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Water Use and the Built Environment: Patterns of Water Consumption in Sydney

Patrick Troy, Darren Holloway and Bill Randolph

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Abstract

The research reported here is built on three assumptions:

1. That it is possible to extract from existing records the water consumption measures for different kinds of dwellings in different parts of the Sydney Metropolitan Area, and
2. That it is possible to identify the socio-economic determinants of domestic consumption by linking water records to Census data, and
3. The knowledge resulting from this approach may be used to construct appropriate location specific policy and program initiatives designed to reduce water consumption in an efficient and equitable manner.

The research explores the water consumption profiles of households living in different forms of residential development in a range of locations across Sydney. In particular, it seeks to understand how different types of dwellings – separate houses, semi-detached houses and flats – are related to household and per capita water consumption propensities.

An overall finding of the research is that the per capita consumption of water is, for all practical purposes, the same for people living in traditional houses as it is for those in high density dwellings.

The report concludes by presenting a range of realistic policy options aimed at better managing the demand for water in the city.

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All errors of omission and commission remain the responsibility of the authors whose views may not be endorsed by Sydney Water.

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Section 1 of the report sets out the background to the current concern over water consumption in Sydney and reviews the findings of other comparable studies to set the context for the following analysis.

Section 2 outlines the data used in the analysis and the method used for selecting the 140 collector districts (CDs) that form the basis of the study. These CDs were sampled to provide representative sub-groups of the four main dwelling types as defined by the census: separate houses, semi-detached houses, flats in blocks under 4 storeys and flats in blocks in blocks over 4 storeys.

Section 3 presents the overall water consumption patterns for Sydney over the 1987 to 2003 period, focusing on household (i.e. dwelling) and per capita consumption.

Section 4 looks at consumption patterns in eastern and western Sydney.

Sections 5 and 6 focus on the consumption profiles of separate houses and multi-unit dwellings. These analyses present detailed accounts of the water use by these two main dwellings categories for the four dwelling type CD areas, by region and over time. In addition, Section 5 also includes detailed analyses for separate houses only of consumption patterns by dwelling tenure (owners/purchasers and tenants), mortgage status, land value and block size. These latter variables were derived from Sydney Water's and the Department of Lands' databases for each address.

Section 7 turns to a discussion of the role gardens might play in explaining water consumption in Sydney, including an analysis of the relationship between rainfall patterns and consumption to explore the explanation of the influence of garden watering.

Section 8 presents maps of household and per capita consumption profiles for all CDs in Sydney.

Section 9 proposes a new approach to Sydney's water supply.

Section 10 presents some concluding comments.

1 INTRODUCTION

The current drought (2001-2005) has raised the issue of water consumption to centre stage in public debate in Sydney. Ever since it was settled Sydney has drawn its supply of potable water from a variety of small sources. By the mid 1940s the series of dams that were the basis of Sydney's water supply could not maintain unrestricted supplies especially during the long hot summers when restrictions on water use were a frequent occurrence. Prior to 1940 the water supply authority, now called Sydney Water, investigated new sites to construct a dam to guarantee supplies into the future. The decision to build Warragamba Dam was based on the assumption that it would impound sufficient water to make Sydney 'drought proof'. However, for the first time since the dam was constructed in 1960 Sydney has experienced water restrictions, now at level 3 and unlikely to be relaxed anytime soon.

Although it was claimed that Warragamba Dam would be sufficient to supply Sydney over a lengthy drought it became clear by the early 1980s that it would be prudent to investigate alternative supplies of potable water. The last possible major supply of potable water within practical reach of Sydney was the Shoalhaven River to the south of the city. The proposal to dam that river and pump the water to Sydney was strongly opposed by a wide variety of interests including farming and environmental groups. The New South Wales government decided in March 2002 to defer indefinitely the construction of a dam on the Shoalhaven River. The decision was justified on the grounds that the success of the environmental education initiatives had meant that Sydney-siders had reduced their consumption and Warragamba Dam held reserves adequate to supply Sydney through long dry periods (Sydney Morning Herald 2003a).

Four factors have now cast doubt on the accuracy of the claim.

The first is that the population of the Sydney Metropolitan Area has grown much larger than was anticipated when the Dam was planned - Sydney's population was 2 million in 1951 but grew to 4 million in 2001 and is expected to reach 5 million by 2030. Warragamba Dam was built on population forecasts that envisaged adequate storage capacity until about 1980 (Sydney Water Board, 1968a). In fact, the Sydney Water Board at the same time were contemplating that major works, including the Welcome Reef Dam, should be undertaken on the Shoalhaven River area to cope with an expected population of 5 million by the year 2000 (Sydney Water Board, 1968b).

Secondly, the gross per capita water consumption of Sydney residents has increased above the ‘design demand’ as their standard of living has risen (White et al 2003), an increase which again was not anticipated. We note that the ‘designed’ daily consumption for the Melbourne water supply in the 1850s was 30 to 40 gallons (136 to 182 litres) per head (Dingle and Doyle 2003) while the designed demand for Newcastle in 1878 was estimated to be 20 gallons per head (91 litres) for ‘daily washing, drinking and culinary purposes’ although it was estimated that this could rise to 50 or even 80 gallons (227 to 364 litres) to allow for manufacturing and garden irrigation. The present gross per capita consumption in both these cities significantly exceeds these levels. The combined effect of these two factors is that the total consumption now exceeds the safe yield or design demand for the water supply system.

Third, in recent years there has been a general increase in the level of concern for environmental issues in urban water management (Kallis and De Groot 2003). This increasing concern over environmental issues has been reflected in the management of Sydney's water supply. One aspect of this has been a growing appreciation of the need to maintain environmental flows (Fitzhugh and Richter 2004) downstream of dams which has had particular significance on the Hawkesbury River, and has meant that water has had to be released from Warragamba Dam to improve the health of that river.

Finally, the rainfall pattern in the Sydney Metropolitan Area appears now to be less predictable (Flannery 2004) than it was assumed to be when Warragamba Dam was built. The claim made by Flannery appears to contradict the claims made by Pittock (1975) who found evidence that there was a major increase in annual rainfall in the middle to late 1940s over much of eastern Australia, and that by Suppiah and Hennessy (1998) that there have been large increases in both summer and winter rainfall in the eastern and south eastern regions of the country over the period 1910-1990. All of these commentators may be right because there is evidence in the rainfall records since the 1880s that there are 50 year ‘swings’ in the rainfall pattern for SE Australia. Without further detailed evidence of the pattern of rainfall in Warragamba's catchment or of the record of runoff from it we cannot conclude that Flannery's claim is correct. Whether this apparent variability in rainfall is due to long run statistical variability in precipitation in the catchment or to changes in the weather pattern (global climate change) induced by human agency is as yet unclear. If it is true that there is now less average runoff in the catchment the long term ability of Warragamba Dam to provide a reliable supply to Sydney Metropolitan Area without some reduction in demand must be brought into question. However, little research on water demand has been published and none that explores the spatial and special aspects of consumption, nor has there been any systematic research into water consumption and the urban environment despite claims that a more compact city will result in lower water consumption.

One of the ambitions of this research is to map water consumption for different kinds of development in different parts of the city so that water planners can better develop policies and programs to achieve a reduction in demand. A second ambition is to produce maps that will strengthen urban planners in their pursuit of planning, development and management policies that help reshape the demand.

The Context

The Australian Bureau of Statistics (ABS) reports *Water Account: Australia 2000-01* (ABS 2004a) and *Environmental Issues: People’s Views and Practices* (ABS 2004b) provide an analysis of the broad outlines of domestic water consumption by State. The ABS also conducted a survey of domestic water use in New South Wales in 2002 (ABS 2003) which found that 98.3% of the 1.5089 million dwellings in Sydney were connected to mains water - meaning the reticulated supply - of which 98% had no other source of supply. The overwhelming majority (97%) of those connected to mains water were also connected to a sewerage system. The great majority of these services, 1.1872 million, were provided by Sydney Water.

But what of the dwellings connected to the Sydney Water mains water supply? The 2002 ABS survey found that the bulk of them (94%) had a clothes washing machine with 99% of houses, but only four out of five flats, having one[1]. Some 39% of houses used washing machines six or more times a week compared with 14% of flats (houses used them on average 5.4 times compared with 3.5 times for flats). If we adjust this to account for the occupancy rate of the two dwelling types we find that houses use their machines 1.9 times per person and flats use them 1.7 times per person. This difference in use probably reflects the fact that houses are more likely to include young children who generate significant washing loads. Fewer than half the houses (47%) and only one in five flats or units had a dishwasher, although more than 35% of flats with a dishwasher had a new one compared with 27% of houses. All dwellings had at least one shower with 54% of houses and 86% of flats or units having one only. Only 9% of houses had no bathtub compared with one in five flats or units. Only one third of houses but four out of five flats or units had only one toilet. Of separate houses, semi-detached, row or terrace houses or town houses in Sydney, 17% had a pool, but only 5% had no garden.

The Problem

Whatever the cause of the growing inability of the water supply system to meet demand, whether it is due to growth in demand exceeding the supply, the need to maintain environmental flows, or reduced runoff in the catchment due to long run climatic cycles or to global climate change, the New South Wales government feels the need to act prudently. The safe yield from the system now has been exceeded on a number of occasions and the New South Wales government has been seeking ways of reducing consumption or reshaping demand. One of the policies the government has pursued over the last twenty years to reshape demand is that of urban consolidation. A cornerstone of the policy of urban consolidation was that it led to reduced stress on the environment. An essential element of this was the claim that higher density housing led to reduced water consumption (Holliday 2000). This argument seems to be 'intuitively obvious' and has therefore attracted political support, although the scientific or behavioural evidence to support the proposition was and remains lacking (Troy 1996).

A second, more recent initiative by Sydney Water Corporation has been to administer, since 1999, a major exercise in demand management (Turner et al 2005)[2]. Mandatory restrictions on water consumption with severe penalties for those breaking the restrictions were also introduced in 2003 (Sydney Water Corporation 2003). The government has also sought to introduce higher charges for higher volume consumers (Sydney Morning Herald 2003b). In 2005, outside the period of this study, IPART recommended that higher charges for water consumption be introduced to further curb consumption (Sydney Morning Herald 2005).

Most studies of consumption have focussed on the price of water and have sought to identify the price at which water consumption can be reduced (Davies and Dandy, 1995; Espey *et al*, 1997). Others have sought to establish socio-demographic explanations of water consumption (Aitken *et al* 1991, Askew and McGuirk 2004,

[1] In this ABS report reference to houses includes separate houses, semi detached, row or terrace houses or town houses, and flats includes both low and high rise flats or units.

[2] Note that water restrictions and demand management initiatives are introduced by the NSW Government but are administered, conducted or managed (depending on the initiative) by Sydney Water under requirements in their operating licence.

Dandy 1987, Loh and Coghlan 2003), while some have accepted physical determinist explanations based on simple comparison of household consumption for households in different forms of accommodation. The research reported in this paper seeks to develop on these analyses to explore in more detail for Sydney the links between water consumption, dwelling type and social composition and in doing so is based on the assumption that explanations of water consumption can be efficiently extracted from existing consumer records and by using Census and other property databases.

Other research on household water consumption

Several recent research studies have also explored the social and housing correlates of water consumption. It is useful to summarise the key findings of this research before proceeding, as they shed significant light on the issues that are the main focus of this paper.

The IPART study (2003)

The Independent Pricing and Regulatory Tribunal (IPART) of New South Wales advises governments on the pricing of urban services including energy and water supplies and the regulatory framework within which such services are delivered. In accordance with this remit IPART surveyed 2600 households in the Sydney, the Blue Mountains and Wollongong in 2003 (IPART 2004a and b) as part of a sophisticated exploration of the socio-demographic determinants of urban water demand.

Data from the study indicates that, on average, households in separate houses consume 304 kilolitres (kL) per year compared with 211 kL for those in semi detached dwellings or town houses, 192 kL for those in low rise flats and 148 kL for those in high rise flats (Figure 1). However, if the household consumption data are standardised to allow for the occupancy rates of the various dwelling types the picture changes significantly. Reworking the published IPART data indicates that there was virtually no difference between the *per capita* consumption of those who live in separate houses compared with those who live in flats, once allowance is made for the number of occupants (Table 1). The average annual per capita consumption of those living in fully owned houses and flats was essentially the same, at 104 kL per capita per year. The per capita consumption of those paying off their house or flat was also very similar: 82 kL per capita per year for houses compared with 78 kL for units. These levels of consumption are noticeably less than for those in houses and flats that were fully owned. The per capita consumption of those in privately rented houses was higher than that for those in privately rented flats, but both were lower than houses or flats owned or being paid off - households in privately rented houses consumed 85 kL per capita per year compared with 62 kL for those in privately rented units. Public housing tenants have higher per capita consumption whether they live in houses or flats: 106 kL per capita per year for houses compared with 92 kL for units. This may be due to the propensity of people who live in public housing to spend more of their time at home, but it may also be due to the fact that public housing tenants do not pay separately for water usage.

Figure 1: Average annual household water consumption by dwelling type 2003 (kL)
Source IPART 2004a

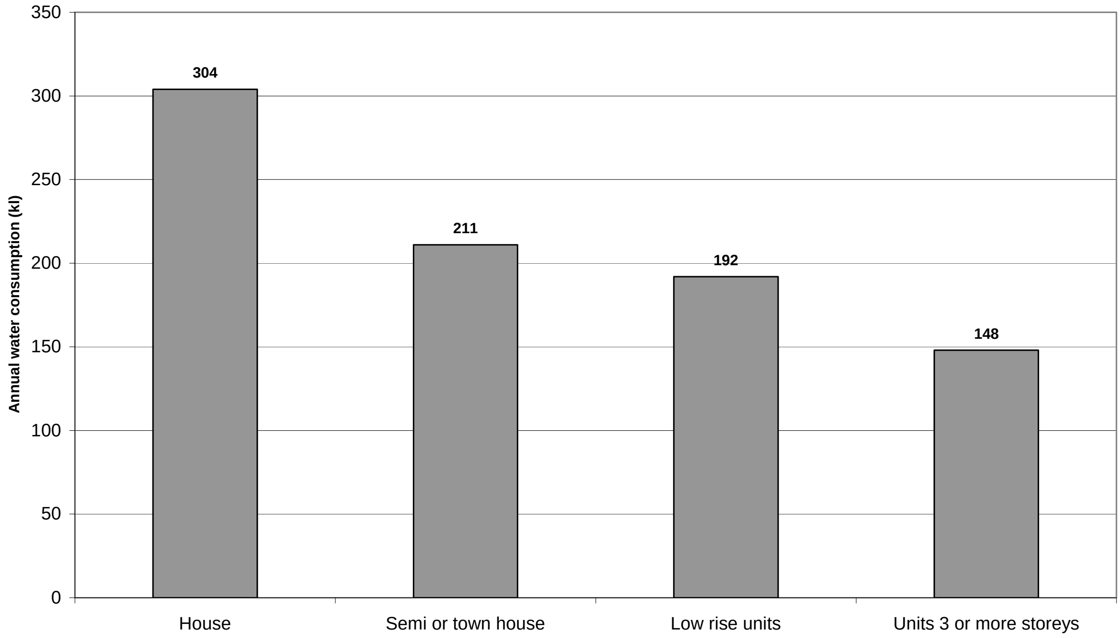


Table 1: The average annual per capita consumption for houses and units by tenure, 2003 (kL/p)
(derived from IPART, 2004a)

	Household Consumption (kL)	Average Household Size	Consumption per capita (kL)
Houses			
Owned	282	2.7	104
Paying Off	312	3.8	82
Rent Privately	289	3.4	85
Rent Publicly	339	3.2	106
Units			
Owned	176	1.7	104
Paying Off	203	2.6	78
Rent Privately	155	2.5	62
Rent Publicly	175	1.9	92

IPART offers some suggestions as to why the per capita consumption may not be simply a function of the physical form of accommodation. They suggest that consumption is more a function of the number and composition of the occupants, household income, dwelling tenure, the age of the dwelling and the number of water consuming services available in the dwelling. For example, in discussing the determinants of demand IPART estimated that, on average, households with single flush toilets used 21kl per year more than households with dual flush toilets.

The IPART study suggests that the size of household is a key determinant of consumption, but indicates that there are some economies of scale. Two person households consume 67% percent more water than a single person house while a three person household only uses 23% more water than a two person household. In their study of the social and spatial correlates of water use in the Sydney region Eardley *et al* (2005) also suggest that household size exerts an independent influence on per capita consumption.

These economies of scale are unlikely to be related to the number of toilets - people do not need to use toilets more frequently simply because there are more toilets. The economy of scale is more likely to be associated with the number of showers or baths in the dwelling, the use or dish and clothes washers and the way households function. Households with more than one member develop a 'rationing' or queuing approach to the use of bathrooms. It is a commonplace that household members trying to prepare themselves for the day find pressure on access to the bathroom becomes a determinant of the length of showers members take (unless they are teenagers!). This is made more pressing if the toilet and shower are in the same room. Dwellings with more than one bathroom are able to reduce this pressure with the consequence that household members' showers are likely to be longer.

The length of showers is also affected by the availability of hot water. The size of the hot water storage tank in the dwelling being the most obvious limitation to length of showers. The most common sized hot water tank in older houses and flats is 80 litres, although in new houses it is about 250 litres and about 120 litres in new flats, so that a 'physical' measure such as the volume of hot water storage may influence the length of showers, this is particularly so in dwellings where water is heated ‘off peak’. Small households can manage with a small tank and still enjoy long showers whereas the larger households are forced by household behaviour to share the limited resource. There are likely to be household behaviour economies when there are children in the household. For example, when children are small they have small baths, and are often bathed together. Parents are often too busy getting themselves ready for the day and preparing breakfasts and school lunches, etc., that they are too pressed for time to have the 'luxury' of a long shower. This pressure is especially acute in households where all adults work and are themselves pressed for time to get themselves and their children 'out of the house' on time. The anecdotal evidence, often repeated to the point of urban truth, of the tensions in households caused by teenagers who, it is claimed, spend too long in the shower is indication of the existence of these pressures but may also indicate that shower water consumption increases as children reach teenage years. However, households with ‘instantaneous’ or ‘endless’ supplies of hot water, particularly those with gas fired hot water systems, reduce this limitation on household and individual behaviour and consumption.

A small economy of scale may also be seen in the way households prepare food in the kitchen and in the way they use clothes washing and dish washing machines. Households with two members are not likely to use twice as much water as those with one member for cooking or clothes and dishwashing. Unfortunately the magnitude of this economy is not measured.

Domestic water consumption in Perth (2003)

A study of domestic water consumption in Perth between 1998 and 2001 (Loh and Coghlan 2003) supports the IPART findings with respect to the differences of consumption between houses and flats. The Perth study found in-house consumption *per capita* per day was essentially the same for both single residential dwellings and multi-residential dwellings (155 L/person/day compared with 166 L/person/day). The study also found that the components of in-house consumption were essentially the same for single and multi-residential development. But total average annual water consumption for single residential dwellings was substantially above that of multi-unit dwellings: 460 kL compared with 280 kL.

Both of these are significantly higher than the IPART data on consumption for dwellings in Sydney. However, total consumption in Perth includes a significant level of bore water usage (32% of houses in Perth have a bore) whereas in Sydney few houses have water bores. This, together with climatic differences, may well account for the differences between the Sydney and Perth studies.

2 SYDNEY METROPOLITAN AREA DOMESTIC WATER CONSUMPTION

Following a pilot study of water consumption in Adelaide by Troy and Holloway (2004), this paper explores the distribution of water consumption in Sydney. The research was designed to explore the consumption by dwelling types in different parts of Sydney. The research is based on a stratified sample of 140 census collector's districts (CDs) (each with approximately 250 dwellings) drawn throughout the Sydney Metropolitan Area (SMA).

Data

A range of data was assembled for each property address in these 140 CDs from six sources:

1. The land use cadastre: plot size.
2. The NSW Department of Lands property data base: mortgage status and land value.
3. Sydney Water consumer database: property level water consumption records for the period 1987-2003 (note that multi-unit developments typically have a ‘common’ supply) and housing tenure status.
4. The ABS census of population and housing for 2001: Collector District level data on socio-economic profiles for the 140 CDs.
5. The ANU SPLIN rainfall modeling package: estimated total monthly rainfall and moisture rates for each CD.
6. A land use survey

Data sources 1 to 3 were assembled into an address level database for all addresses in the 140 CDs. These CDs contained approximately 29,000 addresses for which matched data was sought. This approach allowed data from the three sources to be cross-analysed together. It also allowed aggregated CD level consumption averages to be analysed with CD level data from the census and for rainfall.

It is important to note that dwellings in which household consumption was less than 25kL were excluded from the data set as they were considered to be unoccupied (see Section 3 below). Further, those residential dwellings with extremely high consumption, or in mixed use developments were also excluded from the database.

Selection of CDs

Stage 1

The aim of this research was to estimate the consumption of water for different types of dwellings and areas by linking property details to individual water consumption records at the address level. A practical solution to ensuring sufficient samples of dwelling types were included in the analysis was achieved by targeting CDs with predominantly similar dwelling types.

Initially, all CDs in the Sydney Statistical Division (SD) were ranked by the proportion of dwellings in the 4 dwelling categories used by ABS to report the census of population and dwellings. These are:

- Areas of Wholly Separate Houses

- Areas of Predominantly Semi Detached Dwellings
- Areas of Predominantly Flats in a block of less than 4 storeys
- Areas of Predominantly Flats in a block of 4 or more storeys

Thresholds were set for CD selection in each of four strata to ensure sufficient numbers of CDs would be available to include in the subsequent analysis. CDs for the 'separate house' stratum were selected if 99 per cent or more of the dwellings were of this form. As the proportion of dwellings that are semi-detached is lower than for separate houses and they are more widely distributed than separate houses, the threshold for semi detached CDs in this stratum was set where at least 50 per cent or more of the dwellings in the CD were of this form. The thresholds for CDs in the stratum in which flats in a block of less than 4 storeys were the predominant form was 70 per cent, while the 'cut-off' point for CDs in the stratum where the predominant form of dwelling was in flats in a block or 4 or more storeys was 50 per cent. A total of 1,577 CDs was selected by these means (see Appendix 1).

Stage 2

The second stage of the selection process was undertaken to ensure that the choice of CDs for the study broadly reflected the socio-economic profile of the dwelling types across Sydney. A factor analysis was undertaken on each of the four sub-groups of CDs to identify factors that described the socio-economic composition within each sub-group. The analysis was based on a number of socio-economic variables from the 2001 Census. For further information about the factor analysis see Appendix 1.

After the factor analysis was run on CDs in each of the four strata, 35 CDs from each were selected as case study areas (Appendix 1) on the basis of the proportion of variance explained by each factor and its geographical distribution. Five factors explained 60-70% of the variance within each dwelling type stratum. For the four strata, 9 CDs were selected that scored highly on Factor 1, 8 from Factor 2, 7 from Factor 3, 6 from factor 4, and 5 from Factor 5. These 35 CDs were also chosen to reflect the range of locations across the Metropolitan Sydney area. Consequently, the 35 selected CDs for each dwelling area stratum not only had high scores for each factor within the sub-group, but were also distributed across four broad sub-regions (Inner Sydney, Northern Sydney, Inner West and Southern Sydney, and Western Sydney). In this way, the CDs selected for the analysis can be taken to reflect the main sub-market segments of each of the four dwelling type strata.

It should be stressed at the outset that the 140 CDs are not a simple random sample but constitute a stratified sample drawn from the total for Sydney. In this important respect, this study differs from that of the IPART study discussed above. Nevertheless, as we note below, the results are broadly consistent with this and other comparable studies into water consumption in Sydney.

It should be noted that all consumption estimates in the following tables derived from this analysis were significant at $p<0.05$, that is, the estimate is significant at the 95% confidence level. The tests applied were either a t-test or ANOVA test.

Figure 2 maps the distribution of the 140 sampled CDs across the metropolitan area overlaid on a Digital Elevation Model (DEM) of the Sydney basin derived from a 250 metre 9 second DEM with a national coverage (Stein *et al*,1998) developed using the ANUDEM program (Hutchinson, 1989). Most of the sampled CDs are in the lower elevation areas in the Metropolitan Area – the areas most easily settled and serviced.

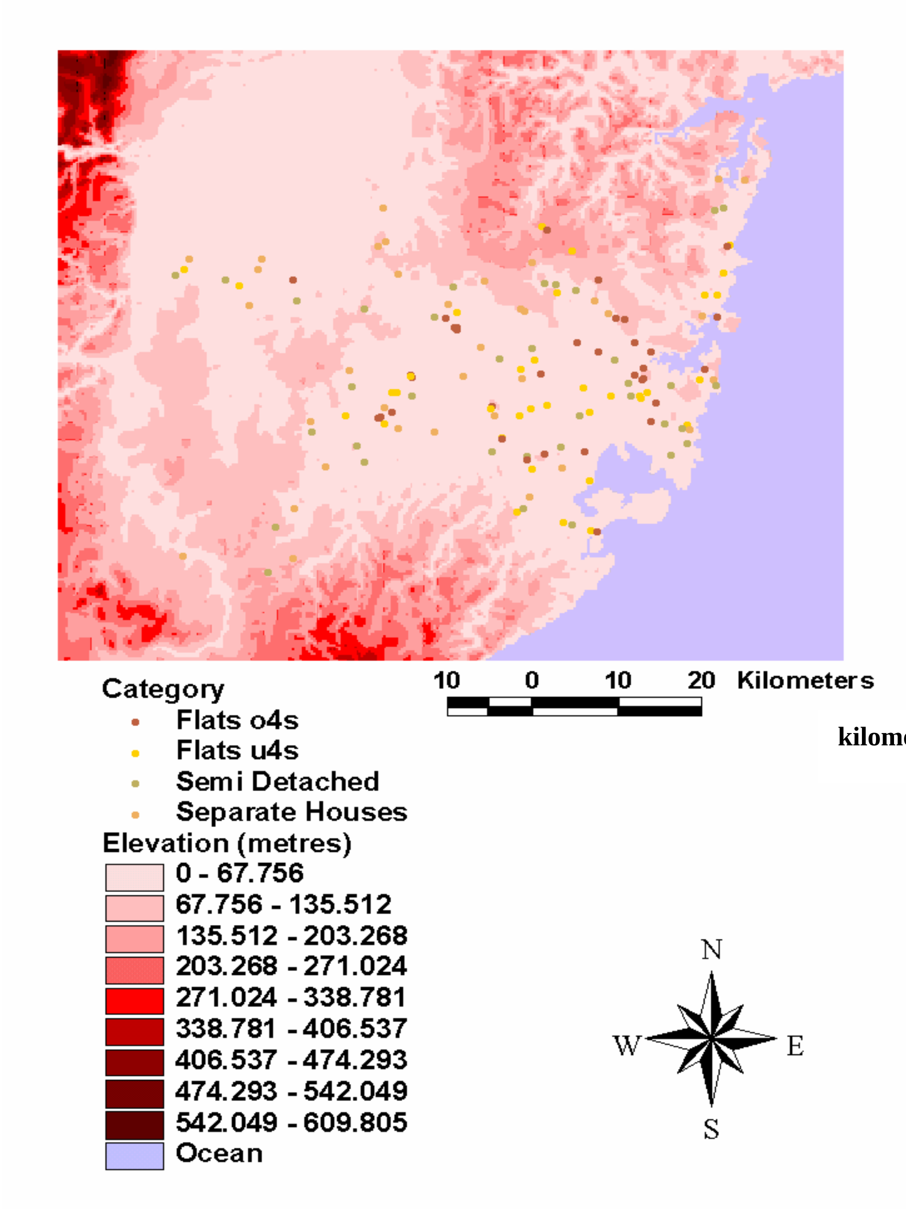
Land Use Survey

As the emphasis of this study was the examination of water consumption for different dwelling types across Sydney, a land use survey was undertaken to accurately identify the types of dwellings in each CD. The Sydney Water database obtained for this project contained some information about dwelling type. However, there was some confusion as to which dwelling description 'semi detached dwellings' pertained too. For flats and separate houses the dwelling type identifier used by Sydney Water was adequate for the purposes of this study, in CDs that were solely separate houses or flats. In areas where there were semi detached dwellings, or there was some conflict between the Sydney Water database and the Census, an on-ground survey was carried out to accurately identify the dwelling type for each address in the CD. In all over 80 CDs were surveyed to establish an accurate property descriptor for each property.

Consumer Survey

In addition to extracting data from property based records for all properties in the 140 CDs a household survey was carried out on a sample of 2200 households randomly chosen from the households in the 140 CDs. The sample was drawn to enable comparisons of the behaviour and attitudes to water consumption of households in the four types of housing. Qualitative surveys were also conducted by constructing focus groups to elicit insights into the attitudes of households to water consumption and conservation (Troy et al 2005 forthcoming).

Figure 2: Distribution of sampled CDs in the Sydney Metropolitan Area



3 OVERALL PATTERNS OF WATER CONSUMPTION

Average per dwelling consumption

Table 2 sets out the average annual household consumption for dwellings in each of the four development areas at five yearly intervals over the 1987 to 2003 period. Figure 3 charts the average consumption per dwelling for each of the four development areas over the whole period. Records where the consumption per dwelling was less than 25kL per year were removed from the analysis. Most of the low consumption single dwellings are in areas where the number of dwellings unoccupied or vacant at the time of the census was greatest. This suggests that many of the lowest consumption single dwellings were, to all intents and purposes, unoccupied at the time of the census and the 'consumption' may be due to substantial periods when they were unoccupied together with leakages in their water supply. Similarly, properties with abnormally high consumption were removed from analysis. The abnormally high consumption properties tended to be higher density dwellings the removal of which tends to reduce the apparent consumption per household of higher density housing.

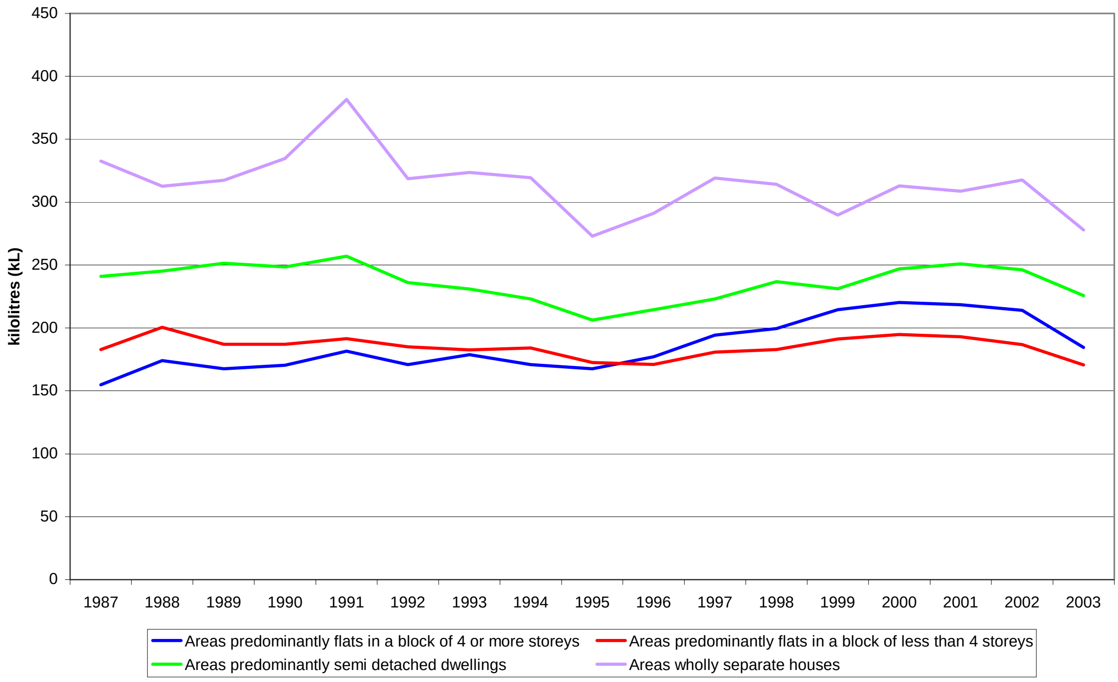
Table 2: Average annual water consumption per dwelling for the stratified sample 140 CDs, selected years 1987-2003 (kL)

		1987	1991	1996	2001	2002	2003
Areas predominantly flats in a block of 4 or more storeys	Total Consumption (kL)	830,585	1,002,220	1,101,272	1,577,159	1,632,178	1,196,373
	Total Dwellings	5,361	5,517	6,221	7,221	7,623	6,482
	Consumption per Dwelling (kL)	**155**	**182**	**177**	**218**	**214**	**185**
Areas predominantly flats in a block of less than 4 storeys	Total Consumption (kL)	1,177,227	1,282,179	1,205,197	1,422,555	1,385,877	1,173,769
	Total Dwellings	6,436	6,694	7,046	7,365	7,417	6,880
	Consumption per Dwelling (kL)	**183**	**192**	**171**	**193**	**187**	**171**
Areas predominantly semi detached dwellings	Total Consumption (kL)	751,693	943,561	848,807	1,174,970	1,242,347	1,003,132
	Total Dwellings	3,118	3,671	3,956	4,683	5,046	4,442
	Consumption per Dwelling (kL)	**241**	**257**	**215**	**251**	**246**	**226**
Areas wholly separate houses	Total Consumption (kL)	1,628,423	1,904,120	1,474,076	1,804,434	1,950,059	1,665,924
	Total Dwellings	4,896	4,990	5,064	5,847	6,137	5,996
	Consumption per Dwelling (kL)	**333**	**382**	**291**	**309**	**318**	**278**

Note: $p<0.05$

Properties classified as 'mixed development' were removed from the data set because they included commercial or industrial consumption which was not separately measured and for which it was impossible therefore to obtain accurate measures of domestic consumption for the residential units. This has the effect of slightly understating the consumption of multi-unit housing.

Figure 3: Average annual water consumption per dwelling for the sample 140 CDs, 1987-2003 (kL)



Note that 1991 was a drought year and 1995 was a wet year and consumption was affected by water restrictions that were in force from November 1994 until March 1995 but were then relaxed.

Taking 2001 as a benchmark year (and one that will be used later in the report to correlate with 2001 Census data), the average annual dwelling consumption figures across the 140 sampled CDs ranged from 309kL for CDs comprised of houses to 193kL for areas of predominantly low rise flats (Table 2 and Figure 4).

CDs in the separate house category had the highest water usage per household, decreasing from 333kL per annum in 1987 to 278kL per annum in 2003, and peaking in 1991 at 382 kL per annum. Dwellings in CDs with predominantly semi-detached housing had the second highest levels of water consumption over the period.

CDs with a predominance of flats in a block of less than 4 storeys (low rise flats) had the third highest rates of water consumption up until 1996 when CDs with predominantly flats in a block of 4 or more storeys (high-rise flats) overtook low-rise flats. This may reflect the fact that the more recent high-rise flats are of a higher standard, and include more appliances, than the older apartments.

Over the period 1987 to 2001, average household consumption figures for areas predominantly comprising separate houses declined due initially to Sydney Water's educational programs but later (since 1999) to its programs directed at demand management (Turner et al 2005). Household consumption for all other forms of housing has fallen since 2001 due, no doubt, to the combined effect of community awareness of drought conditions, the educational campaigns of Sydney Water and its demand management programs together with the effect of recent water restrictions (Figure 3).

Evidence to explain some of these differences was found in the household survey. Households in low-rise flats were less likely to have access to swimming pools and inside and outside spas compared with high-rise flats which is likely to lead to higher levels of consumption in high-rise flats. Low-rise flats, however, are less likely to have dual flush toilets which would imply higher levels of consumption compared with high-rise flats or houses (Troy et al 2005).

Another behavioural factor that tends to explain the difference in consumption between households in separate houses compared with higher density forms of housing is the way in which dish washing is managed. Households in separate and semi-detached houses have a greater tendency to never rinse their dishes (28.4% and 29.7% respectively). compared with households in low rise and high-rise flats (21.7% and 23.4% respectively) This is confirmed by the proportions that rinse their dishes before and after washing them (18.7% for separate houses, 20.5% for semi-detached house, 22.35 for low-rise flats and 24% for high-rise flats). This may be due to the fact that households in flats are supplied from a 'common' supply whereas those in separate and semi-detached houses have their supplies individually metered. We note as an extension of this point that more than a quarter of households in high-rise flats wash their dishes under running water whereas only half that proportion of those in separate houses do.

Households in low and high-rise flats are more likely to obtain their hot water from a communal supply compared with those in separate house which may also tend to lead to greater consumption in the higher density housing.

The higher density forms of housing are also more likely to be rented which in turn leads to another systemic explanation in factors that are likely to lead to higher recorded consumption in those forms of housing compared with separate houses. This is reflected in the higher proportions of higher density housing reporting drips or leaks in showers, toilet cisterns, taps and pipes than for separate houses. The percentages are low in all forms of housing but the ratio between the forms may be high e.g. 1.8% of separate houses reported leaks in showers whereas 4.8% of low-rise flats and 2.7% of high-rise flats did. Similar differences were reported for leaks in toilets, taps and pipes. That is, it may be posited that renters are less likely to take action to eliminate leaks and or their landlord does not take action on their complaints. The common supply to flats may also encourage flat dwellers to ignore leaks because they do not separately pay for their water compared with households in houses who do.

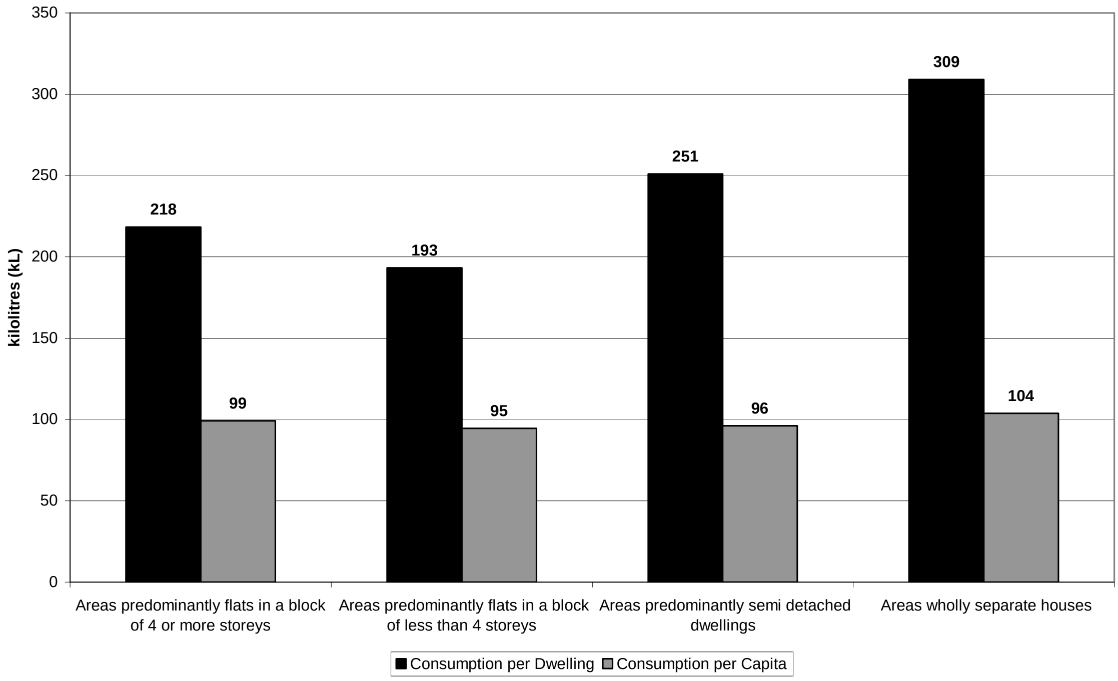
Average per capita consumption

Using the 2001 Census population counts for each CD, it is possible to estimate the per capita water consumption in different kinds of dwelling for that year. The per capita measures were derived by taking the total consumption for each different dwelling type in each CD, then dividing these figures by the census population count for that dwelling type. The average per capita consumption for all the CDs in each development category was then calculated.

Using consumption and population data from the 2001 census, it is clear that CDs in areas wholly separate houses had the highest annual per capita consumption at 104 kL per person (Figure 4 and Table 3). This was closely followed by areas of predominantly flats in a block of 4 or more storeys (99 kL per person) and areas of predominantly semi detached dwellings (96 kL per person). Areas predominantly of flats in a block of less than 4 storeys had the lowest consumption per capita at 95 kL per person in 2001.

Low-rise flats tend to have fewer washing machines or shared laundries. Presumably they use Laundromats for their washing which means the 'real' per capita consumption of households in low rise flats is understated.

Figure 4: Average annual water consumption per dwelling and per capita for the four dwelling type areas, 2001 (kL)



The results presented in Table 3 show that average per capita water consumption for multi-unit dwellings ranged from 85kL per year in semi-detached housing areas to 98kL per year in areas predominantly comprising flats in blocks of 4 or more storeys. Annual per capita consumption for separate houses averaged 104kL, in areas of wholly separate houses increasing to 115kL for separate houses in areas predominantly comprising flats in blocks of four or more storeys.

Table 3: Average annual water consumption per capita for the sample 140 CDs, 2001 (kL)

		Separate Houses	Semi Detached Dwellings	Flats	*Multi-Unit Dwellings*	Total
Areas predominantly flats in a block of 4 or more storeys	Total Dwellings	240	40	6,941	6,981	7,221
	Consumption per Dwelling	358	244	213	214	218
	Persons per Household	3.10	2.84	2.16	*2.18*	2.20
	Consumption per Capita	**115**	**86**	**99**	**98**	**99**
Areas predominantly flats in a block of less than 4 storeys	Total Dwellings	506	320	6,539	6,859	7,365
	Consumption per Dwelling	333	198	182	183	193
	Persons per Household	3.03	2.30	1.96	*1.97*	2.04
	Consumption per Capita	**110**	**86**	**93**	**93**	**95**
Areas predominantly semi detached dwellings	Total Dwellings	2,050	1,779	854	2,633	4,683
	Consumption per Dwelling	302	242	146	211	251
	Persons per Household	3.13	2.55	1.77	*2.47*	2.61
	Consumption per Capita	**97**	**95**	**82**	**85**	**96**
Areas wholly separate houses	Total Dwellings	5,847	NA	NA	*NA*	5,847
	Consumption per Dwelling	309	NA	NA	*NA*	309
	Persons per Household	2.97	NA	NA	*NA*	2.97
	Consumption per Capita	**104**	**NA**	**NA**	***NA***	**104**

Notes: $p<0.05$; multi-unit dwellings include flats and semi detached dwellings

Comparison with other research findings

Comparison of these results to other similar research provides some degree of confidence in the levels of consumption revealed in the above analysis. As we noted above, reworking the 2003 IPART survey data shows that water consumption per capita in Sydney, Blue Mountains and Wollongong was on average 92 kL per year (IPART 2004a) The IPART derived per capita estimates ranged from 62 kL per year for privately rented units to 104 kL per year for fully owned houses and for fully owned units. The IPART data also show that single person households had the highest per capita consumption (128 kL per year), followed by couples without children (113 kL per year), single parent families (90 kL per year) and two parent families (84 kL per year).

The Australian Bureau of Statistics 2000-01 audit of water usage in all States and Territories (ABS 2004a) gave an average per capita water consumption for NSW of 101 kL. While acknowledging the different methodologies and geographical coverage involved in these various estimates of consumption, the range of results produced by the present analysis is broadly supported by those of other comparable research.

Eardley et al (2005) estimated the per capita consumption in Sydney to be 70.5kL in 2001. This estimate is significantly lower than all other estimates and may be an artifact of the methodology employed in this study which relied on gross average consumption for CDs.

4 WATER CONSUMPTION BY SUB-REGION[3]

Does the consumption of water vary by broad sub-region in Sydney? It might be thought that more suburban locations will have higher water consumption averages than those to the east and inner city areas. To explore this issue, we have split the 140 CDs into two groups for Eastern and Western Sydney (see Appendix 3 for a definition of these regions).

Household consumption by region

Taking CDs in areas of wholly separate houses first, eastern Sydney CDs consistently had higher annual average household consumption rates than those in western Sydney in 2003 (Table 4). Illustrative figures for 2003 were 298kL per annum in the east and 270kL in the west.

Households in CDs of predominantly high-rise flats consumed an average of 170kL in eastern Sydney in 2003 compared with 206kL in western Sydney. This may be due to the generally larger size of households in western Sydney CDs compared with those in eastern Sydney CDs.

The trends for the other two dwelling type categories showed that average household consumption was higher in the west than the east of Sydney. For example, in 2003, households in areas of predominantly low-rise flats consumed an average 164kl per annum in the eastern suburbs compared with 187kL in western suburbs. Households in CDs of predominantly semi-detached dwellings in the eastern suburbs had the second highest levels of water consumption consuming 218kL per year in 2003 compared with 238kL for the western suburbs.

Since 2001 average annual household consumption appears to have fallen about 10% in both eastern and western suburbs. Most of the fall in consumption appears to have taken place in the eighteen months to the end of 2003, indicating that households have responded well to the educational programs of Sydney Water and to the demand management initiatives in place since 1999. Mandatory water restrictions did not come into force until October 2003 so had little effect on the consumption in the period of the study.

Per capita consumption by region

Average annual water consumption per capita in 2001 was also calculated for eastern and western Sydney CDs (Table 5 and Figure 5). In 2001, the highest per capita rates of consumption were recorded in CDs of wholly separate houses in eastern Sydney (113kL per person per annum) and in CDs of predominantly high rise flats in eastern Sydney (105kL per person per annum). In western Sydney, the highest per capita water consumption levels were recorded in CDs wholly of separate houses (100kL per person per annum), followed by CDs of predominantly low-rise flats and CDs of predominantly high-rise flats (92kL per person per annum). Areas of predominantly high-rise flats in eastern Sydney had significantly higher per capita levels of water consumption than those in western Sydney. CDs of predominantly low rise flats in eastern Sydney had roughly similar levels of per capita consumption in 2001 (95kL

[3] For a list of the local government areas in eastern and western Sydney see Appendix 2.

per person per annum) to those in western Sydney (92kL per person per annum). Areas of predominantly semi detached dwellings had rates of water consumption per capita of 103kL in eastern Sydney and 89kL in western Sydney.

The higher per capita consumption of households in areas of predominantly high-rise flats in eastern Sydney is unlikely to be solely attributable to the separate houses in the areas. It may simply be a reflection of the fact that households in the higher rise flats in the eastern suburbs tend to have higher income, live in more modern dwellings with more appliances and have gardens or pools in their developments. They also tend to have smaller sized households which, as the IPART study showed, have higher per capita water consumption.

Table 4: Average annual water consumption per dwelling in Eastern and Western Sydney, selected years, 1987-2003 (kL)

		1987	**1991**	**1996**	**2001**	**2002**	**2003**
		Eastern Sydney	Eastern Sydney	Eastern Sydney	Eastern Sydney	Eastern Sydney	Eastern Sydney
Areas predominantly flats in a block of 4 or more storeys	Total Consumption (kL)	460,581	567,643	616,288	954,464	1,011,288	661,038
	Total Dwellings	3,040	3,069	3,600	4,386	4,785	3,880
	Consumption per Dwelling (kL)	**152**	**185**	**171**	**218**	**211**	**170**
Areas predominantly flats in a block of less than 4 storeys	Total Consumption (kL)	812,123	859,548	788,039	983,001	963,870	820,562
	Total Dwellings	4,537	4,579	4,794	5,236	5,291	4,993
	Consumption per Dwelling (kL)	**179**	**188**	**164**	**188**	**182**	**164**
Areas predominantly semi detached dwellings	Total Consumption (kL)	444,968	542,687	494,961	653,482	690,535	576,476
	Total Dwellings	1,938	2,112	2,321	2,687	2,895	2,647
	Consumption per Dwelling (kL)	**230**	**257**	**213**	**243**	**239**	**218**
Areas wholly separate houses	Total Consumption (kL)	601,764	674,187	507,053	572,499	599,738	507,155
	Total Dwellings	1,666	1,696	1,718	1,736	1,731	1,703
	Consumption per Dwelling (kL)	**361**	**398**	**295**	**330**	**346**	**298**

		1987	**1991**	**1996**	**2001**	**2002**	**2003**
		Western Sydney	Western Sydney	Western Sydney	Western Sydney	Western Sydney	Western Sydney
Areas predominantly flats in a block of 4 or more storeys	Total Consumption (kL)	370,004	434,577	484,984	622,695	620,890	535,335
	Total Dwellings	2,321	2,448	2,621	2,835	2,838	2,602
	Consumption per Dwelling (kL)	**159**	**178**	**185**	**220**	**219**	**206**
Areas predominantly flats in a block of less than 4 storeys	Total Consumption (kL)	365,104	422,631	417,158	439,554	422,007	353,207
	Total Dwellings	1,899	2,115	2,252	2,129	2,126	1,887
	Consumption per Dwelling (kL)	**192**	**200**	**185**	**206**	**198**	**187**
Areas predominantly semi detached dwellings	Total Consumption (kL)	306,725	400,874	353,846	521,488	551,812	426,656
	Total Dwellings	1,180	1,559	1,635	1,996	2,151	1,795
	Consumption per Dwelling (kL)	**260**	**257**	**216**	**261**	**257**	**238**
Areas wholly separate houses	Total Consumption (kL)	1,026,659	1,229,933	967,023	1,231,935	1,350,321	1,158,769
	Total Dwellings	3,230	3,294	3,346	4,111	4,406	4,293
	Consumption per Dwelling (kL)	**318**	**373**	**289**	**300**	**306**	**270**

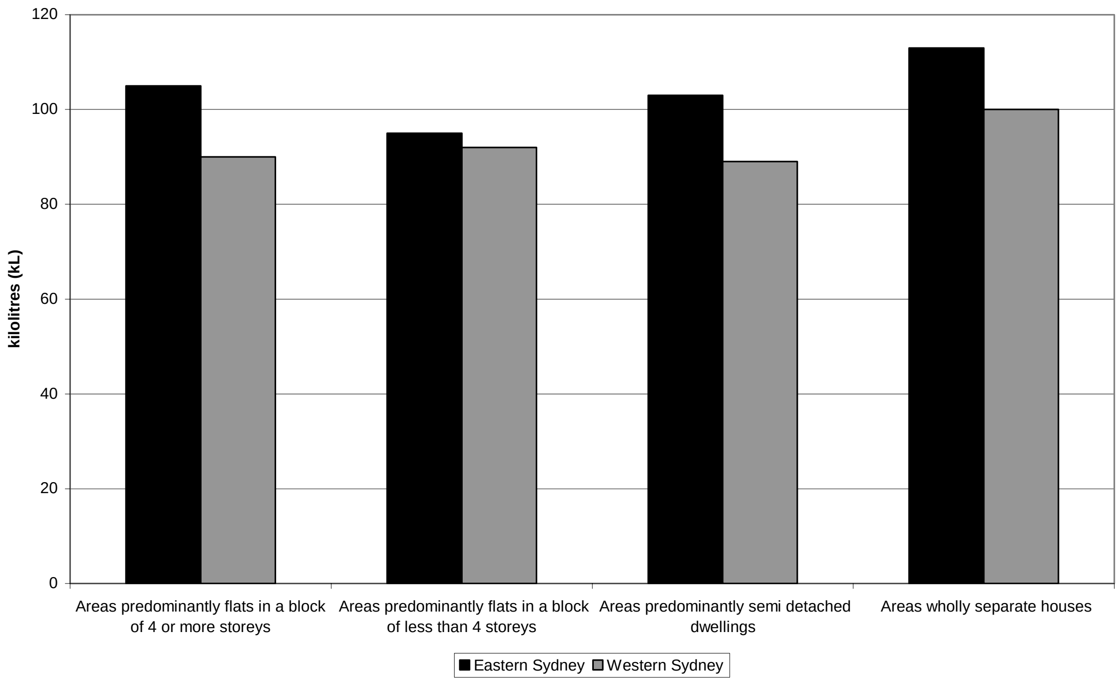
Note: $p<0.05$

Table 5: Average annual water consumption per capita for CDs with high concentrations of particular dwelling types, 2001 (kL)

		Eastern Sydney	Western Sydney	Total
Areas predominantly flats in a block of 4 or more storeys	Total Dwellings	4,386	2,835	7,221
	Consumption per Dwelling	218	220	218
	Persons per Household	2.07	2.44	2.20
	Consumption per Capita	**105**	**90**	**99**
Areas predominantly flats in a block of less than 4 storeys	Total Dwellings	5,236	2,129	7,365
	Consumption per Dwelling	188	206	193
	Persons per Household	1.97	2.23	2.04
	Consumption per Capita	**95**	**92**	**95**
Areas predominantly semi detached dwellings	Total Dwellings	2,687	1,996	4,683
	Consumption per Dwelling	243	261	251
	Persons per Household	2.37	2.94	2.61
	Consumption per Capita	**103**	**89**	**96**
Areas wholly separate houses	Total Dwellings	1,736	4,111	5,847
	Consumption per Dwelling	330	300	309
	Persons per Household	2.91	2.99	2.97
	Consumption per Capita	**113**	**100**	**104**

Notes: $p<0.05$

Figure 5: Average annual water consumption per capita for CDs with high concentrations of particular dwelling types, Eastern and Western Sydney, 2001 (kL)



5 WATER CONSUMPTION FOR SEPARATE HOUSES

This section focuses on the water consumption outcomes for separate houses. Water consumption records for each house in the case study CDs were selected from the Sydney Water database in combination with the land use survey. In addition, the Department of Lands property database includes information on the mortgage status and land value of the property for separate houses, while the land use cadastre provides data on the block size. These have been linked together with the water consumption records to provide additional analyses of the characteristics of consumption.

Household consumption

The range of consumption per separate house is very wide with the top 2.5% of consumers in separate houses in the 140 CDs having a mean consumption in 2001 of 3.2 times the average for all houses and over 20 times the consumption of the lowest 2.5% of consumers (Table 6). That is, the 2.5% highest consuming households consumed about 8.2% of the total consumption in 2001, while the lowest 2.5% consumed only 0.4% of total consumption. By 2003 the top 2.5% still consumed 3.3 times the average and more than 21 times the lowest 2.5%. We cannot say what the per capita consumption is for these households, although it is likely that the lowest consuming households are single person households. It is also unlikely that household size is the major determinant of household consumption for the top 2.5% of consumers.

Table 6: The proportion of total household water consumption for separate houses from the top and bottom 2.5% and middle 95% of records for selected CDs in selected years (kL)

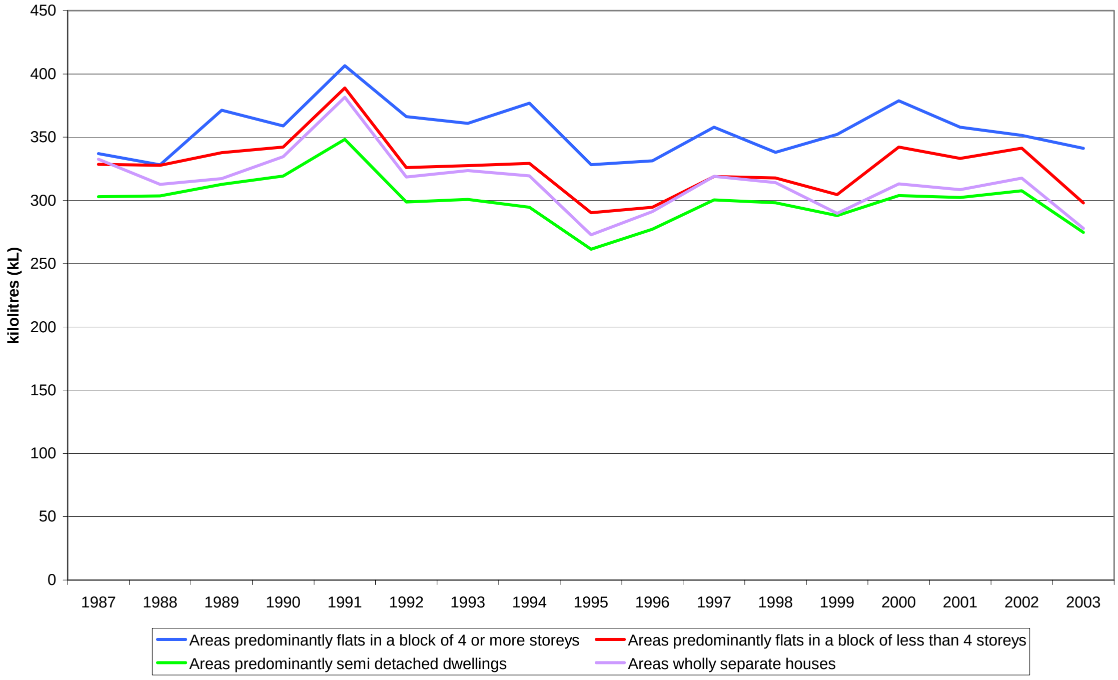
		1987	1991	1996	2001	2002	2003
Bottom 2.5% of Consumers	Total Consumption	4,727	5,890	7,157	9,548	9,461	9,052
	Proportion of Total Consumption	0.2%	0.2%	0.3%	0.4%	0.3%	0.4%
	Total separate houses	107	115	163	201	199	211
	Consumption per Dwelling	44	51	44	48	48	43
Middle 95% of Consumers	Total Consumption	2,085,091	2,491,082	1,951,083	2,448,785	2,627,843	2,209,635
	Proportion of Total Consumption	91.3%	91.6%	91.5%	91.4%	91.4%	91.0%
	Total separate houses	6,688	6,914	7,001	8,219	8,612	8,231
	Consumption per Dwelling	312	360	279	298	305	268
Top 2.5% of Consumers	Total Consumption	195,184	221,689	175,065	220,485	238,710	210,208
	Proportion of Total Consumption	8.5%	8.2%	8.2%	8.2%	8.3%	8.7%
	Total separate houses	202	202	199	223	246	229
	Consumption per Dwelling	966	1,097	880	989	970	918

Note: $p<0.05$

If the data are disaggregated into sub-regions, we see that relatively few of the lower consuming households are in the Eastern suburbs whereas a high proportion of the high consuming households are located there. The reverse is true in the Western suburbs. In fact, half of the top 2.5% consumers live in the higher socio-economic suburbs such as Coogee, Pennant Hills, Rose Bay, Strathfield, and Carlingford.

Separate houses in areas that were predominantly flats of four storeys and above had higher per household consumption than single dwellings in areas that were predominantly flats three storeys and less, terrace or semi-detached housing or wholly separate houses (Table 7 and Figure 6). The differences are not substantial but are consistent over time, although we note that the differences tend to narrow over time. This may be, in part due to the higher status locations of areas of flats four storeys and above.

Figure 6: Average annual household water consumption for separate houses by area category, 1987-2003 (kL)



Note: $p<0.05$

Figure 6 reveals that there has been a long run small decline in domestic consumption of water for houses in the different development categories, with a stronger downward trend in the period from 2000. It also suggests that the consumption peak in 1991 and the lowest consumption in 1995 might each be affected by the rainfall pattern over the period - 1991 was a drought year and 1995 was a high rainfall year (see Appendix 4 for the rainfall records of Sydney from 1987 to 2002) and, as we have noted, water restrictions were in force from late 1994 until mid 1995. The long run decline in domestic water consumption for houses may be due in part to the introduction of dual flush toilets, the fall in lot sizes that has occurred over the last twenty years and the increase in size of houses which has reduced the garden area as well as to the increase in the planting of native plants in house gardens. The more recent decline may also have been due to the effectiveness of the demand management initiatives taken by Sydney Water.

Table 7: Average annual water household consumption for separate houses by area category, selected years 1987-2003 (kL)

		1987	1991	1996	2001	2002	2003
Areas predominantly flats in a block of 4 or more storeys	Total Consumption	77,861	96,351	80,207	85,886	85,066	83,613
	Total Separate Houses	231	237	242	240	242	245
	Consumption per Dwelling	337	407	331	358	352	341
Areas predominantly flats in a block of less than 4 storeys	Total Consumption	158,048	193,317	148,197	168,603	172,698	149,285
	Total Separate Houses	481	497	503	506	506	501
	Consumption per Dwelling	329	389	295	333	341	298
Areas predominantly semi detached dwellings	Total Consumption	420,670	524,873	430,825	619,895	668,191	530,073
	Total Separate Houses	1,389	1,507	1,554	2,050	2,172	1,929
	Consumption per Dwelling	303	348	277	302	308	275
Areas wholly separate houses	Total Consumption	1,628,423	1,904,120	1,474,076	1,804,434	1,950,059	1,665,924
	Total Separate Houses	4,896	4,990	5,064	5,847	6,137	5,996
	Consumption per Dwelling	333	382	291	309	318	278

Note: $p<0.05$

Although there has been a useful reduction in household water consumption for separate houses the lack of detailed end use studies of internal and external water consumption means that we cannot say with certainty how the reduction in consumption over the recent past has been achieved. The recent drought has raised understanding of the critical stage reached in water supplies that has also undoubtedly raised awareness of the need to reduce consumption. The introduction of mandatory water restrictions since 2003 is also likely to have modified general behaviour. The pronounced decline in total consumption since water restrictions were introduced is evidence of their efficacy but these effects are not reflected in the study period.

Per capita consumption by region

While water consumption for separate houses does not vary much whether the houses are in the areas of predominantly higher density dwellings or whether the areas are wholly separate housing, once we take account of the house occupancy rates we see a different picture. Moreover, there is a distinctive geographical variation in the results. Households in the western suburbs tend to be larger than those in the Eastern suburbs with the result that those living in separate houses in the Eastern suburbs consume more water per capita than those in the Western suburbs (Table 8).

The most prominent feature of Table 8 is the difference between eastern and western Sydney in the per capita consumption levels of separate houses in areas of high-rise flats:

Figure 7: Average annual household water consumption for separate houses by area category, selected Eastern and Western Sydney CDs, 1987-2003 (kL)

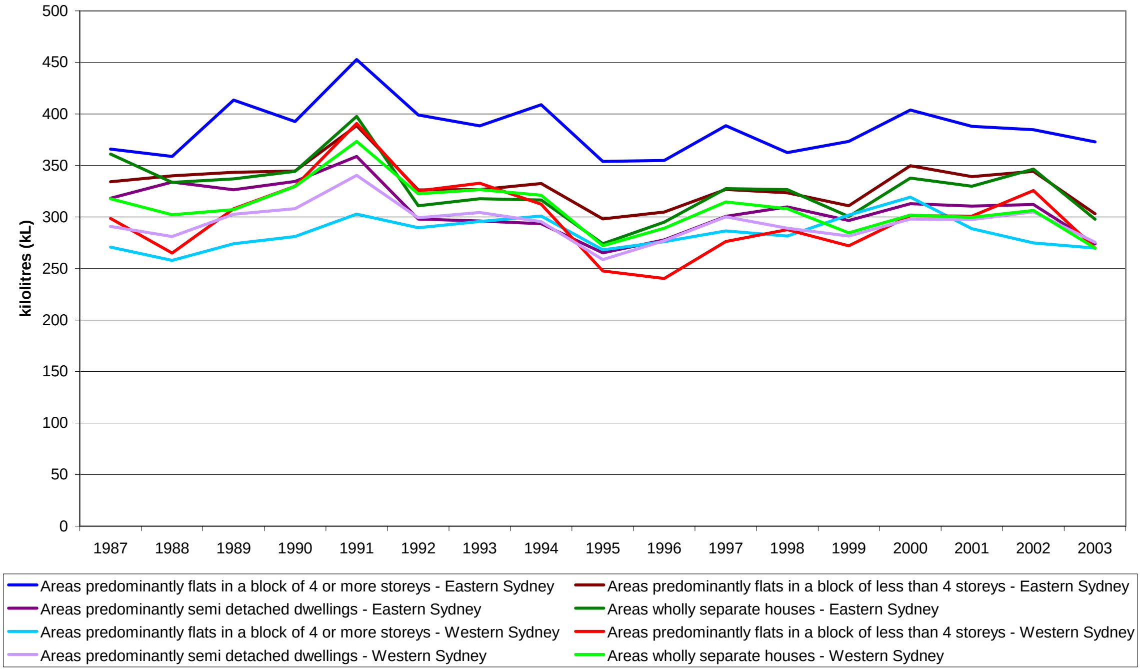


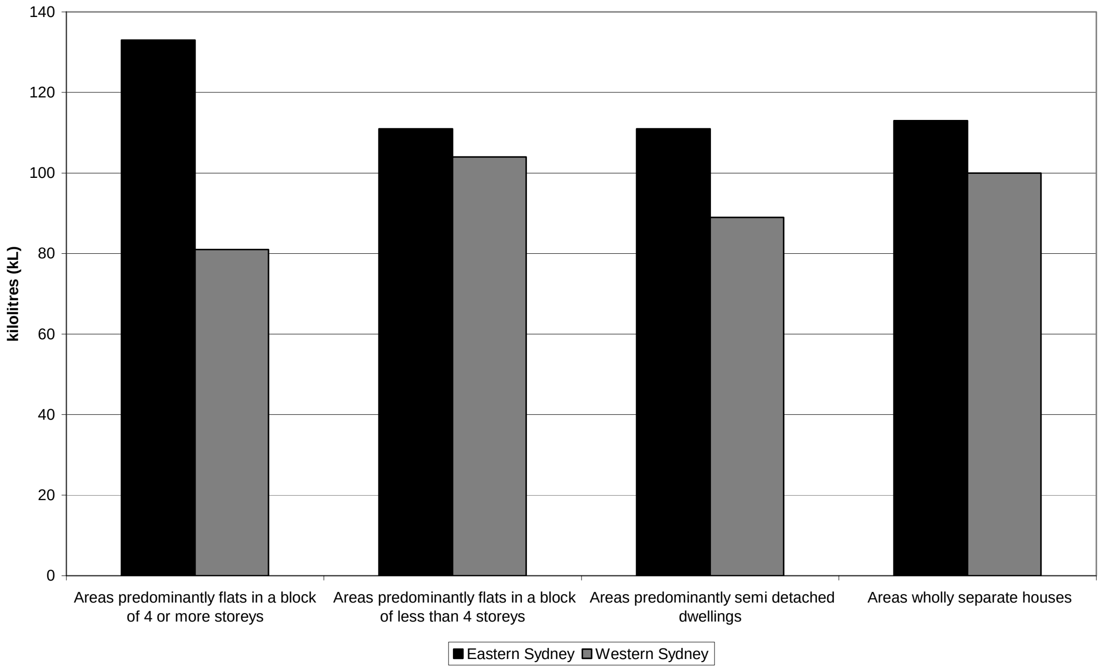
Table 8: Average annual per capita water consumption for separate houses in Eastern and Western Sydney CDs by area category, 2001 (kL)

		Eastern Sydney	Western Sydney	Total
Areas predominantly flats in a block of 4 or more storeys	Total Dwellings	167	73	240
	Consumption per Dwelling	388	289	358
	Persons per Household	2.92	3.56	3.10
	Consumption per Capita	**133**	**81**	**115**
Areas predominantly flats in a block of less than 4 storeys	Total Dwellings	427	79	506
	Consumption per Dwelling	339	301	333
	Persons per Household	3.06	2.89	3.03
	Consumption per Capita	**111**	**104**	**110**
Areas predominantly semi detached dwellings	Total Dwellings	758	1,292	2,050
	Consumption per Dwelling	311	298	302
	Persons per Household	2.81	3.36	3.13
	Consumption per Capita	**111**	**89**	**97**
Areas wholly separate houses	Total Dwellings	1,736	4,111	5,847
	Consumption per Dwelling	330	300	309
	Persons per Household	2.91	2.99	2.97
	Consumption per Capita	**113**	**100**	**104**

Notes: $p<0.05$

133 kL for the former and 81 kL for the latter in 2001 (although note the relatively small number of cases in these sub-samples). Overall, this relationship is maintained for separate houses in other areas, although the differences are much less pronounced (Figure 7). In general, then, per capita consumption of those who live in separate houses in the Eastern suburb CDs is higher than that for selected Western suburb CDs, which is consistent with the general picture noted above.

Figure 8: Average annual per capita water consumption for separate houses by different area categories in selected Eastern and Western Sydney CDs, 2001 (kL)



Using the Department of Lands identification of whether houses were rented or owner occupied it is clear that in recent years households in rented houses tend to have slightly higher levels of consumption than those that are owner-occupied (Table 9). We can only speculate whether this difference is because renters tend not to pay separately for their water. For this analysis we use 2003 for the study year because we could not extract Department of Lands data for earlier years. In 2003 for example houses in areas of wholly separate houses being rented consumed 287 kL per annum compared with 272

Table 9: Average annual household water consumption of separate houses by area category by tenure, 2003 (kL)

		Owners/Purchasers	Tenants	Total
Houses in areas predominantly multi-unit dwellings	Total Consumption	443,160	319,811	762,971
	Total Separate Houses	1,586	1,089	2,675
	Consumption per Dwelling	279	294	285
Houses in areas of wholly separate houses	Total Consumption	958,243	707,681	1,665,924
	Total Separate Houses	3,526	2,470	5,996
	Consumption per Dwelling	272	287	278

Note: $p<0.05$

kL for owners/purchasers. In addition, households in separate houses in areas wholly comprised of separate houses consumed less water than those in houses in areas predominantly comprised ‘other residential’ dwellings, regardless of tenure. A possible explanation for the differences in consumption is likely to again lie in the different household composition of households in different tenures.

Table 10: Average annual household water consumption for owners/purchasers in separate houses by mortgage status, 2003 (kL)

		Without a Mortgage	With a Mortgage	Not Stated	Total
Areas predominantly flats in a block of 4 or more storeys	Total Consumption	6,735	16,981	26,681	50,397
	Total Separate Houses	23	44	82	149
	Consumption per Dwelling	**293**	**386**	**325**	**338**
Areas predominantly flats in a block of less than 4 storeys	Total Consumption	13,819	25,441	52,441	91,701
	Total Separate Houses	49	80	183	312
	Consumption per Dwelling	**282**	**318**	**287**	**294**
Areas predominantly semi detached dwellings	Total Consumption	24,409	128,054	148,599	301,062
	Total Separate Houses	111	464	550	1,125
	Consumption per Dwelling	**220**	**276**	**270**	**268**
Areas wholly separate houses	Total Consumption	97,185	405,702	455,356	958,243
	Total Separate Houses	396	1,473	1,657	3,526
	Consumption per Dwelling	**245**	**275**	**275**	**272**

Notes: $p<0.05$

The IPART study indicated that households *with* a mortgage who reside in separate houses consumed more water than those that owned their property outright (see Table 1) typically because they have more people per dwelling. This analysis, using the Department of Lands records of whether a household has a mortgage, also found that, in 2003, households *with* a mortgage consumed 14 percent more than those *without* a mortgage (Table 10). The greatest difference between the two categories was between separate houses in areas of predominantly high rise flats where separate houses with a mortgage consumed 24 percent more than for those separate houses without a mortgage. Households in separate houses in areas of predominantly semi detached housing had the lowest consumption overall, and those households with no mortgage consumed 20 percent less water on average than those with one. The higher consumption of households with a mortgage may reflect that households with a mortgage tend to be larger and younger than those without.

The relationship between site value and household water consumption

Using the Department of Lands valuation data it is possible to show that households living in separate houses on higher valued sites consumed more water annually than those with lower site values. There is a consistent increase from an average of around 262 kL for properties valued under $200,000 to 307 kL at the $700 - $799,000 value level (Table 11 and Figure 9). But for separate houses with a land value of over $800,000, household water consumption appears to rapidly increase to 418kL per annum, some 36% greater than separate houses valued between $700,000 and $799,999. These houses are on larger blocks (averaging 1,420 m2), and presumably have extensive gardens and/or significant water consuming facilities such as swimming pools and spas.

Whether households have mortgages on their homes or whether they live in homes on the more highly valued sites might be seen as surrogate measures of wealth or stage in the life course of households. The results of this research tend to support the general finding of IPART that the most significant determinant of household consumption is the household size. That is, although wealth and income may be a factor in determining household water consumption, the most significant determinant seems to be household size. Nevertheless, it is clear from the analysis of consumption by site valuation, a small number of the most valuable properties have considerably higher water consumption levels than the rest of the population.

Figure 9: Average annual household water consumption per separate houses by land value, 2003 (kL)

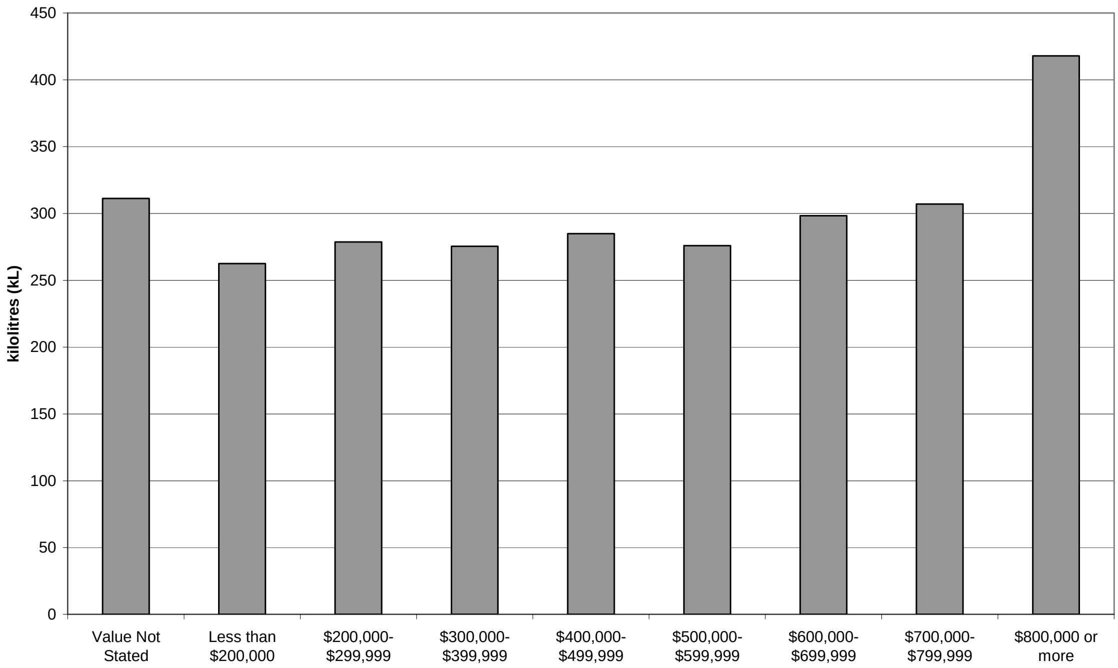


Table 11: Average annual household water consumption for separate houses by land value and block size, 2003 (kL)

		Land Value									
		Value Not Stated	Less than $200,000	$200,000-$299,999	$300,000-$399,999	$400,000-$499,999	$500,000-$599,999	$600,000-$699,999	$700,000-$799,999	$800,000 or more	Total
Houses in areas of predominantly flats in a block of 4 or more storeys	Total Consumption	11,431	NA	6,303	13,324	5,311	10,845	8,070	931	27,398	83,613
	Total Houses	28	NA	22	47	18	41	25	2	62	245
	Consumption per House	408	NA	287	283	295	265	323	466	442	341
Houses in areas of predominantly flats in a block of less than 4 storeys	Total Consumption	24,300	20,263	25,649	25,315	8,854	13,669	8,605	2,436	20,194	149,285
	Total Houses	81	73	85	81	36	54	31	9	51	501
	Consumption per House	300	278	302	313	246	253	278	271	396	298
Houses in areas of predominantly semi detached dwellings	Total Consumption	52,672	153,277	135,300	88,984	54,008	15,044	15,285	6,798	8,705	530,073
	Total Houses	165	578	486	350	214	51	52	19	14	1,929
	Consumption per House	319	265	278	254	252	295	294	358	622	275
Houses in areas of wholly separate houses	Total Consumption	34,237	661,845	369,222	220,521	161,518	83,794	33,980	25,449	75,358	1,665,924
	Total Houses	120	2,532	1,332	786	538	301	113	86	188	5,996
	Consumption per House	285	261	277	281	300	278	301	296	401	278
Total separate houses in selected CDs	Total Consumption	122,640	835,385	536,474	348,144	229,691	123,352	65,940	35,614	131,655	2,428,895
	Total Houses	394	3,183	1,925	1,264	806	447	221	116	315	8,671
	Consumption per House	311	262	279	275	285	276	298	307	418	280
	Average block area m^2	772	601	644	638	807	787	858	1,214	1,420	697

Note: $p<0.05$

6 WATER CONSUMPTION OF HIGHER DENSITY HOUSING

We now turn to explore the consumption levels of households in higher density forms of housing. The Sydney Water description of the property to which a water supply is provided is a mix of the description of the type of development and the type of title under which it is held. This means that there is no precise ‘fit’ between the Sydney Water descriptions of dwellings and those provided by the Census.

By undertaking a physical inspection of the housing in the sample CDs we have been able to disaggregate the Sydney Water dwelling categories into separate houses, semi-detached dwellings and flats and in doing so obtain a more accurate measure of houses and other forms of accommodation. This section focuses on the semi detached dwellings and flats which we collectively refer to as multi-unit dwellings or higher density housing.

Further, the selection of CDs in each of the four kinds of development resulted in CDs with different 'mixes' of dwellings. Those with 99 per cent separate houses have been discussed above. The following discussion is focused on the average consumption of dwellings in the three areas of predominantly higher density housing.

Household Consumption

Table 2 above indicated that the average annual household consumption for areas wholly comprised of separate houses was significantly higher than the average annual household consumption for dwellings in areas where higher density forms of housing predominate.

Further analysis of those properties classified as being of higher density shows that the average annual household consumption for multi-unit dwellings in areas of predominantly higher rise flats increased over the period 1987-2001, although it fell sharply after that. In 2001, multi-unit consumption in areas of predominantly semi detached dwellings was lower again while areas of predominantly low rise flats had the lowest consumption (Figure 10 and Table 12). The fall in consumption since 2001 for all multi-unit types may well reflect the increasing public campaign to reduce water consumption and the more recent mandatory water restrictions which have made all households aware of the water supply problem. By 2003, multi-unit dwellings in areas predominantly semi detached dwellings had the highest consumption (188kL per dwelling). This was followed by multi-units in areas of high-rise flats (178kL) and then areas of low-rise flats (161kL).

Compared with Table 7, it is clear that the average annual consumption of households in separate houses in each of the three areas of mixed development type is higher than the average annual consumption for all multi-unit dwellings in each of these areas.

Figure 10: Average annual household water consumption for higher density dwellings by area category, 1987-2003 (kL)

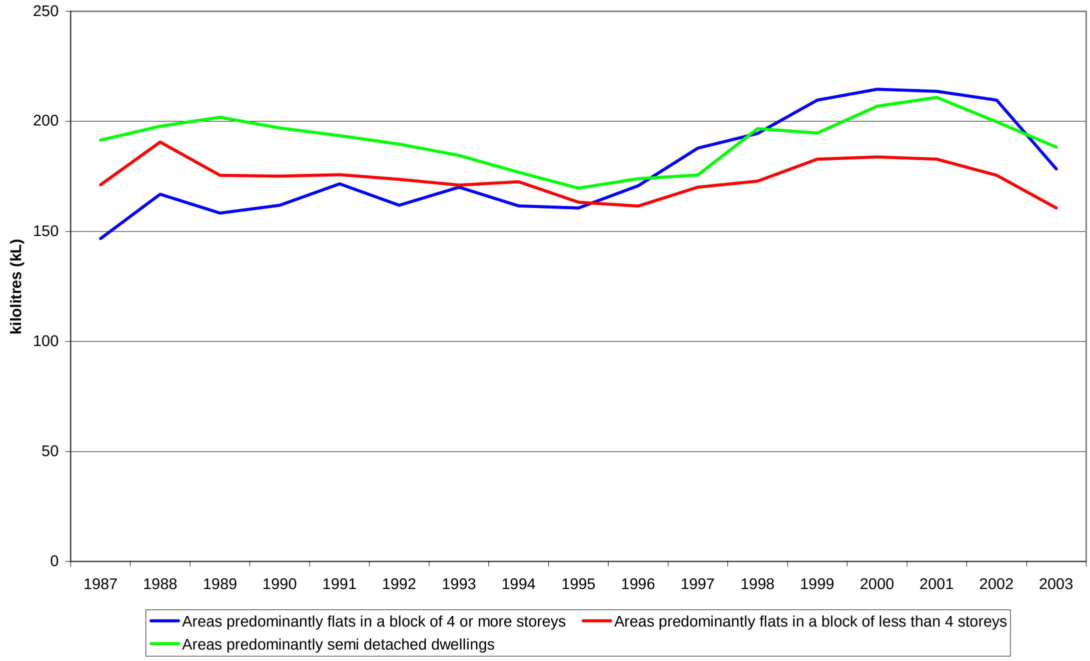


Table 12: Average annual household water consumption for higher density dwellings by area category, selected years, 1987-2003 (kL)

		1987	1991	1996	2001	2002	2003
Multi-Units in areas predominantly flats in a block of 4 or more storeys	Total Consumption (kL)	752,724	905,869	1,021,065	1,491,273	1,547,112	1,112,760
	Total Dwellings	5,130	5,280	5,979	6,981	7,381	6,237
	Consumption per Dwelling (kL)	**147**	**172**	**171**	**214**	**210**	**178**
Multi-Units in areas predominantly flats in a block of less than 4 storeys	Total Consumption (kL)	1,019,179	1,088,862	1,057,000	1,253,952	1,213,179	1,024,484
	Total Dwellings	5,955	6,197	6,543	6,859	6,911	6,379
	Consumption per Dwelling (kL)	**171**	**176**	**162**	**183**	**176**	**161**
Multi-Units in areas predominantly semi detached dwellings	Total Consumption (kL)	331,023	418,688	417,982	555,075	574,156	473,059
	Total Dwellings	1,729	2,164	2,402	2,633	2,874	2,513
	Consumption per Dwelling (kL)	**191**	**193**	**174**	**211**	**200**	**188**

Note: $p<0.05$

Per capita Consumption by region

The per capita water consumption of households in multi-unit housing reveals a different picture to that of households in separate houses. The estimated per capita water consumption of people in multi-units in high-rise flat areas is lower than those who live in separate houses (98kL compared to 115kL) (Table 13).

Per capita consumption in multi-units in areas of low-rise flats was estimated at 93 kL per annum. Multi-units in areas predominantly comprising semi-detached dwellings had even lower consumption estimates, at 85kL per annum. The average across the three types of mixed development CDs was 91 kL per annum, 12% below the equivalent figure for separate houses reported above.

Table 13: Average annual per capita water consumption for multi-unit dwellings by development area and region, 2001 (kL)

		Eastern Sydney	Western Sydney	Total
Multi-Units in areas predominantly flats in a block of 4 or more storeys	Total Consumption	889,651	601,622	1,491,273
	Total Dwellings	4,219	2,762	6,981
	Consumption per Dwelling	211	218	214
	Persons per Household	2.05	2.42	2.18
	Consumption per Capita	**103**	**90**	**98**
Multi-Units in areas predominantly flats in a block of less than 4 storeys	Total Consumption	838,155	415,797	1,253,952
	Total Dwellings	4,809	2,050	6,859
	Consumption per Dwelling	174	203	183
	Persons per Household	1.88	2.2	1.97
	Consumption per Capita	**93**	**92**	**93**
Multi-Units in areas predominantly semi detached dwellings	Total Consumption	417,966	137,109	555,075
	Total Dwellings	1,929	704	2,633
	Consumption per Dwelling	217	195	211
	Persons per Household	2.3	2.77	2.47
	Consumption per Capita	**94**	**70**	**85**

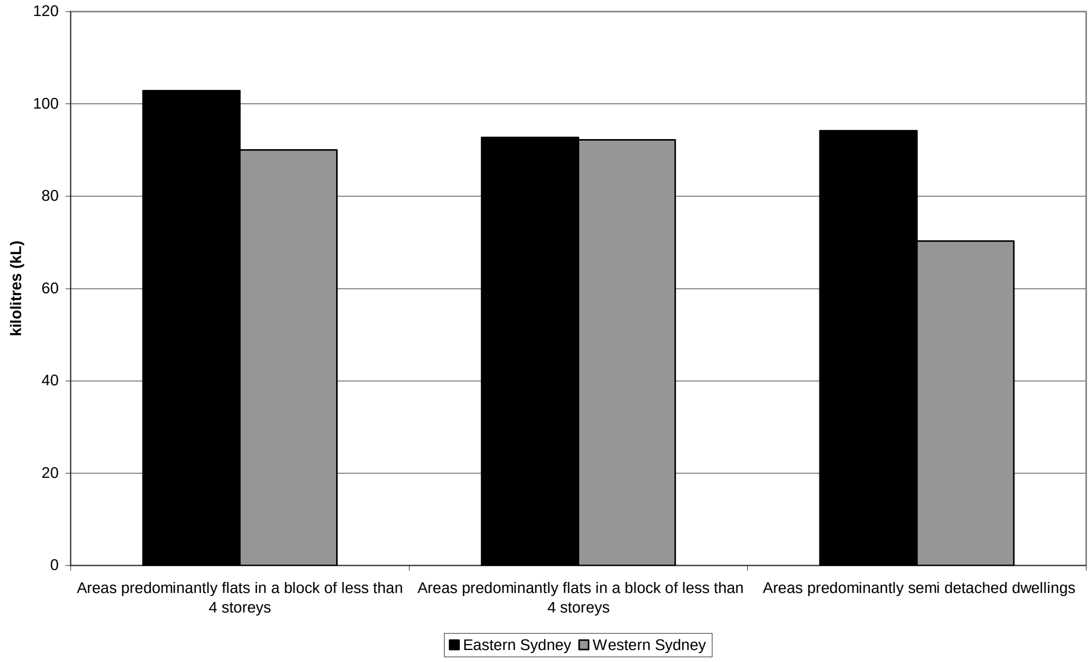
Note: $p<0.05$

It is possible the difference in consumption figures between multi-unit properties in areas of low-rise flats and semi detached housing and those in areas of high-rise flats is due to the greater prevalence of communal gardens, swimming pools and spas in more recent high rise developments and the higher standards of amenity associated with more recent construction of high rise flats. Modern high-rise flats often have more than one bathroom or toilet and will usually have individual washing machine and dishwashing facilities. Many low-rise and semi-detached multi-units are much older and have more basic amenity standards, often with communal washing facilities and little in the way of gardens or recreational facilities. Where communal laundries are present, then the water consumed will be included in the average consumption for each unit. Many older blocks of flats, however, have no common or shared laundry, nor are the individual flats necessarily equipped with washing machines. Given that those who live in older flats also need to clean their clothes, those who have no washing machine will use public facilities such as laundromats. That is, their personal consumption of water for self maintenance is not confined to water consumed in their own dwelling. This means the per capita consumption of water of those living in such flats will be understated.

As many as 20% of flats in Australia do not have washing machines (ABS 2004a). Assuming that most high-rise flats have washing machines, the proportion of low-rise flats without washing machines is therefore higher than 20%. We are not able to measure separately the use of water in washing machines or dishwashers of those who live in flats with such equipment, but it is possible to estimate from the 2003 ABS Survey of Water Consumption in Australia that those in houses with washing machines use them an average of 5.4 times per week compared with 3.5 times per week for those in flats (ABS 2004a).

We cannot offer an estimate of the real annual water consumption of those who live in dwellings without washing machines and who wash their clothes in laundromats. But given the percentage of flat dwellers who do not have washing machines, this amount

Figure 11: Average annual per capita water consumption for multi-unit dwellings by development area and region, 2001 (kL)



may not be trivial and may well largely account for the difference between those who live in 'low-rise flats' compared with those who live in 'high-rise flats' or houses.

Per capita multi-unit consumption in eastern and western Sydney shows significant variations (Figure 11). Average per capita consumption in multi-units in high rise areas in eastern Sydney was 14% higher than that in high rise blocks in western Sydney in 2001 (103kL and 90kL respectively). This gives support to the proposal made above that much of the difference in water use between higher rise and other multi-unit properties relates to the prevalence of new high amenity flat blocks in the inner areas of the city. Average per capita water use in multi-units in areas of low rise flats was very similar between east and west Sydney. But once again, water consumption in eastern Sydney multi-units in areas of semi-detached housing was substantially higher – 34% – than for comparable areas in the west of the city (94kL and 70kL respectively).

7 THE ROLE OF GARDENS IN WATER CONSUMPTION

The *Australian Water Account, 2000-01* (ABS 2004a) indicates that on average households in New South Wales consumed 250 kL per year in 2001 which was equivalent to 101 kL per capita. It also reports that 25% of this consumption was for outdoor or external purposes. The differences in water consumption noted for 1991 and 1995 above suggests that this might be an accurate estimate. Unfortunately no regional 'breakdown' of this consumption is offered in the ABS report. Given the great proportion of this consumption data is accounted for by households in Sydney, we have taken the NSW figure as a close proxy for the Sydney Metropolitan Area.

When the estimates of consumption are expressed in terms of per capita consumption the only differences that are statistically significant between the States are those for outdoor or external use (Table 14). That is, the internal consumption patterns of households across the nation are remarkably similar which, given the shared cultural values and equal level of development across the Nation's cities, is not surprising.

The reported level of consumption on external uses by the ABS (2004a) including gardens raises some questions. Victoria, for example, has the reputation that it is the 'Garden State' and compared with New South Wales it has a higher level of household production of fruits and vegetables (ABS 2004a, 69). We might therefore expect to find that the amount of water used in outdoor uses in Victoria is higher than in New South Wales. On the other hand, the higher proportion of households with a swimming pool in Sydney compared with Melbourne would tend to have an opposite effect as would the differences in rainfall and evaporation between the two cities.

In fact, the data in Table 14 shows the level of water usage in Queensland, South Australia, Western Australia and the Australian Capital Territory on external activities is much higher than in New South Wales. The authors can find no evidence that gardening practices are so different in the four States that they consume proportionately more than twice as much water as New South Wales households. The sandy soils of Perth and its Mediterranean climate with high winter and low summer rainfall might need more water to sustain gardens compared with Sydney, but whether they use twice as much on external consumption must be open to question. The data presented by the ABS (2004a) includes the water extracted by householders from bores or wells for use in their own gardens. A study of domestic water use in Perth (Loh & Coghlan 2003) reveals that 56% of total domestic water use for single residential development is for external uses, but this figure includes a significant volume drawn from bores (an estimated 32% of Perth houses surveyed had a bore).

The gardens of Sydney do not seem any less verdant than those of Perth although they rely to a higher degree on mains (potable) water for their watering. Only 74% of households in NSW have gardens and of these 43% grew fruit and vegetables (ABS 2004 b; Tabs 3.39 and 4.10). A much higher proportion of NSW households compared with those in Western Australia do not water their gardens at all (12% versus 2%). The household survey conducted by the authors found that 7.2% of houses had no garden, a further 7.1% had only a courtyard garden and 4.7% of houses had no lawn which helps explain why garden watering may not be a significant consumption issue for many houses (Troy *et al* 2005) The difference in the annual rainfall and its seasonal distribution together with the differences in soil structures in the major urban centres seems a likely explanation for the differences between the States in their outdoor water consumption, as might be differences between them in the availability and use of swimming pools. We offer no evidence on these questions at this stage of our research, although they will become issues to be explored in later stages.

Table 14: Average annual per capita water consumption by location of use in 2001 (kL)

	NSW	VIC	QLD	SA	WA	ACT
Bathroom	26.3	26.5	26.0	18.5	22.4	23.4
Toilet	23.2	19.4	16.4	16.0	14.5	16.4
Laundry	16.2	15.3	13.7	16.0	18.5	11.7
Kitchen	10.0	5.1	12.3	12.3	10.6	5.9
Outdoor	25.3	35.7	69.0	62	66.0	64.4
Total	101	102	137	123	132	117

Derived from Tables 9.6 and 9.7 in ABS 2004a

The largest exercise to estimate the level of external water use in Sydney was conducted by IPART as part of its study of residential energy and water use (IPART 2004a). This study estimated that households in conventional houses used, on average, 13% of their consumption on the garden and a total of 23% on external uses (IPART 2004b), which for all practical purposes is the same as the estimate reported by the ABS (ABS 2004b). No evidence is presented on what proportion of total consumption was used on gardens of those living in higher density housing. However, the Perth study was able to provide estimates of ex-house consumption which indicates significant levels of external water usage in higher density housing (Loh and Coghlan 2003: Table 3.1), which would support the findings in Section 6 above.

As we noted above, many higher density developments maintain gardens and swimming pools and, in addition, significant numbers of households in flats maintain collections of pot plants. The household survey found that 20% of flats had balcony gardens and 70% of low-rise and 75% of high-rise flats had collections of pot plants. Many of the gardens in high density developments include exotic species that require watering during long dry periods (Troy *et al* 2005). Higher density housing also includes 'town houses', 'villa units', terrace and semi-detached houses that have usable private outdoor space that is often fitted with reticulated watering systems to maintain the gardens during summer.

The 'counter intuitive' evidence of the IPART survey and the findings presented here on the comparative per capita consumption of water of households in houses and flats may, in part, simply reflect changing standards of flats. Whereas older private flats had little or no garden space and those developed in the 1960s and 1970s, especially those built in the era of 'six pack' developments, tended to have open space as parking or hard standing, those built more recently have been to a higher standard with landscaped external areas and gardens. And the tendency to include swimming pools and other recreational facilities in new blocks of flats noted above will also lead to increased external water consumption. We note too that the household survey reveals that 5.8% of houses have rainwater tanks that are used for garden watering and in 5.2% of houses are also used to flush toilets. Grey water is used in 4.5% of houses to water their gardens (Troy *et al* 2005). These actions tend to reduce the 'apparent' consumption of houses but are options rarely available to those in flats.

Given that higher density housing is usually provided with a 'common' supply (one that provides one meter to the site regardless of the number of dwelling units served) analysis of consumption per unit in this report is based on the average for the units on that site. This means that water used in 'external uses' including gardening etc for that development is averaged for each unit. Without micro-metering we cannot say with confidence how much of the consumption of those who live in higher density dwellings is used in gardening or other shared consumption. It does seem appropriate to assume that the proportion of water consumption for 'gardening' or external uses in higher density dwellings is not trivial. The Perth study of domestic water consumption (Loh & Coghlan 2003) concluded that half the annual water usage of water in multi-residential development was used on external uses.

In the absence of detailed end use consumption for Sydney we are forced to develop estimates of the proportion of consumption used to maintain gardens. The most obvious measure should relate to the size of gardens. Here again we have no accurate measure of garden size. Sydney Water and Department of Lands records, however, include the size of allotments for separate houses.

The property record does not give the floor area of separate houses so we have used the size of allotment as a surrogate measure of garden size. We adopt this approach with caution because the size of separate houses has increased markedly over the last four decades while block area has decreased, leading to smaller gardens. In the following section we explore the consumption per m^2 of separate house blocks in different kinds of development, again using 2001 as the benchmark year to allow the use of census data.

In 2001 the average block size for separate houses in the selected CDs was $705m^2$. Houses in Western Sydney CDs tended to be on smaller blocks ($673m^2$) than those in Eastern Sydney where the average block was $763m^2$. However, the consumption per m^2 of house blocks in the western suburbs is slightly, but consistently, higher than it is for house blocks in eastern suburbs (Table 15).

Separate houses in areas of predominantly low-rise flats have water consumption levels approximately 7-12% per m^2 higher than that in areas wholly developed for traditional housing or in high rise areas (Table 16). Separate houses in the western suburbs consistently consume more water per m^2 than those in the eastern suburbs (Figure 12).

Table 15: Average annual water consumption per m^2 of separate house block area in Eastern and Western Sydney, 1987-2003 (kL)

	Eastern Sydney	**Western Sydney**	**Total**
1987	0.47	0.43	0.45
1988	0.44	0.41	0.43
1989	0.45	0.43	0.44
1990	0.45	0.45	0.45
1991	0.51	0.51	0.51
1992	0.41	0.45	0.43
1993	0.41	0.45	0.43
1994	0.41	0.44	0.43
1995	0.36	0.37	0.37
1996	0.38	0.40	0.39
1997	0.42	0.43	0.43
1998	0.42	0.43	0.42
1999	0.39	0.40	0.40
2000	0.44	0.44	0.44
2001	0.43	0.44	0.44
2002	0.44	0.46	0.45
2003	0.39	0.41	0.40

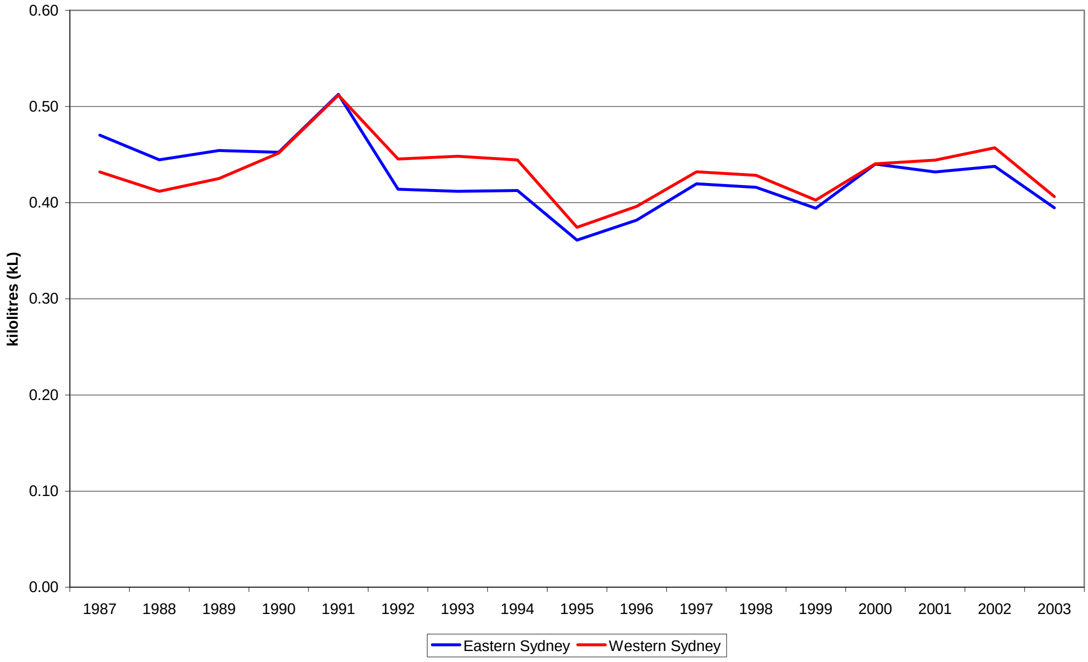
Note: $p<0.05$

Table 16: Average annual water consumption per m^2 of property area for separate houses, selected years, 1987-2003 (kL)

		1987	1991	1996	2001	2002	2003
Houses in areas predominantly flats in a block of 4 or more storeys	Total Consumption	77,861	96,351	80,207	85,886	85,066	83,613
	Total Houses	231	237	242	240	242	245
	Property Area (m^2)	185,728	189,297	193,437	191,555	193,597	194,519
	Consumption per m^2	**0.42**	**0.51**	**0.41**	**0.45**	**0.44**	**0.43**
Houses in areas predominantly flats in a block of less than 4 storeys	Total Consumption	158,048	193,317	148,197	168,603	172,698	149,285
	Total Houses	481	497	503	506	506	501
	Property Area (m^2)	314,950	326,891	328,906	329,116	329,144	327,149
	Consumption per m^2	**0.50**	**0.59**	**0.45**	**0.51**	**0.52**	**0.46**
Houses in areas predominantly semi detached dwellings	Total Consumption	420,670	524,873	430,825	619,895	668,191	530,073
	Total Houses	1,389	1,507	1,554	2,050	2,172	1,929
	Property Area (m^2)	1,083,658	1,221,718	1,318,180	1,520,893	1,675,327	1,431,783
	Consumption per m^2	**0.39**	**0.43**	**0.33**	**0.41**	**0.40**	**0.37**
Houses in areas of wholly separate houses	Total Consumption	1,628,423	1,904,120	1,474,076	1,804,434	1,950,059	1,665,924
	Total Houses	4,896	4,990	5,064	5,847	6,137	5,996
	Property Area (m^2)	3,519,307	3,570,611	3,628,612	4,053,650	4,197,953	4,090,058
	Consumption per m^2	**0.46**	**0.53**	**0.41**	**0.45**	**0.46**	**0.41**
Total separate houses in selected CDs	Total Consumption	2,285,002	2,718,661	2,133,305	2,678,818	2,876,014	2,428,895
	Total Houses	6,997	7,231	7,363	8,643	9,057	8,671
	Property Area (m^2)	5,103,643	5,308,517	5,469,135	6,095,214	6,396,021	6,043,509
	Consumption per m^2	**0.45**	**0.51**	**0.39**	**0.44**	**0.45**	**0.40**

Note: $p<0.05$

Figure 12: Water consumption per m^2 of property area for separate houses in Eastern and Western Sydney, 1987-2003 (kL)



The relationship between water consumption and rainfall

To explore the variation in consumption and the extent to which garden watering is affected by rainfall we obtained estimates of the rainfall pattern over the Sydney Metropolitan Area for every year since 1987. The ANUSPLIN package, version 4.2 (Hutchinson, 2002) was used to fit elevation dependent splines to the monthly rainfall data and interrogate these surfaces using the DEM as shown in Figure 2. The total monthly rainfall at each CD location was derived from the spatial rainfall surfaces. A geographical X Y coordinate was provided for each CD location. The program GROWEST (version 2.0) was used to determine a moisture index for each CD location. The moisture index is given as the ratio of the actual evapotranspiration to the potential evapotranspiration and is calculated from rainfall and pan evaporation surface data files.

It is clear from the rainfall record that there is high variability between years and for the seasons within any year. Figures 13a and 13b map the distribution of rainfall over the Sydney Metropolitan Area for the summer months of 2001 and 2002. We have taken these two years because they may be regarded as more ‘normal’ in the sense that the measures of consumption are less likely to be affected by community responses to the prolonged dry period or to the restrictions introduced by Sydney Water. Appendix 4 illustrates the variation over the summer months. The most obvious fact to emerge is that rainfall in the eastern suburbs is significantly higher than that in the western suburbs.

Figure 13a: Cumulative Spatial Rainfall for Sydney (January, February, March) Quarter 2001

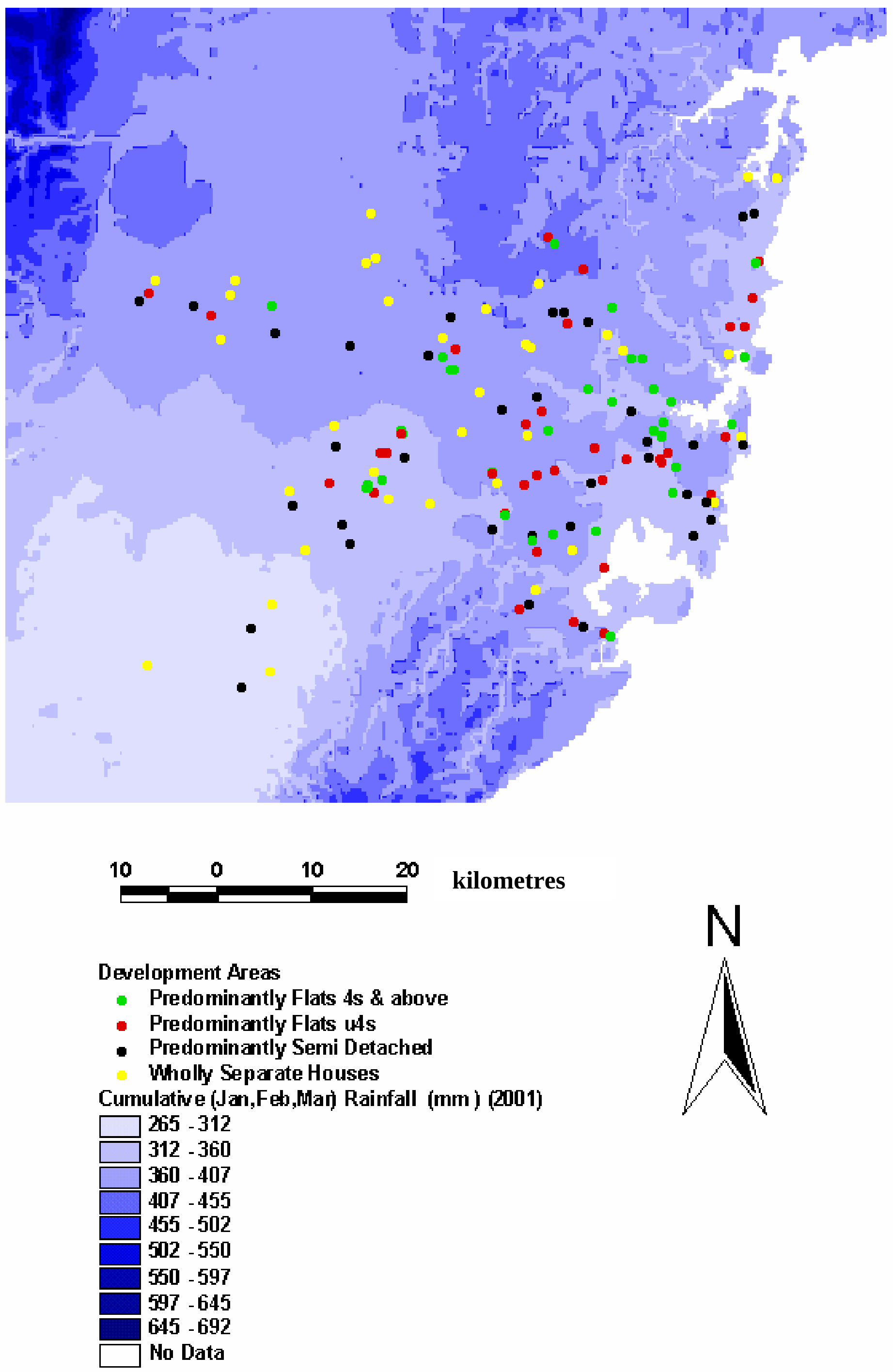
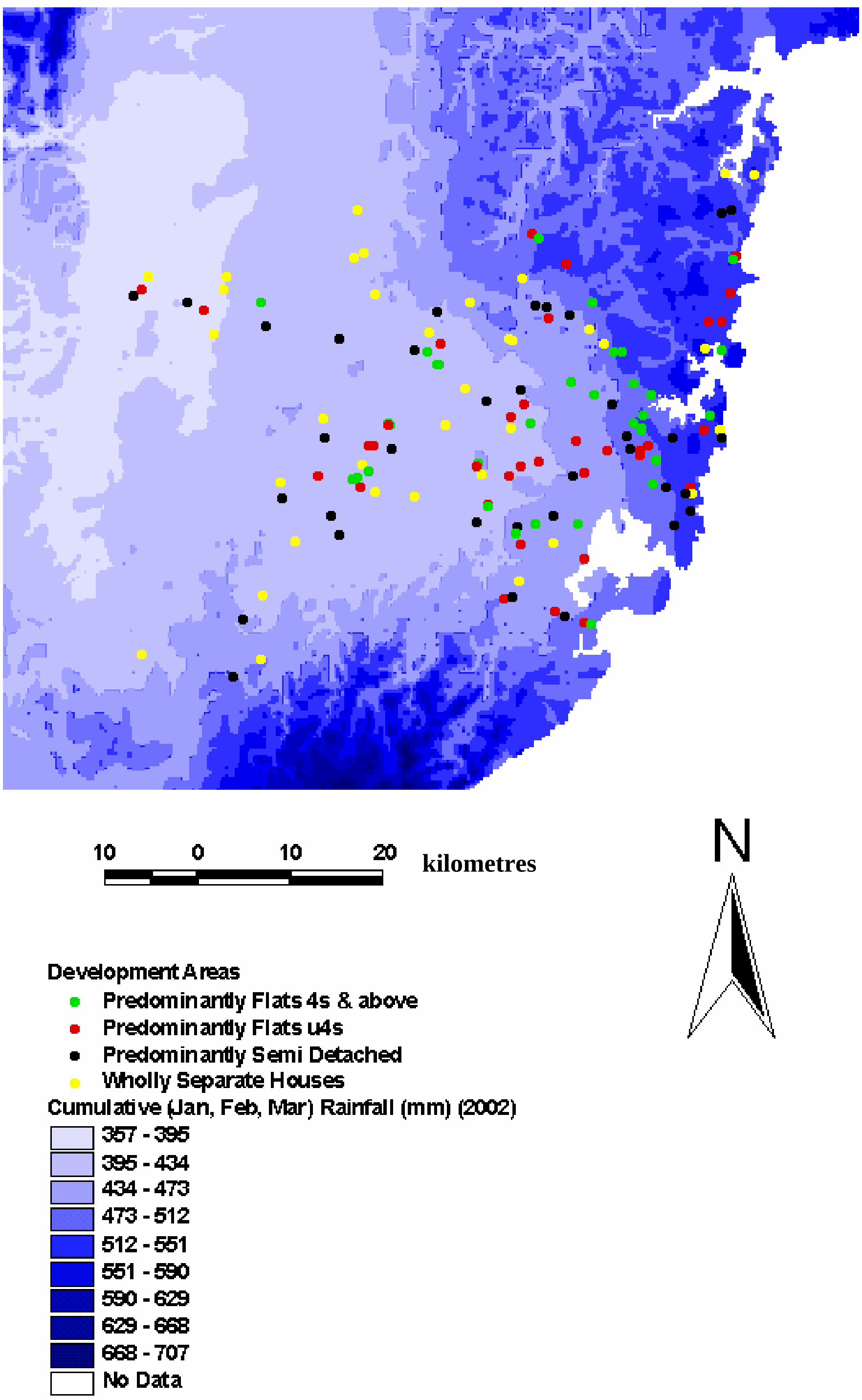


Figure 13b: Cumulative Spatial Rainfall for Sydney (January, February, March) Quarter 2002



It is likely that seasonal variation in rainfall affects garden water consumption. To test this hypothesis we looked for a relationship between summer water consumption (SWC) of separate houses in the 140 selected CDs to see if it was affected by the size of allotment or block area (as a surrogate for garden area) and the rainfall in each CD over the three summer months in 2001. We also introduced a Constant variable (average household size for separate houses in each CD) as a surrogate for 'internal consumption'.

The first stage of analysis was to explore the relationship between average household water consumption, average household size, average block size and the socio economic characteristics of the population supplied, the latter data derived from the 2001 Census for each selected CD. This research follows both the approach taken by IPART and that taken by Dandy (1987) (see below).

To try to identify the relationship between summer and winter consumption and rainfall we analysed consumption over the period 1988 – 2003 by season. Tables 17a and b set out the summer (Dec-May) and winter (June-Nov) consumption for separate houses in the eastern and western suburbs and compares them with the rainfall over the same period. We took the difference between summer and winter consumption as a first approximation for external water consumption. As a ‘control’ we also analysed the summer and winter consumption of multi-unit dwellings[4] in areas of predominantly high and low rise flats and compared the seasonal difference in their consumption with rainfall over the same period (see Table 18). The results of this exercise are presented graphically in Figures 15 to 18.

In general, the variation between winter and summer consumption is more variable for houses than for multi-unit dwellings, as might be expected. This, coupled with the fact that summer rainfall is typically higher than winter rainfall (Tables 17 and 18) suggests that households tend to rely on the rainfall to irrigate their gardens. The proportion of households who never water their gardens (ABS 2004a) also tends to support this conclusion.

Importantly, policies designed to reduce water consumption by focusing on reducing garden watering may not produce the total savings sought. For example, IPART concluded that approximately 13% of total household consumption was used on the garden. The relatively small reduction in average total household consumption following the introduction of voluntary water restrictions relating to external water consumption also supports this view. The restrictions were nonetheless important because they raised and reinforced general awareness of the need to reduce water consumption. The restrictions were introduced following a sophisticated educational program mounted by Sydney Water over a long period to encourage households to reduce consumption and generally appear to have been effective. The restrictions were also introduced after a series of demand management initiatives that had led to significant reductions in consumption (Turner *et al* 2005). It is important, however, to recall from Section 5 above that there are some households with very high water consumption levels and many of these are houses on large blocks and presumably have large gardens. The more recent

[4] In this case multi-unit dwellings excludes dual occupancies.

mandatory restrictions on garden watering and other external water consumption activities has had a more dramatic impact on reduction in consumption but is still less than the target of 40% reduction needed to regain security in supply.

Table 17a: Rainfall and water consumption for separate houses – Eastern Sydney, 1987-2003

	Average Summer Water Consumption per house (kL)	Average Winter Water Consumption per house (kL)	Seasonal Difference Water Consumption per house (kL)	Average Summer Rainfall per CD (mm)	Average Winter Rainfall per CD (mm)
1988	173	166	7	1,133	548
1989	166	170	-4	1,024	395
1990	179	158	21	1,405	489
1991	222	182	40	340	521
1992	198	155	43	854	396
1993	170	154	16	492	438
1994	186	160	26	463	272
1995	163	143	20	643	492
1996	153	146	7	559	528
1997	180	153	27	552	451
1998	201	151	50	719	791
1999	181	148	33	736	567
2000	187	169	19	495	355
2001	196	163	33	801	360
2002	199	176	22	657	137
2003	199	152	47	NA	NA

Note: Figures round to nearest whole number

The ‘external’ consumption of dwellings is not confined to garden irrigation, it includes water used for car washing, washing drives and pathways.

Water restrictions whether voluntary or mandatory are often directed at car washing and washing drives and pathways. These activities are ‘obvious’ targets but may over emphasise their importance. The household survey found that half the households in houses with one car never washed their car at home and a further 14% said they did so only six monthly. More than 60% of flat dwellers never washed their car at home and a further 11% said they did so only six monthly. Households with more than one car were even less likely to wash their cars at home (Troy *et al* 2005).

The survey results relate to behaviour in late 2004 and early 2005 so they may, to some degree, reflect heightened awareness to drought, to the educational programs of Sydney Water and to the introduction of water restrictions. We note however, that when asked if they had reduced the number of times they washed their cars at home 70% of those in houses said they had not rising to 85% of those who lived in high-rise flats. That is, about two third of households that washed their cars at home said they reduced the number of times they do so. They, no doubt, now use a bucket and sponge rather than a hose. The significant message from the household survey is that while focusing on activities like car washing may be a very important element in the campaign to make households aware of the need to reduce their consumption it cannot be expected to lead to major savings.

Table 17b: Rainfall and water consumption for separate houses – Western Sydney, 1987-2003

	Average Summer Water Consumption per house (kL)	Average Winter Water Consumption per house (kL)	Seasonal Difference Water Consumption per house (kL)	Average Summer Rainfall per CD (mm)	Average Winter Rainfall per CD (mm)
1988	155	150	5	950	450
1989	143	154	-11	805	265
1990	166	146	20	1,121	365
1991	208	167	41	237	443
1992	188	155	33	719	266
1993	168	152	16	436	314
1994	183	156	27	345	179
1995	151	135	16	536	358
1996	145	139	6	489	361
1997	170	150	20	412	245
1998	190	146	45	538	533
1999	176	149	27	497	447
2000	186	171	15	421	302
2001	204	181	24	581	224
2002	225	202	23	514	71
2003	214	169	45	NA	NA

Note: Figures round to nearest whole number

Table 18: Rainfall and consumption for multi unit dwellings in areas of predominantly high and low rise flats, 1988-2003

	Average Summer Water Consumption per Dwelling (kL)	Average Winter Water Consumption per Dwelling (kL)	Seasonal Difference in Water Consumption per Dwelling (kL)	Average Summer Rainfall per CD (mm)	Average Winter Rainfall per CD (mm)
1988	91	91	0	1,079	518
1989	86	85	1	954	354
1990	86	84	2	1,318	450
1991	92	85	8	308	501
1992	90	83	7	804	359
1993	85	83	2	473	401
1994	87	83	4	427	245
1995	81	81	1	608	455
1996	80	82	-1	541	478
1997	88	86	2	508	388
1998	91	85	6	665	711
1999	95	91	3	666	530
2000	99	93	5	470	339
2001	99	92	7	738	321
2002	95	90	5	612	116
2003	92	85	7	NA	NA

Note: Figures round to nearest whole number

Figure 14: Summer and winter average water consumption for separate houses, 1988-2003, Sydney (kL)

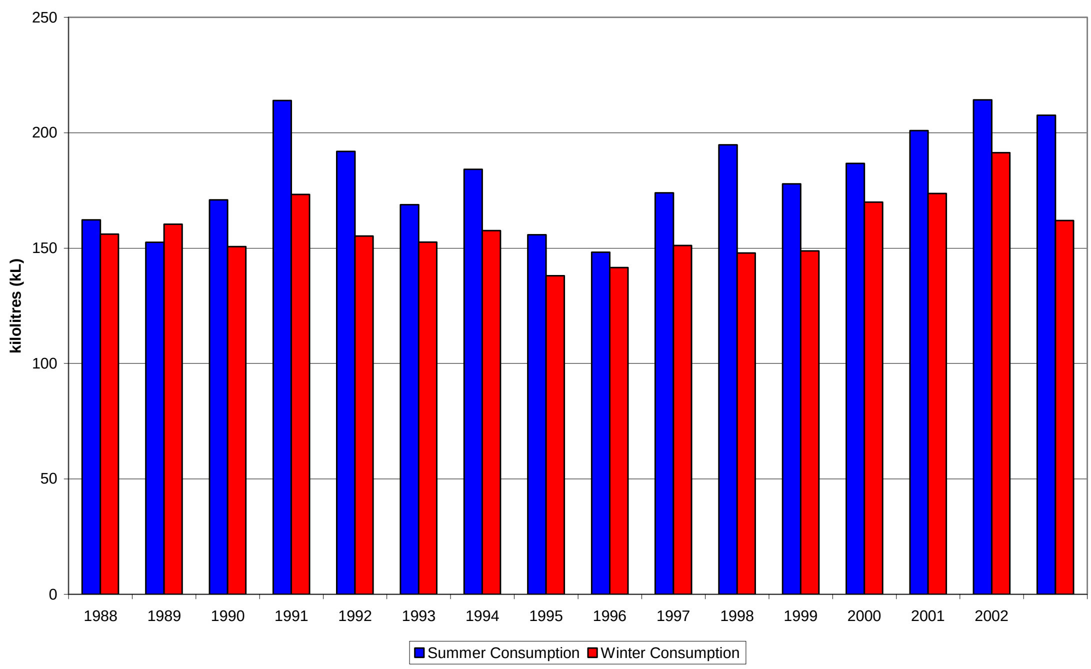


Figure 15: Seasonal difference in average water consumption for separate houses (difference between summer and winter consumption), 1988-2003 (kL)

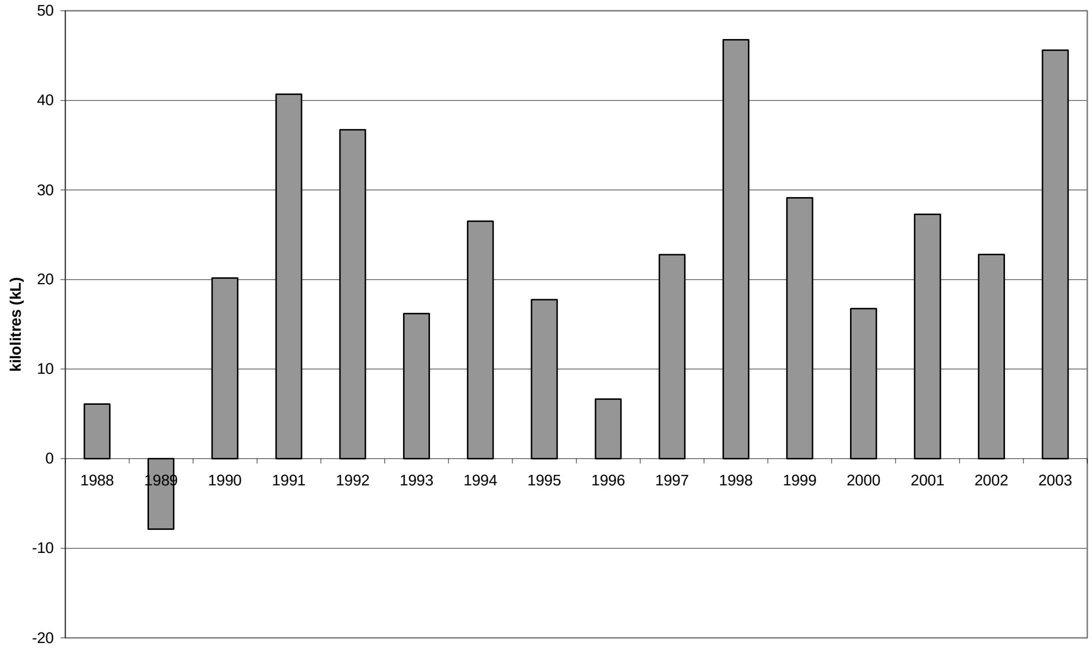


Figure 16: Summer and winter water consumption for multi unit dwellings in areas of predominantly high and low-rise flats (kL)

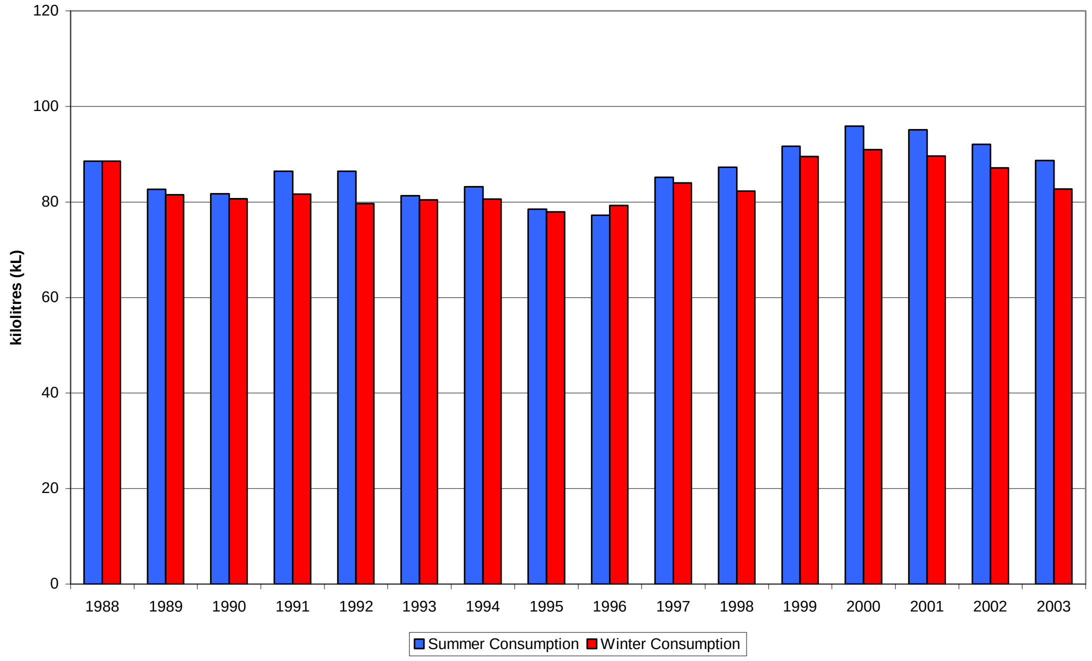


Figure 17: Seasonal difference in consumption of multi unit dwellings in areas of predominantly low and high rise flats (kL)

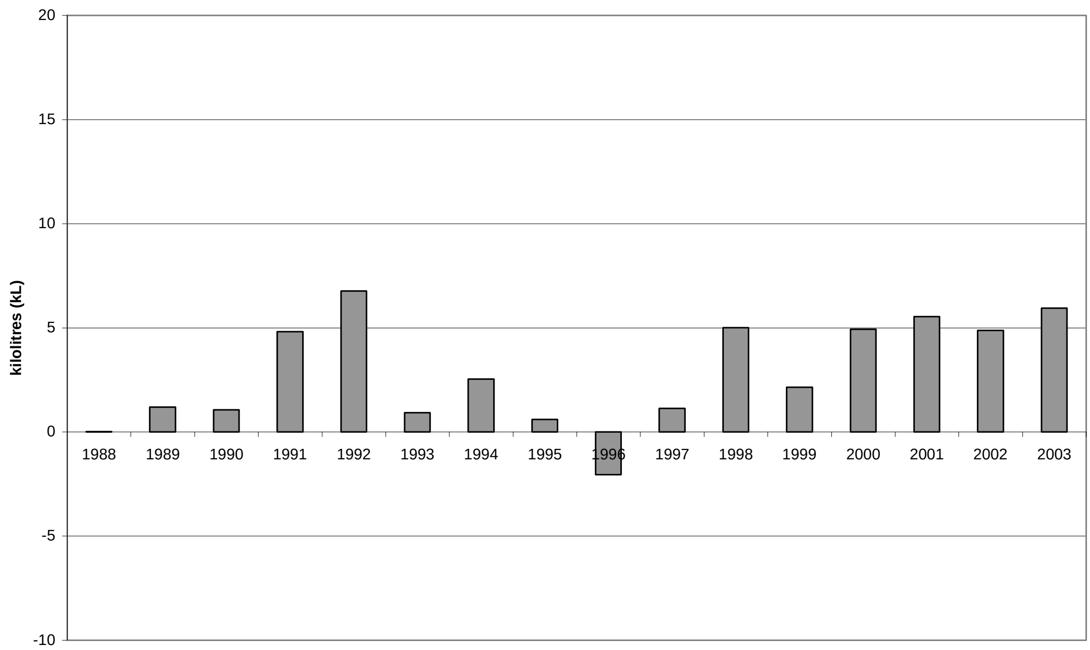
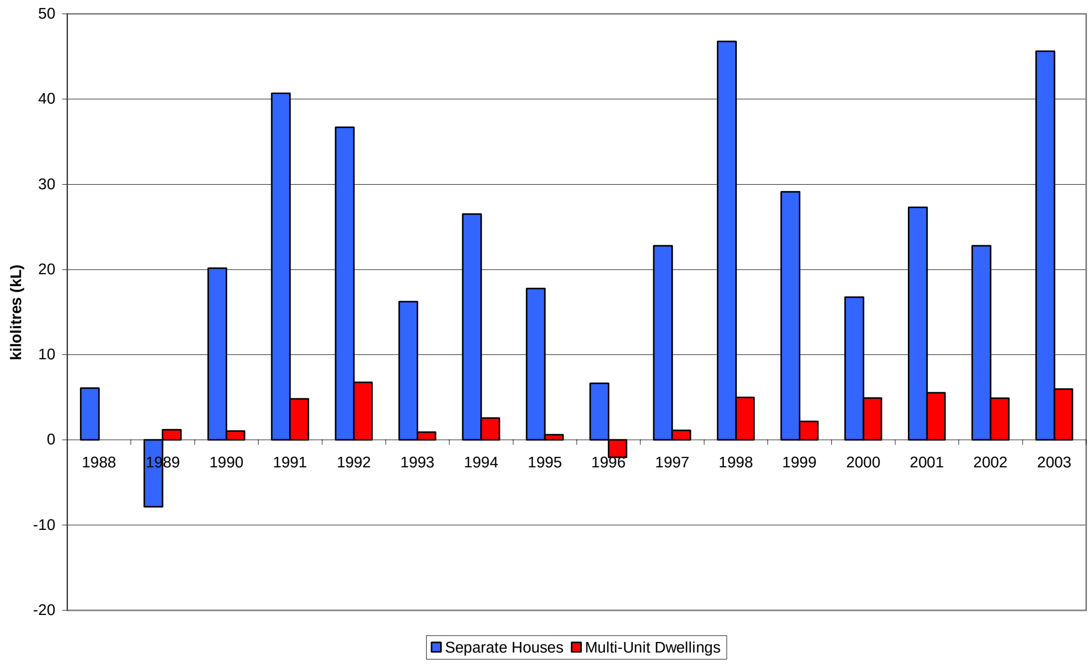


Figure 18: Seasonal difference in water consumption for separate houses and multi-unit dwellings in Sydney (kL)



A note of caution must be entered in discussions of seasonal variations in consumption because the measure of water consumption is effectively a 'rolling' measure of dwelling consumption (reading of water meters is continuously conducted which means that not all dwellings have their meter read on the same date). This introduces a high level of variability in the estimated consumption for an individual house over any short period. There remains some variation in estimates of annual consumption although this is smaller than for short periods such as the 'summer' and 'winter' periods we have identified. We should also note that the summer/winter consumption estimates for medium and higher density housing may have high levels of variation because they are themselves averages derived from the measured common supply.

Multiple Regression Analysis at the CD Level

The data for the 92 CDs that contained separate houses was assembled to explore the relationship between rainfall and water consumption in more detail through a multiple regression analysis. Data related to the socio-economic character of households available at the CD level were also extracted for each CD from the 2001 Census and included in the regression analysis. CDs with missing records were excluded from further analysis. In the end, three variables that best predicted water consumption per separate house at the CD level were identified. These were:

- Average property area
- Persons per house
- Proportion of public housing

These three variables explained 37% of the variance within the data set. While this is not as high as we might expect, these variables have been established by other researchers as influencing levels of water consumption (e.g. IPART 2004a and b; Davies and Dandy 1995; Dandy 1987).

The following equation best predicted water consumption for separate houses at the CD level:

Water Consumption Per Separate House (kL) at the CD level = 115.5 + 0.066(Average property Size) + 45.6(Persons per house) + 61.6(Proportion of Public Rental)

The three variables in the equation have a positive relationship with water consumption. That is, as the average size of a property increases water consumption will slightly increase. Similarly, as the number of persons per separate house and the proportion of public housing increases, so does the level of water consumption per dwelling across the CD. Importantly, the regression equation found no significant relationship between *total* household consumption and rainfall. This is despite the suggestion that rainfall affects garden consumption.

We note that Eardley *et al* (2005) found in their CD level analysis of consumption that socio-demographic factors explained around three quarters of the variation in average water use between CDs. They also found that block size had only a limited impact on per capita water use. This result is at slightly at variance with this research. We also note, however, that the household survey conducted in 2005 indicated that a about 7% of households in houses had no garden and that a high proportion of those that did have one rarely watered them. This tends to support the observation that there is little difference in average per capita consumption between those who live in houses and those who live in flats.

Table 19: Results of the multiple regression analysis

	Unstandardised Coefficient	Standardised Coefficient	T statistic	Significance
Constant	115.500	-	2.808	0.006
Average property size	0.066	0.566	6.505	0.000
Persons per House	45.647	0.301	3.527	0.001
Public Rental	61.581	0.174	2.004	0.048

	ANOVA				
	Sum of Squares	df	Mean Square	F	Significance
Regression	270825.43	3	90275.14	17.91	0.00
Residual	423322.24	84	5039.55		
Total	694147.67	87			

	Collinearity Statistics	
	Tolerance	VIF
Constant	-	-
Average property size	0.960	1.042
Persons per House	0.999	1.001
Public Rental	0.960	1.041

Note: Dependent variable: Consumption per House

Multiple Regression Analysis at Household Level

A number of multiple regressions were also conducted at the household level to examine summer water consumption in a sample of separate houses. The regression analyses used data for the summer water consumption as well as for the total annual consumption. The emphasis in these analyses focused on three variables – household size, property area and rainfall. The separate houses selected for analysis consumed more than 25kl of water per annum.

The regression equation that explained the most variance within the data set was that for summer water consumption. However, this explained only 6% of the variance within the data set. Although this is a very small level of explanation, it is interesting that household size and property area were positively associated with summer consumption, while rainfall over the January to March period was negatively associated with water consumption.

No increase in explained variance was achieved by extending the summer rainfall period, using annual rainfall, or by substituting the soil moisture index in each CD for the rainfall measure.

The analysis confirms what we would expect: that is, increased summer rainfall slightly reduces water consumption presumably because it reduces garden watering. The evidence presented above suggests that the generally higher level of rainfall during the summer months effectively minimises the need for gardening watering during hot weather. The fact that the difference between summer and winter consumption is highest in periods when the summer is unusually dry tends to support this conclusion.

Further analysis of the relationship between summer rainfall and summer consumption (defined in this instance as the three month period January – March, not the six month period December to May previously used) is also weaker than we might expect. Sydney gardeners plant out in October-November and may use water to sustain their plants during the summer. Extending the summer period to be the six month definition (December through to May) as used by Dandy (1987) or by taking the ‘summer’ period to be October-March did not increase the level of variance explained. A theoretically more rigorous approach in which we used the estimated net water balance over the same six month period compared with consumption did not increase the level of explained variance.

8 MAPPING CONSUMPTION

One of the objectives of this research project was to develop a detailed CD level map of water consumption across Sydney without recourse to a major data analysis of water records from all addresses and all CDs. To produce a map of metropolitan Sydney's water consumption we have therefore applied the average consumption for the different dwelling types in Eastern and Western suburbs on a pro-rata basis for 2001 to each CD across the metropolitan area reflecting the dwelling mix or profile of each CD. This allows us to estimate the consumption for all CDs and to then represent their consumption in the form of a map for Metropolitan Sydney.

Figure 19 shows how average annual household water consumption varies across the metropolitan area. This is useful for planners and policy makers alike who can immediately see where high consumption areas are, so that initiatives can be targeted at these areas to reduce consumption.

The areas of highest consumption are associated with areas with the largest blocks and generally with the higher socio-economic status. These are concentrated in the northern and western suburbs as well as in areas such as Hurstville and Sutherland to the south. Some of the areas of low domestic consumption also include industrial areas, many of which have industrial undertakings which use significant volumes of water. The areas of lowest domestic consumption generally are the same as the areas of highest rainfall – this is eloquent confirmation and presentation of the conclusions presented above.

Figure 20 shows how the average annual per capita consumption of water varies across the Metropolitan Area. Here, per capita consumption appears higher in several areas, including North Sydney, the Northern Beaches, the inner and central west (including Parramatta), along the Canterbury and Hurstville boundary into Bankstown, as well as areas identifiable as being larger concentrations of public housing, such as Mount Druitt in Blacktown. Further research will be needed to explain these patterns. Nevertheless, such maps could be used to identify areas with households with high per capita consumption to more effectively focus education programs. If the maps were updated following each census the water and planning authorities would be able to be used to assess the effectiveness of policies designed to reduce consumption. They may also be used to estimate demand in new areas and therefore accurately estimate the need for network investment.

Figure 19: Estimated average annual per household water consumption for CDs in urban Sydney, 2001

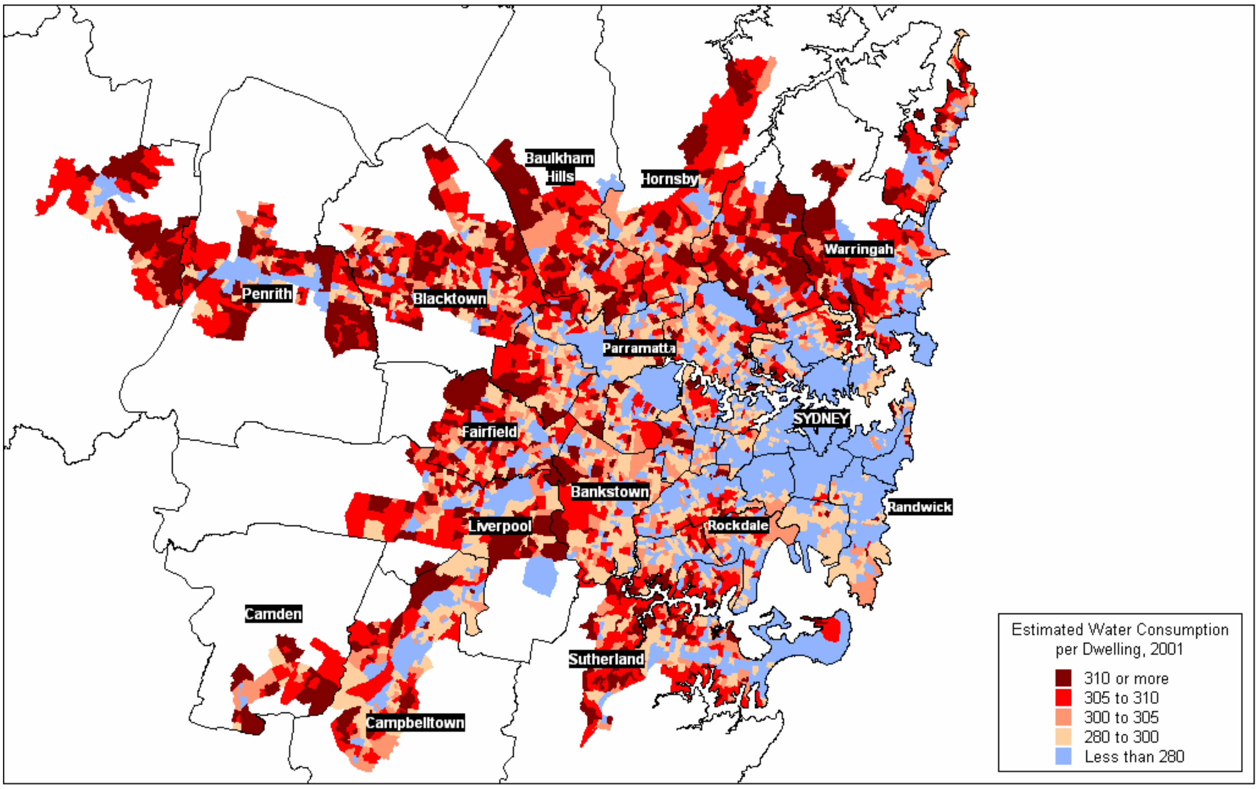
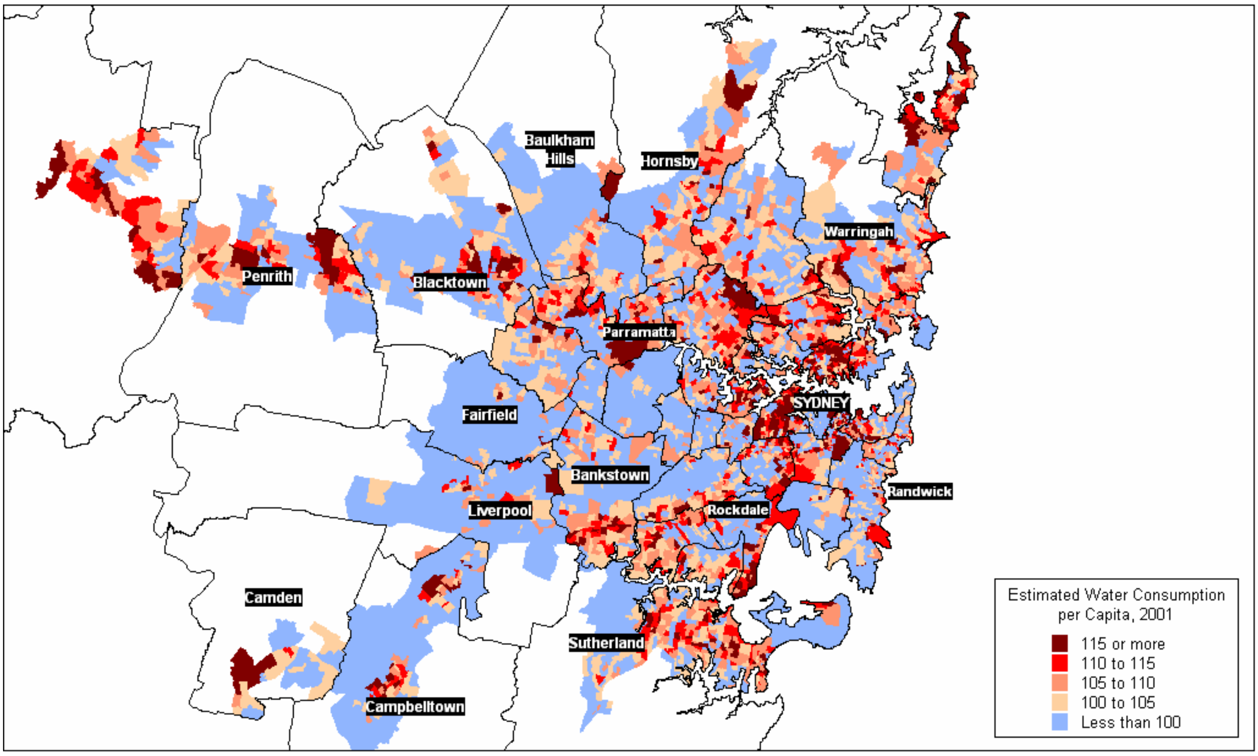


Figure 20: Estimated average annual per capita water consumption for CDs in urban Sydney, 2001



9 A NEW APPROACH TO SYDNEY'S WATER SUPPLY

This study of Sydney's domestic water consumption found that the per capita water consumption of Sydney households is relatively constant for high rise flats and separate houses, although there is variation between different dwelling types in different locations. The study confirmed data derived from the IPART study of Sydney water consumption in 2003 which also found that the per capita consumption was the same for owner-occupied flats and separate houses. The recent study of domestic water consumption in Perth also found that the per capita internal consumption of households in separate houses was virtually the same as for those in multi-unit developments. This suggests that policies designed to reduce water consumption based on housing form may not achieve the desired end.

Policies designed to reduce total water consumption by reducing garden watering may lead to less savings in total water consumption than generally thought. A small proportion of households clearly have a high level of consumption which may be due to heavy watering of gardens, but they may be too few in number to provide the substantial system reductions in total water consumption thought to be desirable. This does not mean such reductions should not be sought, but it does imply other strategies are required to ensure demand for total water consumption is reduced.

The *Metropolitan Water Plan of 2004: Meeting the Challenges - Securing Sydney's Water Future* (DIPNR 2004) says that 'all new houses built in Sydney must reduce their mains water consumption by 40% compared to the current average for similar sized homes'(DIPNR 2004, 6). It is argued that this level of saving can be achieved by installation of water efficient fixtures and either by installing a rainwater tank or connecting to a recycled water system.

The demand management policies and programs adopted by Sydney Water achieved a saving of 20% in total water consumption between 1991 and 2004 although much of this was due to savings in the business and industrial sectors (Turner *et al* 2005). The Metropolitan Water Plan indicates that best international practice in demand management has achieved water consumption savings of only 10% except in exceptional circumstances. This suggests that it will be difficult to achieve savings of more than 10% under the current demand management programs. If we accept that there is a need to reduce the consumption by 40% and that total external consumption is 25% (ABS 2004a, Tables 9.6 & 9.7) it is clear that it even if **all** external consumption was eliminated there would remain at least 15% shortfall in the consumption reduction target. Assuming that the 10% reduction in consumption under the current demand management programs continues to be obtained we would need to obtain savings of at least 5% from other sources. The obvious target is to seek further reduction in internal consumption through the current demand management programs or to seek alternative ways of meeting the demand while reducing reliance on the reticulated supply of potable water. The savings reported in the Metropolitan Water Plan 2004 of another 10% against the 10-year average in the year following the introduction of mandatory water restrictions suggests that it will be hard to maintain high levels of reduction in consumption.

The water supply and sewerage services in Sydney were developed on the notion that a supply of high quality potable water could be found to meet all the demands of modern society. One of the paradoxes facing water managers is that although there has been a determined and successful effort to provide a reliable supply of drinking water, little of it is actually drunk. The volume of water actually consumed or used in food preparation is about 10%. Moreover, we have adopted a 'once only use' of water to support life, meet our needs for a healthy environment, enable us to pursue notions of cleanliness, transport the wastes of our life style, and meet our needs for recreational uses. This led us to develop water supply, sewerage and drainage systems which at first seemed modest. The development of reticulated water supply and sewerage systems did lead to improved personal hygiene which was reflected in dramatic improvements in the health of communities. This success has coloured the way we have approached water supply and management ever since.

Origins of Current Problems

The current problem facing Sydney arises because Sydney Water has been too successful in delivering water of a quality, quantity and reliability exceeding its original undertaking. Its performance has raised community expectations that it can continue to do so. The growth of Sydney's population and the increased per capita consumption, which is now three times as much per person as it was when our forefathers built the present systems over a century ago. The community should now recognise that Sydney Water cannot continue to meet the demand for water in the manner the community has enjoyed without extreme exploitation of rivers in the near region or of massive increases in supply from desalination. Both of these options carry significant environmental and financial costs.

When the water supply and sewerage systems were first developed, the per capita consumption of water for domestic purposes was generally low. Changing attitudes to personal hygiene meant that people used flush toilets and flushed them with each use compared with earlier toilet practices. They also washed themselves more frequently. At first this was by bathing, but this was replaced by the increasing popularity of showering which, while quicker and more convenient than bathing, led to increased water consumption. To some degree the popularity of showering is related to the pleasure of the act – especially once heated water was more readily available – as much as it was to notions of personal hygiene. A recent survey of Sydney households' attitudes revealed their strong determination to maintain their level and nature of shower use suggests that programs designed to reduce the length of showers and the nature of the delivery of shower water may encounter strong passive resistance. That is, some of the water consumption is life style and fashion driven and only tangentially related to concerns for hygiene (Troy *et al* 2005).

Changes in attitudes to 'dirt' also led to increased water consumption. This is nowhere more obvious that in relation to clothes washing. Even where occupations and activities do not lead to soiled clothing, strong expectations have developed that people will wear fresh clothes every day – often changing clothes more than once daily. This inevitably increases the consumption of water for clothes washing. Water consumption in the kitchen also increased although it remains a small proportion of total internal household consumption.

External consumption of water also increased with the increasing popularity of swimming pools and more recently of spas. Garden usage is important, but because most Sydney households rely heavily on rainfall to maintain their gardens, it is less significant than might be assumed.

It is clear that Sydney cannot simply continue to harvest waters from sources outside its region to meet what appears to be an unquenchable demand without serious environmental consequences. This is acknowledged in the Metropolitan Water Plan (DIPNR 2004). The Plan, however, proposes major initiatives to increase the supply of water, including extraction of more water from the Shoalhaven River and investment in recycling in new release areas. It also is predicated on further reduction in demand. In essence the Plan is based on developing a major infrastructure program which is focused on growth areas, particularly those in Western Sydney.

A different strategy is required to obtain significant reduction in the consumption of reticulated water of potable quality. The strategy must acknowledge that the need to supply potable water remains. The question is: How is this to be achieved at the same time as we reduce the use of potable water for purposes and activities that do not need to use water of drinking quality and do so in an equitable manner?

The strategy should have seven elements and its central objective should be to try to make the city as water independent as possible so that it is less vulnerable and imposes less stress on the ecosystems within which it functions:

Element 1: Educational Campaign
Element 2: The supply obligation of the water supply authority should be limited to the volume of potable water needed for the health of the population
Element 3: Consumers should be required to accept some responsibility for their own behaviour by making use of the water resources locally available
Element 4: Waste water flows should be reduced to minimise pollution of receiving waters
Element 5: Any program of development should be capable of being progressively introduced
Element 6: Equitable Pricing Regime
Element 7: No human consumption of recycled water

Element 1: Educational Campaign

Element 1 would include a continuation and expansion of Sydney Water's campaign to educate people to the need to use non-potable water for laundry, bathroom and toilet consumption. Such a campaign might also include educating people to make less use of high phosphate detergents and a variety of toiletry products.

It will also require a different approach to the harvesting of water that falls as rain in the metropolitan area as well as to the recovery and treatment of water used within dwellings. That is, the solution must lie in a combination of measures to affect both demand and supply.

The campaign should also continue the attempt to educate the community to better ways of maintaining gardens while consuming less water.

On equity grounds this would require an approach which recognised that households in existing dwellings consume a far greater proportion of total water consumption than those in new housing. This would mean developing a program for the retrofitting of existing development to make it more environmentally sustainable as well as requiring all new developments to meet targets to reduce consumption of potable water. All housing, new and old, would thus become more water independent.

Element 2: The supply obligation of the water supply authority should be limited to the volume of potable water needed for the health of the population

Element 2 would include programs to reduce reliance on the reticulated supply of potable water for domestic consumption for activities and uses that do not need to use potable water. One approach would be to try to reign in the consumption by returning to volumes of potable water delivered to households to the quantities closer to the original 'design' consumption for the water supply system.

How might this be achieved?

The current estimate for external consumption is approximately 25% of the total household consumption (about 10% of this is used on gardens). The volume used for toilet flushing is almost the same at 23%. That is, almost half the water consumed per capita used on external uses and toilet flushing could clearly be of less than drinkable standard.

The volume used for laundry and bathroom purposes is about 42% of the total. Much of this could also be of less than potable quality.

Only 10% of total consumption used in the kitchen for drinking, food preparation and cleaning utensils, plates etc need be of the highest standard.

This suggests that there is a basic need to supply only 10% of the water used in households at the highest quality. If we allow that some of the bathroom consumption should also be of the highest standard, e.g. the bathroom hand basin and the shower/bath, we might settle on a need to supply potable water up to 20% of total consumption: say, 10% for kitchen use and 10% for bathroom use. This should become the supply obligation of Sydney Water.

Element 3: Consumers should be required to accept some responsibility for their own consumption behaviour by making use of the water resources locally available

The present water supply and sewerage systems create significant management problems and lead to higher cost of operation because of the tragedy of the commons issues. Households are under minimal pressure to reduce their consumption. They are also under little pressure to desist from discharging difficult or dangerous material to the sewage stream which complicates or makes difficult the operation of sewage treatment systems.

The low price of water also means that they are under little economic pressure to reduce their consumption.

The problem is to devise a water supply and waste management system which encourages people to accept responsibility for their own behaviour while pursuing the public health objectives that were central to the remit of public water authorities and do so without penalising or excluding low income households from the benefits of a high quality, low cost water supply and waste management system.

The challenge is to develop such a system and simultaneously reduce total consumption by 80%. The most obvious way to make households responsible for much of their own consumption would be to make use of local water resources.

Two possible sources suggest themselves:
1. Rainwater capture and storage in a household tank.
2. Recycling and storage of treated grey water in a household tank.

1. Rainwater tanks

Rainwater tanks were, until the 1890s, the most common supply for most city households. They were made illegal initially to ensure the finances for the then developing water supply authorities. They were also thought to be a health hazard for three reasons:

1. Rainwater washed bird and other animal droppings into tanks,
2. Birds and other vermin might be drowned in tanks resulting in pollution of the tank water from their decomposition.
3. Tank water had high levels of lead due to the use of lead flashing and lead based paints on roofing and lead pipes for internal reticulation.

Little evidence was presented in support of these propositions. Whatever the justification for the position taken then, the current situation is that it is now possible to discard the first rainfall to flush the roof clean ensuring that contamination of the tank water by bird and animal droppings is negligible. It is also possible to ensure that birds and vermin cannot gain access to the water tank. Finally, lead flashing and lead based paints and pipes have not been permitted in buildings for nearly a century so that this source of pollution is not relevant today.

It should also be noted that the great majority of farms and many dwellings and commercial undertakings in country towns rely entirely on tank water for their supplies. If tank water is a serious threat to health the question that has to be asked is: Why is the health threat of tank water only a problem in the city?

Assuming that capturing and storing rain water does not pose a health threat what size rainwater tank would be needed to meet household demand?

The new BASIX system already requires savings of ‘up to 40% of the potable water consumption of the current average of a similar sized home’. Much of this can be achieved to meet the license provisions by installation of dual flush toilets, efficient shower heads and taps as well as development of gardens using native plants and mulching. BASIX does not require the plumbing of the rainwater tank to provide a supply to facilities that do not require water to be of potable quality nor is there any monitoring to ensure that households achieve the level of savings sought in the license provisions. That is, the BASIX system only goes part of the way and is unlikely to reach the consumption reduction target unless the regulatory framework is strengthened to ensure that the rainwater tank is plumbed into the dwelling. The system proposed here differs from BASIX in that it proposes to continue to treat and recycle the grey water so that its end uses are either toilet flushing or gardening which would enable a much greater reduction in consumption of potable water.

Assuming that capturing and storing rain water does not pose a health threat what size rainwater tank would be needed to meet household demand?

If collected rainwater was reserved for use in the bathroom by plumbing the rainwater tank into the bath, shower and handbasin, then taking the figures for NSW (ABS 2004a) as a guide, it would need to be able to supply, on average, 16 kL per person per year (26kL – 10kL from the potable water supply). This would be equivalent to 1.3kL per person per month. Assuming the average size of households is that for Western Sydney, i.e. 3.05 persons, this would equal 4kL per month

A roof area of 140 square metres would yield 56kL if the tank it fed stored 60% the 668mm rainfall falling in the worst drought year (1994) (140*0.6*0.668= 56kL). Assuming relatively equal distribution of rainfall throughout the year, this would require a 4.7kL storage tank to meet all the needs of the average Western Sydney suburbs household (Sydney Water recommends a minimum size tank of 5kl). Increasing the storage to, say, 10kL, would allow for the contingency of unequal rainfall or of a larger than average sized household. A larger rainwater storage tank would simply give households a greater security of supply. Rainfall in non-drought years would be more than sufficient to meet the bathroom consumption for the average household assuming 60 percent of the average rainfall was collected from a roof area of 140 square metres.

2. Recycling and storage of treated of grey water

As noted above, modern rainfall collection systems allow the first flush of rain falling to be discarded to ensure that the water stored is of the highest quality. This discarded water could be diverted to a recycled water treatment system and then stored in a recycled water tank for use as recycled water.

In most years the rainfall available for collection would greatly exceed the storage capacity of the average tank. This 'surplus' water could also be redirected to the 'recycled water tank'. Rainwater runoff in excess of the combined capacity of the primary rainwater tank and the recycled water tank would be discharged to the storm-water drainage system.

The recycled water tank would be used to store the kitchen and bathroom consumption water once it had passed through a grey water treatment system. That is, the tank would need to be able to store the water used in food preparation and cleaning of utensils and plates, etc., plus the bathroom consumption.

Assuming that the collected 'kitchen' water was 75% of the average annual per capita kitchen consumption and the bathroom consumption was also stored the volume available to be treated for recycling would be 7.5 + 26= 33.5 kL per capita per year.

As noted above, modern rainfall collection systems allow the first flush of rain falling to be discarded to ensure that the water stored is of the highest quality. This discarded water could be diverted to a recycled water treatment system and then stored in a recycled water tank for use as recycled water.

Laundry consumption is approximately 16.2kL per capita per year which would, in turn, be recycled assuming a net recovery of 80% of the laundry water.

To improve the 'recyclability' of washing machine water it might be necessary to introduce regulatory changes to phase out the use of inefficient appliances and the use of high phosphate detergents and other cleaning agents which make it more difficult to treat effluents to recyclable quality.

While top loading washing machines use more water they are generally faster and more flexible in their use than front loading machines. If the washing machines in a dwelling are supplied with water from water harvested from the roof or with water recycled within the household there may be no need to change the 'mix' of washing machines.

Regulatory changes could include tighter regulation to control the discharge of effluents from commercial and industrial concerns to increase the 'recyclability' of water discharged to the sewerage system.

Assuming no change in the 'mix' of 'top' loading and 'front' loading washing machines would mean a reduction of 3.4kL per person per year. That is, the volume available for toilet flushing would be 33.5 – 3.4= 30.1 kL per person per year which is in excess of the 23.2kL per person per year used in toilet flushing. Toilet flushing water, i.e. 'black water', would be discharged to the sewerage system.

Assuming that the average size of households is that for Western Sydney suburbs, i.e. 3.05 persons, and that their use of the toilet is the same each month the size of recycled water tank to meet the total demand for toilet flushing would be 23.2*1/12*3.05 = 5.9kL. To store all the recycled water for the average household from the kitchen, bathroom and net laundry use, the tank would need to be 30.1*1/12*3.05 = 7.7kL capacity. This would mean that 1.8kL of water was available each month for external uses. A tank of 10kL capacity would enable 4.1kL of water to be used for per month for external use or provide additional security in supply of water for toilet flushing.

The water 'supply' system for a house would then have six components:

1. A connection to the reticulated water supply
2. A 10kL rainwater storage tank plumbed into the bath, shower and bathroom basin
3. A grey-water recycling treatment system for each house
4. A recycled storage water tank of 10kL capacity plumbed into the toilet and laundry with a upper level 'take off' for garden watering
5. A connection to the sewerage system for 'black water' waste
6. A connection to the storm-water management system.

The present system has three of these components viz 1, 5 and 6. The new system would require dwellings to install and maintain the two tanks and the grey water recycling system to Sydney Water standards. These components would increase the cost of dwellings but there would be significant savings in the water supply system, the sewerage system and the storm-water management systems. We would also expect that reduction in the volume of potable water supplied by the water supply network would leave more water to be applied to maintain environmental flows.

Reduction in the sewage discharge from dwellings would lead to smaller volumes requiring to be treated at sewage treatment plants and in turn smaller volumes to be discharged into receiving ecosystems.

Collection of rainwater, including that stored in the recycled water tank, would significantly reduce the storm-water runoff peaking problem.

By careful use of appropriate detergents and cleaning agents households would be responsible for the efficiency of their own recycling of grey water. That is, household behaviour would directly affect the volume and quality of the recycled water supply available for their own laundry and other uses.

Securing a similar degree of water independence for households in multi-unit developments would, in principle, be no different although the collection of rainwater and the processing and storage of recycled water would present slightly different challenges. It would be just as feasible to incorporate rainwater collection and storage facilities in new developments. The collection and treatment of recycled grey water would also present options under existing technology for new developments. Retrofitting existing multi-unit developments with rainwater tanks and grey water treatment and storage capacity might be harder to achieve than in traditional houses although on equity grounds it would be important to attempt to do so and there are already storage systems in use that could be adapted for many existing developments.

Taking a similar approach to the water supplied to new and existing industrial and commercial undertakings would also reduce the demand on potable water supplies and lead to similar economies in the water supply, sewerage and storm-water management systems.

Sensitivity of assumptions

Consumption

The estimates of consumption for the different uses within the household are averages reported in ABS 2004a. More detailed micro-metering measures are needed to improve on these estimates. It is clear that several of the internal consumption measures reported could be reduced if households adopted different usage patterns. The adoption of dual flush toilets has led to some reduction in toilet consumption and as they become the norm this consumption is likely to be further reduced. The use of high efficiency shower heads could also lead to reductions in bathroom consumption. Lower consumption appliances are already being more widely installed in new housing, so that as these appliances become the norm the average consumption for these uses will fall.

This means that the average consumption estimates used in the estimations above are at the higher end of the predicted consumption, thus providing a greater 'safety' margin in the estimated tank capacities. Should bathroom efficiency of use increase faster than toilet flushing or laundry usage it is possible that the 'system' as proposed might be inadequate in extended drought periods. Lower bathroom consumption would mean that less water was available for recycling and that a smaller tank would be needed for rainwater storage. This would allow more of the rainwater to be redirected to the recycled water tank. The balance between the two storage tanks would need to be worked out with more precise estimates of the consumption for different uses within the dwelling.

The illustrative model of the appropriate sized storage tanks was based on the average size of households in houses. It may be more appropriate to design the tank capacities having regard to the distribution of size of households. The ABS Census in 2001 (ABS 2003) indicates that only 61% of households in houses are less than or equal to three persons (the estimate used in the illustrative model was 3.05). Increasing the estimated household size to 5, say, would mean that 94% of houses with the system described would be able to meet the demand for water. The larger sized households tend also to live in larger houses which presumably have larger roof areas and therefore would be able to collect more water. We note that 94% of semi-detached dwellings housed four or fewer people per dwelling which means that a high proportion of households in such dwellings could also potentially collect sufficient rainwater to be water independent.

The amount of water used in gardens is heavily dependent on the gardening practices employed. Households in the coastal strip can more readily rely on summer rainfall to maintain gardens especially if the gardens are mulched and contain regionally appropriate native plants. In the system proposed a small volume of water would be available to help maintain gardens, the amount could be increased by the amount of any efficiency in internal consumption. To ensure that the recycling storage tank always held sufficient water for toilet flushing the ‘off-take’ for garden watering would have to be set at a level which retained the required volume.

Supply -Roof Area

There are no precise figures for the roof area of the stock of houses in Sydney. The average floor area of new separate houses (excluding the very large houses with more than 250 square metres floor area) increased significantly from 135 square metres in 1981 to 151 square metres in 1992 (Troy 1996:182). The average floor area of more modern houses is more than 150 square metres. The floor area is not the same as the roof area (in most cases the roof area is significantly greater because of the overhanging eaves that most houses have) so we cannot assume that the roof area has increased at the same rate although it is probable that roofs, including carport roofs, increased at a greater rate.

The roof area of 140 square metres assumed in this estimation is at the lower end of the distribution of roof area for the newer separate houses. This means that the roof area for a very large proportion of separate houses in the Sydney Metropolitan Area is large enough to provide a greater degree of security of supply than assumed in this estimation.

Rainfall capture

We have assumed 60 percent capture of rainfall for the bathroom supply. Modern systems can collect a greater proportion although we believe that basing estimated storage at a low proportion gives a margin of safety which allows for good capture in heavy storms that might exceed the capacity of the delivery system. Currently almost 6% of houses have rainwater tanks which is likely to be largely in response to Sydney Water and local government authority subsidies and encouragement.

Grey-water treatment system

The capacity of the treatment system would have to be large enough to process a day’s consumption. There are several systems on the market employing different approaches to the treatment and management of grey-water - each producing water of high standard (the water is generally of potable water standard but for aesthetic reasons we do not propose that the water should be used for human consumption). It should be noted that about 5% of houses already use grey water on their gardens although this is not generally treated (Troy *et al* 2005).

Pricing strategy and regulatory framework

To achieve a high level of compliance it would be necessary to construct a pricing strategy and regulatory framework that increased the probability of achieving the desired reductions in consumption. The price of the mandated maximum volume of potable water to be delivered to each dwelling might be set at the current level. Any consumption above that level would be priced at a rapidly increasing rate to discourage excess consumption and to encourage efficient use of on-site water.

Sydney Water would be required to ensure that the rainwater collection system and storage, the grey-water treatment system and the recycled water storage system were appropriately plumbed into the dwelling's reticulation, sewerage and storm-water disposal systems. To ensure continuing compliance and maintenance of the systems in a healthy condition the systems would need to be regularly inspected. These inspections could be made part of the regular reading of water meters. It might be appropriate to charge an annual 'connection and inspection' fee to cover the cost of these services.

Element 4: Waste water flows should be reduced to minimise pollution of receiving waters

The strategy would be to organise the storm-water drainage system and the sewerage networks and sewage treatment systems that as much use was made of local storm-water and recycled treated sewage for irrigating local parks and playing fields as well as for commercial and industrial uses as was possible.

This would be accompanied by a greater effort to ensure that the design and construction of developments was pursued to ensure that the runoff characteristics of catchments were as close as possible to their 'natural' profile prior to development. The cost of development would undoubtedly increase. A rainwater storage tank plus a grey water treatment system and a treated water storage tank and associated plumbing would cost about $8,000, for new developments and about $9,000 for retrofitting. These costs could be expected to fall if volume production took place. There are, however, significant off-setting benefits including reduced consumption of potable water which should also be taken into account. One immediate benefit would be a significant reduction in the need for investment in a major recycled water reticulation system. The lower flows in the sewerage system would also lead to significant reduction in investment in the sewerage system.

Households, industry, commerce and public facilities would use significantly less potable water which in turn would mean that the construction of new storage and large scale treatment plants could be delayed, possibly indefinitely. There would be less need for high volume reticulation of water supply systems as well as for sewerage system and treatment plants. A major benefit would be that households, industrial and commercial undertakings would become more responsible for managing their own affairs. An additional benefit would be that the storm water runoff problem would be reduced which in turn would reduce the pollution load in Sydney Harbour, Botany Bay and the Hawkesbury River systems. The water supply system would also be less vulnerable to attack or other disruption.

The benefits of the approach outlined include reducing the flow of sewage which means that the sewerage systems would be able to treat the lower volumes to a higher standard making it available for industrial use and for irrigation of parks and large public spaces. This would also minimize the discharge through outfall sewers with consequent reduction in environmental stress to the near ocean or river waters into which such flows are currently discharged.

The reduced stormwater runoff could also be captured for treatment and recycling for industrial use as well as for irrigation of public parks and gardens. It could also be used to maintain the environmental flows in rivers and other water bodies. Capturing and treating the reduced stormwater runoff would lead to reduction in the environmental stresses currently experienced by near coastal and river waters into which untreated stormwater currently drains.

This approach would require a different approach to the management both of sewerage systems and to stormwater drainage systems. Instead of the large scale drainage to a small number of points, the systems would ideally be managed as a series of systems on each of the sub-catchments that make up the city.

A significant benefit of this approach is that the city as a whole would be less vulnerable to break downs in the system and consumers would be made more directly responsible for the environmental health of the water catchments as well as to the security of their supply.

Element 5: Any program of development should be capable of being progressively introduced.

The current rate of additions to the stock of housing is between 1 and 1.5% per year depending on the stage of the building cycle. By requiring all new housing, whether on greenfield or redevelopment sites, to reduce their consumption of potable water supplied by water authorities the reduction in supply of potable water from central sources would begin to decline. The BASIX system now in NSW takes a useful first step in this direction in requiring greatly improved consumption standards in all new house construction but, as argued above, needs to be more definite and to aim for a higher level of savings to be effective.

An important element of the strategy, on equity grounds, would be to ensure that requiring all new dwellings to meet objectives to reduce consumption of potable water would be accompanied by programs to retrofit existing developments to meet the same objectives. In this manner the rate of reduction in consumption could be significantly increased.

To ensure wide support for the policy of reduction in water consumption, an integrated strategy would also need to develop programs, pricing strategies and regulatory frameworks to apply to new and existing industrial and commercial undertakings. That is, it would be essential to develop a transition program to ensure that the burden of achieving a significant reduction in demand for potable water was not borne only by the new additions to housing stock or to new industrial and commercial undertakings. New development whether on green-field sites or redevelopment, including significant renovation and extensions, could be required to comply with reduced consumption targets and the levels of water independence. Programs to retrofit existing areas of urban development could be progressively introduced to ensure that all areas of the city met the new reduced consumption targets. Such programs might be a mixture of phased introduction of regulations and price rises as well as subsidies, where appropriate, to enable dwellings and industrial and commercial undertakings to operate at the new reduced consumption levels.

Some forms of housing and commercial and industrial building lend themselves more easily to retrofitting than others. Areas in which there are concentrations of the dwellings and buildings more easily retrofitted should become the targets for programs designed to increase the rate at which consumption is reduced. An energetic, targeted campaign could over a decade, say, lead to a significant reduction in the demand for potable water supplied from central sources. If a retrofitting program was of the same scale as the new development additions to stock we could expect that in a decade 20-30% of households would consume approximately 80% less potable water than they otherwise would - assuming no change in behaviour. A more rapid rate of reduction could be achieved by a larger retrofitting program. Additional reductions in consumption due to changes in behaviour could be expected as households become more aware that their own behaviour directly affects both consumption and the efficiency of waste water treatment.

The net effect of such a strategy would inevitably mean that all housing, new and old, as well as commercial and industrial undertakings would become more water independent.

The approach of separately managing black and grey water waste streams from dwellings and industrial and commercial operations would leave open options for the later adoption of alternative approaches or technology for the management of either waster water stream. This is particularly important for black water flows.

Element 6: Equitable Pricing Regime

The regulatory and retrofit strategy would need to be buttressed by a pricing policy which ensured that water was supplied to households at the minimum guaranteed volume per person at an equitable price. In this way lower income households and lower consumption households would not be penalised. Nor would there be any discrimination between old and new building stock.

The price charged for consumption volumes above the minimum guaranteed volume should be set at a rapidly escalating rate to ensure that those who used more than the minimum paid significantly more for water. This would mean that those with high external consumption paid significantly more.

Under present pricing strategies rainwater collection and grey water recycling treatment and storage systems are simply uneconomic. Adopting an escalating rate for potable water consumed above the minimum guaranteed volume would rapidly change the economics of rainwater tank and grey water recycling systems and storage making such systems attractive. The new pricing regime for water announced recently (Sydney Morning Herald 2005a) partially acknowledges the importance of this argument although it could be argued that because the price increase is a simple two step tariff and does not come into full effect until water consumption exceeds the average, a very large proportion of households will be unaffected and will not be pressured to accept their responsibility to collect and store rainwater and to recycle grey water.

Financial problems that might develop for households, commercial and industrial undertakings that are in transition from the present system to a new system relying on greater independence of water services, particularly through retrofitting, might need to be addressed by creating new mechanisms to allow such consumers to pay for the new services over a specified period. These could include allowing the services to be paid off by a deferred charge calculated for each account to be added to their annual water service charges. Sydney Water currently offers a subsidy of up to $650 for the installation of a rainwater tank. This could be increased for the installation of a recycled grey water treatment and storage system. It might also be appropriate to develop greater subsidies for the retrofitting of existing dwellings. The offset to the net costs of rainwater and recycled grey water treatment and storage systems or deferred charges outlined above would be the savings from reduced consumption of potable water supplied by the water authority.

The water utilities and government should work out a suitable subsidy component to encourage consumers to move towards more sustainable water usage. One possibility would be the hypothecation for a specified period of all or a part of the revenue derived from Sydney Water's activities, currently paid to State Government as an addition to general revenue, to support the transition to sustainable water uses would be a positive indication of the need to take water conservation seriously and provide a major impetus to the transition process.

Element 7: No human consumption of recycled water

Given that there is popular resistance to the human consumption of recycled water (Sydney Morning Herald 2005b) this proposed strategy has a significant advantage because it does not entertain the idea of human consumption of recycled water.

The blackwater and stormwater drainage system should be organised to facilitate the drainage to local points within each sub catchment and the water treated for recycling so that it is available for industrial and commercial use and for irrigation of parks gardens and playing fields. Water surplus to these requirements should be used to maintain environmental flows in the rivers and bays of the Metropolitan region.

These local treatment plants could be progressively developed but initially would focus on areas of new development and areas of intensive redevelopment.

The proposed system for each house is outlined in Figure 21. It illustrates the way the water supplied to, collected, stored and used for the various activities in a dwelling could be arranged.

Major advantages of the proposed system are:

- Households are made more responsible to reduce their consumption of potable water.

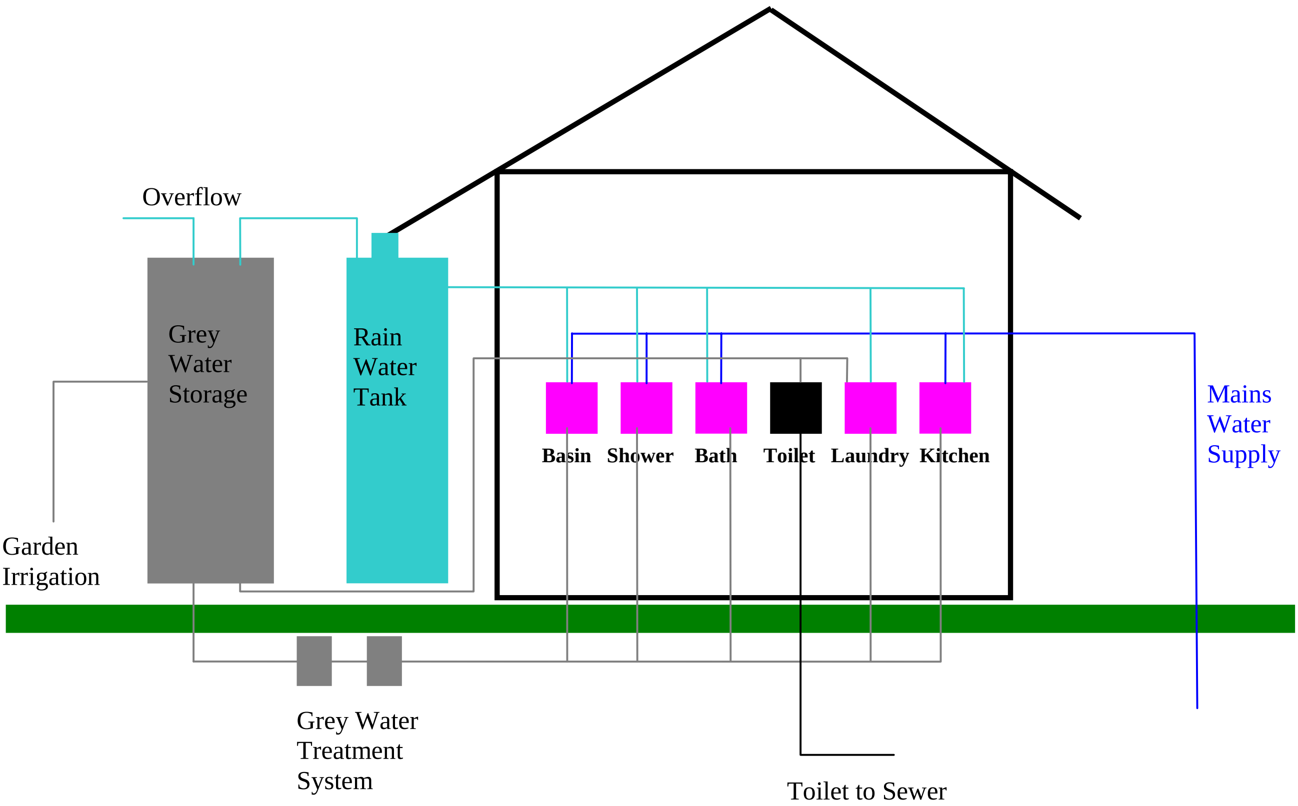
- Warragamba Dam would be able to meet the demand for water without further investment.

- The program could be phased in.

- Stormwater runoff would be reduced thus reducing pollution loads on Sydney Harbour, Botany Bay and the Hawkesbury River system.

- Pressures on Government investment in water and sewerage infrastructure would be reduced.

Figure 21: Schematic Design of Sustainable Household Water Supply System



10 CONCLUSION

This study of domestic water consumption in Sydney concludes that per capita water consumption in different types of dwelling were comparatively similar. While people living in houses consumed the highest amount of water on average, this was only marginally higher than the amount consumed by those in high rise flats, with people in low rise flats and semi-detached houses only marginally below this. Moreover, there was also a clear indication that socio-economic status has an impact on consumption at the metropolitan level, with per capita consumption in the east of Sydney being higher on average than that in the west. Overall consumption levels appear to be trending down in more recent years, a possible reflection of both declining lot sizes of new house development, and behavioural changes in consumption patterns following recent demand management initiatives by Sydney water to promote more efficient domestic water use.

While garden usage is thought to be a significant source of demand for water, the results reported here suggest that, at least until recently, climatic conditions in Sydney have acted to ameliorate overall water consumption for houses to the extent that average house consumption does not dramatically differ from that in higher density housing. This may be due to the fact that Sydney is located in a region where summer rainfall is higher than winter rainfall and is generally high enough to maintain moisture levels in the average garden environment for houses. In addition, there is also substantial external water usage in many higher density developments that contribute to comparable average water consumption levels.

Nevertheless, there can be no doubt that the education campaigns and water management initiatives by Sydney Water over the last decade or so to encourage households to economise on water consumption, including changing their gardening practices, have contributed to this felicitous outcome. The trends in average household consumption suggest a down turn in average consumption in all forms of dwelling in the past few years, a trend that is likely to have continued under the current water restrictions.

Another conclusion we may reach is that policies designed to reduce water consumption of households will need to include initiatives other than those related to external uses if they are to significantly reduce total demand. Behaviour and attitudes to water consumption are likely to hold the key to future conservation efforts. These issues are explored in more detail in a parallel report by the authors (Troy, *et al*, 2005).

Policy responses to the provision of the future water requirements for Sydney's growing population are likely to need a range of integrated measures. Importantly, for urban planners, this research has confirmed that policies designed to reduce water consumption based on housing form alone are unlikely to achieve any significant reductions in consumption levels. We have canvassed a range of policy options in this paper. Some of these are in line with current policy settings. Others would require new approaches to be adopted and developed by water utilities and the regulatory authorities. All these offer realistic options for the better management of water demand in Sydney.

We would argue that the greatest potential for securing the future water supply for Sydney, as in other Australian cities, lies in focusing on how demand for water can be best managed. A program of costed subsidies to encourage adoption of the options discussed above could achieve substantial savings in water consumption, especially over the long term. They offer a realistic alternative to the expensive large scale infrastructure solutions being canvassed to increase water supply for Sydney at the present time.

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APPENDIX 1: CHARACTERISTICS OF FACTORS OBTAINED FROM FACTOR ANALYSIS

Separate Houses

A total of 572 CDs were selected with 99% or more of the CD having separate houses only. Five factors explained 57% of the variance in the data set. Factor 1, explained 19%, Factor 2 12%, Factor 3 11%, Factor 4 8% and Factor 5 6%.

Factor 1 was characterised by individuals in low paying occupations (labourers and tradespersons), public rental accommodation, 'one parent' families. Individuals were more likely to be single and young. Persons of old age were negatively correlated with this factor as were 'couple only' households and those with higher level the occupations.

Factor 2 was characterised by an older population, either 'lone person' or 'couple only' households. Individuals may be separated or divorced.

Factor 3 is characterised by family households whose members are more likely to be in lower paying occupations. Individuals in this group are not mobile and do not rent, some are also born overseas.

Factor 4 is characterised by individuals aged 15-24 or over 65 who rent privately, some were born overseas. They typically have no motor vehicle and have middle income or have lower paying occupations.

Factor 5 is characterised by individuals in middle income jobs who were not born overseas. People in this group tend to be young (15-24) or more mature (45-64). They may also be of indigenous origin and may be separated or divorced.

Semi Detached Dwellings

223 CDs were selected each of which had 50% or more semi detached dwellings. Five factors explained 60% of the variance within the data set. Factor 1 explained 15% of the variance, Factor 2 14%, Factors 3 and 4 each explained 12% of the variance in the data set while Factor 5 explained 8% of the variance.

Factor 1 is characterised by couples without children, they have university qualifications and are in higher paying occupations. Individuals in this group are not likely to be of indigenous origin or be born overseas. Households in this group are more likely to own or be purchasing their dwelling.

Factor 2 is characterised by individuals who are aged 45-64, are more likely to be 'one parent' families or 'lone person' households, they do not rent privately or own a dwelling, suggesting most are in the public housing sector. Individuals in this group may have lower paying occupations and may be of indigenous origin.

Factor 3 is characterised by households that are likely to be 'one parent' families in middle to lower paying occupations, members are not likely to have tertiary education.

Factor 4 is characterised by family households (both 'couple' and 'one parent'). Individuals are in lower paying jobs and are mainly overseas born. Some households may also be purchasing their dwelling.

Factor 5 is characterised by young households who have well paying jobs, they may be purchasing their own home but are more likely to be renting privately.

Flats in a block of less than 4 storeys

A total of 341 CDs which had 70% or more of dwellings as flats in a block of less than 4 storeys were selected. Five factors explained 60% of the variance in the data set. Factor 1 explained 19% of the variance, Factor 2 13%, Factor 3 12%, Factor 4 9% and Factor 5 explained 7% of the variance in the data set.

Factor 1 is dominated by 'couples without children', who are owner-occupiers or purchasers. They are also highly educated and have higher paying occupations.

Factor 2 is characterised by households in publicly rented dwellings, they tend to be 'lone person' or 'one parent' families, have low incomes, they may be separated or divorced, be of indigenous origin and are predominately age 45-64 years

Factor 3 is characterised by older persons aged over 65 who are 'lone person' households and on low incomes. Tenure is not highly correlated.

Factor 4 is dominated by 'one parent' families on middle to lower incomes. Individuals in this sector are also more likely to be separated and divorced.

Factor 5 is similar to Factor 3. Households are older, on lower incomes are more likely to be 'lone person' households. Factor 5 differs from Factor 3 in that individuals in this sector are more likely to be owner-occupiers.

Flats in a block of 4 or more storeys

A total of 441 CDs in which 50% or more of the dwellings in the CD were flats in a block of 4 or more storeys were selected. Five factors explain 67% of the variance within the data set. Factor 1 explained 18% of the variance within the data set, Factor 2 16%, Factor 3 14%, Factor 4 11% while Factor 5 explained 8% of the variance in the data set.

Factor 1 is characterised by both 'couple' and 'one parent' families. All households have low incomes with members employed in lower level occupations and having no tertiary education. Households are more likely to have members of indigenous origin.

Factor 2 is dominated by the single mature and older housing sector. Households are predominantly over 45 years of age, are 'lone person' households, separated or divorced, and on lower incomes and are not likely to own a motor vehicle.

Factor 3 is dominated by households of 'couple with children' who are purchasing or own their dwelling and have multiple vehicles.

Factor 4 is characterised by 'lone persons' aged 35-44 who rent privately or are purchasing their dwelling, they are highly educated. There are some couples with children.

Factor 5 is characterised by low income persons who were born overseas. There are some couples with children in this sector, however it is dominated by overseas born people, who work in lower level occupations and have no motor vehicles.

APPENDIX 2: LIST OF CASE STUDY CDS

DWELLING CATEGORY	CD_Code	Suburb	LGA
Wholly Separate Houses	1240104	Church Point	Pittwater
	1240515	Newport	Pittwater
	1242807	Balgowlah	Manly
	1251302	Pennant Hills	Hornsby
	1260322	Rouse Hill	Baulkham Hills
	1261001	Carlingford	Baulkham Hills
	1270301	Tregear	Blacktown
	1271805	Lalor Park	Blacktown
	1272910	Parklea	Blacktown
	1272918	Stanhope Gardens	Blacktown
	1280207	North St Marys	Penrith
	1280503	Penrith	Penrith
	1281507	St Clair	Penrith
	1290216	West Hoxton	Liverpool
	1290806	Warwick Farm	Liverpool
	1291012	Moorebank	Liverpool
	1291907	Camden South	Camden
	1300108	St Andrews	Campbelltown
	1301201	Ingleburn	Campbelltown
	1301701	Bradbury	Campbelltown
	1310811	Kareela	Sutherland
	1320210	Bossley Park	Fairfield
	1330404	Northmead	Parramatta
	1331507	Sefton	Parramatta
	1340501	Auburn	Auburn
	1341506	Bankstown	Bankstown
	1341806	Milperra	Bankstown
	1361601	Carlton	Kogarah
	1371212	Lindfield	Ku-ring-gai
	1380304	Denistone	Ryde
	1380305	Eastwood	Ryde
	1382207	Chatswood	Willoughby
	1410603	Strathfield	Strathfield
	1431210	South Coogee	Randwick
	1441310	Dover Heights	Waverley
Predominantly Semi Detached Dwellings	1240202	Warriewood	Pittwater
	1240207	Ingleside	Pittwater
	1272403	Blacktown	Blacktown
	1272503	Minchinbury	Blacktown
	1280609	Penrith	Penrith
	1281209	Werrington	Penrith
	1291311	Casula	Liverpool
	1291324	Horningsea Park	Liverpool
	1300412	Claymore	Campbelltown

	1300506	Rosemeadow	Campbelltown
	1301405	Glenfield	Campbelltown
	1310907	Kirrawee	Sutherland
	1311813	Caringbah	Sutherland
	1321111	Cabramatta	Fairfield
	1321608	Bonnyrigg	Fairfield
	1330402	Wentworthville	Parramatta
	1332803	Baulkham Hills	Parramatta
	1340203	Lidcombe	Auburn
	1342611	Padstow	Bankstown
	1351808	Earlwood	Canterbury
	1360902	Mortdale	Hurstville
	1362010	Bexley	Rockdale
	1380108	Marsfield	Ryde
	1380111	Marsfield	Ryde
	1380908	Macquarie Park	Ryde
	1400506	Erskineville	South Sydney
	1410104	Liberty Grove	Concord
	1412606	Balmain	Leichhardt
	1413105	Glebe	Leichhardt
	1421805	Daceyville	Botany Bay
	1431301	Kingsford	Randwick
	1431609	Maroubra	Randwick
	1431812	Matraville	Randwick
	1440409	Paddington	Woollahra
	1441405	North Bondi	Waverley
Predominantly Flats in a block of less than 4 storeys	1240911	Narrabeen	Warringah
	1242314	Dee Why	Warringah
	1242511	Harbord	Warringah
	1242608	Manly Vale	Warringah
	1250608	Hornsby	Hornsby
	1280506	Penrith	Penrith
	1281311	St Marys	Penrith
	1290308	Miller	Liverpool
	1290709	Liverpool	Liverpool
	1310401	Sutherland	Sutherland
	1311611	Caringbah	Sutherland
	1312101	Cronulla	Sutherland
	1320804	Fairfield	Fairfield
	1321303	Cabramatta	Fairfield
	1321310	Cabramatta	Fairfield
	1330505	North Parramatta	Parramatta
	1341612	Bankstown	Bankstown
	1350102	Riverwood	Canterbury
	1350602	Lakemba	Canterbury
	1350802	Belmore	Canterbury
	1350909	Campsie	Canterbury
	1361305	Oatley	Kogarah

	1363209	Dolls Point	Rockdale
	1370811	Turramurra	Ku-ring-gai
	1380114	Macquarie Park	Ryde
	1400708	Waterloo	South Sydney
	1400815	Waterloo	South Sydney
	1400902	Redfern	South Sydney
	1410116	North Strathfield	Concord
	1410409	Homebush	Strathfield
	1411602	Summer Hill	Ashfield
	1420608	Marrickville	Marrickville
	1421005	Stanmore	Marrickville
	1431110	South Coogee	Randwick
	1441010	Rose Bay	Woollahra
Predominantly Flats in a block of 4 or more storeys	1241005	Collaroy	Warringah
	1243301	Manly	Manly
	1251513	Hornsby	Hornsby
	1270913	Mt Druitt	Blacktown
	1290710	Liverpool	Liverpool
	1290711	Liverpool	Liverpool
	1290902	Liverpool	Liverpool
	1290910	Warwick Farm	Liverpool
	1312105	Cronulla	Sutherland
	1320711	Fairfield	Fairfield
	1320803	Fairfield	Fairfield
	1330411	Westmead	Parramatta
	1330605	Parramatta	Parramatta
	1330609	Parramatta	Parramatta
	1330611	Parramatta	Parramatta
	1341608	Bankstown	Bankstown
	1350111	Riverwood	Canterbury
	1360813	Hurstville	Hurstville
	1360913	Mortdale	Hurstville
	1362803	Kogarah	Rockdale
	1371104	Killara	Ku-ring-gai
	1381507	Gladesville	Hunters Hill
	1382003	Lane Cove North	Lane Cove
	1382305	Artarmon	Willoughby
	1390313	Wollstonecraft	North Sydney
	1390603	Kirribilli	North Sydney
	1400103	Sydney	Sydney
	1400209	Pyrmont	Sydney
	1402016	Haymarket	Sydney
	1402017	Sydney	Sydney
	1410511	Strathfield	Strathfield
	1412104	Drummoyne	Drummoyne
	1421711	Eastlakes	Botany Bay
	1430212	Kensington	Randwick
	1441004	Rose Bay	Woollahra

APPENDIX 3: LGAS IN EASTERN AND WESTERN SYDNEY

Eastern Sydney	Western Sydney
Ashfield	Auburn
Burwood	Bankstown
Canada Bay	Baulkham Hills
Canterbury	Blacktown
Concord	Blue Mountains
Drummoyne	Camden
Hornsby	Campbelltown
Hunters Hill	Fairfield
Hurstville	Hawkesbury
Kogarah	Holroyd
Ku-ring-gai	Liverpool
Leichhardt	Parramatta
Manly	Penrith
Marrickville	
Mosman	
North Sydney	
Pittwater	
Randwick	
Rockdale	
Ryde	
South Sydney	
Strathfield	
Sutherland	
Sydney	
Warringah	
Waverley	
Willoughby	
Wollondilly	
Woollahra	

APPENDIX 4: MONTHLY RAINFALL FOR STUDY CDS IN SYDNEY, 1987-2003

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
January	54	169	132	77	83	80	71	27	119	154	162	101	156	40	145	75
February	30	111	73	558	45	350	71	87	56	49	133	46	170	22	125	299
March	149	79	145	126	22	65	94	145	169	43	31	25	44	226	93	81
April	40	469	327	289	31	77	43	90	26	39	6	221	177	53	87	32
May	61	151	123	127	75	47	17	26	170	154	113	220	46	37	200	72
June	60	67	207	27	329	80	44	63	76	90	69	94	63	33	18	21
July	87	138	19	57	88	12	76	39	3	60	99	84	151	28	101	17
August	213	48	43	183	7	28	51	15	0	119	15	357	62	20	50	21
September	9	108	2	99	15	21	89	19	201	85	98	42	30	32	23	18
October	202	1	16	42	11	65	51	34	39	27	50	36	157	68	37	10
November	135	145	54	28	38	137	76	64	118	78	34	72	54	151	74	22
December	78	133	111	41	178	173	39	59	90	48	30	43	86	60	39	79
Total Rainfall in Case Study CDs	1,118	1,619	1,252	1,655	924	1,135	721	668	1,067	947	842	1,341	1,198	771	992	749
Average per month	93	135	104	138	77	95	60	56	89	79	70	112	100	64	83	62