



Evaluation of alternative water sources for commercial buildings: A case study in Brisbane, Australia



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ABSTRACT

Commercial buildings are central to cities and contribute significantly to the urban demand for natural resources, including freshwater. Green building benchmarking tools include more efficient water use as key indicator of sustainability. This paper explores options for substituting mains drinking water with an alternative, non-potable water source on a fit for purpose basis. The research findings are based on a monitoring study of a commercial building in Brisbane, Australia that is harvesting rainwater for meeting non-potable water demand. The results demonstrated that the system is only achieving moderate reliability in meeting demand due to operational problems. The case study analysis has highlighted the need to include validation and monitoring to ensure the system is operating as per design intent. The paper also investigates the potential of other local, non-potable water sources for high-rise commercial buildings, in particular air conditioning condensate and groundwater inflow to a basement wet well. The paper concludes by comparing the advantages and disadvantages of different local water sources which highlights the need to undertake a site specific investigation to identify a suitable alternative water source, which considers O&M complexity and the capacity of facilities management.

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1. Introduction and background

Commercial water use is a significant component of overall urban water demand. In Australia commercial water use makes up around 15% of the total demand for urban water (ABS, 2010). Water audits of commercial office buildings have revealed that non-potable applications, in particular for toilet flushing and cooling tower blowdown, accounts for between 50% and 90% of total building water demand (Seneviratne, 2006). The influence of office buildings on the urban form of cities means there is need to incorporate this sector in seeking more sustainable development (Burnett, 2007). This includes exploring opportunities for conservation of mains drinking water through substitution with alternative water sources.

The need to explore alternative water sources in cities is being driven by uncertainty in the future reliability of traditional water supply sources due to climate change impacts and growing demand from increasing urban populations (Ruth et al., 2007; Sharma et al., 2012). However, a lack of reported monitoring studies on the performance of alternative water servicing options against

sustainability objectives has impeded mainstream adoption in the development sector (Sharma et al., 2012).

The role of alternative local water sources in reducing demand for imported potable water and reducing the environmental impact of urban development has received considerable attention in the residential sector from both researchers and policy makers (Imteaz et al., 2013; Jones and Hunt, 2010; Khastagir and Jayasuriya, 2010), but there are limited studies that report on the implementation of alternative water sources for commercial buildings (Ward et al., 2012). Notable exceptions include: Chilton et al. (2000) who evaluated the performance and value proposition of a scheme that harvested runoff from a supermarket roof for toilet flushing, while Imteaz et al. (2011) detailed the optimisation of storage tank sizes for a system harvesting roof runoff from large roofs at a university campus, which was used for landscape irrigation. Zhang et al. (2009) provided a comparative assessment of using rainwater or greywater for reducing mains water demand in a high-rise building. Their assessment found that greywater provided a more suitable source due to the constant supply when compared to the episodic nature of rainfall events.

This paper – based on a monitoring study of a commercial building in Brisbane, Australia – provides a case study analysis on the reliability of roof-harvested rainwater in meeting non-potable demand, and the pumping energy required. This paper also

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explores other potential non-potable water sources for commercial buildings in terms of yield and quality while also taking into account energy and life cycle costs. The complexities of managing and operating decentralised water systems are also considered.

1.1. Water use in commercial buildings and drivers for efficiency

Minimising mains water use through source substitution is part of a broader shift in cities to improve the environmental performance of the built environment through Ecologically Sustainable Development (ESD) (Najia and Lustig, 2006).

The drivers for incorporating sustainability initiatives are both top-down and bottom-up (Newell, 2008). Top-down drivers for ESD in the commercial development sector include regulation through building codes and legislation, and also rising costs for utility services. While, bottom-up drivers include corporate sustainability objectives, marketability of sustainable buildings, and the introduction of industry rating schemes that benchmark the sustainability performance of a building (Newell, 2008). In Australia the Green Building Council introduced the Green Star Rating, with analogous sustainability benchmarking schemes in other countries including BREEAM in the United Kingdom and LEED in the United States (Wang et al., 2010). Drivers such as sustainable benchmarking are providing the impetus for the commercial development sector to incorporate ESD initiatives, such as source substitution with alternative water sources. However, there is uncertainty about the performance of alternative water systems and their contribution to improved sustainability in green buildings (Wedding and Crawford-Brown, 2007). In encouraging the wider adoption of alternative water systems, there is a need to validate their performance so that lessons can be applied in future developments (Cook et al., 2013). More monitoring and evaluation of existing alternative water systems can enable evidence-based benchmarking of performance for similar buildings and inform improved design guidelines.

2. Methodology

Fig. 1 summarises the key steps of the methodology. The research was grounded in the monitoring study of a rainwater system that supplied non-potable demand in a commercial office building. This primary data collection and analysis provided a foundation for considering overall performance of the rainwater harvesting system in reducing demand for mains drinking water. The research included consideration of social aspects through interviews with the building owners, the designers of the rainwater system and the building facility managers. The interviews focussed on the issues experienced with the implementation and operation and maintenance of the rainwater harvesting scheme. The technical feasibility of other non-potable water sources were assessed in terms of their ability to provide cost effective solutions that maximise mains water savings, while minimising adverse environmental impacts and considering user operating requirements. The application of the methodology provided a basis for assessing the relative strengths and weaknesses of different local water sources, and how a combinatorial approach may provide the best outcome for meeting local non-potable water demand.

2.1. Case study

The case study building, Green Square North Tower (GSNT), is located in Fortitude Valley, which forms part of the central business district of Brisbane, Australia. GSNT is a twelve-storey commercial office building that was designed to meet a 6 star standard under the Green Star Rating scheme (Steinfeld et al., 2011). The initiatives for mains water conservation included waterless

Table 1

GSNT rainwater scheme yield and energy demand (monitoring period March 2010–April 2012).

Supply and demand	Daily average
Demand for toilet roof tank	7.8 kL/day
Demand for irrigation tank (no potable top-up)	0.7 kL/day
Overall demand for non-potable system	8.5 kL/day
Rainwater supplied from basement tank	3.2 kL/day
Top-up to toilet flushing roof-top tank from municipal supply	5.3 kL/day
Specific energy for rainwater system	Specific energy
Energy for rainwater system (pumping rainwater from basement tank)	0.44 kWh/kL

urinals and the harvesting of roof runoff for substituting mains water for toilet flushing and landscape irrigation demands. Fig. 2 depicts the hydraulic circuit of the GSNT rainwater system, and the metering system that was used to validate the reliability of the system in meeting non-potable demand, and the associated pumping energy demand. Rainwater was harvested from an effective roof area of approximately 1600 m² then gravity fed via downpipes to a 110 m³ basement storage tank. The water in the basement tank was then pumped back to the roof to two smaller tanks (21 m³ and 28 m³) that were used to satisfy toilet flushing and garden irrigation respectively, with gravity feed to points of use. The header tanks had pressure floats, so that when the water level fell to the low-level float a pressure switch activated pumping from the basement tank. In the case of the toilet tank, there was back-up supply from the mains water if demand could not be satisfied by harvested rainwater. Overflow from the basement rainwater tank, following heavy rainfall events, was directed to a wet well where it was then pumped for discharge to the stormwater drain.

The toilet tank was used to satisfy the demand for flushing of 147 toilets that had full and half flushes, with an estimated water efficiency of 6 l for a full flush and 3.8 l per half flush. The irrigation tank was used for watering window planter boxes; however the area under irrigation was small, so the water demand was negligible. The occupancy of GSNT was estimated at 1200 workers based on office floor space of 24,000 m² and a density of 20 m² per worker (Saari et al., 2006).

GSNT is located in a sub-tropical climate zone where the annual rainfall is around 1000 mm (Bureau of Meteorology, 2013). The rainfall distribution over the year is marked by distinct wet and dry seasons.

2.2. Monitoring system

Monitoring of energy and water fluxes at GSNT was undertaken using a high-frequency logging device that recorded water flows and energy pulses at each 6-min time interval. A data logging system stored the data in 6-min, hourly and daily data files. Manual recordings taken monthly from the water and energy metres were used to calibrate the electronically logged data.

3. Results

Table 1 summarises the rainwater yield and energy intensity of the GSNT system over the 26-month monitoring period. This showed that the system could be characterised as fair to moderate level of reliability, as only 37% of the non-potable demand was satisfied by harvested rainwater. However, the system delivered water supply at a low energy intensity. The demand for toilet flushing was around 7.8 kL per day. This equated to around 54 l per day for each of the 146 toilets or 15 flushes per day (3.5 l average flush volume). There was minimal demand for irrigation due to the limited

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