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On-site water recycling — a total water cycle management approach

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Abstract

Water recycling is one of the important strategies that are currently being considered to reduce mains water consumption and relieve the pressure on Sydney's water supply. However, water recycling is only one element of the total water cycle of the site and its integrated water resource management. BASIX is a web-based sustainability indexing tool that is currently used by the NSW Government to reduce water consumption for residential developments by 40% through assessing their potential performance against the performance of benchmarked dwellings. The introduction of BASIX is an important step to promote the use of recycled water for new residential developments. However, the current approach needs to consider many other issues such as total water cycle performance of the development, reforming regulatory guidelines to encourage reliable decentralised recycled water systems and broadening the criteria for sustainability to account for social and environmental objectives. These issues and elements of a framework to sustainably manage water recycling schemes are discussed in this paper such as the need for comprehensive water cycle decision support tools, establishing links with the water cycle related issues of the catchment and providing new risk-based regulatory guidelines. Special emphasis is given to the use of BASIX as a water cycle decision support tool through a case study and indicating ways to improve its comprehensiveness.

Keywords: Water recycling; BASIX; Decision support tools; Total water cycle management; ESD

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1. Introduction

The extended drought that Sydney and its water catchments have recently been exposed to, has resulted in extreme lowering of the water levels in the water supply dams and the introduction of mandatory water restrictions. The use of recycled water for non-potable uses at development sites is one of the options which have been seriously considered by the NSW Government and the water agencies in NSW.

Since July 2004, BASIX was introduced as a regulatory framework to reduce water consumption for single houses by 40%. Similar targets should be achieved for all residential developments from February 2005. The Building Sustainability Index, or BASIX, is a web-based planning tool designed to assess the potential performance of residential developments against a range of sustainability indices. The first stage of BASIX includes targets for water and energy. The Water module of BASIX uses information provided by the user such as site location, dwelling size, roof area, landscaped area and services to compare the proposal to the average of existing housing stock. The proposal is scored according to its potential to consume less potable water than the average existing dwelling. Water recycling is one of the strategies provided by BASIX to be used to achieve the required water reduction target.

In an urban environment, BASIX is currently considered the main driver for the use of recycled water in new developments, especially for decentralised applications that do not use reticulated recycled water provided by central schemes such as Sydney Water's Rouse Hill and the Sydney Olympic Park.

While the introduction of BASIX is considered an important step to promote the use of recycled water in urban environments, several issues have to be considered in order to ensure that recycled water is managed in an ecologically sustainable way. These issues include providing a total water cycle perspective for the management and impact assessment of recycled water, addressing the social and economic implications of water recycling and reforming the regulations concerning the use of recycled water. These issues are discussed in the following sections of this paper with emphasis on the use of water cycle assessment tools for options analysis and impact assessment.

2. Sustainability considerations

Sources of recycled water could be from rainwater (roof water), stormwater (runoff from paved areas), greywater (household wastewater other than from the toilet) or combined wastewater.

2.1. Total water cycle considerations

Urban developments generally modify the water cycle balance of their sites by reducing water infiltrating to the groundwater system, increasing runoff volume and pollution, reducing evapotranspiration, discharging highly polluted wastewater and drawing on high quality potable water supply. The types of recycled water used and how they are managed greatly influence the water cycle balance of the development site, the potential impact of the development on the receiving environment and the effectiveness of achieving the water cycle objectives for the development.

Generally, the performance criteria for the water cycle system on the site are based on its environmental management objectives, reflecting the site's environmental issues, water cycle infrastructure and the water cycle quantity and quality needs of the different receiving environments. Examples of such environmental issues include the following:

- On-site issues such as salinity, soil contamination and public health.
- Water quantity and quality constraints of different receiving environments such as native bushland, stream health, stream form, wetlands and estuaries.
- Downstream water infrastructure issues. Recycling wastewater achieves the water reduc-

tion objective as well as potentially reducing the number of sewer overflows if properly targeted. Recycling rainwater/stormwater on the other hand, achieves the water reduction objective as well as potentially relieving the drainage infrastructure especially in minor storm events. Additionally, a well targeted recycling system could also reduce the peak flow design criteria for mains water and sewerage sizing, thus reducing headwork charges for new developments.

2.2. Social implications

Social issues influence choosing the type of recycling water system, its potential uses, design of the system and management regimes.

Naji and Lustig [1] have attempted to apply the principles of ecological economics on integrated water cycle management by addressing the physical, biological and social impacts of water cycle systems. They suggest that promoting people's sense of control over their lives is a criterion for social sustainability, as people need to feel that they are self-organising and self-actuating individuals. If people feel in control, they are able to use resources more effectively.

Applying this concept to water recycling would entail increasing the degree of people's control over their water management systems, but this would also mean that people should be confident that the water recycling systems are reliable and trustworthy. One type of sustainable water recycling systems is operationally decentralised to promote the people's sense of control over their management but centrally monitored to ensure adhering to the regulatory standards that protect public health and the environment. Regulatory guidelines should be reformed to encourage such applications by providing guidance to the planning, design, monitoring and operational management of recycled water that is risk-based and reflects the key factors influencing the sustainability of such systems.

2.3. Economic implications

The economic effectiveness of recycled water systems is governed by many factors such as:

- The cost of mains water supply. The current cost of mains water is considered cheap and not reflecting the limits to available water resources and the true cost of the water management infrastructure.
- The cost of treatment technologies. This is influenced by the source of recycled water and the economies of scale.
- The cost of discharging and treating wastewater and stormwater to ensure that the receiving environments are adequately protected.
- The headwork charges for the water, wastewater and stormwater infrastructure to cater for increased demand on the water services due to development and the increase in population density. Mains water, sewerage and stormwater schemes could be smaller and recycle more to allow significant reduction in the sizing of such infrastructure. This improves the cost effectiveness of water recycling.

Investigating such issues and constantly aiming to improve the cost effectiveness of recycling water schemes should be fundamental to the process of promoting recycled water as a sustainable water resource.

3. Towards a sustainable framework for water recycling

The following sections discuss elements of a management framework that can deliver water recycling schemes which are planned, developed and operated in a sustainable way that is integrated with the other water cycle systems on the site.

3.1. Decision support tools

Decision support tools play an important role in optimising the performance of the water cycle system and ensuring that the potential environmental impacts of the proposal meet the environmental objectives for the site. BASIX is essentially a tool that helps to address total water cycle management at the site level. The stormwater module of BASIX [2] estimates stormwater runoff volume and pollutant loads likely to be discharged from the proposed development, and allows the user to test management options such as rainwater tanks, filtration/infiltration systems and swales, and assess their relative effectiveness in meeting performance standards. The water module of BASIX [3] measures the expected amount of potable water consumed by the proposed development and the potential savings resulting from the use of a variety of management measures. Such measures include water efficient devices for showerheads, toilet flushing, taps, water efficient appliances such as clothes washers and dishwashers, and the use of recycled water such as rainwater, storwater and treated wastewater/greywater.

The hydrological module for the current version of BASIX simulates the main soil physical processes such as runoff, infiltration, soil moisture balance and percolation as well as estimates the evapotranspiration losses for the plants depending on their water demands and the available soil moisture store. However, the chemical characteristics of the soil and its pollutant transformation and mobilisation processes are not properly considered in the current version of BASIX. As such, the qualitative aspects of water recycling are not adequately modelled in BASIX, which limits the environmental assessment capability of the tool. The main structural elements of the water cycle model of BASIX are presented in Fig. 1.

A case study is considered here to illustrate the use of water cycle models like BASIX for options evaluation and for assessing the environmental impact from a proposed development. The proposed development is an inner-city terrace house. Lifecycle costs, savings in mains water, wastewater reduction and stormwater reduction were used as indicators for the water cycle performance of the proposed development.

The results of the options analysis (Table 1), show that water cycle systems with multiple objectives are subject to diminishing returns. To economically evaluate the options, the net cost effectiveness of each option is calculated (net benefit $\$/m^3$ saved). The results of this analysis, which are presented in Fig. 2, show that only options 1 and 3 are relatively cost effective if we consider savings in mains water only. Options 2, 4 and 5, which significantly outperform options 1 and 3 from an environmental sustainability perspective, have negative cost effectiveness indicating their inability to recover their costs over the life time of the water cycle system. However, if we consider the other water cycle benefits such as reduction in wastewater and stormwater discharges, we find that the cost effectiveness of options 2, 4 and 5 significantly improve, but do not yet move to the positive side of the scale. This situation could improve if the cost of treatment falls due to economy of scale (such as for a large multi-unit development), if the price for water increases as suggested by Wallace and Barnett [4], or if we consider the value of the other environmental benefits such as the reduction in the wastewater and stormwater discharges from the development site. In the current circumstances, option 2 is considered the optimal option as it is the most cost effective option that meets the water conservation target set by BASIX, whereas option 3 is more cost effective than option 2 in addition to performing well from a total water cycle perspective.

In order to take account of the qualitative aspects of the development's water cycle performance, especially in relation to water recycling, the following elements of the BASIX water cycle model will need to be improved:

- Crop modelling to simulate plant growth and nutrient uptake from the recycled water.
- Soil pollutant transformation modelling to simulate soil processes such as nutrient recycling, pollutant adsorption, soil salinisation and contaminant mobilisation (erosion, wash-off and leaching).

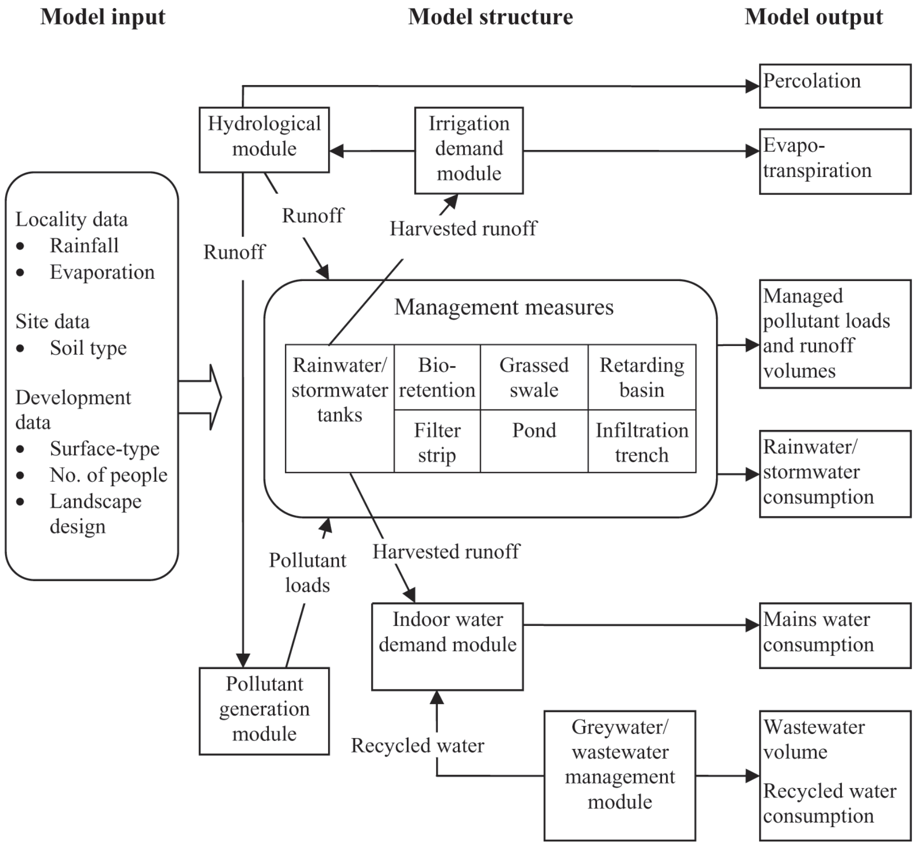

Fig. 1. Structural elements of the water cycle model of BASIX.

Table 1
Options analysis results for a case study using BASIX

Management option	Mains water savings (%)	Wastewater discharge reduction (%)	Stormwater volume reduction (%)	20 y $ costs ($)	20 y $ savings ($)
0 Baseline option, no management measures	0	0	0	0	0
1 Best practice water saving devices and appliances	30	33	0	1,000	1,200
2 Same as 1 and 5 m^3 rainwater tank for toilet flushing, laundry, garden and car washing.	56	33	43	7,500	2,250
3 Same as 1 and greywater diversion for sub-surface irrigation.	35	40	0	1,800	1,430
4 Same as 1 and greywater treatment for toilet flushing, laundry, garden and car washing.	62	69	0	15,600	2,500
5 Same as 4 and 5 m^3 rainwater tank for potable use after filtration and disinfection.	94	69	55	27,600	3,820

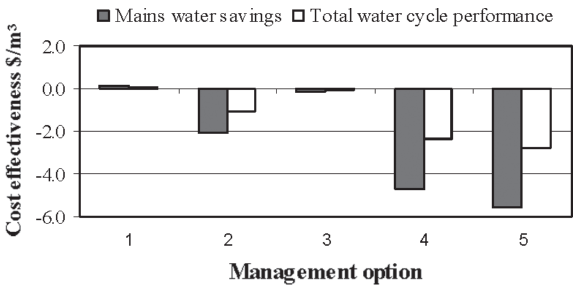

Fig. 2. Comparison of the cost effectives of the different management options.

To illustrate the application of the suggested improved elements of the BASIX water cycle model, the same case study is considered but with more stringent environmental management objectives for the proposed development site. If we assume the site is located in a catchment draining to a sensitive water body, then the environmental impact assessment process will have to be more rigorous, demonstrating that the proposal does not have a negative environmental impact on the downstream water body and is sustainable over the long term. The BASIX water cycle model in its current capability is not adequate to assess the additional assessment criteria, which should include:

- Pollutant loads exported from the site by leaching to the underlying soil and by runoff from the site.
- Soil salinity, which if built up over the long-term, could impact on the health of the plants and soil structure, thus jeopardising pollutant assimilation on the site.
- Phosphorus saturation level, which indicates the ability of the site soil to adsorb phosphorus.

Such rigorous environmental impact assessment cannot be undertaken without a comprehensive water cycle decision support tool incorporating the suggested improved elements to the BASIX water cycle model. A potential conceptual structure of the improved water cycle model for BASIX is presented in Fig. 3.

3.2. Policy and planning

An important issue that is overlooked by the current planning framework is the link between achieving water cycle management objectives at the site and the broader management objectives for the receiving environments and downstream water cycle infrastructure as well as the social benefits. Consideration of cumulative downstream environmental and social issues when assessing water cycle performance at the site is of paramount importance. For example a high rate of rainwater harvesting in urban areas could impact negatively on the low flows from the catchment, especially if these low flows have high ecological values for the downstream environment. In such a case, the adopted water conservation strategy could be in the form of using greywater or wastewater instead of rainwater as the source for water recycling. This requires a cooperative regulatory framework at a catchment scale from the different government departments managing the various facets of the water cycle in the catchment. Currently, this framework is lacking and could be addressed either via the catchment management bodies or via a new government initiative similar to BASIX but targeting catchment scale issues.

3.3. Regulatory management guidelines

Regulatory guidelines play an important role to ensure that recycled water is safe, environmentally sustainable and cost-effective. This goal is best achieved by matching the quality of recycled water to its intended uses safely and cost-effectively. The sources of recycled water vary considerably in their water quality (Table 2), which greatly influences the practicality of treating the wastewater to an adequate water quality standard for different applications.

A new performance-based regulatory approach is needed, which reflects the risks of the proposed use of recycled water. The new guidelines should not simply aim to protect public health and the receiving environment, but to improve them. It

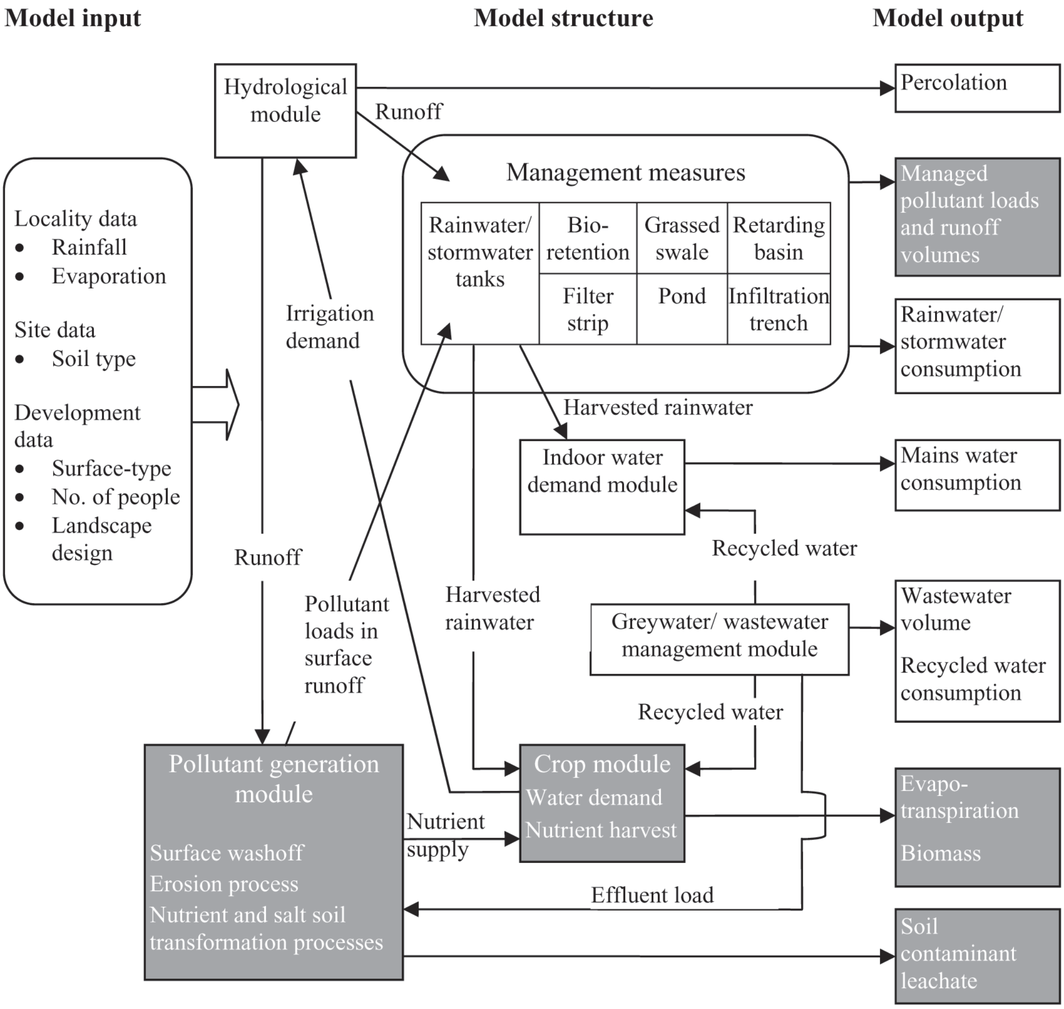

Fig. 3. Conceptual structure of a potentially improved version of the water cycle of BASIX. The dark boxes indicate the components which could improve in the model.

should also identify the management and monitoring requirements that largely depend on the quality of the source water, the adopted treatment process and the end use. Using combined wastewater for uses with high human contact requires more stringent management and monitoring safeguards than using greywater for the same use because combined wastewater quality poses greater risk to public health and the environment than would the water quality of greywater.

4. Conclusion

Water recycling is considered one of the main strategies to reduce water consumption in NSW. The introduction of BASIX is an important step to promote the use of recycled water for new residential developments. However, the current approach needs to consider many other issues such as total water cycle performance of the development, reforming regulatory guidelines to encourage reliable decentralised recycled water

Table 2
Water quality and potential reuse options for the various recycled water sources

Water source	Characteristics					Potential reuse	Required treatment
	TSS (mg/l)	TP (mg/l)	TN (mg/l)	BOD (mg/l)	FC (#/ 100 ml)		
Rainwater [5]	50	0.13	2.0	10	200	Potable in-door	Water filtration and disinfection.
						Hotwater, toilet flushing, laundry, irrigation	Tank pre-treatment
Stormwater [5]	250	0.4	2.0	20	4000	Irrigation	Tank pre-treatment
Greywater (other than kitchen) [6]	48	0.7	6.6	97	100	Sub-surface irrigation	Diversion systems
						Toilet flushing, laundry, irrigation, fire protection	Secondary treatment systems
Wastewater [7]	300	11	48	325	107	Toilet flushing Irrigation	Tertiary treatment systems

systems and broadening the criteria for the sustainability of water recycling to account for social and environmental objectives. Elements of a management framework that can deliver sustainable water recycling schemes, integrated with the other water cycle systems on the site are discussed. These elements include providing comprehensive water cycle decision support tools, establishing links between the development site and the water cycle related issues of the catchment and new performance-based regulatory approach, reflecting the risks of the proposed use of recycled water.

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