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# Analysis of water savings: a case study during the 2004/05 water restrictions in Cape Town

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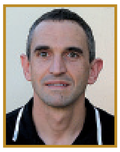
In October 2004 the City of Cape Town implemented water restrictions in line with the city's holistic approach to water demand management. To better understand the savings and improve the effectiveness of future restrictions, a detailed demand analysis was conducted during this period. In this paper the authors report on various aspects pertaining to the savings achieved. Emphasis is placed on the residential sector, but savings from other sectors are also presented. This is the first reported work in South Africa on the analysis of metered water demand and savings obtained in different consumer categories during water restrictions. Monthly metered consumption prior to and during water restrictions was recorded and analysed. The analysis shows that the water restrictions resulted in notable water savings in all administrative areas and for all land use, stand size and income categories included in the analysis. The residential sector is found to have a significant contribution to the total water saving. The paper explains the nature of these savings and also addresses the pitfalls and successes of the project.



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## INTRODUCTION

### Background

This detailed investigation of water consumption of users in the City of Cape Town (COCT) and water saving during restrictions provides interesting and useful information on a topic often riddled with guesswork and estimates. The study is a comprehensive analysis of the metered water consumption in the COCT prior to and during water restrictions implemented at the end of 2004 (COCT 2005). Comprehensive demand analysis is achieved by the application of recognised computer models.

The study area includes the six administration areas in the COCT at the time of this study, namely Blaauwberg, Cape Town City, Helderberg, Oostenberg, South Peninsula and Tygerberg, as depicted in figure 1 (page 17).

The results provide insight into the water savings achieved, thus making this paper particularly relevant for water managers and practitioners alike. Further research in this field is also encouraged by the results.

### Objective and approach

The study objectives include implementation of a comprehensive water demand model for the entire study area in order to investigate the water savings achieved. The objectives are achieved by implementing the following step-wise approach:

- Extraction of individual water meter readings from the COCT's treasury system for all customers and the two periods applicable to this study, namely 1 October 2003 to 1 April 2004 and 1 October 2004 to 1 April 2005
- Analysis of the above data, mainly by means of the Swift software tool
- Investigation of the water saving that was realised by the water restrictions. This was achieved by comparison of the individual water meter readings of the summer periods 1 October 2004 to 1 April 2005 with 1 October 2003 to 1 April 2004

### The October 2004 water restrictions

The COCT receives water mainly from the Berg and Breede River catchments, and this water is shared with a number of other users like agriculture and smaller local authorities. The management of these resources is the responsibility of the Catchment Management Agency (CMA) as per the National Water Act. In the absence of a CMA – as is the case for the Berg River system – the Department of Water Affairs and Forestry (DWAF) executes this function.

In this regard, a number of stakeholders are involved with the DWAF in a forum known as the Western Cape Water System Consultative Forum (WCWSCF). The main objective of the WCWSCF is to monitor the levels of the different supply reservoirs (dams) and to make decisions regarding the required curtailment in demand and subsequent restriction levels. Decisions made by the WCWSCF are aimed at ensuring a sustainable supply to all water users in the Berg

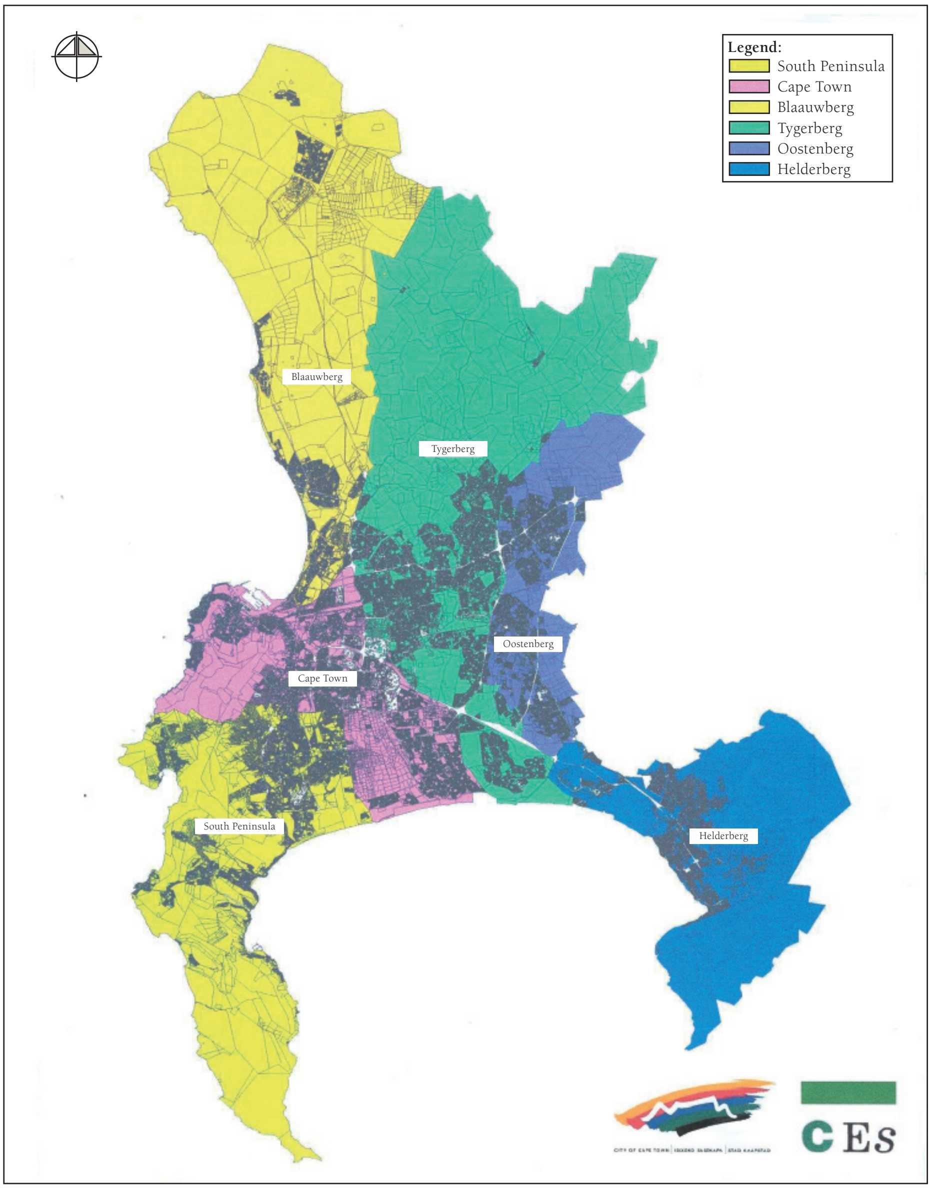


*Figure 1 Administration areas in the City of Cape Town (at time of this study)*

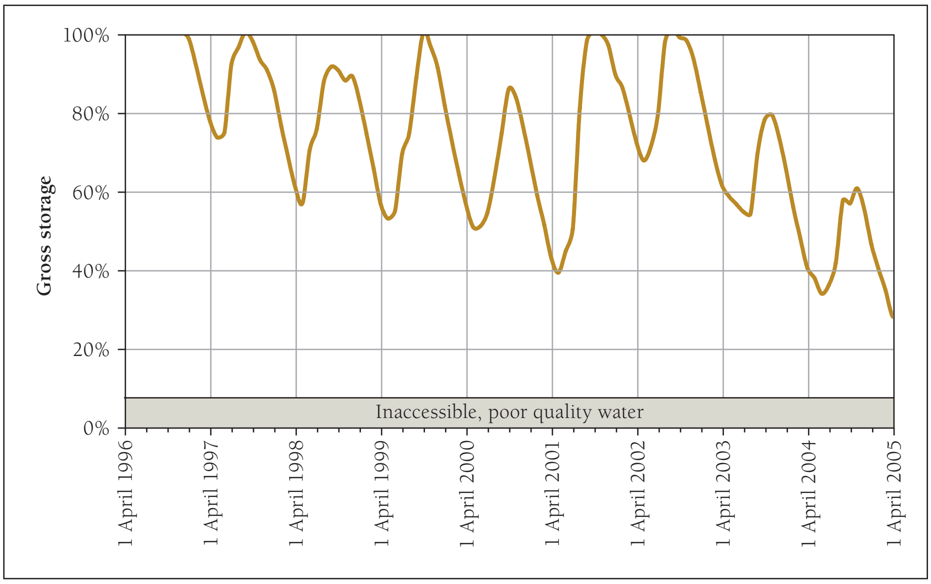


*Figure 2 Storage history for the Berg River system (DWAF, 2005)*

River system. These possible drought mitigation measures are assessed by the WCWSCF on an ongoing, monthly basis in the spirit of the COCT's water demand management (WDM) programme.

During the winter season of 2004 (rainy season), the catchment areas of the main supply systems to the Cape Town area received a mere 56 % of the average historical rainfall for this period. The combined storage of all the reservoirs in the system is shown in figure 2. It dropped to only 57 % and on 1 February 2005 was about 20 % lower than the storage at the same time in the previous year, which in turn was 20 % lower than the previous year. The WCWSCF recommended that restrictions be imposed to achieve at least a 20 % reduction in water demand compared to the 2003 consumption figures. A tool used for this purpose by the WCWSCF is shown in figure 3 and presents the level of curtailment required for a given storage volume at a given time (DWAF 2005).

The COCT responded to this requirement with an official notice calling for Level 2 restrictions in accordance with their bylaws, with effect from 1 January 2005. An awareness campaign was initiated three months prior to this date in October 2004. Level 2 restrictions have a target of 20 % water saving and entail the following:

- Limited watering of gardens, lawns and public open spaces – watering is only allowed between the hours of 18:00 and 10:00 and up to twice a week
- The use of hosepipes for washing motor vehicles, motor boats, paths and paved areas is prohibited
- Limited use of irrigation systems is allowed – only a single hand-held hose (fitted with a control nozzle) or buckets may be used
- Automatic flushing urinals (AFUs) are to be turned off in all public buildings when vacated and are prohibited in new buildings
- Increased water and sanitation tariffs to ensure cost recovery and discourage high consumption patterns

The measures pertaining to Level 2 restrictions listed above were pre-designed, form part of the holistic approach to WDM in the COCT and did not form part of this investigation or analysis. Such 'drought measures' call for immediate action with a focus on customer awareness, increased tariffs and effective enforcement of regulations by policing.

Comments regarding the effectiveness of the particular measures that were implemented, or improvement of the measures and WDM programme, are beyond the scope of this investigation. However, it is worth noting that some of the measures implemented during Level 2 restrictions have subsequently been incorporated in the COCT's new Water Bylaw. The new bylaw is explicit in regards to such issues, for example the AFU regulation outlined above has been included in the bylaw.

## METHODOLOGY

### Analysis of treasury data

The COCT uses the SAP treasury system to record all water meter and billing informa-

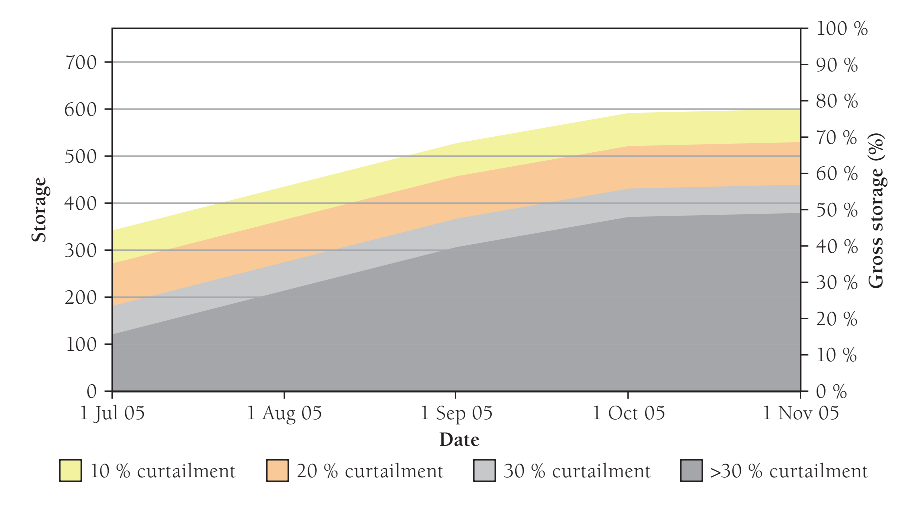


***Figure 3 Required curtailment levels used by the WCWSF (DWAF, 2005)***

tion. Water meter readings obtained from treasury systems have been analysed in previous research (Jacobs *et al* 2004; Van Zyl *et al* 2007) and a similar approach was considered appropriate for this study. In order to compare pre- and post-restriction consumption, it was necessary to extract data from the older treasury systems' data bases that used to be in use in the different administration areas in Cape Town prior to the implementation of SAP. Description of the data extraction process is beyond the scope of this investigation; suffice it to say that the monthly water consumption information could successfully be obtained in a format suitable for demand analysis and direct comparison for all users recorded in the SAP system.

The Swift software program for demand analysis was used in previous studies (Jacobs *et al* 2004; Van Zyl & Geustyn 2007) and is a tool for extracting and analysing water demand data from municipal treasury systems. As part of this investigation Swift was used and the data was also linked to the COCT's geographic information system (GIS) cadastral data base. This made it possible to spatially inspect the results.

The demand modelling software was set up to produce different data sets, one for each of the administrative areas in the COCT. This was advantageous for three reasons:

- The method of data storage in SAP and the previous (older) treasury systems is simplified by first extracting records according to administrative area
- Verification of data and results is possible – at various stages in the process – by comparing the sum of the six administrative areas' results to the total COCT data set
- The COCT is interested in results for each administrative area from a management point of view, while the complete result set – split along different lines – is valuable for research purposes, as discussed in this text

In all six administrative areas the complete record period is 1 February 2003 to 30 April 2005 and covers at least one summer season prior to and after the implementation of water restrictions. The complete period of record was split into different time series sections, of which the following two pertain to this study:

- Period 1: 1 October 2003 to 1 April 2004 – the summer average daily water demand (SADD) for the pre-restriction period, used to report the summer seasonal water use prior to the implementation of restrictions
- Period 2: 1 October 2004 to 1 April 2005 – the SADD for the period during restrictions

Individual users' readings from Period 1 and Period 2 are compared directly in this study to obtain information about changes in summer use brought about by restrictions. The summer period is particularly relevant, because most components of the Level 2 restrictions target outdoor use, which in turn contributes significantly to the seasonal peak. For this reason these two six-month 'summer' periods form the focus of this study.

The different periods of analysis and the fact that individual meter records could be identified in each of the five administrative areas enable substantial resolution to be obtained for analysis of the savings achieved. The four parameters used extensively in this study are water meter readings, land use codes, stand size and property valuation. These values are recorded in the SAP system and GIS of the COCT, for each user. The data extracted from the SAP system that survived screening based on record quality (AADD > 0, SADD > 0) was considered to be relatively robust in terms of this analysis and was used without amendment. The records surviving this phase – about 95 % of those initially extracted – were used for analysis.

Records lacking any of these four parameter values (say, with no land use code) were grouped together during analysis in appropriate categories. In addition to the initial robust screening phase the built in functionality of the demand analysis software was applied to identify and correct typical incidences relating to water meter readings (for example meter clock-overs or replacement).

## Land use codes

The land use code for a record is recorded in SAP, thus enabling the statistics of water demand to be broken down into the corresponding land use categories. The land use codes in the complete data set include 43 different codes in Blaauwberg, 49 in Cape Town Central, 44 in Helderberg, 42 in Oostenberg, 50 in South Peninsula, and 51 in Tygerberg. In order to compare the different data sets, 16 land use categories were defined and used in the demand analysis by mapping the different codes in each administrative area to these 16 codes. For presentation of results in this paper the 16 codes were grouped into the following four land use categories that are particularly relevant to this study:

- Residential – the residential land use category represents only single residential dwellings and forms the crux of this study
- Industrial, commercial and institutional (ICI) – the land uses grouped in this category include 'industrial', 'business', 'commercial', 'institutional', 'education' and 'government'
- Unknown – a category created for all records with no land use codes in SAP, or codes reflecting an unknown use
- Other – a category representing all remaining land uses recorded in the data base, including for example 'group housing', 'flats', 'farmland' (agricultural holdings), 'medical', 'other', 'parks' and 'sport'

However, in this paper the focus is on residential land use, since it is the most notable and best defined category of those considered in the study and contributes most to water savings in this case.

## Scope, limitations and focus of this study

The analysis of water use as per this study includes only those water consumers who are included in SAP, thus being metered consumers. The COCT data extract from SAP includes all water meter records for both paying and non-paying customers. However, because of ethical and confidentiality issues the information regarding customers' payment history was withheld during the extract procedure. Water saving by unmetered water users is thus not included in this study, while saving by all metered users – both paying and non-paying (with no means to distinguish between the two) – is included. Savings by consumers making use of stand pipes and other means of supply are often not included in the treasury system (where included it would

*Table 1 Number of water users in Period 1 and Period 2*

| Administration area | Residential | | ICI | | Other | | Unknown | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 |
| Actual number of water users | | | | | | | | | | |
| Blaauwberg | 35 631 | 39 364 | 1 549 | 1 725 | 977 | 1 203 | 202 | 258 | **38 359** | **42 550** |
| Cape Town | 143 666 | 146 598 | 6 073 | 6 288 | 5 520 | 5 975 | 16 870 | 17 065 | **172 129** | **175 926** |
| Helderberg | 28 433 | 30 437 | 1 312 | 1 432 | 2 992 | 3 340 | 879 | 1 051 | **33 616** | **36 260** |
| Oostenberg | 57 316 | 59 555 | 1 524 | 1 607 | 723 | 803 | 4 570 | 4 844 | **64 133** | **66 809** |
| South Peninsula | 61 951 | 65 657 | 1 842 | 2 794 | 2 099 | 2 909 | 2 515 | 4 339 | **68 407** | **75 699** |
| Tygerberg | 136 475 | 140 473 | 4 179 | 4 556 | 2 093 | 2 511 | 6 950 | 7 250 | **149 697** | **154 790** |
| **COCT (all areas)** | **463 472** | **482 084** | **16 479** | **18 402** | **14 404** | **16 741** | **31 986** | **34 807** | **526 341** | **552 034** |
| Expressed as a percentage of the total number of water users (%) | | | | | | | | | | |
| Blaauwberg | 92,9 | 92,5 | 4,0 | 4,1 | 2,5 | 2,8 | 0,5 | 0,6 | **100,0** | **100,0** |
| Cape Town | 83,5 | 83,3 | 3,5 | 3,6 | 3,2 | 3,4 | 9,8 | 9,7 | **100,0** | **100,0** |
| Helderberg | 84,6 | 83,9 | 3,9 | 3,9 | 8,9 | 9,2 | 2,6 | 2,9 | **100,0** | **100,0** |
| Oostenberg | 89,4 | 89,1 | 2,4 | 2,4 | 1,1 | 1,2 | 7,1 | 7,3 | **100,0** | **100,0** |
| South Peninsula | 90,6 | 86,7 | 2,7 | 3,7 | 3,1 | 3,8 | 3,7 | 5,7 | **100,0** | **100,0** |
| Tygerberg | 91,2 | 90,8 | 2,8 | 2,9 | 1,4 | 1,6 | 4,6 | 4,7 | **100,0** | **100,0** |
| **COCT (all areas)** | **88,1** | **87,3** | **3,1** | **3,3** | **2,7** | **3,0** | **6,1** | **6,3** | **100,0** | **100,0** |

resort under 'other' land use category in this study). Although the use of SAP records could be viewed as a limitation in analysing total water supply volumes (and losses), it provides the researchers with valuable focus to better understand changes by metered consumers at the end-user level.

The focus of this text is the scope of savings achieved and identification of groups and consumer categories responsible for such savings. For the purpose of this analysis, such savings are considered to be the direct result of the Level 2 restrictions implemented on 1 January 2005 and the awareness campaign initiated in October 2004, three months prior to the formal implementation date – in time to reduce the 2004/2005 summer demand. Apart from restrictions, various factors are known to influence demand, such as price (Arbués *et al* 2004; Van Zyl *et al* 2003; Espey *et al* 1997), income (Van Zyl *et al* 2007), geographic location (Jacobs & Haarhoff 2004), weather parameters (Kulik 1993) and system pressure (Haarhoff *et al* 2002; Gebhardt 1975).

The Level 2 restrictions target various aspects of consumer behaviour while factors such as those mentioned above simultaneously influence demand, leading to a complex interaction. In the process water demand is adjusted by users, part of which could be ascribed to the water restrictions. This study aims to provide insight into the specific water savings brought about by the combined effect leading to demand reduction during the specified restriction period. Explanation of the complex relationship between the explanatory variables influencing demand and the savings noted is beyond the scope of this paper.

The impact of growth in water demand with time, due to development, is accounted for in this study by considering the unit water demand of users, instead of the total demand. Analysis of unit water demand is possible since the number of water users is known by consumer category for each period of analysis. However, the total demand and volume of savings over the period of analysis is also included in this text to ensure a comprehensive presentation of results.

Stand size (A) and property value (PV) are used in this study to investigate the savings achieved. The modern tendency towards high-income group housing with individual title deeds and individual water meter connections complicates the smaller size categories. Small stands might have a high PV or low PV. This is not often the case for large properties. It is generally accepted that small stands have low values, but this is not always the case. This aspect could be included in future investigations to better understand the savings achieved by the smallest stand size category. The number of low PV stands in the smallest size category (typical of RDP-type housing schemes) is considered for the purpose of this work to notably outnumber those stands with a high PV.

## Water saving – a limitation

The term 'water saving' should be viewed in the correct perspective. The word 'save' is defined as 'to avoid the spending, waste, or loss (of something)' and 'to treat with care so as to preserve (Collins 2004). For this reason the term 'water saving' is often used in relation to water demand reduction. However, without additional explanation the term could be misinterpreted completely because the SAP data is analysed instead of 'actual water use' – given analysis of municipal water meter readings, as is the case here.

The water use records extracted from SAP in this study are based on the corresponding consumer meter readings and is an indication – hopefully a relatively accurate one – of how much water the consumer actually uses. In addition to meter error, the meter reading does not represent actual use. This is illustrated by, for example, customers bypassing a municipal water meter with an illegal connection, thus creating the perception of a 'saving' from the municipal supply because of the reduction in metered demand. Boreholes are another example: when water supply from the municipal system is replaced by a borehole to meet a consumer's demand (or part thereof), the water is in turn abstracted from an alternative water source (groundwater aquifer). From an environmental viewpoint it could be argued that the water is not 'saved', since the efficiency of use does not improve in such cases.

Users with rainwater tanks or on-site reuse technology may be 'saving water' by making use of more effective means, also leading to a 'saving' being recorded as a result of reduced municipal water meter reading – despite no change in the actual water used by end-users on the property.

For the purpose of this study the change recorded by the municipal water meter at a particular property with a metered water connection, as recorded in SAP, is considered to represent a change in the consumers' water use. Two subsequent summer seasons are evaluated for this purpose. Any reduction in the consumers' water use is thus considered to constitute a water saving.

# OVERVIEW OF RESULTS

## Sample size

The relatively large sample size used for analysis is reflected by the data shown in table 1. The total number of records for Periods 1 and 2 are 526 341 and 552 034

*Table 2 Summer average daily water demand (SADD) for Period 1 and Period 2*

| Administration area | Residential | | ICI | | Other | | Unknown | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 |
| SADD (kℓ/d) | | | | | | | | | | |
| Blaauwberg | 33 160 | 27 868 | 4 218 | 3 897 | 21 324 | 22 359 | 502 | 431 | **59 203** | **54 554** |
| Cape Town | 109 511 | 99 244 | 13 435 | 12 453 | 75 497 | 70 849 | 11 589 | 10 089 | **210 033** | **192 635** |
| Helderberg | 27 034 | 20 407 | 2 156 | 2 044 | 21 424 | 14 035 | 988 | 880 | **51 602** | **37 367** |
| Oostenberg | 45 326 | 38 207 | 3 327 | 2 992 | 12 078 | 15 016 | 3 296 | 2 940 | **64 026** | **59 155** |
| South Peninsula | 58 696 | 47 083 | 3 772 | 4 039 | 20 427 | 24 600 | 2 906 | 2 807 | **85 801** | **78 529** |
| Tygerberg | 110 848 | 92 317 | 9 976 | 8 993 | 100 705 | 71 901 | 5 350 | 4 464 | **226 879** | **177 676** |
| **COCT (all areas)** | **384 576** | **325 126** | **36 884** | **34 418** | **251 454** | **218 760** | **24 629** | **21 612** | **697 543** | **599 916** |
| SADD expressed as a percentage of the total (%) | | | | | | | | | | |
| Blaauwberg | 56,0 | 51,1 | 7,1 | 7,1 | 36,0 | 41,0 | 0,8 | 0,8 | **100,0** | **100,0** |
| Cape Town | 52,1 | 51,5 | 6,4 | 6,5 | 35,9 | 36,8 | 5,5 | 5,2 | **100,0** | **100,0** |
| Helderberg | 52,4 | 54,6 | 4,2 | 5,5 | 41,5 | 37,6 | 1,9 | 2,4 | **100,0** | **100,0** |
| Oostenberg | 70,8 | 64,6 | 5,2 | 5,1 | 18,9 | 25,4 | 5,1 | 5,0 | **100,0** | **100,0** |
| South Peninsula | 68,4 | 60,0 | 4,4 | 5,1 | 23,8 | 31,3 | 3,4 | 3,6 | **100,0** | **100,0** |
| Tygerberg | 48,9 | 52,0 | 4,4 | 5,1 | 44,4 | 40,5 | 2,4 | 2,5 | **100,0** | **100,0** |
| **COCT (all areas)** | **55,1** | **54,2** | **5,3** | **5,7** | **36,0** | **36,5** | **3,5** | **3,6** | **100,0** | **100,0** |

*Table 3: Summer unit water demand (SUWD) for Period 1 and Period 2*

| Administration area | Residential | | ICI | | Other | | Unknown | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 |
| SUWD (ℓ/stand·d) | | | | | | | | | | |
| Blaauwberg | 931 | 708 | 2 723 | 2 259 | 21 826 | 18 586 | 2 484 | 1 671 | 1 543 | 1 282 |
| Cape Town | 762 | 677 | 2 212 | 1 980 | 13 677 | 11 858 | 687 | 591 | 1 220 | 1 095 |
| Helderberg | 951 | 670 | 1 643 | 1 428 | 7 160 | 4 202 | 1 124 | 838 | 1 535 | 1 031 |
| Oostenberg | 791 | 642 | 2 183 | 1 862 | 16 705 | 18 700 | 721 | 607 | 998 | 885 |
| South Peninsula | 947 | 717 | 2 048 | 1 446 | 9 732 | 8 456 | 1 155 | 647 | 1 254 | 1 037 |
| Tygerberg | 812 | 657 | 2 387 | 1 974 | 48 115 | 28 634 | 770 | 616 | 1 516 | 1 148 |
| **COCT (all areas)** | **830** | **674** | **2 238** | **1 870** | **17 457** | **13 067** | **770** | **621** | **1 325** | **1 087** |

respectively. A relatively small fraction of about 6 % of the records have an 'unknown' land use allocation in the data base and is not a concern in view of this work. All such records were grouped as 'unknown' during the analysis as a unique set in order to prevent them from influencing the results for the 'known' land use categories.

Owing to spatial development the number of records increases from Period 1 to Period 2 for all land use categories in all six administration areas. With consideration for the number of users, the residential land use is dominant and contributes 88,1 % and 87,3 % to the total for the COCT in Periods 1 and 2 respectively. In Period 2 the fraction varies between the administration areas from 83,3 % in the Cape Town City area to 92,5 % in Blaauwberg.

This study encompassed the analysis of 463 472 residential users' water demand prior to restrictions (Period 1) and 482 084 during restrictions (Period 2). However, only those data points present in both periods – that is, 463 472 users – could be used to investigate savings. The size of the data set makes it the largest reported analysis of water savings at individual properties that could be traced in the literature review of local and international sources.

## Total water demand

A summary of the actual total water use is presented in table 2, showing the consumption as an average daily value (in kℓ/d). The following interesting characteristics are noted when inspecting the results for total water use:

- The total demand for all users in all land use categories combined reduced by 97 627 kℓ/d (±14 % decrease) from Period 1 to Period 2, despite the number of users increasing over the corresponding period by 25 693 (±5 % increase)
- The residential consumer category contributes about 55 % to the total demand
- The total demand for the residential consumer category reduced by 59 450 kℓ/d (±15 % decrease) from Period 1 to Period 2, despite the number of users increasing over the corresponding period by 18 612 (±4 % increase)
- For the COCT as a whole, the water used by ICI, 'other' and 'unknown' land use categories also decreased from Period 1 to Period 2, with a corresponding increase in the number of users
- The residential fraction of the total volume of water used contributes respectively 55,1 % and 54,2 % to the total water use in the COCT in Periods 1 and 2. These fractions are significantly smaller than the fractions of 88,1 % and 87,3 % stated earlier for the number of users. This result is a common phenomenon and is ascribed to water users in the ICI category contributing little to the number of users, but significantly to the volume of water used

## Unit water demand

The Period 1 and Period 2 summer unit water demand (SUWD) is shown in table 3 for all land use categories and all administration areas. The following interesting characteristics are noted when inspecting the results for unit water use:

- The unit demand for residential users is the lowest of all land use categories, with ICI, unknown and other type users having substantially higher unit demands in most cases
- There is notable variation in the residential unit demand between different administration areas, with values for Period 1 ranging

*Table 4 Unit water demand saving*

| Administration area | Residential | ICI | Other | Unknown | Total |
|---|---|---|---|---|---|
| SUWD reduction from Period 1 to Period 2 (ℓ/stand·d) | | | | | |
| Blaauwberg | 223 | 464 | 3 240 | 813 | **261** |
| Cape Town | 85 | 232 | 1 819 | 96 | **125** |
| Helderberg | 280 | 216 | 2 958 | 286 | **505** |
| Oostenberg | 149 | 321 | -1 996 | 114 | **113** |
| South Peninsula | 230 | 602 | 1 275 | 508 | **217** |
| Tygerberg | 155 | 413 | 19 481 | 154 | **368** |
| **COCT (all areas)** | **155** | **368** | **4 390** | **149** | **239** |
| Saving achieved in comparison to initial unit water demand (%) | | | | | |
| Blaauwberg | 23,9 | 17,0 | 14,8 | 32,7 | **16,9** |
| Cape Town | 11,2 | 10,5 | 13,3 | 13,9 | **10,3** |
| Helderberg | 29,5 | 13,1 | 41,3 | 25,5 | **32,9** |
| Oostenberg | 18,9 | 14,7 | -11,9 | 15,8 | **11,3** |
| South Peninsula | 24,3 | 29,4 | 13,1 | 44,0 | **17,3** |
| Tygerberg | 19,1 | 17,3 | 40,5 | 20,0 | **24,3** |
| **COCT (all areas)** | **18,7** | **16,4** | **25,1** | **19,4** | **18,0** |

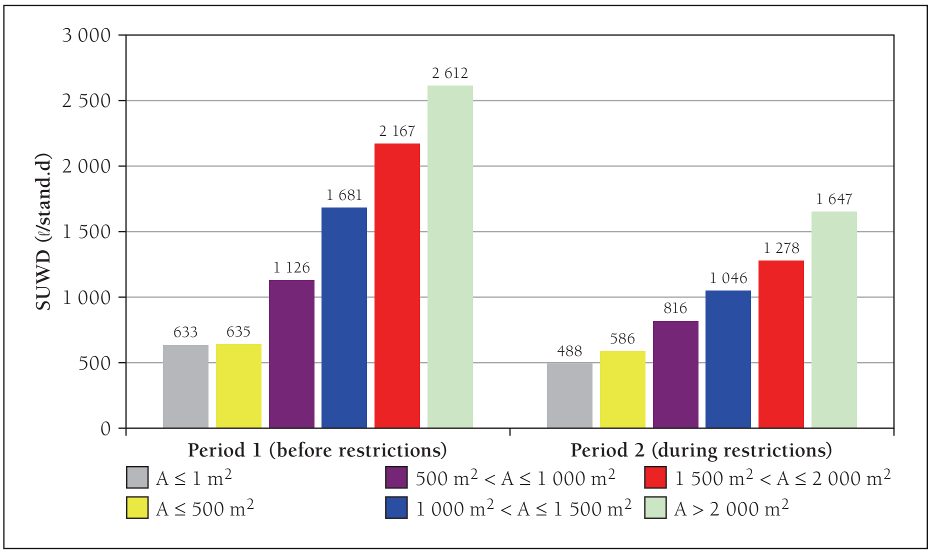


*Figure 4 Residential SUWD by stand size category for Period 1 and Period 2*

*Table 5 Residential unit water demand saving*

| | Reduction from Period 1 to Period 2 | | | |
|---|---|---|---|---|
| | Period 1 | Period 2 | Saving | |
| | (ℓ/stand·d) | (ℓ/stand·d) | (ℓ/stand·d) | (%) |
| Stand size category | | | | |
| $A < 1\ m^2$ (note A) | 630 | 490 | 140 | 22,2 |
| $A \leq 500\ m^2$ | 640 | 590 | 50 | 7,8 |
| 500 m2 $< A \leq 1\ 000\ m^2$ | 1 130 | 820 | 310 | 27,4 |
| $1\ 000\ m^2 < A \leq 1\ 500\ m^2$ | 1 680 | 1 050 | 630 | 37,5 |
| $1\ 500\ m^2 < A \leq 2\ 000\ m^2$ | 2 170 | 1 280 | 890 | 41,0 |
| $A > 2\ 000\ m^2$ | 2 610 | 1 650 | 960 | 36,8 |
| Property value category | | | | |
| R 0 (note A) | 1 300 | 830 | 470 | 36,2 |
| R 1 – R 200 000 | 820 | 680 | 140 | 17,1 |
| R 200 000 – R 400 000 | 1 100 | 770 | 330 | 30,0 |
| R 400 000 – R 600 000 | 1 390 | 910 | 480 | 34,5 |
| R 600 000 – R 800 000 | 1 630 | 1 050 | 580 | 35,6 |
| R 800 000 – R 1 000 000 | 1 870 | 1 190 | 680 | 36,4 |
| R 1 000 000+ | 2 440 | 1 620 | 820 | 33,6 |

**Note**
(A) These records with no values in the SAP system are grouped together in one category and removed from the analysis.

from 762 ℓ/stand·d in Cape Town City area to 951 ℓ/stand·d in Helderberg

- The unit demand for users in the category for 'other' land use shows the greatest variation from one area to the next, probably due to the poorly defined nature of users grouped in this category

## Water savings

The change in unit water demand from Period 1 to Period 2 is calculated to obtain an indication of the water saving brought about by the restrictions. The results presented in Table 4 show that the unit water demand decreases substantially from Period 1 to Period 2 for all land use categories in all six administration areas, bar the 'other' land use category in Oostenberg. An overall unit water demand saving of 18 % was achieved, with savings recorded throughout the entire spectrum of water users and administration areas.

The average reduction in residential unit water demand from Period 1 to Period 2 in the COCT is 155 ℓ/stand·d (suggesting a saving of 19 %). This varies between 85 ℓ/stand·d in Cape Town City area (saving of ±11 %) to 280 ℓ/stand·d in Helderberg (saving of ±30 %). This relatively large variation in saving between different administration areas – represented by arbitrary boundaries with no impact on water use – is best explained by extending the analysis to include parameters known to describe water use. Two characteristics that proved the most sensitive were:

- Stand size – known to explain water demand (Jacobs *et al* 2004), stand size is available from the data set for each property and is well suited for data analysis
- Household income – this is another known explanatory variable for demand and is often replaced by a suitable surrogate, namely stand value. The stand value, based on property valuations recorded in the data base, is readily available for further analysis and has been used for this purpose in previous research (Van Zyl *et al* 2007)

## RESIDENTIAL WATER SAVINGS BY STAND SIZE

Figure 4 shows a frequency histogram of the residential SUWD for the following stand size categories and for Periods 1 and 2:

- $A < 1\ m^2$, in other words, no or incorrect stand size is recorded in the data base
- $A \leq 500\ m^2$, excluding cases where $A < 1\ m^2$
- $500\ m^2 < A \leq 1000\ m^2$
- $1000\ m^2 < A \leq 1500\ m^2$
- $1500\ m^2 < A \leq 2000\ m^2$
- $A > 2\ 000\ m^2$

The unit water demand increases with increased stand size category for both Period 1 and Period 2. Also, when comparing the unit water demand for each stand size category in Periods 1 and 2, it is evident that the unit water demand remains rela-

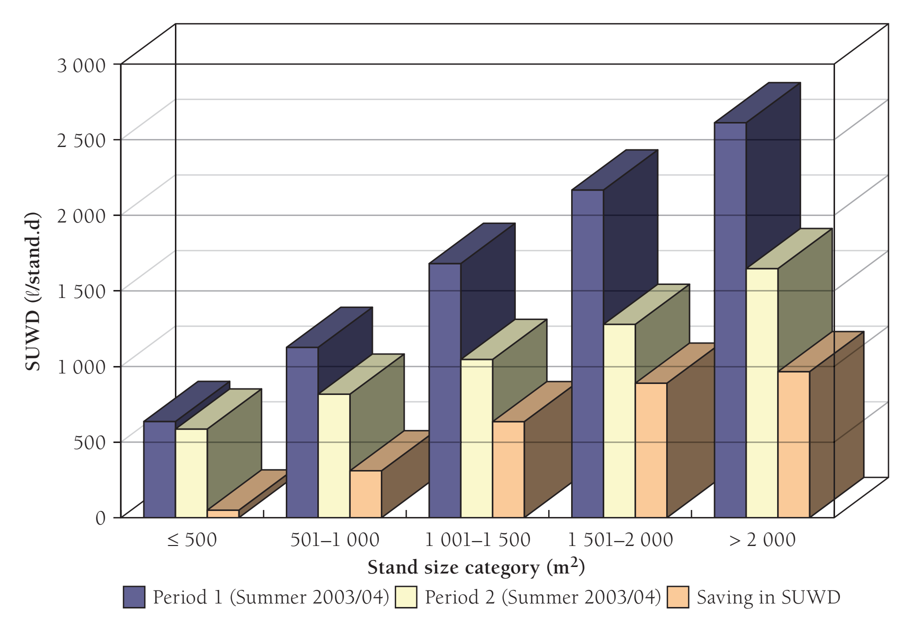


***Figure 5 Residential SUWD and saving by stand size (refer to table 5)***

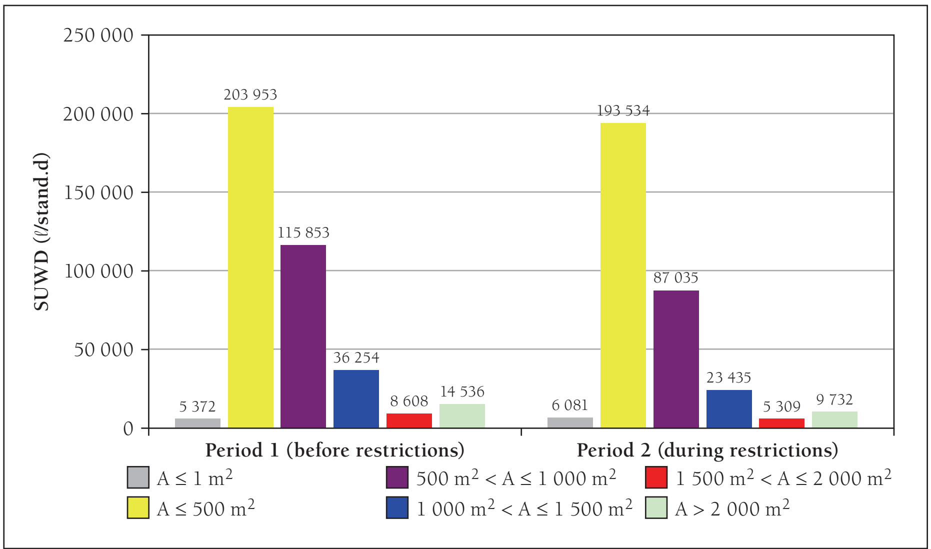


***Figure 6 Residential SADD by stand size category for Period 1 and Period 2***

tively constant in the smaller size categories while the larger size categories represent a substantially reduced residential SUWD.

The water saving is summarised in table 5, showing that the percentage saving increases from 7,8 % for the smallest size category to 36,8 % for the largest size category. This increase in the saving achieved with increased stand size is shown in figure 5. The histogram of residential SUWD for Period 1 and Period 2 suggests a linear trend. However, a linear fit to the data is not attempted, since detailed statistical analysis is beyond the scope of this study. This implies that savings achieved in the COCT are limited to the periods under discussion and are not intended for extrapolation to other areas.

It is also interesting from the viewpoint of water saving to consider the total volume of water used by all users combined in each category. Figure 6 shows the frequency histogram of the total residential water demand for each stand size category in Periods 1 and 2. The total demand decreases with increased stand size category. For example, the SADD by all users in the category for A ≤ 500 m$^2$ in Period 1 is 203 953 kℓ/d (193 534 kℓ/d in Period 2). This is almost 20 times more than the total volume of 8 608 kℓ/d in Period 1 in the category for 1500 m$^2$ < A ≤ 2000 m$^2$.

With reference to figure 4, this is in contrast to the increase noted in the unit demand by stand size for the same time periods. The largest volume of water (203 953 kℓ/d in Period 1) is used by the large number of users in the smallest stand size category and the least water is used by the small number of users in the largest stand size category. This apparent anomaly makes sense when considering the two extremes: there are 318 676 users in the size category for A ≤ 500 m$^2$ and only 5 569 users in the largest category, A > 2 000 m$^2$. Thus, there are about 57 times more users in the smallest size category than in the largest category. The unit demand for the largest size category is 2 612 ℓ/stand·d (Period 1), which is only four times higher than the unit demand of 635 ℓ/stand·d for the A ≤ 500 m$^2$ category in the same period. The consumers in the small size categories are as important, if not more so, than the larger properties in view of the total saving achieved. Also, water losses on private properties (often termed plumbing leaks) are often considered to be more prevalent among properties in the smaller stand size categories.

The following can be noted from the stand size-based results:

- The saving in unit water demand increases approximately linearly with increased stand size and varies between 50 ℓ/stand·d and 960 ℓ/stand·d (table 5)
- The category for A ≤ 500 m$^2$ contributes by far the most to the total volume of water used in each administrative area and for all time periods analysed, while the two categories for A > 1 500 m$^2$ contribute least to the total demand (figure 6)
- The highest residential SUWD is noted for the largest stand size category, and the smallest residential SUWD for the smallest stand size category
- There is a notable reduction in the residential SUWD for the large stand sizes with water restrictions, but it is much less notable in the smallest stand size category
- The unit water demand increases approximately linearly with increased stand size for both Periods 1 and 2, but the rate of increase reduces in Period 2 (figure 5)

## RESIDENTIAL WATER SAVINGS BY PROPERTY VALUE

Consideration of the available data for property value (PV) led to the final selection of the following seven PV categories:

- PV ≤ R 1 – a category to include all records with a property value smaller than R1, in other words those properties with no value recorded in SAP
- R1 < PV ≤ R200 000
- R200 000 < PV ≤ R400 000
- R400 000 < PV ≤ R600 000
- R600 000 < PV ≤ R800 000
- R800 000 < PV ≤ R1 000 000
- PV > R1 000 000

The residential SUWD per valuation category for Period 1 and Period 2 is shown in figure 7. The unit water demand increases with increased PV for both Period 1 and Period 2. When comparing the unit water demand for each PV category in Periods 1 and 2 the same finding is made as is the case with stand size categories: the unit water demand remains relatively constant from Period 1 to Period 2 in the smaller PV categories, while the categories with larger PV represent a substantially reduced unit water demand in Period 2. The saving in unit water demand is summarized in table 5, showing that the percentage saving increases from

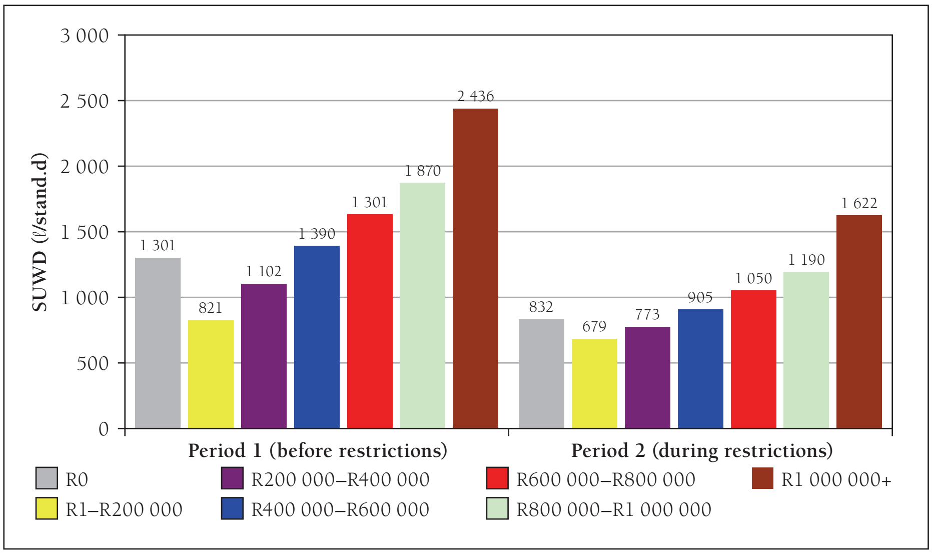


***Figure 7** Residential SUWD by value category for Period 1 and Period 2*

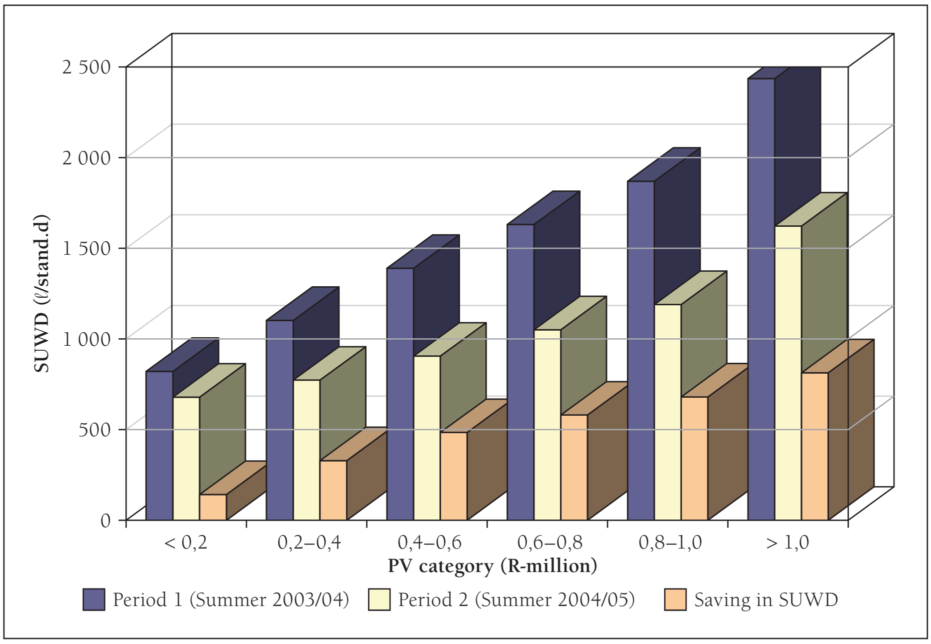


***Figure 8** Residential SUWD and saving by property value (Refer to Table 5)*

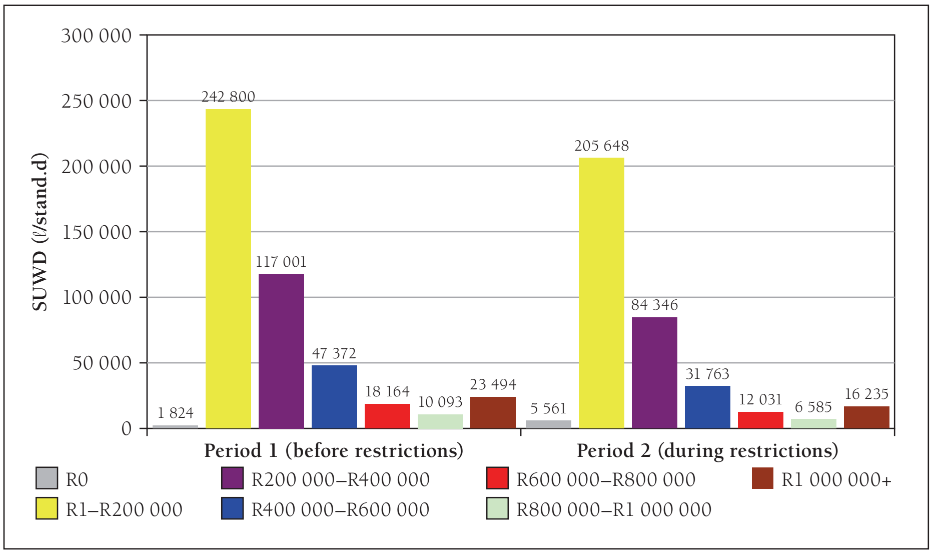


***Figure 9** Residential SADD by value category for Period 1 and Period 2*

17,1 % for the smallest PV category to 33,6 % for the largest PV category.

The increase in the saving achieved with increased PV is similar to that for stand size, as shown in figure 8. In accordance with the result for stand size, the SUWD values for both Period 1 and Period 2 are approximately linear when plotted against the PV categories, but this does not describe a linear fit to the data for the same reasons as stated before.

Figure 9 shows the frequency histogram of the total volume of water used in Periods 1 and 2 by all users combined in each PV category. The total demand decreases with increased PV category. For example, the SADD by all users in the smallest PV category, R 1 ≤ PV < R200 000, in Period 1 is 242 800 kℓ/d (205 648 kℓ/d in Period 2), while the total for the largest PV category is 23 494 in Period 1 (16 235 kℓ/d in Period 2), that is about 10 times less. This decrease is in contrast to the increase noted in the SUWD by PV for the same time periods – a similar result to the one obtained for the analysis by stand size. The relatively large number of users with low PVs are as important from the viewpoint of total volume saved, if not more so, than the significantly smaller number of users in the larger PV categories.

The following can be noted from the PV-based results:

- The saving in residential SUWD varies between 140 ℓ/stand·d and 820 ℓ/stand·d (table 5)
- The two categories with the lowest PV (R 1 ≤ PV < R200 000 and R200 000 ≤ PV < R400 000) contribute by far the most to the total volume of water used in each administrative area and for all time periods analysed, while the three highest value categories are responsible for the smallest volumes of use (figure 9)
- The residential SUWD and saving increases approximately linearly with increased stand size for both Periods 1 and 2, but the rate of increase reduces in Period 2. In other words, people living on properties with a higher PV use more water per household than those on properties with lower PVs (figure 8)

## DISCUSSION

### Water demand for the residential consumer category

Although comparison of SADD and AADD values may appear inappropriate, the SADD from this study for the six-month summer period could be superimposed on AADD values. This would give an indication as to whether the SUWD is in fact higher than the theoretical AADD, based on guideline curves – as would be expected. The result is shown in figure 10, where it is compared to two recently published AADD guidelines: the winter rainfall region proposed by Jacobs *et al* (2004) and the coastal data set by Van Zyl *et al* (2007). It is interesting to note that the six-monthly summer ADD corresponds roughly to the guideline curves for AADD values.

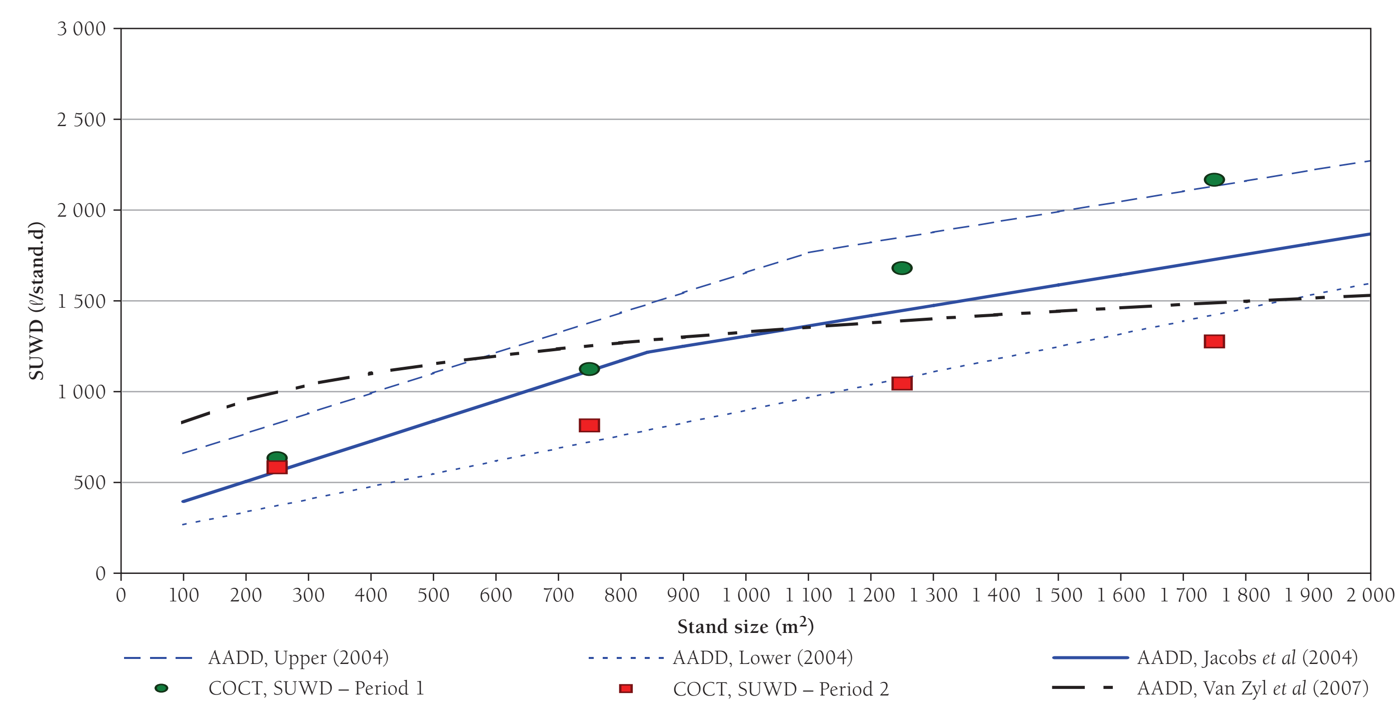


***Figure 10** Residential SUWD versus stand size based guidelines for AADD*

The SADD during restrictions is lower than before restrictions – as expected – and corresponds to the lower envelope, despite it not being an annual average value. This suggests that use of the AADD guideline curves proposed by Jacobs *et al* (2004) would have led to over-estimates for demand during the Level 2 water restrictions in Cape Town. This is despite the results by Jacobs *et al* (2004) being much less conservative than previous guidelines (CSIR 2000).

## Water saving for the residential consumer category

The results suggest that properties in the lower size and PV categories (and all administration areas independently, although this is not shown in the graphs) do not adjust water consumption considerably with water restrictions, but those in higher categories do. Garden water demand is known to be relatively price elastic, while indoor demand is considered to be inelastic. In addition, mainly garden water use is targeted by the Level 2 restrictions – an end-use more common to the properties with a higher value or larger stand size, thus leading to a more significant unit saving per property in the larger categories than the smaller ones.

For residential land use the saving achieved in each administration area for the smallest and largest stand size categories is:

- Blaauwberg: 11,8 % reduction ($A \leq 500$ m$^2$) and 40,2% ($A > 2\,000$ m$^2$)
- Cape Town: 4,6 % reduction ($A \leq 500$ m$^2$) and 31,7% ($A > 2\,000$ m$^2$)
- Helderberg: 12,5 % reduction ($A \leq 500$ m$^2$) and 44,0% ($A > 2\,000$ m$^2$)
- Oostenberg: 12,2 % reduction ($A \leq 500$ m$^2$) and 35,2% ($A > 2\,000$ m$^2$)
- South Peninsula: 13,8 % reduction ($A \leq 500$ m$^2$) and 35,3 % ($A > 2\,000$ m$^2$)
- Tygerberg: 5,9 % reduction ($A \leq 500$ m$^2$) and 40,3% ($A > 2\,000$ m$^2$)

The saving for the combined COCT region increases with stand size category and with PV category, as shown in table 5.

In both instances the percentage saving achieved rises steeply in the lower two categories to an apparent asymptotic value of about 40 % in the large categories. This percentage saving in SUWD is in broad agreement with savings reported elsewhere. A 46 % saving was achieved during drought conditions in California (Loaiciga 1997) and a saving of up to 50 % is reported by Hunt et al (1998) for gardens that are extensively xeriscaped. Extensive xeriscaping of gardens in Cape Town might hold promise for additional savings in the larger stand size category (and PV category) where garden irrigation is common.

In South Africa a saving of 36,8 % was achieved with a retrofit project in Sebokeng, while a saving of 18,5 % was reported for 946 flats in central Johannesburg after a plumbing repair project (McKenzie *et al* 2002). The latter example does not include properties with gardens, thus restricting the potential savings achieved in that case to a lower value.

## Nature of residential water savings

The Level 2 water restrictions target mainly outdoor residential water use. The impact is clear from this research, where a significant reduction in SUWD is noted in the large stand size and large property value categories where outdoor use for garden irrigation is common.

However, it is important not to underestimate the significant contribution to water savings by the numerous residences in the small stand size and low value categories, despite a relatively small percentage saving by customers in this group. The achieved saving of about 10 % in SUWD for customers in the small stand size and stand value categories, where indoor demand is considered to be dominant, suggests that a saving in indoor demand was also achieved with water restrictions in this group specifically (indoor demand savings could also have been achieved for the other categories, but this is clouded by the addition of notable outdoor use volumes).

Work by Van Zyl *et al* (2003) shows that the short-term price elasticity for indoor demand in townships is –0,30. To achieve the observed saving of 7,8 % in this category in COCT, a price increase of 26 % would have had to be observed by a customer in this volume bracket – based purely on theory and the published price elasticity value. This is of the right order of magnitude: the actual water account for a 15 kℓ/month use at the time of implementing the Level 2 restrictions would have increased from R25,80 to R32,37 – an increase of 25 %. In the same manner the actual price increase faced by a 10 kℓ/month and 20 kℓ/month user under Level 2 restrictions would have been 8 % and 33 % respectively. The saving brought about by these low-use customers could thus be ascribed mainly to the price increase brought about by the restrictions implemented.

## Comparison of results to the total volume of water supplied

The monthly total volume of water supplied to the COCT from all water sources combined is presented in table 6. The monthly

*Table 6 Total water supply to COCT during study period*

| Reading date | Month | Period | Total COCT water supply (kℓ/month) | Sub-total (kℓ) |
|---|---|---|---|---|
| 1 November 2003 | October | Period 1 | 30 677 703 | 179 888 609 |
| 1 December 2003 | November | | 30 563 598 | |
| 1 January 2004 | December | | 32 470 015 | |
| 1 February 2004 | January | | 31 749 010 | |
| 1 March 2004 | February | | 30 609 480 | |
| 1 April 2004 | March | | 23 818 803 | |
| 1 May 2004 | April | – | 24 797 357 | – |
| 1 June 2004 | May | | 21 908 381 | |
| 1 July 2004 | June | | 21 825 276 | |
| 1 August 2004 | July | | 21 754 961 | |
| 1 September 2004 | August | | 23 609 633 | |
| 1 October 2004 | September | | 23 742 054 | |
| 1 November 2004 | October | Period 2 | 26 069 970 | 151 424 631 |
| 1 December 2004 | November | | 27 722 759 | |
| 1 January 2005 | December | | 26 677 153 | |
| 1 February 2005 | January | | 23 904 865 | |
| 1 March 2005 | February | | 25 282 823 | |
| 1 April 2005 | March | | 21 767 061 | |
| | | **Average Period 1** | **29 981 435** | **kℓ/month (summer)** |
| | | **Average Period 2** | **25 237 439** | **kℓ/month (summer)** |
| | | **Reduction (Period 1 to Period 2)** | **4 743 996** | **kℓ/month (summer)** |
| | | **Percentage reduction** | **15,8** | **%** |

record presented in the table covers the complete study period. The six-monthly summer average for the total supply volume to the COCT reduced by 15,8 % from Period 1 to Period 2. This reduction in the total volume supplied is slightly more than the 14,0 % reported earlier (refer to table 2) for the total reduction from Period 1 to Period 2 during analysis of the individual users' water meter readings as per the SAP records.

## Additional research

The findings from this study present substantial results in a field of critical importance to water managers and engineers. Water restrictions and water saving should receive renewed attention, with particular focus on specific results based on measured data. This study was limited in a few ways, as discussed before, most of which could be addressed by means of future research shedding light on the following topics:

- Extension of the work beyond the limitation of metered, billed users included in the SAP system to also include all water use (and losses)
- Knowledge of the water source at each residence, including the use of boreholes, rain water and on-site grey water reuse. These alternative methods of supply are often intended to meet garden watering demand
- Investigation into the scope of illegal connections, including temporary connections, provided by consumers during restrictions. Such connections would create the false impression of savings and have the additional negative effect of increased non-revenue water volumes
- Evaluation of plumbing leaks on private properties, particularly in the small stand size- and low value categories
- Detail financial analysis regarding the impact of tariff structures and pricing during restrictions
- Comprehensive statistical analysis of the available data to extrapolate the savings achieved in the COCT to other regions
- Investigation into the permanent versus temporary nature of the savings
- Investigation into water use and saving as a function of PV value for properties with relatively small areas

## CONCLUSION

A substantial reduction in demand was achieved when comparing the summer period prior to restrictions (1 October 2003 to 1 April 2004) to the summer period after the implementation of water restrictions (1 October 2004 to 1 April 2005). The overall reduction in SUWD achieved in the COCT is 14 % and is substantial in all categories, with a clear trend of increased percentage saving with increased stand size and also with increased PV.

The larger stands were found to achieve a much larger unit water demand reduction than the smaller stands (the reduction per stand is more, but there are relatively few users within categories defining low-density and high-income areas). The maximum percentage reduction in SUWD from Period 1 to Period 2 is achieved in the second largest stand category and second largest value category. In both cases the saving is about 40 %.

For the high-density areas the SUWD reduction is only 8 %, but because of the much larger number of users in the smaller categories, this results in a larger total volume saving for the high-density and low-income areas.


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## REFERENCES


Arbués, F, Barberán, R and Villanúa, I 2004. Price impact on residential water demand: a dynamic panel data approach. *Water Resources Research*, 40(11).

COCT (City of Cape Town) 2005. City of Cape Town water consumption study – progress report 1, a report by Community Engineering Services and Africon to the COCT.

Collins 2004. *Student's dictionary*. HarperCollins.

CSIR (Council for Scientific and Industrial Research) 2000. *Guidelines for human settlement planning and design*. A report compiled under the patronage of the Department of Housing by the CSIR Building and Construction Technology.

DWAF (Department of Water Affairs) 2005. Western Cape Water Supply System monthly monitoring report. A monthly report compiled by Ninham Shand Consulting Engineers for DWAF and the WCWSCF.

Espey, M, Espey, J and Shaw, W D 1997. Price elasticity of residential demand for water: a meta-analysis. *Water Resources Research*, 33(6):1369–1374.

Gebhardt, D S 1975. The effects of pressure on domestic water supply including observations on the effect of limited garden-watering restrictions during a period of high demand. *Municipal Engineer*, 6(6):41–47.

Haarhoff, J, Geustyn, L C and Van Zyl, J E 2002. Compilation of a residential water use model for Rand Water with elasticity for price, erf area, income and pressure, pilot study. A report compiled by the RAU and GLS Civil Consulting Engineers for Rand Water.

Hunt, J B, McDevitt, W and Hunt, G 1998. *Water efficiency manual for commercial, industrial and institutional facilities*. A joint publication of the Division of Pollution Prevention and Environmental Assistance and Division of Water Resources of the North Carolina Department of

Environment and Natural Resources, and the Land-of-Sky Regional Council – WRATT Program.

Jacobs, H E and Haarhoff, J 2004. Application of a residential end-use model for estimating cold- and hot water demand, wastewater flow and salinity. *Water SA*, 30(3):305–316.

Jacobs, H E, Geustyn, L C, Loubser, B F and Van der Merwe, B 2004. Estimating residential water demand in southern Africa. *Journal of the South African Institution of Civil Engineering*, 46(4):2–13.

Kulik, V 1993. Simple weather-water demand model. *International Journal of Water Resources Development*, 9(3):293–304.

Loaiciga, H A and Renehan, S 1997. Municipal water use and water rates driven by severe drought: a case study. *Journal of the American Water Resources Association*, 33(6):1313–1326.

McKenzie, R S, Wegelin, W A and Meyer, N 2002. Leakage reduction projects undertaken by Rand Water. A report compiled by WRP Water Resource Planning and Conservation for Rand Water WDM Pilot Projects.

Van Zyl, H J, Van Zyl, J E, Geustyn, L C, Illemobade, A and Buckle, S J 2007. Benchmarking of water consumption in selected South African cities. *WRC Report K5/1525.*

Van Zyl, J E and Geustyn, L C 2007. Development of a national water consumption archive. *WRC Report 1605/1/07.*

Van Zyl, J E, Haarhoff, J and Husselman, M L 2003. Potential application of end-use demand modelling in South Africa. *Journal of the South African Institution of Civil Engineering*, 45(2):9–19.

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| A | Property area or stand size ($m^2$) |
| AADD | average annual daily water demand (kℓ/d) |
| AFU | Automatic flushing urinal |
| CMA | Catchment management agency |
| COCT | City of Cape Town |
| d | day |
| DWAF | Department of Water Affairs and Forestry |
| GIS | Geographic information system |
| ICI | Industrial, commercial and institutional (land use category) |
| kℓ | kilolitres (thousand litres) |
| kℓ/stand·d | volume of use (kℓ) per stand, or property, per day |
| ℓ/stand·d | volume of use (ℓ) per stand, or property, per day |
| PV | Property value (according to municipal valuations) |
| RDP | Reconstruction and development programme |
| SAP | A treasury system used by the COCT |
| SADD | Summer average daily water demand (kℓ/d), 1 October to 31 March |
| SUWD | Summer unit water demand (kℓ/stand·d), 1 October to 31 March |
| WCWSCF | Western Cape Water System Consultative Forum |
| WDM | Water demand management |