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Literature review on SuDS: definitions, science, data, policy and legal context in South Africa

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Growing Gauteng Together

COLOPHON

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ACRONYM LIST

AMD	Acid Mine Drainage
ARC	Agricultural Research Council
CiWARD	Centre in Water Research and Development
CMA	Catchment Management Agency
CoE	City of Ekurhuleni
CoJ	City of Johannesburg
CoT	City of Tshwane
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DHS	Department of Human Settlement
DWA	Department of Water Affairs (predecessor of DWS)
DWS	Department of Water and Sanitation
EbA	Ecology Based Adaptation
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency of the United States
EPWP	Expanded Public Works Programme
GBCSA	Green Building Council of South Africa
GCRO	Gauteng City Region Observatory
GDARD	Gauteng Department of Agricultural and Rural Development
GEF	Global Environmental Facility
GIS	Geographical Information System
GPEMF	Gauteng Province Environmental Management Framework
IDP	Integrated Development Plan
IEEP	Institute for European Environmental Policy
JCPZ	Johannesburg City Parks and Zoo
JRA	Johannesburg Road Agency
LID	Low Impact Development
LUS	Land Use Schemes
MIG	Municipal Infrastructure Grant
NDP	National Development Plan
NBR	National Building Regulations
NEMA	National Environmental Management Act
NWA	National Water Act
NWRS	National Water Resources Strategy
PCSWMM	Personal Computer Storm Water Management Model
PICC	Presidential Infrastructure Coordinating Commission
RDP	Reconstruction and Development Programme
RQO	Resource Quality Objectives
SA	South Africa(n)
SANBI	South African National Biodiversity Institute
SANRAL	South African National Roads Agency Limited
SANS	South African National Standards

SAWS	South African Weather Services
SCS	Soil Conservation Service of the United States
SDF	Spatial Development Framework
SDG	Sustainable Development Goal
SIP	Strategic Integrated Project
SLAMM	Source Loading and Management Model
SPLUMA	Spatial Planning and Land Use Management Act
SuDS	Sustainable Drainage Systems
ToR	Terms of Reference
UCT	University of Cape Town
UK	United Kingdom
UN	United Nations
WMA	Water Management Area
WRC	Water Research Commission
WSUD	Water Sensitive Urban Design
WSUDS	Water Sensitive Urban Design Standards
WSUM	Water Sensitive Urban Management
WSUP	Water Sensitive Urban Design
WUL	Water Use License
WWAP	World Water Assessment Programme of the United Nations

1 INTRODUCTION

As part of the GDARD project Research on the Use of Sustainable (Urban) Drainage Systems (SuDS), the Terms of Reference identify this report as 'Literature review of SuDS research in South Africa'. Furthermore, a review of the policies and governance context was necessary, not just academic research. Therefore, this report is titled 'Literature review on research on SuDS in South Africa and policy and law context'.

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 and policy and legal context in South Africa** (this report)
3. Selection of three specific study areas
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

The objective of this report is to identify Research; Data; and Policy, law and implementation Gaps and state how/if the rest of the project plans to address these:

• **Research gaps**: What should research – by this project and otherwise – focus on to assist in implementation of SuDS in Gauteng?
• **Data gaps:** What information is missing for implementation of SuDS in Gauteng?
• **Policy, law and implementation gaps**: What aspects are missing in the policies of South Africa and the policies and By-laws of the municipalities to support the implementation of SuDS in Gauteng?

The gap identifications are colour coded in this document as above.

Research on SuDS in South Africa has taken place since the 1990s but often been site specific or addressing specific aspects of stormwater management. As result it had limited uptake in general practice. Guidelines addressing the general principles and practice of stormwater management for South Africa only really started emerging post-2010, with the South African SuDS guidelines published in 2013 (Armitage et al., 2013), which will be further referred to as the South African SuDS guidelines, as they form the 'baseline' against which this literature review measures progress in research. The University of Cape Town has made great strides in developing these guidelines and the broader guidelines of Water Sensitive Urban Design (Armitage et al., 2014) but also in applied research, mainly focusing on the Western Cape context. The Universities in Gauteng have contributed with research that focus more on certain aspects of SuDS, with few (but good) examples of evaluation of implementation on the ground. This literature review focuses on new research since the publication of the South African SuDS manual in 2013, that can shed additional light on implementation challenges in Gauteng. Since Gauteng is the most urbanised province, this project focuses on stormwater as this is 1st step for provincial government in working towards Water Sensitive Urban Design

As for the policy and law context, national policies and laws play a role in giving guidance to environmental impact assessment and water use licenses. However, the municipalities are the custodians of stormwater management, and therefore the main impact on SuDS implementation is by the policies and by-laws of municipalities. Metropolitan centres have taken the lead in adopting sustainable drainage. The City of Cape Town and eThekwini being the first to adopt them in municipal policy. In Gauteng, the City of Tshwane introduced SuDS into stormwater guidelines in 2016 and the City of Johannesburg is developing a design manual whose application will be prescribed by its by-laws.

The starting points of this 'literature review' also need some explanation:

- This report is not strictly a literature review, in the academic sense. During the development of this report, it became clear that there was a need to also explain concepts and practices around SuDS in South Africa, from the experience of the authors.
- The scope of the ToR is clear in that only South African resources are to be consulted. However, in cases when it was necessary for the analysis of gaps, additional international references have been added.
- SuDS are a wide topic, with many technical solutions, requiring all kinds of data sources and touching on many policies and laws. The report is therefore answering a mixture of questions that are useful for SuDS implementation.
- Background drivers for SuDS implementation include climate change adaptation, widening the the water resources mix, job creation potential, the need in Gauteng for water dilution of other pollution by sewage or mine (residues), co-benefits such as amenity values and food production are mentioned in the policy documents studied. This literature review does not go into South African research on these aspects, but they are considerations that are part of the research project, e.g. the decision support for SuDS in Gauteng and the Implementation Manual.
- As the Decision Support on SuDS is a separate deliverable in the project, literature on economic evaluations has not been reviewed but will inform that deliverable.

Although the original scope was to use this Literature Review to identify gaps, this report can also serve to see what is already happening in South Africa and specifically Gauteng that can support SuDS implementation.

2 WHAT ARE THE INSIGHTS THAT ARE IMPACTING SUDS-DESIGN IN SOUTH AFRICA?

2.1 Introduction

This chapter provides an introduction of the SuDS concepts and design processes and explains the status of affairs currently in South Africa in relation to trends on SuDS related concepts in the world.

2.2 SuDS as a subset of Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design (WSUD) is a "philosophical approach to urban planning and design that aims to minimise the hydrological impacts of urban development on the surrounding environment" (Lloyd et al., 2002, as cited in Fletcher et al., 2014). The term originated in Australia but is now broadly used internationally. Water Sensitive Urban Design (WSUD) is linked to the concept of Integrated Urban Water Management (IUWM) that relates to all aspects of the urban water cycle. Stormwater management and more specifically SuDS is part of the urban water cycle and one of the subsets of WSUD because it aims to protect and enhance natural water systems, maximises the visual and recreational amenity of developments, improves water quality, and reduces run-off and peak flows (Fletcher et al., 2014). Water Sensitive Urban Design is the process via which the goal of a Water Sensitive City can be achieved. The approach of Water Sensitive Urban Design (and the terminology as such) is also gaining more momentum in South Africa, often here shortened to Water Sensitive Design, with WRC supported research projects such as that of Fourie et al. (2019a and b) and the initiatives and collaboration of WRC with the Future Water Institute of the University of Cape Town (http://www.futurewater.uct.ac.za/FW-wsd and Armitage et al. 2014). The long game is to move to water sensitive cities, as explained further in Section 2.6.

2.3 Principles of SuDS design

The South African SuDS manual explains that "Conventional drainage systems are generally focused on eliminating local flood nuisances and largely ignore the need to preserve or improve water quality and the associated aspects of amenity and biodiversity" (Armitage et al., 2013), therefore the need for SuDS. The principles of Sustainable Drainage Systems (SuDS) are perhaps best described in the CIRIA SuDS Manual (Woods Ballard et al., 2015). The four main categories of benefits (the Four Pillars) are; water quantity, quality, amenity and biodiversity (Woods Ballard et al, 2015). Central to optimising the benefits across all categories is treating stormwater as early as possible, preferably from where the rain falls, and ideally using systems that mimic natural catchment processes; interception by vegetation and infiltration into soils. The benefits arising are summarised in Figure 1.

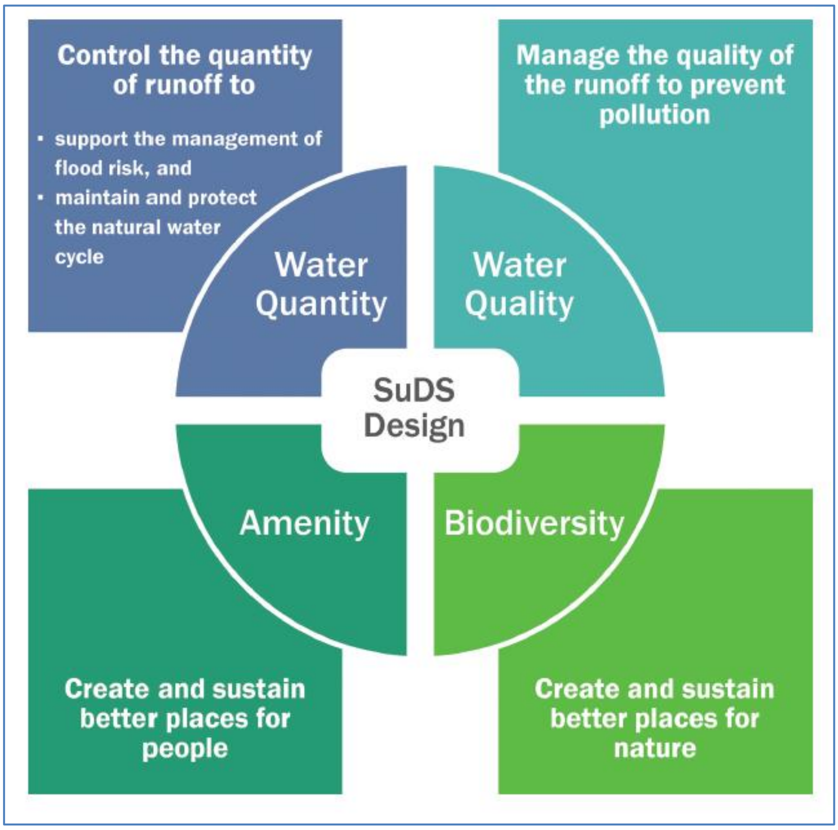

Figure 1: The "Four Pillars of SuDS Design" (Woods Ballard et al, 2015)

Most of the vegetated SuDS will address all four pillars, but a combination of SuDS facilities is usually required to obtain the objectives. These combinations work together on a site, in a community, or at a catchment scale to not only protect the downstream areas, but also to enhance the local environment. These combinations of SuDS measures are referred to as "treatment trains" (Armitage et al, 2013), that are intended to start at the point of rainfall and usually extend over the length of the local drainage system. This combination or 'treatment train" is a fundamental principle of SuDS – water overtopping one element flows into the next and in this way can address a wide range of storm types. SuDS can as such bring stormwater management into the public open space or create visibility in private development sites. This is a different approach to the conventional buried network of pipes and drains that convey stormwater as a wastewater product.

Armitage, et al (2013) also places SuDS in the South African context, proposing a hierarchy of priorities in the development of SuDS measures, see Figure 2. They give emphasis to addressing quantity and secondary quality as the primary problems in South African urban areas. "*Simply put, there is no point focussing on biodiversity if life and property have not been protected*" (Armitage et al, 2013).

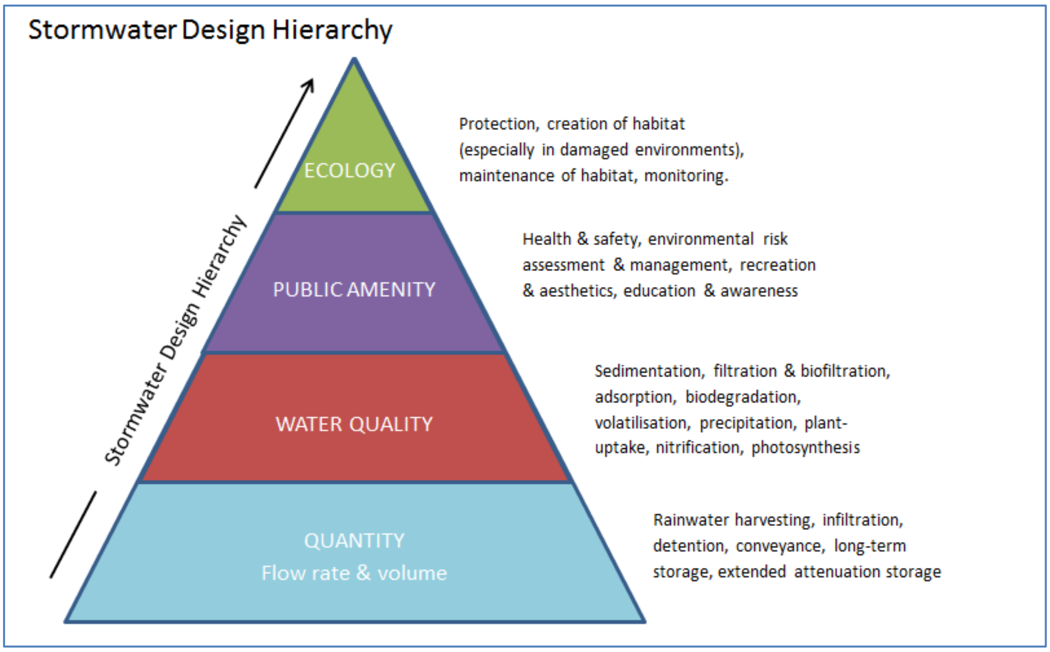

Figure 2: SuDS design hierarchy (after Armitage, et al, 2013); in the figure below the original 'biodiversity' is replaced by 'ecology' which the authors of this report find more appropriate.

As explained, the first priority is bringing the quantity of flows back to a more natural level. Urban hardening (buildings, roads, pavements) substantially alters the hydrology of a catchment (illustrated in Figure 3). In Gauteng the difference between hydrological responses from natural and developed surfaces is more extreme than shown in the figure, although no definitive figures can be quoted and local differences can be large. But to give an impression, modelled natural catchment runoff in the Upper Vaal catchment of Gauteng is between 1.5 and 7.7% of annual rainfall at quaternary catchment level (www.waterresourceswr2012.co.za). For urbanised catchments, the average runoff increases considerably, mainly due to larger impervious areas draining faster to stormwater systems, typically 20-50% on average (Armitage et al., 2013 referring to SANRAL-manual version 2006). At quaternary catchment level, these influences on mean annual runoff are not really measured, as flows can be considerably influenced by return flows from sewage and wastewater treatment works.

SuDS seek to address the effect of urban paved surfaces by trying to re-balance the hydrological response to reflect the natural catchment condition as far as possible. Hence, breaking it down to its simplest form, the predominant focus of SuDS is on increasing infiltration (soils), storage and evapotranspiration (vegetation). This presents a substantial departure from the more traditional stormwater planning and management, that is focused on grey infrastructure, with quick disposal of peak flows and some engineered detention in case maximum flow capacities downstream are not sufficient.

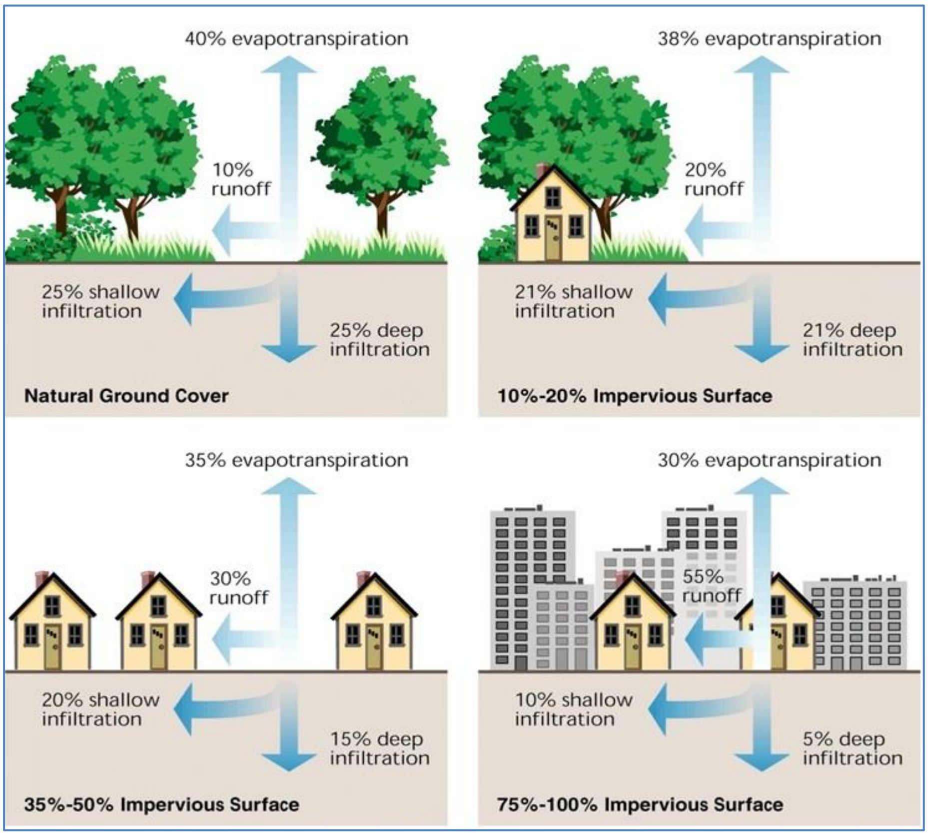

Figure 3: The impact of urban hardening on the natural hydrological balance. Note: % values not for Gauteng but same principles (after FISRWG, 1998)

2.4 Stormwater management and Biodiversity

Both Green Infrastructure and Ecology Based Adaptation measures are based on a strong foundation of eco-system based services which may not be supported by the hierarchy proposed by Armitage et al (2013) in Figure 2. At the same time, urban drainage lines provide the ideal framework for Green Infrastructure (Dunsmore, 2016).

The strongly anthropocentric view in Figure 2 is not necessarily shared by conservationists in South Africa. There is a shift in urban restoration ecology towards emphasizing the importance of taking a landscape perspective when setting regional objectives and tailoring site-level responses. Indeed, in a review of river restoration strategies, Dufour (2009) argues that the aim of returning streams to a reference state should be replaced by an objective-based approach where river repair or improvement is valued in terms of the provision of ecosystem goods and services, and where objectives are defined by reference to a broad array of factors, including conservation, aesthetics, resource extraction, water quality, heritage protection and flood management. As such, biodiversity aspirations need to be balanced against the need to meet other (often considered more important) objectives.

It is also recognised that the biodiversity and the broader ecological functioning associated with drainage lines and watercourses are strongly dependent on the state of underlying drivers, and that if these are not correctly managed, ecology will ultimately be affected. This is in support of the hierarchy as presented Figure 2.

Targeting biodiversity / ecological objectives without suitable quantity and quality of water will be difficult. However, when assessing the SuDS objectives for a site, the approach adopted in this study has been to start from the position of equivalence between the components of the stormwater hierarchy. This has helped encourage a more in-depth evaluation of the full potential is a SuDS intervention, as well as potential weaknesses that will be critical in design development. There are certainly instances where biodiversity considerations need to receive greater attention due to the presence of critically endangered fauna or flora or the need to maintain or enhance critical ecological linkages as identified in Gauteng Conservation Plan (Pfab, 2017), see further Section 6.5.

2.5 Paradigm shifts worldwide influencing SuDS design in South Africa

2.5.1 Introduction to overlapping concepts

The terms in South Africa used for more sustainable urban water management have their origin in other parts of the world. The project that developed this literature review carries in its title 'Sustainable Urban Drainage Systems'. However, with the introduction of the 'Alternative Technology for Stormwater Management - South African Guidelines for Sustainable Drainage Systems' (Armitage et al., 2013), the word 'urban' has been removed in stormwater design circles in Europe and the abbreviation is SuDS instead of SUDS. In Australia, the concept of 'Water Sensitive Urban Design' is more common and that has also made its way into South Africa, with the publication of the 'Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines' (Armitage et al., 2014) by the same University of Cape Town group that designed the SuDS-manual. The WSUD guidelines refer back to the South African SuDS-manual (Armitage et al., 2013) for specifications on stormwater management, but demonstrate a further paradigm shift from sustainable drainage management to fully integrating water management in urban design. The context of SuDS in the United States and Canada is more commonly referred to as 'Low Impact Development' and in France as 'Alternative Techniques or Compensatory Techniques' (Fletcher et al., 2014). The different terms are explained further below. Although there are various terms used in different countries to describe the concept of sustainable stormwater management, they all focus on water quantity and quality improvement and the enhancement of amenity values and biodiversity. Fletcher et al. (2014) show that all terms have gone up in terms of publications on Google Scholar, showing increased numbers of publications for all, with some terms becoming more frequent than others.

2.5.2 Low Impact Development (LID) and Low Impact Urban Design and Development (LIUDD)

Low Impact Development is the term commonly used in North America and New Zealand to describe the stormwater approach that discourages large end-of-catchment solutions and pioneers environmentally sensitive area planning (Fletcher et al., 2014). The United States Environmental Protection Agency (EPA) describes Low Impact Development (LID) as "a variety of practices that mimic or preserve natural drainage processes to manage stormwater" (EPA, 2012, Huber, 2010). Among the benefits of LID, the EPA identifies water quality, flood management, improved aquatic habitat, improved groundwater recharge and "enhanced neighbourhood beauty" as the main benefits. However, they also identify other benefits that resonate with some of the key issues currently of concern in Gauteng (EPA, 2012):

- the mitigation of climate change (sequestering carbon in plants),
- mitigating heat island effects (shade and infiltration),
- energy saving (green roofs and shading),
- air pollution reduction (reduced power consumption and reduction in ground level ozone), and
- improved property values (improved community amenity and neighbourhood aesthetics).

2.5.3 Best Management Practices (BMPs)

The concept of Best Management Practice (BMP) originates in North America and "is used to describe a type of practice or structured approach to prevent pollution" (Fletcher et al., 2014). The performance of urban BMPs in the national urban runoff program of USEPA (1979-1983) the BMPs were specifically grouped into four categories namely; detention devices, recharge devices, housekeeping practices and others. The CoJ Stormwater Bylaws 2010 makes specific mention of the use of BMPs (CoJ, 2018b), but this is more to emphasize that the best available method to design erosion and sediment control should be used.

2.5.4 Green Infrastructure

A more holistic approach to sustainable urban drainage systems is often referred to as the Green Infrastructure approach, which not only entails stormwater drainage but also focuses on maximising the benefits of green spaces (Fletcher et al., 2014). In South Africa, and particularly in Gauteng, this is also a relevant concept and the City of Johannesburg is currently developing a Greening and Green Infrastructure Strategy.

The Gauteng City Region Observatory (GCRO) provided a definition of Green Infrastructure that is being increasingly adopted in the Gauteng region. Green Infrastructure is defined as "*the interconnected set of natural and man-made ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing services and strategic functions in the same way as traditional 'hard' infrastructure*" (Schäffler et al., 2013).

This definition sets out the value of urban green spaces as providing multiple municipal services within an environment that supports ecological function. This presents Green Infrastructure as both complimentary to and potentially in conflict with SuDS where ecological function is a beneficiary, but not its primary function. This has led to debates on the importance of the stormwater management performance of SuDS, against the value of the co-benefits of SuDS and the compatibility with Green Infrastructure, which potentially can be in conflict (see also Section 2.4).

It is worth noting that the definition Green Infrastructure of GCRO also encompasses water elements, while in other countries, the water elements are referred to as blue infrastructure, and often the term green-blue infrastructure or green-blue grids is used (e.g. Pötz, 2016).

Another term overlapping with green infrastructure is nature-based solutions. The nature-based solutions report of the UN (WWAP-UN, 2018) states that 'green infrastructure is the application of a nature-based solution'.

The research by Schäffler, et al (2013) into the state of Green Infrastructure in Gauteng highlights the problem of placing value on eco-system-based services. For example, there is limited information about the value of natural assets in the urban environment and this is not usually included in decision-making processes, particularly in municipal systems. Fiscal systems are aligned to measures of consumption (e.g. of time or resources), and taxation (rates and levies), and on capital investment where returns can be calculated through the levies that will be charged. Green infrastructure tends to appreciate over the same timeframes that depreciation rates are calculated for traditional infrastructure. Hence, eco-system based services are not an easy fit into these systems of evaluation and the public sector has been slow to adapt to a means of accounting for green systems, and this will most likely apply to appreciating the full value of SuDS.

The GCRO continues to expand research into the role, value and uptake of Green Infrastructure in Gauteng. Culwick & Bobbins (2016) draw on experiences of valuing ecosystem goods and services in other parts of South Africa and their relevance to Gauteng. They also look at the opportunities and limitations for 'shovel ready' Green Infrastructure projects in Gauteng, mostly centred on stormwater services (Dunsmore, 2016), many which will apply to the roll-out of SuDS in the province. One of the key outcomes is that confidence and motivation in new technologies such as Green Infrastructure (and therefore SuDS) is building a strong base of case studies relevant to the local environment.

Research Gap 1:

Placing value on eco-system-based services of green infrastructure, which can be SuDS measures, is a recognized problem in Gauteng. However, globally there is recognition of the fact that the effectiveness of nature-based solutions is difficult and very site specific (WWAP-UN, 2018) and the economic valuation is still evolving (IEEP & RAMSAR, 2013) and dependent also on the interests of the investors.

Reaction of this project: While the impact on biodiversity will be discussed in the Analysis of Study Areas (Deliverable 5) and where possible in the Cost-Benefit Analysis (Decision Support for SuDS, Deliverable 6), not much attention is placed on further establishing the value of eco-system based services and this is a significant research gap.

Data Gap 1:

The asset values of green infrastructure, which can be SuDS measures, are generally unknown for Gauteng. Inclusion of green infrastructure into asset registers were already identified as a potential solution for some of the barriers identified in the Data collection on SuDS in Gauteng (Deliverable 3). However, it needs to be noted that worldwide, even in progressive towns which implement SuDS, there are large differences in the asset registration on SuDS.

Reaction of this project: This will not necessarily be researched in the project, but some information might be collated in the Cost-Benefit Analysis (Deliverable 6) or might be recommended in the Best Management Practices (Deliverable 7).

2.6 The Long Game: Water Sensitive Cities

By 2017 the towns and cities of South Africa held almost two thirds (65.85%) of the national population (Statista, 2019), while in 2007 this was still 60.62%. This is part of a global trend, and the portion in urban areas is increasing, as well as the densification and therewith hardening of existing urban areas which also put additional pressure on the drainage system. Combining this with the increasing risk of climate change induced water stress, there is a move to encourage cities to make the change from “water wasteful” to “water sensitive” (Armitage et al, 2014).

The notion of a Water Sensitive City is described by Brown, et al (2016), as follows:

> ***Water Sensitive City*** *is a vision based on holistic management of the integrated water cycle. It seeks to protect and enhance the health of receiving waterways, reduce flood risk, and create public spaces that harvest, clean, and recycle water. It advocates fit-for-purpose water use and delivery of water through both centralised and decentralised infrastructure. Ultimately, the Water Sensitive City vision integrates water and urban planning in order to facilitate better liveability outcomes more broadly, through enhancing biodiversity and providing increased public green space, healthy waterways, and connected communities.*

Stormwater is an important component of the urban water cycle. It is estimated that the paved surfaces of the three main metropolitan centres in Gauteng (Ekurhuleni, Johannesburg and Tshwane) generate extra runoff equivalent to between 30% and 50% of their annual potable water purchased (Dunsmore, 2016). SuDS would be central to converting stormwater runoff to a harvestable resource. Vogel and Molefe (2019) assessed the City of Johannesburg in terms of water sensitivity and identified stormwater management, both quantity and quality, as one of the areas where the City is starting to make inroads on the path to transition to a Water Sensitive City state (see Figure 4).

The transition to a Water Sensitive City can be broken into a series of development states that cities would move through, towards increased water sensitivity (e.g. Brown, et al, 2016). In the South African framework and guidelines for WSUD (Armitage et al., 2014) some of the unique aspects of South African cities, especially those relating to the differences between informal and formal areas, are explained as needing attention. The guidelines suggest the notion of Water Sensitive Settlements has more relevance in the South African context and they propose that the planning of Water Sensitive

Settlements consists of three components; Water Sensitive Urban Design (WSUD) ensuring that urban design is undertaken in a 'water sensitive' manner, Water Sensitive Urban Planning (WSUP) ensuring that urban planning is undertaken in a manner that considers and treats water sensitively, and Water Sensitive Urban Management (WSUM) dealing with post construction management of infrastructure, supporting the urban water cycle that is sensitive to the ecosystem and the needs of affected individuals.

Fourie, et al. (2018) explored the introduction of WSUD into the South African municipal planning environment. They identify the significant roles of Spatial Development Frameworks (SDF) and Land Use Schemes (LUS) in urban planning, but that these "fall drastically short" in considering the combined implications of future development and water availability. They set out a framework to include water needs and water sensitivity into the urban planning context.

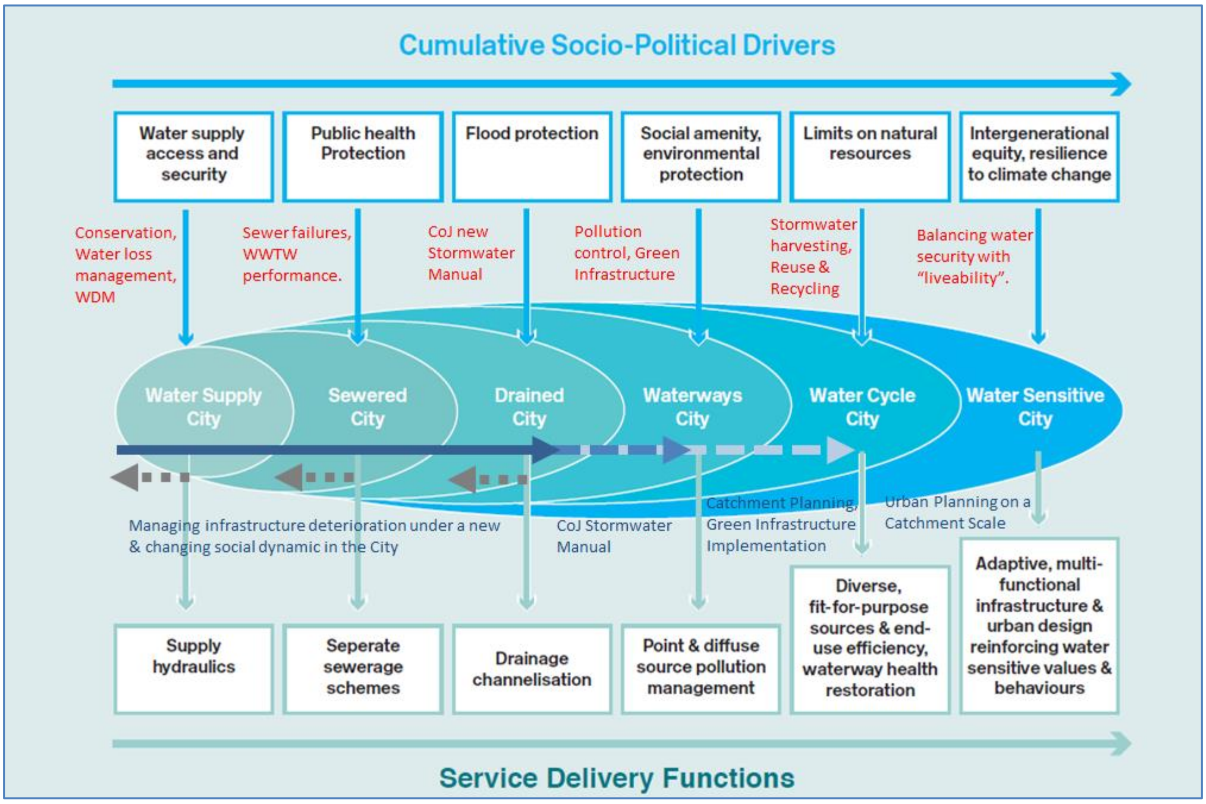

Figure 4: Stages of Transition to a Water Sensitive City relevant to the City of Johannesburg (Vogel & Molefe, 2019, after Brown, et al, 2009)

Research Gap 2:

The Water Sensitive Urban Design pleads for full integration of water management in the design of the cities or urban settlements. This is not only related to urban drainage, but also related to for example water cycle management and re-enforcing water sensitive values and behaviours through infrastructure and urban design.

Reaction of this project: In terms of water cycle design, 'harvestability' of the stormwater is expected to be discussed in the Analysis of Study Areas and in the Cost-Benefit Analysis. The involvement of an urban designer and urban planner in the research team, will already gear the project up for the long game of Water Sensitive Urban Design.

2.7 Design process of SuDS in South Africa and differences with conventional design of stormwater systems

To reflect on the potential gaps in knowledge for SuDS application in South Africa, it is perhaps best to also compare with how SuDS design is different to the more conventional stormwater design that is largely still in practice. This section is not so much a literature review, but a description of the practice of SuDS design by the authors of this literature review, to be reflected on in the rest of the project and literature review.

Design principle

The selection of facilities to be used in a treatment train for a certain area, depends on the nature of the area being drained and the requirements of the receiving environment. An understanding of the receiving environment is critical and will highlight both opportunities and constraints for the SuDS design. Catchment management plans are used to determine streamflow and flood management requirements. Groundwater management plans will similarly inform designs that aim to recharge aquifers. In the absence of such plans the precautionary principle should be applied, and studies may be necessary to confirm downstream (surface), hydropedological and geotechnical (subsurface), or geology and aquifer (groundwater) conditions.

Analysis of rainfall events

Design storm analysis is the main focus of the conventional approach, and hydrological analysis is limited to flood estimation. This is reinforced by the requirements of the municipalities (which will be further explained in Chapter 7). The SANRAL Drainage Manual (SANRAL, 2013) is a standard reference in conventional urban stormwater design, even though it is not developed for that purpose and is intended for the design of roads.

As with conventional design, rainfall is a primary input for SuDS design. The context of rainfall in Gauteng may be changing, with more frequent high intensity storms. Fatti and Vogel (2008) found that trends for thunderstorms – are that the number of thunderstorms is decreasing significantly from 30-45 per year to 10 -25 storms per year, with the total rainfall produced by these thunderstorms showing a slight increase, and the average rainfall per storm also. However, the size of extreme events was not analysed (analysis of data of 1960-2008 for OR Tambo Airport).

The South Africa SuDS guidelines explain that a common way of designing SuDS systems is through consideration of a number of ‘design storms’ (Armitage et al., 2013) which is also common for conventional systems. This might be still common, but it is important to note that SuDS are often not just designed based on large storm events, the preferred analysis is more about all rainfall events. Because storage is central to SuDS performance, the performance of a treatment train is best analysed by applying a time series of rainfall to the system. A time series of rainfall events and dry periods reflects the natural wetting and drying cycles that will determine the overall performance of the SuDS treatment train. Weather station records are available from the South African Weather Services and will typically include evaporation data (or data to derive potential evaporation) that is also needed for SuDS analysis. Records at 5 minutes to 1-hour intervals are best for SuDS design, especially in Gauteng where rainfall events are typically short duration, intense storms. In these conditions, SuDS facilities will typically flood and drain over short cycles which will affect design aspects such as selection of soil type and depth, plant selection and detention storage capacity.

Gauteng has a better rainfall gauge network than many other parts of the country, including a number of 5-minute recording stations that measure storm intensities. However, there is marked rainfall variability across the province (Dyson, 2009) and there is a need for more local rainfall information to design SuDS at a site scale. Some of the potential gaps are currently being covered by nine new 5 minute weather recording stations provided by Trans-African Hydro-Meteorological Observatory (TAHMO) (info: www.aqualinks.co.za), but is will take another three to four years before a meaningful time series is available.

Research Gap 3:

While conventional flood design is based on design storms and design floods, and this is currently improved with research by UKZN, the SuDS designs need timeseries of rainfall of sufficient length. While the SAWS series are best in terms of length, they might not reflect the local condition for the site for which SuDS are designed. Using shorter timeseries, the longer timeseries could be adjusted for local conditions.

Reaction of this project: This is not addressed by this project.

Performance evaluation in terms of stormwater management

SuDS facilities generally treat the overall yield from a site or a catchment. Performance is often measured in terms of total yield from a site (e.g. m^3/yr for runoff, kg/yr for pollutant load) in much the same way as many water resources planners do for catchment analysis. Traditional stormwater management typically just looks at peak flows from large storms (measured in m^3/s), and attenuation (detention) storage (m^3 or m^3/ha), which can also be important for SuDS, but many SuDS measures can only accommodate peak flow reduction for non-extreme events (less than 1-2 year return period). Apart from the water quantity impacts, SuDS performance will be evaluated on pollution treatment capacities, which will be further explained below.

Retention versus detention

General searches for explanations of the differences between detention and retention facilities will often point to detention ponds being dry ponds and retention ponds being wet ponds. On their own, these characteristics don't describe their respective functions, and in fact the opposite could also be true.

To re-balance the hydrological impact of urban hardening (as is illustrated in Figure 3), stormwater retention becomes the fundamental hydrological function of a SuDS treatment train, not only through retention ponds, but also to enable the increased urban runoff to be 'harvested'. In terms of design, this is an important departure from the principle of detention. Detention on its own merely delays the stormwater runoff but it still releases the unnaturally high volume of runoff from urban areas into the receiving river systems. Detention is useful for reducing flood risk, but it doesn't alleviate the high average flows that urban streams have to carry.

To achieve retention, the excess stormwater (generated by paved surfaces) needs to be held on site, or released very slowly over time (weeks and months) instead of over a few hours as happens with detention which captures and attenuates. On a natural catchment the soil layer plays a key role in retaining (storing) rainfall. As such, the soil retention model is reflected in most of the systems employed in SuDS (See Figure 5). In South Africa it is not yet common to have real-time control of any retention or detention ponds, but this could increase the efficiency potentially.

Note also that retention does not necessarily have to be done above ground, but can also be done through groundwater recharge through soakaways etcetera, usually called part of "Managed Aquifer Recharge" with case study proposals using stormwater as a source, for Hermanus and Lephalale having been described for South Africa (DWA, 2010).

Analysis of soils

On a natural catchment the soil layer plays a key role in retaining (storing) rainfall. As such, the soil retention model is reflected in most of the systems employed in SuDS (See Figure 5).

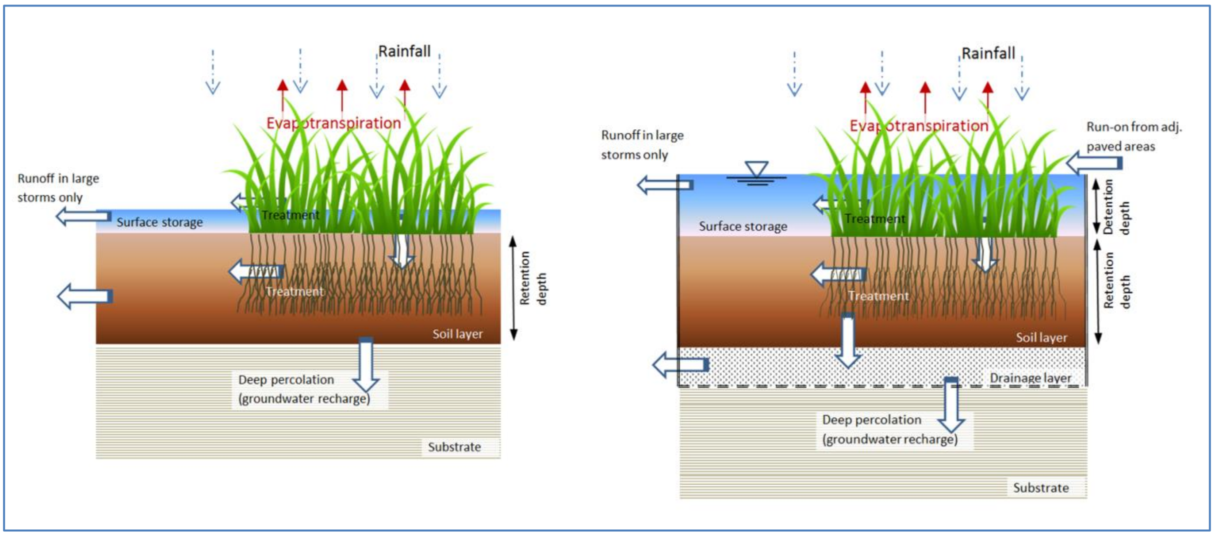

Figure 5: SuDS model (right) derived from a hydrological soil model (left)

The hydrological characteristics of South African soils are covered quite extensively. Key references for SuDS design will include:

Macvicar, et al, 1977. Soil Classification: A Binomial System for South Africa. This describes all the soil series in South Africa.

ARC-ISCW, 2011. Land types of South Africa. This set of GIS maps provides information on the distribution of soils across the country, and is a key resource for assessing pre-development runoff conditions.

Schulze, et al, 2001. Chapter 5: Soils. In: Hydrology and Agrohydrology – A Text to Accompany the ACRU3.00 Agrohydrological Modelling System. Provides hydrological characteristics of South African soils and detailed information for each soil series.

Schulze, et al (2001) provide a comprehensive breakdown of the soil model Figure 5. It is developed for hydrological applications in agricultural catchments, but is also used in the SCS Method for design flood analysis in South Africa which is often applied on urban catchments (Schmidt and Schulze, 1987, SANRAL, 2013). However, soil water characteristics can be highly variable, especially in urban conditions where they may be disturbed from their natural state. Hence good practice requires that site investigation of soil conditions is an important part of SuDS design (e.g. City of Johannesburg, 2018).

Source-control, local control and regional control working together

Effective retention requires space. In a natural catchment the entire area performs retention functions. In the urban space the portions of hard surfaces and non-permeable areas usually means the remaining areas of soils will not have the capacity to retain the extra runoff generated by a developed site. Hence SuDS looks at adapting many of the traditional areas of a development to provide stormwater functions, such as roofs (rainwater harvesting, green roofs) and pavement areas (permeable paving). Additionally, the development will utilise landscaped areas to provide stormwater retention functions and engineered soils with enhanced soil-water characteristics are employed to improve retention capacity. Therefore, in SuDS design all parts of a site are 'encouraged' to contribute to stormwater management, in much the same way a natural site would do.

The planning and design methods required to address these aspects of SuDS design are largely available. The methods are based on the principles in Figure 3, but their application is supported by software that enables the designers and planners to run the necessary combinations of SuDS facilities to optimise the treatment train and determine performance. Some of the commonly available software options are listed in Section 2.7 below.

Pollution treatment

Another key performance criterion for SuDS design is pollution treatment. The processes in different types of SuDS measures that treat pollution are described in the South African SuDS guidelines (Armitage et al., 2013) as sedimentation, filtration, biofiltration, adsorption, biodegradation, volatilisation, precipitation, plant-uptake, nitrification and photosynthesis. Each of the possible SuDS measures can have one or a few processes, and the risks of particular pollution at the site for which the SuDS are designed determines what kind of processes need to be applied. For example, if the stormwater can be expected to be influenced by road traffic, or in industrial areas, processes for hydrocarbons, heavy metals and total suspended solids may be important. If the area can be expected to have sewage pollution, or high contents due to fertilization, this requires other processes. In

Gauteng, the water quality measurements in urban areas are limited, other than those by the Department of Water and Sanitation. The website www.waterresourceswr2012.co.za provides good general overviews of water quality in rivers and updated contact details for persons to contact at DWS for the latest data. However, these are river pollution data, and not data on the sources that could pollute stormwater. Thus, pollution treatment really requires site analysis and while design guidelines of different SuDS facilities can give an indication, the final performance of the SuDS on the aspect of pollution treatment remains still a bit of a trial-and-error, partly because the performance mechanisms are not yet fully known but also because in general the loads of pollution are not known in detail for the design life of the facility. The advances in research in the treatment of pollution by the different types of SuDS options are discussed in the next Chapter.

2.8 Research on governance aspects of SuDS implementation

The decision to introduce SuDS and the aspects of governance that have to be taken into account when designing SuDS, are also subject of research and critical for the success of SuDS implementation. Hetz (2015) studied political barriers to synergistic climate adaptation in Johannesburg, focusing on stormwater. She concluded that in Johannesburg political decision making at the time (in the research period from 2011-2014) had more pressing development issues prioritized than climate change adaptation or ecologically sensitive designs, but that large scale eco-city projects (Steyn City, Waterfall City) have been "tactically used as infrastructure subsidy machines in order to rapidly realise extensive infrastructure upgrades without having to mobilise the city's or province's scarce financial and organisational resources". The negotiations around these projects between initiators and government parties (political as well as through civil servants), gave in on some ecological considerations.

Molvi (2017) also tried to identify challenges and obstacles to achieving a water sensitive Johannesburg. He concludes, on the basis of interviews with officials from EISD, JRA, JPCZ and Joburg Water, that the perceived challenges of implementing WSUD include the likes of (1) convincing engineers, (2) lack of clarity between parks and stormwater and roads departments (in Johannesburg para-statals) on budgets for maintenance, and (3) the perception that SuDS are expensive. Also, for the case of Johannesburg, the mandate of Johannesburg Water as a sole water supply provider is considered to be a potential obstacle.

Fitchett (2017), Craig (undated, probably 2017), Adegun (2014), Morgan (2019) all conducted action research in low income neighbourhoods in different areas of Johannesburg, respectively Diepsloot (both Fitchett and Craig), Joe Slovo settlement (Adegun) and Sjwetla (Morgan). The challenges of engagement with informal communities, the impacts of heterogeneity in communities, the competition for space and the daily uncertainty are common themes in these research reports. Vandalism, illegal dumping and stormwater management not being a priority issue for the community, as well as lack of understanding of engineering principles, are also commonalities. Nevertheless, conclusions are optimistic in that the likes of SuDS can work if the conditions are relatively stable and the communities are sufficiently incentivised.

Hetz (2015) comments on the RDP housing policy led to high density areas with insufficient open green spaces and infringing on wetlands, increasing flooding risks, even more so because of the development of backyard shacks after development. The recommendation of Hertz is to anticipate the establishment of back-yard shacks in new townships, make the necessary adjustments for budgeting for and designing the stormwater infrastructure.

Ndetekeya and Dundu (2019) specifically studied the obstacles for the uptake of rainwater harvesting in Johannesburg. They regard the Tshwane green building by-laws (see Section 7.2) as conducive to address cross-cutting issues of water-energy-property nexus, which could hamper implementation of rainwater harvesting. They explain that previously initiated efforts to introduce rainwater harvesting at schools were hardly implemented due to budgetary constraints (Maru-a-Pula Project for 500 schools country wide and Rand Water initiative for 15 schools in Alexandra township). They are of the opinion that the Water Services By-Laws in Johannesburg (see Section 7.4) are restrictive in terms of Council permit requirements. Ndetekeya and Dundu encourage the facilitation of comm and plea for standard-based policies, which they specify in this case as a chart to size the tank and water quality guidelines[1] for the prospective user. Enforcement measures, such as certification or compliance monitoring programmes, along with incentive programmes as well as a penalty systems may be considered. Incentive programmes could include rebates on property tax and rainwater harvesting equipment, or by subsidising materials. Other incentives could be to decrease administrative burden, given the financial constraints of the current local government. Introducing municipal stormwater tariffs or decreasing the cost of certification by the Green Building Council of South Africa – with more emphasize on rainwater aspects – are other suggested measures.

Eberhard (2018) discusses urban water security as a whole and explains that in terms of national policy, all economic projects should be paid for through user charges. Therefore, if SuDS are used for creating a water resource, commercial finance would need to be raised on the basis of cost-recovery user charges with only small grant components for the social infrastructure component.

2.9 Software models to assist in SuDS design

The South African SuDS guidelines (Armitage et al., 2013) present a list of potentially suitable software for modelling and designing SuDS. The WSUD guidelines (Armitage et al., 2014) also discusses some of the relevant software models. As an extension of this the University of Cape Town: Urban Water Management has what is understood to be a more recent list (http://www.uwm.uct.ac.za/uwm/modelling-tools) [Accessed April 2019]). This table is not complete in terms of popular models worldwide, but at least lists those models that UCT refers to or that are known to be applied by the authors of this report. The model choice normally depends on the objectives of the modelling, the familiarity of the modelling team and/or client with the software package or the producers of the package, and the costs of the modelling software. In models there are 'horses for courses' but the extent of this literature review is not sufficient to define all models and their differences. For guidance to further reading, Table 1 below can be used.

Most of the developers of software that model urban drainage systems have incorporated stormwater Best Management Practices that covers SuDS, LID and WSUD.

[1] Sizing standards are given in the Tshwane green building by-laws, see Section 7.2.

Of the list in Table 1 below, the last four are known to be in general application in South Africa. SWMM is free urban stormwater software developed in the United States and well suited to the planning and design of SuDS. PCSWMM and HydroSWMM are built around the SWMM engine and offer advantages of analytical tools and GIS representation that can substantially improve the modelling and design process. PCSWMM is well adapted to model SuDS and is relatively widely used in South Africa. It is not known whether any South African municipality had adopted any particular software, but it is known that eThekwini uses PCSWMM and it is also widely applied in Johannesburg. It is the preferred software in the City of Cape Town. It was also used by a COGTA project to analyse flood risks in Gauteng (Scheepers et al., 2018) and it is widely used in the engineering firms in South Africa (https://www.pcswmm.com/ClientsAndTestimonials).

HydroSWMM is being developed in South Africa by GLS Software. At the time of writing it is not certain how far the software is adapted for the design of SuDS.

MUSIC is currently being trialled in South Africa, particularly on SuDS and Green Infrastructure analysis in Gauteng and in this project. The system is sold under licence by eWater in Australia and is unique in that it only models SuDS treatment trains (i.e. hydraulic capacity and flood management are only addressed at a very basic level). It is developed to analyse and optimise treatment of pollutant loads at conceptual and planning level, and it addresses all the stormwater management options identified by Armitage, et al (2013). Furthermore, it is specifically adapted for municipalities to check SuDS designs, thereby improving authorisation processes. Though not suitable for detailed design, MUSIC provides a rapid assessment of treatment performance. Early indications in the trials thus far in Gauteng, the combination of MUSIC for planning with other software (e.g. SWMM, PCSWMM) for detailed hydraulic design is proving attractive. In addition, the adoption of MUSIC by the City of Johannesburg is being considered to assist with the evaluation and approvals of Site Development Plans and Stormwater Management Plans.

For the impact of stormwater management in the context of river basin management, decision support tools such as WEAP can be used, that facilitates scenario analysis of water resources and includes scenario evaluation tools. This software is not specifically designed for SuDS.

In the South African context, the purchase price of software, and whether it is freely available to train students, is also relevant. Some of the software packages have high annual subscription fees, which make it difficult for Small Enterprises, and even larger ones, to maintain software licenses for their employees that potentially could contribute to stormwater designs. The low costs make models developed by United States Government Agencies so popular in South Africa. The data needs of the models also can play a role in the model choice, as well as the experiences of the modellers with a certain model. Prescribing a certain model for a certain area (municipality), which regularly happens in tender processes in South Africa, has the advantage that civil servants can become acquainted and that next modellers can build on work done by previous modellers. However, it does not stimulate innovation and could lead to model choices that are not most appropriate to answer the research question. The authors could not trace research in South Africa that compared different stormwater models for the same case study area and same problem to be solved.

Table 1: Models and the further reading in alphabetical order

Name of model	Explicit capabilities as per SA- SuDS guidelines (2013 but with reference to source 2006 in table 2.7)	Category where discussed in SA-WSUD Guidelines (2014)	Information on Future Water (UCT) website (see link above)	Model applied in South Africa as known to authors of this report	Link to website
Innovyze Software suite, including: InfoWorks ICM, MicroDrainage	N/A	N/A	N/A		https://www.innovyze.com/en-us/solutions-products/stormwater-sewer-and-flood-modeling; https://www.innovyze.com/en-us/products/infoworks-icm; https://www.innovyze.com/en-us/products/microdrainage
HydroSWMM	N/A	N/A	N/A	Yes, local production.	https://www.gls.co.za/software/products/hydroswmm.html
Mike Urban (previously named MOUSE)	Discussed as MOUSE	Water Cycle Model	N/A	Unknown; but local DHI-agent.	https://www.mikepoweredbydhi.com/products/mike-urban
MUSIC	Discussed	Stormwater Model	Explained	Yes, trialled in Gauteng, see text below.	https://wiki.ewater.org.au/display/MD6
P8	Discussed	N/A	N/A		http://www.wwwalker.net/p8/
PCSWMM	N/A	Stormwater model	N/A	Yes, widely applied, see text below.	https://www.pcswmm.com
Source Urban	N/A	Water Cycle Model	Explained		https://ewater.org.au/products/ewater-source/for-urban/
StormTac	Discussed	N/A	N/A		http://www.stormtac.com/

Name of model	Explicit capabilities as per SA- SuDS guidelines (2013 but with reference to source 2006 in table 2.7)	Category where discussed in SA-WSUD Guidelines (2014)	Information on Future Water (UCT) website (see link above)	Model applied in South Africa as known to authors of this report	Link to website
SWMM; Stormwater Management Model	Discussed	Stormwater model	N/A	Yes, widely applied, see text below	https://www.epa.gov/water-research/storm-water-management-model-swmm
SUSTAIN; System for Urban Stormwater Treatment and Analysis Integration	N/A	Stormwater Model from EPA	Explained		https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain
Urban Developer	N/A	Water Cycle Model	Explained		https://ewater.org.au/products/music/related-tools/urban-developer/ (same developer eWater as MUSIC)
WaterCress (Water Community Resource Evaluation and Simulation System	N/A	N/A	Explained		http://www.waterselect.com.au/watercress/watercress.html
WEAP: Water Evaluation and Planning system	N/A	Water Cycle Model	Explained		https://www.weap21.org/
WinSLAMM; Source Loading and Management Model	Discussed	Stormwater Model	Explained	Unknown; no known application in South Africa	http://www.winslamm.com/default.html

3 HOW IS THE SCIENCE ON THE VARIOUS SUDS FACILITIES PROGRESSING IN SOUTH AFRICA?

3.1 Introduction

The South African SuDS guidelines present a set of stormwater management facilities deemed suitable for application on South African conditions. To date this list remains the authoritative guide for South African conditions, see Table 1 and Box 1. This Chapter does not repeat much of the South African SuDS guidelines, apart from some definitions, but rather focusses on further research done after the finalisation of these guidelines in 2013 and research gaps already identified in these guidelines. University available search engines were used.

Note: Between the different facilities there are facilities that focus on surface water detention and retention and on managed aquifer recharge. This also depends on the way these facilities are constructed. For example, bio-retention areas can be lined underneath, and then the infiltrated water flows to surface water, or alternatively can be constructed to recharge groundwater. Permeable pavements, filter strips, swales can also be designed to partly infiltrate stormwater to groundwater. Soakaways and infiltration trenches are typically designed for groundwater recharge.

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

Source Controls	Local controls	Regional detention
Green Roofs*	Filter strips*	Detention (attenuation) ponds
Rainwater harvesting	Swale*	Retention ponds*
Soakaways	Infiltration trenches	Constructed wetlands*
Permeable pavements	Bio-retention areas*	
	Sand filters	
*Note: *SuDS facilities that typically support vegetated and ecological systems*		

Box 1: Definitions of SuDS facilities as per the SA guidelines for SuDS (Armitage et al., 2013)

Green roofs are roofs on which plants and vegetation can grow. The vegetated surface provides a degree of retention, attenuation, temperature insulation and treatment of rainwater.

Rainwater harvesting is the direct capture of stormwater runoff, typically from roof-tops, for supplementary water uses on site.

Soakaway is a subsurface structure that is designed to promote infiltration into the ground.

Permeable pavements are pavements that are constructed in such a manner that they promote the infiltration of stormwater runoff through the surface into the sub-layers and/or underlying strata.

Filters strips are maintained grassed areas that are used to manage shallow overland stormwater runoff through several filtration processes.

Swales are shallow vegetated channels designed to convey stormwater, but also permit infiltration. The vegetation assists in filtering particulate matter.

Infiltration trenches are excavated trenches that are filled with rock or other relatively large granular material, or commercial void forming products, with a geotextile underneath. Unlike soakaways, infiltration trenches are usually designed without piped outlets, but rather with perforated pipes in the trench.

Bio-retention areas, also referred to as 'rain gardens' or 'bio-retention filters' are landscaped depressions typically employed to manage the runoff from the first 25 mm of rainfall and passing it through several natural processes.

Sand filters normally comprise of sedimentation chamber linked to an underground filtration chamber comprising of sand or other filtration media through which stormwater passes.

Detention ponds or detention basins are temporary storage facilities that are ordinarily dry but are designed in such a manner that they are able to store stormwater runoff for short periods of time.

Retention ponds, also referred to as retention basins, have a permanent pool of water in them and are generally formed through construction of a dam or weir. The water level is kept lower than maximum in normal conditions, to be able to store a relatively large incoming storm. The water can potentially be used.

Constructed wetlands are man-made systems designed to mimic the natural systems with usually an inlet zone for removal of course sediments, a macrophyte zone, for removal of fine particles and uptake of soluble nutrients, a macrophyte outlet zone which channels stormwater into adjoining downstream structures and a highflow bypass channel for abnormal high flow that would damage the wetland.

3.2 Source controls

The South African SuDS guidelines explain that '*source controls are structural or non-structural best management practices to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source'*. The 'source' is the location where the rain fell.

3.2.1 Green roofs

A green roof is a roof on which vegetation is growing. Armitage (et al., 2013) mentioned the importance of the type of vegetation used for attenuation, retention and temperature decrease.

The eThekwini has an extensive practical guideline for creating green roofs (Van Niekerk et al., 2010), with special focus on the biodiversity aspect and the explanation of the suitability of indigenous plants for green roofs in South Africa. In the guideline, the eThekwini Municipality has also summarized results of on a 'green roof pilot project' on the building of eThekwini Engineering Services (166 KE Masinga Road). Different types of green roofs are tested at this pilot site, and regularly studied by students.

Sucheran (2018) investigated the three different green roofs (each about 50 m^2) in the eThekwini pilot study, against the normal (control) roof in the same pilot, for water quality and water quantity impacts. While the efficiency for small and medium storms detention was proven, the water quality of the outflows of the green roofs were worse than the conventional roof. The green roofs often performed worse than the control roof, in particular for Total Dissolved Solids, free chlorine, orthophosphates and phenols but also for amounts of metals such as iron, aluminium, zinc and lead. Whether the soil mixtures or the layers underneath caused pollution is not investigated. The author suggests from literature review that the metals found in the outflow of green roofs are caught by the vegetation from the air, but this seems to the authors of this literature more unlikely than the roof itself being the source. The differences of outflow pollution concentrations between two roofs with the same mixture and the same substrate depth of 10 cm are large, which seemed surprising to the authors of this literature review. In terms of volume control, the green roofs performed well for the light to moderate rainfall investigated (peak intensity 0.4 - 3.8 mm/h). The control roof only had 21.5% of retention, while the others varied between 88.0 – 100 %. The efficiencies of the roofs do not seem to be consistently decreasing with increasing rain depth or decreasing substrate depth. This is not further discussed. The study also compiled the model PCSWMM (see Section 2.9) for all flat roofs in a block. The peak flow rates reduction was only valid for the '1 in 2'-year events, not the more extreme events of 1 in 5 years or more. However, the author follows another reasoning, and seems to compare inflows between green and conventional roofs, and outflows between green and conventional roofs. The authors of this literature review did not fully understand this reasoning.

Van der Walt (2018) conducted a study on 'retrofitting South Africa's cities with green roofs' and used a selected number of buildings in the CBD of Johannesburg as case study area do conduct a Cost Benefit Analysis. The study looked at the 'spekboom' and other succulents typically found in South Africa as examples. The amount of water for the vegetation required in a day would be 1.875 l/m^2/day. The installation and planting costs were estimated at 1.5 MR for a 550 m^2 green roof, while for a conventional roof only about 0.3 MR was needed, to be replaced once in 20 years. Once fully functional the only cost would be for fertilisation and manual labour for housekeeping, in the first year about R 90 000 and after that about R 40 000. Other associated cost would include water required for watering during seasons where there is minimal rain (from R 11 000 – R 25 000/year). It was assumed that a green roof would only be considered once the conventional roof needed replacement, but still the conclusion would be that for building owners the benefits of some energy consumption reduction would not outweigh the additional costs, therefore either building owners would have to see additional value in amenity value, or subsidies would be required.

Chalatse (2003), was one of the earlier researchers to conduct an MSc-study on green roofs. It discusses a usability of Concrete prestressed C-beams for creating potted rooftop gardens on lower- and middle-income houses with little gardens. It focuses mainly on how to strengthen the existing steel sheet roofs, although stormwater management together with amenity values (food production, safe playground) are mentioned as objectives of the green roofs created.

3.2.2 Rainwater harvesting

An extensive resource guideline for rainwater harvesting in South Africa is made by Mwenge Kahinde et al. (2017), ranging from causes of pollution to different design considerations for different users.

Carden et al. (2017) based on the PhD thesis by Fisher Jeffes (2015) present that stormwater harvesting rather than rainwater harvesting will help South Africa manage its water shortages and reduce its peak flows. Stormwater harvesting is typically done from stormwater drains or small streams, whereas rainwater harvesting is typically done on site by collecting roof runoff from buildings.

Mannel et al. (2014) conducted face-to-face interviews with 68 respondents in Kleinmond, where harvested rainwater is used for washing clothes, other cleaning activities and in a few cases for garden irrigation. More than 80% used the water at least a few times a week. While most owners where unemployed, most would repair their rank when broken, and would like to learn more about maintenance.

Ndiritu et al. (2018) from University of Witwatersrand did daily time-step hydrological simulations of potential rainwater harvesting systems for Johannesburg and included stormwater harvesting in his discussion of rainwater harvesting. Based on simulations with daily rainfall, yield curves were derived as a function of different ratios of average annual supply to average annual demand and for different ratios of tank capacity to average annual demand. Comparing the outcomes of eight different rain stations, the conclusion was that no different design rules were necessary for different parts of Johannesburg. Either the minimum tank size can be derived for an annual supply to demand ratio, or from the tank size a maximum demand can be derived. It is surprising to the authors of this report, that the paper does not consider the variability of the demands, only annual average demands. This is even the case for the example given in the paper of supplementary irrigation, in which case demand is always higher when supply (rain) has been low, and therefore relatively higher storage capacities would be needed then when working with averages.

Ndtekeya and Dundu (2019) researched the governance issues related to the implementation of rainwater harvesting, as explained in Section 2.8.

3.2.3 Soakaways

Armitage, et al. (2013) presents common technology derivatives of soakaways and they include: oil and grit separators, and modular plastic geo-cellular structures. The soakaways research however since then mainly refers to almost swale like structures.

Fitchett (2017) from University of Witwatersrand studied two sites in Diepsloot, Johannesburg. Both sites had existing “rudimentary drainage constructed” by residents. The challenge with the design of the drainage constructed by the residents was that the stormwater was directed away from the dwellings into a dumpsite and it would then flow to the river without any channelling. This dumpsite was cleared and replaced by a bio-retention area. SuDS options were introduced to the area, including soakaways. The introduced SuDS options were built to supplement the already existing initiatives and not to completely remove them. At the one site, trey water from households percolated almost immediately and stormwater (higher volumes) infiltrated within few hours, therefore the performance in terms of flow reduction was good. In the other site, the vegetated channel retained more water than the paved area. The nitrates, phosphates and dissolved oxygen indicated decreased values at the outflows with more promising than expected given the expected pollution from litter. The degree of change was also not investigated in detail and the monitoring period was only a few weeks. The most interesting conclusion for the authors of this literature review, is that the research proved that two sites very close together in the same community had completely different social dynamics around it. At one site the stakeholders were very active, soon expanding the soakaways and preventing landfills, while at the other site the social cohesion was less and involvement on workdays and commitment to maintenance was less. While both communities had already tried interventions to prevent flooding, stormwater management was not considered less a priority issue in comparison to the problem of the illegal littering and associated health risks

3.2.4 Permeable pavements

Schieritz (2016) and Biggs (2016) investigated the water quality performance of permeable pavement at the UCT campus, based on the aggregates and geotextile layers underneath. The aggregates proved insufficiently washed, causing pollution. Schieritz found that Total Suspended Solids pollution levels were still acceptable, but the greater concern was that this caused clogging of the lower layers. Nutrient concentrations, in particular orthophosphates, were also a concern. Schieritz recommends a sand layer rather than a gravel layer for reasons of clogging. Biggs concludes positively about adding geotextiles to diminish clogging, while the latest conclusions of Winston and Armitage (2019) are that the risk of adding wrong geotextiles or at the wrong location is high and therefore solutions without geotextiles should be preferred. The practitioners were not yet unanimously convinced at the seminar in Johannesburg in May 2019, therefore further research on established sites would probably be required. The impacts of using unwashed aggregate, or the risk of the aggregate being not sufficiently washed, are another lesson learned for the implementation of permeable pavements in South Africa. Armitage (Winston and Armitage, 2019) also showed further indications that clogging of permeable pavements happened at most of the investigated sites. The required maintenance to prevent clogging is quite involving (either very labour intensive by hand, or requiring specialized washing trucks, both with associated costs) and does not happen in the sites investigated in Cape Town. Bio-retention cells seem a solution which requires less maintenance and has less risk of clogging.

3.3 Local controls

Armitage, et al. (2013) refers to local controls as measures put in place to manage runoff in public areas such as roads, parks, etc. No recent published research on filter strips, swales, infiltration trenches or sand filters could be found. For bio-retention research is ongoing and reported on.

3.3.1 Bio-retention

A similar situation exists for South African research on bio-retention facilities. No recent published South African research could be found, but nine locally occurring dryland and wetland plant species where tested in a nursery setting at in total 150 containers by Milandri et al. (2012). The removal of orthophosphate (PO_4^{-3}), ammonia (NH_3) and nitrate (NO_3^-), as found in urban stormwater, was tested on a bed of sand. Two types of stormwater were tested, with low pollution rates (S1: PO_4^{-3} at 1.470 mg/l, NH_3 at 0.567 mg/l, NO_3^- at 3.117 mg/l) and higher pollution rates (S2: PO_4^{-3} at 2.620 mg/l, NH_3 at 2.202 mg/l, NO_3^- at 5.983 mg/l). The species that performed well for all three nutrients include common agapanthus (indigenous), buffalo grass (indigenous) and kikuyu grass (non-indigenous). Proportion of nutrients can be captured or absorbed by plants are considerable, with the three species performing for the three pollutants all over 80% as an average. The treatment of nitrate was clearly affected by the plan species, but the removal of orthophosphate and ammonia mostly occurred within the soil medium, with only limited additional benefits of certain plants over the control. For the experiment Malmesbury soil was used, common in Western Cape, but for Gauteng another soil medium with similar treatment capacities could probably be selected. The matured plants were then irrigated under Western Cape wettest months typical rainfall conditions of once in 3 days.

Table 3: List of species and soil-only control (control) in order of average performance values (per cent removal) for each nutrient. Each value is the mean percentage removal of S1 and S2 adapted from Milandri et al. (2011). Dryland plants in orange: Agapanthus praecox (Common agapanthus), Carpobrotus eduli (Sour fig), Elegia tectorum (Thatching reed), Pennisetum clandestinum (Kikuyu grass), Stenotaphrum secundatum (Buffalo grass). Wetland plants in blue: Zantedeschia aethiopica (Arum lily), Ficinia nodosa (Knobby club-rush), Phragmites australis (Common reed) and Typha capensis (Bulrush).

Rank	PO_4^{-3}	NH3	NO3-
1	Agapanthus (92%)	Pennisetum (99%)	Pennisetum (81%)
2	Pennisetum (91%)	Stenotaphrum (98%)	Stenotaphrum (80%)
3	Stenotaphrum (91%)	Typha (93%)	Agapanthus (72%)
4	Phragmites (86%)	Agapanthus (91%)	Zantedeschia (69%)
5	Typha (86%)	Phragmites (91%)	Carpobrotus (63%)
6	Zantedeschia (85%)	Zantedeschia (91%)	Ficinia (62%)
7	**Control (79%)**	Ficinia (89%)	Typha (56%)
8	Carpobrotus (77%)	**Control (85%)**	Elegia (36%)
9	Elegia (46%)	Elegia (83%)	Phragmites (25%)
10	Ficinia (15%)	Carpobrotus (80%)	**Control (22%)**

For bio-retention, the Department of Civil Engineering of the University of Witwatersrand is currently doing MSc research (student Jennifer Mengelli) on different types of set ups for different polluted stormwater types, but this is not yet published. While Permeable Paving is applied more widely in South Africa than bio-retention, bio-retention is considered a more suitable option for South Africa, with less risk of failure after a few years and less complicated maintenance required (Winston and Armitage, 2019).

3.4 Regional controls

Regional controls are large interventions used as the last level for stormwater management and applied generally on municipal or government owned land. For detention ponds and retention ponds, the authors could not find recent scientific research. Constructed wetlands, however, had some research groups working on them.

3.4.1 Constructed wetlands

Much of investigations on constructed wetlands in South Africa focus on treatment of municipal or mining wastewater, not stormwater as such. This type of research is therefore not discussed in this section. However, with much of the stormwater / river water in Gauteng being polluted with wastewater, when designing SuDS constructed wetlands, consulting such research or researchers might be useful, therefore some research is explained below.

The Industrial and Mining Water Research Group together with the Centre in Water Research and Development (CiWaRD), both of the University of Witwatersrand, have conducted together with German Universities, research at lab scale on polluted wastewater (Aylward et al., 2016). The system was able to degrade high rates of carbon and transform nitrogen. However, the wastewater used was according to specifications of German wastewater, and therefore not similar to stormwater (mixed with wastewater) in Gauteng. The research concludes that the fields of engineering, microbiology, chemistry and biomimicry should be better merged in the development of methods. The research was the first in a series and therefore has built research capacity on constructed wetland in South Africa.

Follow up research of the same group (Bonner et al., 2018) investigated clogging mechanisms in constructed wetlands at laboratory scale, and used dolomitic gravel and indigenous plant species in series (*Zantedeschia aethiopica, Cyperus papyrus nana, Typha capensis, Juncus effusus, Chondropetalum tectorum),* different from those used by Milandri et al. 2011 as shown in *Table 3* under bio-retention. The plants were not fully developed yet, when already some clogging in dead zones appeared. Based on hydraulic modelling, another set up was proposed.

The University of Pretoria is also conducting a research on constructed wetlands, on the microbiological / micro-ecological aspects of it, with Dr Jean-Baptiste Ramond as the main researcher. However, he mainly focuses on winery wastewater and acid mine drainage. Research on SuDS has not yet been published.

Mabhena (2013) studied the 10-year-old surface water constructed wetland built in the Johannesburg City Parks Zoo, with common reeds (*Phragmites Australis*), although by accident also duckweed grows in the settlement tank, while duckweed is also known to have pollution treatment capacity. The wetland receives stormwater not only from the Zoo but also from the canalized Braamfontein and Rosebank streams, also with spring water from the Berea spring. Grab samples of one field visit in different locations in the treatment path were analysed. The wetland is well maintained, with maintenance on pumps and harvesting of reeds every June or July. The low levels of dissolved oxygen concentration remained in the wetland, and therefore also in the effluent limited ecology is probably possible. The report also mentions the efficiency in decrease of Dissolved Oxygen (DO) of 86%, but an increase of Dissolved Oxygen will show efficiency not a decrease, as it is a negative impact, although common. The nutrient levels in the influent were remarkably low, and decreased slightly towards the effluent. The metals were already at or below trace levels at the influent points, so efficiency of the constructed wetland for treatment of these metals is minimum. The main pollutant of the system is the bacteria stream from the stormwater (and animal excrement) of the zoo itself. For *E.coli* bacteria the system seems to perform quite well with 87% efficiency but for total Coli the efficiency is far lower at 28%. However, the inlet concentrations at the site are lower than 10 000 bacteria per 100 ml, which is probably far lower than *E.coli* concentrations in stormwater systems that are polluted by stormwater in other parts of Gauteng.

The School of Animal, Plant and Environmental Science of Witwatersrand University has also been researching the impact of plants on pollution, in particular Acid Mine Drainage. The research group might also be a good source for other knowledge of plant impacts on stormwater pollution treatment, although no references on urban stormwater pollution treatment were sourced for this literature review. The Durban University of Technology and the University of Zululand have also started research on the viability of constructed wetlands for wastewater treatment (Mthembu et al., 2013).

3.5 Conclusions on current South African Research on SuDS options

While the separate SuDS facilities and their technical requirements are the study of several research groups in South Africa, the challenge for developing guidelines for implementation in Gauteng (the scope of this project) remains that:

- The amount of experimental research, based on experimental sites with community engagement in high density areas and on site at universities, or in a laboratory set up, is very useful. Clearly there is interest in SuDS research throughout the country and there are several research groups that not necessarily gain knowledge on SuDS as such, but that may also be gaining useful knowledge for vegetated SuDS, in particular those that are studying wastewater treatment by constructed wetlands.

- Hardly any research is done on existing SuDS type interventions being evaluated on their performance in the field, and what has affected this performance. Apart from Mabhena (2013) who evaluated the constructed wetland in the Johannesburg Zoo, and Fitchett (2017) evaluating some soakaways, no such research is available. Research is typically at MSc level, with monitoring periods and methods being selected for short term research.

- Localised interventions, such as rainwater harvesting, permeable paving, green roofs and constructed wetlands seem to get more research attention than research of more integrated “treatment trains”.

- With Bio-retention being identified as a promising SuDS facility with relatively high efficiency and low maintenance, more emphasis would be deserved for this SuDS facility.

- Overall, the Gauteng Universities (University of Witwatersrand, University of Pretoria and University of Johannesburg) with additional support from the Tshwane University of Technology could further contribute to research on SuDS, adding to the lead that University of Cape Town is still having in this field, but under Gauteng climate and other conditions.

- No research could be sourced that would really need a revision of the SA Guidelines on SuDS (Armitage et al., 2013).

- There is very limited research on the evaluation aspects of SuDS versus conventional stormwater management. Apart from Van der Walt's (2018) research on green roofs, no such research was sourced. The SA Guidelines on SuDS are still the best to go by in this respect.

Research Gap 4

The research of most universities on SuDS focuses on a certain SuDS facility, which contributes to the essential knowledge required on better performance of these facilities, but does not address the challenges of implementation, designing treatment trains and dealing with decisions between conventional and SuDS options, as well as dealing with governance aspects.

Reaction of this project: The implementation manual which is the main objective of this research project, cannot add in depth research on SuDS facilitaties, but is based on an evaluation of three case study areas in which the combined effect of SuDS facilitaties are evaluated. This literature review in itself can assist in scoping future research projects.

4 WHAT IS THE NATIONAL POLICY AND LEGISLATIVE CONTEXT FOR SUDS?

4.1 Introduction

The purpose of this section of the report is to review relevant planning legislative and policy frameworks and guidelines, on a national and provincial level, in as far as they promote the concept of Sustainable Urban Drainage Systems (SuDS). The question against which this review is conducted is:

> *"Does planning, policy and legislation oblige mandated authorities to include SuDS in spatial planning and design not only as a mitigation measure against the implications of climate change but also to promote appropriate storm water management in the making and shaping of urban space?"*

Grant, et al (2017) report that in the United Kingdom, SuDS are still not working as intended, despite SuDS being promoted as part of Best Practice for more than a decade. They note main obstacles to the implementation of SuDS are still political and institutional. Hence, legislation and policy are among the primary enablers for Sustainable Drainage. The documents below are as mentioned in the ToR 'linkages to government priorities and strategies as per ToR section 3'. The ones not mentioned below, are otherwise discussed in this report: stormwater by-laws, or these documents were not South African. The municipal documents, different throughout Gauteng, are not discussed in this chapter but in the next.

4.2 International obligation: Sustainable Development Goals

South Africa committed to the 2030 Agenda for Sustainable Development Goals (SDGs) in April 2016. The SDGs set out to address poverty and inequality in the face of a changing climate (SA News, 2016). Although SuDS is not specific to any of the goals, it is inherent in a number of them; Goal 6: Clean Water and Sanitation and Goal 11: Sustainable Cities and Communities, as well as Goal 13: Climate Action and Goal 15: Life on Land. Goal 9 on Industries, Innovation and Infrastructure also has a target on infrastructure which could relate to SuDS. See Box 1.

Box 2: Selection of Targets in Sustainable Development Goals related to SuDS

(Note: the numbering is from the official SDG website, sometimes a number with a letter, for ease of reference)

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.A By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

6.B Support and strengthen the participation of local communities in improving water and sanitation management

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

9.A Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States 18

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.A Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.B By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

4.3 Legal framework

4.3.1 Constitution of the Republic of South Africa

The Constitution (Government of South Africa, 1996) does not address the concept of SuDS directly but it does oblige mandated authorities to: -

In section 24 “have the *environment protected for the benefit of present and future generations* through reasonable legislative and other measures, which include a land use planning system that is protective of the environment”;

In section 26 of the Constitution, “to have the right of access to adequate housing which includes an equitable spatial pattern and *sustainable human settlements*”; and

In section 27(1)(b) of the Constitution, “to ensure that the State takes reasonable legislative measures, within its available resources, *to achieve the progressive realization of the right to sufficient food and water*.”

All of these are supported by the introduction of SuDS into the urban environment. The Constitution does speak to the concept of sustainable settlement planning within which SUDS is an obvious planning instrument; although understandably, only at a level of principle.

Coordination between government departments is key to enabling SuDS, and the Constitution also prescribes the cooperative governance of the three layers of government. The stormwater management for the built environment is defined as a responsibility for the local government. SuDS relate to the Bill of Rights in case SuDS increases the water security and/or protects the environment (Everyone has the right to sufficient water; Everyone has the right to an environment that is not harmful to their health or wellbeing and that is protected, for the benefit of present and future generations).

4.3.2 National Environmental Management Act

The National Environmental Management Act, briefly NEMA (Government of South Africa, Department of Environment, 1998) prescribes that an environmental authorisation for a listed activity can only be given after (a) investigation of the potential consequences or impacts of the alternatives to the activity on the environment and assessment of the significance of those potential consequences or impacts, including the option of not implementing the activity and (b) an investigation of mitigation measures to keep adverse consequences or impacts on the environment to a minimum. Both to diminish potential adverse consequences or as a mitigation measure, SuDS measures may be positively supported by the NEMA act. Another key to supporting SuDS is that an Environmental Management Programme resulting from a project for which an Environmental Impact Assessment is conducted must “contain measures regulating responsibilities for any environmental damage, pollution, pumping and treatment of polluted or extraneous water or ecological degradation which may occur inside and outside the boundaries of the operations in question.” The NEMA does not make specific reference to ‘stormwater’, ‘drainage’, ‘runoff’.

Policy, law and implementation gap 1

The associated NEMA Regulations and the EIA process have seen a number of revisions that attempted to address accusations that the environmental authorisation process impedes development progress. Notwithstanding the guidelines in the GPEMF (see Section 6.4 below), there is concern that the impacts of stormwater initiatives tend to be poorly evaluated due to either one or more of the following; (1) avoidance of appointment of specialist expertise, (2) limitation of the EIA process (e.g. the Basic Assessment Report scope is too narrow to pick up impacts), and (3) lack of a comprehensive catchment management plan that will present both a baseline condition and a vision for the recovery of the watercourse(s). This leads to both poor stormwater design and the continued use of grey infrastructure stormwater solutions instead of SuDS based solutions that would mitigate the impacts of urban stormwater discharges more effectively.

Reaction of this project: Input for discussion on Best Management Practices or during the formulation of the Implementation Manual.

4.3.3 National Water Act

The National Water Act (Government of South Africa, Department of Water Affairs and Forestry, 1998) uses the term “run-off water”, which is said to include stormwater. The Act explains that permissible use of water, subject to the Act, is allowing a person to among others, store and use run-off water from a roof or discharge run-off water. Further references to run-off water are not given. The Act is important for SuDS implementation in that it regulates the use of servitudes for water management, answers the questions on to whether a Water Use License would be required, and explains the legal obligationson environmental flow protection which are underlying the SuDS principles. Also, to be able to design SuDS and assess their impacts, the monitoring of the water courses regulated by the Water Act is important.

The National Water Act requires that all water resources are protected in order to secure their future and sustainable use. Enshrined in the NWA is the Polluter Pays Principle that enables penalties to be applied to those responsible for polluting water resources. This has had some effect in addressing point source pollution discharges from the like of mines and industry, but has found limited implementation for diffuse pollution sources such as agriculture and urban stormwater. This is compounded by a reluctance of one arm of government (e.g. the Dept. Water and Sanitation) prosecuting another government office (e.g. a municipality). Thus far, the polluter pays principle has had negligible effect on improving urban stormwater discharges, resulting in the steady degradation of urban streams and river over decades.

The National Water Act also introduces the intention to establish Catchment Management Agencies (CMAs). While most CMAs have been established, they are not yet operational in Gauteng Province. The CMAs are required to ‘progressively develop a catchment management strategy for the water resources within its water management area’. While stormwater is not mentioned, this offers a potential for SuDS, as it is also mentioned that the strategy must be ‘taking into account all matters relevant to the protection, use, development, conservation and management and control of water resources’, therefore stormwater management and the principles of SuDS are implicitly important.

As SuDS try to restore the flows to a more natural situation, an important part of the National Water Act is the Reserve, which reserves water for nature (environmental flows and groundwater) and for immediate human needs. As a result of the Reserve, water bodies are classified and procedures are put in place to set Resource Quality Objectives. The RQOs for water resources give direction for future management activities in the Water Management Area (WMA). According to the National Water Act, the purpose of RQOs are to establish clear goals relating to the quality of the relevant water resources (not just water quality but also quantity). The NWA stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them (Department of Water Affairs, 2011). Thus the "working part" of the classification of water resources, are the RQOs that are produced. These are numerical and narrative descriptors of conditions that need to be met in order to achieve the required management scenario. Such descriptors relate to the:

(a) quantity, pattern, timing, water level and assurance of instream flow

(b) water quality including the physical, chemical, and biological characteristics of the water

(c) character and condition of the instream and riparian habitat; and

(d) characteristics, condition and distribution of the aquatic biota (Department of Water Affairs, 2011).

Once gazetted, these RQOs are legally binding and need to be integrated into decision making. As such, these objectives provide a critical starting point for understanding catchment context and SuDS design and should therefore be informed by a catchment perspective rather than simply focussing on site level impacts and or aspirations.

The National Water Act is also clear on the obligation to create Catchment Management Strategies, once Catchment Management Agencies are established. This part of the Water Act has not yet been implemented in Gauteng. Understanding catchment context is critical to ensuring that SuDS are designed to make a meaningful contribution to water resource management challenges. Identifying and understanding of the key risks associated with the catchment, including the nature of the water quality problems, flood risks and the potential consequences that any remedial interactions may have on downstream or onsite users, is therefore essential and such Catchment Management Strategies can therefore be helpful.

Policy, law and implementation Gap 2

The Water Use Licence (WUL), which reflects on Resource Quality Objectives and other regulations, is an important facility within the NWA to control the likes of stormwater systems, and their impacts on watercourses and water resources. The scope of the WUL sets it up for being a primary enabler of SuDS. However, the licensing process has come to be seen as an obstacle to development due to the delays in awarding licenses and the uncertainty of departmental officials in considering non-standard stormwater systems.

Reaction of this project: Input for discussion on Best Management Practices or during the formulation of the Implementation Manual.

4.3.4 Spatial Planning and Land Use Management Act

The Spatial Planning and Land Use Management Act (Government of South Africa, No. 16 of 2013, SPLUMA) has a clause in section 3*(d)* is to "provide for the sustainable and efficient use of land". Furthermore, one of the principles in section 7*(d)* of SPLUMA is "the principle of spatial resilience, whereby flexibility in spatial plans, policies and land use management systems are accommodated to ensure that sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks, are made provision for.

Storm water drainage is defined in SPLUMA as part of an "engineering service" which refers to a "system for the provision of water, sewerage, electricity, municipal roads, *stormwater drainage*, gas and solid waste collection and removal required for the purpose of land development".

As in the case of the Constitution, the SPLUMA embraces and promotes the principles of sustainable development and resilience against negative environmental impacts in spatial planning and land development. However, there is no direct obligation placed on the part of mandated authorities to approach and implement storm water drainage from a SuDS perspective. If anything, storm water appears to be defined conventionally, as a hard engineering service associated with engineered pipelines and channelization. There is no direct obligation in terms of SPLUMA to consider sustainable closed loop systems for urban drainage that operate at catchment or any other scale.

4.3.5 Draft Climate Change Bill

The draft Climate Change Bill (Government of South Africa, 2018) is clear in the mandates of national government and provinces and municipalities to make adaptation plans and climate change response implementation plans. For the National Adaptation plan, it mentions that the aims are*"(a) reduction of the vulnerability of society, the economy and the environment to the effects of climate change, strengthening resilience of the socio- economic and environmental system and enhancing the adaptive capacity of the national environment and economy to the impacts of climate change;(b) minimising the risk and vulnerabilities to current and future climate scenarios …"* which could be a driver for SuDS.

4.4 National Policies and Strategies

4.4.1 National Development Plan

While the co-benefits of SuDS talk potentially to a lot of the targets of the National Development Plan (National Planning Commission, 2012), the word 'stormwater' or 'drainage' is not mentioned in the whole National Development Plan. The goals for environmental sustainability focus on a low-carbon economy, to which the green areas that are part of SuDS may contribute, because they are green or because they give opportunities for non-motorized transport. Access to water for all is a clear goal of the NDP and in that sense SuDS can also have a co-benefit, in keeping the rain where it falls and creating opportunities for harvesting. However, in terms of water provision the NDP is more focused on getting water supply infrastructure in place, although it makes mention of a national water conservation programme and the reduction in water demand in urban areas by 15% below the business-as-usual scenario is a clear target under 'economic infrastructure'. The other two important targets to be aware of, are related to water resources as part of economic infrastructure:

"A comprehensive management strategy including an investment programme for water resource development, bulk water supply and wastewater management for major centres by 2012, with reviews every five years." At the time, the investment programme was done through reconciliation strategies for major towns, but to our knowledge very limited attention was given to possible SuDS contributions to water security.

4.4.2 National Water Resources Strategy

In the second National Water Resources Strategy, NWRS II (DWS, 2013) the word 'stormwater' is only mentioned once, as an example of water re-use in Saldanha Bay. 'Drainage' is only mentioned as a resource in the context of acid mine drainage. However, the foreword already mentions *"catchment rehabilitation, clearing of invasive alien plants and rainwater harvesting is growing in importance"*. While rainwater harvesting gets a separate section, not much mentioned further on catchment rehabilitation. In Annexure B Understanding Water Resources, mention is made of the impact of litter: *"Much more can be done to remove litter from urban storm water runoff before this enters rivers."* While the strategic themes could almost all speak to SuDS, in particular 'water resources planning, development and infrastructure management', 'water resources protection', 'water conservation and water demand management' and 'managing water resources for climate change', the impact of urban stormwater does not get specific attention.

Of main importance for SuDS implementation, is that the NWRS II again confirms the National Water Acts intention to establish Catchment Management Agencies (CMA). The NWRS II does not mention flood management as task of the CMAs but mentions disaster management. It further emphasizes water resources protection, planning and management, of which SuDS could be part. The operationalization of CMAs has been halted over the past few years, but is again on the agenda of the Department of Water and Sanitation.

4.4.3 National Water and Sanitation Master Plan

This document was not mentioned in the ToR. The National Water and Sanitation Master Plan which is currently in the making (DWS, Draft, 31 October 2018) was added to the list of documents mentioned in the ToR. The status of the plan is debatable, as there is no reference to the plan in the Water Act or in the Water Services Act.

The words 'stormwater' and 'drainage' are not mentioned in the Draft plan, other than acid mine drainage and agricultural drainage. However, there are chapters on 'improving raw water quality' and 'protecting and restoring ecological infrastructure'. There is mention of source control in the chapter, and mention is made of "a need to develop a diffuse source control pollution strategy that will include improved regulation of land use in order to reduce diffuse source pollution". However, at the municipal level only the infrastructure for water supply and sanitation is mentioned in the focus on maintaining or improving water quality. The ecological infrastructure strategy seems to imply to relate to non-urbanized environments.

4.4.4 South African National Infrastructure Plan

The South African National Infrastructure Plan (Presidential Infrastructure Coordinating Commission - PICC, 2012) emphasizes the economic importance of Gauteng, its urban sprawl and fragmentation being a challenge for infrastructure investment. The plan identifies Strategic Integrated Projects (SiPS) of which 'SiP 7 Integrated urban space and public transport programme' has a bearing on Gauteng and SuDS in that its goal is for all metros to "coordinate planning and implementation of public transport, human settlement, economic and social infrastructure and location decisions into sustainable urban settlements connected by densified transport corridors". The emphasis on more public transport is there. Public transport corridors could create room for SuDS but this link is not made in the document. While the ToR of the PICC was to expand maintenance, no reference to this is made further in the document other than that skills have to be improved in terms of maintenance. As space is also critical for SuDS, the challenge posed in the document on the long time needed for approvals of space (6.5 year is mentioned, including expropriation and EIAs) is a point in case. The document also states that action should be taken to plan and build projects that promote low life-cycle costs, which can be used as an argument for SuDS, in case the Cost-Benefit Analysis later in this project supports this.

4.5 Conclusions on National Policies and Legislative Framework

In conclusion, the review of planning legislation reveals that the legislation does not directly oblige mandated authorities to include and/or enforce SUDS in spatial planning and design at a reasonable scale that will assist to mitigate the impacts of climate change. However, to varying degrees, the legislation encourages and embraces the principle of sustainable development within which SuDS falls thus various tiers of government involved in spatial planning and design may encourage SuDS, where possible, and particularly where the impacts of climate change have to be addressed and / or mitigated. The following key points summarise the findings of the review.

The Constitution embraces the concept of sustainable settlement planning within which SUDS is an obvious planning instrument; although understandably, only at a level of principle. It is not the place of the Constitution to outline the detail or specificities of how sustainable settlements are planned sustainably. Similarly, implementing SuDS can contribute to some of the Sustainable Development Goals.

The National Environmental Management Act (NEMA), the National Water Act (NWA) and the Spatial Planning and Land Use Management Act (NWA) all have a bearing on the implementation of SuDS although they do not refer specifically to stormwater management. The SPLUMA, which is the law that regulates the initiative of any development before NEMA and NWA are applied, embraces and promotes the principles of sustainable development and resilience against negative environmental impacts in spatial planning and land development. However, there is no direct obligation placed on the part of mandated authorities in terms of SPLUMA, to approach and implement storm water drainage from a SuDS perspective. The planning legislation generally regards stormwater as a conventional engineering service i.e. a hard engineering service associated with engineered pipelines and channelization. As in SPLUMA, also in NEMA and in NWA there are no direct obligation in terms of the legislation to consider sustainable closed loop systems for urban drainage that operate at catchment or any other scale.

However, while the planning legislation reviewed above generally does not make any direct reference to the nature, scale and form of sustainable development and SuDS in particular, it leaves the door open for SuDS to be considered and implemented in the management of storm water drainage particularly in respect of land development. It is the intention of planning law to achieve and promote sustainable development, achieving a balance between the social, economic and environmental agendas. This intention together with land use planning and management of our growing urban areas, is the primary responsibility of Local Government. This highlights the importance of SuDS being embedded in the lower levels of planning legislation. The Integrated Development Plans of local government could consider SuDS considerations as well, but in the Gauteng IDPs reviewed we could not see a clear 'water sensitive' line of thinking. What is apparent is that local government can only act in terms of its By-laws on a site by site basis which may compromise the role of SuDS as the application of SuDS in loco often needs to be considered at a scale greater than the application site in question.

To consider the impacts of a shift in stormwater management on a larger catchment scale than the local municipality, the Catchment Management Agencies are intended to have impact. The question is whether Catchment Management Agencies, only operational in parts of the country and not yet in Gauteng, will fulfil this role, but their mandate is most closely related to this task.

Stormwater does not seem to be considered yet as a water resource in the national water resources strategy and the water and sanitation master plan and is no topic in the South African Infrastructure Plan.

Policy, law and implementation gap 3

Since 2012, the several severe droughts have sharpened focus on all potential sources of water, including both wastage and recovery of the likes of wastewater and stormwater. Also, the growth of urban centres and the needs for higher service levels fuel the need for alternative sources such as stormwater harvesting. The NDP and the NWRS are due for updates and must acknowledge current thinking about water resources in the context of urban and metropolitan areas.

In the National Water and Sanitation Master Plan, Wastewater recycling and the impact of Waste Water Treatment Works (WWTW) are increasingly discussed in relation to water security and water resource management. That the draft of the current plan doesn't acknowledge stormwater management shows that work needs to be done to bring multi-disciplinary planning into the national thinking. As shown in Chapter 5, there appears to be more integration at municipal level.

Reaction of this project: This can only possibly become a recommendation during the writing of the Implementation Manual. The stakeholder workshops will also help spread the message.

5 WHICH SOUTH AFRICAN FRAMEWORKS, GUIDELINES OR STANDARDS ARE RELATED TO SUDS?

5.1 Introduction

While the South African Guidelines for Sustainable Urban Drainage have already been referred to in previous sections, as well as the Framework and Guidelines for Water Sensitive and Urban Design, in this Chapter they are reviewed separately, as well as the 'Red Book' and 'Green Book' for Human Settlements, the Guidelines for Catchment Management Strategies (See also section 4.3.3 on NWA and section 4.4.2 on NWRS II), the Framework for Investing in Ecological Infrastructure and the Green Building Standards. This is followed by conclusions as regards south African frameworks, guidelines or standards.

5.2 South African Guidelines for Sustainable Drainage Systems

These SA guidelines for SuDS (Armitage et al., 2013) are mentioned in the ToR of this project as a possible national priority, but the document is not an indication of a government priority as such. The guidelines, referred to in this literature review in many sections and considered the 'baseline', are the product of a study funded by the Water Research Commission. The aims of the guidelines are ”i) To identify and develop new and appropriate, practical and affordable alternative stormwater management technologies for South Africa in line with Water Sensitive Urban Design (WSUD) principles. ii) To evaluate the identify technology options …, iii) To develop practical and user-friendly guidelines…”. As concluded from the research developments in South Africa in Chapter 3, these guidelines still have their value, although some updates based on international experiences might be due for revision.

5.3 Water Sensitive Urban Design for South Africa: Framework and Guidelines

The SA framework and guidelines for WSUD (Armitage et al., 2014) discuss the governance challenges related to WSUD which are also those faced by SuDS implementation. The framework offers 'institutional considerations' but does not go as far as giving guidance, probably also because of the uniqueness of every situation. The guidelines themselves mainly focus on the technical and environmental aspects of WSUD, and not on how to implement.

The philosophy of Water Sensitive Urban Design (WSUD), was discussed in section 2.6. This Framework and Guidelines contextualizes the concept of WSUD with the purpose of being able to guide municipal managers and other local authority officials towards adopting a WSUD philosophy in the context the urban transformation agenda.

The WSUD Framework reminds us that WSUDs has the potential to mitigate the negative effects of water scarcity, reduce water pollution, develop social and entrepreneurial equity, increase sustainability and develop resilience within the local water systems. The WSUD's approach requires an integrated and holistic approach to planning and implementation whereby different sectors and spheres of government as well as the private sector work together. It also requires a proactive approach, especially while the WSUDS approach is not fully institutionalized and embedded in law. The framework explains the challenges this gives and highlights the current silo'ed institutional management and planning, limited resources and lastly, mindset changes that are necessary. It is therefore a good document to get introduced to the governance challenges of WSUDs and therewith also SuDS.

The framework also identifies the challenges in South Africa between formal and informal areas and has thus adapted the Australian based 'Brown Framework' for visualising transitions within the urban water management sector (See section 2.6) (Brown et al., 2009) to a framework that is more adequate for developing countries like South Africa (see Figure 7 below). Formal areas in South Africa resemble developed areas in developed countries with adequate services however informal areas are lacking in basic service provision and contend with high densities and poor infrastructure. The adapted framework demonstrates how it may be possible to affect the transition in both formal and informal areas (Armitage et al., 2014). (See also Section 2.8 on further research on governance aspects in Gauteng).

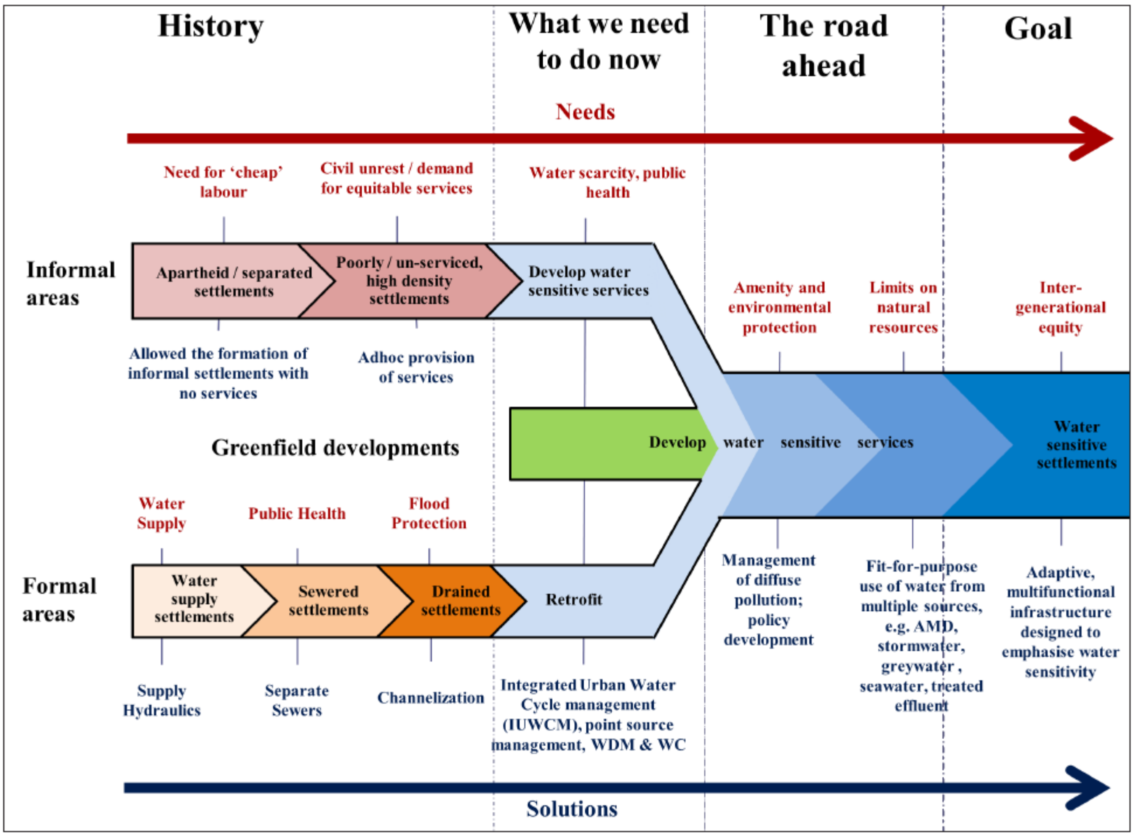

Figure 7: Framework for Water Sensitive Settlements in RSA (Armitage et al., 2014)

5.4 Guidelines for Human Settlement and Planning and Design ('Red Book' and 'Green Book')

The Guidelines for Human Settlement and Planning and Design, the so-called Red Book, was developed by the CSIR in 2000 (CSIR, 2000). It was updated in July 2019 (CSIR, 2019) and is now called The Neighbourhood Planning and Design Guide. The updated version makes mention of the concept of WSUD and how it integrates all facets of the urban water cycle. It also provides a planning and design guideline for SuDS in South Africa. The concept of WSUD and SuDS has also been partly been addressed by what is now called the 'Green Book', with the title 'Adapting Human Settlements for the future'. It is a website (www.greenbook.co.za) also developed by CSIR, that supports municipal planning with the development of climate resilient strategies. The Green Book mentions as adaptation measures the 'identification of suitable sites for infiltration of rainwater runoff', 'design stormwater and rainwater harvesting systems', 'use cool permeable paving', 'reduce contamination of stormwater runoff' and 'diversify water supply'.

5.5 Guidelines for catchment management strategies

The Guidelines for Catchment Management Strategies – towards equity, sustainability and efficiency – were finalized as first edition in 2007 (DWA, 2007) and no update was published since. These guidelines were meant for Catchment Management Agencies (CMA) to formulate strategies. However, the CMAs which are relevant for Gauteng (Limpopo and Vaal) are not yet operational so the guidelines have very limited value and will probably have to be reviewed once established. The catchment management strategies will however play a valuable role once made. The Guidelines prescribe how to do a catchment description, a situation assessment, doing a reconciliation (balancing water availability with water requirements), formulating a vision. Then it prescribes certain sub-strategies: water resource protection, regulating water use, public engagement and monitoring & information. All could be related to SuDS, but no specifics are given of stormwater management or drainage. The guidelines are more a process description, making reference to the National Water Act and other relevant policies.

5.6 Framework for investing in ecological infrastructure in South Africa

The Framework for investing in ecological infrastructure in South Africa was prepared by SANBI (2016). As stated: "Within the South African context, ecological infrastructure refers to naturally functioning ecosystems that deliver valuable services to people, such as healthy mountain catchments, rivers, wetlands, coastal dunes, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape. Ecological infrastructure is therefore the asset, or stock, from which a range of valuable services flow." The framework was written to "understanding and communicate the core intention of maintaining and restoring natural ecosystems that provide valuable services". The framework does not specifically refer to drainage or stormwater management, but discusses measures that are close to SuDS although not really SuDS, such as rehabilitation of wetlands, and buffer zones of natural vegetation along rivers. The impact on water and on disaster management, as well as ecological infrastructure supporting built infrastructure is well recognized and core to the SuDS concepts as well. The marriage between ecological and stormwater functions is discussed further in section 2.4.

5.7 Green Building Standards and Green Star rating

A green building is defined by Green Building Council South Africa as energy efficient, resource efficient and environmentally responsible. SuDS is considered a good fit for these requirements, and complying with the Green Building Standards seems to have been the driver of many SuDS projects in mainly commercial developments and estates, as concluded Deliverable 4 on Data collection on SuDS installations in Gauteng. However, the challenge was identified in that stormwater plans were often finalized before green building experts got involved in the building process.

Many developers are choosing to walk the Green Star route seeking a long-term cost saving benefit and the comfort that they are impacting less on the environment, with additional attractiveness for tenants and buyers. The Green Star rating employed by the Green Building Council of South Africa (GBCSA) is based on the Green Star Council of Australia Green Star System and provides the development sector with an objective guideline tool and basis for measurement against a set of sustainability criteria and targets. The South African state is slowly adopting the Green Star Rating as a benchmark to ensure their own buildings are compliant with national objective to be more sustainable. (Green Star Building Council of South Africa, 2014)

The Green Star rating tool includes reference to technological solutions typically utilized in a SuDS approach in their Water Course Pollution Category of assessment. This is to encourage minimization of stormwater run-off and the pollution of natural watercourses and wetlands. This category recognizes the benefits of groundwater recharge through infiltration, storage and reuse of stormwater.

The Green Star Rating Tool is not however obligatory and is currently only used by the larger private sector developers and more recently the upmarket residential sector as the certification requires substantial upfront investment in relatively sophisticated technology and additional professionals and skills in the development team.

(Note: Tshwane has Green Building By-Laws, see Section 7.2.)

5.8 Building Regulations

However, apart from those that would like to go the green route, there is now SANS 10400 XA standard with which all new buildings should comply. The document was checked and is mainly about energy efficiency of buildings. The SANS 204 is stricter, but voluntary and also with focus on energy usage. (www.SABS.co.za). These are the only Green Building South African Bureau of Standards regulations related to green building, presumably without direct reference to SuDS.

In terms of design and construction of rainwater harvesting infrastructure, this must be consistent with the National Building Regulations (NBR) SANS 10400. The NBR fall under the National Building Regulations and Building Standards Act (Act 103 of 1977), which governs all building and construction work in South Africa. The NBR are divided into 23 chapters, none of which deals directly with water installations such as rainwater collection tanks in buildings other than those part of fire installations in SANS 10400 W. The regulations are generally enforced by building control officers who are appointed by local governments.

The Water Research Commission on the Legal framework and institutional arrangements for rainwater harvesting notes the following: "On the one hand, it may not be a bad thing that South Africa has no direct language in the national building codes referring to rainwater harvesting. This has enabled, over the past decades, local governments to regulate more freely. On the other hand, it faces serious challenges with respect to monitoring compliance with and enforcing contraventions of these by-laws due to the fact that they do not have the capacity to enforce them." (Water Research Commission, 2018)

5.8.1 Conclusions on national frameworks, guidelines, regulations and standards

The SA Guidelines for Sustainable Urban Drainage Systems seem to be the practical guidelines, but do not give guidance to how to promote SuDS in a private or municipal stormwater management plan. The guidelines for catchment management strategies are a guidance, but could be more explicit in stormwater management and in particular the choice between SuDS and conventional stormwater management. The Green Building Guidelines already have had impact on SuDS although they are also not explicit. SuDS are not yet included in the ecological infrastructure framework, probably because their biodiversity impact is generally not addressed (See section 0).

Policy, law and implementation gap 4

While technically and environmentally, the SuDS community is helped with the guidelines and standards developed, what seems missing is a guideline to guide the process of decision making between conventional stormwater management and SuDS.

Reaction of this project: This is a potential topic for the implementation guideline, though this literature review shows there is limited material already available in South Africa that can assist herewith, if not in other than Gauteng municipalities.

6 HOW DO THE GAUTENG POLICIES, STRATEGIES, PLANS AND OUTLOOK RELATE TO SUDS?

6.1 Introduction

Gauteng is the smallest of the nine provinces and considered to be the powerhouse of the country however it is also, as a result, under enormous pressure to accommodate land uses that drive the economy and support the economy that in turn require land, generate high levels of waste and pollution and further strains on the natural environment.

The above documents of Gauteng were reviewed in detail in separate sections below:

- Gauteng Climate Change Response Strategy and Action Plan (Gauteng Provincial Government, 2018)
- Province of Gauteng: Planning and Development Bill (Gauteng Provincial Government, 2018)
- Gauteng Provincial Environmental Management Framework (Gauteng Provincial Government, 2014)
- Gauteng Province Environmental Outlook (not a policy document but a monitoring and evaluation document, Gauteng Provincial Government, 2017a)

Apart from the above documents the following documents were consulted and formed part of the documents discussed in the conclusions of this chapter:

- Gauteng Conservation Plan Version 3.3 (C-Plan 3.3) (Gauteng Provincial Government, 2011b)
- Gauteng Province Environmental Outlook Report (Gauteng Provincial Government, 2017a)
- Gauteng Sustainability Development Guidelines (Gauteng Provincial Government, 2017b)
- Water Security Perspective for the Gauteng City-Region (GCRO, 2019, quoted in Deliverable 8 of this project, the implementation manual)

6.2 Gauteng Climate Change Response Strategy and Action Plan

The Gauteng Climate Change Response Strategy and Action Plan of 2011 (Gauteng Province, 2011) did not yet mention 'stormwater' or 'drainage' other than acid mine drainage. However, the topics of 'water' and 'human settlement' had quite clear objectives related to SuDS. The Gauteng Climate Change Response Strategy and Action Plan which was published in final draft in 2018 (Gauteng Province, 2018) has specific actions on Sustainable Urban Drainage Systems as priority action: "Research, pilot and implement Sustainable Urban Drainage Systems (SUDS) and Ecologically based Adaptation (EbA) approaches to stormwater management". (The project Research on the Use of SuDS in Gauteng Province which produces this report is part of the research part). Targets for this action are:

- Develop provincial manual for SuDS implementation by 2020 (this project);
- All municipalities to include green infrastructure elements in their stormwater management plans by 2022.

To achieve the above targets a number of role players will have to work together. They include the Department of Water and Sanitation (DWS), Department of Human Settlement (DHS), Municipalities and GDARD. Potential sources of financing are also listed. They include Water Research Commission (WRC), Municipal Infrastructure Grant (MIG) and the Urban Settlements Development Grant.

While the principles of utilising the same space for stormwater and ecological functions in the urban space are strong, the practical implications of this still needs to be ironed out. This is addressed in more detail in Section 5.

There are other priority actions mentioned in the Gauteng Climate Change Response Strategy and Action Plan which do not mention SuDS explicitly but are clearly related:

- Safeguard and rehabilitate wetlands and watercourses, especially in urban and agricultural areas, through municipal planning and building approvals and the Environmental Impact Assessment regulatory scheme with the aim to improve ground- and surface water management. The target is conduct provincial research on constructed wetlands by 2020 and appropriate zoning or formal protection for all urban wetland areas and watercourses by 2022 (DWS, Municipalities, GDARD, DAFF, DEA with funding from GEF);

- Pilot project aimed at improving the coverage of effluent collection and treatment systems, with specific reference to informal settlements. The target is to develop three pilot projects that demonstrate innovation in effluent management in informal settlements by 2022 (WRC);

- Litter management in storm water systems and watercourses. The target is to have stormwater and watercourse litter management included as performance standard in municipal development and budgetary plans, with associated monitoring and reporting based in GDARD standards on an annual basis by 2022 (Municipalities and EPWP, monitoring by GDARD: Waste management and Environmental Empowerment).

- Re-use of secondary water sources; recovery of runoff, AMD water, grey water and industrial recycling. As for recovery of runoff, the target is to have by 2022 a regulatory requirement in place in at least one Metro that makes rainwater capture and greywater re-use mandatory in all new buildings (DWS, Municipalities funded by MIG and Urban Settlements Development Grant).

The action plan therefore identifies many responsibilities for other parties than the Province of Gauteng, but does not explain to what extent these parties have committed to these responsibilities. The report mentions only that “For each of the response programme a responsible department is identified and the role(s) of government, target and project types detailed.”

6.3 Province of Gauteng: Planning and Development Bill

While SPLUMA was promulgated in 2013, the Gauteng Provincial Legislature has not subsequently approved the Gauteng Planning and Development Bill which, once passed, as an act, was to replace the Gauteng Planning and Development Act (No.3 of 2003). The Bill thus has no legal status (draft 2012) but is noted here as the anticipated provincial planning legislation for the Gauteng province.

In accordance with SPLUMA, stormwater drainage is covered under the definition of engineering services which means “a facility for the provision of water, sewerage, electricity, municipal roads and *stormwater drainage*, and refuse removal required for the purpose of land development.” In addition, chapter 9 of the Bill makes provision, among other things, for the Premier to "publish and amend guidelines not inconsistent with this Act in respect of engineering services and development contributions" in terms of Section 73 (1) (b) of the Bill.

What this implies for SuDS is firstly, as with SPLUMA, there is no direct obligation placed on the part of mandated authorities such as the Local Authority who is responsible for the provision of external services as defined in accordance with SPLUMA, to implement storm water drainage from a SuDS perspective. Again, storm water appears to be defined conventionally, as a hard engineering service. However, given the provision of the Bill to permit the Premier to publish and/or amend guidelines in respect of engineering services, there is room for the Premier to consider enforceable sustainable urban drainage systems that operate at catchment or any other scale that makes sense from a sustainability and climate change mitigation perspective.

6.4 Gauteng Province Environmental Management Framework

The Gauteng Province EMF, 2014 (gazette in 22 May 2015) was compiled to ensure sustainable land use management through the establishment of a set of guidelines for Environmental Impact Assessment Practitioners and officials to ensure that particular objectives such as sustainable development (energy efficiency in buildings, waste minimization etc. and green infrastructure in urban areas including SUDS) are promoted. It also defines a set of Environmental Management Zones which help to guide municipalities in understanding which natural systems and areas require protection and / or careful consideration and management.

The Gauteng Province Environmental Management Framework which was promulgated in March 2018 (Government Gazette, 2018), is clear in stormwater management being one of the generally applicable environmental management specifications, which is a generally applicable environmental management specification with specifications for the three principles here quoted: "

- *Management of stormwater runoff must take place as close to the source as possible, therefore first consideration of source control, then local control, then regional control;*
- *The management of stormwater must ensure that additional runoff water is stored and released at a rate that will not impact negatively on the natural flow capacity of rivers, wetlands and streams;*
- *Development and operation activities must not encroach onto the '32 meter'-buffer from a water course. "*

This Gauteng Province Environmental Management Framework therefore goes quite far in obliging the serious consideration of use of SuDS, with the measures in point 2 referring to those listed in the South African SuDS manual (Armitage et al., 2013).

Point 3 refers to water quantity aspects but not to water quality aspects that need to be the objective of the stormwater design. It is up to the initiator of the Activity that needs to undergo an Environmental Impact Assessment to prove serious consideration is given, therefore this Framework can be a very useful tool for the introduction of SuDS in Gauteng.

The Gauteng Province EMF is a legal instrument of the Environmental Management Framework Regulations (2010) with the purpose of assisting EIA processes, spatial planning and sustainable development, but remains a guideline for provincial officials to use to encourage a move towards more responsible planning including the incorporation of SUDS.

6.5 Gauteng Conservation Plan

The Gauteng Conservation Plan (Pfab, 2017) identifies areas that are required for the conservation of a representative and sustainable sample of the province's biodiversity, where converting land uses should be excluded, where land uses incompatible with biodiversity should be avoided and where special management measures are required to maintain and protect biodiversity. Biodiversity considerations must therefore be specifically integrated into planning to ensure that SuDS support and compliment biodiversity objectives in priority areas.

6.6 Gauteng Province Environmental Outlook

The Gauteng Province Environmental Outlook (2017) is not a policy document, but a monitoring and evaluation tool. It is remarking that urban stormwater runoff influences the water quality in Gauteng. "Urbanisation and increased population growth intensify the pressures on aquatic systems as the human demand for water increases, along with a growing need to deal with stormwater runoff and wastewater. Inadequate water resource management is impeding ecosystems functioning, therefore reducing the ability of ecosystems to provide ecological services effectively." The impact of good waste management on water resources is also recognized: "General waste such as litter or informally disposed of domestic waste tend to spread across the landscape and end up in stormwater infrastructure or open spaces. This degrades the natural resource quality and can create hazards such as pipe blockages during storm events." The report summarizes the water quality parameters monitored but further does not provide data on stormwater management systems, as that is beyond its scope.

6.7 Conclusions on Gauteng related documents

As a result of the strains on the environment, the Province is pro-active in supporting development of the municipalities in a way that achieves a balanced approach whereby the economy can still thrive and grow and the critical natural systems are protected. The most powerful tool for SuDS implementation currently available in Gauteng at provincial level seems to be the Gauteng Province Environmental Management Framework, promoting SuDS through its EIA processes. The initiatives and management as regards SuDS are mainly left at the local level. This is not surprising or wrong, as that is the level where stormwater management normally sits. Gauteng, from its provincial perspective, can only be a facilitator in order for municipalities to learn from each other and for neighbouring municipalities not to be confronted with the stormwater challenges caused by upstream municipalities.

It appears however that the C-Plan 3.3 which forms the basis of the Environmental Management Zones and which in turn informs the municipal level SDF's, focuses less on the hydrological systems than is necessary to make physical space for stormwater collection, attenuation, retention and infiltration in a more ecologically and people friendly manner than is currently done through the construction of hard infrastructure.

While there is mention of SuDS in the more recent policy documents, namely the Gauteng Province EMF, the Gauteng Environmental Outlook Report and the Gauteng Sustainability Development Guidelines, there is little commitment to ensuring that catchment scale planning across the municipalities and districts is undertaken to facilitate SuDS through the scales. This may require the Province to play a more significant role in coordinating catchment planning to ensure that the current Water Management Areas (WMA's) and Drainage Regions, focus not only on water supply but a wider array of issues and strategies to address water quality and flooding, while preparing for the operationalization of the Catchment Management Agencies for Limpopo, Olifants and Vaal CMAs, or as a stakeholder in these WMAs. Furthermore, as suggested in section 3, there appears to be a distinct gap in stormwater catchment planning at the regional scale (see box below).

The Gauteng Sustainability Development Guidelines, compiled more recently, are intended to form the basis for more localized (and contextually specific) sector guidelines.

The Water Security Perspective for the Gauteng City-Region (GCRO, 2019) briefly stormwater as 'an alternative water source' fitting in the ambition to diversify sources of supply, but puts more emphasis on the flood and health hazards of stormwater and therefore stresses that stormwater systems need to be maintained properly and to avoid stormwater getting into sewers and vice versa. It is stated that stormwater management should be given more attention in new and existing settlements. The draft Water Security Plan emphasizes that climate change will make a smaller proportion of rain come to runoff (not discussing the changes in rainfall itself) and therefore promotes to protect the rivers in natural streams, concluding that 'it will often be inappropriate to adopt drainage practices that reduce overall runoff and that stormwater should rather be safely channelled into natural streams'. This will need to be a point of discussion for the targets that will be set for SuDS in Gauteng.

Policy, law and implementation gap 5

It is clear from the review of the Gauteng related documents, as well as the national laws that the role of a province in promoting SuDS is not clearly defined and neither is it very well defined for Catchment Management Agencies, although it would fit in the mandate of those, once operationalized for the WMAs in which Gauteng is a stakeholder: Vaal, Limpopo, Olifants.

Reaction of this project: The implementation guideline that is the main objective of this project, does not have a clear legislative mandate, but can guide Gauteng in the implementation of the Environmental Management Framework, its most powerful tool for SuDS implementation currently. It also could serve ad interim for guidance on catchment management, and later for inputs as a stakeholder in the catchment management strategy. The development of the guidelines will decide which role is envisaged.

7 WHAT IS THE MUNICIPAL FOUNDATION IN GAUTENG FOR SUDS?

7.1 Introduction

The adoption and implementation of SuDS largely happens at the municipal level of government. Municipal policies, by-laws and guidelines are often seen to be among the key enablers (or obstructions) for mainstreaming SuDS (Dunsmore, 2016, Grant et al., 2017).

7.2 City of Tshwane

CoT Consolidated Building By-laws (undated)

The City of Tshwane's (CoT) by-laws define stormwater as "a liquid resulting from natural precipitation or accumulation, and includes rainwater, spring water and groundwater" (CoT Consolidated Building By-laws, undated). They also specifically exclude stormwater from the definition of the term "waste water", and that waste water is to be prevented from entering stormwater networks. Natural watercourses are used to convey stormwater. There is a sense therefore that stormwater runoff is seen more as a resource than as a waste product.

CoT Guidelines for Compilation of Stormwater Management Reports (2016)

The guidelines introduce both SuDS and WSUDS and recommend their adoption rather than enforce them. It is an important first step in promoting SuDS and is likely to be updated and enhanced as the principles and implementation of SuDS are more widely adopted in Gauteng.

CoT Green-Building Development Policy (2009) and By-Law (2013)

Tshwane has Green-Building Development by-law and policy with mandatory or promoted standards for buildings and sites that need building control and planning approval respectively. Promoted standards are (to be) promoted through incentives schemes. Rainwater harvesting is promoted, with for different classes of occupancy of buildings (from place of worship to covered parking areas) different storage capacities in litres per m^2 of surface area. On-site stormwater retention is also promoted for sites with over 500 m^2 of hardened surface, to retain 80% of rainfall on site (time period and design return period not clear).

City of Tshwane Draft Adopt-a-Spot Policy (2018)

The Draf Adopt a Spot Policy clarifies how voluntary arrangements by communities / private companies are allowed to do for maintenance and beautification of public open space, and what support they can expect from the Municipality. This might be relevant for further development of community engagement in SuDS maintenance, or even introduction of SuDS.

7.3 City of Ekurhuleni

Draft CoE Spatial Planning and Land Use Management By-law (2015)

Still in Draft form and circulated for comment in 2017, the Draft Ekurhuleni Spatial Planning and Land Use Management By-law has to date not been promulgated.

As is the case for the City of Johannesburg by-law (2016), and in accordance with SPLUMA, engineering services "means a system for the provision of water, sewerage, electricity, municipal roads, *storm water drainage*, gas and solid waste collection and removal required for the purpose of land development in terms of the draft By-law. Chapter 8 of the Draft By-law deals specifically with the provision of engineering services, determination of capacities for infrastructure provision, roles and responsibilities in respect of external and internal engineering services to be provided and as defined by the By-law. This chapter also covers development contribution levies related to land development.

There is no direct reference in the By-law to SuDS and / or particular requirements in respect of storm water discharge from a sustainability perspective and/or using SuDS as a tool for mitigating the impacts of climate change in the municipal area.

CoE Stormwater Management Requirements (2007)

The CoE does not have by-laws specific to stormwater management. In 2007 the Department of Infrastructure Services: Roads, Transport and Civil Works (Northern Region) issued their General Stormwater Management Requirements (CoE, 2007) which have since been adopted by the all the regional departments in the City. The document makes provision for limiting post-development runoff to pre-development conditions over a range of return periods up to 25 years, although the means of control is specified as peak flow management (by attenuation) rather than control of runoff volume. It also defines a natural watercourse in terms of hydraulic capacity and requires a servitude to be registered for all such watercourses on private land. This is an important step for the long-term protection of stormwater assets. The CoE is currently revising its stormwater By-laws, with a draft to be released soonest.

CoE Waste Water By-laws (2001) & Public Health By-laws (2009)

There are important references to stormwater management aspects in the Public Health (CoE, 2009) and Waste Water (CoE, 2001) by-laws. A similar definition of stormwater to that used by the City of Tshwane is applied; that it includes rainfall runoff, but specifically excludes wastewater and industrial water. Hence again stormwater is treated more as a resource than a waste product.

The wastewater by-laws focus on the importance of separating wastewater and stormwater systems, but emphasis is also given to preventing contaminated rainwater runoff from entering the stormwater system (CoE, 2001, p16-17). The public health by-laws go further, requiring a landowner to prevent stormwater contamination and, if contamination occurs, to collect and treat it (CoE, 2009, p22). It also makes specific mention of protecting natural watercourses from pollution and addresses the potential impacts of different land uses a property and the need for containment onsite.

CoE Climate Change Response Strategy (2015)

The City of Ekurhuleni recognizes in its Climate Change Response Strategy the risk of floods, the need for better water quality conservation of biodiversity. Direct links with SuDS are given in that the strategy expresses aims to 'develop a rain water harvesting industry and design a programme for all commercial and residential customers' and is explicit on the biodiversity conservation of the Municipality by means of open space systems, that use indigenous plants and trees, reduce water use, and keep grass cutting limited to areas of recreational use. Stormwater management is hardly referred to though in the document, only that poor stormwater management impacts negatively on streams and therefore stormwater management needs to auditing 'at construction sites, slimes dams, feedlots and livestock sheds.' Also, regular clearing of dirt road shoulders, kerbs and drains and erosion control is mentioned.

CoE's other planning documents

The City of Ekurhuleni has committed to certain relevant objectives through the following policies and guidelines:

- Ekurhuleni Environmental Management Framework (CoE, 2007a)
- Ekurhuleni Revised Environmental Policy (CoE, 2013)
- Ekurhuleni Bioregional Plan (CoE, 2014)
- Ekurhuleni Growth and Development Strategy 2055 (CoE, 2005)
- Ekurhuleni IDP 2018/2019 – 2020/2021 Annexure A: 2018-2019 review (CoE, 2018)
- Ekurhuleni Metropolitan Spatial Development Framework (CoE, 2015b)

The Ekurhuleni Revised Environmental Policy suggests that there is support for an approach to stormwater management that addresses both quantity and quality.

Furthermore, the CoE has prepared the Ekurhuleni Bioregional Plan, which is in turn informed by the C-Plan v3.3 and in line with other municipal spatial plans such as the Ekurhuleni Biodiversity and Open Space Strategy. This allows for protection of critically sensitive parts of the natural environment.

What is noteworthy is that the SDF acknowledges not only the Biodiversity Network and Open Space System but also the hydrological system which provides a strong and distinct natural backbone to the municipal area. The SDF acknowledges that the hydrological systems are vital when it comes to the biological functioning of the area. It proposes that the natural hydraulic functions must therefore remain intact. On the open space layer of the spatial plan there are "hydrological protection zones" which implies there is an attempt to spatially determine the extent of land required for natural hydrological systems.

Key spatial objectives in the SDF to support a more sustainable approach to stormwater including SuDS, include firstly, creating a sustainable and functional open space network, secondly, identifying the spatial impact of Climate Change (through flooding for example) and thirdly, promoting sustainable development (through the use of stormwater plans addressing flooding and enabling the protection of Ekurhuleni biodiversity and open space and improved water resources management and disaster risk reduction management).

With this conceptual high-level commitment, the envisaged by-laws for stormwater management are promising.

7.4 City of Johannesburg

CoJ Municipal Planning By-law (2016)

In accordance with SPLUMA, engineering services "means a system for the provision of water, electricity, gas, roads, *storm water drainage* and collection and removal of solid waste or sewerage, required for the purpose of land development in terms of the By-law; and storm water drainage forms a part thereof.

The City of Johannesburg (CoJ) is responsible for the provision of external engineering services and the developer (if not the City itself) is responsible for the provision of internal engineering services, as defined in the by-law and in accordance with SPLUMA, as follows.

External engineering service "means an engineering service situated outside the boundaries of a land area required to serve the use and development of the land area and is either a link engineering service or a bulk engineering service or an engineering service which has been classified by agreement as such in terms of section 46(6) of the By-law; and

Internal engineering service "means an engineering service situated within the boundaries of a land area required for the use and development of the land area and which is to be owned and operated by the City or a service provider".

Chapter 6 of the By-law makes provision for the roles and responsibilities of different operators in respect of engineering services provision, engineering services agreements as well as the development contribution levies and norms and standards that apply in respect of land development. While there are no specificities in the By-law in respect of storm water drainage in particular, section 46(7) makes provision for internal engineering services to be provided to the satisfaction of the City. This provision, together with the City's ability to impose conditions on development applications empower the City to introduce relevant SuDS-related guidelines and conditions that may contribute to a more sustainable environment.

Notwithstanding the generalized approach to storm water drainage in the By-law as one component of "engineering services", the City of Johannesburg not only has the ability in terms of the By-law to influence SuDS-related strategies in land development but also has a dedicated set of Storm Water Management By-laws to regulate the management of storm water within the Johannesburg municipal area (see below).

CoJ Storm Water Management By-laws (2010)

The purpose of the By-laws is to manage, control and regulate the quantity, quality, flow and velocity of stormwater runoff from any property which it is proposed to develop or is in the process of being developed or is fully developed, in order to prevent or mitigate -

- erosion and degradation of watercourses;
- sedimentation in ponds and watercourses;
- degradation of water quality and fish habitat; and
- excess stormwater runoff onto a public road which may pose a danger to life or property or both.

These By-laws pertain to developers, contractors and owners contemplating either minor or major land development as defined in the By-laws.

Part 2 of these By-laws make specific provision for storm water management at different scales. It provides for drainage facilities on site/s being developed and makes specific reference to flood attenuation and prevention and ensuring that pre-development run-off is equal to post development run-off in both quantity and quality. In addition, where storm water is directly discharged from development sites into natural wetlands, requirements are stipulated to control the quantity and quality of discharge. Mitigation for the loss of natural wetlands through the development of constructed wetlands and the simultaneous treatment of storm water is also provided for in the By-laws.

At the regional scale, provision is made to accommodate stormwater discharge from a number of development sites where deemed appropriate by the City of Johannesburg and where developers can contribute to the construction of a regional stormwater facility.

Furthermore, section 46 of the By-laws makes provision for local planning policies and storm water management and control of catchment areas to "develop requirements for a catchment area for the control at source of stormwater, stormwater treatment and erosion control at any water course and requirements relating to wetland or other water quality sensitive area."

In summary, the By-laws (CoJ, 2010) preceded SPLUMA (Government of South Africa, 2013) and the CoJ Municipal Planning By-law (CoJ, 2016) thus they reference sustainability as a planning and design principle but specific reference to SUDS per se as a planning and mitigation tool against the impact of climate change do not feature directly in the By-laws (CoJ, 2010). However, the By-laws make provision at a broad-brush level for SuDS to be considered in land development and catchment planning policies to be created so there is room in the By-laws for the consideration of SuDS in the future. Some of the requirements and provisions of the By-laws broadly embrace SuDS principles. However, it is difficult to apply SuDS principles in a holistic manner when the By-laws primarily deal with individual properties being developed at one at a time.

CoJ Draft Water Services By-laws (2018c)

The CoJ Draft Water Services By-laws (2018 for public comment – last available version May 2019) are permitting the use of water from other than the Council's water supply system (Chapter 10). The Council regulates the use of such water if it used for consumption not specified which consumption), connected to the water supply system and connected to the sewerage disposal system. In the draft By-law, all rainwater harvesting installations must be installed by a professionally registered plumber, with the water not to be used for drinking or other potable water uses and without blending with municipal supplies. While not made explicit, it is assumed that irrigation water harvesting use is excluded from the need for a plumber, as this water is not drained on the sewerage system. Furthermore, it is mentioned that the tank sizing for rainwater harvesting should be in line with the CoJ's Rainwater Harvesting Guidelines, which we have not managed to source, and any overflow must be directed to the stormwater drainage. Ndetekeya and Dundu (2019) see the requirements for getting permission and the restriction to retrofitting existing water supply as a restrictive pressure on customers to introduce rainwater harvesting.

CoJ design guidelines for stormwater management manual (draft 2018) and asset management register

As a result of the CoJ's stormwater By-laws a stormwater management manual is currently being developed (CoJ, 2018). The manual supports the principles of SuDS and gives guidance on designs. As it is not yet final, the document is not further reviewed here. A launch is planned for June 2019.

The management manual for the City of Johannesburg (CoJ, 2018) requires that, like conventional grey infrastructure assets, SuDS treatment trains should also be recorded as stormwater assets. This implies that all features of the Stormwater Management Plan signed off by the municipality as part of the Site Development Permit should be captured on an asset register. The register should capture the performance requirements (quantity, quality, amenity and ecology) of the treatment train.

The importance of this register includes:

- The stormwater performance of each part of the treatment train is defined so as to ensure the desired level of protection to upstream or downstream systems is preserved.
- To ensure that each part of the system, especially the vegetated components are protected, and not re-landscaped for other purposes at a later date.
- That each part of the system is maintained as per specification, to ensure the long-term performance of the system.

Where there are potentially conflicting demands on maintenance, these should be identified before sign-off of the Stormwater Management Plan. This is a part of the manual, that would benefit many other municipalities in Gauteng.

CoJ's Climate Change Adaptation Plan "A Climate of Change: Enhancing Climate Adaptation in the City of Johannesburg" (draft 2019)

[Note: At the time of writing the CoJ's climate change adaptation plan was in draft and not yet available for wider circulation.]

Vogel and Molefe (2019) reviewed the Climate Change Adaptation Plan of the City of Johannesburg of 2009 and assessed those aspects that are working and not working. The review brings out some of the critical concerns raised by the City, but also investigates current thinking in key risk areas, one of which is water security which is seen as one of the major threats of climate change. The report investigates the City's readiness for holistic water management, including the management of their surface water (and stormwater) resources, and explores the possibility of Johannesburg as a Water Sensitive City (see Figure 3 above).

CoJ's other planning documents

Apart from the documents above the following documents have been reviewed:

- CoJ Climate Change Strategic Framework (CoJ, 2015b)
- Joburg 2040 Growth and Development Strategy (CoJ, 2016b)
- CoJ Integrated Development Plan Review 2018/2019 (CoJ, 2018)
- CoJ Municipal Spatial Development Framework 2040 (CoJ, 2016)
- CoJ Environmental Management Policy (CoJ, 2015a)
- CoJ Built Environment Guidelines and Standards (CoJ, 2014)

The CoJ's IDP contains specific output deliverables, related to the Joburg 2040 Growth and Development Strategy, which relate to the following: sustainable and integrated delivery of water, sanitation, energy and waste; and climate change resilience and environmental protection. The output deliverables identified include amongst others, investment in green infrastructure, protection of water bodies and encouragement of natural hydrological functioning. These are all in directly supportive of SUDS.

The CoJ's Municipal Spatial Development Framework is part of the IDP and is obviously informed by the same outputs and objectives and to this end identifies the natural environment as a means to structure the city and provide eco-system services. It is however unclear how informed the natural systems network is by the natural hydrological systems that flow across the municipal area. The IDP and SDF defined objectives are in conclusion, each in their own way, supportive of SuDS. This should begin to impact on the manner in which the authority goes about planning and implementing stormwater infrastructure and managing the development pressures in time.

This support for SuDS in the high-level policy has filtered through to lower level policies contained in the CoJ Built Environment Guidelines and Standards within which the Catchment Management Policy is contained.

7.5 Other Gauteng Municipalities

Although an effort was made to find relevant documents from other Gauteng Municipalities, only readily available and relevant documents are discussed below. Mogale City and West Rand District Municipality (in which Mogale City lies) got extra attention because one of the case studies in the next deliverable "Analysis of Study Areas with Recommendations" is within Mogale City Local Municipality.

Sedibeng District Municipality

The Climate Change Vulnerability Assessment and Response Plan by the Sedibeng District Municipality recognises that informal settlements will be particularly affected by storm events due to their location within flood plains and the poor drainage infrastructure around them (Sedibeng District Municipality, 2017). The industrial pollution in the area and poor drainage system has resulted in less water available for irrigation and drinking (Sedibeng District Municipality, 2017). The Response Plan recommends SuDS as a response to increased occupational health problems and increased impacts of flooding from litter blocking sewer systems (Sedibeng District Municipality, 2017). To manage the quantity of water available for irrigation and drinking and to manage health impacts from increased storm events, the sector response plans suggest investigating the new technologies related to stormwater reuse (Sedibeng District Municipality, 2017).

West Rand District Municipality

West Rand District Municipality is currently experiencing issues of water scarcity and water quality and it is expected that informal settlements will be particularly affected by storm events due to their location within flood plains and poor drainage infrastructure (West Rand District Municipality, 2016). Due to poor road drainage, flash floods and increased runoff from developments that cause the collapse of stream embankments, the Climate Change Vulnerability Assessment and Response Plan suggests the enforcing of SuDS to assist with mitigating the effects on strategic infrastructure and to improve human health (West Rand District Municipality, 2016).

Mogale City Local Municipality

The Climate Change Framework and Operational Climate Change Plan Strategy for Mogale City suggests that in order to reduce the impacts of flooding and increased runoff, storm water drainage systems can be upgraded by improving of natural barriers and increasing water holding capacity (harvesting rainwater, increasing vegetation cover) (Mogale City Local Municipality, 2014). The strategy suggests that drainage systems can be designed to divert rainwater from gutters to the street root zone. Potential Climate Change adaption and mitigation actions identified in this document include 1) protection and restoration of wetlands, 2) increase in water storage capacity, 3) improving flood control, 4) supporting use of rain water, 5) planting of trees to reduce runoff, 6) planting to reduce heat island effect, 7) maintaining and upgrading of stormwater infrastructure, 8) improvement of natural barriers to stormwater surges, and lastly, building design and town planning to accommodate green infrastructure.

Mogale City Local Municipality Spatial Development Framework (Mogale City Local Municipality, 2009) and the Mogale City Local Municipality IDP, 2018/2019 Review of 2016-2021 IDP (Mogale City Local Municipality, 2018), it appears that there is minimal capacity in the Mogale City Local Municipality to support and drive planning for SuDS. The current policy suggests that even the concept of using the open space network to structure the urban area, is new. The SDF of 2009 suggests that the open space network still requires formalization and protection.

The Spatial Planning and Land Use Management By-law (Mogale City Local Municipality, 2016), Chapter 8 (Part 1) makes provision for engineering services and engineering services contributions. Engineering services are defined in much the same way as the CoJ and Ekurhuleni By-laws in accordance with SPLUMA. Interestingly, the section on engineering services, section 71 (1) embraces the concept of sustainable development and states that "Every land development application approved in terms of the provisions of this By-law shall be provided with such engineering services as the Municipality deems it necessary to ensure sustainable development." While this provision does not make any direct reference to the nature, scale and form of sustainable development and SuDS in particular, it leaves the door wide open for SuDS to be considered and implemented in the management of storm water drainage in respect of land development.

The high-level review indicates that there is substantial work to get SuDS embedded into the institutional and legislative frameworks.

7.6 Opportunities for mitigation by municipalities

Fisher-Jeffes and Armitage (2012) investigated the potential for charging for stormwater services. This is one of the approaches that have been adopted internationally to improve both maintenance of drainage systems and community behavioural patterns. The cost of stormwater services is typically hidden within municipal rates whereas water supply and sanitation are charged as separate services and residents are more aware, and typically more mindful, of the importance of these services. As a result, stormwater services are often underfunded. Fisher-Jeffes and Armitage (2012) considered the benefits of charging as a means of improving water quality of stormwater, including options for incentivising good stormwater management practices. Using three South African municipalities as case studies the study demonstrated charges to be reasonable and could substantially improve the funding of stormwater services. This would lead to improved stormwater quality, but not necessarily the widespread implementation of SuDS unless an incentive is introduced. However, the larger problem would be whether those communities where pollution levels are highest are reliable rate payers and would be affected by the new service charge.

7.7 Conclusions on Gauteng's municipal documents as regards SuDS

The municipalities of Gauteng clearly each follow their own approach in stormwater management, as is their prerogative. The asset register for stormwater assets, as now implemented by the City of Johannesburg, as well as the stormwater manual background information for the Gauteng climate, may serve as a good example for other municipalities to follow.

Where there are By-laws related to stormwater, these typically predate the SuDS approach and remain unhelpful in the drive to adopt a more sustainable approach to handling stormwater as a resource. Where stormwater related By-laws don't exist, the officials do not have sufficient 'teeth' to demand that new developments implement SuDS. It seems that the time is ripe for a drive to ensure local authorities develop and adopt their own set of guidelines, by-laws and new improved approval mechanisms, as is shown that they are currently busy with in Gauteng.

The review has also provisionally indicated that there is a gap in the stormwater planning realm. It appears that there should be more emphasis on mapping and defining district and / or regional scale hydrological systems at catchment scale that can in turn inform where and how SuDS can be accommodated. Biodiversity categorization and spatial definition of environmental management zones has helped the respective local authorities to protect the open space networks, where these contain critical biodiversity areas. However natural water flows and the habitats that rely on these are not necessarily accounted for in the Spatial Development Frameworks which are instrumental in protecting land required for SuDS. SuDS will require space which is already at a premium in this highly urbanized region and more effective planning at catchment scale that can feed into the Municipal SDF's may be required to ensure land area is set aside for effective SuDS interventions across the scales.

Policy, law and implementation Gap 6

Each municipality in Gauteng seems to be 're-inventing the wheel' as regards their own by-laws and manuals.

Reaction of this project: The Best Management Practices and Implementation Manual that are deliverables for this project, could come up with recommendations on how the different documents of Municipalities in Gauteng – or elsewhere in South Africa – can be feeding policy and implementation development in the other parts of Gauteng. However, it remains the prerogative of Municipalities to accept and implement these recommendations.

8 IDENTIFIED GAPS

As this Literature Review is meant as input in the further project "Research on the Use of Sustainable Drainage Systems in Gauteng", it is not a literature review in the academic sense, but it is meant to identify gaps in knowledge / gaps in policies and regulations that will be important for the formulation of an Implementation Manual for SuDS in Gauteng.

This chapter therefore repeats the earlier identified gaps, since gap identification was the major objective of this literature review. It then goes on to explain how this research project aims to react to these gaps. The conclusions of this document are further spread per chapter. As mentioned in the introduction, this literature review had a very wide range of topics 'SuDS in South Africa' and was based on both research and legal, policy and strategy documents. While many documents studied identified 'gaps' it was beyond the scope of this report to repeat all those recommendations for further research or actions. The choice made is either those that can be addressed in the project, or those that cannot but should stay on the radar of initiatives that try to improve / support implementation in Gauteng.

Although this chapter only repeats the gaps mentioned earlier in this report, as mentioned in the introduction, this Literature Review is also meant to celebrate what is already there in South Africa can support SuDS implementation.

Research Gap 1 - Effectiveness

Placing value on eco-system-based services of green infrastructure, which can be SuDS measures, is a recognized problem in Gauteng. However, also globally, there is recognition for the fact that the effectiveness of nature-based solutions is difficult and very site specific (WWAP-UN, 2018) and the economic valuation is still evolving (IEEP & RAMSAR, 2013) and dependent also on the interests of the investors.

Reaction of this project: While the impact on biodiversity will come back in the Analysis of Study Areas (Deliverable 5) and were possible in the Cost-Benefit Analysis (Deliverable 6), not much attention is placed on further establishing the value of eco-system based services and this will remain a research gap.

Research Gap 2 – Water Management beyond Stormwater Management

The Water Sensitive Urban Design pleads for full integration of water management in the design of the cities or urban settlements. This is not only related to urban drainage, but also related to for example water cycle management and re-enforcing water sensitive values and behaviours through infrastructure and urban design.

Reaction of this project: In terms of water cycle design, 'harvestability' of the stormwater is expected to come back in the Analysis of Study Areas and in the Cost-Benefit Analysis. The involvement of an urban designer and urban planner in the research team, will already gear the project up for the long game of Water Sensitive Urban Design.

Research Gap 3 – Flood design

While conventional flood design is based on design storms and design floods, and this is currently improved with research by UKZN, the SuDS designs need timeseries of rainfall of sufficient length. While the SAWS series are best in terms of length, they might not reflect the local condition for the site for which SuDS are designed. Using shorter timeseries, the longer timeseries could be adjusted for local conditions.

Reaction of this project: This is not addressed by this project.

Research Gap 4

The research of most universities on SuDS focuses on a certain SuDS facility, which contributes to the essential knowledge required on better performance of these facilities, but does not address the challenges of implementation, designing treatment trains and dealing with decisions between conventional and SuDS options, as well as dealing with governance aspects.

Reaction of this project: The implementation manual which is the main objective of this research project, cannot add in depth research on SuDS facilitaties, but is based on an evaluation of three case study areas in which the combined effect of SuDS facilitaties are evaluated. This literature review in itself can assist in scoping future research projects.

Data Gap 1 – Asset values for green infrastructure

The asset values of green infrastructure, which can be SuDS measures, are generally unknown for Gauteng. Missing asset registers were already identified as a potential solution for some of the barriers identified in the Data collection on SuDS in Gauteng (Deliverable 3). However, it needs to be noted that worldwide, even in progressive towns which implement SuDS, there are large differences in the asset registration on SuDS.

Reaction of this project: This will not necessarily be researched in the project, but some information might be collated in the Cost-Benefit Analysis (Deliverable 6) or might be recommended in the Best Management Practices (Deliverable 7).

Policy, law and implementation Gap 1 – NEMA regulations

The associated NEMA Regulations and the EIA process have seen a number of revisions that attempted to address accusations that the environmental authorisation process impedes development progress. Notwithstanding the guidelines in the GPEMF (see Section 3.5.3 below), there is concern that the impacts of stormwater initiatives tend to be poorly evaluated due to either one or more of the following; (1) avoidance of appointment of specialist expertise, (2) limitation of the EIA process (e.g. the Basic Assessment Report scope is too narrow to pick up impacts), and (3) lack of a comprehensive catchment management plan that will present both a baseline condition and a vision for the recovery of the watercourse(s). This leads to both poor stormwater design and the continued use of grey infrastructure stormwater solutions instead of SuDS based solutions that would mitigate the impacts of urban stormwater discharges more effectively.

Reaction of this project: Input for discussion on Best Management Practices or during the formulation of the Implementation Manual.

Policy, law and implementation Gap 2 – Implementation of legislation

The Water Use Licence (WUL) is an important facility within the NWA to control the likes of stormwater systems, and their impacts on watercourses and water resources. The scope of the WUL sets it up for being a primary enabler of SuDS. However, the licensing process has come to be seen as an obstacle to development due to the delays in awarding licenses and the uncertainty of departmental officials in considering non-standard stormwater systems.

Reaction of this project: Input for discussion on Best Management Practices or during the formulation of the Implementation Manual.

Policy, law and implementation Gap 3 – National Policies

Since 2012, the several severe droughts have sharpened focus on all potential sources of water, including both wastage and recovery of the likes of wastewater and stormwater. Also, the growth of urban centres and the needs for higher service levels fuel the need for alternative sources such as stormwater harvesting. The NDP and the NWRS are due for updates, and must acknowledge current thinking about water resources in the context of urban and metropolitan areas.

In the National Water and Sanitation Master Plan, Wastewater recycling and the impact of Waste Water Treatment Works (WWTW) are increasingly discussed in relation to water security and water resource management. That the draft of the current plan doesn't acknowledge stormwater management shows that work needs to be done to bring multi-disciplinary planning into the national thinking. As shown in Chapter 5, there appears to be more integration at municipal level.

Reaction of this project: This can only possibly become a recommendation during the writing of the Implementation Manual. The stakeholder workshops will also help spread the message.

Policy, law and implementation Gap 4 - Guidelines

While technically and environmentally, the SuDS community is helped with the guidelines and standards developed, what seems missing is a guideline to guide the process of decision making between conventional stormwater management and SuDS.

Reaction of this project: This is a potential topic for the implementation guideline, though this literature review shows there is limited material already available in South Africa that can assist herewith, if not in other than Gauteng municipalities.

Policy, law and implementation Gap 5 – Role of Province

It is clear from the review of the Gauteng related documents, as well as the national laws that the role of a province in promoting SuDS is not clearly defined and neither is it very well defined for Catchment Management Agencies, although it would fit in the mandate of those, once operationalized for the WMAs in which Gauteng is a stakeholder: Vaal, Limpopo, Olifants.

Reaction of this project: The implementation guideline that is the main objective of this project, does not have a clear mandate, but can guide Gauteng in the implementation of the Environmental Management Framework, its most powerful tool for SuDS implementation currently. It also could serve ad interim for guidance on catchment management, and later for inputs as a stakeholder in the catchment management strategy. The development of the guidelines will decide which role is envisaged.

Policy, law and implementation Gap 6 - Municipalities

Each municipality in Gauteng seems to be 're-inventing the wheel' as regards their own by-laws and manuals.

Reaction of this project: The Best Management Practices and Implementation Manual that are deliverables for this project, could come up with recommendations on how the different documents of Municipalities in Gauteng – or elsewhere in South Africa – can be feeding policy and implementation development in the other parts of Gauteng. However, it remains the prerogative of Municipalities to accept and implement these recommendations.

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