Gauteng Sustainable Drainage Systems Implementation Manual

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Growing Gauteng Together

TABLE OF CONTENTS

ACRONYM LIST

BAR	Basic Assessment Report
CBD	Central Business District
CMA	Catchment Management Agency
CMP	Catchment Management Plan
COGTA	Department of Cooperative Governance and Traditional Affairs
CoJ	City of Johannesburg
GDARD	Gauteng Department of Agriculture and Rural Development
GCR	Gauteng City Region
DWS-Gauteng	Department of Water and Sanitation - Gauteng Region
DHSWS	Department of Human Settlements, Water and Sanitation
EIA	Environmental Impact Assessment
EAP	Environmental Assessment Practitioner
IEMP	Integrated Environmental Management Plan
JDA	Johannesburg Development Agency
JRA	Johannesburg Road Agency
m.a.s.l.	Meters above sea level
MISA	Municipal Infrastructure Support Agent
MLUS	Municipal Land Use Scheme
MSDF	Municipal Spatial Development Framework
PICP	Permeable Interlocking Concrete Paving
SAICE	South African Institute for Civil Engineering
SALGA	South African Local Government Association
SDF	Spatial Development Framework
SDP	Spatial Development Plan
SPLUMA	Spatial Planning and Land Use Management Act
SuDS	Sustainable Drainage Systems
SWMP	Stormwater Management Plan
WISA	Water Institute for Southern Africa
WRC	Water Research Commission
WSUD	Water Sensitive Urban Design
WULA	Water Use License Application

FOREWORD

The Gauteng Department of Agriculture and Rural Development is, among other things, mandated to develop strategies for environmental management, including response to the challenges and potential impact of climate change within the Gauteng City Region (GCR).

The Gauteng is South Africa's smallest but most populous province with approximately over 14 million people. Most of its residents live in urban areas (STATS SA: 2018). Urbanisation impacts on the natural water cycle, resulting in increased runoff, decreased infiltration, and waste management challenges related to increased littering and so forth.

The Province experiences the following problems: high demand on resources and less supply. This leads to shortages, e.g. water shortage. The population growth in urban areas also leads to an increase in the number of informal settlements, bringing the challenge of infrastructure maintenance. This, combined with the impact of climate change, contributes to failing stormwater drainage systems. The conventional approach of building wider and deeper drains to quickly collect and channel rainwater runoff away from the urban catchments is no longer adequate or sustainable.

The above challenges prompted the need for research into methods and technologies that could improve the management of stormwater and Sustainable Drainage System (SuDS) is one of the options. The implementation of SuDS technologies will result in a decrease in flooding and increase in water availability and in some cases sustainability of ecosystems.

Accordingly, GDARD has introduced a manual that explains how these technological interventions will help make Gauteng a greener and more climate resilient province. The implementation manual is intended to target decision makers in municipalities, especially those involved in guiding and regulating development, and in particular stormwater planning and implementation in the Province. It will also be a useful guide for Environmental Assessment Practitioners (EAPs) and their specialists, as well as developers and their project teams.

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PREFACE

As part of the project Research on the Use of Sustainable (Urban) Drainage Systems (SuDS) of GDARD, the Terms of Reference identify this report as 'Implementation Manual'. The total list of deliverables is as follows:

1. Inception report and skills transfer plan (not public)
2. Literature review on SuDS: definitions, science, data, policy and legal context in South Africa
3. Selection of three specific study areas: Kagiso, CBD Johannesburg and Bonaero-Atlasville
4. Data collection on SuDS installations in Gauteng
5. Analysis of Study Areas with recommendations
6. Decision Support Tools
7. Best Management Practices
8. **Implementation Manual**

All the previous delivered documents 2-7 are background documents to this Implementation Manual and available from www.futurewater.uct.ac.za/gauteng-suds-research or from http://www.gcro.ac.za/news events/news/detail/gauteng-launches-sustainable-drainage-manual/. As this is a research project, culminating in an implementation manual, the manual is not all encompassing, but comprises lessons learned from the research, that can contribute to accelerating SuDS implementation in Gauteng, where appropriate. The manual can also not be prescriptive but is more of a guideline than envisaged when the decision was made on the deliverables.

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1 INTRODUCTION

1.1 The reason for this manual

Gauteng is the most developed and most densely populated province in South Africa. It is the main economic hub in the country, with three metropolitan cities, and there continues to be growing demand for development space. The urban catchment areas are large, many are over 100 km^2, and the impact of traditional stormwater management has left many of the urban river systems severely degraded. The effect of rapidly expanding populations has placed severe strain on municipal systems and the province has the reputation of having the most severely polluted rivers in the country, impacting on water security.

Sustainable drainage systems (SuDS) are now recognised internationally as stormwater management Best Practice and they are starting to be adopted in municipalities in Gauteng. Policies and bylaws are being amended to address new development practices and there are studies looking at retro-fitting existing stormwater networks. Provincial departments are looking at SuDS as one of the measures available to address the development, environmental and climate (change) challenges facing the province.

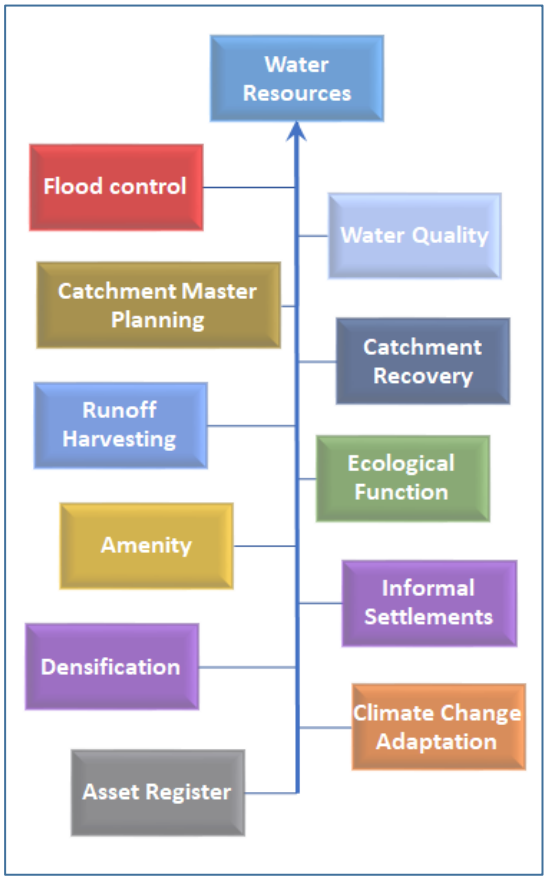


Figure 1: Factors influencing the management of stormwater as a resource (adapted from CoJ Stormwater Design Manual, 2019)

SuDS were initially conceived as a means of limiting the adverse effects of urban development on watercourses (Digman et al., 2012). In this study a review of current thinking around urban drainage undertaken showed a heightened level of research into SuDS and application in South Africa over the last decade. In the context of growing urban populations, climate change related threats and increasing focus on water security, urban runoff and the contribution of SuDS has taken on wider significance. There is now an increasing focus on its role in water security, and particularly in terms of water quality (see **Figure 1**).

However, the promotion of SuDS is not meant to imply that traditional grey stormwater infrastructure is excluded from stormwater solutions. In most cases a mix of grey and green (SuDS) are expected and should be accepted, as long as the discharge quantity and quality targets are met. In some cases, SuDS facilities

may be difficult to implement or will be insufficient to meet the discharge targets. In these instances discussions need to be held with the municipality to explore alternative solutions, which may include off-site interventions, such as strategic SuDS (see Chapter 7).

1.2 The scope of this manual

This manual seeks to provide a baseline reference for action to implement SuDS across the province. It is not a technical guideline for designing SuDS, but it draws on technical analyses of case study sites across the province, on consultation with stakeholders and on the experience of municipalities who are driving the transition to using these technologies.

Purpose of this Manual

This manual targets decision makers in municipalities especially those involved in guiding and regulating development, and in particular stormwater planning and implementation in the Province of Gauteng. It will also be a useful guide for Environment Assessment Practitioners and their specialists, as well as developers and their project teams. There is no legal status to this document; it is meant to support SuDS implementation, but it also tries to avoid presenting SuDS as a silver bullet.

This manual is not intended to cover all the requirements for expert users. Those planning, designing, constructing and maintaining SuDS will need to make use of additional training and references, many of which are identified in this document. Additionally, it is also expected that public officials, decision makers and EAPs who deal with applications of SuDS will need to invest time in understanding relevant details of SuDS technologies that may not be covered in this manual.

Main objectives

1. Introduce SuDS at a non-expert technical level to assist planners, developers, designers and authority reviewers;
2. Provide guidance and decision support to further the roll-out of SuDS in Gauteng and potentially elsewhere in the country;
3. Emphasize the benefits towards climate adaptation and water security objectives.

1.3 How to use this manual?

The Table of Contents gives an overview of the key questions answered in this manual. As SuDS systems are such an integrated topic, different aspects might come back in different chapters. Given the broad scope of this manual, it targets very diverse user groups, as summarised in **Table 1**. They might want to focus on looking up what is interesting for them in particular. Icons in the footer on the right pages will also guide different readers to relevant sections for themselves. Summaries of 'Key points' and tips for 'Further reading' and 'Recommended actions' are also shown with icons and placed in boxes.

Table 1 Target groups and relevant chapters

	User groups	EAPs and Reviewers of EIAs	SWMP designers	SWMP reviewers and municipal SWMP planners	Drafters of municipal bylaws and policy makers	Planners and Environmental managers	Developers	COGTA, SALGA and MISA
	Symbol in footer							
Chapter								
2	Understanding the basics of SuDS	✓	✓	✓	✓	✓	✓	✓
3	Understanding the current status of SuDS implementation in Gauteng	✓	✓	✓	✓	✓	✓	✓
4	Understanding the importance of catchment planning		✓	✓		✓		
5	Understanding the performance of SuDS	✓	✓	✓				
6	Dealing with retro-fit situations		✓	✓			✓	
7	Solving catchment challenges with strategic SuDS			✓		✓	✓	
8	Implementing sustainable SuDS	✓	✓	✓			✓	
9	Implementing through the planning and land development processes	✓	✓	✓		✓	✓	
10	Implementing by the province of Gauteng	✓						✓
11	Implementing by municipalities			✓	✓	✓		
12	Understanding the limitations of SuDS	✓	✓	✓	✓	✓	✓	
13	Recommendations				✓	✓		✓

Legend

Icon in footer	Targeted user Group
	EAPs and Reviewers of EIAs
	Stormwater Management Plan (SWMP) designers
	SWMP reviewers and municipal SWMP planners
	Drafters of municipal bylaws and policy makers
	Planners and Environmental managers
	Developers
	COGTA, SALGA and MISA
Icon in box	**Box contents**
	Key Point
	Further Reading
	Key action points

The planning and design of SuDS systems is best achieved through multi-disciplinary collaboration. This is addressed in more detail in the report 'Best Management Practices' prepared as part of this study. It identifies the roles of the different specialists who would typically participate in these projects; urban planners and designers, stormwater design engineers / hydrologists, ecological specialists, landscape architects and those involved in community liaison / stakeholder engagement facilitators.

2 UNDERSTANDING THE BASICS OF SUDS

2.1 What are SuDS?

SuDS use natural drainage systems to help to maintain or restore flows in urban streams and surface water systems to more stable and sustainable conditions. SuDS help manage both stormwater quantity and quality and integrate with other parts of the urban hydrological cycle including soil water, groundwater and evaporation. This also gives an opportunity for harvesting stormwater as part of building resilience for water security.

SuDS use techniques based on natural systems to control stormwater runoff from paved urban spaces. At the same time these natural systems are able to support biodiversity and add to the open green space which is important to the wellbeing of communities. The objective is to convert as much of the urban space to surfaces that absorb rainfall in the same way that natural vegetation and soil does (**Figure 2**). Hence most SuDS technologies are based on the functions of the hydrological soil model as shown in **Figure 3**. This is a central feature of SuDS design.

The soil (or other porous media) in SuDS facilities provides the stormwater retention capability that helps reduce the overall stormwater runoff from a site over time, while improving its quality. In between rain events soil-water storage capacity is continually restored through evapotranspiration back into the atmosphere (1 in **Figure 3**), lateral movement as subsurface flow and deeper infiltration into soil substrate and local aquifers (2 in **Figure 3**). SuDS also offer a third means of reducing surface runoff; the option to harvest water from the system (3 in **Figure 3**). These are referred to here as the key "retention factors" that SuDS designers will use to control site runoff to achieve stormwater objectives.

In the design of a SuDS facility these three "retention factors" may be rebalanced or individually enhanced depending on site conditions and the priorities for stormwater management. This also enables SuDS facilities to perform when receiving runoff from adjacent paved areas of the site. The ability to rebalance the retention factors also expands the potential for managing stormwater as part of the urban water cycle, creating water resource potential and working towards Water Sensitive Urban Design (WSUD).

WSUD was explored in the South African context by Armitage, et al (2014). It places stormwater as an important part of the urban water cycle that includes water consumption (supply), waste water (sanitation) and groundwater (see also Section 5.2). The adoption of WSUD in South Africa (CSIR, 2019) has placed greater emphasis on the water resource management functions of SuDS. Stormwater quality and quantity is now more critically analysed and the potential to enhance the performance of the three "retention factors" creates opportunity for sustainable stormwater management across all urban land uses.

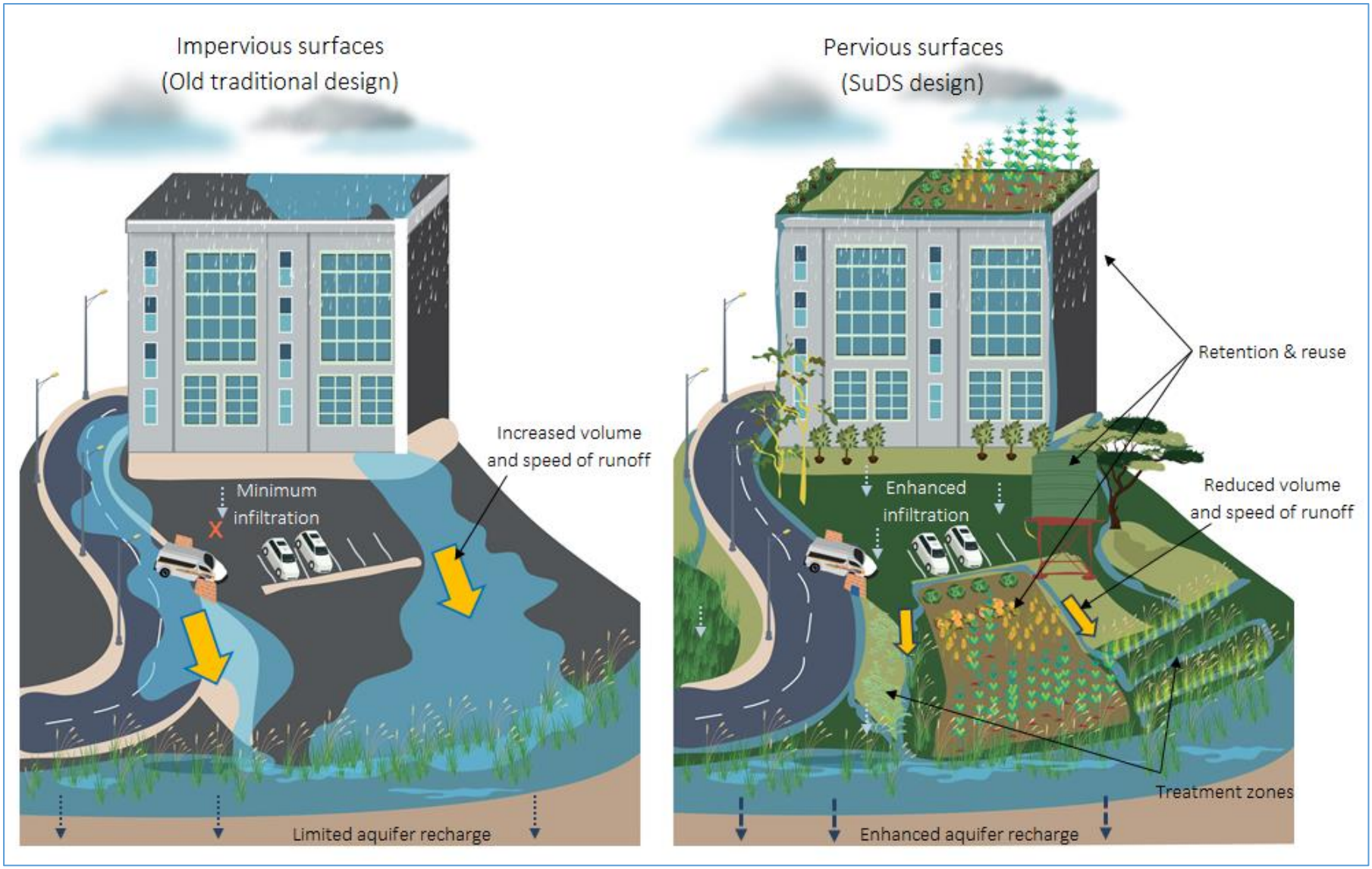


Figure 2: The effect of changing hard impervious urban spaces to greener, absorbent pervious spaces. (Courtesy of Urban Rivers Alliance).

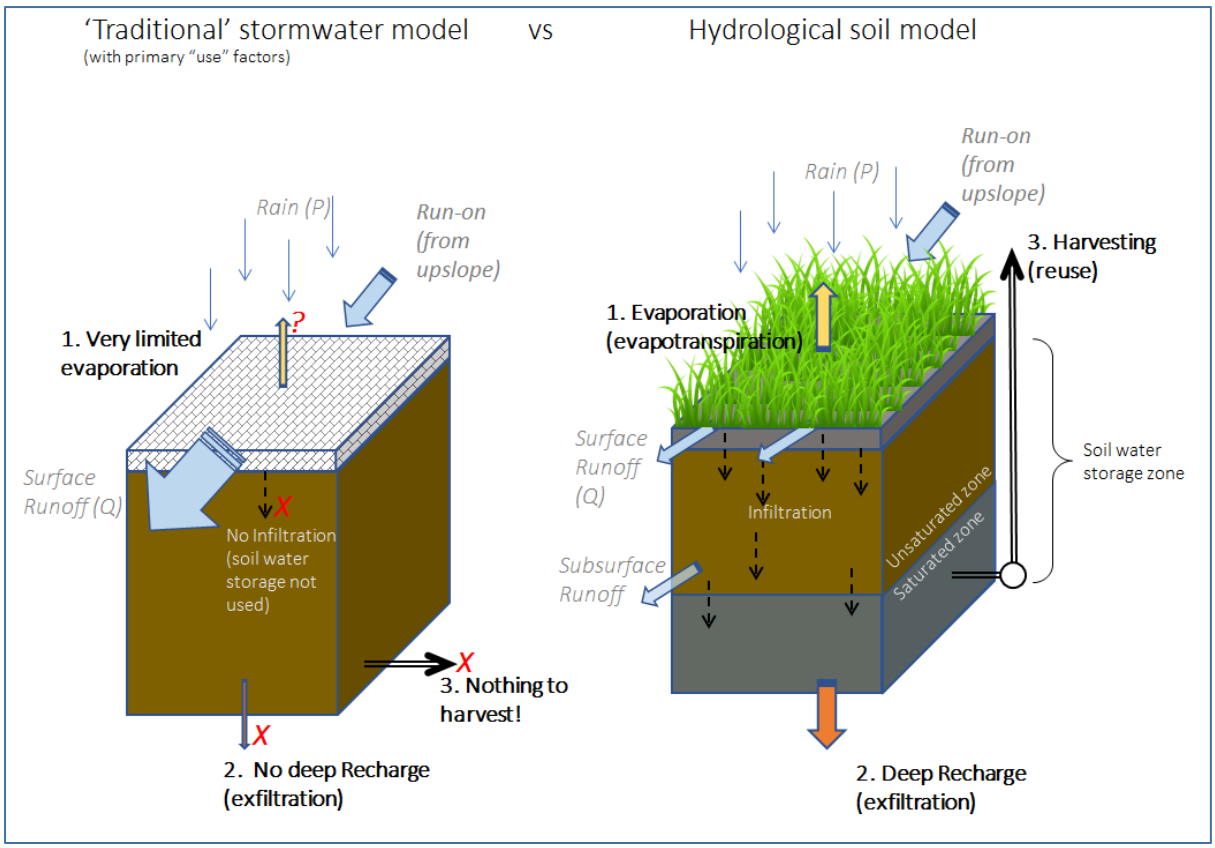


Figure 3: Hydrological soil model compared to a 'traditional' pavement runoff model, showing primary "retention factors"; (1) Evaporation & evapotranspiration, (2) deep recharge and (3) harvesting (reuse). (Courtesy of Fourth Element Consulting).

2.2 What are typical SuDS facilities?

SuDS comprise of many different facilities that can be used to design tailored solutions and that can be adapted to for different urban development requirements. SuDS facilities perform best when combined together in a 'treatment train', designed with knowledge of the properties of the soil water storage zone, and site-specific conditions.

A comprehensive introduction to SuDS-facilities is provided in 'The South African Guidelines for Sustainable Drainage Systems' by Armitage, et al (2013) is available from the Water Research Commission website. SuDS facilities are summarized in **Table 2** below.

All persons involved in the planning, design and implementation of SuDS should make themselves familiar with the South African Guidelines to different levels, in order to develop and evaluate SuDS solutions. This will include developers, designers and planners, along with EAPs and EIA reviewers, and municipal Roads and Stormwater departments. In time, more specific design guidelines and specifications will need to be developed for each technology for specialist applications (see also CSIR, 2019).

Table 2: SuDS facilities for treatment (Armitage et al., 2013)

Source controls	Local controls	Regional detention
Green Roofs[1)]	Filter strips[1)]	Detention (attenuation) ponds[2)]
Rainwater harvesting[3)]	Swale[1)]	Retention ponds[1) 3)]
Soakaways	Infiltration trenches	Constructed wetlands[1)]
Permeable pavements	Bio-retention areas[1)]	
	Sand filters	

Note:

1) *SuDS facilities that typically support vegetated and ecological systems.*
2) *SuDS facility that can be designed to also serve as sports field / recreational park (subject to addressing any associated hazardous conditions).*
3) *SuDS facility typically better suited to surface water harvesting.*
4) *All of the facilities offer treatment of stormwater quality. The only facility with limited potential is rainwater harvesting. Enhancing treatment potential is part of the design of each facility. Almost all SuDS facilities offer the potential for shallow or deep aquifer recharge. The exception may be rainwater harvesting, but even that could be adapted by promoting the infiltration of stormwater overflow. Aquifer recharge offers potentially significant water resource benefits in Gauteng, but not all sites are automatically suitable for deeper infiltration and recharge. This must be addressed with care in the design of SuDS systems at a site.*

As mentioned, the soil water storage zone is the key element of the hydrological model and is the main difference with traditional stormwater analysis on paved areas. Soil water characteristics vary between soil types. Hence soil selection is important, but most SuDS designs seek to improve aspects such as infiltration rates, storage capacity and pollution treatment potential. For example, the adaptations will include engineered soils in bioretention filters (special mixes of sand, silt and clay), and different grades of stone or aggregate in permeable paving or infiltration trenches.

As in nature, the soil water zone provides a temporary storage of stormwater which fills and drains over a series of rain events. This water balance is an important part of the analysis of the performance of SuDS facilities as it affects the overall contribution of stormwater runoff into the receiving stormwater network, and it helps estimate the harvesting potential of the treatment train.

The importance of the SuDS treatment train, instead of just relying on single SuDS facilities, is described in literature, and particularly by Armitage, et al (2013). The treatment train offers considerable flexibility for developers to integrate SuDS across site developments without compromising wider development objectives, and still meet stormwater control requirements. Hence, there are often many potential solutions to stormwater management on a site and adjustments to site layouts may continue well into the detailed design stages. This places particular requirements on

the SWMP permit, EIA and WULA processes that the authorities need to consider in the future implementation of SuDS in the province (see Chapters 9, 10 & 11).

In deliverable 2, the report 'Literature review on SuDS definitions, science, data, policy and legal context in South Africa', Chapter 3 discusses relevant South African research since 2013 for different SuDS facilities. It also explains data and models that may be useful for SuDS design. The Literature Review gives an overview of insights gained through South African research on SuDS facilities since the publication of the South African SuDS Guidelines (Armitage et al., 2013). The South African SuDS Guidelines itself is very useful for giving guidance on the choice of SuDS facilities and for determining design parameters.

2.3 Do we need sticks, carrots, own initiatives and oversight?

Legal enforcement will remain the primary incentive for the uptake of SuDS, but this needs to be backed up by authorities with efficient permitting processes and administration of the bylaws, as well as better oversight of the maintenance of stormwater systems. Other incentives may be explored, but existing municipal challenges of financing and maintaining stormwater systems, and enforcing bylaws, may limit tariff related incentives in the short-term.

The sticks

Presently (2019) stormwater management is enforced through the land development process. Therefore, the framework provided by municipal policies and bylaws is critical to the uptake and enforcement of SuDS in the short-term (see Chapter 11). The EIA and WULA processes can also help in enforcing SuDS but municipal legislation will be the primary vehicle for enforcement. Therefore, an important step towards implementation of SuDS across the province will be to ensure that all municipalities include requirements for SuDS in all stormwater permits.

However, as water sensitive urban planning and catchment management processes begin to take effect, these will reinforce the role of SuDS in the urban landscape. They will provide more specific targets for surface water management at a catchment scale that will assist in the land development processes at a site scale. Hence developers will have a clearer framework for stormwater management before they start planning their site.

The legislation should allow for creative design solutions and include the requirements for monitoring and maintaining the facilities once constructed to evaluate performance against pre-development baseline conditions. These baseline conditions should be captured in the planning and design phases and reported in the design reports and EIA reports.

Creative design can be an iterative process that is not an easy fit into a "step-by-step" design guide. Therefore, a recommendation in this manual is that the permitting processes (SWMP, WULA and EIA) are adapted to make provision for the issue of an "Agreement in Principle" at concept design stage for SuDS drainage systems where system performance targets are set but the details will continue to be refined through iterative interaction with the multi-disciplinary team as the detailed design develops. Performance targets will include stormwater quantity and quality as well as ecological, amenity targets and any other potential "use value" factors (see also Chapters 8, 9 & 11).

Details of all stormwater assets, including monitoring and performance data should be captured in an asset register. The register should seek to include stormwater assets on both municipal and private properties. The asset register may be best held and maintained by each municipality, though alternatives could be considered. Provincial oversight of the asset register will be important.

Registration and oversight of stormwater assets on private property is often a point of concern raised by municipalities. However, efforts will need to be made to address this if catchment targets for water quality and quantity (including flood control) are to be assured. Town planning instruments such as conditions of establishment and stormwater servitudes are examples that may assist, but this needs to be taken up at municipal level.

Good municipal policies and bylaws will mean little if they are not adequately backed up by efficient municipal administration. This backing will include effective guidance provided by municipal officers in the consultation stages and an efficient permit approval process. Problems in these areas will undermine the value of the bylaws, and a breakdown of the system will occur (see Section 9.5). SuDS should become increasingly attractive for many development projects.

The carrots

Incentives to introduce SuDS will also be an important part of the attractiveness of SuDS. Most of the benefits of the SuDS referred to in literature are linked to the benefits of ecological enhancement and amenity services associated with SuDS interventions, as well as the belief that investment in SuDS is for the greater good of the environment. Developers will generally accept these incentives if there is clear follow through by municipalities in encouraging SuDS (e.g. by good administration of SWMP permits) and by enforcing the bylaws equally across the municipality. However, much of the stormwater value of SuDS is only experienced downstream of the SuDS facilities. Reducing maintenance on stormwater networks, reducing flood risk, improving resource quality and river health, and delaying bulk infrastructure upgrade and investment are some of the benefits to downstream systems, many of which will help to alleviate the financial burden on municipalities. Therefore, acknowledgement of all upstream efforts through positive incentives may be an important part of municipal strategies to encourage SuDS. There are examples internationally where municipal tariff related incentives have been applied, but in South Africa there is no direct stormwater related tariff. Fisher-Jeffes and Armitage (2013) identified the problem of underfunding of municipal stormwater services and that there is merit in introducing a stormwater charge as part of the monthly municipal bill in a manner similar to the wastewater charge. They then propose that a discount would

be applied for those properties that demonstrated SuDS measures and a reduction in stormwater runoff. However, the tariff system needs to be in place first. Alternatively, an approach based on the bulk services contributions that some municipalities currently apply, may be opportunities to be considered. Ideally such measures would be structured in a manner that ensures the long-term performance of the facilities.

However, it is acknowledged that the financing of and maintaining stormwater infrastructure is problematic in many municipalities in the province and this will complicate the setting of tariff incentives. Additionally, the enforcement of bylaws equally across the entire municipal area is also a challenge. As such even the downstream benefits of SuDS will not be obvious if significant areas of the urban catchment have stormwater systems that are compromised, for example, by high levels of sewage and wastewater. Hence, the efficient administration of the SWMP permitting processes where SuDS are applied is likely to be the main incentive towards the uptake of SuDS in the short-term. This will apply to all stormwater related permits (EIA, WULA) and is addressed further in Chapter 9. Municipal and provincial government will have key roles to play in this.

Own initiatives

Some developers have already demonstrated willingness to introduce SuDS-based stormwater management. They recognise the added value of SuDS as part of the amenities and green open space of a development. Even in the inner city areas there have been significant rejuvenation projects where SuDS were identified as opportunities to introduce green spaces. However, many of these initiatives appear to be linked to high value developments, and the challenge will be to encourage developers at all levels to see the advantage of SuDS based stormwater systems.

Government and municipalities also have opportunity to take the initiative. Municipalities have their own stormwater infrastructure (around roads and streams), as do provincial entities (e.g. provincial roads, provincial properties). In places they may also need to consider strategic SuDS interventions to address catchment related problems (See Chapter 7) and these will invariably involve municipal land. Initiative can also be applied to the planning process, especially urban rejuvenation and densification plans.

Oversight by authorities

The current oversight role of government focuses on the establishment stages of land development (e.g. spatial planning and development approvals). Opportunities for SuDS in these stages are addressed in Chapters 9, 10, and 11. There is also a need to focus on the post-construction stages where monitoring and maintenance is an essential part of confirming the performance of the stormwater systems that have been built. This is also a key part of monitoring the resilience of the stormwater systems, and a measure of the progress towards longer-term water security objectives.

2.4 Who is responsible for SuDS installations?

SuDS need different stakeholders and multiple disciplines to be involved, but someone (a department or a group) must take responsibility for initiating and managing the program to 'pull the cart'.

Typically, traditional stormwater systems on private land are the responsibility of the landowners (including homeowners associations and estates), and systems in the public space (including most bulk systems) are the responsibility of the municipality. Responsibilities include planning, designing, building and maintaining. Maintenance includes ensuring the long-term performance of the system. Although this framework will still apply for SuDS systems, SuDS are generally established as part of a shared space with multiple actors involved.

Loading the cart…

A multi-disciplinary, multi-departmental and cooperative governance approach to SuDS, along with community involvement (and "buy-in") will make SuDS more acceptable, robust, and sustainable. In the public space, the Stormwater department / entity of the Municipality should cooperate with the Parks department / entity and the Environmental Department. When different departments / entities and the community are involved SuDS projects can be perceived as risky unless "ownership" of the SuDS treatment train can be clearly identified. The "silo" factor in municipalities and professional sectors, and the institutional boundaries between province and municipalities, are examples of obstacles that stakeholders will see as impediments to the implementation of SuDS. Also, if a SuDS project is developed in this manner, as recommended, it will require a team to execute the multiple tasks well.

Pulling the cart…

It is just as important to ensure that someone (department or group) oversees the effective operation of SuDS facilities. Within municipalities it is logical for the Stormwater department or entity to 'pull the cart' with a dedicated champion assisting in the culture change. On the developers side it is ideally the developer who would 'pull the cart' and drive the sustainable development approach of which SuDS will be part. Typically, developers assemble teams they are comfortable working with and so they may not appoint a professional team expert in SuDS unless they are looking for this. However, in the transition phase while developers become aware of the need for, and benefits of, SuDS it will be important that the professional team provides the right guidance. At the forefront will be the urban designer, civil engineer, stormwater specialist, landscape architect and EAP.

Like all services, SuDS will need maintenance, mostly "low tech" maintenance, but observation and monitoring of the performance of the system will also be critical or the facility will eventually fail. This may be a particular challenge for municipal structures where change will be needed to enable sharing of personnel and budgets. Professional institutions should also coordinate multidisciplinary teamwork training (see Chapter 9).

Deliverable 7, the report 'Best Management Practices' explains what each type of expert needs to do to improve on SuDS uptake, design, implementation and sustainability.

2.5 What is the contribution of SuDS to climate change adaptation and water security?

The important contribution of SuDS to climate change adaptation is to reinforce water security measures. This will be a combination of water quality improvements and creating opportunity for stormwater harvesting. Other benefits such as mitigation flood of flooding problems and heat island effects will add value and should be part of strategic initiatives targeted at specific problem areas.

Climate projections point to the kinds of changes that may be expected for Gauteng. These include higher temperatures, greater inter-annual variability of rainfall and stream flows, and increasing flash flood conditions (GDARD, 2018). Water security for the province is also cause for vigilance. The province is dependent on water imported from other provinces and Lesotho that are also subject to climate variability and change. The limited local water resources in the province are severely polluted by its own drainage and sewerage networks. This will need to be addressed if the province is to achieve the diversified water resource mix needed to ensure water security (GCRO, 2019).

SuDS clearly have a role to play in addressing all of the above, although it is not the 'silver bullet'. Its capacity to mitigate the effects of urban land development on the hydrological cycle will help buffer the effects of the projected climate changes anticipated for the province, in the following ways:

- **The ability to retain storm rainfall within urban catchments will help regulate stream flows and make stormwater runoff more accessible for harvesting.** The nature of stormwater runoff in urban catchments makes it difficult to harvest; the volumes are too large and it passes too quickly. SuDS reduce runoff volume and increases response time, creating more opportunity for harvesting. In doing so it also creates more opportunity for soil water and aquifer recharge and storage which can counter the effects of urban paving and improve the local water resources potential in the catchment. Although there are potential risks associated with increasing infiltration and seepage conditions at a site (for example the impacts on foundations of nearby structures and buildings), local aquifer recharge is a significant area of research into water security for Gauteng.
- **SuDS can reduce the effects of flash flooding if it is designed to do so.** Although SuDS facilities can be vulnerable to flood conditions (and therefore they may be bypassed by flood storm flows), they can be designed to manage flood peaks. A combination of detention and retention methods applied across a site or catchment can be designed. Detention ponds in SuDS treatment trains will usually be smaller than the equivalent units in traditional typical grey infrastructure networks.

- **SuDS treat stormwater quality at source, improving the resource value of the water and increasing its re-use potential.** Stormwater has a serious impact on the water quality of the river systems around Gauteng. SuDS have the ability to treat a range of pollutants including sediment and sewage loads which the two most common across the province. Designing for water quality treatment performance is an important addition to stormwater management on a site, but setting catchment targets will be needed to develop a framework for SuDS interventions across a catchment. This may point to the need for more than incremental application of new or retro-fit SuDS as land development projects arise (see Chapter 6), and more strategic SuDS interventions will be required (see Chapter 7).
- **SuDS are also an important part of Green Infrastructure that can help mitigate the effects of urban heat effects at a local scale.** SuDS treatment train corridors provide opportunity for introducing tree planting and shade generation that will help mitigate the effects of exposure during the day (see Chapter 12). These benefits will only be seen at a city scale with the roll-out of SuDS across the urban areas of the province. Therefore, considering SuDS as part of a climate adaptation strategy for the province will place emphasis on retrofitting SuDS (see Chapter 6).

Box 1: Quotes from the Executive Summary of "Water Security Perspective for the Gauteng City-Region – Securing water for continued growth and wellbeing"

"In the longer term, this urban province must work to build a more resilient community that can live comfortably with its available water resources and manage the risks that it faces. This requires action well beyond the water sector. Settlement planning and housing design can dramatically change peoples' water needs – for better or worse. Careful consideration of how peoples' built environment interacts with natural ecosystems can reduce risks of natural disasters and contribute to a safe and productive environment. Critically, the people of Gauteng need to understand how their water reaches their homes and workplaces, where their wastewater goes to and how their behaviour can keep that cycle working."

"Stormwater - The management of stormwater – and subsequent risk of flooding - is a municipal responsibility, often assigned to their roads divisions. Urban planning and development must take account of the management of stormwater to reduce flooding risks and health hazards as well as water supply and wastewater disposal requirements. In the long term, the goal must be to make Gauteng's cities greener and more sustainable. "

"The water mix must be diversified where possible. Groundwater, wastewater re-use, treated acid mine drainage, and rainwater harvesting are potential sources of water that can improve water security in the province. " (GCRO, final draft August 2019)

The Climate Change Adaptation Framework for the City of Johannesburg (Vogel and Molefe, 2017) provides a very useful overview of developing the adaptive capacity necessary for proactive adaptation to climate change.

To all wanting to become acquainted with and contribute to SuDS implementation:

- Use the South African Guidelines for Sustainable Drainage Systems (Armitage et al., 2013) as your first basis for understanding SuDS and SuDS facilities.
- Realize the reasons why people / organisations design, implement or maintain SuDS (sticks, carrots, own initiative, oversight) and define your own reason and role in adding to these reasons.
- Realize that SuDS need a multi-disciplinary team involving different stakeholders and initiate such a team, or identify the person / organisation to 'pull the cart'.
- Make use of the role that SuDS can play in water security and climate change adaptation as well as important design approaches such as 'nature based solutions', 'green infrastructure', 'water sensitive urban design'.
- Use this to convince others of the importance of SuDS or consider SuDS as they fit in these design approaches.

3 UNDERSTANDING THE CURRENT STATE OF SUDS IMPLEMENTATION IN GAUTENG

3.1 How far are we with the uptake of SuDS in Gauteng?

There is awareness around the possibility of implementing SuDS in Gauteng, but mostly not in a manner targeted at stormwater management, and with very different approaches between the different municipalities and no coordinators 'pulling the cart'.

This project identified 45 existing SuDS locations in Gauteng, though few were designed specifically as stormwater management functions. Most were implemented by developers of estates, at their own initiative. In many cases, they were designed for their amenity value in the landscape or for water harvesting. More examples of SuDS projects are emerging as discussions on the topic spread. For Johannesburg, more are already being identified by the Water Sensitive Urban Design project of the University of Cape Town on Johannesburg. (see further reading below)

The project also interrogated some lessons learned with implementation of such SuDS by the early experts in SuDS. Generally, SuDS implementation was hampered because developers did not see the added value in terms of cost savings (i.e. water harvesting) or municipal stormwater managers were sceptical, or the team working on the development did not have sufficient expertise to design the SuDS.

The need for an inventory, asset register or similar reference for case histories and learning points for application of SuDS in Gauteng conditions is clear. This will assist in developing a community of practice (see below) that will help drive the uptake and implementation in the province.

Deliverable 3, the report 'Data collection on SuDS installations in Gauteng' provides a preliminary inventory of SuDS projects Gauteng. It lists some 45 SuDS related projects in the province and describes important learning points that they offer. They are also publicly available on www.climatescan.org. This inventory on www.climatescan.org is being added to further through the Future Water Institute at the University of Cape Town (www.futurewater.uct.ac.za), for Johannesburg, as part of a Danida-funded project on water sensitive urban design in Johannesburg ('Pathways to water resilient South African cities'), thus not only comprising SuDS but also other projects contributing to water sensitivity. The University of Cape Town is also facilitating the Water Research Commission in setting up a community of practice around water sensitive urban design.

3.2 What policy and bylaws are already in place that support the uptake of SuDS?

The municipalities of Gauteng have very different approaches to SuDS and there are insufficient coordinators 'pulling the cart'.

The metropolitan municipalities in Gauteng are moving towards SuDS awareness and implementation though they are at different levels of policy and bylaw development. References to SuDS are sometimes scattered over different policies, but the concept of SuDS is gaining traction. Some highlights:

- The GDARD has in its 'Gauteng Environmental Management Framework' certain regulations to promote SuDS. The department also has the Gauteng Sustainable Development Guideline – A condensed version I of 2016 which also speaks to stormwater designs to accommodate SuDS technologies.

- The draft water security perspective for the Gauteng City-Region Observatory (GCRO, 2019) states that the province needs to diversify water sources and mentions that stormwater as an alternative source requires investments (See **Box 1**).

- The City of Tshwane uses its regulatory role and incentive schemes to encourage developers to introduce SuDS through its Green Building By-law (CoT, 2013). Water harvesting as well as stormwater retention is promoted with incentive schemes, with a simple target of 80% of overall average rainfall to be retained on site. This approach is common internationally where the primary focus is on flood management, but it raises questions about impacts on stream flow and water resources, including environmental flow requirements, which would be addressed through a WSUD based approach. The City of Tshwane also has a policy for communities to be engaged in the management of open space and is piloting the roll-out of Cool Surfaces interventions (surfaces and materials that help in reducing heat stress). SuDS can fit as a measure, dependent on the surroundings and choice of vegetation.

- The City of Johannesburg has developed a detailed stormwater design manual (CoJ, 2019) that places emphasis on stormwater as a resource. It presents methods for analysing the stormwater yield from a site (or catchment) which provides a basis of determining the performance of a SuDS treatment train (and a stormwater network). The approach places greater demand on modelling and expertise and there are early concerns about the practicality of the approach. However, it directly addresses the requirements of the current bylaws (CoJ, 2010) and provides a platform for stormwater design under the principles of WSUD. In parallel with the stormwater manual the City is also busy developing a Greening and Green Infrastructure Strategy.

- The City of Ekurhuleni is in the process of reviewing its stormwater policy and has targets to 'develop a rainwater harvesting industry'. Details of this are still to emerge.

- The Sedibeng District Municipality and the West Rand District Municipality in their climate change vulnerability assessment (West Rand District Municipality, 2016) mention SuDS as a solution to their flooding problems and also as a source of water. Mogale City has also been positively involved in this project.
- The Gauteng Department of Infrastructure Development in conjunction with Gauteng Department of Education, have the programme 'Green Technologies in existing and new Infrastructure' in which they install water harvesting tanks in schools to promote food gardening.

This shows awareness is already there at municipal level about SuDS, or certain SuDS facilities, playing an important role in stormwater management. However, local municipalities have expressed concerns about the limited resources they have to manage the shift away from the common grey infrastructure management approach towards a SuDS approach. Also, there are no efforts yet to learn from each other and standardize the different policies and approaches (see Section 10.4).

Deliverable 2, the report 'Literature review on SuDS definitions, science, data, policy and legal context in South Africa' has an overview of relevant municipal and provincial documents in which the highlights mentioned in this chapter are explained and referenced.

For all:

- When working in a certain municipality, recognize which policy and by-law conditions in that municipality are favourable and less favourable towards SuDS. At the same time, do not hesitate to 'look over the fence' and learn from what other municipalities are doing.
- Contribute to the body of experience on SuDS projects, by, for example, also uploading implementation projects and best practices to www.ClimateScan.org.

For Gauteng Province, with support of CoGTA and SALGA:

- Encourage alignment between the different municipal stormwater regulations, policies and those influencing SuDS implementation (see further Chapters 9, 10,11).
- Coordinate the body of experience from SuDS projects and lessons learned (see further Sections 11.4 & 12.5)

4 THE IMPORTANCE OF CATCHMENT PLANNING

4.1 Why does the small scale implementation of SuDS hardly make a difference in the larger catchment?

"The impact of the whole is greater than the sum of the parts". The intention, therefore, is that the greater part of an urban catchment converts to implementing SuDS over time.

Each component of a SuDS system makes a difference, but it is the cumulative effect of all the components together that makes significant impact. This is confirmed in the case studies investigated as part of this project. The impact of a treatment train on site scale will be significant, but when viewed in the wider catchment context, where few other sites have implemented SuDS, the effect can appear to be lost. The intention, therefore, should be that the greater part of an urban catchment converts to implementing SuDS over time.

In Gauteng, where large areas are already fully developed, "recovering" a catchment back to its natural, pre-development, hydrological condition may not be practical, and it may also not be the best WSUD objective if stormwater harvesting can help support the catchment water demand requirements. Hence catchment "recovery" will be defined in a long-term vision that will set catchment objectives in stormwater management. In turn these will help guide the stormwater discharge objectives for site development planning. However, this vision will need support from policies and bylaws as well as their enforcement and a change in mind-set on how the planning and implementation processes are integrated (see Chapter 9).

4.2 What role can Catchment Management Plans play?

Objectives for SuDS should be set out in a Catchment Management Plan (CMP). Objectives may vary between catchments.

The Catchment Management Plan (CMP) currently has no legal status, but the outcomes of this research study reinforce its importance in stormwater planning and design, and it will also be important in helping set out WSUD objectives in an urban area. A CMP will help set the vision for an urban catchment and it can demonstrate what progress is required in implementing SuDS to make a noticeable difference. The vision should include how stormwater runoff is to be managed; whether there is an interest in harvesting for reuse, for ecological function and/or amenity use, or how it should be managed to achieve a balance of these interests. Spatial variation in objectives across the urban catchment can also be entertained, provided they work towards the overall objectives of the CMP. The CMP will also highlight parallel initiatives that will be needed to achieve water resource goals. These may include measures to improve sewage services, litter management and water conservation

measures by municipalities or landowners. A CMP should provide a framework within which the respective initiatives, including SuDS, need to perform.

A key outcome of the analyses of the case study sites showed that while the benefits of SuDS measures in a treatment train are cumulative, the combination of SuDS technologies should be optimised for performance and investment. Thus, all analysis should be done within the CMP based framework, where SuDS applications in other parts of the urban catchment will inform the selection of the components of a treatment train at a site.

It is important that municipal CMPs acknowledge wider regional water resource strategies that may be put in place by the catchment management agencies established in terms of the National Water Act 36 of 1998. Consultation with the Department of Water, Sanitation and Human Settlements, Gauteng office, will be important in this process. The essence is that stormwater management – from the private property scale up to catchment scale – plays a crucial role in water security and environmental protection.

In the hydrological water cycle, stormwater management also influences how much water ends up as groundwater. With the tendency in Gauteng to make more use of groundwater as a potential resource, the recharge of this groundwater through stormwater management will need to be given sufficient attention in the CMPs.

Hence there is a clear need to include Catchment Management Plans into the legislative framework that recognises its functions at both a municipal and regional scale.

4.3 How does catchment planning need to link with water supply and sanitation?

Stormwater planning needs to set targets to play a role in providing water security in Gauteng through allowing natural infiltration and/or direct water harvesting and/or through the appropriate treatment of stormwater.

To support the water security perspective of increasing the water mix in Gauteng (GCRO, 2019), the demand on the potable water supply systems as provided by the water services authorities (such as Rand Water) need to be decreased (See **Box 2**). Apart from significantly decreasing household water demand and leakage levels, there is potential to use SuDS in achieving this target in three ways: firstly rain and stormwater harvesting options provided by SuDS, secondly decreasing demand for irrigation of gardens and parks by utilising captured water from SUDS and thirdly increasing groundwater recharge through SuDS interventions. With Rand Water and the other Water Services Providers and Authorities being such key players in communication with the public on water, this requires coordination with them. The City of Johannesburg, as a water services authority, is formulating a new policy to create more options for SuDS. Rand Water and the water services providers could provide inputs where SuDS pilots should be prioritized from a water supply perspective and assist in

communicating to developers / property owners on how site specific SuDS can increase their own water security and/or reduce their water bills.

Land development pressures have also resulted in significant impacts of water services on stormwater and river systems. Informal settlements and informal densification of residential areas are generally the cause of severe sewage, sediment and litter loads in receiving networks. Hamman, et al (2018) reported a 51% increase in informal dwellings across Gauteng between 2001 and 2016. The increase in backyard shack dwellings in the same period is 205%. The impact of informal development on stormwater systems is likely to be increased by the provision of partial water services, or of inadequate services, resulting in overloading of sanitation and stormwater systems. In these areas strategic SuDS–based solutions may provide the only opportunity for relief in the receiving stormwater and river systems in the short-term (see Chapter 7). Also, stormwater ingress into sewerage systems can cause temporary overloads at wastewater treatment works which can have big impacts on pollution in rivers. Engaging with those responsible for wastewater treatment works can help to set priority areas for the prevention of such ingress with SuDS to help overcoming part of the problem.

Box 2: Rand Water targets in decreasing central water supply

Rand Water, which supplies water to practically the whole of Gauteng, is targeting water demand in its supply area not to surpass 1600 Mm^3/year, at least until the next phase of the Lesotho Highlands water project is in place. This means that industry and consumers need to decrease their use of water provided. The per capita water use of Rand Water (including industrial use) needs to decrease from about 300 l/c/d to on average 220 l/c/d by 2028, based on a population growth rate of 3.07%. (GCRO, final draft August 2019)

When planning or reviewing site SWMPs:

- Ask if there is a Catchment Management Plan (CMP) or a Catchment Management Strategy (CMS by Catchment Management Agency) in the catchment where the SuDS project site is located. If a CMP is not available[1] then confirm what basis (or method) was used to determine how runoff from a site is to be managed to achieve long-term objectives. This may vary between municipalities[2] and even catchments.

For municipal stormwater departments:

- Include CMPs into municipal planning and stormwater legislation and policy.
- Initiate catchment management plans and link these to water supply and sanitation planning to set the right targets and priorities.

For Gauteng Province, led by GDARD:

- Include CMPs into planning and water resource legislation and policy.
- Oversee the establishment of Catchment Management Plans (CMPs) by the municipalities for all catchments in the province. These CMPs need to be reviewed and updated every five years, in line with Catchment Management Strategies. Once the Catchment Management Agencies (CMAs) are operational in Gauteng, these tasks can be taken up by the CMAs.
- Provinces can also lead the process of developing Catchment Management Plans, as most catchments traverse municipal boundaries. This must be done in consultation with the Department of Water Affairs. The province should support CMPs for catchments straddling more than one municipality to ensure provincial coordination and consistency.

[1] At the time of writing there are very few catchment management plans across municipalities in the province that give guidance on the management of stormwater in terms of development control. Until these become more widely available, developers and practitioners will need to rely on other municipal guidelines.

[2] Default values are used by some municipalities. These may vary from discharge limits based on very old assumptions, or precautionary defaults such as is adopted by the City of Johannesburg: “post-development discharge may not exceed pre-development discharge under all rainfall conditions”.

5 UNDERSTANDING THE PERFORMANCE OF SUDS

5.1 Why is it important to understand the stormwater management performance of SuDS?

The intended performance of a SuDS system for stormwater management is the performance within a treatment train which needs to meet the overall performance requirements of the downstream drainage system.

The benefit of an integrated stormwater network is that downstream areas benefit from upstream investment. This also means that investment in downstream stormwater infrastructure should be less, if the upstream controls can be relied upon. This is the cumulative benefit of an integrated system. Therefore, some assurance of the performance of the individual components of the system is important. As cities transform to WSUD the performance of the integrated stormwater network, both stormwater quantity and quality will become increasingly important.

Like conventional ('grey') stormwater infrastructure systems, SuDS facilities must perform stormwater functions to identified targets of runoff quality and quantity control. This requires the integration of SuDS facilities into a treatment train, and the integration of the treatment train into the downstream drainage network. Importantly, the downstream network will become reliant on the performance of the upstream systems. Hence understanding the intended performance of a SuDS facility, or treatment train, is critical to wider network planning and performance.

Unlike well maintained conventional stormwater systems, the hydraulic performance (and therefore the treatment performance) of nature based systems is highly variable. For instance, seasonal variations in vegetation cover can change the hydraulic capacity of a facility, and infiltration rates may vary with soil compaction, changes in organic content in the soils and sediment build-up. SuDS design technology has advanced enough to enable the performance of SuDS systems to be estimated to a level sufficient for treatment train and network planning and design. It is important for municipalities and GDARD to become familiar with the levels of performance of these systems.

The natural variability of the performance of SuDS facilities also places extra importance on the monitoring and maintenance of the systems. Changes in performance are often an indication of the need for maintenance interventions such as sediment removal, soil replacement, infiltration media cleaning, etc. Poor maintenance is one of the main reasons for the poor performance of SuDS systems.

5.2 How to check whether the design approach is appropriate for different types of stormwater management methods?

The performance measures, the design methods and the expertise required are different for the different stormwater management methods. The management methods include traditional municipal drainage systems, those with additional attenuation facilities, those with SuDS and those for Water Sensitive Urban Design.

Traditional municipal stormwater systems

The primary objective of grey infrastructure systems as designed through 'traditional' stormwater management methods is to drain the rainwater runoff from a site. There is no intent to alter the nature of the runoff (volume, peak flow, water quality). Hence performance is measured in how effectively and efficiently the runoff is removed from the site area. Hard conveyance systems (concrete drains and pipes) are ideal for this kind of system.

Measures, Methods and Expertise for traditional municipal stormwater systems

Performance measures will include:	**Design methods** will include:	**Expertise** required:
• Assessment of the frequency and depth of surface ponding in the site area, to overcome inconvenience, and risk of damage (flooding or erosion) to property.	• Analysis of the site under one or more individual storm events (e.g. the 2 year, 5 year and 10 year storm event).	• General civil engineering practitioner with an understanding of basic runoff calculations from paved areas (e.g. Rational Method) and basic hydraulic calculations (pipe and drain capacity).

Stormwater management was generally not seen as a specialist function. It was seen as an 'add-on' to the design of services for a site, often taken designed by engineers with expert focus in other aspects of the design; structural engineers, geotechnical engineers, roads engineers, etc. The calculations were simplistic and required very little understanding of hydrological processes.

Traditional stormwater systems with attenuation facilities

The primary objective remains the effective and efficient drainage of the site, but there are now downstream considerations. Stormwater peak flows (flash floods) are seen to be a primary cause of damage (and cost) to downstream properties and stormwater networks. To prevent this damage an attenuation facility is introduced to reduce the downstream peak flow in a storm event (but not the quality or the overall volume of the stormwater runoff).

Measures, Methods and Expertise for stormwater systems with attenuation facilities

Performance measures will include:	**Design methods** will include:	**Expertise** required:
• The same assessment of on-site ponding and flood risk as the traditional method, and • The reduction of the peak of the stormwater runoff to some target defined by the municipality (e.g. the peak should not be greater than the peak of the same storm on the site area in its natural state)	• The same tests of one or more individual storm events but these may include a series or larger events (e.g. the 10 year, 20 year and 50 year, or even the 100 year events). • Analysis will include estimates of the storm hydrograph. Only certain methods are suitable for this. The Rational Method is commonly used but is not suitable. The SCS-SA method is an example that would usually be suitable (CoJ, 2019).	• Attenuation design requires a more detailed understanding of hydrograph analysis and antecedent conditions. This requires an expert level of understanding that is not usually covered in undergraduate training. Hence post graduate experience and training will be important and because liability (in terms of flood risk and mitigation) will be a factor professional registration will be necessary. Such a person would be considered a stormwater expert by her/his peers.

The poor state of many of the drainage networks and river systems in Gauteng suggests that not many of the attenuation systems that have been constructed over more than two decades have been successful. Limited design and maintenance expertise within both the design practitioners and authority officials is often raised as one of the biggest problems, along with a lack of adequate local design standards.

The underlying principles of design storm analysis and attenuation are not covered by all undergraduate curricula and the subject requires some postgraduate specialisation. Although more advanced design methods were available for attenuation design, the older methods were also ‘adapted’ to provide rudimentary volume calculations, allowing many of the practitioners to convert to the new requirements of attenuation without the understanding necessary for correct design. As a result, stormwater management was still often seen to be a non-specialist design function.

SuDS based stormwater systems (typically a combination of grey and green infrastructure)

The primary objective is volume control to reduce the impact of urban development on receiving systems. Effective and efficient drainage of the site and peak flow control remain priorities, but the intent is to achieve these and additionally improved water quality largely through infiltration-based SuDS systems. Most of the SuDS technologies referred to in this manual were developed for this purpose.

Measures, Methods and Expertise for SuDS based stormwater systems

Performance measures will include:	**Design methods** for the selection and testing of the SuDS treatment train will include:	**Expertise** required:
• Ability to absorb a given depth of rainfall on a contributing catchment. Target rainfall depths will usually be set by the local municipality. • Water quality discharge from the SuDS facility that meets municipal objectives. • Any flood management targets (if required) as set by the local municipality. (Note: A fairly common standard is to match the runoff quality and quantity of the pre-development condition.)	• A range of tests on individual storm events similar to attenuation ponds. Full hydrograph analysis is important (see design methods for attenuation facilities above). • Antecedent conditions on the soil water (or stone fill media or retention pond) needs to be clearly stated with assumptions. • Analysis of the overall performance of the entire treatment train is required. (Refer to Armitage, et al, 2013, and CoJ, 2019 for further design guidelines)	• Stormwater expert (see comments on expertise required for attenuation facilities above). • The hydrological functions of SuDS is more advanced than that required for the design of attenuation systems, and the expert needs to have experience in the hydrological soil modelling. • Multi-disciplinary input for urban design, landscape and ecological functions.

SuDS performance is not always linked to wider catchment requirements (i.e. in a Catchment Management Plan). Default standards may be deemed by a municipality to be sufficient across the entire municipal area. In fact, by setting the pre-development runoff quality and quantity to be the target post-development runoff limits is a precautionary approach that may not need a Catchment Management Plan. However, this approach might not be optimal as explained in the section 4.2 above.

This level of analysis and design requires post-graduate training and experience. It is seen to be a specialist function even within the range multidisciplinary team members.

SuDS based stormwater systems for Water Sensitive Urban Design

In a municipality targeting the ambitions of Water Sensitive Urban Design (WSUD), stormwater is an important part of the urban water cycle. In Gauteng, and in many urban areas in South Africa, stormwater, sanitation and water supply are often mixed in the same networks, the role of SuDS has even greater significance (see **Figure 4**). As such it is seen as a resource that will play an important part of sustainable South African cities (Armitage, et al, 2014). SuDS performance is evaluated for its role in augmenting water supply as well as its impacts on river flows and groundwater, and not just for design storm event conditions. This helps quantify the resource in terms of its potential returns, and therefore the allocation of the resource to different needs; ecological, amenity, downstream water resource needs, and the potential for local harvesting. SuDS is also linked to key water resource attributes; deep groundwater, hydropedological resources, and surface water storage.

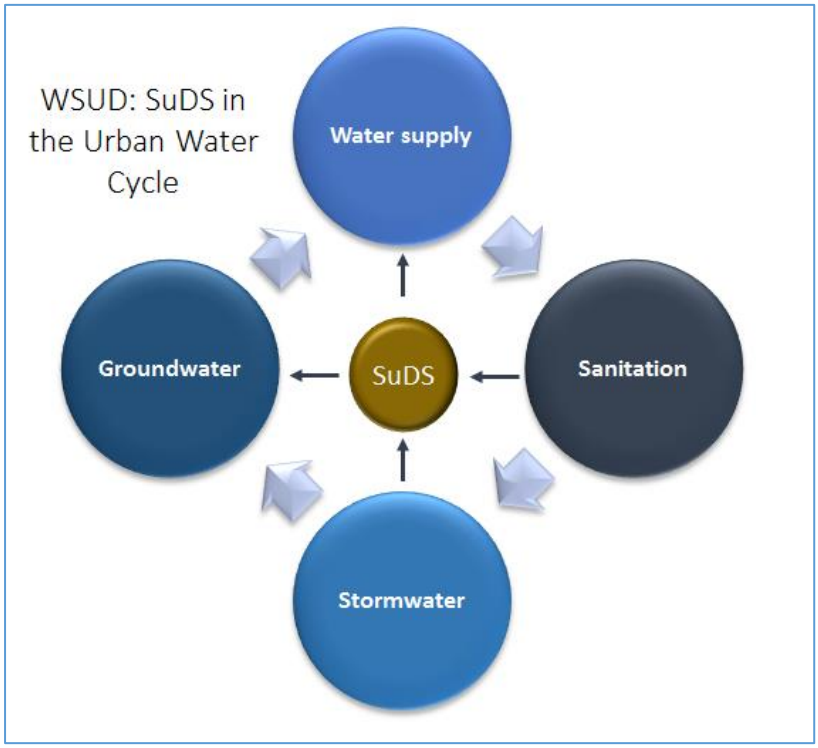


Figure 4: SuDS in the Urban Water Cycle

 **Measures, Methods and Expertise for stormwater systems for Water Sensitive Urban Design**		
Performance measures will include: • Annual surface water yield (e.g. m^3/ann) • Flow-Duration curve analysis (CoJ, 2019) • Annual sediment & pollution loads (e.g. kg/ann) • Flood management targets (if required) as set by the local municipality. (Note: A Catchment Management Plan that sets resource management targets will be a critical requirement for setting WSUD objectives, and therefore SuDS targets.)	**Design methods** for planning and testing SuDS treatment trains will include: • Stormwater network modelling (quality and quantity). • Analysis of a number of annual rainfall cycles (e.g. by continuous simulation). • In cases where stormwater is affected by sewage pollution, SuDS can be specifically designed to reduce organic/bacteriological pollution, if this can be shown as the most appropriate and cost-effective solution. • Simulation of hydropedological and groundwater exchanges (where relevant). • Design storm analysis (as required for flood management). (Refer to CoJ, 2019 for further design guidelines)	**Expertise** required: • SuDS stormwater expert (see all the expertise requirements for SuDS-based stormwater systems above). Additional expertise (as required): • Additional specialist hydropedological and groundwater modelling expertise. • Urban designer (for retro-fit solutions). • Landscape designer (for soil and vegetation specifications). • Ecologist (for environmental water requirements). • Water resources expert for integration with wider water resource strategies.

Closing the gap between stormwater practitioners and municipal officials

Hydrological modelling has become an integral part of stormwater design as performance measures become increasingly complex. There has also been a transition from assessing stormwater systems under individual extreme storm events (single event analysis) to analysing the performance of a system over a period of years (continuous simulation). This has led to an increasing separation of technical capacity between stormwater practitioners and municipal officials and is often linked to delays in reviewing and approving SWMP permits. Closing that gap will be an important part of implementing SuDS, and it is acknowledged by some municipalities that this is going to be a challenge. Lessons from the stormwater sector in Australia offer a potential break-through in this regard as discussed in Chapter 9, and particularly Section 9.5 (see also **Box 7,** towards the end of section 9.5).

5.3 Why is performance assessment and monitoring important for decision making on SuDS?

Understanding stormwater management performance is key in determining the investment value.

Analysing performance provides a means to determine investment value of different SuDS interventions. Typically, all SuDS measures will provide stormwater quantity and quality benefits, but at a given location some will perform better and may be more cost effective than others. Some will perform additional urban functions that have value to the local community, landowners and the whole city. Life-cycle costing analysis can be used to support decisions on this basis.

While methods to estimate the performance of nature based systems are continually improving, there remains an element of uncertainty. Hence performance monitoring is important, particularly at the initial stages of SuDS implementation in Gauteng. Monitoring activities will be determined by the performance objectives of the design, but would typically include regular measurements of outflows (quantity and usually quality too) and inflows as well. Types of monitoring and frequency should be specified in the SWMP. It may include several measurements along the treatment train, as well as in the downstream receiving environment. Measurements may be required during, or soon after storm events, and rainfall data for storm events may also be necessary. Monitoring prior to implementation is necessary to establish baseline conditions, and this would be part of the design and environmental impact stages of the land development process.

Monitoring should also include regular condition assessments of the treatment train facilities, including such aspects as sediment build-up, types of and condition of vegetation, damage to structures, etc. Monitoring will assist in assessing the success of the design and construction processes, and the suitability of the maintenance programme. New technologies are being developed and available to improve on monitoring, with citizens science, with remote sensing, or with automatic sensors using 4IR technology.

The maintenance of SuDS is more than landscape and garden management, as hydraulic and water quality treatment performance also needs to be ensured. Sediment removal, testing of infiltration capacities, and vegetation cutting and replanting are typical activities. There is limited experience of this in Gauteng and oversight by the authorities in this phase will be crucial. Developers, Businesses and Communities can benefit from the additional ‘use values’ of SuDS, as they usually enhance their open space areas, increase the value of their investments and save costs in the long term. The oversight role of the authorities should include exploration of these opportunities which improve the sustainability of SuDS projects. Experts are there to advise developers, authorities and stakeholders. All have a role to play. Additional comment on monitoring and maintenance is also given in Sections 2.4 & 8.2.

More information in the following reports prepared as part of this research project:

- Analysis of Study Areas with Recommendations (Deliverable 5)
- Decision Support Tools (Deliverable 6)
- Best Management Practices (Deliverable 7)

In addition, Armitage, et al (2013) provides more details on design, performance and maintenance of SuDS.

On citizen monitoring, deliverable 7, Best Management Practices give some useful methods in Chapter 8 'Community Liaison / Stakeholder engagement Facilitator'.

For assessors of stormwater masterplans and reviewers of EIAs:

- Realize that SuDS require a different design approach than conventional systems and check if the correct conditions are met in terms of performance measures, design methods and expertise required.

For developers and decision makers:

- Oversee municipal establishment of Catchment Management Plans (CMPs) for all catchments in the province. These CMPs need to be reviewed and updated every five years.
- Municipalities to record all SuDS installation in the Asset register with links to SWMP and monitoring plans
- Consider use of new technologies for more efficient and effective monitoring. Oversee and publicise use of River health data to support performance monitoring.

6 DEALING WITH RETRO-FIT SITUATIONS

6.1 Why is retro-fitting SuDS so important in Gauteng?

Gauteng is to a large extent built up and improving on stormwater management or accommodating densification will need retro-fitting. Retro-fitting stormwater systems will typically piggy-back on other refurbishment and renewal initiatives.

Large areas of Gauteng are already covered by urban development and most of the river systems are severely degraded. The long-term recovery of streams and rivers in the province will depend on more than just the implementation of SuDS in new land development projects. Retro-fitting of SuDS will be part of the long-term plan to improve sustainability of historic development, and it should form part of Spatial Development Frameworks (SDFs) and Integrated Development Plans (IDPs) as they are reviewed and updated across the province. It is expected that retro-fit programmes will become a particular focus of SuDS implementation plans once WSUD objectives are contemplated and CMPs are established

Retro-fitting will typically piggy-back on other refurbishment and renewal initiatives. It is important that SuDS are always a primary planning consideration in the planning of all of them and are not left as an “add-on” to later detailing of the sites. Retro-fitting SuDS will typically address existing problems in the drainage network such as pollution loads or flooding. They will often be more strategic in nature (see Chapter 7), and they can benefit from pre-design monitoring and sampling to get a detailed profile of input parameters of flow and water quality. In contrast, greenfield site SuDS applications need to work with estimated parameters of flow and pollution loading.

Retro-fit solutions require even closer cooperation between all stakeholders, particularly between the implementer (usually a municipality) and the local communities (see Section 8.2 & Chapter 9) which may resist the proposed changes.

6.2 What open spaces can be considered for SuDS?

Existing open spaces and areas having other functions such as road verges, traffic islands, sport fields, servitudes, parking areas can be often used creatively for SuDS and open space will need to be reserved for SuDS, whilst also having other functions.

The creative use of existing open space areas is possible across many parts of the Gauteng city environments. Road verges, traffic islands, sports fields, servitudes, and parking areas are examples of the kinds of areas that should be considered for SuDS development. The Kagiso Case Study included an analysis of the potential of using existing open space within the residential area (see **Box 3**). The results showed important benefits could be achieved even at a local catchment scale. Even in the densely developed city CBD environments suitable space was seen to be available for use (see **Box 4**). The principle that "No space is useless" (Digman, et al, 2012) should encourage to consider extensive SuDS development. This was reinforced in a study by Bakwunye et al. (2019) that assessed the potential of water re-use from basements and roof tops in the Johannesburg CBD. They identified that many roofs in the CBD have accessible flat areas. Some are being converted to rooftop agricultural projects, although for hydroponic farming, not based on rainwater and with very low water use. However, that roofs are being used and accessible, suggests there may be potential for green roofs on existing buildings in the CBD, although choice of vegetation would have to be carefully selected. The CBD case study covered in this research project demonstrated that green roofs can substantially reduce the runoff from a city block in the Johannesburg CBD (see Deliverable "Analysis of Study Sites with Recommendations").

"No space is useless"

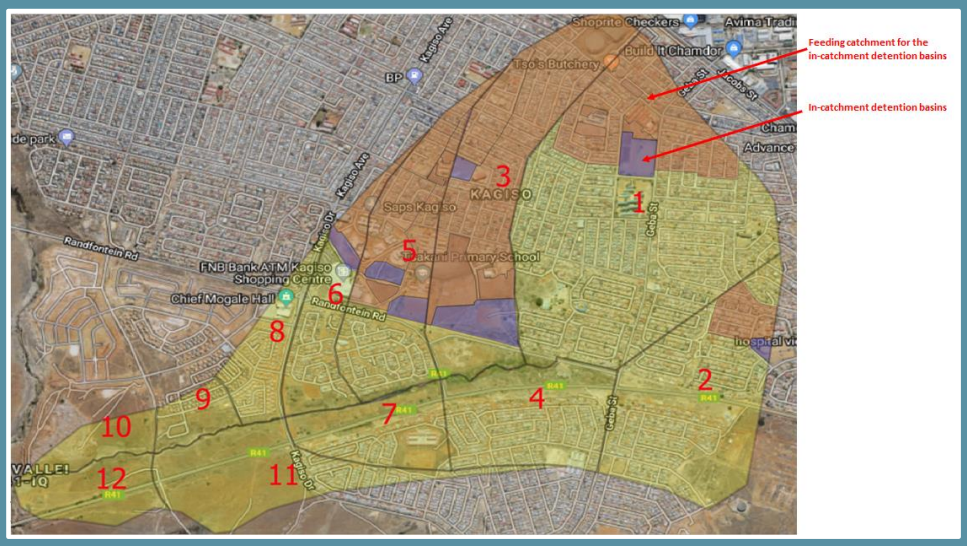
(Digman, et al, 2012)

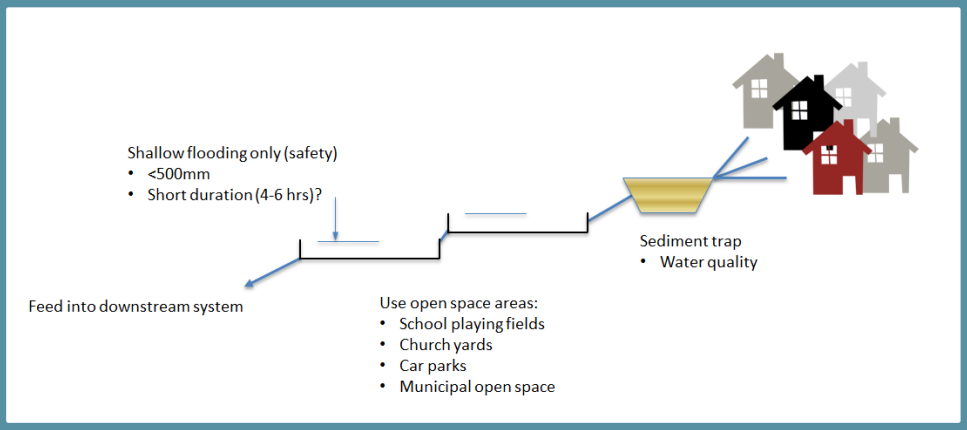
Retro-fit solutions are mainly a response to particular problems in the stormwater system, but they should still form part of strategic programmes for roll-out across a city region. Examples where these may be applied include piggy-backing on the Johannesburg Road Agency's "Clean Streets" initiative, or the roll-out of the Green Infrastructure programmes proposed by the Gauteng City Region Observatory (Culwick, et al, 2019).

This ties in with the principle of "Making space for stormwater" in the City of Johannesburg's Stormwater Design Manual (CoJ, 2019).

Box 3: Kagiso Case Study: In-catchment SuDS interventions ("No space is useless")

As part of an investigation of possible Retro-fit SuDS in a township environment, various open areas within the established residential area of Kagiso in the West Rand Municipality were explored. These included school sports fields (catchment 1 in the schematic diagram below) and various vacant areas owned by the municipality (catchments 2, 3, 5 & 6). The principle of converting these to shallow detention basins is presented in the schematic diagram below.





Though the areas of the detention basins (DB, the purple areas) are small in relation to their supply catchments areas, the overall impact on total suspended sediment (TSS) and pollution levels (total nitrogen TN & total phosphorus TP) on the outflow at catchment 12 is significant (table below), even though the % points increases in load reduction (runoff) and GP (litter) is small.

	"Do nothing"	"In-catchment" DB
% Runoff Load Reduction	8.99	12.2
TSS % Load Reduction	57.5	71.3
TN % Load Reduction	25	35.5
TP % Load Reduction	47.3	59.1
GP % Load Reduction	94.3	94.1

6.3 How to make use of opportunities in the case of urban renewal programmes and ageing infrastructure?

Urban renewal programmes and the replacement of ageing infrastructure are windows of opportunity to look at space differently and introduce SuDS.

"Make space for stormwater" (CoJ, 2019) is a principle that applies to all site redevelopment as much as to greenfield site developments. Thus, it is applicable to urban renewal programmes and to the replacement of ageing infrastructure as discussed below.

Urban renewal programmes

"Make space for stormwater"

(CoJ, 2018)

Renewal plans arise as cities and towns look to adapt areas in decline and to address pressures of growth. The plans typically include substantial densification and intensification, refurbishment of existing buildings and public spaces, new public transport infrastructure and the upgrading of other services. Johannesburg's inner city regeneration initiated by the Johannesburg Development Agency (JDA) is a case in point (see **Box 4**). Public and private investment focussed on infrastructure, public space upgrades and other strategic projects. Plans to renew or adapt urban areas are prime opportunities to introduce SuDS. What will be important is that all plans for change should be treated in the same way. Hence, plans for inner city urban renewal, for example, need to accommodate stormwater runoff and should make space for SuDS to the same extent as other parts of the city.

Ageing infrastructure

As grey stormwater infrastructure ages, the functional performance decreases and budgets become available for their replacement. This provides an opportunity to incorporate SuDS technologies, or a combination of "grey & green" infrastructure. Examples include programmes for "daylighting drains" where parts of piped stormwater networks are converted to vegetated open channel conveyances. In constrained areas, the piped sections may need to be retained, but the target would be to open as much of the system as possible as long as security of users is ensured.

Box 4: Johannesburg CBD Case Study – Kopanong Precinct Urban renewal (Making Space)

The Gauteng Provincial Government is looking at modernising and consolidating their operational space in the Johannesburg CBD. The Kopanong Precinct Project has been conceived for this purpose. 18 buildings in the CBD have been identified for modernisation (see below). Modernisation includes meeting sustainability and climate change adaptation goals. This gives opportunity to include space for SuDS. Suitable SuDS technologies could include green roofs and bioretention units that were shown to offer a high level of improved stormwater quantity and quality management. Rainwater harvesting is another option, not further investigated in the case study.

Analysis of potential green roof area:

<u>Using available space ("no space is useless")</u>

Median block area = 4536m^2

Median roof area = 3455m^2

Usable green roof area = 1900m^2

Assume 20% for services & access

"Functional" Green roof area = 1520m^2

<u>"Making space" (for new Kopanong Precinct)</u>

Set a target of 75% of all roof area as green roof (for example).

= 0.75 x 3455 = 2590m^2

6.4 Competing for space?

SuDS based stormwater management may find competition with other 'use-value' options for the same space. Developers, landowners and entrepreneurs should have the freedom to explore options, while municipal officials and EIA reviewers need to evaluate each case on its merits. Key aspects include land ownership, community support and understanding the 'use-value' of the options.

As progress is made in the implementation of SuDS, and in particular retro-fit SuDS, situations may arise where other retro-fit development proposals may look at the same available space. An example of this is a question raised during the stakeholder consultation process of this research. It referred to the opportunistic use of roof tops in the Johannesburg CBD for urban agriculture projects and whether plans for introducing green roofs for stormwater management would either see competition for rooftop space or even a threat to these urban agriculture projects.

This question is seen to be particular to the retro-fit situation where existing space is proposed to be converted to some other beneficial use. It does not apply to land development, or re-development, situations where developers may argue there isn't sufficient space to incorporate SuDS. Here development projects need to comply with development bylaws and policies and follow the development planning and environmental processes identified in this manual. This will include the EIA process where analysis of project alternatives will take place. Hence the urgent need for such policies and bylaws to be reviewed and updated to reflect SuDS stormwater management best practice.

Therefore, in a discussion on rooftop agriculture versus green roof SuDS for a new building on a land (re)development project, the stormwater bylaws should have some influence on the decision. Instead, addressing this question for an existing building it is expected that the building owner will have final say. Here the 'use-value' of the options will be considered by the owner (see deliverable 6 'Decision Support Tools for SuDS in Gauteng'). For example, rooftop agriculture offers an income stream for an otherwise vacant area, but it also offers important sustainability credentials linked to food security, job creation and even water re-use that may be important to the owner and even key tenants. Other similar 'use-value' options include restaurants and bars as already evident in the Johannesburg CBD. Alternatively, the roof space could be an amenity area for the wellbeing of the employees of the tenants, and a SuDS green roof area may be a suitable fit. It is significant that there are currently no 'use-value' (e.g. municipal tariff or rates reduction) benefits associated with reducing stormwater in the receiving network.

Other SuDS retro-fit examples would include municipal space that is either vacant or has a level of informal land use. The Kagiso case study is an example; a mix of formal (waste recycling) and informal (subsistence agriculture and grazing) land uses exists in the stream corridor that also demonstrates levels of stream flow and ecological degradation. The concept developed for the Kagiso site explored the integration of these land uses with SuDS facilities, and the results suggested that a successful solution could be achieved, though this would need the 'buy-in' by the community.

Integrating SuDS with other land uses is one of the primary benefits of SuDS solutions and this should be explored in each case. However, as the roll-out of SuDS develops other examples will emerge of which some may see SuDS stormwater management objectives being in competition with other land uses in the same space. It will be up to the municipal officials and EIA reviewers at GDARD to evaluate each case as they occur. The experience gained will be important to other officials and developers and practitioners alike. Key aspects will include land ownership, community support and 'use-value'. Guidelines in this manual and in the supporting project documentation (e.g. Decision Support Tools for SuDS in Gauteng) will assist the review of such projects.

Appendix H: 'Working SuDS into the City' in Armitage et al (2013).

'Retrofitting to manage surface water' from CIRIA (Digman, et al, 2012).

'The investigation of basements and rooftop survey in selected buildings of the inner city of Johannesburg Metropolitan Municipality' (Bakwunye, et al, 2019; Appendix to Deliverable 5)

Deliverable 6, the report 'Decision Support Tools for SuDS in Gauteng' prepared as part of this research study.

For urban designers, urban planners and stormwater plan designers:

- Look differently at open space; use existing open space also for SuDS and reserve space for stormwater management.

For municipal bylaw and policy makers:

- With Tshwane and Johannesburg having taken a different approach, both supporting SuDS, evaluate in a few years' time which approach was most effective and efficient and consider adopting it.
- When catchment specific objectives are (becoming) available, review the bylaws and policies.
- Negotiate with organisation such as Green Building Council to support SuDS implementation

Civil Engineers Association/universities

- Introduce basic SuDS training as part of Civil Engineers training

7 SOLVING CATCHMENT CHALLENGES WITH STRATEGIC SUDS

7.1 Why would Gauteng need to solve its catchment challenges through strategic SuDS?

To address the existing severe water pollution and water quantity challenges in Gauteng rivers and decrease the downstream impacts, strategic SuDS will be needed if upstream measures are not considered feasible or cost effective.

Although strategic SuDS would be designed to address existing problems, they should still seek to support other catchment objectives of water resources management, habitat and amenity enhancement. Hence other SuDS related functions (e.g. harvestability, recharge, etc.) would be considered in developing the scheme.

An important part of SuDS implementation will be the potential for strategically placed solutions to address problems from a wider catchment area (See **Box 5**). The principle is similar to that of a regional[3] attenuation pond where the SuDS facility becomes part of the bulk services in the wider stormwater network. Strategic SuDS are best defined as key stormwater control points in a river catchment, providing strategic flood and/or water quality management to the benefit of downstream water resources and receiving systems. They are most often located on municipal land to address a pre-existing problem and maintained by the municipality and may still provide additional services (e.g. amenity). They could be on private land, for example on larger estate developments (e.g. like Steyn City in Johannesburg along the Jukskei River, or like Rainbow Junction in Tshwane along the Apies River) where there are multiple major stormwater systems. However, they would not be considered strategic facilities if they only served a townhouse complex that falls under the control of a body corporate.

The role of strategic SuDS interventions will be particularly important in retro-fit applications to address the existing severe conditions in many Gauteng rivers. A SuDS intervention may be the only solution in cases where fixing problems in a catchment may take decades and a shorter-term solution is important for water security reasons (among others). An example of strategic SuDS is the integrated wetland and pan system at Bonaero in Ekurhuleni (see **Box 6**).

Strategic SuDS interventions often only benefit downstream systems. Hence selection of their locations should be carefully considered. They are best planned as part of a Catchment Management Plan, though these are still to be developed for much of the province. In the interim, strategic

[3] The use of "regional" in this context is a stormwater term and refers to an attenuation facility that serves multiple properties in a catchment, or a sub-catchment area in a larger catchment. Hence it is not regional in the sense of the Gauteng region, for example.

interventions will be initiated as a result of specific problems and both municipalities and provincial government should be proactive in considering strategic SuDS as a solution.

The planning of strategic SuDS should always first consider fixing problems at source. In many situations, the problems originate higher up in a catchment and these should be addressed before any other solution is considered. However, many of the underlying problems can be complex, often linked to socio-economic conditions and the desperate need for accommodation of a growing urban population. Technical solutions in these situations may be linked to a re-planning and general upgrade of the impacted urban areas, with the potential for substantial community upheaval. To date municipalities in Gauteng have struggled to address these challenging areas. In these situations, a strategic SuDS intervention may offer a municipality the only solution that will mitigate the impacts on downstream systems in the short-term, while allowing more time to address the more complicated conditions in the catchment area.

The concept of a strategic SuDS facility should not be seen as something completely new. Regional attenuation facilities are a form of SuDS and these are commonly chosen as a flood management solution to upstream catchment over development. The adoption of strategic SuDS for water quality treatment should be seen in a similar manner.

Box 5: Urban catchment impacts on the water quality of stormwater and river systems

Many of Gauteng's urban areas experience problems with the mixing of flows from sewer and stormwater systems. This has implications for both the performance of Waste Water Treatment Works (WWTW) and the quality of stormwater entering urban rivers. Some of the causes of the problems have complex societal and socio-economic factors underlying the technical failings that municipalities are finding difficult to address. Examples of these that particularly impact urban river systems include:

- Informal densification of large residential areas due to the high demand for accommodation. Back yard shacks result in overloading of sewer systems which flood and spill into stormwater systems.
- Inappropriate toilet behaviour, such as use of newspaper, that leads to blockage of sewer lines.
- Disposal of household waste into sewer systems, again leading to blockages.
- "Mining" of sewer lines for valuables (coins, jewellery, etc.) achieved by blocking sewer pipes.
- Illegal connection of stormwater to sewer systems.

7.2 How to design strategic SuDS?

To address the already severe water pollution and water quantity changes in Gauteng rivers and their downstream impacts, strategic SuDS are needed if upstream measures are not considered feasibly.

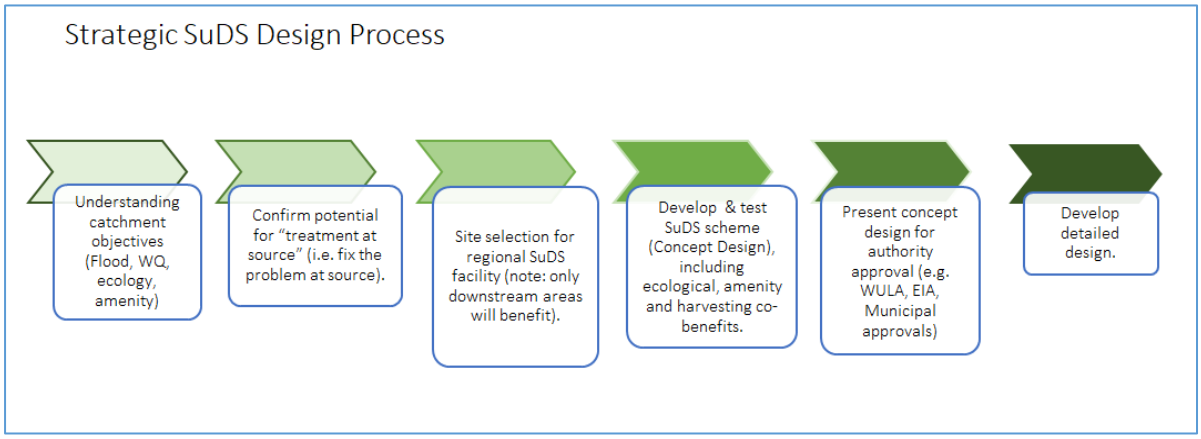


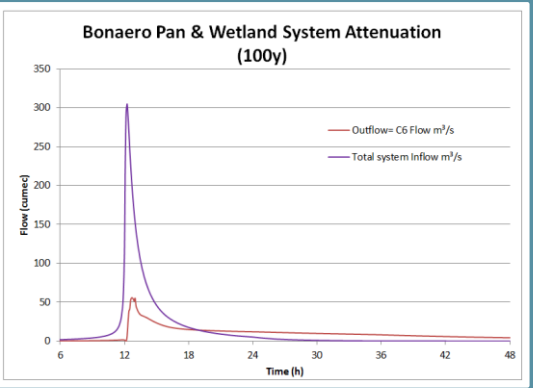
Figure 5: Outline of the design process for strategic SuDS

An outline design process guideline is provided in **Figure 5**. The first step is to understand catchment objectives. A catchment management strategy or catchment management plan will set out the catchment objectives (See Chapter 4). The second step is to confirm that treatment at source is not feasible and cost effective, because if feasible that would normally be the preferred solution. The third step is site selection, which depends on the availability of suitable space. Ideally more than one option should be explored. This step would overlap with the next as concept solutions develop into concept designs. The concept design is developed to a level of detail which is sufficient for submission to the municipality for approval, and with an EIA for submission to GDARD and a WULA for submission to DWS-Gauteng. The EIA and WULA processes will be critical points of control on whether a strategic SuDS solution should be adopted (See further section 9.5). It will be important to evaluate the project alternatives to ensure the best solution is identified. It is also important that the EAP and the reviewing case officers have the necessary skills and experience for this type of project. Then after approval or changes, the multi-disciplinary team can do the detailed design.

The design process is ideally undertaken by a multi-disciplinary team, possibly with one or two key experts in the initial stages, but the number of experts most likely growing as the complexity of the urban issues increases. As with other SuDS projects, local community acceptance of the preferred solution is important to ensure the long-term operation and performance of the scheme.

Box 6: Bonaero Case Study: Strategic flood attenuation and conservation value of integrated wetland system

The Bonaero case study site included a 187 ha system of wetlands and pans that over time had been appropriated for stormwater and landscape assets for sections of land development. Despite development disturbance they offer an important ecological conservation asset if considered as an integrated eco-zone, and achieve strategic flood control. This natural system has inherent strategic SuDS functions of flood management, water quality control, and has ecological value and high amenity potential that are not available in the wider area.



A preliminary assessment of the attenuation ability of the system is significant, potentially reducing flood peaks to the suburb of Atlasville downstream by 80%. Yet the system is under threat by the likes of the future Aerotropolis commercial and industrial development. The strategic flood and ecological functions of the system are at risk of being compromised.

For urban designers, urban planners and provincial and municipal managers:

- Create awareness that it is not feasible to solve some challenges in the upstream catchment where the challenge exists. These challenges will however need to be solved to protect the downstream catchment and Strategic SuDS may be the best way of doing so. These SuDS will need space and a budget for implementation.
- Initiate or assist in the preparation of strategic SuDS where needed.

For EIA and WULA reviewers:

- Make use of the role of EIA and WULA processes, which are important check points in the planning and design of strategic SuDS proposals. For example, they can challenge the assessment of the ability to address problems at source (rather than implementing a strategic solution). However, officials will need to invest time and effort to understand the complexity of the situations present in many of the urban catchments in Gauteng. Engagement with municipal officials and participation in stakeholder engagement processes required for the preparation of WULA and EIAs will provide important insights to particular problem areas.

8 IMPLEMENTING SUSTAINABLE SUDS

8.1 What conditions guide whether to implement SuDS?

Bylaws specifying SuDS systems will be instrumental in promoting their adoption. Any on-site constraints will need to be presented by the developer and any alternatives proposed will have to be justified. Few sites are completely unsuitable for SuDS.

If municipal policy and bylaws specify SuDS as the method to be used to control stormwater this will set the legal obligation to implement SuDS. If there are technical reasons why SuDS measures will not work at a location, or if the requirements of the bylaws are deemed to be unreasonable, then the developer will need to be put a case to the municipality for consideration. Note, this will extend the permitting process. High risk locations, such as sites on dolomitic geology, must be highlighted, but SuDS solutions are still often possible.

There are expected to be few situations where some form of SuDS should not be applied. Some SuDS facilities may be more expensive (e.g. green roofs) but their full value to society will need to be evaluated before cost concerns are presented. If such concerns are presented, alternatives, including alternative site layouts, will need to be proposed and justified by the developer. Additionally, stormwater requirements considered late in the planning and design stages should not be a suitable excuse. Good planning will address most stormwater challenges fully.

There are situations where municipalities have expressed concerns about specific SuDS technologies. There are usually good reasons for these concerns and early consultation with municipalities will identify them. For example, underground tanks were raised as a concern at the July 2019 stormwater conference hosted by the City of Johannesburg. The concern relates to the challenges of monitoring and maintaining buried facilities (underground tanks). All too often they are forgotten after the developer leaves the site and they are easily seen by municipalities as unreliable (unsustainable) solutions. Early warning of this will assist the developer to explore other alternatives.

It is also unlikely that a single type of SuDS facility will achieve the target discharge requirements for a site. Instead a SuDS treatment train will usually be necessary, presenting the developer with a range of options that can be adapted to suit most development types and site conditions. Even site constraints such as dolomitic areas can be accommodated by lined SuDS facilities, or a combination of grey and green infrastructure, though expert input will be necessary. Hence the onus is largely on the developer to present a means of achieving discharge targets, and SuDS are expected to be viable in most situations.

8.2 What preparation is needed for SuDS to be sustainable?

Sustainability needs to be addressed during community engagement, the design process, the construction stage and during maintenance. Moreover, monitoring and evaluation are essential for adjusting the maintenance and sometimes even the design, and for learning so that mistakes are not repeated.

During the project, in particular the five different stakeholder consultation workshops, different suggestions were given towards ensuring the sustainability of SuDS. These are summarized as key questions below:

Community Engagement

- Is the community ready or can it be persuaded to support SuDS with their added amenity and ecology benefits? Will they keep the space for SuDS uncluttered so that it keeps functioning? Will they be willing to assist with the maintenance, if this is not provided by the municipality?
- Can SuDS create jobs in the community (litter control, maintenance) and will this be essential for the sustainability of SuDS?
- Does the community want to be involved in maintenance and monitoring on a voluntary basis? Or, will it finance the maintenance and monitoring through, for example a Home Owners Associations levy?
- Is it clear who guides the process of engaging the community and in what way the process should be guided?
- What are safety and security measures to be taken at the location?

Design process

- Is the design sufficiently tested on weather conditions that can damage the functioning of SuDS? (e.g. droughts killing plants, or floods eroding the facility or filling it up with sediment)
- Is the design sufficiently specific with respect to what material should be used and how it should be constructed? (For example, for the soil-water model to function well under permeable paving, the stones might have to be washed but if this is not specified the contractor will not do it. Contractors can also give useful suggestions for cost savings or better performance.)

Construction

- Are the building specifications and other communication lines such as for contractor and community capacity building of contractors sufficient to ensure that the SuDS are constructed correctly as planned? (right materials and execution are essential and cost cutting measures that will damage the design need to be avoided; contractor and community suggestions, however, can be very helpful provided they are carefully evaluated.)
- Is there sufficient site supervision to make sure that the SuDS are constructed as specified?

Maintenance

- Were the maintenance needs to be specified and agreed before the decision was made to implement? What needs to be done where, and with what frequency? (See also Recommendations in Section 13.2)
- Has it been ensured who the custodian of this maintenance after implementation will be? Who finances what? Who does what?
- On municipal SuDS facilities, are there the necessary agreements between departments (e.g. Roads & Stormwater with Parks Department and Solid Waste Department) to coordinate and undertake maintenance? Which departmental budgets are assigned to maintaining SuDS facilities? Is there budget sharing?

Monitoring and evaluation

- Will the performance of the SuDS be sufficiently monitored?
- Can the community be involved in monitoring to help in reducing costs and/or increasing awareness and a sense of ownership?
- Can the maintenance - or even design - be adjusted if monitoring indicates this is necessary?
- Will lessons learned feed back to the municipality / province?
- Is the municipality or CMA monitoring the integrated SuDS network at a catchment level?
- Does the municipality request monitoring reports for SuDS on private property?

(See also Section 5.3 on maintenance and performance of SuDS).

Deliverable 7, the report 'Best Management Practices' of this project specifies what is considered important for community engagement and also focuses on design aspects for SuDS that facilitate sustainability.

Deliverable 6, the report 'Decision Support Tools for SuDS in Gauteng' looks at the importance of determining the 'use value' of a SuDS project on a site.

At the time of writing, attention to SuDS in Gauteng has focused on the planning and design processes e.g. Johannesburg Stormwater Design Manual (CoJ, 2019), where hydrological and treatment performance, along with integration of the ecological and recreational space are key topics related to sustainability. However, consultation during this study has emphasised important priorities after the design stages related to commissioning, monitoring, fine tuning and maintenance, that also need to be addressed to ensure the long-term sustainability of SuDS projects. They are indicative of the areas of research and experience that still need to be expanded for Gauteng applications.

For urban designers, developers and EIA reviewers:

- When initiating or reviewing a SuDS proposal, design or implementation plan, check that conditions for sustainability are met.

For GDARD, with support of COGTA and SALGA:

- Engage with municipalities to see how monitoring of SuDS performance can be used to derive learning points for other SuDS implementation projects (See also Chapter 3).

9 IMPLEMENTING SUDS THROUGH THE PLANNING AND LAND DEVELOPMENT PROCESSES

9.1 Why do SuDS need to be integrated in the planning and land development processes?

SuDS should support and enhance land development objectives, but this will only be achieved if SuDS is integrated into both the planning and land development processes.

SuDS should ideally be implemented to support and enhance land development objectives and should not be imposed as an additional condition (Fourie et al., 2019 a and b). Implementation of SuDS in synergy with land development objectives is the goal. In these situations, the objectives of sustainable drainage are convergent with the wider land development objectives, and there will be little need for compromise between the two. Many SuDS options need space but are ideally suited to existing in a shared space providing multiple benefits (e.g. ecological services and amenity), see also Chapter 6.

The planning and land development stages are outlined in **Figure 6**. Consideration for stormwater management should be made throughout the two processes. Hence the Catchment Management Plan becomes an important reference across both stages. If these processes are not inclusive of SuDS from the beginning it is likely that space for SuDS becomes a contested issue where compromises have to be made (e.g. between the developer and the municipality). This will usually extend the land development process and timelines.

The planning phase requires forward thinking and should provide a baseline for land use that should include space for stormwater management (see also Section 9.2). In the land development stages the stormwater performance objectives are set for a site and the SuDS concepts and detail are developed. Overall stormwater performance (particularly stormwater quantity and quality) would be set at a concept design stage and presented for authority approval (see 'Agreement in Principle' in Section 9.5 and **Figure 8**). The detail of the treatment trains, network layout and integration with ecological and amenity functions would then be refined in the detailed design stages. This is often an iterative process with input from a range of specialists.

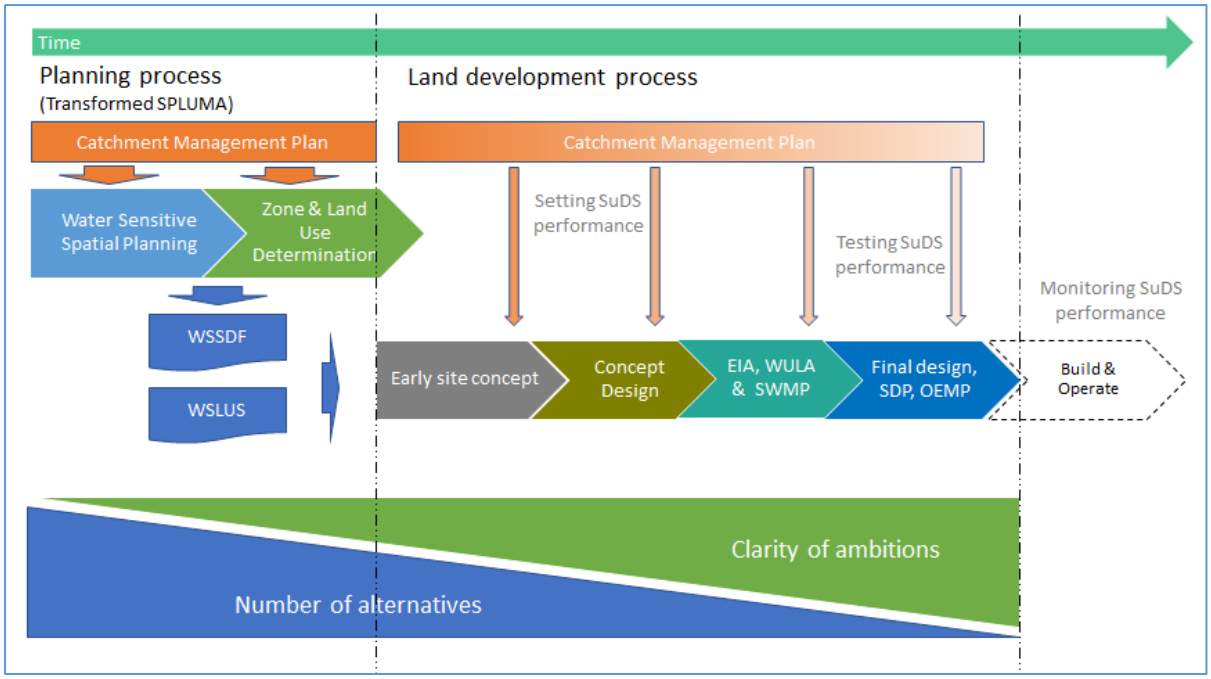


Figure 6: Planning process and land development process in case of water sensitive planning.

9.2 How do SuDS fit into the planning process?

The Municipal Spatial Development Framework and the Municipal Land Use Scheme provide opportunities for a more water sensitive planning approach, including the implementation of SuDS, which are currently largely ignored.

The Municipal Spatial Development Framework (MSDF) and Municipal Land Use Scheme (MLUS) are the current municipal planning instruments required by the Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA). The MSDF provides the baseline of the land development objectives across a municipality (and is therefore an important reference for developers in advance of preparing site development layouts) and the MLUS provides the legal enforcement of land development stipulations. Initial site-level development parameters are outlined in the MLUS and include details of acceptable coverage, open spaces and any additional controls.

Both the MSDF and MLUS are required by law but SPLUMA does not require them to address water resources management, or the potential negative impacts of land development on water resources. Instead it is left to the municipalities themselves as to whether they want to include any environmental, water or climate related criteria. At the time of writing in Gauteng there is very little attention given to water resources in the development planning processes. However, recent research commissioned by the Water Research Commission provides guidelines on compiling water sensitive spatial plans for municipalities in South Africa (Fourie, et al, 2019a and 2019b). This research provides guidance on planning for SuDS, blue and green corridor planning, planning for pollution control, etc. This is considered a key reference in support of the uptake and implementation of SuDS in Gauteng.

The impacts of SuDS on the public realm, and in particular green open space, means that municipal open space planning should be informed by higher level catchment planning and localised planning for SuDS. Large scale open space planning must also be integrated with catchment scale planning in the provincial and municipal SDFs to ensure strategic SuDS can be accommodated and stormwater flows across the municipality boundaries can be accommodated into the future. Fourie, et al (2019a) make reference to the regional Catchment Management Strategies as contemplated in the National Water Act (No.36 of 1998) as the baseline reference water sensitive spatial planning. However, as previously mentioned (Chapter 4) these are not yet readily available and the municipal Catchment Management Plan will be better suited to stormwater planning and water resource management at a municipal scale.

Chapter 3 in the deliverable 7 report, 'Best Management Practices', explains further the outcomes of research by Fourie et al. (2019 a, b) on how to transform MSDF and MLUS for water sensitive spatial planning.

9.3 How do SuDS fit in the Land Development process?

SuDS requirements should be introduced at the early concept stages as trying to fit in SuDS later in the land development can lead to conflict and delays.

Introducing SuDS into the early planning of a development project is considered a critical success factor in gaining momentum in the implementation of SuDS in the province. This is a distinct departure from current practice where stormwater infrastructure is largely considered after the site layout has been confirmed. **Figure 7** sets out the principal stages in the planning and design of a development. Stormwater management is often first introduced as part of the EIA and WULA processes, just before final design. At this late stage, the available space for stormwater is usually very constrained and SuDS system performance will be limited.

Introduction of SuDS before Concept Design improves the chances for synergistic solutions (and therefore the adoption by the stakeholders). The later the consideration of SuDS in the design process the more likely the requirement for compromise and trade-off, and less likely the stakeholders and occupants of the site will understand and see value in the SuDS interventions. This is important for greenfield developments, but is also important for retrofit projects, if SuDS are to be appropriately integrated into the design.

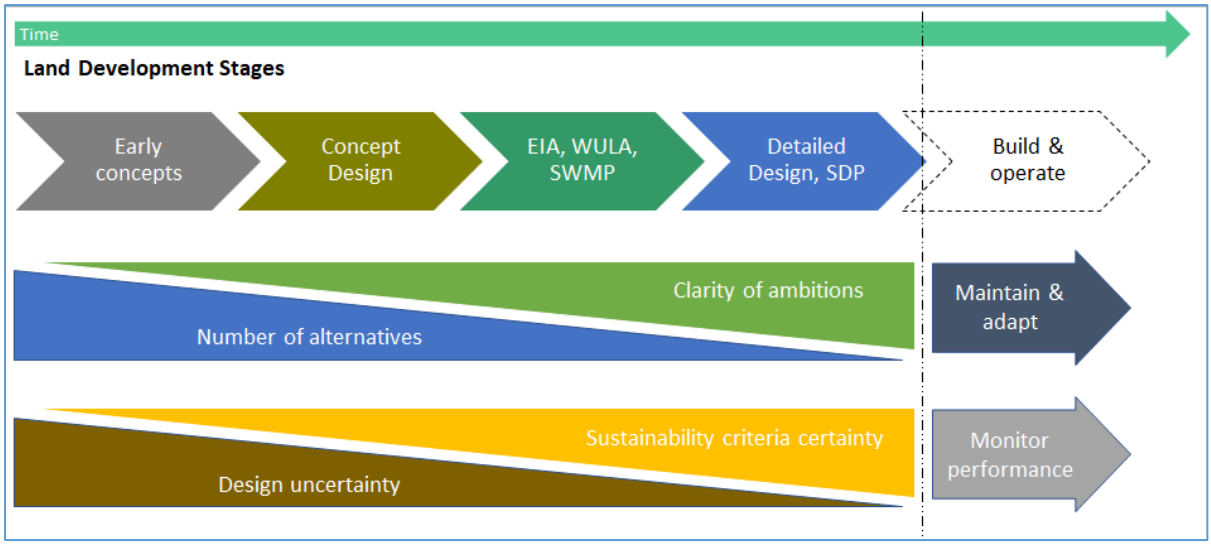


Figure 7: Land development design process

The deliverable 4 report 'Data collection on SuDS installations in Gauteng' of this project, shows that inconsistencies in the land development process can be detrimental for SuDS implementation. Also, the Bonaero Park-Atlasville Stakeholder workshop (part of the deliverable 4 report 'Analysis of Study Areas with Recommendations) showed stakeholders had experienced inconsistencies. The reports of the Final Stakeholders Workshop also provide recommendations.

9.4 How to choose between different alternatives at the concept stage?

Decision Support Tools (methods) can assist in the analysis needed to support selection of different SuDS options.

For support during the land development process, evaluation methods can assist in better informed decision making. In a separate report, (deliverable 6 of this study) different decision support methods are discussed. The following methods are considered promising for deciding on appropriate implementation of SuDS in Gauteng:

- **Life-Cycle Analysis**, a form of Cost Benefit Analysis particularly suited to evaluating SuDS and to the requirements of the local municipality.
- **Trade-Off Analysis**, a qualitative Multi-Criteria Analysis method, that has been adapted for this research project, from the 'Wet-Services tools for wetlands in South Africa'. This analysis allows for stronger representation of broad economic, ecological and social impacts and benefits.

- **Land value assessment**, usually a sub-set of a Cost Benefit Analysis, it can be used as both an economic evaluation and a measure of social (community) support. Community support is identified as a significant success factor for SuDS and is a key outcome of this study.

The deliverable 6 report 'Decision Support Tools for SuDS' of this study provides further insights in the advantages and disadvantages of different evaluation methods.

9.5 How to make better use of the WULA, EIA and SWMP processes?

Stormwater projects may require as many as three separate licences from three different public institutions, and inconsistencies between these application processes can impact on the land development timelines. Streamlining the processes will assist the take-up and implementation of SuDS, but it will require important cooperative governance actions, and upskilling, to put this into effect.

Stormwater projects, and therefore SuDS projects, may require authorisation as follows:

Authorisations that have influence on stormwater projects

Stormwater permit (or sign-off of a Site Development Plan, SDP)	**Municipality:** • Roads & Stormwater Dept. (or Agency), • Sometimes in conjunction with the Environmental Dept.	This is the official permit for proposed stormwater works. It usually requires the submission of some form of Stormwater Management Plan (SWMP) with layout plans, design calculations and intended performance (including food lines where necessary).
Environmental Authorisation	**Provincial Government:** • Gauteng Dept. Agriculture and Rural Development (GDARD)	An EIA (or BAR) will usually consider stormwater as part of a larger project. Ideally a specialist report will be included addressing the anticipated impacts of the proposed stormwater scheme on the receiving drainage environment. The SWMP could form the basis of the impact assessment.
Water Use Licence	**Regional office of the national Dept. Water & Sanitation (DWS):**	Although not directly addressing stormwater design, a Water Use Licence

	• DWS - Gauteng	will have important bearing on how stormwater is released into watercourses (rivers, wetlands and groundwater). A WULA is submitted that sets out sufficient detail of the scheme such that the DWS can assess the impact on water resources.

There are differences in the requirements for each permit, but they are essentially all derived from the same baseline information. While the permitting processes are renowned for resulting in project delays, this project also encountered anecdotal evidence of inconsistencies between permits approved for the same site. For example, an environmental authorisation may be awarded for a stormwater proposal that is different to the one that was submitted for the stormwater permit. As a result, officers in the authorities become distrustful of developers. Meanwhile, developers report that some municipalities are not ready to approve SuDS systems, and thus traditional grey infrastructure systems are presented to them while SuDS based systems may be presented to GDARD. Trying to avoid delays is offered by developers as the main reason for this approach, rather than avoiding the adoption of SuDS. Apart from potentially serious legal implications of this approach, this situation is certainly not in the interest of the uptake and implementation of SuDS based stormwater solutions. A review of the permitting processes is necessary.

The changing nature of stormwater management has increased the demands on the permitting processes. In times of traditional stormwater management, developers would prepare the stormwater plans in the latter stages of the design of the development and according to a set of standards. Provided they complied with the standards (channel and pipe sizes, kerb inlet spacing, etc.), obtaining the necessary permits was reasonably assured. However, stormwater designs have become increasingly complex as requirements for downstream flood risk (requiring attenuation), river stability, amenity and ecological functions (requiring SuDS) and water resource targets (under WSUD) have all become important. Stormwater solutions are now more tailored to address a wider range of environmental issues and the solutions themselves may vary from site to site. Hence it is important to start planning for stormwater much earlier in the project cycle, but equally important to gain some measure of official support in the early stages to avoid potentially substantial changes to the whole development layout later on.

Design standards for stormwater management are tending to be replaced by design guidelines and site solutions are the creative effort of multiple disciplines, often developed over a series of site design iterations. Thus, instead of just presenting a standardised attenuation facility, the developer now has to prove to the authorities that the proposed stormwater treatment train will work. This requires of the authorities that they have a comprehensive technical understanding of the interconnected issues. There may be more than one solution at a site, and a process of consultation between the developer and the authorities is good practice.

The earlier this consultation is initiated the better, preferably at the early stages of project conceptualisation. The purpose of this early consultation is to provide opportunity for officials to guide the developer on issues of concern to the relevant authority. In the process the developer gains confidence in what needs to be provided to meet the requirements of each of the respective government departments and will develop the site plans, including stormwater plans, to reflect this. Developers generally prefer to present design concepts to officials in an attempt to confirm they are on the right track before embarking on more detailed design. This informal "agreement in principle" will be sought from all permitting offices before detailed design starts, as any later changes in the stormwater system may impact on the site layout. Unfortunately, it is not uncommon for permits and authorisations to be rejected or delayed when the formal applications are submitted (at detailed design stage) and circulated to officials who were either not part of the consultation process, or who did not offer sufficient guidance at the time.

An important recommendation of this study is for the respective authorities to seek a means to formalise the outcome of the consultation process. The intention is to encourage both the developer and the authorities to consider the requirements and implications of stormwater management as early as possible in the consultation process and to develop a common understanding, with the developer, of the desired outcomes of a new stormwater system on a site. A proposal is to introduce an "Agreement in Principle" at concept design stage that demonstrates what the developer and officials have discussed and agreed. The outline for such a process is outlined in **Figure 8**. It places the SWMP as central to each of the applications for the stormwater permit, EIA and WULA, and proposes that an "Agreement in Principle' of the SWMP is achieved before the detailed design process is initiated.

Hence the SWMP will be a concept design of the proposed stormwater system, but it will need to contain sufficient detail to confirm that the intended performance of the system (quantity and quality targets) can be achieved. The "Agreement in Principle" should essentially fix the performance targets while still allowing some flexibility in the detail of the treatment trains.

Such an "Agreement in Principle" is currently not part of the legislated processes for any of the permits mentioned. Its integration into existing policy and legislation may need to be applied in a different manner in each case, but there needs to be some coordination between the different authorities. Opportunities to adapt existing processes may be explored in place of introducing a new step. For example, the Scoping Report in the EIA process could cover the requirements of such an agreement. However, this step is not available in the BAR process which may the more frequently used process for site development projects. Hence it is a recommendation of this manual that the review of the permitting processes (SWMP, EIA and WULA) is undertaken that will:

- Accommodate the nature of planning and design of SuDS based stormwater management at a site scale. In particular, this looks more at setting performance targets at concept stage while allowing the developer some flexibility in refining the stormwater layout of the site as the detailed design develops.

- Align the permit submissions such that submissions to all authorities are based on the same concept design and performance targets.

The introduction of an Agreement in Principle based on an approach outline in **Figure 8** is proposed as an efficient means of gaining the support of the developer and avoiding the submission of different SWMPs.

In time, the guidelines for SuDS are expected to become more detailed as experience and practice develops, and in some cases design standards may be developed as municipalities better understand catchment objectives (e.g. under WSUD) and the implications of design and maintenance on SuDS performance. As such the design and approval process outlines in **Figure 8** will become easier to apply, but there is still seen to be a need to change the permitting processes to allow an interim point of approval such as the 'Approval in Principal'.

The authorising institutions (municipality for SWMP, GDARD for EIA and DHSWS-Gauteng for WULA) will need to cooperate to align their respective permitting and application processes. COGTA could be instrumental in this transformation which will need to look at the technical capacities across the institutions (see **Box 7**). The aligned permitting process will also need to address inconsistencies within the institutions where the response to a license (or permit) application can be negatively affected by the "silo" focus of internal departments.

Although adapting existing legislation is often considered with some reluctance, it is not expected that current legal frameworks will be an obstacle: the National Water Act, the Gauteng Environmental Management Framework and the different municipal bylaws give an opportunity to implement SuDS. The National Water Act does not address stormwater management in detail, but it does support the instrument of a Catchment Management Strategy in water resource management which can be tailored to address urban catchment requirements as a key support function. Similarly, though municipal bylaws vary across the province, they are slowly adapting to SuDS as best practice and in time will become aligned as the province moves towards WSUD. Perhaps in time the larger metropolitan catchments can merge the Catchment Management Strategies and municipal CMPs to provide a single integrated management reference.

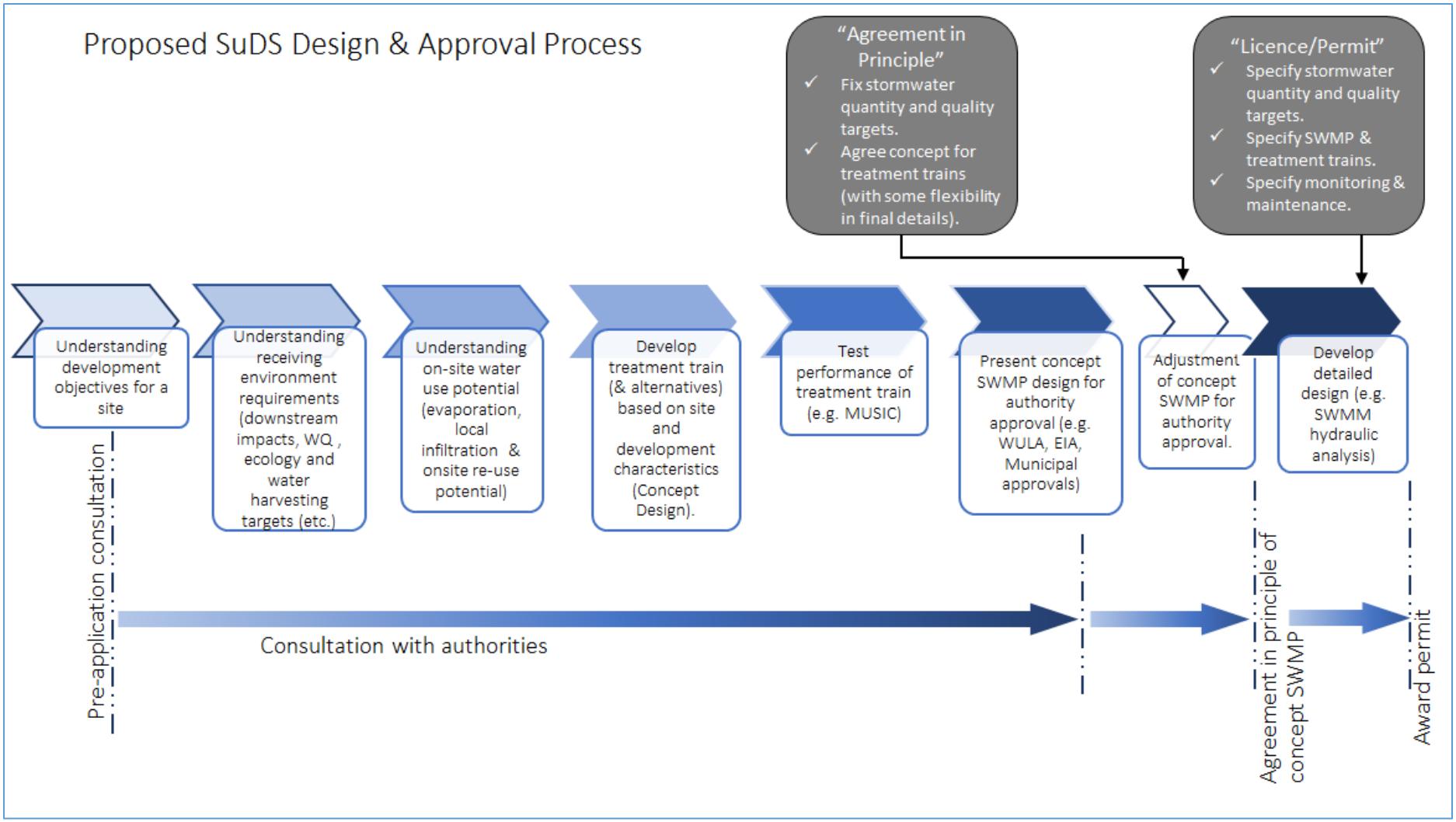


Figure 8: Proposed SuDS design development and approval process.

Box 7: Software support for developing technical stormwater capacity in municipalities and government offices – example of Australia

At a time when Australia was looking to increase the design and implementation of sustainable stormwater measures, they identified the need for an effective, easy to use decision support tool that would focus on water quality and treatment measures, but based on a strong scientific foundation that enabled the evaluation of the performance of a treatment train by providing the right kind of statistics. They also identified a need to streamline the process that the local municipalities needed to follow to review development proposals and award stormwater permits. The software is tailored to contain the municipality's compliance requirements for stormwater management, and enables a rapid assessment by municipal officials of submitted stormwater plans.

The hydrological software is MUSIC and the review software is MUSIC-link. It was conceived and developed by many of the researchers who first documented the WSUD approach. The introduction of this software in municipalities provided a rapid increase in institutional capacity, and improved SWMP review times appreciably. It also enabled developers and practitioners to develop concept designs with the necessary detail for review and approval by the municipalities.

The MUSIC software has been successfully trialled in this research project, and the model output and results have been reported in multiple reports in the study. Given the concerns raised by the participating municipalities in this study, of their challenges in developing the technical capacity necessary to meet the requirements for implementation of SuDS, the kind of approach undertaken by municipalities in Australia is worth considering.

The software is designed to be used by a range of SuDS practitioners including ecologists and landscape architects, and is not for the expert hydrologists or stormwater engineers. It would also be suitable for EAPs and EIA reviewers.

https://ewater.org.au/products/music/music-link/

(MUSIC = Model for Urban Stormwater Improvement Conceptualisation, by eWater)

For urban planners:

- Plan for SuDS and WSUD through the MSDF and MLUS (see this Chapter 9, section 9.2) will provide an important foundation for implementing SuDS in a catchment and will reserve space for SuDS (See Deliverable 7 report 'Best Management Practices').

For developers:

- Develop the SWMP through the concept and detailed design phases in a way that this includes a record of all consultations with the authorities. Utilise the concept design SWMP to motivate an "Agreement in Principle" from the authorities, and then the detailed design updated SWMP for award of permits (or licences) by the authorities. **Be sure that a consistent approach is employed to all authorities.**

For EIA, WULA and SWMP reviewers:

- Encourage pre-application consultation. Ensure understanding of the technical solutions and the requirements of the receiving environments.
- Encourage general and project specific collaboration between municipalities, GDARD and DWS-Gauteng offices.
- Use the SWMP as central to the technical submissions for licence applications.

For Province, with support of COGTA and SALGA and municipalities:

- Review and streamline the permitting processes with the introduction of an "Agreement in Principle' (or alternative statement, e.g. in Scoping Report) of the concept design SWMP, but ensure the developer demonstrates achievable SuDS performance targets (stormwater quantity and quality). This may require changes to legislation.
- Fast track the necessary licences and permits when the detailed design SWMP is submitted and the developer has demonstrated that the SuDS performance targets will be achieved.

For COGTA:

- Work with the three institutions (Province, municipalities, and DHSWS) to streamline the permitting processes and common skills development.

10 GAUTENG PROVINCE ROLES FOR IMPLEMENTING SUDS

10.1 What are the responsibilities of the Province with regards to SuDS?

In promoting and obliging the implementation of SuDS, the Gauteng Department of Agriculture and Rural Development leads the sustainability agenda via its oversight role in environmental management and in climate adaptation.

This implementation manual was initiated by GDARD as a priority project motivated through the Gauteng City Region Overarching Climate Change Response Strategy and Action Plan (GDARD, 2018). Provincial government has an important role to play in the uptake and implementation of SuDS. Among these responsibilities is their role as Asset Owner, Regulator and Facilitator. GDARD, with its oversight roles in environmental management and climate adaptation, is ideally positioned to facilitate the implementation of SuDS in other parts of the Provincial Government of Gauteng.

Several Gauteng policies and strategies have a bearing on SuDS: the Gauteng Climate Change Response Strategy and Action Plan (Gauteng Provincial Government, 2018), Gauteng Province Environmental Management Framework: Standard (Gauteng Provincial Government, 2017), the Gauteng Conservation Plan (Pfab MF et al, 2017). The Water Security Perspective on Gauteng (GCRO, final draft 2019) which was developed as an advice document to the Office of the Premier, is not particularly detailed on stormwater management but recommends the diversification of water resources, including the use of stormwater (See Chapter 3 of this document).

The deliverable 2 report 'Literature review on SuDS definitions, science, data, policy and legal context in South Africa', chapter 6, prepared as part of this project, summarizes the relations of SuDS with several provincial policies.

10.2 What can the Province do as an Asset Owner?

Land parcels and buildings owned by the Province can be used for implementation of SuDS, such that the province will lead by example.

As an asset owner, the Gauteng Department of Infrastructure Development owns many buildings and properties. Many government buildings are in Marshalltown, in the Johannesburg CBD, which has been the subject of a feasibility study for urban renewal; the Kopanong Precinct (see section 6.3). This precinct was therefore one of the study areas of this research, to inform the Province on how to lead by example.

The opportunity for SuDS is also there for provincial roads and other properties of Gauteng Province.

Further, land parcels along rivers that could potentially be needed for strategic SuDS (see Chapter 7) could be either purchased or are already owned by the Province.

10.3 What can the GDARD do as Regulator in the Province?

The Environmental Authorisation process is important in the increased uptake of SuDS and the correct way of dealing with SuDS. For strategic SuDS the provincial Spatial Development Framework is important. The Strategic Environmental Assessments (SEA) can also be used.

As a regulator, GDARD is responsible for the Environmental Authorisation of new development projects, which since 2017 has set clear targets for SuDS through the Province's Environmental Management Framework: Standard (Gauteng Provincial Government, 2017). This implementation manual is part of the capacity building effort to ensure the SuDS approach. Also, in the options analysis for strategic SuDS the environmental authorisation process plays an important role (See Section 7.2).

GDARD cooperates with Municipalities and gives them the opportunity to have inputs in the Environmental Authorisation process. However, GDARD realizes that streamlining the approval of stormwater management plans, WULAs and EIAs is not always seamless. This Research helped to clarify some improvements that can be implemented and further guidelines for reviewing conceptual SWMP may need to be developed (See Section 9.5).

For strategic SuDS (see Chapter 7) the provincial Spatial Development Framework will be important to reserve space.

10.4 What can the GDARD do as Facilitator?

As SuDS is part of climate change adaptation, GDARD can have a facilitating role in its implementation as part of the role of facilitating climate change adaptation.

GDARD is one of the drivers of the climate change adaptation agenda in Gauteng and has identified SuDS as one of the strategies of that agenda, particularly in terms of water security of the province, and GDARD can play a facilitative role across the Provincial departments as part of the climate adaptation role. Also, SuDS are linked to urban river and catchment restoration, and there is a need for GDARD to facilitate proactive forward planning across the three tiers of government, whereby broader water and environmental targets can be reached.

Policies at municipal level need to be aligned with catchment management strategies by Catchment Management Agencies as envisaged in the National Water Act. However, CMAs are not yet operational in Gauteng; but because of its understanding of the importance of water security, the

Province has taken the initiative to get engaged in water security (GCRO, 2019). In this implementation manual (Chapters 4 and 11), it is suggested that the municipalities develop local catchment management plans that acknowledge the wider regional catchment impact.

Further suggestions to support GDARD's ambitions as a facilitator are as follows:

- Setup bilateral discussions with Office of Premier Planning Commission, Road & Transport, Infrastructure Development, COGTA and Human Settlements;
- Partner with municipalities and possibly SALGA to support the compilation and adoption of by-laws and regulations utilising knowledge from the metros for lesser capacitated districts/local municipalities;
- Input to strategies, frameworks and plans at a national level (e.g. Climate Change Adaptation, Water, Roads & Transport, National Treasury, particularly in connection with Municipal Infrastructure Grants and Cities Support Programme);
- Establish, share and maintain a SuDS inventory for Gauteng Province (See Chapter 3) and support municipalities in inclusion of SuDS in asset registers and maintenance of registers.(See Section 11.4);
- Support new research on SUDS and facilitate the sharing of outcomes such as linking up with the Water Research Commission initiative to promote the wider uptake of SuDS and WSUD, and to disseminate the knowledge through the Community of Practice such that it reaches a nation-wide audience.

For EIA reviewers:

- Coordinate your judgement of site development plans with WULA, SWMP and other EIA reviewers so that it is consistent.

For Province, with the support of COGTA, SALGA and/or MISA:

- Engage with municipalities to use SPLUMA more actively to introduce water sensitivity and SuDS and to learn from each other

11 MUNICIPAL ROLES IN SUDS IMPLEMENTATION

11.1 What are the responsibilities and instruments of municipalities with regards to SuDS?

Municipalities have many means and responsibilities for introducing SuDS and for contributing to their sustainability.

As noted earlier, as custodians of stormwater management, the role of municipalities is crucial. The possible roles and instruments of municipalities related to SuDS implementation are outlined below. Municipalities may choose a different emphasis in each of the roles, but it is important to be aware of the full scope of possible interventions that may benefit SuDS implementation. Not all roles have equal importance in this manual or are equally relevant for green field developments or for retro-fitting, but these roles do give an idea of the possibilities that a municipality has.

As an owner of assets and as a service provider, municipalities should take the lead in implementing SuDS or can implement them or plan for them on private land where servitudes are formalised. Rainwater harvesting techniques can be applied in their own buildings and conditions can be set when selling their properties.

As a service provider, most responsibilities are not about the introduction of SuDS, but more about sustaining SuDS once they are there, such as waste collection, policing and parks management. These roles are mainly to prevent littering and vandalism and contribute to maintenance.

As a regulator, municipalities create by-laws, develop stormwater policies and approve stormwater management plans, and therefore have a central role in promoting SuDS. Introduction of “Agreement in Principle” for conceptual SWMP is particularly powerful change that will help SuDS adoption (See section 9.5). This may require additional capacity building in using tools such as MUSIC software.

Municipalities often acknowledge that compliance monitoring and penalties structures are crucial to get things implemented, but they often do not have sufficient capacity to make these work. Development levies are another instrument that can be used to promote and support SuDS rather than grey infrastructure.

As a facilitator, municipalities actively choosing to promote SuDS may have most influence. To gain traction and acquire budgets, SuDS promotion should be formulated within the IDP. While the role of facilitator is not an obliged task of the municipality, and therefore might not be prioritized, it may be the most efficient and effective way to reach developers through awareness raising campaigns, advice on stormwater management plans, data collection on existing stormwater assets and the costs and benefits of those, subsidies, procedural incentives (such as the City of Tshwane is doing with its green building policy), or assistance in coordination between departments or State Owned Companies that are involved.

Responsibilities of municipalities ant the instruments they have in facilitating SuDS

Responsibilities			
Owner of Assets • Roads and stormwater • Water supply and wastewater infrastructure • Parks • Human Settlement	**Service Provider** • Waste Collection • Sewerage and WWTWs • Policing • Parks	**Regulator** Formulation and compliance monitoring of municipality specific policies, strategies, Integrated Development plans and bylaws	**Facilitator** Initiating and facilitating IDP related targets
Instruments			
• Servitudes • Long Leases • Service Level agreements	• Service Level Agreements	• IDP, SDF • Policies • By-laws • Approvals of stormwater management plans • Compliance monitoring and penalties structure • Development levies	• Programme management • Awareness raising • Advice • Data collection and sharing • Subsidies • Procedural incentives • Coordination between departments / State Owned Companies and / or private parties

11.2 What role do municipal bylaws and policies have?

Municipal bylaws and policies may vary across the province, but they generally do not prohibit SuDS and will support SuDS for retro-fitting and new developments.

Site re-developments are typically controlled through municipal bylaws and policies. Hence it is critical that across the province these are updated to include requirements for SuDS. For example, the City of Johannesburg's Stormwater Bylaws (CoJ, 2010) require all land development projects, including land re-development, to limit runoff from the newly developed site to that of its original natural state. The City of Tshwane has adopted an alternative approach through their Green Building policy, prescribing that 80% of rainfall needs to be retained on site. Ultimately both approaches should be reviewed when catchment specific objectives are established.

Waste collection is a key service of a municipality, and crucial for the satisfactory functioning of SuDS systems, as they can get blocked, polluted or are not able to fulfil their amenity function anymore. Similarly, sewerage systems that leak, or are (illegally) connected to stormwater systems, cause SuDS to become overloaded with pollution, thus affecting their functioning. In systems where this is a persistent problem SuDS based design may still provide suitable solutions, but they will need to be designed fit-for-purpose. Also, non- or poorly functioning Waste Water Treatment Works (WWTWs) make the effort towards water quality improvements by SuDS insignificant, but strategic SuDS solutions may be employed as part of the integrated system. Hence bylaws and policies can have multi-departmental relevance, but as shown below this is a potential obstacle.

11.3 How to work together across departments and organisations?

SuDS need departments to work together, and this can be achieved by training and appointing dedicated 'ambassadors' in each department.

Within municipalities, the multi-disciplinary approach needed for SuDS was seen as a stumbling block during stakeholder engagement sessions. This is even more so in the City of Johannesburg with its State Owned Companies like the Johannesburg Road Agency, City Parks and Pikitup for waste management. The ambition to change organograms of municipalities is too high at this stage from a SuDS implementation perspective. However, collaboration between the key role players, including; town planning, stormwater management, open space management / parks and waste management, in each municipality is crucial to make SuDS work. Perhaps the most effective approach is to identify champions in each silo, and make them 'ambassadors', with Key Performance Areas to make collaboration work. These champions should be "T-shaped" individuals; i.e. with sufficient depth in their own discipline but broad enough and skilled in making connections with other disciplines. They will also need to be passionate and taken seriously within their own department, which does not mean they are necessarily seniors. The stormwater department could lead in these multi-disciplinary interactions but it also can be driven from Mayoral office or environmental section.

As explained in Section 4.3, stormwater management departments also need to link with water services authorities and providers and water boards such as Rand Water and waste water companies such as ERWAT, to get the required links with water supply and sanitation. This is a role such an 'ambassador' could adopt.

The Parks Department also has an important role to play. Stormwater systems that are not 'grey' often fall between the cracks with respect to maintenance, partly because there is no specialized unit that knows how to maintain them. The maintenance of 'green' SuDS will require trained teams, with advice from landscape architects and/or ecologists on the way to maintain these ecological systems. It is considered more efficient to give this task to the Parks departments and their depots.

11.4 How to improve the asset register and information for stormwater management?

It is difficult to evaluate stormwater management or make new appropriate stormwater plans, if the key data are not accessible.

Asset registers are also crucial for monitoring and protecting stormwater facilities, particularly those on private land, and those that may be mistaken for landscape features.

For informed decision making, data and analytical tools are crucial. In many municipalities, the maintenance of the stormwater facilities or the change in land use upstream is not recorded well. In fact, even records of the assets themselves may not be available. Stormwater management plans submitted for previous developments cannot be retrieved. This hampers informed designing of new developments and retrofitting projects in the same catchments. It also hampers targeted asset management, as well as the quantification of benefits and costs (See Section 9.4). Setting up improved information systems requires long-term commitments.

The benefits of asset registers were typically linked to monitoring and maintenance requirements, development control, as well as planning replacement programmes. However, with a greater focus on water resource and flood risk management, the range of stakeholders has increased substantially. In addition, as the cumulative benefit of SuDS interventions take effect, the need to manage these on both private and public property in an integrated manner will increase.

Asset registers were originally and typically in the form of drawings or plans with a stormwater network layout (e.g. for a township), recording attributes such as location, pipe diameters, depth of pipe, material (e.g. concrete) and age of the pipe, along with location of kerb inlets, outfalls, inspection manholes, etc. Over time these drawings may have been transferred to CAD (computer aided design) systems, and more recently GIS (geographic information systems) with increased capacity for more records to be retained for each component of the system.

The earlier networks were usually just focussed on municipal assets, and they would have reflected connections to private properties but usually very little about the stormwater assets on these properties. With the introduction of attenuation into stormwater management, many of these were on private property and not captured on the asset registers. As a result, an increasing portion of the stormwater network has not been transferred to the asset register, and in Gauteng it is not clear whether there any municipality with a protocol for capturing assets on private land. In time these assets are forgotten and are not accounted for in any new catchment plans. Thus, the value and benefit of these assets are lost.

The introduction of SuDS brings an even broader data set that needs to be captured, and that will cut across departmental boundaries. In addition to location, size and materials uses, information such as performance targets (stormwater quantity and quality), ecological and amenity functions, maintenance frequency and priorities (e.g. manage for water quantity performance in preference to

ecological habitat health), as well as monitoring data, and potentially many other attributes (see Culwick, et al, 2019). The municipalities need to regain the habit of maintaining asset data bases and making these accessible to a range of stakeholders (mainly internal municipal departments; Roads & Stormwater, Parks, Water & Sanitation, Housing, Planning, Disaster Management, etc.).

From experience, many water related information systems in South Africa have collapsed after the funding for licenses expired, or were only designed and never commissioned or used. Ambitions for the capacity and functionality of asset registers may need to be at an appropriate scale, but at the same time allow the agility to upgrade to meet the demands of multiple stakeholders and increasing water resource based decision making. Building on existing corporate capacity will be important, but discipline will still be needed at department level to ensure the correct data is captured. For example, when a SWMP is approved by the Roads & Stormwater Department the information is provided by the developer in GIS format and uploaded onto the asset register. Acquiring data for assets on private land should be the same as for those on public land.

Additionally, information for designers of SuDS can be improved by making available baseline information, such as rainfall series and land use maps and, when available, Catchment Management Plans. The City of Johannesburg is in this regard already setting up a system to provide rainfall series.

11.5 Why is it necessary to start implementing SuDS now?

To find out which SuDS designs and implementation processes work best in Gauteng and to gain confidence, projects need to be implemented as soon as possible.

The start of a transition process can be slow, especially where there are too few reference examples to learn from. Engineers, developers and municipalities can be too easily put-off new technologies. For example, during the period of this study a talk by an international expert on permeable pavements fed scepticism in a Gauteng municipality about the suitability of the technology for use and there was a suggestion of a moratorium on permeable paving until the technology was proven. Suppliers and practitioners in permeable paving reacted and a dialogue was initiated to demonstrate the examples of the range of performance achieved. This is an example of a critical part of the transition process. Opportunities for pilot studies should be encouraged. For example, in Johannesburg the JDA is conducting Eco-District studies around Louis Botha Avenue, around which a SuDS study could piggy-back.

Design guidelines for SuDS are available (e.g. Armitage, et al, 2013) but design standards for performance are still to be developed for Gauteng. This does not mean that the implementation of SuDS should be delayed. Projects should be implemented as soon as possible. Municipalities should support SuDS projects where the anticipated performance (quantity and quality) is determined during design, and where there is a clear plan for performance monitoring. Ideally, monitoring data should be relayed to the municipality who should maintain a database for research and development of SuDS. Municipalities are therefore not necessarily the initiators of pilot applications, but should work with

developers to help build the base of experience. Performance monitoring performance is key to building this experience.

See Chapter on "Options for green asset registries in Gauteng" in "*Towards applying a green infrastructure approach in the Gauteng City-Region"* published by the Gauteng City Region Observatory(Culwick, et al, 2019)

For urban designers, urban planners and stormwater plan designers:

- Look differently at open space; use existing open space also for SuDS and reserve space for stormwater management.

For municipal bylaw and policy makers:

- Evaluate in a few years' time, which SuDS approaches – e.g. adopted by Tshwane or Johannesburg – and which designs were most effective and efficient and consider adopting them. Review the bylaws and policies once catchment specific objectives become available.

12 UNDERSTANDING THE LIMITATIONS OF SUDS

12.1 Introduction

The understanding of benefits of SuDS can be vulnerable to generalisations. This can lead to expectations of performance that may not be realised if the systems are not properly planned, designed, constructed and maintained. This is particularly relevant in Gauteng context where climate, soil and socio-economic conditions all place practical constraints on SuDS implementation. During the research, a range of constraints were identified which warrant further discussion and clarification. This includes the role of SuDS in flood reduction, the potential for SuDS to deliver tangible improvements in heat island management and the potential for SuDS to deliver multiple benefits.

12.2 Role in flood reduction

SuDS installations do not necessarily provide flood relief (unless they are specifically designed for this purpose). Understanding the designed performance of SuDS installations is critical to their operation and management.

Most SuDS facilities are designed to treat the smaller, more frequent rainfall events and are vulnerable to damage by large storm events. These SuDS facilities will be designed with by-passes to protect them against large storm events, and as a result will offer minimal flood attenuation or retention benefit. Therefore, flood management still needs to be specifically designed for and flood management cannot be left to dispersed SuDS facilities around an urban catchment. SuDS technologies can be effective in reducing the overall hydraulic load in a large storm event, but in most urban applications the detention pond facility will still be the primary flood control unit. However, as part of a SuDS treatment train the size of the detention facility will usually be smaller than a site drained by grey infrastructure. In addition, if infiltration through the base of the detention pond can be achieved, the detention pond can be an important part of the treatment train performance even in small events and can improve groundwater recharge and storage.

12.3 SuDS benefit for heat island management

SuDS contribution to urban heat island management requires inclusion of shade plants (e.g. trees) and the benefits are local.

The comparison of temperatures at different weather stations showed that the effect of altitude and lower humidity in the Johannesburg CBD appear to mitigate inner city heat islands effects (**Box 8**). Although this would need to be further investigated, other densely developed city areas along the continental divide in Gauteng may experience the same effects (e.g. Ekurhuleni, Johannesburg, West Rand). In fact, heat intensity may be a greater problem in the lower lying suburban areas than in the

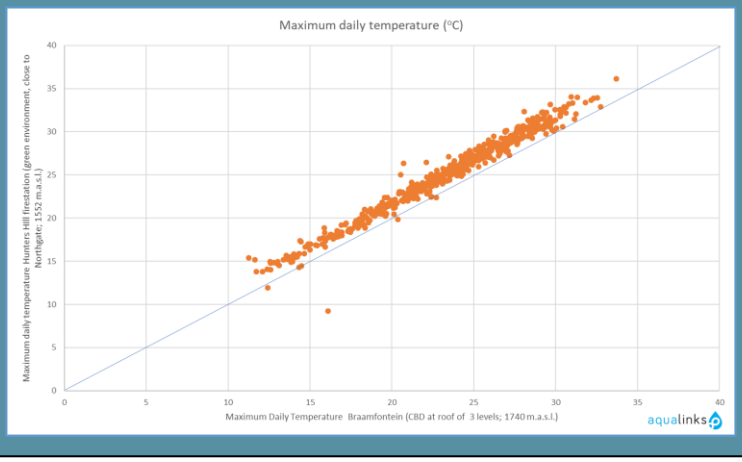
CBD, although for the whole of Gauteng the climate projections show significant increase in the number of heat wave days.

The study suggests that attention should not be so much on SuDS providing green wet areas, but rather to be given to mitigate exposure to sun, particularly for pedestrians exposed to high day-time temperatures. Provision of shade is important for this, and the chosen SuDS design should support this through the introduction of shade trees. However, the effects will be localised and their impact on the overall temperatures in the city will be insignificant unless implemented at a large scale. SuDS that are wetter (cooling by evapotranspiration) and/or have high reflective properties (high albedo) are expected to have less effect than shade in Gauteng.

Green roofs will also offer some benefit, particularly to the upper floors of a building which typically are most affected, but the effect is again localised. Impacts on micro-climates in built up environments can only be achieved if the greening of the city space is extensive. The 'tipping point' for this is unknown for Gauteng, but research suggests that at least 25% of the inner city areas needs to be greened. Municipalities must strive to utilise open areas, abandoned areas and pavements for this purpose.

Box 8: Johannesburg CBD temperatures compared to Suburb temperatures

The chart below indicates the comparison in maximum daily temperature between Braamfontein in the CBD and Hunters Hill in a suburban environment next to the large Golden Harvest Park. Despite its favourable surroundings for creating a cooler climate, the Hunters Hill maximum temperatures are consistently higher than those in Braamfontein. The reason seems to be that the higher altitude of Braamfontein is having a greater impact than these other conditions. A similar comparison was done with other TAHMO stations and the altitude seems to be consistently the greatest impact on maximum daily temperatures. (Period of comparison is August 2017 to March 2019; data from weather stations of TAHMO at Hunters Hill fire-station, at an altitude of 1552 m.a.s.l, next to the large green Golden Harvest Park with a water dam in a park itself; and in Braamfontein 28 Juta Street, at an altitude of 1740 m.a.s.l., on top of a concrete roof of 3 levels high).



See further on heat management with SuDS, in the deliverable 5 report 'Analysis of Study Areas', section 2.3 general, and then for the CBD only: 3.4.5 green roofs, 3.5.4 bioretention cells, 3.6.4 catchment scale interventions.

12.4 Water harvesting and benefits for water security

SuDS installations can be designed to support water harvesting, but plans for the use of the water are equally important.

Rainwater harvesting, by harvesting runoff from roof areas, is often presented in international literature as an important part of SuDS. It is also often the only harvesting option considered when the water resource value of urban stormwater is discussed. However, the long dry season in Gauteng means that, for efficient water resources management, rainwater and stormwater should be used when it is available – in the wet season – in place of drawing on potable supplies, and that this will reduce drawdown on bulk water systems (e.g. Vaal Dam) and improve water security. This requires a disciplined approach to rainwater harvesting, which may be somewhat eased by investment in additional infrastructure, to make a difference in preserving bulk supplies. Feedback from stakeholders during the study showed that:

- Most local storage systems are small and may run dry within a week or two if there is no rain to refill them. But to have a stormwater management impact, the stored rainwater still needs to be used as soon as possible to allow space in case it rains sooner than expected. This is best achieved by using the water for a range of purposes.
- The municipal water supply is seen to be a right in some communities, and it will be used in preference to local alternatives. Even communities with unreliable supply and who have invested in (or been supplied with) rainwater tanks will avoid using rainwater when municipal supplies are available. Hence, these residents will allow tanks to stand full, and even overflow without using any of the water, until municipal supply fails. Then they will use the rainwater, may even drink it, creating potential health risks.
- Municipalities are reluctant to promote rainwater harvesting in case this rainwater may be used for potable supplies despite the risk of contamination.

Simple rainwater (and stormwater) harvesting systems are unpressurised and using the water usually requires additional manual interventions. Hence there will be a tendency to allow tanks to stand full until there is no easier alternative. This not only offers very little benefit to wider water conservation and water security objectives, it also offers very little to stormwater management objectives. Instead of reducing stormwater runoff, authorities are currently being advised to assume that rainwater harvesting measures should not be accepted as part of a SWMP unless clear economic and reliable benefits can be demonstrated. Typically, this is only demonstrated for commercial or industrial

applications. Thus, incentives to use harvested water in domestic applications such as flower and food gardening and dual tank filling systems for flush toilets, need to be developed.

In contrast, stormwater harvesting in a catchment offers significantly greater volumes and potentially more control, especially if the operation is managed by a municipality or a commercial operation. Storage facilities can include SuDS retention ponds that offer ecological and amenity services and are attractive features of the river system. However, the downside is that stormwater is usually more polluted, requiring greater levels of treatment even for non-potable use. Sediment will be a major problem in Gauteng, and sewage loads will be high in many Gauteng catchments. However, stormwater harvesting directly supports water security and stormwater management objectives if these problems are overcome, and thus meets the objectives of WSUD. This is a strategic catchment management, although the practicalities still need to be demonstrated.

The report 'Development of Resource Guidelines for Rainwater Harvesting' commissioned by the Water Research Commission and written by Mwenge Kahinda et al. (2017) is useful for further design of rainwater harvesting systems.

12.5 The need for Gauteng experience

The performance of SuDS in Highveld climate and soil conditions and with the communities in Gauteng will need to be further tested in future.

Research on and implementation of SuDS in South Africa has been documented mainly for coastal areas, predominantly in the Western Cape where much of the pioneering work on SuDS in South Africa has been done. Although there are examples of SuDS applications in Gauteng, there are few that have any stormwater design, and there have been concerns raised that SuDS performance in Highveld conditions may be as much a problem as a solution.

Gauteng specific research on SuDS undertaken to date (e.g. Culwick & Bobbins, 2016, Culwick, et al, 2019, City of Johannesburg, 2019), as well as current research by the GCRO and the case studies done as background to this study, all indicate that SuDS technologies will work in Gauteng. What is lacking is the experience and knowledge gained from the implementing SuDS projects that will help refine the design and maintenance of the systems for optimum performance in the province. Hence it is important that developers and the authorities (municipalities, GDARD and DWS-Gauteng) adopt a proactive approach to adopting SuDS, and even adopt a partnership mentality on the SuDS implementation. As long as there is monitoring of the performance of the new SuDS that are authorised and constructed, and that the resultant data is shared with the practicing community, this partnership will show substantial benefits.

For SuDS facilities designers:

- Determine the intended performance of SuDS facilities (both SuDS units and whole treatment trains) in consultation with the developer and have them reviewed and approved by a municipality. Performance criteria will include runoff quantity and quality targets, as well as ecological and amenity targets.
- Design specifically flood management targets into the SuDS treatment train.
- Integrate SuDS functions with other services and land uses, as it is one of the main benefits of SuDS but it needs the careful planning (and usually multi-disciplinary input). One example of this would be integrating shade tree planting within the SuDS treatment train to help mitigate local heat effects.
- Water harvesting from SuDS treatment trains offers prime water security benefits. This includes both rainwater harvesting (from roof areas) and stormwater harvesting (within stormwater networks). However, water use plans are a critical part of the success of these systems and should be developed as art of the design of the SuDS scheme. The plans should identify a clear water demand (and even a cost saving) for the water and demonstrate the method(s) for harvesting the water.

For government and municipal departments:

- Encourage the planning, design and implementation of SuDS projects to help build that important baseline experience of success and failure under Gauteng conditions. This will only be understood if the intended performances of the SuDS projects are known and are monitored once implemented.

13 RECOMMENDATIONS

13.1 Adding further implementation effort

The Province needs a follow up after introduction of this implementation manual to further the transition to SuDS. In particular, the facilitator role will need to be fleshed out (programme coordination and management, capacity building and lobbying).

This manual will need a coordinated effort to get to the next step. While the legal framework does not prohibit SuDS, large scale implementation to have an impact at catchment scale, will need lobbying for all parties to play their roles. SuDS will have a low priority on the agenda of smaller municipalities in particular, where capacity is limited and the IDPs have other priorities. Developers also have to become convinced more than they are currently. In this manual, lobbying is part of the facilitator role of the Province, with support where useful of COGTA and SALGA. This requires programme management capacity and coordination. The Environmental Policies, Planning and Coordination Directorate in GDARD is recommended to take this lead.

Willing municipal civil servants were clear in that they needed support. It was suggested to have continued support from the Province to (1) assist in drafting policies and bylaws, (2) include discussion on SuDS in fora of inter-municipality learning with champions from municipalities learning from each other and being trained together. Examples of fora to draw from are the global C40 (climate change adaptation and mitigation by metropolitans worldwide), SuSdrain (community of practice in UK on SuDS but not only for municipalities) and www.klimaatverbond.nl (association in Netherlands for participating municipalities, water boards, provinces to learn from each other for climate adaptation). The University of Cape Town, through its Future Water Institute, has been tasked by the Water Research Commission to grow a 'Community of Practice' around Water Sensitive Urban Design. The forum will need to tackle different aspects of SuDS implementation and can engage jointly with relevant parties to make contributions (such as the Department of Human Settlement, Water and Sanitation, Rand Water, Magalies Water, Departments of Economic and Social Development and the Property developers, as well as Departments of Finance, Transport, Public Works and Infrastructure).

The introduction of SuDS instead of conventional stormwater infrastructure will place demands on the expertise of municipal officials who will approve stormwater designs, the DHSWS officials who approve water use licences, and the EIA reviewers at GDARD. The methods for design and specification of SuDS systems will become standardised in time, relieving some of the requirement for expert knowledge, but the management of stormwater as a water resource will always remain more demanding than the historic approaches, and developing expertise in the sector will need to be an important objective of all related institutions in the province, for which the Province can and should lobby.

13.2 Working towards a better knowledge base

Gauteng specific performance monitoring data and experiences need to be collated and analysed to develop the best practice recommendations for design and maintenance.

The performance of SuDS systems in Gauteng needs to start feeding back into the practicing community and officials. Maintenance and monitoring guidelines are outlined here and are addressed in some detail in referenced texts. Therefore, the monitoring of existing sites would be an important element in developing an asset register and performance history of SuDS to be used as an important reference for designers and planners. A champion for holding and maintaining the inventory needs to be identified, possibly in each municipality, but a more central position in provincial government would also be suitable. A manual could be designed, based on experiences on the ground, which will improve over time to guide the maintenance. The knowledge base that will need to inform improved maintenance can also inform improved designs, and link to the recommendations for the asset register improvements.

13.3 Having a better grip on the financing question

Ways of financing SuDS or convincing investors of the business case for them will need more research and dissemination of knowledge.

SuDS are not necessarily more expensive than traditional water systems, but as any investment in infrastructure, the financing question is important, particularly in South Africa with so many other issues competing for funding. Financing SuDS has not been the topic of this research project, but will become critical during implementation, and has been mentioned in workshops as a challenge. For South Africa, the introduction of separate stormwater fees has been studied (Fisher-Jeffes and Armitage, 2013). While this can have a direct link with property, it will require a good asset register and asset management, as well as a very good campaign on user engagement. It may be more practical to remain with stormwater management as part of the general municipal rates, but for planning purposes, a ring-fenced budget for stormwater management or even specifically for SuDS may work well to include in the municipal budgets.

When planning big infrastructure investments for water supply or for wastewater treatment or sewage collection, municipalities would be recommended to think about how such investment could be allocated differently to also benefit stormwater management and open space.

Financing SuDS in private developments will benefit from decision support methods that can also estimate the indirect benefits typically associated with SuDS projects. Studies in other countries and this research seem to indicate that it is critical to be able to highlight the additional benefits of SuDS to get investors on board, as they add to the business case.

13.4 Thinking through ownership, access and maintenance

SuDS can be owned and maintained by different stakeholders. But whatever ownership and maintenance decisions are being considered the decision must take into account that access of the open space used for SuDS is important for society. Different permutations are possible to share responsibilities of ownership, access and maintenance but these permutations need further research.

A model can be chosen that keeps the municipality as the owner of the asset, but arrange for the local community to take responsibility for the maintenance. The stakeholder engagement, in particular in the City of Joburg CBD area and also during the second large workshop, indicated that it was important to have written agreements for such maintenance arrangements. City of Tshwane has a policy in place for how such an agreement could look, but the research did not yet interrogate this policy further for its applicability for SuDS. With the limited openly accessible space existing in Gauteng, we warn against maintenance, renting or ownership agreements that lead to areas being less accessible for recreational or walking or cycling passageway purposes.

13.5 Appreciating the key role of landscape architects

Landscape architects have a critical function in the implementation of SuDS and their experience and insights for Gauteng should be further researched and reported.

The scope of this project did not include the expertise of a landscape architect. Landscape architects made their voluntary contribution during stakeholder engagements and during the report writing on the Inventory of SuDS in Gauteng. With most SuDS being vegetated and having an impact on the open space, the expertise of landscape architects is important. They also have been the drivers of existing SuDS in Gauteng and country-wide and have experience. Landscape architects have a critical role in multi-disciplinary teams as well in lobbying for SuDS with developers gets sufficient recognition. An additional chapter in the Best Management Practices report is still outstanding. The climate, soils, biodiversity and landscaping trends in Gauteng and how these are used by landscape architects, is also an important body of knowledge for future implementation.

13.6 The need for expertise and experience

The importance of stormwater as a water resource and part of the urban water cycle, as well as the multidisciplinary requirements for planning, designing and maintaining SuDS facilities, requires a greater depth and understanding of stormwater systems than was required for traditional stormwater design. There is a need to develop this expertise across all practitioner disciplines and among municipal and government officials.

Development of expertise across all sectors is a key requirement for the uptake and implementation of SuDS. It is not the intention of this report to set out roles and responsibilities in this regard, but the following organisations have a role to play:

- The requirement for experience cuts across all practitioners and professional bodies involved in SuDS planning and design; urban planners, urban designers, landscape architects, ecologists and engineers. The same may also be considered for EAPs.
- Academic institutions and professional bodies play important roles in this regard but establishing standards will be important and there will need to be some auditing and quality control of the accrediting bodies.
- Specialist water institutions such as the Water Research Commission (WRC) and the Water Institute of South Africa (WISA) are already active in promoting sustainable water resources management across all aspects of the water cycle, and the WRC is directly involved in research in SuDS and WSUD.
- Municipalities, through their bylaws and policies can influence the requirement of expertise and experience in the practitioners submitting SWMPs. For example, the City of Johannesburg requires the SWMP to be prepared by a professionally registered engineer who can demonstrate the necessary expertise and experience to carry out the planning and design of SuDS based stormwater systems.
- However, ensuring the practitioners have the necessary experience also requires the municipal officials to have similar experience and there is a critical need for municipalities to acquire the necessary expertise.
- Similarly, provincial government also has influence over sustainable stormwater management and it is recommended that EIA reviewers in GDARD and WUL case officers in the DWS-Gauteng should also have the necessary experience to review and interrogate EIAs and WULAs submitted for SuDS projects.

There may be some discussion about the need to simplify SuDS design to accommodate skill shortages. Best practice guidelines encourage that the necessary expertise be employed to plan, design and review sustainable drainage systems and it is expected that a coordinated programme of training can address short-term skills requirements. This may be developed through the cooperation of the parties listed above.

13.7 The need to review and align the stormwater permitting processes.

The alignment of the main permitting processes related to stormwater management (the SWMP sign-off, Environmental Authorisation and the Water Use License) are seen as obstruction to the uptake and implementation of SuDS. Included in the review is the recommendation for the introduction of an 'Agreement in Principle' of the concept design of the SuDS based SWMP.

Aligning the main permitting processes will improve decision making process, improve the uptake of SuDS by developers, and will generally improve the relationship between developers and the authorities.

The introduction of an "Agreement in Principle' at concept design stage, confirming the performance of the proposed SuDS based stormwater system, but allowing the developer latitude to refine the final layout of the treatment trains and stormwater system, will minimise project delays and work at risk. It is also likely to influence the introduction of stormwater management earlier in the development planning programme, ensuring more space is reserved for the necessary SuDS interventions.

This approach should also improve the decision making time lines by municipal and government departments, but it will require changes to legislation and coordination between government departments. Cooperative governance oversight will be important. The approach to accommodating this step may differ between the different authorities, and existing processes may be adapted to cover the requirements. A more detailed review of each of the processes will be required to identify the best approach.

This effort could be seen as part of the transition phase in moving towards Water Sensitive Urban Design.

13.8 The importance of the Catchment Management Plan

This manual highlights the importance of the CMP as a backdrop to planning, design and implementation of SuDS (and WSUD).

The CMP should refer to, or integrate with, Catchment Management Strategies that may become available for all regional catchment that may be impacted by Gauteng, but the scope of the CMP will need to provide guidance for decision making at both a site scale and a catchment scale.

CMPs are most likely to remain the responsibility of a municipality, but rather than just a narrow focus on such aspects as flood management or river health, the CMP will need to address the wider requirements of WSUD and address the water resources of the catchment.

At the time of writing a pilot CMP study has been initiated in the City of Johannesburg, with the intent to provide guidelines for the development of similar CMPs in the area. It is also expected to challenge perceptions about and objectives for urban surface water management in the circumstances of the Highveld location and associate urban and climate conditions. Oversight by Province (GDARD and DHSWS-Gauteng) and COGTA would be beneficial.

13.9 Developing an understanding of 'Use-Value' in Gauteng

A key outcome of the research study is the importance of community acceptance, and even adoption, of a SuDS project. The term 'use-value' has been adopted to describe the value a community places on a piece of land. If SuDS can enhance that value, the more likely the SuDS facility will survive and function.

The research identified that those projects with a strong SuDS theme were those supported by the local communities or landowners, and typically maintained by their own efforts. In contrast, those sites where the perceived value, or importance, of the property was seen to be low the more risk that the site would suffer degradation (by dumping, for example). Further, if stormwater management is seen as just a municipal responsibility then no effort would be made to prevent it from being damaged.

Improving property value is one form of 'use-value'. Another may be providing an area of enhanced amenity, but in parts of Gauteng those attributes are not always seen to be of value. Hence the need to explore other forms of 'use-value' that SuDS may be able to support to the benefit of the local community. Without a broader range of 'use-value' options, there is a danger that SuDS may only be successful in a limited range of communities.

Experience in exploring options for SuDS across a wide range of communities will provide an important database for this. In particular the EIA process of stakeholder consultation should be guided to explore these aspects. GDARD will have a pivotal role to play in this, by guiding developers and EAPs to investigate community attitudes to SuDS projects and what makes them interested, or not interested. Low to middle income communities are particular target groups.

Data and findings could be collated and reported at local conferences, to municipalities and professional bodies.

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