Valuing stormwater, rainwater and wastewater in the soft path for water management: Australian case studies
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ABSTRACT
A Water Sensitive City is now commonly acknowledged best practice for designing the cities of the future. In Australia, the National Water Initiative has allocated high priority towards offering insight into successful water sensitive urban development projects, to facilitate capacity building within the industry. This paper shares innovative water sensitive projects implemented at Kogarah City Council, in Sydney. Four key projects are discussed, demonstrating how stormwater, rainwater and wastewater can be incorporated into decentralised water systems to offer sustainable water management of the future. The case studies included in the paper highlight Kogarah’s journey towards the Soft Path for Water Management.

Key words | constructed wetland, rainwater harvesting, rainwater tanks, soft path for water, stormwater reuse, wastewater reuse

A ‘SOFT PATH’ FOR WATER
With the Industrial Revolution, the size of our cities has grown rapidly. Large amount of water needed and the sewage generated, as well as the increased stormwater from the vast urban areas requires a new management approach. “Big pipe engineering approach”—for bringing drinking water into the city and for removing wastewater and stormwater away from the city, became the standard water management technique (Newman 2007). The resulting centralised system that we now inherit is based on sourcing large quantities of water from one location, adding a number of nutrients to it during its once-only use, and finally disposing the waste stream at another point location.

It is now well acknowledged that sustainable water management of the future is significantly different from the traditional water management paradigm that focused on meeting the demand for water by augmenting supply and disposing wastewater and stormwater to prevent the spread of disease. Sustainable urban water systems need to focus on achieving a ‘closed loop’ through initiatives such as rainwater harvesting and reuse. As outlined in Figure 1, such an approach treats stormwater runoff and sewage as resource and cuts down on their wasteful pollutant loaded discharge into waterways (Stenkes et al. 2004).

Decentralised systems
It is safe to conclude that when it comes to water management systems, building ‘big’ might just have become a thing of the past. In the new geo-political world order with the challenge of changing climate, decentralised water management options will undoubtedly play an important role in the cities of the future. There are several benefits associated with decentralised options, including (Pinkham et al. 2004):

- By (typically) moving capacity costs to the future, the net present value of costs for decentralised systems is reduced compared to centralised systems of similar or even somewhat lower nominal costs
- Decentralised systems can reduce the net present value of system costs by deferring or downsizing the need for replacement systems
Decentralised systems can help extend the useful service life of existing conventional infrastructure. Shorter lead-time and smaller size shorten the planning horizon, consequently decreasing the amplification of errors in forecasting demand with the passage of time. While centralised systems are essentially out of sight and mind for most property owners (excepting payment of water/sewer bills), decentralised systems require greater awareness and participation. Decentralisation allows for preservation of open space and its attendant values without the costs of unnecessary infrastructure. By avoiding the capital and operational expenses of large re-distribution networks, decentralised systems provide opportunities for cost-effective reuse of water at the site and neighborhood scale. Integration of wastewater and stormwater systems can be considered, under particular conditions, across a range of scales. On average, the risks and costs of system failure are probably less for decentralised systems than centralised systems, because the consequences of small, widely distributed failures are limited while the consequences of large, concentrated failures can be severe.

Detailed knowledge of local natural processes is a necessary prerequisite for successful designing of water sensitive cities and implementing appropriate water recycling initiatives. ‘Such intimate knowledge of local soils, slopes, creeks, wetlands, as well as knowledge of the urban aspects of nature, i.e. open space, community gardens, street trees are ideally suited to the role of a local environmental scientist working in a local authority’ (Newman 2007). Large centralised water utilities framework is therefore argued as ineffective in providing the specialised local level knowledge needed for developing the water sensitive cities of the future.

APPLICATIONS OF WATER SENSITIVE URBAN DESIGN

Monash University (2008) suggest that water sensitive cities enable linkage between the community and their local environment through landscape design. These cities focus on the degrading urban waterways and incorporate ‘green stormwater treatment technologies such as constructed wetlands’ to protect the waterways from pollution. At the same time these cities maximise the benefit from stormwater as a source of water supply by harvesting and reusing stormwater runoff and rainwater. The following section discusses four key water sensitive projects implemented in Kogarah Local Government Area in Sydney that range from stormwater treatment at a regional scale to wastewater reuse.

Rainwater harvesting

Rainwater harvesting is defined as the practice of collecting water from surfaces on which rain falls, and storage of this water for later use. The concept of rainwater harvesting is believed to have been in practice for thousands of years. Indians learnt this water arithmetic as far back as 5,000 years. The city of Dholavira of the Indus Valley civilisation was harvesting rainwater in the dry Thar Desert of western India (Kumar 2000). Some of these practices continue to remain in use even today.

According to Pandey et al. (2003), the antiquity of rainwater harvesting as an adaptation to climate change is intrinsic. In a fluctuating holocene climate, rainwater harvesting in response to climate extremes enhanced the resilience of human society. Archaeological investigations have unearthed examples of rainwater harvesting world over, including ancient reservoir technology developed by the Mayan people, large-scale earthworks in Bolivian
Amazon, and check-dams in Wadi Sana in United Arab Emirates dating back 15,000 years (Pandey et al. 2003). The knowledge of the historical adaptive processes that are still functional is important to deal with and global climatic changes, and rainwater harvesting is one such process.

Despite being the driest inhabited continent on Earth, most of Australian cities, which happen to be located along the coastline actually receive adequate amounts of precipitation each year to satisfy their various needs. For instance, a typical Sydney household on average generates 300 kL of stormwater every year (PMSEIC 2007). With a water demand of about 220 kL, rainwater could provide a potentially significant source of water for Sydney metropolitan area (PMSEIC 2007). Rainwater harvesting can significantly reduce drinking water consumption.

Kogarah town square development: stormwater & rainwater reuse

Stormwater is defined as the rainwater that has fallen on the round. In the Kogarah Town Square, stormwater from paved surfaces is collected and passed through a gross pollutant trap to remove any litter and large pollutants. The water is then collected in a separate storage tank. This water is then pumped under pressure and is used for irrigation of the landscape areas within the large courtyards (Kogarah Council 2003). The landscaped areas act as a bio-filter for the water, removing the excess nutrients and fine particles. As shown in Figure 2 below, the filtered water is collected and stored in a separate clean water tank and is used as a primary top up supply for the other tanks. It is estimated that this system saves up to 2,130 kL of potable town water per annum that would otherwise be used for irrigation (Kogarah Council 2003).

Rainwater is collected from the roof surfaces and the upper level terraces of the development. Compared to stormwater, this water is considered ‘clean’. It flows through the downpipes to a large storage tank under the public carpark, labelled Clean Water tank in Figure 2 below. Water is filtered through a screen filter and is then pumped under pressure and used for toilet flushing, car washing and in the water feature located in the Town Centre. It is estimated that rainwater harvested on site saves up to 5,789 kL of potable town water per annum that would otherwise be used for toilet flushing, car washing and public space irrigation (Kogarah Council 2003).

According to Hermann & Schmida (1999), rainwater usage is most effective for the drainage system when it is applied in multi-storey buildings and densely populated districts. It is because the specific roof surface per head is low, and therefore the total roof runoff can be consumed. Kogarah Town Square is a medium density development, where 85% of the rain that falls on the site is collected for onsite reuse. When compared to water consumption rate for a typical development of similar size, annual water consumption rate at Kogarah Town Square is approximately 42% less (Kogarah Council 2003). In summary, the integrated water sensitive design features implemented at this site result in:

† 85% of the 8,230 kilolitres of rainwater falls on the site annually is captured and used;
† 60% is used to flush toilets and the remainder to irrigate the gardens in the courtyards of the development;
† 25% of the water collected passes through the gardens and is purified and stripped of most of the nutrients it contains.
Rainwater tanks in school: rainwater harvesting for education & reuse

At a decentralised level, Kogarah Municipal Council is the first local government authority in Sydney to promote the use of rainwater tanks in all the schools within the council area. This project involved continuous simulation modelling to determine the appropriate tank volumes, based on factors including water usage patterns and available roof surface areas for harvesting. The major outcome of the project was the installation of rainwater tanks in all 22 schools in the Kogarah Council area. 20 of the 22 schools connected their rainwater tanks to toilets and the remaining two schools used the water for irrigation purposes only. Connecting rainwater tanks to toilet flushing maximised the reduction of potable water use for the majority of schools that participated in the project (Chanan et al. 2008).

Optimal rainwater tank size for each school (see Table 1) was determined keeping in mind their water usage patterns as well as known constraints on the down-stream stormwater network in the vicinity of each school, using the continuous simulation model (Beecham 2004).

Once appropriate tank sizes were determined for each school, Council officers undertook an analysis of the water consumption patterns of each school within the LGA. Council staff with the experts from the University of Technology, Sydney also conducted site visits at all of the schools that were meeting the target. These visits were to identify potential sites for installation of the tanks, from where water could be used for toilet flushing as well as irrigation. Once these sites were confirmed with the relevant schools, Council engaged contractor carried out the installation. In addition to installation of rainwater tanks, a complementary water education program was also developed and is currently being implemented. Education program included carrying out water audits, tank decorating initiatives as well as the development of a Water Conservation Action Plan.

According Chanan et al. (2008), numerous outcomes have been achieved from the Rainwater Tanks in Schools project, not only in water savings but also in fostering water conservation behaviour within the pupil population (Figure 3).

Table 1 | Required tank sizes to achieve 50 and 70% supply security

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Roof area (m²)</th>
<th>Tank size to achieve 50% supply security (kL)</th>
<th>Tank size to achieve 70% supply security (kL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>100</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>200</td>
<td>300</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>200</td>
<td>500</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
<td>23</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>300</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>500</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>1,000</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1,000</td>
<td>300</td>
<td>23</td>
<td>100</td>
</tr>
<tr>
<td>1,000</td>
<td>500</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Constructed wetland: improving urban waterways

Constructed wetlands use natural processes for the treatment of polluted stormwater. According to Moat et al. (2008), there are four major system components of constructed wetlands for treatment:

- Wetland vegetation or macrophytes—play a major role in treatment of stormwater. The biomass of the plant slows the pathway of stormwater, enhancing the sedimentation of solids. There is also uptake of some pollutants in stormwater by these plants.
- Media or substrate supporting vegetation—comprising coarse and fine gravel, physically supports macrophytes in a constructed wetland and also acts as the principal storage of all biotic and abiotic (non-living) components that exist in a wetland.
- Water column (in or above the media)—pollutants are transported by the water column above and below the substrate to active biological zones of a wetland system. It also provides the environment for the biochemical treatment reactions to occur and to transmit the resultant products such as gases that are formed during these reactions.
- Living organisms—micro- and macro-organisms form a part of wetlands. The microorganisms attach to the substrate and help assimilate, transform and recycle chemical constituents that are found in stormwater and aid their removal.

Construction wetlands provide an ideal mechanism to improve the quality of stormwater runoff that drains into...
the local waterways, in urban catchments where natural wetland systems have been lost due to pressures of urbanisation. Constructed wetlands also enhance the ecological, recreational as well as aesthetic value of the river and foreshore public open space (Idris et al. 2008).

At Kogarah, a constructed wetland was implemented at Moore Reserve (Figure 4). The wetland has a surface area of 9,500 m² and combined with the Gross Pollutant Trap (GPT) it is able to treat 95% of all stormwater from the catchment. The wetlands volume is approximately 6,120 cubic metres, its depth ranges from 2 m in the northern end to 0.5 m in the macrophyte zone in the middle.

The wetland and filtering system treats stormwater from surrounding residential, industrial and commercial areas to remove litter, nutrients, heavy metals and sediments. Stormwater enters the wetland near an island that slows down the flow of the water. The wetland is designed to be 2 m deep here so that sediment with heavy metals attached can settle and remain undisturbed. Water moves slowly through the wetland into a shallower section (0.5 metres) filled with reeds and sedges (macrophytes). These plants take up nutrients from the stormwater and use them for plant growth. This shallow zone has the most aquatic life and includes turtles, invertebrates, birds and frogs.

The final deep section of the wetland allows sunlight and wind to continue to break down bacteria that remains in the water. Cleansed water then flows to an outlet pipe and into Oatley Bay. Analysis of stormwater water quality entering Oatley Bay at Moore Reserve show dramatic improvements since the project was implemented. In 1996, before construction of the wetlands, water samples from the stormwater drain showed high levels of heavy metals such as copper (5 micrograms per litre) and zinc (55 micrograms per litre). By 2003, stormwater samples...
downstream of the wetlands showed maximum copper readings of just 2 micrograms per litre, and that of zinc at 11 micrograms per litre.

**Beverley park water reclamation: wastewater reuse**

The Beverley Park Water Reclamation Project is the flagship project in Kogarah’s journey towards being a water sensitive city. It reclaims up to 750 Kilolitres of sewage every day for treatment and reuse for irrigation at the golf course and other parks and sporting fields in Kogarah. This project will reduce potable water use in Kogarah by as much as 160 ML every year. The project scope also included upgrading of irrigation equipment and practices so that this new recycled source was used efficiently.

At the time of project planning, a combination of State and Federal “guidelines” existed to assist in establishing re-use systems that was “fit-for purpose”. However, given that the project was the first application of water mining in Sydney, considering possible community concerns, council in collaboration with NSW Government Departments (Health, Water and Energy) and the community, developed specific targets for the Beverley Park Water Reclamation Project. **Table 2** provides the proposed water quality objectives that were endorsed by Kogarah Council for this project, and compares it with the National and NSW Guidelines for Urban and Residential Use of Reclaimed Water.

The project uses the ReAqua-Chemical Assisted Separation (CAS) process for treating and reusing wastewater. ReAqua CAS is a hybrid technology that utilises biological processes in conjunction with chemical and physical removal processes of coagulation and filtration. **Figure 5** below outlines the ReAqua CAS process, which involves coagulation to remove fine solids, followed by a submerged aerated filter for biological treatment. Effluent from biological process is further polished through sand filter. The last component of this process train is disinfection by UV, in case of Kogarah there is also chlorination prior to site storage. Chlorination is an important step to meet the residual chlorine requirements stipulated by the regulator.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>NSW residential re-use guidelines 1993</th>
<th>Victorian class A 2004</th>
<th>NWQMS November 2000 (uncontrolled access)</th>
<th>Proposed Beverley Park targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical oxygen demand (BOD₅)</td>
<td>&lt;20 mg/L</td>
<td>&lt;10 mg/L</td>
<td>Tertiary</td>
<td>&lt;10 mg/L</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>&lt;30 mg/L</td>
<td>&lt;5 mg/L</td>
<td>Tertiary</td>
<td>&lt;5 mg/L</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>&lt;10/100 mL</td>
<td>Not specified</td>
<td>Not specified</td>
<td>&lt;10/100 mL</td>
</tr>
<tr>
<td>Faecal coliforms</td>
<td>&lt;1/100 mL</td>
<td>&lt;10/100 mL</td>
<td>&lt;10/100 mL</td>
<td>&lt;1/100 mL</td>
</tr>
<tr>
<td>Bacteriophage/viruses</td>
<td>&lt;2 per 50 L</td>
<td>&lt;1 per 50 L</td>
<td>Tertiary</td>
<td>&lt;1 per 50 L</td>
</tr>
<tr>
<td>Parasites/protozoa</td>
<td>&lt;1 per 50 L</td>
<td>&lt;1 per 50 L</td>
<td>Tertiary</td>
<td>&lt;1 per 50 L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>&lt;5 NTU</td>
<td>&lt;2 NTU</td>
<td>&lt;2 NTU</td>
<td>&lt;2 NTU</td>
</tr>
<tr>
<td>pH</td>
<td>6.5 to 8.0</td>
<td>6 – 9</td>
<td>(n/s)</td>
<td>6.5 to 8.0</td>
</tr>
<tr>
<td>Colour</td>
<td>Not specified</td>
<td>(n/s)</td>
<td>Possible reduction</td>
<td>&lt;15 TCU</td>
</tr>
<tr>
<td>Residual chlorine</td>
<td>0.5 mg/L</td>
<td>1.0 mg/L</td>
<td>1.0 mg/L</td>
<td>0.5 mg/L</td>
</tr>
<tr>
<td>Salinity</td>
<td>Not specified</td>
<td>Not specified</td>
<td>&lt;175 mg/L (low)</td>
<td>&lt;500 mg/L</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Ortho phosphorus</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

**Table 2** | Summary of water quality targets (Source: Chanan & Ghetti 2006)
CONCLUSION

Sustainable water management of the future is expected to be significantly different from the traditional water management paradigm that focused on meeting the demand for water by augmenting supply and disposing wastewater and stormwater to prevent the spread of disease. Sustainable urban water systems need to focus on achieving a ‘closed loop’ through initiatives such as harvesting and reuse of rainwater, stormwater and wastewater. Case studies of projects implemented in Kogarah Council in Sydney that range from constructed wetlands to water mining facility highlighted Kogarah’s journey in being a water sensitive city.

Water Sensitive Cities is a priority objective identified under Australia’s National Water Initiative (NWI) for Urban Water. Under this objective, NWI aims to provide guidance and insight into successful water cycle management projects and to stimulate further innovation and capacity building (National Water Commission 2009). The challenges faced by Australian cities in light of the current drought, along with ageing infrastructure and increasing population pressures are not unique to Australia. These challenges are also being faced by other major cities across the world. Australian case studies are therefore relevant to all major cities.

The lessons learnt from these projects have been incorporated into Kogarah Council’s Water Management Policy that encourages water conservation and water quality improvement requirements for all new developments. Similar development controls could also benefit other cities facing similar pressures, and may also assist in developing the water sensitive cities of the future.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the support from Sydney Water Corporation and the NSW Department of Environment and Conservation for supporting these innovative water sensitive projects. We would also like to thank Dr Simon Beecham, of University of South Australia; current and former staff from the Institute for Sustainable Futures at UTS, current and former staff from the Assets & Services Division of Kogarah Municipal Council for their valuable input at various stages of these innovative projects.

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