Water Benchmarks for Offices and Public Buildings

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EXECUTIVE SUMMARY

This report summarises findings of a study undertaken by Exergy on behalf of the Department of the Environment and Heritage into the water consumption of office building and public buildings in Australia. This project was jointly funded by the Australian Government and the governments of Western Australia, South Australia, Victoria, the ACT, New South Wales and Queensland.

Data on water consumption and water consumption features was gathered from 132 office buildings and 18 public buildings around Australia.

Office Building Water Consumption

Office building water consumption intensity (water consumed per m²) was shown to be approximately constant relative to identifiable technical and operational features of the buildings but subject to significant climate effects. To create a water consumption benchmark, the following process has been developed:

Water consumption intensity in kilolitres per m² W is normalised for climate via the following equation to become normalised water consumption intensity N:

$$W_{corr} = 0.56158 - 0.001038 CDD_{15wb}$$
$$N = W + W_{corr}$$

Where CDD_{15wb} refers to cooling degree days calculated to base 15ºC wet bulb. The normalised water consumption intensity can then be assessed on the following scale, which has been designed to follow the same scoring methodology as the National Australian Building Environment Rating system and the Australian Building Greenhouse rating scheme:

Rating	Water consumption (kl/m² per annum)	% of sample rating at this level or better
1/5	1.50	80%
2/5	1.25	63%
2.5/5	1.125	50%
3/5	1.0	36%
4/5	0.75	17%
5/5	0.5	5%

Assessment of the deviation of the raw water consumption data from the median climate corrected benchmarks indicated no statistically significant influence on water consumption from any of the following factors:

- Occupant density of buildings
- Hours of use of buildings
- Use of water cooled chillers

- Exterior water features and irrigation systems*
- Water management practices and systems
- Water pricing

In most cases, there is also no discernable difference in median water consumption either. Only in the case of water cooled chillers does it appear likely that a larger data set would ultimately yield a statistically significant result.

Public Building Water Consumption

The small size of the public buildings sample dictated a simple benchmark approach. An average water consumption intensity of 3.34kl/m² per annum and a best practice target of 2 kl/m² per annum have been identified based on the data. It would be desirable to supplement this benchmark with additional data to ensure its full validity.

Further Work

It has been recommended that, should further data collection be considered, it should focus on office building data in climates from Brisbane to the tropical regions, and on Western Australia. Any further data for public buildings would also be useful.

1. INTRODUCTION

This report summarises findings of a study undertaken by Exergy on behalf of the Department of the Environment and Heritage into the water consumption of office buildings and public buildings in Australia.

1.1 Background

Water consumption has become a defining environmental issue for Australia in the first decade of the 21st century, with drought conditions causing near-universal restrictions in temperate areas and placing pressure upon infrastructure.

The built environment, although dwarfed by agricultural water consumption, represents a major consumer of the potable water that is managed through man-made infrastructure such as dams. As a result, there is significant pressure to reduce water consumption in the built environment to decrease the stress on the potable water infrastructure.

For commercial buildings, recent investigations have demonstrated that there is little knowledge as to what constitutes good or bad performance with respect to water consumption. This lack of knowledge is a barrier that inhibits the ability of the market to respond to poor performance with appropriate actions.

The purpose of this benchmarking project is to develop benchmarks for office buildings and public buildings in a manner that is compatible with the performance–based approach used in the Australian Building Greenhouse Rating scheme (ABGR) and the National Australian Built Environment Rating System (NABERS). Both of these schemes characterise the distribution of performance across the building population in terms of a 9 point scale. In ABGR this ranges from 1 star to 5 stars, with half stars, where 2.5 stars is average, 5 stars is exceptional and 1 star very poor. NABERS is similar except that the star terminology is not used and the final score is converted to a score out of 10 rather than 5. In both cases, the rating scale is based on the statistics of the building population, thereby ensuring its relevance to the market.

2. METHODOLOGY

The methodology used for this project is as follows:

- The Department of the Environment and Heritage identified a number of public-sector stakeholders, mainly representatives of state governments.
- These stakeholders nominated a range of buildings for inclusion in the study. These were generally government owned buildings; however one jurisdiction provided contacts to private sector portfolios as their primary data source.
- A data collection form was developed covering all the key issues, plus some ancillary issues, associated with water consumption.
- The data form was sent out to the various sites or portfolio contacts nominated by the stakeholders
- Site and portfolio contacts were contacted regularly over an approximate 8 week data collection period
- Data was assembled and processed.

Through this process, data was gathered on a total of 132 office buildings and 18 public buildings nationwide.

Copies of the data collection form are provided in the Appendix.

2.1 Data sample characteristics

The geographic distribution of the data is as shown in Table 1. While the total sample size is good, there is inadequate data to formulate state-specific benchmarks with sufficient certainty. As a result, the analysis focuses on national benchmarks for performance.

The sources of data, cross linked to the stakeholder responsible for the initial contacts are as listed in Table 2. It can be seen that the data collection was aided considerably by the private sector, indicating a high level of market interest in water consumption issues.

State	Office Buildings	Public Buildings
ACT	22	12
NSW	43	1
VIC	21	3
QLD	16	0
WA	9	2
SA	22	0
Total	**132**	**18**

Table 1. Geographic distribution of data.

Jurisdiction Contact	Office Buildings	Public Buildings
Australian Government, Department of the Environment and Heritage	Government portfolio – 5	Government portfolio – 6
Environment ACT	Government portfolio – 6	Government portfolio – 6
NSW Department of Energy Utilities and Sustainability	Government portfolio – 7 Mirvac – 22 Colonial First State – 26 Investa – 23 ING Real estate – 5	Government portfolio – 1
VIC Department of Environment and Sustainability	Government portfolio – 9	Government portfolio – 3
QLD Department of Public Works	Government portfolio – 9	
WA Government	Government portfolio – 1	Government portfolio – 2
SA Department of Environment and Heritage	Government portfolio – 19	

Table 2. Data sources. Note that some buildings marked as being government portfolio are actually government leased rather than owned properties.

2.2 Characteristics of the office building sample

The office building sample covered a wide range of building sizes, as shown in Figure 1. The climate zones for the sample were divergent but heavily biased towards the main centres, as shown in Figure 2.

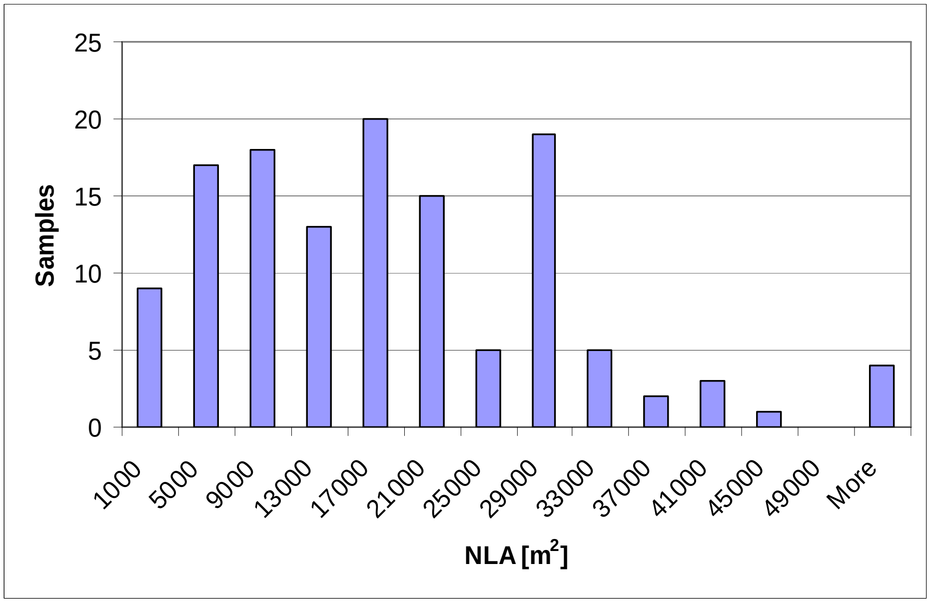

Figure 1. Office building data - area characteristics.

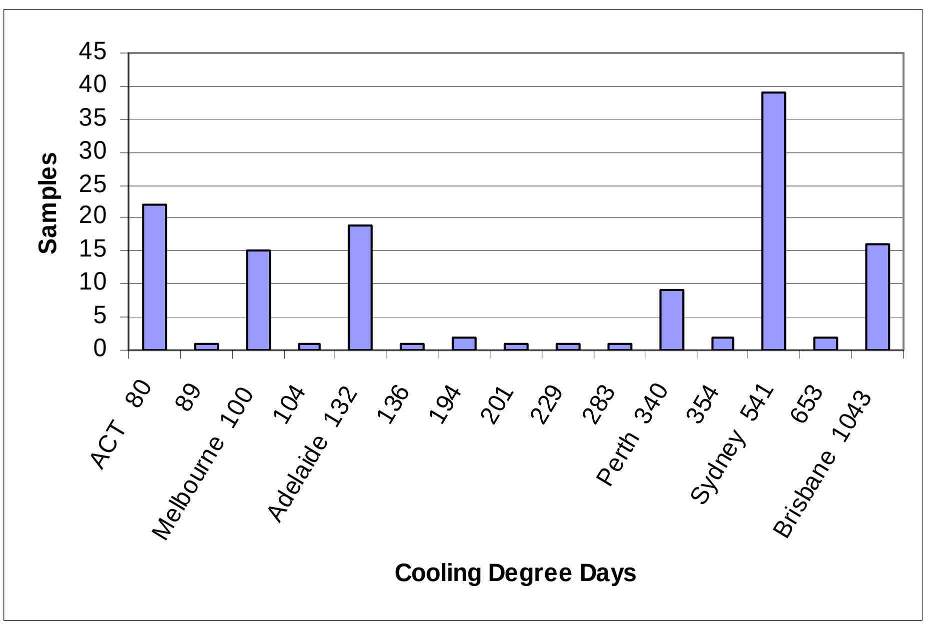

Figure 2. Office building sample – climate range

2.3 Characteristics of the public building sample

The public building sample was as follows:

Site	Location	Floor area [m^2]
Belconnen Library	ACT	1,596
Canberra Theatre	ACT	8,350
Dickson Library	ACT	1,095
National Archives of Australia	ACT	5,486
National Gallery of Australia	ACT	29,500
National Museum of Australia	ACT	16,781
Questacon	ACT	13,671
Screen Sound	ACT	7,876
The Street Theatre	ACT	1,300
Magistrates Court	ACT	10,100
Canberra Museum and Gallery	ACT	7,677
Woden Library	ACT	1,954
Australian National Maritime Museum	Sydney	14,721
Melbourne Museum	Melbourne	17,450
Scienceworks Museum	Melbourne	10,069
The Arts Centre	Melbourne	41,150
Alexander Library	Perth	18,200
Art Gallery of WA	Perth	44,000

Table 3. Public building sample.

3. BENCHMARKING ANALYSIS – OFFICE BUILDINGS

3.1 Primary benchmark derivation

The office building sample was tested for correlation through the assessment of the coefficient of correlation, or “r^2”. The r^2 value is a measure of the degree to which one variable appears to explain the behaviour of another variable. An r^2 of close to zero indicates that there appears to be no relationship between the two variables being assessed; an r^2 approach 1 indicates a strong relationship between the two variables. Note however that a high r^2 is not a guarantee of a causal relationship between variables. However, r^2 analysis is a reasonable and simple methodology for the assessment of data relationships.

The relationship between annual water consumption and the following key variables was assessed in terms of r^2 values as listed below:

- Net lettable area - $r^2 = 0.6899$
- Occupant density - $r^2 = 0.0008$
- Hours of use - $r^2 = 0.0010$
- Cooling degree days[1] - $r^2 = 0.2585$

On this basis it was established that net lettable area and cooling degree days form the best basis for the benchmark. The relationship between water consumption and net lettable area is illustrated in Figure 3 below. The reasonably good correlation between the net lettable area and the total water consumption can be seen in Figure 3. On this basis it was considered the most appropriate basis for the benchmark would be water consumption per unit area, corrected for cooling degree days. This cooling degree day correction reflects the increased consumption of water due to heat rejection via cooling towers in warmer climates.

[1] Cooling degree days are a measure of the total estimated cooling demand for the year. The actual figure is based on the temperature difference relative to a fixed figure multiplied by the amount of time spent at that temperature difference. In this instance, the cooling degree days have been evaluated on the basis of wetbulb temperatures relative to a base of 15°C wetbulb.

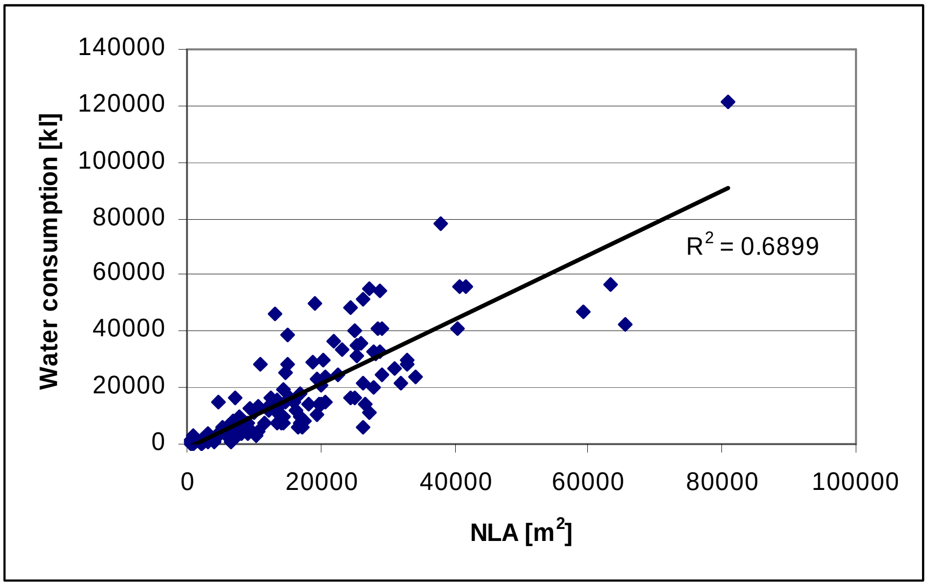

Figure 3. Water consumption as a function of floor area.

The median water consumption intensity across the entire data set was 0.91 kl/m² per annum. However, this varies from centre to centre as shown in Table 4. It can be seen that there is a general increase in water consumption by a factor of two from cool centres through to warmer centres, as illustrated in Figure 4. This supports the potential value of a climate normalisation.

Centre	Median water consumption intensity (kl/m² per annum)	Number of points
Melbourne	0.70	15
Adelaide	0.70	19
Sydney	1.13	39
Canberra	0.72	22
Brisbane	1.56	16
Perth	0.61	9

Table 4. Median water consumption intensity for major centres.

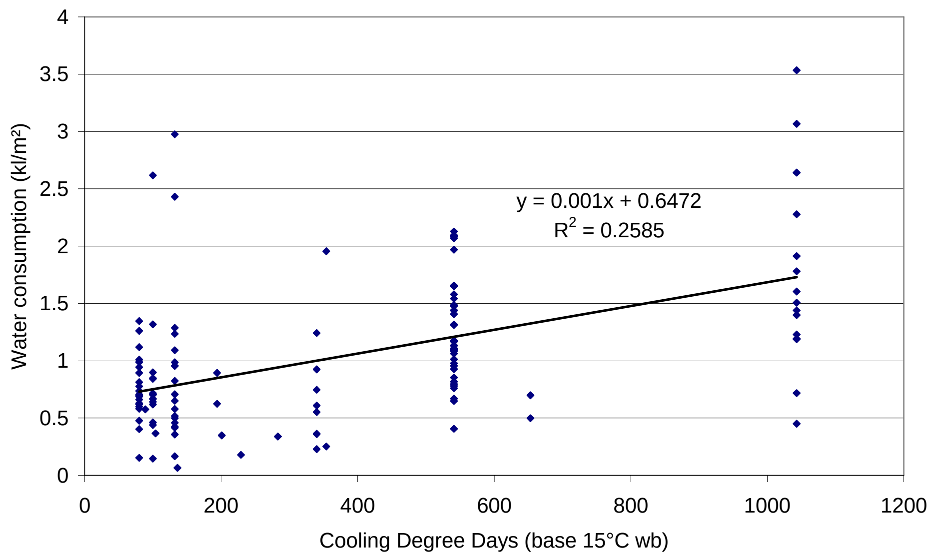

Figure 4. Water consumption versus cooling degree days.

In Figure 4, it can be seen that the climate correlation does appear to be substantive. However, the possibility that the climate correction is non-causal has also been investigated by assessing the presence of key water efficiency features against cooling degree days. None of the factors assessed were found to have a significant relationship to cooling degree days, indicating that the climate correction is not caused, for instance, by an excess of air-cooled chillers in Melbourne relative to Brisbane. Given that a climate relationship is expected, due to the impact of cooling towers, it seems reasonable to conclude that the climate correction is causal rather than coincidental.

Following the general practice adopted within ABGR, an empirical climate normalisation has been developed that normalises water consumption effectively to the Sydney median. This means that buildings in Sydney experience no climate correction, buildings in Brisbane are normalised downwards and cold climate buildings are normalised upwards. The normalisation equation is:

$$W_{corr} = 0.56158 - 0.001038 CDD_{15wb}$$
$$N = W + W_{corr}$$

Where W is the water consumption intensity in kl/m² per annum, W_{corr} is the climate normalisation, CDD is the cooling degree days base 15°C wetbulb (as per ABGR climate correction) and N is the normalised water consumption intensity in kl/m² per annum. The normalised water consumption figures (in kl per annum) for the sample data has an r^2 of 81% with floor area.

The distribution of normalised water consumption was tested for secondary correlations to other operational variables. However both hours of use and occupant density showed no correlation (r^2<2%) with normalised water consumption intensity. As a result, it is proposed that normalised water intensity is used as the primary benchmark for assessment of water consumption intensity.

The distribution of normalised water consumption is shown in Figure 5.

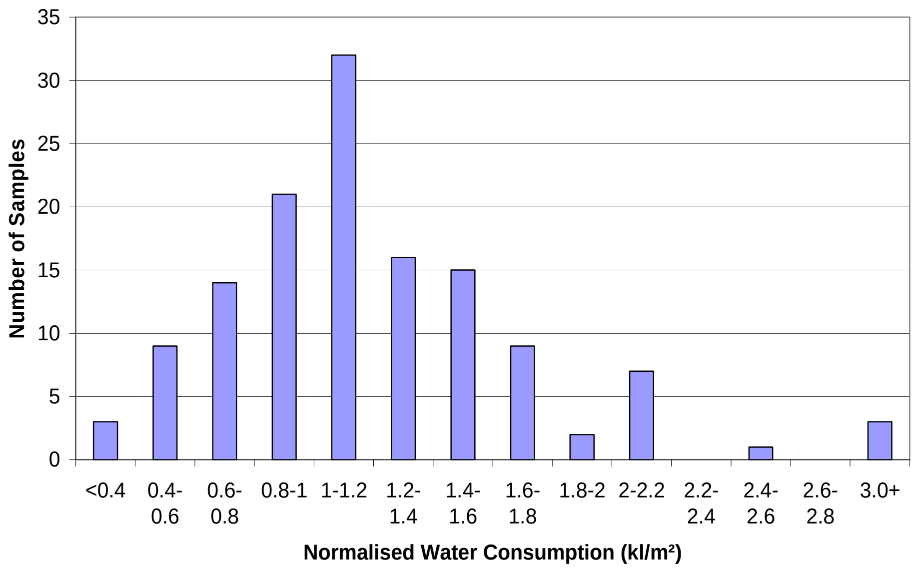

Figure 5. Distribution of office building water consumption after climate normalisation

3.2 Influence of technical factors

Data was gathered on the technical factors, as listed in Table 5, that may underlie aspects of the performance of buildings in the sample. These were then subjected to statistical testing to determine the significance of apparent correlations. The results are summarised in Table 5. It can be seen that no factors recorded statistically significant differences, and that in most cases there was no discernable difference even disregarding statistical rigour.

The two factors that show discernable differences – water cooled chillers and exterior water features – may show statistically significant differences if the sample size is increased. At present the small sample size of sites without water cooled chillers (23) or with exterior water features (9) works against statistical significance.

Under the formulation philosophy of ABGR and NABERS, technical factors such as the presence or otherwise of cooling towers are not provided with credit or punishment. As a result, no further analysis of this issue is required.

Item	**Median consumption with item [kl/m^2 per annum]**	**Median consumption without item [kl/m^2 per annum]**	**Statistical significance at 95% confidence**
Features expected to decrease water use			
Waterless Urinals	1.13	1.13	No
Sensor or Manual Urinals	1.14	1.11	No
Dual Flush Toilets	1.09	1.13	No
Submetering of Water to Major Uses	1.13	1.12	No
Formal Water Management Plan Being Implemented	1.16	1.10	No
Water Audit Conducted in Past 3 Years	1.13	1.13	No
Water Saving Measures Implemented in Past 3 Years	1.16	1.07	No
Water Savings in Response to Recent Restrictions	1.13	1.10	No
Features expected to increase water use			
Water cooled chillers	1.13	0.95	No
Exterior Water Features	1.25	1.12	No
Irrigation System	1.13	1.11	No

Table 5. Impact of technical factors on water consumption. No statistically significant differences were found.

The interpretation of the results in Table 5 provokes some interesting questions.

Of all the factors, only water cooled chillers show a substantial difference in median from the counter data set (i.e. the air cooled chiller buildings) – and yet this factor , which one would consider to be of great importance – does not achieve statistical significance. This lack of significance appears to be caused by the high diversity in the data, such that there are air-cooled chiller buildings with higher water consumption than water-cooled chiller building. In this instance, the presence of a reasonably large difference in medians suggests that, with a larger data set, a statistically significant difference would be likely to be found.

For the other factors the most surprising result is how little effect any appear to have on the median performance. Given the reality that in each case it is known that the individual measure would have an impact on the performance of an individual building, the lack of correlation is at first sight puzzling. This does not mean, however that the application of water savings measures (for instance) has no impact on water consumption of an individual building. Rather, the impact achieved on such building has not yet been sufficient to differentiate such buildings *as a group* from the general population. To understand the average savings achieved by, for instance, waterless urinals, one would have to look at before and after performance for individual buildings and average the change, thereby removing the general “noise” of variability from building to building from the assessment.

3.3 Financial information

Sample water bills were received from 41 sites across Australia, illustrating a wide range of tariff structures and costs. These were analysed in terms of the incremental cost of water, in $/kl, and the total cost including fixed charges, in $/kl.

There was a large range of costs across the sites in both incremental and absolute terms, as shown in Figure 6. The data certainly indicate that there is little consistency of policy with respect to water charges nationally and that in most areas the fixed charges significantly outweigh the variable charges, providing limited motivation for behavioural change.

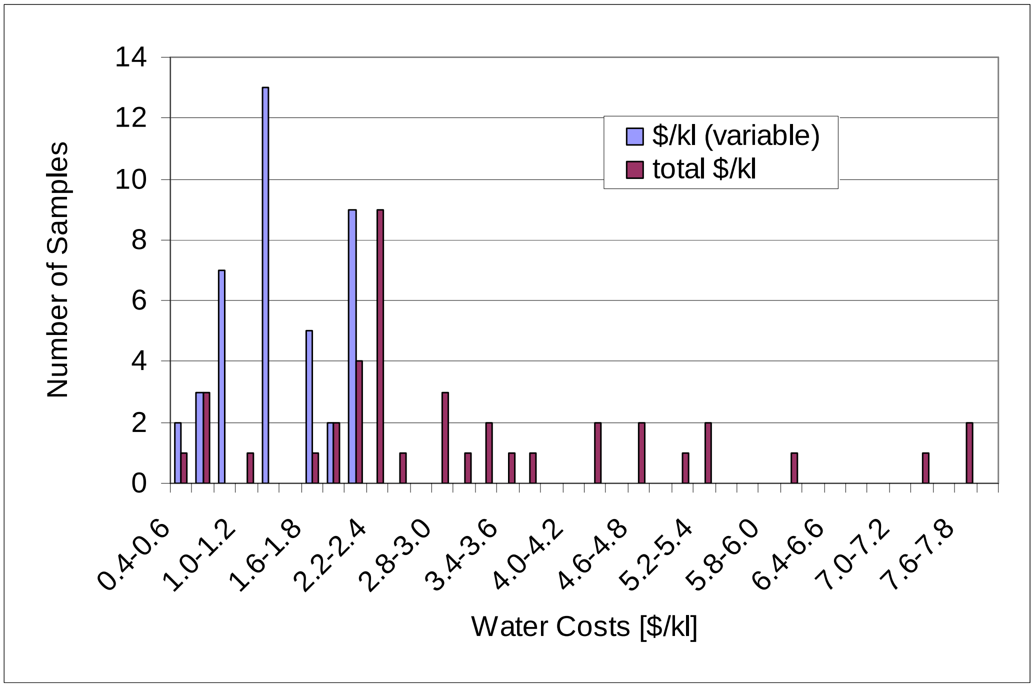

Figure 6. Distribution of the incremental and the total water costs; data points are for individual buildings within the sample for which bills were obtained.

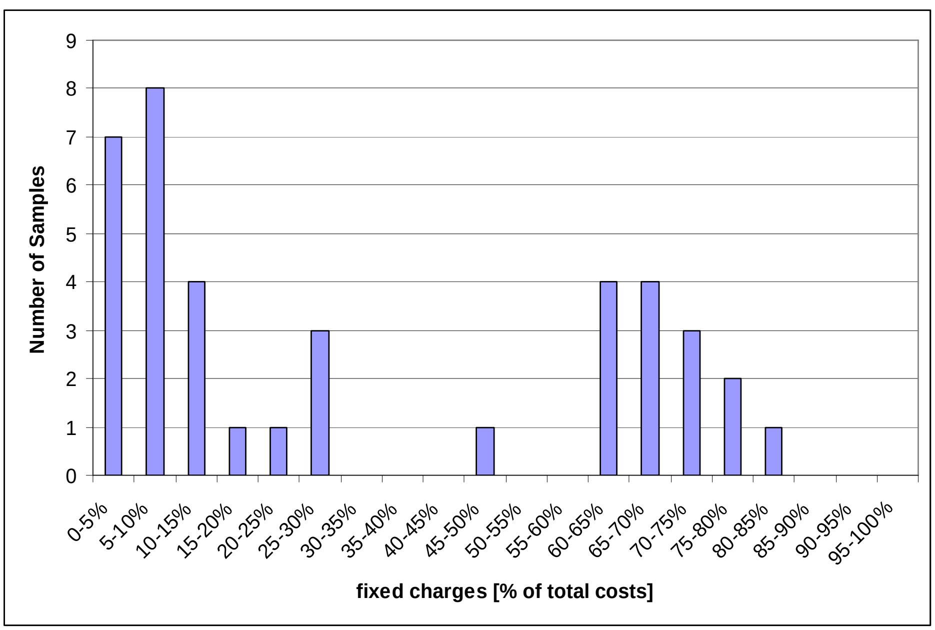

Figure 7. Distribution of the fixed charges share in the total costs

The possibility that the charging regime for water may have an impact upon the results of this study was investigated by evaluating the r-squared for a number of relationships as shown in Table 6.

	Water consumption (kl/m² per annum)	Normalised water consumption (kl/m² per annum)	Cooling degree days
Incremental water cost ($/kl)	0.0075	0.0188	0.0019
Total water cost ($/kl)	0.0380	0.0061	0.2032

Table 6. Relationships, assessed by r-squared values, between financial factors and water consumption factors

It can be seen from Table 6 that there was no relationship between the financial factors and the water consumption or climate, thereby indicating that the impact of water cost on consumption is negligible. Inspection of the strongest relationship (total $/kl to cooling degree days) indicates almost no slope in the relationship, i.e. there is little evidence of one variable changing the other.

3.4 Derivation of rating bands

As discussed in Section 1.1, the NABERS rating uses bands that are based on the position of the building within the building population in terms of efficiency. There are a number of rules used to determine the rating bands for a particular population, being:

1. The rating scale should encompass at least 80% of the population

2. The mid point score should be based on the population median

3. The full mark score should represent a level of efficiency essentially beyond normal technological solutions, but attainable through innovation

4. The rating bands should be linear

In the inevitable event of conflict between these requirements, the midpoint and linearity rules dominate the setting of the scale.

The application of these rules to the sample can be depicted on the cumulative frequency diagram shown in Figure 6 and as listed in Table 7.

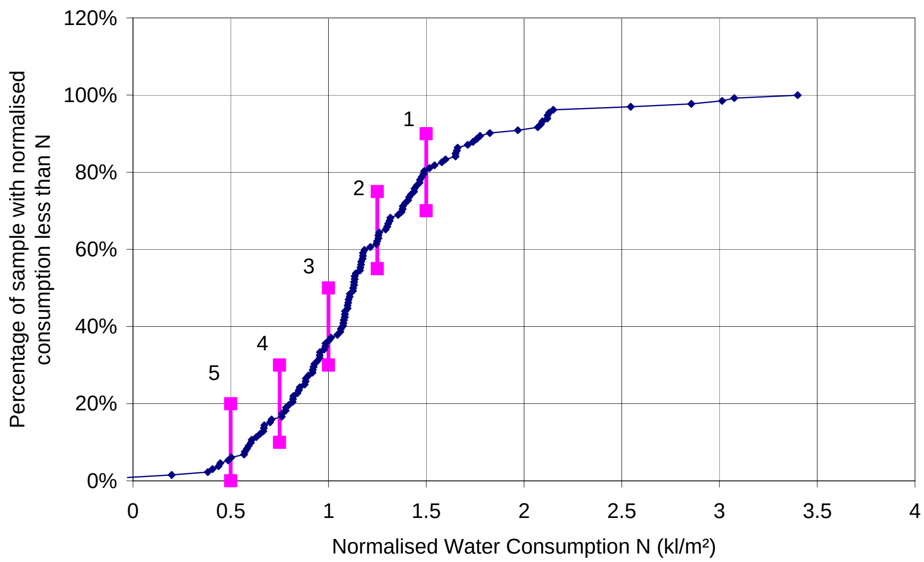

Figure 6. Cumulative frequency diagram for the sample population, showing proposed rating thresholds.

Rating	Normalised water consumption (kl/m² per annum)	% of sample rating at this level or better
1/5	1.50	80%
2/5	1.25	63%
2.5/5	1.125	50%
3/5	1.0	36%
4/5	0.75	17%
5/5	0.5	5%

Table 7. Proposed rating bands.

3.5 Comparison with overseas benchmarks

Comparatively little work appears to have been done internationally towards that actual characterisation of water consumption as an empirical benchmark. The best example appears to be encapsulated in the UK Watermark program. This identifies a water consumption benchmark of 9.3m³ per person per annum and a best practice target of 6.4 m³ per person per annum. Translated at an occupant density of 1 per 18m² these figures become 0.52kl/m² and 0.36 kl/m² respectively. Using a notional cooling degree day figure of zero for the UK climate (by comparison it is noted that Invercargill in New Zealand has 26 cooling degree days to the same base as the benchmark), these figures normalise to 1.08 kl/m² and 0.92 kl/m² (2.7/5 and 3.3/5) respectively. This shows a high degree of comparability in the benchmarks.

3.6 Further work

While the sample data size is of a reasonable size, there are some limitations within the data set that pose limitations on the validity of the benchmark. In particular, the lack of data from sub-tropical and tropical climates means that the extension of the climate normalisation to areas warmer than Brisbane is a pure extrapolation and thus somewhat risk-prone. The first emphasis for additional data collection should therefore be on such climate zones, including Brisbane itself which remains a relatively small sample. Furthermore, it would be desirable to strengthen the data set from Western Australia, as this state is underrepresented in the overall data set.

4. BENCHMARKING ANALYSIS – PUBLIC BUILDINGS

4.1 Primary Benchmark

The benchmarking analysis for public buildings is necessarily simpler than for office buildings because of the small sample size and the diversity of the sample.

The data for public building shows a reasonable relationship between the water consumption and the total floor area, as shown in Figure 7.

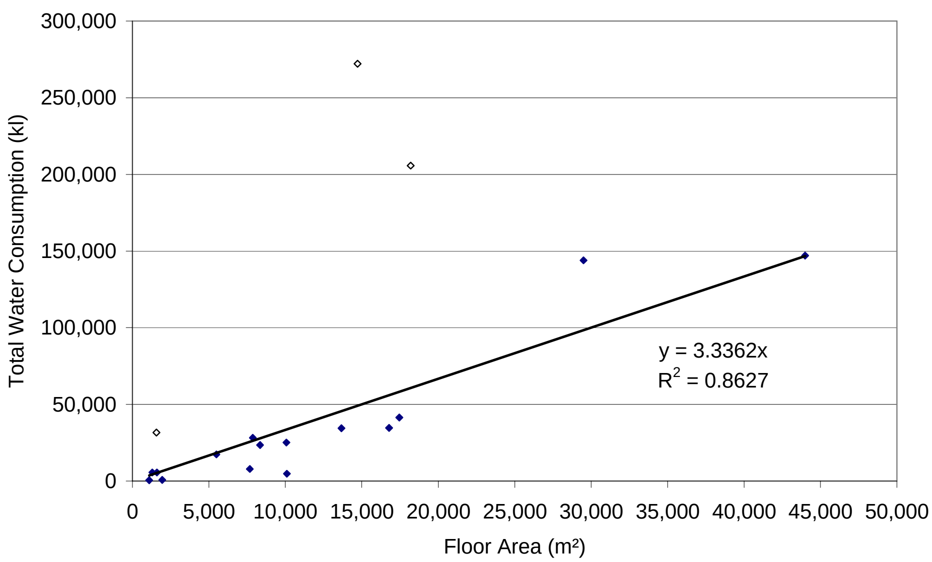

Figure 7. Water consumption – public office buildings. Hollow data points are outliers that have been excluded from the regression.

On the basis of the regression shown in the figure, it is recommended that a general benchmark for average performance of public buildings is set at 3.34 kl/m² per annum. This benchmark fits the data with an r^2 of 86%, which is similar to that achieved for the office data set. However, given the smaller size of the data set, the physical diversity of the sites and the uneven distribution of the data points across the data range, the benchmark is somewhat less well defined than for the offices.

To set a best practice benchmark, the average performance benchmark needs to be reduced until approximately 75% of site use more water than the benchmark. On this basis, the best practice benchmark is 2 kl/m² per annum.

4.2 Comparison with overseas benchmarks

As with office buildings, there is a shortage of international precedents for water consumption benchmarks in this sector, and the UK Watermark program provides the best comparator. The program has two benchmarks relevant to the public buildings sector:

- Museum and art galleries: Benchmark: 0.332 kl/m^2, best practice 0.181 kl/m^2.
- Library: Benchmark 0.203 kl/m^2, best practice 0.128 kl/m^2

These figures are notable by the fact that they are lower by a factor of ten than those determined in this study. It is expected that climate has a significant role to play in this, but insufficient data is available to assess this empirically.

4.3 Further work

The small size of the dataset indicates that there is a good deal of potential for further work in respect to the gathering of additional data, which may in turn yield more information and more detail in the benchmark than is currently apparent.

5. CONCLUSIONS

Data on water consumption for 132 offices and 17 public buildings around Australia have been gathered for the purpose of the development of water consumption benchmarks.

The office building water consumption benchmark has been established on the basis of a normalised water consumption intensity figure that corrects for climatic impacts. The benchmark has been established in terms that are fully compatible with the NABERS methodology. The benchmark – expressed in terms of the NABERS rating scores, is summarised in the table below:

Rating	**Normalised water consumption (kl/m² per annum)**	**% of sample rating at this level or better**
1/5	1.50	80%
2/5	1.25	63%
2.5/5	1.125	50%
3/5	1.0	36%
4/5	0.75	17%
5/5	0.5	5%

For the public buildings, a simple benchmark based on water consumption per unit floor area has been established. The average performance benchmark is 3.34 kl/m² per annum and the best practice benchmark is 2 kl/m² per annum.

6. APPENDIX – DATA COLLECTION FORMS

6.1 Office building data collection form

Water Use Data Collection Sheet
Office Buildings

Site Identification

Building Name	
Site Address	
Postcode	
Site Contact Name	
Site Contact Position	
Site Contact Phone	
Site Contact Email	

Enter Data in the yellow cells - Click in the cells for detailed instructions.
Leave the cells blank if you don't have the correct data for a particular question.

Site Details

Year of Construction / Refurbishment	

Site Areas

NLA of Office Space (m²)	
NLA of NON-Office Space (m²)	
Area of Irrigated Grounds (m²)	

Weekly Hours of Occupancy / Open Hours (insert additional rows if required)

Space ID	Occupancy	Area (m²)	Hrs/wk
Total			

Annual Water Use Note: 1kL = 1 m3

Potable Water Use (kL/yr)	
Submetered Irrigation Water Use (kL/yr)	
Submetered NON-Office Potable Water Use (kL/yr)	
External Greywater & Borewater Use (kL/yr)	
Water Use in Exterior Water Features (kL/yr)	

Water Supplier Name	
Sample Bill Attached	
Tariff	

Water Use Features On Site

Waterless Urinals	
Sensor or Manual Urinals	
Other Urinals	
Dual Flush Toilets	
Rainwater Re-use	
Greywater Recycling	
Exterior Water Features	
Irrigation System	
Water Cooled Chillers and Cooling Towers	
Direct Evaporative Cooling	
Cooling Towers for Supplementary Cooling	
Submetering of Water to Major Uses	
Formal Water Management Plan Being Implemented	
Water Audit Conducted in Past 3 Years	
Water Saving Measures Implemented in Past 3 Years.	
>>Percentage Savings Achieved by These Measures	
Water Savings in Response to Recent Restrictions	
>>Percentage Savings Achieved by These Measures	

Additional Information

Exergy - April 2005

6.2 Public building data collection form

Water Use Data Collection Sheet
Public Buildings

Site Identification

Building Name	
Site Address	
Postcode	
Site Contact Name	
Site Contact Position	
Site Contact Phone	
Site Contact Email	

Enter Data in the yellow cells - Click in the cells for detailed instructions.
Leave the cells blank if you don't have the correct data for a particular question.

Site Details

Type of Site	
Year of Construction / Refurbishment	

Site Areas

Total Public Space Floor Area (m²)	
Total Non-Public Space Floor Area (m²)	
Area of Irrigated Grounds (m²)	

Weekly Hours of Occupancy / Open Hours (insert additional rows if required)

Space ID	Occupancy	Area (m²)	Hrs/wk
Total			

Annual Water Use Note: 1kL = 1 m3

Potable Water Use (kL/yr)	
Submetered Irrigation Water Use (kL/yr)	
External Greywater & Borewater Use (kL/yr)	
Water Use in Exterior Water Features (kL/yr)	
Water Costs Included in Building Budget	
Water Supplier Name	
Sample Bill Attached	
Tariff	

Water Use Features On Site

Waterless Urinals	
Sensor or Manual Urinals	
Other Urinals	
Dual Flush Toilets	
Rainwater Re-use	
Greywater Recycling	
Exterior Water Features	
Irrigation System	
Water Cooled Chillers and Cooling Towers	
Direct Evaporative Cooling	
Cooling Towers for Supplementary Cooling	
Submetering of Water to Major Uses	
Formal Water Management Plan Being Implemented	
Water Audit Conducted in Past 3 Years	
Water Saving Measures Implemented in Past 3 Years.	
>>Percentage Savings Achieved by These Measures	
Water Savings in Response to Recent Restrictions	
>>Percentage Savings Achieved by These Measures	

Additional Information

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