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WATER SENSITIVE URBAN DESIGN
Securing Water in Urban Settlements

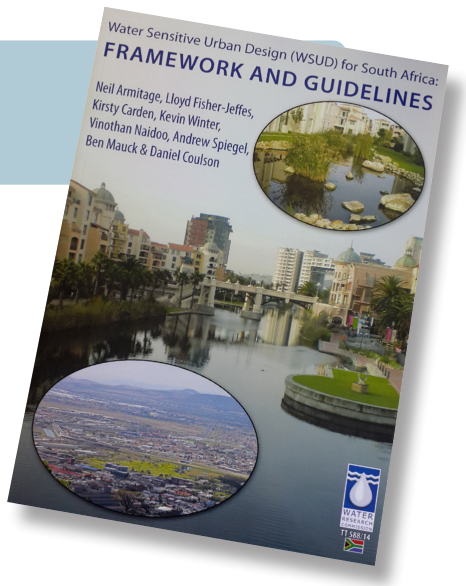
WATER RESEARCH COMMISSION

ABOUT THIS PUBLICATION

This publication is compiled from the Water Research Commission (WRC) Research Report entitled *Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines* (WRC Report No. TT 588/14, April 2014) by Neil Armitage, Lloyd Fisher-Jeffes, Kirsty Carden, Kevin Winter, Vinothan Naidoo, Andrew Spiegel, Ben Mauck and Daniel Coulson.

It is written primarily for councillors, city managers and other local authority officials, as well as national government policy developers and legislators.

The document provides an understanding of a new paradigm in urban water management (including for towns and villages), and starts to build the vision and case for its adoption in a water-scarce country such as South Africa.



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CONTENTS

ACRONYMS

AMD	Acid Mine Drainage
CBD	Central Business District
CoGTA	[Department of] Cooperative Governance and Traditional Affairs
DWA	Department of Water Affairs [now Water and Sanitation]
DWAF	Department of Water Affairs and Forestry [now Water and Sanitation]
NRW	Non Revenue Water
NWA	National Water Act
NWRS-2	Proposed National Water Resource Strategy 2
NWSA	National Water Services Act
SuDS	Sustainable (urban) Drainage System
WC	Water Conservation
WDM	Water Demand Management
WRC	Water Research Commission
WSA	Water Services Authority
WSC	Water Sensitive City
WSDP	Water Services Development Plan
WSS	Water Sensitive Settlement
WSUD	Water Sensitive Urban Design

1 INTRODUCTION

1.1 What is "Water Sensitive Urban Design" (WSUD)?

The adequate provision of basic services – including water – to South Africa's citizens is one of the most significant challenges facing the country, and is felt most strongly in the rapidly growing urban areas. According to Census 2011, more than 63% of the South African population already live in urban centres – which include a wide range of settlement types from small towns with populations of 15 000 to large cities and metros with populations of millions. It is estimated that the proportion of urban dwellers will increase to over 70% by 2030. In this context water security is a major concern, particularly since climate change has the potential to worsen systemic water shortages over the medium to long term.

Alternative, systems-based approaches to conventional water management of water supply and modes of ensuring water quality are required. New models of water capture, provision, treatment and governance must be developed to improve and enhance the effectiveness of interaction between the multiple actors who determine water use. The systems approach must take into account community values and aspirations when dealing with water supply, wet and dry sanitation, biological and chemical treatment of associated contaminants, drainage and the management of industrial effluents, while acknowledging the range of users. Such an approach has the potential to facilitate a change from 'water-wasteful' to 'water-sensitive' urban areas.

The notion of a Water Sensitive City (WSC), a 'city' where water is given due prominence in the design of urban areas, was first proposed by Wong and Brown (2008) and Brown, *et al*. (2008) at the 11th International Conference on Urban Drainage.

With this in mind the Water Research Commission (WRC) solicited research in 2011 aimed at providing guidance to urban water management decision-makers on the use of WSUD in a South African context. The research was designed to introduce the approach, and provide a context-specific framework and guidance for urban water management.

According to Wong (2006), the term WSUD *"... reflects a new paradigm in the planning and design of urban environments that is sensitive to the issues of water sustainability and environmental protection. The term comprises two parts: 'Water Sensitive' and 'Urban Design'. Urban Design is a well-recognised field associated with the planning and architectural design of urban environments, covering issues that have traditionally appeared outside of the water field but nevertheless interact or have implications to environmental effects on land and water. WSUD brings 'sensitivity to water' into urban design, i.e. it aims to ensure that water is given due prominence within the urban design processes. The words 'Water Sensitive' define a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of water services including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore water management practices. Collectively WSUD integrates the social and physical sciences. WSUD pertains to the synergies within the urban built form (including urban landscapes) and the urban water cycle (as defined by the conventional urban water streams of potable water, wastewater and stormwater). WSUD may thus be viewed as integrating the holistic management of the urban water cycle into the planning and design of the built form in an urban environment."*

1.2 Water Sensitive Settlements (WSS) in the South African context

Since WSUD is a multi-disciplinary approach to urban water management that aims to holistically consider the environmental, social and economic consequences of water management infrastructure, it is understood that a Water Sensitive Settlement (WSS) is a human settlement where the management of the urban (including cities and villages) water cycle is undertaken in a 'water sensitive' manner within the philosophy of WSUD. By considering all aspects of the water cycle and their interaction with urban design, WSUD aims to be the medium through which sustainable development can be achieved.

The vision for WSSs is one where the urban water cycle is managed for the benefit of all while simultaneously protecting the environment. This is increasingly being referred to as the provision of 'blue-green infrastructure', or the creation of 'blue-green cities' – aimed at recreating a natural water cycle while contributing to the amenity and liveability of urban environments (Novotny *et al.*, 2010).

In the South African context, WSUD has the potential to mitigate the negative effects of water scarcity; manage and reverse water pollution; develop social equity; develop intergenerational equity; increase sustainability; and develop resilience to natural disasters and climate change within water systems. In particular, it has the potential to transform our extremely divided settlements into ones where water can be used to connect disparate communities and bring about significant change.

1.3 Issues to consider in implementing WSUD in South Africa

Implementing WSUD in South Africa requires consideration of issues such as:

i) **Institutional structures:** The fragmented 'silo-management' of different aspects of the urban water cycle occurs, in part, because of the allocation of different responsibilities to different municipal departments. For example, stormwater management is often undertaken by the roads department – with stormwater seen as hazardous water that must be disposed of as rapidly as possible. Water supply is often separated from sewage collection, treatment and disposal, etc.

ii) **Champions:** Identifying and supporting champions is essential to introducing and embedding a WSUD approach in South Africa. Unfortunately the institutional silos described above have precluded these initiatives from being followed by water and sanitation departments in larger municipalities, and capacity / skills shortages hamper these efforts in smaller municipalities.

iii) **Equity:** Includes dignity, ownership and respect. South Africa already faces challenges in the delivery of services to the previously disadvantaged. Attempting to do this in a 'green' or water sensitive manner adds another layer of complexity. It will be difficult for government to implement 'green' projects when basic services do not exist, unless these are accomplished simultaneously.

iv) **Health aspects:** The planning for, and implementation of, the WSUD approach needs to take into account the potential health risks, particularly in respect of the creation of different pathways (mainly waterborne) for spreading disease.

v) **Adaptability and uncertainty:** South Africa has technical capacity and skills constraints at local and national government level, and it is crucial that any developments do not 'lock' the country into overly complex technologies. Furthermore, there is a great deal of uncertainty about the future, including the impacts of climate change, politics, demographics and resulting water demand patterns that result in policy makers being risk-averse.

vi) **Mitigation:** South Africa needs to manage its environmental impacts. According to the World Bank (2011), we have the 42nd highest (out of 224 countries) output of CO_2 per capita. This is a powerful argument for a WSUD approach if this means keeping energy usage in check, e.g. by preventing the general move to the desalination of seawater.

vii) **Ecosystem goods and services (EGS)**: Ecosystem services are defined as the benefits people derive from ecosystems – these include provisioning services such as food, wood and other raw materials; plants and animals that provide regulating services such as pollination of crops, prevention of soil erosion and water purification; and cultural services. Given the widespread poverty and inequality in South Africa, politicians are likely to consider EGS as an unaffordable luxury and may well question the reliability, maintenance requirements, appropriateness, and ability to deliver services quickly in a WSUD approach.

2 STRATEGIC FRAMEWORK FOR WSUD

2.1 Research focus areas

The WRC Research engaged with the four metropolitan municipalities of Cape Town, eThekwini, Johannesburg and Tshwane. Together these municipalities represent three different climatic zones, *viz*. coastal winter-rainfall, coastal summer rainfall, and inland highlands summer rainfall; an estimated 13 million people, i.e. 26% of South Africa's population of approximately 50 million; and about half of its urban population.

2.2 Components

Historically, water systems were developed using a linear design approach i.e. source, treat, transport, distribute, collect, treat and dispose. In order for WSSs to become embedded in South Africa several important questions must addressed:

- What are WSSs? What do we need to do to support a transition – understood as a change in infrastructure and services in societal systems towards WSSs? How can this be achieved, especially with limited funding and capacity?
- What is the long term goal?
- How can the WSUD 'message' be conveyed so that all stakeholders are 'speaking the same language'?

- How can under-capacitated municipalities be expected to transition to WSSs? What new governance systems are required to influence a step change in this regard?

In response to this, a framework with four components was developed:

- Research (how capacity can be built).
- Vision (the long term direction in which to move).
- Narrative (the story which is agreed to by all stakeholders).
- Implementation (a simple and adaptable approach in order to move towards a WSS).

2.2.1 Research

There is a need for on-going research and capacity-building in the water sector in order to develop South Africa-relevant guidelines for the realisation of WSUD. This WRC research (the proposed framework and associated reports) is an important 'tool', and will necessitate further research, along with recommendations to be realised in policy documents and additional a pilot studies to build the case.

2.2.2 Vision

The well-recognised 'Brown framework' (Brown et al., 2009) for visualising transitions within the urban water management sector details the critical stages through which towns and cities progress as they become more sustainable. The 'Brown framework' does not take into account the impact on the urban water cycle of a number of factors unique to South Africa. The WRC research, therefore, adapted it for our context, as shown in Figure 1 below – where the legacy of Apartheid has resulted in significant backlogs in infrastructure. Typical of these backlogs are the large numbers of poorly-serviced informal settlements.

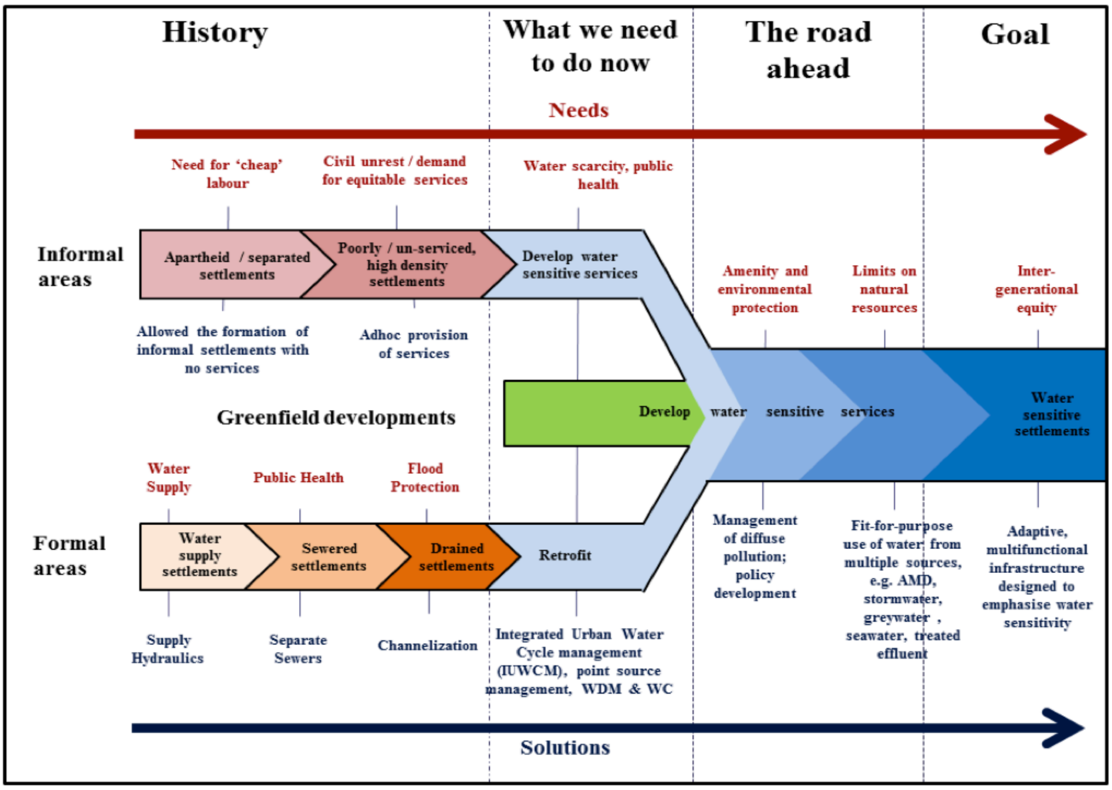

Figure 1: Framework for Water Sensitive Settlements in South Africa, "Two histories, one future" (adapted from Brown et al., 2009)

Any attempt to transition to WSSs will need to consider both the formally-developed areas as well as the informal settlements where high densities and limited infrastructure are common. Figure 1 provides a vision of how it may be possible to effect the transition of both formal and informal areas in South Africa as follows:

i) **Formal (brownfield) areas**: Currently developed mostly as 'drained cities' (the former "white" settlements), these areas should attempt to transition towards WSSs through retrofitting and redeveloping brownfield sites in a water sensitive manner.

ii) **Informal areas**: Once formal areas have begun to be retrofitted and the technologies tested on the mainly wealthy people there, informal areas (currently developed as 'water supply cities' with limited sanitation) should be redeveloped in as water sensitive a manner as possible. Any development of informal settlements should attempt to 'leapfrog' the stages through which formal areas develop, thus negating the need at a later stage to retrofit these areas.

iii) **Greenfield developments**: Greenfield developments should be done in as water sensitive a manner as possible from the outset, particularly in the case of private developments where the municipality can use development planning approval processes to ensure that the concept of water sensitivity is incorporated.

Figure 1 emphasises the fact that enhancing water sensitivity in settlements has the potential to not only address issues of resource availability and environmental damage, but also to address related problems of social exclusion, equity and equality.

2.2.3 Narrative

Narratives *"… simplify and offer a stable vision and interpretation of reality and are able to rally diverse people around particular story lines"* (Molle, 2008). This concept may be applied to the vision of a WSS where frameworks often fail to capture and express why a WSS should be adopted. The narrative 'tells the story' in order to draw people in; it expresses why a WSS is needed; how a WSS can be implemented; and what the outcome should be. The WSS narrative for South Africa has been developed to tie together the other three components of the framework so that, at the very least, all stakeholders should understand and engage with the idea of a WSS:

Why?

"…mitigating water scarcity, improving water quality, thereby protecting ecosystems, through the development of water sensitive urban areas (for all) that are sustainable, resilient and adaptable to change, while simultaneously being a place where people want to live…."

How?

Result!

2.2.4 Implementation

Various aspects are involved with the implementation of WSUD: policy development; institutional structures; community participation; construction of infrastructure; and operation and maintenance. However, the most important consideration in South Africa is how to effect a transition to WSS in the context of limited resources – both human and financial.

A municipality cannot focus on establishing ecosystem sustainability and intergenerational equity unless it can simultaneously provide adequate and safe water to all of its citizens. Conditions may however exist where this will not be possible (for example, the emergency provision of water services in an informal settlement after a fire); thus municipalities should target their initiatives with the underlying philosophy of: "*Do what you can with what you have*". This should be done while keeping in mind that, in achieving short-term goals, it is important not to jeopardise the long-term goal of a transition to a WSS; i.e. attempt to "*Do no harm*". Furthermore, individuals and developers in formal areas often have the capacity to develop in a water sensitive manner independently of the local authority. Municipalities should therefore ensure that they strengthen local legislation and regulations to encourage this – thus freeing up resources for other areas.

2.3 Relationship with national development instruments

2.3.1 Proposed National Water Resource Strategy 2 (NWRS-2), 2012

The NWRS-2 (DWA, 2012) is the primary mechanism to manage water across all sectors towards achieving Government's development objectives. In particular it addresses concerns that South Africa's socio-economic growth will potentially be restricted if water security, resource quality and associated water management issues are not resolved.

The vision underpinning the NWRS-2 is centred on the notion of 'Sustainable, equitable and secure water for a better life and environment'. Towards achieving this vision, the overall goal is of water being efficiently managed for equitable and sustainable growth and development. There are three main objectives, as follows:

i) Water supports development and elimination of poverty and inequality.
ii) Water contributes to the economy and job creation.
iii) Water is protected, used, developed, conserved, managed and controlled sustainably and equitably.

2.3.2 Towards an integrated development approach, 2013

Government has committed to an "*integrated urban development approach*" (COGTA, 2013) to assist local authorities in managing the effects of rapid urbanisation as follows:

- A national integrated urban development policy framework is advocated to improve planning and resource efficiencies so that better returns on investment can be achieved for every Rand spent on infrastructure in cities.
- Return on investment is envisaged as extending beyond economic returns to encompass social returns (i.e. improved quality of life, especially for the poor) and environmental returns (i.e. minimising

damage and re-establishing ecosystem health).

- The assumption is that if South African towns and cities calibrate their infrastructure planning, investment and management, they can foster more resilient and inclusive settlements.
- Infrastructure is understood as a socio-technical construct – i.e. it is more than just pipes. The success or failure of technologies will be strongly influenced by the institutional structures that support them and the people that use them.
- Environmental concerns do not take priority over social concerns – the focus is rather on achieving univesal access to basic services in a manner that is resource-efficient so as to minimise environmental impact and improve affordability.
- Resource-efficient infrastructure service approaches include those that:

    1. Minimise the use of raw materials and fossil fuels through efficiencies.
    2. Substitute non-renewables with renewable alternatives.
    3. Minimise the amount of waste and pollution dumped into the air, water and land by re-using waste streams as substitutes for raw materials.

2.4 Institutional considerations in implementation

2.4.1 Organisational arrangements

The formal organisational arrangements in the four metropolitan municipalities of Cape Town, eThekwini, Johannesburg and Tshwane were assessed to determine how urban water systems are managed in these cities. The assumption that both core (e.g. supply, storm and wastewater) and ancillary (e.g. environmental management) urban water management functions are currently being 'compartmentalised' was confirmed in all four metros, albeit with some notable differences. In general, stormwater management is paired with roads and transport, which operates separately from the supply and treatment of water that is typically housed in a department of water and sanitation.

Related to the compartmentalisation of urban water management functions is the fact that it has side-lined the adoption of an ecological or environmental focus to engineering water services in these metros – even though there are generally some 'environmental management' roles. At a strategic level environmental management tends to function separately from the main water resource management functions – although it was observed that an 'environmental' focus has been incorporated directly into the stormwater management function in three of the four metros (excluding Johannesburg which has devised co-ordinating structures to link the two functions). This suggests that administrative arrangements have, in some measure, accommodated planning and implementation at a 'catchment' level to address ecological concerns. It was also clear that there is an increasing emphasis on augmenting the knowledge and skills of engineering staff to promote a more holistic approach to stormwater engineering in particular, informed by Sustainable (urban) Drainage Systems (SuDS). This does not necessarily mean that structural integration at a line function level would provide the desired WSUD catalyst. Structural reform to drive WSUD is more likely to happen at a non-line function executive level (‘higher up’ the organisational chart) where it is driven from the level of a metro’s executive or ‘corporate’ management, which could facilitate inter-departmental co-ordination and ensure that additional resources are earmarked.

Figure 2 is provided by the Research Study as the typical organisational arrangements for WSUD-related line functions in South Africa:

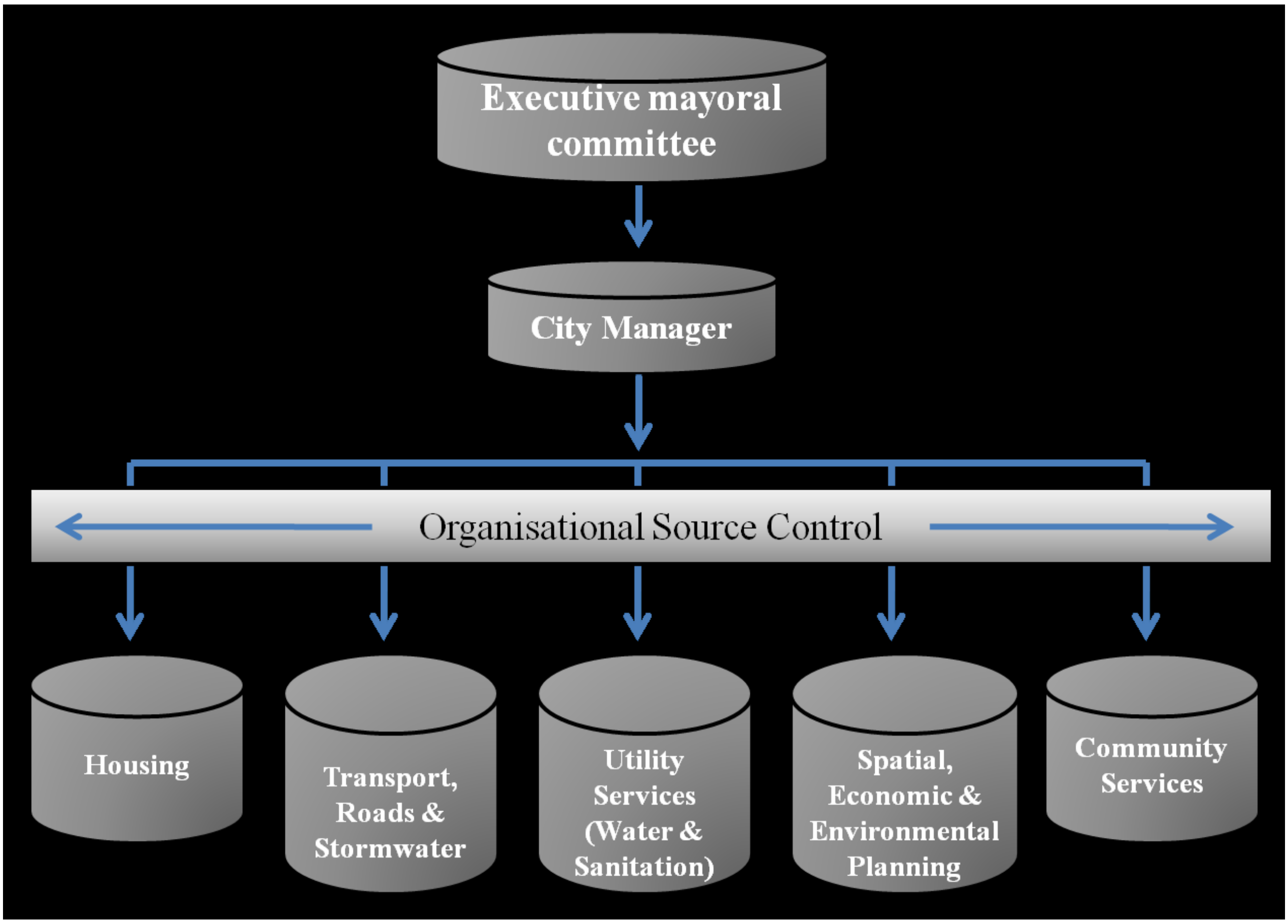

Figure 2: Typical organisational arrangements for WSUD-related line functions in South Africa (Armitage et al., 2012)

While there is evidence of municipalities responding to individual WSUD principles, this did not necessarily translate into corresponding levels of co-ordination and integration across water and other related services (such as Planning, Urban Design, Housing, etc.). There is potential for extensive co-ordination – which could be facilitated by urban and strategic planning fora. There were also examples of co-ordination driven by the stormwater (through catchment management), as well as environmental management, portfolios. Despite these efforts, a number of constraints continue to impede their full potential – including a lack of enabling council-approved policy and guidelines (with political backing and the force of by-laws), and the need for interventions to effectively re-train (capacity-build) technical officials on water sensitive approaches. This reinforces the need for policy advocacy of SuDS and WSUD at an executive level. In this regard, it may be more effective for metros to push WSUD as part of complementary initiatives that have greater and wider public and policy appeal, such as 'greening' initiatives which promote energy efficiency, as well as climate change mitigation.

2.4.2 Enablers and challenges

Enablers and challenges were assessed by examining the institutional arrangements that metros have put in place for urban planning; the various technical services involved in the delivery, storm and wastewater management; as well as environmental management services. Below is a summary of those identified as promoting and / or hindering co-ordination and integration in water services:

Enablers

- Increasing emphasis on re-use of water / wastewater.
- Increasing sensitivity to monitoring water quality.
- Strategic clustering of functional activities to spur on more substantive co-ordination and integration of water services.
- Protection of urban catchments (i.e. spatial focus) to facilitate functional co-ordination.
- Existence of auxiliary structures, e.g. those additional to traditional line function structures, such as special committees, to facilitate co-ordination and integration.

Challenges

- Cost-recovery demands / pressures of water and sanitation (reticulation services) hinder the pace of co-ordination and integration with other water services functions.
- Synchronising planning at settlement-wide level (e.g. strategic, spatial) with infrastructure planning at a line-function level (e.g. in water services departments).
- Delays in finalising planning and regulatory instruments with legal force inhibit cross-departmental co-ordination and integration.
- Advocating WSUD principles in policies aimed at retro-fitting existing settlements, especially those targeted for municipality-financed low-cost housing are confronted by challenges of density, scale of demand and political sensitivities concerning the perceived quality of engineering options.

3 TYPES OF INFRASTRUCTURE-RELATED WSUD ACTIVITIES

This section provides the types of urban water infrastructure-related activities that can be implemented as part of WSUD: where all infrastructure elements of the water cycle are considered concurrently so as to sustain the environment and meet human needs:

- Stormwater management.
- Sanitation / wastewater minimisation.
- Groundwater management.
- Sustainable water supply options.

It is noted that the four activities are intricately linked; different technologies and strategies apply to each of the streams with several strategies applying to one or more of the streams. The streams may interact through a number of WSUD activities, the ultimate goal being the holistic management of the urban water cycle to simultaneously achieve the desired economic, environmental, and social benefits.

3.1 Stormwater management

3.1.1 Introduction

The WRC research outlines how SuDS may be used to holistically manage urban drainage as a component of WSUD. Stormwater management in the urban areas of South Africa has focused and continues to predominantly focus on collecting runoff and channelling it to the nearest watercourse. This means that stormwater drainage currently prioritises quantity (flow) management with little or no emphasis on the preservation of the environment, with the result that there have been significant negative impacts on the environment from erosion, siltation and pollution. An alternative approach is to consider stormwater as part of the urban water cycle.

SuDS offers an alternative approach to conventional drainage practices by attempting to manage surface water drainage systems holistically. They achieve this by mimicking the natural hydrological cycle, often through a number of sequential interventions in the form of a 'treatment train'. The key objectives of the SuDS approach include the effective management of stormwater runoff quantity and quality, promoting the amenity value, and preserving / encouraging biodiversity value. Simply put, there is no point focusing on biodiversity if life and property have not already been protected.

Prior to the design of any stormwater system there are a number of factors to be considered:

- The local hydrological cycle.
- The local ground conditions – including unusual geological formations.
- The different challenges of development on greenfield vs. brownfield / retro-fitted sites.
- The impact of different types of development.
- Compliance with the law – particularly local by-laws which are often quite specific with respect to allowable development.

3.1.2 Urbanisation and the water cycle

Urbanisation affects many resources and components of the environment in urban areas. Water is just one of the resources affected. The 'water cycle' has "been used to represent the continuous transport of water in the environment" (Mitchell *et al.,* 2001). Urbanisation results in the natural water cycle being altered, as highlighted in Figure 3:

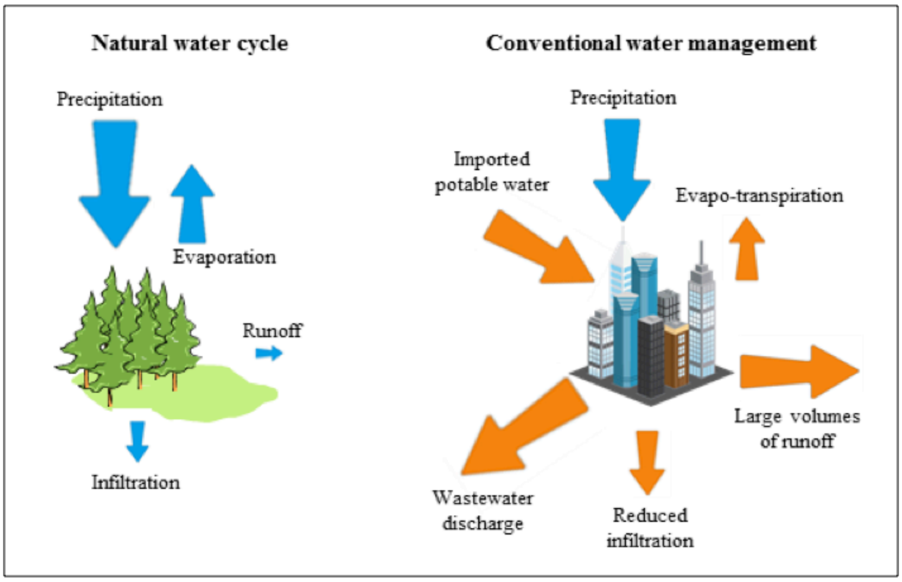

Figure 3: Urban water cycle showing changes to the natural water cycle with traditional urban development (adapted from Hoban and Wong, 2006)

The differences between the natural and urban water cycles as it impacts on conventional stormwater management is as follows:

- **Reduced infiltration** – Results in a decrease in infiltration which in turn decreases groundwater recharge while increasing runoff volumes and peak flows.
- **Changes in runoff conveyance networks** – Runoff conveyance replaces natural channels and streambeds with manufactured channels and sewers.
- **Increased water consumption** – Results in generation of wastewater which must treated and released to receiving water bodies.

3.1.3 Overview of SuDS options

It is important to recognise that certain SuDS options may be inappropriate under certain conditions. The advantages and limitations of each alternative system should be identified during the planning and design. The South African SuDS Guidelines group the different SuDS options according to the scale at which they are most likely to be used – See Figure 4 below:

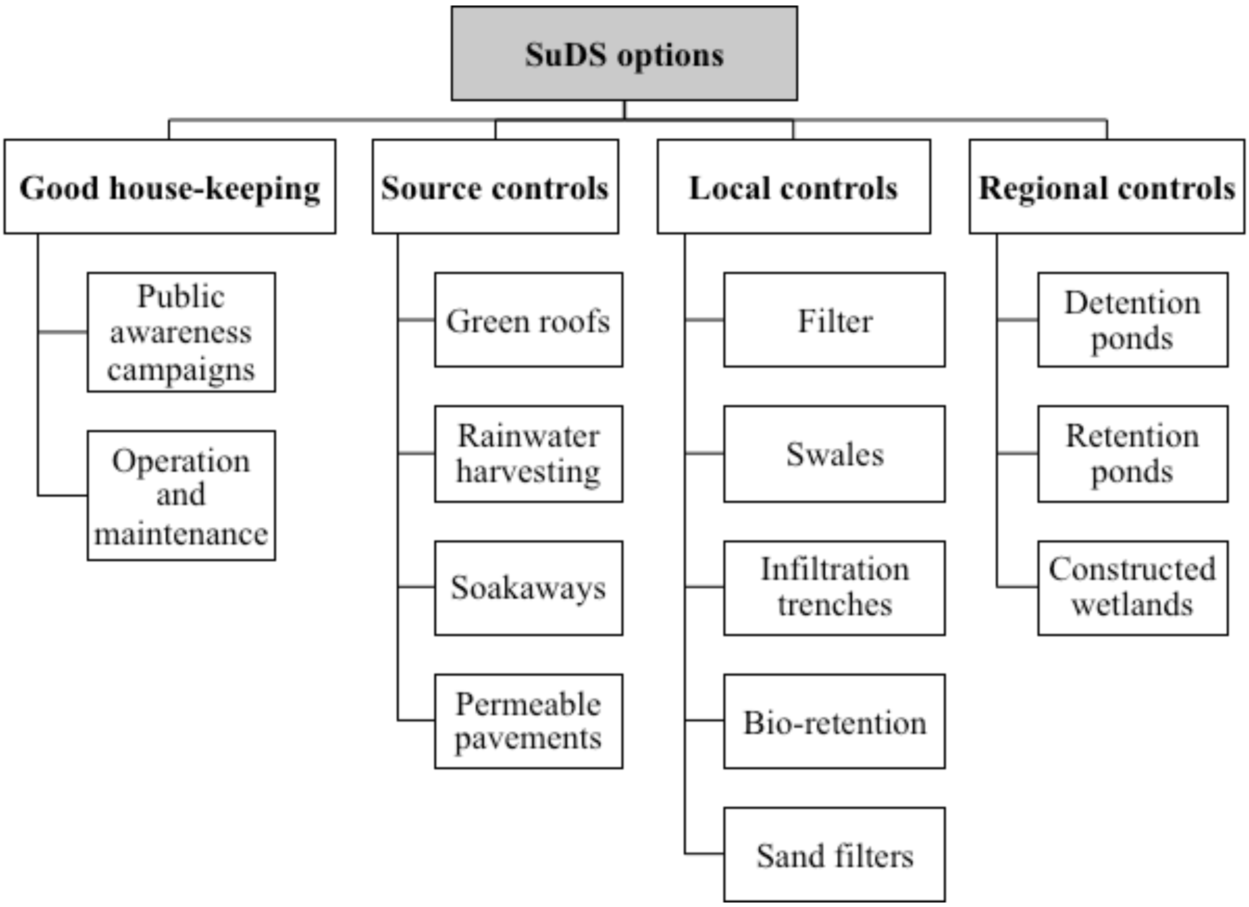

Figure 4: Grouping of SuDS options from the South Africa SuDS Guidelines (Armitage, et al., 2013)

The South African SuDS Guidelines were recently been published by the WRC (Armitage *et al*., 2013). They summarise key material from stormwater management manuals from around the world so as to be relevant to all South African professionals working with stormwater. They are not intended to be a design manual but a means to highligh opportunities for better stormwater management. The Guidelines are available on the WRC website (www.wrc.org.za) and on the South African WSUD website (www.wsud.co.za).

3.2 Sanitation and wastewater minimisation

3.2.1 Introduction

The primary objective of any sanitation system is to protect and promote human health through the creation of a healthy and clean environment. There is a clear correlation between sanitation and health; improved sanitation reduces the risk of gastro-intestinal faecal-oral diseases as well as disease carried by insect vectors. The provision of sanitation is a basic right in South Africa and national policy requires that all citizens have access to a basic level of service. There are a range of technical sanitation options available; however it has become clear that selection of these options is heavily dependent on social acceptance. A lack of or inadequate sanitation services can have serious detrimental effects on the environment, the economy and social stability. Thus a variety of drivers for sanitation need to be considered in the selection of any sanitation option.

Managing sanitation in an urban environment is a difficult task and there are many facets to the challenge of achieving the WSUD objective of transitioning to WSSs. The sanitation challenge from a WSUD perspective is split into four main components:

- **Appropriate sanitation** – This covers issues related to the provision of sanitation and the challenges associated with providing alternative sanitation to the urban poor.
- **Sanitation options** – The range of sanitation options that could be used in place of conventional waterborne sewerage.
- **Wastewater as a resource** – This highlights the potential for wastewater re-use as a substitute for potable water.
- **Wastewater and ecological sustainability** – This highlights the link between effective wastewater management and healthy ecosystems, as well as the need to integrate sustainable water management with other sectors involved in urban sustainability.

3.2.2 Sanitation and wastewater as components of WSUD

There are particular challenges to implementing WSUD in South Africa related mainly to a different social and economic reality with high levels of poverty and inequality. The question of how to incorporate the sanitation component in the context of low-income urban areas in South Africa is still a work in progress. It is important to note that sanitation in the context of WSUD should not be conflated with dry sanitation options alone – particularly since the fraction of water used directly by lower-income South Africans for domestic purposes is significantly lower than in higher income brackets.

One of the features of a more sustainable sanitation system is that it should optimise the use of resources such as nutrients, water and energy. This would include, but not be limited to, the adoption of alternative sanitation technologies such as dual reticulation systems, urine diversion, or composting. Another key feature is the potential for greater inclusion of low-income urban areas into a more holistically designed and managed urban water cycle – provided there is a clear understanding of responsibilities for operation and maintenance, as well as community expectations regarding the provision of sanitation. Greater inclusivity and secondary benefits from sanitation could be achieved through not only well-designed infrastructure, but also through the city-wide social and institutional processes of negotiation, participatory planning / visioning, consensus building, etc.

South Africa's towns and cities produce large quantities of wastewater on a daily basis; most of this is passed through wastewater treatment works and is discharged into receiving waterways. The exploitation of this valuable water source could significantly reduce potable water demand within urban areas as well as the quantities of wastewater generated. The level of treatment required before re-use is dependent on the quality of the wastewater recovered as well as its intended end use. Wastewater can be split into two broad components, blackwater and greywater. There are a variety of strategies that can be used to recover wastewater at different scales for a range of applications.

Wastewater is a major component of the urban water cycle. There is significant potential to exploit this resource on a 'fit for purpose' basis. Not all water use activities require potable water; treated wastewater can provide a very useful and economically feasible alternative. It must be borne in mind, however, that untreated wastewater can adversely impact natural environments, and the proper treatment of wastewater before discharge is a critical component of sustainable wastewater management strategies. Many wastewater treatment works in South Africa do not comply with the minimum water quality standards and the management of these facilities will need to undergo significant improvement if the transition to sustainable wastewater management is to be realised.

3.3 Groundwater management

3.3.1 Introduction

The most established role of groundwater within WSUD is in stormwater management, where recharge of stormwater to groundwater provides a means of treatment, as well as storage. In simple terms, rainwater either leaves the land surface as runoff, or it infiltrates into the soil. Once infiltrated, water can move vertically until it recharges the groundwater, or it can flow laterally within the vadose (unsaturated) zone as interflow, eventually reaching the groundwater surface and adding water to the aquifer, occurring as the net gain from precipitation or runoff.

Many of the world's largest cities, such as Mexico City, Shanghai, Jakarta, Cairo, London and Beijing rely on groundwater for more than 25% of their water supply (Wolf *et al*., 2006). South Africa, on the other hand, depends largely on surface water resources, with less than 15% of the total water supply estimated to be groundwater. However, at least 80% of South Africa's available surface water resources have already been allocated, and many parts of the country are approaching the point at which all of the easily accessible freshwater resources will be fully utilised. Given the strain on surface water resources, groundwater may hold the potential to meet some of South Africa's growing water requirements.

Sustainable groundwater development is critical for urban planning and management; however, if groundwater management is to be successfully achieved then a strong institutional framework is required which includes the regulation of groundwater. Even if the appropriate institutional framework and legislation is in place, there still needs to be public and political will to manage and protect groundwater.

3.3.2 Groundwater in South African metropolitan areas

The City of Johannesburg has incorporated groundwater into its Water Services Development Plan (WSDP), and acknowledges groundwater as a valuable resource that could be used for bulk water supply and which requires protection if it is to be available for future use. There are, however, problems regarding Acid Mine Drainage (AMD) – the flow of heavily contaminated water from old mining areas, and its impact on the quality of groundwater in the area. The monitoring of groundwater in Johannesburg is relatively poor and the majority of the established groundwater monitoring network is out of service (CoJ, 2009).

The City of Tshwane has historically used groundwater as a water supply source, and currently parts of the Central Business District (CBD) and the suburbs to the east and west of the city centre still use groundwater. The City receives approximately 57 Mℓ/day of water from groundwater springs and boreholes south of the city. It is noted that Tshwane is also under threat from AMD (Gauteng Province, 2006).

The City of Cape Town has access to a number of groundwater resources such as the Albion Spring, Atlantis Aquifer, Table Mountain Group Aquifer, the Cape Flats Aquifer and the Newlands Aquifer. Currently, only the Albion Spring and the Atlantis Aquifer are used for bulk water supply. The City of Cape Town actively promotes groundwater use for urban irrigation. However, this usage is largely unregulated and the only requirement is that households using groundwater for irrigation purposes must indicate, by way of a notice fixed on the property, that water is being used from a well-point or borehole. The City's WSDP is set to include consideration of increasing future groundwater abstractions. Currently, a feasibility study is being conducted on the Table Mountain Group Aquifer, with future feasibility studies on the Newlands Aquifer and Cape Flats Aquifer also under consideration.

The WSDP for the eThekwini Municipality (which includes Durban) shows no plan for the inclusion of groundwater management. The KwaZulu-Natal Groundwater Plan published by DWAF (DWAF, 2008) suggests however that groundwater in eThekwini is mostly used for industrial purposes, and that the groundwater is heavily polluted. It also suggests that groundwater monitoring in eThekwini is poor, with an overall lack of data management.

3.3.3 Concluding remarks on groundwater as a component of WSUD

WSUD draws attention to the value of groundwater in general. This is particularly important in South Africa where groundwater is undervalued. There is a need to consider the interaction of groundwater with urban infrastructure, ecosystems and storage, and thus identify the risks and opportunities of groundwater use. It is important that groundwater experts are included in the identification of the risks and opportunities associated with groundwater interactions in WSUD, so that there is an opportunity to formulate a suitable response in terms of mitigating these risks and optimising the opportunities.

The use of groundwater as a resource should be considered a key part of the WSUD approach based on the fact that it is intimately linked to ecological goods and services. Additionally, groundwater protection measures are required to ensure sustainability of urban aquifers. WSUD encourages all urban water stakeholders to attach value to groundwater and to begin to monitor, evaluate and understand urban groundwater processes.

3.4 Sustainable water supply options

3.4.1 Introduction

Ensuring the sustainability of South Africa's water supply requires a move beyond the construction of large scale water supply schemes to satisfy the growing demand for water. Water is a scarce resource and it is imperative that water management strategies begin to make use of the available water resources in the most efficient and effective manner. Here, the concept of 'sustainable water supply' is used to describe the alternative approaches needed to secure South Africa's water resource requirements. Sustainable water supply can be defined as the use of water in a manner that does not deplete or permanently damage the resource. Sustainable water supply strategies aim to have an impact on the urban water cycle; reducing potable water supply requirements, minimising wastewater generation, and maximising the use of alternative water sources. Figure 5 illustrates how sustainable water supply strategies affect the various streams of the urban water cycle.

3.4.2 Water conservation and water demand management

There are significant challenges with respect to water losses in general and non-revenue water (NRW) in particular. While some municipalities and other institutions have begun to address these challenges, it has become apparent that

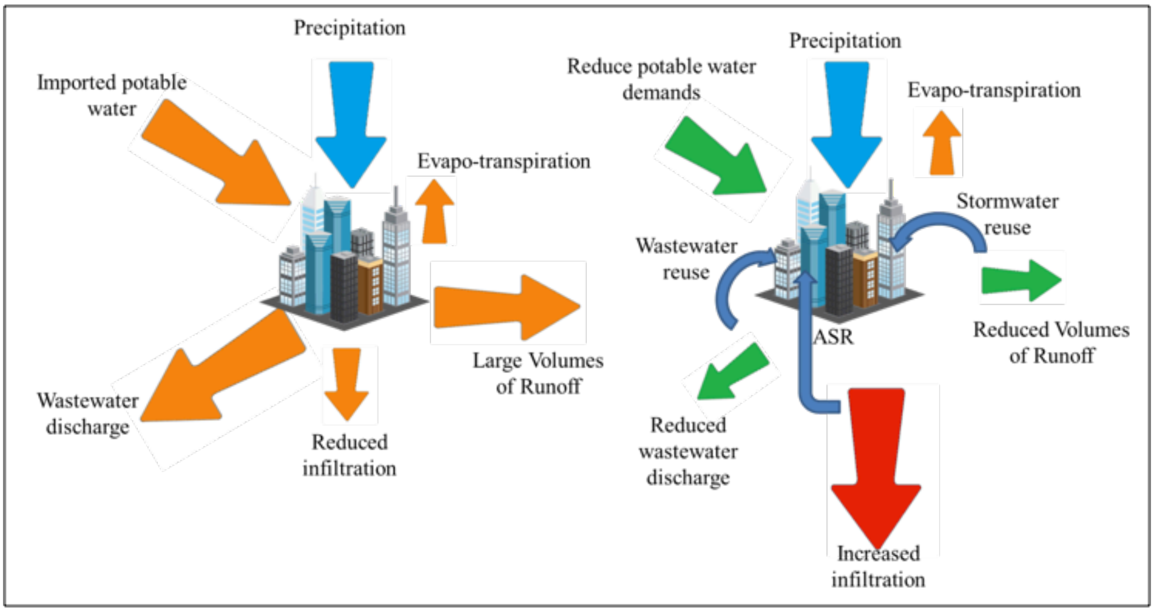

Figure 5: The impact of sustainable water supply strategies on the urban water cycle (adapted from Hoban and Wong, 2006)

efforts must be intensified with specific targets set to reduce water losses. Water Conservation (WC) and Water Demand Management (WDM) strategies aim to improve the sustainability of urban water use, and have multiple benefits in terms of the postponement of infrastructure augmentation, mitigation against climate change, support to economic growth, and ensuring that adequate water is available for equitable allocation. As South Africa's conventional water supply options approach their full potential, and it becomes increasingly expensive to develop further resource capacity, WC and WDM offer more economical means of balancing the country's water demand with its available supply. The definitions of WC and WDM are very closely aligned as follows:

- **Water Conservation** – Refers to the minimisation of water loss or waste, the care and protection of water resources, and the efficient and effective use of water.
- **Water Demand Management** – Refers to any action or process that promotes the more efficient and sustainable use of water resources. The scope of the definition incorporates issues such as social development, social equity, political acceptability and economic efficiency.

3.4.3 Overview of WDM strategies

Figure 6 illustrates some of the more common strategies available to improve the sustainability of water supply through the application of WDM:

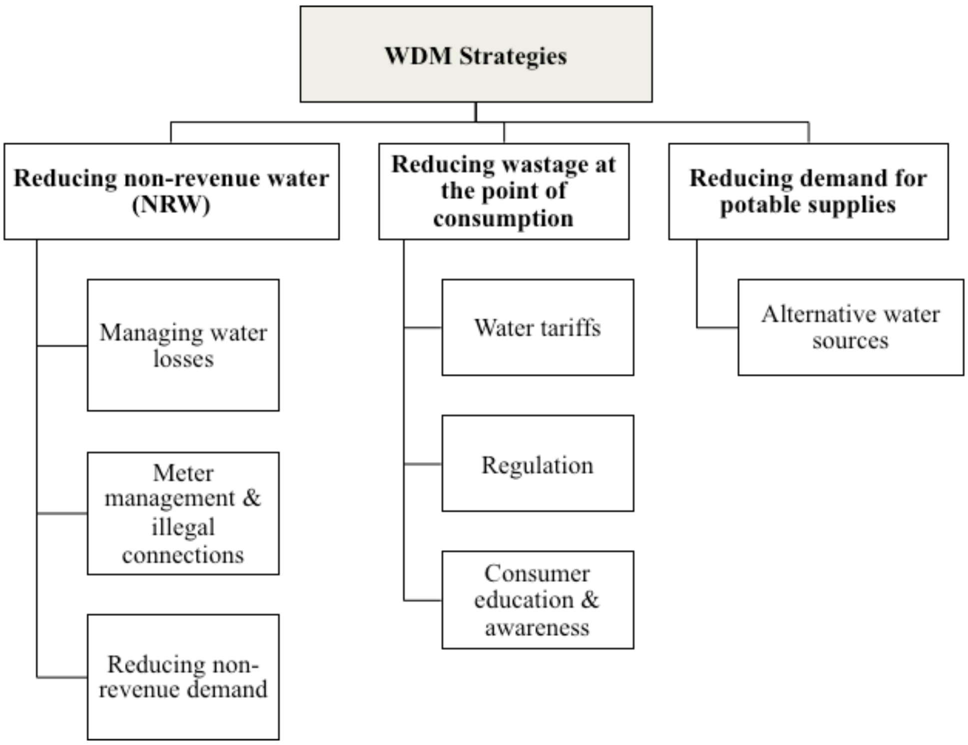

Figure 6: An overview of WDM strategies

There is vast literature on implementing WDM strategies, and the reader is encouraged to secure a copy of the WRC Research Report entitled *Guidelines for Reducing Water Losses in South African Municipalities* (WRC TT 595/14) by R S McKenzie. The *Guidelines* are practical and extremely useful. They are based on work over a period of 20 years in about 20 countries.

4 MODELLING

To date there has been a significant focus on modelling one specific part of the urban water cycle – the stormwater system, with a particular emphasis on water quality.

While a number of models have been developed which represent the total urban water cycle, most of these models are simplistic water balance models. Many cannot simulate both the water quantity and water quality of an integrated urban water management system, and few can track waterborne contaminants. Even fewer can simulate the effects of the use of alternative water sources on the urban water cycle and on contaminant flows. Urban water cycle models should at least be capable of simulating flows and their pollutant characteristics over porous and non-porous surfaces as well as through channelled and piped networks (Zoppou, 2001). They should model the hydrological aspects (such as rainfall, infiltration, overland flows and evaporation), as well as the hydraulic aspects (pipe and channel flow) of urban environments (Siriwardene and Perera, 2006).

Despite the limitations of some computer models, they allow the simulation and evaluation of the environmental impact of various design and operational scenarios without the need for costly and time consuming physical testing. However, computer modelling requires expertise and experience as well as input data that is appropriate and relevant. The process requires calibration and verification of the chosen parameters in order to produce useful results. The reliability of the models also depends on the accuracy of the parameters chosen for the catchment to be investigated.

The WRC research reviewed models identified as appropriate for use in WSUD modelling for South Africa. A selection of models found in Chapter 14 of the Research Report was based on the following criteria:

- Available model support.
- Ability of the software to model integrated urban water management / sustainable urban drainage systems / water sensitive urban design.
- Model capabilities.
- Cost.

Please refer to the full Research Report for an in-depth discussion of models relevant for different settlement types and situations, noting that information is continuously changing, and updated details on specific models and their capabilities are available through the WSUD website (www.wsud.co.za).

5 CONCLUSION

Perhaps the most important question to be answered in implementing the concept of WSUD is **"How can the WSUD philosophy be used to integrate water into urban design so as to bring about fundamental change in South African communities?"**

There is a need for national government to offer guidance, capacity and policies to support local authorities in the planning and design of urban settlements. The Framework – were it to be adopted as the vision for managing urbanised areas in South Africa – is the first step. It sets the vision and addresses how South Africa can move forward in terms of achieving this vision. It offers a means to improve the protection and restoration of urban environments; to safeguard water security; to enhance public health and economic sustainability in the urban setting; to increase social and institutional investment into urban water management; and to actively lead in exploring a suite of appropriate, sustainable social technologies in a transition to water sensitive settlements. The NWRS-2 and Framework both provide input into the management of water resources in South Africa. Together these documents could provide a comprehensive vision for the future management of water resources in South Africa. The merging of the National Water Act (NWA) and the National Water Services Act (NWSA) (policy review process currently underway) may also offer an opportunity to bring WSUD into legislation. Consultation with the relevant authorities at national government level will be necessary to take this further and to gain their acceptance of the WSUD vision.

Brown *et al.* (2009) claim that there are currently no examples of a truly water sensitive city anywhere in the world. This raises the question of whether the vision of a WSC and WSSs is a realistic one for South Africa. On the other hand, whilst it may not seem to be wholly achievable, it should be remembered that it is a long-term vision with no specific deadline for implementation. Having this vision means that, as far as possible, and within the means available, decision-makers in South African towns and cities are encouraged to continuously improve the management of their urban water systems with a view to transitioning 'closer' to the ideals of water sensitivity. This will ensure that alternatives to conventional urban water management will always be considered.

Repurposed for a wider audience by

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