WATER CONSERVATION & AUDITING IN SCHOOLS: FINDINGS FOR GREATER SAVINGS

John Hunt[1], Martin Anda[2], Kel Medbury[3], Goen Ho[4], Dan Li[5]

ABSTRACT: *A desktop study examined water meter readings of secondary schools in the Perth metropolitan area of Western Australia. From this, a suitable metric for measuring water use in secondary schools was determined. Water use quartiles on a per person basis were also calculated based on 70 secondary schools and benchmarks were established. In addition, a water audit of 9 high water using secondary schools (>20,000 kL/a) was performed to identify key areas where water is used and where water savings can be made. Total water use of these schools decreased by 13% in the 12 months following the completion of the water audits. Having determined water use averages, benchmarks and key areas for water savings, the education industry can make informed decisions about their water use and how to increase efficiency at the schools.*

KEYWORDS: Water audit, Secondary school, Water efficiency, Benchmark, Education, Urban water demand

[1] John Hunt, School of Engineering & IT, Murdoch University. Email: j.hunt@murdoch.edu.au
[2] Martin Anda, School of Engineering & IT, Murdoch University. Email: m.anda@murdoch.edu.au
[3] Goen Ho, School of Engineering & IT, Murdoch University. Email: g.ho@murdoch.edu.au
[4] Kel Medbury, Water Efficiency Progams, Water Corporation, Email: kel.medbury@watercorporation.com.au
[5] Dan Li, School of Engineering & IT, Murdoch University. Email: l.li@murdoch.edu.au

1 INTRODUCTION

The use of water in the education sector is a knowledge gap that has not been well documented, particularly in Perth. The opportunity for water efficiency savings is significant with over 1083 schools in Western Australia (WA) and 100 secondary schools in the metropolitan area of Perth, WA. In 2017, these secondary schools used approximately 1,000 ML of water. Improving water efficiency has the important outcomes of both saving water and saving education dollars which could then be better spent directly on education.

There has been significant work in advancing the water efficiency of schools through utility or government programs such as WaterWise Schools [1], Green Schools [2], Schools Water Efficiency Program (SWEP), SA Water smart schools etc. These programs aim to improve the water efficiency in schools by identifying inefficiencies but also have a significant focus of teaching the students about the value of water and water efficiency.

It was identified by the authors' that schools generally did not have an understanding of what their expected water use should be and therefore whether they were wasting little or great amounts of water. They also had no ability to compare their water use to other schools. This research aims to provide the sector with this knowledge through analysing school water use data, conducting water audits as a touch stone, identifying a suitable metric for measuring school water use and setting benchmarks based on actual, local water use history of a similar sample of schools.

2 METHOD

2.1 ESTABLISHING A METRIC

The use of a clearly defined, standardised metric for educational institutions would greatly assist the education sector in water management. The current most common metric used is "litres per student per day" (L/s/d). This metric is useful only if the terms in the metric are qualified which often is not been the case. It is therefore difficult to ensure any comparisons using this metric are of value.

A metric is a unit of measure (or a parameter being measured) that can be used to assess the rate of water use during a given period of time and at a given level of data aggregation (e.g., system-wide, sector-wide, customer level, or end-use level) [3].

Thus, the issue of choosing a benchmark can be divided into (1) the choice of a metric and (2) the choice of a benchmark (a particular value of the chosen metric) [3].

In terms of determining a metric, several factors are to be considered including:

- Ease of obtaining data to inform the metric,
- Ease of calculation using the data,
- Ease of understanding the value of a metric unit i.e. making it relatable ,
- Relevant to the end users' situations, and
- Comparable to multiple users i.e. the metric is not too specific [4].

The use of kilolitres per person per year (kL/p/a) seems a suitable metric however the definition of the second and third parameters requires qualification; specifically who is included in the 'per person' and, what is meant by 'per year'. There are several possibilities in a school setting for what is meant by 'per person'. For robustness, these should be limited to those that have data sets that are easily obtainable. In the case of schools, the three potential population sets are:

- Students only, as is often used,
- Teaching staff and students, and
- All staff and students.

In this study Full Time Equivalent (FTE) numbers were used for determining population, rather than total number, as this would be expected to better correlate to actual water use.

The use of only FTE students as a population for water use is the simplest in terms of defining the population. The metric would then be kilolitres per student per year (kL/s/a) or litres per student per day (L/s/d). The issue of using 'per day' or 'per year' will be discussed shortly. The use of students only as the population would be effective, and if broadly accepted as the metric, would provide a comparison point for schools. It does however; over-simplify the metric unnecessarily as it does not include a significant portion of school water users, the staff.

Of the 70 school data set used in this study, teaching staff numbers (averaged across five years) was 7.5 teaching staff per 100 students with a standard deviation of 0.8. Non-teaching staff numbers were 3.3 staff per 100 students with a larger standard deviation of 1.3.

Assuming staff water use is the same as students, the use of staff in the population would provide a more accurate representation of 'per person' than by omitting their 7.5% contribution to water use. Likewise an additional 3.3% contribution from

non-teaching staff is a significant contributor, and more so for those schools where non-teaching staff numbers were similar in numbers as teaching staff. With data for the number of teaching and non-teaching staff readily available, it is not a burdensome complication to include FTE staff numbers in the school population to determine the 'per person' component of the metric, and will provide a more accurate representation of the 'per person' usage if all 'persons' are accounted for.

The assumption that staff use the same volume of water as students should be tested as it is expected they would use more. From the water audits, it was reported that staff who rode bicycles to work were more likely to shower at the school compared to students who rode. It was also identified in some schools that staff showers were not water efficient compared to the student showers which were often upgraded as a result of damage. Many schools had showers for students to use after using the gym, but these were reportedly not used or had been decommissioned. Staff also would be more likely to spend more hours at the school increasing the likelihood they would use more water.

In the remainder of this paper the metric will include FTE teaching staff, FTE non-teaching staff and FTE students in the school population and will therefore be either described as kilolitres per person per year (kL/p/a) or litres per person per day (L/p/d). If this metric definition becomes widely accepted, the definition of school population to include all FTE staff should be clearly qualified.

It was noted from the school audits that some of the larger schools had a large number of functions at the school (up to 200, 000 catered meals per year for functions); had other guests such as church groups or sporting clubs use the school's facilities; or use the boarding facilities for camps or retreats when the boarders were not there. This does add another dimension to the school population metric issue which it is not easily measurable and therefore has been left out of the population in this study.

The use of either annual water use (kL/p/a) or daily water use (L/p/d) is less significant as they are the same value stated differently. The conversion from one to the other can be achieved without additional information. A complication is ensuring that the meaning of 'day' or 'year' is consistent. A school year consists of approximately 200 days whereas a calendar year is 365 days. Using 200 days as a time period (year) for the metric is useful in that it will provide a simple to use, fairly accurate and relatable daily volume for each student.

The argument against this approach, assuming the acceptance of the above to include all FTE staff in the population, is that staff are likely to be at school more than 200 days of the year. Additionally other water uses that are not directly related to population, such as irrigation and pool cleaning, continue throughout the year. Also the use of a 365 day year is standard for other sectors. It also simplifies disaggregating or refining of data if all of the year is included. It is the authors' opinion that these factors outweigh the advantages of the simpler approach of using a 200-day-year.

It is therefore recommended that the time frame component of the metric for schools should be a 365-day-year. This approach will be taken in the remainder of this paper.

For the reasons outlined above, this paper recommends a metric for school water use of kilolitres per person per year (kL/p/a) where all FTE staff and FTE student numbers represent the school population and a year consists of 365 days.

2.2 DESKTOP STUDY

A desktop study was performed using reticulated water meter readings delivered by the city's main water service provider, the Water Corporation, and did not include self-supply water use. This data was analysed and matched to the population for each school. Analysis of this data provided quantified per person water use data and allowed the establishment of relevant benchmarking. To complement the desktop study, learnings from the water audits of nine large water using schools were incorporated to provide an understanding of where schools use their water and where efficiencies can be achieved (Section 2.3).

There are 100 secondary schools in the Perth metropolitan area [5]. Of these, 70 cater specifically for grades 7 to 12. This subset was used in this study for consistency. Of these 70 schools, 65 had bores or access to bores; 66 had access to playing fields (ovals), although not all were managed by the school; and 20 had swimming pools, 19 of which were 25m long and 1 was 50m long. 3 of the pools were indoor pools. Each of these is easily measurable and can have a significant effect on the schools water use.

The water use data set was water meter readings for the water years for 2012 to 2017. Water years vary between each customer and do not necessarily correlate with a calendar year. Water meter reading frequency changed in 2014 from 6 monthly to bimonthly creating a higher resolution of water use. All schools had completed the 2017 water year at the time of analysis.

School population data was obtained for each of the years 2012 to 2016. 2017 data was not available therefore no 2017 data was used in the desktop study analysis. Three population data points were obtained for each school being:

- Full-time equivalent student enrolments,
- Full-time equivalent teaching staff, and
- Full-time equivalent non-teaching staff

Water use for each year was divided by that year's population (FTE staff and students) to obtain an average in kilolitres per person per year (kL/p/a). For each school, these five yearly water uses were averaged.

2.3 WATER AUDITS OF SECONDARY SCHOOLS

Schools in the Perth Metropolitan area with water use over 20,000 kL/a were invited to participate in a project which involved a Water Auditor assess the school's water use using water auditing guidelines [4]. The use of Water auditing is an important means of identifying efficiency improvements, achieving savings and identifying alternate water sources [4]. From this project, opportunities to save water were identified and were used to inform the development of the metric and benchmarking.

This project aimed to guide the schools that were involved in the project in preparing their Water Efficiency Management Plans (WEMP). These schools had water use ranging from 21,000 kL/a to 65,000 kL/a in the 2016 water year. Data loggers were placed on the schools' water meters and water use was logged for approximately two months before the auditor visited each school.

Approximately 12 months later, each school was revisited. Some schools still had the data logging continuing and this provided insight into daily, weekly and monthly patterns and showed the impact of changes to the school's water systems. This information was presented to the schools along with a water use comparison with the previous 12 months.

3 RESULTS

3.1 WATER AUDIT RESULTS

Water use of eight of the schools decreased by a total of 13% in the 12 months following the beginning of the project (Figure 1). One school (School 1) was excluded from the analysis as several water meter failures resulted in a lack of usable data. The 13% saving represents an average of approximately 3000 kL/a per school. The dollar value of this amount of water saving is approximately $14,000 per school.

Not all of this saving can be attributed to the intervention by the water auditor. Some saving was made by the completion of construction projects, some by the cessation of the use of scheme water for irrigation after the reinstatement of failed groundwater bores and others were by finding leaks before the project began. Six of the eight schools reduced their water use (Figure 1) while School 2 and School 5 both had difficult to locate leaks increasing their water use in 2017.

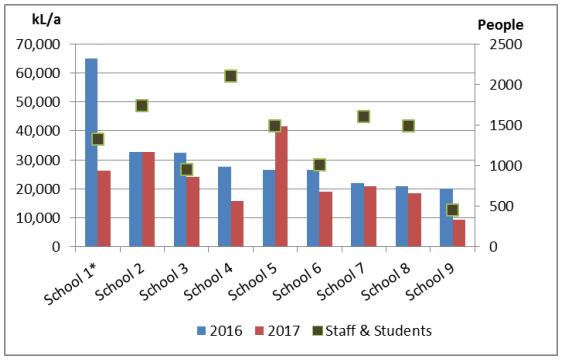

Figure 1: *School water use comparison*
**Complete water use not available due to meter failure*

From the data gathered during the course of this project the average water use in 2017 (FTE staff and student, 365 days) was 18.1 kL/p/a. This is significantly more than other benchmarks of 3.6 to 6.6 kL/pupil/a in Sydney, 6.03 kL/pupil/a in the UK but less than 20.4 kL/pupil/a in the U.S.A. Note that the metrics of these comparison averages are not fully qualified in terms of included population or definition of the time period used and are therefore only cited here as a preliminary measure.

Key non-quantifiable findings of the study included:

- Many schools did not examine their water bills but had the accounts department just pay them. Having a person responsible for water management in the school creates a focus and improves the likelihood of improvement,
- Tracking weekly water use in a spreadsheet provides a data history set useful in identifying problems and allows projections to be made,
- Weekly water meter readings were determined to provide an appropriate resolution of data,

- Developing a fault reporting culture on its own will not be self-sustaining if the reporting is not followed up and the outcome reported back to the initial fault reporter,
- The use of sub-meters is an important tool in identifying leaks and prioritising areas for improvements; at least until a high level of efficiency is achieved,
- Swimming pools account for approximately 10% of school water use,
- Students were generally compliant with efforts to not waste water,
- Boarding houses were high water users, and
- Almost all irrigation was from bore water. Exceptions were where there was insufficient groundwater, where conversion to groundwater was planned, or where the cost of connecting to groundwater water due to physical barriers was not warranted.

3.2 DESKTOP STUDY RESULTS

School water use ranged from 0.9 kL/p/a to 45 kL/p/a. The mean and median were 8.9 and 6.4 kL/p/a respectively with an averaged standard deviation from the mean of 2.9 kL/p/a. Figure 2 shows the per person usage for each of the 70 schools arranged in per person water use order. Also plotted is the total school water use.

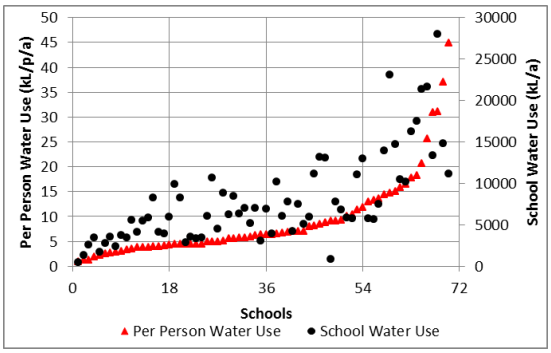

Figure 2: *Per person water use*

Figure 3 shows the relationship between school population and per person water use at each school. The smaller schools on average have a larger per person water use than the larger schools (Table 1). The correlation shown by the exponential trend line may be sufficient to warrant differentiating larger schools from smaller schools in terms of benchmarking and should be investigated further.

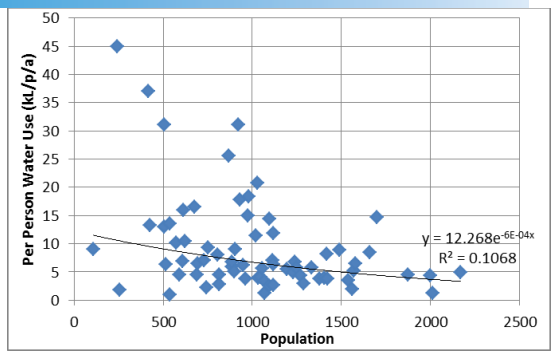

Figure 3: *Water use vs population*

Table 1: *Water use of population bands*

Population	Number of Schools	Average Water Use (kL/p/a)
0 to 500	5	21
501 to 1000	30	11
1001 to 1500	25	6
1501 +	10	6

With schools ranked in order of water use (kL/p/a), quartiles were identified and are presented in Table 2.

Table 2: *Quartile bands*

Quartile	Schools	Lower bound kL/p/a	% total water use
Q1	17	0.9	11%
Q2	18	4.3	19%
Q3	18	6.4	24%
Q4	17	11.1	45%

The sum of the annual water use of the Quartile 4 schools account for 45% of all annual school water use, while the 1st quartile accounts for only 11%. This supports previous findings that targeting the 4th quartile with water efficiency will yield best results.

3.2.1 Swimming Pools

There were 20 schools in the study with swimming pools. Having a swimming pool at the school did not appear to provide guidance on per person water use for the school. Figure 4 and Table 1 show that swimming pools were fairly evenly distributed across the range of schools ranked by per person water use. Calculations showed that expected

water loss from a 25m swimming pool in a median population school using the median volume of water per person would use the equivalent of 11% of the schools population's water use.

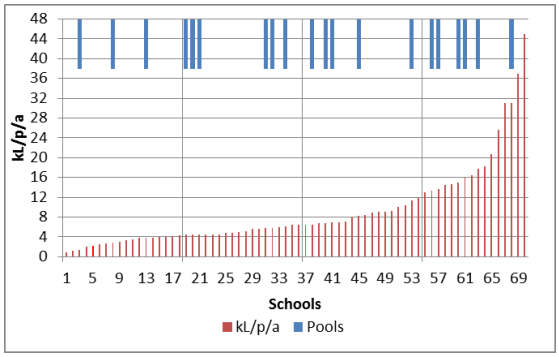

Figure 4: *Water use and pool occurrence*

3.2.2 Ground water and playing field use

65 of the 70 schools in the study had access to groundwater bores for irrigation. The schools that didn't were either in high density areas such as city centres that did not require large irrigation volumes or were in areas of limited groundwater availability such as the Perth hills. Schools which had groundwater bores with insufficient volume were not identified. Given the high percentage of schools with groundwater, no distinction was made in terms of analysis between those with and those without access to groundwater.

Similarly for school playing fields, 66 of the 70 schools had access to a school playing field, although there were several that were not managed by the school. Irrigation of a typical one hectare school playing field in Perth is estimated to use approximately 7500 kL/a of water. With a school median water use of approximately 6100kL/a, maintaining a playing field without a groundwater bore would add significantly to a school's scheme water use. Given the high percentage of schools with bores, this is not common and was therefore not deemed a necessary caveat in determining the benchmarking.

3.3 DETERMINING BENCHMARKS

A benchmark is a particular (numerical) value of a metric that denotes a specific level of performance, such as a water efficiency target [3]. It also provides a point or reference from which water use can be compared. Placements of benchmarks are subjective and can be influenced by ideals, desire to achieve change versus the desire to support and encourage, industry knowledge and knowledge of behaviour change science. The goal of benchmarking is to assist in reducing water use, thus making the benchmarks outdated and regularly requiring revision [7]. The benchmarks proposed here represent the authors' best judgement based on the above factors.

Adopting benchmarks from other Australian States or even internationally is problematic due to differences in climate, irrigation regimes, building and population densities and behavioural approaches. Industry based water efficiency standards, whether either recommended or prescribed, such as in fixture standards or building codes, would also make a difference to water use. Therefore referencing alternate benchmarks may be a useful first pass for assessing water use if no other standard is available, but is not useful for more robust guidance. This paper attempts to provide a locally relevant benchmarking system for Perth schools by drawing on water use data from the schools themselves, removing the need to refer to other non-local benchmarks or water use estimates.

Benchmarks for secondary schools in Perth are proposed in three bands (Table 3) [8]. Band 1 represents those schools that achieved better than 5% of the schools in the data set and represent the high achievers. Band 2 represents schools that have achieved better than 20% of schools in this data set. Band 3 schools are schools that achieve above the median water use of schools.

Table 3: *Benchmark bands*

Band	Achievement	Benchmark (kL/p/a)	Benchmark (L/p/d)
Band 1	Top 5%	<2	<5.5
Band 2	Top 20%	<4	<11
Band 3	Top 50%	<6.4	<17.5

This work produced broad benchmarks suitable to a large range of secondary schools. Further refinements of benchmarks could be made by further analysing subset characteristics of schools that affect water use, in order to make them more relevant to schools with those characteristics. Such refinements include:

- school population or demographic,
- high density, urban or regional location,
- pool or no pool and pool size,
- sufficient ground water availability for irrigation and irrigable area per person,
- age of school, and
- schools with various year ranges including primary schools only.

These characteristics would require additional data collection and analysis to ensure they have a substantial effect on school water use that justifies the additional complexity.

4 CONCLUSION

The total water use of eight of the schools decreased by 13% in the 12 months following the completion of water audits. This is approximately 3000 kL/a per school on average. The cost savings to each school of this amount of water is approximately $14,000. The water audits of the schools provided some ground truthing of concepts used to establish the metric and the benchmarks.

The application of the benchmarking bands (and quartiles) may be limited to individual schools setting targets for themselves. It will at the very least provide the schools with an indication of how the school is performing compared to other similar schools and possibly provide an indication if there is a fault in their system. The benchmarking may be used by Water Service providers and used as part of the WaterWise schools program or similar. They would also provide other regions a point of comparison for their secondary school water use. Researchers and those estimating water use volumes for secondary schools may also find this data of value.

The use of water meter readings from a sample of high schools has informed the development of a proposed metric and benchmarks for secondary school water use for Perth which have not been documented before. This paper recommends a metric for school water use of kilolitres per person per year (kL/p/a) where all FTE staff and FTE students represent the school population and a year consists of 365 days. A median secondary school water use of 6.4 kL/p/a was also determined.

Further work in this area of research may include:

- Refining of the benchmarks to make them more relevant to schools with differing characteristics as discussed in Section 3.2.2,
- Examine the correlation of building area per student to water use,
- Extend the study to other education institutions such as Primary schools or tertiary colleges, and
- Examine the assumption that staff use the same volume of water as students.

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