Article:
Ashley, R, Lundy, L, Ward, S et al. (6 more authors) (2013) Water-sensitive urban design: opportunities for the UK. Proceedings of the Institution of Civil Engineers: Municipal Engineer, 166 (ME2). 65 - 76. ISSN 0965-0903

https://doi.org/10.1680/muen.12.00046

Municipal Engineer
Volume 166 Issue ME2

Water-sensitive urban design: opportunities for the UK
Ashley, Lundy, Ward *et al.*

ice | proceedings

Proceedings of the Institution of Civil Engineers
Municipal Engineer 166 June 2013 Issue ME2
Pages 65–76 http://dx.doi.org/10.1680/muen.12.00046
Paper 1200046
Received 09/08/2012 Accepted 08/01/2013
Keywords: buildings, structures & design/sewers & drains/water supply

ice Institution of Civil Engineers publishing

Water-sensitive urban design: opportunities for the UK

Richard Ashley MPhil, CEng, MICE, MCIWEM, CEnv
Professor of Urban Water, Pennine Water Group, Universities of Sheffield and Bradford, UK

Lian Lundy BSc, PhD
Reader, Department of Natural Sciences, Middlesex University, London, UK

Sarah Ward MRes, PhD, AHEA, MCIWEM, CWEM, CEnv
Business Engagement Manager, Centre for Water Systems, College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter, UK

Paul Shaffer BSc
Research Associate, Construction Industry Research and Information Association, London, UK

Louise Walker BSc, PhD, MCIWEM, CEnv, CSci
Research Officer, water@leeds, Department of Geography, University of Leeds, Leeds, UK

Celeste Morgan BA, BE, LEED, AP
Director, Sustainability, Design and Planning, AECOM Ltd, London, UK

Adrian Saul BSc, PhD, CEng, FICE
Professor of Hydraulics, Pennine Water Group, Universities of Sheffield and Bradford, UK

Tony Wong BE (Hons), PhD
Chief Executive, CRC for Water Sensitive Cities, Monash University, Melbourne, Australia

Sarah Moore MSc
Research Associate, Pennine Water Group, Universities of Sheffield and Bradford, UK

Water-sensitive urban design (WSUD) is a concept that is gaining support as a means to manage urban water systems in an integrated way through the better positioning of the topic of water in urban planning and design processes. Water-sensitive urban design is emerging in the UK and this paper sets the scene and identifies the opportunities and constraints from a UK perspective. Recent developments in integrated water management, ecosystem services and multifunctional land use provide new opportunities for 'getting more for less'. These can range from seeing all forms of water as a resource, exploiting opportunities to contribute to the green and blue infrastructure agendas, resilience to climate and other changes. This paper draws on international experience as to how water-sensitive urban design can deliver opportunities; mitigate the urban development challenges; implement and support institutional, regulatory and practical opportunities and demonstrate the benefits of taking a water-sensitive urban design approach in the UK. The key requirements for delivery are highlighted and a proposed vision for water-sensitive urban design in the UK outlined.

1. Introduction

The food–energy–water nexus is seen as the next major human challenge for global survival, with water being a growing future problem (Beddington, 2010). The summer of 2012, with a drought followed by floods, illustrated that the UK is not immune from problems of water stress and also excess, all in a single season. The Institution of Civil Engineers' *State of the Nation* report (ICE, 2012) highlights UK water stress. Yet there is plentiful rainfall in the UK, and areas of water stress could be better supported by changes to the way in which water is managed (House of Lords, 2006), managing demand and reducing leakage from water mains. Longer term, the potential impacts of climate change and population growth on water and waste water systems need to be addressed, particularly in the already water-stressed south-east. Institutional players often frame these issues from the perspective, 'we have always done it this way' (Laws and Loeber, 2010; Newman *et al.*, 2011), leading to a reluctance to change practices away from centralised water services to the integrated, yet more diverse, provision needed to be better address new challenges now and in the future.

Increasingly, efforts have been made to integrate the water cycle and ensure that urban design and planning properly incorporate the opportunities that this can provide (e.g. Grigg, 2008). In many places water-sensitive urban design (WSUD) is seen as crucial to the delivery of cities of the future and 'water-sensitive cities' by way of a transdisciplinary approach to urban water management that aims to holistically consider the environmental, social and economic consequences and opportunities of water management strategies (Wong and Eadie, 2000; Thurston, 2012). There are a number of definitions of WSUD. It is essentially a process rather than an end condition. WSUD is described by Wong and Brown (2009), when defining the water sensitive city, as

> based on the integration of the two key fields of 'integrated urban water cycle planning and management' (IUWCM) and 'urban

design'. WSUD brings 'sensitivity to water' into urban design, as it aims to ensure that water is given due prominence within the urban design process through the integration of urban design with the various disciplines of engineering and environmental sciences associated with the provision of water services including the protection of aquatic environments in urban areas.

WSUD treats urban surface water run-off as a resource rather than a nuisance or liability (BMT WBM, 2009).

2. Traditional versus new water management approaches

There is growing realisation that there are alternatives to the traditional and dominant water management paradigm of the developed world where supply and sanitation systems are designed, operated and managed in isolation, based on the desire of 'getting all waste(water) quickly and efficiently out of towns' (Allen, 2008, p. 12; Nelson, 2012). Traditional systems consume resources and energy (Kenway and Lant, 2012) and do not exploit the wealth of opportunities of water collection at source, the enhancement of urban space and living, and resource recovery (e.g. Cities as Water Supply Catchments, 2012; MacPherson, 2012). Traditional engineering of water and waste water systems is still often institutionally fragmented, while operationally centralised and constrained by a problem-solving rather than opportunistic approach.

Recently, urban designers, architects and planners have recognised the potential value of water (e.g. Elmer and Fraker, 2012) and green infrastructure (GI) in the urban landscape as a key component of multifunctional land use and climate change adaptation (Landscape Institute and Town and Country Planning Association, 2012) – even leading to the retrofitting of GI and sustainable drainage systems (Suds) measures to buffer future climate problems (e.g. Islington Council, 2010; Digman *et al.*, 2012). There is now a major opportunity to provide water, drainage and associated services at the right time in the right place and in the right way. By linking water with other urban services, significant and multiple benefits can be achieved at lower costs compared with the traditional ways of dealing with water, urban design and associated services separately (Potter *et al.*, 2011). For example, in the City of Philadelphia in the USA the benefit of using GI to manage the excess surface water, currently causing unacceptable discharges from combined sewer overflows into the Delaware River, is some US$ 3 billion (Philadelphia Water Department, 2009).

In the UK there have been major changes to the way in which surface water is expected to be managed, with a growing preference for Suds. For example, more than half of local authorities now include Suds in their development policies (Woods-Ballard, 2012). However, surface water is but one part of the water cycle and a more comprehensive approach looking at the opportunities available from all parts of the water cycle is now feasible.

2.1 Water sensitivity

The concept of water sensitivity provides a vision to identify the most viable options for managing water availability (either too little or too much) and water quality. In urban areas it is vital to link this with urban design, place-making and liveability (e.g. Howe and Mitchell, 2012), potentially moving towards sustainable urban water management within a sustainable, water-sensitive city (Figure 1).

In Australia a number of interlinked programmes are attempting to deliver on this vision of water sensitivity, recognising that cities there are placed around the 'waterways city' stage of development (Figure 1), with an emphasis on environmental protection and providing, among other services, potable supplies, public health and flood protection. These programmes include initiatives to harvest rainwater on a large scale from urban areas (Cities as Water Supply Catchments, 2012) and a AUS$ 120 million (AUS$1 = 1.03 USD) Cooperative Research Centre (CRC) aiming to develop strategies to make a transition to water-sensitive cities (CRC for Water Sensitive Cities, 2012). On a global scale the International Water Association's (IWA) 'cities of the future' programme has developed a shared vision that includes WSUD (Binney *et al.*, 2010), and many countries, such as Singapore, are starting to take this up (Khoo, 2009).

2.2 WSUD process

Wong (2006a) indicates that the definition of WSUD among practitioners includes a wide range of functions in a WSUD process that include the natural environment as well as urban design. The term 'water-sensitive' integrates both the engineering and ecological professions associated with the protection of urban water resources (Wong and Ashley, 2006), and WSUD is a process for facilitating the interaction between the urban built form and water management (Wong, 2006b) as illustrated in Figure 2.

Initially WSUD was aimed towards environmental protection (Figure 1) but it has now become linked with the need to provide water at a time of prolonged drought and, recently, to concerns resulting from catastrophic events (e.g. Queensland Floods Commission of Inquiry, 2012). This means that urban flood risk management is becoming more fully integrated in the process, although the term storm-water does not fully define the various facets of flood risk in WSUD, as illustrated in Figure 2.

WSUD is more than storm-water management and WSUD is not a form of super-Suds, as Suds deal with drainage, although

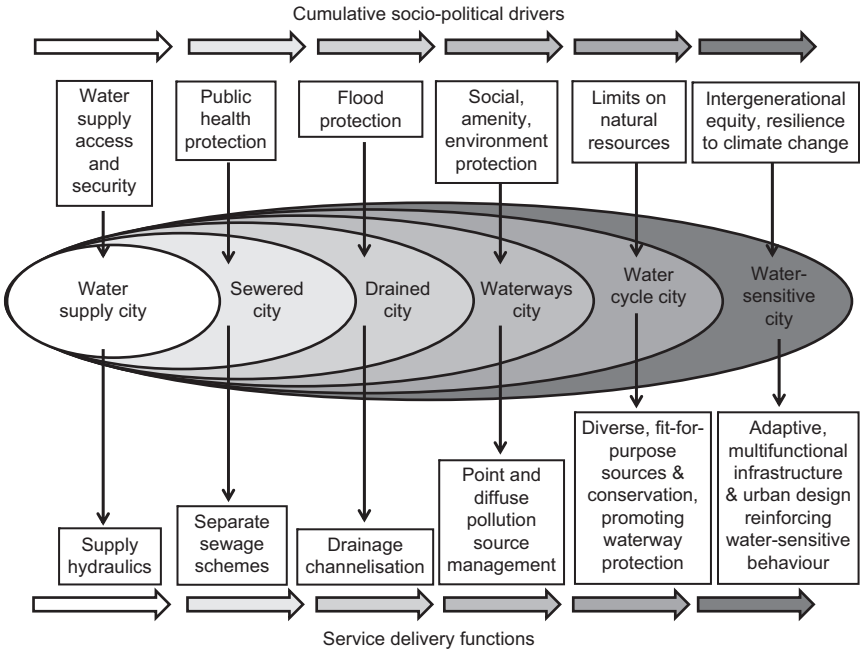

Figure 1. Evolution of the water-sensitive city (adapted from Brown *et al.*, 2009)

Suds may also utilise rainwater as a resource (Ciria, 2007). WSUD seeks to maximise opportunities for living with and exploiting the supply, use, reuse and management of waste water to enhance and support human health and wellbeing by minimising the impacts of urbanisation on the natural environment and water cycle. This may be achieved by protecting and enhancing natural aspects of landscapes, allowing the reconnection of built and natural forms, by

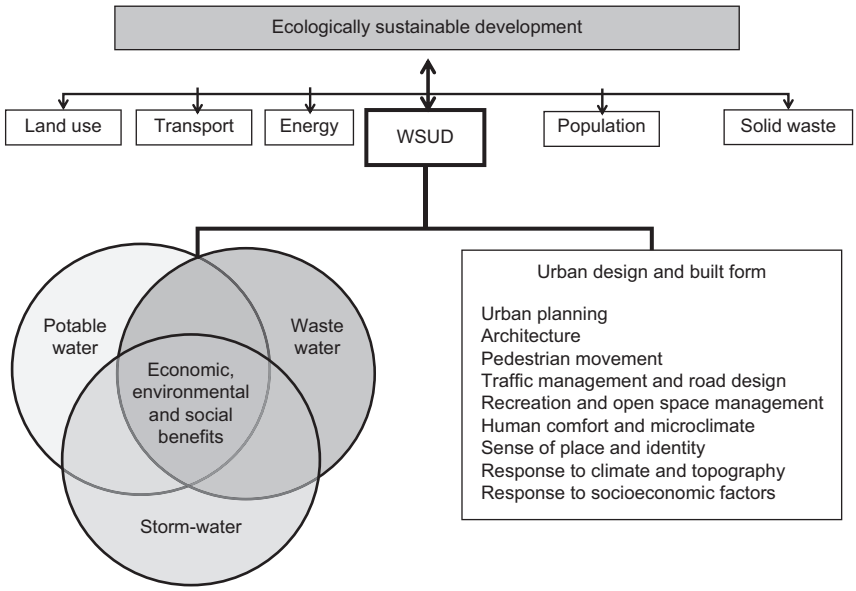

Figure 2. The interactions between WSUD, the built environment, and the urban water cycle (adapted from Hoban *et al.*, 2006)

surface water. Other techniques include reducing the demand for potable water through efficiency, or rain or surface water harvesting and waste water reuse; minimising waste water generation and the treatment of waste water so that it can be reused or discharged with less impact on the receiving waters; or by integrating vegetated surface water treatment and harvesting systems into the landscape. All this will provide additional benefits such as increased biodiversity, a more favourable microclimate or increased amenity. The principles of WSUD are applied to make the most of opportunities to manage the water cycle in the context of good urban design and planning to improve the quality of life and use land in the best way, often by multifunctional use and delivered by multidisciplinary teams. Figure 3 shows the traditional water supply and disposal system and the maximisation of opportunities approach that WSUD takes. Like Figure 2, this does not adequately show flood risks and their management as is usual in Australian illustrations of WSUD.

This paper, through a review of the context of UK water management and examples of WSUD applications, sets out an initial vision of how the WSUD process modified from Figure 3 might function in a UK context.

2.3 Valuation of WSUD

Improvements to water quality, flood management, the provision of opportunities for recreation and amenity are some of the ecosystem services and goods identified as being derived from or enhanced by taking a WSUD approach (Lundy and Wade, 2011). The Millennium Ecosystem Assessment (2005) raised international awareness of the importance of the services, goods and benefits gained from the environment (Everard, 2011). It recognises that the natural environment can provide supporting, provisioning, regulating and cultural services that benefit people and need to be valued within policy development and implementation, although this utilitarian attitude to natural systems is not shared by all (e.g. Monbiot, 2012).

Applications of WSUD, including GI, enhancing amenity and mitigating environmental pollution, should include a fuller consideration of multiple benefits to demonstrate the true scale of costs and benefits. Methods for the appraisal and valuation of multiple benefits and ecosystem services still require further development, as ecosystem management and valuation is complex and uncertain (Defra, 2007). Nonetheless, Eftec (2010) and Everard (2011) show that it is necessary to ensure that ecosystem services are included in the wider understanding of how they can provide multiple benefits. For example, the Mayes Brook Park retrofit surface water management scheme in north-east London was shown to have a substantial benefit–cost ratio of 7 (Everard, 2011). Such approaches need to be incorporated into WSUD processes (Cities as Water Supply Catchments, 2012).

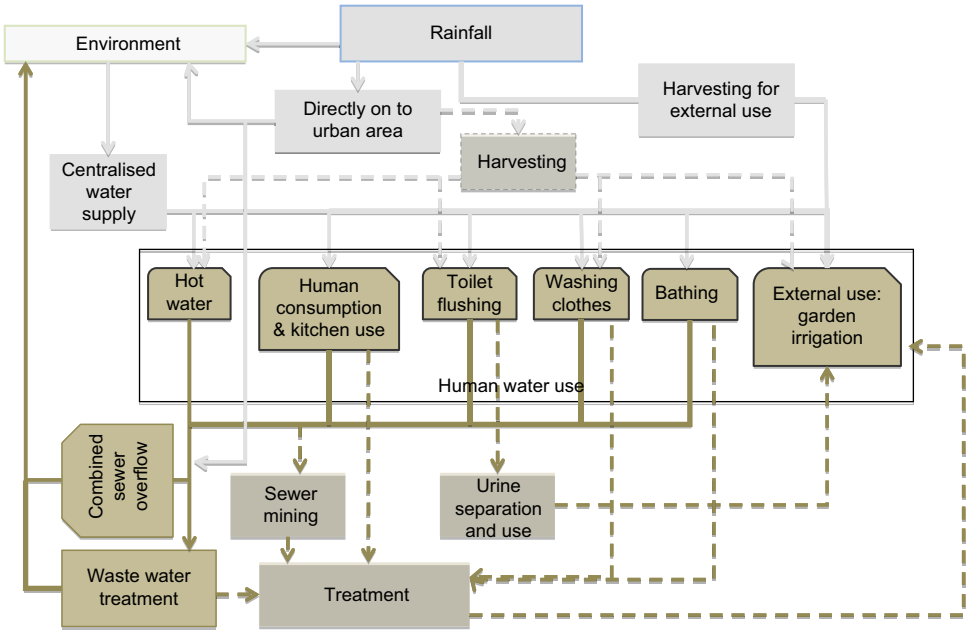

Figure 3. The conventional (solid lines) and the added components of direct use and reuse of water in WSUD (dashed lines)

3. A vision for WSUD interpreted in a UK context

The realisation that water in urban areas in the UK can be managed very differently has been growing and is considered by many to be essential for future sustainability (Ellis and Revitt, 2010; Potter *et al.*, 2011; Yorkshire Water, 2012). WSUD is a process that can help to focus attention on the opportunities from better management and by bringing together a range of considerations not traditionally included in water system planning.

3.1 Current context

The way in which water is managed in the UK varies between the constituent countries, although common aspects are that the main water supply, waste water collection and disposal functions are managed by organisations separate from those responsible for urban design and planning (Ashley and Cashman, 2006; Potter *et al.*, 2011). Municipalities have the planning powers and also a number of flood risk management functions. Environment protection agencies are also involved to various degrees in flood risk management and in managing the delivery and overviews of environmental quality. In order to deliver effective WSUD in the UK all these organisations (and more) need to work together.

There are a number of instruments, including planning guidance, policy documents and codes and standards, that relate to aspects of how WSUD may be applied in the UK. Here, only the principal instruments are outlined. Of general applicability in England and Wales, the *Code for Sustainable Homes* (DCLG, 2011) has the greatest influence on property developments, and, despite their consolidation into a new *National Planning Policy Framework* (NPPF) (DCLG, 2012), planning policy statements and formerly planning policy guidance have helped shape planning in England for more than a decade.

The water white paper for England refers to technologies that facilitate the integration of the water cycle but does not refer specifically to the integrated water cycle (HM, 2011a). Hence, there is a timely opportunity for water management professionals to work with policymakers, urban planners and landscape architects to develop a common language and approach to facilitate effective collaboration and future integration of the water cycle within the built environment by means of WSUD. With the enactment of the Flood and Water Management Act 2010 in England and the Water Environment (Controlled Activities) (Scotland) Regulations (HMG, 2011b) Suds are beginning to be preferred to traditional piped drainage systems for new developments (e.g. Duffy *et al.*, 2012).

The draft water bill 2012 (Defra, 2012) is mainly concerned with competition in service provision for non-domestic properties in England and Wales, although it does propose that there should be better coordination between planning and the water sector. Such approaches could help to promote WSUD and there may be a window for action on domestic properties, although here we illustrate that there is a need to improve the key linkages with the wider aspects of land-use planning, which so far are missing.

In contrast, Scotland, with a devolved parliament and a publicly owned water service provider, has the notion of being a 'hydro nation'. This approach values water in all forms and seeks to exploit its benefits for the Scottish economy and society, holding the view that 'water is a commodity owned by the people for the people' and a key element of human rights (Scottish Government, 2012, Foreword). There is therefore an opportunity in Scotland influence the need for integrated water management and WSUD.

Although sustainability is not mentioned explicitly in most of the definitions of WSUD, Figure 1 illustrates that the water-sensitive city is seen as being as sustainable as practicable. In England NPPF (DCLG, 2012) is premised on the attainment of sustainable development, and in respect of water is primarily driven by the need to fund and reduce major flood risks (Defra, 2011) but with the reduction of carbon dioxide emissions for achieving more sustainable living. The links between carbon and water are evident and traditional water cycle management uses large amounts of carbon (Novotny, 2010; Water UK, 2011; Waterwise, 2009), and the opportunity to link water, energy and carbon within a WSUD context has, in the opinion of the authors, never been more timely and desirable.

In England water cycle studies guidance was introduced in 2009 to support regional spatial strategies (EA, 2009) to support extensive housing growth across England, and have been used to determine the timing, location and requirements of planned new water infrastructure. In Wales, new housing development must be in accordance with level 3 of the *Code for Sustainable Homes*, which includes mandatory performance levels for energy, water, materials and waste and which can incorporate non-traditional indoor and outdoor water use, flood risk and surface water management measures and the enhancement of ecological value (DCLG, 2011).

The regional spatial strategies programme has now given way to local neighbourhood development plans (NDPs) in England (DCLG, 2011), through the move to a localism agenda. The application of NDP has illustrated the challenges in transitioning to a WSUD approach and the delivery of integrated water cycle management. This is a prerequisite for eco-towns (DCLG, 2009), where master plans envision holistic water management (Shaffer *et al.*, 2012). However, new eco-towns are no longer being promoted and the more comprehensive

planning policy statement on sustainable development has been superseded by the NPPF, which concentrates almost exclusively on the flood risk aspects of water. Hence, the current water management approaches in England associated with planning, new development guidance and regulation illustrate that there is a general lack of appreciation or encouragement for the integration of all WSUD aspects of the water cycle. This is a consequence of the number and diversity of the institutional organisations, government departments, regulators and other major stakeholders which are involved in the water cycle or associated systems, such as the energy and food production sectors (Ellis and Revitt, 2010; Potter *et al.*, 2011).

3.2 Looking to the future

Potentially, a more comprehensive and inclusive process of WSUD delivering multiple benefits linked closely with urban design may make its uptake easier and more appealing in the UK. Urban designers and landscape architects are realising that they can utilise water management as a way to make improvements to the public realm that are otherwise mainly seen as optional aesthetic requirements. These initiatives are driven by the place-making agenda, rather than any explicit need to manage surface water in these areas (Landscape Institute and Town and Country Planning Association, 2012).

In England surface water management is mainly based on flood risk management with less interest in controlling receiving water pollution (e.g. NAO, 2011), unlike in Scotland, where water quality is considered to be more important. In the integrated system, Figure 4 illustrates the interaction between flood risks and WSUD opportunities that need to be considered in terms of the various opportunities (Cities as Water Supply Catchments, 2012). Each type of rainfall event in upland and urban areas, however large, can provide potentially beneficial opportunities (Gersonius *et al.*, 2012).

In comparison with Figure 3, it can be seen in Figure 4 that the sources and pathways for flood risks in urban areas are also opportunities for water supply. A change in vision is required to recognise that, in fact, all types of water offer opportunities. Such a vision may be able to utilise and build on the studies already done on the water cycle in England. As security of water supply becomes more important, all forms of water source need to be considered as opportunities to deal with future stress. Linking main river flood risk management and coastal erosion and protection appropriately into WSUD is essential in a UK context, and the application of multi-value land use and multiple and societal benefits, for example by way of ecosystem services (e.g. Ashley *et al.*, 2011; Eftec, 2010; Everard, 2011), needs to be routinely included in how water is managed in urban areas.

In the future, the visions for WSUD in Australia and the UK should move closer, especially as the water quality requirements and the integrated approach promoted by the water framework directive and the river basin management plans raise the relative importance of diffuse pollution in urban water planning in the UK. This is illustrated in Figure 5, where urban diffuse run-off pollution is shown being treated in GI in Melbourne. The flooding in Australia in 2011 and since has prompted renewed

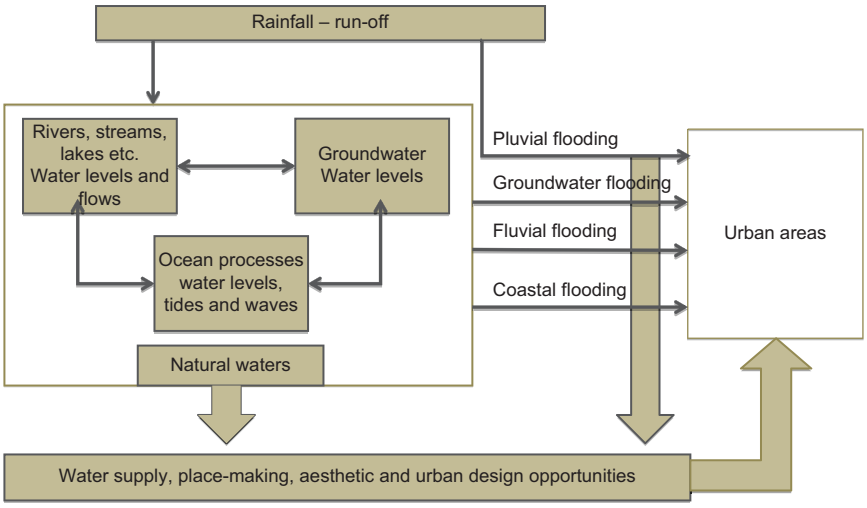

Figure 4. Flood risks and associated WSUD opportunities

Figure 5. Wetlands for treating surface water in Melbourne Docklands redevelopment

interest in how best to include the wider aspects of excess water in WSUD processes (CRC for Water Sensitive Cities, 2012), and Australia can learn from recent UK experience in dealing with floods to enhance its own basic guidance on WSUD, which tends to focus on the system shown in Figure 3.

3.3 Opportunities

Interpretations of WSUD in a European context have been made in the Switch (Hoyer *et al.*, 2011) and Skint (Potz and Bleuze, 2012) projects. These formulations may be appropriate where the water cycle is managed by a single (usually municipal) organisation or a few closely collaborating organisations. However, the responsibility for town planning functions held by local authorities, separate from the increasing commodification of water services (Defra, 2012) in England, provides a major challenge to utilising the wide range of WSUD opportunities. As local authorities gradually assume all the responsibility for non-main river surface water over time, as a logical consequence of the unfolding of the Suds Approval Body responsibilities under the Flood and Water Management Act 2010 (2010), there may be fewer opportunities for water service providers in England to take the integrated approach to the water cycle that traditional WSUD assumes, although the local authorities are in a strong position to take up the WSUD vision, especially in their planning processes (Donovan and

Organisation/key players	Opportunities afforded by a WSUD approach
Government departments	Linking water with place-making, cities of the future, energy, waste management, ecosystem health, and community health and welfare can save money and demonstrate commitment, vision and caring. It can also create green and community-related jobs and contribute to security of supply.
Municipalities	A key tool in the development of a common vision and approach to water in local authorities that is properly embedded in urban design and planning processes and brings together local flood risk management and urban run-off pollution control with local and green agendas. Fulfils many obligations in relation to highway drainage, mitigating and adapting to climate change, and the health and welfare of communities.
Regulators	Compliance with EU directives. Integrating planning activities such as river basin management plans, water resources planning and drought planning (e.g. European Commission, 2012). WSUD could help with payment for ecosystem services. Water is valued, giving credibility to policy decisions. People become involved in local decision-making about water in their environment, contributing local knowledge to urban planning and design.
Water service providers	Valuation of WSUD necessary in order to include water coherently in business plans. Will address some supply security and energy use issues and may provide new business opportunities. WSUD can reduce need for waste water transport and treatment, reduce urban heat island effects, capture carbon and provide energy recovery.
Developers, communities and individuals	Opportunity to fulfil quality standards for sustainable construction, scoring highly with codes and assessments, such as the Building Research Establishment Environmental Assessment Method. Added value if GI considered in WSUD. WSUD can make communities and individuals more aware of and able to take advantage of water opportunities as part of the localism agenda (e.g. WSUD techniques could provide alternative water and nutrient sources, helping urban horticulture).

Table 1. Opportunities for key players in taking a WSUD approach

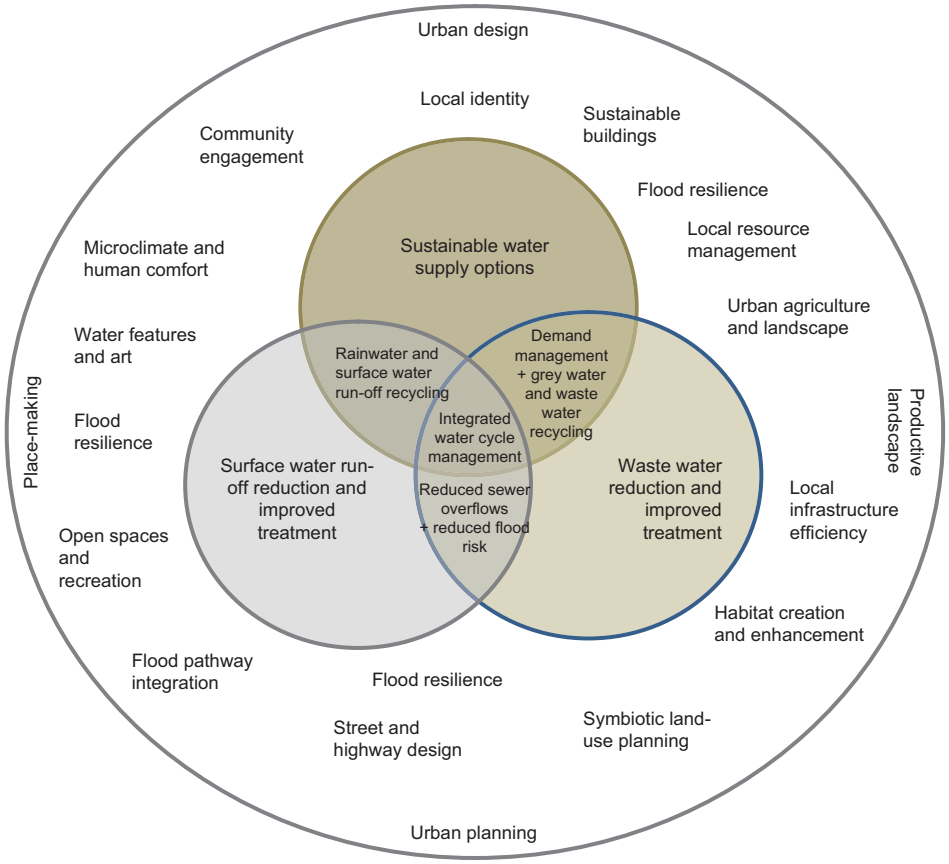

Figure 6. Water and the urban context of WSUD

Naji, 2003). Table 1 shows a number of key players and identifies a number of possible reasons (expressed as opportunities) for these to become better engaged in embracing a WSUD approach.

A vision as to how WSUD could be utilised within a UK context and what the WSUD process could potentially comprise is shown in Figure 6. The primary driver is that WSUD describes a much more intrinsic interrelationship between communities, services and utility functions when considering the entire water cycle in an integrated way and abandons the existing, traditional piecemeal approach with separated components of water systems (e.g. EA and EST, 2009). While water and energy create the most obvious synergy there are also important and significant interactions with the quality of the urban environment, solid waste, air pollution and transport systems that can be considered in a more integrated way.

Figure 6 is an adaptation of Figure 2 that puts more emphasis on flood risk management (Figure 5) and incorporates the WSUD concepts from Figure 3.

The three main principles of WSUD that are the most relevant to UK (and EU) applications are

- manage water to deal with both water scarcity and water excess, managing both water quantity and quality, concurrently and in an integrated way
- manage and utilise the water cycle as locally as possible as all aspects and occurrences of water are potential opportunities (exploit local opportunities)
- deal with water appropriately and synergistically in urban environments, including ecosystems, and across urban services, design and planning processes (maximise wider value opportunities and more effective integration and utilisation in urban areas).

WSUD should be implemented as appropriate at the various spatial scales, with applications integrated to produce an effective whole that is as sustainable as possible. The need to consider temporal scales is now much more significant than in the past, due to the non-stationarity of environmental systems (e.g. Milly *et al.*, 2008). WSUD provides an opportunity to

Traditional UK approach	Opportunities (what we should do)
Water supply, sewerage and flood management is provided for economic and population growth and the protection of public health	Ensure that multiple benefits for water, including environmental and other sectoral needs (i.e. transport, recreation/amenity, microclimate, energy and food production), are utilised over long-term time frames. Link water in cities more effectively to land-use planning.
The separate components of the water cycle are compartmentalised and optimised	Deliver adaptive, integrated, sustainable management of the total water cycle (including land use) designed to secure a higher level of resilience to future uncertainties in climate and water services requirements while enhancing the liveability of urban environments
Disciplines are narrowly focused on technical, environmental and economic factors	Engender and utilise transdisciplinary, multi-stakeholder learning across social, technical, economic, design and ecological spheres
Delivery is centralised, linear and predominantly technologically and economically based (one size fits all)	Seek diverse, flexible solutions at multiple scales by way of a suite of approaches (such as technical, social, economic and ecological). Context is important especially locally (e.g. for property flood risk management)
Water is managed by government on behalf of communities. Risk is regulated and controlled by government	Co-manage water in partnerships and engagement between government, business and communities to provide multi-value benefits. Share and diversify risks by means of private and public instruments as well as individual property owners/dwellers

Table 2. Changes in approach required to deliver WSUD in the UK

build into water systems an inherent flexibility and adaptability that is not possible using traditional water assets (Sieker *et al.* 2008), and, by using GI, synergies and benefits with natural processes can help cope with an uncertain future.

Whether or not the current governance, institutional and regulatory processes prevalent in the UK are fit for purpose is likely to be the subject of much debate, especially as WSUD is inevitably taken up. In Australia changes in governance regimes have been required (Brown, 2012) and in Philadelphia the significant rewriting of statutes and regulations has been required to allow the widespread uptake of GI for storm-water management (Maimone, 2012). Despite apparent governance barriers in the UK there are nonetheless signs that WSUD is starting to be taken up, for example, in Wales (Burton, 2012).

Case studies now emerging in the UK (e.g. Morgan *et al.*, 2012) show how various aspects of the water cycle are being managed opportunistically to provide a number of functions, such as from rainwater harvesting for irrigation and toilet flushing. These uses can also be linked to energy use and carbon reductions as co-primary drivers in the UK, although aesthetic and other applications are now growing in importance. Elsewhere, such as in Singapore (Armitage *et al.*, 2012; Khoo, 2009; Luan, 2010), the motives for taking a WSUD approach are usually increased access to locally available water and environmental protection. Nonetheless, most applications in Australia and the USA relate to surface or storm-water management, rather than the management of the water cycle as a whole (e.g. for blue-green infrastructure, London Borough of Croydon *et al.*, 2011).

4. Future outlook

Table 2 considers how the current approach in the UK could be modified to deliver a WSUD approach in the future.

There are strong signs that locally changes are happening and a more integrated approach is being taken to accessing the many benefits of tackling the water cycle as a whole in new developments in urban areas. There are, however, impediments due to the institutional difficulties outlined above and the need for the various players to work together more effectively across their traditional boundaries.

5. Summary and conclusions

A vision for WSUD in a UK context has been outlined above based on the potential for new approaches and the experience in its application that has been gained elsewhere. In the UK, for the foreseeable future, the wider aspects of flood risk management need to be given greater consideration in WSUD and here it is recommended that greater recourse be made to the expanding opportunities afforded by global WSUD applications. For example, river flooding, and coastal flooding and erosion management have not figured centrally in WSUD applications elsewhere in the world. However, there are now signs that in both Australia and the USA flood risk management is becoming more central in the application of water management principles (e.g. CRC for Water Sensitive Cities, 2012).

The main principles proposed here for WSUD in the UK include the need to manage water excess, scarcity and quality concurrently within a vision of managing water as locally as possible and to utilise key synergies with land-use planning and the management of other urban systems and services.

Land use is at the heart of urban design but it also can be used as the focus for the opportunities to best manage water within the inseparable tripartite of the land use–energy–water nexus when aiming to respond to the challenges of the future, including climate change (e.g. Dale *et al.*, 2011; Novotny and Novotny, 2012). It is clear that placing water more centrally in the land-use planning process could be a realisable and practical goal for promoting WSUD in the UK in the short term (e.g. Carmon and Shamir, 2009; Potter *et al.*, 2011).

It is unlikely that water will ever be at the heart of the way in which our cities and urban areas are laid out and function in the UK. Elsewhere, evidence shows that eco-cities are frugal in terms of water use and, although they are being planned using WSUD principles, water is by no means the primary consideration in their layout and function. However, recent UK government initiatives indicate that there is an awareness and an increasing willingness to place water much higher up the development agenda than it has traditionally been located. This paper has presented an overview of some of the opportunities and limitations for the take-up of such an approach in the UK, based on WSUD.

REFERENCES

Allen M (2008) *Cleansing the City*. Ohio University Press. Athens, Ohio, USA.

Armitage N, Coulson D, Teuchert S, Aadnesgaard O, van Zyl H, Carden K, Fisher-Jeffes L (2012) *Water Sensitive Urban Design (WSUD) for South Africa. D1: Draft Literature Review*. WRC Project K5/2071. Department of Civil Engineering, University of Cape Town, Cape Town, South Africa (unpublished).

Ashley RM and Cashman A (2006) The impacts of change on the long-term future demand for water sector infrastructure. In *Infrastructure to 2030: Telecom, Land Transport, Water and Electricity*. OECD, Paris, France, pp. 241–349.

Ashley RM, Nowell R, Gersonius B and Walker L (2011) *Surface Water Management and Urban Green Infrastructure. Review of Current Knowledge*. Foundation for Water Research, Marlow, UK.

Beddington J (2010) *Food, Energy, Water and the Climate: a Perfect Storm of Global Events?* UK Government Office for Science, London, UK.

Binney P, Donald A, Elmer V, Ewert J, Phillis O, Skinner R and Young R (2010) Cities of the future program. Spatial planning and institutional reform. Conclusions from the World Water Congress, Montreal, Canada.

BMT WBM (2009) *Evaluating Options for Water Sensitive Urban Design (WSUD) – a National Guide*. Joint Steering Group for Water Sensitive Cities, BMT WBM, Sydney, Australia.

Brown RR (2012) Transitioning to the water sensitive city: the socio-technical challenge. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)), Chapter 3. WA, London, UK, pp. 29–39.

Brown RR, Keath N and Wong T (2009) Urban water management in cities: historical, current and future regimes. *Water, Science and Technology* **59(5)**: 847–855, http://dx.doi.org/10.2166/wst.2009.029.

Burton A (2012) *Valleys to Coasts – Water Sensitive Brynheulog. WSUD Case Study Proposal*. Environment Agency Wales, Cardiff, UK.

Carmon N and Shamir U (2009) Water-sensitive planning: integrating water considerations into urban and regional planning. *Water and Environment Journal* **24(3)**: 181–191, http://dx.doi.org/0.1111/j.1747-6593.2009.00172.x.

Ciria (Construction Industry Research and Information Association) (2007) *SuDS Manual*. See http://www.susdrain.org/resources/ciria-guidance.html (accessed 25/01/2013).

Cities as Water Supply Catchments (2012) Stormwater Management in a Water Sensitive City. Blueprint, March.

CRC for Water Sensitive Cities (2012) http://watersensitivecities.org.au (accessed 06/07/2012).

Dale VH, Efroymson RA and Kline KL (2011) The land use-climate change-energy nexus. *Landscape Ecology* **26(6)**: 755–773.

DCLG (2009) *Eco-towns – A Supplement to Planning Policy Statement 1*. DCLG, London, UK.

DCLG (2011) *Code for Sustainable Homes – Technical Guide*. DCLG, London, UK.

DCLG (2012) *Technical Guidance to the National Planning Policy Framework*. DCLG, London, UK.

Defra (Department for Environment, Food and Rural Affairs) (2007) *An Introductory Guide to Valuing Ecosystem Services*. Defra, London, UK.

Defra (2011) *Mainstreaming Sustainable Development – The Government's Vision and What This Means in Practice*. Defra, London, UK.

Defra (2012) *Draft Water Bill*. Cm 8375. The Stationery Office, London, UK.

Digman C, Ashley R, Balmforth D, Stovin B and Glerum J (2012) *Retrofitting to Manage Surface Water. CIRIA C713*. Ciria, London, UK.

Donovan I and Naji F (2003) *Water Sensitive Planning Guide for the Sydney Region*. Upper Parramatta River Catchment Trust, Sydney, Australia.

Duffy A, Lucey M and Buchan D (2012) Adapting to the sustainability challenge – managing the risk of public SUDS. *Proceedings of the IWA Congress on Water, Climate and Energy*. Dublin, Ireland.

EA (Environment Agency) (2009) *Water Cycle Study Guidance*.

EA (2011) Environment Agency Flood pages Home http://www.environment-agency.gov.uk/homeandleisure/floods/default.aspx (accessed 31/10/2011).

EA and Energy Saving Trust (EST) (2009) *Quantifying the Energy and Carbon Effects of Water Saving.*

Eftec (Economics for the Environment Consultancy) (2010) *Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects. Handbook for the Environment Agency for England and Wales*. Eftec, London, UK.

Ellis JB and Revitt DM (2010) The management of urban surface water drainage in England and Wales. *Water and Environment Journal* **24**: 1–8.

Elmer V and Fraker H (2012) Water, neighbourhoods and urban design: micro utilities and the 5th infrastructure. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)). IWA, London, UK. pp. 193–206.

European Commission (2012) *Water Scarcity and Droughts – 2012 Policy Review – Building Blocks Non-Paper.* Directorate-General Environment, Unit D1: Water, Chemicals and Biotechnology.

Everard M (2011) Why does 'good ecological status matter? *Water and Environment Journal* **26(2)**: 165–174, http://dx.doi.org/10.1111/j.1747-6593.2011.00273.x.

Flood and Water Management Act 2010 (2010) *Elizabeth II*. The Stationery Office, London, UK.

Gersonius B, Ashley R, Richter S *et al.* (2012) Water sensitive urban design as an essential component of adapting water systems to cope with flood risks. *Proceedings of the 7th International Conference on Water Sensitive Urban Design*, Melbourne, Australia.

Grigg NS (2008) *Total Water Management: Practices for a Sustainable Future*. American Water Works Association, Denver, CO, USA.

HMG (Her Majesty's Government) (2011a) *Water White Paper*. The Stationery Office, Norfolk, UK.

HMG (2011b) *Water Environment (Controlled Activities) (Scotland) Regulations*. SSI 2011/209. The Stationery Office, Edinburgh, UK.

Hoban A, Wong T and Breen P (2006) Water sensitive urban design for resilience to climate change. *Proceedings of the 1st Australian International Hydropolis Conference*, Perth, Australia.

House of Lords (2006) *Water Management Volume 1: Report*. The Stationery Office, Norwich, UK.

Howe C and Mitchell C (eds) (2012) *Water Sensitive Cities*. IWA, London, UK.

Hoyer J, Dickhaut W, Kronawitter L and Weber B (eds) (2011) *Water Sensitive Urban Design: Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*. Jovis, Hamburg, Germany,

ICE (Institution of Civil Engineers) (2012) *The State of the Nation: Water 2012*. ICE, London, UK.

Islington Council (2010) *Sustainability Strategy 2010–12. London Borough of Islington*. Islington Council, London, UK.

Kenway SJ and Lant P (2012) The influence of water on urban energy use. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)). IWA, London, UK. pp. 63–77.

Khoo TC (2009) Singapore water: yesterday, today and tomorrow. In *Water Management in 2020 and Beyond* (Biswas A (ed.)). Springer Verlag, Berlin, Germany, pp. 237–250.

Landscape Institute and Town and Country Planning Association (2012) *Green Infrastructure Scoping Study WC0809*. Landscape Institute, London, UK

Laws D and Loeber A (2010) Sustainable development and professional practice. *Proceedings of the ICE – Engineering Sustainability* **164(1)**: 25–33, http://dx.doi.org/10.1680/ensu.2011.164.1.25.

London Borough of Croydon, Kingston University and URS (2011) *Developing Urban Blue Corridors – Scoping Study.* FD 2619, final report prepared for Defra and EA.

Luan IOB (2010) Singapore water management policies and practices. *Water Resources Development* **26(1)**: 65–80.

Lundy L and Wade R (2011) Integrating sciences to sustain urban ecosystem services. *Progress in Physical Geography* **35(5)**: 653–669.

MacPherson L (2012) Water: nature's amazing reusable resource. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)). IWA, London, UK. pp. 123–135.

Maimone M (2012) The SUDS challenge – Philadelphia's green city clean waters program. Keynote presentation at the *IWA World Congress on Water Climate and Energy*, Dublin, Ireland.

Millennium Ecosystem Assessment (2005) Ecosystems and their services. In *Ecosystems and Human Well-being: A Framework for Assessment*. See http://www.maweb.org/documents/document.300.aspx.pdf (accessed 25/01/2013).

Milly PCD, Betancourt J, Falkenmark M *et al.* (2008) Stationarity is dead: whither water management? *Science* **319(5863)**: 573–574, http://dx.doi.org/10.1126/science.1151915

Monbiot G (2012) Putting a price on the rivers and rain diminishes us all. *The Guardian*, 6 August, p. 25.

NAO (National Audit Office) (2011) *Flood Risk Management in England*. The Stationery Office, Norwich, UK.

Nelson V (2012) Achieving the water commons – the role of decentralized systems. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)). IWA, London, UK. pp. 9–14.

Newman R, Ashley RM, Molyneux-Hodgson S and Cashman A (2011) Managing water as a socio-technical system: the shift from 'experts' to 'alliances'. *Proceedings of the ICE – Engineering Sustainability* **164(ES1)**: 95–102. http://dx.doi.org/10.1680/ensu.1000032.

Novotny V (2010) Water and energy link in the cities of the future – achieving net zero carbon and pollution emissions footprint. *Water Science* and *Technology* **63(1)**: 184–190. http://dx.doi.org/0.2166/wst.2011.031.

Novotny V and Novotny E (2012) Water centric cities of the future – towards more macro-scale assessment of sustainability. In *Water Sensitive Cities* (Howe C and Mitchell C (eds)). IWA, London, UK. pp. 171–188.

Philadelphia Water Department (2009) *Philadelphia Combined Sewer Overflow – Long Term Control Plan Update – Supplemental Documentation. Vol. 2. Triple Bottom Line Analysis*. See http://www.phillywatersheds.org/ltcpu/Vol02_TBL.pdf (accessed 25/01/2013).

Potter K, Ward S, Shaw D *et al*. (2011) Engineers and planners: sustainable water management alliances. *Proceedings of the ICE – Engineering Sustainability* **164(4)**: 239–247, http://dx.doi.org/10.1680/ensu.2011.164.4.239.

Potz H and Bleuze P (2012) *Urban Blue-Green Grids*. Coop for Life, Delft, The Netherlands.

Queensland Floods Commission of Inquiry (2012) *Final Report.* See http://www.floodcommission.qld.gov.au/publications/final-report (accessed 25/01/2013).

Scottish Government (2012) *Scotland The Hydro Nation – Prospectus and Proposals for Legislation.* See http://www.scotland.gov.uk/Publications/2012/02/9536 (accessed 25/01/2013).

Sieker H, Helm B, Krebs P, Schlottmann P and Tranker J (2008) Flexibility – a planning criterion for stormwater management. *Proceedings of the 11th International Conference on Urban Drainage*, Edinburgh, September, CD-ROM.

Shaffer P, Ashley RM and Morgan C (2012) Water sensitive urban design as a delivery mechanism for water cycle management in England and Wales. *Proceedings of the International Conference on Water Sensitive Urban Design*, Melbourne, Australia.

Thurston HW (ed.) (2012) *Economic Incentives for Stormwater Control*. CRC, Abingdon, UK.

Water UK (2011) *Sustainability Indicators 2010/2011*. Water UK, London, UK.

Waterwise (2009) *The Water and Energy Implications of Bathing and Showering Behaviours and Technologies*. WaterWise, London, UK.

Woods A and Morgan C (2012) Adapting to climate change in the UK: a water sensitive urban design approach applied to NW Cambridge. *Proceedings of the International Conference of Water Sensitive Urban Design*, Melbourne, Australia.

Woods-Ballard B (2012) Where are we now (issues and opportunities). *National SuDS Conference, 'Getting on with SuDS'*, Thame, UK.

Wong T (2006a) Water sensitive urban design – the journey thus far. *Australian Journal of Water Resources* **10(3)**: 213–222.

Wong T (2006b) An overview of water sensitive urban design practices in Australia. *Water Practice and Technology* **1(1)**: 9–16.

Wong T and Ashley R (2006) International working group on water sensitive urban design. Submission to the IWA/IAHR Joint Committee on Urban Drainage, IWA, London, UK.

Wong THF and Brown RR (2009) The water sensitive city: principles for practice. *Water Science and Technology* **60(3)**: 673–682, http://dx.doi.org/10.2166/wst.2009.436.

Wong T and Eadie ML (2000) Water sensitive urban design – paradigm shift in urban design. *The International Water Resources Association for the Xth World Water Congress*, Melbourne, Australia.

Yorkshire Water (2012) *Taking Responsibility for the Water Environment for Good*. Kelda Group, Keighley, UK.