lesser degree. For this; lot area was recoded into a categorical variable, with five equal interval quartiles; small (<600m2), small-medium (600-1200m2), medium-large (1201-2000m2), large (2000m2 – 10,000m2) and very large (>10,000m2). The categories were chosen to correspond with the Questionnaire survey, conducted in another phase of this study, which was, in turn, based on property sizes in certain SEQ Planning Schemes (i.e. Moreton Bay).

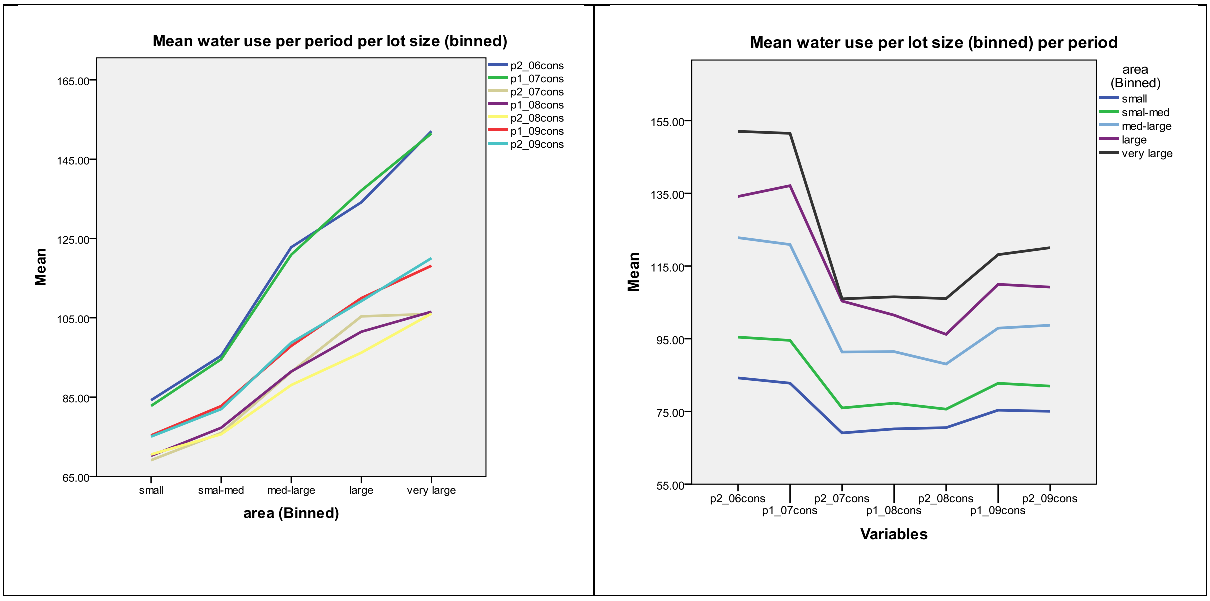
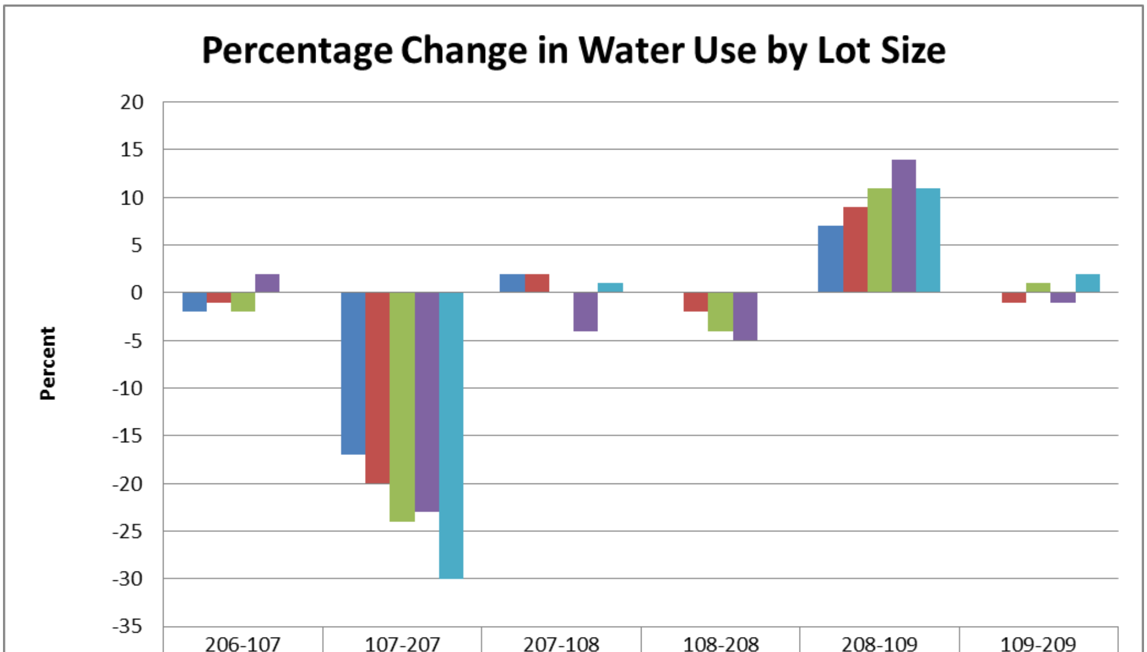


Figure 17 Mean Water Use per period and Lot Area (binned) by Period and Grouped

As shown in Figure 17, the smaller the lot, the lower the water use; and the larger the lot, the higher the water use. The difference between Small and Small Medium lots was not significant; but over time, all lot areas experienced a decrease in mean water use, particularly in the period P1_07 to P2_07 (January to June 2007).

Fifth; to calculate the magnitude of the change between the periods (i.e. whether the reduction in water use was more notable for dissimilar lot areas) “Cohen’s d” effect size statistics were calculated (Thalheimer & Cook, 2002). The standard deviations of the water data was used in preference to the F statistic, because of the highly intercorrelated nature of the longitudinal panel dataset (Becker, 2010).

As can be seen in Figure 18, for all lots, the percentage change between P1 2007 and P2 2007 was largest. An increase in water use was also notable between P2 2008 and P1 2009. Large and very large lots had proportionately the largest change in water use, both in reduction, and the subsequent increases in consumption.



	206-107	107-207	207-108	108-208	208-109	109-209
SMALL	-2	-17	2	0	7	0
SM-MED	-1	-20	2	-2	9	-1
MED-LRG	-2	-24	0	-4	11	1
LARGE	2	-23	-4	-5	14	-1
V. LRG	0	-30	1	0	11	2

Figure 18 Proportionate Change between Lot areas and Water Use

Sixth; to test the significance of this change for dissimilar lot areas, Tukey and Bonferroni post hoc tests were conducted as part of a GLM analysis. For Brisbane and Maroochy, the change between periods for all lot areas was significant, but for Caloundra, the change between Medium Large and Very Large was not significant[19]. Therefore, lot area predicted higher levels of water use, but with low significance levels. Larger lots used more water, but also reduced their water use to a greater extent.

Land Value and Mean Sale Price

Additional analyses were conducted on land value, to see if this independent variable was significant for higher levels of household water use. Income was not available at the property level, but the water database included information on land value and sale price. Land value and sale price do not necessarily correspond to income, but both are related to asset value and overall wealth (Harlan et al., 2009; Troy et al., 2005). Therefore, it was considered useful to investigate whether households with higher land value used more water.

First; because of data confidentiality, the water data, land value and mean sale price were aggregated to CCD level. This aggregation also enabled comparisons with ABS Census data, to identify any significant correlations between land value, mean sale price and mean income. Mean sale price was only used as an aggregate index against which to estimate if land value was significantly correlated with income (at the CCD level scale) as, of course, not all properties changed hands during the drought.

Second; as with lot area, ArcGIS was used to map lot area, using the default, Jenks Algorithm. The mean water use layer was superimposed on this, and symbolised with proportional quantitative symbols (also using Jenks). As with lot area, Figure 19 shows an apparent relationship between higher value lots and higher water use.

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[19] (*error term is Mean Square (Error) = 2732.938, $p < .05$*)

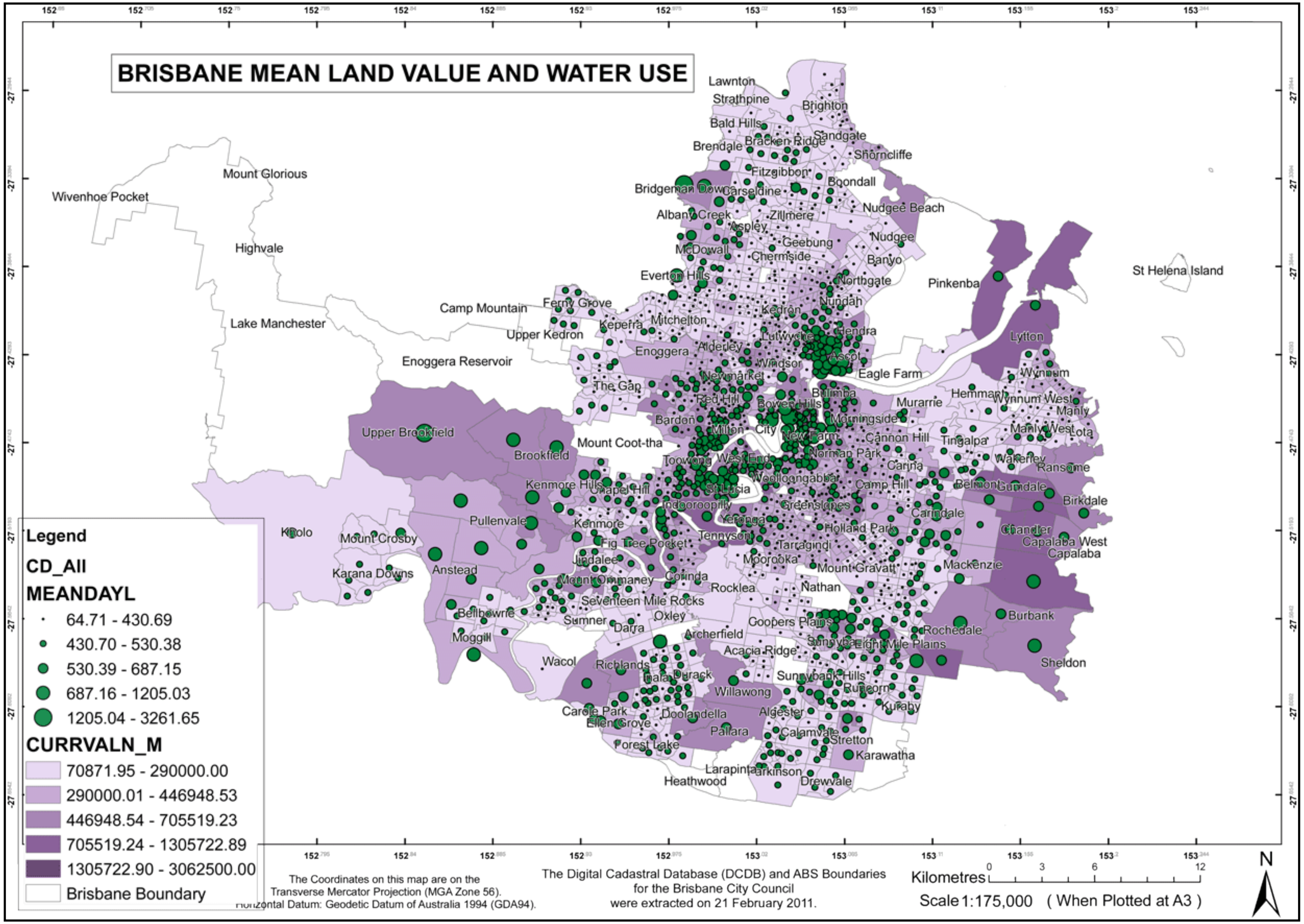


Figure 19 Land Value and Mean Water Use

Third; to test this assumption, a simple bivariate correlation was conducted between mean land value and sale price, and the ABS Census variables (median household and family income, and median home loan repayments). All variables were significantly correlated (*p<.01*) (Table 15). Of note, although the ABS data is based on medians for a specific CCD, the Valuation and Sale Price data were also highly correlated (*.750, p<.01*). Therefore land value was considered a useful proxy for income, and because that land value was available for the entire dataset, it could be used in further analysis.

Table 15. Bivariate Correlations: Aggregate Property Level Variables and Census Data

	Land Value (mean)	Sale Price (mean)	Median Household Income	Median Home Loan
Sale Price (mean)	.791**			
Median Household Income	.305**	.334**		
Median Home Loan	.453**	.441**	.551**	
Median Individual Income	.420**	.366**	.750**	.519**

**. Correlation is significant at the 0.01 level (2-tailed).

Fourth; these simple correlations indicated a relationship between the dependent variable, household water consumption, and the independent variable of land value. Therefore, to test for the influence of these independent variables, a multivariate statistical procedure, GLM Repeated Measures ANOVA was conducted. The independent variables, Mean Rainfall and Lot Area, were also included in the model. To enable the use of the rainfall data, this model was run on the CCD level dataset.

In the first model, the dependent variable “watercons” (water consumption averaged per biannual period, to enable comparison between LGAs) was the repeated measure, LGA Code the between subjects factor, and Mean Current Valuation, Lot Area, and Mean Annual Rainfall, 2006 to 2009 were the covariates. All independent variables, with the exception of Mean Total Rainfall, contributed significantly to the model (Table 16)[20]. The most significant interaction was between water use per period and Mean Value, thereafter with LGA, and finally, with Mean Lot Area.

Table 16. Dependent Variable – Test of Between Subjects Effects

Source	Type III Sum of Squares	df	F	Sig.	η_{p2}
Intercept	3426732.91	1	517.436	.000	.202
Mean Area	288123.305	1	43.507	**.000**	.021
Mean Value	2027083.50	1	306.089	**.000**	.130
Mean Rain	3591.52	1	.542	.462	.000
LGACode	1423686.41	2	107.488	**.000**	.095
Error	1.354E7	2044			

*a. Computed using alpha = .05**

Fifth; the dataset was split by LGA Code to compare the differences between the LGAs. As per the previous analyses, Mauchley's tests of sphericity were significant, so degrees of freedom were corrected using Greenhause-Geiser estimates of sphericity. As Table 17 shows; for Brisbane, Mean Value and Mean Lot Area were significant predictors of higher water use, with the most significant of these being Mean Value. For Caloundra, only Mean Land Area was significant, and for Maroochy, Mean Land Value was a significant predictor of higher water use.

Table 17 GLM Repeated Measures on Split Dataset – Test of Between Subject Effects

LGACode	Source	df	Mean Square	F	Sig.	η_{p2}
Brisbane	Intercept	1	3455603.31	637.07	.000	.275
	Mean Area	1	187279.98	34.53	**.000**	.020
	Mean Value	1	1903356.21	350.90	**.000**	.173
	Mean Rain	1	6433.216	1.19	.276	.001
	Error	167 6	5424.224			
Caloundra	Intercept	1	279138.98	16.96	.000	.104
	Mean Area	1	158531.48	9.64	**.002**	.062
	Mean Value	1	26375.69	1.60	.208	.011
	Mean Rain	1	15554.01	.95	.333	.006
	Error	146	16454.43			
Maroochy	Intercept	1	153769.80	17.45	.000	.075
	Mean Area	1	32018.14	3.63	.058	.017
	Mean Value	1	93874.21	10.66	**.001**	.047
	Mean Rain	1	24763.78	2.81	.095	.013
	Error	216	8810.68			

*a. Computed using alpha = .05**

[20] Mauchley's test of sphericity was significant (*chi square =1055.606, P<.05*) so degrees of freedom were corrected using Greenhause-Geiser estimates of sphericity (*epsilon = 0.735*)

Mean Land Value and then Mean Local Government Area were the most significant predictors for differences in water use for the full dataset (Table 16). For the split dataset, Mean Land Value was the most significant predictor for differences in water use for Brisbane and Maroochy, but was not significant for Caloundra. Lot area was significant for Brisbane, but not for the other LGAs. Rainfall was not a significant predictor for differences in household water use.

<u>Swimming Pools</u>

The presence of a swimming pool can have a strong positive relationship with higher household water use (Eardley et al., 2005; Harlan et al., 2009). Therefore, a large random sample (81,918) of properties with swimming pools was analysed to investigate if these used more water.

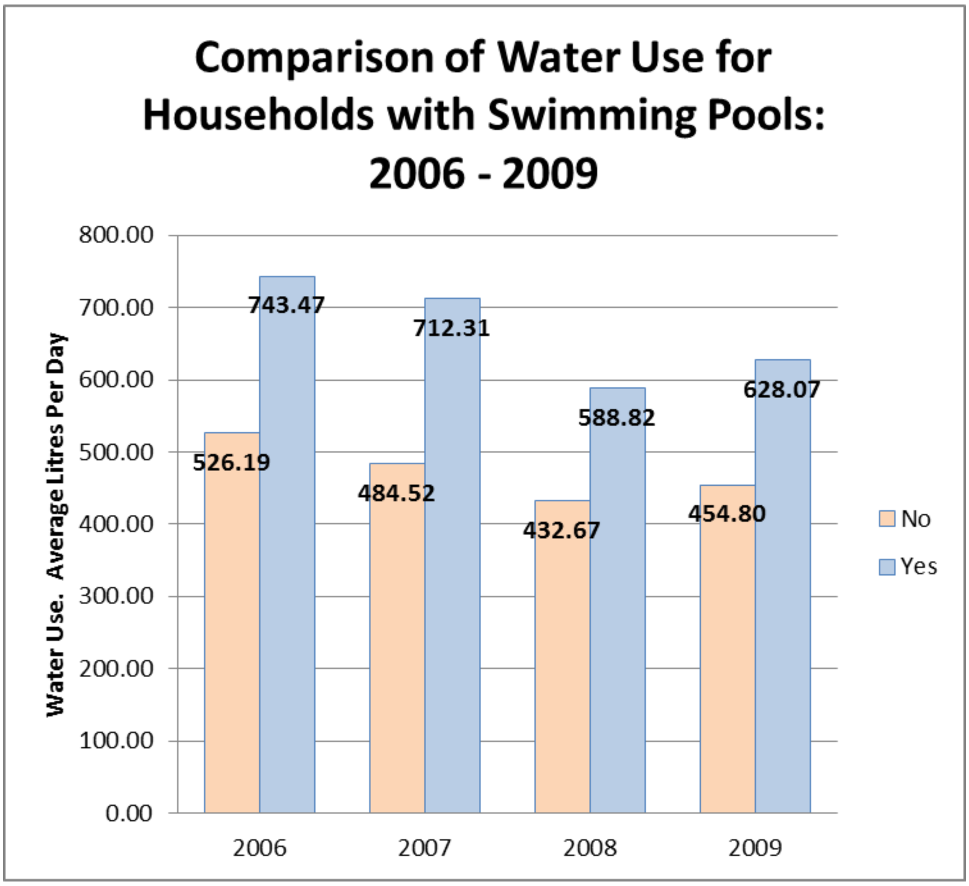


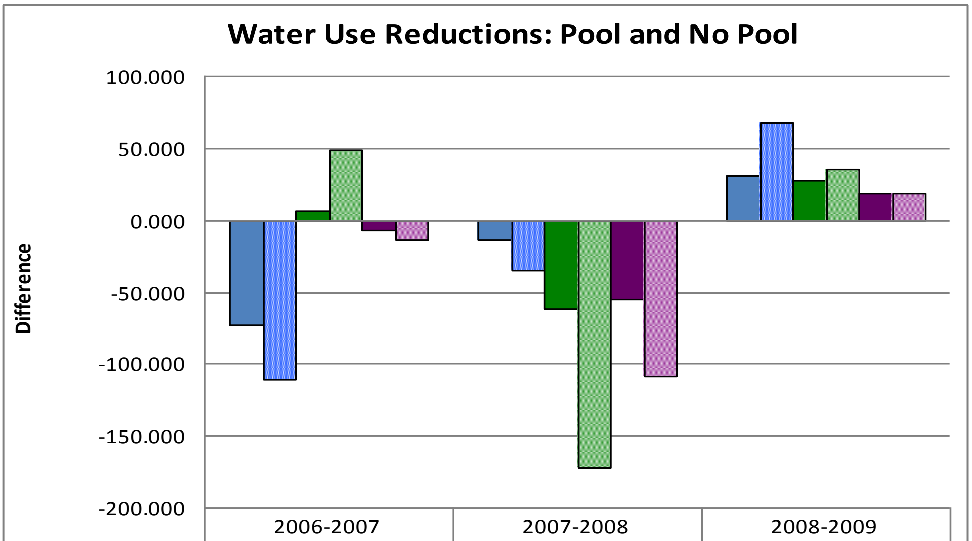
Figure 20 Water Use for Households with Pools

Of the sample (n=81,892), approximately 30% (20,201) had swimming pools, and for every year, mean water use for houses with pools was higher (Figure 20). To verify this statistically, a one way between subjects ANOVA was conducted to compare water use of households with pools with those without pools. Unsurprisingly, having a pool had a significant effect on water use every year (*p*>*.05*), with the strongest relationship in 2006, and the weakest in 2008 (Table 18).

Table 18 ANOVAs Table Water Use and Swimming Pools

		SSquares	df	Mean Square	F	Sig.
Avg litres per day 2006	Between Groups	7.19E8	1	7.19E8	**4297.28**	.000
	Within Groups	1.37E10	81890	167190.62		
Avg litres per day 2007	Between Groups	7.90E8	1	7.90E8	**5592.28**	.000
	Within Groups	1.16E10	81890	141204.83		
Avg litres per day 2008	Between Groups	3.71E8	1	3.71E8	**3390.66**	.000
	Within Groups	8.96E9	81890	109443.68		
Avg litres per day 2009	Between Groups	4.57E8	1	4.57E8	**3875.32**	.000
	Within Groups	9.66E9	81889	117898.39		

Of more interest was investigating the change in water use between years and LGAs for properties with swimming pools. As expected, properties with pools had proportionately greater increases and decreases in water use (Figure 21). For all properties, the most dramatic drop in water use occurred between 2007 and 2008.



	2006-2007	2007-2008	2008-2009
Brisbane No	-72.891	-13.469	31.104
Brisbane Yes	-110.831	-34.889	67.439
Caloundra No	6.830	-61.508	27.207
Caloundra Yes	48.487	-171.800	34.996
Maroochy No	-7.201	-55.017	18.152
Maroochy Yes	-13.301	-108.357	18.152

Figure 21 Pairwise Change, Properties with and without Swimming Pools

Combined Variables

To identify the combined influence of structural drivers on household water use, the independent variables of swimming pools, lot size and land value were analysed with a GLM Repeated Measures ANOVA (Table 19). Rainfall was not used, as this was not significant in the previous analysis. To use the swimming pool data, a smaller sample (n=81,918) was investigated. Of note, sample selection was not strictly random but clustered, as pools were selected manually from all lots in individual CCDs. However, the final sample included approximately 25% of the full dataset.

Before running the analysis, the dataset was investigated for multivariate and univariate outliers, using Cooks and Mahalanobis distances. Univariate outliers were removed as these could skew the results, but multivariate outliers were retained, as these were assumed to reflect "normal" water use. The dataset was slightly positively skewed, but applying log normal and square root transformations did not significantly change the skew, so normalisation procedures were not used. Moreover, ANOVA models such as GLM Repeated Measures are relatively robust, particularly for equal sized groups (Field, 2009).

For every LGA, the most significant influence on household water use was the presence of a swimming pool[21]. As expected, the average water use of households with pools for all areas was significantly higher than for households without pools. However, the influence of the other variables differed by LGA (Table 19). For all LGAs, all independent variables were significant for higher levels of domestic water use. For all LGAs, swimming pools then mean land value were the most significant predictors of higher water use. Mean Land Area was significant, but the effect was relatively weak in comparison to land value and swimming pools. Of note, the effect sizes are relatively low, due to the large size of the dataset.

21 Post hoc tests were conducted using Bonferroni adjusted alpha levels of P<.05 per test

Table 19 GLM Repeated Measures on Split Dataset – Test of Between Subject Effects

LGA	Source	df	Mean Square	F	Sig.	η_p^2
Brisbane	Intercept	1	1.254E9	27698.42	.000	.451
	area	1	633958.74	**14.01**	.000	.000
	currvaln	1	7.137E7	**1576.77**	.000	.045
	Pool	1	7.769E7	**1716.29**	.000	.048
	Error	33759	45265.35			
Caloundra	Intercept	1	1.702E9	14766.93	.000	.425
	area	1	2034129.93	**17.64**	.000	.001
	currvaln	1	8.403E7	**728.89**	.000	.035
	Pool	1	1.682E8	**1459.17**	.000	.068
	Error	20015	115287.67			
Maroochy	Intercept	1	2.527E9	28494.84	.000	.503
	area	1	2785343.99	**31.41**	.000	.001
	currvaln	1	1.007E7	**113.59**	.000	.004
	Pool	1	1.343E8	**1514.80**	.000	.051
	Error	28105	88679.41			

*a. Computed using alpha = .05**[22]

Proportionate change in water use

Therefore, structural variables were significant predictors of higher water use, particularly swimming pools. Thus, further analysis was conducted to identify if households with particular structural characteristics changed water use to a greater or lesser degree during the drought. The dependent variable ConsDiff was created by subtracting Average Liters per Day (2006) from Average Liters per Day (2008) to give a difference in total water consumption for the drought period. The sign of the results were reversed, and a whole integer equal to the lowest result (*n+1*) added, so the largest number reflected the greatest degree of change. Water use in 2006 was also subtracted from water use in 2009, to give the total difference (ConsDiffTot). In addition, ConsDiff was subtracted from ConsDiffTot to give the post drought water consumption (PostDrought). These created variables were then used in further statistical analysis to investigate whether the influence of independent variables, Land Value and Lot Area, changed during the period. To filter the data, z-scores were used, and any property with

[22] For each LGA, Mauchley's test of sphericity was significant, so degrees of freedom were corrected using the Greenhause-Geiser estimates of sphericity.

higher (or lower) than 4 SD above the mean was removed. This normalising exercise removed 1,864 records, with a final n=326,144.

To identify initial relationships, a simple bivariate correlation was calculated for land value, lot area and pools. During the drought, water use was negatively correlated with swimming pools ($r = -.069, p < .01$); land value ($r = -.070, p < .01$) and lot area ($r = -.015, p < .01$). However, after the drought, these correlations were positive, but were not significant for lot area. When splitting the dataset, the relationships between the independent variables and water use differed between areas. For Caloundra, lot area was not significant at any time. Maroochy was similar to Brisbane, although after the drought, only land value was significant. Although significant, all correlation coefficients were weak (Abrahamse & Steg, 2009). As a graphical indication of these trends, Figure 22 plots the water use over time for properties with swimming pools, of differing values. It clearly shows that for all LGAs, properties with swimming pools used more water than those without. It also shows that for Brisbane and Maroochy, higher value properties without pools used more water, and for all LGAs, higher value properties with pools used more water.

The above statistical analyses showed that household water consumption was influenced by static, structural variables, particularly swimming pools, mean land value and lot area. However, the influence of all these diminished during the drought, leading to the conclusion that other temporal factors took precedence. Of these, arguably the strongest influence was the prescriptive water restrictions. The following section investigates the influence of the water restrictions.

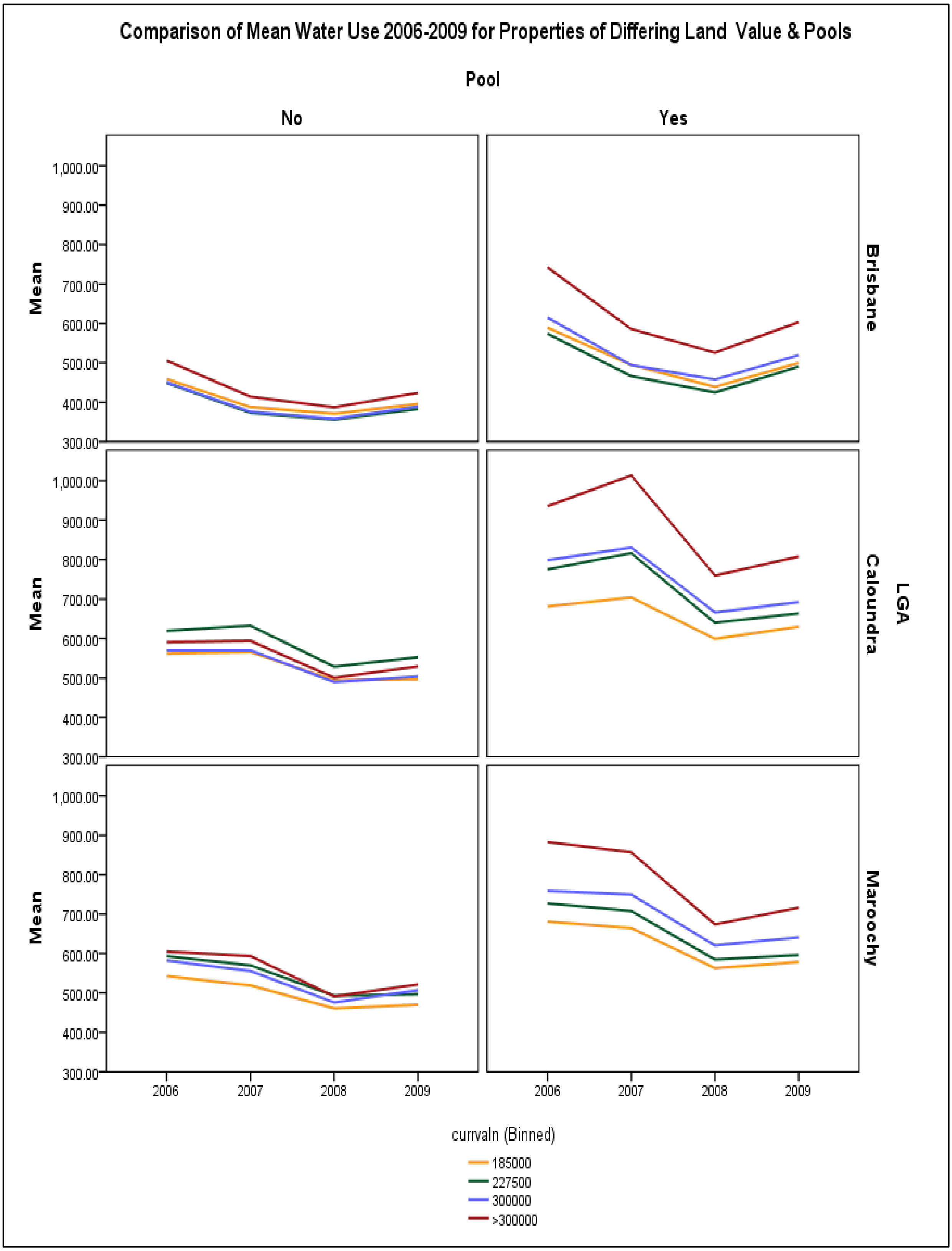


Figure 22 Comparison of Mean Water Use 2006- 2009 for properties of Differing Land Value and Swimming Pools

4.2 Section Two

4.2.1 Significant Policy measures for household water use

Water Restrictions

As the dataset contained actual water consumption data, together with dates of meter readings, it was possible to analyse the effect of the water restrictions in detail, and to control for confounding variables such as rainfall. To do this, it was first necessary to calculate average household water use per month. However, Brisbane water meters were only read at quarterly intervals, and without consistent periods between readings (for example, consecutive readings could range from one to three months). Therefore, a smoothing procedure was applied to the water data, to estimate monthly household water use.

To calculate monthly water use, for each household, the number of days between readings was calculated, by subtracting the date of first reading from the date of the subsequent reading. Then, the water consumption for the period (measured at the later date) was divided by the number of days, to give the average daily use per period. This average daily use was allocated to each month, proportional to the number of days in that month)[23]. Although this method smooths intermonthly variation, the large size of the dataset enabled the estimated aggregate use to mimic the actual pattern of intermonthly variation (Martinez-Espineira, 2007). As some households had missing data; the analysis only used consumption data from August 2006 to August 2009. The smoothing procedure is summarised in Figure 23, below.

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[23] *"For example, if the reading period goes from 28-04-00 to 03-08-00 and the reading is 91 m3, since the length of the period is 97 days, average daily use is 0.93 m3. This average daily use would be multiplied by 2 to obtain April's consumption, by 31 for May, by 30 for June, by 31 for July and by 3 for August*." (Martinez-Espineira, 2007)

—

n = *n*th calendar month
x = number of months prior to month n in billing period
y = number of months after month n in billing period
i = summation index (*i*th month)
= quantity of water used in month n
Ni = number of days in *i*th month proportioned to consumption in month n
= average daily water consumption for billing period represented by month n

Figure 23 Calculation of Monthly Smoothed Averages

Initially, the full dataset was graphed per month, to visually identify any obvious seasonality or other temporal anomalies. Figure 24 shows no obvious seasonal trend to the water consumption data. However, a notable drop in water consumption was evident from December 2006 to June 2007, and a more gradual drop until February 2008. This apparently relates to the dates of Level 4 and Level 5 Water Restrictions (Level 4: 1 November 2006, and Level 5: 10 April, 2007).

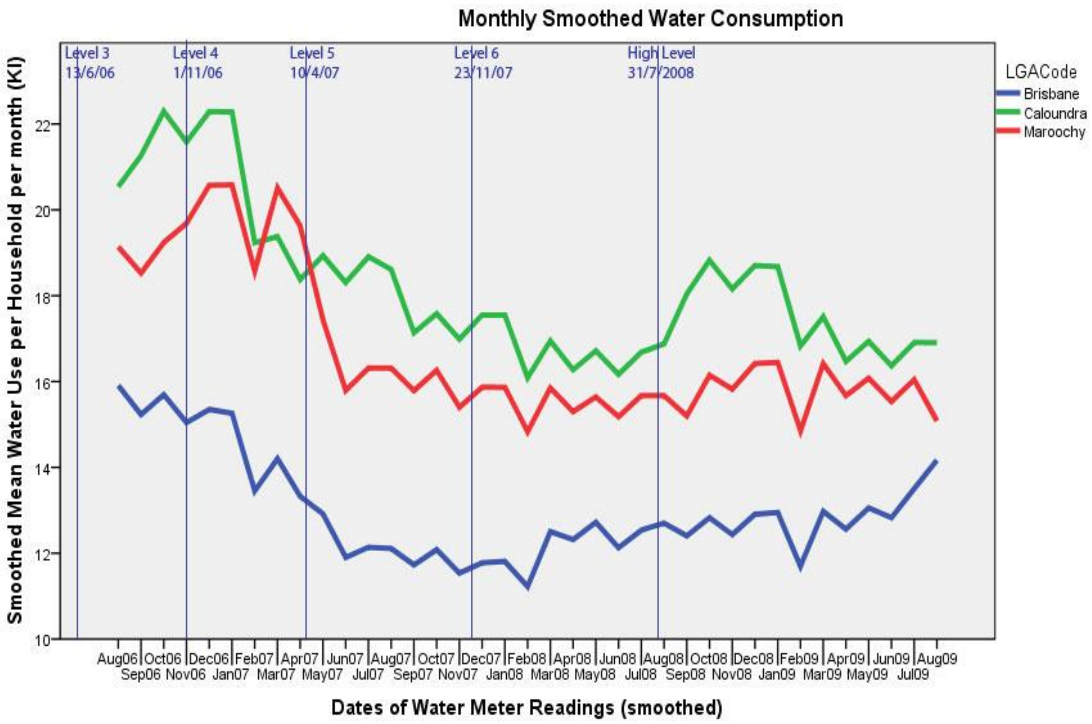


Figure 24 Monthly smoothed water consumption – split by LGA – showing dates of imposition of Water Restrictions

Thereafter, the dataset was split by LGA Code, to observe any differences between the LGAs. Despite Maroochy and Caloundra having no water restrictions, their water use showed similar trends as Brisbane (Figure 25). Brisbane water use also rose more in the latter half of 2009 than the other LGAs. Although no overall seasonal component was apparent, an apparent summer rise in water use occurred in late 2008.

Because the graphed monthly data apparently indicated some temporal influence, Cumulative Sum Control (CUSUM) Charts were calculated on the dataset (split by LGA) to visually identify any notable changes in mean over the period. CUSUM Charts are often used in changepoint analysis to identify marked changes in time series or panel data, such as this dataset. For this exercise, the average monthly consumption was not used, as this method tends to smooth changes of time, making it more difficult to identify significant changepoints. Instead, mean consumption was aggregated to CCD level. In addition, the original Brisbane dataset with quarterly water data was analysed separately from the biannual Sunshine Coast dataset, to give a finer level of detail.

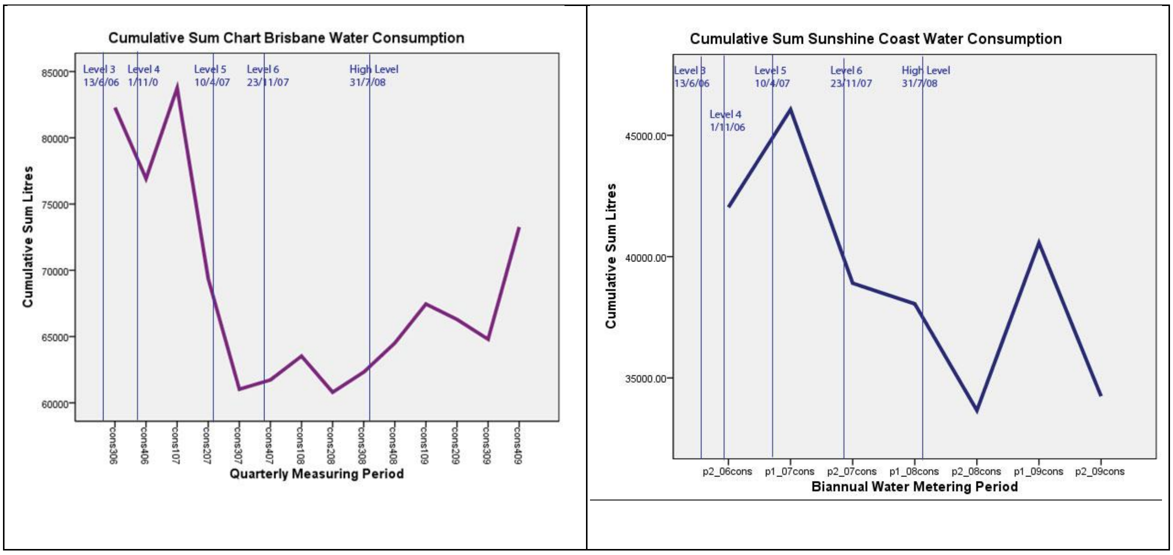


Figure 25 Cumulative Sum Charts of Brisbane and Sunshine Coast Water Data, showing (approximate lines) dates of imposition of water restrictions.

As Figure 25 shows, a striking change occurred in Brisbane between the 1st and 3rd Quarters of 2007 (January to September 2007). The same trend was evident for the Sunshine Coast, although over a longer period, between the 1st Period 2007 and the 2nd

Period 2008. These periods correspond approximately to January to September 2007 (Brisbane) and January 2007 to December 2008 (Sunshine Coast). These major reductions apparently relate to the dates of imposition of Levels 4 and 5 water restrictions (Brisbane only); the dates of which were:

- Level 3: 13-Jun-2006
- Level 4: 01-Nov-2006
- Level 5: 10-Apr-2007
- Level 6: 23-Nov-2007
- High Level: 31-Jul-2008[24]

Linear Mixed Models

To investigate whether the water restrictions had a statistical significance on household water use, a fixed effects Linear Mixed Models (LMM) procedure was conducted. First, a LMM was run on the Brisbane dataset with Restriction Code as a Fixed Factor, and mean rainfall as a Covariate. Rainfall was not significant and was removed for future analyses. For each level of water restrictions, the influence on household water use was significant (Table 20). These results also corresponded with the visual evidence of the CUSUM charts, and graphed monthly water use—the most significant reduction in water use occurred after Levels 4 and 5 water restrictions.

Table 20 Estimates of Fixed Effects Water Restrictions

Parameter	**Estimate**	**StandardError**	**df**	**T**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	Upper Bound
Intercept	38.68	.02	3568170	1603.65	.000	38.64	38.73
[Restricts=3]	7.97	.06	3568170	**144.09**	.000	7.86	8.079
[Restricts=4]	8.38	.05	3568170	**164.50**	.000	8.28	8.48
[Restricts=5]	-1.29	.04	3568170	**-29.78**	.000	-1.37	-1.20
[Restricts=6]	-2.50	.05	3568170	**-49.36**	.000	-2.60	-2.40
[Restricts=7]	0[a]	0	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Dependent Variable: cons.

Second; to investigate additional structural variables and to compare LGAs; the LMM was rerun on the split dataset with LGA code, lot area, land value and swimming pools controlled as Fixed factors. LMM is capable of dealing with unbalanced datasets,

[24] Note: High Level Restrictions were an easing of Level 6 Restrictions, from 140 – 170LCD

so the varying dates of the Sunshine Coast readings were not an issue. Although the Sunshine Coast did not have water restrictions, a restrictions variable was created for the dataset, to see if the dates of Brisbane water restrictions (which were well publicised in the media) had any influence over the nearby Sunshine Coast.

As can be seen in Table 21; the influence of the restrictions was still highly significant, as were swimming pools and land value, and to a lesser extent, lot area. For Brisbane, the water restrictions had the most influence on water use, thereafter swimming pools and land value. For Caloundra, swimming pools and land value had the most influence; and for Maroochy, the water restrictions, then swimming pools, then land value had the most influence.

Table 21 Estimates of Fixed Effects, Lot area, Land Value and Swimming Pools Controlled

LGA	Source	Numerator df	Denominator df	F	Sig.
Brisbane	Intercept	1	36002.33	29887.52	.000
	Pool	1	33792.65	1643.80	.000
	Restricts	4	199238.18	1770.63	.000
	area	1	33633.96	13.08	.000
	currvaln	1	33857.17	1399.11	.000
Caloundra	Intercept	1	20504.87	14726.27	.000
	Pool	1	19993.77	1452.02	.000
	Restricts	4	119964.46	295.18	.000
	area	1	19983.41	17.10	.000
	currvaln	1	20006.39	797.12	.000
Maroochy	Intercept	1	31041.52	29654.82	.000
	Pool	1	28140.44	1480.03	.000
	Restricts	4	171661.94	1801.51	.000
	area	1	28113.68	26.44	.000
	currvaln	1	28135.06	121.76	.000
a. Dependent Variable: cons.					

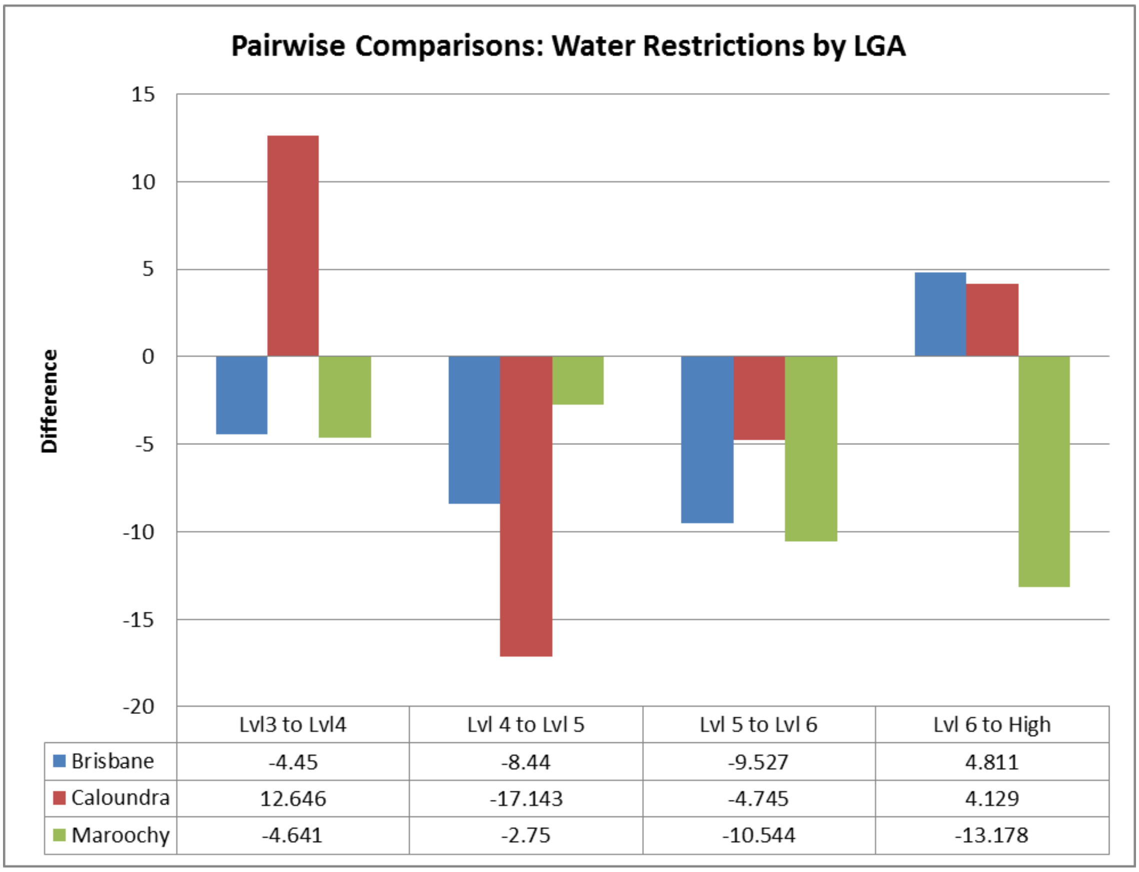
A Scaled Identity Covariance structure was used to examine the relationship between water consumption and levels of water restrictions. This relationship showed significant variance in intercepts across properties (Lot and Plan). In addition, the slopes varied across properties, and the slopes and intercepts negatively and significantly covaried. The most significant predictors were the presence of a swimming pool and then the water restrictions. Lot area was the least significant independent predictor. For each LGA, all independent variables significantly predicted household water consumption (Table 22).

Table 22 LMM Estimates of Fixed Effects

LGA	Parameter	Estimate	Std. Error	df	t	Sig.	95% CI	
							Lower Bound	Upper Bound
Brisbane	Intercept	81.05	.32	231215	255.30	.000	80.41	81.66
	[Pool=0]	-21.95	.26	231215	-84.51	.000	-22.45	-21.44
	[Pool=1]	0a	0	.	.	.	.	.
	[Restricts=3]	14.02	.55	231215	25.30	.000	12.93	15.11
	[Restricts=4]	12.64	.33	231215	37.89	.000	11.99	13.29
	[Restricts=5]	2.72	.25	231215	10.89	.000	2.23	3.22
	[Restricts=6]	-5.18	.27	231215	-19.04	.000	-5.72	-4.65
	[Restricts=7]	0a	0	.	.	.	.	.
	Lot Area	0.00	.00	231215	7.40	.000	0.00	0.00
	Land Value	0.00	.00	231215	78.35	.000	0.00	0.00
Caloundra	Intercept	116.94	.70	139931	167.96	.000	115.58	118.31
	[Pool=0]	-37.00	.55	139931	-66.80	.000	-38.09	-35.92
	[Pool=1]	0a	0	.	.	.	.	.
	[Restricts=3]	5.47	.77	139931	7.10	.000	3.96	6.98
	[Restricts=4]	18.89	.77	139931	24.43	.000	17.38	20.41
	[Restricts=5]	1.63	.77	139931	2.13	.033	0.13	3.13
	[Restricts=6]	-4.12	.77	139931	-5.36	.000	-5.62	-2.61
	[Restricts=7]	0a	0	.	.	.	.	.
	Lot Area	0.00	.00	139931	7.26	.000	0.00	0.00
	Land Value	0.00	.00	139931	49.28	.000	0.00	0.00
Maroochy	Intercept	96.79	.48	196672	203.18	.000	95.85	97.72
	[Pool=0]	-26.28	.39	196672	-68.02	.000	-27.04	-25.52
	[Pool=1]	0a	0	.	.	.	.	.
	[Restricts=3]	30.01	.87	196672	34.44	.000	28.30	31.71
	[Restricts=4]	27.31	.61	196672	44.78	.000	26.12	28.51
	[Restricts=5]	24.57	.43	196672	57.36	.000	23.73	25.41
	[Restricts=6]	13.17	.51	196672	26.06	.000	12.18	14.16
	[Restricts=7]	0a	0	.	.	.	.	.
	Lot Area	0.00	.00	196672	9.18	.000	0.00	0.00
	Land Value	0.00	.00	196672	19.40	.000	0.00	0.00

a. This parameter is set to zero because it is redundant. b. Dependent Variable: cons.

When graphing the pairwise differences between Level 3 and 4 water Restrictions, both Brisbane and Maroochy dropped in water use, but Caloundra rose (Figure 26). However, in the next period (Level 4 to Level 5), Brisbane and Maroochy continued to drop, but Caloundra dropped dramatically. From Level 5 to Level 6, all LGAs dropped in water use, with Maroochy and Brisbane dropping the most. However, between Level 6 and High Level restrictions, both Brisbane and Caloundra rose, and Maroochy continued to decrease. Maroochy used greater quantities of water, but the pattern of reduction largely mirrored that of Brisbane.



	Lvl3 to Lvl4	Lvl 4 to Lvl 5	Lvl 5 to Lvl 6	Lvl 6 to High
Brisbane	-4.45	-8.44	-9.527	4.811
Caloundra	12.646	-17.143	-4.745	4.129
Maroochy	-4.641	-2.75	-10.544	-13.178

Figure 26 Mean Water Use per LGA at Restriction Periods

The previous analyses investigated the influence on household water use at the Lot and Plan scale of independent structural variables, such as lot area, land value and swimming pools; as well as the water restrictions. The most significant influencing factors were swimming pools, water restrictions and land value. Therefore, in keeping with the research question; the next phase of the analysis investigated the possible influence of socio-demographic variables on household water use.

4.3 Section Three

4.3.1 Significant socio-demographic variables for water use at the Census Collection District (CCD) scale

The relationship between household water use and land value, sale price and swimming pools apparently indicated that household water use at the CCD level was influenced by socio-demographic variables, such as income. Clusters of higher water use generally mapped to CCDs having proportionately higher income and larger lot sizes. Therefore, further statistical tests were conducted to identify which socio-demographic variables were significant for household water use, and if their influence changed during the drought.

Prior to statistical analysis, a visual analysis was conducted. The ABS_info table added to the GIS map, to observe any noticeable patterning of socio-demographic variables. Many patterns were intuitively obvious, such as a greater percentage of people over 65 in communities such as Caloundra. Noticeable clusters were also observed of non-English speaking migrants, high-income professionals and some of the traditional indicators of socio-economic disadvantage, such as housing commission properties and lone parents.

<u>Dependent Variables</u>

To investigate socio-demographic influences on household water use, and change in water use in response to policy measures (i.e. if any socio-demographic groups were more or less likely to reduce water consumption), two dependent variables were used in the analysis.

The first dependent variable used was log transformed mean water use per household per day (for 2006-2009). It could be argued that mean water use for 2006 was a more valid measure, as the Census 2006 was conducted in August 2006. However, the 2006 consumption dataset was not suitable because of missing data. Water use was log transformed because, at the CCD level, it was positively skewed. To estimate the validity of this measure, paired samples t-tests were used to compare the log transformed mean water use per annum with log transformed total mean water use; all were highly correlated (*r .098, p>0.01*).

The second dependent variable used was change in water use (ConsDiff). ConsDiff was calculated by subtracting the average daily water use of 2006 from that of 2008. Because the difference ranged from negative to positive, the variable ConsDiff was transformed, by adding a positive integer (*n+1*), and changing the sign of the variable. By doing this, the highest numbers reflected the greatest degree of change, making the results of the analysis easier to interpret. One extreme outlier was also removed from the analysis, because it excessively skewed the results.

Analysis One: Socio-demographic Influences on Household Water Use

The analysis was conducted on the whole dataset and on the dataset split by LGA, to compare predictor variables for water consumption. Prior to running the model, scattergraph plots were used to identify if a linear model was suitable for the variables. The final variables chosen were: Mean Sale Price; Aged 15-19; Mean Land Area; Journey to Work Public Transport; Average Household Size; Median Age; Median Home Loan repayments; Family Households; Household Income over $3,000; and Mean Land Value.

First, a multiple regression analysis was performed to establish variables significant for water consumption at the CCD level (Table 23). When the Variance Inflation Factor (VIF) was over 4, variables initially entered into the regression analysis were removed, to ensure against collinearity[25]. All final variables selected had acceptable part and partial correlations, and the final model was a significant predictor for mean water use at the CCD level ($F(10, 1987) = 196.967, p = <.05$). Prior to this,

[25] The rule of thumb is that VIF > 4.0 when multicollinearity is a problem (Garson, 2010)

some CCDs with high Mahalanobis Scores (over the critical χ^2 value >22 Mahalanobis) were filtered from the dataset. Removing these better explained the variance in household water use ($R^2 = 49.8\%$).

Table 23 Dependent Variables: Log Transformed Mean household water consumption: 2006 – 2009 (p<.05)*

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.379	.019		123.987	.000
	AvHHSize	.082	.005	.361	18.126	.000
	@15_19	.004	.001	.143	7.817	.000
	@MedAge	.001	.000	.104	5.731	.000
	@MedHomeLoan	1.731E-5	.000	.070	3.297	.001
	@HHInc3000Over	-.002	.000	-.116	-4.780	.000
	@FamHH	.000	.000	-.057	-2.463	.014
	@JTW_PT	-.004	.000	-.424	-21.647	.000
	area_mean	3.098E-7	.000	.043	2.643	.008
	currvaln_mean	5.918E-8	.000	.146	4.871	.000

*a. Dependent Variable: LogMeanWater; *p<.05*

For the final model, the variables explained 49.8% of the variance in water use, similar to other studies of water consumption (Birrell et al., 2005; Clarke et al., 1997; De Oliver, 1999; Domene & Sauri, 2006; Hoffmann et al., 2006; Troy et al., 2005; Wentz & Gober, 2007). The most influential variables for higher levels of water use were Average Household size, Children in Education aged from 15-19, and Median Home Loan. The most influential variables for lower levels of household water use were Journey to Work by Public Transport, Household Income over $3,000 and Family Households.

Second, a regression analysis was performed on the split dataset. Splitting the dataset increased the R^2 for Brisbane, with the combined variables now explaining 56.9% of the variance, but Median Age was no longer significant. Variables found significant for household water use at the CCD level were:

Brisbane (R^2=.569); Relevant for higher levels of water use were: Average Household Size, and Children in Education 15-19. Relevant for lower levels of water use were Journey to Work Public Transport and Family Households.

Caloundra (*R^2=.420*); Relevant for higher levels of household water use were; Average Household Size, Median Age and Family Households. No variables were significant for lower levels of water use.

Maroochy (*R^2=.521*); Relevant for higher levels of household water use were; Household Income over $3,000 and Family Households. As with Caloundra, no variables were significant for lower levels of water use.

Analysis Two: Socio-Demographic Factors Relating to Change in Household Water Use

As with the previous analysis, regression analyses were conducted on the total, and split datasets, to investigate which socio-demographic variables were significant for changes in water use. For this analysis, water use for 2009 was not counted, as many policy measures were no longer applicable (such as the water tank rebate) or were less onerous (such as the water restrictions).

At the CCD level, the variables found to predict the greatest change in water use between 2006 and 2008 were very different between LGAs. Therefore, the file was split by LGA (Table 24). For Brisbane, the following variables were found to predict greater reductions in water use (39.9% of the variance ($R^2 = .399, F(7, 157.780) = 48.766, p < .05$)); Household Income over $3000, Mean Land Area, Working in Professional and Scientific occupations, Average Household Size, Postgraduate Qualifications, Children in Education 15-19, and Journey to Work Public Transport.

For both Maroochy and Caloundra, the proportion of variance in changes in water use explained was very low. For Maroochy, only two variables were found to predict greater reductions in water use (11.5% of the variance ($R^2 = .115, F(2, 14.048) = 98.708, p < .05$)). These were, Median Household Income and Fully Owned Houses. For Caloundra, the variance (14% ($R^2 = .140, F(2, 12.008) = 88.59, p < .05$) was only explained by Family Households, and Volunteers (negative for changes in water use)

Table 24 Coefficients, Change in Household Water Use 2006 – 2008 (by LGA)

LGA	Model	Coefficients[a] Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Brisbane	(Constant)	503.829	9.553		52.742	.000
	HHInc3000+	2.308	.293	.225	7.869	.000
	area_mean	23.979	1.479	.333	16.213	.000
	ProfSci	1.288	.412	.090	3.130	.002
	AvHHSize	14.342	2.789	.107	5.143	.000
	Postgrad	3.160	.607	.153	5.203	.000
	Edu15_19	2.142	.555	.084	3.858	.000
	JTW_PT	.596	.200	.066	2.986	.003
Caloundra	(Constant)	533.344	48.853		10.917	.000
	@FamHH	2.417	.598	.315	4.042	.000
	@Volunteer	-5.178	1.487	-.271	-3.481	.001
Maroochy	(Constant)	483.263	32.285		14.968	.000
	@MedHHInc	.115	.028	.266	4.157	.000
	@OwnTotal	1.814	.576	.201	3.149	.002

a. Dependent Variable: *ConsDiffTran*

Therefore, because the above regression analyses found a range of variables were related to household water use in the LGAs, a series of Principal Components Analyses was conducted to identify if a smaller set of variables existed in the dataset, and whether these were significant predictors for differences in household water use at a CCD level.

4.3.2 Composite Socio-Demographic Groupings in the Population

A series of Principal Components Analyses (PCA) were used as an exploratory tool to identify a set of common factors (or Components) in the data. Variables included in the PCA were those commonly used in demographic profiling, those found significant in the literature as determinants of household water use, and those found significant in the previous regression analysis. Composite variables were also calculated (Table 25).

The bivariate correlation matrix of all the variables was examined. The variables were restricted to those with correlation coefficients significant at the 1% level. Highly intercorrelated variables were eliminated from the analysis; for example, one of each pair of highly intercorrelated variables (negative or positive correlation coefficient over 0.9) was eliminated, retaining the variable with strongest correlation with the other variables. Each iteration of the PCA eliminated further variables, which added little to the variance; with extremely small populations; with minor loadings on Components, and not significant at 1% level on the Bivariate Pearson correlation matrix).

Table 25 Rotated Component Matrix – Factor Analysis

	Component			
	1	**2**	**3**	**4**
Proportionate Variable from ABS BCP (2006)	**High Income & Education**	**Families with children**	**Born Overseas**	**Welfare Recipient**
% Bachelor Degree	.930			
% Professionals	.920			
% Professional and Scientific	.870			
% Completed Grade 12	.866			
%Postgraduate Degree	.845			
% Household income >$3,000r	.790			
% Labourer	-.701			
% Median Home Loan	.682			
% Machine Workers	-.667			
% Working in Finance	.437			
% Average Household Size		.895		
% In Education 5_14		.885		
% Total Couple Family with Kids		.844		
% Two Cars		.775		
% Married		.771		
% Total Mortgaged		.769		
% Non English speaking			.962	
% Asian			.932	
% Not Born in Australia			.921	
% Buddhist			.864	
% Hindu			.554	
% Rent State				.818
% Single parent family w. kids				.758
% Lone Parents				.731
% Total Unemployed				.495

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

After five iterations, and Varimax rotation, the set of variables was narrowed to 25, which revealed a similar set of 4 common factors having Eigenvalues over 1, and explained 72.148% of the variance (Table 25). A scree plot was also used to identify an appropriate cut-off point beyond which the variables explained little extra variance.

These first four factors explained 26.9%, 16.9% and 16% and 12.3% of the variance respectively, and the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were significant[26].

Using the methods of McIntyre & Okorafor (2003), the final variables that loaded on each Component were standardised and multiplied by their factor score coefficients, summed and averaged to give a weighted mean variable. Bivariate correlations were performed between the composite Factor variable and its constituent variables, to ensure these were highly correlated. For Factor 1, items with negative correlations were removed, as was the Median Home Loan (removing this markedly improved the Cronbach's Alpha (a) reliability of the composite variable)[27].

The Factors were linked with the unique CCD code, and mapped in ArcGIS to give a graphical indication of their distribution (Figures 30 - 33).

Factor 1 (Figure 27) was labelled "*High Income and Education*" because of positive loadings on Degree Qualifications, Household Income Over $3,000 Per Week and Professionals. In Brisbane, Auchenflower, Toowong and Paddington scored highly. Suburbs with low scores included Inala, Acacia Ridge and Durack. On the Sunshine Coast, no suburbs scored in the top quartile, and those scoring highly on the second quartile included Alexandra Headland, Buderim and Minyama. Those with low scores included Nambour, Kuluin and Wurtulla.

Factor 2 (Figure 28) was labelled "*Families with Children*" because of high loadings relating to factors characteristic of families, such as Married, with Children 5-14 in Education, Couple Family with Children, and Average Household Size. In Brisbane, high scoring suburbs included Ferny Grove, Bridgeman Downs and Seventeen Mile Rocks; and low scoring suburbs were Auchenflower, Bowen Hills and East Brisbane. On the Sunshine Coast, high scoring suburbs included Pelican Waters,

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[26] (*KMO =.892*) and Bartlett's test (*p<.05*)

[27] Internal consistency tests indicated that the composite Factors had good internal validity; Cronbach Alpha results: (*Factor 1=.866; Factor 2=.871; Factor 3=.840; and Factor 4*=.700).

Maroochy River and Mountain Creek; and low scoring suburbs included Mooloolaba, Warana and Caloundra.

Factor 3 (Figure 29) had positive loadings on Non English Speaking, Born in China and Vietnam, and Buddhist; and was labelled "*Born Overseas*". In Brisbane, suburbs scoring highly included, Darra, Inala and Durack. Low scoring suburbs included Newmarket, Alderley and Northgate. On the Sunshine coast, few suburbs scored in the 3rd quartile, and included Pacific Paradise, Sippy Downs and Peregian Beach. Most of the Sunshine Coast scored low on this Factor, indicating its relative cultural homogeneity

Factor 4 (Figure 30) had high loadings on State Rentals, Single Family with Children and Unemployed Persons, and was labelled, "*Welfare Recipient*". In Brisbane; Acacia Ridge and Inala scored highly; and low scores were found in Bulimba, New Farm and Hawthorne. On the Sunshine Coast, Nambour, Yandina and Aroona scored highly; and Minyama, Parrearra (Kawana Island) and Mons had low scores.

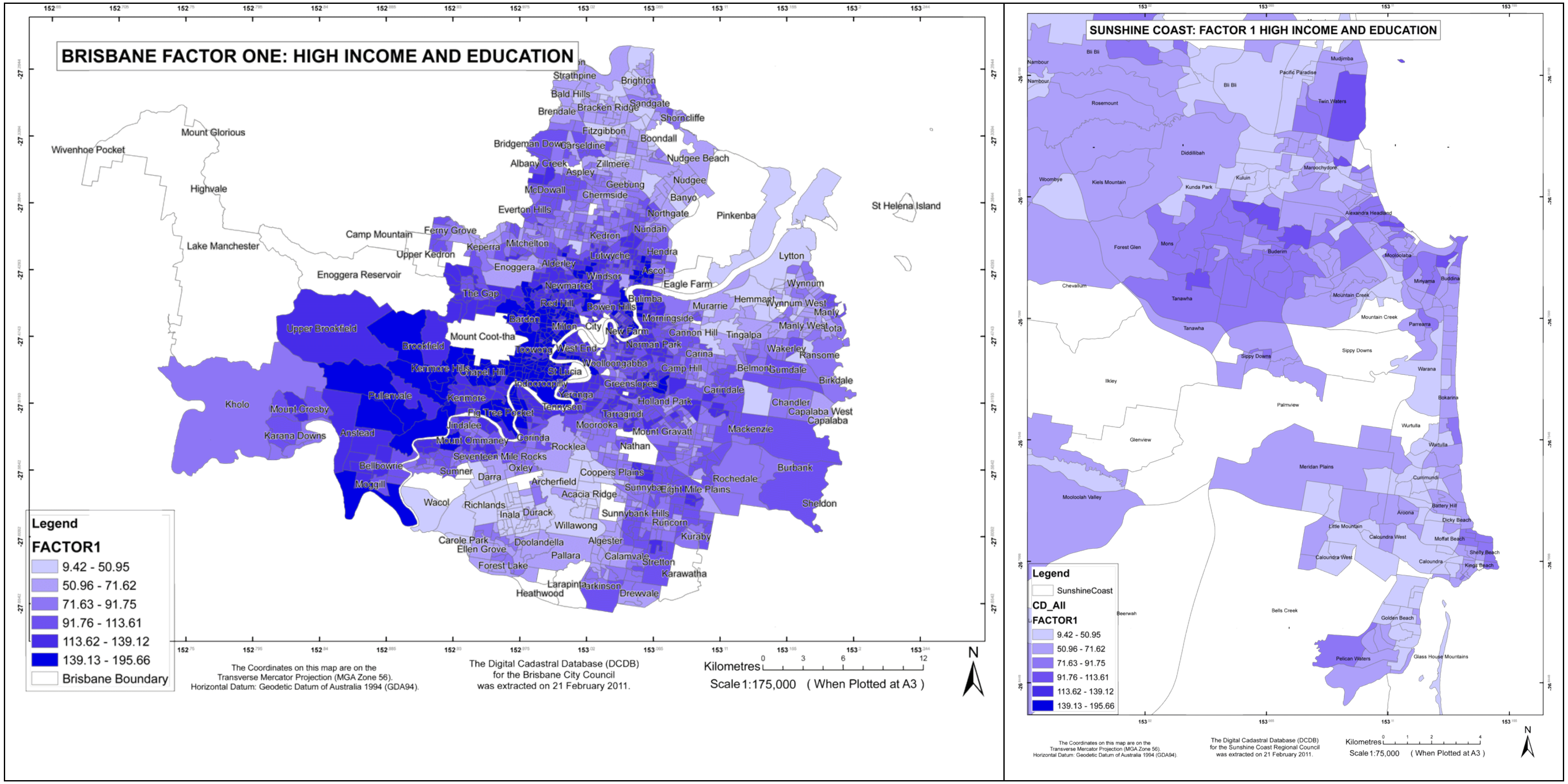

Figure 27 Results of Principal Component Analysis. Factor 1 – Brisbane and the Sunshine Coast

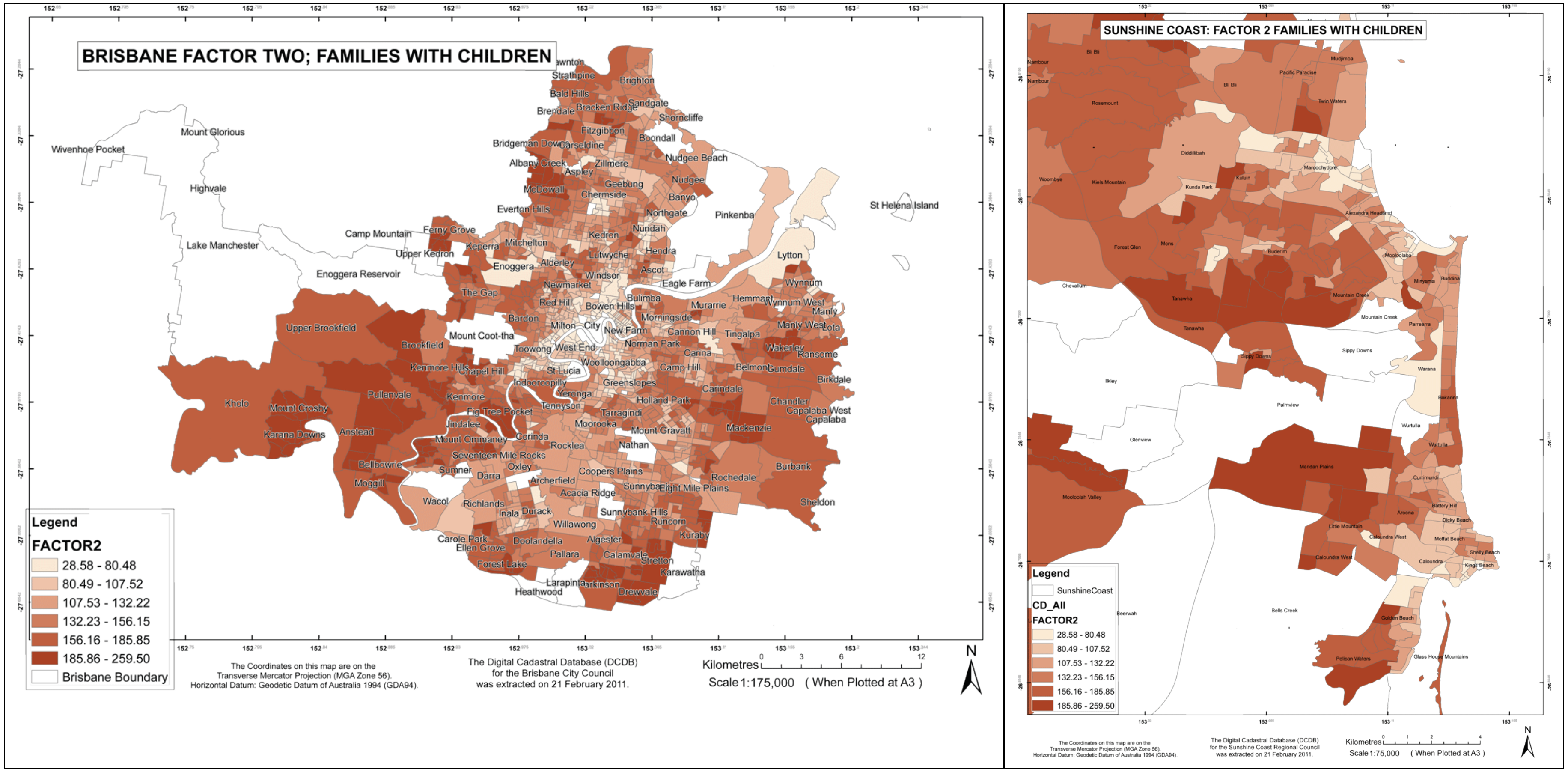

Figure 28 Results of Principal Component Analysis. Factor 2 – Brisbane and the Sunshine Coast

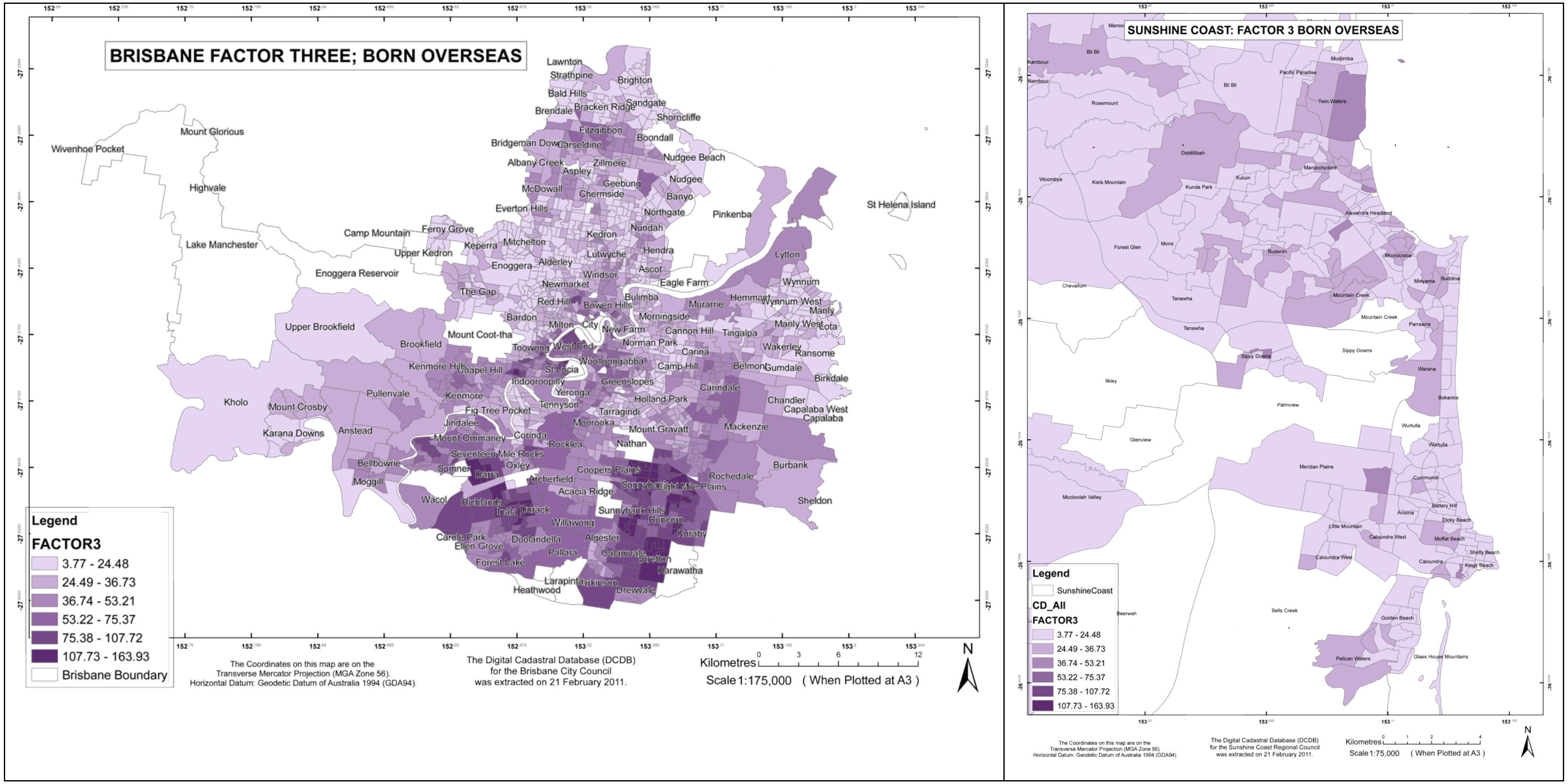

Figure 29 Results of Principal Component Analysis. Factor 3 – Brisbane and the Sunshine Coast

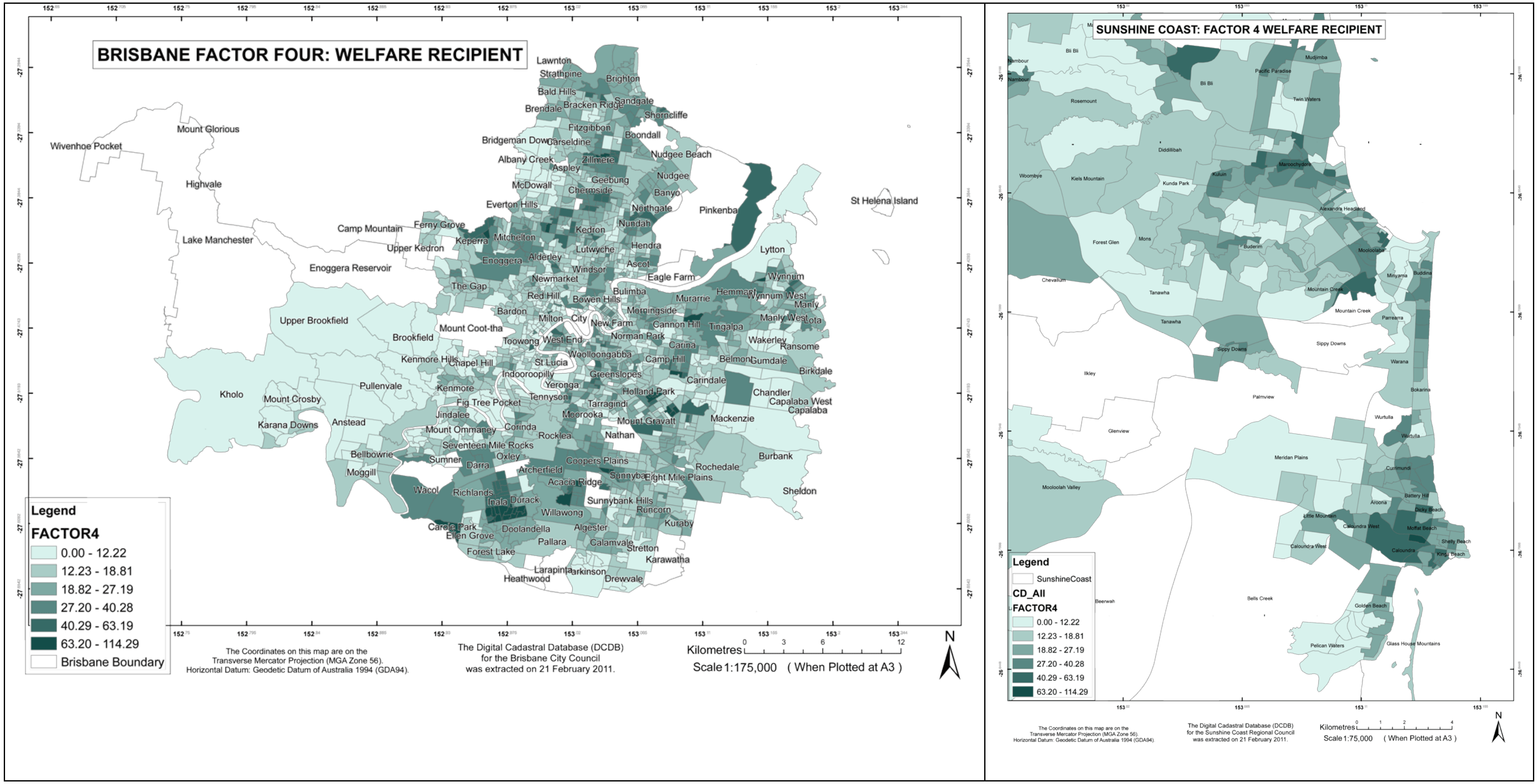

Figure 30 Results of Principal Component Analysis. Factor 4 – Brisbane and the Sunshine Coast

As a further test, the composite Factors were compared with the SEIFA Scores from the ABS, at a CCD level (ABS, 2006a). "*High Income and Education*" was highly correlated with the Index of Occupation and Education (*r=.958*). The Index of Economic Resources was also highly correlated with the "*Families with Children*" Factor (*r=.762*). The Index of Relative Socio-Economic Disadvantage was strongly negatively correlated with Factor 4 "*Welfare Recipient*" (*r=-.839)* as was the Index of Economic Resources (*r=-.786)* [28]. The other Factors had lower correlations with the SEIFA Indices, particularly "*Born Overseas*", but all were significant (*p>.01*).

4.3.3 Composite Socio-Demographic Influences on Water Use

Initially, a bivariate correlation was conducted on the log transformed mean water use and the combined Factor Variables obtained in the Principal Components Analysis. In every year and every LGA, Factor 2 (*Families with Children*) was strongly positively correlated with higher levels of water use (*p =<0.1*). This is in accordance with the individual regression analyses. Factor 1 (*High Income and Education*) was positively correlated with water use every year in Maroochy, and from 2006-2008 in Brisbane. It was not significant for Caloundra. Factor 3 (*Born Overseas*) was positively correlated with water use in Brisbane from 2006 – 2008; every year for Maroochy, and for Caloundra in 2008 and 2009. Factor 4 (*Welfare Recipient*) was negatively correlated with water use every year in Brisbane and Caloundra, but not in Maroochy.

To investigate these correlations, the Factor Scores obtained with the PCA were used as independent variables in a multiple Regression analysis (Table 26). The combined Factors significantly predicted household water use at the CCD level; but R^2 was very low (R^2*=0.122*) and the predictive ability of Factors 1 and 4 similarly low.

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[28] Note, in this analysis, a higher Factor Score indicated a higher level of the combined variables, hence the negative correlation, because for all SEIFA Indices, relative disadvantage is associated with lower numbers (ABS, 2006a).

Factor 2 (*Families with Children*) best explained the variance in household water consumption, then Factor 3 (*Born Overseas*). The regression coefficient of Factor 4 (*Welfare Recipient*) was negative; hence, it inversely predicted household water use.

Table 26 Coefficients for Split Dataset

LGA	Model		Unstandardized Coefficients		Standardised Coefficients	t	Sig.
			B	Std. Error	Beta		
Brisbane	**2006**	(Constant)	1.86	.006		300.48	.000
		Factor2	.00	.000	.304	**13.06**	.000
Caloundra		(Constant)	1.77	.038		46.67	.000
		Factor2	.00	.000	.409	**5.45**	.000
Maroochy		(Constant)	1.88	.020		92.80	.000
		Factor2	.00	.000	.362	**5.74**	.000
Brisbane	**2007**	(Constant)	2.12	.006		369.29	.000
		Factor2	.00	.000	.282	**12.06**	.000
Caloundra		(Constant)	2.07	.032		63.75	.000
		Factor2	.00	.000	.504	**7.10**	.000
Maroochy		(Constant)	2.19	.021		102.57	.000
		Factor2	.00	.000	.259	**3.95**	.000
Brisbane	**2008**	(Constant)	2.09	.005		400.18	.000
		Factor2	.00	.000	.273	**11.62**	.000
Caloundra		(Constant)	2.07	.030		70.13	.000
		Factor2	.00	.000	.433	**5.84**	.000
Maroochy		(Constant)	2.08	.017		122.28	.000
		Factor2	.00	.000	.378	**6.03**	.000
Brisbane	**2009**	(Constant)	2.12	.005		397.39	.000
		Factor2	.00	.000	.304	**13.06**	.000
Caloundra		(Constant)	2.12	.027		79.22	.000
		Factor2	.00	.000	.462	**6.34**	.000
Maroochy		(Constant)	2.08	.020		106.50	.000
		Factor2	.00	.000	.346	**5.44**	.000

A regression analysis was also performed on the split file. Splitting the dataset resulted in improved explanatory power, with R2 for each LGA around 25%; and for all years, the F-change between LGAs was significant. Because Factor 2 was the most significant, and the other Factors only had only minor significance, only the results for Factor 2, Families with Children, are shown in Table 26.

4.3.4 Summary, Results Phase 1

Brisbane had consistently lower water use than both Sunshine Coast LGAs, for every year. However, historical data (circa 2005) showed that Brisbane households used similar water to Sunshine Coast households. However, since 2005, the water use of most Brisbane suburbs reduced by around 50%, and by 2007/2008, to an even greater proportion. A GLM Within Subjects Repeated Measures test was used to analyse the water data. The differences in mean water use were statistically significant between groups (LGAs) and within subjects (biannual time periods).

To visually highlight changes in household water use, the water data was aggregated to Census Collection District (CCD), and mapped for each year using equal intervals, and Standard Deviations. Brisbane water consumption noticeably "flattened" during the period 2006 – 2008. By 2008, the water use of the majority of CCDs fell in the lowest 2 classes. This was particularly apparent for the smaller, more central CCDs, and larger CCDs (generally those with larger lots) had higher water use, with less variation. By 2009, water consumption displayed more variance, similar to 2006. The same trends were also apparent for the Sunshine Coast.

Structural variables were also analysed using a GLM Repeated Measures ANOVA. As expected, for every LGA, the average water use of households with pools for all areas was significantly higher than for households without pools. However, the influence of the other variables differed by LGA. In Brisbane, swimming pools, mean sale price and land area were significant, and in Maroochy, all independent variables were significant, with swimming pools and mean sale price accounting for the most variance. For Caloundra, only swimming pools were significant. Current land value was not significant for Brisbane, and only weak for Caloundra.

To investigate whether the water restrictions had a statistical significance on household water use, a fixed effects Linear Mixed Models (LMM) procedure was conducted. For each level of water restrictions, the influence on household water use was significant. The most significant reduction in water use occurred after the imposition of Levels 4 and 5 water restrictions. When including the water restrictions in an analysis with the structural variables, the most significant predictors of water use were the presence of a swimming pool, then the water restrictions. Lot Area was the least significant independent predictor.

This analysis was conducted using proportionate variables calculated at CCD level from the Basic Community Pack (BCP). First, a multiple regression analysis was performed to establish variables significant for water consumption at the CCD level. At the CCD level, the variables found to predict the greatest change in water use between 2006 and 2008 were Household Income Over $3,000, Average Household Size, Mean Land Value, Employed in Professional and Scientific Occupations, Mean Sale Price and Mean Land Area. These variables explained 32.4% of the variance in change in household water consumption 2006 – 2008.

A series of Principal Components Analyses (PCA) were used as an exploratory tool to identify a set of common factors (or Components) in the data. Four Components were extracted, and these were named (according to the variables from which they were comprised): Factor 1 "*High Income and Education*", had high loadings on Degree Qualifications, Household Income Over $3,000 Per Week and Professionals. Factor 2 "*Families with Children*", had high loadings relating to factors characteristic of families, such as Married, with Children 5-14 in Education, Couple Family with Children, and Average Household Size. Factor 3 "*Born Overseas*" had high loadings on Non English Speaking, Born in China and Vietnam. Factor 4 "*Welfare Recipient*", had high loadings on State Rentals, Single Family with Children and Unemployed Persons. None of these Factors had a strong relationship with household water use.

These results indicate that structural factors (swimming pools), policy factors (water restrictions) and demographic factors (household size and structure) were all significantly related to household water use. Therefore, these (and other independent variables) were tested in a smaller sample, the Questionnaire Survey.

CHAPTER 5 RESULTS PHASE 2: QUESTIONNAIRE SURVEY

This Chapter presents the results of the Questionnaire Survey. The overall aim of this was to investigate the influence of psychological factors and individual characteristics on household water use. The questions were designed to explore some individual attitudes and beliefs about water conservation and about the Queensland demand-side policies; as well as barriers preventing reducing household water use. The Questionnaire also sought to explore the utility of using an extended Theory of Planned Behaviour to help understand water conservation behaviour and response to policy.

5.1 Analysis of the Questionnaire Survey

The sample for the Questionnaire Survey was randomly chosen from the entire population of detached households in Brisbane, Maroochy and Caloundra with four years of water consumption data, and identified with the GIS methods. A total of 1680 households were surveyed, with 351 valid responses received. The sampling methods are detailed in Chapter 3 "Methods", in Section 3.2 (and in Appendix A).

Was the sample representative of the population (dependent variable)?

The population mean was calculated for the total and for the split dataset. A one-sample t-test was conducted with Average Litres per day for Questionnaire respondents (split by LGA) against the full water dataset. Average Litres per day was selected in preference to Total Kl per annum because of incomplete data in 2006.

Table 27 Survey Statistics and t-test results [29]

	N	Mean	Total Mean	T	P<.0.5*	SD	Variance
AvLtd2006	258	545.49	541.47	.159	.874	407.54	166091.93
AvLtd2007	258	470.70	463.64	.313	.257	362.55	131439.81
AvLtd2008	258	414.47	421.75	-.374	.709	313.02	97981.05
AvLtd2009	258	434.55	453.25	-1.010	.314	297.66	88602.25

[29] Of note, Table 24 only reports survey responses able to be coded by area, and actual water use known.

As shown in Table 27, the water data for the survey did not significantly differ from the population norm (detached houses). Therefore, the sample was judged representative of the population, at least for the dependent variable, Average Litres per day (per household).

Of note, the water data was not normally distributed, and was positively skewed; a finding relatively common in studies on domestic water use (Vairavamoorthy & Mansoor, 2005). Therefore, for some analyses, (particularly those more sensitive to non-normality, such as regression analyses), the mean water data for the survey was transformed by calculating a new variable (after eliminating outliers) by taking the Log10 of the variable. After running a non-parametric 1-sample KS test, none of the test results were significant, indicating the data was normally distributed (Table 28).

Table 28 KS Test, Log Transformed Variables

		LnAv06	LnAv07	LnAv08	LnAv09
N		258	258	258	258
Normal Parameters[a,,b]	Mean	2.62	2.55	2.50	2.54
	Std. Deviation	.35	.35	.34	.32
Most Extreme Differences	Absolute	.051	.04	.05	.08
	Positive	.041	.04	.04	.04
	Negative	-.05	-.04	-.05	-.08
Kolmogorov-Smirnov Z		.81	.69	.734	1.32
Asymp. Sig. (2-tailed)		.52	.74	.66	.06

a. Test distribution is Normal.

5.1.1 Descriptive Analysis of the Questionnaire

<u>Demographic Information</u>

The majority of respondents lived in two person households, and owned their own homes. The returned sample was strongly biased to older residents, with over 90% of respondents over 35, and 29.4% over 65. Of these, 50% owned their homes outright, and 42% of households had only two members. Household size was similar to that of Australia (2.6 persons) (ABS, 2007). A t-test was conducted to determine if this differed significantly from total sample mean. As this was not significantly different, the sample was considered representative of the population, at least for household size, although not for age or home ownership (described further in Section 5.3.2 (p200).

Per capita water use was also analysed, and was highest for two and then one-person households (Figure 31). The least water per capita was used by 3 person households, and by 6 or more person households. However, per capita water use for households with greater than 5 persons should be interpreted with caution, as the sample sizes for these were low. To analyse if these differences were significant, the dataset was split by household size, and paired samples t-tests run. There was a significant effect for all sizes of households for every year ($p<.05$).

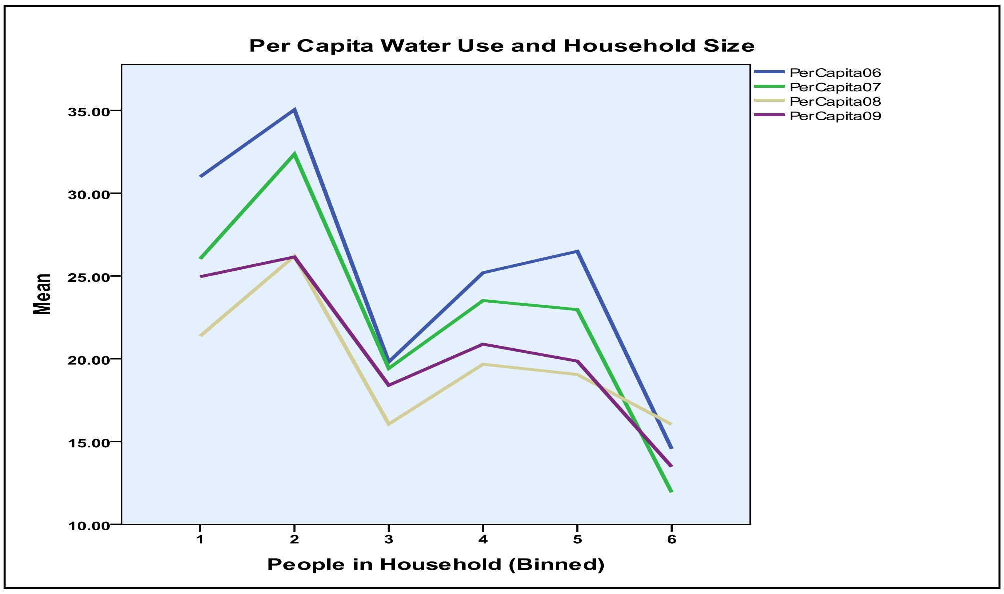


Figure 31 Per Capita Water Use and Household Size

Thereafter, a Spearman Rho correlation analysis was conducted between the demographic variables and the annual log transformed water use. Overall household size contributed the most to the variance, and it was significantly correlated with water use for every year ($p<0.1$). Income was also positively correlated ($p<0.01$) with water use, and was significant for every year; as were children (of all ages). Age was negatively correlated with water use ($p<0.01$); in general, average water use decreased with age. Employment was also negatively correlated with water use; those in full time employment and self-employed were more likely to use more water than those retired, not in the labour force and students. Education was not significant, and Gender was only significant in 2006 and 2007, with women using less water.

About Your House

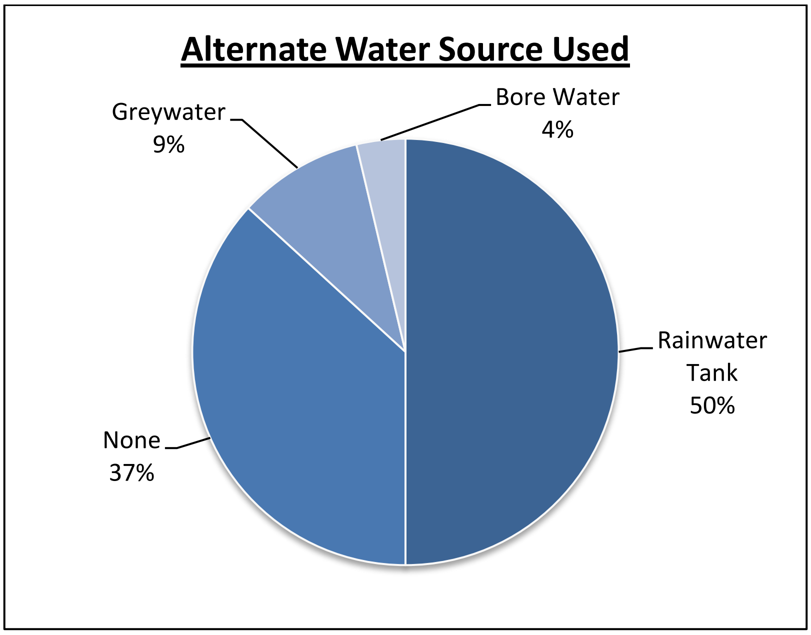


Figure 32 Proportion of Sample Using Alternative Water Sources

Water Tanks: Approximately half the households had a water tank, but relatively few used other sources of non-reticulated water (Figure 32). Of the households with water tanks, the majority were from Brisbane, and installed the tanks in 2007. Of the total 165 households with water tanks, 97 were from Brisbane, 35 were from the Sunshine Coast and 33 were unidentified. Most had installed their tanks in 2007 (34.80%), then 2008 (23.90%) and prior to 2005 (15.2%).

House Size: The majority of respondents lived in small to medium sized houses (under 300m^2) (Figure 33). Most Brisbane residents lived in smaller houses than the Sunshine Coast residents. However, despite the slightly higher proportion of larger houses on the Sunshine Coast, more Brisbane residents lived in very large houses (> 400m^2). The majority (32%) lived in houses between 200 and 300m^2; 21.6% lived in houses under 200m^2; 16.5% 301m^2 - 400m^2 and 7.2% larger than 400m^2.

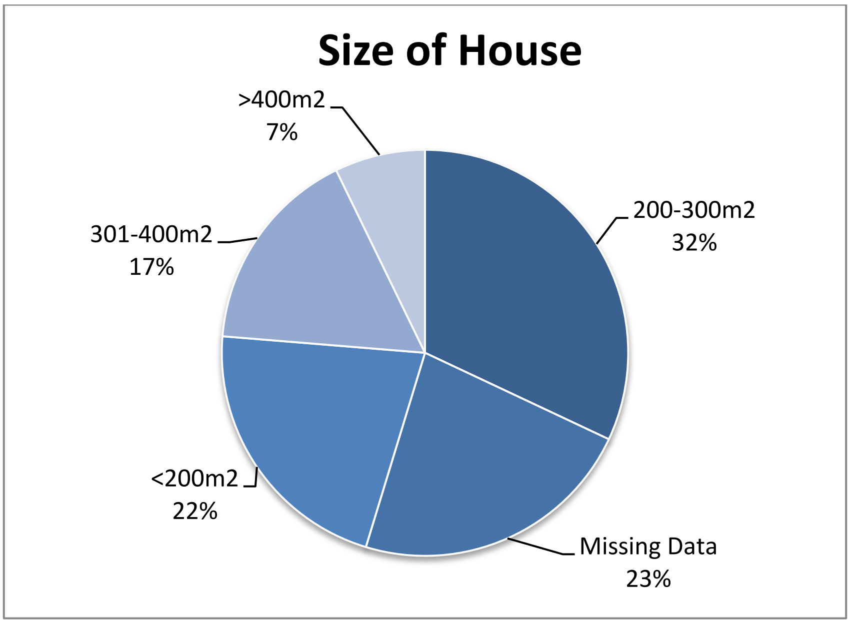


Figure 33 House Size of Sample

For Brisbane, house size was correlated with water use in 2006 and 2007, but not 2008 or 2009. Of note, 2006 and 2007 were the years in which more stringent levels of water restrictions, particularly on outdoor water use, were imposed on Brisbane. For Maroochy, house sizes for all years, with the exception of 2008, were correlated with higher water use. In Caloundra, house size was not correlated with water use.

Lot Area: The stated survey responses differed from actual lot area (matched with Lot and Plan). However, taking into account missing data, and those who did not know their lot size, the stated lot area was similar to the actual lot area, and to the full dataset. Most survey recipients (89.4%) lived on lots under 1200 m^2 (20.1% on lots less than 600m^2, and 57.3% on lots between 601m^2 and 1200m^2 (Figure 34)). Of note, households on large lots (>2ha) were not surveyed, as they were assumed to be rural residential (thus using water for non-urban purposes, such as horses or market gardens).

The majority of Brisbane and Sunshine Coast lots were 1200m^2 or smaller. Of note, a greater proportion of unidentified respondents lived on lots *larger* than 1201m^2, and in very larger houses. 12.3% did not know their lot size, but by using the coded Lot and Plan data, could be matched with actual lot size. With regard to the generalisability of lot area to the wider population; the mean lot area of the survey respondents was

694.35m² (Brisbane) and 1095.92m² (Sunshine Coast). This is in comparison with the total water database, where the mean lot area was 1005.24m² (Brisbane) and 1476.49m² (Sunshine Coast). The smaller mean of the lot area for survey respondents is likely because properties larger than 2ha were eliminated from the Survey because they were deemed to be agricultural. Although these figures for the entire database appear high, these are values for all detached properties connected to reticulated water.

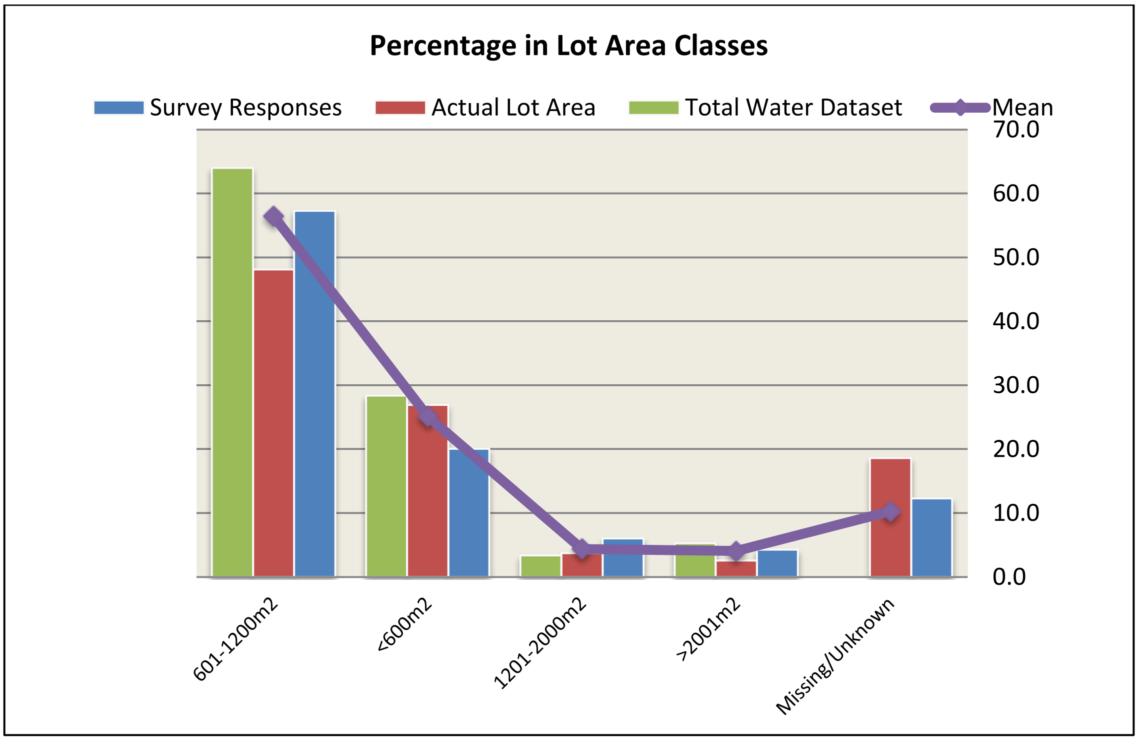


Figure 34 Stated and Actual Lot Area of Questionnaire Respondents; in comparison with Lot Area of Total Dataset

Unsurprisingly, the larger the lot, the larger the house, and the larger the lot, the greater the mean water use. House and lot area were significantly correlated, with mean annual water use significantly correlated with lot area for 2006 and 2007 ($p<.01$) and for 2008 and 2009 ($p<.05$)[30]. However, lot area was only significant for Brisbane in 2006 (n=160), no year in Maroochy (n=61), and every year in Caloundra (n=37).

[30] Spearman Rho coefficients were calculated in preference to Pearson coefficients, because survey items on tenure, house age and house size were nominal, and the dependent variable water use was interval. Total dataset : $r(394) = .394, p>.01)$; Sunshine Coast: $r(102) = .555, p<.01$; Brisbane: $r(168) = .341, p<.01$.

Age of Houses: Age of houses for the two areas was very dissimilar, with most Brisbane houses were older than Sunshine Coast houses. Over 30% of Brisbane houses were built before 1950, in compared with only 2.9% of Sunshine Coast houses. On the other hand, only 2.3% of Brisbane houses were built after 2001, in comparison with 25.7% of Sunshine Coast houses. Older houses used less water; but all house types reduced water use until 2008. Houses built from 1991 – 2000 generally used the most water, then houses built after 2001 (Figure 35).

House age was not correlated with Lot Area ($r(278) = .69$, $p < .25$) but was strongly correlated with house size ($r(325) = .192, p < .001$). Houses built after 2001 were significantly larger than previous years. This is in accord with research showing that the average size of Australian houses has increased (Demographia, 2009). In general, larger and newer houses used more water than did older, smaller houses.

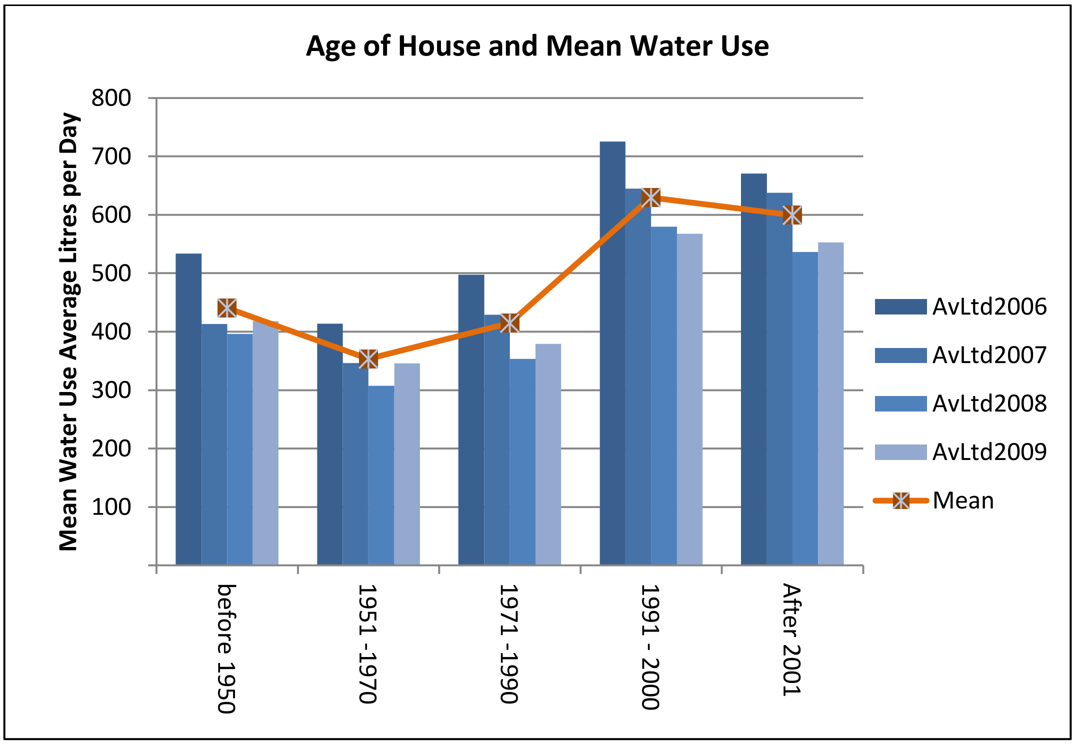


Figure 35 Age of House and Mean Water Use – Survey Sample

There were no significant correlations between house age and mean water use for Brisbane and Maroochy. However, house age was significantly correlated with water use for every year in Caloundra[31]. In general, houses built from 1991-2000 had the highest range and highest mean water use.

Tenure: The majority of houses were fully owned, and 46% were owned outright, 38% mortgaged and 12% rented privately. Only a very small percentage were rented from the government, or had other tenures (Figure 36). As shown in Table 29, Tenure was significantly correlated with water use every year in Brisbane and Caloundra, but not at any time for Maroochy[32]. Unlike house and lot area, the strength of the correlation *increased* over the period 2006-2008, and began decreasing again in 2009.

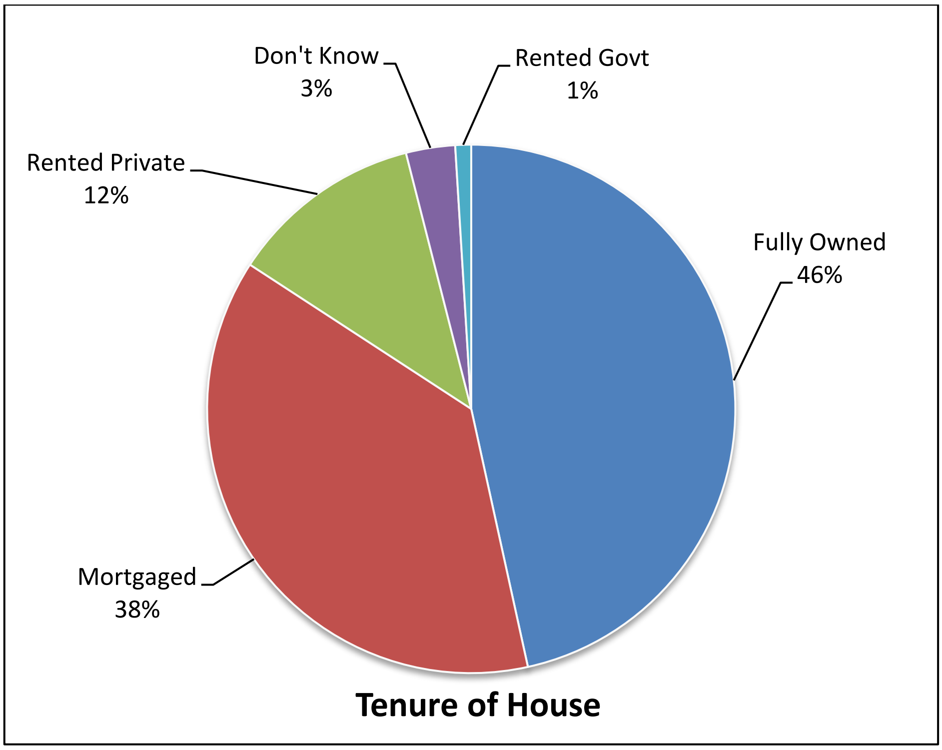


Figure 36 Tenure of House - Questionnaire Sample

[31] House age was an ordinal variable, and coded as follows: 1 – Before 1950; 2 – 1951 – 1970; 3 – 1971 – 1990; 4 – 1991 – 2000; and 5 – After 2000. Thus, the higher the score on House Age, the more likely the house was newer.

[32] Of note, tenure was coded as follows (1 – Fully Owned; 2 – Mortgaged; 3 – Rented Private; and 4 – Rented State). Thus, the lower the score on Tenure, the more likely a property was owner-occupied.

Table 29. Spearman Rho Correlations between water use and Questionnaire variables

LGA		LnAv06	LnAv07	LnAv08	LnAv09
Brisbane	Size house	**.246****	**.225****	.124	.139
	Age house	-.007	.008	.032	.037
	Tenure	**.254****	**.306****	**.400****	**.384****
Caloundra	Size house	.270	.264	.231	.315
	Age house	**.448****	**.435****	**.381***	**.325***
	Tenure	**.416***	**.414***	**.462****	**.369***
Maroochy	Size house	**.345****	**.340****	.219	**.263***
	Age house	.198	.192	**.270***	.189
	Tenure	.160	.115	.154	.099

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

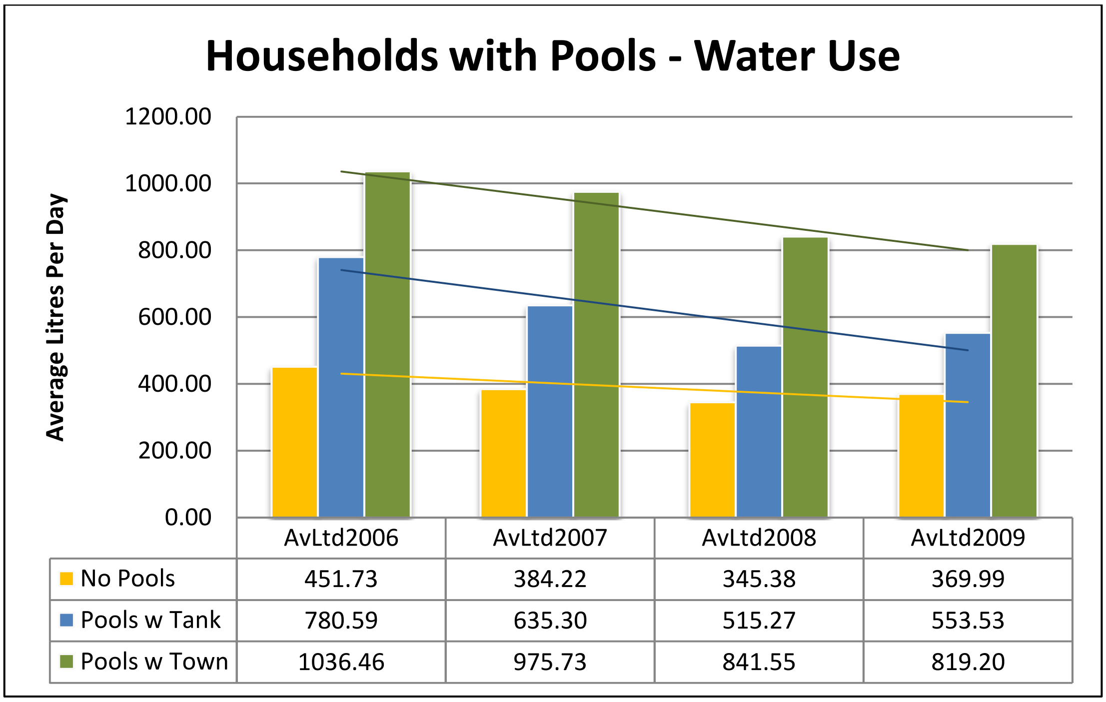
Indoor Water Use

As most responses for the Indoor Water Use section were relatively similar, these are not reported in detail. Almost all (99.7%) respondents owned a washing machine, and 58.6% owned a dishwasher. Of washing machines, 32.6% were front loaders, and 66.2% top loaders. A large majority (87.9%) reported “Always” using water saving settings on their appliances, although when asked if they rinse cutlery and crockery, responses were almost equally distributed between the three choices; “*under running water; in a plugged sink”;* or *“don’t rinse cutlery and crockery*”. Most households rinsed food before eating under running water (49.8%), slightly fewer in a plugged sink (39%) and 11.2% did not rinse food.

Outdoor Water Use

Swimming Pools: Approximately one-fifth (21.4%) of total respondents (n=318) had pools or spas; 92.7% of which were uncovered. Nearly one-third (28.3%) of Sunshine Coast respondents had pools, and the majority were filled with town water; but only 15.2% of Brisbane residents had pools, with a slight tendency for filling with tank water.

Mean water use was higher for households with pools, and highest for households with pools filled with town water; almost double the water use of households without swimming pools. However, for each successive year, water use in all categories was lower (Figure 37).



	AvLtd2006	AvLtd2007	AvLtd2008	AvLtd2009
No Pools	451.73	384.22	345.38	369.99
Pools w Tank	780.59	635.30	515.27	553.53
Pools w Town	1036.46	975.73	841.55	819.20

Figure 37 Water Use for Households with Pools

To test the significance of this result, a one way ANOVA was calculated. Households with pools used significantly more water. For every year, the average daily water use of households differed significantly if they had swimming pools, and according to the source of water used to fill pools[33]. An additional ANOVA was conducted to compare the water use of households differentiated into type of water (town or tank) used for filling pools. For this, Tukey post-hoc comparisons of the three groups indicate that the households with pools filled with town water used significantly more water than those with no pools or pools filled with tank water[34].

Other Outdoor Uses

Most respondents (85%, n=176) reported never watering lawns. However, these results differed according to area; 98% of Brisbane residents never watered their lawns, in comparison to 68% of Sunshine Coast residents. The percentages are for respondents using reticulated (town) water supplies, but the results for tank water were similar.

33 2006 (F(1,256) = 55.310, p<.05); 2007 (F(1,256) = 64.813, p<.05); 2008 (F(1,256) = 55.270, p<.05); and 2009 (F(1,256) = 49.845, p<.05).

34 Town water : (*M = 1132.4333, 95% CI [949.2382, 1315.6285]*); Tank water (*M =762.889, 95% CI [615.488, 910.2902]*); No pools (*M= 474.772, 95% CI [432.464, 517.080]*).

Respondents also infrequently washed vehicles or outdoor hard surfaces from any water source. However, Sunshine Coast residents did so more frequently than Brisbane residents (where such practices were banned), with one respondent reporting washing driveways weekly.

If respondents washed cars, this was generally on a monthly or twice yearly basis. In Brisbane, 53.3% of residents, and in the Sunshine Coast, 91.6% of residents, washed cars at least once yearly with town water. However, for tank (or other sources of water) the reverse was the case; 77.8% of Brisbane residents and only 37.3% of Sunshine Coast residents washed their cars at least once yearly. Sunshine Coast residents also washed their cars more frequently, most washing cars monthly or at even shorter intervals. As shown in Figure 38; those who washed cars regularly with town water used more water than those who regularly washed cars with tank water. However, for infrequent washers, those using tank water used more water.

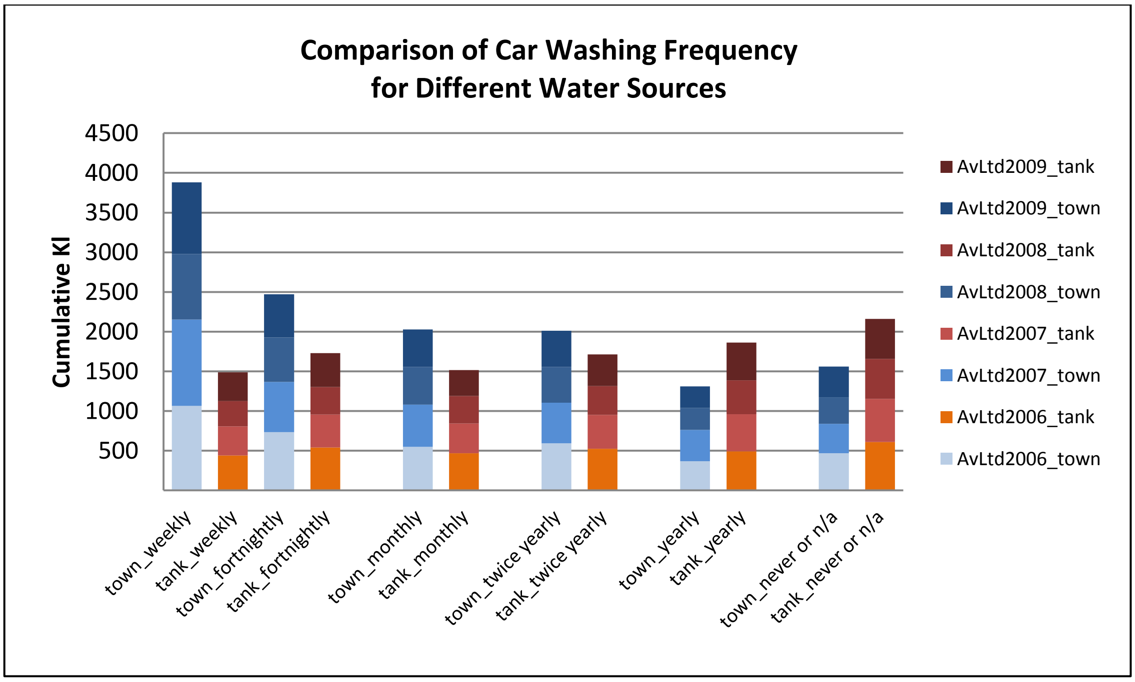


Figure 38 Average water use by frequency of car washing and water source

Spearman Rho correlations were calculated between mean water use for each year, and outdoor water uses. The frequency and type of outdoor water use was highly significant for outdoor water use. Residents washing cars, watering lawns and filling pools with town water used significantly more water ($p<.0.01$). For every year, significant positive correlations existed between water use and washing cars with town water ($p<.01$) and slight negative correlations between washing cars with tank water. The frequency of washing other types of vehicles (such as boats and motorbikes) was extremely low, so was not analysed.

For the split dataset; for Brisbane, with the notable exception of swimming pools, outdoor uses and mean water use were not significantly correlated. For Caloundra, using tank water for outdoor uses, was negatively correlated with water use, but for Maroochy, was positively correlated with water use. Watering lawns from any source was not significantly correlated with water use, except for Caloundra in 2006 and 2007 (town water), and watering lawns with tank water was not significantly correlated with water use. Although mean water use was higher for those frequently watering lawns, particularly with town water, this result should be viewed cautiously, as the numbers of respondents watering lawns was very low (n=32); and most (85%, n=176) reported never watering lawns.

5.1.2 Attitudes to Policy Measures

Respondents general supported most of the government policy measures (Figure 39). However, some displayed a strong geographical bias, likely due to the NIMBY (Not In My Back Yard) effect. In particular, strong opposition to the now defunct Traveston Dam proposal and the Water Grid was apparent on the Sunshine Coast, but not in Brisbane. There was little opposition to recycled water or desalination plants, although many open-ended responses specifically mentioned that they only approved of recycled water if it was not for potable use.

The strongest approval ratings were for two now defunct demand-side policies, the water tank rebate (88%) and Home WaterWise (82%). Over 60% of respondents had installed water tanks, and most of these had installed these in 2007, at the height of the drought. Several had more than one tank, and one person had five. A noted difference was that Brisbane householders used tank water for car washing and watering gardens, but even if they had tanks, most Sunshine Coast residents still used reticulated supplies.

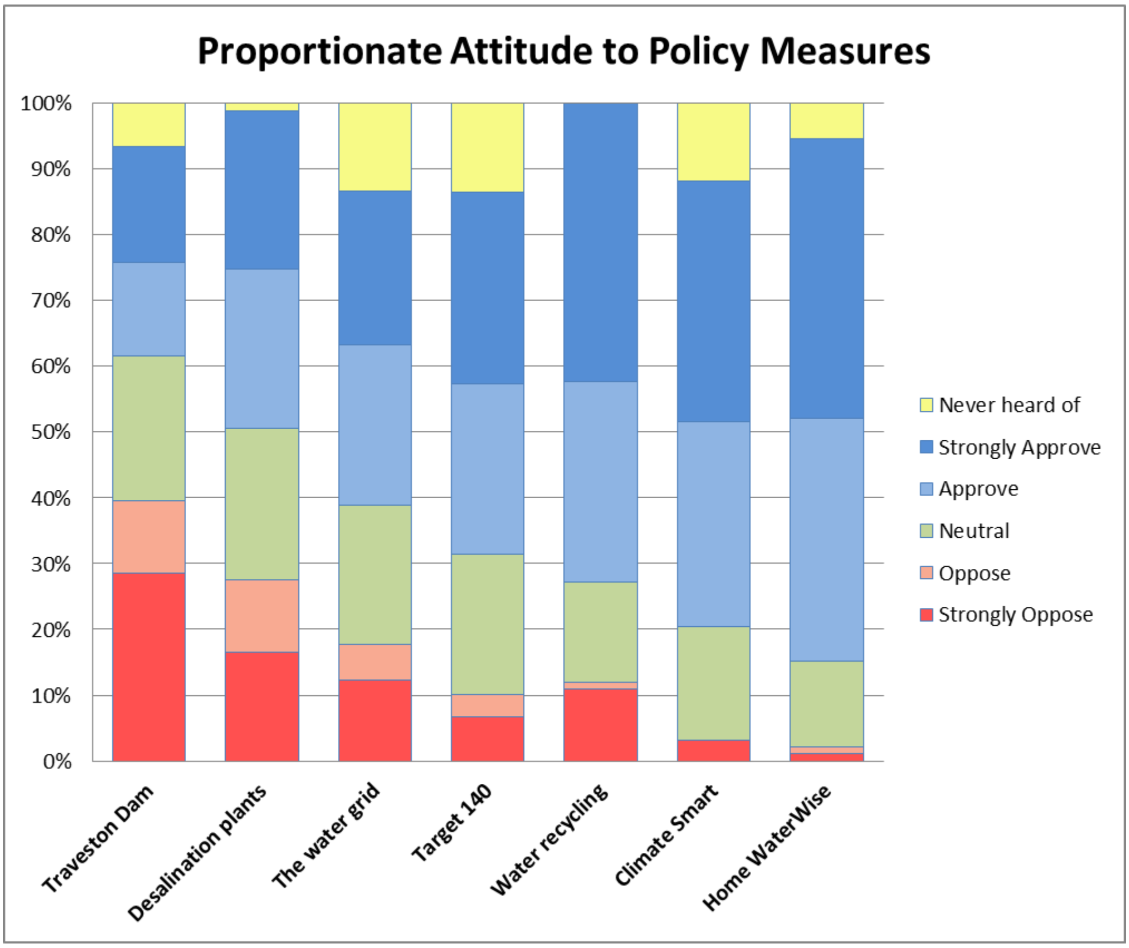


Figure 39 Summary of Responses, Attitudes to Policy

The survey did not ask directly about water restrictions, but asked indirectly about Target 140. The majority of respondents approved of restricting water use. However, many respondents had no idea of the current level of water restrictions; 43.3% "didn't know" the level of water restrictions at the time of the survey (Figure 40). At the time of the survey, Brisbane respondents were on High Level (170), and Sunshine Coast residents not on any water restrictions. A higher proportion (60.7%) of Sunshine Coast respondents did not know their water restriction level, but neither did 29.9% Brisbane respondents. Furthermore, only 22.6% of Brisbane residents correctly named their restriction level as 'High Level 170' (as of August 2010).

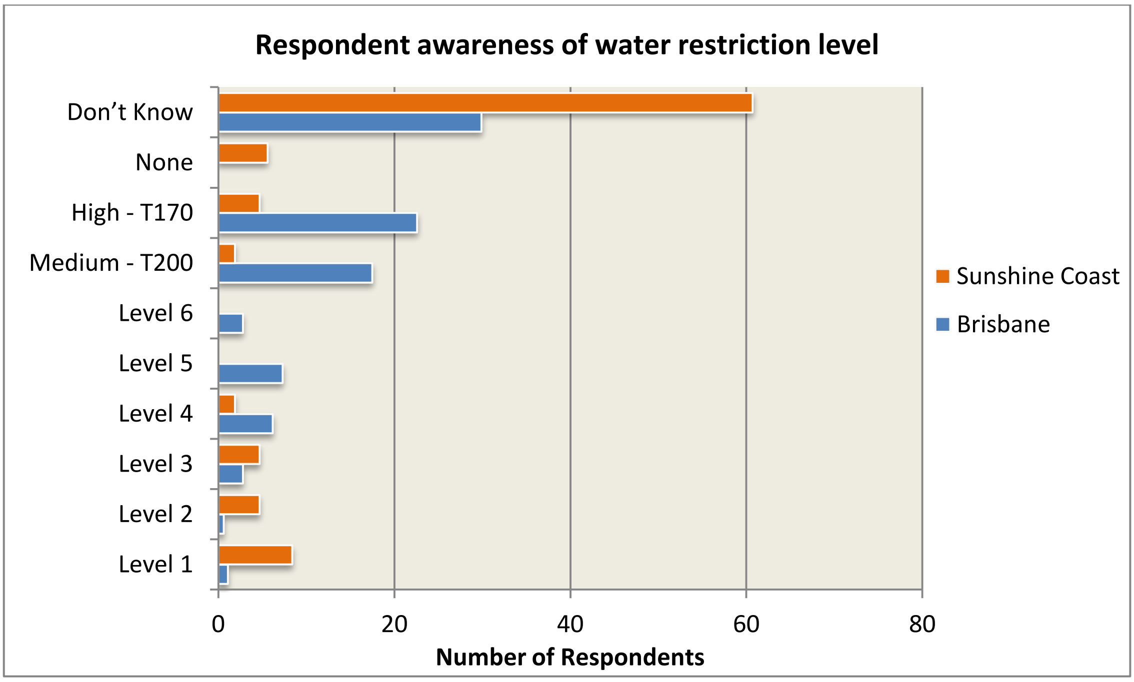


Figure 40 Graphical Response to Level of Water Restrictions

Of the media source for information on the demand-side policies, the majority of respondents (*n=312*) received information from government and news websites, and 87.25% of received information from 5 or fewer sources. There was no significant relationship between the number of media sources and mean water use. However, the greater the exposure to media, the more likely the respondent practiced water conservation behaviours.

Question 30 was a multi-part question (on a 5 point Likert Scale, from Strongly Disagree to Strongly Agree) that asked respondents to reply to the statement, "*My household uses less water than similar households*": 22.2% of respondents strongly agreed, 41.6% agreed, and 29% were neutral (cumulative percentage = 91.3%). The dataset was split on actual water use (randomly selected houses were assigned into quartiles, named High, Medium High, Medium Low or Low water use, depending on their position in relation to the mean water use of the High and Low properties selected). Cut-off points for quartiles were calculated using SPSS Frequencies. Even some High water users (those who used an average of greater than 676l per day) considered their water use average or below average. However, most high water users did not think their household used less water. When the dataset was split on area, the Sunshine Coast and Brisbane had similar results; 91.7% of Brisbane and 93.4% of Sunshine Coast households thought they used average or less water than other households.

Only 6.6% of respondents agreed or strongly agreed in response to the statement; "*I don't have to save water now the dams are full again*". A majority of respondents (76.7%) agreed in varying degrees that their household could save more water. The larger the household, the more likely it was that respondents agreed with the statement "*My household can do more to save water*" (Figure 41).

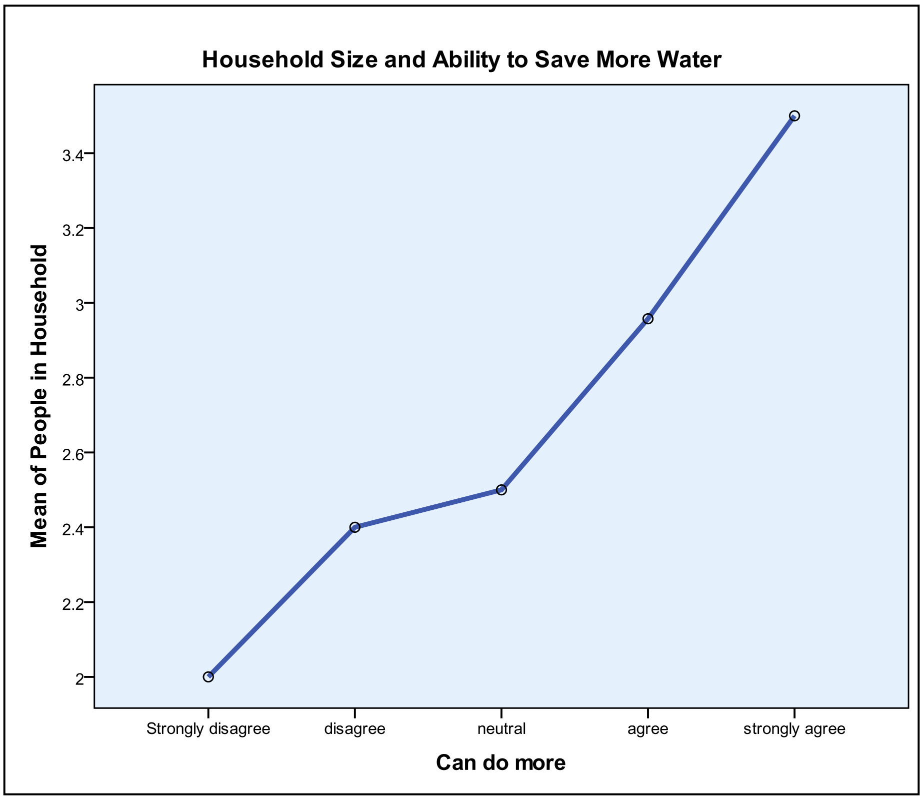


Figure 41 Household Size and Perceptions of Ability to Save More Water

Most respondents agreed that they had changed their water use since the water policies were implemented. These results were similar for the split file; 93% of Brisbane residents and 75.7% of Sunshine Coast residents agreed with the statement.

Question 31 was also a multi-part question, which aimed to identify some attitudes to government, as well as water rights. A 5-point Likert Scale, ranging from strongly disagree to strongly agree, was used. The statements for response included: "*The government should build more dams"; "I trust the State Government to plan Queensland's water resources wisely"; "Having a reliable, clean supply of water is the right of all people";* and *"If householders don't save water, there will not be enough to meet future needs*".

With regard to building more dams, a relatively high proportion of respondents (30.8%) strongly opposed the Traveston Dam. However, a Crosstabulation analysis indicated that, of these, 13% strongly agreed and 19% agreed that the Government should build *more* dams. When the dataset was split by area, there was little difference between the Sunshine Coast and Brisbane, although a lower percentage of Brisbane (2.8%) than Sunshine Coast residents (12.4%) strongly disagreed with the statement.

Most also distrusted the Government, with 82.1% of Sunshine Coast and 69.4% of Brisbane residents rated the State Government's management of water resources from neutral to strongly disagree. The majority (97.8%) agreed that a reliable, clean supply of water was the right of all, as did 83.2% to the statement "*if householders don't save water, there will not be enough to meet future needs*".

Principal Components Analysis – Opinions on Government Policies

A Principal Components Analysis (PCA) with Varimax rotation was performed to identify if clusters of households favouring certain types of policies were evident. The first PCA was performed on the overall dataset and after Varimax rotation, extracted five Components that explained 46.98% of the variance[35]. This Rotated Component Matrix is shown in Table 30, and the variables listed in refer to Survey Questions 26 – 38 (Appendix B, Section 8.2.2).

[35] KMO *(.701*) and Bartlett's were significant.

Table 30 Rotated Component Matrix – Questionnaire Factors

	Component				
	1 Incentive	**2 Concern**	**3 Behaviour**	**4 Infrastructure**	**5 Garden**
Home Waterwise	.765				
ClimateSmart	.738				
Tank rebates	.570				
Recycling	.496				
GHG concerns		.676			
Not enough water future		.636			
A_Composite		.609			
Trust Govt		.519			
SN_Composite		.513			
SEQ run out		.467			
HH uses less water			.718		
PBC - Target 140			.661		
Changed Use			.595		
CombinedQ26_1			.590		
CombinedQ26_2			.560		
Traveston				.789	
Build more dams				.601	
Water Grid				.601	
Used more water				.425	
A- green garden					.837
SN- green garden					.751
Sad garden suffered					.666
Banned pleasurable					.370

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Variables that loaded highly on Component 1 were Home WaterWise, Climate Smart, Water Tank Rebates, and Recycling, so was named "*Incentives*". Variables loading on Component 2 were; Concerns over Global Warming, Not enough water in the future, Attitude to water conservation, Trust in the Government, normative opinions, and concern that SEQ would run out of water, so was named "*Concern*". Variables that loaded on Component 3 were Household uses less water, Target 140 changing behaviour, Changed use over the drought period, and behaviour changes during and after the drought, so was named "*Behaviour*". Variables that loaded on Component 4 were the Water Grid, Traveston Dam, Build more dams, and Used more water in the past, so was named "*Infrastructure*". Variables loading on Component 5 were Sad garden suffered, Attitude and social norms related to gardening and Banned water uses pleasurable, so was named "*Garden*".

These combined variables were saved during the PCA and used in subsequent analysis. Bivariate correlations were used against the square root normalised water use. For the non-split dataset; Behaviour was strongly negatively correlated with water use for every year, and the strength of the correlation increased during the period of the drought[36]. Infrastructure was positively correlated with water use for every year, except in 2007[37]. Garden was positively correlated with water use, but only for 2007[38]. Neither Incentives nor Concern were significantly correlated with water use. After splitting by area; for Brisbane, Concern and Behaviour were strongly negatively correlated with water use for every year. However, there were no significant correlations with Incentives, Infrastructure or Garden. For Caloundra, the only significant correlation was for Infrastructure in 2009. For Maroochy, Behaviour was strongly negatively correlated with water use in 2006 and 2007 but no other Factors were significant.

Bivariate correlations were conducted on the Components against socio-demographic variables (Table 31). Incentive was positively correlated with gender, and negatively correlated with education and income (Males with lower education levels and income preferred Incentive measures). Concern was positively correlated with gender and income, and negatively correlated with age (younger males with higher incomes were more concerned about issues such as global warming). Behaviour was positively correlated with gender and negatively correlated with household size (males in smaller households changed behaviour more). Infrastructure had no significant correlations with demographic variables, and Garden was positively correlated with employment (people not in the labour force were more concerned about gardens).

[36] Factor 3: (2006: $r(160) = -.251, p<.01$); 2007 r$(160) = -.312, p<01$); 2008 $r(160) = -306, p<01$) and 2009: $r(160) = -278, p<01$).

[37] Factor 4: (2006 r(160) = .213, p<.01); 2008 r(160) = .165, p<.01); and 2009, r(160) = .186, p<.01).

38 Factor 5, 2007; ($r\ (160)= .164, p<05$).

Table 31 PCA Component Correlations with Demographic Variables

	Gender	Age	Educate	Employ	HH Size	Kids < 18	Kids 18 +	Income
Incentive	**.212****	-.092	**-.196****	.030	-.018	-.139	-.218	**-.137***
Concern	**.143***	**-.164****	.103	-.077	.116	.010	.079	**.178****
Behaviour	**.132***	.059	.112	-.057	**-.207****	-.083	-.206	.082
Infrastructure	-.041	.015	.112	.005	-.006	.142	.007	.045
Garden	-.075	.119	-.010	**.121***	.109	.058	.212	.083

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Thereafter, another PCA was performed on the split dataset. Householder opinions on polices seemed to reflect three dissimilar components. In Brisbane, 62.86% of the Variance was explained by 3 components; Component 1 (Home WaterWise, Target 140 and Climate Smart); Component 2 (Traveston Dam and the Water Grid); and Component 3 (Desalination, Recycling and Water Tank Rebates). Results for the Sunshine Coast were similar, with 3 components explaining 57.99% of the variance; Component 1 (ClimateSmart and Home WaterWise); Component 2 (the Water Grid and Traveston Dam) and Component 3 (Desalination and Water Recycling). Only two components were extracted for the Unidentified group; Component 1 (Climate Smart, Home WaterWise, Target 140 and Water Tank Rebates) and Component 2 (Traveston, Desalination, Water Grid and Recycling).

5.2 Results: Water Conservation Behaviour

Section Five (b)

For Question 36A; most (73.2%) agreed or strongly agreed that they had "…*used more water in the past*". A larger proportion of Brisbane residents (80.1%) than Sunshine Coast residents (67.5%) agreed with this statement. There was no significant relationship with water use. Question 36B was not significant; 83.9% of people disagreed that it was difficult to change wasteful water use habits.

For Question (37), "*In the past we had to use water more sparingly, i.e. only had tank water*"; although non-significant, an ANOVA indicated that if people had not been connected to reticulated water in the past, they used *more* water. This was the case for every year, and in both areas, except for Brisbane in 2008, where the direction of the relationship was reversed. Answering "Yes" to this question was not a significant predictor for water use behaviour, intention to conserve water, or actual water use. However, age was significantly related to past water use, with older respondents generally more frugal than younger respondents[39].

Water Conservation Behaviour

The Questionnaire included a question aimed to identify water conservation behaviours practised during the drought, and if this behaviour was maintained after the drought ended. Question 26 comprised 9 sub questions on whether water use behaviour was practised during the drought, will be practised in the future, or will not be practised in the future. Yes answers were coded as "1" and No or missing answers were left blank. Sub-questions included, "*Did you use half flush on the toilet*" and "*Did you change your gardening practices, such as mulching, planting drought resistant species, etc*" and respondents could tick multiple columns; the headings of which were; During the Drought; Intend to do in Future, and Do not intend to do in Future. To calculate the variables, each Yes answer (coded as 1) was summed to form three composite variables, "*Behaviour During Drought", "Future Behaviour*" and "*No Intention*".

Respondents practising more water conservation behaviours in the past were significantly more likely to continue these in the future. *Behaviour During Drought* and *Future Behaviour* were significantly positively correlated ($r=.501, p>0.01$) and both were significantly negatively correlated with *No Intention* ($r= -.465, p>0.01$).

Attitudes to Water Consumption

This section aimed to identify some of the constructs of the Theory of Planned Behaviour. Each of the Attitude (A) and Social Norm (SN) questions comprised a three-part question, numbered on a 5-part Likert scale, from very unimportant to very

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39 ($r(327) =.146, p<.01$)

important. However, an initial scan of the responses noted that most respondents answered this question similarly, with important ratings given to conserving water, and protecting the environment, but not to maintaining a green garden.

The Attitude section comprised three sub items; "*I believe that conserving water is:", "For me, to conserve water to help protect the environment is:",* and "*To me, that my garden looks green is:*"

The Social Norm section also comprised three questions: "*My family and friends believe that conserving water is important*"; "*My family and friends agree that it is important that my garden looks green is*:" and "*Most people who are important to me think that it is necessary to conserve water to help protect the environment".*

For Perceived Behavioural Control, this question was made up of four sub questions (C*onserve* was inadvertently omitted from the paper surveys, so was eliminated in the final analysis); and included: "*To keep my garden looking green during restrictions was*:"; "*For my household, using less than 140litres per person per day was*:"; "*Controlling the water use of other household members (like children) is*"; and "*For me, to install water saving devices like water tanks, is...*"

Unlike Attitude and Social Norm, this question was not in strict Ajzen form (paraphrasing the same question using terms relevant to the construct being measured, as described above for Attitude and Social Norm) (Ajzen, 1991). The alternate phrasing of the question aimed to answer other aspects of the research questions, for example, whether it was difficult to control the water use of other household members. Although some part items were significantly correlated, some were not relevant for respondents (the question about children was irrelevant for older householders, as was the 140 litre question for Sunshine Coast householders). Therefore, some questions were also analysed individually.

5.2.1 Path Analysis –TPB Variables

The statistical technique, Structural Equation Modelling (SEM), was used to analyse the relationship between water use and psychological and socio-demographic variables (Corral-Verdugo et al., 2008). Because of missing data, the SEM was run using Maximum Likelihood analysis, with the estimation of means and intercepts. However, with this method, it is impossible to calculate Modification Indexes or the Bayesian Information Criterion (BIC); thus complicating any analysis of model fit. It was thus necessary to analyse a number of models to establish the model with the most parsimonious fit.

Initially, a number of latent exogenous variables were created (using Amos Graphics, v.17). In this preliminary analysis, the combined variables only explained 19% of the variance in water use. Because these were created from individual items on the nominal scale, a Cochran's Q reliability test was performed. The result was significant ($p<.01$), thus the combined measure was not an adequate representation of general behaviour. Therefore, some items with low intercorrelations were dropped and new composite measures created.

The final latent exogenous variables were: Policy, Garden, TPB Combined and Water Conservation Behaviour (Table 32). Two latent variables extracted in the PFA (Concern and Infrastructure) were eliminated as these had no significant covariances with the other latent variables, or with water use. In addition, the initial correlation analysis indicated swimming pools and household size had high, individual explanatory power over the dependent variable, so these were used as stand-alone predictors in the model. This exercise resulted in a marked improvement to the predictive power of the final SEM model; which then achieved identification, and did not require the imposition of additional constraints.

Table 32. Variables used in Structural Equation Modelling

Latent Exogenous Variables	**Indicator Variables (survey items)**
Policy: Opinion on policies? (1 Strongly Disagree – 5 Strongly Agree)	(HWW) Home WaterWise (CS) Climate Smart (Rebate) Water Tank Rebates (Recycle) Recycling
Garden: (1 Very Unimportant to 5 Very Important); and (1 Strongly Disagree to 5 Strongly Agree)	(Sad) Sad garden suffered during water restrictions (AGrn) To me, that my garden looks green is: (SNGrn) My family and friends agree that it is important that my garden looks green
TPB Comp: (1 Very Unimportant to 5 Very Important) and (1 Strongly Disagree to 5 Strongly Agree)	(AComp) Composite of Attitude Questions TPB (e.g. I believe that conserving water is:) (SNComp) Composite of Social Norm TPB (Future) Belief not enough water in the future
Water Cons Behaviour: (1 Very Easy to 5 Very Difficult); and (1 Strongly Disagree to 5 Strongly Agree)	(HHLess) Household uses less water than similar (Changed) I've changed my water use since the water policies were implemented (During) Composite of water conservation behaviours during drought (Intent) Composite of water conservation behaviours intended to perform after drought
Direct, Observed Variables	
Water Use	Average Daily Water Use per household
Swimming Pool	Yes (1) No (2)
Household Size	Interval variable, number of people in household

For the final analysis, the model with the lowest Chi Square (χ^2) was chosen. Of note, despite the χ^2 for the final default model being significant (*198.724 at 113df, p<.05*), other measures of model fit were more positive[40]. However, despite the significant χ^2, it is difficult to fit models with multiple variables and missing data (Abrahamson et al, 2005; Schreiber et al, 2006). In addition, model χ^2 is a conservative measure and prone to Type II errors so, given the relatively large sample size (n>200), and the good fit as indicated by the other measures, the final model was not rejected.

[40] For the unconstrained model, CMIN/DF was 1.759 *(Kline (1998a) says 3 or less is acceptable)*; RMSEA was 0.47 (should be <.05) and CFI was .913 (should be >.90).

As indicated in Figure 42, the final model explained 45% of the variance in water use. However, the majority of the variance was explained by the structural variables, household size and swimming pool. Despite previous analysis that found lot area was significant, removing this variable considerably improved the final model fit.

The TPB variables alone did not add significantly to the model. However, creating two combined variables, *Attitude Composite* and *Social Norm Composite*, and including the variable *Future* (concern about not enough water for the future) was more useful in explaining water conservation behaviour (the latent endogenous variable). The initial model separated Attitude and Social Norm, but this created problems in model structure (negative variances in error terms), so in the final model, these were combined in a single exogenous latent variable.

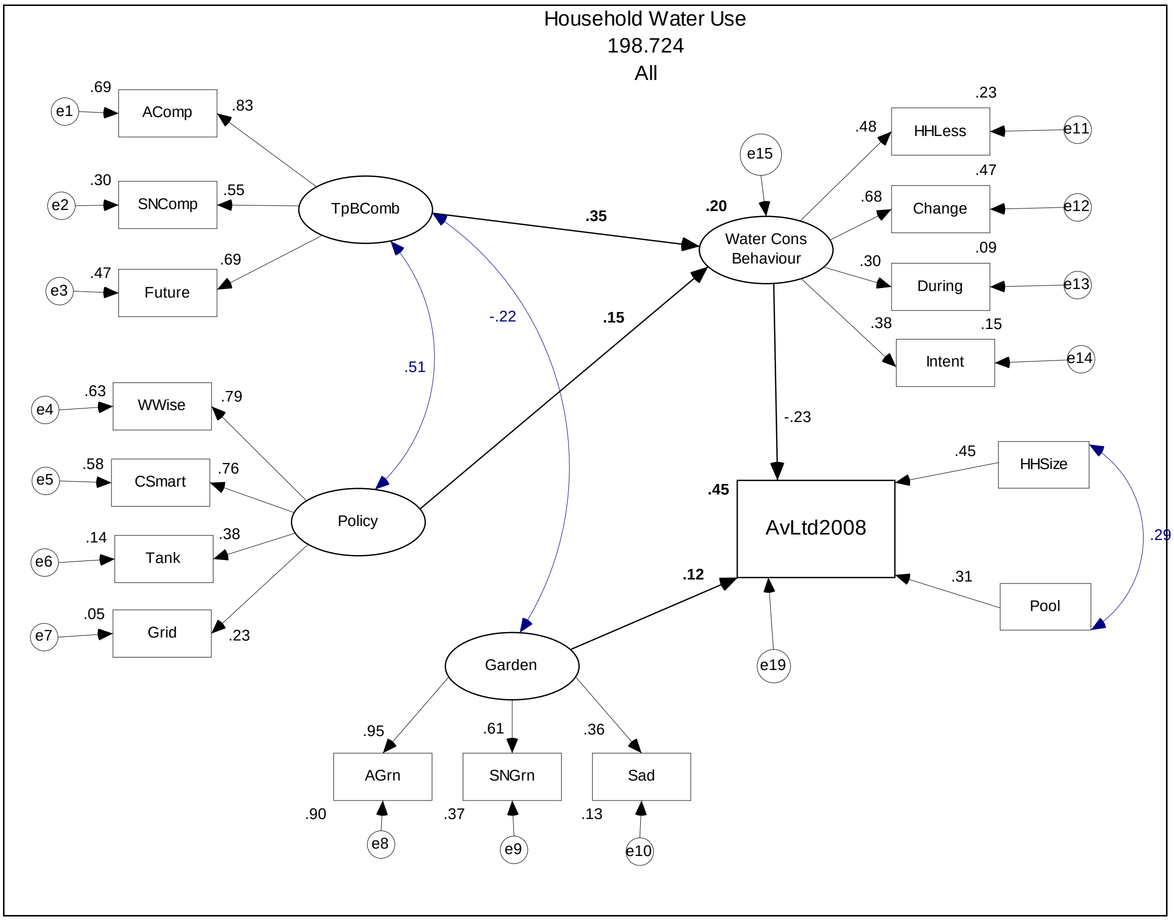

Figure 42 Average Water Use 2008 All Areas

The Combined TPB variable was positively correlated with Policy; those with positive Attitude and Social Norm more strongly supported Policy Measures (Table 33). On the other hand, the Combined TPB variable was negatively correlated with Garden; the greater the concern about water and attitudes to conservation and environment, the lower the concern about green gardens. A visual scan of the responses, also indicated similarities between questions comprising the composite variables.

Table 33 Regression Weights Structural Equation Model - All

Variable		Variable	Estimate.	S.E	C.R	P
Water Cons_Behaviour	<---	Policy	.05	.04	1.54	.125
Water Cons_Behaviour	<---	TPBComb	.41	.13	3.16	.002
Attitude_a	<---	TPBComb	1.29	.15	8.37	***
Climate Smart	<---	Policy	1.00			
Home WWise	<---	Policy	.85	.10	9.03	***
HH uses less	<---	Water Cons_Behaviour	1.00			
Water Tank	<---	Policy	.29	.05	5.83	***
Water Grid	<---	Policy	.32	.09	3.48	***
Attitude-Green	<---	Garden	1.00			
SN-Green	<---	Garden	1.19	.20	5.99	***
Sad Garden Died	<---	Garden	2.12	.44	4.78	***
BehaviourIntent	<---	Water Cons_Behaviour	1.56	.34	4.53	***
BehaviourDuring	<---	Water Cons_Behaviour	.80	.21	3.86	***
Changed Behaviour	<---	Water Cons_Behaviour	1.26	.24	5.26	***
Future Concern	<---	TPBComb	1.67	.20	8.25	***
SocialNorm	<---	TPBComb	1.00			
AvLtd2008	<---	HH Size	102.67	11.40	9.00	***
AvLtd2008	<---	Pool	239.68	38.78	6.18	***
AvLtd2008	<---	Garden	81.28	35.52	2.29	.022
AvLtd2008	<---	Water Cons_Behaviour	-165.81	49.08	-3.38	***

Neither Policy nor TPB Combined added significantly to the latent variable, Water Conservation Behaviour, nor were they significant for water use (Table 33). However, creating two combined variables, Attitude Composite and Social Norm Composite, and including the variable Future (concern about future water supplies) improved the predictability for water conservation behaviour. Household size and swimming pool contributed most to the variance in water use, then Garden. The higher the scores on Garden, the larger the household and the presence of a pool, the greater the water use. Water Conservation Behaviour was negatively related to water use.

After splitting the dataset, the Chi Squares were lower but significant, but other measures of fit were sufficient, particularly for Brisbane (Table 34).

Table 34. Comparison of Models and Groups (Area)

Model	Chi Square	DF	SIG	CMIN/Df	CFI	RMSEA	AIC
Total (all)	198.72	113	0.00	1.76	.913	.047	312.72
Sunshine Coast	149.74	113	0.12	1.35	.880	.055	263.74
Brisbane	166.12	113	0.01	1.47	.897	.052	280.12

As illustrated in Figure 43, the explanatory power of the combined variables for water use was greater for the Sunshine Coast (58% of variance) than Brisbane (39% of variance). However, for Brisbane, the attitudinal variable TPB Comp better explained Water Conservation Behaviour (Brisbane (.42) and Sunshine Coast (.28). Water Conservation Behaviour for the Sunshine Coast (-.16) was less significant for actual water use than for Brisbane (-.24). Garden was similar; Sunshine Coast (.12) and Brisbane (.13); but it was not significantly correlated with TPB Comb for the Sunshine Coast. The influence of household size was greater for Brisbane (.52) than the Sunshine Coast (.45); but the reverse was the case for swimming pools, with the Sunshine Coast (.44) greater than Brisbane (.12). Policy was not significant for Water Conservation Behaviour for either area. However, it had a significant relationship with TPB Comp, and its removal negatively impacted on model fit.

Thereafter, the water use variable was split into categories based on standard deviations (and Visual Binning in SPSS), and the water restriction level at the time (Low < 140l ; Medium 141-400l; High 401-700l; and Very High >700l). It was difficult to identify cut-off points from the literature, because SEQ water use at the time was exceptionally low[41]. Therefore, the categorisation was based on the total dataset and not the survey data. When splitting the dataset by water use, the Chi Square was not significant for any of the water use categories, indicating the model better fitted the data (Table 35).

[41] In the SEQ Urban Water Study, median water use per Brisbane household in 2007 was 280KL per annum, whereas for this study, median household water use was 136KL pa; and for the survey was 116KL pa

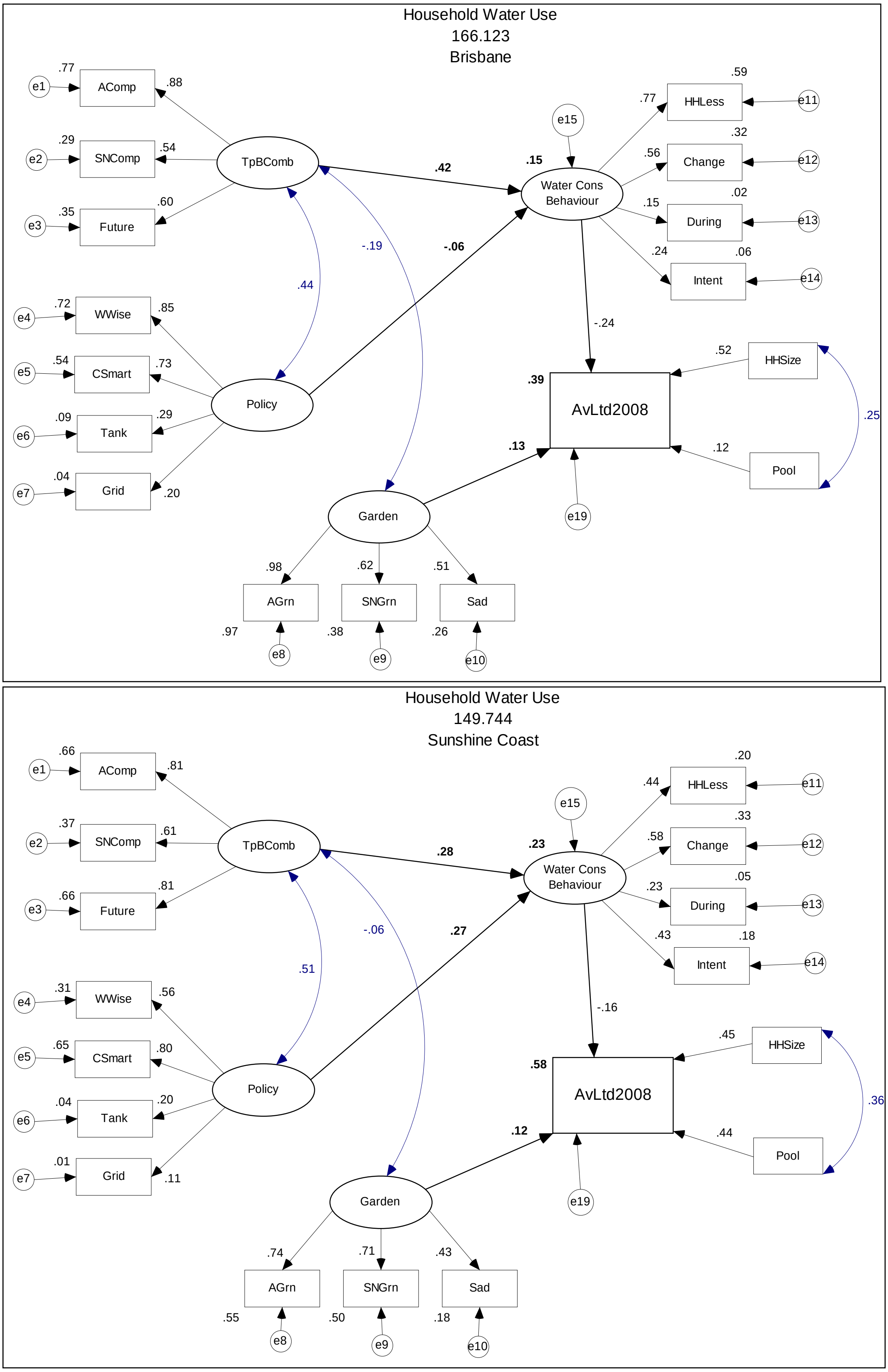

Figure 43 Brisbane and Sunshine Coast Water Use

Table 35. Comparison of Models and Groups – Water Use

Model	Chi Square	DF	Sig (<.05)	CMIN/Df	CFI	RMSEA	AIC
Low	128.26	113	.155	1.14	.878	.059	242.26
Medium	143.51	113	.028	1.27	.860	.050	257.51
High	115.00	113	.430	1.02	.987	.016	229.00
Very High	135.01	113	.077	1.20	.785	.073	249.01

For Medium water users (Figure 44), the influence of TPB Comp (.42) on Water Conservation Behaviour was less than for low water users, Policy was negative (-.10) and not significant. However, Garden (.12) was positive and Water Conservation Behaviour was negative (-.19) for water use. Household size was positive (.35) as was pool (.19). The combined variables explained 19% of the variance in Medium water use.

Figure 45 shows that for Low water users, the influence of TPB Comp (.77) was positive for Behaviour, but Policy (-.18) was negative. Garden (-.01) was negative for water use; although Water Conservation Behaviour (-.12) was also slightly negative. Household size was negative (-.10) and pool was zero (.00). However, the combined effect of the variables was extremely low (3%) and did not adequately describe low water users.

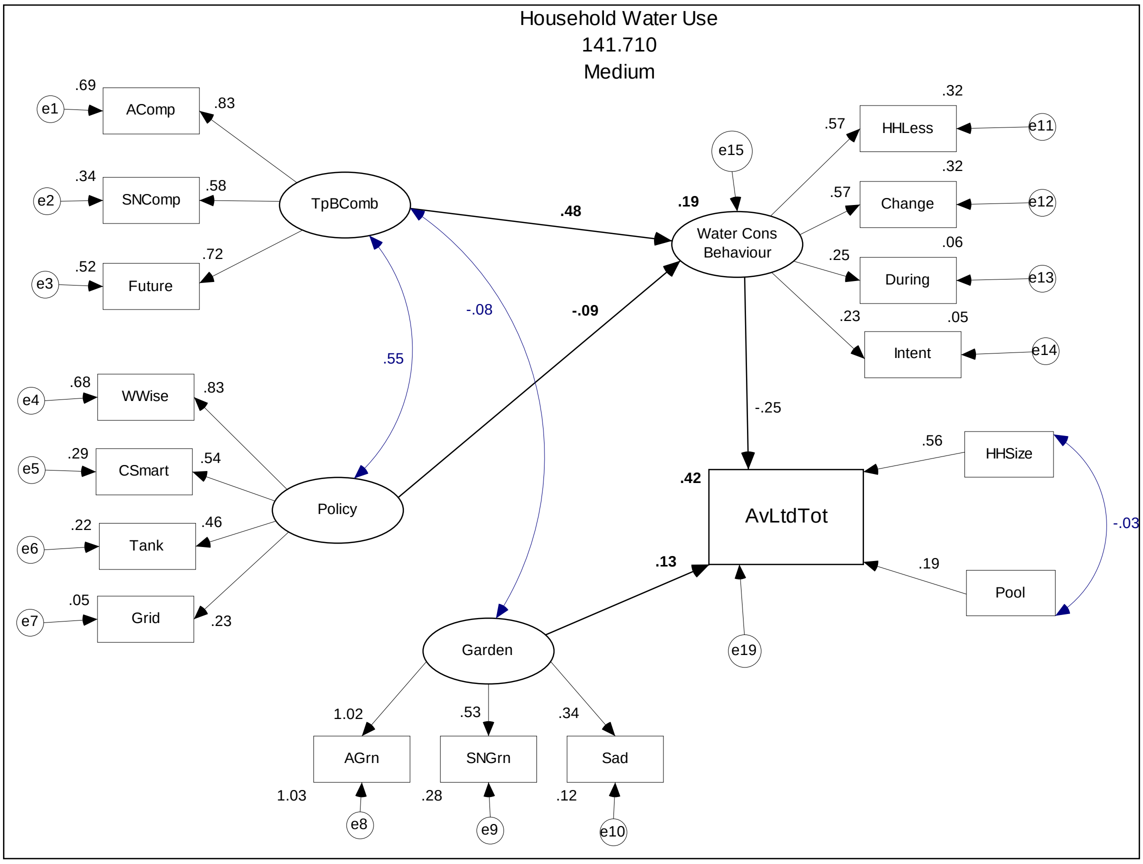

Figure 44 Medium Water Users

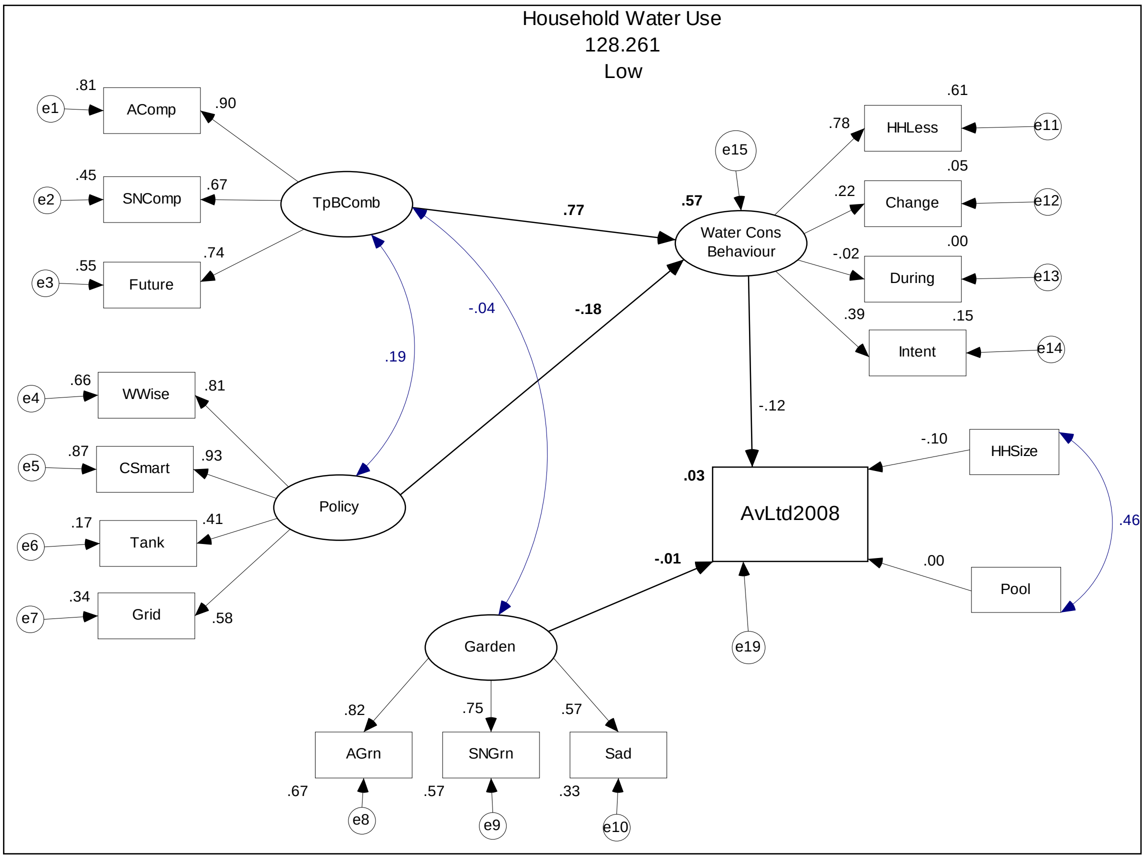

Figure 45 Low Water Users

Therefore, because the model only satisfactorily explained “Medium” water users; additional models were created to attempt to explain “High” and “Low” water users. However, it proved impossible to fit any models to low water users. Regarding high water users, the final model explained 51% of the variance in high water use (Figure 46). In this model, neither behavioural nor attitudinal variables were significant for water use. The most significant predictors of high water use were structural variables, such as land value, swimming pools and tenure (fully owned or mortgaged). Outdoor water use and support for infrastructure based policies were also significant.

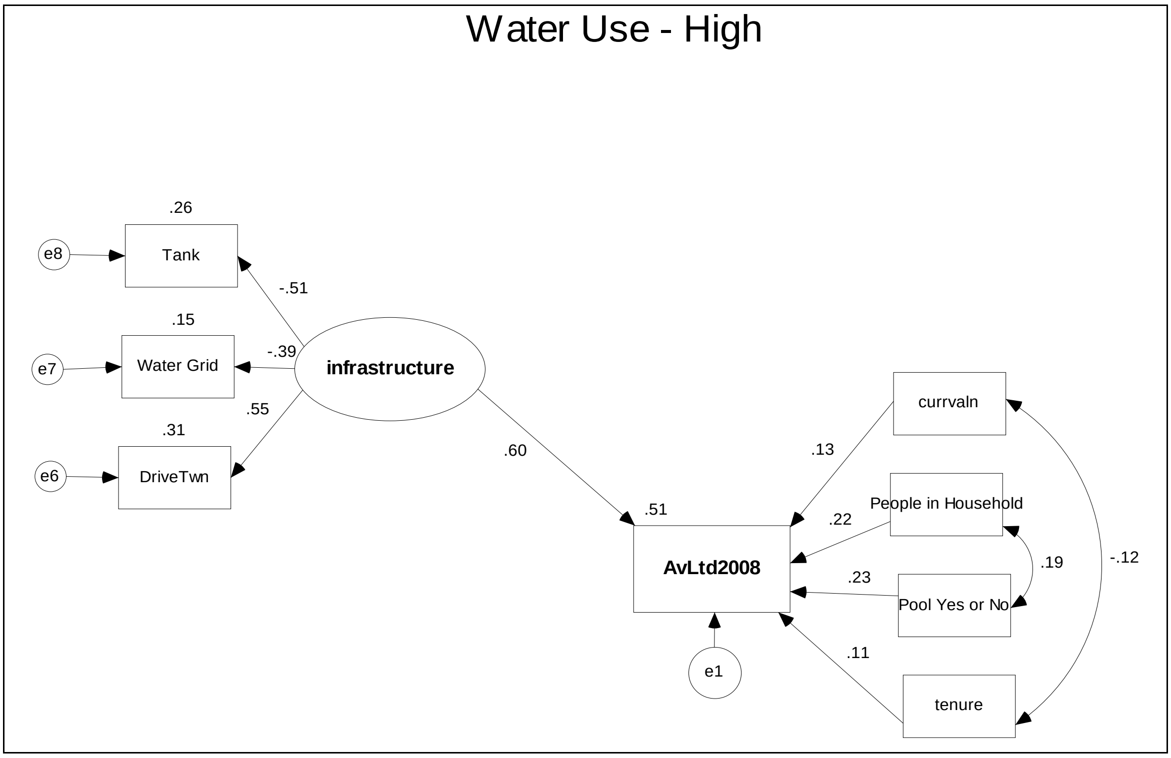

Figure 46 Path Diagram of High Water Users

5.3 Analysis of Open Ended Responses to Questionnaire

In an attempt to value add to the quantitative results, and delve deeper into how householders feel about water consumption, and the water policies, the Questionnaire included a final, open ended question: No. 47” *Do you have any final comments on water consumption or water policies*? Approximately half (47.72%) of respondents answered this question, which provided valuable supplementary information to the main Questionnaire (full text in Appendix B, Section 8.2.3). The question aimed to provide more in depth and nuanced material, to inform the wider study. However, due to the relatively small proportion of more qualitative information, research methodologies, such as content analysis, were not used. Instead, common themes were identified, and the number of responses referring to these themes was counted.

5.3.1 Key Categories

In general, the responses could be categorized into three main themes; *Policy* (Government, Price, Restrictions); *Supply* (Local, Dams, Tanks, Other Supply); and *Behaviour/Attitude Change* (Awareness, Changes in Behaviour, Changes in Garden Behaviour, Special Needs, Personal Control). These are summarised, together with the number of responses in each category, in Table 36; below.

Table 36. Most Common Themes in Open-ended Survey Question 47.

KEY CATEGORIES		No.	Tot
Policy (Government, Legislation, Restrictions)			
Costs	Increased costs (i.e. lawn died)	3	**11**
Price	Charged same, even though used less	2	
	Need fines for excess use	2	
	Need block pricing	2	
	Water saving appliances/tanks too expensive	2	
Government	State Govt Poor Planning	22	**47**
	State Govt corrupt/ waste money	17	
	State Govt Reactive	4	
	State Govt lack transparency	3	
	Govt doing well	1	
Restrictions	Permanent restrictions/ T140	8	**19**
	Restrictions T140 too strict	5	
	Permanent restrictions on pools	3	
	Ban hosing permanently	2	
	Always obeyed restrictions	1	
Supply (Alternates, Dams, Tanks)			
Local	Govt must pay for tanks, supply all houses	9	**34**
	Industry/Commercial Use Excess water	8	
	Capture Local Runoff/ Harvest rain water	7	
	Limit Population Growth/immigration	6	
	Brisbane steal SC water	4	
Other Infrastructure	Recycling Non Potable Only	9	**32**
	Recyling Yes (potable ok)	7	
	Interbasin transfers	5	
	Desalination (No)	4	
	Fix Leaks/ clean pipes	3	
	Desalination (Yes)	2	
	Some water saving tech incompatible gas/solar	2	
	Support Water Grid	1	
	Concerns for water quality	1	
Dams	No Traveston	13	**31**
	More Dams	9	
	Agricultural land lost	6	
	Why didn’t build Wolffdene?	3	
Tanks	Strongly support tanks	8	**13**
	Need to retrofit new/old homes	2	
	Renting – installing tanks is too difficult	2	
	No room for tanks	1	

KEY CATEGORIES		No.	Tot
Behaviour Change			
Awareness	Drought good for awareness	5	**22**
	Need constant awareness of use	5	
	Need more education/information, e.g. dams	4	
	Want real-time water metering	3	
	More publicity Qld Reductions	2	
	Need better research future/govt listen research	2	
	T140 excellent awareness	1	
Attitude/ Behave Change	Recognise need to always conserve water	15	**48**
	Past history made water aware	7	
	Water not valued enough	7	
	Took up WaterWise/installed flow restrictors	5	
	Restrictions/Drought changed behaviour/habits	5	
	Water taken for granted	2	
	Concern for future generations	2	
	GHG denier	2	
	Varying attitudes within same household	1	
	Community came together in crisis	1	
	Young people no respect	1	
Garden (Changes)	Reused water on garden plants/lawn	7	**18**
	Lawns water wasters	5	
	Rely on rain to keep garden green	2	
	Type of Garden (veg good, ornamental "bad")	2	
	Sad garden suffered	1	
	Garden benefit environment	1	
Individual Responsibility	Personal control/total water limit	8	**14**
	Household self sufficiency	3	
	Individual responsibility	2	
Special Needs	Difficult for older/special needs (handicapped)	5	**11**
	Families/large HH need more water	4	
	Need hot showers medical	2	

1. Policy and Legislation

The most striking theme was general distrust of the State Government and to a lesser extent, of Local Government. This distrust generally related to the perceived lack of planning and infrastructure provision, as well as the delayed reaction to the drought. Many commented on SEQ's high rainfall, but lack of water storages in suitable areas.

"*...the government has failed to adequately plan for the population growth of SE Queensland - in every aspect i.e. water, public transport, roads*."

"The State Govt should have thought about infrastructure to provide Brisbane's growing population with water supplies years ago instead of waiting until now."

In addition, many felt the State Government lacked transparency, and did not want to make unpopular decisions. The State was largely seen as reactive, and poorly prepared. Many respondents supported the water supply infrastructure, such as the water grid, but they felt that the Government should have made past, difficult political decisions to build infrastructure, such as the Wolffdene Dam.

"*Govt needs to listen to advice from experts and then follow it, not ignore it because it might be unpopular"*

"...I feel utterly frustrated by the wastage of public money because of poor or rushed decision making (e.g. the desalination plant problems), and the hypersensitivity of government to any questions or suggested alternatives. The perceived lack of openness and objectivity in response does not engender trust in the efficacy of their programs."

There was general support for other policy measures, such as the water restrictions. However, respondents were equally divided on whether restrictions were easy or difficult to follow. Many felt that some level of restrictions should be permanently in place, although not at the same level as during the drought. However, others felt the water shortages were the result of poor planning by Government, and that there should have been no need for restrictions (which, in their opinion, were implemented too late, too quickly and too strictly). In addition, many felt that certain uses, such as hosing driveways, should be permanently banned, as well as only permitting pools filling with tank water.

> *"I think water restrictions should be maintained to a certain level in the future."*

> *"Prefer a policy of educating people to use less water and permanent tighter water restrictions than before the drought, but a bit more relaxed than during it."*

Opinions on pricing were not asked in the questionnaire, as this was not implemented as part of the demand-side policy measures; nevertheless, some still commented on water pricing. A noticeable theme was the paucity of economic incentives for reducing water use; the base rate remained the same, no matter what quantity of water was used. Many seemed willing to support some sort of block pricing, charging a base rate for essential supply, and thereafter, an increasing block rate depending on use.

Other monetary issues were related to the cost of returfing lawns that died during the drought, and repairing irrigation systems that had deteriorated from lack of use. Some commented on the high cost of water efficient appliances and water tanks, and said they would install these if they were less expensive. Many commented on the cost of water supply infrastructure, such as the water grid and Traveston Dam, and even stated that the State Government was "*money grabbing and corrupt*".

"Disgusted with the water charges - *the less we used the more each litre cost us. We were charged approx 3x the price per litre than had we used the top limit (800litres) per household per day."*

"…have no faith in Governments as it is all about business and how they can keep the money flowing into the government bank accounts to help pay for the future development (sic) and fixing up the problems that are caused through not well thought out policies"

2. Supply Alternatives

These comments were categorized into Dams, Other Infrastructure, Water Tanks, and Local Supply alternatives. Dams were placed in a separate category, because of the highly polarized opinions about the now defunct Traveston Dam proposal. Comments on the loss of agricultural land generally related to the Traveston Dam proposal. A common theme was that local solutions were preferable to building large infrastructure such as dams.

In general, opinions on the water tank rebates were highly positive, and many expressed disappointment about the ending of the subsidy on water tanks. Water tanks were also related to cost and pricing, some suggested that the State Government fund water tanks for every house as a better alternative than building dams. Two respondents commented that they wanted to install water tanks but were unable to do so because lived in rental houses.

"Instead of Traveston dam, government to supply tank to every house. Combined storage surely equal to dam."

"My suggestion was that they should be decreasing base water rates, and increasing consumption charges as a fully user pays system would provide a financial incentive to install the larger tanks and pump equipment to make many households independent from the grid."

Most supported recycling, although the majority preferred it for industrial or commercial uses only. Desalination did not engender strong negative or positive attitudes, except for its cost. Likewise, the water grid was mentioned, but apart from Sunshine Coast residents who resented Brisbane "*stealing their water*", criticisms were largely on the basis of cost. Some mentioned that certain water and/or energy saving appliances were incompatible with their gas or solar water systems.

"I do not support or agree with recycling sewage for drinking water. I do support it being used for industry."

"Use water conservation measures including recycling and the option to bring on desalination plants in an emergency"

Another common theme was interbasin transfers. Various alternate water sources were suggested, including the Northern NSW Rivers, Burnett River in Central Queensland, Eli Creek on Fraser Island, and even "…*a huge underwater reserve (many times more than Sydney harbour)…in Western Australia*".

3. Behaviour Change

Another striking theme was changes in attitude and behaviour, especially as a result of the water policies (restrictions) and the drought. This was categorized into Awareness, Attitude/Behaviour Change, Individual Responsibility for Water Use, Changes in Gardening Practice, and Special Needs.

A common theme was how the drought and the water restrictions had made people more aware of water conservation. No-one commented on the medium by which they had received information, but some expressed a desire for more, current information. One respondent said it was easy to keep to the Target 140 restrictions by reading their water meter every day, but others felt that a system, similar to the Smart Metering used for electricity, might be useful to monitor personal water use.

"*I think target 140 was very effective at raising the public's awareness about water conservation."*

"The availability of remote water meter display devices similar to those now available for monitoring electricity usage would be very helpful and would further encourage people to maintain awareness of their water consumption."

Regarding attitude and behaviour change, many felt continuing water conservation would always be necessary. Many respondents also said that the drought and the water restrictions had permanently changed their water use. For example, some realised it was not necessary to regularly water lawns; or had replaced lawns with other vegetation, or hard surfaces.

"Attitudes have changed in a good way - people frown on people who hose their paths and driveways now."

The water restrictions during the drought had a lasting impact on my usage. I now realise how little water the garden needs to survive. I'll never waste water on my lawn again as I now realise it greens up as soon as it rains."

Some commented that their own past history made them more aware of water use, and they had always conserved water. Some phrased this according to cultural background, but others thought it was because of past experience of having to rely on non-reticulated water sources. Of note, in other analysis, past history of conserving water was not significant for water use.

"*People should learn to appreciate and conserve water…lived on farm as child and only had tank water."*

"…it's also the household you have grown up in and your culture. I notice many European and Asian cultures tend to let the hot water tap run Although washing dishes as they have no concept of water saving in their countries, nor were they taught to save water growing up in Australia."

In addition to installing water tanks (some respondents had several water tanks); others also took advantage of the Home WaterWise Program, had put in bores, purchased more efficient appliances and fixed water leaks. These technological and alternative supply responses to the drought were relatively popular; the only negatives being affordability, or renters lacking the ability to install tanks.

A strong theme was for self-sufficiency, and personal control over water use. Although many were happy to restrict their water use, even permanently, they wanted control over how and when it was used. A per capita limit (200LCD was a commonly stated figure) was generally approved, but respondents preferred to use water as they wished. For example, some wanted to reduce indoor water use to allow for increased outdoor water use, such as garden watering. Many re-used laundry, kitchen and shower water to keep gardens alive. One commented that carting buckets was detrimental to health, especially for the elderly.

"*If there is a household total volume allowed to be used per day, why can't we use it for anything, washing cars, gardens etc, if we cut down on internal use? All use 200 litres per day on what we want*."

"…having to bucket water (in the garden) is ridiculous and very dangerous for the elderly, small statured person. Dreadful dreadful social outcomes, medical outcomes. May well be unlawfully discriminatory. Limit the amount of water you can use, not the way it is used. I'm ok with reducing consumption, but totally object to being told how and when I can use town water when I'm staying within reasonable limits. People should be allowed to make their own decisions and have to pay (or be fined) when their usage exceeds deemed limits."

Perceptions on saving water differed according to the age of the respondent. Some elderly respondents thought it was easier for younger people to save water; as some elderly "*needed long hot showers for medical reasons*". On the other hand, those with larger families and young children felt that it was much more difficult to save water. Others commented that it was difficult to reduce water use because of health issues, such as disabled family members.

5.3.2 Summary, Results Phase 2

The Questionnaire survey was sent to a random sample of 1680 residents in detached houses in Brisbane and the Sunshine Coast. The response rate of 20.8% was relatively low, but 47.72% of respondents provided additional qualitative responses. The majority of respondents lived in two person households, and owned their own homes. The returned sample was strongly biased to older residents, with over 90% of respondents over 35, and 29.4% over 65. Of these, 50% owned their homes outright, and 42% of households had only two members.

Therefore, these sample results are not representative of the population as a whole. In 2007/8, only 33% of Australians owned their homes outright, and the median age of Queenslanders was 36.2 years (ABS, 2010a). With respect to this, caution needs to be exercised with regard to any extrapolation of these results to the population. However, with regard to population size, the results were not significantly different to the population mean.

With regard to socio-demographic influences on water use; per capita water use was highest for two and then one-person households. Household size contributed the most to higher water use, thereafter, income and children (of all ages). Age was negatively correlated with water use, as was employment, with those in full time employment and self-employed more likely to use more water. Neither education level nor gender was significant for water use.

Regarding structural factors, the most significant variable for higher levels of household water use was the presence of a swimming pool. Furthermore, the larger the lot, the larger the house; and the larger the lot, the greater the mean water use. Larger houses were also correlated with higher levels of water use in Maroochy for all years, but only for 2006 and 2007 in Brisbane, and not at all for Caloundra.

There were no significant correlations between house age and mean water use for Brisbane and Maroochy. However, house age was significantly correlated with water use for every year in Caloundra. In general, houses built from 1991-2000 had the highest range and highest mean water use, and those built after 2001 had similar water use to those built from 1970-1990. Tenure was significantly correlated with water use for every year in Brisbane and Caloundra, but not at any time for Maroochy.

Most never watered lawns, but these results differed according to area; 90% of Brisbane residents never watered their lawns, in comparison to 53% of Sunshine Coast residents. The frequency and type of outdoor water use was highly significant for outdoor water use. Residents washing cars, watering lawns and filling pools with town water used significantly more water.

Responses to government policy were generally positive, but some responses displayed a strong geographical bias, with opposition to the now defunct Traveston Dam proposal more apparent on the Sunshine Coast. There was little opposition to recycled water or desalination plants, although many respondents only approved of recycled water for non-potable use. The strongest approval ratings were for the water tank rebate (88%) and Home WaterWise (82%). Over 60% of respondents had installed water tanks, and most of these had installed these in 2007, at the height of the drought. A noted difference was that Brisbane householders used tank water for car washing and watering gardens, but even if they had tanks, most Sunshine Coast residents still used reticulated supplies. The majority of respondents approved of restricting water use.

However, many respondents had no idea of the current level of water restrictions; 43.3% “didn’t know” the level of water restrictions at the time of the survey.

Structural Equation Modelling (SEM) was used to analyse the relationship between water use and psychological and socio-demographic variables. The final model explained 45% of the variance in water use. Most variance was explained by the structural variables, household size and swimming pool. However, this model only satisfactorily explained “Medium” water users, so another model was created to explain “High” and “Low” water users. This new model explained 51% of the variance in high water use, but not low water use. For high water users, neither behavioural nor attitudinal variables were significant, and the most significant predictors were the structural variables, land value, swimming pools and tenure (fully owned or mortgaged). Outdoor water use and support for infrastructure based policies were also significant.

The most noticeable theme was a general mistrust of the Government, especially the State Government. A common perception was of failure to plan for the future, and wasting taxpayer’s money on “knee-jerk and reactive schemes”. The State was perceived to be largely incompetent, but this criticism was mostly aimed in generic terms at “the Government”. Respondents generally confused levels of Government, and responsibility for water policy, and levelled criticism at the State for cancelling the popular water tank rebates.

Major themes included a desire for self-sufficiency and personal control over water allocations. Instead of building large infrastructure, many felt local solutions, such as water tanks for every house (paid for by the Government) was more cost effective, and better for the environment. “*Instead of spending billions on dams, give every house a tank*”. Permanent water restrictions, per capita limits on water use, and the need to conserve water, were all acceptable.

CHAPTER 6 DISCUSSION

6.1 Introduction

In response to a suite of demand-side policies imposed during a severe drought, SEQ household water use dropped nearly 80% in less than five years. This research project aimed to understand some of the reasons for this dramatic reduction. To do so, it investigated how household water use varied spatially from 2006-2009; and what structural, socio-demographic and psychological factors contributed to this variance. In addition, the research sought to identify if specific household types respond differently to the South East Queensland demand-side policies, and which of the policy measures were the most effective, and why.

The initial phase of the study used a large, household-level database of four years of water consumption data, which then informed the second phase, a Questionnaire survey. The water use dataset contained such property level identification (Lot and Plan numbers), so it could be georeferenced with spatial datasets, such as valuations data, and thus mapped. As it included household-level water meter readings and dates of reading, it could also be used to analyse the efficacy of time-based policy measures such as the water restrictions, as well as compared to survey information.

This section briefly summarises the results of the study, then discusses significant variables for higher levels of household water use in greater detail. The section begins how household water consumption varied spatially and temporally. Thereafter, the various independent variables are described according to the categorisation used in Literature Review; structural, socio-demographic and Psychological factors.

6.2 Summary

In line with previous studies, household water use was spatially dissimilar at a range of scales, and these patterns changed during the drought (Birrell et al., 1999; Clarke et al., 1997; Durga Rao, 2005; Troy et al., 2005; Wentz & Gober, 2007). During the study period, average water use for Brisbane was significantly lower than that of Maroochy and Caloundra, but prior to 2006, it had already dropped by nearly 50%. Mean water use of all areas decreased over time, primarily in 2007, which coincided with stricter water restrictions, with the Target 140 campaign and the media reporting the water issue as a "crisis"(Jorgensen et al., 2009; Syme et al., 2000). Despite having no water restrictions and normal rainfall, the Sunshine Coast water use also dropped significantly, with Maroochy water use dropping proportionately more than the other LGAs. When water restrictions were eased in late 2008, household water consumption rose again. Thus, the demand-side policies most likely contributed to the major drops in water use.

The study also investigated the relationship between higher levels of household water use and structural, socio-demographic and psychological factors; and whether the strength of these relationships changed during the drought. At the household scale, the most significant driver of higher water use was the presence of a swimming pool, then higher land value and larger lot areas (Eardley et al., 2005; Harlan et al., 2009; Randolph & Troy, 2008; Willis et al., 2009). These drivers differed between LGAs; in Brisbane, properties with swimming pools, larger lot sizes and higher land value used more water, and on the Sunshine Coast, higher water use was related to swimming pools and higher land value. The influence of these diminished during the drought; leading to the conclusion that other, temporal factors, such as water policy, took precedence. Rainfall was not a significant predictor of water use in any area, for any year.

Socio-demographic variables were also significant determinants of household water use at CCD scale. The most notable predictors of higher water consumption for Brisbane were larger households, teenage children and mean sale price. The most significant predictor for lower levels of water use was those who used public transport. For Caloundra, predictors of higher water use were larger family households and median age. For Maroochy, predictors of higher water use were family households, mean sale price and higher incomes. No variables in Caloundra or Maroochy were significant for lower levels of water use.

Further, CCDs with larger household sizes, and higher income and education levels, reduced water use to a greater extent than those with smaller, lower income households. Other research supports this finding; smaller households have a lesser capacity to reduce water consumption, because of economies of scale (Harlan et al., 2009; Troy et al., 2005). This is also likely because higher educated and higher income households have greater access to information materials, and have a greater capacity to purchase more water efficient appliances (Harlan et al., 2009).

This was supported by a geodemographic analysis using Principal Components Analyses. Four factors (or components) were extracted, and named; "*High Income and Education"; "Families with Children"; "Born Overseas";* and *"Welfare Recipient*". Only *Families with Children* was significantly related to higher water use. As with structural factors, the influence of socio-demographic factors decreased from 2006 until the lowest level in 2008; but after 2008, began, once again, to increase.

A Questionnaire survey allowed additional analysis of structural, socio-demographic and psychological factors, as well as per capita water use. In accordance with previous research, per capita water use was highest for two, and then one person households (Birrell et al., 1999; Domene & Sauri, 2006; Harlan et al., 2009; Troy et al., 2005). Other results supported the first phase of the study; structural factors—pools and land value, together with the socio-demographic factors—household size and income; were the most significant drivers of higher levels of household water use.

The demand-side policies were generally supported, especially the water tank rebates. The now defunct Traveston Dam proposal was a divisive issue, opposed mainly by Sunshine Coast residents. Arguably, this opposition was only in response to local issues and not to dams per se, as some opposed to the Traveston dam, supported building other dams and large infrastructure (elsewhere). Recycled water was strongly supported, but for non-potable use. Finally, there was very strong support for personal, local solutions. Respondents supported water quotas, but did not support limitations on how the quota should be used.

The research also aimed to identify if variables from an expanded Theory of Planned Behaviour significantly predicted household water use behaviour. The TPB variables alone did not add significantly to the model, or explain water use. However, creating two combined variables, Attitude Composite and Social Norm Composite, and including the variable *Future* (concern about not enough water for the future) was useful in explaining water conservation behaviour and attitudes to policy. For high water users, the majority of the variance was explained by structural variables; especially household size and swimming pools. Water Conservation Behaviour was also negatively correlated with water use.

6.3 Spatial and Temporal Scales of Household Water Consumption

Spatial Scales of Household Water Consumption

In keeping with previous studies, this study found household water use varied significantly at a range of scales, with significant differences in household water use apparent at the LGA, CCD and household scale(Durga Rao, 2005; Troy et al., 2005; Wentz & Gober, 2007). At the LGA scale, Brisbane had consistently lower average water use than the Sunshine Coast; and within the Sunshine Coast, Maroochy had lower average water use than Caloundra. At the CCD scale, spatially contiguous CCDs had similar water use; with noticeable clustering of higher and lower water use. This was striking in Brisbane; with significant clusters of high and low water use in bands parallel to the Brisbane River. Clusters of higher water use coincided with higher value properties on large lots; along the Brisbane River, and to the south east and west. Clusters of lower water use occurred in the north and inner southern suburbs. On the Sunshine Coast, marked clusters of higher water use coincided with higher value properties on the central, coastal strip. Lower water use clustered in the north and the hinterland suburbs. Unlike Brisbane, areas of higher water use did not correspond to larger lot areas.

This concurs with research showing that water use can differ significantly between households with similar socio-demographic characteristics, with residents more likely to use water at similar levels to their neighbours than those not in spatially contiguous areas (Aitken et al., 1991). It is also consistent with research that shows household water consumption is spatially distributed, and some high income areas can have significantly higher water use (Wentz & Gober, 2007, P1855-6).

In all areas, household water use became “flatter” and less variable over the study period. Therefore, the study then investigated how household water conservation differed on the temporal dimension.

Temporal Scales of Household Water Consumption

Mean water use decreased for all areas; regardless of prescriptive policy measures. Mean water use was highest in 2006, dropped to its lowest level in 2008, and rose in 2009. During the period 2006-2009, Brisbane average water use was significantly lower than Sunshine Coast average water use. However, prior to 2006, Brisbane residents had already reduced water consumption by around 50%. For the

Sunshine Coast, Caloundra had the highest water use for all years; but the water use for Maroochy dropped proportionately to a greater extent. With the exception of 2006, the differences between periods and water use were significant for all LGAs.

The steepest reduction in water use occurred in Brisbane between the 1st and 3rd Quarters of 2007 (January to September 2007). A similar trend was evident for the Sunshine Coast from the 1st Period 2007 to the 2nd Period 2008 (January 2007 to December 2008). These drops in water use largely corresponded with the dates of stricter water restriction levels, the Target 140 campaign, and the media terming the drought a "crisis". This is in accord with some research, showing that prescriptive water restrictions and media labelling issues as crises can have a significant influence on household water use (Chong & White, 2009; Jorgensen et al., 2009; Syme et al., 2000). However, the sheer scale of the drops in water use counters other research, where it has been found that restrictions may not markedly reduce total water demand (Birrell et al., 2005; J. Stewart et al., 2005; Troy et al., 2005; Zhang & Brown, 2005)

Water use was also mapped, and characterised using Equal Intervals and Standard Deviations (to enable comparisons between periods). A distinct "flattening" of water use was evident as the drought progressed, with water use clustering more around the mean, with fewer extremes. This was particularly evident in Brisbane; by 2008, few areas in Brisbane fell outside 1.5 SD of the mean. A similar trend occurred on the Sunshine Coast, but the difference was less marked. By 2009, both areas once again began to diverge from the mean.

The degree of clustering also increased during the drought. In 2006 in Brisbane, clusters of higher and lower water use were relatively small, but by 2009, clustering had spread to spatially contiguous suburbs. On the Sunshine Coast, the central, coastal area had significant clustering of higher water use, but this decreased in size during the drought; and contracted to a smaller, central core of higher water use; as did clusters of lower water use. However, some areas, such as Maleny, changed from being significantly lower in 2006, to significantly higher in 2009.

Therefore, domestic water use differed at small spatial scales, and over time. Given the aim to inform policy designed to target groups that use the most water; the study investigated selected structural and socio-demographic variables and how these influenced household water use over time (Allon & Sofoulis, 2006; Jorgensen et al., 2009).

6.4 Structural influences on household water consumption

Previous studies suggest that household water use can differ markedly according to structural factors; often clustering in areas of similar household size and type, climate, lot area, type of garden, and swimming pools (Harlan et al., 2009; Jorgensen et al., 2009; Troy et al., 2005; Wentz & Gober, 2007).

Swimming pools were the most significant predictor of household water use[42]. Approximately 30% of sampled households had a swimming pool. The presence of a pool had a significant positive effect on water use; with the strongest relationship in 2006, and the weakest in 2008. This accords with research showing swimming pools are highly significant for water use (Wentz & Gober, 2007, p1853).

Lot area is often intercorrelated with the presence of swimming pools, as larger lots often have water features and larger landscaped gardens; and can also be a significant predictor of higher outdoor water use (Syme et al., 2004; Wentz & Gober, 2007, p1853). In this study, higher levels of household water use were significantly correlated with lot area, with mean water use increasing with mean lot area. However, the significance of lot area differed spatially. Lot area was only significant for Brisbane in 2006 and 2007; for every year in Caloundra, and not significant for Maroochy, and

[42] For a smaller sample (*n=81,918*) of the whole dataset, as well as for the Questionnaire sample

the strength of the relationship between water use and lot area decreased each year until 2008, when water restrictions were eased.

The study also investigated whether households on specific lot areas reduced water use to a greater or lesser extent. For example, San Antonio households on large lots had higher water use, but when prescriptive restrictions were imposed, the water use of such households dropped significantly, and the lower use continued after the restrictions were eased (De Oliver, 1999). In this study, large reductions in water use occurred for households on medium/large (1201-200m^2) and large (>2000m^2) lots; with smaller reductions for households on small (<600m^2) and small/medium (601-1200m^2) lots. Householders on lots over 1200m^2 reduced water consumption to the greatest extent, and this lower level was maintained over time. Overall, houses on smaller lots (<600m^2) used the least water.

Therefore, lot area was a significant predictor of total water use, but the strength of the relationship decreased over time, most likely in response to the demand-side measures, which mostly targeted outdoor water use. Householders on larger lots also reduced water use to a greater extent, and these reductions were sustained over time. In addition to policy measures targeting outdoor water use, the greater water use reductions by householders on large lots likely arose because of changing garden practices, and purchasing water efficient appliances. Therefore, by specifically targeting households on larger lots, policy makers can encourage such householders to maintain lower water use over time, without impinging on comfort and convenience.

Another structural variable, related to lot area and swimming pools is land value. Land value was a significant predictor for higher levels of domestic water use. However, land value is also intercorrelated with income, so it is often difficult to control for the specific influence of this variable. The influence of property value on domestic water use has not been extensively studied, so is a fruitful area for further research.

House size can also be an important factor for increased levels of indoor water use (Harlan et al., 2009). Australian house sizes are generally increasing; at 215m^2, the average Australian house is the largest in the world (Demographia, 2009; Martin, 2009). Mean water use increased with house size, but was correlated with house age and lot size. Houses built between 1950 and 1970 used the least water, and those built between 1990 and 2000 used the most water. In general, larger and newer houses were built on larger lots, and used more water. However, houses built after 2001 used less water than those built in the previous decade.

Therefore, it is likely that the lower water use of newer houses, in comparison to those built from 1990-2000, resulted from stricter building regulations, such as compulsory installation of water tanks. Although the difference in water use between the two decades (1990-2001 and 2001-2008) was not great, houses built after 2001 were significantly larger than in previous years, and were generally on smaller lots.

Given that larger houses generally use more water than smaller houses, this decrease in water use for newer, larger houses indicates that improved building codes to encourage sustainability such as mandatory water tanks and flow restrictors, can have a small but noticeable reduction in domestic water use. In addition, larger houses on smaller lots also used less water. Therefore, urban policies that encourage densification, could potentially maintain lower levels of urban water use for detached households.

Tenure was also significantly correlated with water use, with owner occupied houses using more water. However, tenure is also intercorrelated with age and with income, so this finding may not be particularly meaningful. Broadly, owner occupied houses use more water for outdoor uses, as these have better gardens, and water using facilities such as swimming pools (Syme et al., 2004, p136).

Of interest, nearly 85% of respondents reported never watering their lawns or washing cars (and 98% of Brisbane residents). It must be noted that the survey was conducted during a time when these activities were specifically forbidden, with fines imposed on those contravening the restrictions. This was a positive result for adherence to the water restrictions, showing that the majority of householders were obeying these.

Indoor water use is relatively consistent no matter what the rainfall or temperature (Syme et al., 2004; Wentz & Gober, 2007). However, climate can be a significant predictor of outdoor water use, with water use peaking during Summer (Harlan et al., 2009; Jorgensen et al., 2009; Kenney et al., 2008). In drier climates, households often use more water to maintain gardens and fill swimming pools. Therefore, did temporal changes in climate influence SEQ water use during the drought, and did water consumption show any significant seasonality?

From 2005-2008, Brisbane's rainfall was significantly lower than average, whereas the nearby Sunshine Coast had average to high rainfall. If rainfall was a major determinant of water use, households in Brisbane, which had higher mean temperatures, and less rainfall, should have used more water than the cooler and wetter Sunshine Coast. However, at all times, the Sunshine Coast used more water than Brisbane. This study found that rainfall was not a statistically significant predictor of household water use, in any year, except 2006 (and only in Brisbane). Moreover, household water use had no seasonal component. SEQ has a sub-tropical climate, with the driest period normally occurring in Winter. This was further emphasized in the qualitative study; respondents stated that they never watered lawns because "*they always greened up*" after rain. Therefore, factors other than climate were likely more influential for reductions in household water use.

6.5 Socio-demographic influences on household water consumption

Understanding how socio-demographic groups respond to changes in policy is potentially of great significance for future targeted policy iterations (Allon & Sofoulis, 2006; Jorgensen et al., 2009). Therefore, the study also aimed to identify if household water use was related to socio-demographic variables, and if households with certain socio-demographic types were more or less likely to reduce overall water consumption.

Socio-demographic factors, such as household size, income, age and education, can be significant drivers of indoor water use (Birrell et al., 2005; Syme et al., 2000, p 122; Troy et al., 2005; Wentz & Gober, 2007). Household size, land value and income were the most significant predictors of water use. High income households initially used more water, but also reduced water use to a greater extent than other household types. Other socio-demographic variables, such as income, education, age and gender, were less significant, particularly in comparison to structural property factors.

Household size is possibly the most significant socio-demographic predictor of total water use (Birrell et al., 2005; Domene & Sauri, 2006; Syme et al., 2000, p 122; Troy et al., 2005). Likewise, in this study, the most significant socio-demographic determinant of total water use was household size.

In contrast to total water use, per capita water use is generally highest for single person households and decreases in a non-linear fashion for every additional member of the household (Birrell et al., 1999; Domene & Sauri, 2006; Troy et al., 2005). Per capita water use generally increases as household size decreases, because indoor water consumption is influenced by economies of scale (Troy et al., 2005). Because of this, it is difficult for smaller households to reduce per capita water use; these can reduce personal use, but find it more difficult to reduce general household use (Birrell et al., 1999; Domene & Sauri, 2006; Troy et al., 2005; Turner et al., 2005, p6). However, per capita water use is important for water demand, given the increasing trend to greater numbers of smaller households.

Although per capita water use could not be calculated for the larger dataset, it could be estimated from the Questionnaire survey. For the survey respondents, per capita water use was largely in accordance with the literature; highest for two person and then one person households (Birrell et al., 1999; Domene & Sauri, 2006; Harlan et al., 2009; Troy et al., 2005). When respondents were asked if their household could save more water; the larger the household size, the more likely it was that they agreed, with an almost direct linear response between household numbers and level of agreement. The majority of respondents assumed that water use was higher for larger households, and that water restrictions penalised larger households. For example, one said, "*The rules are biased against families with children. Single or dual person households get to use the same volume as 5 or more people in the same house*".

Income can also be a significant determinant of water use; higher income households generally use more water because, as affluence increases, so do numbers of appliances, larger gardens, and swimming pools (Corral-Verdugo et al., 2003; Gregory & Di Leo, 2003; Harlan et al., 2009; Randolph & Troy, 2008; Syme et al., 2004, p126). However, it is difficult to obtain accurate income data. Actual (stated) income was only available for the small survey sample, and income data from the Census is unsuitable because of the methodology used to calculate income categories (ABS, 2006a). To overcome this problem, land price and mean sale price were used instead. These do not directly correspond with income—many can have high value properties without correspondingly high incomes—but were used as a broad proxy for wealth (Harlan et al., 2009; Troy et al., 2005). Mean land value and sale price were also significantly intercorrelated with one another, and with income-related Census variables such as median household income and median home loan.

The results of this study largely concurred with the research finding that higher income households used more water (Harlan et al., 2009; Troy et al., 2005). Statistically significant clusters of high water use occurred in traditionally "high income" and high value suburbs, such as those adjoining the Brisbane River, and ocean-side suburbs on the Sunshine Coast. Income-related variables were significant predictors of higher household water use, particularly for Brisbane and Maroochy. Self-employed and fully employed respondents also used more water than retired or unemployed residents. However, higher income households also have a greater capacity to afford more water efficient appliances than do lower income households, and can maintain lower water use over time (De Oliver, 1999; Harlan et al., 2009; Troy et al., 2005).

Of note, income and employment are also interrelated with education; higher income householders are generally employed, and better educated (Clark & Finley, 2007b; De Oliver, 1999). Despite other studies finding education was significant for water conservation behaviour, neither employment nor education were significant predictors of water use (Clark & Finley, 2007b; De Oliver, 1999).

The study investigated additional socio-demographic variables, including age, gender, education level and children in education. The influence of age on household water use is contested—younger children use less water, but older children and teenagers are often blamed for high levels of water use (Domene & Sauri, 2006; Troy et al., 2005; Wentz & Gober, 2007). On the other hand, young people and teenagers are often more environmentally aware than adults, and practise water conservation to a greater extent (Corral-Verdugo et al., 2003; Corral-Verdugo et al., 2008). The study found higher levels of household water use (at the CCD scale) was related to "family" type socio-demographic variables, such as larger household sizes, teenage children and higher home loans. The most influential variables for lower levels of household water use were public transport use and higher household incomes.

Because the individual variance explained by each was relatively low, selected variables were combined to create an index that aimed to predict water use at the CCD scale. The four main components extracted described diverse groups of socio-demographic variables. These were termed, *High Income and Education; Families with Children; Born Overseas;* and *Welfare Recipient*. The *Families with Children*

Component was the most significant determinant of higher levels of household water use, but the variance in water use explained by these was low, around 12%.

When split by LGA, the composite Factors had better explanatory power; accounting for approximately 25% of the variance in household water use. *Families with Children* remained the most significant, accounting for 17% of the variance in water use for Caloundra, 10% for Maroochy, but only 4% for Brisbane. Similarly to structural determinants, the influence of these Factors decreased until the end of 2008, and increased again in 2009. In general, as the drought progressed, the influence of all socio-demographic and structural variables became less marked, but once the drought broke, their influence once again increased.

In general, older people used the least water, and households with younger children used the most water. This finding contradicts studies showing that increasing age was negatively related to environmental attitudes, with older people less likely to conserve water (Gilg et al., 2005; Gregory & Di Leo, 2003). Of note, unlike the majority of findings, the strength of association for increasing age and lower water use *increased* for every year of the drought. This could indicate that older residents were more likely to respond to policy measures aimed at reducing water use. However, it could also be related to banning outdoor hosing, and the concomitant difficulties with bucket watering gardens; "…*having to bucket water (in the garden) is ridiculous and very dangerous for the elderly, small statured person*". However, age was not a major predictor for household water use; and the finding that older respondents used less water was likely related to household size and a sample that was skewed towards older residents (Tonglet et al., 2004). Therefore, a degree of caution needs to be exercised when extrapolating these results to the general population.

The results of this study largely support other research showing that the major influences on household water use are structural and socio-demographic; such as lot area, pools, household size and income (Aitken et al., 1991; Clark & Finley, 2007b; Troy et al., 2005). However, larger, high income households also have a greater capacity to reduce consumption, have greater access to information materials and a greater capacity to purchase more water efficient appliances (Harlan et al., 2009). Although their water use was relatively low, households with one resident, no internet and less than Grade 10 schooling reduced water use to a lesser extent. This concurs with research that shows smaller households have a lesser capacity to reduce water consumption, because of economies of scale for larger households (Troy et al., 2005).

It was also possible to identify groupings of similar socio-demographic characteristics which mapped to certain areas. However, these groupings were not particularly useful in predicting household water use and simpler measures, such as household size, income and swimming pools were better predictors. However, *High Income and Education* households apparently responded better to policy measures. Finally, the influence of socio-demographics and structural, property level variables decreased over the period of the drought. It is likely that, over time, other factors, such as the policy measures, became more influential in changing household water use.

Therefore, the awareness of the spatial extent of structural and socio-demographic factors can be of great value in refining future demand-side policies; to enable strategic targeting of groups that use the most water, as well as those with the greatest capacity to change (Allon & Sofoulis, 2006; Jorgensen et al., 2009).

6.6 Policy influences on household water consumption

Structural property factors—lot area and swimming pools; and socio-demographic factors—household size, age and income; were the most significant drivers of household water consumption. However, the influence of these decreased over the period, in concert with decreases in household water use. Given that none of these could have changed in the short term, it is likely the reduction in water use was due to the demand-side policies, such as the prescriptive water restrictions, the Target 140 Campaign and the high water user program.

In 2006, Brisbane residents used significantly less water than Sunshine Coast residents, but was this due to the water restrictions, or was Brisbane water use always lower? Annual average household water use for selected Brisbane suburbs (2004-2005) ranged from 286 to 340Kl (J. Stewart et al., 2005), but Brisbane mean household water use in 2007 was approximately 163Kl. Therefore, Brisbane residents did not use significantly less water than the Sunshine Coast in the past. So, what caused the dramatic reduction in water use?

During the drought, all LGAs in SEQ, with the exception of the Sunshine Coast, were subject to water restrictions, the primary demand-side policy measure [43]. Ancillary policies included penalties for excess water consumption, targeting high water users, and reporting breaches. Restrictions mostly target outdoor water use, such as washing cars and watering lawns (Chong & White, 2009). Water restrictions can significantly reduce household water use, although are generally more effective in times of drought, or "crisis" (Chong & White, 2009; Jorgensen et al., 2009; Syme et al., 2000).

Likewise, the SEQ water restrictions were highly significant in reducing household water use. Significant reductions in water use occurred after the imposition of every level of water restrictions. The strongest effect was for Level 4, and then Level 5. Although Level 6 restrictions were the strictest, these had the least additional effect. However, as all levels after Level 4 completely banned hosing; arguably, by Level 6, householders had already reduced water use to the maximum they were able without impinging on comfort and convenience (Allon & Sofoulis, 2006).

[43] Of note, the previous Maroochy Shire did implement minor restrictions in July 2007, which only permitted garden watering at certain times, and alternate days.

In Brisbane, household water use dramatically dropped between the 1st and 3rd Quarters of 2007 (January to September 2007). Of interest, the water restrictions also had a significant influence on Sunshine Coast water use, which generally exhibited the same trends as Brisbane; with Levels 4 and 5 having the greatest influence, and Level 6 the least. The greatest drops in water use on the Sunshine Coast occurred over a longer period than Brisbane, approximately January 2007 to December 2008. This is likely indicative of the media campaign rather than the restrictions, and changed attitudes due to the ongoing drought. For example, restrictions are often most effective when people consider water to be scarce, and that other people are conserving water (Corral-Verdugo, FrÃas-Armenta, PÃ©rez-Urias, OrduÃ±a-Cabrera, & Espinoza-Gallego, 2002; Jorgensen et al., 2009).

In all areas, water use rose when restrictions were eased, but restrictions are commonly less effective during wetter periods, and if maintained after the end of dry periods, can often lead to community dissatisfaction (Chong & White, 2009). Further, some consider water shortages resulting from political mismanagement and the tardy provision of infrastructure, instead of from drought (Browne et al., 2007; Spearritt, 2008; Troy et al., 2005). As one respondent commented; "*The lack of foresight and planning of the Queensland and municipal governments with respect to ensuring adequate water supply is appalling. There should be no need for water restrictions*."

However, many strongly supported permanent water restrictions; "*Water restrictions should be an ongoing practice even when dams are full*". Others commented that the restrictions and the drought had permanently changed behaviour; "*The water restrictions during the drought had a lasting impact on my usage*". However, nearly 50% of respondents had no idea of the current level of water restrictions, which to some extent, could be expected on the Sunshine Coast but, interestingly, also included many Brisbane residents.

Therefore, as major reductions in household water use coincided with strict restrictions, it is likely that the restrictions had a significant influence on household water use. However, restrictions generally only target outdoor water use; in general, it is only in crisis situations that householders willingly forego comfort and convenience, and reduce indoor water use. But reducing all outdoor water use generally only reduce total water use by approximately 10-30% (Birrell et al., 2005; Zhang & Brown, 2005). Given that SEQ water use reduced by as much as 45%, it is likely that factors additional to water restrictions were also influential in reducing water use. Furthermore, the Sunshine Coast had little or no water restrictions, yet had significant large and proportionate drops in household water consumption, which were sustained over a longer period.

Therefore, the study also investigated another major component of the SEQ demand-side policies, the Target 140 Awareness Campaign. The Target 140 awareness campaign and the policy measures were primarily communicated to the public in the popular media, which are distributed beyond Brisbane City. The major newspaper (the Courier Mail) and television channels have a state-wide distribution.

In general, as support for Target 140 increased, water use correspondingly reduced. Respondents largely concurred that the campaign successfully reduced household water use. As one respondent stated, "*I think target 140 was very effective at raising the public's awareness about water conservation. Attitudes have changed in a good way - people frown on people who hose their paths and driveways now for example*."

Further, the number of media articles about the drought and the water policy coincided with reductions in water use, and with the imposition of each level of water restrictions. Media articles peaked in the first half of 2007, concurrent with the greatest reductions in household water use. Although a causal relationship cannot be assumed, it is common that greater levels of water conservation are achieved when an issue is branded as a “crisis” (Syme et al., 2000). The tone of media articles was consistent with the severity of the drought. The drier it was, the more prevalent were the themes of emergency and crisis. Reductions in water use were praised, as was the effectiveness of the policy measures. However, once the drought eased, the tone of the media articles changed. Criticism and complaint about the continuing water restrictions were more common, together with an increase in positive reporting about supply-side measures.

The water restrictions and Target 140 were only part of the suite of demand-side policy measures implemented during the drought. Furthermore, with the exception of the now defunct Traveston Dam proposal, most respondents strongly supported the demand-side policies; especially the water tank rebates and the Home WaterWise program. Given that older and larger houses tended to use more water, such retrofitting initiatives could save additional water, and be acceptable to the community. However, it is important to note that water tanks can be expensive and do not necessarily lead to large water savings. In Sydney, water savings for non-plumbed rainwater tanks were lower than estimates, with higher costs (Turner et al, 2006). Plumbed water tanks may be more efficient, and this is a fruitful area for further research.

In conclusion, higher levels of household water use were significantly influenced by structural factors, particularly swimming pools and lot area; and by socio-demographic factors, particularly household size and income. However, reductions in water use occurred in concert with increasing strict water restrictions, together with the media labelling the drought as a crisis. As the drought progressed, the influence of policy measures increased, whilst the influence of structural and socio-demographic factors lessened.

These results supported the premise in the research question that the demand-side measures influenced the water use of Brisbane and the Sunshine Coast. However, the primary demand-side policy was the water restrictions, and as these were not imposed on the Sunshine Coast, this does not fully explain reductions in water use on the Sunshine Coast. In practice, and in non-experimental designs, it is often very difficult to separate the effects between components of demand-side policies (Kenney et al., 2008, p194). Therefore, how did the policy measures influence water use behaviour? The final stage of the study investigated how demand-side policy interacted with some psychological determinants of household water use.

6.7 Psychological Influences on Household Water Use

Psychological constructs, such as attitudes, values and beliefs, can influence water use. This section first discusses some general findings on attitudes to water use and the demand-side policies. Thereafter the significance of constructed variables is discussed, then finally, if the extended TPB model was useful as a framework to describe household water use behaviour.

Attitudinal change is generally a necessary precursor for behavioural change, and the basis on which most demand-side policy, particularly voluntary policy, is effective (Jackson, 2005; Syme et al., 2000). Although behaviour can change without a corresponding change in attitude, this is rare (Jackson, 2005). Furthermore, awareness-based change is generally more effective if citizens can monitor their own behaviour, and have some mechanism to compare their behaviour with others (Beekman, 1998; Syme et al., 2000). Without this, householders commonly underestimate their own water use; with many assuming that their own consumption is the same or less than similar households ((Syme et al., 2000; Troy et al.).

Attitudes towards conserving water were strongly positive. Nearly all (97.3%) of respondents agreed that conserving water was important, and similar numbers agreed or strongly agreed that it was important to conserve water to protect the environment.

Furthermore, 79.1% agreed that there was insufficient water for the future, and that SEQ might run out of water.

Most respondents strongly supported the demand-side policies, and agreed that they had changed their water use since the water policies were implemented. Attitudes to policy displayed a strong geographical bias, most likely due to the NIMBY syndrome, particularly to the now defunct Traveston Dam proposal. The strongest approval ratings were for the water tank rebate and Home WaterWise Schemes.

Furthermore, a majority of respondents (63%) agreed with the statement, "*My household uses less water than similar households*". However, when cross-tabulating this with actual water use, householder perceptions were largely inaccurate, as even very high water users generally agreed with the statement. Thus, the ability for householders to monitor their actual water use in real-time, for example, by smart metering, could be a useful policy tool. As one householder stated: "*The availability of remote water meter display devices similar to those now available for monitoring electricity usage would be very helpful and would further encourage people to maintain awareness of their water consumption*."

Despite positive attitudes to water conservation; Questionnaire respondents generally distrusted the State Government, 82.1% of Sunshine Coast and 69.4% of Brisbane residents disapproved of the State Government's management of water resources. In total, 46 negative comments were made about the State Government; for example , "*I am putting down a bore to protect me from the stupidity of government*." Most criticism related to a perceived lack of planning for drought, and lack of infrastructure provision. The State was accused of being reactive; responding too late and too sharply to the water crisis and being non transparent. However, it is common that many prefer to blame government for not providing infrastructure instead of taking personal responsibility for excess water use (Browne et al., 2007; Head & Muir, 2007).

Of note, this negative attitude is more likely indicative of the media focus at the time of the survey, in early 2008. At the time, the media published regular criticisms of the Government, particularly for lack of infrastructure planning. In particular, the Sunshine Coast media strongly criticised the planned Traveston Dam, and the Water Grid; and these attitudes were probably reflected in responses such as this: *"I live on the Sunshine Coast and I disagree with having to provide Brisbane and suburbs with our water. The State Govt should have thought about infrastructure to provide Brisbane's growing population with water supplies years ago instead of waiting until now".*

Finally, attitudes to gardens may influence water use; as householders with a greater affective connection to their gardens have been found to use more water (Aitken et al., 1991; Syme et al., 2004). In this study, the majority of householders surveyed were unconcerned with keeping gardens green; 71.3% Brisbane and 67.6% Sunshine Coast residents considered this unimportant, and fewer felt that significant others thought it was important. Positive attitudes towards keeping gardens green were correlated with slightly higher, but non-significant, levels of water use; perceived social pressure and affect had no relationship with water use. Therefore, to a minor extent, these results generally do not accord with other research that found positive attitudes towards gardening were significant for higher water use (Syme et al., 2004, p128).

To see if attitudes had any influence on household water use behaviour, a Principal Components Analysis was run on all attitudinal variables in the Questionnaire, including the TPB variables. This PCA extracted 5 Components, which were named (in order of extraction); Incentives, Concern, Behaviour, Infrastructure and Garden[44].

- [44] *Incentives* (Home WaterWise; ClimateSmart; Tank rebates; Recycling);
- *Concern* (GHG concerns, Attitude_Composite, Not enough water future, Trust Govt, Social Norm_Composite, SEQ run out);
- *Behaviour* (CombinedQ26_2(Change behaviour future); CombinedQ26_1 (changed behaviour during drought); HH uses less water, PBC – Target 140 and Changed Use);
- *Infrastructure (*Traveston, Build more dams, Water Grid, Used more water in past); &
- *Garden* (A- green garden, SN- green garden, Sad garden suffered, Banned pleasurable*)*

In general, higher scores on *Concern* and *Behaviour* were associated with decreases in water use; and higher scores on *Infrastructure* were associated with increased water use. Like other measures, the strongest relationships occurred in 2007, and decreased until 2009. Of note, these relationships were only significant for Brisbane, and not for the Sunshine Coast. This is likely because water conservation in Brisbane was mandatory, whilst voluntary for the Sunshine Coast. Therefore, the positive attitudes and lack of actual water conservation of Sunshine Coast residents seem more consistent with the Attitude Behaviour Gap; in that attitudes often don't predict actual behaviour (Allon & Sofoulis, 2006; Gilg et al., 2005; Gregory & Di Leo, 2003; Jackson, 2005). This concurs with research that found that, although strongly supported, voluntary conservation measures are less effective than mandatory measures (Gregory & Di Leo, 2003; Harlan et al., 2009).

These Components were also analysed against socio-demographic variables, *Incentives* was negatively correlated with age and positively correlated with Income. *Infrastructure* was positively correlated with age, household size and employment. *Concern* was negatively correlated with income and positively correlated with education level and gender. *Behaviour* was positively correlated with gender, and no socio-demographic variables correlated with *Garden*.

In general, increasing household size, older aged, and retired or unemployed persons approved of infrastructure-based policy measures; and younger, higher income residents approved of incentive-based policy measures. This makes intuitive sense; higher income residents are in a better position to take advantage of rebates, and those less able to afford such measures, might be more likely to support measures not directly related to personal income, such as building more dams.

6.7.1 Path Analysis: Theory of Planned Behaviour

The study also sought to explore whether a modified Theory of Planned Behaviour could be used to describe household water use. The TPB variables were analysed to identify if any were significant for either intention to behave, or actual water use behaviour. A series of Structural Equation Models were created to explore the significance of the TPB model; and the models that best explained the variance in household water use were chosen for analysis. In choosing the most parsimonious model, some variables were eliminated because of lack of explanatory power.

After running a Confirmatory Factor Analysis, four latent composite variables were created; and these were added to a model in combination with two directly observed variables with high explanatory power, swimming pools and household size. The latent endogenous variables were named as follows; Policy, Garden, TPB Future and Water conservation Behaviour [45]. The final model explained 45% of the variance in water use, with the majority of the variance explained by household size and swimming pool. Lot area had minor significance, but its removal considerably improved model fit.

The *TPB Future* variable was positively correlated with *Policy* (the higher the concern for the future and positive attitudes to water conservation, the higher the approval for the Policy Measures). On the other hand, *TPB Future* was negatively correlated with *Garden*; therefore, the more positive the attitudes to water conservation, the lower the concern about green gardens. Despite both composite variables adding significantly to the latent variable, *Water Conservation Behaviour*, neither *Policy* nor *TPB Future* were significantly related to actual water use. The composite variable *Garden,* together with Household Size and Swimming Pool, were significantly positive

- [45] *Policy* (Home WaterWise, ClimateSmart, Water Tank Rebates and Recycling);
- *Garden* (Sad Garden Suffered; Attitude Green; and Social Norm Green);
- *TPB Future* (Attitude_Composite; Social Norm_Composite; and Belief in Not Enough Water for Future); and
- *Water Conservation Behaviour* (Household Uses Less Water; Water Use Changed Since Policy; Composite of Behaviour During Drought; and Composite of Behaviour Intentions After Drought).

for water use. On the other hand, *Water Conservation Behaviour* was negatively related to water use.

As this model did not satisfactorily explain the water use of households with high levels of water use, an additional model was constructed, which explained 51% of the variance of high water users. No behavioural or attitudinal variables were significant for high water users; and the most significant predictors were structural variables, including land value, swimming pools and tenure (fully owned or mortgaged).

These results concur with most TPB studies; showing that such models often explain a relatively high proportion of the variance in intention to perform a behaviour; but have a much lower predictability for actual behaviour (Armitage & Christian, 2003; Jackson, 2005). In addition, the findings that structural and socio-demographic variables were the most significant determinants of actual water use behaviour differed from a study showing that TRA variables explained most of the variance in a model that included socio-demographics, environmental attitudes, information and concern about the future (Trumbo & O'Keefe, 2005). No PBC variables significantly explained water use, most likely because the water restrictions were mandatory, and not voluntary.

Finally, the study hypothesized that householders with past experience of water shortages would use less water, but this proved incorrect. A past history of using non reticulated water revealed no significant relationship with actual water use. This finding is contrary to research which found that past behaviour added significantly to the predictive ability of a TPB model (Tonglet et al., 2004).The only significant relationship with past history was with age; a higher proportion of older than younger people were more likely to have experienced past water shortages. Given the generally older age of the respondents, this was not unexpected. Of note, some respondents specifically commented on past behaviour; for example, "*We don't waste water at all; we are conscious of water use having lived in Germany*".

Most respondents self-reported as responsible users of water, and supporting ongoing conservation. However, this could indicate the "*Hawthorne Effect*" whereby survey respondents seek approval, and modify responses according to the perceived attitudes of the questioner (Sim et al., 2007).

The strongest theme was a general mistrust of the Government, especially the State Government. A common perception was of failure to plan for the future, and wasting taxpayer's money on "*knee-jerk and reactive schemes*". The State was also perceived to be largely corrupt and incompetent, but with the exception of one respondent, criticism was aimed in generic terms at "*the Government*". Respondents generally confused levels of Government, and responsibility for water policy. The State was criticised for cancelling the Home WaterWise Scheme and the water tank rebates, with many expressing regret that they had missed out.

Major themes were the desire for self-sufficiency, personal control over water allocations, and for local solutions to water problems. Instead of building large infrastructure, many felt local solutions, such as water tanks for every house (paid for by the Government) was more cost effective, and better for the environment. *"Instead of spending billions on dams, give every house a tank".* Permanent water restrictions, per capita limits on water use, and the need to conserve water, were all acceptable.

6.8 Conclusions about the Research Problem

During a recent drought, household water use in SEQ dropped dramatically. During the drought, the Queensland government implemented a range of prescriptive and voluntary demand-side measures. The aim of the research was to understand how this behavioural change happened so rapidly and on such a large scale. Understanding this could be of great significance for the future management of domestic water use.

The research sought to identify some of the socio-demographic and behavioural drivers of household water use; and the types of households more or less likely to respond to demand-side policy. To do so, Brisbane (which was subject to water restrictions) was compared to the nearby Sunshine Coast (which did was not subject to water restrictions). In this manner, the research aimed to tease out some of the more nuanced determinants of water use, by controlling the influence of the water restrictions.

Few studies have explored the determinants of household water by using disaggregate data at smaller scales, such as households (Clarke et al., 1997; Domene & Sauri, 2006; Kenney et al., 2008). However, this research used property level data, in an integrated two-phase research methodology to explore the determinants of household water use.

The Conclusion discusses this issue, under each of the research questions, which were broken down into a number of sub-questions (see Table 1, p14).

<u>Question One</u>: *How did household water use vary spatially and temporally from 2006–2009, and what structural, socio-demographic and psychological factors contributed to this variance*?

Household water use exhibited significant spatial variation, at a range of scales, with higher water use clustering in areas characterised by higher value properties, and larger lot sizes. Structural characteristics were the major predictor of higher water use, with the most significant driver being the presence of a swimming pool. Socio-demographic drivers were also significant, particularly household size and families with teenage children. These factors are, of course, intercorrelated, family households with higher incomes tend to live in larger homes, on larger lots and often have swimming pools. This largely accords with other research (Campbell et al., 2004; Cavanagh et al., 2002; Renwick and Green, 2000; Syme et al., 2004) (Aitken et al., 1991; Clark & Finley, 2007a; Troy et al., 2005). Other socio-demographic characteristics, such as age, gender and ethnicity, had little influence on water use, although older, female, retired householders reported more water conservation behaviours than did younger males.

Psychological factors were less significant in the variation of household water use, with none significant for high or low water use; although these did contribute to positive attitudes towards water conservation and the demand-side policies. The expanded TPB did not significantly predict water use at the household level, but it did predict conservation attitudes.

Question Two: *Did specific household types and regions respond differently to the South East Queensland demand-side policies*?

Although larger households on larger lots with swimming pools used the most water; these also reduced their water use by a greater degree. However, households with swimming pools still used more water than those without pools, even during the period when it was forbidden to fill pools with town water. Further, because of economies of scale, it is easier for a large household using large quantities of water to reduce this, for example, by only washing full loads. It is much more difficult for a single person, perhaps on a low income in a rental property, to reduce already low use, or to purchase water efficient appliances, which are often relatively expensive.

Interestingly, householders who had lived in past water stressed areas did not use less water than those who had always had town water. However, there was a slight relationship between increased age and lower water use, with some commenting that they had grown up in rural areas, so were always conscious of water use.

Notably, the influence of structural and socio-demographic factors decreased over the period, with the least influence in 2008. Household water use also showed less variance; by 2008, there was relatively little variance in household water use across Brisbane, and to a lesser extent, in the Sunshine Coast.

Question Three: *Which of the policy measures were the most effective, and why*?

The most significant drivers for reductions in water use over time were the water restrictions, and socio-demographic factors (high income and high education households). However, the greatest reductions in water use largely corresponded with the imposition of water restrictions, particularly Levels 4 and 5 (April and November 2007); and rises in water use occurred when restrictions were eased. However, the water use of the Sunshine Coast (which had no restrictions), also declined sharply; over a longer period, but at similar times to Brisbane. This suggests that demand-side measures additional to the water restrictions contributed to changes in water use behaviour; such as the Target 140 awareness-raising campaign, and the media branding the issue as a "crisis" (Clark & Finley, 2007a; Syme et al., 2000).

In general, the demand-side policy measures were supported, particularly the water tank rebates. Many felt that some degree of water restrictions should remain permanently in place, and that the drought and the restrictions had permanently changed behaviour. There was strong support for personal control; householders generally supported limits on water use, but wanted personal control over the water allocation. Finally, many distrusted the State Government; accusing it of being reactive and poorly prepared for droughts because of not building past infrastructure.

6.8.1 Recommendations

The results of this study provided further information on the determinants of water use, which may benefit policy makers in SEQ, and other areas with similar climates and socio-demographics (such as Townsville or Northern NSW). It was also possible to identify socio-demographic communities that were most likely to make meaningful behavioural changes (Mankoff et al., 2007).

Higher income households, on larger lots, with pools, and higher levels of education, tended to use more water, but also reduced water use to a greater extent. Theoretically, demand-side policy, such as water restrictions, mostly aimed at reducing outdoor water use, could be specifically targeted at such households. In the short term, policy makers could target swimming pool owners, particularly as pool covers can significantly reduce evaporation, and the vast majority of pool owners do not use these. In the long term, the significant influence of lot area appears to support the policy aim of reducing lot sizes (Bunker, et al. 2005).

However, water use did not drop significantly after the highest level water restrictions, which were also aimed at restricting indoor use. Therefore, how can lower water use inside the home be encouraged? Although socio-demographic characteristics were influential in higher levels of water use, targeting policy on this basis could be extremely complex, raise equity issues, and be politically fraught. Therefore, policy measures at reducing indoor use could be achieved by providing subsidised water saving technology or even financial assistance to households. The success of the rainwater tank subsidies indicates that these measures can be very popular; and these can be implemented without much, if any, impacts to comfort and convenience. However, more research is needed on the efficacy and total savings of water saving technology. In addition, the lower water use of newer houses also supports increased strengthening of building codes, and more efficient appliance standards.

One largely unexplored method of reducing both indoor and outdoor water use is by behavioural change campaigns. The drops in water use of the Sunshine Coast, concurrent with that of Brisbane, despite having no water restrictions, points to the influence of voluntary campaigns, on an area that was not in drought. Further understanding of why this area also reduced water use could be of value in policy formulation.

The consistently higher water use by the Sunshine Coast, despite higher rainfall, also supports the hypothesis that the demand-side measures, in particular, the water restrictions, were the strongest factor in reducing household water consumption. However, although a community might willingly accept stringent restrictions during a “crisis”, once the drought breaks, and the media is not publicising water shortages to the same extent, will these behavioural changes be maintained? Continuing high level water restrictions when “normal” rainfall resumes and dams refill can lead to community backlash (Chong & White, 2009). When rains fall regularly, and gardens can be maintained without irrigation, the community will likely continue to accept restrictions without too much complaint. However, if the dry seasons return and restrictions are imposed while dams are relatively full (particularly given the 2010/2011 floods) community dissatisfaction with the legislative regime may become apparent.

Therefore, will continuing restrictions give rise to generalised community resentment, and a reversion to wasteful water using practices? This was possibly foreshadowed in the media; few complaints were reported during the drought, but once the rains began to fall again, the media began to criticise the water managers.

Therefore, for maintaining lower levels of household water use, an integrated strategy of longer-term land use changes (such as encouraging smaller lot sizes and other urban densification options), together with voluntary and mandatory demand-side policy (such as permanent low level restrictions, and awareness and education campaigns), could provide a major component in planning for a sustainable urban environment.

6.8.2 Limitations

Limitations of the Data

The major limitation of this analysis was the inability to calculate per capita water use for the full dataset, as the detached houses count for CCDs did not correspond with the lot count for the water data. Although some CCDs had similar counts, others differed markedly; thus, it was impossible to extrapolate per capita water use from means. Possible reasons for this have been covered elsewhere, but are irresolvable because the water data is a longitudinal dataset, and the Census data, a cross-sectional dataset. The count of properties with water data was, in most cases, less than the Census data, because all properties without records for the entire period were eliminated as were all properties with any non-residential uses (even if used as residences).

In addition, for the geodemographic analysis, the study used data at the CCD level from the 2006 Census. The typical count of households in a CCD is approximately 220, which is still relatively large. In the 2011 Census, a smaller unit, the mesh block, will include approximately 30 to 60 dwellings. This micro level data will be invaluable for future analysis. It would have also been valuable to access more comprehensive data on household income as, due to the analytical methods used by the ABS, the Census BCP data is not particularly useful. However, this limitation was addressed to some extent by using property valuation data. Furthermore, making assumptions from aggregate data such as the Census is subject to the Ecological Fallacy and the Modifiable Areal Unit Problem. These issues are irresolvable, but research using such data must always be cognizant of the issues.

With regard to the water data; much of 2006 data was incomplete, so for that year, only mean water use could be calculated. However, mean water use calculated from actual readings is generally suitable for most statistical analysis. In addition, detailed household level data prior to 2006 was not available. The analysis would have been improved if a longer data period, preferably prior to the drought and the implementation of the demand-side measures, were available. However, due to LGA amalgamations, and lack of comprehensive and consistent data collection, it was impossible to overcome this limitation. Furthermore, comprehensive data for the northern Sunshine Coast (ex Noosa Shire) was unavailable. This was not considered a major limitation, as it has a relatively small population, and mostly rural, thus many households were outside the scope of the analysis.

Furthermore, the water data did not differentiate between indoor and outdoor water use, so it was impossible to calculate the exact proportions. Arguably, in Brisbane, most of the water used was for indoor purposes (as the water restrictions banned most outdoor uses) but this was impossible to prove, as the LGAs do not differentiate between indoor and outdoor water consumption.

With regard to outdoor water use, there is relatively little information on garden size and type, as well as swimming pools and spas. As gardens and water using equipment are the major users of outdoor water, this information would have been of great value. In addition, despite rainfall found not to be a significant predictor of household water use, more comprehensive analysis of rainfall could have had a different outcome. For example, the study did not take into account geographical features, such as hills and valleys, which affect microclimate. This is a fruitful area for future research.

A brief analysis of the media reports during the drought was conducted, but a more in depth analysis of the media and the awareness campaign would have provided greater insight into the response of households to the demand-side measures. However, it is virtually impossible to conduct quantitative research such as this on response to awareness campaigns, and to do this, a totally different research design would have been necessary.

Finally, although significance levels are reported for the statistical tests, this dataset could be considered enumeration (or whole of population) instead of a sample, so some statements about normality may not be relevant. Thus, it is cautioned that even minor relationships may be significant in large datasets, such as this. However, given that this could be considered an enumeration dataset, these results are likely suitable for generalization to water use for detached houses in similar urban areas. Furthermore, only South East Queensland was studied, therefore these results may not be relevant to an area with a different climate and policy environment.

Limitations of the Questionnaire Survey

Some postal respondents omitted the compulsory Code question, so unless they entered the competition or expressed a desire to participate in further research, it was impossible to link their response to actual water use records. In some cases, it was still possible to place them in Brisbane or the Sunshine Coast because of ticking either "biannual" or "quarterly" for water bill, but 65 respondents were unidentifiable

The Questionnaire could have been much shorter, without losing valuable information. Despite piloting twice, some questions were badly phrased and confused respondents, particularly the TPB questions. In addition, the section on Attitude to Policy, should have been more upfront. Response rates were relatively low (around 23%), but it was not cost effective for a single researcher to run additional tranches.

Most indoor water use questions were redundant, as were choices of alternate waters supplies (i.e. grey water systems). For outdoor use, water source and types of watering, could have been omitted, as these confused recipients, and provided little useful information. In addition, the actual water restrictions were only inferred to indirectly, through reference to Target 140. In the information (awareness) section, a choice of medium, television, was also omitted.

The sample was also skewed to respondents aged over 35. This is common in survey research, because younger residents are less likely to be homeowners, and the bill-paying member of a household tends to be older (Tonglet et al., 2004).

6.8.3 Future Research

The release of the 2011 Census will enable a finer level of geodemographic analysis. While the Ecological Fallacy and Modifiable Areal Unit Problem are irresolvable unless doing individual research, using micro-scale data from mesh blocks will improve future data analysis. In addition, future research could investigate per capita water use more comprehensively, using more current data.

Another potentially useful research area would be to investigate in greater detail the relationship of income and land value with water use. Other fruitful areas for future research include the proportion of total domestic water supply used by gardens of varying size and type, as well as the influence of tenure; as would be quantifying the actual water savings of houses with water tanks (plumbed and unplumbed).

It would be useful to conduct future research on the efficacy of media campaigns. However, to do this would require an alternate research design, as it is very difficult to isolate the effects of media from other drivers of behaviour (Syme et al., 2000).

With regard to the Questionnaire, a follow-up survey might be valuable, to identify if households continued to practice water saving measures after the drought ended. Given future funding, a much larger sample also might be surveyed. Finally, given more funding and time, a better designed Questionnaire might give an improved response rate.

A further dataset of water use has been acquired with household level water readings for detached houses from 2006 – 2012. This will allow comparison of households in three case study areas across SEQ; Brisbane, the Sunshine Coast and the Gold Coast. Further it will also allow follow-up research into how household water use has changed since the drought ended, particularly given the widespread floods of late 2010/ early 2011. A follow-up questionnaire may also be used to identify changes in attitude now that the major dams are full. Potential avenues for collaboration with researchers in other major centres, such as Melbourne, Perth and Sydney, are also being explored.

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CHAPTER 8 APPENDICES

8.1 Appendix A: Detailed Methods

8.1.1 Creation of GIS water data layers

- A combined table was created in SPSS, using variables from the BCP dataset, such as household size, age of residents, education, income and industry of employment. A percentage was calculated for each variable, by dividing the count per CCD by the total population and multiplying by 100. Because Census data consists of counts of ordinal data per CCD, this method enables comparison of CCDs with dissimilar populations.
- The combined table with 2016 CCDs, and 1983 proportionate variables was added to ArcMap, joined to CCD_Only, and exported to a new, final Shapefile (ABS_Info). The ABS_Info layer was then further filtered to remove CCDs that were predominantly commercial or industrial; with greater than 75% proportion of non-detached households (matching ABS data with count of actual houses for which water data was available); and with significantly skewed areas (such as offshore islands).
- Finally, CCDs with exceptionally mean high water readings were further investigated by overlaying on to satellite imagery (LGA_Mosaic) for visual inspection. Some CCDs had predominantly non-residential uses, such as prisons, and were deleted. With the data now cleaned and filtered, statistical tests were conducted on the water data and the ABS data (ABS_info).

8.1.2 Selection of Variables for PCA

- The CCD table was filtered to remove CCDs with fewer than 75% of detached houses. In a similar study, all CCDs with less than 99% of detached houses were removed (Troy et al., 2005). However, given the smaller size of the study area, this was considered too prescriptive, as it eliminated CCDs with high quality water data [46].
- Variables included were those commonly used in demographic profiling and research into household water use, such as household size; income; children at school; proportion of state housing; and industry of employment (Baum et al., 2004; Clark & Finley, 2007b; Troy et al., 2005). Some composite variables were calculated [47], as were variables found significant in the previous regression analyses.
- The bivariate correlation matrix of all the variables was examined (in accordance with the methods of the Australian Bureau of Statistics, Socio-Economic Indexes for Areas (SEIFA))[48]. A correlation matrix provides information on the extent of association between each pair of variables (Garson, 2010). As the purpose of a PCA is to create a composite, summary index, it is essential that the variables used to form the composite factors correlate. A correlation matrix helps identify which variables are closely related, and highlights those reflecting any underlying drivers. The variables

[46] Of note, the results of the PCA with these CCDs eliminated did not differ significantly to that of the full dataset; the final extracted variables were identical, and the only difference was a slight change in the component loadings.

[47] i.e. *People with a Post Graduate Qualification* (postgraduate + graduate degree + graduate certificate)/total people over 15 * 100)

[48] "*Each of the four indexes summarises different aspects of the socio-economic conditions of people living in an area; each is based upon a different set of social and economic information from the 2006 Census. The indexes provide more general measures of socio-economic status than is given by measuring, for example, income or unemployment alone.*" (ABS, 2006a)

were restricted to those with correlation coefficients significant at the 1% level. A 1% significance level was used to reduce the possible margin of error and ensure the analysis was in line with generally accepted practice for PCAs (Garson, 2010).

- Highly intercorrelated variables were eliminated, because these could be "double-counted" and measure the same underlying factor. One of each pair of highly intercorrelated variables (negative or positive correlation coefficient over 0.9) was eliminated; for example, *Percentage of people with IT qualifications* and *Percentage of people working in IT*. Where two variables apparently measured the same factors, the variable with strongest correlation with the other variables was retained (ABS, 2006a; Garson, 2010). However, some highly intercorrelated variables considered relevant to the analysis, for example, the correlation of *Professionals* and *Persons holding Degree Qualifications*, were retained, as these were measuring diverse factors, education and employment.
- Additional variables were eliminated after each iteration of the PCA. The eliminated variables were those that added little to the variance (i.e. scoring below 400 on the communalities table; with extremely small populations (i.e. Indigenous or born in the USA); were not significant at the 1% level of significance on the Bivariate Pearson correlation matrix) or had minor loadings on Components (i.e. *Agriculture).*

8.1.3 Selection of Sample for Questionnaire Survey

Method 1. Random Selection (Clustered Multistage)

The sampling frame for this was the mapped DCDB_Merge layer (the total dataset consisting of all detached residential properties in Maroochy, Caloundra and Brisbane with a four years of water data). All households identified with the GIS mapping exercise had an equal chance of selection. The sub dataset used for sample selection was the table CCD_only, with an extra column (calculated from DCDB_Merge and summarized in ArcGIS) which linked the CCD unique identifier code (Code_2000) with the total households in each CCD.

The sampling methods used multistage cluster sampling, with Probability Proportionate to Size Sampling (PPS) (ABS d, 2006). PPS Sampling is often used in clustered sampling, when sampling units are of disproportionate sizes (CDC, 2009).

> *"Probability Proportional to Size Sampling (PPS) is a sampling technique, commonly used in multi-stage cluster sampling, in which the probability that a particular sampling unit will be selected in the sample is proportional to some known variable (e.g., in a population survey, the population size of the sampling unit)" (CDC, 2009).*

Although the commonest proportion used in PPS sampling is the '**30 x 7**' **cluster** survey method; for this study, a larger 60*14 proportion was chosen. This method was chosen, as it was considered important to select as many primary clusters as possible; (CDC, 2009; Milligan et al., 2004). Using the CDC methods, the PPS sampling methods was carried out on the ABS_Info table as follows:

In brief, the PPS sampling methods was carried out on the ABS_Info table as follows:

- First, all CCDs were sorted by Code_2000 (the unique CCD identifier code), an extra column was added with the Excel Function Random pasted, then sorted on Random (PPS methods requires random listing of sampling units, and the Code_2000, is not random). The random number column was kept for documentation purposes, but hidden. Thereafter, a further column was added, and a cumulative population total calculated (n=274,467).

- Second, it was necessary to select a systematic sample, from a random start. To do so, a sampling interval had to be calculated. Of the final set of 2051 identified CCDs, 60 primary clusters (CCDs) were to be selected. Therefore the population n=274,467 was divided by 60, giving a sampling interval of 4574.
- Third: a random number generator was used to choose a number between 1 and the sampling interval. The CCD in which the random number generated fell, was chosen as the first of the 60 CCDs, and a "yes" added to a "selected" column. The sampling interval (n=4574) was added to the random number until the remaining 59 clusters were chosen.
- Fourth: 14 secondary clusters (households) were selected from within each of the 60 clusters. A simple SQL Select Query matched "yes" CCDs with household data, resulting in a subset linked by Lot Plan, with address data for each household. A random number column was added, and the first 14 households in each CCD were chosen by simple random sampling without replacement. These 840 households formed the first tranche for the sample.

Method 2: Random selection of Households by Water Use

Because 840 households were selected in the first tranche, to ensure a proportionate sample, the same number was chosen for the second tranche. However, as the Sunshine Coast had higher water use (mean and variance) than Brisbane, to prevent bias (i.e. more high water users selected in Sunshine Coast and more low water users selected in Brisbane), the area was stratified into two regions, Brisbane and the Sunshine Coast, and 420 households selected from each. Within each LGA, 420 households were chosen by simple random selection: 50% in the group having the lowest 20% of water use; and 50% in the group having the highest 20% of water use.

This was carried out as follows:

- First, the DCDB_Merge table was exported to SPSS (SPSS v17), and the file split on LGA. SPSS was used to calculate a new variable, mean water use for the total period (AvLtdDay). A "rank cases (by quintiles)" was calculated on the annual average water use for each property; as well as on total mean water use. This was exported to Excel 2007.
- Second, to select the households, a random number column was added, pasted as value, and sorted ascending. From this, 210 low water users (rank 1) and 210 high water users (rank 5) were selected from each LGA.
- Third, to ensure that the selected households' water use was not too highly skewed, the data was sorted on the column, Mean Total Water Use. Any households that were exceptionally skewed (i.e. with water readings higher than a factor of 10) were to be removed from analysis, but no households chosen in the random selection process had such high readings. In addition, each household's mean water use (total) was compared to the mean water use (for each year) to identify if high water use was characteristic for that household, or

was an anomaly. However, all chosen households water use was consistently high or low for the entire period.

For both methodologies, all chosen properties were saved in Excel spreadsheets and named according to the method used as in the random selection phase; i.e. SunshineCoastLow20%, etc. This created 7 spreadsheets (with one total), which were coded to enable matching Survey responses with street addresses as follows:

Method 1 – M (2000+)LGA(Sunshine Coast/BR)=M2055BR (these are the randomly chosen houses from the CDs chosen by the PPS method; code numbers linked back to the Excel spreadsheet, postcardsdatabase.xls)

Method 2 – A(Low)Z(high)(1000+)LGA(Sunshine Coast/BR) i.e. A1010Sunshine Coast (These are the randomly chosen houses from the high and low water readings, linked back to the same Excel spreadsheet, postcardsdatabase.xls)

8.2 Appendix B: Survey on Household Water Use

8.2.1 Advance Postcard

If undelivered, return to:
H L Shearer
c/o P O Box 573
NAMBOUR 4560 QLD

SUNSHINE MC 582 2/[redacted]

NAMBOUR
QLD, AUST
4560

THE HOUSEHOLDER
(Code: M2252BR)
[redacted]
EAST BRISBANE QLD 4169

RETURN TO SENDER

☐ Insufficient Address
☑ Left Address/[redacted]
☐ Refused
☐ Unclaimed

DATE 28/8

Removable Label

8838522 (FFB/09)

DO NOT PLACE THIS STICKER OVER CUSTOMER BARCODE OR ADDRESSEE'S NAME AND ADDRESS

Questionnaire: Household Water Use

You will shortly receive a questionnaire regarding an important research project being undertaken by Griffith University, Brisbane. The questionnaire surveys household water use, and your response to policies, such as water restrictions. This is part of an investigation to help understand how people reduced their water use, and to understand some attitudes to conserving water.

I am writing in advance because we have found many people prefer to know before receiving such a survey. You have been selected because of your household's location in the study area.

To complete the survey online, please login to:

http://www.heathershearer.com/survey.html

WIN! $300 Voucher!
See Online

Thank you for your time and consideration. It's only through the generous help of people like you that our research can be successful.

Heather Shearer: Griffith University
Email: *Heather.Shearer@student.griffith.edu.au*
Tel: 0439 479 005

Griffith UNIVERSITY

8.2.2 Questionnaire

Please fill in the Identification Number on the Postcard/Questionnaire that was delivered to your home (On Address Label; similar to this "CODE: M2645BR")

____

2. Information on your house

2. Do you have any of the following? (If No, please go to Question 5)

Rainwater Tank	☐Yes	☐No
Bore Water	☐Yes	☐No
Grey Water System	☐Yes	☐No

3. If you have a rainwater tank, when did you install it?

☐Pre 2005 ☐2005 ☐2006 ☐2007 ☐2008 ☐ 2009

4. If you have a rainwater tank, what size is it?

________________________Litres OR _____________________Gallons

5. How big is your house?

☐Under 200 m2 (<21.5 Sq) ☐ 301-400 m2 (32.31–43.05 Sq)
☐200–300 m2 (21.51–32.3 Sq) ☐ 401 + m2 (greater than 43.06 Sq)
☐Don't Know

6. What size is your house lot?

☐Under 600 m2 (under 23.7 Perch) ☐1201–2000 m2 (47.45–79.07 Perch)
☐601–1200 m2 (23.71–47.44 Perch) ☐Greater than 2000 m2 (>79.08 Perch)
☐Don't Know

7. This house was originally built?

☐Pre 1950 ☐1951-1970 ☐1971-1990 ☐1991-2000 ☐Post 2001

8. What is the nature of your housing tenure?

☐Fully Owned ☐Mortgaged ☐Rented Private ☐Rented Govt ☐Other

10. My water use, as recorded on my last water bill was (if known):

___________________________**Biannual/Quarterly** (delete not applicable)

On rates notice, or
https://obonline.ourbrisbane.com/services/water/wco/account/1.do.

3. Indoor Water Use

11. Do you have a dishwasher?

☐Yes ☐No

12. When using the dishwasher, do you use water saving practices (such as only washing with a full load, selecting the correct setting for the load)?

☐Always ☐Sometimes ☐Never

13. Do you rinse cutlery and crockery?

☐Under running water ☐In a plugged sink ☐I don't rinse cutlery & crockery

14. Do you wash food, such as vegetables, before eating or cooking?

☐Under running water ☐In a plugged sink ☐I don't rinse food before eating

15. Do you have a washing machine?

☐Yes ☐No

16. What type of washing machine do you have?

☐Front Loader ☐Top Loader ☐Twin Tub

17. When using the washing machine do you use water saving practices (such as only washing with a full load, selecting the correct setting for the load)?

☐Always ☐Sometimes ☐Never

4. Outdoor Water Use

18. Do you have any of these outdoor facilities/ appliances? Tick all that apply.

	Yes, filled Town Water	Yes, filled Tank Water	Covered	Uncovered	Don't have
Pool	☐	☐	☐	☐	☐
Outdoor spa	☐	☐	☐	☐	☐

19. How often, if at all, do you wash vehicles?

	Daily	Weekly	Fort nightly	Monthly	Twice Yearly	Yearly	Never	N/A
Cars	☐	☐	☐	☐	☐	☐	☐	☐
Bikes	☐	☐	☐	☐	☐	☐	☐	☐
Boats	☐	☐	☐	☐	☐	☐	☐	☐

20. If you wash vehicles, from what water source do you wash them?

☐Town Water ☐Tank Water ☐N/A

21. How often do you water your garden?

	Daily	Twice Weekly	Weekly	Monthly	Twice Yearly	Yearly	Never	Depends weather	N/A
Garden beds	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potplants	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lawn	☐	☐	☐	☐	☐	☐	☐	☐	☐

22. If you water your garden, from what water source do you water it?

☐ Town Water ☐ Tank Water ☐ N/A

23. If you water your garden, what do you use to water it? Tick all that apply.

Watering Can/Bucket	Handheld Hose	Sprinkler	Irrigation System	Soaker Hose
☐	☐	☐	☐	☐

24. How often do you wash driveways or the house exterior?

	Daily	2xWeek	Weekly	Monthly	2xYearly	Yearly	Never	N/A
Driveways/Paths	☐	☐	☐	☐	☐	☐	☐	☐
House Exterior	☐	☐	☐	☐	☐	☐	☐	☐

25. If you wash driveways or the house exterior, from what water source?

☐ Town Water ☐ Tank Water ☐ N/A

26. Which of the following water conservation actions did you do during the drought (from 2005 to 2008); and are you likely to do in the future (from now on)?

	Did during drought	Intend to do in future	Don't intend to do in future
Take shorter showers	☐	☐	☐
Use economy settings on appliances	☐	☐	☐
Obey all water restrictions	☐	☐	☐
Use the half flush on toilet instead full flush	☐	☐	☐
Not flush the toilet every time it is used	☐	☐	☐
Always turn off the tap when brushing teeth	☐	☐	☐
Use a plug more often in sinks and basins	☐	☐	☐
Re-use shower/ washing machine water	☐	☐	☐
Change gardening practices to reduce water use (i.e. plant native species, mulch more)	☐	☐	☐

5. Awareness of Queensland Government Water Policies

27. From how many of these did you obtain information on water policies?

☐Government websites (i.e. Qld Water Commission)
☐News or current affairs sites (News.com/ ABC)
☐Regional/Local Papers (i.e. Sunshine Coast Daily)
☐Major Newspapers (i.e. Courier Mail)
☐Radio stations
☐Magazine/Journal Articles
☐Friends, Family, Work
☐Neighbours
☐Flyer or Mail Box Drop
☐None

28. What is your opinion about the following water policies?

	Strongly Oppose	Oppose	Neutral	Approve	Strongly Approve	Never heard of
Target 140	☐	☐	☐	☐	☐	☐
Home WaterWise	☐	☐	☐	☐	☐	☐
Climate Smart	☐	☐	☐	☐	☐	☐
Water tank rebates	☐	☐	☐	☐	☐	☐
The water grid	☐	☐	☐	☐	☐	☐
Traveston Dam	☐	☐	☐	☐	☐	☐
Water recycling	☐	☐	☐	☐	☐	☐
Desalination plants	☐	☐	☐	☐	☐	☐

29. Did you take up any of the incentives offered by the Government?

☐Water tank rebate ☐Home WaterWise ☐Climate Smart

30. Please respond to the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My household uses less water than similar households	☐	☐	☐	☐	☐
I've changed my water use since the water policies were implemented	☐	☐	☐	☐	☐
My household can do more to save water	☐	☐	☐	☐	☐
I don't have to save water now the dams are full.	☐	☐	☐	☐	☐

31. Please respond to the following statements about water use

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The government should build more dams	☐	☐	☐	☐	☐
I trust the State Government to plan Queensland's water resources wisely	☐	☐	☐	☐	☐
Having a reliable, clean supply of water is the right of all people	☐	☐	☐	☐	☐
If householders don't save water, there will not be enough to meet future needs	☐	☐	☐	☐	☐

32. What level of Water Restrictions are you currently on?

☐Level 1 ☐Level 3 ☐Level 5 ☐Medium - Target 200 ☐Don't Know

☐Level 2 ☐Level 4 ☐Level 6 ☐High- Target 170

6. Attitudes to water use

33. Please respond to the following statements

	Not at all important	Un-important	Neutral	Important	Very important
I believe that conserving water is:	☐	☐	☐	☐	☐
To me, that my garden looks green is:	☐	☐	☐	☐	☐
For me, to conserve water to help protect the environment is:	☐	☐	☐	☐	☐

34. I wish to find out how you think important other people (such as your family, friends and neighbours) feel about your own and your household's water use.

	Very important	Important	Neutral	Un-important	Not at all important
My family and friends believe that conserving water is:	☐	☐	☐	☐	☐
My family and friends agree that it is important that my garden looks green:	☐	☐	☐	☐	☐

People who are important to me think conserving water for the environment is:	☐	☐	☐	☐	☐

35. I am trying to find out what you think about how much control you think you have over your own and your household's water use.

	Very easy	Easy	Neutral	Difficult	Very difficult	N/A
To keep my garden looking green during restrictions was:	☐	☐	☐	☐	☐	☐
For my household, using less than 140litres per person per day was:	☐	☐	☐	☐	☐	☐
Controlling the water use of other household members (like children) is	☐	☐	☐	☐	☐	☐
For me, to install water saving devices is	☐	☐	☐	☐	☐	☐

36. I am trying to find out if your past behaviour (such as living in a water stressed area) has influenced your water use habits of today.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I have used more water in the past than today	☐	☐	☐	☐	☐
It is difficult for me to give up habits, like leaving the tap running while cleaning teeth:	☐	☐	☐	☐	☐

37. In the past, we had to use water more sparingly than nowadays; i.e. only had tank or bore water

☐Yes ☐No

38. I wish to explore how you feel about water use.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A
Some banned water uses, like hosing my driveway, are pleasurable	☐	☐	☐	☐	☐	☐
I'm sad that my garden suffered during the water restrictions	☐	☐	☐	☐	☐	☐
I enjoy having long hot showers	☐	☐	☐	☐	☐	☐
I am worried South East Queensland will run out of fresh water	☐	☐	☐	☐	☐	☐
I'm worried Global Warming will mean further reductions in water use	☐	☐	☐	☐	☐	☐

7. Demographic Questions

40. Are you?

☐Male ☐Female

41. Your Age

☐Under 18 ☐35-44 ☐65 plus
☐18-24 ☐45-54 ☐Prefer not to say
☐25-34 ☐55-64

42. What is the highest level of education that you have achieved?

☐Grade 10 and under ☐Bachelor Degree
☐High School Certificate ☐Postgraduate Degree
☐Certificate/Diploma ☐Prefer not to say

43. Are you:

☐Self Employed ☐Casual employee ☐Retired
☐Full time employee ☐Student ☐Not in the labour force
☐Part time employee ☐Unemployed ☐Other

44. Number of people normally living in household

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 or more

45. If you have children, the age of any children living at home

Age 0-4	No.__________	Age 10-14	No.__________
Age 5-9	No.__________	Age 15-17	No.__________
Age 18+	No.__________		

46. Annual Household Income

☐Up to $20,000 ☐$40,001 - $60,000 ☐Greater than $80,001
☐$20,001 – $40,000 ☐$60,001 - $80,000 ☐Prefer not to say

47. Do you have any final comments on water consumption or water policies?

____

____

48. Do you wish to take part in further research?

This research will take the form of a short Focus Group, which will be at no expense to you, and at a convenient time and location. If yes, Please fill in the following information. All such details are confidential, will not be associated with your survey responses, and such information will be permanently deleted after the focus groups.

Name:____
Email:____
Telephone:____

49. Do you wish to enter our competition?

You can also elect to be in a draw for these great prizes: Your entry into the draw will not be associated with your survey response in any way.

- **1st Prize: $300 Voucher from either BCF or WoW Sight and Sound**
- **2nd Prizes: 5 x $50 Vouchers from BCF or Wow Sight and Sound**

If you wish to enter the competition; please fill out your details below; detach the form, and either include it in the envelope with your survey response; or email to heather.shearer@student.griffith.edu.au:

Name:____
Street:____
City:_____________________________________Postcode:____________
Email:____
Telephone:____

8.2.3 List of Open-Ended Survey Responses

RESPONSE
Do not proceed with the Traveston Dam. It is a flawed scheme with significantly more negatives than positives. It also destroys good agricultural land. We need to eat as well as drink. It is only still an option because of state govt arrogance and ineptitude. Council amalgamations are creating extra cost burdens on Sunshine Coast with no benefits. It only occured because the state govt wanted to appropriate our water because of poor planning for Brisbane population growth and without paying for the original infrastructure.
All large industrial sheds should be capturing water in tanks. We also need to find a way to capture run off water that is going down the drain. No more dams...
I think target 140 was very effective at raising the public's awareness about water conservation. Attitudes have changed in a good way - people frown on people who hose their paths and driveways now for example.
I believe the benefits to the environment of keeping my large garden alive, are worth the extra water I now use. During the drought I obeyed the restrictions religiously.
Don't ever let our water supply to drop to such low levels again. Use water conservation measures including recycling and the option to bring on desalination plants in an emergency. Limit our growth!
Although the water grid is good in theory (linking state water resources to channel water from surplus to where it is needed) I fear that we will be paying an unnecessary premium for the government's long inaction and therefore 'knee jerk' reaction. The Gold Coast desalination plant has been & still is an abominable waste of money. Re gardening: I think there should be a differentiation between landscape/decorative home gardens versus home vegetable gardens which require daily water. It should be illegal to water lawns or hose concrete with town water.
I feel very strongly about the water issues in Sth East Qld and will always do everything I can to help conserve our water.
I strongly believe that the conservation of water is should be an ongoing policy of any government. Water is precious and I have always used every measure possible to use as little water as possible in everyday tasks. Water restrictions should be an ongoing practice even when dams are full.
recycling waste water for consumption will be essential. IT is done all over Europe and modern technology renders the practice safe! We replaced 50% of our lawn with pebbles.
we will as a family be more aware of our water usage .
I think it is the responsibility of all community members to concerve water however, I do think the government has failed to adequately plan for the population growth of SE Queensland - in every aspect i.e. water, public transport, roads.
State govt hasnt got a clue. I dont know who or why anyone would vote for the current govt.
Seems not quite right for private households to worry about being vigilant about water use when businesses are not. Its just common sense to save water. I don't own a pool spa dishwasher so I am more lindulgent with my shower use and use it as long as it takes to wash my hair etc especially in winter. I disagree with front loaders being water savers, as the cycles take 3 times a long as a top loader and waste more water, with smaller loads. I have Westinghouse commercial style top loader washing machine. I had waterwise commission plumber come out and fix my taps, put a water saver on my shower now I notice the water pressure has reduced especially when the washing machine is in use. One small hot water leaking tap sent my water and power bill sky high, plus the plumber fees to fix a one small washer and call out fee. washers. its also the household you have grown up in and your culture. I notice many european and asian cultures tend to let the hot water tap run Although washing dishes as they have no concept of water saving in their countries, nor were they taught to save water growing up in Australia. So its the ingrained environmental and cultural issue that has to be changed, and education at early childhood is where it should start.
It's not hard for younger families to conserve water, but I felt that it was hard on older people (over 60's) as they couldn't water plants etc. It was such a big change for them.

You don't mention other water saving devices such as flow restrictors on taps and showers.
I don't feel that the government is on the same page as to where we are with the current water supply holding and local council are just in it for how much they can steal from us to feather their nests!
Water has been taken for granted for too long. Everyone needs to do more
I believe we need to save water .... But i dont believe in Global Warming and I do not think global warming has anything to do with our water problems
We are currently renting and feel that it is unfair that we cannot get some sort of rebate if we were to fit a water tank as we would really like to do so.
Just a comment on the survey - it assumed that we have previously had water restrictions in place - I'm not aware that any have been in place in Caloundra on the Sunshine Coast - I know that the old Maroochy Shire had some but Caloundra Council didn't implement any.
In question 38 the tense of questions 1, 3, &5 can completely change the meaning so I have not answered them.
water saving showers heads are apparently incompatible with continuous gas hot water - this makes it difficult to set the temperature appropriately and you end up taking more time before you actually gte in - this was an error in the water wise strategy
It is very important to conserve water
Govt doing well up to individuals to be more aware and to save water. in 1993 in Sydney, were told this country could NEVER afford to waste water! 21 pot plants watered by catching sink water running to hot shower water caught in buckets for garden Although (cold?) also. such a lot can be wasted Although waiting for HOT water!
I support the government concepts for water conservation: a water grid, recycling, more dams, desalination. However, I feel utterly frustrated by the wastage of public money because of poor or rushed decision making (e.g. the desalination plant problems), and the hypersensitivity of government to any questions or suggested alternatives. The perceived lack of openness and objectivity in response does not engender trust in the efficacy of their programs.
there are no water restrictions on the sunshine coast. Brisbane has caused their own problems by electing incompetent governments. Let them wear the consequences. There is ample water up north - burdekin or ord, pipe it from there
In the early 80's with three teenage children still at home, we relied solely on beautiful clear clean bore water that was more pure than the then Maroochy Shire Council water supply was after treatment - their own test results. We then had a soil and compost mixing plant start up over the road from our semi rural property and upstream on our water source. Not wishing to risk contamination, we then put in the 12,000Lt tank and started practicing water conservation as a necessity, as no town water supply is available to this area, even today. We paid for the lot, reticulation from down-pipes to the tank, electricity to pump water from both the tank and the bore, and still would not have it any other way, no flouride, no other chemical additives. Today our bore is used for laundry purposes, toilet flushing and all external hose points for gardens and lawns.
I've contacted both local and state governments about water policy and been brushed off. State said it was a local gov issue, local said that it's state etc. I suspect they are not genuinely interested in people being significantly water self sufficient because they want / need the revenue. It's a fundamental conflict to have the people selling the water also responsible for policy. My complaint was that they continue to increase base water rates to compensate for revenue losses caused by decreases in water consumption. My suggestion was that they should be decreasing base water rates, and increasing consumption charges as a fully user pays system would provide a financial incentive to install the larger tanks and pump equipment to make many households independant from the grid.
Thank you for taking the time in putting this survey together. Hope our answers are of some help. With water usuage in the garden for us we grow our own vegetables to save money & to be able to eat fresh & healthy. We have no interest in watering lawns as they are a waste of time & water. A lawn should be replaced with food! My partner is trade qualified in horticulture & permaculture so we use waterwise practices to the best we can with producing food for ourselves. Mulch is an enormous water saver too! With everyone growing their own fresh fruit & vegetables just think how much water could be saved (no monocrop culture) as well as transport cost incurring massive fossil fuels usage damaging the environment we could all save. Sorry could go on quite a bit about the wrongs we humans do these days! Thanks again & good luck :)
The campaigns against the Traveston Crossing Dam and the Water Grid are anti-Labor campaigns characterised by parochialism and disinformation and, on the Sunshine Coast, driven by a coalition of convenience of The Greens, the LNP and a small but vocal group of ultra-conservative rural Beattie/Bligh haters,

aided and abetted by the Sunshine Coast Daily which enthusiastically expedites APN policy of reflecting the voting behaviour of the communities in which it is represented.
I think that state governments have let us down as dam building is extremely unpopular, I remember that Wolfdene Dam did not go ahead because it was so unpopular the Goss government was elected on a promise to shelve the project, if it had been built we wouldn't be in the situation we were in during the drought. Wivenhoe Dam was NOT built to give us drinking water that fact that the annual precipitation rate in the catchment is lower than the evapouration rate means it is quite ineffectual as a water supply source, it was built for flood mitigation and for that purpose was a success.
I live on the Sunshine Coast and I disagree with having to provide Brisbane and suburbs with our water. The State Govt should have thought about infrastructure to provide Brisbanes growing population with water supplies years ago instead of waiting until now. Our water costs will increase to do this, and I dont think thats fair. Our population is growing as well.
I feel that federal and state have missed the boat when it comes to water conservation and the future. it feels as if water as a resource is not given the due right as coal and iron ore (mining)as governments get royalty's from these companies (not water)but if water is in the way for example sitting under a deposit of ore etc it becomes part of doing business. All governments see is the money coming from these companies. They are very short sighted eg the liverpool valley with the farmers. big mining companies wanting to mine and giving assurences that water will be protected and not comtaminated. how many times has this been proven wrong. When big business is involved money always speaks. If water is important why don't why start reflexing it's worth by valuing it. As a comunity we are tired of been told that the sky is falling in and that we have to make cuts. we understand this but have no faith in Governments as it is all about business and how they can keep the money flowing into the government bank accounts to help pay for the future development and fixing up the problems that are caused through not well thought out policies.
we were prevented from installing a good grey water system by council due to our proximity to the brisbane river. - we would install MORE tanks if the rebate was available. (note by inputter; has three tanks already)
the old (fart?) at the water commission have made a complete stuff up of the whole shortage and drought management - gross incompetence, mismanagement and chronic waste of taxpayer's funds; eg grid desalination plant, traveston etc
essential that the state gov plan long term. the traveston dam proposal was a knee jerk reaction and poorly researched. better options are available.
1) the cost of the grid could probably have been avoided if the previous governments had made the political difficult decisions and build the then proposed dams. 2) the bar chart comparative water consumption on the rates notice does not seem reflective of usage. I don't believe it. Eg away from home for 1 of 3 months period but no drop in usage.
I am angry that despite Brisbane householders saving water they are still charged more for their water usage. Working people pay tax and we expect services from the elected governments. Qld receives plenty of rain, it is the job of the govt to supply services to taxpayers. I have done far more to save water by purchasing an extra tank and am using all grey water on the garden than any other person i know. The rules are biaised against families with children. Single or dual person households get to use the same volume as 5 or more people in the same house. The Govt. should be encouraging people to have families, not making it harder.
get rid of half the bureaucrats
The government needs to act more sensibly and stop wastage for both commercial and power generation. I am putting down a bore to protect me from the stupidity of government.
consideration should be given by the govt to put hold on new permanent residents. huge expenses but make use of (?) water, eg Eli Creek Fraser Island tropical northern rain when it occurs. This year at buderim copious amounts of rain flowed to sea.
more thought should be given to grey water on new and older homes
rain water harvesting is essential
I do not believe the current labor govt has a clue on how to manage anything, let alone the state's water supplies. They are nothing but a load of self serving cronies more interested in lining their own pockets than the needs of the state's population. as long as we have corrupt politicians, we will lurch from one crisis

to the next, water included.
Most young people have no regard or respect for their fellow man. It is this attitude that will be their downfall. Restraint is not part of their life, re water conservation.
Definite BAD management by our elected politicians. Stupid.
A positive outcome of the drought was the extent to which profligate water wasters changed their ways.
I really think it is a great opportunity to teach our children waterwise responsibility.
It is everyone's responsibility INCLUDING BUSINESS to severely reduce our H2O consumption. As a renter, I feel restricted in some of the changes I would like to make, including: install tank, install dual-flush toilet; install solar hot water system. We don't need desal plants if we conserve and recycle H2O at a household level. The technology is there, we just need to implement it.
The water restrictions during the drought had a lasting impact on my usage. I now realise how little water the garden needs to survive. I'll never waste water on my lawn again as I now realise it greens up as soon as it rains.
When under the shower, it is not the time spent showering, but the volume of water used to clean oneself. A ticking device installed or decent indicator on water meter activated when water flows through meter. This would indicate any leakages when taps are all turned off.
The community benefitted from coming together and doing something positive about water use. There is no reason to ease water restrictions - it's good to encourage people to be conscious of their use.
water saving devices is difficult to install because of cost
Everyone seems to live a life of excess in everyway. Everyone needs to tone it down more.
I believe we will always need to watch our water and believe there should always be water restrictions.
we have only had a pool and water tank since june 2009
We should all use water conscientiously, being aware that our own negligence can affect future generations and our natural resources.
Longer range planning, not short. Notice changes.
We take too much crap from our MPs (?). I dont want to drink their sewage as well. Build dams and we have unprocessed water for farming and wildlife. With processed water the cost is high and there is no excess for nature. I just came back from Japan, with a population of 16 million in Tokyo and they dont have a water problem. So lets not blame population for our water problems.
build the damn dam!
(note, commented on water use with visitors vs normal) It is upsetting that councils don't regularly maintain pipes so that pipe bursts don't occur with loss of water. It is also upsetting that water is not turned off to prevent loss of water when owners of the property are away if the leak occurs in their property's pipes and they are charged for the loss of water.
people to use an allocated allowance
I have a encourage short showers. have installed a (?) water tank which is hooked up to front loader washing machine. I installed dual flush toilet.
make rainwater tanks paid for by the government
(note installed water tank at previous address) I would like more consideration being applied to large households. We have up to 9 people living under our roof at different times during a week, and we still get letters saying we use more than the average.
we all need to do our bit to conserve water and save the environment
Prefer a policy of educating people to use less water and permanent tighter water restrictions than before the drought, but a bit more relaxed than during it. Definitely against desalination but recycled water ok, especially if it can be used by industry but ok in water supply too.
Our household has a severely disabled young adult and his care requires more water usage than normal and this isn't taken into consideration.

Your survey didn't include attitudes to flouridation of the town water supply.
I would like to see recycled water being put to agricultural and industrial uses, rather than mixed into the domestic water supply
State government has failed to plan strategically for both population growth and seasonal impacts, such as drought. The water grid is a typical knee jerk reaction to being caught short. Better research is required for the future.
All people need to realise water will be like liquid gold and will be in short supply. Every Australian needs to conserve water in whatever way they can. My tips are to wash up in ice cream container and tip out on grass. Have bucket in shower and use for gardens use. Use wetta soil for grass and gardens and pots. I use tank water for washing machine, do all washing and wring out into tub then spin, then fill tub and rise and spin dry machine. short showers with timer. user bore water where possible for gardens and lawn.
I think the water meter reads more than actual use.
I think it was ridiculous for the government to lift the restrictions when the dam levels rose fractionally.
Instead of Traveston dam, government to supply tank to every house. Combined storage surely equal to dam.
we are rental tenants of the property
The drought was a great reality check for all water users, especially those who had never considered water conservation
noted that SC does not have water restrictions (correct)
Government need to find out from the public what they think.
Some questions were difficult to answer as we did not and do not have water restrictions.
Even though dams have currently been well replenished, I fell caution should prevail in case of future droughts. I would hate to see the dams go very low again through careless use of our precious water. At least some level of restrictions should remain and sensible use encouraged.
Differing attitudes between spouses can cause difficulties. I'd like to think my habits re water conservation are changed for ever.
Water recycling in addition into dams when dams are full enough.
The restrictions on water use for outside use (water gardens) are too strict and very hard to comply with. Why is watering restricted rigidly to the same half hour period two days a week? Why not be able to do it during any half hour period at any time of the day. If there is a household total volume allowed to be used per day, why cant we use it for anything, washing cars, gardens etc, if we cut down on internal use? All us 200 litres per day on what we want
Should normalise current "restrictions". We dont need to go back to wasting water. Rain kept garden green without having to water.
Govt needs to listen to advice from experts and then follow it, not ignore it because it might be unpopular
I disagree with the adding of flouride to the drinking water. I believe using flouride tablets is best. Ultimately, every dwelling should use dam water for drinking only
If the pipes were cleaned out, it might help! (note; 90 year old pensioner!)
Sweep my outside areas, dont hose and most of the time, rely on rain for garden and pool. we get a lot of rain up here. NO TRAVESTON DAM.
note: has hot showers for arthritis
I am very careful with water use. Unfortunately I do not have room on my land for tanks and am sad that the garden has suffered. Would like to have the freedom to hose gardens but still stay within the allocation by saving in other areas. I used to live on a boat, and REALLY know about water usage!
I think water restrictions should be maintained to a certain level in the future.
I believe that the financial assistance on water tanks shold remain to catch more water for garden use. ie. (midday(?) 8/9 25mm rainfall on our house gardens are watered but we now have 7000l of water to use at some other time to water our garden and plants
1) having to bucket water (in the garden) is ridiculous and very dangerous for the elderly, small statured person or (pwd?). Dreadful dreadful social outcomes, medical outcomes. May well be unlawfully discriminatory. Limit the amount of water you can use, not the way it is used.

2) I'm ok with reducing consumption, but totally object to being told how and when I can use town water when I'm staying within reasonable limits. People should be allowed to make their own decisions and have to pay (or be fined) when their usage exceeds deemed limits. 3) Should be more pressure on businesses reducing consumption, eg take a look at the cleaning practices at the fishmarkets. 4) Pool owners should not be allowed to fill NEW pools with town water.
I dont believe we will run out of water. Climate is cyclic. Some years will be good, others will be bad. The govt over dramatises the issue to deflect focus on other matters. The general public is apathetic to such matters and other lifestyle issues (home, dollars etc) take priority in general living
I worked for one year on the water treatment plant at Gibson Is Brisbane. I cant believe the plant is not being used to fill out dams. It is fully constructed and not being used to its full capacity due to "politics". What a huge waste of money.
We try to use as little water as possible, mostly goes on garden
More consideration as to the location of the dam sites would appear to be necessary to resolve issues such as Traveston. More studies into affects of desalination plants on environment prior to building
I feel that more influence needs to be put into water conservation since the dam levels have increased. Water from the coastal strip also needs to be collected in some way before it is left to run off into the sea.
commented that a) missed out on water tank rebate because moved; also b) very aware of water shortages as had moved from SA
Maleny has a good supply of water. Boreen Dam supplies the coast all along its own water supply. Brisbane should use (own?) water for supply
upgrade existing dams, use storm water harvesting for parks and gardens (council owned), keep tank rebates for homes. NO TRAVESTON DAM - prime farming land gone. Recycled water used for power stations and industry at all times and maybe used for household gardens and lawns. A second water supply pipeline.
yes i prefer to do (?) on the rich areas or suburbs where is swimming pools and lots of water use
note: would have liked water tank, but could not afford - pensioner
There should be more publicity in Queensland on how well Queenslanders continue to do in saving water (compared to the rest of Australia) - I do not support or agree with recycling sewage for drinking water. I do support it being used for industry. - There should be stronger impetus for industry to save water, they have not done as well as households have! -NB I still use water from shower to water pot plants
note: knew restriction regime but not level. I would prefer the half hour watering was allowed in the morning, much better for the garden
It is frustrating that the government didnt have the foresight to better plan for the dire situation we experienced during the drought (ie by building the proposed dams to accommodate the increased growth in Qld) (note; Happy to do surveys/focus groups, prefers interviews/telephone due to young children)
Gumdale, though can't find address on database
We shouldnt have to conserve water due to lack of infrastructure, but I dont just waste water. Two young children, need lots of water
the public should be made more aware of what water level restriction we are currently on, as Toowoomba is still showing level 5, 10% dam level; Brisbane should have a sign like this around different areas so we are aware of water capacity in different areas beside weather report on TV
The Tweed River owned by NSW should be used as 5 1/2 times the Sydney Harbour volume flows out to sea each year. In the 1980s, the Federal govt surveyed the Tweed for several dams. The States cannot agree on ownership. it should be the fed govt organising the water on a national basis (ps the Tweed is only 70km from Brisbane). (noted, putting in grey water tank for garden, and 5000l rain water tank - have 9 panels of solar and another 8 due shortly. Says Traveston will be too shallow and covering too much productive land. The Tweed River is the simple solution for the future, Traveston will only be a stop gap and rarely full)
I have seen practices by businesses that make our efforts feel a bit useless. Surely wise use of water is for everyone to practice? We will not cease water wise,

but the government could do more. Maybe asking "everyday" consumers to be waterwise reporters?
were doing most of the actions in Q26 before the drought. note: said SN question was too broad (agree)
I live half a year by myself and half a year with my parents. We dont waste water at all; we are conscious of water use having lived in Germany
check that all taps are turned off tight after use to avoid dripping
The aluminium refinery being built in gladstone was promised by a former premier if it was built the govt would supply the electricity (powerstations need water) and water (lots of water needed for refineries) two water pipelines are to be built to supply water from the Burdekin storage and one from Brisbane. Hence Brisbane's water problems, water recycling for industries only. Area where Traveston Dam is to be built is very porous and water will soak into the ground. Check with the Deagon hydraulics laboratory for results of model testing
Introducing water meters was a wonderful idea. People value what they pay for. Instead of spending billions on dams, give every house a tank, federalise water and build dams for Brisbane in Northern NSW where they have regular floods
I think industries only should use recycled water. I think the govt acted too slow in its effort to conserve water use
I have always hated flagrant abuse of water use. The drought has served us well to remember that water is a resource, privilege not a right. We'd all do well to treat it as such. Able bodied people whinge but I have far more empathy for the physically challenged who dont mind carrying water but find it too hard to do so. I often pray that when it rains here, it will rain on your catchment area too. Even in the bad times, we are far better off than many places overseas where children die from water borne diseases because their drinking water is contaminated. I hope you find good solutions in your studies. Note: author is disabled, finds hot showers helpful
There are no water restrictions on the Sunshine Coast (Caloundra). That won't happen until Brisbane starts taking our water. The Mary River dam going ahead is a disgrace. All the experts say it won't work. Why are they not listening. How can they destroy all that beautiful land?
Governments should not be so short term aware (in other words, re election conscious). They need to make more long term policies and put them in place instead of wasting taxpayers money on feasibility studies and then not putting things into place
Traveston Dam should be built and recycled water piped to it and back to the power stations and industry
I think every household should take the responsibility for their water use and only use what they have in the tank - as people in the country do. Large areas of grass and pools should be discouraged.
It is amazing how fast people can change behaviour when they have to. I think more limits should be put on the potable water use by industry.
I would like to be able to receive rebates on things like water tanks. I was not ready to take advantage of the scheme when it was on. Now the offer has ended.
Should stay on Target 140, culturally seem to have adapted
Re consumption, we had bathroom reconstruction and Caroma Opal toilet installed. If it extremely water efficient.
using water is necessary, wasting water is uneccesary
Important stuff. Keep up the awareness campaign.
It would help a lot of councils/ governments made it cheaper for people to install solar/water tanks etc and use their own water wisely
The Traveston Dam is a huge waste of time and money as it will be too shallow to be of any use, not to mention the effects on the Mary River and the flooding of some of the best farming land in the country.
Dont want Traveston Dam or water grid taking our Sunshine Coast water!!
People should learn to appreciate and conserve water. (note: lived on farm as child, only had tank water)
Dislike restrictions as I have to pay for water. I use water wisely and sparingly, but if I need to wash a car (on loan) I should be able to.
Restrictions were not imposed early enough, then went to very tight. A more gradual approach should be taken.

If dams propsed in the past (Wolfdene) had gone ahead, there would not have been the same problem, plan for more dams NOW All new housing should have to have substantial water storage and high efficiency appliances
My family and I have absolutely no faith in the current state govt to manage the water issues and we voted labor! The state govt should manage what water it has and use it more wisely. There are many other ways than building dams, to harvest water, then use and reuse it.
Disgusted with the water charges - the less we used the more each litre cost us. We were charged approx 3x the price per litre than had we used the top limit (800litres) per household per day
Ironically, the 2005-2008 drought was beneficial in that it forced Brisbane residents to become much more aware of their water usage. I would hope that regardless of dam levels in future, we are unable to return to wasteful water practices.
I feel that if you are given a target of 140 litres per person (which our family was well under) you should be able to use the water as you wish. If you want to have really short showers, you should be able to use a handheld hose to water potplants for a few minutes. Using a bucket was back breaking. Seems unfair that anyone can stand in the shower for half an hour with no penalty but I can't water plants for a few minutes.
Local communities should be self sufficient when it comes to water resources. Relying on water from outside your region (eg Brisbane using Sunshine Coast water) is unsustainable, inefficient, irresponsible and dangerous!
I think most people have taken on water reduction practices as a result of the drought. eg. Most people now would not hose their driveway. Tanks should be made mandatory and plumbed in, as in Toowoomba, for example. Trigger nozzles should also be mandatory.
If we have to have recycled, could it be used for other than household use initially - not possible even now i guess.
I have lived in Buderim for 15 years - I am not convinced that this area should be subject to any water restrictions at the present! Am strongly opposed to Traveston Dam. The high quality, high productive area should be protected for permanent crop purposes, dam not necessary
The government and society is very slow to embrace global warming. (note; says exempt from water restrictions due to OCD? person in house)
A user pays system is the fairest system - making people more responsible for their own water usage. And we need to capture more wasted water, ie storm water People need educating that you dont need 2 showers (or more) a day, that you dont need to fill the sink to wash up, that you can bath in a small amount of water...we only know what we learn
In the future we will again have droughts, so we do need the Traveston Dam built to cater for the future water needs of our fast growing communities.
I am very aware of water consumption but feel 140 litres per person per day is totally unacheivable.
We have installed solar hot water. It now has to travel longer to reach outlets, resulting in an increase in water use. If use returns to level 6 restrictions, this is very difficult when people are in their 70s. What is more important, saving water or saving electricity?
The lack of foresight and planning of the Queensland State and municipal governments with respect to ensuring adequate water supply is appalling. There should be no need for water restrictions.
Reading and recording the household's water meter on a daily basis during the period of the 140l per person per day restrictions made it relatively easy to manage daily usage to keep within that level on a weekly total basis. - The availability of remote water meter display devices similar to those now available for monitoring electricity usage would be very helpful and would further encourage people to maintain awareness of their water consumption.
irrigation system fell apart when not used during drought. reused water ruined grass over time
More dams should have been in place earlier; ie. Burdekin
It would be nice to have a one-off water usage day or weekend like the Gold Coast had. My house has not been cleaned externally for 7 years, the irrigation system has been off for years, and the grass is now green with weeds. It is going to cost a lot to re-turf - a resultant incumbent cost of the Govt's water restrictions. I believe the water crisis will worsen as the population of SEQ continues to grow. Perhaps a new dam in an area where it rains consistently, ie. the Gold Coast hinterland?

Both my partner and I believe we shold always behave (with water) in a way that suggests that the supply is grossly limited. The more stringent the policies, the better as perhaps we will always have drinking water available. Note: said both partner and self were saving water long before govt. took it up as an issue as the signs were worrying us before then.
More information on water restrictions, watering days and dam levels in the local paper. People should be made to be water conscious all year round, not just in drought.
Why should "water police" employed by council have up to date modern vehicles and all the perks when rating is decreased. Should not be a waste of money for ratepayers.
commented re my boo boo on cutting,
The state govt spending all that money to take over assets and now council amalgamations of retail is wrong.
Always use tap water carefully
Saving water has become harder with children. ie. we bath rather than shower and wash huge amounts of clothes and nappies. I also like to let my children water the garden.
Since the drought and the imposition of water restrictions, I do treat water as a precious resource
Water tanks for households should be a minimum size, ie. >10,000l. Commercial buildings should be saving rain water as well as households, another minimum size >100,000l. Hospitals are a major water user and waster. Rainwater tanks and water treatment plants should be placed at these facilities. Just a few examples.
I think people should still be vigilant still even though our dam levels have risen. Little rain has fallen over the past couple of months. Put a stop on people moving up and people from overseas.
I understand there is a huge underwater reserve (many times more than Sydney harbour) could be in Western Australia. The government could tap on this natural water.
I am happy to restrict water, as I am concerned about when I have grandchildren the problem will be worse for them.

8.3 Appendix C: Mapping Water Use (A3 Mapping)

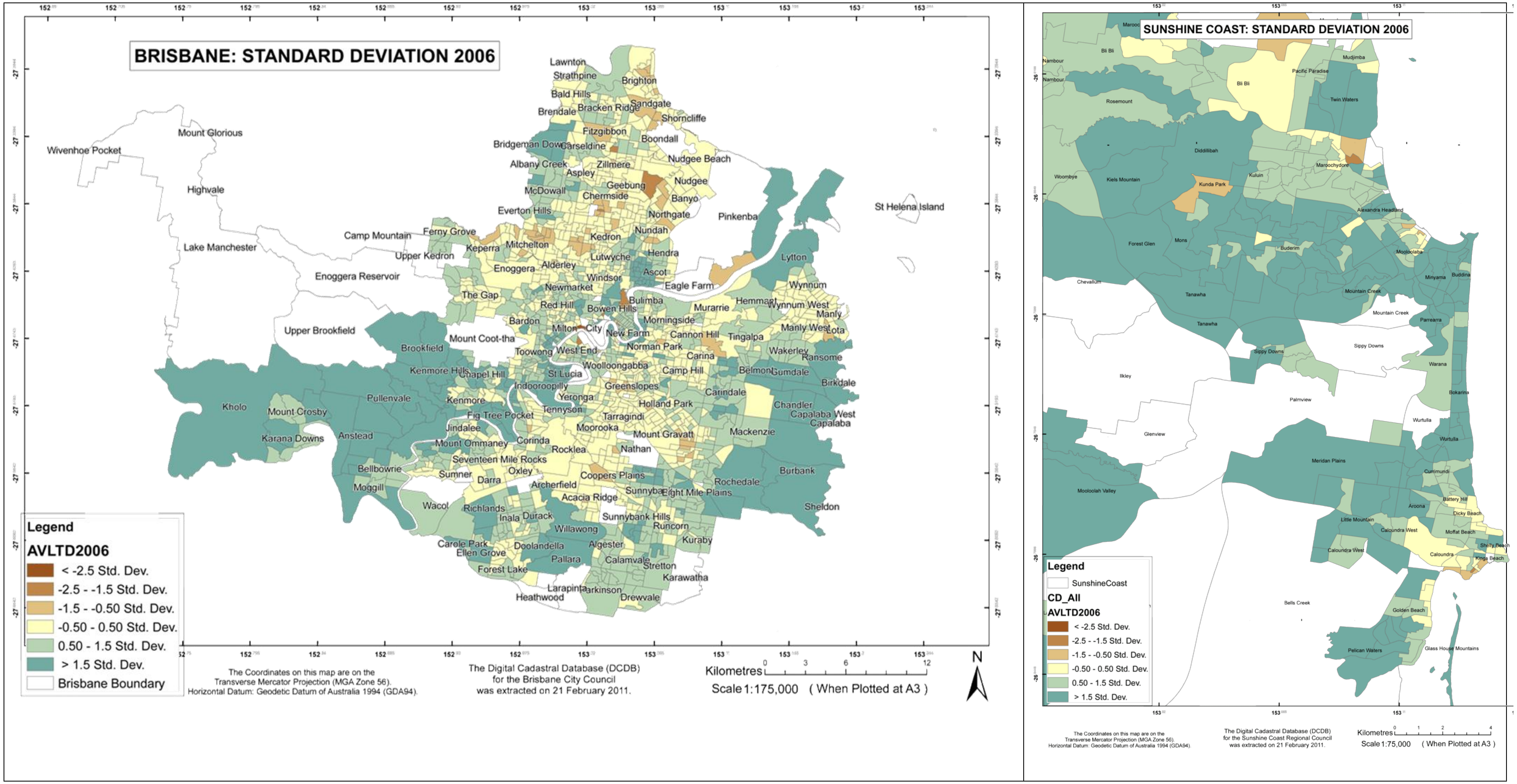

Figure 47 Standard Deviation Mean Water Use per CCD 2006 Brisbane and Sunshine Coast

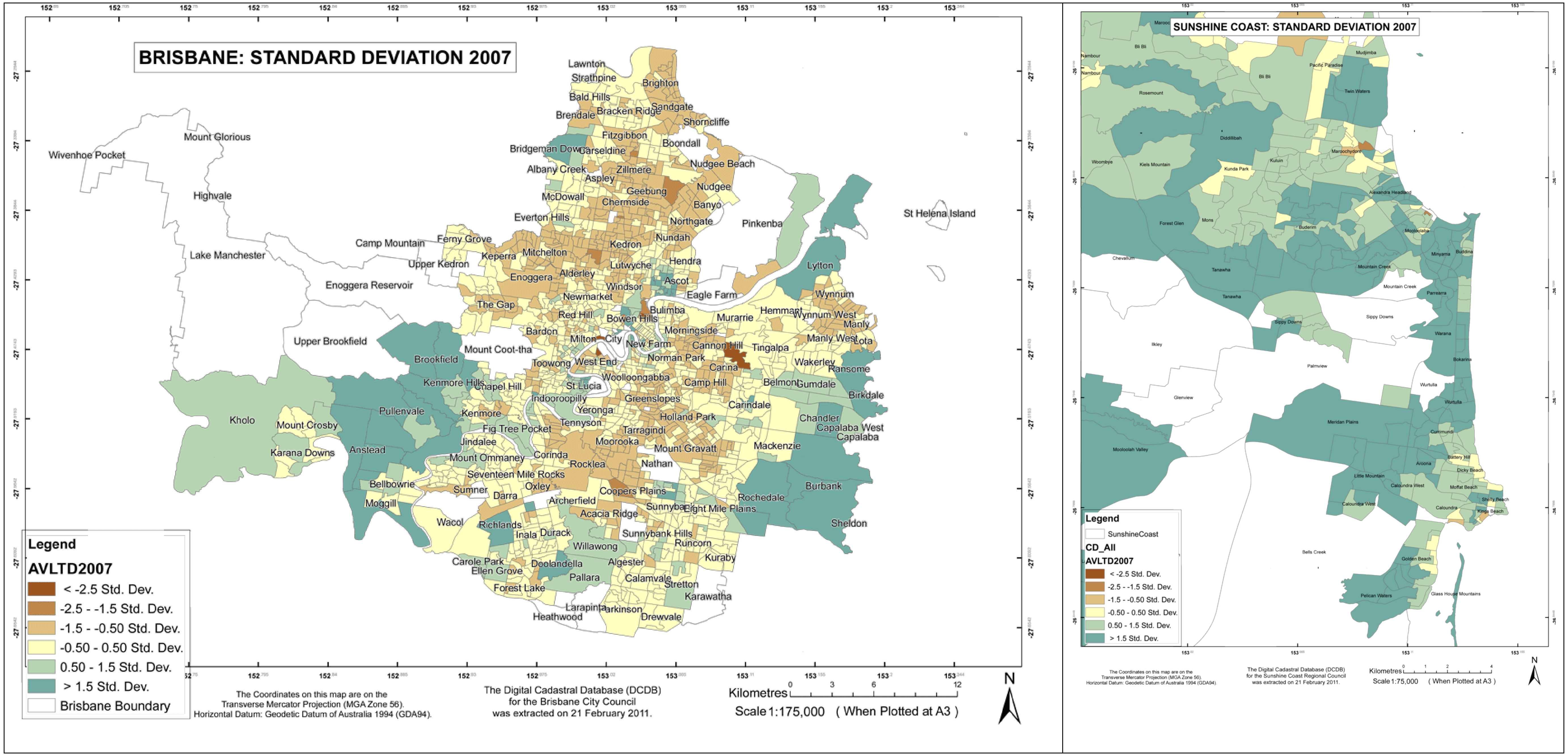

Figure 48 Standard Deviation Mean Water Use per CCD 2007 Brisbane and Sunshine Coast

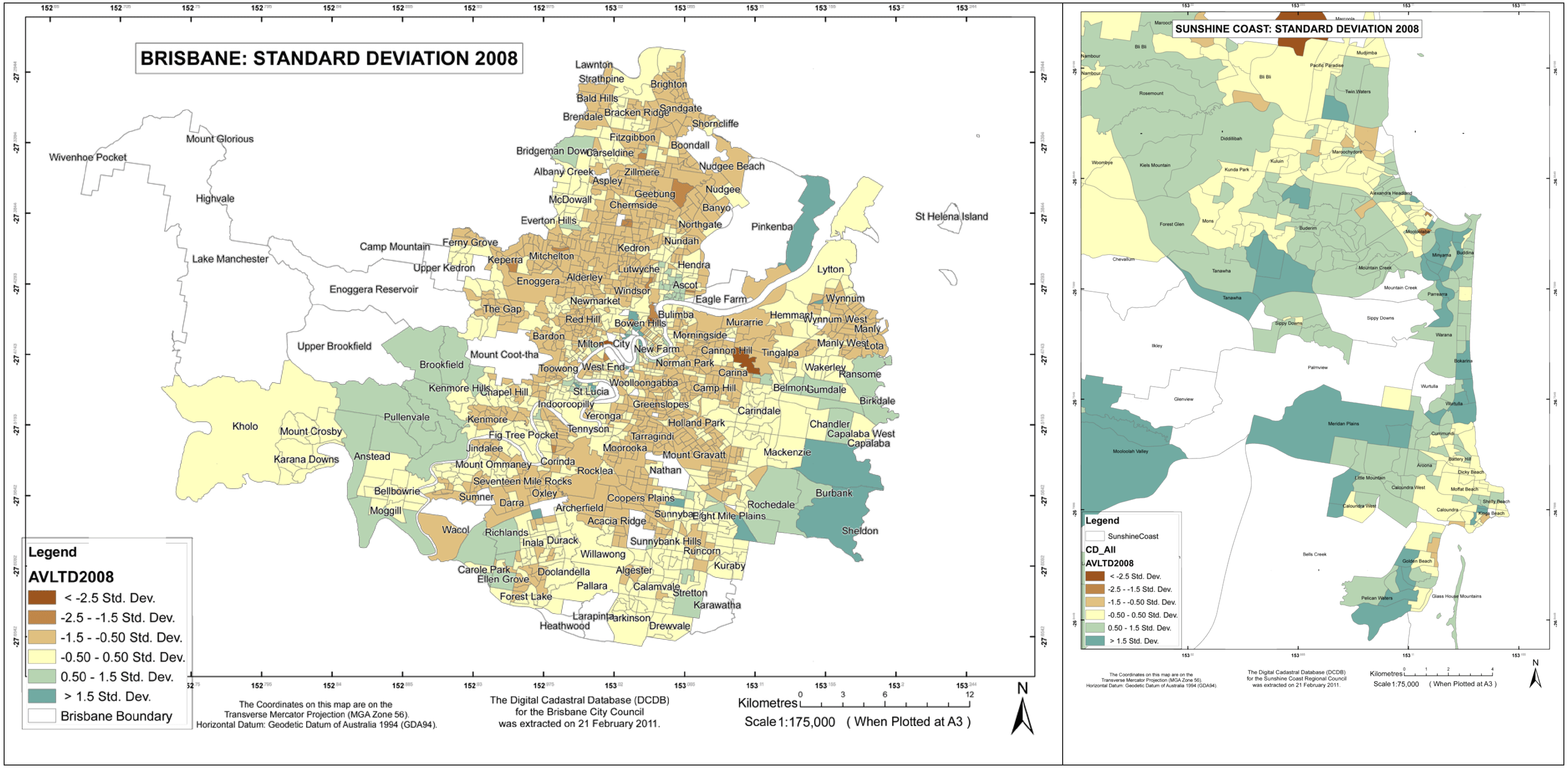

Figure 49 Standard Deviation Mean Water Use per CCD 2008 Brisbane and Sunshine Coast

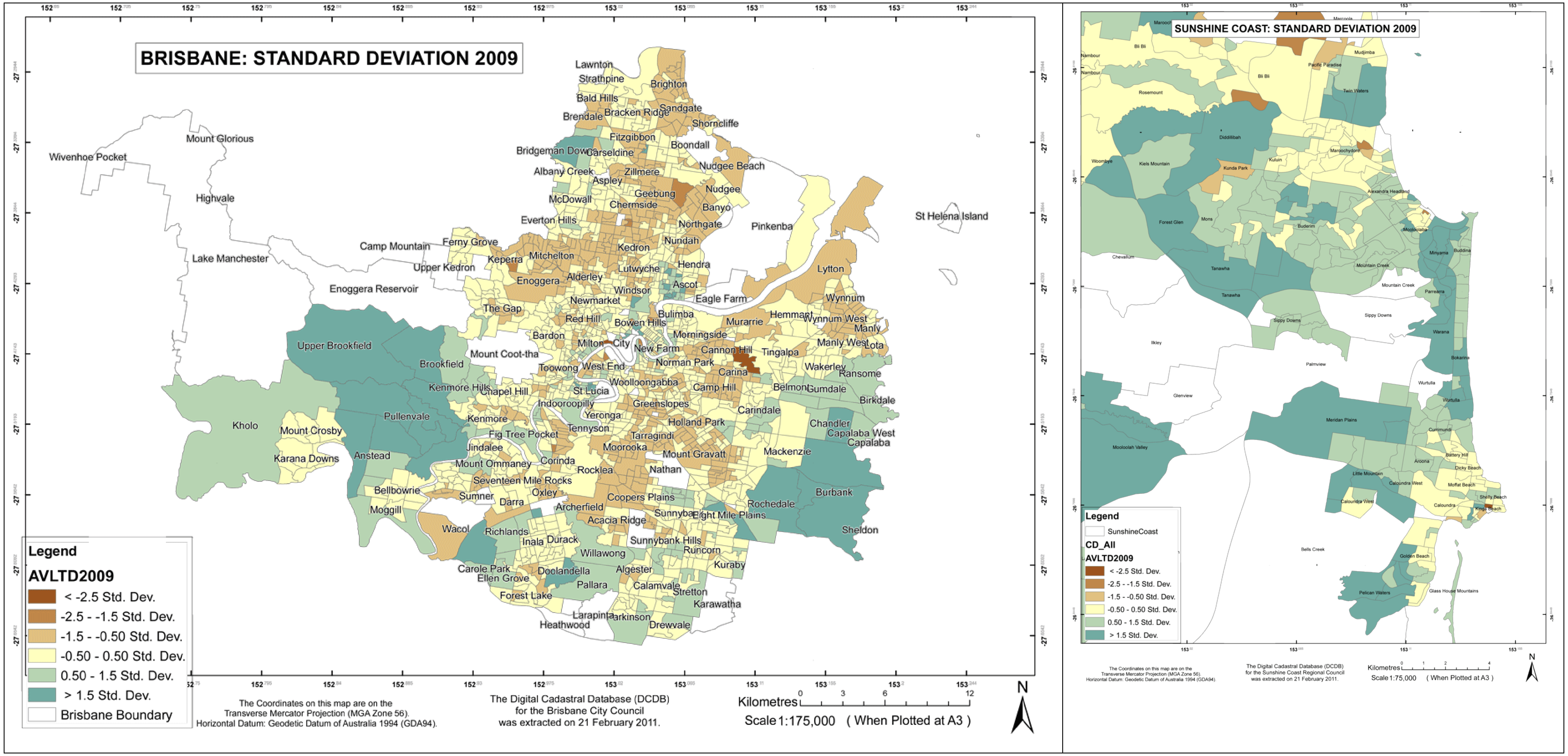

Figure 50 Standard Deviation Mean Water Use per CCD 2009 Brisbane and Sunshine Coast

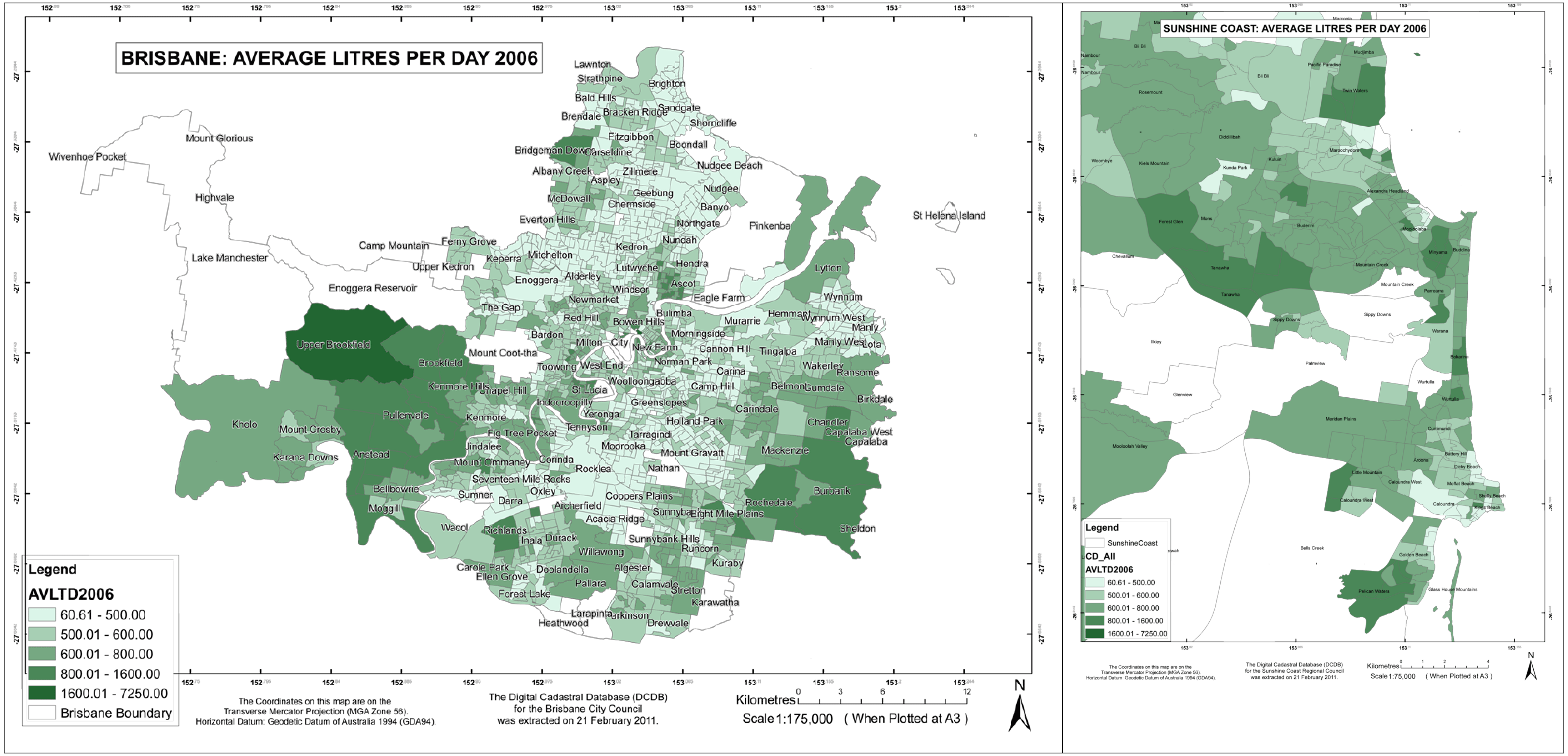

Figure 51 Average Litres per Day per CCD 2006 Brisbane and Sunshine Coast

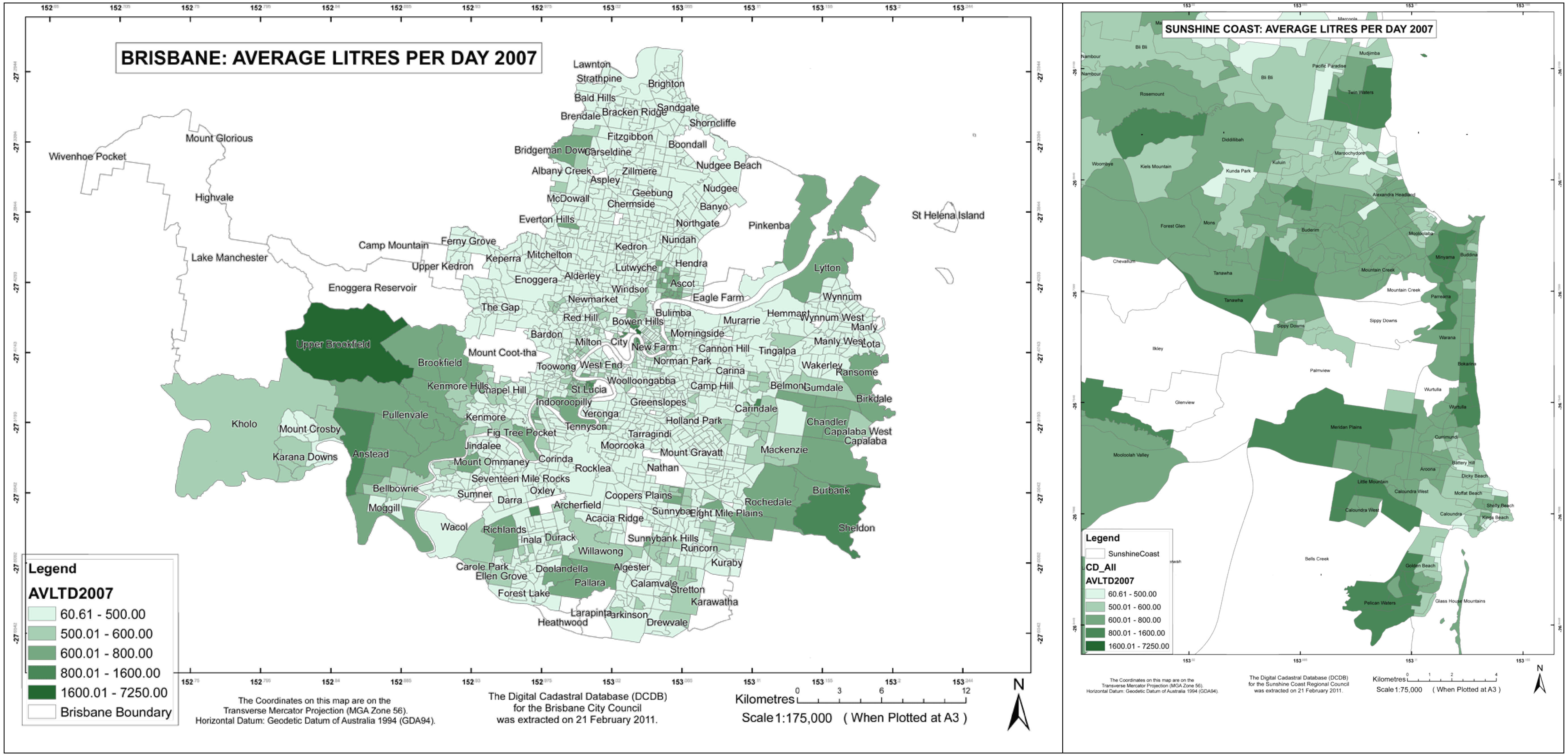

Figure 52 Average Litres per Day per CCD 2007 Brisbane and Sunshine Coast

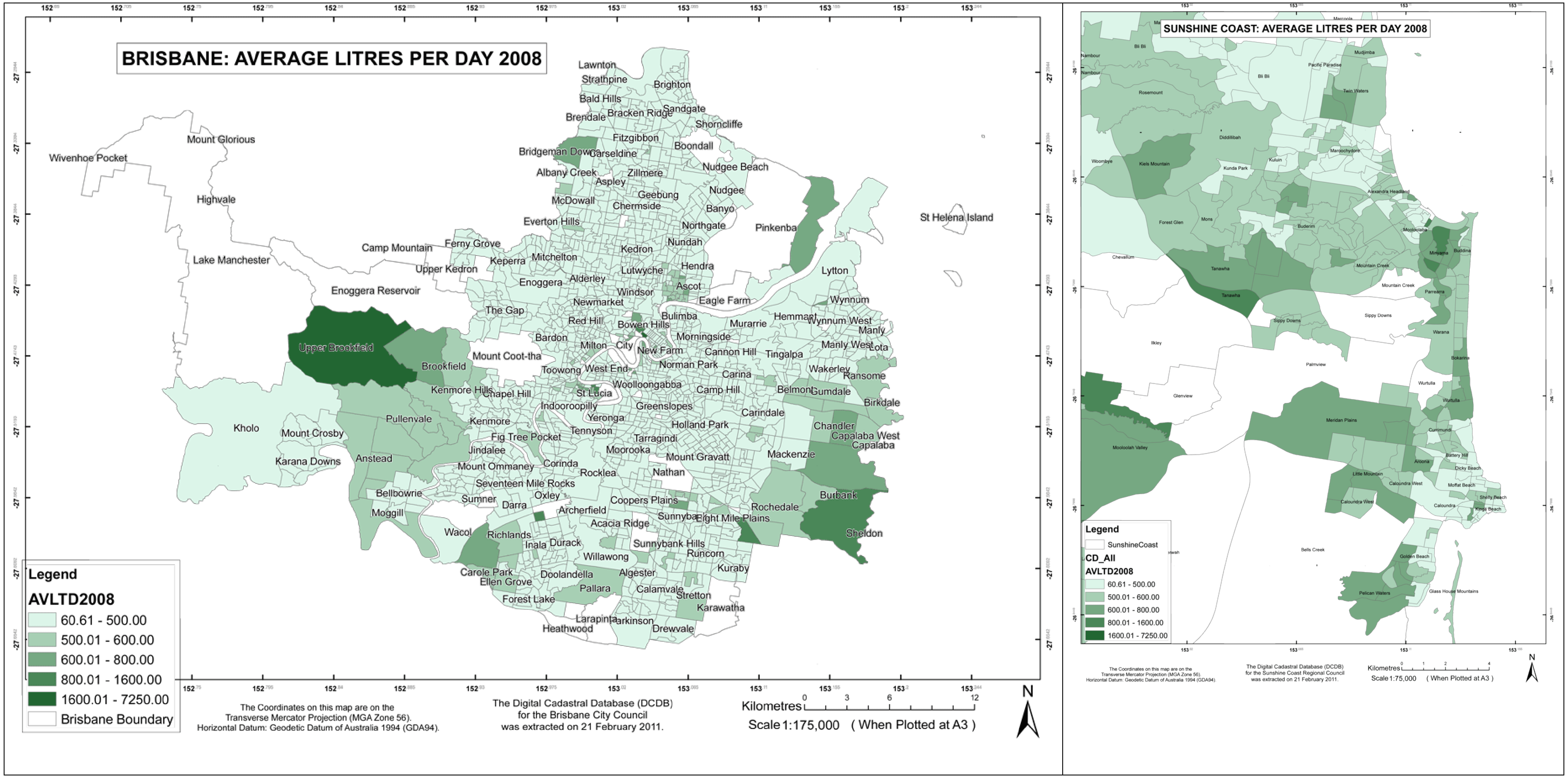

Figure 53 Average Litres per Day per CCD 2008 Brisbane and Sunshine Coast

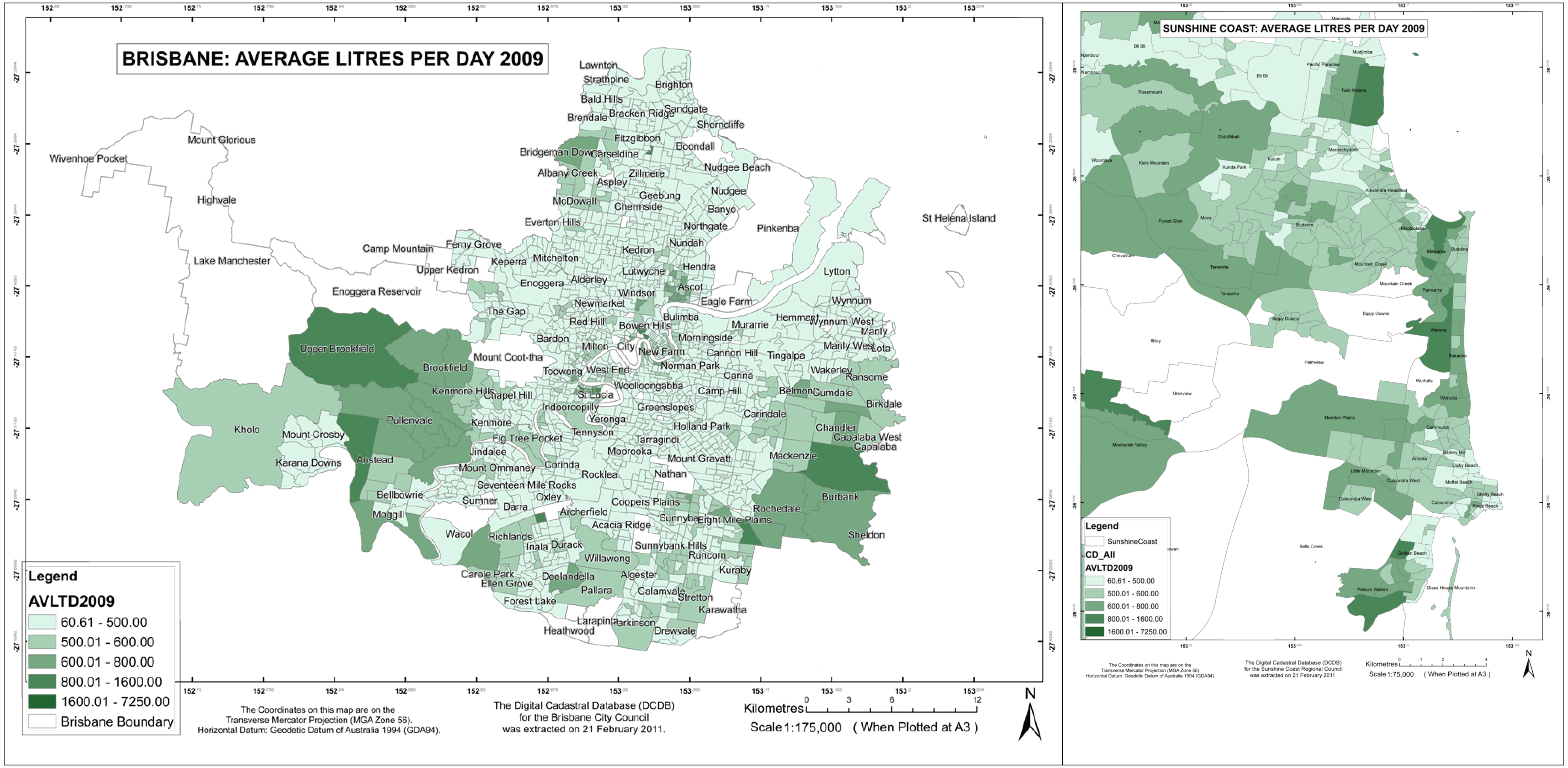

Figure 54 Average Litres per Day per CCD 2009 Brisbane and Sunshine Coast

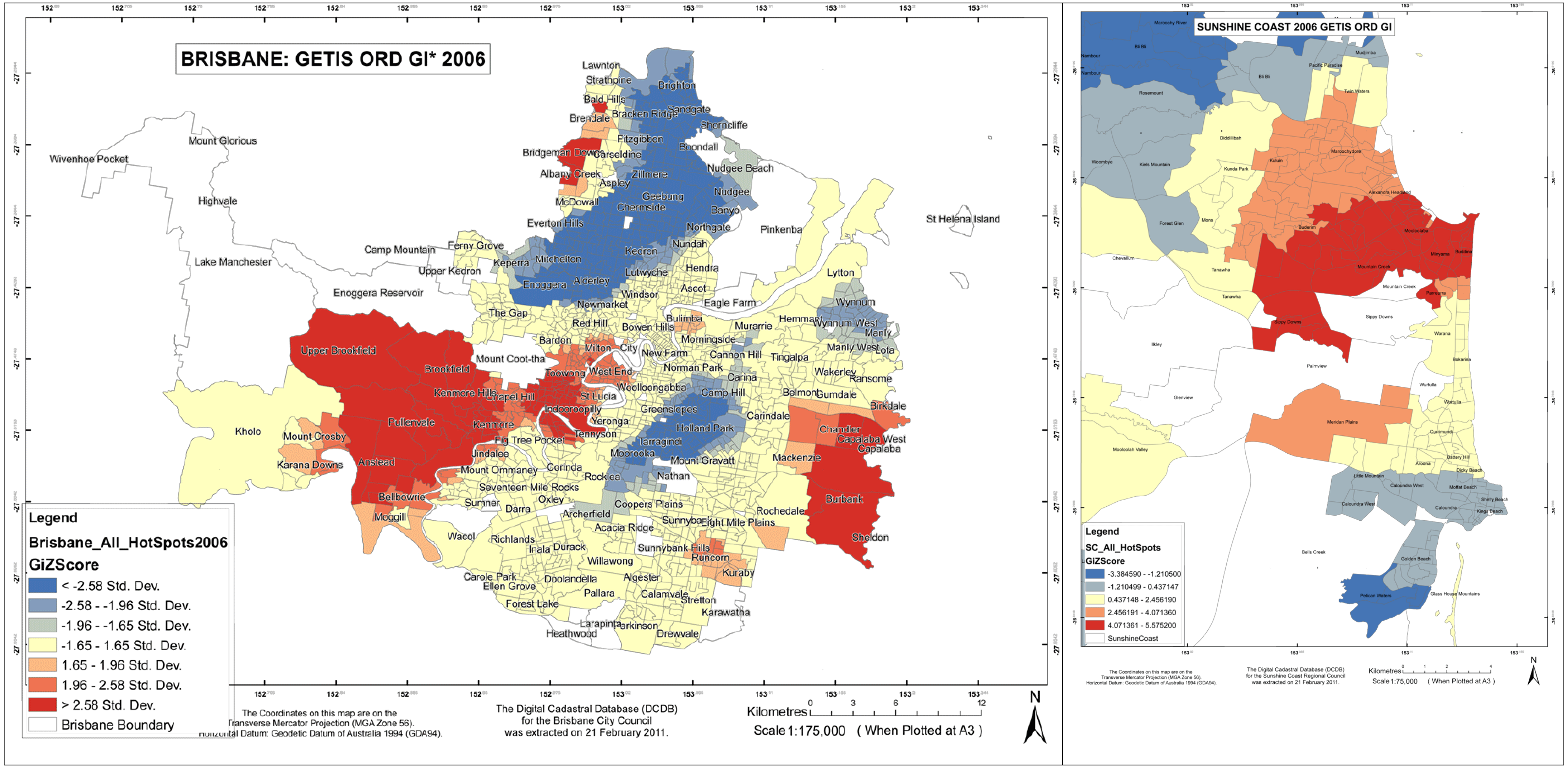

Figure 55 Comparison of the Getis-Ord Gi Scores for Brisbane and the Sunshine Coast - 2006*

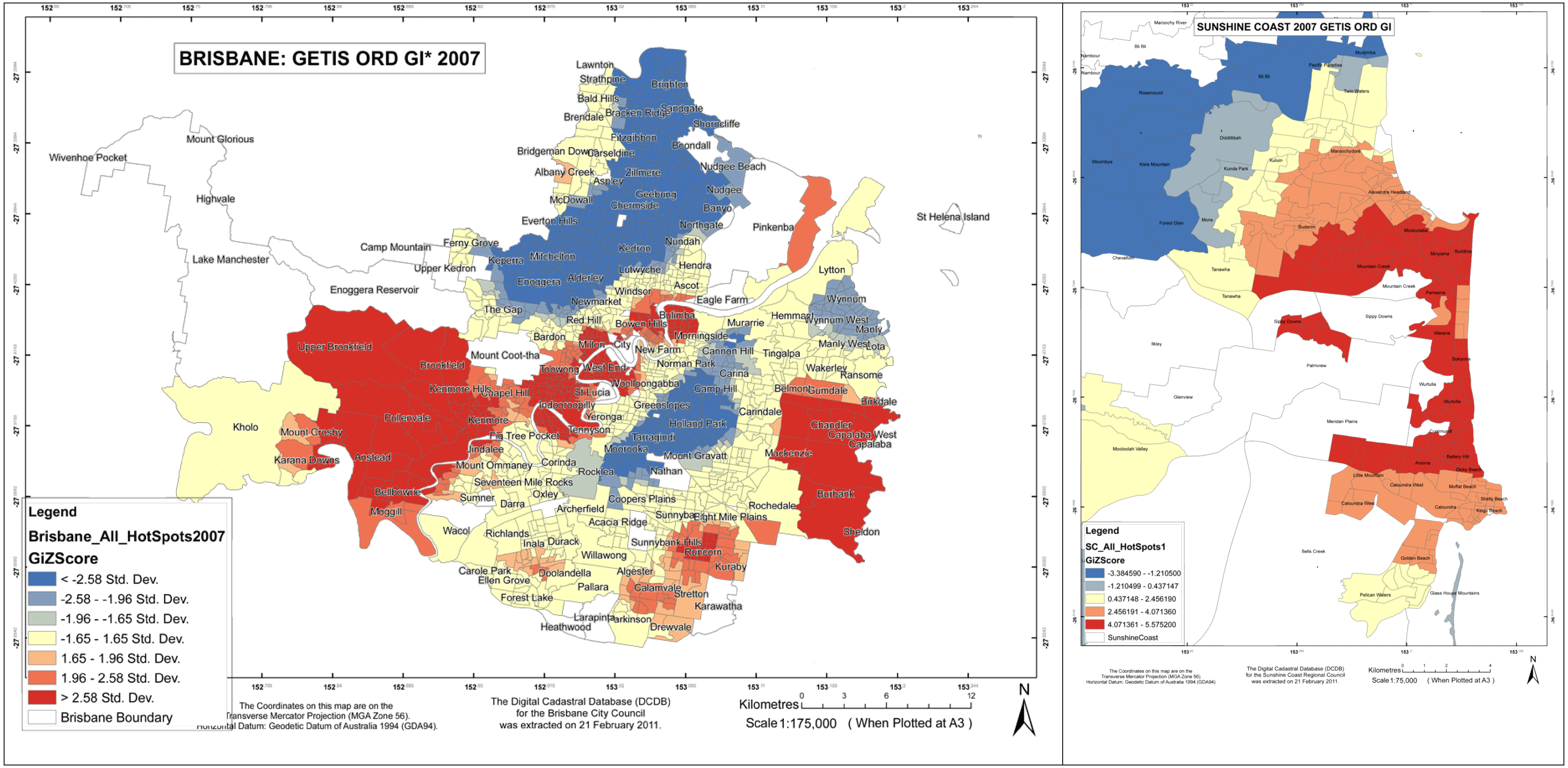

Figure 56 Comparison of the Getis-Ord Gi Scores for Brisbane and the Sunshine Coast - 2007*

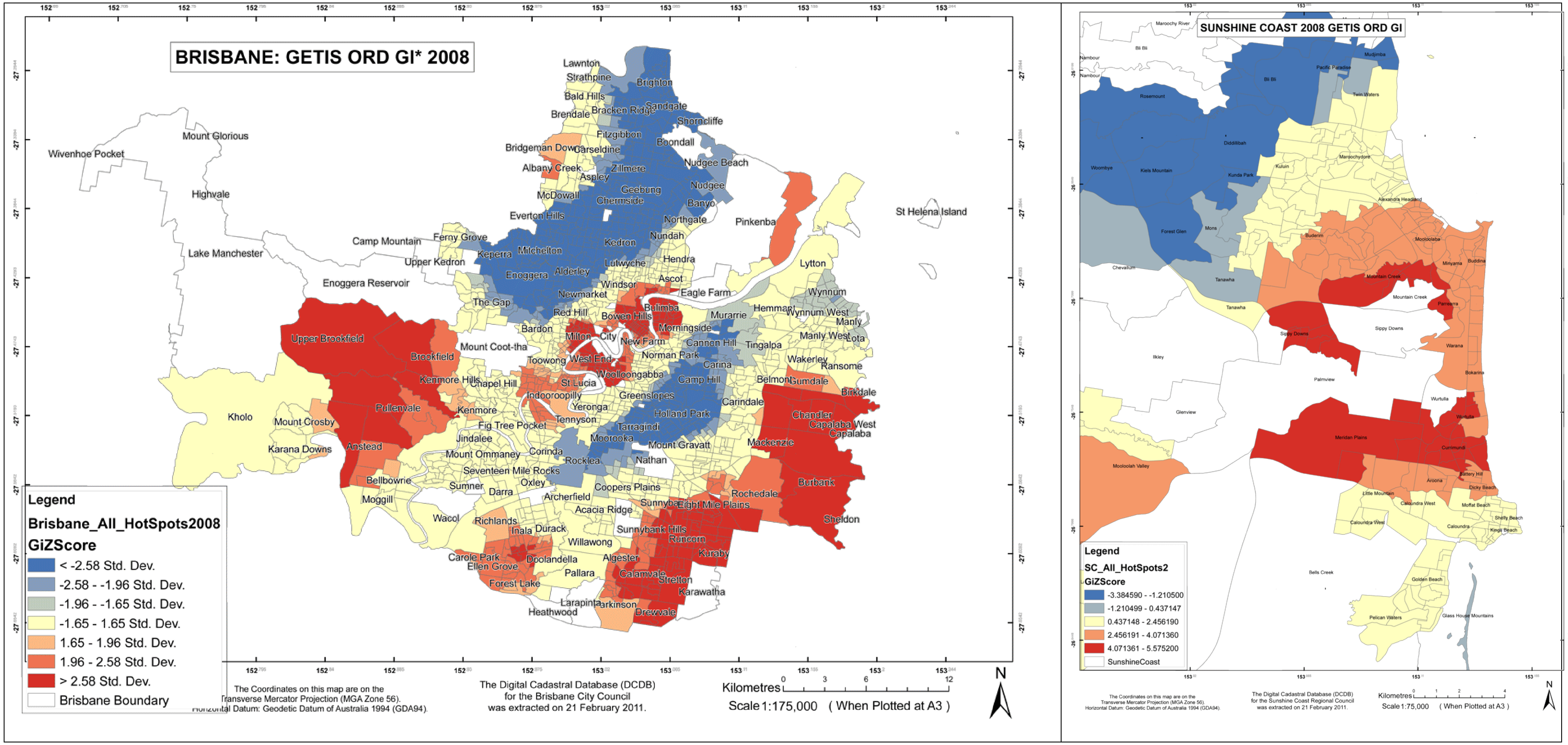

Figure 57 Comparison of the Getis-Ord Gi Scores for Brisbane and the Sunshine Coast - 2008*

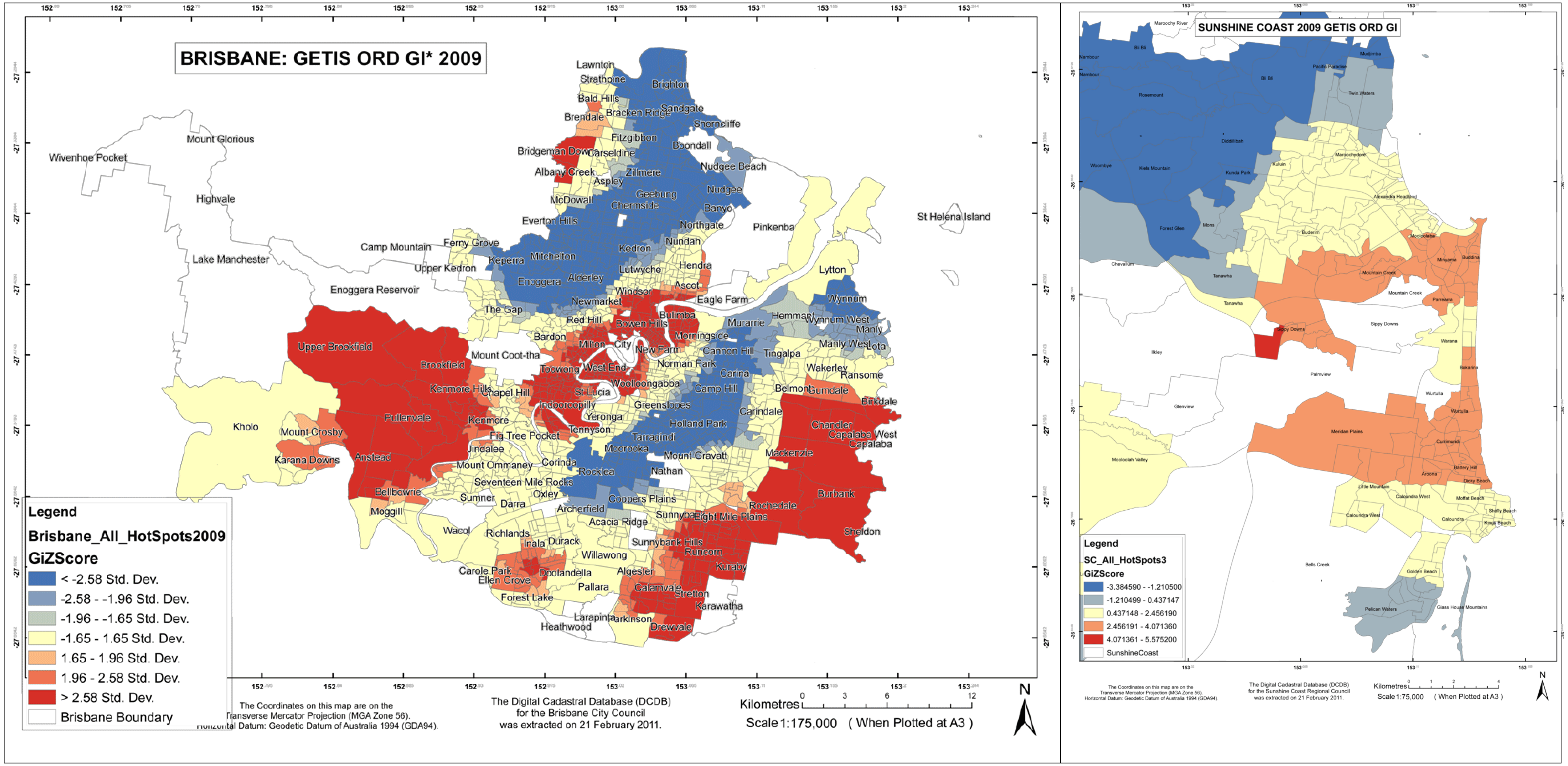

Figure 58 Comparison of the Getis-Ord Gi Scores for Brisbane and the Sunshine Coast - 2009*

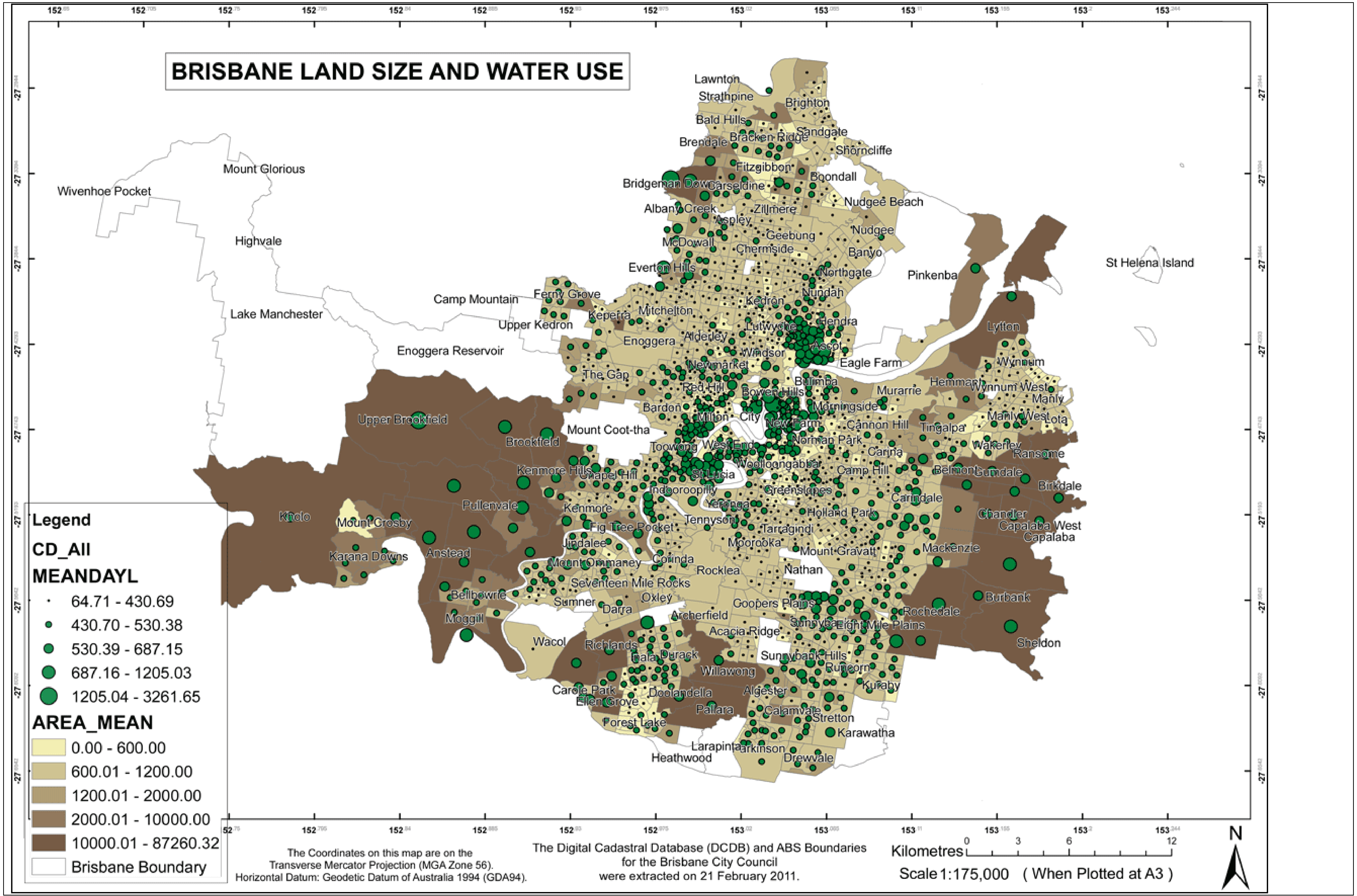

Figure 59 Mean Water Use per CCD and Lot Area

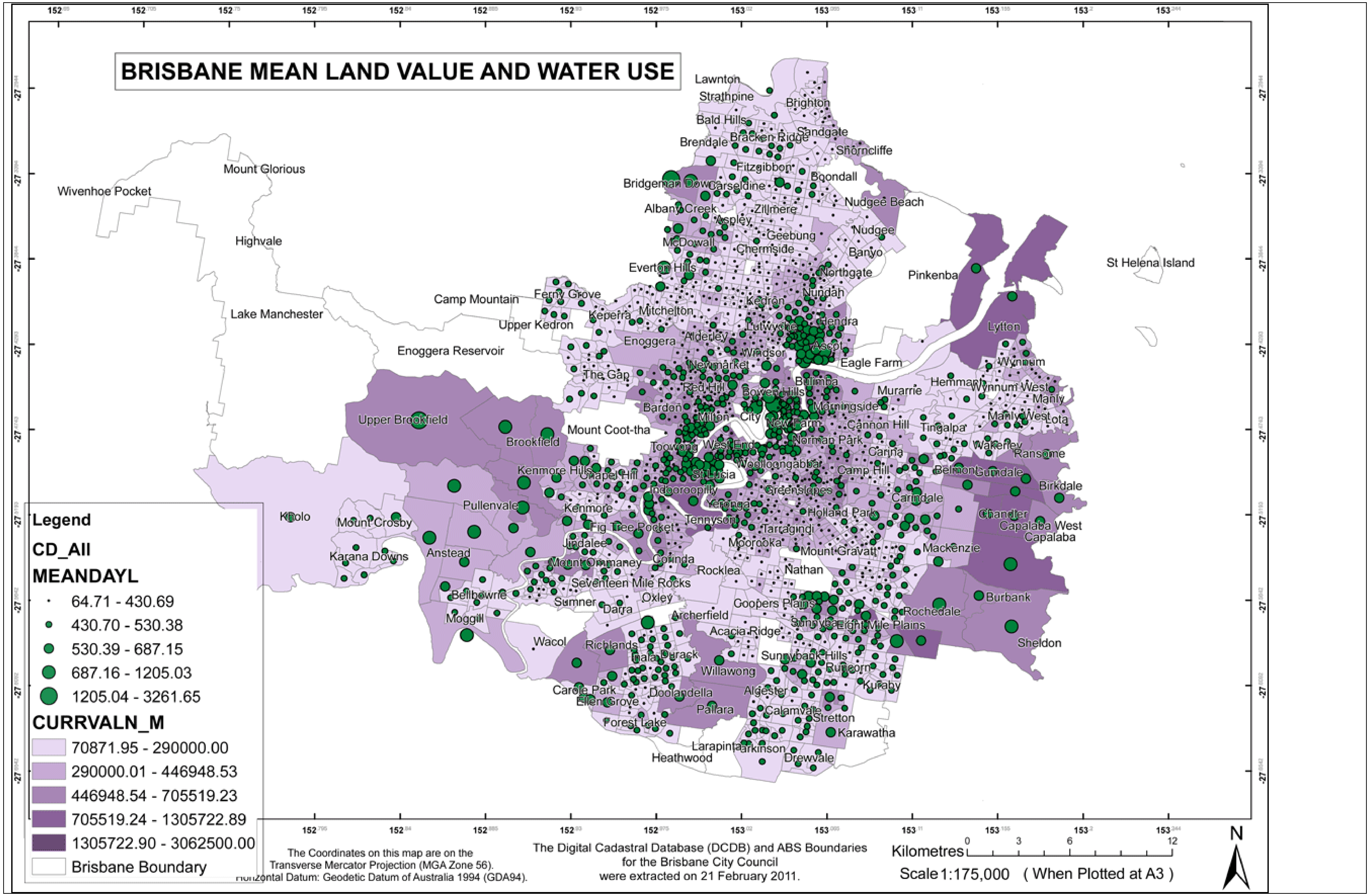

Figure 60 Land Value and Mean Water Use