Innovative approaches to urban water management in developing countries

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Abstract

The expansion of our towns and our limited land resources have led to the need for multifunctional land use in densely populated cities like Kuala Lumpur, Malaysia and Adelaide, Australia. Recently in Kuala Lumpur, Sustainable Urban Drainage Systems (SuDS) have been being adopted as a component of integrated urban water management. However, even SuDS technologies still often require dedicating areas of land to a single land use such as water conservation, flood control or water quality treatment.

This paper investigates how innovative approaches to urban water management can lead to multi-functional landuse where habitat connections, flood storage, water reuse and social amenity are all integrated in the same land corridors. This could potentially release flood fringe areas for development which in turn could provide the economic driver to achieve higher level outcomes such as enhancement of urban ecology. However, further research is needed to inform practice in this important area.
Keywords: sustainable urban drainage systems (SuDS), multi-functional landuse, urban ecology, urban water management.

1 Introduction

In recent years most stormwater management regulations have been concerned primarily with reducing peak flows and volumes of runoff into the stormwater system. While this is still very important, little emphasis has been given to the quality of the water that is reaching the waterways. These waterways support sensitive ecosystems that can be easily impacted by increased stormwater pollution. It is important to ensure that future developments are implemented using an integrated urban water management approach. This can be achieved

WIT Transactions on Ecology and the Environment, Vol 150, © 2011 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/SDP110211

through the integration of water quality controls, flood detention and water sensitive urban design (Collins et al. [1]). Equally important is the need to design smarter, more resilient and most of all adaptive water systems. Examples include permeable pavements with underlying storages, on which cars can be parked and vegetated stormwater systems that include below soil storage systems that enable the vegetation to be sustained during longer interevent dry periods. Both these systems achieve multifunctionality of landuse by providing flood control, stormwater treatment, habitat connectivity and public space amenity.

In developing countries both sustainable water management and multi-functional landuse are being practised. In particular, Malaysia is an interesting country to study as it is rapidly urbanizing. Rainfall in Malaysia is typically characterised by very intense and short duration storm events, which makes urban water management very challenging. The regular traffic gridlocks that occur in Kuala Lumpur following rainfall deluges are a symptom of these issues. However, urban planners and engineers are looking for ways to both control and make better use of water in the ever expanding cities. This paper examines innovative stormwater management methods currently being in Malaysia and compares them with Australian design and practice.

2 Water Sensitive Urban Design

The term Water Sensitive Urban Design (WSUD) was first referred to in various Australian publications exploring concepts and possible structural and non-structural practices in relation to urban water resource management during the early 1990s. Parallel design philosophies, such as Sustainable Urban Drainage Systems (SUDS), were also developing in Europe and the United States. SUDS is now generally referred to as SuDS to reflect the wider application of Sustainable Drainage Systems. In the USA and Japan, SuDS is known as Low Impact Urban Design (LIUD), or just Low Impact Development (LID). WSUD, LID and SuDS embrace the concept of integrated land and water management and in particular integrated urban water cycle management. This includes the harvesting and/or treatment of stormwater and wastewater to supplement (normally non-potable) water supplies. More generally SuDS focuses on the interaction between the urban built form and the natural water cycle. It may be regarded as an alternative to the traditional 'catch and convey' approach to stormwater management. From this point in the paper the term SuDS will be used to represent WSUD and LID.

SuDS embraces the concept of integrated land and water management, in particular integrated urban water cycle management. In terms of typical SuDS components (Beecham [2]) includes rainwater tanks, grassed swales, biofiltration swales, bioretention basins, sand filters, infiltration trenches and basins, vegetated filter strips, permeable pavements, wetlands and ponds. These components can be combined into very sophisticated systems (Dunphy et al. [3] and Kandasamy et al. [4]) that treat stormwater to almost drinking water standards.

3 Permeable pavements

Pavements are ubiquitous in urban areas. However, for developers, industrial facilities, and local authorities addressing stormwater and associated water-quality guidelines and regulations, pavements stay very much at the forefront of planning issues. Pavements designed for use by vehicular traffic typically consist of a sub-grade, one or more overlying courses of compacted pavement material and a surface seal. An integral aspect of conventional pavement design involves preventing entry of water to the pavement via the seal to protect the integrity of the underlying base course, sub-base and sub-grade.

Conversely a permeable pavement has quite different objectives and design requirements to conventional pavements. The pavement is designed to infiltrate stormwater through to the underlying layers. Water passes to the open graded single sized gravel sub-structure and is drained through to the sub-grade. The pavements therefore perform the dual functions of supporting traffic loads and of stormwater drainage. Pollutants within the stormwater also infiltrate, with the majority being trapped within the pavement layers.

Permeable pavements may be designed to incorporate an underlying storage volume for:

- Water harvesting and reuse
- Flood attenuation
- Enhance water quality treatment.

Permeable pavements present a unique opportunity to harvest and store urban stormwater that would otherwise contribute to overland runoff into the conventional stormwater pipe and channel network. With minimal surface infrastructure, permeable pavements provide a serviceable, hard standing area that facilitates water harvesting, treatment and reuse (Beecham [2]).

There are several options for the design and construction of such a system. After infiltrating through the pavement surface, the stormwater can be stored in a submerged tank, or in proprietary plastic cell systems. It can also be stored in a matrix of base course aggregate contained within an impermeable membrane. This is shown in Figure 1.

Researchers at the University of South Australia recently completed construction of a conceptual prototype facility, shown in Figures 2 to 4 features a pavement the size of a standard car space (in accordance with AS/NZS 2890.1) Storage is provided within a limestone base course aggregate material. There is also a window cut into the side to view the depth of the water in the reservoir.

In constructing the pavement, a procedure similar to the construction of a standard pavement was followed. Excavations were undertaken according to plan, ensuring adequate water storage volume was available. Laboratory tests indicated that voids in the base course aggregate material were 40% of the overall sub-base volume. This initial testing suggested that the overall storage of this facility is approximately 3,600 litres. The excavation varied between 650 mm and 750 mm depth overall, sloping downward to a sump at one end, where a submersible pump was located.

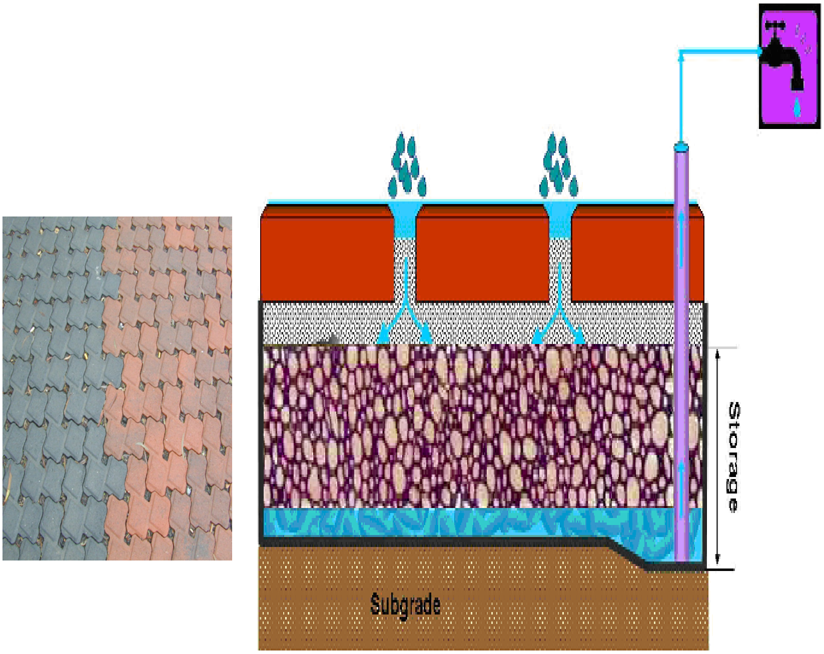

Figure 1: The pavement reuse concept.

Figure 2: Pavement excavation.

Figure 3: Perforated pipe for retrieving harvested stormwater.

Figure 4: The completed UniSA prototype facility.

A 0.75 mm polypropylene material was used to line the excavation. To access the stored water, a stormwater pipe was installed prior to filling. The pipe was perforated at sufficient intervals to allow the ingress of water, whilst preventing the ingress of aggregate stones to the submerged pump reservoir.

Following the placement for the storage access pipe, 14 tonnes of 20 mm dolomite aggregate was placed on top of the liner and compacted using a vibrating plate compactor. Permeable pavers are laid in a similar fashion to conventional concrete block paving units. The upmost layer of aggregate (the 'laying course') is screeded to a desired level and pavers are placed according to manufacturers' instructions. The pavement itself is then compacted with a vibrating plate compactor. The installation of appropriately designed edge restraints completes the construction procedure.

The stormwater harvested from this system is extracted using a small solar pump and is used to irrigate plants in an equivalent sized adjacent rainwater garden. The total installation cost of this system was AUD 3,100 (GBP 1820).

4 Sustainable urban drainage systems in Malaysia

An example of Malaysian best practice in integrated urban water management is the recent adoption of the principles of sustainable urban drainage systems (SuDS) into the upgrade design for the Humid Tropics Centre (HTC) in Kuala Lumpur. As shown in Figure 5, porous paving, rainwater tanks, green roofs, vegetated swales and bioretention basins are integrated into a space-constrained office complex. This has been designed as an exemplar case study of SuDS for Malaysian conditions.

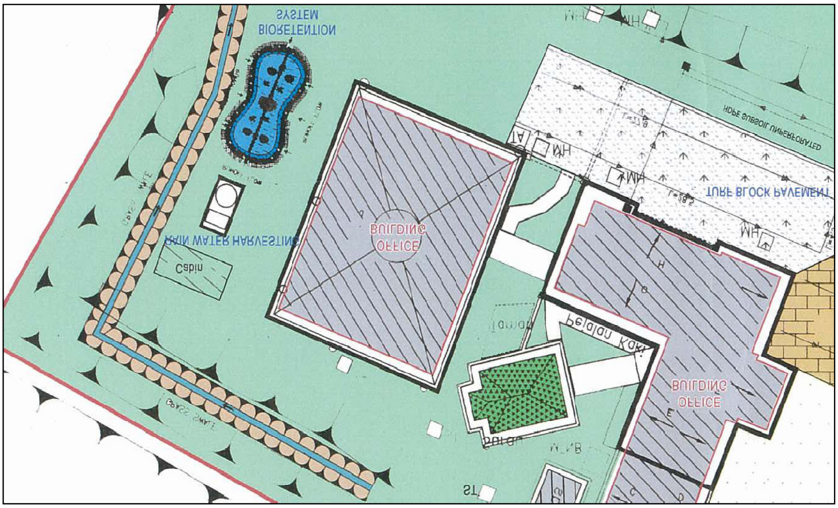

Figure 5: SuDS features at the HTC in Kuala Lumpur (drawing courtesy of both HTC and ZHL engineers).

In order to compare the Malaysian and Australian design approaches for SuDS, the case of permeable pavements is selected. The design shown in Figure 5 was conducted in accordance with the Malaysian Urban Stormwater Management Manual, known locally as MSMA [5]. The permeable pavement system shown in Figure 5 is 279.5 m^2 in area and was designed for a two year average recurrence interval (return period) design rainfall event of duration 15 minutes and intensity 181.2 mm/h. This immediately demonstrates the very high rainfall intensities faced by designers in Malaysia. Indeed this design storm is very close to the 100 year average recurrence interval, 5 minute duration design storm for Adelaide Australia, which is 186 mm/h. The MSMA design process involves the following steps, with only the summary calculations shown for conciseness:

Step 1: Determine the permissible site discharge (PSD).
PSD = 7 L/s

Step 2: Determine the site storage requirement (SSR).
SSR = 7.4 m^3

Step 3: Determine the required reservoir depth (d).
d = 105.9 mm

To compare this with Australian design practice, the PERMPAVE software (Beecham et al. [6]) was run for the same two year average recurrence interval event (15 minute duration) for Adelaide, Australia. This design storm has a much lower rainfall intensity at 35.6 mm/h. PERMPAVE is freely available from the Concrete and Masonry Association of Australia (www.cmaa.com.au). Figures 6 and 7 show screenshots from the program output.

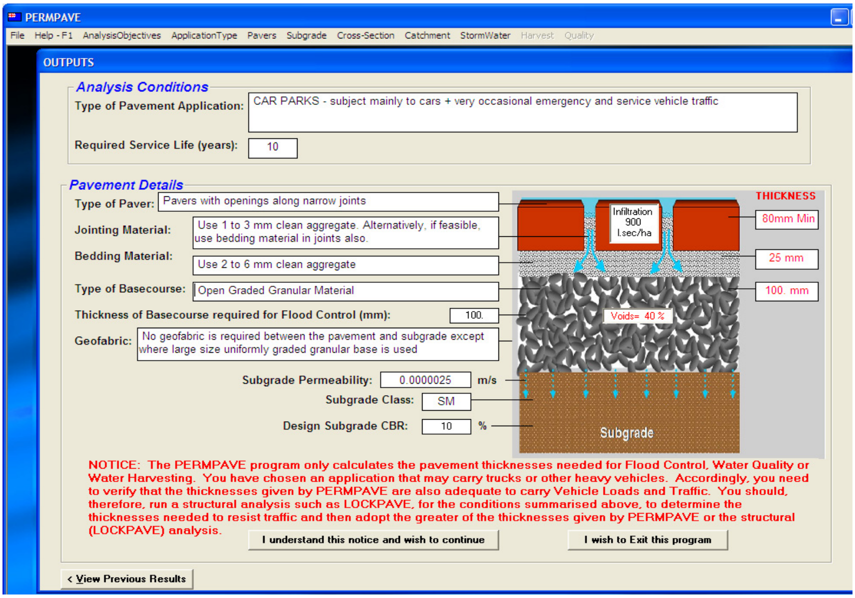

Figure 6: PERMPAVE computed inflow hydrograph.

For the Australian design the main limiting factor is the maximum infiltration rate through the pavers, rather than the depth of basecourse required to infiltrate and store the design storm runoff. A basecourse depth of 100 mm provides 11.2 m^3 of storage when the voids ratio is 0.4. This is sufficient to cope with the

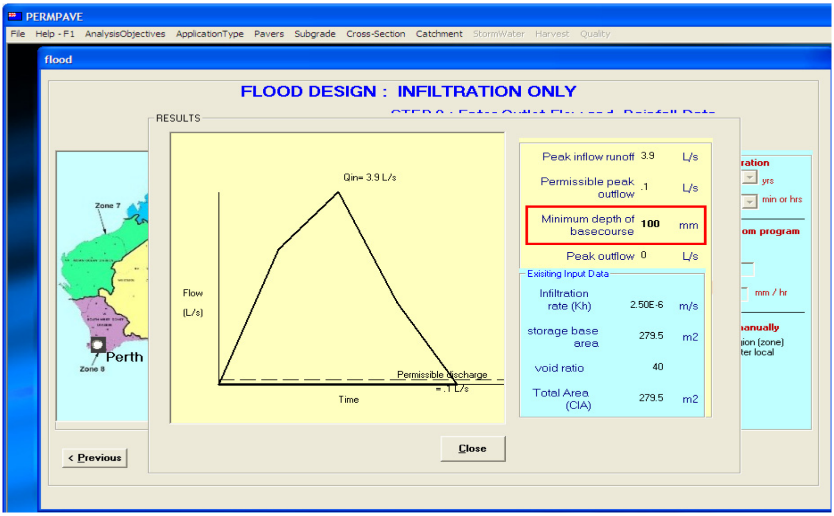

Figure 7: PERMPAVE program outputs.

runoff volume from the 2 year event. However, because of the lower rainfall intensity, the peak inflow to the Adelaide system is 3.9 L/s compared to 13.9 L/s for the Malaysian design storm event. This means that high infiltrative capacities are required for pavement systems in Malaysia. It also means that partial clogging of permeable systems is likely to have more significant affects on system performance in Malaysia than in Australia. Pezzaniti et al. [7] showed that partially clogged systems in Adelaide can still continue performing adequately for over ten years with minimal maintenance. This is unlikely to be the case in Malaysia but further research would be required to accurately determine the differences.

In Malaysia permeable pavements are not yet designed for harvesting and reuse of stormwater. However, the average annual rainfall in Malaysia is 2,500 mm and this results in high volumes of urban runoff. Therefore permeable pavements with significant underlying storage would provide both effective flood control and high security of supply for stormwater reuse.

5 Conclusions

This paper has examined how sustainable water management can be achieved using multifunctional urban landuses. Examples have been presented where flood control has achieved using innovative SuDS technologies in both Kuala Lumpur, Malaysia and Adelaide, Australia. The design approaches used in both countries have been compared and the emerging use of permeable pavements for water harvesting and reuse has been discussed.

However, this paper has also clearly identified that more research is needed to inform practice in the areas of water quality treatment, flood control and water harvesting and reuse. One of the most important considerations in stormwater management is provision of sufficient water storage. If the development of SuDS in Australia can be criticised, it would have to be in the way in which inadequate attention has been paid to the incorporation of sufficient storage volumes

Developing countries such as Malaysia can learn from these experiences (Beecham [8]).

Acknowledgements

The support of the Australian Research Council for funding under grant DP0877707 is gratefully acknowledged, as is the ongoing support provided by Alan Pearson and the Concrete and Masonry Association of Australia (CMAA). Our deep gratitude is also extended to A/Prof Lariyah Sidek of UNITEN, Putrajaya and to Zul Mohd Roseli, Director of ZHL Engineers Sdn. Bhd., Malaysia for their considerable assistance in comparing Malaysian and Australian design techniques for SuDS technologies.

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