Saving Water in Sydney

Reid Butler
BMT WBM Water and Environment Sydney
Email: rbutler@wbmpl.com.au

A greater need for reducing water consumption and advances in water flow monitoring have led to a better understanding of the effectiveness of various water efficiency measures. It is now possible to know the amount of water saving a particular strategy can achieve which assists in deciding on a cost effective solution.

This paper will outline the practical application of water monitoring technology to assess a range of successful and unsuccessful water efficiency improvements and water supply substitution projects in Sydney. The case studies are set out in terms of the type of water user that was addressed. The range of facilities includes:

Cooling Towers - rainwater harvesting and utilizing an existing groundwater storage.

Large entertainment venues - change in management procedures to save water.

Public Domain facilities - treated wastewater re-use for toilet flushing.

Each case study will illustrate how to achieve best practice and some will show where mistakes can be made when the right method is not used.

There are several key steps to follow when attempting reduce water consumption.

1. Use accurate water use data logging equipment on correctly positioned water meters.

2. Inspect all water using fixtures in a site audit to prepare a site water balance showing where and how much water is used.

3. Implement the cost effective water efficiency improvement measures, from repairing leaking fixtures to replacing older fittings with new, efficient ones.

4. Assess water substitution options based on the achieved efficient usage rate, considering all aspects including energy and chemical demands.

5. Use accurate monitoring data in models to design an alternate water supply system.

These steps can assist in reaching a cost effective solution to reduce potable water use and will result in a much lower water demand.

1. Accurate water flow monitoring

Water flow monitoring provides a clear and accurate view of how much water is being used by all water using fixtures at a site. It also allows for the early identification of problems such as leakage and illegal usage and can help to benchmark the efficiency of water using equipment.

Water flow must first be measured using water meters. Effective metering of a site's water distribution system includes the main meter (from which water bills are determined) and sub meters installed in critical points of the hydraulic system to capture the larger water users. A rule of thumb is to capture any use consuming 15% or more of the site total.

Most meters emit a pulse through a reed switch (on and off) for every 1, 5, 10, 100 or 1000L flowing through them. Dataloggers measure these pulses in 5-minute intervals and send the data via mobile phone to a web server, which manages and displays the data via an internet access page. The web page can be viewed from any computer using a secure user name and password. On the site, data can be manipulated with various functions including graphing, adding and subtracting meters, viewing time intervals, changing units from litres per second to litres per minute or kilolitres per day. All of the raw data can be viewed for greater detail and copied to other spreadsheets or data management programs such as building management systems.

The remote loggers themselves have features including alarms, which can send an SMS when a set threshold is reached, and battery life of around five years. They can be plugged into mains power or use solar panels to charge the batteries.

There are several providers of dataloggers and we-based monitoring services.

Figure 1 shows an example of monitoring one main meter serving a medium sized office building (120 staff) with over 0.6L/second baseflow (continuous water flow independent of known uses). The drop in usage in the graph represents saving 60kL/day, when a broken pipe was repaired.

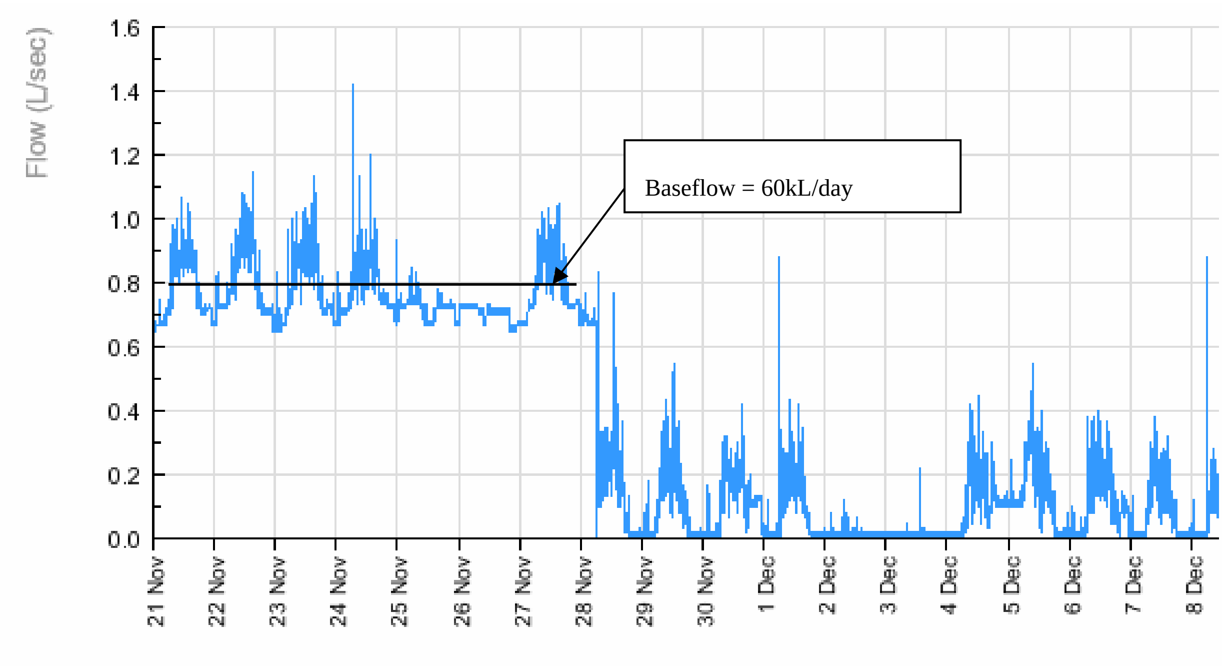

Figure 1: Monitored water usage profile in an office building showing baseflow repair

To get an idea of the value of this one datalogger, it is interesting to review the reason it was installed. The excess usage at this site was identified after water bills continued to show abnormally high usage amounts. After the third high quarterly bill (9 months), the accountant paying the bill informed building management who conducted an audit of the buildings fixtures to identify any issues. Several leaking amenities were found and repaired but the next bill was also high. Monitoring was eventually installed after 9 months leakage at 60kL/day, a total loss of 16,200kL, costing over $35,000 in water and sewerage charges (at 2007 rates). The logger cost just $600 to install and monitor.

2. Audits

In conjunction with monitoring, a detailed investigation of the site needs to be carried out to establish exactly where the water is being used and the condition of the fixtures. This step often reveals many issues with the hydraulic system and results in a better understanding for the site staff. The process of bringing together all relevant staff with a responsibility of knowledge of the water system develops communication and increases awareness of water usage.

The resulting inventory of all water using fixtures and relating usage to patronage or production levels per day allow a water balance to be set up. The one in Figure 2 shows a site with potable and recycled water supply.

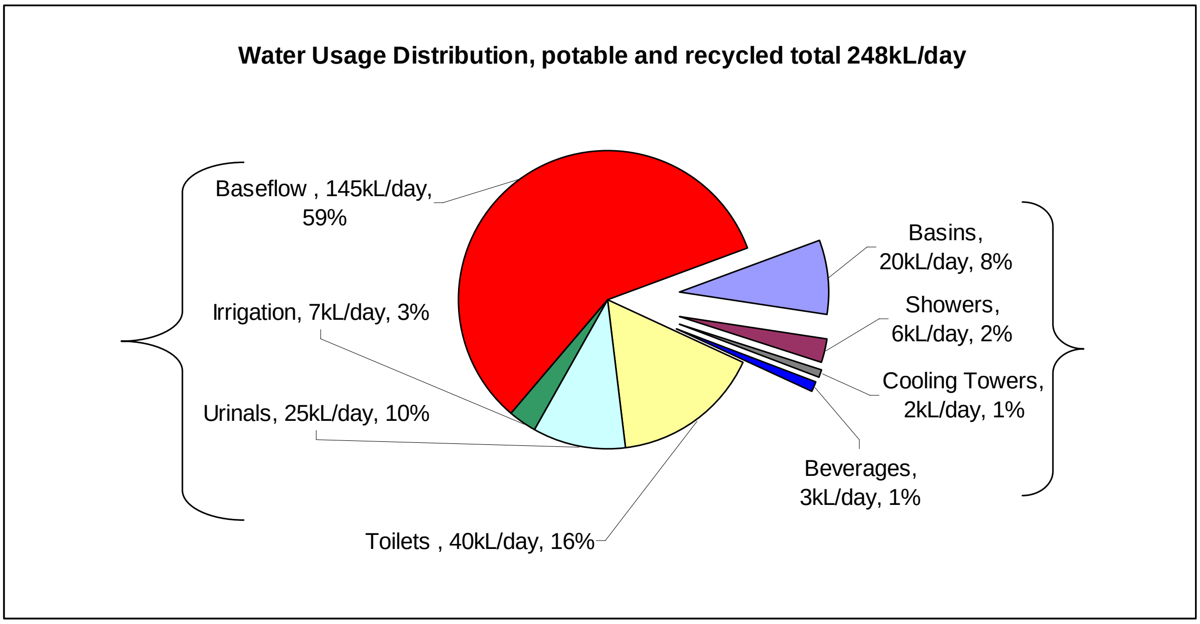

Figure 2: Example water balance

The first thing a water balance shows is where baseflow is occurring as discussed above. The next thing is to assess how much water is actually needed by the site if it were functioning at best practice levels with all water efficient fixtures. The difference in water use between operating at current and best practice levels is used to determine how much money can be saved through reducing water bills and then spent to implement water savings options.

There are several water wasting issues which appear frequently at all kinds of sites and provide similar levels of savings when remedied. Table 1 shows what these are and how much water commonly is lost.

Issue	**Potential water wastage**	**Economic Savings (per annum at 2008 rates)**	**Cost to fix**
Cooling towers			
TDS level set too low or not calibrated	2 – 40 kL/d	$2,000 - $40,000	$200 - $600
TDS probe fouled	10 – 30 kL/d	$10,000 - $30,000	$400 - $1,500
Float valves for make-up stuck open	20 – 100 kL/d	$20,000 - $100,000	$400 - $1,500
Control mechanisms not functioning as designed	20 - 40 kL/d	$20,000 - $40,000	$3,000 - $8,000
Excess drift due to damaged sides	1 - 15 kL/d	$1,000 - $15,000	$200 - $5,000
Urinals			

Continuously flushing due to solenoids corroded	10 - 300 kL/d	$10,000 - $300,000	$2,000 - $5,000
Sensors activated by everyone entering toilet	5 - 30 kL/d	$5,000 - $30,000	$100 - $500
Toilets			
Worn washers result in continuous dribble	2 - 90 kL/d	$2,000 - $90,000	$20 - $2,000
Flush volumes high	2 - 20 kL/d	$2,000 - $20,000	$500 - $5,000
Taps and showers			
High flow rates and worn washers	1 - 60 kL/d	$1,000 - $60,000	$50 - $2,000
Irrigation			
Moisture sensors incorrectly placed or not calibrated	15 - 80 kL/d	$15,000 - $80,000	$300 - $2,000
Amount of water required for soil and grass types not determined, usage based on allowed time only	20 - 100 kL/d	$20,000 - $100,000	$50 - $3,000
Watering during rain	40 - 80kL/day	$40,000 - $80,000	$0
Header, flusherette and make up tanks			
Overnight overflow from mains pressure	10 - 100 kL/d	$10,000 - $100,000	$50 - $1,000
Float valve sticking or bent	8 - 25 kL/d	$8,000 - $25,000	$100 - $500
Liquid ring vacuum pumps			
Water seal dumped when not needed	30 - 120 kL/d	$30,000 - $120,000	$10,000 - $50,000
Sterilizers			
Cooling water sent to waste	15 - 35 kL/d	$15,000 - $35,000	$5,000 - $50,000
Cleaning			
Wasteful cleaning practices by staff	5 - 100 kL/d	$5,000 - $100,000	$200 - $10,000
Inefficient spray fixtures	5 - 25 kL/d	$5,000 - $25,000	$300 - $3,000
Inefficient washing machines	1 - 25 kL/d	$1,000 - $25,000	$1,500 - $30,000
Steam Systems			
Losses of condensate return	5 - 25 kL/d	$5,000 - $25,000	$300 - $4,000
Hot Water			

Leaking hot water heater valves	1 - 8 kL/d	$1,000 - $8,000	$50 - $200
Overflowing office hot water boiler units	3 - 12 kL/d	$3,000 - $12,000	$150 - $400

Table 1: Common water wasting issues

These issues all vary depending on the size of the site, number of fixtures and the time taken to identify the problem. Some of these issues are considered normal operating practice for older fixtures where the economics of replacing them with a more efficient version does not add up. Only when the issues are investigated and options for improvement provided does any action happen. This impetus has recently come from governments in Australia and Singapore to name two, by both requiring audits to be undertaken and providing funding to implement actions.

3. Case studies

3.1 Cooling Towers

A water efficiency audit of NSW Parliament House identified the highest water user was the cooling towers, which supply chilled water to five neighbouring government buildings. After all efforts were made to reduce the usage by improving efficiency of the towers, the option of using water from the underground tunnel was investigated and found to be feasible.

There were two stages to this project:

1. Redirect downpipes from the roof and balconies to an existing sump tank in the basement and pump this water to new tanks on the roof for use in the cooling towers and flusherette.
2. Pump water from the railway tunnel to the basement sump to provide a potentially continuous alternative supply to the re-use system.

The volumes of the storages were limited by space and the structural capacity of the roof. The sustainable yield from the tunnel was estimated through survey and water quality monitoring conducted to determine the requirement for treatment.

A detailed model was developed using sub-daily water use monitoring data and climate inputs to accurately determine the critical volumes required. This was useful in checking whether the limitations of space and structure would make the project unfeasible.

Further investigations into the yield of the tunnel revealed that there was potential to provide a water supply to other users in the area such as the Royal Botanic Gardens and office buildings in the CBD. The yield can also be increased by redirecting stormwater runoff from the Parliament House precinct in Macquarie St as well as another project aimed at pumping water from the train stations on the city circle, which previously was pumped to sewer at a great cost.

This project involves many aspects of designing a stormwater re-use system and is an interesting case study for future building retrofit options.

Monitoring

Monitoring was installed on the main meter, cooling tower make-up (through two meters, one high and one low flow) and the flusherette tank outlet. Figure 3 shows water flow data collected at five minute intervals. This showed baseflow was occurring, in the flusherette system and elsewhere in the building through the main meter.

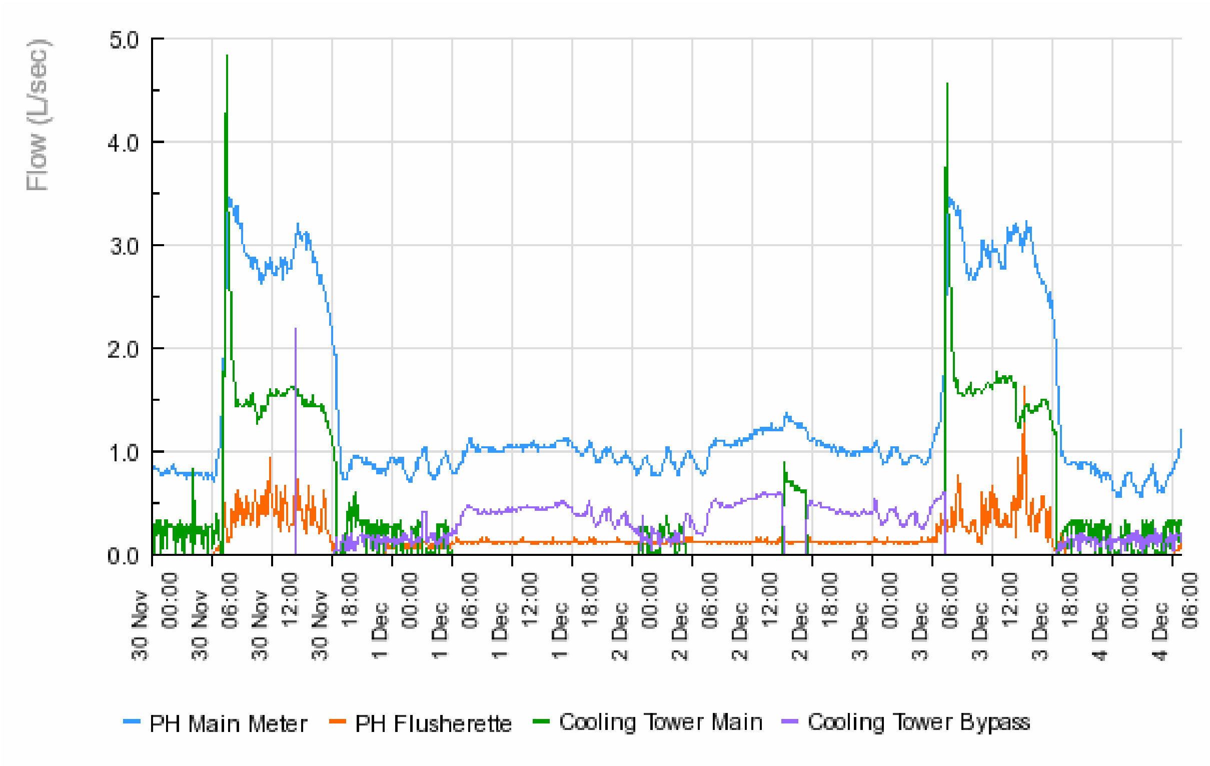

Figure 3: Monitoring data of the main, cooling tower and flusherette water meters.

There was not significant baseflow in the cooling tower usage, as site engineering staff had recently repaired the inlet sections of each tower. They had also been checked for operational efficiency. The flusherette baseflow was found to be several small leaks throughout the building and these are being repaired as part of an ongoing monitoring and maintenance program.

The larger baseflow through the main meter was investigated and is still being repaired. The monitoring however was able to establish that an alternate supply was not going to be part of the main baseflow.

Usage in the cooling tower averaged 50kL/day after efficient usage and toilet flushing usage was 10kL/day. These varied greatly between parliamentary sitting times, weekends and seasonal influences with cooling tower usage reaching 120kL/day on hot days.

Hydraulic System Investigations

From hydraulic diagrams, the potential connections and inputs were investigated. A sump in the basement of the building collected groundwater leakage from around the building, condensate from the HVAC system and some rainfall runoff from the roof areas. Fire testing was also directed to the sump. Two pumps had historically been operating to pump this water up five storeys to street level to be released into the city stormwater network.

It was found that one downpipe flowing directly to the city stormwater drainage collected water from half of the building and could easily be redirected to the sump. This was stage one of the project, as shown in Figure 4.

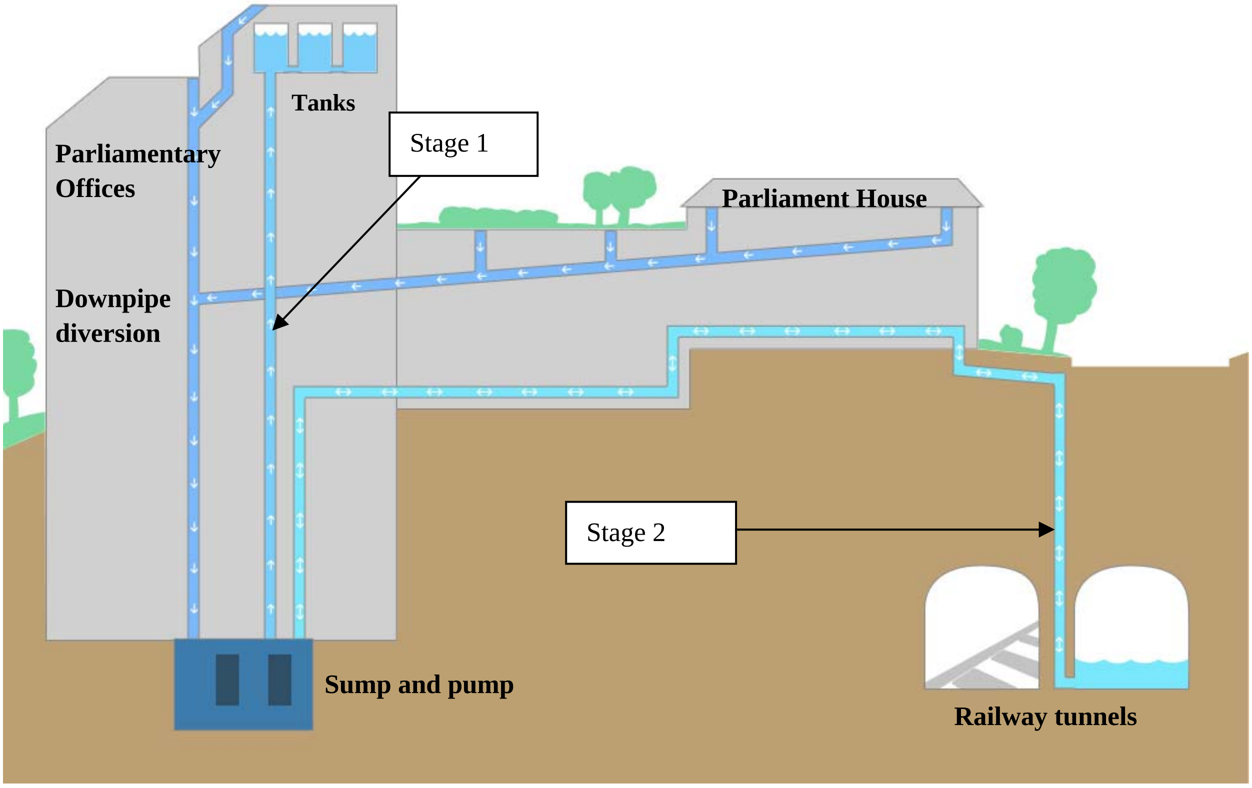

Figure 4: Layout of the water collection and re-use system

Modelling

From these investigations, modelling was undertaken to establish the best size of storage, pumps and pipes required to ensure sufficient water could be made available to the cooling towers and header tank to be a cost effective proposal.

The model was set up using five-minute time step climate data and five-minute demand data from monitoring. An average daily demand does not allow for a temporal distribution across a 24 hour period, resulting in a lumped application of water. This can be critical when trying to match peak demand periods (e.g. usage during the middle of the day when most fixtures are operating) and seasonal variability to available supply.

A diurnal usage pattern can be generated to accurately construct demand profiles when monitoring is installed over a long period, and allows the design of storages, treatment systems and piping to reflect actual requirements rather than over-designed and expensive systems or under-designed and non-functional systems. This is especially important when cost effectiveness is difficult to achieve because of the low price of water.

There was a space and structural constraint for the storage tanks on the roof which allowed for a maximum of 60 tonnes (60kL of water) in the best location. The model revealed that a potential average of 47kL/day could be supplied by installing 60kL tanks on the roof. This would only supply 40% of the demand on peak days and the tanks would most probably be emptied on a hot day with no recent rainfall. Therefore, the potential extra supply from the railway tunnel was investigated.

Railway tunnel investigations

Survey information of the tunnel was old and unreliable so a new survey of the tunnel was conducted. This included water quality monitoring, level surveying and checking the stability of the tunnel wall. Figure 3 shows the tunnel, looking to the north.

Figure 5: The disused railway tunnel

The tunnel was constructed in a cut and fill method, with formwork built and concrete poured to create the roof. This allows water to seep in through the sandstone on the sides. The reason the tunnel was not used for railway lines was it began filling with water from a spring during construction. This inflow continues today.

The survey and assessment of groundwater seepage found that the current available volume in the tunnel was 500kL. The wall survey found it structurally sound to handle increasing water levels with some sealing and this was proposed to create increased available volume.

Water quality monitoring found no harmful pathogens and an acceptably low level of TDS. Pumping water from the tunnel meets all available health standards because chemical dosing in the cooling towers acts as a final barrier to possible contamination.

The natural seepage inflow was difficult to determine so options for inputting water from other sources was investigated. These included pumping water into the tunnel from the Parliament House sump when full, collecting water from the other government buildings in Macquarie St and pumping stormwater from the train stations on the City Circle line. Each of these has additional issues, in particular water quality.

Final system design

Four tanks (2x10kL and 2x20kL) were installed on the roof next to the main cooling tower (Figure 4). Two new pumps were installed in the sump to ensure adequate pumping to avoid flooding a 100 micron filter was put on the outlet of the pumps. A 50mm line was run through a service void to take the water to the roof tanks. The 150mm downpipe from the office roof to the street stormwater system was cut into and diverted to a conveniently adjacent downpipe leading to the sump.

Figure 6: Storage tanks on the roof

Meters were installed throughout the system to monitor performance in the first months of operation which has revealed some issues with the system. Pumps are activated by float switches in the sump and the tanks on the roof responding to the demand of the cooling towers. The levels the float are set at are causing the pumps to operate in short bursts to meet demand throughout the day rather than one long session to fill the tanks overnight which would be preferable using off peak power.

The next phase of the project, to include the tunnel as a storage vessel, is currently underway and depending on implementation costs and available funding, should go ahead early next year.

3.2 Amenities – toilets and urinals

Through our work with the Sydney Water Every Drop Counts program, we have conducted audits on several large entertainment venues in Sydney. These facilities have hundreds of toilets and urinals, used for one large even per week when leaks and breakages occur and these flow on throughout the week until the maintenance run before the next event.

Figure 7 shows the effect of a large event on generating many small leaks which add up to large volumes of wasted water. The graph shows that once all the toilet leaks are repaired there is no other baseflow in the stadium.

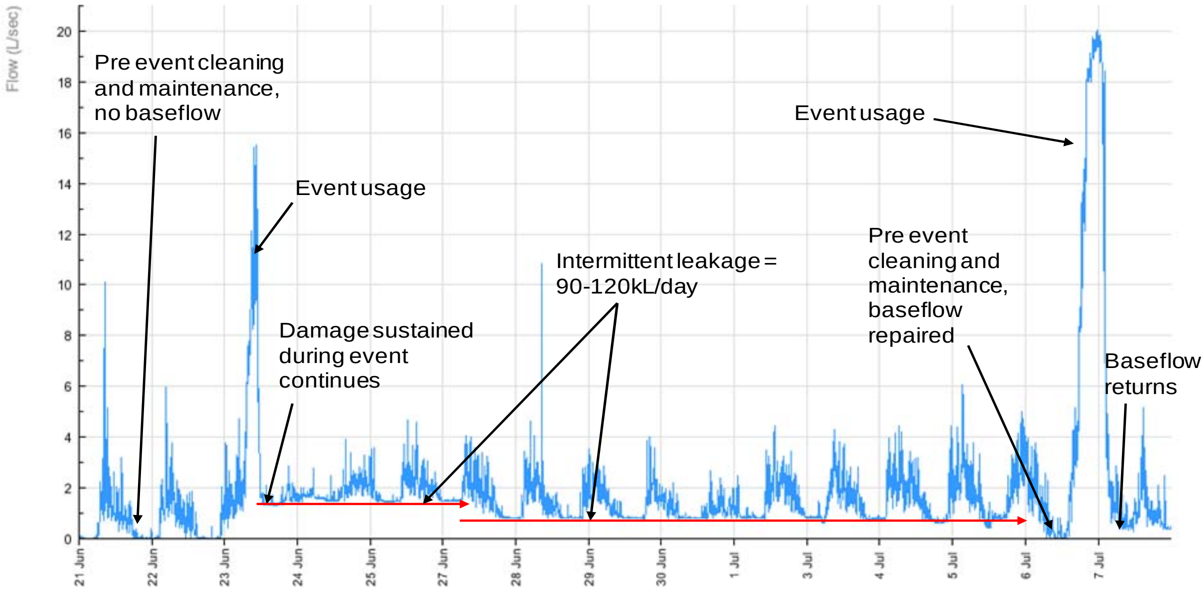

Figure 7: Monitoring of a two week period showing the impact of large event usage

Monitoring of a facility like this using a network of sub-meters allows the maintenance staff to target problem areas and make repairs where needed.

3.3 Alternate water supplies

A large public facility in Sydney which pioneered water recycling faced an issue with the efficiency of using that recycled water. Obviously it is important to use both potable and recycled water efficiently because of the high energy and chemical costs associated with treatment.

The following graphs provide an example of where an alternate supply was implemented prior to addressing efficiency. Initial monitoring (Figure 3) revealed a considerable baseflow and the audit found that to be through several urinals around the site which were flushing continuously because of faulty sensor flush mechanisms.

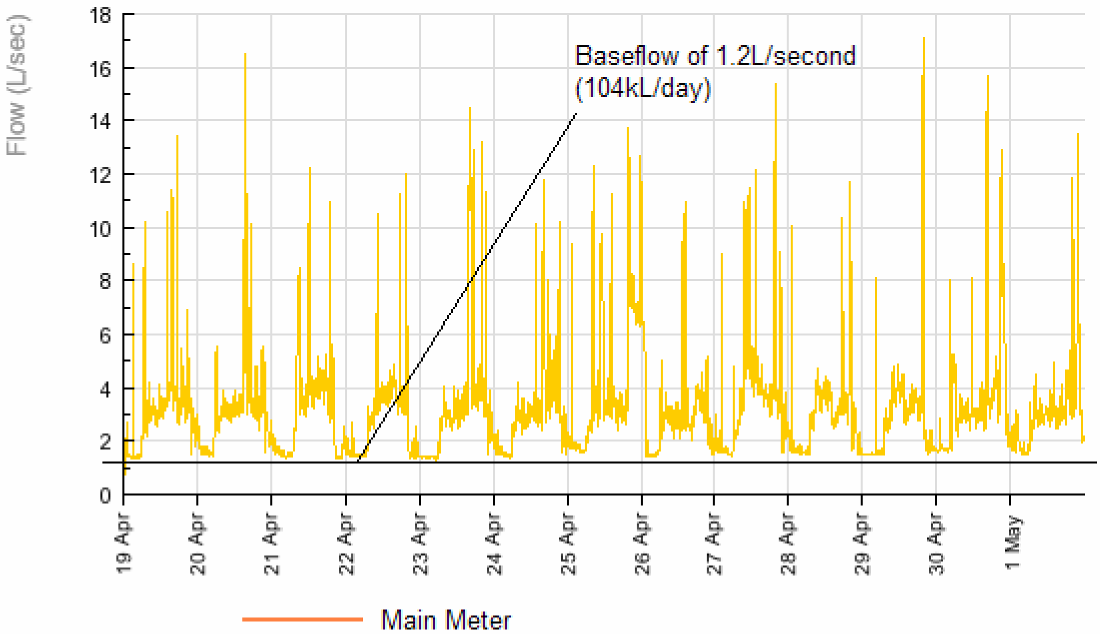

Figure 8: Main meter water usage profile showing 1.2L/second baseflow

The result was the 1.2L/second baseflow (104kL/day) was transferred from potable water to recycled water (Figure 9). The recycled water connection costs in excess of $200,000 and continued to waste water. Repairing the urinals to stop baseflow would have cost $8,000 to install push button flush mechanisms or $14,000 to replace the sensors with new ones.

Figure 9 shows that without baseflow, the daily recycled water demand is very low and the cheaper options to repair the leakage would have saved just as much potable water as the more expensive.

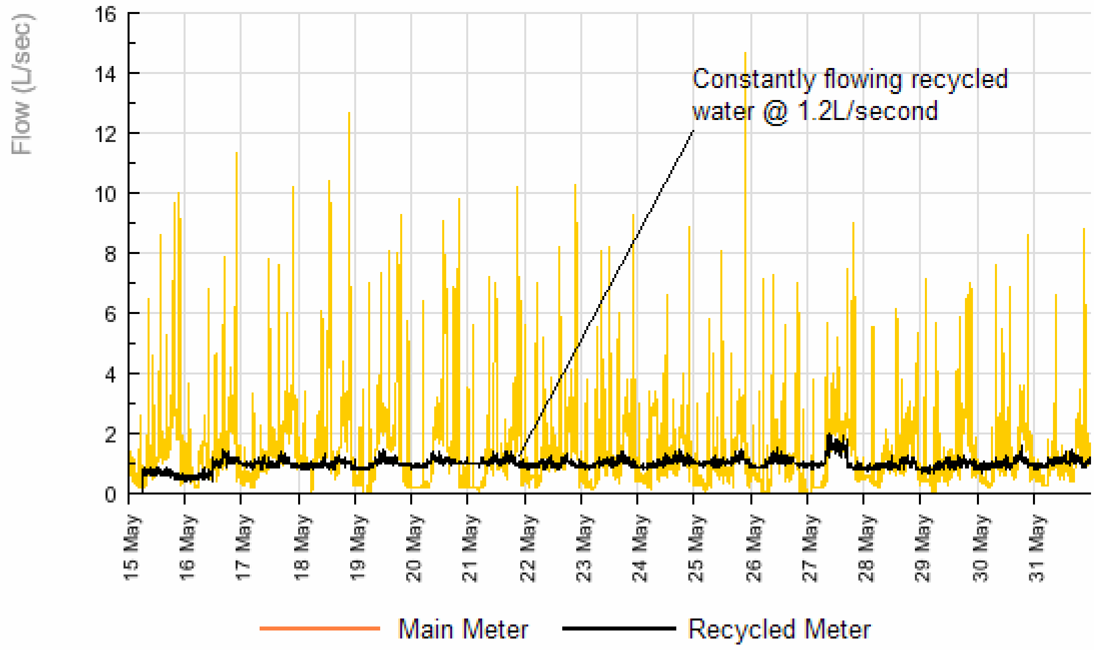

Figure 9: Main meter and recycled water meter usage profiles showing baseflow transferred to recycled water

Solutions

The approach to implementing solutions should be done in stages to ensure resources are not wasted. The steps are shown below:

1. Identify and repair leakage
2. Replace or repair all water using fixtures with the most efficient models
3. Identify areas where once used process water can be captured, treated and reused
4. Identify alternate supplies of water and replace potable water streams.

Only after steps 2 and 3 are completed and an efficient usage level is occurring should step 4 be investigated. Potable water replacement/recycling schemes should not be considered until process efficiency and leakage has been addressed (Mouritz, 2007). This is a common mistake, where the idea of recycling water or using rainwater to supplement a supply is done without regard for improving the efficiency of the usage first. This can lead to the alternate supply option being oversized, too expensive and ultimately not adopted.

In many cases, the water saved through improving efficiency is more cost effective and can achieve greater savings than an alternate supply. However, an alternate supply can become more economically feasible after water usage has been reduced.

Monitoring allows facility managers a detailed understanding of both their hydraulic system's structure and the way it is used. This helps to better manage it with regards to reducing water losses and excess usage, but also provides detailed data to assess and design systems to reduce water consumption including improved efficiency and using alternate water supplies.

Current technologies can be tailored to suit any kind of site and specific requirements for data display and analysis tools provided. The key to a good monitoring system is installing sufficient meters at key locations to capture major users. Again, there are a range of meter types suitable for different purposes.

This paper also presents some case studies, illustrating the power of monitoring to save large volumes of water and aid in the design and management of alternate supply systems. When considering the cost of installing a monitoring system, the resulting potential to save water should not be underestimated.

References

Coombes P, Kuczera T and Jetse K (2003) *Economic, Water Quantity and Quality Impacts from the use of a rainwater tank in the Inner City.* Published in the Water Sensitive Resource Kit for the Sydney Region

Mouritz M (2007) Urban Water Systems and Sustainability*.* In *Water that Works* (CEDA)

Sweeting H, Wilkins D (2007) *The Effectiveness Of Facility Level Water Saving Measures.* Presented at OzWater 2007

Seneviratne M (2007) *A Practical Approach to Water Conservation for Commercial and Industrial Facilities,* Elsevier UK

Trow S, Farley M (2006) Developing a Strategy for Managing Losses in Water Distribution Networks. In: *Water Demand Management,* Butler, Ali Memon (Ed) IWA Publishing