Project Nr:	GT/GDARD/094/2018
Project:	Research on the Use of Sustainable Drainage Systems in Gauteng Province
Date of Publication:	14 February 2020
Document:	Analysis of Study Areas with Recommendations

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Growing Gauteng Together

COLOPHON

TITLE DOCUMENT: Analysis of Study Areas with Recommendations

PROJECT NAME: Research on the Use of Sustainable Drainage Systems in Gauteng Province

PROJECT NUMBER GDARD:

GT/GDARD/094/2018

DATE:

14 February 2020

REPORT STATUS:

Final (Deliverable 5)

CARRIED OUT BY:

fourthelement

As part of the Urban Rivers Alliance:

- Fourth Element (Pty) Ltd.
- AquaLinks Research and Implementation (Pty) Ltd.
- Eco-Pulse (Pty) Ltd.

And: NM & Associates (Pty) Ltd, GreenVision Consulting, TAUW

COMMISSIONED BY:

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Gauteng Department of Agriculture and Rural Development

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Phathu Nembilwi from phathudesigns

CITATION:

Gauteng Provincial Government (2020) *Analysis of Study Areas with Recommendations*, for project 'Research on the Use of Sustainable Drainage Systems in Gauteng Province' produced by Fourth Element, AquaLinks, Eco-Pulse, NM & Associates and GreenVision Consulting and commissioned by Gauteng Department of Agriculture and Rural Development

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ACRONYM LIST

ACSA	Airport Company South Africa
EbA	Ecosystem based Adaptation
CBD	Central Business District
COJ	City of Johannesburg
CSIR	Council for Scientific and Industrial Research
DWAF	Department of Water Affairs and Forestry (former DWS, soon to be renamed again)
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EIS	Ecological Importance and Sensitivity
NFEPA	National Freshwater Ecosystems Priority Areas
NMT	Non-Motorized Transport
GCRO	Gauteng City Region Observatory
GDARD	Gauteng Department of Agricultural and Rural Development
JDA	Johannesburg Development Agency
JRA	Johannesburg Road Agency
Id	identification
JICP	Johannesburg Inner City Partnership
m.a.s.l.	metres above sea level
Ml	Megalitre (1 x 10^6 litres)
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NMT	Non-Motorized Transport
NPO	Non-Profit Organization
OPH	Olitzki Property Holdings
PCSWMM	Personal Computer Storm Water Management Model
PES	Present Ecological State
PET	Physiological Equivalent Temperature
PT	Public Transport
RWH	Rainwater Harvesting
SCS	Soil Conservation Service of the United States after which SCS method is named
SuDS	Sustainable Drainage Systems
TN	Total Nitrogen
ToR	Terms of Reference
TP	Total Phosphorus
TSS	Total Suspended Solids
TT	Treatment train
TAHMO	Trans-African Hydro-Meteorological Observatory
WIBC	Wouldn't It Be Cool; company that supports set up of small new companies.
WMA	Water Management Area

1 INTRODUCTION

1.1 Research study overview

As part of the project 'Research on the Use of Sustainable Urban Drainage Systems in Gauteng' of the Gauteng Department of Agriculture and Rural Development (GDARD), the Terms of Reference identify this report as 'Analysis of study areas with recommendations'.

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 Selection of three specific study areas
3. Selection of three specific study areas
4. Data collection on SuDS installations in Gauteng
5. **Analysis of study areas with recommendations** (this report)
6. Cost Benefit Analysis
7. Best Management Practices
8. Implementation Manual

This report follows **Deliverable 3: Selection of three specific case study areas**. It identifies and studies possible measures in the three case study areas to investigate what impact and consequences possible Sustainable Drainage Systems (SuDS) could have. It is important to note, this is from a research perspective, to inform the follow up deliverables, in the end leading to a SuDS implementation manual for Gauteng. The case studies are examples that do not cover every possible situation in Gauteng, but from which learning lessons are derived.

1.2 Study areas

The three study areas are (**Figure 1** and **Figure 2**):

- Central Business District (CBD) of the City of Johannesburg, Marshall town – Newtown part
- Bonaero-Atlasville, City of Ekurhuleni
- Kagiso, West Rand Municipality

The study areas are described in detail in Chapters 3, 4 and 5 respectively. The three sites were chosen to reflect a combination of both the typical conditions in CBD, township, suburban areas as well as highlight certain aspects of the urban environment that encourage the creative application of SuDS. Sustainable drainage applications are designed to fit the individual requirements of each site. There is not a "one size fits all". Hence there are a wide range of potential study sites that fit the general requirements of the study objectives, and most would benefit the study. Hence it was agreed that to shorten the selection process, the project team would draw on their experience to identify suitable sites, typically in consultation with representatives from each of the three municipalities. The municipalities and the type of area (CBD, township, suburban) to look for within these municipalities were already selected in the Terms of Reference.

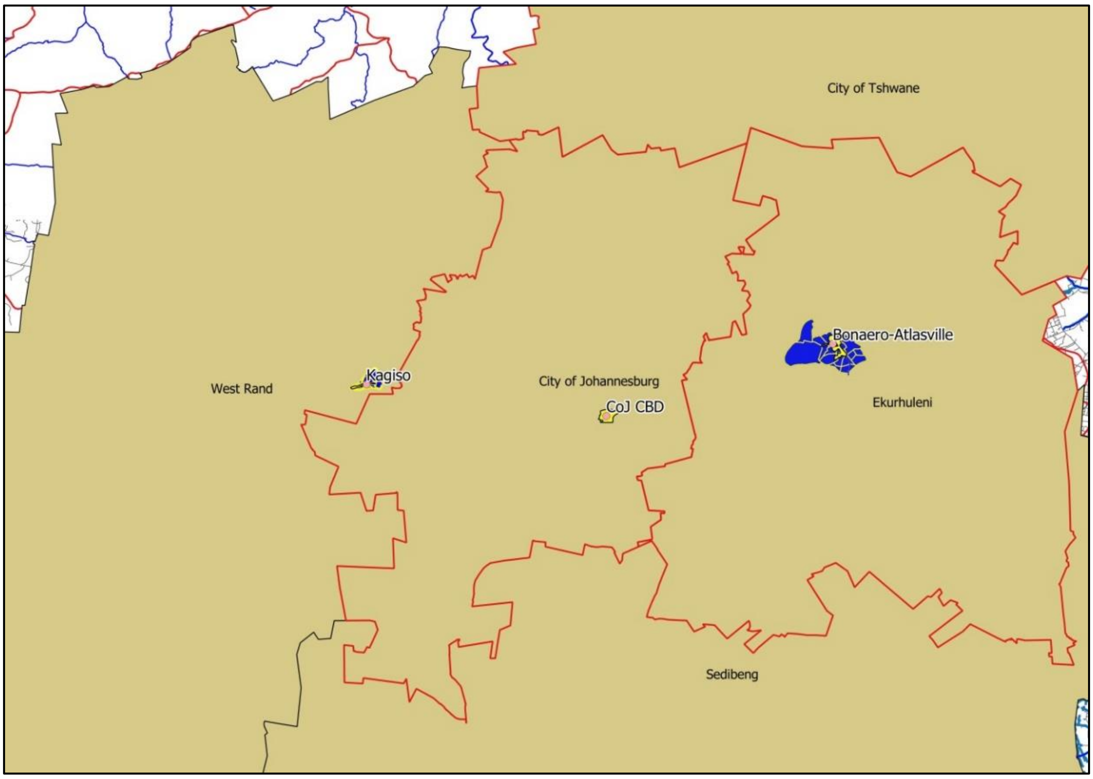


Figure 1: Study areas in the provincial context

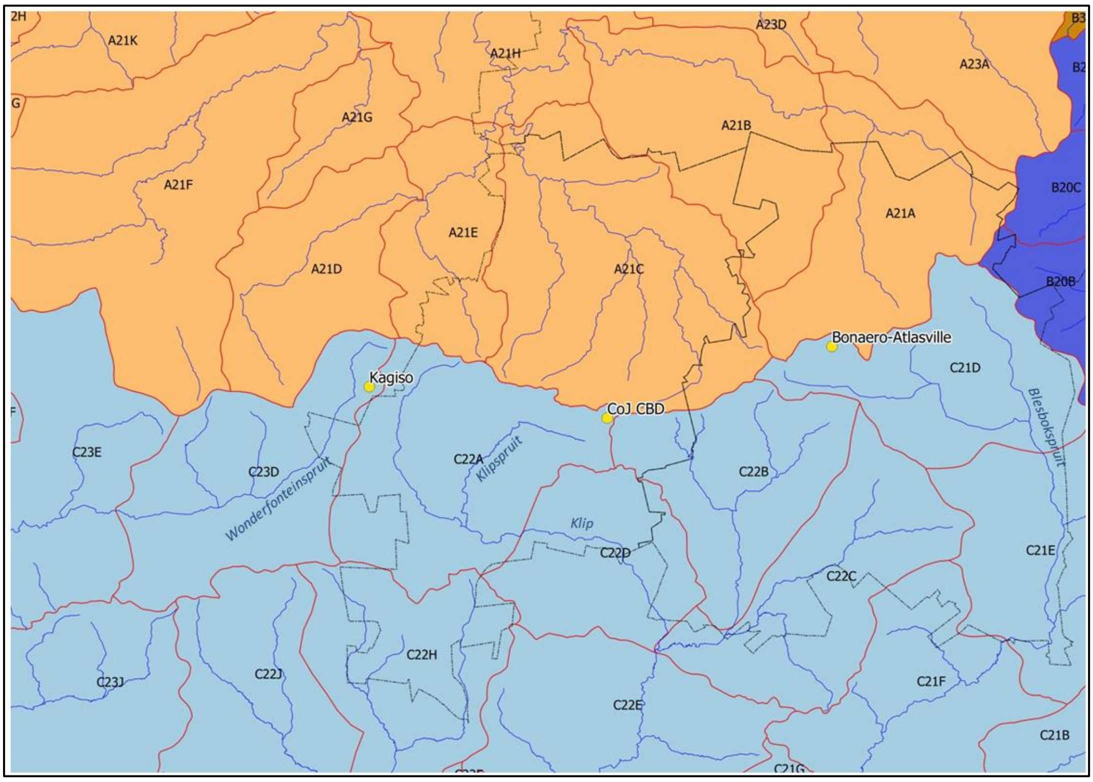


Figure 2: Location of study areas in the quaternary catchments

These study areas were considered relevant for the Research on the Use of SuDS in Gauteng, which leads to an implementation manual of SuDS in Gauteng, for the following reasons:

- The study area within the CBD of Johannesburg was chosen around the presence of the Gauteng Provincial Government buildings and the potential future development of the 'Kopanong Precinct' within the city centre that will house government offices. The results of this study can therefore be of benefit in further development of the Kopanong Precinct plans, particularly because this study is for Gauteng Provincial Government. To review the SuDS performance, catchment boundaries needed to be used, so the larger catchment studied was the Newtown-Selby area, draining to the Robinson Canal, which later drains to the Klipspruit catchment.
- The suburban Bonaero-Atlasville study area in Ekurhuleni was selected because of its strategic importance for flood management and the significant conservation value of the site, as well as its heterogeneity. There are three different pans with adjacent wetland areas in the study area, each with different influences and management aspects either by local government as a park, or by companies around the pan or by residential estates around the pan. The ecological functioning of the pans and how it relates to water quantity and quality priorities, was an interesting research question in this study area. The functioning of mainly the northern pan (Blaauwpan) is influenced by the drainage of OR Tambo airport which has had severe pollution incidents in the past. There are also plans to develop the area, such as the Aero-Blaaupan Precinct (GAPP, 2018), making that the results of the study can potentially be used further. As part of the Consultant's team had already done some preliminary work on this study area, this study benefited from this work and the established contacts with the municipality.
- The study area within Kagiso allowed analysis of in-catchment township conditions, the creation of possibly important community space around a SuDS site, and wider catchment benefits. The area is for township conditions quite well developed and maintained, with no informal settlements. Kagiso is in the upper areas of the Wonderfonteinspruit catchment, which is highly impacted by mining and industrial development, as well as urban residential development (both formal and informal), which is relevant for Gauteng. In the middle of Kagiso there is a green drainage stretch along a provincial road. The lower portions of the area exhibit wetland features and the upper areas are a combination of a wetland and open drain with some informal agriculture and a waste recycling facility but limited further use value for the community as an open space. At least three road crossings provide opportunity for stormwater retention or attenuation. The municipality of Westrand was very supportive in the choice of this study area.

Some of the information above only became available during the preparation of this Analysis of Study Areas report, but for a further basis of the selection of the study areas reference is made to **Deliverable 3: Selection of three specific case study areas,** in which also additional alternative study areas were considered, namely Khutsong in Westrand and the Maboneng Precinct in the CBD of Johannesburg.

2 METHODOLOGY

2.1 Approach

The primary steps in the approach to analysing each of the study areas are summarised as follows. A more detailed description of the main themes is presented thereafter.

I. Desk top identification of possible measures,
II. Site visits with local authorities and area experts and review of possible measures,
III. Hydrological modelling (MUSIC and PCSWMM),
IV. Public consultation workshops per stakeholder area; 2nd to review suitable measures,
V. Additional modelling in MUSIC and research inputs,
VI. Analysis, integration and reporting.

2.2 Stormwater management methodology

Stormwater management through the implementation of SuDS is described in Deliverable 2: Selection of study areas (January 2019). The essence of SuDS is to address the quantity and quality stormwater runoff from urban areas. The objective is to mimic the hydrological response of a natural catchment (or site) to mitigate against flood hazard, pollution of water resources, and loss of amenity and ecological systems. The methods to achieve this are generally based on natural hydrological systems where rainfall interception (e.g. by vegetation), infiltration (into soils) and evaporation (and evapotranspiration) are dominant. The objective is generally considered to be achievable on a greenfield site development, especially where there is good coordination between the developer, the planners, the environmental team and the stormwater designer. However, in established metropolitan areas where the negative effects of urban development are already evident, attention needs to be given to retro-fitting SuDS. Here the objective of mimicking natural hydrological responses becomes a very long-term plan, identifying opportunities as they arise. In addition to employing the natural hydrological process listed above, the opportunity for stormwater harvesting and reuse becomes an important means of stormwater runoff reduction.

All the study areas selected in this study have SuDS retrofit cases. Each study area presents a different scenario in which urban development interfaces with the environment. The analysis explores how that interface can be enhanced for the benefit of stormwater management, but also for community and ecological benefits, as is the opportunity of implementing Green Infrastructure (SuDS) over Grey Infrastructure.

Central to the stormwater focussed methodology is identifying hydrological and water quality priorities at each site and testing possible SuDS. This approach is more in line with stormwater planning than design and will be relevant to cooperation of the Province with Gauteng municipalities. The hydrological and water qualities should be defined by a catchment management plan. However, there are very few of these in the Gauteng area, and none are available for any of the catchments where the study areas are located. The priorities have therefore been identified through consultation with municipal officials and stakeholders in each case. As a result, the priorities are more derived from a qualitative than quantitative evaluation of catchment requirements.

Modelling and rainfall

An important tool employed in the analysis of the sites has been the MUSIC software, currently on trial in South Africa. This was introduced in Deliverable 1: Inception Report (November 2018), and its functionality of outlined in more detail in Annexure 1. Software used for the complexity of modern stormwater systems typically require an expert user which can slow the uptake and implementation of SuDS. The initial rationale for selecting MUSIC is that it has been designed for use by the multiple stakeholders in planning of SuDS, including landscape architects, urban designers, ecologists, and municipal officials. The use of models by municipal officials in particular is a point of discussion in the City of Johannesburg where a first version of the new Stormwater Manual is being launched (June 2019). Application of MUSIC in this study highlights the ease with which treatment trains can be applied and tested at a site, suggesting it will also shorten design timelines if used in parallel with other expert software such as PCSWMM (see Deliverable 1: Inception Report).

A key input to the MUSIC software is 5½ years of 5-minute rainfall records (January 2010 to June 2015). For this analysis data from the Grand Central weather station have been used. This is not the closest station to two of the study areas (CBD and Kagiso), but it was used because of its availability and the ability to convert it into a compatible format for incorporation into the MUSIC model. A breakdown of the rainfall data is summarised in the **Table 1** below.

Table 1: Statistics from the 5½ year (5-minute interval) rainfall record used in the study

Characteristic	Number
No. days with rain	564 (28% of time)
No. days with rain > 6 mm	189 (9% of time)
No. days with rain > 10 mm	121 (6% of time)
Max 24 h rainfall	75.8mm (~5 year return period)
No. days with rain ~2 year return period or greater	2
Max 5 minute rainfall	14mm (~10 year return period)
Max 15 minute rainfall	23mm (~7 year return period)
Notes: 1. *All days of rain are used in determining the hydraulic load on a SuDS system.* 2. *Larger events described by return periods are used in flood analysis.* **3.** *Short duration storms (e.g. 5 minute and 15 minute) are particularly important in urban stormwater management.*	

Selecting SuDS Technologies

There is a relatively standard range of SuDS technologies available and these are described in some detail by Armitage, et al (2013). They also present a "SuDS conceptual design framework" that sets out the primary steps to designing a treatment train. These include (after Armitage, et al, 2013):

1. Site investigation and setting out priorities.
2. Determining the characteristics of the site (soils, storm responses, flood risk, water quality, etc.).
3. Developing a concept (or more than one) of a potential treatment train.
4. Testing the concept(s) through modelling and treatment performance analyses.
5. Refinement of the system and detailed design.

Stormwater quantity and quality targets may take higher priorities in the initial selection of technologies to be used, but the design will ultimately need to consider the requirements of biodiversity and amenity as well. Indeed, once the general hydrological requirements of the treatment train are understood, these other aspects will (at least they should) play an increasing role in the later design stages of a SuDS. This adds to the iterative stages in the design process which is largely beyond the scope of this research study.

Although there appears to be a wide range of SuDS technologies available, their functions can be narrowed down to the five main functions in **Table 2**. A treatment train would ideally have at least one of each of them.

Table 2: Grouping SuDS into primary functions

Primary Function	SuDS technologies	Method of analysis
Sediment trapping	Sediment traps, sediment basins.	Detention pond analysis
Retention and water quality treatment	Bio-retention filters, infiltration trenches, filter strips, rain gardens, sand filters, green roofs, permeable pavements, soakaways, retention ponds, constructed wetlands	Hydrological soil model
Reuse	Rainwater harvesting, underground tanks	Water balance and detention pond analysis
Conveyance	Swales, inlet and outlet structures, outfalls.	Hydraulic analysis
Flood management	Detention basins	Detention pond analysis

All systems will need conveyance components, and these may only be designed late in the design process when other components have been selected. SuDS related conveyance measures (e.g. swales) do allow for some treatment, but retention times are necessarily short and the bulk of the treatment is provided by the other features in the network designed for this purpose. Hence, in this study the conveyance systems are not addressed directly, and it is assumed that existing conveyance systems will be used. In Gauteng, sediment trap and detention facilities are very likely to be standard requirements in most treatment trains. Reuse may be limited by a combination of opportunity and cost-benefit and may not be considered on all sites.

The function that is central to the principles of SuDS and is relatively new to stormwater management internationally is the retention/water treatment function of which the bio-retention system is perhaps best known. It is based on the hydrological soil model (see **Deliverable 2: Literature Review**), and all of the technologies listed with it are variations on the application of the soil model. The hydrological soil model will simulate the natural variation of soil water content during the hydrological cycle, accounting for soil water storage and changes due to deeper infiltration or evapotranspiration. Currently many stormwater models still treat soils very simplistically, usually assuming rainfall infiltrating the soil is lost.

In this study all technologies are considered, but the central focus is on the retention/treatment function which includes bio-retention filters and green roofs in the case of the CBD and constructed wetlands in the case of both Kagiso and Bonaero-Atlasville.

2.3 Heat Stress Reduction and SuDS assessment methodology

Methodology

The aspects of heat stress reduction through SuDS have been studied for the CBD area only, as that is where the heat island effect was expected to be most prominent. This will be further discussed in the case study itself.

For this report, a general introduction to heat stress and SuDS in Johannesburg is provided, after which the proposed interventions are studied by the heat stress and SuDS specialists using Google Earth. Expert judgement is used to reflect on the possible interventions at roof level, at street level, and at treatment train level.

Do we need to stress about heat stress in Gauteng?

Heat stress is a real concern worldwide. For instance, the heat wave of 2003 in Europe resulted in 40 000 people passing away earlier than otherwise (Ten Brinke, 2019). Heat island effects and heat stress are important, and heat stress has priority in Climate Change Adaptation in Johannesburg (Vogel et al., 2019).

Due to climate change the number of very hot days and heat waves is expected to increase in Gauteng. In South Africa (www.greenbook.co.za by CSIR, 2019) very hot days are defined as days (per 8 x 8 km grid point) at which the maximum temperature exceeds 35 °C. Heat-wave days, in CSIR's and SAWS definition, are days with maximum temperatures exceeding the average maximum temperature of the warmest month of the year at that location by 5 °C, for a period of at least three consecutive days.

The threshold temperature for this in Johannesburg is not clear in the references consulted. Current heat wave days for Johannesburg are a maximum 7 days per year (see **Figure 3,** www.greenbook.co.za) The green book also makes mention that currently for ~4 months per year (using 1979-1999 as a base period), temperatures in Johannesburg cause human health risks, while this will increase to ~7 months and to ~9 months in the year 2100 for the low emission scenario (RCP 4.5) and the high emission scenario (RCP 8.5) respectively.

The estimated number of heat wave days for October – March goes up from a median of around 1-1.2 days/month to 3 to 8 days/month, with highest values in January and October for the RCP 8.5 scenario (and considerably lower values for the milder RCP 4.5 scenarios). All the figures mentioned are from downscaling climate models, but do not fully bring into account the effect of what is happening at the level of where people live.

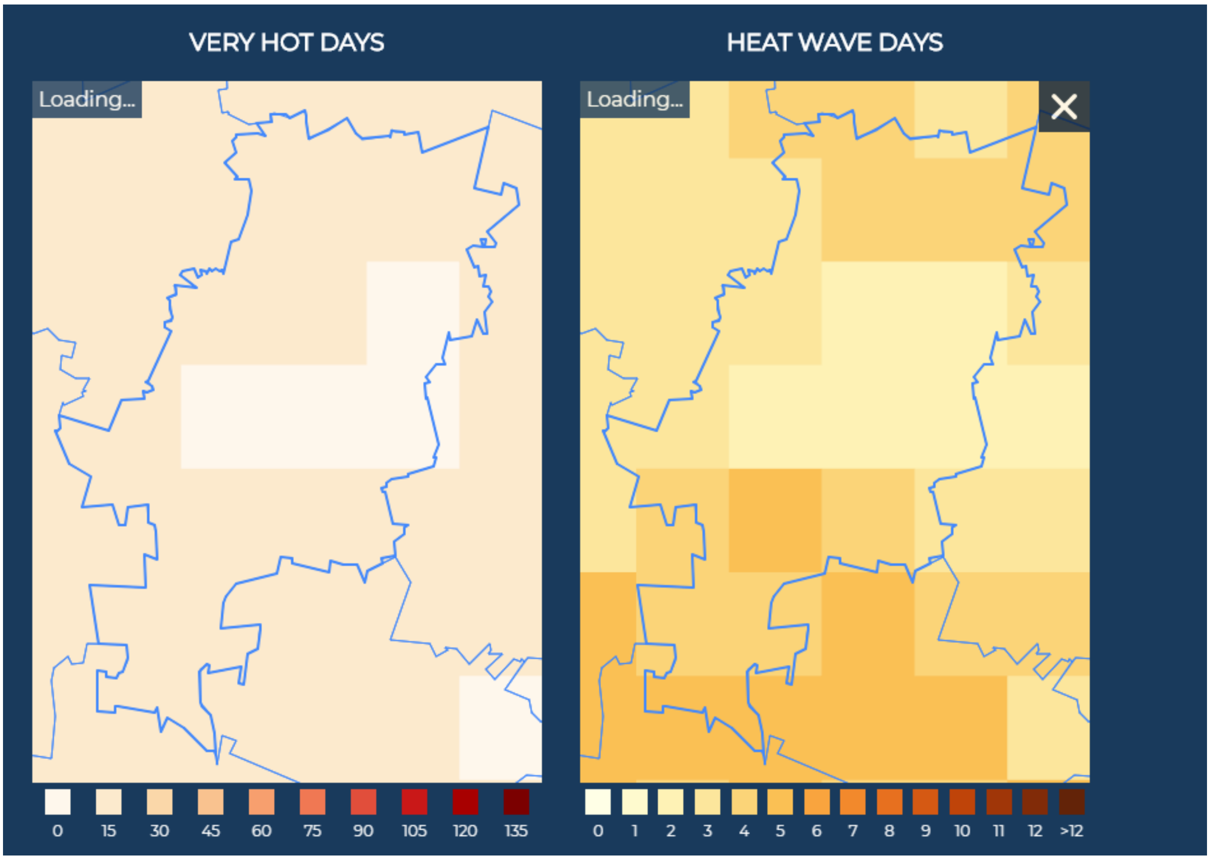


Figure 3: Current situation climate modelling for very hot days and heat wave days – see definitions in text - (CSIR, www.greenbook.co.za consulted April 2019)

For Gauteng and in particular for Johannesburg, there is a need to be aware of the particular situation that is not necessarily valid for other places with heat stress and heat island effects:

- The nights in Gauteng are relatively cool in comparison to most cities in the world were heat stress is a major concern; hence the focus in Gauteng should be on maximum day temperatures and exposure to these temperatures;
- The effect of altitude plays a role in Gauteng. In Johannesburg, the CBD is at a much higher altitude than many of the suburbs. While the densities and exposure (walking) of people in the CBD might be much higher, comparison of data between Braamfontein (CBD

Johannesburg) and other TAHMO weather stations show that Braamfontein has relatively higher maximum temperatures on a day and lower humidity. The maximum temperatures per day have similarly been compared with that of Braamfontein for seven other stations in Johannesburg and the same picture emerges, with Orange Farm having the highest maximum temperatures (See **Figure 5**) without having systematic differences in humidity (See **Figure 6**). Temperatures in Gauteng are generally a bit lower in Johannesburg than in for example Tshwane, because of Johannesburg's higher altitude;

- Humidity in Gauteng drops considerably during the day and is low in comparison to more coastal areas; higher humidity results in more unpleasant experiences of heat than low humidity. In the case of Gauteng, average humidity is on warmer days also lower than on cooler days, show analysis of TAHMO weather data in Johannesburg (see **Figure 4** for Braamfontein). Humidity in Braamfontein is also lower than in other areas of Johannesburg, with Alexandra (London Road, next to Jukskei River) having the highest humidity (See **Figure 7**);
- Illnesses related to heat in Gauteng may also be related to food hygiene and air pollution, which may be more damaging than 'heat stress' itself (defined as the inability of the body to cool itself sufficiently which consequently results in heat strokes, heat exhaustion or heat cramps, also dependent on dehydration);
- The City of Johannesburg does not have a heat wave plan at this time (Vogel et al., 2019), but has started initiatives such as "Corridors of Freedom" of which the inner city is part, that aim at increasing public transport and non-motorized transport. This will on the one hand decrease emissions and heating by cars, but on the other hand it will increase the exposure of people to outside temperatures, therefore making it more important that this environment is pleasant.

In Johannesburg the heat island effect might be compensated by altitude, but in general cities are usually hotter than the countryside, as concrete and tar exacerbate heat build-up and evaporation in cities is less, although the effect is mostly in the nights. However, also in Tshwane where the CBD is surrounded by two mountain ridges south and north of the CBD, the atmospheric temperatures and the land surface temperatures measured do not seem to confirm a clear heat island effect (Monama, 2016). The CBD recorded lower atmospheric temperatures than much of the surrounding areas. The study of land surface temperatures by remote sensing, revealed that the open bare areas – without much trees – where hotter than built up areas (Monama, 2016). The translation from land surface temperatures to atmospheric temperatures is however difficult, therefore further atmospheric measurements would be needed, not just of atmospheric temperature but also of wind speed and humidity and solar radiation.

SuDS can assist to address temperatures locally, due to local impacts of individual measures, but for real heat reduction, the impact is only major if shade is increased through planting of trees in SUDS bioretention areas for example or if the overall greening of the urban area is so extensive that the total atmospheric conditions are changed (micro-climate impacts).

Besides improving governance around heat stress (through communication and organisation, capacity building of emergency services, early warning system, protecting of current open areas / green spaces, increase of frequency of waste removal etc.) there are practical technical suggestions to mitigate temperatures in the urban dense area that are not related to SuDS. The Green Book mentions different types of heat stress reduction measures such as: less dead-end streets (more "permeable patterns") to decrease walking distances, or thinking on what direction the buildings should have to the sun, or cool paving (lighter in colour). Urban planning measures including the use of different types and colours of building and street materials, and decreasing the width of streets to height of buildings ratio may be important for heat stress reduction but are less related to SuDS (see Kleerekoper, 2016). The Sustainable Development Guidelines of Gauteng (GDARD, draft 2016) also recommend insolation of floors and roofs in Gauteng's new buildings to reduce the need for cooling and heating.

In general, only if SuDS provide more shading, and considerably increase urban water and urban green they will have a positive effect on the thermal comfort PET (physiological equivalent temperature) of urban spaces during hot summer afternoons. But every specific implementation has an effect that is strongly dependent on the details of the implementation and location and depend on custodians of these measures that take care of maintenance and protection.

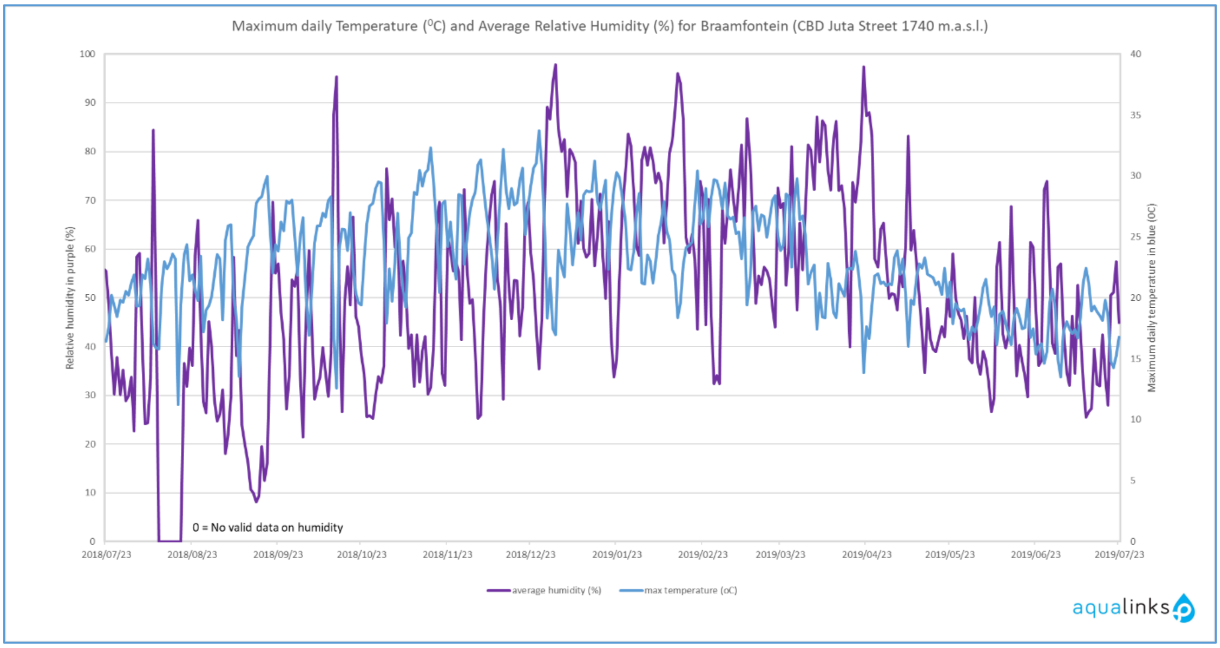


Figure 4: Timeline of maximum daily temperature (blue) and average daily humidity (purple) for Braamfontein TAHMO weather station (28 Juta Street, at an altitude of 1740 m.a.s.l., on top of a concrete roof of 3 levels high.)

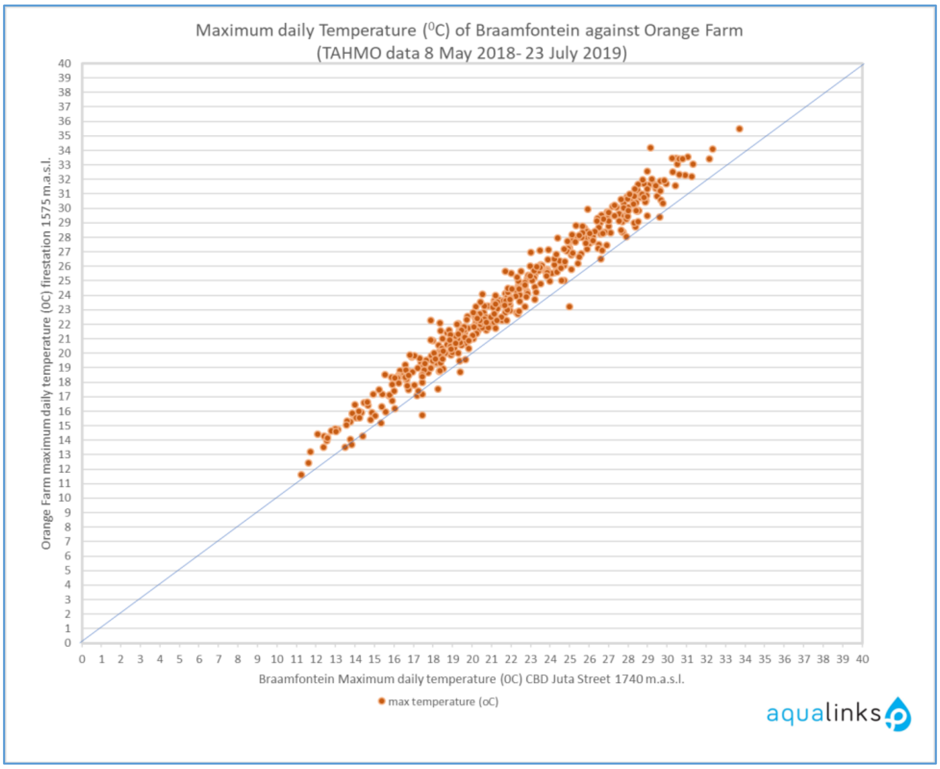


Figure 5: Comparison of maximum daily temperature measured in Braamfontein 28 Juta Street on level 3 (1740 m.a.s.l.) against the maximum daily temperature measured at Orange Farm fire station – both TAHMO stations, with around 2 degrees Celcius higher at Orange Farm.

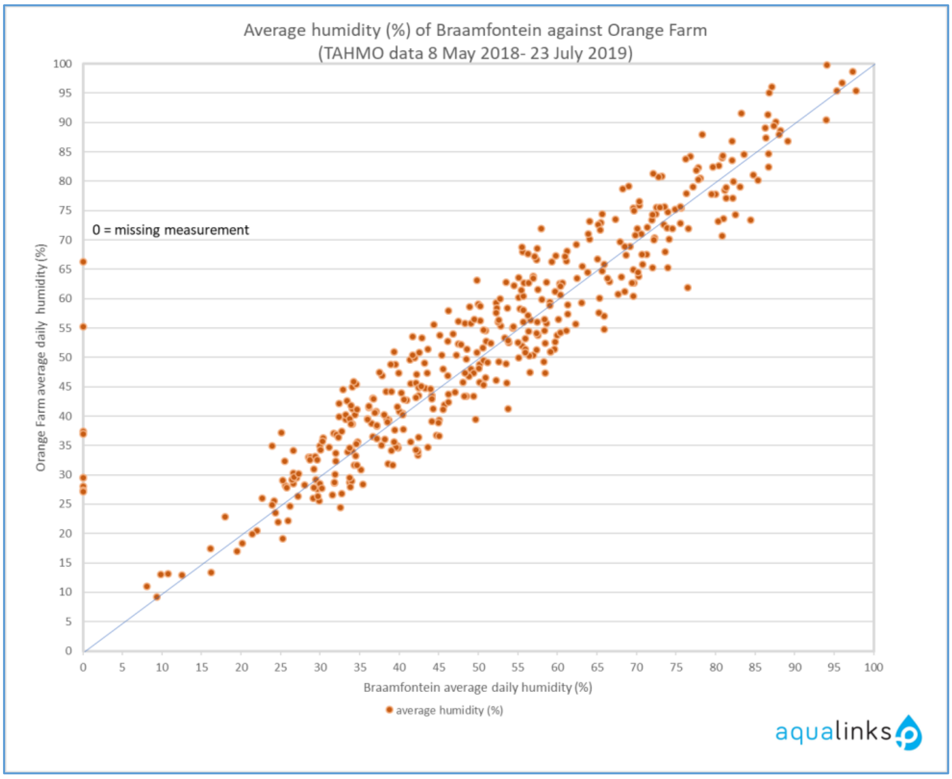


Figure 6: Comparison of average daily humidity measured in Braamfontein 28 Juta Street on level 3 (1740 m.a.s.l.) against the same measured at Orange Farm fire station – both TAHMO stations, with no systematic difference.

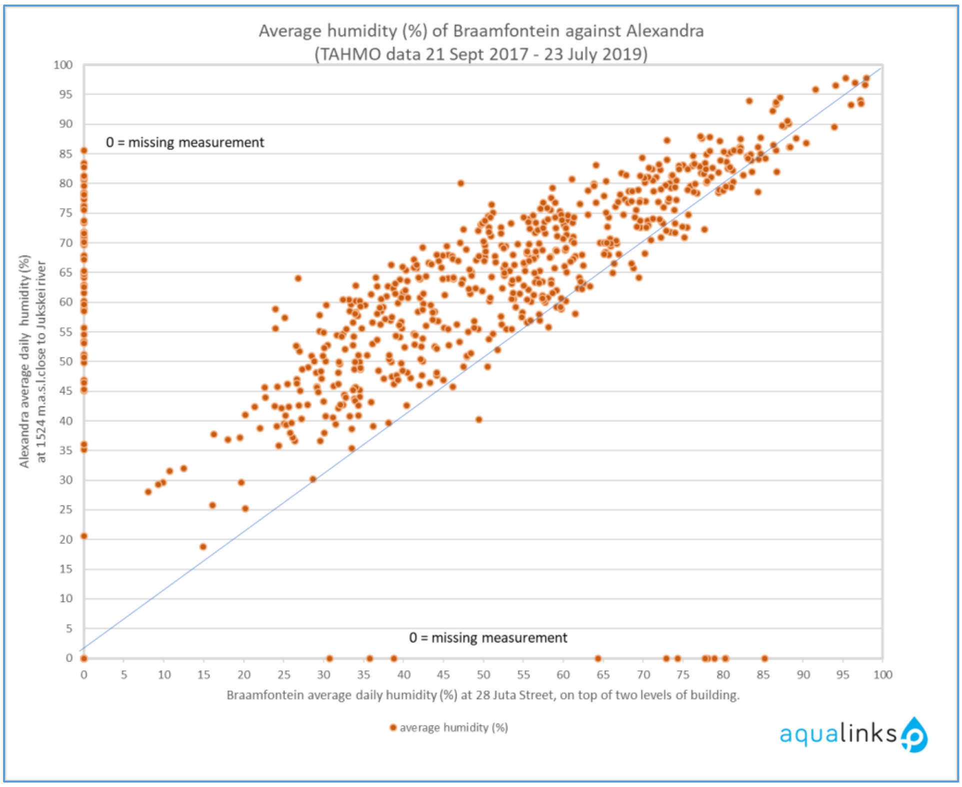


Figure 7: Comparison of humidity in Braamfontein 28 Juta Street on level 3 (1740 m.a.s.l. horizontal axis) against the same measured at Alexandra London Road, close to Jukskei river – both TAHMO stations, higher humidity for Alexandra.

Recommended methodology of heat stress reduction and SuDS assessment beyond the scope of this report

The authors' usual approach to heat stress management and SuDS is to recommend detailed heat stress mapping under different scenarios of heat, in which the presence of water or greenery shows as a cooling effect. This is because evapotranspiration from water or greenery costs energy, which is withdrawn from the heat. Such maps present the Physiological Equivalent Temperature (PET) at the hottest hour of an almost windless day and are presented relative to the rural temperature of a meadow in a qualitative way, for example in the map below in red 'much warmer' and in purple 'very much warmer'. The maps are informed by a detailed Digital Elevation Model and information on presence of buildings, trees, greenery and water. The PET is then calculated from the derived estimation of air temperature (influenced by shade), wind and humidity, such as shown for a part of Johannesburg in **Figure 8** (Boogaard et al., 2018). For more detailed design exercises, materials used, as well as details of water ways and heights of infrastructure and trees, combined with aerial photographs are used. The maps then give an estimate of the maximum PET during a heat wave, and a separate analysis can be made for the extent of the heat wave. These maps are then combined with maps on vulnerability of people (age, means) and flooding issues and other information to inform SuDS design. The time of exposure of different people to heat is also important to take into account, for example for commuters using public transport combined with waiting and walking (e.g. Hoffman et al., 2018).

Figure 8: Heat stress map for part of Johannesburg (Braamfontein on the left, northern Johannesburg on the right, see extended topographical map (Boogaard et al., 2018)

2.4 Urban design approach and methodology

SuDS interventions within the public open space network are said to have the potential to play an important amenity role as well as a potential social and economic role. Urban Design input into the form, extent and nature of these spaces is essential if SuDS are to play these roles effectively. With Urban Design input into the planning and design of SuDS, it is possible to create spaces that can be used for recreational, social, educational, cultural and economic purposes and in so doing contribute to amongst other things, the formation of healthier and more sustainable communities. When they play these roles effectively, they can also contribute to increased property values in the local area. To be able to perform these multiple roles it is essential for these open spaces to provide improved levels of personal safety, a sense of belonging and basic levels of comfort. They should also be accessible to a range of people in particular pedestrians, given the fact that only 28.5% (StatsSA, 2013) of the population in South Africa own cars and that most are unlikely to in the future.

In the context of South Africa where there are diminishing resources for management and maintenance of open space by the public sector, green open spaces incorporating SuDS need to be designed to withstand high levels of "wear and tear" but more importantly, conceptualised in a manner that ensures that the communities, in which they are embedded, have a direct interest in keeping them clean and safe. The open space must therefore serve a purpose beyond just an infrastructure role. Where communities 'take ownership' of spaces, they tend to respond more positively to them, and instead of turning their backs on them, open up towards them. In the case of public and / or commercial buildings, this opening up, can in turn help to make the spaces even safer as activities spill out into the public realm and offer more surveillance.

With this in mind, the methodology employed was to analyse particular aspects of the built environment in order to be able to recommend where and how the SuDS interventions (as one component of public open space networks), could best achieve some of the urban objectives described above.

A desk top analysis and site visits undertaken in February 2019 therefore focussed on the following key aspects:

Pedestrian movement patterns and access networks

The analysis looked at the local road, public transport and pedestrian connections to assess the site's connectivity to the surrounding areas. The analysis also checked where the public transport stops were as they present opportunities to invest in greening which can play a SuDS and heat reduction role. In the case where major road proposals were on the table, these were noted and assessed for their potential impact on proposed SuDS interventions.

Lastly it was important to understand how the spaces were traversed by pedestrians to ensure future SuDS didn't compromise important existing desire lines across the respective sites but also which streets might benefit from more greenery.

Land Use patterns

Land Use patterns of the area reveal the key generators and attractors of movement and therefore reveal where and how people move through the local areas. If the SuDS interventions are going to play an amenity role, they should be conceptualised as part of the broader public network of spaces and places that attract people. The analysis also considered what additional facilities might be lacking in the area and what might be appropriate to collocate with SuDS interventions.

Building form and typologies

The scale of the buildings and their relationship with the public realm is essential to understand as it affects the way the adjacent open spaces perform. Where the occupants of the buildings can look over the space, this provides necessary passive surveillance. Where high walls and blank facades interface with public space, there is no activity and no surveillance offered by occupants of the buildings which means that the spaces are vulnerable to anti-social behaviour, littering etcetera.

Where buildings define the space, they can help to protect the area from wind but they also provide a sense of containment, adding to the psychological comfort of users of the open space.

In the case of dense built up areas such as the CBD, the bulk of buildings becomes a critical factor when considering the performance of the open spaces as they create micro-climates – shady areas and overheating in other cases. The extent of building coverage is also a critical factor when retrofitting SuDS. High levels of coverage such as is the case in the CBD, provides a particular challenge.

More detailed objectives specific to each of the sites further guided the analysis undertaken. The detailed urban objectives, specific to each of the respective sites are typically informed by broader policy and planning objectives and detailed in the respective chapters.

Each of the SuDS interventions proposed by the Engineering and Ecological Team was assessed in terms of the key findings from the analysis and key opportunities and challenges identified.

2.5 Ecological Objectives

Integrating Ecological and Biodiversity Considerations in SuDS Design

According to the South African Guidelines for Sustainable Drainage Systems (Armitage et al., 2013), the key objectives of the SuDS approach are the effective management of: stormwater runoff quantity, quality and the associated amenity and biodiversity values. It is however argued that these objectives should not be given equal weighting but that they should be viewed in terms of a hierarchy where primary emphasis should be placed on addressing water quantity and quality challenges, rather than focussing strongly on amenity value and biodiversity. In particular, the report states that "there is no point focussing on biodiversity if life and property have not already been protected". It is however critical here to differentiate between drainage systems that are developed to cater for stormwater discharge within a development site (site-scale) and the natural drainage network (local and regional-scale) which can range from non-perennial drainage lines to wetlands and large perennial rivers.

For site-scale interventions, Armitage's views are strongly supported and drainage design (whether through conventional systems or SuDS) should, as their primary objective, seek to limit impacts by meeting clearly defined discharge standards that focus specifically on mitigating flood risks (volumes and peaks) and on preventing pollution of downstream environments. Whilst ecological considerations should be taken into account in SuDS design, opportunities at a site-scale are often limited and would typically focus on indigenous landscaping and minor modifications to artificial drainage features to enhance biodiversity values. These interventions can serve to soften the transition between developments sites and the natural drainage network but should seek first and foremost to manage risks to the downstream environment.

Where developments are associated with natural drainage features and ecological networks, the emphasis should shift strongly towards protecting and enhancing regionally important ecological and functional values as opposed to addressing site-level impacts. Some level of protection can however be achieved through the establishment and management of appropriate buffer zones, which should be adopted as a standard management practice (Macfarlane and Bredin, 2017). Buffer zones not only function as filter strips which can assimilate pollutants from diffuse runoff but contribute to the broader ecological network. There is however a need to move beyond this and to promote investment in the restoration and sustainable management of drainage lines through both regional restoration initiatives and site development planning.

Whilst restoring natural ecosystem functioning is an important consideration, the reality is that there are often a range of competing objectives that need to be considered when developing a management and/or restoration plan for a particular reach of river or wetland system. These may include:

- Enhancing flood attenuation functions to reduce flood risks for downstream communities;
- Enhancing pollutant uptake to help address water quality concerns;
- Securing biodiversity values for species of conservation concern;
- Attenuating and harvesting water for re-use or other purposes;
- Creating opportunities for urban agriculture or livestock grazing;
- Enhancing aesthetic values for local homeowners; or
- Improving access or quality of open space for recreational or educational purposes.

The implication is that the management of the drainage network should not necessarily aim to return drainage lines to a reference state but should be replaced by an objective-based approach where restoration efforts are 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 (Dufour et al., 2009). As such, biodiversity aspirations need to be balanced against the need to meet other (often more important) objectives.

It is also recognised that the suite of biodiversity that are associated with drainage lines and watercourses are strongly dependant on the state of underlying drivers, including water quality and flow characteristics. The implication is that certain river reaches (those that remain largely un-impacted) are better suited to meeting conservation objectives than others. In a heavily developed urban context in particular, where impacts are often severe and competition for space and use is intense, there is therefore a strong argument to focus on maximizing ecological functions that support societal needs and broader water resource management objectives rather than over-emphasizing biodiversity considerations. By doing so, this can also serve to buffer the impacts on downstream areas that have a greater ecological value.

There will, however, be instances where biodiversity considerations need to be prioritised due to the presence of critically endangered fauna or flora or the need to maintain or enhance threatened habitats or critical ecological linkages. These areas are identified in a range of spatial biodiversity products such as the Gauteng Conservation Plan (Gauteng Provincial Government, 2011 and Pfab, 2017) and the Gauteng Environmental Management Framework (Gauteng Provincial Government, 2018). These products identify 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.

With this in mind the methodology employed was to analyse particular aspects of the ecological environment in order to be able to recommend where and how the SuDS interventions (as ecological infrastructure), could best achieve some of the ecological objectives identified within the context of regional catchment management, bioregional, spatial development and conservation plans. A desk top analysis and site visits undertaken in February 2019 therefore focussed on the following key aspects:

1) Analysis of regional spatial data layers

Various spatial reference layers, such as the GDARD Conservation Plan (Pfab et al., 2017), Gauteng Environmental Management Framework, National Freshwater Ecosystems Priority Areas (Nel et al., 2011), and Quaternary catchment PES/EIS (DWS, 2014), and any other pertinent regional spatial layer available at the time of analysing the sites, were interrogated in order to understand the ecological context of each site and to build an understanding of key ecological, biodiversity and catchment management imperatives for each site. Much of this information has been consolidated as part of the EIA screening tool and can be used to obtain a preliminary indication of key ecological (and other) sensitivities prior to undertaking detailed site-level investigations (Department of Environmental Affairs, 2019).

2) Ground Truthing of ecological attributes and conservation imperatives

A site visit was undertaken in order to build a deeper ecological understanding of each site and the opportunities and constraints to enhancing ecological values. Key aspects considered included:

- Building a better understanding of existing stormwater drainage networks, hydrological flow paths and water quality risks associated with each site;
- Assessing the Present Ecological State (PES), including developing an understanding of existing site impacts and broader ecological drivers;
- Investigating the Ecological Importance and Sensitivity (EIS) of each site including biodiversity values such as species of conservation concern and connectivity and social and cultural values;

- Assessing constraints and opportunities for the rehabilitation and enhancement of natural drainage networks and the broader open space network.

3) Stakeholder engagement

Key stakeholders and municipal specialists were consulted with a view to developing a deeper understanding of local conservation imperatives, and sourcing additional specialist reports where available. It is important to note however that focussed aquatic and biodiversity assessments were not undertaken for this project, and where necessary, would usually be prepared in order to better understand local water resource management and conservation values.

4) Refinement of SuDS opportunities in collaboration with the technical team

Ecological aspects were specifically integrated into SuDS planning through interaction with other members of the technical team. The focus here was on balancing ecological considerations against other competing needs and ecosystem services at each site.

3 JOHANNESBURG CBD

3.1 Study area description

The centre of Johannesburg straddles the watershed between the Vaal-Orange (south) and the Limpopo (north) catchments. The Central Business District (CBD) of Johannesburg, located on the southern side of the watershed, has its origins dating back more than a century. The selected study site (**Figure 9**) lies in the Klip River and Klipspruit catchment (quaternary catchment C22A) that flows into the Vaal River (**Figure 10**). As mentioned in the introduction, the study area within the CBD of Johannesburg was chosen around the presence of the Gauteng Provincial Government buildings (**Figure 10**) and the potential future development of the 'Kopanong Precinct' within Marshalltown that will house government offices and be a mixed development (Gauteng Provincial Government, 2018 and Ludwig Hansen Architects and Urban Designers, 2016). To review the SuDS performance, catchment boundaries needed to be used, so the larger catchment studied was the Newtown-Selby area, draining to the Robinson Canal, which later drains to the Klipspruit catchment. (see further **Deliverable 2: Selection of Study Areas**)

Figure 9: Aerial view of the Johannesburg CBD area showing the study catchment and location of recent (Bank City) and future planned developments (Kopanong Precinct and the potential JRA detention basin) that had bearing on the study analysis. The red line is the quaternary catchment boundary and the blue line is the Robinson Canal that receives stormwater from the study area and drains to the Klipspruit.

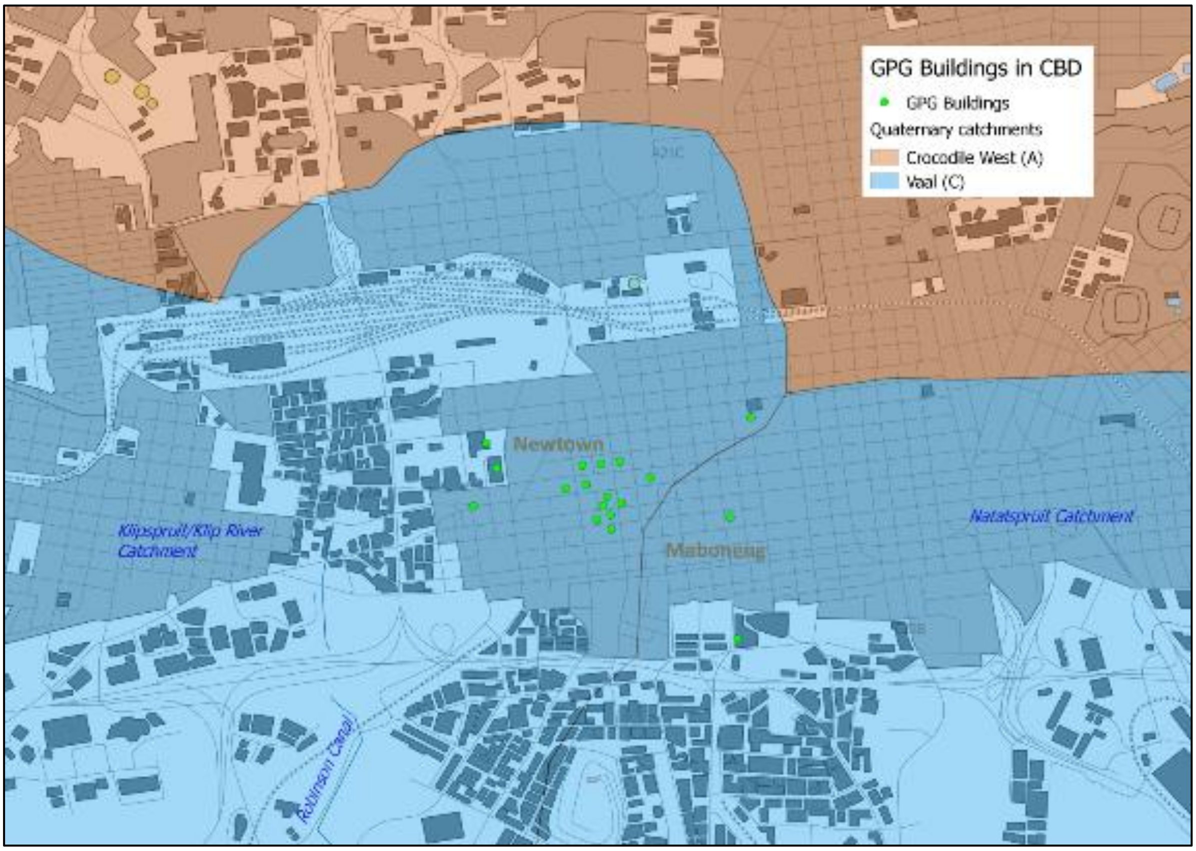


Figure 10: Map showing a demarcation of the Klipstpruit / Klip River Catchment and the Robinson Canal, within the Vaal catchment, and the presence of the Gauteng Provincial Government owned buildings in Johannesburg CBD.

The combination of high-rise buildings, wide streets and a high percentage of hard paving coverage overlying an outdated sewer and stormwater system are evident in the receiving streams around the city which exhibit problems of flooding, erosion and high pollution loads. These conditions are evident in the Robinson Canal and the Klipspruit, the receiving system for this part of the CBD, they provide the basis for the assessment of SuDS interventions in the study area. These include:

- Flood hazard in the Booysens area just downstream of the study area (**Figure 9**).
- Very high levels of sewage pollution in the stream flow in the Robinson Canal and Klipspruit primarily associated with hydraulic overloading of both the old sewer and stormwater systems that run in superimposed networks (one above the other) through the CBD and are prone to blockages.
- High groundwater conditions in the CBD that require many of the buildings with deep basements to dewater on a continuous basis. Discharges are made to the sewer and stormwater systems, adding to the hydraulic loading on these systems.
- Groundwater conditions that require that stormwater is prevented from infiltrating below surface systems.

The field record of conditions in the study area is presented in Annexure 2. Particular attributes of the study area relevant to determining the focus of SuDS interventions are provided in **Table 3**. The largest surface areas in the CBD are the roofs (approx. 40%) and the street surfaces (approx. 30%). Initial analysis gave attention to these two areas as potentially offering the greater stormwater control gains in the CBD environment. However, the practicalities of solutions in these areas need careful consideration. Examples of the spaces in the CBD for potential introduction of SuDS are presented in **Figure 12**, **Figure 13** and **Figure 14**.

The attributes also led to the approach of assessing the potential of SuDS in the CBD by analysing defining a typical city block area using median values of surface cover. The assessment is presented in Figure 11 and the results are broken down in **Table 4**.

Table 3: General attributes of land cover in the CBD study area. (Data obtained from measurements from aerial imagery)

Land cover attribute	Quantity
Total area	43.4 ha
Roof surface area	40 – 45% of entire area
Street surface area (excluding pavements)	30 - 35%
Paved areas at ground level (parking, front of buildings, pavements, etc.)	20 - 25%
Landscaped open spaces	<10% (typically 3-5%)
Open areas at ground level that offer potential for retro-fit SuDS. These include • **Off street parking areas (informal & formal)** • **Parks & landscaped areas** • **Forecourt and apron areas (in front of buildings)** • **Vacant areas** • **Sites under construction**	10 - 15%
Typical area of a block	3600 – 5600m^2 Median 4536m^2
Length of block (in direction of drainage)	60 – 75m
Width of streets (generally 5 lanes, including parking lane)	15m

Table 4: A typical (median) CBD city block area (including pavements, excluding streets).

Type of area within typical block	Area (m^2) and percentage of block area
Roof area	3455m^2 (76%)
Potentially usable flat roof area (excl. existing solar panels, water tanks, etc.)	1898m^2 (42%)
Green roof area (80% of usable flat roof area, leaving 20% for access & services)	1518m^2 (33%)
Total block area (excl. streets)	4536m^2 (100%)

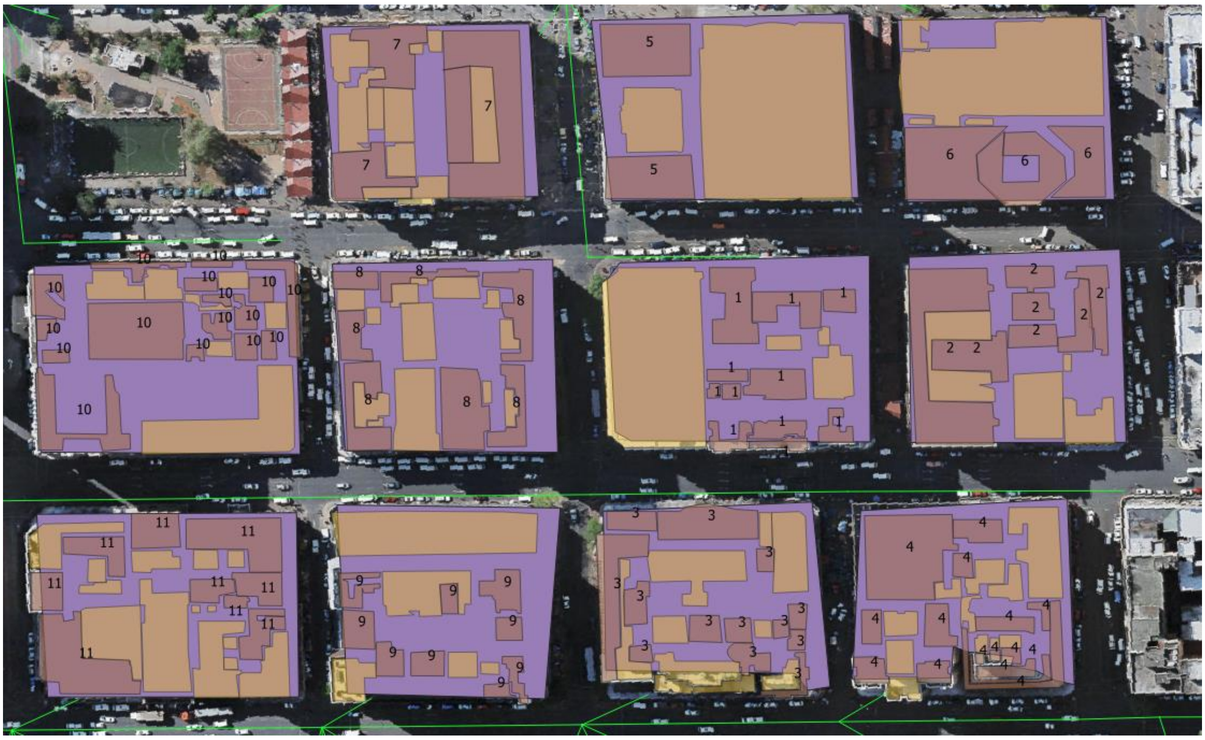


Figure 11: CBD roof space - Analysis of flat roof areas (numbered polygons) per block in the CBD study area.

Figure 12: The street space – 5 lanes, usually including 2 parking lanes.

Figure 13: Open space areas – potential sites for SuDS implementation

Figure 14: Open space areas – potential sites for SuDS implementation

Future urban planning and implications for the CBD:

While policy supported the role of the CBD as a core economic hub of the Region, the Spatial Development Framework for Johannesburg 2040 (City of Johannesburg, 2016), and the Inner-City Transformation Roadmap (City of Johannesburg, 2013), commit to supporting the densification and intensification of land uses and people within the Inner City. This means that there will be a much higher percentage of residential in the CBD in the future, and the need for additional public services, commercial activity that supports resident's basic daily needs and space to socialise and recreate.

In an effort to increase the liveability of the area, the CoJ proposes investment in public open space. Another of their objectives is to make a more connected city, one which provides public transport services and attractive connecting streets, pedestrian streets and an enhanced road network, to be achieved through the incorporation of public spaces around which activities can intensify. This will ultimately see a reduction in the vehicle volumes and parking at ground level and a freeing up of the ground plain for people and landscape interventions that make for a more qualitative experience for those on foot. The last relevant objective is a resilient city which talks to the challenges of Climate Change. They specifically call for investment in strong well-connected open space systems and the refurbishment of buildings to include green infrastructure.

In conclusion the spatial policy supports the greening of the ground plain in the inner city and the shift towards less vehicles and more PT and NMT within the road reserve. This will result in less of a need for parking at ground level and, in time, should free up portions of the cross section of the roads for SuDS interventions including planting.

Following global trends which have shown that where the state and / or the private sector have invested in upgrades of the public realm and greening of squares, sidewalks and other public outdoor areas, there are increased levels of staff productivity and rental or sales returns, the JDA and the COJ are supporting several projects aimed at upgrading and stimulating investment in specific areas in the inner city (City of Johannesburg, 2009). These initiatives acknowledge the importance of making qualitative public environments to improve the experience of commuters, employees, shoppers and residents`. They also acknowledge that investment in the public realm by the state is a way to incentivise private investment.

There are a number of significant projects in process currently including the Kopanong Gauteng Government Precinct focussed around the Beyers Naude Square (Gauteng Provincial Government, 2018) and the Diversity project looking at 6 blocks around the ABSA Towers Main Building. The former is of particular relevance and includes the demolition of selected buildings and the refurbishment of others. Proposals include huge investment in public open spaces which are planted and landscaped to offer increased amenity for new innercity residents and workers. Proposals suggest that roof gardens and planted facades will be incorporated in building designs to address heat build-up in the city.

3.2 Consultation Outcomes

During the large workshop on 5 February 2019, a parallel session was set up for the CBD in which local knowledge and experience was collated. A dedicated workshop on the CBD study area was held on 11 April 2019, with twenty-five participants including researchers, public officials and private practitioners / consultants. The City of Johannesburg was represented by a councillor, stormwater department experts, a catchment management expert and water services planning experts from the infrastructure and water services regulation department. Unfortunately, City Parks were not able to attend. Property owners and their joint forum, the Johannesburg Inner City Partnership, were also represented, as well as an artist who works with green systems to improve the environment and a mentor of the entrepreneurs that do rooftop gardening. The Klip River Water Stewardship Initiative was also represented.

Outcomes of this consultation that are learning points for this analysis are:

- **'Super-Blocks' possible but with concerns for traffic management –** There was discussion on whether to create 'super-blocks', using some streets to accommodate pedestrian courtyards (similar to what has been done with the First National Bank block), or closing off some streets to vehicular traffic to accommodate NMT and landscaping serving SuDS purposes. The opinions on 'super-blocks' were divided. Concern was mainly related to the current congestion, lack of parking and safety aspects which currently present challenges to public transports effective operation and non-motorized transport.
- **Need for alternative water sources agreed -** The participants opinions were positive on the use of stormwater and the groundwater from basements currently pumped in the stormwater system (or the sewer system) as alternative water sources, given the need of Gauteng to increase its water security with alternative sources. There was discussion though on whether SuDS that would impact groundwater, would impact, through pressure, the Acid Mine Drainage areas more to the south. This issue is reinforced by the key outcomes of the site analysis.
- **Many influences on current stormwater system that make SuDS not the first priority –** Participants mentioned examples in the catchment area of the Robinson Canal of intentional blocking of sewerage systems, resulting in sewage mixing with the stormwater; regular drinking water burst pipes; continuous dewatering of basements and draining them either through the stormwater system or the sewer system; illegal sewerage connections draining straight into the Robinson canal and the litter trap being vandalized.
- **Concern that SuDS require additional potable water demands –** Concern was raised that green roofs and bioretention areas would need additional potable water in dry periods.
- **Without private sector and concerned individuals being involved, SuDS sustainability will not be successful –** Concern was also expressed on additional maintenance demands on the City, as current garbage collection is already a challenge. The group of participants was concerned that currently maintenance of the inner city is not up to scratch and introducing further maintenance issues would not be possible without upfront management agreements with the private sector. Therefore, implementation should be on a precinct by precinct basis where there is potential for a good collaboration with the private sector. The City Parks department is developing a policy for co-management, but also JICP has several examples of working co-management arrangements.
- **For private investments in the SuDS at individual building level, the business case needs to be clear unless it is obliged by policy** – The representatives of the private sector in the room were very clear that only if there were financial opportunities or legal risks, would they be willing to invest in SuDS green roofs, amongst other SUDS interventions, on their own buildings. If water or energy saving benefits could be demonstrated, or if the roofs could be

'rented out' for use for water harvesting or for green roofs, the private sector might be more interested. However, in site redevelopment projects the property owners will be obliged to consider sustainable drainage measures to comply with current provincial sustainable development regulations, and green roofs may be one of the better solutions.

- **Many buildings are pumping water from their basements, either to sewerage or to stormwater system.** This water could be potentially used. GDARD (2019) received questionnaires from 19 buildings of which 13 had a dewatering system, 4 did not, 1 did not have a basement and for another 1, the respondent did not know. Only 1 respondent (FNB) used the water, while 7 pumped to the stormwater network and 4 to the sewerage and the other respondents did not know. Water quantities and qualities are generally unknown.
- **Many buildings have roofs that are flat (See** Figure 15**), and in that sense suitable for a green roof, but of course could also be used for hydroponic farming as is currently rolled out.** All buildings reported they had an accessible roof, and for most of them it had a protecting border (Figure 16).

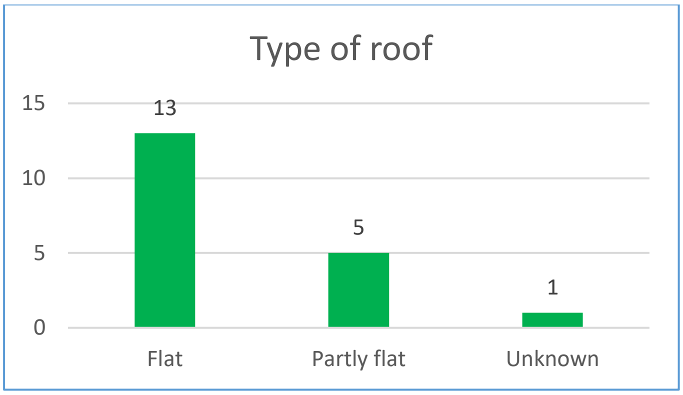


Figure 15: Type of roofs investigated in survey (See Annexure H)

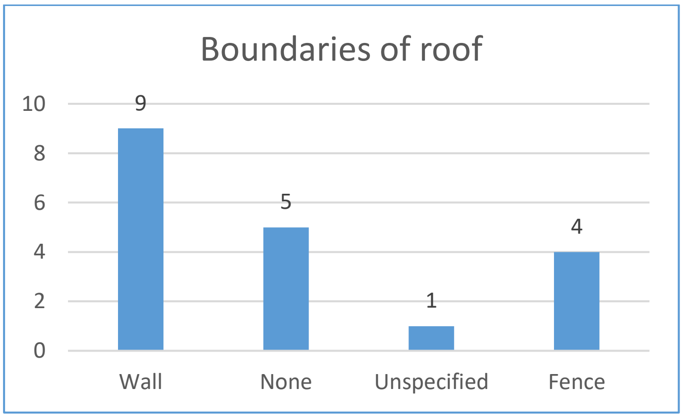


Figure 16: Boundaries of roofs investigated in survey (See Annexure H)

Overall, the introduction of SuDS ideas, was appreciated and considered appropriate given plans to re-develop the current CBD, as well as there being awareness at local and provincial government level that a more water sensitive approach is needed and that there is need for green in the City.

3.3 SuDS Interventions Assessed

SuDS interventions in the CBD have been assessed at two scales; a typical block scale, and at a sub-catchment scale. The former assesses the potential within the two main land covers in the study area; roofs and streets, and the sub-catchment presents an example of an integrated SuDS and its performance.

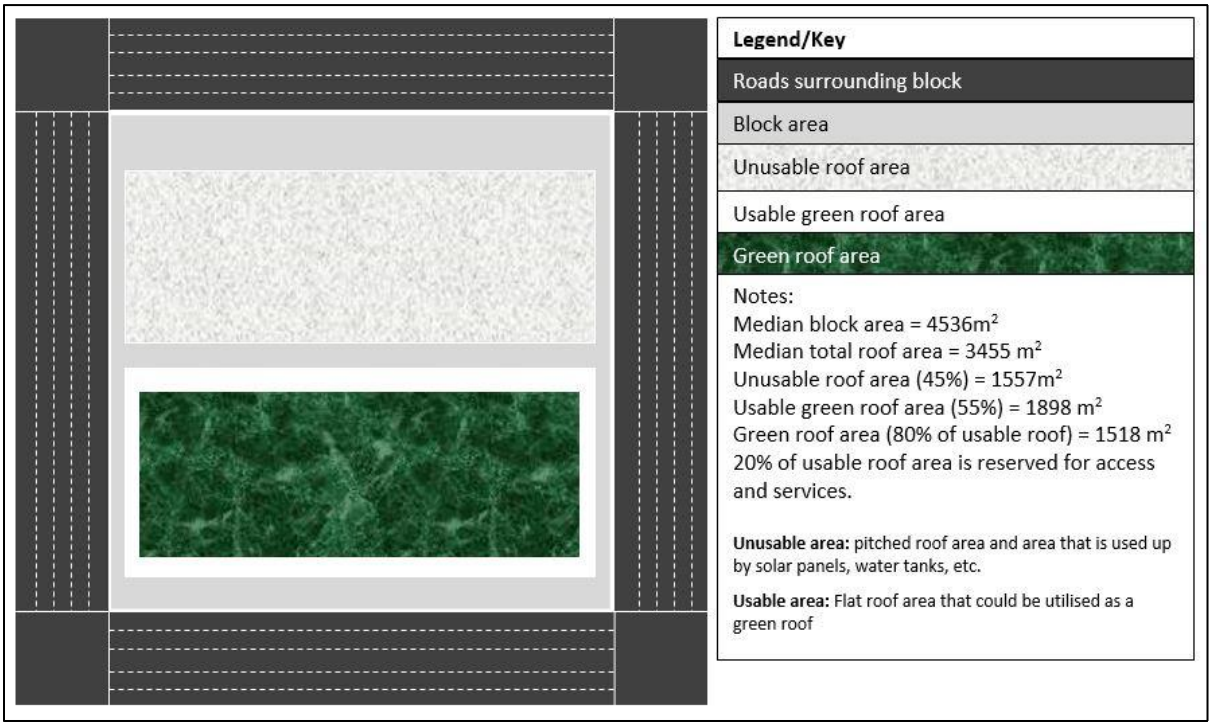


Figure 17: Schematic representation of the median roof areas for the green roof analysis.

Block scale: Roof SuDS Interventions

The attributes in **Table 3** and **Table 4** are simplified in schematic form in **Figure 17**. This represents the basis of the simulation of the green roof system in MUSIC. This assumes that the roof areas that are not converted to a green roof will drain to the green roof area to optimise the benefits of the green roof intervention and the hydraulic loading, as will be demonstrated, is within the capacity of the green roof portion. This kind of solution points to a new building design, or the refurbishment of an existing building where there would be opportunity for any necessary structural reinforcement. Opportunity for this scale of application to existing buildings currently in operation may be more limited, though the results would indicate the potential benefits if implemented at a smaller scale.

The green roof concept is based on the following assumptions:

- Only flat roof space is used. Although green roofs can be established on pitched roofs, flat roof systems generally offer better storage capacity, construction costs are generally lower than on pitched roofs, and opportunities for amenity are expected to be potentially greater.
- A 150mm soil layer (growing and filter medium) is assumed. This is in line with general international guidance for extensive green roofs (e.g. Woods-Ballard, et al, 2015), but it also seeks to achieve a balance between being shallow enough to minimise weight but deep

enough to sustain plant cover with no irrigation. However, this balance is not tested in this study. A loamy-sand soil texture has been used in the simulation in support of this balance: it provides good storage with good drainage potential (and hence 'storage ready' for the next rain event). The estimated dry mass is 196kg/m^2 (~2kN/m^2) and wet (saturated) mass is 250kg/m^2 (~2.5kN/m^2).

- The green roof is planted with succulents for sustainability during the dry season. No irrigation is included in the analysis, but irrigation is considered as part of the implementation plan.

The design of the green roof is based on the system conceptualised in **Figure 18** (top figure). A drainage layer has not been included in the modelled system (to optimise retention), but it is likely to be a requirement in practice.

The hydrological assessment of the green roof was intended to identify the potential of the system to mitigate the runoff response from impermeable roof areas. The analysis included a number of minor adaptations which are outlined in the section to follow.

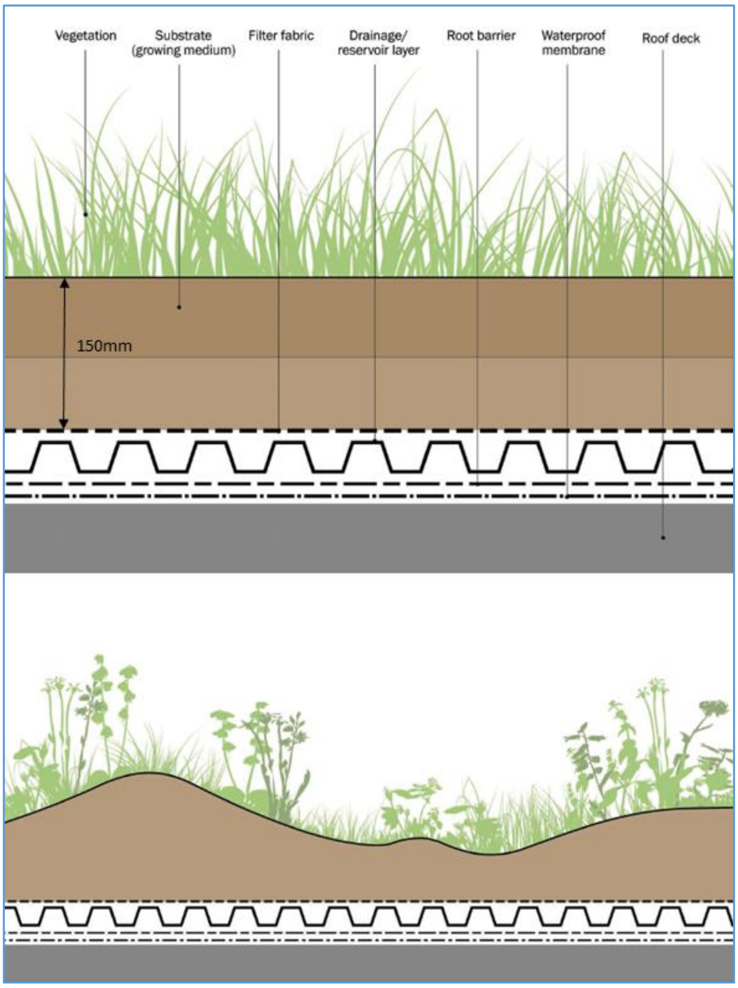


Figure 18: Extensive green roof concept (top) and example for enhanced biodiversity potential (bottom). (after Woods-Ballard, et al, 2015). *[NB copyright]*

Block scale: Street SuDS Interventions

The system considered is depicted in **Figure 19**. It assumes one lane is taken up by a Bioretention system, either as a series of units or a single unit and receives storm runoff from the other four lanes. Depending on the overall size of the system required, it may be expanded to receive runoff from other incoming streets or could be integrated with extended pedestrian access and/or car parking.

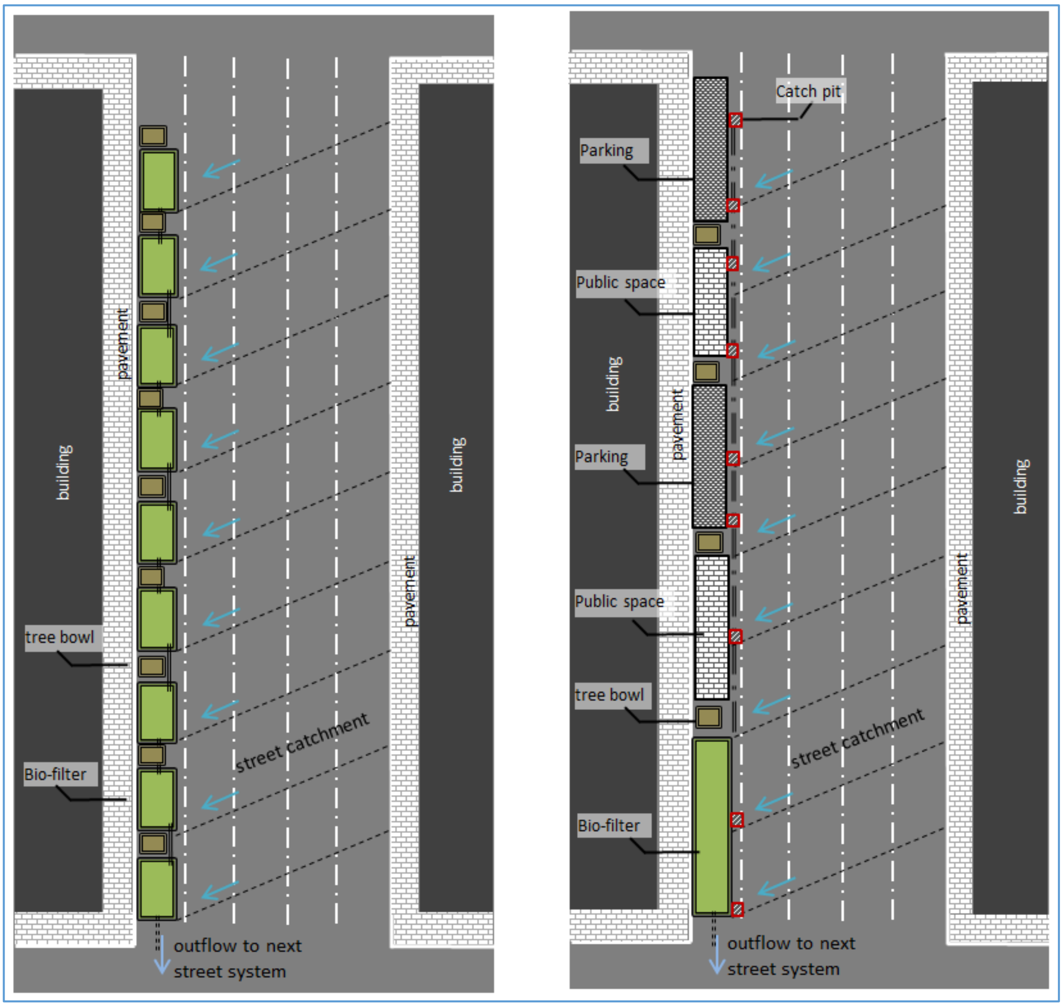


Figure 19: Schematic representation of street level interventions for the sample city block area; (left) Multiple bio-retention filters (each 7.5m^2) interspersed with street features (trees, footpaths, benches, etc.), and (right) a single bio-retention filter (60m^2) at the end of the street with the rest of the lane used for parking or public space

As with the green roof analysis, the intention is to assess the potential of the bio-retention system to address runoff at street level. Unlike the green roof system, both the size and catchment area of the bio-retention system can be varied to obtain the best combination. However, in this study the number of scenarios that can be tested is limited. The sizing of the small units (7.5m^2) was based on landscaping in public areas observed in the CBD (e.g. **Figure 12**). The size of the larger single unit was derived through the analysis. Basic data for the street SuDS interventions are given in **Table 5** below.

Table 5: Base data for street SuDS analysis

Typical lengths / areas of blocks in CBD	Number (see unit on left)
Median block street length (m)	67
Street width (m)	15
Total street catchment area (m^2)	1005
Bio-filter sub-catchment area (m^2)#	126
No. Lanes	5
Width of lane (m)	3
Surface area of cell (m^2)*	7.5
Dimensions of cell (m x m)	2.5 x 3.0
Filter depth (m)	2
Notes ***# Dependent on number of cells. Given area is based on 8 cells*** **** for multi-cell systems***	

Sub-catchment scale: treatment train

The block scale systems are then integrated into a treatment train network of one of the CBD stormwater sub-catchments, determined from the existing CBD stormwater network (**Figure 20**). An additional part of the treatment train is the inclusion of a detention pond formed by creating a temporary flood storage area in one of the open spaces. The catchment and associated treatment train network are presented in **Figure 21** and **Figure 22**. The total catchment area is 43ha, divided into 13 sub-catchments.

The main features of the model are as follows:

<u>Green roofs</u>

> There are 44 blocks allocated to buildings in the main catchment area. Nine of the proposed Kopanong government buildings fall within the main catchment area. Therefore, nine blocks have been classified as “gov” blocks because they contain one or more government building. This is 20% of the blocks of the catchment area. A further 10% was then selected around the catchment, bringing the total to 30% (13 blocks out of 44) that are converted into Green roof blocks. A green roof block is modelled as the “green roof + 100%” scenario described above (where the entire roof area of the block is assumed to drain to the green roof system the source nodes are numbered according to the number of the green roof and either (a) for flat area (usable) and (b) for pitched area (unusable). The run-off from all the green roof systems is then directed towards the Detention basin.

Figure 20: The CBD sub-catchment (blue shaded ground surface) used to analyse an integrated SuDS treatment train.

Figure 21: CBD Sub-catchment integrated treatment train incorporating green roof (top) and street level (bottom) interventions, and a detention pond in the Sci-Bono park area.

Bio-retention cells

The longest drainage line was selected as the bioretention line. It was determined that a total of 13 bioretention cells (where 1 cell is the equivalent of 8 cells – refer to **Figure 19**) would fit alongside the blocks on the drainage line. Each one captures its own catchment (this is the “SealedRoad” source node in the MUSIC model depicted in **Figure 22**) as well as the flow from the previous cell, thus the first cell in the line performs the best and the last cell performs the worst, as expected. The run-off from the cells is directed towards the Detention Basin.

Detention Basin

Sci-Bono’s park area was selected as the site for a detention basin. A main catchment area was then delineated to feed into that detention basin. This main catchment was then divided up into sub-catchments. Each sub-catchment has a source node called “Urban” and that feeds directly in to the detention basin. This “Urban” source node consists of blocks and streets and is classified as a “Mixed” zone. The run-off from the green roofs and from the bioretention cells are also directed into the detention basin.

The size of the detention basin is 6300m2 (the surface area of the park) with a storage depth of 0.5m. The basin will fill within around 30 minutes in a design event and will drain over a period of 5 to 6 hours. Although the intention was to create minimum hazard with the design, this aspect has not been analysed in any detail in this study. At Kagiso where the same system is tested, stakeholders raised concern about anything deeper than 300mm that children would have access to. The site at Sci-Bono is open to the public.

The selection of a 30% conversion of city buildings to green roofs, and a single street treated by bio-retention cells is relatively arbitrary. In more detailed SuDS planning studies a range of scenarios would normally be tested to provide the necessary data needed for the development of a stormwater management strategy. Due to programme limits for this study only one main catchment scenario could be tested, and the combination described above was (a) deemed to be possible within the future plans described for the city, and (b) would provide sufficient insight to support the development of a practical implementation guideline.

Similarly, the selection of a single detention basin rather than more of a scattering of smaller detention facilities throughout the catchment was influenced in part by the additional analysis required to test flood relief. While the MUSIC software does include the analysis of detention facilities, this is focussed on pollution treatment and overall runoff load reduction. The attenuation of individual storms cannot be analysed in the software. Hence an additional analysis is required to do this. As such a single detention was preferred and the Sci-Bono park area offered one of the larger surface areas, and is well located, to perform a catchment attenuation function. Nevertheless, it is still acknowledged that a distribution of detention ponds within a catchment could offer valuable alternatives.

The resulting area of the catchment (to the proposed detention pond at Sci-Bono) under SuDS treatment is relatively small at 13% (5.8ha). This would be a low long-term target for SuDS implementation, but it may also highlight the risks of not setting more ambitious targets for the city centre.

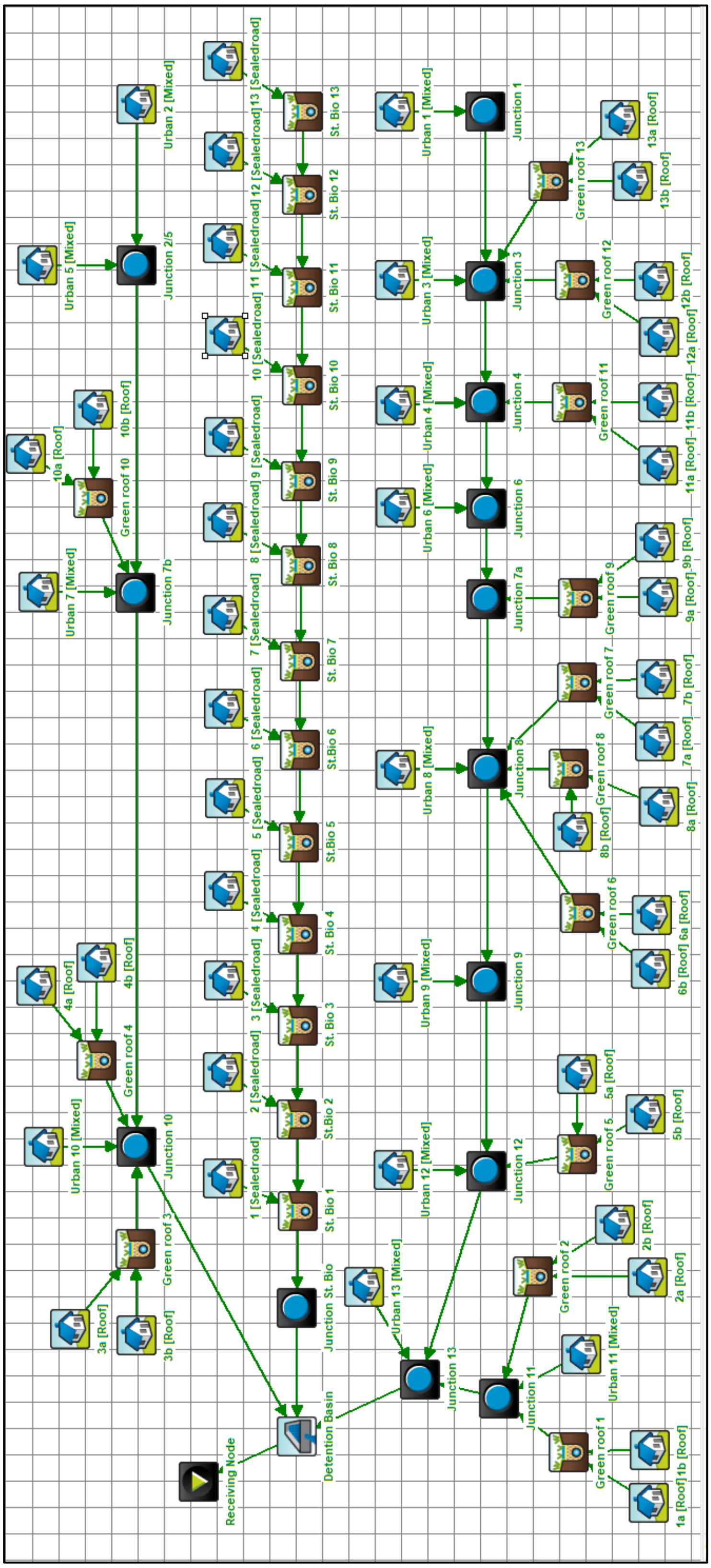


Figure 22: CBD Sub-catchment network layout (MUSIC model)

3.4 Performance Summary - Roof SuDS Interventions

Three scenarios were tested (**Figure 23**):

Green roof only: The green roof area treated only the rainfall falling on it.

50% of pitched roof: The green roof area treated its own rainfall, and runoff from 50% of the pitched roof area of the block.

100% of pitched roof: The green roof area treated its own rainfall, and runoff from 100% of the pitched roof area of the block.

The green roof was modelled as a wide, shallow (150mm deep) bio-retention unit in MUSIC.

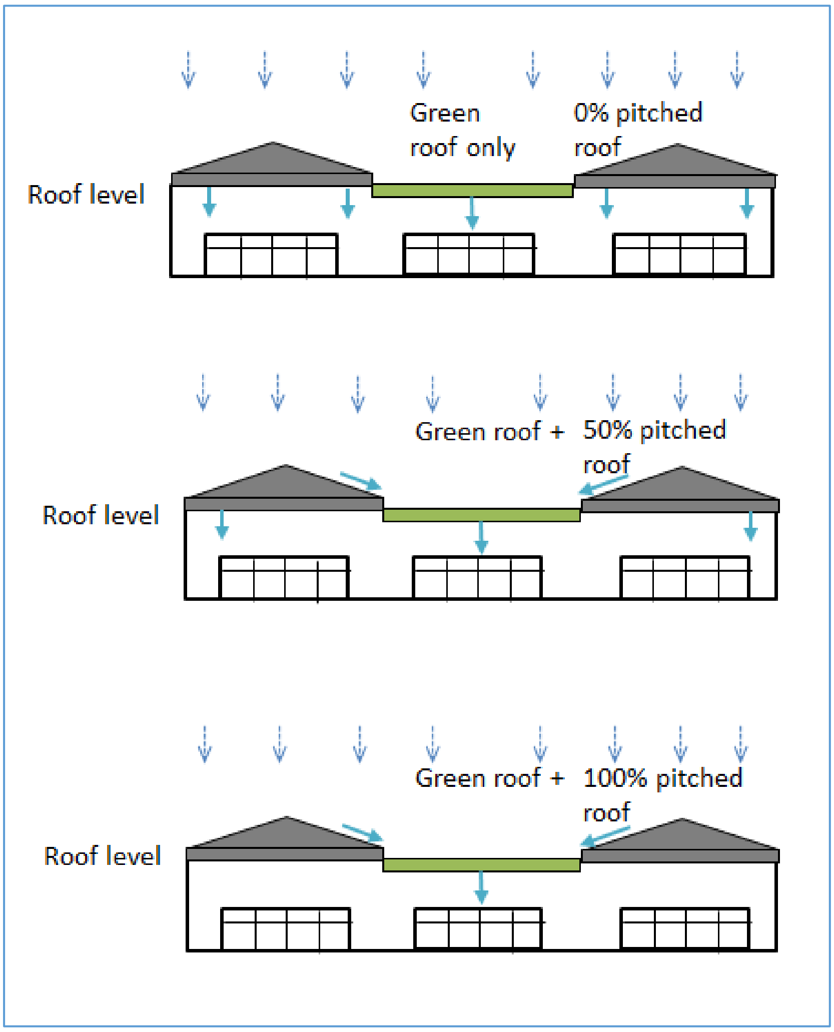


Figure 23: MUSIC modelling scenarios for a median CBD green roof

3.4.1 Quantity and Quality Benefits

All three scenarios show the green roof to offer a high level of performance (**Table 6**). Even when receiving runoff from the entire roof area of a block, the reduction in hydraulic load and the three main pollutants is in excess of 90%. This indicates the loading ratio could be higher, possibly around 1:4, with the green roof area at half the size tested (i.e. around 750m^2 per block instead of 1500m^2).

Table 6: Summary of green roof performance, with incremental contributions from the pitched roof areas (see Figure 23)

Description	Green roof only	Green roof + 50%	Green roof + 100%
INPUTS			
Green roof catchment area (m^2)	1900	2680	3460
Green roof bio-retention area (m^2)	1518	1518	1518
Hydraulic Load ratio (1:X)[1]	1.25	1.77	2.28
Runoff load (Ml/yr)	1.25676	1.70893	2.16126
TSS Load (kg/yr)	25.1	34.1	43.1
TP load (kg/yr)	0.162	0.22	0.278
TN load (kg/yr)	2.51	3.41	4.31
OUTPUTS			
Evaporation (Ml/yr)	1.24966	1.64476	1.98213
Infiltration (Ml/yr)	0	0	3
Runoff yield (Ml/yr)	0.00896	0.06725	0.18449
TSS yield (kg/yr)	0.17921	1.34501	3.68987
TP yield (kg/yr)	0.00116	0.00874	0.02398
TN yield (kg/yr)	0.01278	0.09535	0.26177
EFFICIENCY			
Runoff load reduction (%)	99.29%	96.06%	91.46%
TSS load reduction (%)	99.29%	96.06%	91.44%
TP load reduction (%)	99.28%	96.03%	91.37%
TN load reduction (%)	99.49%	97.20%	93.93%
Note: ***1. The hydraulic load ratio (1:X) is the surface area of the SuDS facility versus the surface are of the contributing catchment.***			

Table 7: Performance of green roof in the context of overall roof and block runoff.

Description	Green roof only	Green roof + 50%	Green roof + 100%
% reduction of entire roof runoff (all impervious)	44%	76%	91%
% reduction of median block runoff (all impervious)	33%	58%	70%

Table 7 shows the performance of the green roof tests in the context of the overall roof runoff, and from the block as a whole. The green roof absorbs most of its own rainfall and so reduces the overall yield from the roof and block areas in proportion to its surface area (44% and 33% respectively). Loading the green roof area with as much of the surrounding roof area as possible will see important gains with model results suggesting that the overall runoff contribution from a block to the receiving stormwater network could be reduced by as much as 70%. The rainfall time series was checked to confirm that it includes both a 5 year and a 2 year event; this result will be an important guide to setting green roof targets.

Similar water quality benefits are also anticipated. The median roof area is approximately 75% of the median block area, and the high pollution reduction levels indicated in **Table 6** will improve the overall block yield, though perhaps not quite at the levels indicated in **Table 7**. This is because the pollution loads at street level will be higher than those at roof level.

Key outcomes:

- An estimate of the practical area that may be converted to green roof (around 44% of existing roof area) shows a high runoff and pollution reduction potential, even when receiving runoff from the entire roof area. This provides a loading ratio of 1:2.3 (green roof to total roof area).
- The performance levels suggest that this ratio may be reduced, possibly to around 1:4, without overloading the green roof treatment capacity.
- A green roof installation may potentially reduce the overall runoff load from a block by as much as 70%.
- Water quality benefits of similar magnitude are possible.

3.4.2 Water reuse

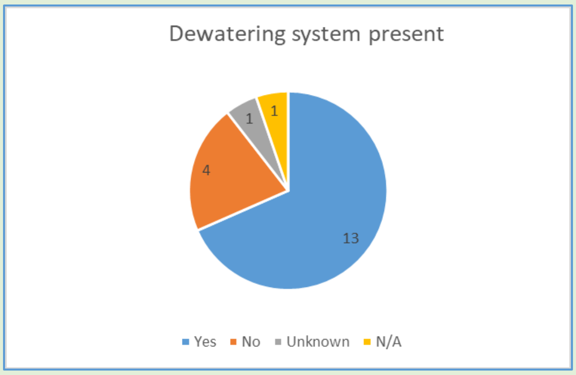
Table 6 shows that evaporation (and evapotranspiration) is the primary water loss from the green roof system. Even with the additional hydraulic loading from the surrounding roof area, evaporation still takes out over 90% of the rainfall and runoff entering the green roof system. Hence the potential for water harvesting from the green roof appears limited.

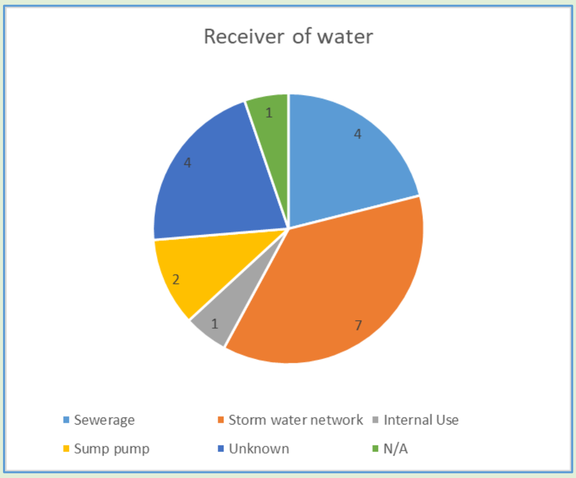
In contrast, the sustainability of the plants on the green roof with such a shallow soil, and such a long dry season, may rely on irrigation. Hence the green roof systems for the CBD may be a net user of water that will have to be transported to the roof tops.

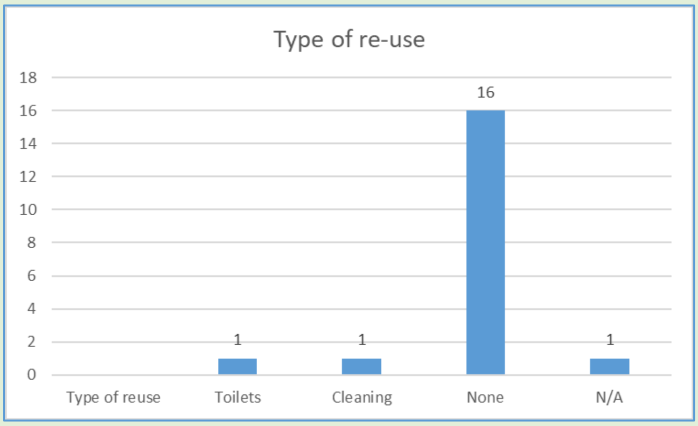
Dewatering of CBD basements may be a useful source of water for irrigation. Currently many buildings are understood to pump basement water ingress to the sewer or stormwater systems. This will exacerbate the existing problems that the Johannesburg Roads Agency (stormwater) and Johannesburg Water (sewer) with the overloading of the respective networks. The quality of the basement water is unknown, but it may have a diluting effect on pollution levels in the sewer and stormwater flows. This may have either beneficial or negative effects that should be explored further. However, there is clearly an alternative use of the basement dewatering as an irrigation source that could benefit the operation and sustainability of green roof systems, allow a more diverse range of plants to be used, and would reduce the hydraulic loading on sewer and stormwater networks. However, data on basement dewatering in the city is limited on both quantities and quality, and in location. The reuse potential of this resource would benefit from a detailed water balance analysis. **Box 1** and Annexure H with the background report, show that there is potential.

Box 1: Groundwater pumping in basements of CBD

In Annexure H of this report, the results of a survey by GDARD on pumping of groundwater in basements in the CBD (and on rooftops) is added. Key figures of the water in the basements, that can be a source of irrigation of green roofs or other SuDS, are specified below. The conclusion is that many basements have dewatering systems (13 out of 19 with 2 unknown or not applicable), several drain on the sewerage network (7 out of 19), but also on the stormwater network (7 out of 19) and many contact persons did not know. Only FNB Bank City reported using the water for internal use.







Key outcomes:

- Stormwater harvesting from a green roof may be limited unless there is a combination of harvesting from a portion of the impermeable roof area and the green roof taking the remaining roof area. This water may be used for irrigation of the green roof, or to meet internal building water demands.
- Perhaps a better combination would be to maximise the green roof area and its roof catchment, and use basement dewatering as a more reliable source for irrigation (wet and dry season supply). An irrigated green roof is more assured of sustainable operation, and may allow a wider range of planting diversity to improve biodiversity.

3.4.3 Alternative uses of the "Green Roof" space

Consultation with stakeholders has highlighted current efforts to utilise the roof areas of buildings in the CBD for urban agriculture (Workshop minutes CBD, Annex 5, inputs WIBC). Among the benefits highlighted include:

- Job creation,
- Food security,
- Converting a typically vacant space into economic use,
- Rent for building owners.

These are distinct advantages over the development of green roofs. Another advantage is that the hydroponic systems typically utilised are likely to have a lighter structural loading than a green roof. The hydroponic systems are water intensive and could also provide an important sustainable "reuse" for basement dewatering (if water quality allows).

Unlike extensive green roof systems, the agricultural systems are usually covered and do not promote infiltration. However, they could potentially be adapted for rainwater harvesting.

The Urban Agriculture Initiative, a project supported by the Johannesburg Inner City Partnership (Johannesburg Inner City Forum, 2018), has successfully piloted a rooftop food garden and is on track to roll out another 24 projects in the inner city area (Watermeyer, 2018). Reportedly property owners have made available some 60 buildings for the project, so there is clear interest for this use of roof space which may slow the progress of developing extensive green roof areas on CBD buildings.

Key outcomes:

- Urban agriculture and green roofs are unlikely to share the same footprint of the roof, and will result in different stormwater benefits, with green roofs being better for stormwater management.
- However, the wider benefits of urban agriculture may make this a more attractive option for property owners and investors.
- Both will benefit from use of basement dewatering, the analysis of which may influence the selection of one use of the roof space over the other.

3.4.4 Flood reduction

Table 6 shows that the net runoff yield, as a percentage of runoff load, is between 1 % and 8%. This is in line with the estimated natural catchment yield of between 1.5% and 7.7% (Bailey and Pitman, 2016). Therefore, even with the entire roof area draining to the green roof system, it has transformed the hydrological response of the buildings in the block to roughly the equivalent of the original site in its natural state. This is the default principle in the new City of Johannesburg Stormwater Design Manual (CoJ, 2018) that seeks to address flood risk, among other sustainable drainage benefits.

However, most SuDS facilities in the treatment train are designed to address the everyday storm event up to perhaps the 2 year, or even 5 year storm event. This addresses the bulk of the hydraulic load in a catchment, and the bulk of the pollutants. But many SuDS designs will by-pass larger storm events to avoid hydraulic overloading and damage. Hence flood management of extreme events is not managed directly through most SuDS applications, including green roofs. For this reason, the detention pond remains an important part of the treatment train as this specifically addresses extreme events. Therefore, the green roofs will not, on their own, address the full range of design flood events, but as indicated above they will play an important part in reducing the overall hydraulic load of the system, which will reduce flood peaks.

Key outcomes:

- Green roofs are shown to play an important part in returning the hydrology of the urban space back to pre-urban times, which in turn reduces the flood responses from the catchment.
- However, this SuDS measure will not address flood risk in the Robinson Canal on its own. It will need to be part of the treatment train that includes a detention pond to mitigate the effects of extreme storms.

3.4.5 Heat Stress Reduction

Green roofs reduce indoor urban heat mainly by insolation, but this is only valid for the upper floor of a building and for roofs that are not already sufficiently insulated and is dependent on soil depth applied. Insulation can also help to reduce the cold in the upper floor of a building during winter time. Dependent on the material and the cover of the roof area that was there before, the temperatures might also be reduced (through albedo effect, thermal emittance, heat capacity).

Green roofs can help reduce outdoor air temperatures in an urban environment by lowering the temperature of exposed surfaces (roof tops, walls). Evapotranspiration assists the cooling effects. Green roofs that are designed and used as accessible cool green areas with shading trees tend to offer the best cooling effects on people.

Green roofs are cooler to reside on than black roofs but not cooler than roofs with white gravel (Heusinger and Weber, 2017; Solcerova et al., 2017; Knowledge Centre T). Most roofs in the study area seem, from Google Earth analysis, to be light coloured concrete roofs, therefore already have quite a high albedo value and thus the difference with green roofs is less than for black roofs.

The cooling effect by evaporation of green roofs will only be effective if water is available, and also depends on the soil mixture and soil depth applied and the vegetation put in place. In Western Europe regular green roofs are not very effective for cooling in cities because the hot summers keep the green roofs too dry. For the study area, in Johannesburg the green roof system modelled adopts a shallow soil depth of 150mm and is not irrigated, so the soil mixture becomes relatively dry during dry spells in summer months and the cooling effect by evaporation will also be only a few days after a rain spell. It has already been indicated that irrigation may be needed to ensure the sustainability of the green roof, so there are wider benefits to maintaining a wet green roof system. This situation warrants further research. Additionally, if a green roof system is intended to provide benefit during a heat wave it would need to be designed as blue-green roof with additional water storage to sustain evaporation during the event.

The potential for evaporation is high in Gauteng (at 2200 mm/year Pan A evaporation). Optimising this potential for cooling with a green roof but at the same time not losing too much water that could be used otherwise, will need further investigation, and will also require careful selection of vegetation. Succulents may be chosen for their water resilience and durability, but their low evapotranspiration rates will offer limited cooling benefits. In that case the cooling effect of green roofs through evaporation is limited. An irrigated system opens the potential for the selection of the best plants for the location. This further advances the discussion in Section 3.4.2 on the use of basement dewatering as a source of irrigation water for green roofs that will offer higher levels of performance. Li et al. (2014, as cited by Van der Walt, 2018) found that for extensively irrigated green roofs near surface temperatures (at 2 m above surface) were 0.4 °C lower, against the surface temperature decreasing with 2.4 °C. For dry conditions, the near surface lowering was 0.2 °C against surface temperature lowering of 1.3 °C.

The lower temperatures on top of a green roof are expected not to have any noticeable effect at street level (where pedestrians walk) even if the buildings are only one floor high. In the study area, many roofs have walls around them and there the effect on the surroundings will be even less. The effects on the temperature will be very local. The air with lower temperatures thanks to the green roof will be easily blown away from where people walk.

The extent of green roof cover to make a significant impact on surface temperatures will need further research. Increasing the present 3% cover to the potential 29% cover indicated in this study, the effect on the larger scale could be significant. A study of the temperature reduction by 100% roof greening by (Sharma et al., 2016) showed a reduction of up to 4 °C on average temperatures over several blocks of buildings. Simulations for Toronto showed that if 50% of all roofs would be green, the air temperature would be reduced by 2 °C (Bass et al., 2003, as cited by Oberndorfer et al., 2007).

However, the effect on the temperature at street level might still be smaller than the effect on the general average temperature, also dependent on the heating up of the surface areas at street level, dependent on their material, their exposure to direct sun light and the albedo of the surfaces of the buildings around them. For most effective cooling at street level, planting providing shadow and evaporation at street level is needed. In summary, green roofs do not offer a solution for outdoor street level exposure to heat stress.

Figure 24: Example of roof to reside on, without wall but with bill board, but too high to have effect on street level heat reduction

3.5 Performance Summary – SuDS Measures at Street Level

3.5.1 Quantity and Quality Benefits

Infiltration from the bio-retention units into the surrounding soils and groundwater has been prevented in this study. Therefore the hydraulic load (total flow) reduction for each system in **Table 8** is almost entirely due to evaporative losses, which increase as the number of cells (and cumulative surface area) increase. These losses are higher than anticipated, ranging from 27% to 72% of the overall stormwater load from the street, but this could be substantially improved if deeper infiltration is allowed.

Table 8: Summary of the performance of bio-retention systems at street level.

CHARACTERISTICS	Changes with increasing number of cells in train			
Total number of cells	**4**	**6**	**8**	**12**
Cumulative length (m)	12	18	24	36
Cumulative area of cells (m^2)	30	45	60	75
Incremental catchment area (m^2)	251	168	126	84
Hydraulic load ratio (1:X)[1]	33.5	22.4	16.8	11.2
PERFORMANCE				
Node hydraulic load reduction (%)	26.9	38.4	49.3	71.5
TSS Node Load Reduction (%)	92.6	95.3	96.6	98.4
TP Node Load Reduction (%)	74.5	79.7	83.8	91.3
TN Node Load Reduction (%)	58.8	68	74.3	85.6
Note: ***1.*** *The hydraulic load ratio (1:X) is the surface area of the SuDS facility versus the surface are of the contributing catchment.*				

The results support the expectation that the treatment of stormwater pollution is the main benefit of these tests. As stated in Section 2.2, there is no catchment management plan for the Robinson Canal or the Klipspruit. Quantity and quality targets in such a plan would be guided by present day conditions. Section 3.3 highlights the very bad water quality in the Robinson Canal, particularly levels of sewage in the stream flow which is partly linked to hydraulic overloading of the stormwater system. Under these conditions the best possible water quality targets should be considered, which will be further reviewed for performance in the catchment treatment train study (Section 3.6) and economically viability in the cost-benefit assessment.

The 12-cell system in **Table 8** clearly offers the best performance. This presents a hydraulic loading ratio of 1:11.2. Guidelines for bio-retention filters suggest a ratio of 1:20 is reasonable (e.g. Winston, 2019), which suggests that the 6-cell and 8-cell systems may offer practical solutions in this situation. For the purposes of this study only the 8-cell system has been carried forward to the catchment study (Section 3.6). Tests showed that combining the 8-cells into a single cell of the same effective surface area results in a treatment performance very similar to the results in **Table 8**. Hence a single cell system as depicted in **Figure 19** has been used.

Sediment loads on the bio-retention system is estimated by the default values for city streets in the MUSIC software at just under 120kg/yr for the 1005m^2 street catchment area. (For comparison, the sediment yield of the median roof area of a block is less than 4kg/yr (**Table 6**) for a surface area of almost 3500m^2). Sediment loading is expected to be one of the main causes of failure of SuDS facilities in Gauteng, and the default values in MUSIC are likely to underestimate sediment loads in the province. Hence it would be suggested that a sediment trap fore bay be added to the bio-retention system in each street to both ensure performance of the unit, and to allow for relatively simple cleaning of the system.

Key outcomes:

- While the 12-cell system offers the best performance in hydraulic load reduction and pollution treatment, the 8-cell and 6-cell systems are still seen to perform well and may offer more practical solutions for the CBD. Especially if the system is rolled out over a wide area of the CBD street network.
- Hydraulic load reduction is limited by the lined bio-retention units assumed in the study (to avoid possible groundwater risks). Group discussions at the stakeholder workshop suggest that further investigation on this issue is warranted, as important opportunities for stormwater load reduction and groundwater recharge and reuse are potentially being missed.
- The 8-cell system is selected for further testing at a catchment scale, but a wider range of trials would be warranted if this type of solution is to be considered for implementation.
- Although the bio-retention units offer high performance in treating sediment, it is suggested that a dedicated sediment trap be included in the treatment train to allow easy maintenance and ensure longer-term performance of the bio-retention facilities.

3.5.2 Water reuse

The MUSIC model simulations predict a mean annual runoff yield of 430kl. There is potential for stormwater harvesting tanks to be introduced into the treatment train. This may be best applied in the 6-cell and 8-cell systems where almost 60% (260kl) and 50% (215kl) respectively of the stormwater runoff passes through the treatment train (**Table 8**). This would offer similar benefits to small volume rainwater harvesting systems and provide a source of water during the wet season.

A more optimal reuse solution would be to recharge local groundwater and harvest from there. This already appears to be done through the practice of basement dewatering. Groundwater systems offer a larger storage and more reliable yield throughout the year. This level of reliability will improve the value of the resource (e.g. for rooftop gardening, green roof irrigation, etc.) if water quality allows. However, the concerns of the JRA of geological and groundwater risks will need to be addressed before this can be taken further.

Key outcomes:

- Harvesting from the bio-retention treatment train is possible. It will be equivalent to a rainwater harvesting system where efficiency of harvesting and the regular use of the water are important in making the system cost effective.
- Local groundwater recharge would offer a better solution if stormwater can be safely infiltrated to groundwater and recycled through the basement dewatering programme already in practice. This will also provide a more reliable supply.

3.5.3 Flood reduction

The results in **Table 8** show that stormwater runoff from the street catchment will still be well above natural catchment conditions. This suggests that there will be benefit to reducing flood risk in the Robinson Canal in extreme storm events, but this will be limited without additional SuDS measures (e.g. detention) in the treatment train. Enabling infiltration into the local groundwater will improve the performance of the bio-retention facilities for flood reduction, but it is likely that a detention facility will still be needed.

Key outcomes:

- The bio-retention units will help lower the annual flow in the Robinson Canal.
- It will help improve flood risk in the Robinson Canal, but in extreme rainfall events (e.g. the 2 year storm and greater) additional attenuation will be necessary (though it will be smaller in volume and surface area).
- There is an option to increase the detention capacity of bio-retention units (e.g. a 300mm detention storage depth on the surface of the unit) which has not been tested in this study due to concerns about the safety and aesthetics of such a facility in a public space. This is certainly an option for further investigation.

3.5.4 Heat Stress Reduction Assessment

In the current situation most streets in Johannesburg CBD have very little planting and many streets appear to have no trees at all (**Figure 12**). The idea to convert one of the car lanes into green lanes, providing space for bio-retention cells and trees, is promising for heat stress reduction, particularly because of the trees.

Providing shade is (next to wind) the most important way to reduce heat stress in streets. To provide shade for the pedestrians, it will be best to have those trees and bio-retention cells at the side of the street which is in the sun in the early afternoon, as that is the hottest time of day. Dependent on the orientation of the street, the other side will then already be in the shade of the buildings.

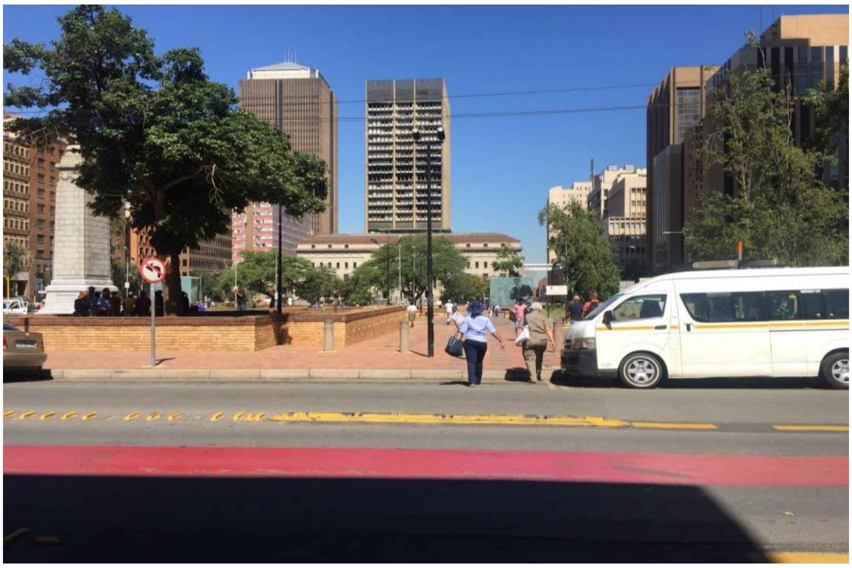


Figure 25: Example of walking area with trees already in place, but which offer limited shade

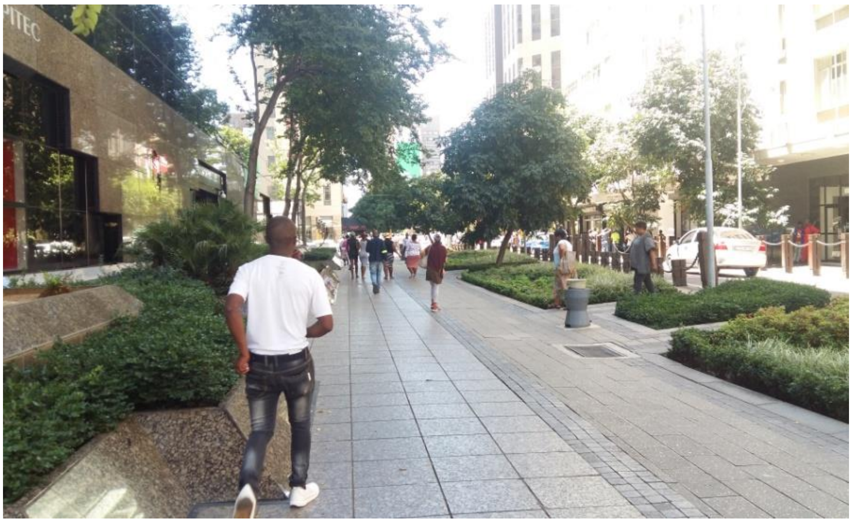


Figure 26: Example of walking area with trees and buildings providing shade,

Figure 27: Example of walking area with trees providing shade

Figure 25, **Figure 26** and **Figure 27** give examples of streets in the study area with trees that provide limited shade, also because of the position they are planted. The design of green lanes should focus on providing shade with leaf cover, the type of which should be carefully considered. Pergolas with climbing plants can also provide shade, but the climbing plants should be sufficiently robust and drought resistance to endure in the CBD environment.

The effect of evaporation of one lane of bio-retention cells and trees has only little effect on the comfort temperature in that street. In fact, providing shade is roughly 5-10 times more effective than providing evaporation by plants for reducing daytime heat stress.

As for surface temperature effects, green stays by definition cooler than darker tar, but the difference with greyer (older) tar and pavement is less obvious.

As explained in the section on green roofs, for reducing the average temperature over several blocks, evaporation is important. If there is lots of green over several blocks that transpires sufficient water, then the cooling effect will be noticeable.

Thus, the design of street lay-outs in such a way that pedestrians can walk or wait for public transport or rest in the shade of trees or buildings at the hot hours of the day is a sensible way of reducing heat stress. The pathways many people follow should have priority. Furthermore, well maintained green makes these pathways more attractive for walking.

Figure 28: Example of person carrying umbrella against the sun and bus stops providing very limited shade

3.6 Performance Summary – SuDS Measures at Catchment scale

The location of the study catchment is presented in Section 3.3 (**Figure 20** and **Figure 21**). The simplified layout in the context of the Robinson Canal is shown in **Figure 29**. A breakdown of the sub-catchment areas is summarised in

Table 9. The entire catchment area is 43.4ha and a total of 5.8ha (13.4%) of the study catchment is treated by SuDS measures. As indicated in Section 3.3, this would be a relatively low target for SuDS implementation.

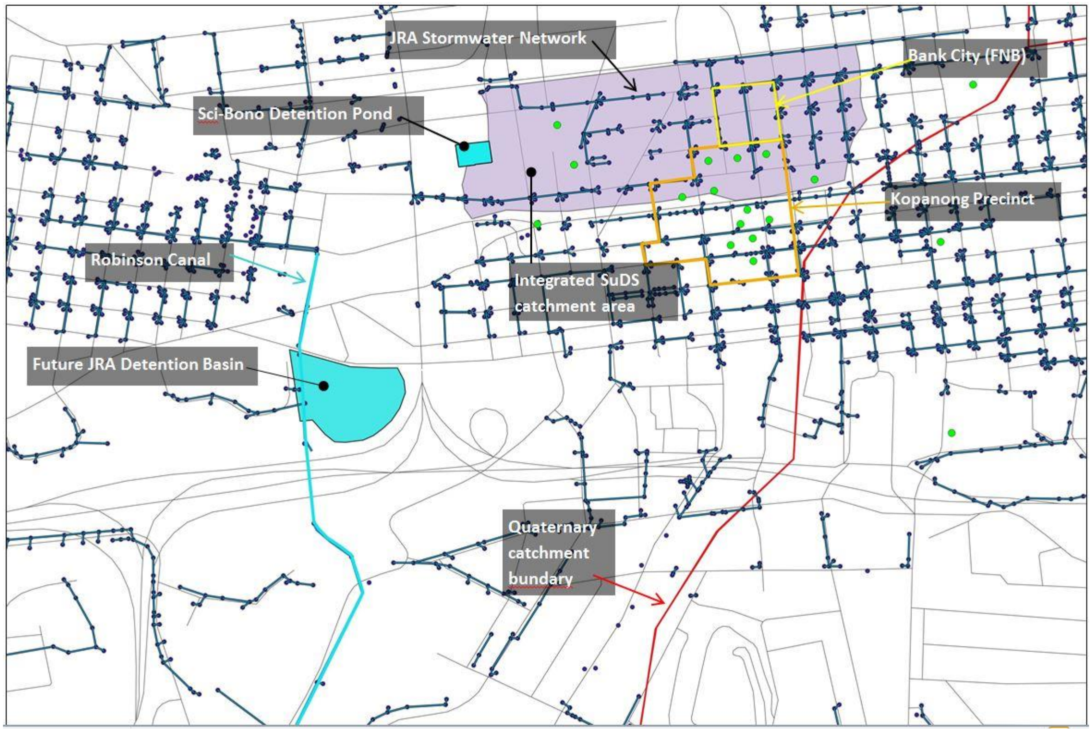


Figure 29: Integrated SuDS catchment area

3.6.1 Quantity and Quality Benefits

The main performance results are summarised in **Table 10**, **Table 11**, **Figure 30** and **Figure 31**.

Table 10 shows that converting 30% of the suitable roof areas into green roofs could reduce the overall hydraulic loading on the catchment by around 10%. The performance of the street bio-retention treatment train is less impressive. The street contributes 3% to the overall catchment yield, but reduces less than half of this (1.2%). **Figure 30** and **Figure 31** show this is because the lower bio-retention units become increasingly overloaded. Catchment runoff combines with overflow (Orifice out plus Weir out) from the upstream unit. This points to the need to progressively increase the size of the bio-retention units along the treatment train, or to increase the losses from the units by allowing exfiltration into the local groundwater, or a combination of the two.

Table 9: Sub-catchment data for the urban catchment analysis.

id	Area (ha)	No. of green roofs	No. of street bioretention cells	Area captured by green roof (ha)	Area captured by bioretention cell (ha)	Area of sub-catchment directed to Detention basin (ha)
1	2.3372	0	0	0.156	0	2.181
2	1.3265	0	1	0.156	0.101	1.070
3	2.9986	2	0	0.536	0	2.463
4	2.892	1	0	0.346	0	2.546
5	1.286	0	2	0.156	0.202	0.928
6	2.8984	0	0	0.156	0	2.742
7	2.8406	2	1	0.536	0.101	2.204
8	4.3256	3	0	0.726	0	3.600
9	3.8087	0	0	0.156	0	3.653
10	6.2164	2	8	0.536	0.808	4.872
11	4.3559	2	0	0.536	0	3.820
12	3.8748	1	0	0.346	0	3.529
13	4.2472	0	1	0.156	0.101	3.990
Total	**43.4079**	**13**	**13**	**4.498**	**1.313**	**37.597**
SuDS areas		**1518m^2**	**60m^2**	**1.9734 ha**	**0.078 ha**	
Hydraulic loading ratio (1:X)				**2.28**	**16.8**	

Table 10: CBD catchment analysis. Separating performance of in-catchment SuDS and the detention basin.

System	Runoff (Ml/yr)	% of total	% overall reduction
Total impervious outflow	253.7		
Roof runoff to green roof	28.1	11.1%	
Green roof bio-retention outflow	2.4		10.1%
Street runoff to bio-retention filters	7.6	3.0%	
Street bio-retention filter outflow	4.6		1.2%
Urban outflow (direct to detention basin)	218.0	85.9%	
Combined Detention Basin inflow	225.0	88.7%	
Detention Basin outflow	219.7		2.1%
Overall reduction in flow			13.4%

Table 10 also demonstrates the limited role the detention basin has in reducing the hydraulic load on the system. This is because almost all the stormflow passes through the basin as no exfiltration is allowed and the detention times are not long enough for evaporation to make much difference.

Table 11 shows the relative pollution treatment performances of the SuDS (green roof and street bio-retention) and the detention basin. The detention basin plays a more important role as it receives the greatest amount of untreated runoff (almost 90% of the catchment runoff) and the detention times are long enough to remove a large proportion (74%) of the sediment (TSS), half of the phosphorus (TP), but only a quarter of the nitrogen (TN) loads.

The low contribution of the other SuDS systems is in large part representative of their small sub-catchment areas and the poor performance of the street bio-retention treatment train.

Table 11: Comparison of performance of SuDS treatment zones with Detention Basin

Type of efficiency	Efficiency
Hydraulic	
SuDS HYDRAULIC LOAD REDUCTION (%)	11.3%
DETENTION POND LOAD REDUCTION (%)	2.0%
OVERALL HYDRAULIC LOAD REDUCTION (%)	13.3%
Total Suspended Solids	
TSS SuDS REDUCTION (%)	6.6%
TSS DETENTION POND REDUCTION (%)	74.2%
TSS OVERALL REDUCTION (%)	80.9%
Total Phosphorus	
TP SuDS REDUCTION (%)	7.5%
TP DETENTION POND REDUCTION (%)	52.2%
TP OVERALL REDUCTION (%)	59.8%
Total Nitrogen	
TN SuDS REDUCTION (%)	9.9%
TN DETENTION POND REDUCTION (%)	24.0%
TN OVERALL REDUCTION (%)	33.9%

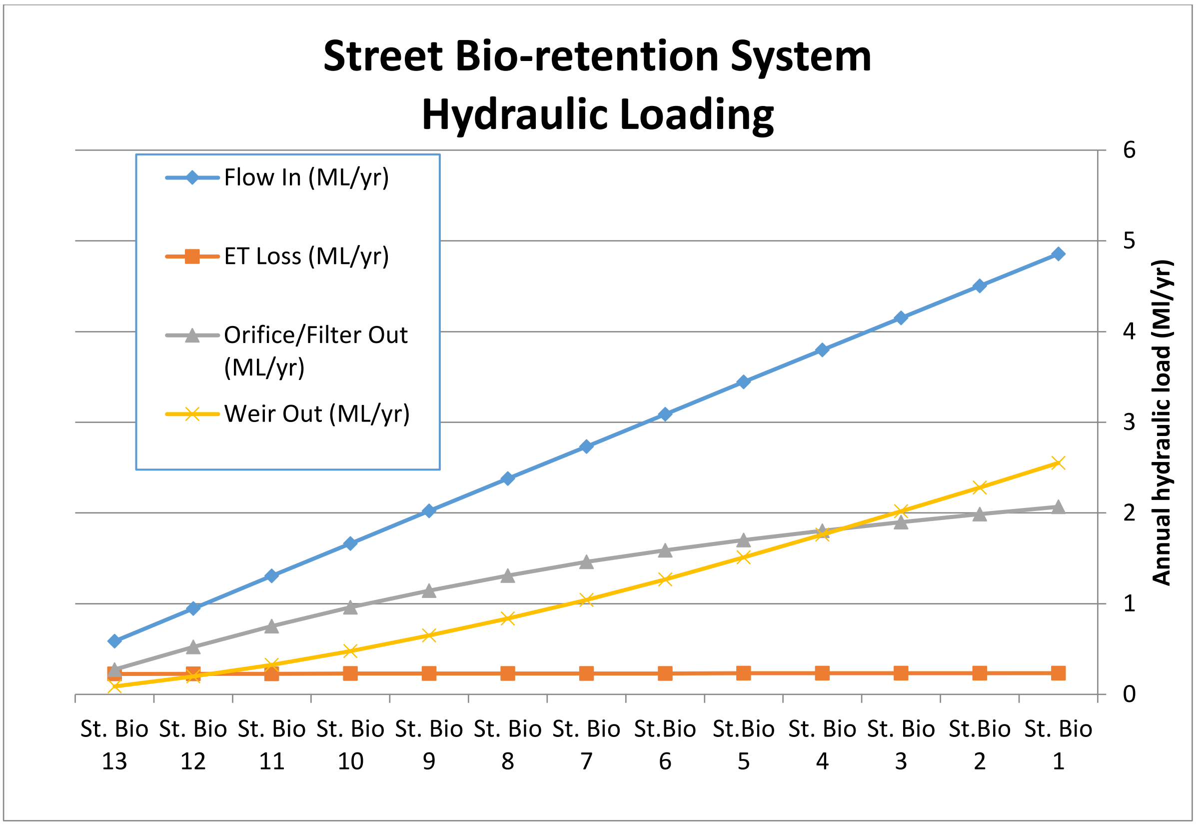


Figure 30: Increasing hydraulic loading along Street Bio-retention treatment train

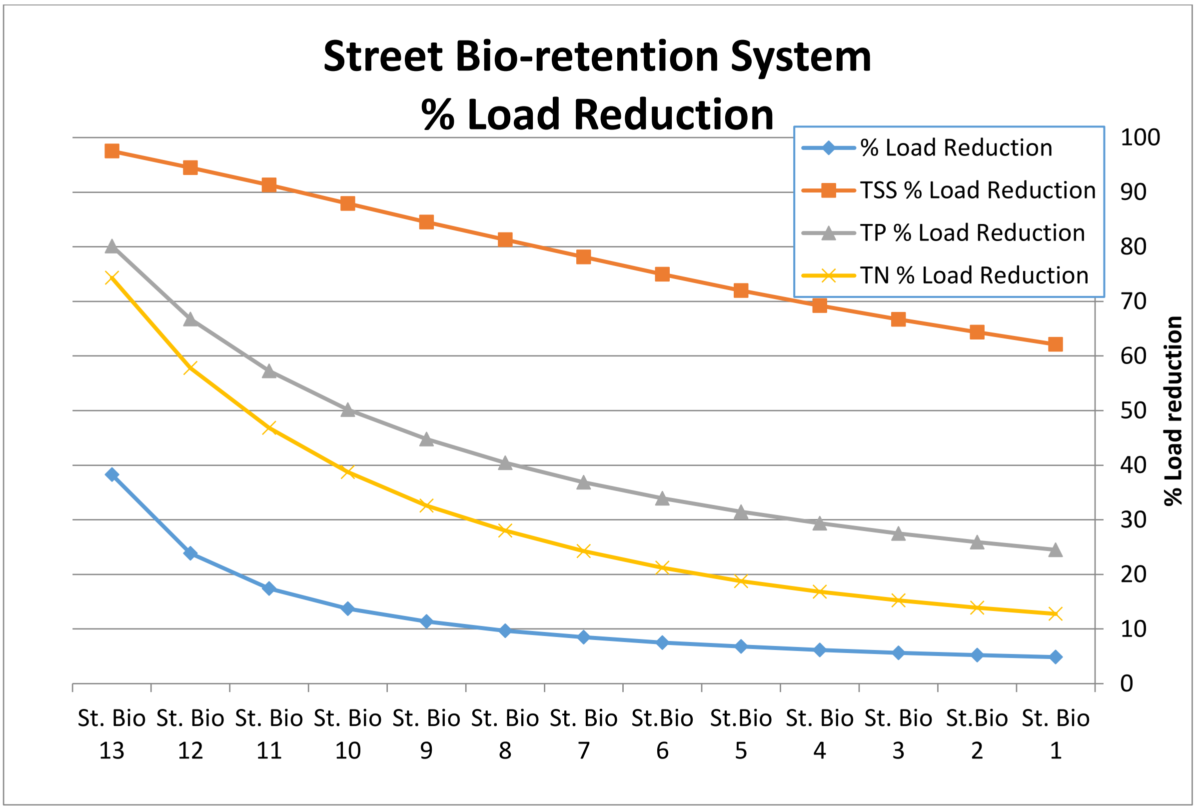


Figure 31: Decreasing treatment performance along Street Bio-retention treatment train

Key outcomes:

In a focussed planning exercise to develop the scope and optimisation of a SuDS implementation guideline the simulation presented here would be among the first of a number of trials to test the potential of combinations of options, and address questions arising. Hence there are typically many questions left at this stage, but some of the main points are seen as follows:

- The greater the area being treated by SuDS within a catchment the better the potential for achieving meaningful outcomes. The 13% of the catchment area under a form of SuDS as in this case study is considered too low. One of the next trials would be to consider something like 30% of the catchment draining to a SuDS facility.
- Retention is critical, and of the three main forms of retention (evaporation, infiltration and reuse) only evaporation was studied as infiltration was not wanted reuse was not the focus. This places greater emphasis on the surface area which, in an inner city environment, will always be limited. This is why the green roof solution has been relatively successful. If evaporation remains the main method of retention, then the importance of green roofs will significantly increase in any strategy for stormwater management in the CBD area. However, before then, there should be more critical analysis of the other two.
- The hydraulic loading of successive units in a treatment train needs careful planning. Guidelines such as loading ratios (1:X) may only be suitable for the upper sections of a treatment train, or for applications of a single SuDS facility in a catchment. Continuous simulation is an important method for analysis of SuDS units in series.

3.6.2 Water reuse

Water reuse is mentioned above as one of the means of retaining stormwater within a catchment. Opportunities for reuse have been explored in previous sections, including the availability of basement dewatering which is another important water resource that is under-utilised. A water balance analysis will help identify the potential for reuse in the CBD area.

The combination of stormwater resources and groundwater resources could make the CBD catchments water positive (more water is generated than can be used in the same area). The 5½ year MUSIC simulation suggests the average annual stormwater runoff yield is of the order of 250 Ml/yr. Assuming 10% of this would be needed for environmental flows (i.e. similar to pre-development catchment runoff), this leaves 225Ml/yr for harvest and reuse. Storage would be a challenge for such volumes and the groundwater recharge and reuse option could be key to a successful solution.

3.6.3 Flood reduction

The primary flood management element of the treatment train is the detention basin. Rainfall for extreme events (typically the design events used in traditional flood analysis; 2 year through to 100 year events) was determined from the Smithers and Schulze (2002) data set and applied to the SCS method for the catchment. The resulting inflow and outflow hydrographs are presented in **Figure 32** and **Figure 33**. They show a significant reduction in flood peak by around 40% to 50% for the larger events. This should have significant impact on flood levels in the Robinson Canal and should provide some flood relief to the Booysens area.

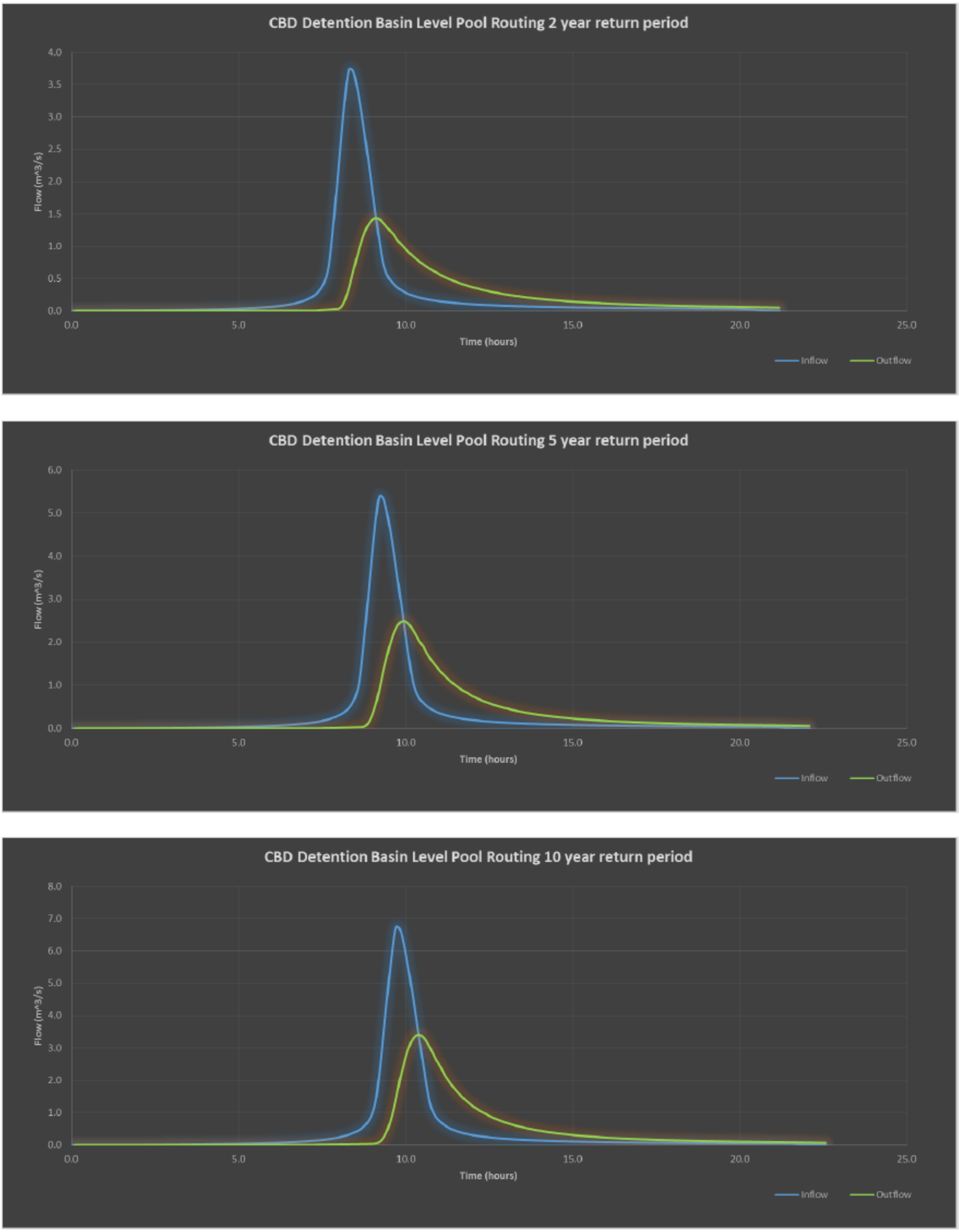


Figure 32: Flood attenuation analysis of the detention basin at the Sci-Bono park; 2 year, 5 year and 10 year return periods.

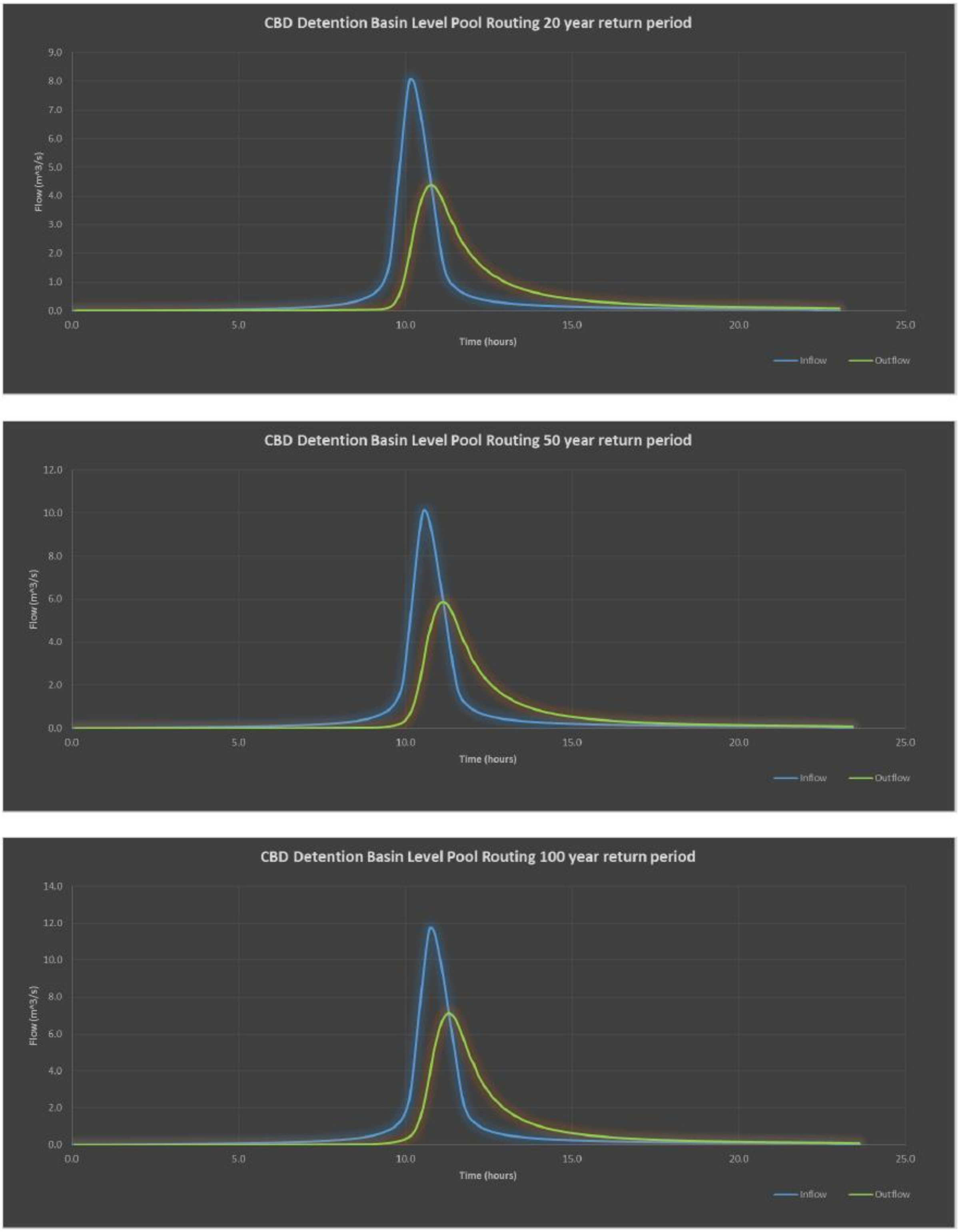


Figure 33: Flood attenuation analysis of the detention basin at the Sci-Bono park; 20 year, 50 year and 100 year return periods.

3.6.4 Heat Stress Reduction Assessment

Where open areas are wet, in the case of retention basins, it needs to be noted that small urban water bodies have hardly any cooling effect on the air temperature. The REALCOOL project (Really Cooling Water Bodies in Cities, Cortesão et al., 2018) found out, via simulation, that the temperature difference at 1.5 m above the water surface was only about 0.5 °C or less in air temperature and 1 °C or less in Physiological Equivalent Temperature (measure of how hot it feels). In the pedestrian areas close to the water bodies the cooling effects were even smaller. Also, water surfaces can be heated up during the day and therewith keep the city at night even hotter than without the water spaces.

Where open spaces are greened with SuDS measures, they should best have sufficient trees in order to provide shading. As mentioned at the street level interventions, this is the most efficient way for cooling. Also, additional green below the trees will help as this provides extra evaporation. Even though the effect of one square meter of green is small on the local air temperature, the greening is important as all the green adds up and contributes to the evaporation, which can create new micro-climates at the level of several blocks, as described also above.

In designing the open spaces, it might be necessary to think about openness for cool breezes. In the countries with high humidity and high temperatures this is a very important way to reduce heat stress. However, in the specific Johannesburg CBD, humidity is relatively low during the hottest period of the day, generally below 50%.

3.7 Recommendations

3.7.1 Stormwater management

Although the analysis of potential at the sites would benefit from an extension of the modelling trials, there are still key outcomes that will provide useful input to the implementation guideline for SuDS in Gauteng. Among these are:

a. Reuse and recharge options are missing in this analysis yet there are expectations (by stakeholders) that either, or both, could have an important role to play in both stormwater management and water resource management in general in the CBD area. Reuse and recharge options should therefore be further researched, before key decisions on SuDS are made.
b. In the absence of a clear option to recharge groundwater, or a clear plan for reuse, green roofs offer the only real potential for reducing stormwater runoff loading in the city stormwater network, which is one of the key factors affecting water quality in the Robinson Canal. This option needs further exploration, especially as target objectives for the likes of the Kopanong Precinct development.
c. Irrigation of the green roofs, preferably with basement dewatering but potentially with rainwater harvesting, could not only improve the options and sustainability of green roof solutions, but will offer greater building-top cooling.
d. Although the trial for street level bio-retention systems did not show the performance hoped for, there are options for improvement that warrant further testing. This includes testing a range of sizes to counter hydraulic overloading in the treatment train.

e. The detention basin was seen to perform well in the catchment trial, both in terms of treatment and flood attenuation. The practicality and acceptability of this system needs to be tested with stakeholders.

3.7.2 Heat stress management

If SuDS design considerations increase the presence of trees and their shadow effect, this is the most effective measure to reduce daytime heat stress in the streets. Green roofs can be considered, for their multi-benefits including heat stress reduction for those residing on the green roof, or on the floor below (insolation). SuDS such as retention basins that create open water should be very large to have any local effect. However, to reduce heat stress, greening of the City is essential, as then another micro-climate can be created and overall average temperatures can drop. The drop of temperatures at street level however is still also dependent on local circumstances including but limited to the type of street paving, building form and albedo effect.

Case studies in Europe show that there, the benefits of green generously compensate for the additional cost of soft landscaping (investment, management and maintenance). The annual benefits (including an estimate for health and comfort) could be a higher than the equivalent annual retrofitting costs (Kluck et al., 2017). The profit would not benefit the municipality that bears the costs directly, but it would benefit the community as a whole.

3.7.3 Adapting the urban space

The CoJ's policy provides clear direction in terms of the role that our public space network including the road network must play into the future. It is against this that landscaping interventions within the street network that incorporate planting, roof gardens and the softening of public spaces is supported.

Planting within the public street network can provide visual relief. As discussed in section 3.5.4, planting can lower surface and air temperatures by providing shade and evapotranspiration and can improve air quality.

Businesses, especially retail and hospitality outlets at ground level benefit from streets that incorporate planting, as they encourage the public to walk, to experience what is on offer and to extend their stay in the area. This has been demonstrated in cities all over the world. When it comes to residential developments, there is also a demand for quality outdoor space.

A further advantage of incorporating planting into street space, is the role it can play in structuring sidewalks and addressing safety of pedestrians. Landscaping along the kerb line can be used to create a buffer between the roadway and the pedestrian realm. This has been used successfully all over the world and is recognised in the *Complete Streets*[1] guidelines as an important strategy to achieving more pedestrian friendly streets (CoJ, undated).

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[1] Complete Streets refers to an approach to street design and operations that acknowledges the needs of a full range of street users including pedestrians, cyclists, motorists and transit riders of all ages and abilities. Its aim is to improve the safety and the comfort of the more vulnerable users in particular. The strategies acknowledge the importance of landscaping in the making of more people friendly spaces bearing in mind the fundamental role of streets as both movement networks and agents of social cohesion.

While permeable surfaces (and therefore planting) are not appropriate everywhere due to the subsurface conditions, the surface can be shaped creatively to accommodate special events, recreational activities (roller skating, amphitheatres etc.), markets and trading as well as attenuation. In areas such as the CBD, where space is at a premium, this should be a standard approach to design of all open spaces.

The location, form and type of planting will obviously have influence on how the street space is used. Street spaces generally benefit from low level planting in beds or boxes in combination with trees. This allows sight lines at eye level to be maintained. Furthermore, the type of planting is critical to the performance of the street spaces and buildings lining the streets as it can address challenges presented by urban micro-climates. Deciduous trees and vines for example are optimal along north facing facades and can benefit ground floor businesses that rely on using the sidewalk as an extension of their premises through the seasons. In open hot spaces, trees with canopies that offer shade all year around are optimal. Vertical planes of planting and water features can also add to the feeling of being cooler. Where planting is combined with seating and carefully considered lighting, the amenity value increases considerably as the streets can provide space for people to relax, socialise and recreate.

Roof gardens can provide benefits for residents and employees in the inner city in the form of relief space and social space. Lower roofs and terraces can also provide visual amenity to occupants of surrounding buildings. Roof gardens can be used to produce food and contribute to job creation and income generation.

With Climate Change being a reality that is affecting the cost of operating large buildings and precincts, developers are acknowledging that it is necessary and beneficial to invest in green infrastructure, including SuDS type interventions that can help to reduce operating costs. Large corporations also need to be seen to be addressing the impact they have on the environment.

Large developers and corporations can therefore be persuaded to contribute to upgrading of their immediate surrounds as they understand that it will benefit not only their pocket but their image.

Given the cost of SuDS interventions and landscaping it is therefore appropriate that partnerships between the public and private sectors are explored. The issue of the privatisation of public space and secondly gentrification, will be two of the challenges faced going forward and should therefore inform discussions between potential partners.

3.7.4 Ecological opportunities

The CBD is regarded as having a low sensitivity from a biodiversity perspective, and is located away from sensitive water resources. As such, the importance of enhancing ecological attributes are regarded as peripheral to this site relative to other SuDS functions. Where possible, it would be recommended that locally indigenous flora be planted within the landscaped ‘green spaces’. Such species are able to withstand the extreme climatic conditions prevalent in the Johannesburg CBD, and would provide habitat for tolerant animal species in an otherwise hostile and ecologically fragmented landscape.

3.7.5 Community opportunities

Stakeholders can be mobilized partly through existing initiatives - The Klip Water Stewardship Initiative is a community and professionals driven initiative that is mostly interested in the impacts of the Robinson Canal, to which the study area drains, on the downstream section of the Klip River. The JICP is an organisation of property owners in the CBD. Together they can mobilize key stakeholders. The momentum created by regeneration of certain innercity precincts, also provides the perfect opportunity for introduction of SuDS.

If there is a business case for investment in SUDS related landscaping, property owners would be interested – The representative of OPH properties as well as the entrepreneurial developer of WIBC confirmed that if government would support studies to determine the business case and requirements for property owners and entrepreneurs, this would help in getting the investment going.

Learning from existing Living Labs - In the Jukskei upper catchment, citizens together with artists and designers are already implementing and testing new ways to improve on water quality and more natural flow levels. The Jukskei Watershed and River Regeneration Project, which is part of the Eco-districts work supported by the City of Johannesburg, (original Soweto Grasslands of the area before urbanisation) are mimicked to absorb downpours. (Contact: www.hanneliecoetzee.com)

3.7.6 Maintenance & Management

All drainage systems need maintenance. Lack of maintenance is one of the primary causes of failure of SuDS facilities globally. In South Africa there are many challenges related to the issue of maintenance. Stormwater infrastructure in particular suffers from poor maintenance largely because they are seen to be low priority assets, and budget allocations are limited.

Good design of SuDS treatment trains can improve the maintainability of treatment trains. Selection of SuDS technologies will be an important part of successful maintenance, including the following recommendations for applications in Gauteng:

- Dedicated sediment management must be considered at the most upstream points on all treatment trains. Sediment traps are most likely to be the most frequently inspected and maintained parts of the system. For this reason, it is recommended that the sediment trap is always a separate unit (e.g. rather than a forebay) from the other SuDS facilities, that it is more hard engineered to allow for mechanical cleaning, and that a dedicated sediment storage capacity is provided in addition to the settling volume.
- Maintenance activities are clearly planned and included in the design. This includes an understanding of whether manual labour or mechanical cleaning will be required, the volumes and type (e.g. sediment, cut vegetation) of material to be moved, and any contamination hazard.
- Access to all SuDS facilities is provided for, ensuring enough space (and load capacity) for the machinery, workforce, stockpiling, etc., necessary to clean the site.
- Safety and security aspects are provided for. This will include access systems (steps, ladders, safe gradients), emergency exit routes, depth of wet zones, contamination, etc.
- Structural stability of inlet and outlet structures need to be designed for. This will include both hard engineered (e.g. concrete) and soft engineered (e.g. berms) parts of the system.

Research by the GCRO (Culwick and Bobbins, 2016) into the implementation of Green Infrastructure in Gauteng highlighted obstacles in municipal institutional structures as being a key risk factor for maintenance. The nature of SuDS facilities, having strong biodiversity and amenity functions, means that interdepartmental cooperation would offer the best solution for maintenance and monitoring. This would require the likes of the Parks department working with the Roads & Stormwater department. Current institutional structures and budgeting processes can make SuDS difficult to implement, administrate and operate.

Discussions with stakeholders during the study identified three key points in relation to maintenance:

- Maintenance is a job creation opportunity and will require a wide range of skill levels.
- Community based initiatives are proving effective in managing systems within their space and may be a more cost-effective and reliable way of ensuring the sustainability of SuDS stormwater systems (in fact all stormwater systems).
- There was a view that society in Gauteng should stop expecting municipalities to perform basic functions such as maintaining infrastructure.

4 EKURHULENI, BONAERO - ATLASVILLE

4.1 Study area description

The study area is a combination of natural pans and a wetland system located between the suburban areas of Bonaero Park and Atlasville, in the northern region of the City of Ekurhuleni. The immediate surrounds of the site is largely residential land use but the wider catchment area includes a mix of light industrial, industrial and commercial areas, as well as the OR Tambo International Airport (**Figure 34**). As explained in the introduction, the suburban Bonaero-Atlasville study area in Ekurhuleni was selected because of its strategic importance for flood management and the significant conservation value of the site, as well as its heterogeneity. As shown in **Figure 34**, there are three different pans with an adjacent wetland areas in the study area, each pan having different influences. The study area two northern pans are part of the Aero-Blaaupan Precinct (GAPP, 2018) within the bigger plans for the Aerotropolis of Ekurhuleni (See further 4.1.2) which plans a freeway PWV 15 through the wetland. This makes that the results of this case study analysis can potentially be used further. However, this study itself focused on improving the current functioning of the pans using SuDS and is not part of the planning process but meant to analyse case studies to provide contents for an implementation manual for SuDS in Gauteng. Interest in the study area centres on how the ecological functioning of the pans may be supported by SuDS interventions, and whether the priority of the ecological functioning of the study area itself may have higher order priority than the water quantity and quality priorities proposed by Armitage, et al (2013).

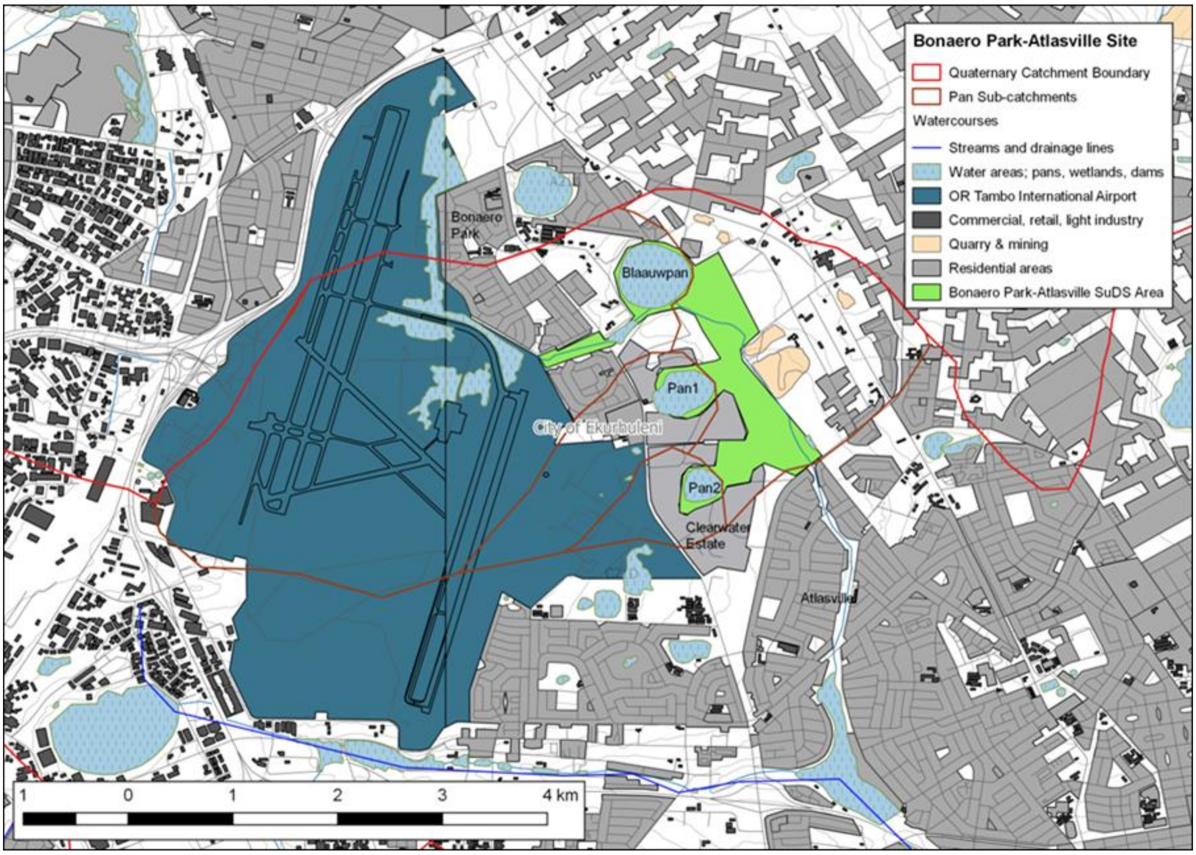


Figure 34: Total Study Area with focus on three southern pans and bright green marked area of wetlands and channels around it.

The pans and wetland lie in the catchment of what has become known as the Atlaspruit, a tributary of the Blesbokspruit in quaternary catchment C21D of the Vaal River system (see **Figure 2**). The catchment of the study site forms part of the watershed between the Vaal and Limpopo catchments.

The field notes for the study area are presented in **Annexure 3**. Although the site is in a heavily urbanised environment, it presently has important ecological, amenity and stormwater functions. Although the stormwater functions are aligned with the principles of SuDS, the inter-relationship with the ecological and amenity functions are not formally established. This could be a situation where the priorities of quantity and quality are subordinate to those of the ecological and amenity values of the site. The key features of the site are summarised in **Table 12** and **Figure 35**.

Table 12: Key features of the Bonaero-Atlasville SuDS study area

Feature	Approximate gross area (including margins)
Blaauwpan	40 ha
Pan 1 (Middle Pan/Parkhaven Pan)	18.9 ha
Pan 2 (Clearwater/La Como Pan)	15.6 ha
Wetland	113 ha
Total area	187.5 ha

Figure 35: Key features of the Bonaero-Atlasville SuDS study area

Blaauwpan

Figure 36: Images of Blaauwpan.

The pan is altered from its natural state. It has permanent standing water with a formal spillway inlet and sluice gate outlet. The park is the dominant feature of the Pomula Park Nature Reserve and is currently used mainly for picnic and fishing recreational activities. It is listed as under the list of "things to do" in Kempton Park (e.g. https://www.property360.co.za/news/places-of-interest-and-things-to-do-in-kempton-park-11240209), and recreational activities and notices for accommodation (e.g. Air BnB) in the immediate area are still advertised online (as at June 2019). The park has reportedly been under offer for private purchase but all except a small area of the north-east portion of the pan is currently still in municipal ownership. Also in municipal ownership is the strip of land between the pan and the airport boundary.

The history of the establishment of the pan in its current form is not known. Reports of early quarrying activities are not confirmed. The construction of the formal sluice gate outlet control implies intent to manage water levels artificially, perhaps for recreational purposes. The direct connection of the pan to the stormwater system of the airport would have increased the yield to the pan, changing the natural hydrological balance and enabling more permanent water retention. The direct link to the airport has also had pollution consequences. Spillages of jet fuel from the OR Tambo International airport occurred a few times in the mid 2000's (see **Box 2**) leading to severe hydrocarbon contamination in the pan. There has seen some intervention in the inlet channel to enable emergency containment of hydrocarbon pollution, but the capacity of the works (concrete lining and low inlet weir) seem small in contrast to the reported spill volumes (see **Box 2**). There is reportedly a large fuel separator on-site at the Airport designed to cater for the 100 year flood (**Annexure 6**). Other pollution risks include sewage effluent from local networks, most recently a leaking sewer line on the east of the pan.

Box 2: Fuel leak drama heads to court (News24 of 8 November 2006)

'Charges of criminal neglect are being planned against Airports Company South Africa (ACSA) and criminal charges against its executive head and the mayor of Ekurhuleni after Tuesday's massive aviation-fuel leak at OR Tambo International Airport. It is estimated that between 500 000 and a million litres of fuel leaked into a storm-water drain at the airport and Blaauw Pan, a protected wetland about a kilometre downstream. There have been two previous leaks - in July last year and September this year. Conservation organisations described Tuesday's spill as an environmental disaster. Waldimar Pelser reports that ACSA became aware of the situation at 05:30, but residents from nearby Bonaero Park told Beeld the stench drifting in from the airport woke them about 03:00.

Tuesday's spill was about three times as big as the leakage six weeks ago, when about 200 000 litres seeped from a burst fuel pipe. Nicole Barlow, chairperson of the Gauteng Environmental and Conservation Association, said at least half a million litres and maybe as much as a million litres of fuel was spilt on Tuesday. ACSA spokesperson Solomon Makgale said they complied with international safety standards and it was not yet clear how much fuel had been lost. Beeld reports that the department of water affairs and forestry called an emergency meeting with ACSA on Tuesday afternoon. The deputy director of water quality management, Marius Keet, said legal steps were being taken against ACSA after the September spill and Tuesday's giant leak would be added to the charges. If negligence was proven, ACSA would be prosecuted. ACSA said it had launched its own investigation. The law compels the authorities and managers to take steps to ensure that water remains potable. Barlow said in a statement that the spill in July last year was possibly an accident, the second in September was "blatant neglect" and the third was "criminal".

[Source: http://www.klasslooch.com/news_z.htm, Accessed June 2019]

The current ecological state of the pan has not been recently verified, although spatial databases such as NFEPA and others have awarded it with a PES class of 'C'. Despite the pollution events there appears to have been recovery to some degree of ecological health. The pan remains to be a popular sport fishing site in the region (mainly carp and bass), and the pan is promoted as a good bird watching location.

Pan 1 (Middle Pan)

Of the three pans in the study site this is the one apparently closest to its benchmark ecological conditions. Development around the pan has sought to balance its use as a stormwater management facility and its ecological value. As a result, a Section 21 company has been formed by land owners surrounding the pan and the company hired an ecological consultant to monitor and manage the pan. Land owners use on-site attenuation to manage stormwater discharge which then discharges to a bioswale that has been established around the pan. In addition, Toyota uses a localised wetland system between their attenuation facility and the bioswale to further treat stormwater. The bioswale and wetland treatment system are established around the margins of the pan. As a result, standing water in the pan is generally fairly temporary and seasonal, with the exception of a small area of previous excavation disturbance in the middle of the pan. Maintenance of the pan by the Section 21 organisation includes regularly cleaning the bioswale, testing the water quality, keeping alien invasive vegetation at bay (removal of exotics every two months) and addressing illegal dumping.

Figure 37: Images of Pan 1 (Middle Pan)

The bioswale is similar in design to a rock-filled filter drain (**Figure 38** and **Figure 39**). It reportedly varies in depth from around 0.5m to 2m deep. It encourages infiltration of stormwater runoff from the surrounding developments for storm events less than the 5 year return period (Bigen Africa, 2006). In addition to stormwater attenuation, a primary objective is to reduce pollution loads entering the pan. This is seen to be a good example of SuDS in action. It was understood from the stakeholder consultation meeting that there is no formal discharge from the pan to the adjacent wetland to the east, but the concept of 2006 presented in **Figure 38** indicates that discharge will occur in larger storm events. In interesting point in the development of this concept was the intention to divert the more polluted 'first flush' of the larger stormwater events to the neighbouring wetland in an attempt to protect the pan.

There is still development pressure on the pan, with planned development on the north-eastern banks being planned. Partial services have already been installed. Wetland delineation studies have been done (see Enviross, 2015a), but the proposed stormwater management plans appear to follow a common grey infrastructure approach with an attenuation pond placed in the wetland buffer zone. It is assumed to be an unlined pond (therefore offering opportunity for infiltration), but no other provision for SuDS is evident. On the information available, it is interesting that the 2006 stormwater design for the pan is much more in line with the principles of SuDS than the 2015 design.

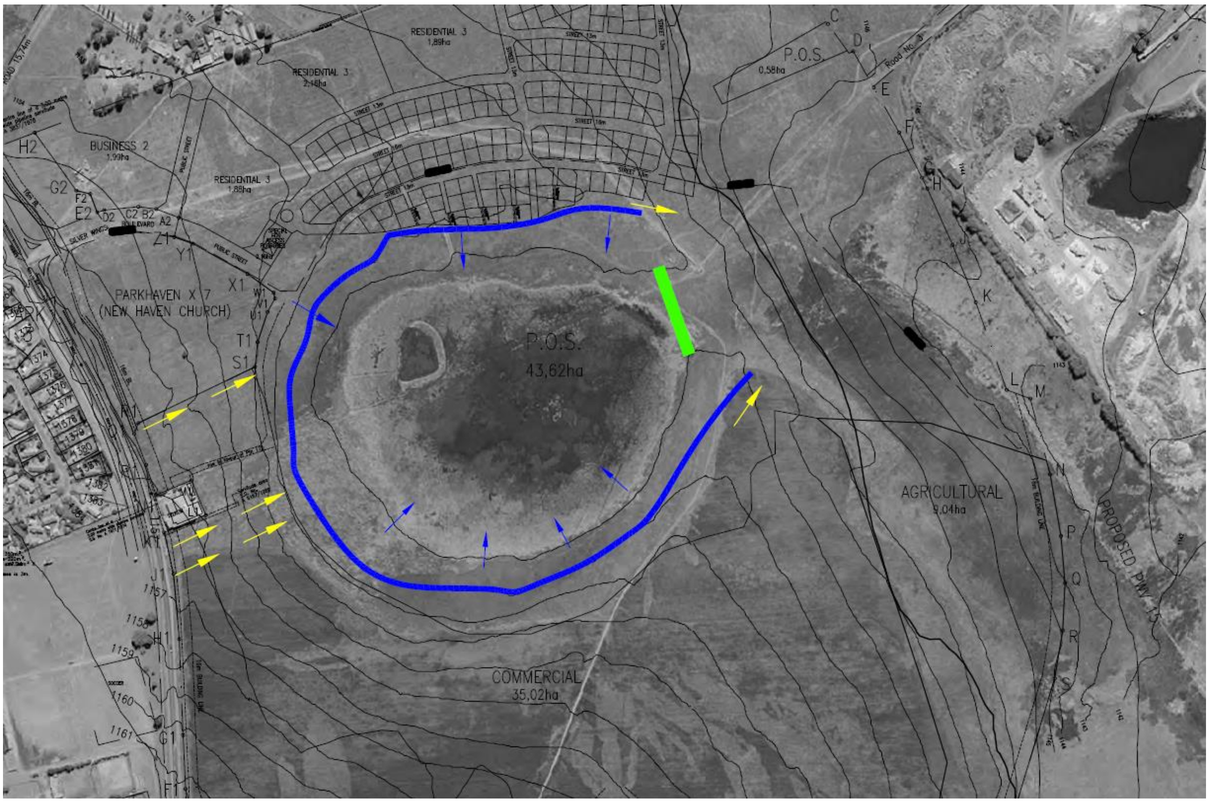


Figure 38: Early concept of the bioswale at Pan 1 prior to development around the pan. (Bigen Africa, 2006)

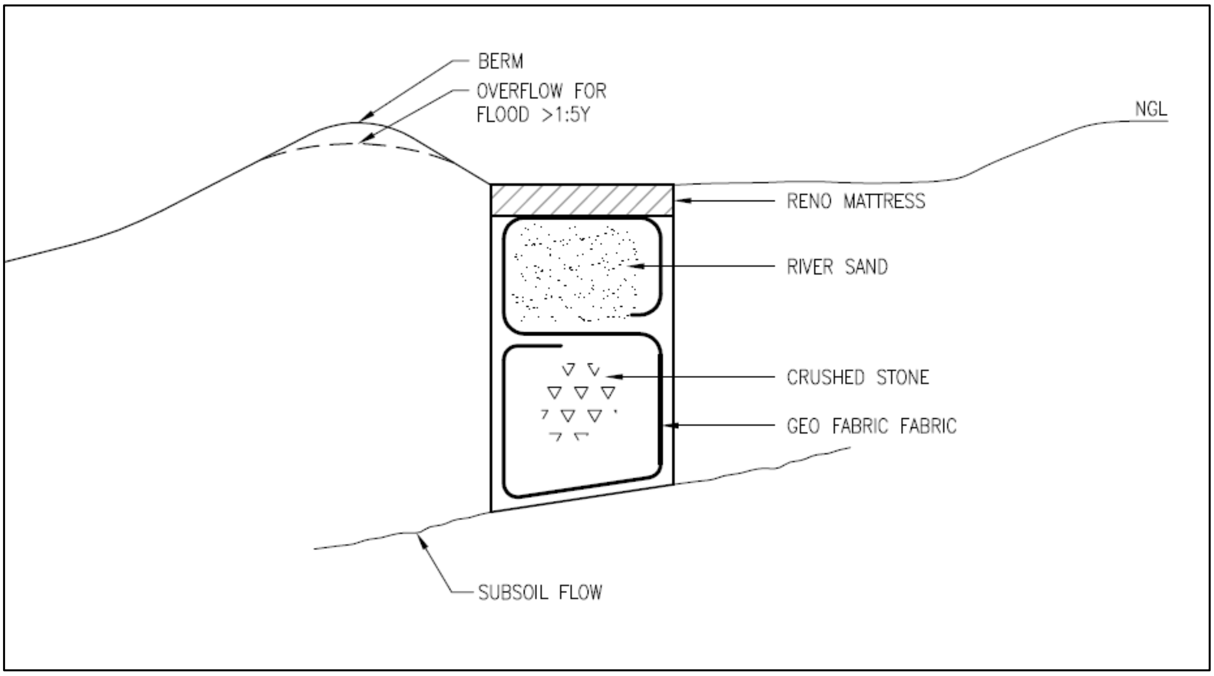


Figure 39: Design of the bioswale. (Bigen Africa, 2006)

Pan 2 (La Como Lifestyle Estate/Clearwater Estate)

The hydrology of the pan has been altered by catchment development. There is now permanent standing water in the pan, though seasonal fluctuations will see water levels drop by about 1m in winter. The pan performs an attenuation function although the details of the intended performance are not available at the time of writing. However, it is reported that water levels in the pan typically return to normal a day or two after storm events.

The pan is incorporated into the landscape of the estate (**Figure 40**) and is managed as a feature of the development. The estates surrounding the pan are satisfied with the current status of the pan, therefore the need for SuDS interventions is limited. Properties closer to the pan attract higher prices than other properties in the estate. The new developments at the Denel site and along Brentwood Park could impact stormwater management and could form a window of opportunity to introduce SuDS.

Figure 40 Pan 2 at La Como Lifestyle Estate.

Wetland

The wetland is a valley bottom system is estimated at over 100ha (see **Table 12**). It receives surface runoff, and potentially important sub-surface runoff, from the three pans to the north and west as well as agricultural holdings and a mine to east. The wetland is estimated to have lost approximately 40% of its original area since the 1970's due to land development pressures. In addition to the more recent land development around the pans, the wetland is subject to future PWV15 east-west highway and K86 road development scheme that will cut across large parts of the remaining wetland. Despite this, the wetland is still seen to be an important ecological resource (see Section 4.1.3 below) and it provides important attenuation and water quality benefits to stream flows (Section 4.1.1). It is also seen to offer important amenity and recreational benefits to the local communities (Section 4.1.2). Together with the pans, the wetland presents an unusually large green system (almost 200ha, **Table 12**) that poses interesting questions about the approach to planning SuDS interventions.

Figure 41: Images of the Wetland in Bonaero Park - Atlasville

4.1.1 Stormwater context

Repeated flooding of residential properties in Atlasville starting in 2006 initiated an investigation into the causes which included a detailed assessment of the flood hydrology of the catchment. Atlasville forms the southern border of the wetland in the study area (see **Figure 35**). It was developed in the late 1970's and into the 1980's and had seen no significant flooding until 2006. The flood assessment identified a number of problems, but it noted the increasingly developed catchment area over time and the particular role that the pans and wetland system played in mitigating the effects of this development. As has been shown, all of the pans are used for stormwater attenuation to some degree, and all discharge into the wetland which provides further attenuation and water quality treatment. The resulting Altasville Flood Relief Scheme, completed in 2013, was designed on the premise that the upstream systems of wetland and pans would continue to perform the flood management function.

4.1.2 Planning context

The site is surrounded by a range of different land uses including high end residential estates, commercial office parks, industrial parks, community uses, high density and suburban residential development, nature reserves, a quarry and wetlands. The area is clearly desirable from an investment perspective given the large industrial giants who have located along Atlas Road recently. The area in which the site is located also includes a significant quantity of vacant and underutilised land especially in the Brentwood Park area.

The biggest challenge of the site and surrounds from a planning perspective is that none of the developments interface with the main wetland system positively. Most turn their backs on the wetlands. This creates a condition in which people are unwelcome and unsafe. In a few cases developments face on to the pans under discussion. Investment in the wetland to increase its amenity role would add value to the adjacent land, and developments on the adjacent sites would contribute to the performance of the wetlands as an amenity by making it safer. Private developers could also potentially help to manage the wetland space in partnership with the local authorities in the future.

The other main planning challenge of the site and its surrounds is that there is no clear legible movement system connecting the various development precincts located adjacent to the wetlands and pans. The area is defined by a higher order ring road that provides access for cars and pedestrians into the various precincts from the external road network, but the wetland prevents any movement between the western and eastern sides of the wetlands. Pedestrians do cross the wetlands informally but there is a real need to formalise some of the paths to support the obvious desire for pedestrians to move across and down the length of the wetlands. The current paths crisscross the space allowing the sensitive vegetation and habitats to be disturbed and in some places severely compromised due to dumping, fires etc. This is clearly something that needs to be addressed in the future.

Due to the sites strategic location adjacent to the OR Tambo International Airport it is the subject of precinct planning. The Aero-Blaauwpan Precinct: Detailed Development Framework, 20 April 2018 (Final Draft) prepared by GAPP Consortium (GAPP Consortium, 2018) has resulted in the compilation of a Detailed Development Framework which looks at the development opportunities in the area in relation to future planned infrastructure and bearing in mind City of Ekurhuleni's (CoE) plans for an Aerotropolis. The site is seen as having great potential to accommodate an Aerotropolis Tech Hub using the vacant and underutilised land to the west and east of the wetlands (see **Figure 42**). Fortunately, the Precinct plan identifies pans and the wetland as a great opportunity to improve and support ecological function, serve as a recreational asset, and provide a high quality public environment. They also make reference to the possibility of using the pans and wetland as green infrastructure. The figure below provides an indication of what is proposed for the site.

Figure 42: Spatial Development Outcome – perspective, extracted from Aero Blaauwpan Detailed Development Framework (Gapp consortium, 2018)

The framework proposes that the pans and wetlands form the central feature within the precinct. "…..to form a regional park and biodiversity system, with passive recreation and leisure activities, including walkways, cycle-ways, picnic areas and parks with play areas. The natural open space system is incorporated into this, improving biodiversity and promoting conservation. This allows for low-impact activities including bird-watching, eco-trails and nature walks. Where appropriate, limited educational and retail activities will be permitted such as a restaurant and information learning centre.

These proposals will be subject to a detailed study and master plan, which is to include a detailed environmental impact assessment to determine development possibilities and establish a precise delineation of the wetland system and open space area" (GAPP Consortium, 2018, p68).

Land Uses planned for the west of the precinct include institutional and hospitality activities in the form of business parks, estates and campuses. Areas to the east of the wetland have been identified for light industrial / business park development with small pockets of mixed use and residential development.

What is of most relevance to the GDARD SuDS project is the proposed PWV 15 highway which will be located down the length of the central wetland. Additional cross routes are also proposed, one of which is provisionally located along the southern edge of Blaauwpan and the K86 east-west link which will be an extension of Merlin Drive over the wetlands towards Daveyton. In this regard the consultants and support specialists to GAPP concluded with the following recommendations:

- The alignment of the proposed PWV 15 road entails that the primary valley-bottom wetland system through which this road is proposed to be aligned (the road is aligned longitudinally through the wetland in the direction of flow and not perpendicularly across it) could be significantly adversely affected by the road through the loss of wetland habitat and the alteration of hydrology (through canalisation, etc.). It is strongly recommended that consideration be given to the realignment of this road to the east of the wetland to avoid such impacts from materialising;
- The concept of linkages between the eastern and western segments of the precinct site is supported, but these must take the presence of the wetland, and potential impacts on the wetland into consideration. Should a road (vehicle) access be required, it is recommended that this connection across the central valley-bottom wetland be located as far north of Brentwood Park Road as possible, in order to cross the valley-bottom wetland at its narrowest point. Crossing the wetland to the north (closer to the church complex) will also avoid the large seepage wetlands located to the west of the valley bottom wetland in the southern part of the site;
- Where new roads are planned in the vicinity of any wetlands, in particular the valley-bottom wetland (e.g. linkage roads planned along the western side of the quarry), the environmentally sustainable planning of stormwater discharge from the road must be incorporated into the design of these roads. No direct stormwater discharge into the wetland should be allowed, and the use of 'soft' engineering features such as swales for attenuation features, in line with the principles of Sustainable Urban Drainage (SUDS) must be implemented;
- Similarly, future development that will result in hard surfaces around wetlands, in particular the pans around the site, must ensure that stormwater runoff from these sites is managed so that inflows into these wetland features do not degrade the wetlands. The use of soft features for attenuation that will allow the gradual inflow of stormwater into these pans must be incorporated into new developments.

It is obvious from the above that a major challenge to preserving the continuity and integrity of the wetland system will be large scale road infrastructure proposals. Future planning for the area must take a view on the future role of the wetland.

The following provides a short description of the four specific focus areas.

Blaauwpan

The Pomula Private Nature Reserve including the permanent water body known as Blaauwpan allows the public access to a unique amenity which is especially important to the fishing community. The water depth and defined water edge seem to suit the requirements of fishermen who comprise the biggest group of users. Access to the reserve is through Mirabel Street where an entrance fee is charged. The reserve offers picnicking and access to the water's edge for fishing. Swimming is forbidden.

The surrounding area comprises a mix of small holdings, suburban residential development, utilities, a mall and high-density housing. The pan is embedded and not visible or easily accessible by the general public from the external road network.

It appears that the pan is currently owned and managed by the CoE: Parks Division and Wetland Unit. This presents challenges as they each have their own needs and performance requirements of the space. A workshop with key stakeholders in the area highlighted the CoE's lack of capacity to manage the pan and there was a suggestion that leasing it to the private sector could provide a solution.

It should be noted that a controversial land sale in 2011 seems to have been halted but there remains a risk that the pan and surrounds can be sold to private developers again. However, this would result in the municipality losing control of the site as a key stormwater control point, environmental asset and public amenity altogether and is thus not an optimal solution.

Pan 1 (Middle Pan)

This pan is located in the middle of a precinct comprising largescale developments. Approximately two thirds of the land surrounding the pan has been developed. The last third remains undeveloped but is the focus of a planned mixed-use development (see Enviross, 2015a).

The properties surrounding the pan which include a large church site and new business/ industrial Park have been designed with little attention given to the potential amenity value that the pan can offer. The buildings seem to turn their back on the space, or are positioned on their respective sites such that there is no direct relationship between the buildings and the pan. There are limited overlooking features that allow the building occupants to enjoy views of the pan from inside of the buildings. There are also no gates for occupants of the surrounding buildings to access the pan directly for managed recreation such as jogging, bird watching or picnicking. Stakeholders at a workshop indicated that there have been requests from Toyota staff for seating overlooking the pan that could be used at lunchtimes which suggest that there is an appetite for more contact with 'nature'.

An additional consequence of the current situation is that the pan area itself suffers from a lack of 'activation' and surveillance by people and feels relatively unsafe.

While access to the pan may be limited, there is a strong awareness of the ecological value and sensitivity of the pan. The pan is currently owned and managed by a Section 21 Company formed by the surrounding landowners. The company has invested in an ecological management plan of the pan that includes the capture of stormwater in a bio-retention swale that they have had constructed around the pan. The pan is monitored and maintained on a regular basis, including inspections, alien vegetation removal, and monitoring of the function of the swale. Stakeholders at a recent workshop suggested that not all land owners buy into the same environmentally responsible vision for the pan which can lead to challenges at times. This points to the need to ensure that those buying into private estates commit to contribute to an agreed vision for open spaces of this type and scale.

Pan 2 (La Como Lifestyle Estate/Clearwater Estate)

Pan 2 is the central feature of the 80ha La Como Lifestyle Estate which markets itself as "an aesthetic delight and the most desirable and trendy place of living" in East Rand. It is a secure estate with access control which limits entry to residents, their guests and visitors to the restaurant only. Pan 2 is seen as a major asset to the development allowing residents and occupants of the offices to enjoy "nature". The entire development is orientated around the feature to ensure that the offices, residences and lifestyle centre have direct views of the water and bird life that it attracts. Green belts link the residential development to the main water body allowing stormwater to drain towards it. The edge of the water body has been fenced off to restrict access to the water's edge where the sensitive habitats are located. A pathway is located outside of this fenced area. Residents and visitors are able to view the water more closely using a walkway connected to a pavilion that is built over the water. The La Como restaurant and club house have spectacular views of the water body adding great value to visitors' overall experience. In summary the amenity value is mostly visual in nature.

Anecdotal evidence from property professionals at the workshop with key stakeholders, suggested that properties in La Como Lifestyle Estate close to the pan sell for more than properties further away from the pan. Furthermore, prices of properties in the Clearwater Estate, which was developed prior to the La Como Lifestyle Estate, have increased three-fold in 10 years since the La Como Estate and its pan were developed. This demonstrates the economic benefits of investing in green open spaces such as Pan 2.

The pan is currently owned, maintained and managed privately. The consequence of this is that those buying into the precinct, pay high levies to cover the costs of maintaining such a system. This in turn limits potential buyers to those at the top end of the market. Lifestyle estates that are targeted for the top end of the market unfortunately also sell 'security'. This leads to the privatisation of open space. This is common to many lifestyle estates.

So, while this arrangement ensures that the private sector contributes to management and maintenance of a key green open space and green infrastructure, it marginalises the poorer citizens from quality open spaces. This is a growing concern in the South African context.

Main wetland

The main wetland is very large and sadly off the public radar as it is not useable. Besides being difficult to move around, there is no to activity or form of facility or infrastructure that attracts people to it. Developments along the edge of the space do not respond to it but rather turn their back on the open space resulting in a lack of passive surveillance and feeling of vulnerability for those having to traverse the space. There is evidence of people moving across and along the length of the site on foot. The space is currently framed by high fences, backyards, vacant land and roads.

4.1.3 Ecological context of the Bonaero-Atlasville study area

Catchment Context

The Bonaero-Atlasville study area is situated in the Upper Vaal Water Management Area (WMA), the Level 1 (Highveld) Ecoregion 11, Quaternary Catchment C21D, and incorporates the major part of the OR Tambo International Airport surface area within its sub-catchment. The Bonaero-Atlasville wetland complex (including the three pans) is located approximately 20km upstream of the Blesbokspruit/ Suikerbosrand Rivers. The Blesbokspruit, which has wetlands that are recognised under the Ramsar Convention on wetlands of international importance as waterfowl habitat, then merges with the Suikerbosrand River, prior to merging with the Vaal River at the Vaal River Barrage approximately 70km south-west of the study area. The C21D catchment falls within the jurisdiction of Rand Water, which also manages the water quality of the Vaal River Barrage Reservoir.

Prevailing Catchment Impacts

Large quantities of urban and industrial effluent, together with urban wash-off and mine dewatering activities, have had a major impact on water quality in some (e.g. the Waterval, Blesbokspruit, Natalspruit and Klip River) tributaries within the north-western part of the WMA. Water quality problems in the sub-catchments relate to contaminants such as hydrocarbons, salinity, organic loads, eutrophication and public health issues. The salinity problems are largely related to mining and other industrial impacts, and seepage (DWAF, 2004). Stormwater run-off from dense regional settlements also add nutrients and sediment to the systems (DWAF, 2004). In addition, local flooding problems are experienced in the Blesbokspruit and Klip River catchments (DWAF, 2004). As an example, the upper reaches of the Klip river, which is the directly neighbouring catchment (C22B) are in a very poor ecological state (PES Category E). This by inference heightens the importance of maintaining and improving the water resources in other catchments of the Upper Vaal River wherever possible.

National Freshwater Priority Areas

According to the available NFEPA wetlands coverage, the seepage wetland directly upstream of Blaauwpan, Blaauwpan itself, as well as Pan 1 represent Wetland Freshwater Ecosystem Priority Areas. Driver et al. (2011) state that FEPAs should be regarded as ecologically important and as generally sensitive to changes in water quality and quantity, owing to their role in protecting freshwater ecosystems and supporting sustainable use of water resources. Wetlands FEPAs that are in a good condition (equivalent to an A or B ecological category) should remain so. Wetland FEPAs that are not in a good condition should be rehabilitated to their best attainable ecological condition. This means that: Land-use practices or activities that will lead to deterioration in the current condition of a wetland FEPA are not acceptable. Land-use practices or activities that will make rehabilitation of a wetland FEPA difficult or impossible are not acceptable.

Vegetation Type and Threat Status

From a terrestrial perspective it is important to note that the historical dominant vegetation type present would have been the Soweto Highveld Grassland, which falls under the Mesic Highveld Grassland Group 3 bioregion (Nel et al., 2011; Mucina and Rutherford, 2006). The vegetation type has been classified as 'Endangered', with only 0.2% receiving formal protection. A status of endangered indicates that there is very little of the original extent of the ecosystem type left in a natural or near-natural state. Most of the ecosystem type has been moderately or severely modified from its natural condition and it is likely that most of the natural structure, functioning and species associated with the ecosystem may have been lost (Nel et al., 2011). Endangered ecosystems are close to becoming critically endangered. Any further loss of natural habitat or deterioration of condition should be avoided and the remaining healthy ecosystems should be the focus of conservation action (Nel et al., 2011).

Gauteng Conservation Plan

The wetlands and fringing grassland habitat have been flagged as being of very high sensitivity. In particular, large portions of this site have been flagged as being Critical Biodiversity Areas, with some areas also earmarked for protected area expansion. Whilst further specialist studies would need to be undertaken to build a more comprehensive understanding of the site, it is clear that the wetland complex targeted for SuDS interventions has been identified as a critical biodiversity area with the fringe terrestrial areas acting as Ecological Support Areas.

In terms of ecological connectivity, road linkages, disturbance, light and noise pollution have reduced the value of the site as a corridor for species movement. The valley bottom wetland and pans are also not well connected to other priority conservation areas downstream. However, it is also important to note that this is an extension of a much larger open space network and priority freshwater resources in the downstream catchments. Based on the underlying conservation values of the site, the wetland and pans have been classified as Environmental Management Zone 2 in the Gauteng EMF. According to the EMF guidelines, this zone is sensitive to development activities and only conservation should be allowed in this zone. Related tourism and recreation activities must be accommodated in areas surrounding this zone.

Resource Management Objectives

The Blesbokspruit as a water resource provides critical ecosystem services to the southern portion of Gauteng, South Africa's most economically important urban area. Many of the rivers in this catchment are heavily impacted and it is important that the freshwater ecosystems in particular are maintained in an acceptable quality (D or better ecological category) so that there can be a continued supply of ecosystem services (Department of Water and Sanitation, 2014). Altered low flows conditions are of particular importance. Elevated low flows therefore need to be managed to be sympathetic to the ecosystem. In addition, there are numerous water quality issues that need to be managed so that wellbeing the ecosystem does not deteriorate to unacceptable conditions, below a D category, suggesting that the management objective for the catchment should be to maintain or improve the current status of water resources in the catchment. This implies that proactive interventions are required to meet water resource management objectives, and that ecological objectives are likely to require higher priority to the generic 'quality/quantity' narrative ordinarily associated with stormwater management. This is supported by a recent study that established Resource Quality Objectives for the Upper Vaal catchment (Department of Water and Sanitation, 2014). The report specifically highlights the need for high impacts to water resources in this region to be managed so that the ecosystem can provide ecosystem services.

Classification and Discussion of the Characteristics of the Bonaero - Atlasville Wetland Complex

The Bonaero-Atlasville wetland complex is comprised of three Depressions or Pans, and one un-channelled valley bottom wetland, all of which are fed by a combination of surface and subsurface water inputs through seepage wetlands and other anthropogenic point sources. Between the pans and the main valley bottom wetland there are strong groundwater linkages, and occasional surface water links after heavy storms. They are therefore reliant on each other as sources of cumulative groundwater recharge. There is a narrow ecological/stream corridor from the wetland to Homestead lake (and other lakes) further downstream, which may constrain the ecological connectivity of the complex to downstream habitats, however within the complex itself, there is good habitat connectivity to allow for movement of fauna throughout its extent.

Recent wetland delineation studies, one just to the north-eastern boundary of Pan1 (Enviross cc, 2015a), and the other just to the east of Pan 2 (Enviross cc, 2015b), suggest some continuity of the present ecological state of the wetland along its length. The authors report that despite evidence of hydrological disturbance and altered vegetation conditions, especially around the margins of the wetland, a Present Ecological State (PES) rating of B/C was awarded and the wetland was placed in a high EIS category (Ecological Importance and Sensitivity). The reports concluded that the wetland should be considered as an important part of the “ecological structures” of the region, and that a holistic habitat conservation approach should be adopted. By inference the system as a complex is therefore more valuable than its individual parts ecologically. It is a heterogeneous network with a larger habitat and habitat diversity. Within most urban contexts the edge effects are significant, but the impact of the edge in a larger undisturbed core is lower and better for biodiversity.

Ecosystem Based Adaptation

Ecosystem-based Adaptation (EbA) is defined as “the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem-based Adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies” (CBD, 2009).

Wetland complexes of the size, nature (type) and ecological condition “B/C” (Enviross cc, 2015a) are not common in highly developed, and largely impacted contexts such as this one. This heightens the value of this complex ecologically, especially as providers of valuable ecosystems services in the landscape. Habitat niche adjustments would be required under climate change in response to changing temperature and rainfall characteristics. For this particular site, the fact that there are a diversity of habitats and local connectivity upstream of the narrow ecological/stream corridor from the wetland to Homestead lake, means that there is some potential for adaptation, and therefore a higher resilience compared with other systems that have low diversity and connectivity.

Key outcomes:

- The catchment area has attracted both strategic (e.g. OR Tambo International Airport) and high value development, including many of the big names in industry and manufacturing. The study area is a focal point for a future development and investment (e.g. the Aerotropolis) that will bring with it upgrades services such as major roads, of which the PWV15 is set to cross the study area.
- Despite this, the integrated area of the pans and wetland is a substantial green space in a city environment, and it has important conservation value.
- The amenity value of the area is under-developed though there are important locations of current amenity. Blaauwpan has regional significance as a fishing spot. Pan 2 at the Clearwater/La Como Estate has been integrated into the landscape of the development as an ecological and amenity feature.
- All three pans now have ecological significance albeit in different measures, perhaps reflective of the nature of integrating ecological zones into city environments. Initiatives to manage the ecology of the pans are *ad hoc*, typically driven by small groups of landowners.
- The wetland currently stands apart from any management initiatives. Hence the pans and wetland are not managed as an integrated system.
- Development has had negative impacts on the integrated system, particularly through pollution spills and changes to hydrological balance of the system.
- Stormwater drainage from the adjacent properties is generally managed in the traditional manner, with attenuation provided on the more recent developments (last 10-15 years). The exception is current drainage into Pan 1 where Toyota and the Christian Family Church International have worked together to provide SuDS based drainage interventions.
- Future development intent is a threat to the ecological sustainability of the integrated pan and wetland system, but is also a potential means for its protection in the long-term.

4.2 Consultation Outcomes

During the large workshop on 5 February 2019, a parallel session was set up for the Bonaero-Atlasville area, but with limited participation of people who knew the area. In the contrary, the dedicated workshop on 4 April had very knowledgeable participants from the local land owners surrounding the pans, including Airports Company South Africa (for Blaauwpan), Toyota, Christian Family Church International and the pan maintenance manager (for Pan 1), and the La Como Estate (for Pan 2). City of Ekurhuleni was represented by the Roads and Stormwater Department and the Parks Division. The gathered knowledge of the catchment areas around the pans was very valuable and has been input in further sections of this chapter.

Outcomes of this consultation that are learning points for this analysis are:

- **A non-profit organisation of direct stakeholders can have a positive effect.** The working of such an organisation mainly depends on committed shareholders who also keep their own house in order. Companies as in this case Toyota, with a clear corporate policy on environmental impact, are crucial, and the International Family Church is also a committed participant in the section 21 company set up to manage the middle pan. One company bordering the middle pan has changed its own property to the detriment of the impact on the pan. Also, properties not bordering the pan, and therefore not represented in the section 21 company, probably have the largest 'low hanging fruit' to further improve on man-made impacts on the pan. In this case the property of Denel, which is also going to be re-developed, is a location to consider interventions in stormwater management for the better functioning of the pan. In pan 2, the most southern pan, the two estates bordering it and owning the pan, have direct interest in water quality and water levels, and the joint management of the pan is going well without further need for a non-governmental organisation.

- **The environmental impact assessment process had a crucial role in protecting the environment.** The representatives of the middle pan were unanimous in explaining that thanks to the clear decisions made during the environmental impact assessment process, the organisation was formed and had strict guidance in what their priorities should be. However, it was also pointed out, that their experience, not necessarily with this pan, is that the stormwater departments are not always consistent with the EIA process results.
- **The organisation and capacity of the local municipality is a main consideration in the responsibility changes that come with SuDS introduction.** The Parks division of the Municipality of Ekurhuleni has a dedicated Wetland Unit. The Roads and Stormwater Department and the Parks department are understaffed for regular monitoring and maintenance of the current stormwater system, and therefore hesitant for SuDS additional monitoring. They stressed the difference with other Metropolitans in Gauteng in that City of Ekurhuleni would have less resources. The Roads and Stormwater representatives in the workshop emphasized that crucial land from a stormwater perspective that is not yet private property (like the two southern pans are) should remain in the hands of the municipality. Innovative ideas such as lease of land to private owners should be further explored, with current limitations being the Public Finance Management Act which only allows lease for a maximum period of three years.
- **The larger upstream property owners have not engaged with downstream affected parties yet.** The Airport Company South Africa (ACSA) was well represented at the workshop with three representatives with backgrounds in environment and stormwater. While they have improved their stormwater practices, an eye-opener for them at the workshop was the impact of the amounts and quality of stormwater generated at their site on downstream properties and the functioning of the system at Bonaero Park–Atlasville as a whole. It added to the realisation for them on the importance of their own attempts within ACSA. While Denel had not been actively approached to come to the workshop, the other property owners emphasized that the effect of stormwater from the Denel site on the two southern pans is quite extensive. There was no mention of real engagement with Denel in this respect.
- **The pans have amenity value.** The Toyota representative mentioned the requests of employees to have more benches for lunch breaks at the site overlooking the pan. The Como Estate person mentioned that the view on the pan was a reason for increased house prices. The residents did not mind another estate at the other side of the pan, as that increased the house prices further.

4.3 SuDS Interventions Assessed

4.3.1 Flood reduction by the existing system

A schematic of the pan and wetland system with main drainage catchments is shown in **Figure 43**. Stormwater management for developments in the catchments around the pans has been to use them as stormwater attenuation facilities. Hence, the initial assessment looked at the SuDS value of each of the features of the existing system.

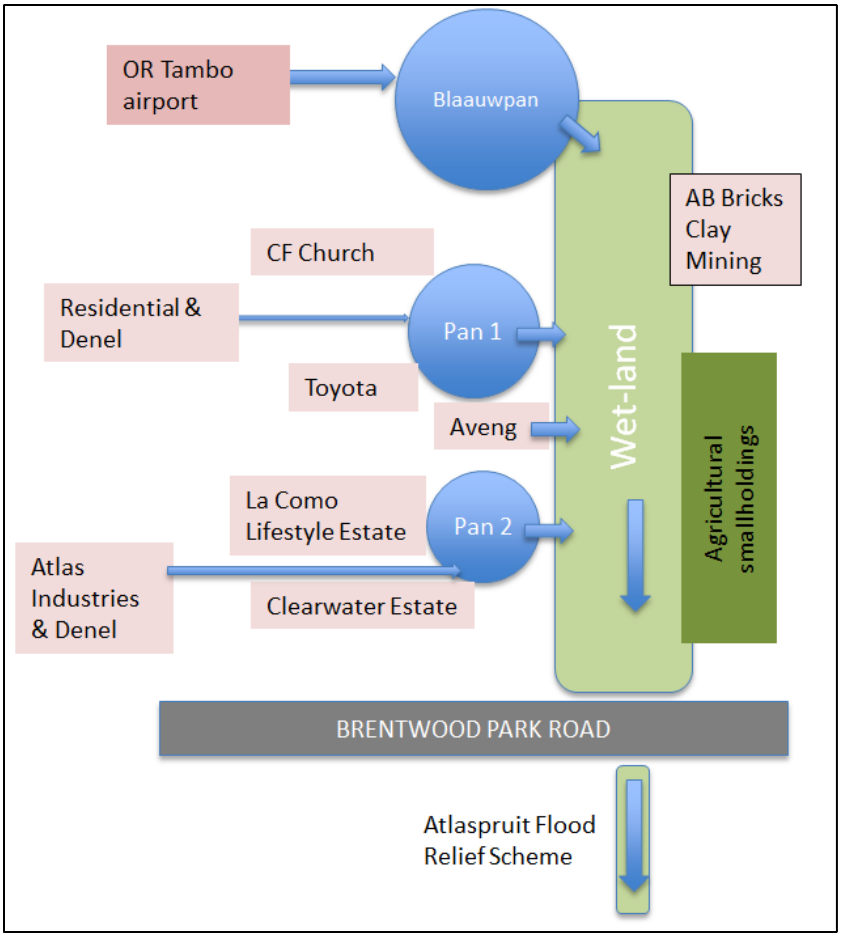


Figure 43: Schematic of the pan and wetland system at Bonaero Park

The significance of the attenuation benefits offered by each of the pans is demonstrated in **Figure 44**, **Figure 45** and **Figure 46**. Blaauwpan reduces the 100 year flood peak by over 90%, while Pan 2 reduces it by around 65%. Pan 1, starting from a dry bed condition has the capacity to contain the entire estimated 100 year flood event from its catchment. In each case it is assumed there is no on-site attenuation in the catchments, and that all impervious surfaces are directly connected to the stormwater network (i.e. catchment runoff is likely to be conservatively high).

The wetland receives the attenuated flows from the pans as well the unattenuated flows from the intermediate catchments. The surface area of the wetland offers attenuation of these storm flows as demonstrated in **Figure 47**. Overall, the integrated effect of the Bonaero pan and wetland system on the estimated 100 year storm event is demonstrated in **Figure 48**.

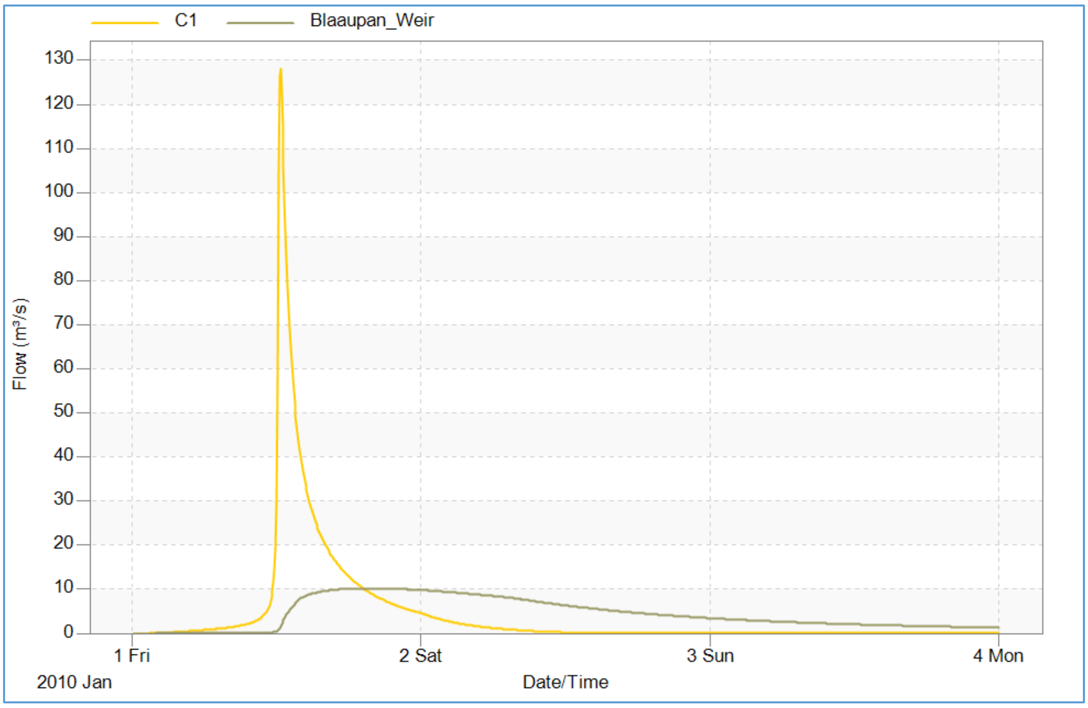


Figure 44: Blaauwpan – attenuation of the estimated 100 year flood hydrograph (PCSWMM simulation using design flood; dates are not actual dates), with C1 being the inflow hydrograph and the weir being the outflow hydrograph

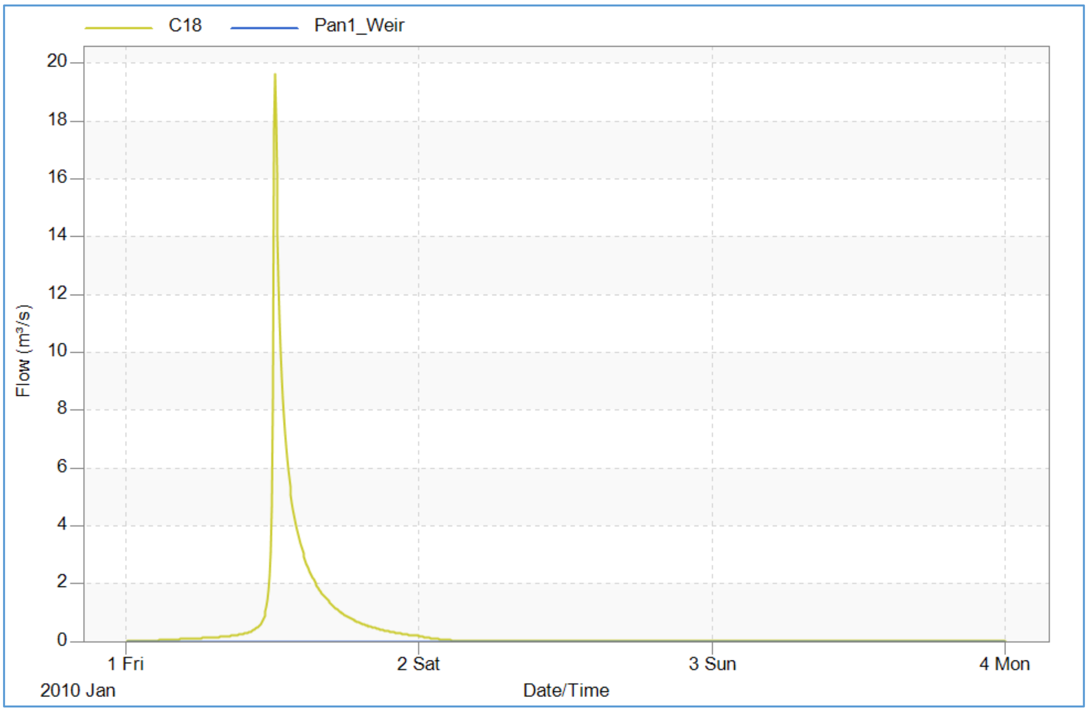


Figure 45: Pan1 - attenuation of the estimated 100 year flood hydrograph (PCSWMM simulation). See further explanation in figure above; outflow zero.

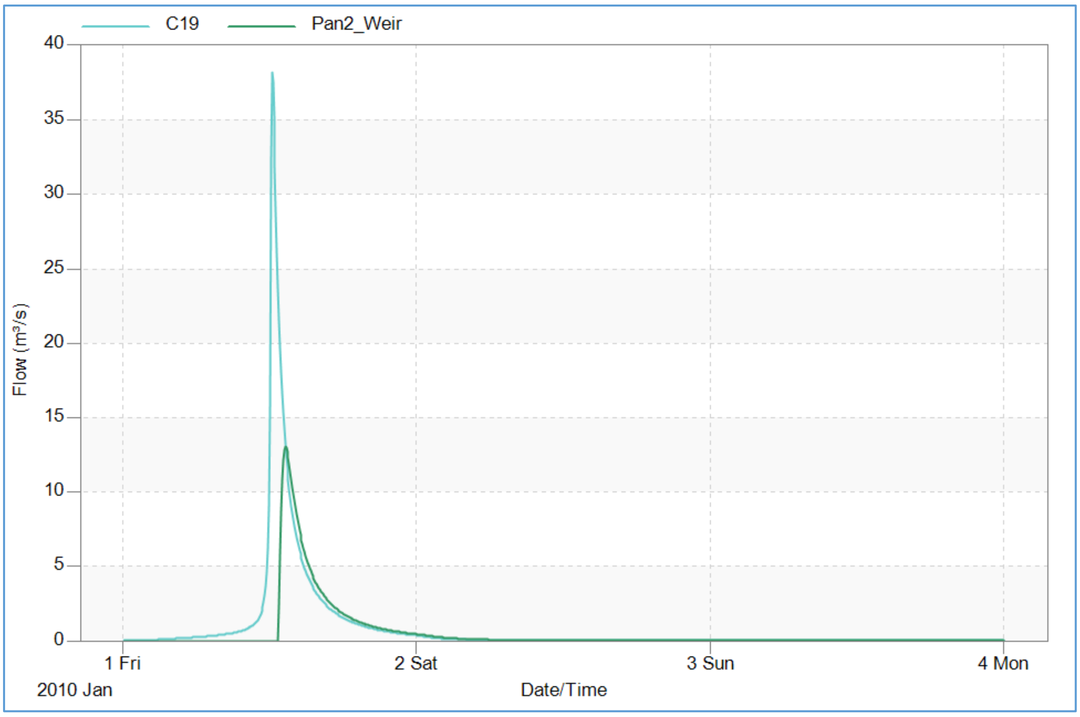


Figure 46: Pan2 - attenuation of the estimated 100 year flood hydrograph (PCSWMM simulation).

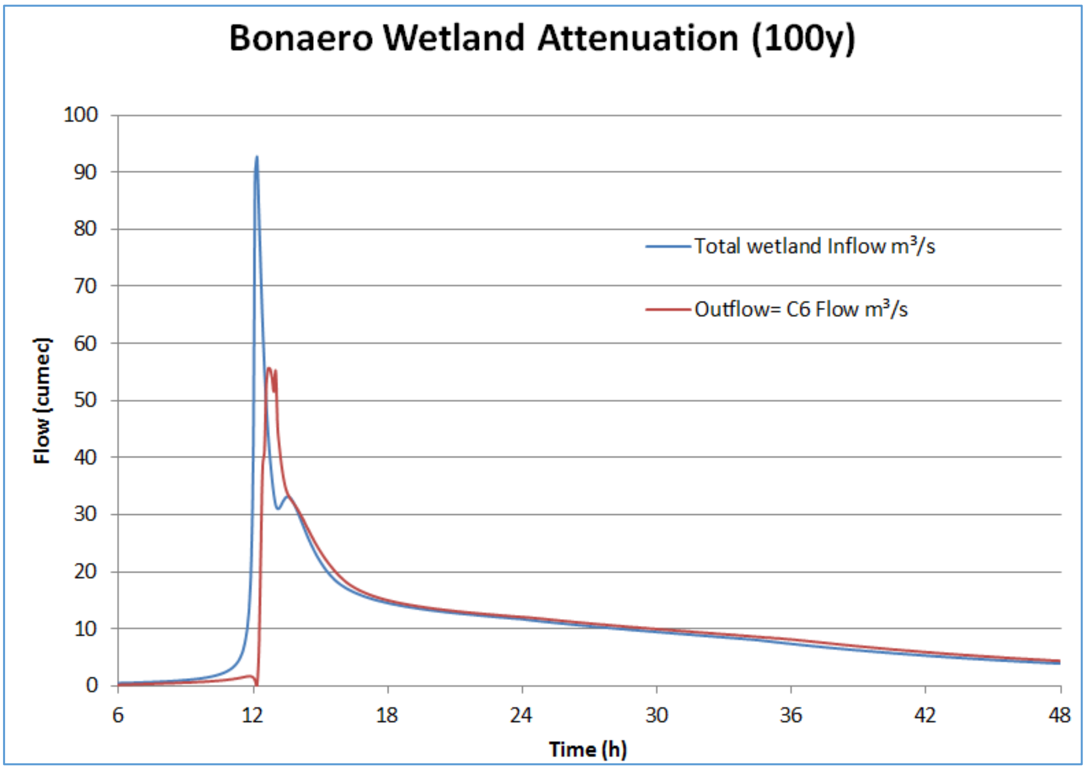


Figure 47: Attenuation effect of the Bonaero wetland on the estimated 100 year flood event (PCSWMM simulation)

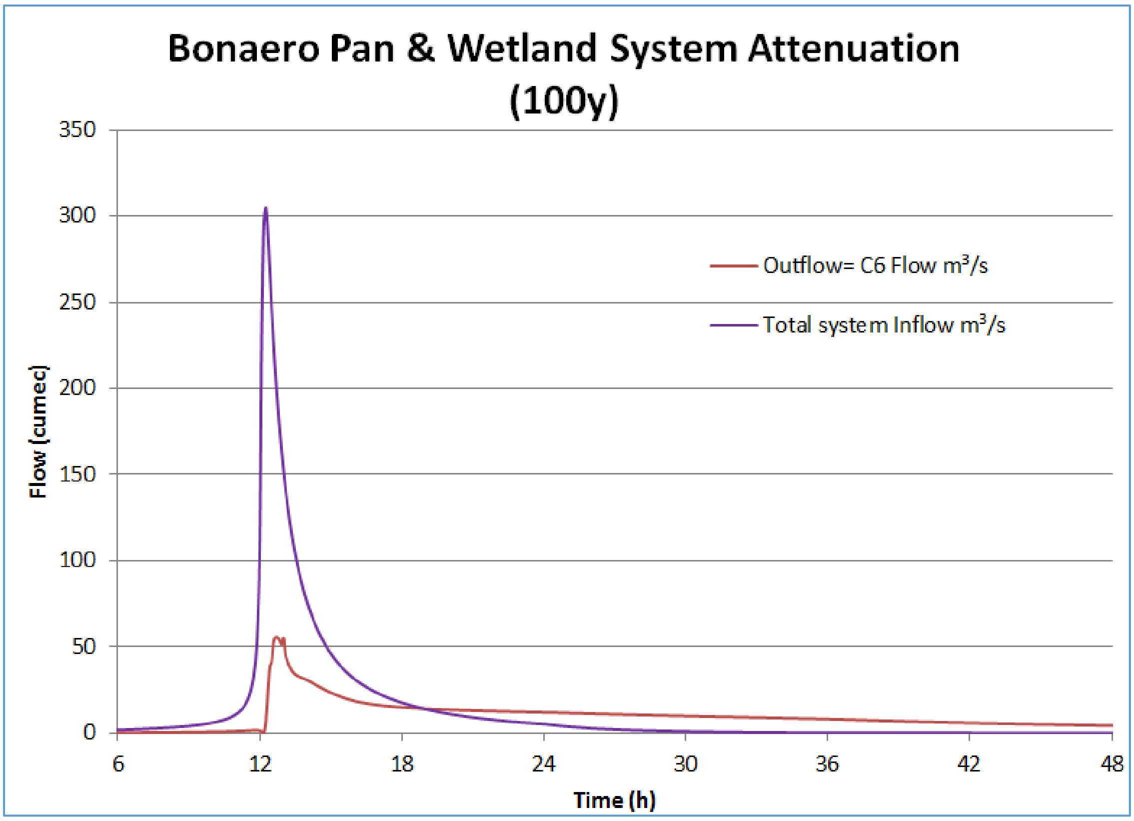


Figure 48: Attenuation effect of the entire Bonaero pan and wetland system on the estimated 100 year flood event (PCSWMM simulation)

The simulated 100 year runoff does not account for any retention or attenuation that is likely to occur within the catchment areas and is therefore expected to be conservatively high (in peak and volume). Nevertheless, the flood control benefits of the Bonaero wetland and pan system, individually and collectively, is seen to be significant. Therefore, although this is a relatively high level analysis there is no doubt these are substantial reductions in flood peak, and these systems are seen to play a key role in flood management for developments in the downstream areas of the catchment.

4.3.2 Water Quality benefits of the existing system

By virtue of their size, they will also offer important water quality functions. **Table 13** shows the treatment potential of the pans, presenting the annual load reductions for a range of standard urban pollutants. Again, these show the important stormwater treatment benefits offered by the pans. However, it also implies that these important ecological systems are accumulating stormwater pollutants. The analysis for Blaauwpan is given in **Table 14**. The pollution loads are indicative and based on default urban pollutant loading for the respective urban land uses (and hence are not calibrated for local conditions).

Table 13: Treatment potential (annual loading) of the pans (MUSIC simulation)

Treatment	% Reduction
Hydraulic load (total flow)	>50%
Suspended solids (TSS)	>90%
Nitrogen (TN)	>70%
Phosphorus (TP)	>80%
Gross pollutants (litter)	100%

Table 14: Indicative pollution loading at Blaauwpan (MUSIC simulation)

Treatment	Annual load	Load/ha (catchment)	Load/ha (impervious)
TSS (kg/hr)	340000	275	520
TP (kg/yr)	600	0.5	1.0
TN (kg/yr)	5000	4.0	7.4

Although indicative, the loads are still significant. For example, they suggest that over 300 tonnes of sediment might be deposited into the Blaauwpan every year (approx. 150 to 180m^3). Some of this may be trapped in parts of the stormwater network upstream, but unless the network is maintained the sediment will eventually pass through to the pan.

4.3.3 Water reuse in the existing system

Water reuse in this part of the catchment was not raised as an active function other than ad hoc rainwater harvesting systems. One such system has been installed at Toyota as a part of their sustainability initiatives, and as a means of water security at times when supply is interrupted. It is understood that the harvesting system is still under development.

However, a key contribution of the existing system to water resources are the water quality improvements achieved by the pans and wetland that enable substantial retention times allowing for settlement and filtration.

Key Outcomes:

- The Bonaero pan and wetland system provide significant stormwater (flood) and water resource (quality) management benefits to the downstream catchment.

- The pans have been incorporated into the stormwater systems for development in the catchment, particularly in Blaauwpan and Pan 2 which show the greatest degree of change from their expected natural state.
- Changes to these pans could have significant consequences to flood risk and water resource quality in the future.

4.3.4 Balancing the objectives for the Bonaero Pan and Wetland System

The Bonaero pan and wetland system should be managed as an integrated conservation area with reduced stormwater functions.

It is proposed that SuDS are used to protect the pan and wetland system, rather than using them as part of the SuDS treatment train.

The pans and wetland should still perform the flood management function it currently provides. It will be relatively difficult to replicate the vast storage capacity elsewhere in the catchment. However, this function should only be required for the larger storm events (for example greater than the 5 year, or 10 year event). This could reduce on-site attenuation requirements (for new developments and site re-development), and will be an incentive for the developer.

This approach will improve the water quality entering the pans.

This is seen to reflect some of the recent initiatives to protect and enhance the pans, and is partly reflected in the master plan for the Aerotropolis. It also draws on the environmental recommendations to manage the pan and wetland system as a whole (e.g. Enviross, 2015a and 2015b).

4.3.5 Preliminary design interventions

Blaauwpan

A sediment trap is introduced in the inflow channel and part of the pan area (approx. 5% of the total area) is converted to a shallow (<0.6m deep) wetland area. The creation of an island within the pan may improve water circulation and at the same time provide a refuge for fauna. However, this aspect may also lead to circulation problems (dead areas) if not carefully planned.

These proposals, as indicated in **Figure 49**, were tested in MUSIC, too understand what they would do for water quality conditions within the pan, means of trapping pollution spills before they enter the pan, and the attenuation of large stormwater events, with the decreased storage volume of the pan.

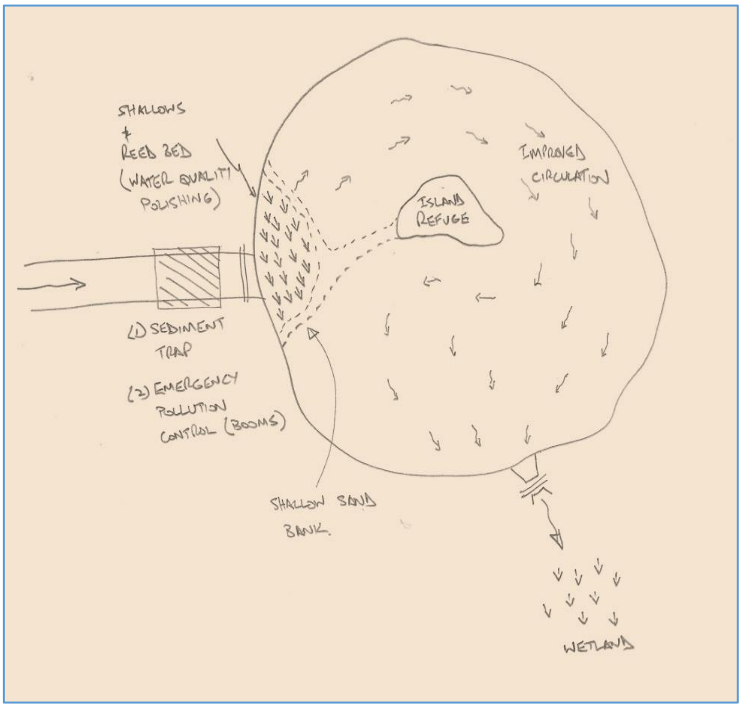
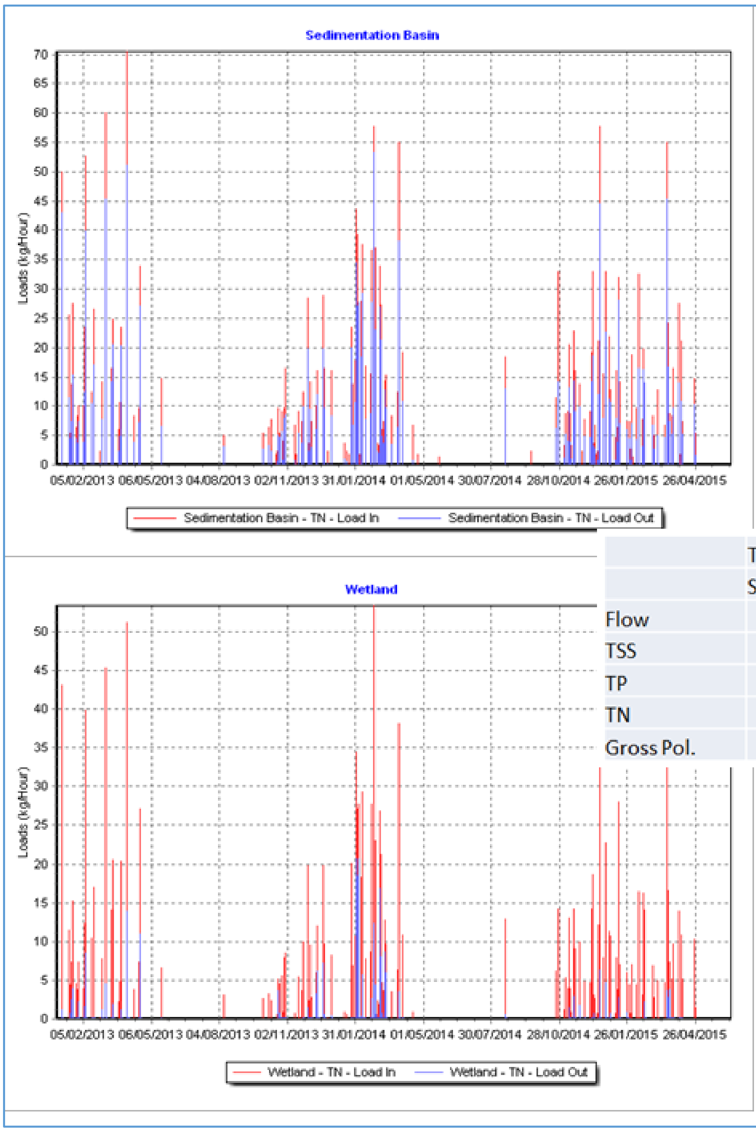


Figure 49: Concept Blaauwpan SuDS interventions.

Figure 50: Blaauwpan SuDS test (MUSIC simulation)

The performance results of the sediment trap and wetland are summarised in **Figure 51**. The sediment trap achieves only 26% reduction in sediment load and is clearly too small for the catchment area. It may be suitable if account is taken of treatment facilities that are understood to have been installed within the airport area, but details of these have not been provided. The possibility of a larger sediment trap is located upstream (at sediment trap 2, **Figure 50**). The land is understood to be owned by the municipality and may be assigned to stormwater assets.



	Treatment Performance		
	Sediment	Wetland	Combined
Flow	0.4%	3.3%	3.8%
TSS	25.7%	44.8%	59.0%
TP	13.3%	34.1%	42.9%
TN	4.0%	15.0%	18.4%
Gross Pol.	100.0%		100.0%

Figure 51: Blaauwpan SuDS performance (MUSIC simulation). Red indicates inflow and blue the outflow pollution loads for each of the sediment and wetland treatment areas.

The performance of the wetland also suggests it is too small and a larger surface area would be needed. Treatment targets in excess of 90% for TSS and above 60% for TP and TN should be expected. This could be an expanded area within the pan, or also part of the inlet channel. The total area for treatment in this channel is between an estimated 9ha and 12ha. However, more than this will be required to effectively address the pollution load from the airport catchment. Hence, it would be reasonable for this to be provided within the airport area itself. Owned and maintained by the airport authorities. These facilities should also be fitted with emergency storage and shut-off valves in the event of spillage.

Pan 1 (Middle Pan)

The initial concept for Pan 1 would utilise space within the pan to retro-fit SuDS measures to mitigate runoff from adjacent properties as shown in **Figure 52**. Consultation with stakeholders superseded these concepts as the efforts to protect and manage the pan were revealed.

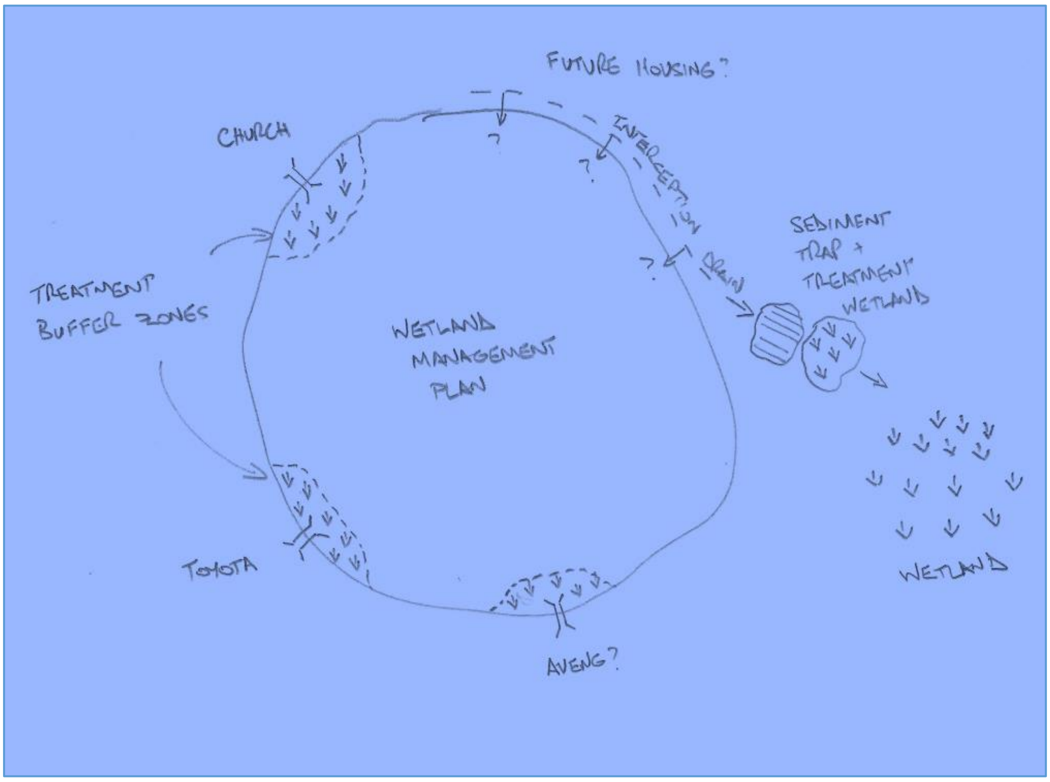


Figure 52: Preliminary SuDS concept for Pan1.

The bioswale presented in **Figure 38** is located in context with the development boundaries in **Figure 53**. This is estimated from site and aerial observations. It shows a narrow 'buffer' between the site boundary and the bioswale in most places. Some of the stormwater outfalls observed appear to cross the bioswale and discharge directly into the pan, but it is expected that in most cases stormwater is discharged before the bioswale. The stormwater then filters into the bioswale, improving the quality of the water before it dissipates into the pan, mainly subsurface. In larger storm events there may be some surcharge of the bioswale (i.e. it becomes flooded and water rises to the surface), but this is in line with the typical operation of these SuDS measures.

The condition of the bioswale is monitored as part of the management of the pan (ref: Mr Greg Crookes of Tellurian). It is observed to perform well, though there are problems with the overloading of the Toyota drainage system as it suffers flooding from neighbouring properties higher up in the catchment. Water quality sampling has been undertaken, but the records were not available at the time of writing. It is also understood that Toyota has established a small wetland area between the stormwater outfalls and the bioswale for added treatment. It is uncertain whether the bioswale enhances or may even disrupt the subsurface drainage patterns of the pan, but it is generally perceived that the ecological health of the pan is good.

Figure 53: Pan 1 showing the estimated location of the bioswale and expected points of stormwater discharge.

Figure 54: Guideline SuDS treatment areas along the boundaries with Pan 1 and the wetland (different colours indicating the different properties).

Figure 54 demonstrates the principle of using an infiltration buffer strip as the primary SuDS measure for treating runoff from adjacent properties. Note this would be in addition to attenuation measures still required for flood management. The width of the strip would vary with the area of the site being drained, as well as the depth of the filter media and exfiltration capacity of the receiving soils, but in general it is estimated that the current three developments around the pan would need buffer strips of between 10m to 18m wide. Though the width between the site boundaries and the bioswale may be a little narrower than this, it demonstrates very good forward stormwater management thinking and planning with the health of the receiving system in mind. **Figure 54** also demonstrates that the same approach should be applied to the development interface with the wetland, as a retro-fit SuDS measure.

However, new development should first seek to manage stormwater within the development footprint, before it is discharged offsite and into the pan area. This includes attenuation facilities. It is noted that even as relatively recent as 2016, stormwater management plans for new development around the pans show attenuation facilities within wetland buffer areas. Ideally stormwater management should be complete (including attenuation) before it enters ecological buffer areas, particularly on sites where environmental conservation is a priority. The approach demonstrated in **Figure 53** and **Figure 54** is laudable for its vision in 2006, but given the importance of the ecological value of the pan would not be the recommended option today for a greenfield development (where all SuDS and stormwater measures, including attenuation would need to be contained within the development footprint). However, as a retrofit measure the infiltration trench makes sense as a measure.

The Christian family church has an extensive parking and would like to extend this parking to the north. A recommendation could be to also consider permeable paving. The effect of this is not further researched.

Application of SuDS will assist a developer to manage stormwater within the development footprint, and this should be the approach adopted for all new development around the pans, and in the wider catchment area. Hence, if an infiltration strip is being considered, then the strips indicated in **Figure 54** would be located before the ecological buffer of the pan (or wetland), and placed within the development footprint. Elsewhere in the catchment, new development, and re-development, should be planned around a SuDS stormwater management system using a wider range of SuDS measures. This would mitigate the current flooding problem that Toyota experiences due to stormwater overloading (flooding) from neighbouring development.

Pan 2 (Clearwater/La Como Estate)

Pan 2 was recognised to be in a different ecological condition to that of Pan 1 but the preliminary concepts for SuDS interventions were somewhat similar to the early concepts for Pan 1; consider treatment within the development space, but look at utilising space within the pan to mitigate stormwater runoff impacts (**Figure 55**).

After consultation with representatives of the estate at the April stakeholder workshop, it is clear the pan is a managed feature of the estate where its landscape value improves land prices and its amenity value is enhanced for access by residents. Water quality is considered good (no sample records were available). The water balance in the pan is not artificially managed. It is fed by stormwater runoff and it fluctuates by around 1m between winter and summer. The pan discharges at surface to the adjacent wetland during storm events and extended wet weather periods. Sub-surface flows through the soil between the pan and wetland are understood to be in effect but this is not a managed part of the system. Overall, the current state of the pan meets the requirements of the land owner, and no additional interventions are required within the estate property area.

Figure 55: Preliminary SuDS concepts for Pan 2 showing a treatment train within the development space, and a possible wetland treatment system (hatched area) within the pan area

There is some concern about stormwater discharge onto the estate from the Denel industrial area (**Figure 56**). Stormwater crosses Atlas Road and affects boundary walls and properties along the western edge of the estate. This stormwater makes its way into the pan though no concerns of any related water quality or flooding in the pan was raised. Instead it is flooding on the western side of the estate that is a concern.

Figure 56: Anticipated new development and re-development in the Pan 2 catchment area

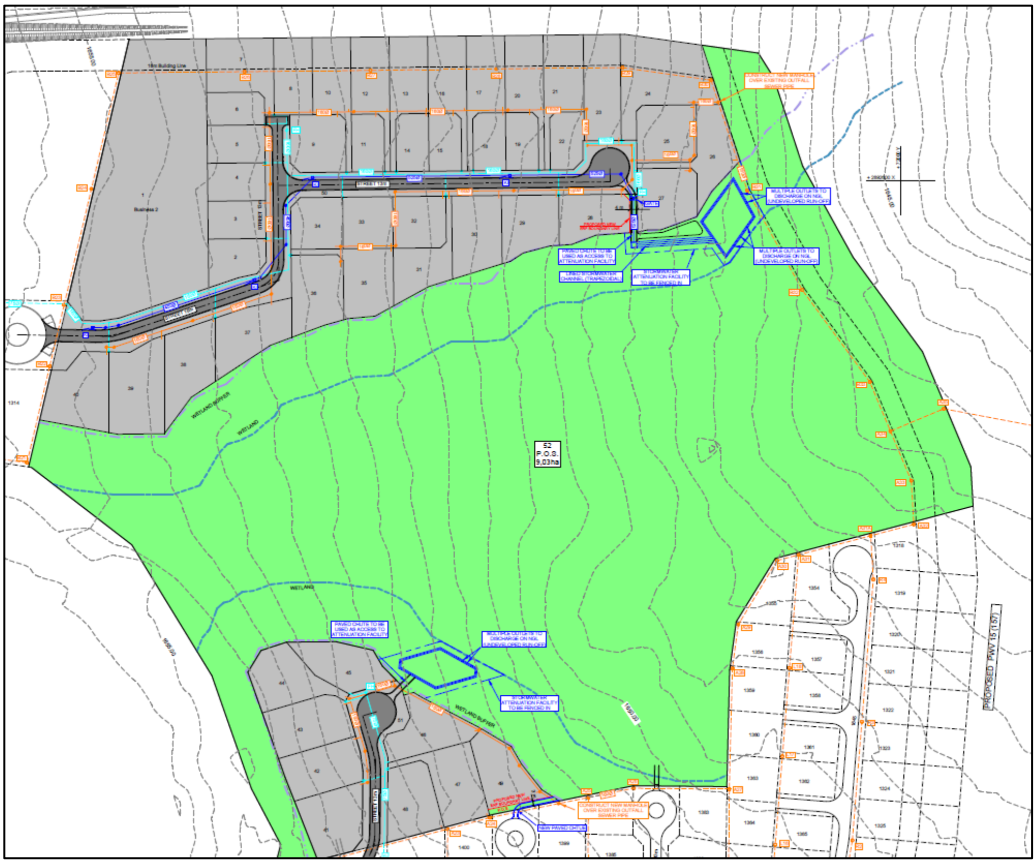


Figure 57: Development plan for Erf 1317 showing delineated wetland and proposed attenuation ponds in wetland buffer area (Protech, 2016)

There is also planned development on the eastern portion of the pan, on the linking corridor with the wetland. Erf 1317 (**Figure 56** and **Figure 57**) is perhaps representative of both the development pressures on the pans and wetland system but also how highly attractive the area around Pan 2 has become for land developers. The proposed development is understood to have passed through the environmental impact assessment process, but it is noted that the wetland report identifies the association of the site with “two wetland complexes” (presumably Pan 2 and the wetland) in good ecological state, that the site is an ecological corridor between the two. It also notes that the conservation of this area should be considered as part of the wider catchment area, with reservation expressed that the proposed development of the corridor will result in the net loss of both wetland complexes.

The acceptability of any development in this kind of location goes well beyond the consideration of only stormwater. Nevertheless, SuDS could play an important role in not just mitigating the impact of stormwater runoff from paved areas, but potentially even enhance the hydrological functioning of the corridor. For example, an infiltration strip between the development and the wetland similar to that adopted for Pan 1 could be considered along the edge of the ecological buffer. Bio-retention systems could be introduced within the stands without compromising on building space. Certainly, the attenuation ponds should be moved out of the ecological buffer area. A concept of what is envisaged is presented in **Figure 58**. The performance of such a system should tie in to ecological objectives and address both runoff yield (quantity) and quality.

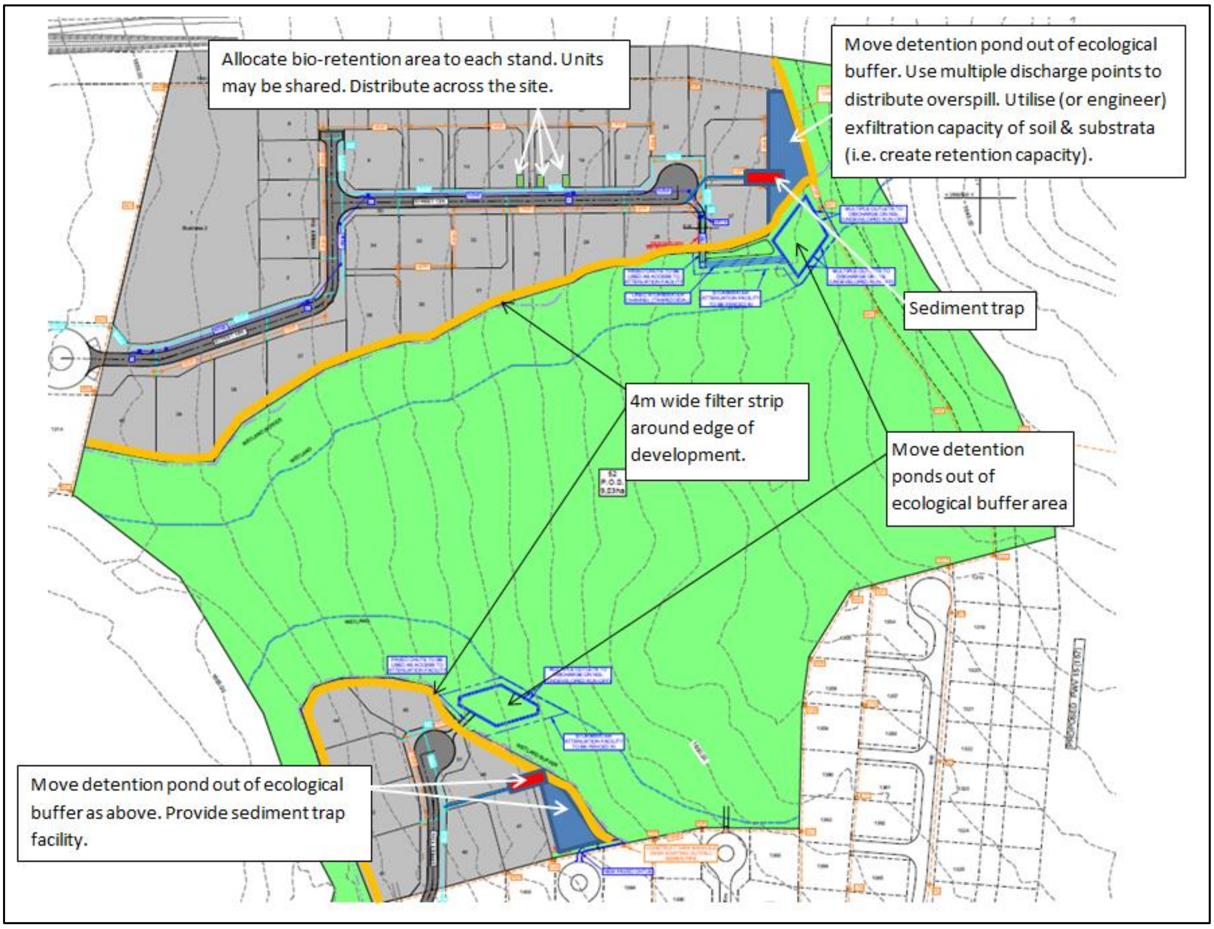


Figure 58: SuDS concept for Erf1317 (adapted from Protech, 2016)

4.4 Recommendations

4.4.1 Stormwater management

The study has confirmed that each component of the system comprising the three pans and the wetland provide significant flood control and water quality management, but that the combined effect of the integrated system is much greater. Preservation of the hydrological functioning of the integrated system should be seen as part of strategic water resources and flood management.

However, in acknowledgement of the important conservation and amenity value of the integrated system, SuDS can play an important role in mitigating the effects of urban development on the pans and wetland. The suggested management targets for each component of the system, and the system overall is the same; manage water quality into the pans and wetland by upstream SuDS interventions, but continue to utilise the substantial flood storage capacity of the system. Details are provided in **Table 15** below.

Table 15: Recommendations for the Bonaero pan and wetland system

Component	SuDS Interventions & Management
Integrated system	Develop an overarching management plan that integrates and balances the targets and objectives of each component of the system (see below). Integrate the wider ecological, amenity and land development targets and adapt the desired functions and performance of the system accordingly. Use the overarching management plan to monitor and adapt the plans for the individual components.
Blaauwpan	Introduce sediment trap and constructed wetland in the channel between the airport and the pan. Develop a management plan for the pan including stormwater quantity, quality, amenity and ecological targets. Clarify land ownership and management responsibilities. *[Alternative approach would be to request ACSA to implement these measures within the airport property area.]*
Pan 1	<u>Existing development:</u> Continue to support the monitoring and management of the bioswale and pan area. Where possible, pull back stormwater outfalls to discharge behind the bioswale (if this is not currently happening). Monitoring data will provide important information for design and management elsewhere in the system. <u>New development (and site re-development):</u>

Component	SuDS Interventions & Management
	Introduce SuDS into the stormwater management plan for all new development and site re-development. Adopt a precautionary approach and seek to mimic natural site hydrological responses under all rainfall conditions on the development site (unless council officials set alternative targets). Determine the quantity and quality performance of the proposed stormwater system. Update and make available to the City of Ekurhuleni the management plan for the pan including stormwater quantity, quality, amenity and ecological targets. Confirm land ownership and pan management responsibilities.
Pan 2	<u>Existing development:</u> Continue monitoring and management of the system. <u>New development (and site re-development):</u> As for Pan 1. Confirm land ownership and pan management responsibilities.
Wetland	Prepare a wetland management plan describing stormwater, amenity and ecological targets. Identify risks to the wetland (in addition to the issues relating to the pans identified in this study – e.g. the impact of quarry and brick making on the wetland). Confirm land ownership and wetland management responsibilities. Introduce SuDS on all new development in the wetland catchment. Establish a monitoring and maintenance programme.

4.4.2 Adapting the urban space

There is considerable potential to increase amenity value of the large wetland and the three pans.

Blaauwpan

Interventions within the pan area should ensure that fishermen and other users of the Reserve can still access the water's edge. Notwithstanding this cautionary note, wetlands can add diversified amenity value by improving habitats for birds thereby providing interest to other user groups.

The reserve should ideally be used by a broader grouping of people and in particular more local residents to ensure this green open space is maximised to its fullest. To encourage use by local residents, it would be preferable to have additional entrances to the reserve allowing access directly from the west as a minimum.

Private development of a commercial nature around the pan could contribute to making the pan into more of a public attraction. Involving private developers could also address the issue of the cost of maintaining such a reserve. Full privatisation of the pan and the reserve should however be discouraged as far as possible unless agreements are put in place to protect the core role and function of the pan as a public amenity, environmental asset and an important part of the broader stormwater system.

Pan 1 (Middle Pan)

The ecological value of this pan is acknowledged, as is the efforts by adjacent landowners to conserve it. However, it currently has limited value for occupants of the adjacent properties beyond visual benefits. There is concern that businesses may lose interest in a space that is not considered essential to production. It will be an interesting test to see whether new developers are willing to support the conservation initiative without much direct benefit.

To ensure the pan can contribute indirectly to increased productivity levels through its maximisation for employees the following is proposed:

- A public walkway around the periphery of the pan itself, accessed via a series of gates from the respective properties;
- Seating along the walkway at strategic points;
- A bird hide; and
- Outdoor seating areas within the private sites but along the boundaries interfacing with the pan.

Lastly but perhaps most importantly is a recommendation suggesting that landowners of the remaining vacant sites, consider more public uses such as hospitality and residential developments that can maximise on the benefits and value that the pan can provide in time. The Aero-Blaauwpan Precinct: Detailed Development Framework, 20 April 2018 makes a proposal for an entertainment venue that uses the pan as a backdrop. This is considered an appropriate use however large areas of parking should be discouraged on the basis that they detract from the experience of the open spaces and that they will contribute to a substantial increase in stormwater runoff. Management of noise and disturbance to the fauna of the pan and adjacent wetland will need to be considered.

Pan 2 (La Como Lifestyle Estate)

Recommendations for Pan 2 are largely related to the issue of access and management and serve more as a means to inform how local authorities should best structure agreements within SLA's for open spaces such as the La Como water body. In this regard, public access should be considered as potential condition of approval where the space forms part of a wider green open space system and recreational realm. In the case of Pan 2, opportunities to create a continuous recreational path between the development and the larger wetland to the east should be considered.

Wetland

With carefully considered development and improved interfaces, development of sites adjacent to the wetland can contribute to making it a safer space.

Significant investment in the space itself and the wetlands is however required to attract people to the space and add value for property developments and future occupants thereof.

This should be led by the municipality but will likely require partnerships with the private sector. The private sector is likely to come on board as an upgraded amenity on their doorstep can increase their own property values as is evident at Pan 2 and the La Como Estate.

Specific design related recommendations from an urban planning and design perspective are as follows:

Development interfaces

Development interfaces along the edge of the wetland need to ensure they can provide passive surveillance. New buildings must therefore face the wetlands and incorporate features (windows, balconies etc.) overlooking the wetlands. Buildings should also be located close to the boundary.

Where sites are located adjacent to access gateways into the wetland area, it is optimal to have more public uses (retail, hospitality, community uses), residential or a combination thereof.

Access

In order for the wetlands to have meaning for citizens of Ekurhuleni, citizens need to be able to see and experience the wetlands. This means that there is a need for a well-considered network of paths along, and where appropriate, across the space for people on foot and on bicycles. Where Non-Motorized Transport (NMT) paths cross the watercourse, bridges should be carefully designed so as not impact the natural habitats negatively. The potentially conflicting objectives between ecological conservation and public amenity are acknowledged. However, in the urban space it is important these open spaces are seen to be of value to the community, and a balance between biodiversity and amenity needs to be considered up front.

Land uses and facilities within the wetlands

It is necessary to ensure that there are no new development footprints within flood hazard areas or sensitive areas and their ecological buffers. However, it is recommended that specific areas outside of these no-go zones are designed around an objective of public access. These land uses would include parklands with play and fitness equipment, picnic areas, kick-about spaces etcetera to attract people to the site and in so doing activate the area. These would need to be carefully managed to ensure that the wetlands are not impacted by the types of activities that occur here and can play a role in the shaping of a more resilient city in the context of Climate Change.

Size of green space

The unusual size and extent of the wetlands and pan system of this nature in a city environment emphasises the opportunity for planning, designing and managing a diversity of open space land uses within an integrated space. This area could be an important anchor point within a citywide strategy to create a more resilient system of interlinked waterways and “sponges” that in turn play a critical SUDS role.

4.4.3 Ecological opportunities

This site has been flagged as a priority conservation area, acting as an extension to a much larger high priority water resource network. Important attributes that have been flagged include the presence of primary vegetation and habitat for plant and mammal species of conservation concern. It would therefore be ideal if habitat in the case study area could be rehabilitated and managed as part of a broader open space network.

It is also important to recognise that this site essentially provides an important role to the broader ecological network, and water quality enhancement and stormwater management functions provided by this area can serve to protect and improve the condition of downstream areas, which are key priority wetland areas. Any actions that can serve to address pollutant impacts and mitigate hydrological changes should therefore be viewed positively from a water resource management perspective.

Given the context and realities of the site, it is recommended that ecological considerations be prioritised within the design of functional enhancement opportunities, the need for amenity opportunities and stormwater management constraints linked to urban encroachment. This could be achieved by focussing strongly on wetland rehabilitation efforts in strategic locations to enhance water quality functions whilst also maintaining appropriate controls to recreational activities and further urban encroachment.

Blaauwpan

The Blaauwpan and its upstream wetland receive a large portion of the stormwater emanating from the OR Tambo International Airport. At present stormwater attenuation is the primary ecological function of the pan mostly due to the large opportunity that it has to perform this service, with recreational activities also being a large attraction of the feature. The case has been made to introduce treatment systems (sediment trap and constructed wetland) in the inlet channel from the airport to improve the water quality in the pan instead of creating sections of seasonal/permanent wetland habitat along the edges and open areas of the pan. Ecologically this would serve to create a greater opportunity for the assimilation of nutrients/pollutants from the surrounding landscape and may create additional habitat for fauna such as frogs, birds and other species, but more importantly it will help stabilise the water quality in the pan. Nevertheless, Blaauwpan will still need to retain its flood control function, therefore the resulting fluctuation of water levels needs to be accommodated.

Pan 1 (Middle Pan)

In Pan 1, the wetland is largely intact with a small piece of seasonal open water in the central portion of the wetland where a small pond was excavated previously. Pan 1 has been subject to an existing bioswale stormwater management intervention along its temporary zone boundary, which diverts a large portion of the stormwater flows away from the pan towards the valley bottom wetland. Research into the degree to which the bioswale may be interrupting natural groundwater movement through the area and the relative protection against stormwater pulses of surface water that it would otherwise receive, may offer interesting insight into how best to plan around and manage the pans in this system. Otherwise the current and ongoing management of the pan including alien plant clearing, defoliation of the wetland by burning or cutting every 2 to 3 years, and monitoring of the water quality inputs into the system would be the only recommendation.

Pan 2 (La Como Lifestyle Estate)

In Pan 2, the system is already managed as a stormwater feature with recreational and amenity value created for the local residents through the open water area. There is a transitional zone located along the edge of the pan, where a mix of seasonal and permanent wetland vegetation is already thriving. Management of this zone through regular defoliation, and ensuring the connectivity of the pan to the main valley bottom wetland hydrologically, as well as for the movement of fauna, would be seen as the main ecological objectives for this pan.

Wetland

A strong ecological focus should be maintained in the valley bottom wetland to maintain and enhance the biodiversity values of the broader open space network. The extent and position of the wetland make it the central cog in this high priority wetland complex. As such, further development around the wetland will need very careful consideration and planning. Whilst efforts to maintain and enhance the ecological functional values and wetland habitat should be promoted through wetland rehabilitation efforts, it is acknowledged that access by the local community is important in ensuring the long-term sustainability of the wetland and system as a whole. The size and nature of the wetland as an un-channelled valley bottom system lends itself particularly towards having extensive water quality enhancement potential, flood attenuation properties, as well as key habitat as a biodiversity feature within an impacted landscape.

General

A specialist multidisciplinary team including wetland ecologists, urban designers and environmental engineers should work with the municipality and the community to establish the best balance of amenity, biodiversity and water resource (including stormwater) functions for the area.

4.4.4 Community opportunities

Legal obligations and self-interests can help to initiate and maintain a successful private partnership for stormwater maintenance. As reported above in Section 4.2, this study area is a good example of a successful cooperation between private partners in the maintenance of the pan and its upstream areas, including the monitoring of its effects, through the formation of a Section 21 company for the middle pan (Pan 1). The southern pan (Pan 2) showed that an estate bordering a water body can out of self-interest take responsibility in maintaining such a pan. This is also because upstream influences are limited in comparison to streams with a larger or more diverse upstream area. The maintenance of public land remains a challenge for the municipality, therefore if companies would have interest in better maintained land at their doorstep, a lease agreement could be considered to be further explored.

4.4.5 Maintenance & Management

The maintenance of SuDS systems, especially in the context of their environment and the desired performance targets, is a critical part of ensuring the sustainability of their sustainability. The recommendations in Section 3.7.6 are generic and will apply here. However, the ecological value and the amenity opportunities are important aspects to the implementation of SuDS in this study area and should therefore be part of the monitoring, maintenance and management of the system. Guidelines for the management of wetland systems are outlined below. These are followed by requirements for monitoring the progress in developing the amenity function of the Bonaero pan and wetland systems.

Monitoring and Evaluation for wetland systems

In this study site, the success of the SuDS interventions will be reflected in the enhancement, or impacts, on the receiving pan and wetland systems. Monitoring of these systems is therefore a recommended part of the long-term maintenance and management of the SuDS interventions.

Firstly, a maintenance and management plan for the integrated system of pans and wetland should be established. This is outside the scope of this study, but it is a key presumption in developing the rationale for the SuDS strategy for the system. It is expected that the wetland management plan will adopt an adaptive management approach that will include regular assessments (both rapid and comprehensive) of the integrated wetland system. These assessments will monitor such aspects as vegetation establishment and spread of aliens, but they should also be expanded to include the monitoring of such aspects as:

- Changes in sediment loading and deposition rates (e.g. in the pans);
- Water quality sampling into the system, including some sampling during and just after storm events;
- Water quality sampling at outflows from the pans and from the wetland at Brentwood Park Road;
- Monitoring of flood events, including minor floods when one or more of the pans spill directly into the wetland system (particularly Pan 1 and Pan 2);
- Monitoring of health of aquatic fauna (e.g. fish health in Blaauwpan and Pan 2). This may include reports from fishermen (Blaauwpan) and residents at La Como (Pan 2);
- Other measures will be introduced as the monitoring programme develops.

This monitoring may indicate problems with SuDS interventions within the system, but will also identify were additional interventions may be required. They will also assist in revising the maintenance frequency of SuDS facilities.

Maintenance and management of SuDS interventions and community participation

In addition to the recommendations in Section 3.7.6, where a network of SuDS interventions is established to address a catchment strategy (in this case improving the water quality in the pans and preserving the flood capacity of the wetland system), the maintenance and management of the network is supported by monitoring at a catchment scale. At an advanced level, this may include:

- A network of rain gauges across the catchment (recording 5 minute intervals);
- Flow meters at locations within the drainage network (real time recording);
- A calibrated catchment model to analyse the data of the recorded events. This would be ideally held and operated by the municipality;
- Remote water quality sampling at key locations in the drainage network, typically at a number of the SuDS facilities.

At a practical level, this approach may be supplemented by spatial monitoring of storm events by members of the community (business and residential) across the catchment area. Past experience with the Bonaero communities suggests the residents have a strong interest in their environment (see **Box 3**). This is also a means of encouraging the community involvement in these facilities and the wetland systems that is identified in Section 4.4.2 as a key part of improving the amenity value of these systems. All of the advanced levels of monitoring listed above can be achieved to an extent that will assist analysis and understanding of the system. Certainly, the continuous monitoring will not be achieved, but sufficient selected observations can still make a difference. This level of monitoring may also be offered by landowners where the SuDS facilities are installed if they see this as contributing to the benefit of the community.

Box 3: Monitoring of flood events by residents of Bonaero Park and Atlasville, 2010

In January 2010 the study area was hit by two flood events within a week of each other, resulting in severe flooding in Atlasville, just south of the Bonaero Pans and Wetland system. Initial analysis of the event using rainfall data from OR Tambo Airport weather station could not replicate the flood that occurred.

After contacting residents associations in the catchment a number of residents came forward with rainfall information from across the catchment, and observations of flood levels (with time of day information) and conditions in the flooded stream. The information showed a marked variation rainfall depth and timing across the catchment that explained why the flood event could not be replicated. Furthermore, information on flood levels and conditions in the stream at the time helped refine the analysis of the event, resulting in improved design of the final flood relief scheme.

The residents proved to be enthusiastic monitors of their environment, and shared the information freely. They were also very curious to see and understand the results of the analysis.

5 WEST RAND, KAGISO

5.1 Study area description

Kagiso is part of Mogale City Municipality and is located approximately 6km south of Mogale City centre. It lies on the eastern boundary of the West Rand District Municipality. It lies in the upper parts of the Wonderfonteinspruit catchment in quaternary catchment C23D (**Figure 2**). The location of the SuDS study site is shown in **Figure 59**.

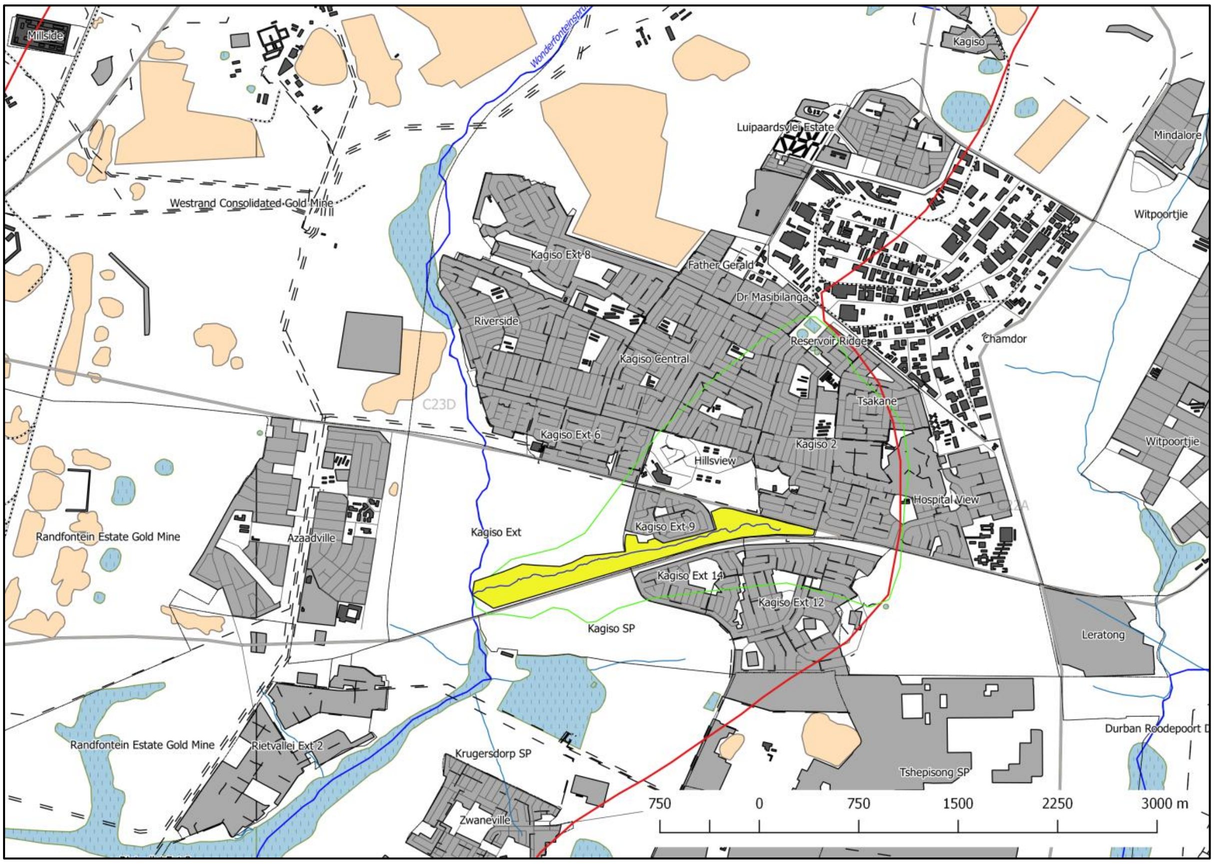


Figure 59: Location of the Kagiso SuDS study area (yellow).

As mentionedin the Introduction, the study area within Kagiso allowed analysis of in-catchment township conditions, the creation of possibly important community space around a SuDS site, and wider catchment benefits. The area is for township conditions quite well developed and maintained, with no informal settlements. Kagiso is in the upper areas of the Wonderfonteinspruit catchment, which is highly impacted by mining and industrial development, as well as urban residential development (both formal and informal), which is relevant for Gauteng. Further reasons for the selection of the study area are described in Section 1.2 and **Deliverable 2: Selection of Study Sites**. The field notes for the study site are presented in **Annexure 4**.

Within the study area, the study focused on a site that follows a tributary of the Wonderfonteinspruit along the R41 Randfontein Road (**Figure 60**). Land use varies from east to west, with the higher intensity use of land in the east (**Figure 61**). It includes a waste recycling centre, an informal landscaping and paving business, and the more intensively farmed gardens are in the eastern sections.

Moving west arable agriculture is less active and the land is more used for extensive grazing. The entire length of the wetland site is just short of 2.7km.

Figure 60: SuDS study site showing current land cover.

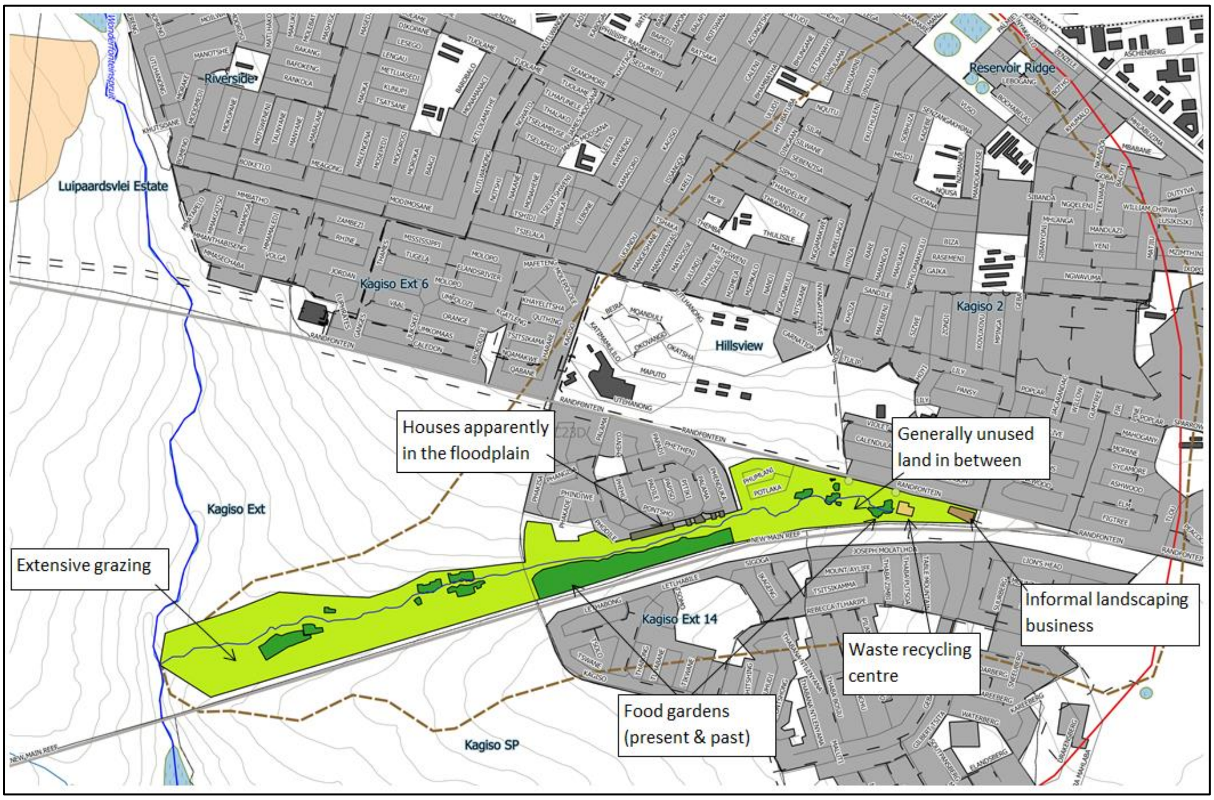


Figure 61: SuDS study site showing current land use and catchment area (brown dashed line).

Figure 62: Kagiso township (1)

Figure 63: Kagiso township (2)

5.1.1 Stormwater context

The site is divided into three treatment zones as shown in **Figure 64**. The sub-catchments contributing to each zone is presented in **Figure 68**. The total catchment area is 447 ha and the total area in the treatment zones is 47.6 ha (**Table 16**).

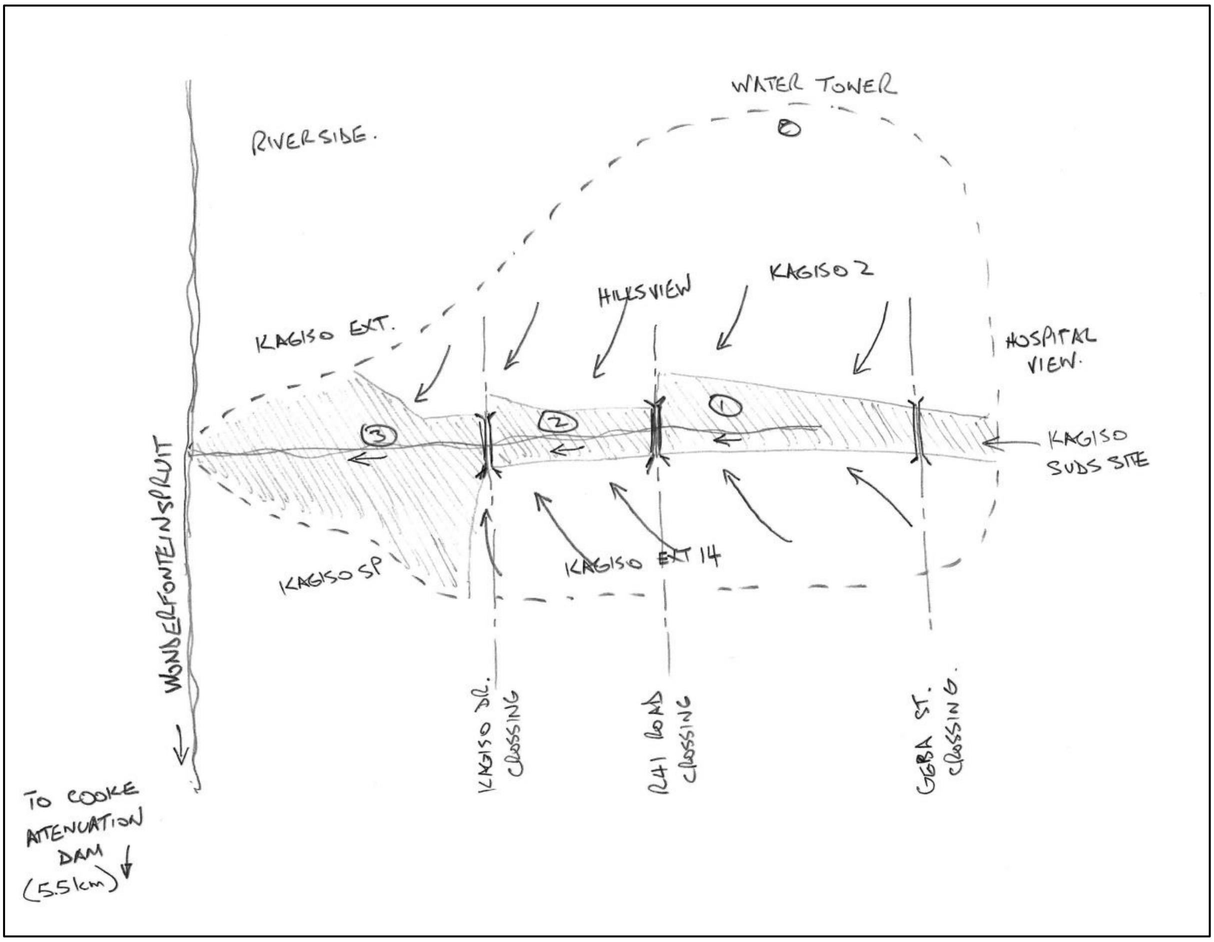


Figure 64: Kagiso SuDS treatment zones

Figure 65: Kagiso SuDS Zone 1

Figure 66: Kagiso SuDS Zone 2

Figure 67: Kagiso SuDS Zone 3

The indicative hydraulic loading ratios are also given in **Table 16**. The loading ratio for Zone 1 is least favourable at 23:1 (catchment area:treatment area). Zone 3 offers better potential at 3.3:1, but this excludes the run-on from upstream treatment zones, so the effective loading ratio will be higher than this. Overall the loading ratio for the system is just under 10:1 which is considered a reasonable loading ratio.

Figure 68: Kagiso Study site sub-catchment layout.

Table 16: Kagiso sub-catchment areas.

Catchment	Area (ha)	SuDS Zone	Area (ha)
1	122.70	Zone 1	12.16
2	57.84		
3	64.12		
4	34.06		
	278.72	Loading (1:X)	23
5	42.77	Zone 2	10.03
6	22.53		
7	20.65		
	85.96	Loading (1:X)	8.6
8	15.53	Zone 3	25.37
9	7.97		
10	9.30		
11	34.19		
12	15.75		
	82.74	Loading (1:X)	3.3
Total	447.41		47.56
		Loading (1:X)	9.4

No water quality data is available for the stream in the study site, but observations on site and discussions with municipal officials highlight the following:

- High gross pollutant loads (litter),
- High sediment loading from stormwater outfalls into the site,
- Reports, and some evidence, of high E.coli levels at times.

The Wonderfonteinspruit (**Figure 69**) is the receiving system and it has a host of problems largely linked to the history of mining in the catchment. These problems have been simplified into two criteria that have influence on the study; (1) flood flows are restricted by downstream flow capacity limits and therefore attenuation of storm flows is important, and (2) tributary flows assist in diluting the stream flows in the Wonderfonteinspruit that are contaminated by mine water discharges, and hence improving water quality from the Kagiso catchment will help mitigate the pollution conditions in the receiving system.

Figure 69: Wonderfonteinspruit showing flows bypassing the Cooke Attenuation Dam, and the flow diversion offtake structure with limited flood capacity further downstream.

5.1.2 Planning context

Kagiso is a well-established residential township outside Randfontein and while it is supported by a number of schools, key institutions and retail nodes, it lacks a legible public realm and public areas to which the community are attracted and in which local residents can gather, socialise, recreate, find relief and interact with nature. Kagiso was developed by the government to house labour working on the local mines and industry. Kagiso's layout was not informed by topography or natural systems but largely by the need to be efficient. The potential to integrate the public space network with a system of green open spaces for water collection, attenuation and cleaning and recreation was never considered. Stormwater is accommodated in a piped system under ground and more recently, in the later township extensions, by a set of narrow stormwater corridors linking down to the site. Backyards and high boundary walls frame these corridors resulting in them being unsafe.

The site itself is currently not identified as a valued part of the public space network or green open space network. It is left over space and appears to be regarded as having a utility role, receiving stormwater flows and accommodating other large water and sewer pipelines. However, the site has ironically become a spatial integrating element thanks to the bridges which connect over the shallow valley and watercourse. These bridges link neighbourhoods and allow residents to access key facilities and retail opportunities and schools on either side of the watercourse. The main Kagiso hub is within walking distance of the site and accommodates not only a large mall and two schools but some very large public buildings including SAPS, Magistrates Court and the Gauteng Provincial Archives Centre.

The bridges are the site of intense pedestrian movement. Where they connect with the R41, they function as public transport hubs around which there is informal business activity. There is also evidence of home based industry and businesses in the properties backing on to the R41 and the Randfontein Rd. There are definitely opportunities for the municipality to formalise transport stops and build trading hubs along the R41 close to the bridge intersections where pedestrian activity is most intense.

Formal economic activity on and in the site is currently limited to a waste recycling depot Itsose. While this is a potentially, complimentary land use, the site is currently not managed in a way that supports ecological functioning of the green systems surrounding the facility. Dumping / sorting and unmanaged vehicular movement has led to pollution of the watercourse and local habitats. Other edges of the site are unfortunately also dirty with evidence of dumping.

There is almost no space provided for recreation in the Catchment Area with the exception of school fields that are mostly secured and unavailable for use by the general public. There is sufficient evidence to demonstrate that there is a need for fields where team sports can be played. Informal kick about spaces have been formed in open flat areas. There are two kick about spaces within 100m of the site but these are basic earth pitches with no formal edging or supporting infrastructure.

The site has been used over the last decades for farming and more specifically the growing of crops such as maize. The areas under cultivation seemed to have changed in extent and location over time but the crops contained within fenced off areas, have become standard feature of the landscape.

Properties adjacent to the site are generally accessed from the reverse side with the**ir back** boundaries defined and secured by means of high boundary walls **facing the site**. These walls restrict views towards and direct access to the site. The other characteristic of Kagiso which is not unique to the area is the phenomenon of backyarding. Properties to which people have title present opportunities to increase household income **through** leasing of accommodation. Additional rooms are built in the backyards of formal houses **for this purpose**. Yards are often hardened to maximise on the space. Rainwater is often channelled into the stormwater network to ensure the yards are not flooded. Backyarding **therefore** puts enormous strain on the services, and in particular the stormwater system.

Residential densities are approximately 30-40 du/ha but with backyarders the density can double if not triple to 90 to 120 du/ha. Officials have suggested that the average number of people per site of between 250m² and 300m² is approximately 12.

5.1.3 Ecological context

This site falls within the Upper Vaal catchment and is currently being highly threatened by water quality impacts associated with the acid mine drainage decant into the Wonderfonteinspruit, from the western basin in Gauteng. Of particular concern are water quality issues where salts, system variables, toxins and nutrients are all at or have transgressed borderline levels and pose a high risk to downstream users.

Desktop information on the condition of the upper Wonderfonteinspruit catchment in which the case study site is located indicates that the river is Critically Modified (E PES Class) and that the site is of moderate ecological importance and sensitivity from a water resource management perspective. This is linked primarily with urban land use and contamination from mines in the upstream catchment. The Desired Ecological Category is indicated as a C, suggesting that the management objective for the catchment should be to improve the current status of water resources in the catchment. This implies that proactive interventions are required in this catchment to meet water resource management objectives.

This is supported by a recent study that established Resource Quality Objectives for the Upper Vaal catchment. The report specifically highlights the need for high impacts to water resources in this region to be managed so that the ecosystem can provide ecosystem services. Broad objectives have been set such that water quality in this catchment must not deteriorate below a D ecological category and the consumption of fish harvested from rivers in the area must not pose a threat to human health.

According to the available NFEPA wetlands coverage, wetlands in the case study area have not been flagged as priorities for wetland conservation. This is likely to be partially attributed to the level of transformation along the river corridor as a result of agricultural activities which are evident in much of the buffer zone and encroach into the wetland in places.

The Kagiso wetland system is broadly described as a channelled valley-bottom wetland. The upper reaches of the wetland are characterised by unchannelled sections however where large reedbeds dominate whilst flows become more concentrated as one moves down the drainage line. This change in characteristics is largely attributed to drainage associated with road crossings and increased runoff from the catchments that promotes channel development.

From a terrestrial perspective it is important to note that the historical dominant vegetation type present would have been the Soweto Highveld Grassland, which falls under the Mesic Highveld Grassland Group 3 bioregion (Nel et al., 2011; Mucina and Rutherford, 2006). The vegetation type has been classified as 'Endangered', with only 0.2% receiving formal protection. A status of endangered indicates that there is very little of the original extent of the ecosystem type left in a natural or near-natural state. Most of the ecosystem type has been moderately or severely modified from its natural condition and it is likely that most of the natural structure, functioning and species associated with the ecosystem may have been lost (Nel et al., 2011). Endangered ecosystems are close to becoming critically endangered. Any further loss of natural habitat or deterioration of condition should be avoided and the remaining healthy ecosystems should be the focus of conservation action (Nel et al., 2011).

The site has been flagged as being of very high sensitivity in the Gauteng Conservation Plan (Critical Biodiversity Area). Whilst further specialist studies would need to be undertaken to build a more comprehensive understanding of the site, it is clear that the river corridor targeted for SuDS interventions has been identified as a critical biodiversity area and has been earmarked as a conservation area. It is also important to note that this is an extension of a much larger open space network which runs along the Wonderfonteinspruit River which includes large areas of intact grasslands and connections to large and important wetlands downstream.

Whilst aspects of the ecological character of the case study site have been changed, it is important to note that the there is a general transition from high levels of disturbance (Lower PES) to the hydrological, geomorphic and vegetative components of the system, to limited disturbance (higher PES) as one moves from the upper reaches of the site towards the confluence with the Wonderfonteinspruit River. Direct disturbance to these three components of wetland condition/integrity is measurable and is largely linked with agricultural activities, whilst dumping, and urban encroachment have served to further undermine the ecological integrity in large parts of the site. Levels of disturbance are lower on the southern bank however, since no formal development has been undertaken between the wetlands and the R41.

In terms of ecological connectivity, road linkages, disturbance, light and noise pollution have reduced the value of the site as a corridor for species movement. The upper reaches of the stream are also not well connected to other priority conservation areas, with a transition to a high use open space zone along the R41 which is bordered by dense residential areas. As such, the lower reaches of the drainage line are regarded as providing supporting habitat to biota using the broader open space network. The upper reaches of the site become progressively less suitable for sensitive species.

Based on the underlying conservation values of the site, the narrow drainage line has been classified as Environmental Management Zone 2 in the Gauteng EMF. According to the EMF guidelines, this zone is sensitive to development activities and only conservation should be allowed in this zone. Related tourism and recreation activities must be accommodated in areas surrounding this zone.

5.2 Consultation Outcomes

During the large workshop on 5 February 2019, a parallel session was set up for the Kagiso area, with good introductions by the Mogale City officials on the particular challenges of Kagiso, but limited outcomes for this report. The dedicated workshop on 9 April had a good representation of the City of Mogale with a councillor from Kagiso, and several representatives from the environmental management and planning department. The Roads and Stormwater department unfortunately had to apologize. The West Rand District Municipality was represented with its section of disaster management, who confirmed that flooding in Kagiso was not a concern. Also, the owner of the Itsose Recycling Centre, which is located at the upstream end of the wetland, was present, as well as a representative of the schools for which rainwater harvesting could be considered.

Outcomes of this consultation that are learning points for this analysis are:

- **SuDS might not be the first priority for the community, but the need for pleasant open space is at municipal level recognized.** While the farmers in the wetland where not directly represented, participants doubted that the current agriculture in the wetland site would be in need of stormwater harvesting for irrigation. The need for additional park area would still need to be confirmed, but the City of Mogale officials thought that greening of streets could be appreciated. The school representative was open to rainwater harvesting at the school and in the neighbourhood, but emphasized before such measures were taken, first a decent time of awareness raising would need to take place, before the need by locals and schools could be confirmed.
- **The lack of follow up on illegal environmental damage reported is a risk for introduction of SuDS.** The Itsose recycling centre owner expressed his concern about the lack of follow up on clearly illegal dumping damaging the stormwater system and creating flood damage and pollution. His experience was being sent from pillar to post. The different local and provincial organisations recognized the problem as a risk, without having yet a solution to propose.
- **Safety is an important aspect.** The discussion during the workshop came back a few times to safety issues. For example, if a pond is introduced, the risk of drowning of children could be there. Park areas needed to be fenced securely, and lack of safety had been to the detriment of the parks that were supported by a provincial initiative. Also, the introduction of rainwater harvesting for use for non-potable demands, could introduce the risk of use for potable demands, in particular because the area regularly had water cuts. The Chief Mogale

community centre clearly was also prone to vandalism, in particular at the sanitation areas, where taps were stolen. This is rather a warning for the way in which further designs should take place, and safety in this respect should also be taken care of.

5.3 SuDS Interventions Assessed

5.3.1 The Baseline Scenario ("Do nothing")

The Baseline Scenario represents a simulation of the present day conditions as a reference for comparison of the performance of other interventions. **Figure 70** presents the model schematic for this condition. It acknowledges there are already two wetland systems on the site. The wetlands are analysed fairly sympathetically even though they are somewhat degraded through erosion. The performance results in **Table 17** are considered fairly optimistic.

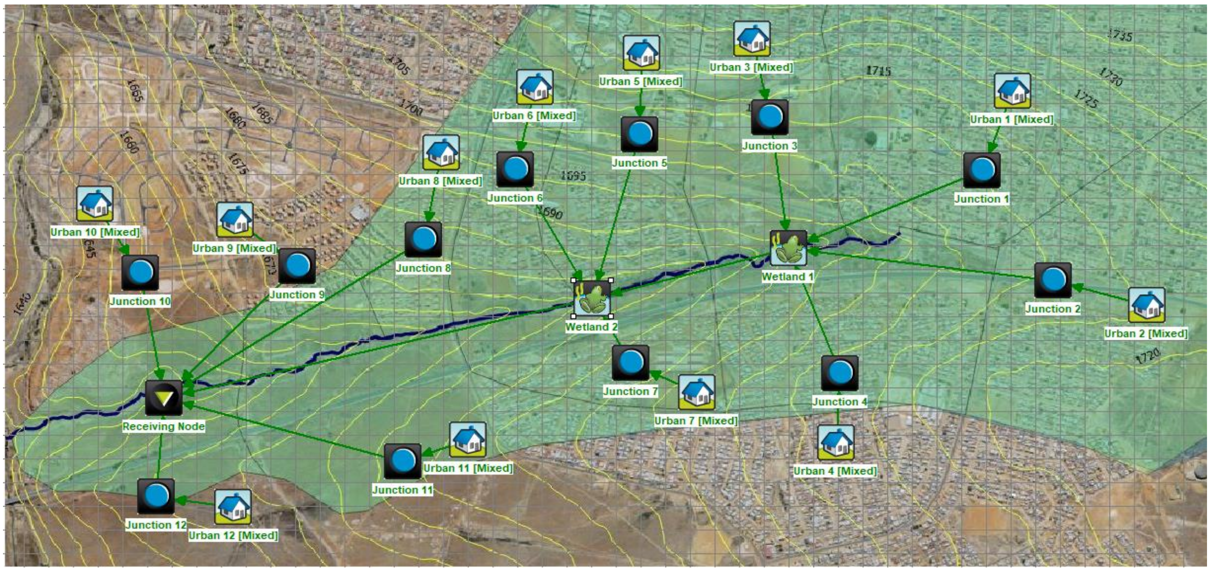


Figure 70: MUSIC model schematic representing the present day Baseline Scenario

Table 17: Baseline ("Do nothing") system performance

Aspect	Performance "Do nothing" scenario
% Load Reduction	8.99
TSS % Load Reduction	57.5
TN % Load Reduction	25
TP % Load Reduction	47.3
GP % Load Reduction	94.3

5.3.2 Assessment of "In-catchment" Detention

This scenario seeks to test the potential for establishing detention facilities in open areas within the catchment area. They typically consider the establishment of shallow detention basins (maximum depth 0.5m) that will drain within a few hours (notional detention time is around 6h). The concept is depicted in **Figure 71**. The concept would be applied to the likes of school playing fields and municipal open space where informal playing areas have been established. The overall system performance (i.e. at the outfall into the Wonderfonteinspruit) is shown in **Table 18**.

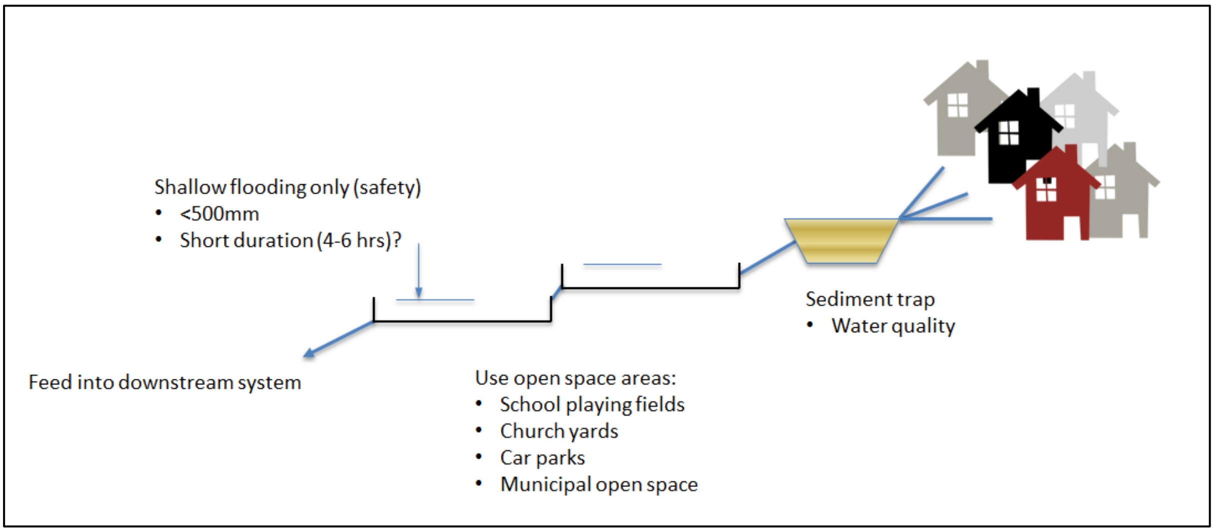


Figure 71: Concept for "In-catchment" detention at Kagiso

Table 18: System performance results for "In-catchment" detention basins

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

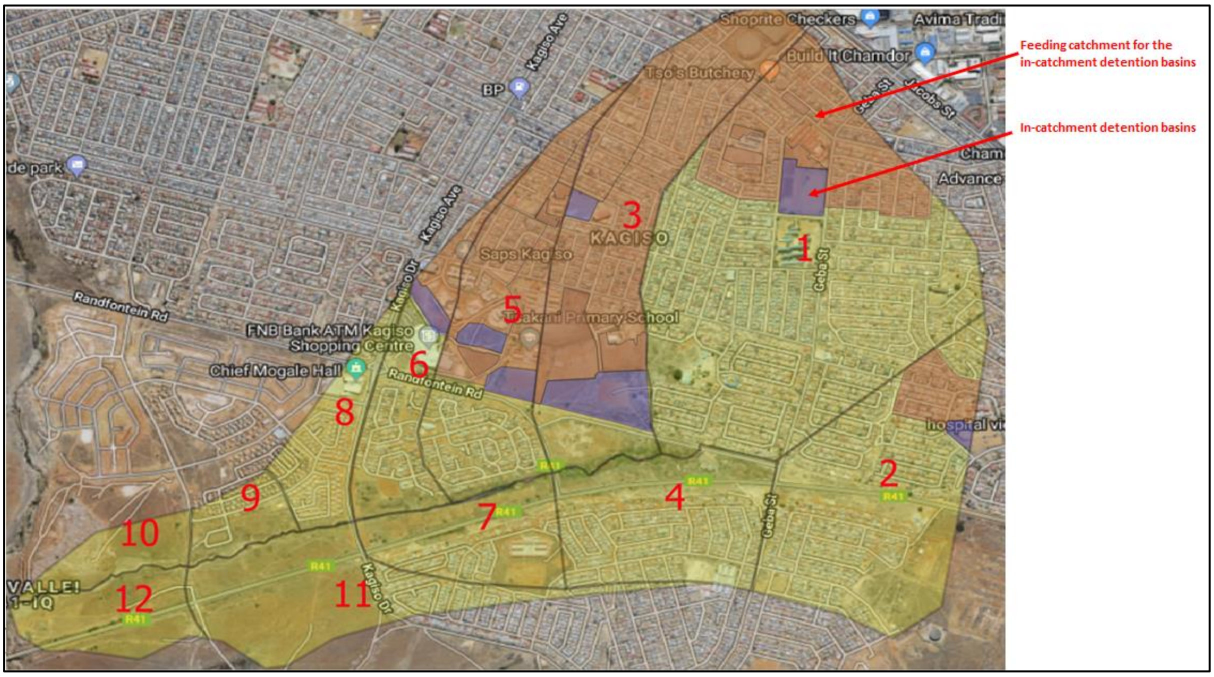


Figure 72: Selected "In-catchment" detention areas utilising available open space.

The In-catchment interventions have been modelled for catchment 1, 2,3,5,6 and have a potentially important impact on the pollution yield of the overall catchment. Performance at an individual sub-catchment level is summarised in **Table 19**. Sub-catchments 3 and 5 show the expected higher levels of treatment performance.

Table 19: Performance at individual catchments for in-catchment interventions.

Location	Catchment 1	Catchment 2	Catchment 3	Catchment 5	Catchment 6
% Load Reduction	1.79	1.03	9.42	6.82	3.99
TSS % Load Reduction	20.5	10.8	75.9	66.5	20.7
TN % Load Reduction	9.67	5.18	38.6	32.2	11.9
TP % Load Reduction	15.3	8.03	57.3	49.7	16.1
GP % Load Reduction	23.5	11.3	85.9	71.2	21.3

5.3.3 Integrated SuDS Treatment Train in the Study Site

The SuDS treatment train was built up zone by zone (**Figure 68**) using a combination of measures in a manner similar to the system shown in **Figure 73** for Zone 1. Sediment management is at the head of each treatment train and is usually first receiver of stormwater flows from the catchment. Thereafter the sequence is dependent on the characteristics and objectives of each zone. The schematic of the full system is fairly complex and is given in **Figure 74**.

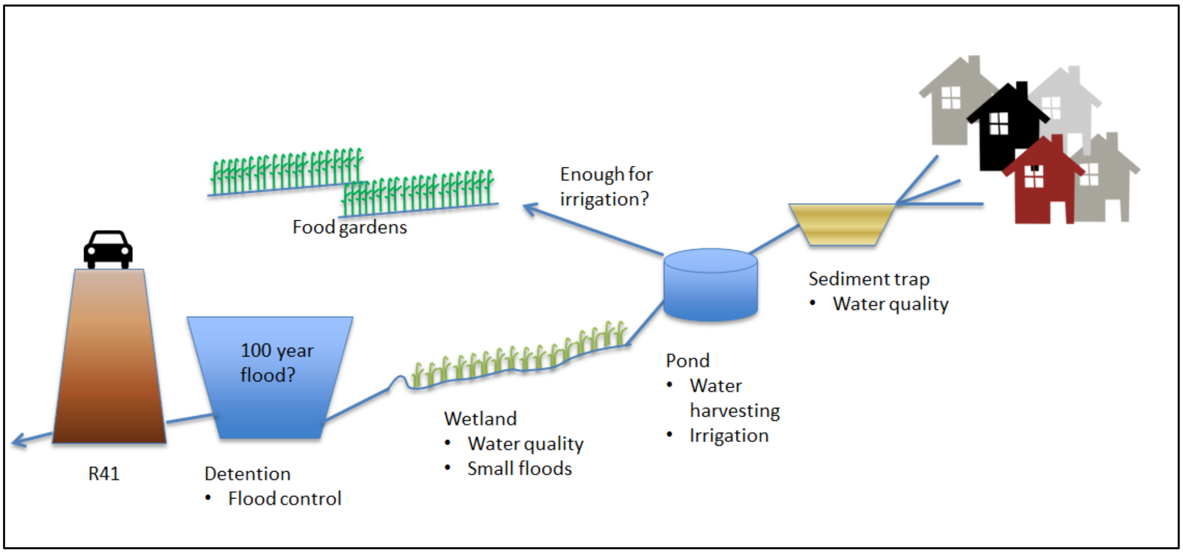


Figure 73: Concept for the treatment Train in Zone 1

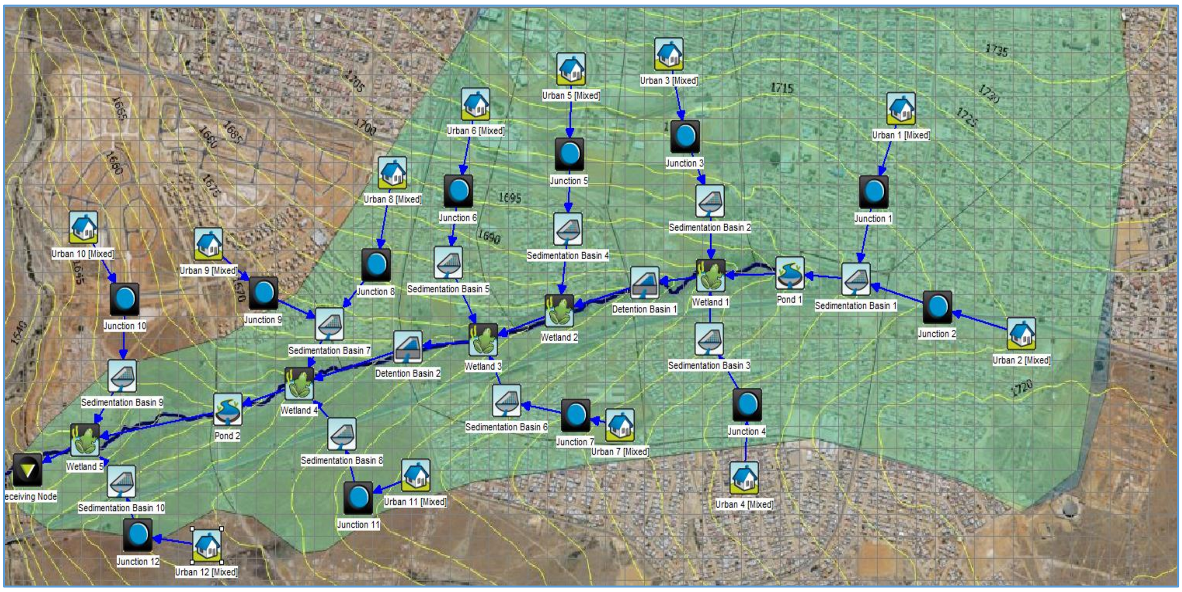


Figure 74: Schematic of entire treatment train for SuDS interventions in the study site.

Table 20: Performance results for the full SuDS Treatment Train in the study site

Aspect	"Do nothing"	Full SuDS TT
% Load Reduction	8.99	41.7
TSS % Load Reduction	57.5	97.5
TN % Load Reduction	25	71.3
TP % Load Reduction	47.3	89.3
GP % Load Reduction	94.3	100

The results of the overall performance of the integrated SuDS treatment train on discharges into the Wonderfonteinspruit are shown in **Table 20**. Apart from the flow reduction of only 42%, all the other treatment measures indicate a high level of performance. However, in a complex system such as this, the results warrant more detailed scrutiny to assess where the system may be streamlined with minimal loss of performance.

5.3.4 Full SuDS Treatment Train with "In-catchment" detention

The performance of the system that combines all In-catchment and on-site SuDS measures is presented in **Table 21** with the results from the previous simulations for comparison. The fully integrated system provides only marginal improvement on the full SuDS treatment train on the study site. This suggests there may be a more cost effective combination of the measures. This will require further detailed analysis of the results.

However, an important outcome is that there is sufficient space to achieve a high treatment performance and substantially improve the quality of the water entering the Wonderfonteinspruit. Space is often a limiting factor in retro-fitting SuDS. Instead, here the aspects of cost and the acceptability of the scheme proposals to the community may have the greater influence. Nevertheless, these results should leave some optimism that wider application of SuDS within the catchment of the Wonderfonteinspruit may enable some important improvements to the water quality in the river system.

The benefits of these schemes in flood management are discussed further below.

Table 21: Summary of performance results including the fully integrated solution.

Aspect	"Do nothing"	"In-catchment" DB	Full SuDS TT	Full SuDS TT + "In-catchment" DB
% Load Reduction	8.99	12.2	41.7	45.3
TSS % Load Reduction	57.5	71.3	97.5	97.7
TN % Load Reduction	25	35.5	71.3	73.9
TP % Load Reduction	47.3	59.1	89.3	90.1
GP % Load Reduction	94.3	94.1	100	100

5.4 Summary of Performance Measures

5.4.1 Water reuse

Facilities for harvesting stormwater have been included in the proposed treatment train as shown in **Figure 75**. Preliminary results show the harvesting potential is greater than initially tested, but further analysis has not yet taken place.

Figure 75: Location of the stormwater harvesting ponds

An irrigation demand of 5mm/day was assumed, irrigating an area just under 5000m^2. This leads to a combined daily drawdown of 24.4 kl/day. A combined site storage of 10 200m^3 (4300 and 5900m^3 respectively) has been used. This was intended as a preliminary scenario for analysis and that further trials would follow. Unfortunately, this was not taken further in the study.

However, the results of the first scenario showed that demand was met in excess of 75% of the time, but that over 95% of the stormflows passed directly through the ponds. Hence the stormwater resource was substantially under-utilised in this trial. Assuming that only 30% of the storm flows that pass through the ponds are harvested, this is equivalent to 1Ml/day harvested (ignoring the effects of seasonal variations). This would provide irrigation water for up to 20ha/day. The science of irrigation has advanced substantially and the size of the irrigated area that could be served by a stormwater harvesting programme could be 10-fold greater than tested in this initial trial. Irrigation improves the production levels of food gardens and creates opportunities for more water sensitive crops to be considered. This may help transform agriculture in the site from a subsistence level to possible commercial potential.

5.4.2 More natural flows and water quality improvement

Table 21 summarises the load (flow) reduction and water quality improvements arising from the SuDS interventions. The flow reduction of up to 45% of the developed catchment yield will still not mimic the original natural catchment yield (likely to be less than 10% of mean annual rainfall), but it will assist in improving the flow duration characteristics of the stream; reducing flash floods and extending the time that the stream flows to represent a more natural flow pattern. Stormwater as a water resource will substantially improve both the ecological health of the river system and the "Harvestability" of the resource.

5.4.3 Flood reduction

The capacity of the system to mitigate flood events is demonstrated by routing design flood hydrographs of 2,5,10 year return periods, through the two detention basins in the SuDS treatment train (**Figure 76**). The flood hydrograph for the upper catchment is routed through Detention Basin 1 (DB1), and then it is added to the flood hydrographs from the intermediate catchment. The results are demonstrated in the graphs of the 2 year, 5 year and 100 year design flood events. The flood hydrographs were prepared using the SCS method (Schmidt and Schulze, 1987).

Figure 76: Location of the detention ponds

Details of the detention basins are summarised in **Table 22**. An attempt has been made to identify achievable storage on the sites without excessive excavation, but this was based on limited information on terrain levels. Review of the storage volumes suggests they may be somewhat optimistic, but they are within the scale of the site.

Guidelines for the planning of attenuation facilities propose that storage requirements in the City of Johannesburg are of the order of 350m^3/ha of development. **Table 22** shows this is achieved for the catchment as a whole, but this is not allocated equally between the two basins, with the upper basin (Detention Basin 1) carrying the heavier flood load. This is demonstrated in the flood attenuation hydrographs in **Figure 77** to **Figure 79**.

Figure 77 to **Figure 79** show the routed hydrographs through the two detention basins is substantially reduced; the 2 year peak is almost 10% of the peak inflow, the 5 year event is reduced by approximately two thirds, and the 100 year event by approximately 30%.

Table 22: Detention Basin data applied in the flood analysis

Detention Basin 1	
Detention Basin volume (m^3)	53 000
Average surface area (m^2)	18 000
Catchment area (km^2)	2.79
Catchment area (ha)	279
Unit storage (m^3/ha)	190
Detention Basin 2	
Detention Basin volume (m^3)	73 000
Average surface area (m^2)	24 300
Intermediate catchment area (km^2)	0.86
Intermediate catchment area (ha)	86
Unit storage (m^3/ha)	850
Integrated detention storage	
DB1 & DB2 (m^3)	126 000
Total Catchment area (km^2)	3.65
Catchment area (ha)	365
Unit storage (m^3/ha)	345

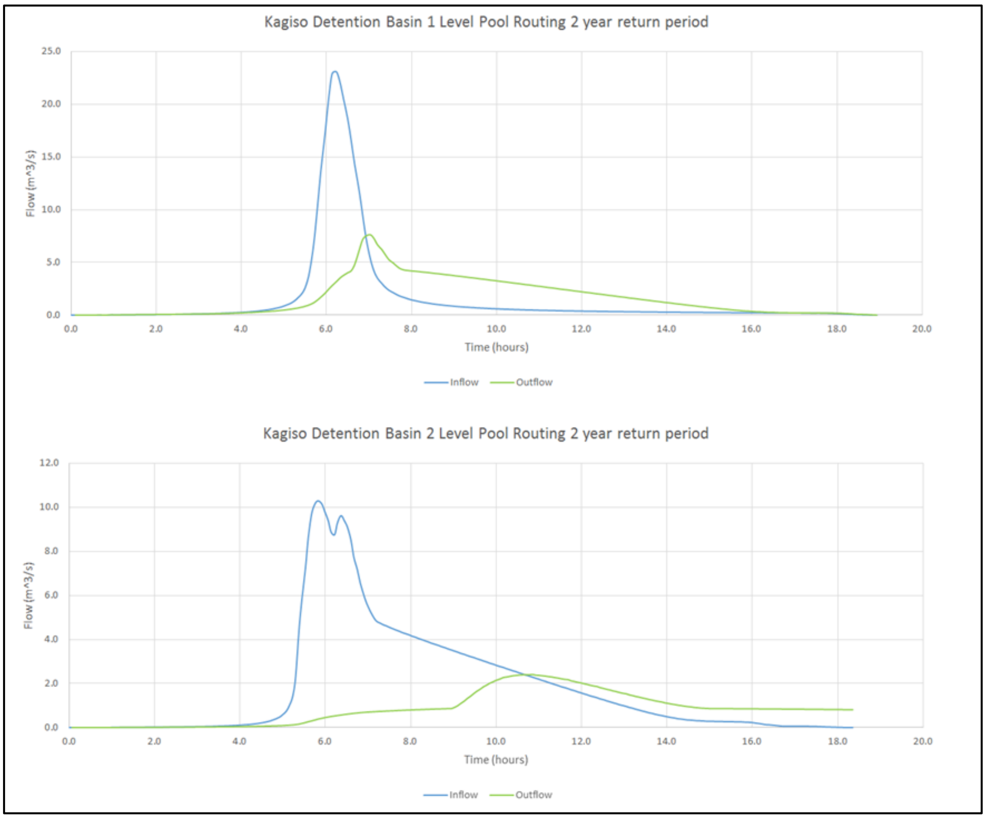


Figure 77: Detention basin performance for the 2 year design event

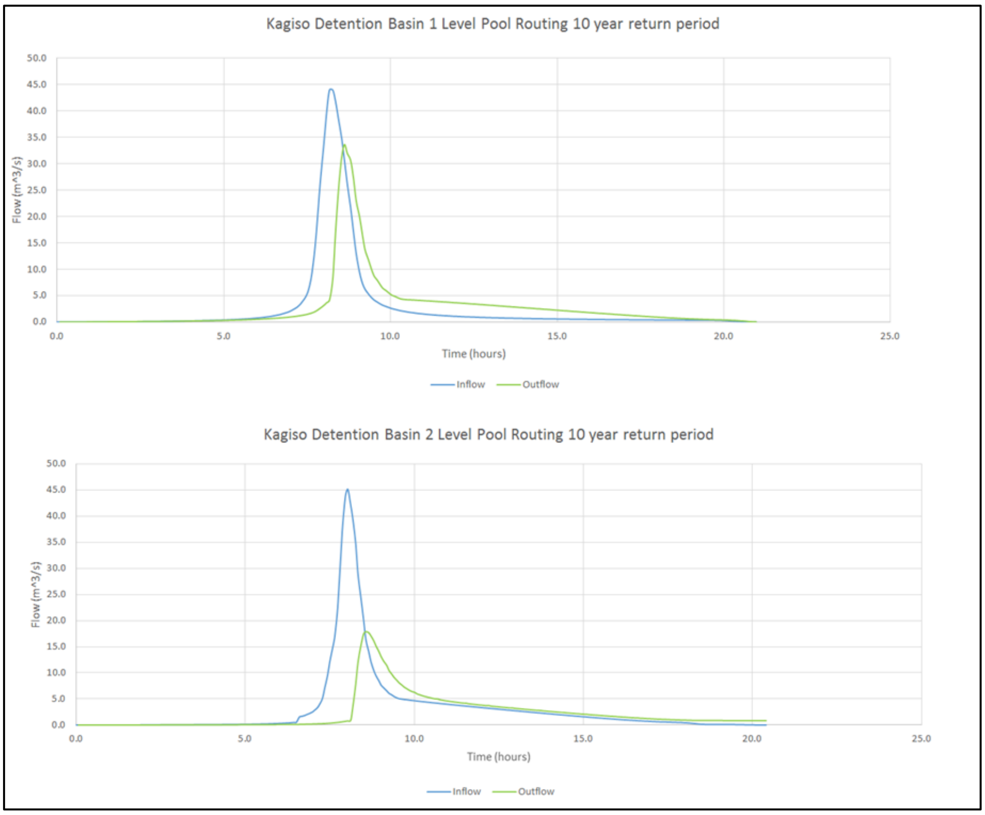


Figure 78: Detention basin performance for the 10 year design event

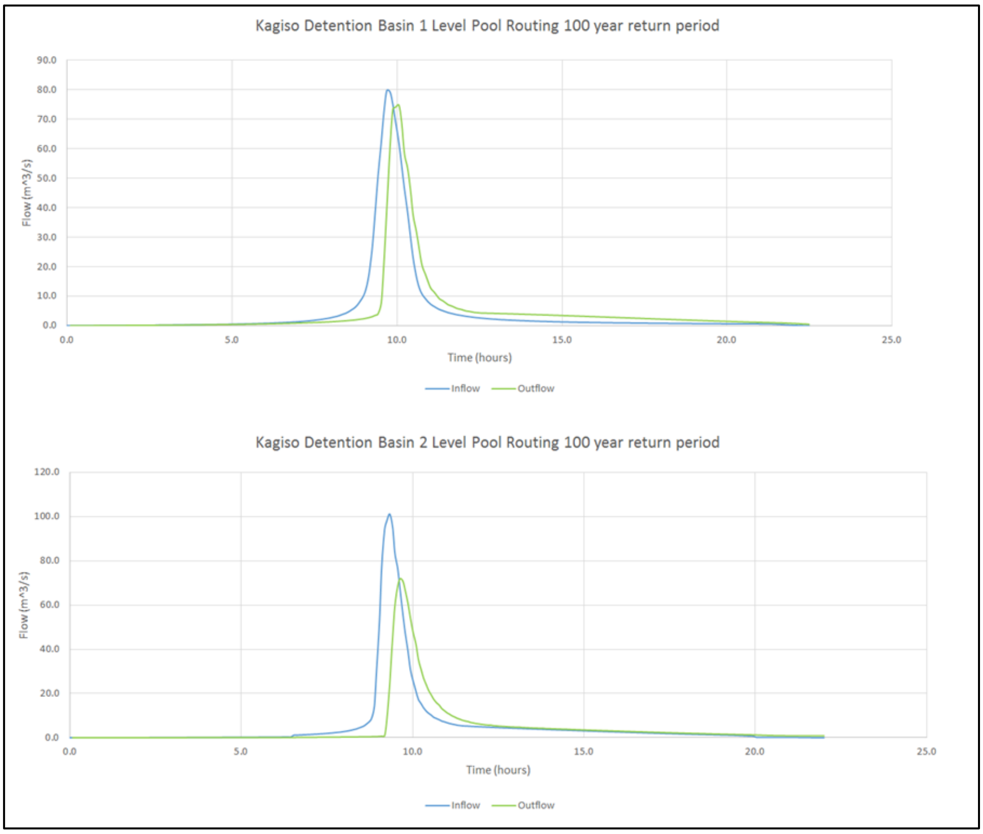


Figure 79: Detention basin performance for the 100 year design event

5.5 Recommendations

5.5.1 Stormwater management

In stormwater terms, the SuDS interventions tested for the study site is equivalent to a regional facility. This is where a larger catchment area is treated by one facility. The equivalent regional facility would be a number of developments contribute to a larger attenuation dam located off-site. This study has shown that a regionally located treatment train can perform to a standard similar to what would be expected for SuDS treatment trains established on an individual site. The cost:benefit analysis may challenge the benefit of this approach, but the study outcomes give helpful insight to the potential for retrofitting SuDS which will be a particular challenge in Gauteng with the already extensive development across the province and the already severely damaged river systems.

Although the “in-catchment” SuDS measures do not appear to add much to the overall performance of the system at this location, their contribution to the study outcomes is still important. The cost:benefit analysis may show opportunity to achieve between local and regional facilities as part of a retro-fit programme. This implied some of the regional SuDS measures may be scaled back to create more space to meet amenity and ecological objectives.

Concerns about the suitability (and safety) of all these measures in the community space still needs to be addressed. For this reason, there may be a preference for the regional interventions rather than the “in-catchment” interventions. However, this may imply that the community will see the regional facility as a municipal responsibility and not as part of the community environment. This would be seen as a concern as the longevity of such interventions is normally reliant in substantial level of community interest and even ownership.

For this reason further research on the potential for stormwater harvesting is a gap in the analysis of this case study, particularly if this is perceived to be a direct benefit of the scheme. It may change the way in which this part of Kagiso is used within the community environment and, as has been already been indicated, community involvement in further decision making on development of the study site is seen as a critical success factor for a project of this nature. There is certainly more that can be explored through the data that has been generated thus far, but time has limited this part of the investigation.

The value of this case study is not that it will make a difference to conditions in the Wonderfonteinspruit, but that it offers a framework for planning similar interventions across the Wonderfonteinspruit catchment, and others in the region. A critical mass of SuDS is needed to make a difference at catchment scale, particularly if water security and climate mitigation are the objectives.

5.5.2 Adapting the urban space

Climate change will affect Kagiso and other former black townships in profound ways as individuals in these areas do not have the financial robustness to address the effects of Climate Change such as increasingly higher temperatures, drought and flooding at household level. Low levels of household income result in a focus on day to day survival including managing the costs of transport, food etc. and do not necessarily allow for a focus on long term strategies to avert disasters and contribute to making more robust and resilient cities.

This means that the state will be largely responsible for driving interventions that address climate change. This is not to say that the state should ignore the potential of residents to engage long term issues related to climate change but that the project in question should acknowledge that investment in green open spaces for SUDS might not be bought in to as a priority at this present point in time. Unless of course the proposed investment in SUDS on the site can address basic needs of local residents simultaneously to addressing stormwater issues. This might involve supporting compatible income generating activities (farming) / food production, allowing places for relaxation and recreation. The following suggestions should be read in light of the proposition that investment in SUDS on the site will be unsuccessful unless there is also investment in infrastructure that addresses functional, social and psychological needs.

The proposed SUDS intervention will not utilise the entire site. The remaining land at the edges of the site will still be available for other compatible uses such as agriculture, relaxation, socialisation and recreation. However, to ensure the space is useable for this purpose, there is a need to make the site safer which can be achieved through a combination of strategies. The first would be to locate future educational, sport or social facilities at strategic points (including close to the current recycling depot) where they can be fed by passing foot traffic, be visible and accessible from the higher order roads in the area but most importantly, provide eyes over the green open space. The second action would be to promote and encourage local residents to take down their walls and put up visually permeable fencing with gates and upgrade their backyards to become part of the larger green zone. The local authority should support small home businesses along the residential properties facing the space. This would help to activate the edge and provide improved surveillance over the valley. Where existing layouts for new housing close to the site are not yet finalised or approved, the local authority should consider the impact of the layout on the proposed plans for the site and ask for revisions thereto, where required.

To address the need for social, recreational and relaxation space it is proposed that a structured play area / parkland is established on the largest most centralised and accessible part of the site. Some parts of this parkland could be less formal and other parts formalised to include mini kick-about spaces or a basketball court. Indigenous vegetation, limited hard surfacing and grassed areas within the identified area should accommodate children's play equipment and picnic areas. A network of new NMT paths running around the periphery of the entire site, including three new NMT bridges over the watercourse, would service the current desire lines and provide opportunities for people to run and cycle safely off the main roads. This network of paths would improve legibility and safety for users of the site.

The issue of water safety of park users and pedestrians will need to be carefully considered. It is critical that edges to water bodies and courses are not steep and that points where people cross the watercourse have the necessary balustrades where drop offs occur. Fences should as far as possible not be used to cordon the watercourse off from the remainder of the site as the watercourse should be experienced as part of the parkland. Edges of the watercourse can be shaped in places to allow children to play in the water but water depths should be shallow and warning signs provided.

Further recommendations would be to terrace parts of the site to accommodate playing fields which in turn could play an attenuation role through the wet seasons. The site is intended to accommodate development in the future but the local authority would do well to insist that future developers accommodate a centralised pedestrian link and open areas for attenuation of stormwater.

Rain Water Harvesting (RWH) which requires action at the level of household will be similarly challenging as it requires upfront investment that is beyond the means of most residents and not understood to be a priority in relation to the basic day to day needs of households. If the RWH were to be sold as a strategy to save monthly costs, it may well be received more easily but with water tariffs structured as they are, it is not likely to be in the interests of households to invest in rain tanks etc. Further complexity lies in the fact that regulators are still in the process of addressing the challenge of regulating water harvesting. Until such time that there is a clear and realistic strategy to ensure water quality issues at household level can be regulated, RWH on residential properties should not be proposed unless there is clear use for non-potable applications only. However, the state and large commercial operators in the area, who can be held accountable and more easily regulated, should be targeted to install comprehensive RWH systems. These will also serve to demonstrate over time the potential advantages of RWH to residents.

5.5.3 Ecological opportunities

This site has been flagged as a priority conservation area, acting as an extension to a much larger open space network. Important attributes that have been flagged include the presence of primary vegetation and habitat for plant and mammal species of conservation concern. It would therefore be ideal if habitat in the case study area could be rehabilitated and managed as part of a broader open space network.

The reality however is that existing conservation values have been significantly undermined in the upper reaches of the site and there is clearly a strong demand for agricultural land that has led to significant transformation of natural habitat along the drainage line. Given this context, it is likely that a compromise will need to be made between agricultural use and conservation efforts, with the management of use of the wetland and buffer zones forming an integral part of an integrated approach to this area that will create and achieve sustainable/achievable social and ecological objectives concurrently.

It is also important to recognise that this site essentially provides a supportive role to the broader ecological network, and water quality enhancement and stormwater management functions provided by this area can serve to protect and improve the condition of downstream areas which are already heavily impacted and in need of positive enhancement interventions. Any actions that can serve to address pollutant impacts and mitigate hydrological changes should therefore be viewed positively from a water resource management perspective.

Given the context and realities of the site, it is recommended that ecological considerations be balanced with functional enhancement opportunities, the need for agricultural land and stormwater management constraints linked to urban encroachment. This could be achieved by focussing strongly on wetland rehabilitation efforts in strategic locations to enhance water quality functions whilst also maintaining appropriate management (see 5.6.5) controls to agricultural activities and further urban encroachment.

In Zone 1 the wetlands still maintain critical functional values, particularly in relation to water quality enhancement values. Erosion in the form of channel incision and head-cut advancement pose a threat to the ongoing provision of these services. The priority in this zone should therefore be to protect and enhance these functional values. Levels of disturbance in the surrounding buffer are widespread including dumping, excavation, and infilling, solid waste with evidence of limited agricultural activities. Maintaining a vegetated buffer is regarded as important in this zone, in particular excluding encroachment of further development which could serve to exacerbate impacts and further undermine ecological values. Agricultural use could be considered on the periphery of the open space system but should be excluded from the wetland and buffer zone.

In Zone 2, wetlands have been encroached upon by residential developments, with a number of houses established within the wetland boundary. Such encroachment has not only affected the wetland but subjects residents to considerable flooding risks. Road drainage and incision has dramatically undermined the functioning of wetlands in this zone whilst the integrity of the buffer zones has also been undermined by agricultural activities which extend right up to the wetland boundary. Whilst there are opportunities to stabilise the wetlands, opportunities are limited in the upper reaches of the site due to stormwater risks associated with neighbouring residential areas. Opportunities do however exist at the base of this zone above Kagiso Drive where wetlands can be enhanced to improve water quality functions. Agricultural activities could be allowed to the south of the channel and could be linked with an appropriate water harvesting structure to facilitate irrigation. Such agricultural activities should however not encroach into the wetlands and should ideally be excluded from a 15m buffer zone.

A strong ecological focus should be maintained in Zone 3 to maintain and enhance the biodiversity values of the broader open space network. As such, agricultural activities should be discouraged whilst efforts to maintain and enhance functional values and wetland habitat should be promoted through wetland rehabilitation efforts.

5.5.4 Community opportunities

Schools and community to be involved before further decision making is done. As explained in the workshop outcomes, the need for public open space, as a park or as a sports field, the need for irrigation water, as well as the safety aspect are important discussion points with the community before further possible design of the proposed options.

Already an employment creation maintenance team in the area. The Chief Mogale community centre, where the workshop was held, had a positive community feeling around it, with a large group of women being employed for maintenance in the Kagiso area from the community centre. The centre had a small bioswale in front, which could be used to further explain the concept of SuDS in a practical way.

5.5.5 Maintenance & Management

Maintenance, monitoring and management of SuDS is as important at this site as it is at the others in this study. The discussions in Sections 3.7.6 and 4.4.5 are relevant here. Perhaps one of the differences with Kagiso is that the importance of getting the community interested and active in the longer-term performance of the scheme is almost a critical challenge for this site. As mentioned above, it could be a critical success factor.

Job creation was mentioned as a possible driver for encouraging community interest, but a higher level of stakeholder interest will also be important. Examples of drivers for this might include:

- Involve the community in monitoring the health and performance of the scheme, and the surrounding environment. The range of monitoring would go well beyond the site itself, in much the same way as catchment monitoring was promoted for the Bonaero Pan and Wetland system.
- Develop a catchment management plan for the wider Wonderfonteinspruit. This would ideally be established by the municipality. Initiate planning for similar SuDS schemes in other communities in the catchment, and the various communities involved may help build the right momentum.

6 CONCLUDING REMARKS

The three case studies present three very different environments and applications of SuDS. Each case study presents a baseline of the potential for the water quality and quantity performance that will provide a platform for shaping and defining a SuDS scheme. Recommendations at the end of each case study will assist. The studies also highlight the urban design and biodiversity opportunities that a community can consider in developing the plans. Hence, each case study represents the first stage in the development and planning of SuDS interventions at a site. It is clear that community participation is an important part of the process in the subsequent stages.

However, the case studies are intended to introduce provincial government to the potential for SuDS in Gauteng, and to assist in defining actions necessary at a provincial level to assist the adoption and implementation of SuDS. The following is an overview of some of the key outcomes.

The outcomes reinforce the understanding that the planning and application of SuDS is context specific. It is widely recognised that planning and design of SuDS requires a multidisciplinary team, but less mentioned is the fact that it is a creative design process. This is an important difference to common stormwater practice.

All sites represent retrofit scenarios. This is arguably the greater challenge for the implementation of SuDS in Gauteng where most of the urban river systems are in a very poor state. SuDS needs to be part of their long-term recovery plan which will be an important step in securing the surface waters in the province as a water resource.

Water resources and water security is a common theme for all three case studies. Overloaded storm and sewer systems in the CBD lead to severely polluted conditions in the Robinson Canal and the Klipspruit. The Bonaero pan and wetland system provides important flood and treatment functions at the headwaters of the heavily developed Blesbokspruit catchment. The Kagiso case study investigates how stormwater management in urban areas around the Wonderfonteinspruit catchment could contribute to the long-term benefit of the highly disturbed system.

Pollution control is a significant function of SuDS. Common practice in South Africa treats stormwater as a waste product and pollution removal has had relatively low attention. A key performance measure in SuDS, and therefore an important consideration in design, is the pollution load reductions. This is not easily addressed in most of the design methods available in South Africa where hydraulic performance can be analysed in detail, but pollutant removal is typically left to broad guidelines, few of which are derived for conditions in Gauteng, or even South Africa. The application of MUSIC in this study has demonstrated the benefits of a model that addresses pollution control directly. This substantially advances the planning and design of a SuDS treatment train which would otherwise be dependent on hydraulic performance to define the make-up and scale of the system. However, MUSIC only addresses nitrogen and phosphorus as the common urban stormwater pollutants. Hence, some of the main pollutants in Gauteng rivers, such as E.coli and high salt loads (dissolved solids) are missing from the analysis. Therefore, there is considerable work to be done to develop appropriate pollution control analysis into stormwater management practice in Gauteng.

Two other aspects of SuDS implementation common to each of the case studies are the importance of planning SuDS as part of the community space and the ecological function of an urban area. It is evident from the case studies that there is considerable thinking around the needs of modern urban spaces in South Africa. While each of the case studies present very different environments and opportunities on how people access and use these spaces, it is common to all that planning for SuDS as an integral part of the urban space requires both forward planning and community support. An important outcome of the study has been that community adoption of the SuDS interventions is a critical success factor. As such, the next step in developing the SuDS plans at each of the sites will need to include community participation.

In contrast, current thinking on ecological functions and biodiversity planning in urban environments in Gauteng appears less advanced. Perhaps, like setting urban catchment water resource and flood management targets, there is a lack of meaningful targets for water management (levels, flows, water quality) to support habitat and biodiversity targets to support site based design decisions. Until such time as the catchment plans are done, site based decisions will be very general and risk being subordinate to other hydrological and urban design targets. Perhaps this is most in evidence at the Bonaero-Atlasville study area where, despite the strong argument for the conservation of the biodiversity of the integrated system, there is a sense that it will be left to the preferences of local landowners to define the future of that site. It is therefore a question whether this is an aspect where provincial government could play a significant role, building on the platform provided by the C-Plan and developing catchment based biodiversity targets that can assist in the planning and design of SuDS at a site scale.

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ANNEXURE A: MUSIC by eWATER

MUSIC by eWater

Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a software developed by research cooperatives, academia and scientists funded by the Australian Government.

The software was born out of a need to analyse and model the behaviour of flow and pollutants in urbanised areas, as well as understand the changes in hydrology both on the urban catchment and downstream of catchment and receiving water bodies. MUSIC now has wide application in Australia, and international adoption and use continues to grow.

MUSIC capabilities and science can be broken down in three parts.

a. Rainfall-runoff modelling. MUSIC has the ability to model volumes of runoff based on:
    a. Rainfall and Evapotranspiration data
    b. Percentage impervious of the catchment
    c. Catchment soil characteristics

   The modelling can be performed at timesteps from 5 minutes all the way to daily, and even custom timesteps.
b. Pollution generation science based on extensive research. The key pollutants modelled in MUSIC are Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorus (TP) and Gross Pollutants (GP).
c. Performance of pollution treatment nodes/elements (e.g. wetland) for TSS, TP and TN pollutants.

MUSIC can model a wide range of treatment devices to find the best way to capture and reuse stormwater runoff, remove its contaminants, and reduce the frequency of runoff. MUSIC helps to evaluate these treatment devices until the best combination of cost, hydrology and water quality improvement is achieved. MUSIC is a purpose built WSUD modelling tool where all commonly used treatment devices (see below) and their specific performance algorithm are represented by dedicated nodes.

Bioretention systems
These are vegetated stormwater filtration systems that use a soil or sand-based filtration medium to remove particulates and soluble contaminants. The system may be lined or unlined and may or may not have an underdrain. In MUSIC, based on significant extra data and research, bioretention nodes take better account of the characteristics of the filter media and vegetation. MUSIC users can now more accurately design or represent a variety of different bioretention systems.

Infiltration systems
Un-vegetated infiltration systems, for removing contaminants, which have no underdrain. MUSIC offers a greatly enhanced infiltration modelling capacity to account for horizontal flows from storage and allow for changes in flow with depth. There is greater flexibility to model systems with lined sides or base.

Media filtration systems
Un-vegetated stormwater filtration systems for removing contaminants, using media such as gravel, sand or other fine granular material. They are assumed always to have an outlet pipe (underdrain).

Gross pollutant traps
These mesh-like devices are designed to remove floating and suspended rubbish and debris above 5mm in size. Many are proprietary off-the-shelf items.

Buffer strips
Strips of vegetated land beside a road are effective in the removal of coarse and medium-size suspended particles; they provide good pre-treatment prior to a bioretention system or other vegetated treatment measures.

Vegetated swales
Open channels that use vegetation to primarily remove suspended solids. Subject to high flows, they rely on shallow slopes and the density and height of vegetation, to work well.

Ponds and sedimentation basins
Open water bodies act as temporary stores to allow the settling of suspended solids. They can include ornamental ponds, but usually lack vegetation. Reuse of the water is an option.

Rainwater tanks
These domestic water stores enable roof runoff to be captured and used. Contaminants can either settle in the tank or are removed when the water is used on a garden. Tanks can reduce stormwater flows and help to counteract the increase in impervious area that urbanisation brings. They also provide an alternative water supply.

Wetlands
These are heavily vegetated water bodies; the physical, chemical and biological processes that they facilitate remove fine suspended sediment and soluble and insoluble contaminants. Wetlands are commonly used as 'end of pipe' measures, but recent research shows they also work well earlier on. MUSIC can also model reuse of the water in a wetland's permanent pool.

Detention basin
Assists in stormwater peak flow management.

Generic treatment nodes
MUSIC allows the user to model a treatment device that is not a specific node within the program if the user has sufficient data to model it effectively; for example, flow diversions, flow dilutions or contamination by sewer overflow. In these cases, MUSIC allows the user to define 'transfer functions' for flows and water quality.

MUSIC is only software currently in the market that offers easy-to-use WSUD modelling capabilities at conceptual and planning level. MUSIC is used and approved extensively by the Australian Local and State Government Authorities, making it an established player in the Australian and International marketplace.

Below there is a (non-comprehensive) list of purposes for which MUSIC has been used in Australia and internationally. The use of MUSIC for these purposes has generally been approved by government, consultants and research organisations.

Different MUSIC uses:

1. Analysis of pollutant generation
   MUSIC allows modellers and developers to create pre and post development scenarios. This informs authorities of the difference in pollutant generation associated with a change in land use.
2. Analysis of treatment efficiencies
   This allows developers and authorities to investigate what is the best use of capital in order to achieve maximum efficiency (maximum pollutant removal) per cost of device. This also allows targeting a specific pollutant. For example, in areas where TSS and TN are not a problem, but TP needs to be controlled, MUSIC informs the modeller of what the best use of land and capital may be.

3. Ability to size devices such as Gross Pollutant Traps (GPTs) for both maximum flow and storage requirements. This allows engineers to specify the most efficient GPT from a space and cost perspective.
4. Analysis of performance of rainwater tanks – sizing for supply security and ability to cater for various demand uses.
5. Ability to calibrate
    a. The pollutant generation, to account for local/country conditions
    b. Pollution removal in treatment nodes, to account for local climate/construction/plants/materials
    c. Pollution removal in treatment nodes, to easily model the performance of devices which are not represented by native MUSIC nodes.

From the above, it can be confidently that MUSIC has great strengths and no other competing software packages exist on the market. MUSIC's clear strengths are:

1. All aspects of MUSIC modelling are based on the best existing science,
2. MUSIC can accept local rainfall and Evapo-Transpiration data, anywhere on Earth,
3. MUSIC source nodes can easily be locally calibrated for modelling of any catchment's pollution generation,
4. MUSIC treatment nodes can be modified so that their performance can be calibrated to local conditions,
5. MUSIC can do life-cycle costing analysis on each device, as well as the treatment train, allowing authorities to break down installation vs maintenance costs, as well as analyse sensitivity to discount rates,
6. MUSIC can lock its parameters so that the Authority can easily ensure all models have the appropriate parameters (anti-tampering auditor) via MUSIC-link.
7. MUSIC can easily analyse the performance of water harvesting devices such as rainwater tanks and ponds
8. Within next one year MUSIC will be integrated in eWater Source, providing a complete solution to water modelling, from small Urban catchments to entire river-basin sized water needs.
9. MUSIC is widely accepted in Australia and internationally as the industry standard for modelling Urban Stormwater.

Since MUSIC was first developed in 2001, the software has been used by thousands of professionals working in private practice and in state, regional and local government agencies throughout Australia.

With rigorous testing by hundreds of users, the feedback we have received about MUSIC has been used to expand its capabilities and make it more robust and reliable.

More information on the software and its application can be found at https://ewater.org.au/products/music/music-overview/

ANNEXURE B: Field notes for Johannesburg CBD

CBD STUDY SITE (City of Johannesburg)

Main features: Former Central Business District of the City of Johannesburg. The CBD layout dates from the late 1800's and is now dominated by high rise commercial buildings, a high percentage of hard surfaces, but with potentially important open space areas that could, over time, be converted to support stormwater management and heat management interventions (i.e. centred on the mutual benefits of SuDS). The area selected for analysis is home to a number of large corporates and offices of the Province and Municipality. This provides great opportunity to promote the upgrade of the public realm which can include SUDS interventions.

Services: Traditional piped sewer systems are employed in the CBD. The JRA describes it as the "superimposed network" where the stormwater network overlies the foul sewer network. There are frequent problems with both systems, resulting in mixing of flows, and resulting in high levels of sewage pollution in the receiving drains and streams.

This part of the CBD area selected for this study drains to the Robinson Canal that passes to the west of the study area. Flooding is a problem in the system, and the JRA is looking at a regional attenuation facility (outside the study area) to mitigate flood risk in the Booysens area.

The JRA has recently appointed a consultant to develop a stormwater master plan for the CBD stormwater system, including condition inspections of the pipe network. SuDS is not included in the scope of the master plan due to concerns with percolation to deeper groundwater. The JRA has instructed the consultants to adopt a very conservative approach and look at an upgrade of the existing network, assuming 100% paved catchments, designed for the 100 year event.

However, the JRA is interested in the outcomes of this study as a guide to the potential for SuDS within the CBD area.

Street widths are typically 5 lanes (~15m), including parking lanes, and sidewalks on either side, of typically 2m to 4m wide each.

Future urban planning and implications for the area:

In the Spatial Development Framework for Johannesburg, 2016-2017, and the Inner City Transformation Roadmap (2013), there is commitment to supporting the densification and intensification of land uses and people within the Inner City. To support an increase in density they propose that efforts are made to increase the liveability of the space by investing in urban amenities, such as public open space. Another objective is to make a more connected city, one which provides public transport services and attractive connecting streets, pedestrian streets and an enhanced road network, to be achieved through the incorporation of public spaces around which activities can intensify. The last relevant objective is a resilient city which talks to the challenges of climate change. They specifically call for investment in strong well connected open space systems and the refurbishment of buildings to include green infrastructure.

In conclusion the spatial policy supports the greening of the ground plain in the inner city and the shift towards less vehicles and more PT and NMT on the road space. This will result in less of a need for parking and, in time, should free up portions of the cross section of the roads that currently accommodate parking along their full length.

The JDA and the COJ have managed several projects aimed at upgrading and stimulating investment in specific areas in the inner city including for example upgrading of Main Street and making it pedestrian-friendly. This initiative acknowledges the importance of qualitative public environment to improve the experience of commuter, employees, shoppers and residents and to incentivise private investment.

There are a number of other significant projects in process currently including the Kopanong Gauteng Government Precinct focussed around the Beyers Naude Square and the Diversity project looking at 6 blocks around the ABSA Towers Main Building. The latter is however outside of the catchment which is the focus on this study. The projects include the demolition of some buildings and the refurbishment of others. Proposals generally include huge investment in public open spaces which are planted and landscaped to offer increased amenity to new inner city residents and workers. Proposals also suggest that roof gardens and planted facades will be incorporated in building designs to address heat build-up in the city.

Key questions:

(1) What difference could rooftop SuDS make to stormwater peak discharge from the CBD area? What percentage cover would be necessary to make a difference?

(2) What street level interventions (e.g. take-up of one lane) could be employed for SuDS?

(3) Explore the potential for utilisation of existing open space (at ground level) for SuDS interventions. These include existing parks, parking areas, landscape areas and building frontage.

(4) How much will the above improve heat management?

Rooftop SuDS

<u>Base data (for the general study area):</u>

Street area (excl. pavements):	32%
Roof area:	44%
Landscaped:	3%
Paving (parking, front of buildings, etc.):	21%
Block area:	$3600m^2$ to $5600m^2$ (max. $10,000m^2$)

<u>Services:</u>

Amenity:	✓✓
Land values:	✓
Ecological:	✓?
Attenuation:	✓?
Infiltration:	X?
Treatment:	✓?
Economic:	✓

<u>Notes:</u>

Roof area coverage is the largest portion of the coverage of the CBD area, and therefore is likely to be the largest contributor of stormwater runoff. There will be structural and architectural limitations for converting existing roofs to green roofs with sufficient depth of soil to result in meaningful contribution to stormwater management. In addition, there is competition with solar energy systems for roof space. Hence, any plan for conversion of roof space to green roofs will be a long-term plan.

However, the study can investigate the potential difference a green roof could make at a single block scale. This would provide baseline data for future planning.

<u>Data requirements:</u>

Stormwater network (JRA) – *already obtained*

WQ monitoring at stormwater outfall (CoJ?)

Terrain (DEM, contours, LiDAR, etc.) (CoJ/JRA)

Rainfall data (SAWS?)

Determine water storage (soil depth) potential.

Determine typical useable roof space (??)

<u>Proposed analysis:</u>

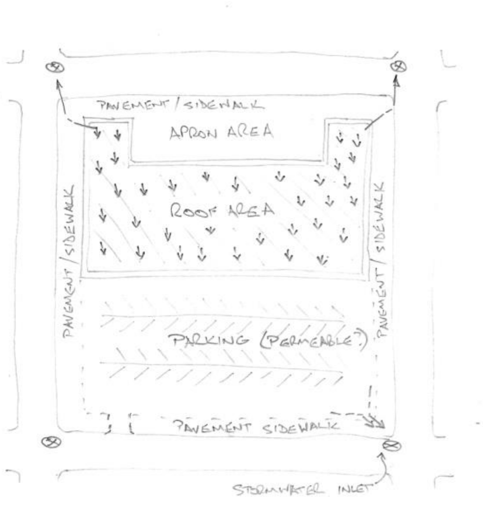
Attenuation size (depth: area) (MUSIC)

Bio-filtration capacity (MUSIC)

Ecological guidelines (??)

Amenity assets/enhancements (??)

<u>Outline sketch of SuDS interventions:</u>



Street SuDS

<u>Base data:</u>

Street width:	15m
No. lanes:	5 (including parking lane)
Length of block:	typically 60-75m (east to west)

<u>Services:</u>

Amenity:	✓✓
Land values:	✓✓
Ecological:	✓?
Attenuation:	✓?
Infiltration:	X?
Treatment:	✓?

<u>Notes:</u>

Streets present the second largest portion of the coverage of the CBD area (approx. 32%), and therefore also a significant. In most places the width of the sidewalk is not large enough to accommodate SuDS interventions, and so it is proposed consideration is given to taking up one of the 5 lanes for SuDS and incorporating this into the sidewalk space.

The study can investigate the potential performance of an interlinked system of bio-retention/filtration units along one of the main streets running east to west across the study area. The primary catchment may be the street, but this can be reviewed.

This would again provide baseline data for future planning.

<u>Data requirements:</u>

Stormwater network (JRA) – *already obtained*

WQ monitoring at stormwater outfall (CoJ?)

Terrain (DEM, contours, LiDAR, etc.) (CoJ/JRA)

Rainfall data (SAWS?)

Land ownership & cadastral information (JRA)

Determine potential depth of bio-retention units (and tree pods).

<u>Proposed analysis:</u>

Bio-filtration capacity (MUSIC)

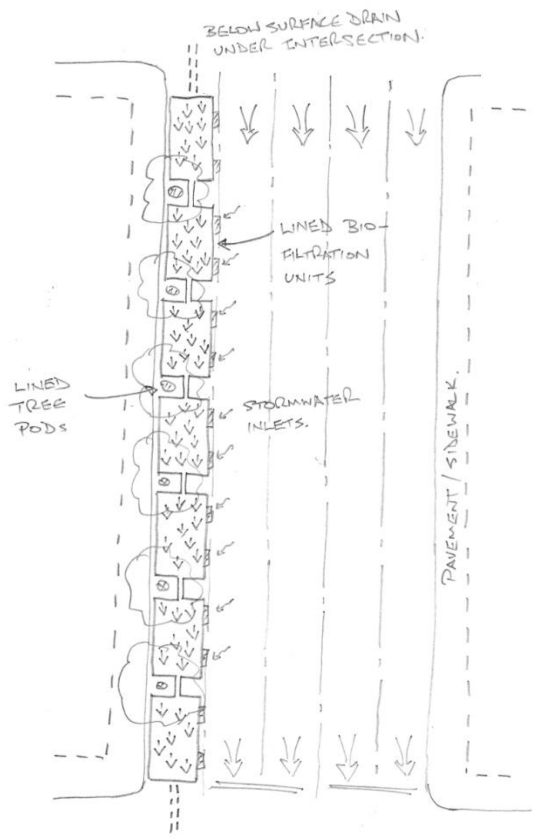
Attenuation potential (MUSIC)

Ecological guidelines (??)

Amenity assets/enhancements (??)

Heat Island effect

<u>Outline sketch of SuDS interventions:</u>



Treatment train

Base data:

Open areas (in study area): 12% of CBD area (approx.)

Includes

- off street parking areas (informal & formal)
- parks & landscaped areas
- Forecourt and apron areas (in front of buildings)
- Vacant areas
- Sites under construction

Services:

Amenity:	✓✓
Land values:	✓✓
Ecological:	✓?
Attenuation:	✓?
Infiltration:	X?
Treatment:	✓?

Notes:

Investigate the creative use of existing open spaces to include stormwater management functions (and still retain their current functions). Examples include lowering forecourt and car parking areas to provide temporary attenuation, re-profile landscaped areas to receive (and infiltrate) stormwater runoff, and use of permeable paving. These would be integrated with the existing stormwater network on a block-by-block basis, and combined with the other initiatives identified above. It is noted that at present there are few plans for a system of interconnected open space/green areas as indicated in the CoJ open space plan (see below).

Data requirements:

Stormwater network (JRA) – *already obtained*

WQ monitoring at stormwater outfall (CoJ?)

Terrain (DEM, contours, LiDAR, etc.) (CoJ/JRA)

Rainfall data (SAWS?)

Land ownership & cadastral information (JRA)

Determine water storage (soil depth) potential.

Determine typical useable roof space (??)

Proposed analysis:

Attenuation size (depth: area) (MUSIC)

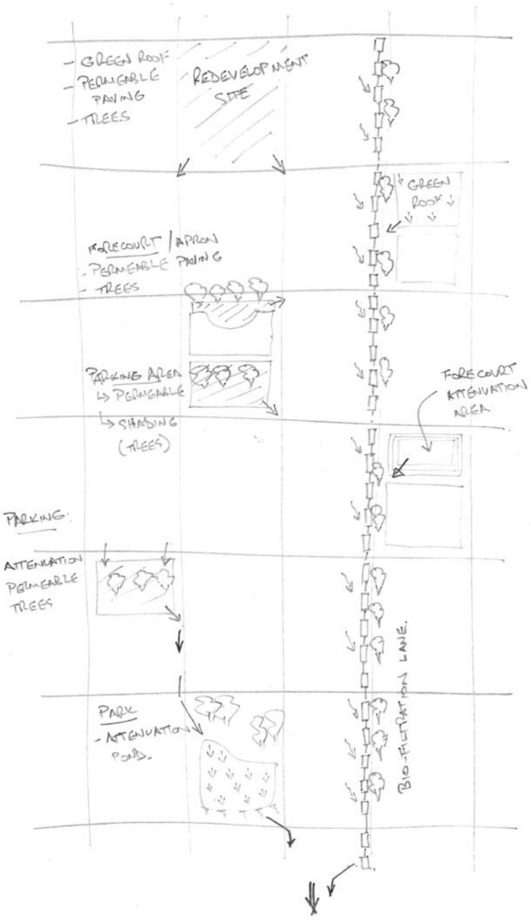
Bio-filtration capacity (MUSIC)

Ecological guidelines (??)

Amenity assets/enhancements (??)

Land Value

Outline sketch of SuDS interventions:



Other potential supporting initiatives:

1. Stormwater harvesting & reuse within the CBD area (e.g. irrigation)
2. Foundation dewatering, harvesting & reuse (e.g. for internal building secondary water use (toilet flushing), irrigation, etc.).

These are not strictly SuDS initiatives and therefore outside of the scope of the study.

ANNEXURE C: Field notes for Bonaero-Atlasville

BONAERO STUDY SITES

Main features: Three pans & large wetland.

Services: Cumulatively, the sites provide important stormwater (quantity and quality), ecological and amenity value to the urban environment and downstream systems.

Future urban planning and implications for the area:

The sites are part of an area currently the subject of precinct planning. The Aero-Blaaupan Precinct: Detailed Development Framework, 20 April 2018 (Final Draft) prepared by GAPP Consortium has resulted in the compilation of a Detailed Development Framework which looks to the development opportunities in the area in relation to future planned infrastructure and bearing in mind CoE's plans for an Aerotropolis. The site is seen as having great potential to accommodate an Aerotropolis Tech Hub using the vacant and underutilised land to the west and east of the wetland. The Precinct plan identifies pans and the wetland as a great opportunity to improve and support ecological function, serve as a recreational asset, and provide a high quality public environment. They also make reference to the possibility of using the pans and wetland as green infrastructure.

The framework proposes that the pans and wetlands form the central feature within the precinct. "…..to form a regional park and biodiversity system, with passive recreation and leisure activities, including walkways, cycle-ways, picnic areas and parks with play areas. The natural open space system is incorporated into this, improving biodiversity and promoting conservation. This allows for low-impact activities including bird-watching, eco-trails and nature walks. Where appropriate, limited educational and retail activities will be permitted, such as a restaurant and information learning centre. These proposals will be subject to a detailed study and master plan, which is to include a detailed environmental impact assessment to determine development possibilities and establish a precise delineation of the wetland system and open space area" (p68)

Land Uses planned for the west of the precinct include institutional and hospitality activities in the form of business parks, estates and campuses. Areas to the east of the wetland have been identified for light industrial / business park development with small pockets of mixed use and residential development. What is of most relevance to the GDARD SUDS project is the proposed PWV 15 freeway which will be located down the central wetland. Additional cross routes are also proposed one of which is provisionally located along the southern edge of Blaaupan and the K86 east-west link which will be an extension of Merlin Drive over the wetlands towards

Daveyton. In this regard the consultants and support specialists concluded with the following recommendations:

- The alignment of the proposed PWV 15 road entails that the primary valley-bottom wetland system through which this road is proposed to be aligned (the road is aligned longitudinally through the wetland in the direction of flow and not perpendicularly across it) could be significantly adversely affected by the road through the loss of wetland habitat and the alteration of hydrology (through canalisation, etc.). It is strongly recommended that consideration be given to the realignment of this road to the east of the wetland to avoid such impacts from materialising;
- The concept of linkages between the eastern and western segments of the precinct site is supported, but these must take the presence of the wetland, and potential impacts on the wetland into consideration. Should a road (vehicle) access be required, it is recommended that this connection across the central valley-bottom wetland be located as far north of Brentwood Park Road as possible, in order to cross the valley-bottom wetland at its narrowest point. Crossing the wetland to the north (closer to the church complex) will also avoid the large seepage wetlands located to the west of the valley bottom wetland in the southern part of the site;
- Where new roads are planned in the vicinity of any wetlands, in particular the valley-bottom wetland (e.g. linkage roads planned along the western side of the quarry), the environmentally sustainable planning of stormwater discharge from the road must be incorporated into the design of these roads. No direct stormwater discharge into the wetland should be allowed, and the use of 'soft' engineering features such as swales for attenuation features, in line with the principles of Sustainable Urban Drainage (SUDS) must be implemented;
- Similarly, future development that will result in hard surfaces around wetlands, in particular the pans around the site, must ensure that stormwater runoff from these sites is managed so that inflows into these wetland features do not degrade the wetlands. The use of soft features for attenuation that will allow the gradual inflow of stormwater into these pans must be incorporated into new developments.

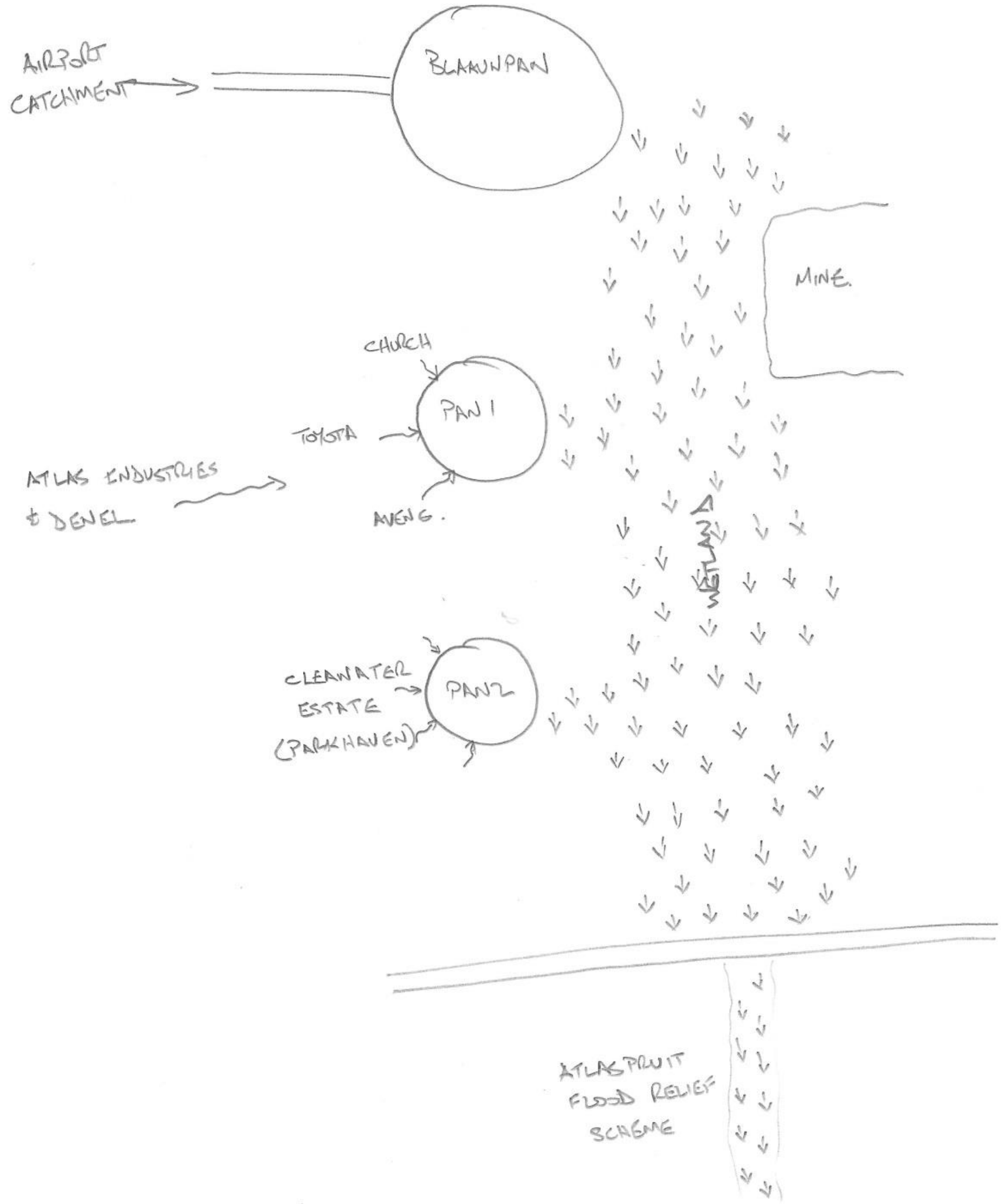
GAPP Consortium Aero-Blaauppan Precinct: Detailed Development Framework

Diagram 34: Spatial development outcome — perspective

Spatial Development Outome – perspective, extracted from Aero Bonaero Detailed Development Framework, 2018

Key questions: (1) Incorporate the pans and wetland as parts of the SuDS system?

(2) Protect the pans and wetland using SuDS in the catchment (retro-fitting)?



Overview of the integrated pan and wetland system

Blaauwpan

<u>Base data:</u>

Surface area:	40ha (approx.)
Land use:	Pomula Private Nature Reserve
Catchment area:	1220 ha (12.2km^2)
Catchment land use:	Airport

<u>Services:</u>

Amenity:	✓✓
Land values:	✓✓
Ecological:	✓
Attenuation:	✓✓✓
Infiltration:	X?
Treatment:	✓✓

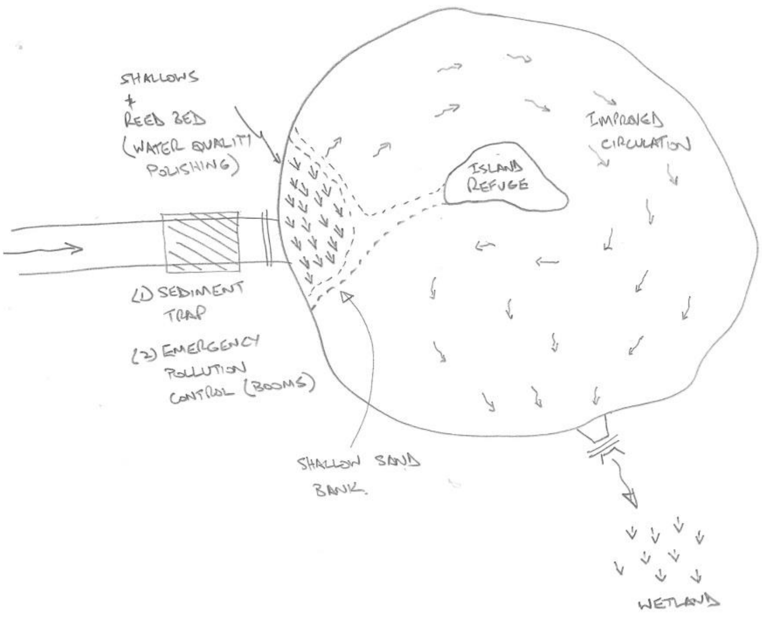
<u>Notes:</u>

The pan is a key stormwater control point and has protected downstream systems from potentially severe flooding and pollution (jet fuel spillages). The flood relief scheme at Atlasville is reliant on the continued performance of the pan as an attenuation feature. References to previous quarrying activities in the pan have not been confirmed, but it may mean the pan is deeper than anticipated.

The pan and park land surrounding the permanent water body allows public access and provides an important amenity service to the local community and visitors from further afield especially the fishing community. The Pan is the central focus of the Pomula Private Nature Reserve. Access to the Reserve is through Mirabel Street where an entrance fee is charged. The Reserve offers picnicking and access to the water's edge for fishing. Swimming is forbidden. A controversial land sale in 2011 seems to have been halted but there remains the risk that the pan and surrounds can be sold to private developers, which would result in the municipality losing control of the site as a key stormwater control point.

The surrounding area comprises a mix of small holdings, suburban residential development, utilities, a Mall and high density housing. The Pan is embedded and not that visible and or easily accessible by the general public.

<u>Outline sketch of SuDS interventions:</u>



Blaauwpan	
Data requirements: WQ monitoring (CoE) PES (?) Airport attenuation systems (ACSA)	Proposed analysis: Pan attenuation capacity (PCSWMM) Retention time & circulation velocity (DWF) Sediment trap size (MUSIC) Reedbed treatment (MUSIC) Ecological guidelines for island & shallows(??) Amenity assets/enhancements (??)

Notes:

The pan serves a very particular purpose. Its water depth and defined water edge seem to suit the requirements of fisherman who comprise the biggest group of users.

Additional wetlands along the edge of the water should therefore ideally be limited in extent to ensure that fisherman and other users of the Reserve can still access the water's edge. Notwithstanding this cautionary note, wetlands can add amenity value by improving habitats for birds thereby providing interest to other user groups.

The Reserve should ideally be used by a broader grouping of people and in particular, more local residents to ensure this green open space is maximised to its fullest. To encourage use by local residents, It would be preferable to have additional entrances. Private development of a commercial nature around the pan could also contribute to making the pan more "visible" to the general public. Involving private developers could also address the issue of the cost of maintaining such a reserve. Full privatisation of the edge of the pan should however be discouraged as far as possible to protect its role as a public amenity.

Ecological enhancements may need to give preference to amenity value and public access. A balance will need to be considered.

Pan1 (Middle pan)

Base data:		Services:	
Surface area:	13.0ha (wet area, approx..)	Amenity:	✓?
	5.9ha (wetland margin area, approx..)	Land values:	✓?
	18.9ha (total)	Ecological:	✓✓✓
Land use:	Open space, ecological area (ownership??)	Attenuation:	✓?
Catchment area:	96 ha (0.96 km^2)	Infiltration:	✓?
	40 ha (between pan & wetland)	Treatment:	X
Catchment land use:	Cultural (church) and industrial		

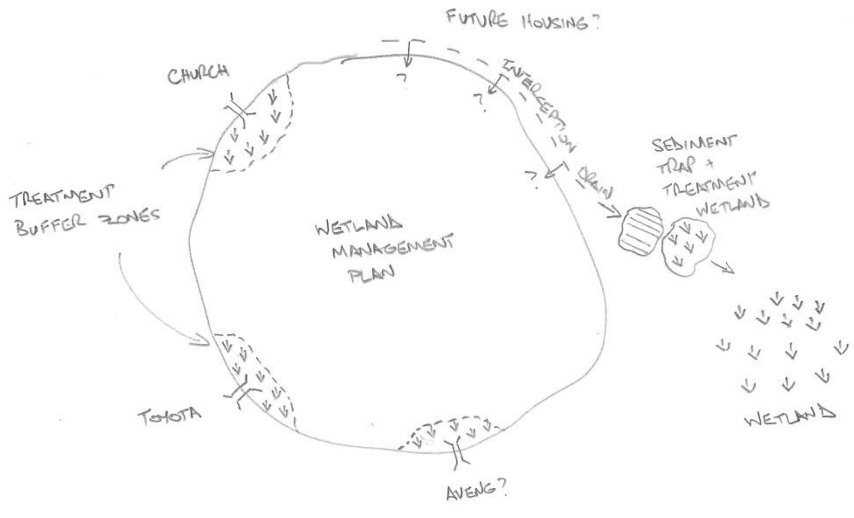
<u>Notes:</u>

Although the pan is not in its original state (e.g. evidence of ground disturbance and excavation), it appears to be in a relatively healthy ecological state with good biodiversity and minimum alien and invasive plant species. If the three pans in the study area, it is also potentially the most representative of the original state of the pans.

The pan receives stormwater runoff from the existing development on its fringes, and there is evidence of more disturbance at these points. The extent of attenuation on these developments should be determined.

The properties surrounding the pan which include a large church site and new business/ industrial developments have been designed with little attention given to the potential amenity that the pan can offer. There are limited overlooking features that allow staff and visitors to enjoy the view. This seems like a wasted opportunity. Visitor areas, meeting rooms, canteens and offices could all benefit from views overlooking the pan. Outdoor eating areas and relaxation areas could be located along the edge of the properties overlooking the pan. There also don't appear to be any opportunities for employees of the industry, business and Church to access the pan directly from the respective properties.

<u>Outline sketch of SuDS interventions:</u>



Pan1 (Middle pan)	
<u>Data requirements:</u> WQ monitoring (CoE, or adjacent developments) PES (?) Attenuation systems as approved by CoE for the church, Toyota, Aveng and other sites. (CoE) Upslope contributions (i.e. Denel)?	<u>Proposed analysis:</u> Sediment trap size (MUSIC) Reedbed treatment (MUSIC) Ecological guidelines for the pan (set outline requirements for the Wetland Management Plan??) Amenity assets/enhancements (??) Land value benefits (??)

<u>Notes:</u>

Connectivity of the outflow to the main wetland is important. The effect of the sub-surface interception drain (filter drain) could be detrimental to the natural hydrology of the system in its current form. Ideally there should not be an outflow at the end of the drain as seems to be the case at present. Plugging the drain at 100m intervals could assist to encourage the transmission of water into the pan along its entire perimeter, rather than draining the water away. [*Post note: it seems that the filter drain was established to reduce the impact of paved area runoff into the pan, minimising ecological imacts.*]

Pathways and seating with bird hides around the edge of the pan could provide local residents and workers opportunities to recreate and enjoy contact with wildlife in a very urban context. Pathways together with outdoor entertainment, eating and socialising spaces on the adjacent properties, overlooking the pan would result in activation of the space and better surveillance. This is important as open space without surveillance is likely to attract anti-social activities such as dumping and vandalism etc. A key challenge to management of a large ecologically functional space such as this pan which is surrounded by multiple property owners is management. It may be that the municipality has to take a lead in setting up some form of co-management arrangement.

This area is clearly desirable given the type of industry giants that have chosen to invest in the area. However given the lack of design response to the opportunity inherent in locating next to an ecological area, one would assume that the current property value is not related to its location on a pan, but the location in relation to the Airport and Atlas Rd which provide good visibility and accessibility to the region. Should co-management of the space result in improved amenity value, there is no doubt that the value of the surrounding properties will increase. Industrial / Business Parks which have invested in wetlands and created positive green spaces and increased amenity for employees and residents , have been popular and deemed successful from a property perspective. Examples include Century City and Capricorn Business Park in Cape Town.

Pan2 (Clearwater/La Como Lifestyle Estate)

Base data:		Services:	
Surface area:	12.3ha (wet area, approx..) 3.3ha (buffer area, approx..) 15.6ha (total)	Amenity:	✓✓
		Land values:	✓✓
		Ecological:	✓✓
Land use:	Water feature, ecological area (private ownership)	Attenuation:	✓?
		Infiltration:	✓?
Catchment area:	178 ha (1.78 km^2) 34 ha (between pan & wetland)	Treatment:	X
Catchment land use:	Mixed use (residential, commercial) secure site		

Notes:

The pan has been converted to a water feature (e.g. a dam) for the development. Although it is primarily a landscape feature, it does offer ecological value which is similar to the Blaauwpan, but likely to be in a better state.

The pan receives stormwater runoff from the surrounding development, evidently with SuDS styled features but these are more likely to be designed by landscape architects than designed by engineers and ecology specialists for specific stormwater bio-retention/attenuation or filtration purposes. Therefore any attenuation or treatment performance may be undefined, but the ecological and amenity services are potentially important.

The edge of the water body has been fenced off to restrict access to the waters edge and transition zone between the aquatic and terrestrial biomes where habitats are often very sensitive. Pathways happen outside of this fenced area. Residents and visitors are only able to access the water at a specific point which has been formalised into a pavilion that is built above the water level. The amenity value is therefore mostly visual with some value related to the opportunity to walk in a green landscape overlooking water. The SUDS type landscape features also provide amenity in that they offer visual relief and areas for communal play, relaxation and recreation.

Data requirements:	Outline sketch of SuDS interventions:
WQ & level monitoring (estate) Water sources for the lake (i.e. is the lake just reliant on stormwater runoff or is it augmented?) Attenuation systems as approved by CoE for the estate. (CoE) Upslope contributions (i.e. above the estate)?	(none)

Pan2 (Clearwater/La Como Lifestyle Estate)

Proposed analysis:

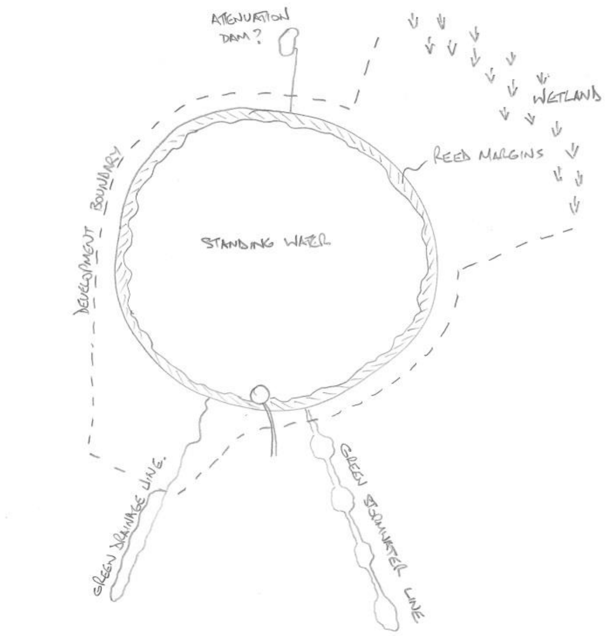
Sediment trap size (MUSIC)

Reedbed treatment (MUSIC)

Ecological guidelines (??)

Amenity assets/enhancements (??)

Land value benefits (??)



Notes:

The facility already provides considerable amenity value. However the amenity value is limited to those who have bought into the secure estates surrounding the pan. This is not an optimal condition although it does allow the municipality a means to ensure that the private sector is responsible for management and maintenance of this part of the broader natural network. See discussion below.

It is clear that investment in the landscaping spaces receiving stormwater and the pan itself have added value to the development and are part of the marketing strategy to encourage people to live in the area. The entire development is orientated around the feature to ensure that the offices, residences and lifestyle centre have direct views of the water and bird life that it attracts. The water itself is out of bounds but the area surrounding the pan has some opportunities for walking and running. The maintenance of the pan and edges requires property owners to pay high levies to cover the costs of maintaining such a system. This in turn limits potential buyers to the top end. This is common of lifestyle estates. However the biggest influencer of value of lifestyle estates such as the La Como Estate is security. Should the Estate have been designed round a publicly accessible feature, the land value created may well have been lower.

Connectivity to the main wetland is important. Ecological buffers (filter strips) are important to note and maintain. Public access via bird hides/viewing decks is suitable.

<table>
<tr><td colspan="2">

Wetland

</td></tr>
<tr><td>

<u>Base data:</u>
Surface area: 66ha (wetland area, approx..)
113ha (incl. margins between wetland and pans)
Land use: Wetland area (municipal ownership)
Catchment area: 1755 ha (17.55 km^2)
Catchment land use: Airport, residential, commercial, industrial, mining, agriculture.

</td><td>

<u>Services:</u>
Amenity: ✓
Land values: ✓
Ecological: ✓✓✓
Attenuation: ✓✓✓
Infiltration: ✓
Treatment: ✓✓✓

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<u>Notes:</u>
The wetland area has reduced by approximately 40% since the 1970's due to land development, and is further threatened by future road development schemes (i.e. PWV 15 and K86). The ecological and hydrological continuity between the wetland and the pans is also threatened by development. However, the wetland still provides important hydrological and ecological services to the surrounding areas and downstream systems. It is also a key link in the Green Infrastructure corridor extending from the airport to Homestead Lake and beyond, a minimum distance of 7km to Homestead Lake dam wall (and as much as 11km to Kleinfontein Lake dam wall).

The wetland is framed by a range of developments and urban landscapes including business parks, residential estates, nature reserves, small holdings, residential development, old industrial areas and old mining sites. None of these developments interface with the wetlands positively. Most turn their backs on the space. This creates a negative environment in which people are unwelcome and unsafe. There is also no clear legible network of pedestrian routes along the space. Paths crisscross the space allowing the sensitive vegetation and habitats to be disturbed and in some places severely compromised due to dumping, fires etc.

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<tr><td>

<u>Data requirements:</u>
WQ monitoring (CoE, or adjacent developments)
PES (?)
Threats (e.g. pollution) from eastern catchments, especially the mine.

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<u>Outline sketch of SuDS interventions:</u>

</td></tr>
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Wetland

Proposed analysis:

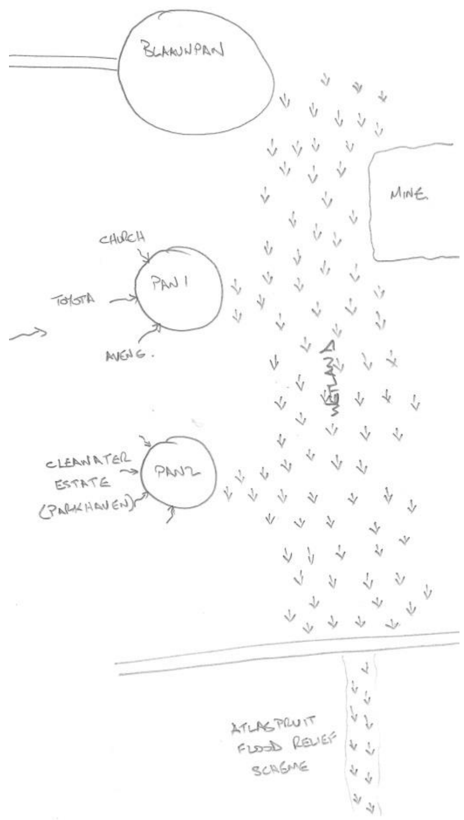
Pan attenuation capacity (PCSWMM)

Reedbed treatment benefits (MUSIC)

Ecological management guidelines (??)

Amenity assets/enhancements (??)

Land value benefits (??)



Wetland

Notes:

Maintenance of corridors between the systems is important. The planned development of major roads through this area is a very significant threat to the wetland.

Ecological enhancements should perhaps focus on enhancing the local ecological attributes, as there is limited connectivity to the broader open space network. Any drains and other impact features should be verified and rehabilitated.

The existing ponds at the base of the system just above the road could perhaps be redesigned/enhanced as open water features as part of the SUDS network below future developments.

There is considerable potential to increase amenity value of this large open green space. With carefully considered development of the edges and improved interfaces, development along the edges can contribute to the making of a safer space, that can be more intensively used. Design of the wetland space will however have to be done in a manner which concentrates human activity and manages this activity. New continuous footpaths along the edge of the watercourse and wetland will allow for passive recreation. Nodes of activity where north-south and east -west pedestrian routes intersect will create a legible system of movement that controls and limits disturbance of the natural habitats. The wetland environment can also be used as an educational tool.

Intervention and ongoing management of this space is likely to be led by the municipality due to its critical role at the broader scale. There is no doubt that investment in the system and the space to improve its amenity value will result in increased property values of the land immediately adjacent to it.

ANNEXURE D: Field notes for Kagiso

KAGISO STUDY SITE (Mogale City)

Main features: Urban stormwater outfalls into drainage line that supports multiple land uses. The site is divided into three distinct sections by road crossings.

Services: Local services currently include stormwater conveyance, socio-economic activities (subsistence agriculture, grazing, and waste recycling), informal waste dumping, pedestrian crossings, and ecological services (which are impacted by all of the above). The amenity potential of the site has not been utilised by the community.

Services to the regional area are currently limited, but are potentially very significant. Particularly flash flood attenuation and water quality improvements for the receiving Wonderfonteinspruit.

Urban structure, land use and property characteristics

Kagiso is a well-established residential township outside Randfontein and while it is supported by a number of schools, key institutions and retail nodes, it lacks a legible public realm and public areas to which the community are attracted and in which local residents can gather, socialise, recreate, find relief and interact with nature. This is partly as a result of its development by the then apartheid government who saw the township as a labour pool to support local mines and industry. Kagiso's layout was not informed by topography or natural systems but largely by the need to be efficient. The potential to integrate the public space network with a system of green open spaces for water collection, attenuation and cleaning and recreation was never considered. Stormwater is accommodated in a piped system under ground and more recently, in the later extensions, by a set of narrow, left over corridors linking down to the site. (See cadastral map below). Backyards and high boundary walls frame these linear spaces ensuring that they remain unsafe and unmonitored. See sketch attached for the location of the green corridors.

The site itself is not identified as a valued part of the public space network or green open space network. It is left over space and appears to be regarded as having a utility role, receiving stormwater flows and accommodating other large water and sewer pipelines. However the site has ironically become a spatial integrating element thanks to the bridges which connect over the shallow valley and watercourse. These bridges link various neighbourhoods and allow residents to access key facilities and retail opportunities and schools on either side of the watercourse. The bridges themselves are the site of significant informal social and economic interaction.

Properties adjacent to the site are generally accessed from the reverse side with the boundaries facing the site, defined and secured by means of high boundary walls. These walls restrict views towards and direct access to the site. The other characteristic of Kagiso which is not unique to the area is the phenomenon of back-yarding. Properties to which people have title present opportunities to increase household income by leasing out of additional accommodation. Additional rooms are built in the backyards of formal houses. Yards are often hardened to maximise on the space. Rainwater is often channelled into the stormwater network to ensure the yards are not flooded. Back-yarding puts enormous strain on the services, and in particular the stormwater system.

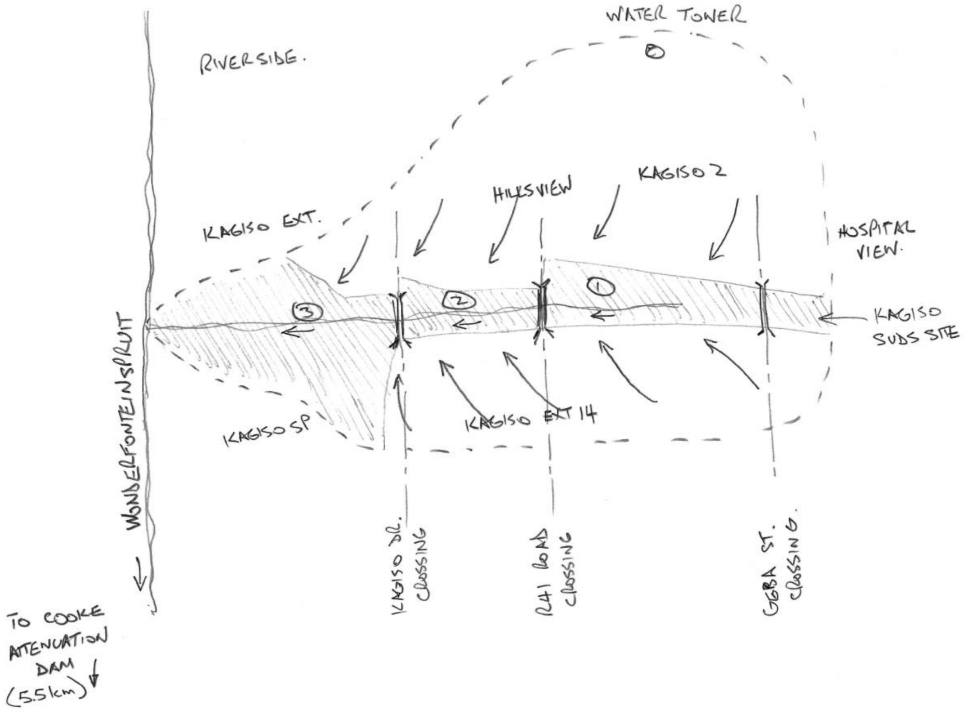
Residential densities are approximately 30-40 du/ha but with backyarders the density can double if not triple. Officials have suggested that the average number of people per site of between 250m^2 and 300m^2 is approximately 12.

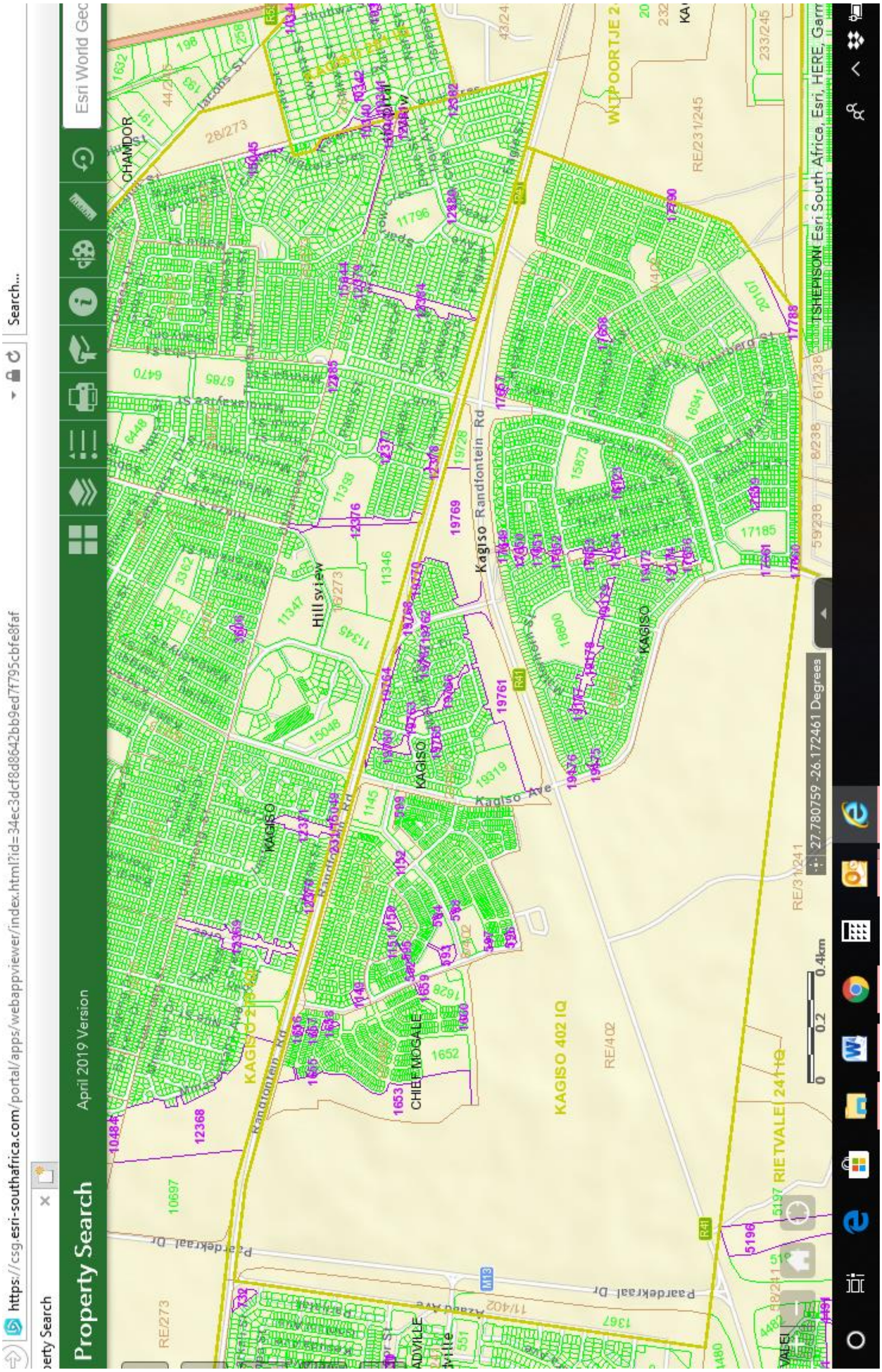
Key questions:

(1) Evaluate the site giving primary focus to the stormwater functions (i.e. a SuDS focus on quantity and quality)?

(2) Evaluate the site as supporting multiple services to the community; socio-economic, ecology and stormwater (i.e. a Green Infrastructure approach)?

(3) What catchment interventions could be employed to make a difference (e.g. rainwater harvesting, attenuation in existing open spaces)?




Property Search
April 2019 Version
Kagiso Randfontein Rd
Randfontein Rd
Hillsview
KAGISO
CHIEF MOGALE
KAGISO 402 IQ
RIETVALEI 241 IQ
Kagiso Ave
Paardekraal Dr
CHAMDOR
27.780759 -26.172461 Degrees
0 0.2 0.4km

Catchment space: Utilise available open space

Base data:

Catchment area:	448 ha (4.48km^2)
Urban area:	373ha (3.73km^2)
Land use:	Residential (~90%), schools, municipal, institutional, religious, & retail.
Density:	32 stands/per hectare (guideline) With back-yarding this could double or triple.
% Impermeable:	85% (within stands).

Services:

Amenity:	✓✓✓
Land values:	✓
Ecological:	✓?
Attenuation:	✓✓✓
Infiltration:	X?
Treatment:	✓?

Notes:

The catchment feeding the site in question is predominantly formal residential but with backyard shack establishment.

There are open areas that may be utilised (in the future) for SuDS. These typically include municipal open space areas, school sports ground, church grounds and undeveloped retail areas. The question is whether these areas are enough to make a difference?

Data requirements:

Stormwater network (MC)

WQ monitoring at stormwater outfall (MC)

Terrain (DEM, contours, LiDAR, etc.) (MC)

Rainfall data (SAWS?)

Proposed analysis:

Attenuation size (depth:area) (MUSIC)

Sediment trap size (MUSIC)

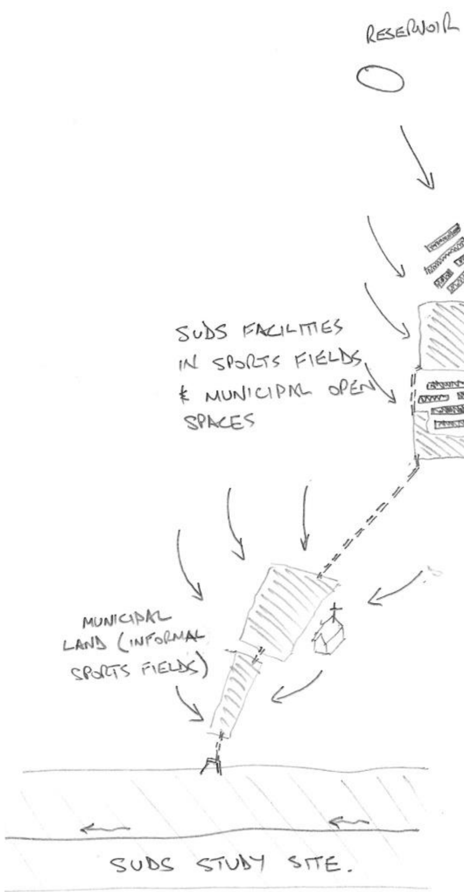
Reedbed treatment (MUSIC)

Network feasibility (inspection)

Ecological guidelines (??)

Amenity assets/enhancements (??)

Outline sketch of SuDS interventions:



Catchment space: Domestic rainwater harvesting

<u>Base data:</u>

Catchment area:	448 ha (4.48km^2)
Urban area:	373ha (3.73km^2)
Land use:	Residential (~90%), schools, municipal, institutional, religious & retail.
Stand size:	250 to 300m^2 (average) up to >500m^2
Occupation:	up to 12persons/stand (Stephan du Toit)
Density:	32 stands/per hectare (guideline), but potentially much higher with the effects of back-yarding
Roof area:	50% stand size (guideline)
% Impermeable:	85% (within stands).

<u>Services:</u>

Amenity:	✓
Land values:	✓
Ecological:	?
Attenuation:	✓✓?
Infiltration:	X
Treatment:	?

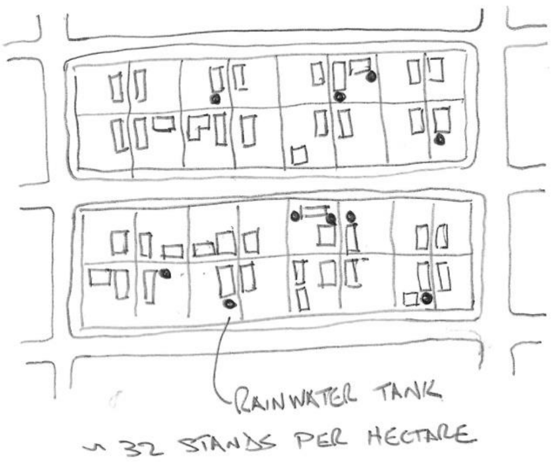
<u>Notes:</u>

A question (raised in the workshop) is whether domestic rainwater harvesting could be relied upon to reduce stormwater runoff?

What are critical success factors? (that makes a difference in stormwater runoff – range of scenarios?)

Are there regulatory constraints and would it be feasibly to change the regulatory environment?

<u>Outline sketch of SuDS interventions:</u>



<u>Data requirements:</u>

Sample stormwater network - optional (MC)

Continuous rainfall data (SAWS)

Determine water use potential (non-potable)

<u>Proposed analysis:</u>

Continuous simulation of water balance & overspill in tanks (MUSIC?)

SuDS Site: Treatment train (combinations)

Base data:			Services:	
Surface area:		46.7ha	Amenity:	✓✓
Zone 1 (Geba St-R41)		12.2ha	Economic (Agric, indust.)	✓✓
Zone 2 (R41-Kagiso Dr)		10ha	Land values:	✓
Zone 3 (Kagiso Dr-Wonderftnspr)		24.5ha	Ecological:	✓✓
Land use:	Subsistence agriculture, grazing, waste recycling, wetlands, vacant.		Attenuation:	✓✓✓
Catchment area:	448 ha (4.48 km^2)		Infiltration:	✓?
Catchment land use:	Residential (est. >85%), commercial, retail, municipal.		Treatment:	✓✓✓

Notes:

Informal (agriculture) and formal (waste recycling) use of the area has been taken up, but large parts of the stream corridor are degraded by erosion, dumping and poor water quality in the stormwater from the catchment.

Also important are a number of pedestrian crossing points along the stream. There is also a Rand Water flushing station in Zone 1 (for flushing sediment out of the bulk water main). Provision should be made for these.

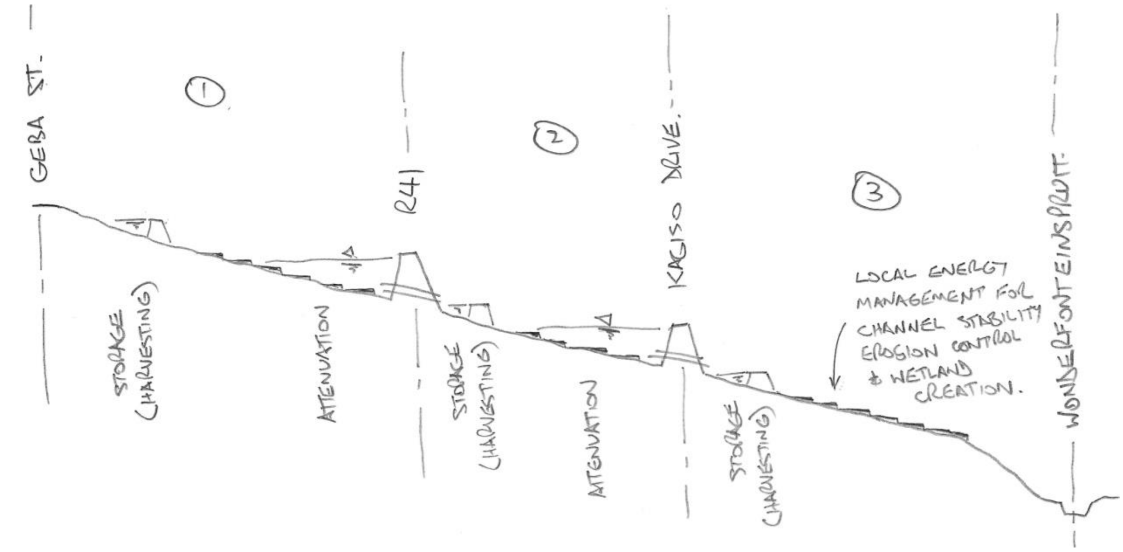
The sewer network crosses the stream corridor (details needed).

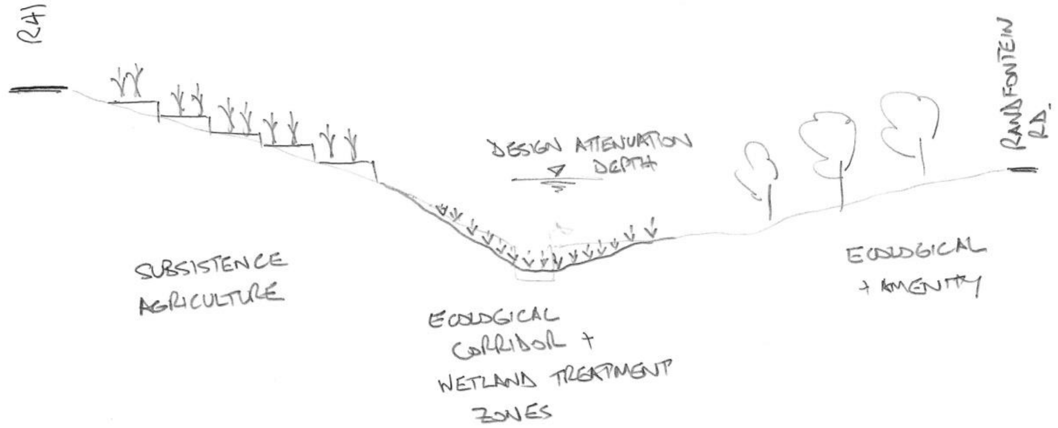
Wonderfonteinspruit:

- Attenuation of urban stormwater runoff is important to reduce flood flows in the spruit.
- WQ conditions are severe in the spruit, and dilution from urban tributaries will be beneficial.

Data requirements:	Proposed analysis:
Any WQ monitoring data (MC)	Attenuation requirements (PCSWMM, MUSIC?)
Municipal services (particularly stormwater & sewer) (MC)	Water balance analysis for harvesting (& irrigation potential) (PCSWMM, MUSIC?)
Details for the Mogale City agricultural assistance programme. (MC)	Sediment trap size (MUSIC)
Any rainfall data for Mogale City (MC)	Reedbed treatment (MUSIC)
	Ecological guidelines (??)

Outline sketch of SuDS interventions:





The study area can be broken into three separate zones:

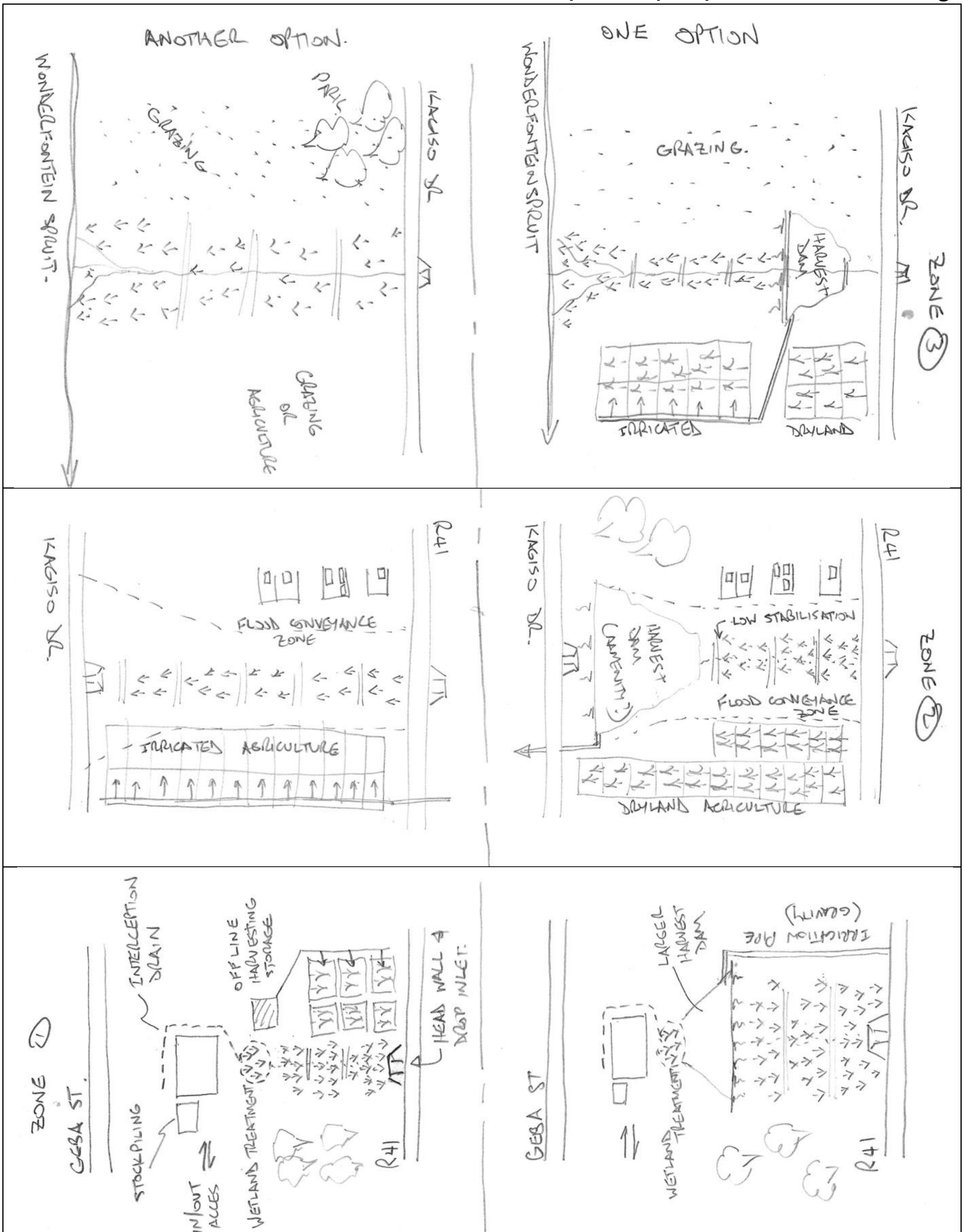
- The solutions can be repeated in each zone, or
- The SuDS facilities can be tailored for each to maximise the potential for the whole area.

Possible priorities:

1. Attenuation & WQ improvement
2. Economic land use
3. Ecological enhancement
4. Public amenity enhancement

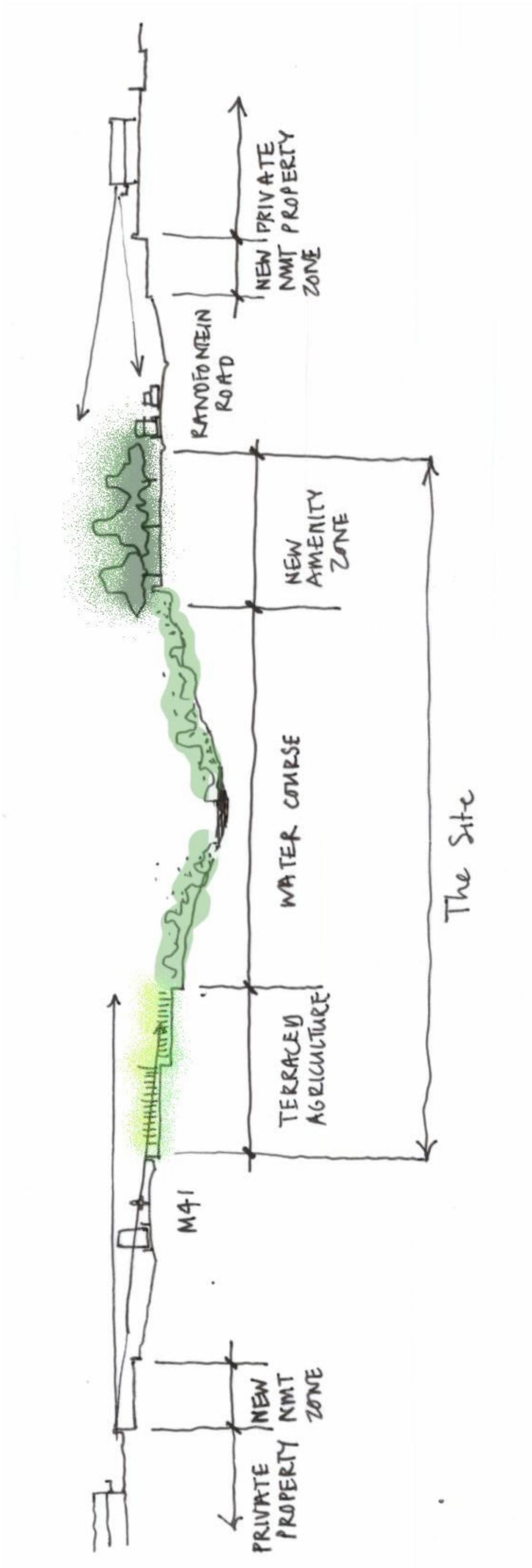
A successful balance of all four priorities would be the best outcome. The key decidng factors may be:

- Surface area needed for effective attenuation
- Water balance (is there enough for meaningful irrigation??)
- Will WQ improvements be enough for (1) ecological enhancement & (2) irrigation?



ONE OPTION	ANOTHER OPTION

Guidelines for increasing amenity and land value:



This sketch can form the basis of guidelines to improve amenity value – talks to the principle of creating defined and activated edges

ANNEXURE E: CBD Stakeholder Workshop Minutes

RESEARCH ON THE USE OF SUDS IN GP	
Workshop report: **Stakeholder CBD Workshop**	Date: **11 April 2019**
Location: **Swan Boardroom, Turbine Hall**	Time: **10h00 - 13h00**
Document: Approved by PMC for sending to participants.	

Present

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
Aa'isha Dollie (AD)	AquaLinks	Research Intern	support@aqualinks.co.za
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Anne Steffny (AS)	JICP	Director	anne.steffny@gmail.com
Dakalo Phaswa (DP)	GDARD	Intern	Dakalo.Phaswa@gauteng.gov.za
Freddie Letsoko (FL)	City of Johannesburg MM	EISD: Catchment Management	FreddieL@joburg.org.za
Greg Crookes (GC)	Tellurian	Environmental Specialist	greg@tenv.co.za
Hannelie Coetzee (HC)	www.HannelieCoetzee.com	Artist integrating science and culture to encourage empathy for and engagement with nature	Hannelie@hanneliecoetzee.com
Jacob Morodi	JRA	Project Manager Robinson Canal	jmorodi@jra.org.za
Kagiso Nonyana (KN)	FNB Bank City	Facilities Manager	KNonyana@fnb.co.za
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Lori Coogan (LC)	City of Johannesburg MM	Government Water, Sanitation and Climate for Gauteng/Enviro specialist for CoJ; going to chair meetings in Environment & Infrastructure	infolcps@mweb.co.za
Dr Michael Magondo (MM)	WIBC & JICP	Idea Sherpa	info@wibc.biz
Marieke de Groen (MG)	AquaLinks (Consultant –	Project manager	marieke@aqualinks.co.za

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
	Project manager and facilitator)		
Ndivhudza Nengovhela (NN)	GDARD (Project manager Client)	Control Environmental Officer: A	Ndivhudza.nengovhela@gauteng.gov.za
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Ngcebo Nsimbini (NN)	Gauteng - DID		Ngcebo.Nsimbini@gauteng.gov.za
Nomvula Mofokeng (NM)	City of Johannesburg MM	EISD: Water Services Regulation	NomvulaMof@joburg.org.za
Ondela Tywakadi (OT)	City of Johannesburg MM	EISD: Water Services Regulation	OndelaTy@joburg.org.za
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Rina Taviv (RT)	GDARD (Project Leader)	Control Environmental Officer: B	Rina.Taviv@gauteng.gov.za
Shaun Burgess (SB)	OPH	Commercial Officer	shaun@ophprop.co.za
Stuart Dunsmore (SD)	Fourth Element (Consultant – Team leader)	Team leader	stuart@fourthelement.co.za
Weivy Makou (WM)	JRA	PM Robinson Canal CBD	wmakou@jra.org.za

Apologies received

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
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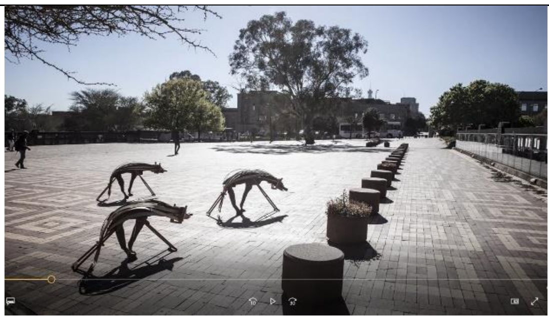
Gerson Nethavhani	GDARD	Control Environmental Officer: A	Gerson.Nethavhani@gauteng.gov.za
Ingrid Shelton	Urban Management - CID Forum	Manager	Ingrid.Shelton@cwexcellerate.com
Inga Jacobs Mata	Klip Water Sustainability Initiative (and IWMI)	Initiator	ingajacobs30@gmail.com
Louise Gordon	Johannesburg City Parks and Zoo	Business Development and Stakeholder Management	lgordon@jhbcityparks.com
Malcolm Fiddes	Johannesburg City Parks and Zoo		mfiddes@jhbcityparks.com

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
Marc Leroy	GDARD	GIS and data specialist	Marc.Leroy@gauteng.gov.za
Werner Mulder	ATTACQ/SAPOA	Sustainability Director	werner@attacq.co.za

Had indicated to come but was not present

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
Eugene Nyetsane	Urban Management - CID Forum	Operations Manager (South Western Improvement District is legislated CID in study area)	Eugene.Nyetsane@cwexcellerate.com
Jane Eagle	City of Johannesburg MM	EISD	JaneE@joburg.org.za
Nardo Snyman	Growth Point Properties	Sustainability Expert	nsnyman@growthpoint.co.za
Salona Moodley	JRA/SAICE	Stormwater Specialist	smoodley@jra.org.za

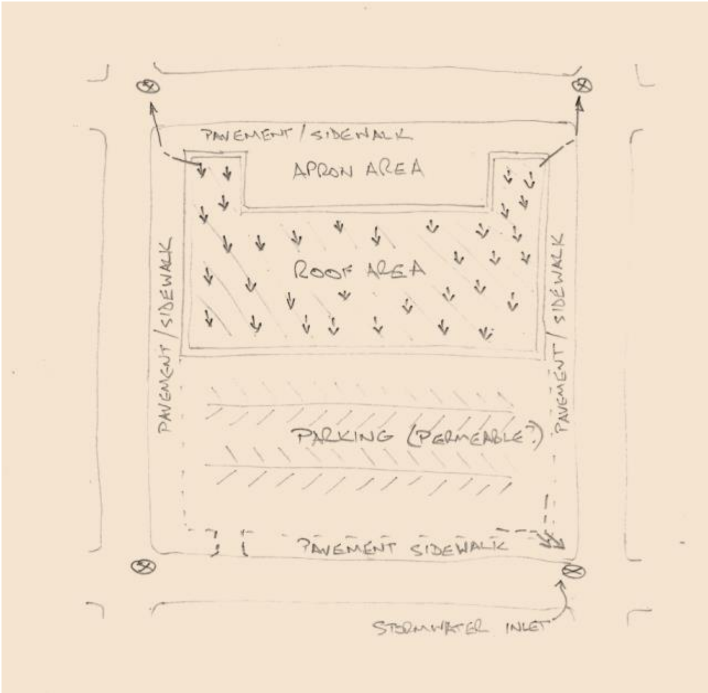
When it is known explicitly who gave the input, initials indicate this in left column. For convenience of reading and follow up, the discussions happening during the workshop are ordered in topics rather than reported chronologically.

Input by	Action item / Notes of the meeting	Respon-sibility	Date
RT	**1. Welcome**		
	Rina Taviv welcomed all who were present on behalf of GDARD.		
MdG	**2. Objective and Introductions**		
	Marieke de Groen outlined the objectives of the workshop and then gave everyone the opportunity to introduce themselves.		
NN	**3. Outline of the Objectives and Scope of the Study**		
	Ndivhudza Nengovhela outlined the objectives of the project and explained the scope of the study. She also provided an update on where the project was at the time, what deliverables had been completed and which ones were in progress.		
MdG & SD	**4. Presentation & 5. Discussion**		
	 The art work "Hyenas walking the intercontinental Watershed" by the artist Hannelie Coetzee was used to introduce the Research on the Use of Sustainable Urban Drainage Systems:		

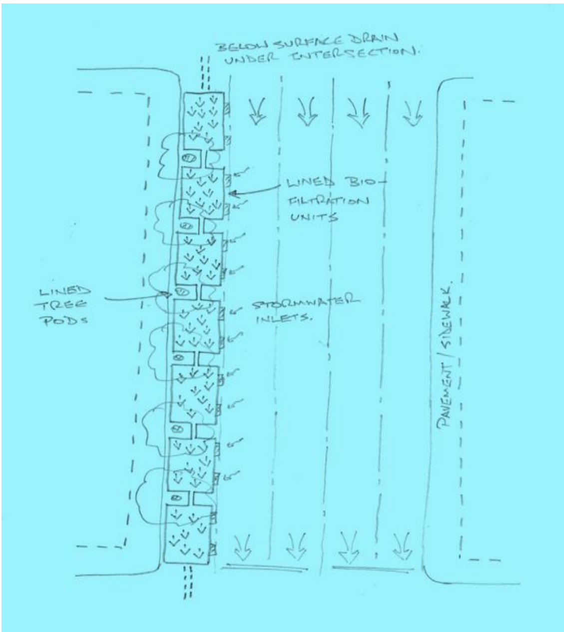
Input by	Action item / Notes of the meeting	Respon-sibility	Date
	• **Watershed:** Some of the stormwater that falls in the study area could be used to replace some of the potable water use that is currently pumped up from a lower point in the catchment; • **Water quality**: Hyenas would probably smell the pollution in Robinson Canal; • **Hardened surfaces:** The square is an example of the hardened surfaces in the CBD leaving no room for infiltration and in most cases draining quickly to the piped stormwater drains; • **People and heat stress:** Those who watch the animation of art work on the artist's website, will see how many people are crossing the square being exposed to heat stress, while a greener environment would have helped them. • **Litter:** The art is made out of waste material, reminding us that litter is the cause of blockages in the study area. • **Nature:** The artists intentions are "to integrate science and culture to encourage empathy for and engagement with nature" (www.hanneliecoetzee.com, 2019). This is similar to what Sustainable Urban Drainage Systems do. Apart from the stormwater function SuDS in most cases have a greening function. They contribute to creating biophilic cities; cities that embrace nature, to make citizens enjoy. Marieke de Groen gave a presentation introducing Sustainable Urban Drainage Systems, explained what they are, how the treatment train works and showed examples of SuDS around Gauteng. Stuart Dunsmore explained the study area and kind of SuDS measures that are being investigated, at building level (green roofs), at street level (bioretention cells), and in open areas. The discussion and the questions during the presentation are integrated in the summary below.		
A.	**General**		
	Design questions		
MM &SD	**Targeted runoff reduction** What would be a significant amount of run-off/reduction which would make measures feasible? The principle of SuDS is to mimic pre-development. In the manual for the City of Johannesburg, if a redevelopment is going to occur, one has to mimic pre-development. The idea is to reduce loads in the system for the site. Hardened surfaces in Johannesburg easily convert as much as 50% or more of the annual rainfall to stormwater runoff. Ideally the target would be to get that back to around 3 to 7% typical for undeveloped catchment areas. It would be great to get down to something like a 20% runoff. This is an off-the-cuff guess, since there is no strong guideline yet. Instead it would be up to the City to see how much could be achieved cost effectively. Studies like this will feed into that kind of decision.		
SD	**Impact of litter and sewage** The impact of sediment and littering on the functioning of bioretention cells needs further attention. Another complication in the CBD is that although it is not a combined system of sewage and stormwater systems, the sewerage is on top of the stormwater systems and leaks in the system make sewage pollute stormwater.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
SD, RT, AB, AS, NN, SB	**Surfaces and block sizes** Based on the Kopanong Precinct, the team found that roof areas constituted 40%, streets 30%, paved areas 20% and landscaped and possibly permeable areas about 10%. This seemed a high percentage for roads to the research team, but has not been internationally benchmarked. It was clarified that the CBD of Johannesburg has a relatively small block size. Then the suggestion was made to make so called 'super-blocks', combining two or more blocks leaving the current road in between for SuDS and Non-Motorized Transport or residential development. While 'super-blocks' have been considered during the development of Kopanong, concerns were expressed that it may increase traffic challenges. 'Superblocks' have already been created for FNB and for the Carlton Centre and the Ghandi East precinct. According to AS some of them are up to 9-12 blocks and she can provide the full list.	AS	
KO, SD, MdG, MM	**Becoming a smart city** Internationally, the development of smart cities could be of interest to this SuDS research. The research team has not looked into it, but indeed acknowledges that with IT opportunities (weather forecasts for example), operational management of stormwater systems and also possibly asset management could be improved. City of Johannesburg is trying to reduce its potable water losses in the system (unaccounted for water part of non-revenue water). The original target of 15% is not met and the City is reviewing its target. MM can share more information on this.	MM	
	Incentives and Opportunities		
AS	**Outreach is possible** The Kopanong precint has 22 buildings, JICP has 24 buildings among its members and 200 buildings in the inner city are going to be renovated. This is an opportunity for the introduction of SuDS at a large scale within the CBD.		
HC, MdG	**The involvement of the individual citizen** Hannelie is confident individual citizens can be more involved, and this workshop is missing that element. For example, by asking citizens to donate a tree back to the city that got damaged – creates a citizen led budget owned by the people to replace trees. Co-designing with communities – who then obtain ownership of the change – is an important recommendation for the Best Practices coming out of this research project.		
KN, FL, NM	**Johannesburg is water scarce and has pipe bursts** Joburg is in need of reduced water pressure, to decrease pipe bursts. With SuDS providing opportunities for alternative sources from stormwater, if this could be a significant portion that could reduce pressure, this would help. Gauteng is in serious need of alternative water sources, we could be structurally worse off than Cape Town in a few years' time, also driving the need for developing local sources. This is not just about drought response but about more urgent needs. The City is working on a review of water services by-laws that will be promulgated in the new financial year, and which will have a chapter on use of alternative sources, which Nomvula Mofokeng can share with the team.	NM	

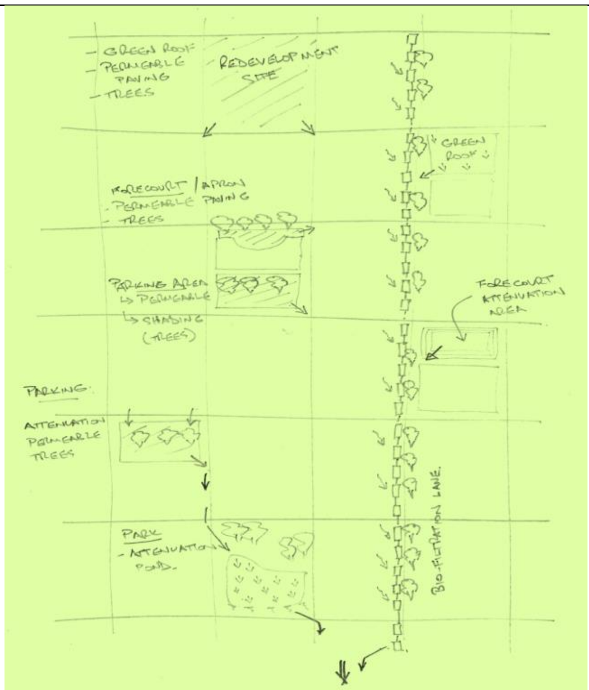
Input by	Action item / Notes of the meeting	Respon-sibility	Date
MM	**Facilitate capital investments by private sector** There is need to find a collaborative way to support cities in their infrastructure plans and the implementation of these plans by the private sector.		
AS, SD, AN (after lunch)	**No Capital Investment without a Management Contract** Many capital investments fail because there is no management contract in place between community (businesses and individuals) and city. Maintenance is essential, and can create jobs. Joburg at Work was considered for JRA a good initiative for improving on maintenance, but failed due to failing financial management. The Expanded Public Works Programme (EPWP) with car guards managed by CIDCO is also said to work well. Out of the 39 contracts Anne Steffny has been involved in, there have only been 4 with financial irregularities.		
AS, HC	**Role of City as enabler** Anne Steffny says that if the City is an enabler, voluntary management initiatives can work, with a mixture of property owners and the community working and living in an area. There are currently 19 voluntary management initiatives within the JICP. Hannelie Coetzee adds that it has taken her three years to understand how the city works, to introduce an initiative that needs more than one department. As an enabler, the city would also have to improve on this, to make use of the innovation capacity of the private sector. Anne Steffny is of the opinion that if the government sets rules, the private sector can respond and deliver. The City Parks is trying to develop a policy on co-management, and Anne Steffny also has several examples of such a policy available. A template could be used for a ‘best management practice recommendation in this SuDS project. Hannelie Coetzee makes the point that communities should also be educated by City Planning departments so that they do not spend effort and money on what might not be realized.	AS	

Input by	Action item / Notes of the meeting	Respon-sibility	Date
B.	**Building Level interventions (green roofs, water harvesting, decreasing groundwater pumped into sewer / stormwater system, permeable parking)**  *Sketch of building level intervention studied*		
	Design questions		
MM, MdG & AD	**Additional potable water demand** Does the introduction of SuDS like green roofs not create higher demand for potable municipal water for irrigation? This is indeed an important design consideration, influencing for example the choice of plants.		
SD & AS	**Green roofs on top of Heritage Buildings** Are Green roofs allowed on heritage buildings? Anne Steffny thought this would probably not be a problem.		
HC, MM	**Food gardens & Rooftop gardening** Introducing food gardens at ground level, soil bound, could help in creating more permeable areas. Current food gardens are in the study area on roofs – mostly introduced by WIBC. These are hydroponic, and therefore have the advantage of low water use. Rainwater harvesting is not needed for the hydroponic gardens, as they use far less water than soil bound gardens, and also have the advantage that they are less heavy which may be necessary for some of the roofs that would structurally not be able to carry the weight of conventional food gardens. However, the suggestion is made to use the roofs of green houses for rainwater harvesting for other uses.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	Incentives and Opportunities		
SB, AB, SD, LC, NM, FL, RT, NN, MM	**Business case for green roofs, rooftop gardening or rainwater harvesting** For property owners the business case for green roofs needs to be clear. If the roof can be rented out for rooftop gardening, that might make more sense to the property owner. However, if the property owner would be obliged, to reduce stormwater impact, or would have less costs on municipal rates (avoid the 'rooftop tax') or less penalties, it could be a business case for them to invest in green roofs. If the green roof or other SuDS measures would also increase the value of the property, it also could add to the business case. For rainwater harvesting, the expectations are that there is no business case yet, as the price of water is relatively low. But the City could introduce incentives for rainwater harvesting. The Planning Department for the City is currently formulating a policy for the greening of the City in which such incentives could be introduced. For existing buildings, the challenge might be large, but such policies could address only buildings that are built new or redeveloped. For Kopanong, there is a more recent revised feasibility study which can be shared with the research team. For Kopanong, also the requirements are still to be specified for the bidders, which provides an opportunity for the inclusion of aspects like SuDS measures, rainwater harvesting and water re-use targets. For the City of Tshwane green building guidelines were adopted, but these miss a well-defined incentive model for property owners. The wish was expressed for the project to contribute to ideas for such an incentive model.	NN	
MM, AB, OT, RT	**Other use of water pumped from basements** The consumptive use of the water pumped from basements can be increased, by actively doing something and giving the opportunity to explore the possibilities (City Labs), which can then later become economic activities (such as a use for car washing – tip AB talk to Mark Kruger. Afternote: Kruger's StopWash uses waterless system.). The water quality could be as good as natural spring water; the inner city used to have springs and there are still some there. The burden of water licensing may have to be reduced to make use of such opportunities, and the scale needs to be sufficient to have sufficient return on investment.		
HC, AN	**Vertical gardens** Instead of only considering green roofs, vertical gardens could possibly also help in stormwater management. Hannelie Coetzee is currently developing a green billboard of 80 m^2 for Sandton Gate. The city has tried vertical walls, but failed as it did not maintain them and did not use succulents.		
	Data collection		
AS, DP, SB, OT	**Inventory of roofs and basements** As for an inventory of roofs and basement pumping, which Dakalo Phaswa is going to conduct: • Anne Steffny can send out questionnaire to her network; • Shaun Burgess can see what he can do for the OPH properties;	DP (initiative) AS SB KN	

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	• Kagiso Nonyana promises to cooperate for the FNB building; FNB currently reuses only 5% of the total water pumped out and opted for artificial grass to reduce maintenance. The rest goes into the stormwater system. The water quality is tested and good; • Ondela Tywakadi can share some research already done on the topic;	OT	
LC, RT, FL, HC	**Choice of plant species on roof tops** Lori Coogan is aware of an Honours thesis of a family member for the choice of grass species in Johannesburg that are indigenous. She can share a link to this Honours thesis. Freddie Letsoko is also aware of a WRC study using grasslands to treat acid mine drainage. (After note: Is it maybe this study by B. Ramla and C. Sheridan? http://www.wrc.org.za/mdocs-posts/se410210/se410210-2/) Rina Taviv is aware of a study at Wits University (see https://www.wits.ac.za/news/latest-news/research-news/2019/2019-02/when-the-water-flows-in-alex.html) . Hannelie Coetzee also knows of a person studying the use of highveld grasses. The team requests contact details and, or the references.	LC, FL, RT, HC	
C.	**Street Level interventions (lined bioretention cells in closed off lane)**  *Sketch of street intervention studied*		
	Design questions		
SB	**Drop off zone for parking** Rather than having a full lane for SuDS could it not be that some drop off zones / short parking spaces are created in between? Currently people being dropped off are creating traffic jams in the City. The research team has made it part of their method to assess what the impact is of not turning a full lane but part of a lane into SuDS, and that would mean part of the lane could indeed be for drop off zones or for other purposes.	SD	

Input by	Action item / Notes of the meeting	Respon-sibility	Date
AN, HC, AD	**Vandalism proof** All creations in the public space have to be vandalism proof. This is a plea for concrete, although cement production is a source of greenhouse gases.		
AN	**Street Hydroponics** Andre Nel is aware of an initiative in the United Kingdom who have street hydroponics, which might be a consideration for the street level interventions. (After note: not easily found by googling – please provide reference).	AN	
	Incentives and Opportunities		
HC	**The beetle 'Shot hole borer' as an opportunity** When trees need replacement because of damage by the shot hole borer this may create an opportunity.		
HC	**Combination with Eco-tree seat** The collective with which Hannelie Coetzee works is currently developing an 'Eco-tree seat' with a community in the upper Jukskei catchment (upstream of Bruma lake). The Eco-tree seat takes stormwater away from the road. The creation of the Eco-tree seat is combined with the timing of earthworks from JRA. A narrative workshop form was used to have the people who will build it, learn the purpose. Combined with a mosaic, the eco-tree seat gets a higher amenity value.		
	Risks, Weaknesses, Threats		
AN, RT, FL, AS, MM.	**Risk for transport** Accessibility of the City is still a problem currently as well as parking space. The Bus Rapid Transit (BRT) system has done more harm than good in that sense. Creating too much green and giving up parkings and lanes is seen as a risk. The CBD is part of the Corridors of Freedom plan therefore public transport and Non-Motorized Transport is high on the policy agenda. Transport planning of the inner city is currently happening and JICP can provide the contact details. The critical issue of a functioning mass public transport system is to have sufficiently short distances from stop to destination and a safe final walk ("last mile"). However, the research team is currently more focused on assumptions on decoupling a certain percentage of buildings from the normal grey water system to check what percentages would make sense from an urban drainage perspective, and not yet deciding necessarily on certain streets or buildings, therefore the integration with transport planning is beyond the scope of this research.		
SD, OT, FL	**Risk of interaction with Acid Mine Drainage** The street level interventions are lined, to avoid contamination and interaction with the groundwater, because of the Acid Mine Drainage (AMD). There is no AMD in the study area, but the ingress could have a pressure influence on areas with AMD, therefore lining is advised. It is not completely certain that the connection to the AMD polluted void exists, but as a precautionary measure, for the purpose of modelling the effect of street level interventions, the assumption of lining is agreed as a safe approach.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
D	**Interventions at a larger scale (treatment trains)**		
	 *Sketch of treatment train at study area level*		
	Incentives and Opportunities		
AB	**New artificial wetland** In the Klip River Valley the plan is to create an artificial wetland of about 20ha to treat the water from the Robinson Canal, which could then form part of the treatment train.		
SD, AN, HC (after lunch)	**Commercial value for silt / sediment?** If sediment had a commercial value, the costs of trapping and collecting it could (partly) be earned back. The value depends on the quality of the silt. Isabel Weyersbye has done research on using trees to clean mine dumps. Maybe some of these species could be introduced in urban areas. Experience with sediment traps was gained in the Jan van Riebeek Park, Alberts Farm, and a dam in Rivonia and one in Lonehill.		
	Risks, Weaknesses, Threats		
	Illegal sewer connections Several new / renovated buildings bordering the Robinson Canal have illegal sewer outlets straight into the Robinson Canal. (As communicated to MdG during lunch break)		
AN, RT, AS (after lunch)	**Capital investments in parks have failed** In the Turffontein Corridor an investment was done in a private park that no one uses, as it is unsafe and is no longer maintained. On the contrary, the Wilds is mentioned as a park of which the use has increased during last few years. Failed projects often do not have a proper management contract in place (see remarks under General). The ‘Adopt a Park’ exercise, should according to Andre Nel of JRA be done with care as communities do not		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	understand the challenges of the parks, with their streams and wetlands. Examples of where 'Adopt a Park' has been done are Winchester Hills and 120 End Street. The process of changes in Parks, which need an EIA, is also considered too complicated. GDARD could possibly consider a general authorisation procedure for urban zone as defined in the Gauteng EMF.		
SD, OT, AN, HC, (after lunch)	**Difficult to get 'house in order' for garbage collection by City** Good garbage collection is important for the sustainability of SuDS. Will the City get its house in order? The workshop participants confirmed the intent of the City, but financial constraints and lack of capacity remain issues.They expressed that the inner city would need additional garbage collection initiated by the private sector. It was an expressed that rather than funding the high operational costs of litter traps, money should instead be made available for the community for litter collection. Communities need to get something out out of it. Dr Melanie Samson of Wits University has "collection by waste pickers" as a research topic.		
AN (after lunch)	**Trapping litter is expensive / difficult** JRA had to remove litter grits on stormwater inlets due to liabilities and because the grits appeared to increase the blockages. A waste management trap in a Johannesburg river has an operational cost of ZAR 120 000 / month, partly for guarding. The one in the Robinson Canal was vandalised. A cheaper litter trap – a steel 'fishnet' - can be stolen and has to be cleaned after every thunder storm.		
AS, MdG	**City maintenance challenges** Even if there is a maintenance and/or garbage collection contract in place (see remarks under general), the City still has to manage these challenges. But this does not happen sufficiently. A WorldBank report on why fixing water pipes did not happen in many countries pointed out that there is no ribbon to cut, not something to win an election campaign on – and in the South Afirican context it is also said that there are no 'interesting' contract opportunities in maintenance. It was questioned whether in fact we should stop expecting the the City will carry out its maintenance obligations. It was noted that many countries experience diminishing budgets for maintenance, and that in many cases stormwater management is last in line for budget allocations. There was some consensus that in fact these guidelines for SuDS implementation should contemplate a reality that the City will not be able to maintain them. This would place greater importance to the community driven initiatives mentioned in the meeting.		
	6. Action Points		
	The meeting did not get time to repeat action points agreed. See in 'Responsibility' column what was noted down as action points.		
NN	**7. Closure**		
	Ndivhudza Nengovhela concluded the meeting by thanking all for being present and contributing to the meeting.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	The meeting closed at 13h00, followed by lunch And then continued for half an hour for those who were interested to stay. These points have also contributed to the notes above.		

ANNEXURE F: Bonaero-Atlasville Stakeholder Workshop Minutes

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

RESEARCH ON THE USE OF SUDS IN GP	
Workshop report: **Stakeholder Suburb Bonaero – Atlasville Workshop**	Date: **04 April 2019**
Location: **Lago Puccini, La Como Lifestyle Estate**	Time: **10h00 - 13h00**
Document status: Approved by PMC for sending to participants.	

Present

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Pastor Simon (PS)	Christian Family Church International	Projects Manager	projects@cfcsa.co.za
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Thsilidzi Rashitanga (TR)	Airports Company South Africa (ACSA)	Senior Technician: Civil Maintenance	tshilidzi.rashitanga@airports.co.za

Apologies received (CC: Workshop report)

NAME	ORGANISATION	POSITION	EMAIL
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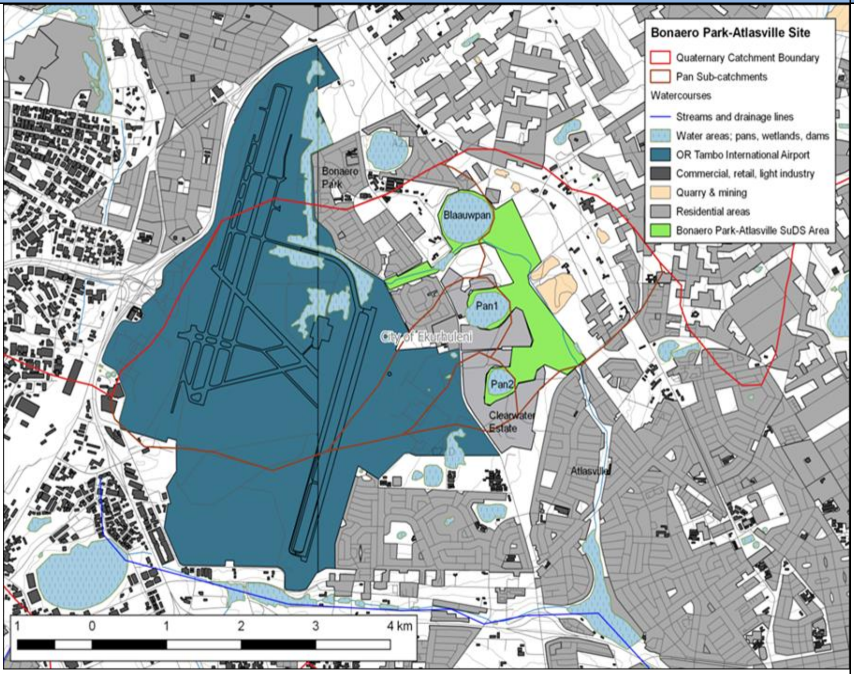
Musa Dlamini	ACSA	Environmental Manager	Musa.Dlamini@airports.co.za

When it is known explicitly who gave the input, initials indicate this in left column. For convenience of reading and follow up, the discussions on the different pans happening during the workshop are combined per pan and in topics such as current situation and governance.

Input by	Action item / Notes of the meeting	Respon-sibility	Date
RT	**1. Welcome**		
	Rina Taviv welcomed all who were present		
MdG	**2. Objective and Introductions**		
	Marieke de Groen outlined the objectives of the workshop and explained that as a research project this project would not come with funding for implementation but rather derive lessons from the case study. She then gave everyone the opportunity to introduce themselves.		
NN	**3. Outline of the Objectives and Scope of the Study**		
	Ndivhudza Nengovhela outlined the objectives of the project and explained the scope of the study. She also provided an update on where the project was at the time, what deliverables had been completed and which ones were in progress.		
SD & MDG	**4. Presentation & 5. Discussion**		
	Stuart Dunsmore gave a presentation introducing Sustainable Urban Drainage Systems and explaining the kind of measures that are being investigated for the study area. After the presentation, discussions were facilitated under the different pans. Summaries are given of clarifications during presentation and after presentation pan below.		

<table>
<tr><th>Input by</th><th>Action item / Notes of the meeting</th><th>Respon-sibility</th><th>Date</th></tr>
<tr><td></td><td>

Total Study Area with focus on three southern pans and bright green marked area of wetlands and channels around it.</td><td></td><td></td></tr>
<tr><td></td><td>On Blaauwpan:</td><td></td><td></td></tr>
<tr><td>SD</td><td>Measures considered to be researched such as: 1) sediment trap combined with emergency pollution control booms; 2) shallows plus a reed bed in front of the inflow to the lake; 3) an island refuge in the centre of the lake for improved circulation. The function of the improved circulation happening and this proposed intervention helping to improve the circulation, would need further assessment. Other preliminary results include:
The modelling of the pan with the software package PCSWMM indicates that the pan already has an important attenuation function.
Modelling of water quality improvements with MUSIC (Model for Urban Stormwater Improvement Conceptualisation) indicate that on its own the pan provides substantial trapping of typical stormwater pollutants (total suspended sediment – TSS, nitrogen – TN, and phosphorus – TP)
Introducing a sediment trap into the inlet canal to the pan enables around 26% reduction in TSS (but other configurations could be tested).
Adding a shallow wetland (5% of the pan area) at the inlet to the pan further improves water quality into the pan (reducing overall TSS by ~60%, TN by ~20% and TP by ~40%). These could provide an important buffer to improve overall ecological condition of the pan.
Hence initial trials suggest there are options of improving the ecological health of the pan while preserving its overall stormwater protection of downstream areas.</td><td></td><td></td></tr>
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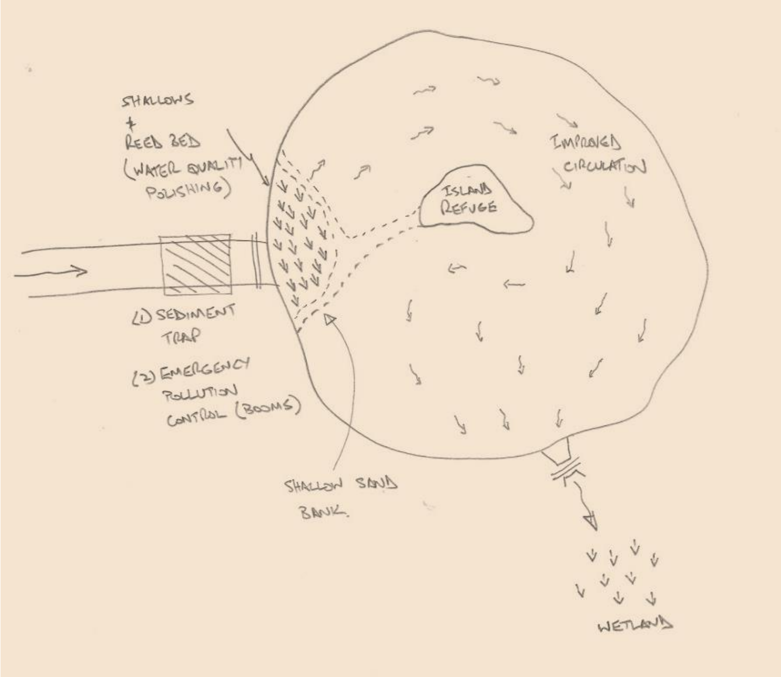
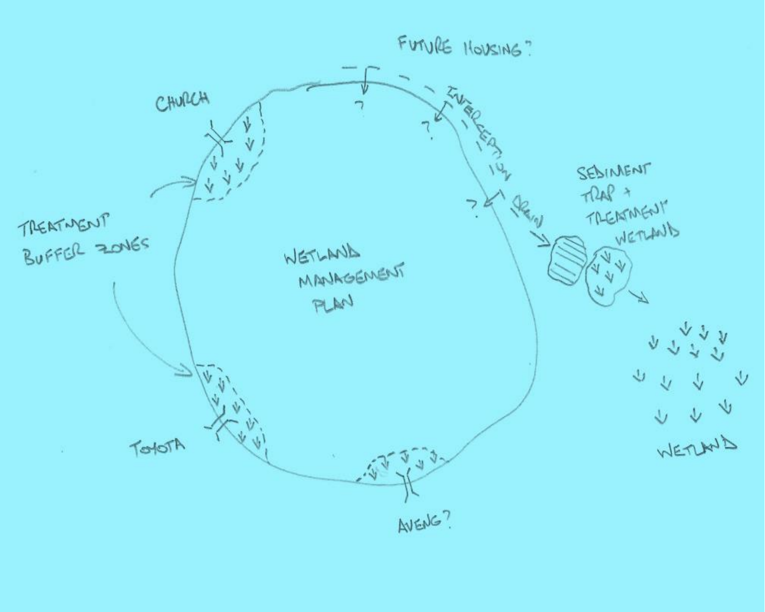
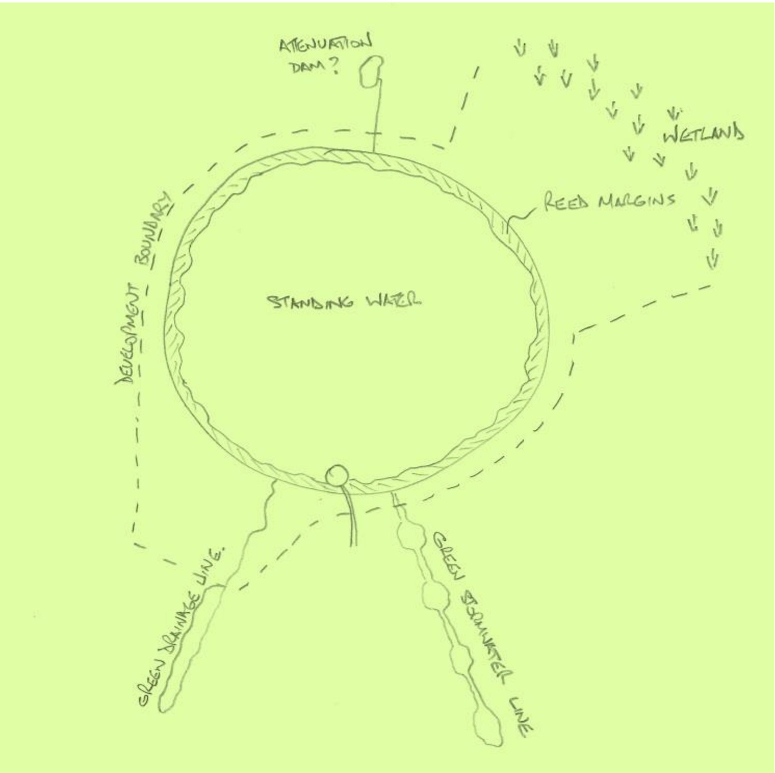
Input by	Action item / Notes of the meeting	Respon-sibility	Date
	 *Sketch of possible measures considered for Blaauwpan.*		
GT & NM	***Current situation*** ACSA has taken measures already to cater for emergency pollution, which makes the proposed emergency pollution control for ACSA accidents suggested less critical.		
GC & NS	There is sewage spilling into Blaauwpan and a sewerage pipe that burst on South-East. The quality of water in the Blaauwpan is therefore also compromised. There is a project to replace a portion of the sewerage pipe to address this.		
NS	The channel that flows into Blaauwpan and the parcel of land around it are probably municipal state land, but this will be confirmed.	NS	
GC & NS & SD	There should be a large fuel separator on-site at the Airport to cater for the 100 year flood as a follow up on the fuel spill in 2008. The outlet of the pan is a simple sluice and outlet without further operational management. The water level is not brought down before heavy rainfall is expected, so the management of the water level is not actively used for flood management	PM	
PM	***Data availability*** ACSA currently does not monitor the water quality on their site, but they are in the final stages of an appointment to get it done going forward. They have a sensor for measuring flows in the channel. The records will be shared. There might also be sediment samples available. ACSA might have stormwater management plans, but the ACSA team attending the meeting would have to find out.	PM	a.s.a.p.
TR	ACSA will share stormwater related information as well as future plans and will find out if stormwater plans and models can be shared.	TR	

Input by	Action item / Notes of the meeting	Respon-sibility	Date
GT PM	Knowledge on data availability (water quality, ecology) in the Blaauwpan itself would have to come from the Wetlands unit from Ekurhuleni, whose representative has apologized for this meeting. On the aspect of ecological functioning of Blaauwpan and the fuel spillage that occurred in 2008, ACSA will find out if they can provide the information that was submitted to GDARD related to the monitoring of the fuel spillage and the mitigation measures thereafter.	PM	
 GT, SD & GC & GT TR SD, GC, IM, NM	***Governance*** Within Ekurhuleni, City Parks is responsible for the area on land and the Wetland Unit for the water bodies. Additionally, currently a conservation unit is being established. It is explained that the differences in staffing for maintenance and management of wetland and park areas within Gauteng is large. Ekurhuleni has relatively very few staff members. ACSA started projects to investigate attenuation of stormwater at the OR Tambo Airport. This was triggered by the flood in 2016, which flooded the airport. According to the research team, the Wetlands Unit, the Parks Division and the Roads and Stormwater Department would need to work together, if SuDS are going to be successfully implemented. It was then suggested that the Private Sector should also be considered in the implementation and maintenance of SuDS because it might be a more successful venture than if it was only left to the government. The Roads and Stormwater representatives agreed that Ekurhuleni MM currently does not have sufficient capacity to maintain SuDS, but would not like to sell current assets such as pans that are having key role in stormwater management. An innovative way, not yet applied in Ekurhuleni Metropolitan Municipalities, could be to lease out such properties to private companies or Not for Profit Organisations.		
	Next steps to finalise site assessment. • The modelling of the sediment trap and wetland will be further refined. • The research team will review pollution loads (and stormwater flows) from the ACSA site on the basis of the information that will be supplied by ACSA. • The function of the improved circulation happening and this proposed intervention helping to improve the circulation, will be further assessed.		
	On the Middle Pan: (Pan 1 in map)		
SD	Of the three pans in the study area, this pan most closely represents its original function. Suggestions that the research team considered were treatment buffer zones at the outlets of the drainage of the different companies and an interception zone at the current planned housing development. However, access to the sites had been limited during the field visit, therefore the importance of this workshop. According to the simulations with PCSWMM the pan currently has almost zero outflow.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	 *Sketch of possible measures considered for the Middle Pan*		
	Current situation		
GC	The pan can successfully serve as a habitat for many fauna and flora species and is close to its natural ecological status.		
GC	There is a bioswale around the pan from where Aveng is located to the Christian Family International Church. In the north it is 0.5 m deep, near Toyota 2 m. This bioswale has been designed by Bigen Africa to serve as a buffer between the stormwater coming in and the pan. This bioswale helps to keep the ecological value of the pan intact and allows it to function as a pan rather than a dam, as the bioswales reduce the flows going into the pan and therefore creates a buffer to reduce peak outflows, but the main reason to introduce the bioswale was to reduce pollution loads on the pan.		
SD	The research team was not aware of this and will incorporate this as part of the treatment measures considered thus far. Any data relating to the design and performance of the bioswale, and existing outfalls into the pan, will be taken into account.	SD	
GC AB	During the initial stormwater design plans, the development team was faced with a dilemma because there were complaints from downstream residents about flooding and requesting upstream corporations to slow down the water to decrease the flooding in the downstream channel (Atlaspruit) and to use the pan rather as a flood protection dam. However, the developers also had to consider the ecological value of the pan and protect it. The current situation is a compromise, as a downstream weir was created to create some more storage capacity to assist in attenuating floods.	GC	
GC	Maintenance includes regularly cleaning out the bioswale, testing the water quality, keeping alien invasive vegetation at bay (removal of exotics every two months) and addressing illegal dumping.		
AB	Toyota Warehouse regularly gets flooded due to the inflow of stormwater from Denel Industries upstream. Toyota already has SuDS		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	in place such as a berm bordering their property and the pan, three bioswales and underground water tank. They use borehole water and are also considering using their harvested water as a potable water source. In addition to the bioswale and the measures at Toyota, Aveng and ID logistics also have their own Attenuation ponds on site.		
PS	The Christian Family Church also has two attenuation ponds in their parking lot and a berm to protect the pan.		
AB	The catchment area as drawn by the research team is smaller than the actual situation. He said that the areas draining into Pan 1 include ACSA and SCM. SCM has approximately 17ha of compacted earth and the stormwater that comes off their site includes the oil spillages. The Bowling Club often gets washed out during intense storms. The Christian Family Church is in the process of extending to the North, which would require a rezoning of the property.		
AB	That the pan has amenity value is expressed in Toyota's workers requesting extra benches for breaks at the sites overlooking the pan		
GC AB	***Data availability*** • There are no flow data available. • Water quality sampling results (4 spots in pan, 2 in river also outflow of Blaauwpan), as well as the environmental management plan can be shared. • The EIA number of the Toyota development can be shared.	GC AB	Done
GC	***Governance*** The measures to protect the pan were taken as a result of the environmental management plan that followed from the environmental impact assessment. Had it not been for GDARDs reactions on the development initiative, then the pan would probably have been far less protected.		
GC	The pan was one property before the surrounding area was developed. It is now owned jointly by the different companies owning a part of the surrounding area, under a Non-Profit Organisation (NPO, established under Section 21). The corporations surrounding the middle pan formed a Section 21 company to protect the pan. Tellurian was involved in the EIA in 2007 and has since been contracted by the Non-Profit Organisation and maintains the pan on their behalf. The NPO was able to achieve this due to GDARD's strict policies in place and together they were able to improve the ecological value of the pan as well as prevent it from becoming an illegal dumping site.		
PS & GC	The NPO functions quite well, but this is because most companies are responsible corporate citizens. One of the owners, however, is not cooperative. For a corporate like Toyota, it gets support from higher management as it implements company policy which includes looking after the environment. Toyota only purchased the land surrounding the pan once the EIA was approved.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
PS, GC & AB	Action does not seem to happen against the owner who illegally graded land, while this company was reported to the authorities. The NPO owns a quite a portion of the land around the pan, but the question is how the sound environmental management is managed around this area at the properties itself.		
	Next steps to finalise site assessment. • The treatment buffer zones will be refined in light of the surrounding bioswale. This will be concluded after the water quality data are received and studied. • The area of Denel will be further studied to consider measures there and note will be taken of already implemented SuDS measures on the attenuation in the properties surrounding the pan.		
	On Southern Pan (Pan 2):		
SD	The water quality of the pan, for an urban pond, seems reasonably good. The pan displays significant attenuation potential and will play an important role in downstream flood risk. The study team has questions on what may be considered for this site. First thoughts included additional attenuation on the north side, or analysis of converting some of the green strips in the development to SuDS treatment trains. The question was put to the meeting and the responses are presented below.  *Sketch of possible measures considered for the Southern Pan*		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	Current situation and future		
CB	Due to the amenity value, houses closer to the pan are more expensive then further away. The Clearwater properties increased in value after the La Como Estate was established (in ten years, property values tripled). La Como Estate also has to deal with large quantities of stormwater from Denel Industries. The Office Parks in the area have attenuation ponds on-site that release into Pan 2.		
CB, & NS	The water level in the Pan is natural and it drains out into the wetland. Usually two days after a storm, there is still stormwater from Denel Industries that is depositing into the pan. In winter, the water level drops about 1 m.		
NS	The Denel industries area will be redeveloped, and it would be helpful to assess SuDS interventions to mitigate existing impacts on the Clearwater Estate and the pan. There is also a proposed development along Brentwood Park Road as well, which will impact on the existing wetland system.		
CB	***Data availability*** • Property prices over the years are known to Clearwater and can be shared. • EIA for Denel and Brentwood Park and possible developments by ACSA are probably available.	CB GDARD	
CB	***Governance*** The pan is privately owned therefore privately maintained.		
SD & NS	The developments and re-development offer some opportunities for stormwater management improvement there, in case the municipality requests consideration of downstream issues. However, the Roads and Stormwater department points out that they can only get involved once the stormwater plans have been submitted and even then, they have no legal standing to enforce on individual residential 1 zoned stand alone stands, only within developments.		
NS et al.	Most new township developments require an EIA, therefore there should be one already for the Denel re-development. But the new Gauteng Environmental Management Framework of 2016 allows for some developments within urban zone and industrial zones (zone 1 and zone 5) to request exclusion from EIA approval.		
SD	***Next steps to finalise site assessment.*** • Leave the current situation as is in the estate itself, • Look at the new (re-)developments planned and the possibilities there.		
	General discussion and conclusions:		
	Governance		
SD	SuDS are not yet a requirement and it is not in the by-laws, although Ekurhuleni is in the process of drafting stormwater by-laws. The purpose of this research project is to help the Gauteng Province drive the municipalities and private sector. Strong guidelines and by-laws		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	would help the environmentally responsible developers. The objective of the workshops is to pick up on policy thinking and the obstacles to SuDS implementation.		
PS & SD	If SuDS became a requirement, it would have to be installed as development takes place. If current developers complied with their original stormwater requirements the law does not give the obligation to retrofit. Downstream stakeholders would have to be aware in the case of up-stream non-attenuation to better inform their stormwater management.		
BN	GDARD aims for this research project to influence the way forward and inform the EIA process and stormwater designs. The Environmental Management Framework is a decision support tool that provides a guide and Minimum standards for exclusion cases, however it does not take preference over the by-laws, even in zone 1 and 5.		
IM	The suggestion was discussed on whether it would be desirable and possible for the Municipality to lease their assets (like the Pans for example) to private stakeholders or NPOs, as the municipality might not have the resources to maintain the asset in that period of time but the private stakeholder will. This would be to ensure that the municipality is able to regain control after a period of time when they have the resources and capacity to properly maintain the asset.		
NS	However, it was stated that the MFMA does not allow the leasing of property for a 99 year lease as in the past, but is now limited to 3 years.		
SD, CB, AB, PS, AD	The uptake of SuDS is slow internationally due to the issue of bad maintenance. Once assets have been privately sold, the stormwater is out of the control of the municipality. This could be solved by at least introducing an institutional arrangement to develop a SuDS asset management registry. The private property owners in the room did not have any objection against such a registry, as a first reaction. It would also be in their own interest to maintain the stormwater system and therefore a check on management and maintenance of their stormwater assets by the municipality would not be objected against.		
GC	The experience was shared that EIA and stormwater management plan approvals are not aligned, and developers then do as if they comply with the contradictory requirements. GDARD authorises projects based on the EIA and the developer agrees to comply with certain requirements of the EIA process, and might have SuDS proposed. Successively, the municipal Roads and Stormwater department would refuse to approve SuDS plans and demand grey infrastructure. As the developer wants to get his plans approved as soon as possible, he changes to grey infrastructure. There is a discrepancy between GDARD and the local municipality where the latter disregards the recommendations of the former.		
	Closing comments:		
GT	Gary Taylor recommended that people should try to work with nature as much as possible. If you know that reeds are going to grow, find ways to make systems work with them. Also, do not try to mow the whole park but leave some grass growing around as this will also benefit nature.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
GC & SD IM ML NS PM CB	Greg Crookes inquired about whether the project is going to look at design components and green ideas and concepts. Stuart Dunsmore responded by stating that the aim of this project is not to go into detailed design, most SuDS systems are creative and standard components perform duplicate functions therefore it is all about the concept behind fitting components together. Isaac Mosoane came up with the idea to introduce warning systems in place for private homeowners to release their harvested stormwater before a major storm event so that they are able to perform the rainwater harvesting function that they are required to and attenuate the water on their property. Marieke said such sensors are indeed existing. Marc Leroy stated that an asset registry should be mapped and understood including the effect of treatment trains to better inform downstream planning. Nathalie Smal remarked that from a municipal point of view, SuDS should be promoted and they should fight hard to protect stormwater management assets as well as create an asset registry Pamela Madondo stated that this workshop was an eye-opener for her, as it made ACSA aware of the downstream effects of its stormwater. CJ Botha stated that the private sector is willing to work with the municipality and that the EIA process and the departments should be catering for SuDS from the outset.		
NB	**5. Action Points**		
	Neggie Bakwunye presented the summary of actions to be completed subsequently:		
	• Pamela Madondo to find out if ACSA can provide flow data from their flow channel sensor, the report submitted to GDARD related to the fuel spillage and to check if there is a fuel separator that caters for the 100 year flood design;	PM	
	• Greg Crookes to provide water quality data for Pan 1, the detailed design of the bioswale and the stormwater management plans for the pan;	GC	DONE
	• CJ Botha to provide the consultants with data on property value improvements related to La Como Estate and the surrounding developments as well as data available for the Pan;	CB	
	• Nathalie Smal to follow up on the status of the sale of a portion of Blaauwpan and the ownership of the channel that flows into Blaauwpan as well as the parcel of land surrounding it. Nathalie to also find the township numbers for the new ACSA and Denel Industries developments;	NS	
	• Tshilidzi Ratshitanga to find out if she can share stormwater related plans and future plans for stormwater management with the consultants;	TR	
	• Andries Botha to provide the consultants with the true catchment area for Pan 1 as well as the EIA reference number and EMPr for Toyota's project;	AB	
	• Greg Crookes to provide a contact for the Department of Water Affairs who works on SuDS;	GC	

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	• Andries Botha or Greg Crookes to provide an estimate of figures regarding maintenance.	AB & GC	
NN	**6. Closure**		
	Ndivhudza Nengovhela concluded the meeting by thanking all for being present and contributing to the meeting.		
	The meeting closed at 13h00, followed by lunch		

ANNEXURE G: Kagiso Stakeholder Workshop Minutes

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

RESEARCH ON THE USE OF SUDS IN GP	
Workshop report: **Stakeholder Workshop Township**	Date: **09 April 2019**
Location: **Chief Mogale Hall, Kagiso**	Time: **10h00 - 13h00**
Document status: Approved by PMC for sending to participants.	

Present

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Ndivhudza Nengovhela (NN)	GDARD (Project manager Client)	Control Environmental Officer: A	Ndivhudza.nengovhela@gauteng.gov.za
Neggie Bakwunye (NB)	GDARD	Environmental Officer: Specialised Production	Neggie.Bakwunye@gauteng.gov.za
Patricia Tshitema (PT)	Mogale City	Environmental Management and Planning	patricia.tshitema@mogalecity.gov.za
Pontsho Modise (PM)	John Martin Catholic School	Educator	admin@johnmartincs.co.za
Rina Taviv (RT)	GDARD (Project Leader)	Control Environmental Officer: B	Rina.Taviv@gauteng.gov.za
Stephan du Toit (SdT)	Mogale City	Environmental Management and Planning	stephan.dutoit@mogalecity.gov.za

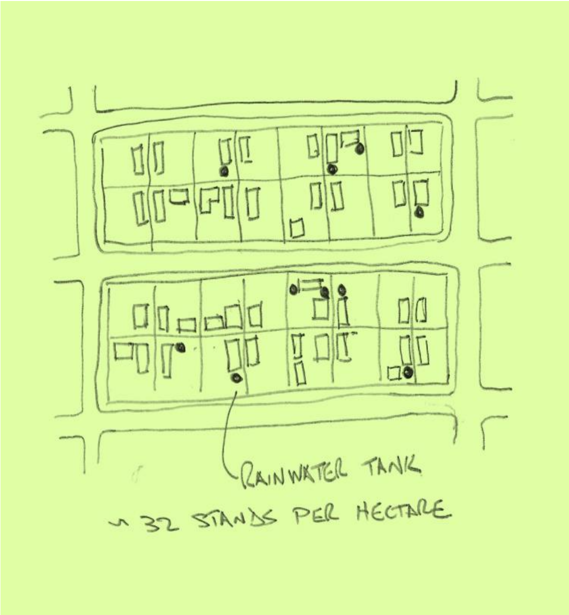
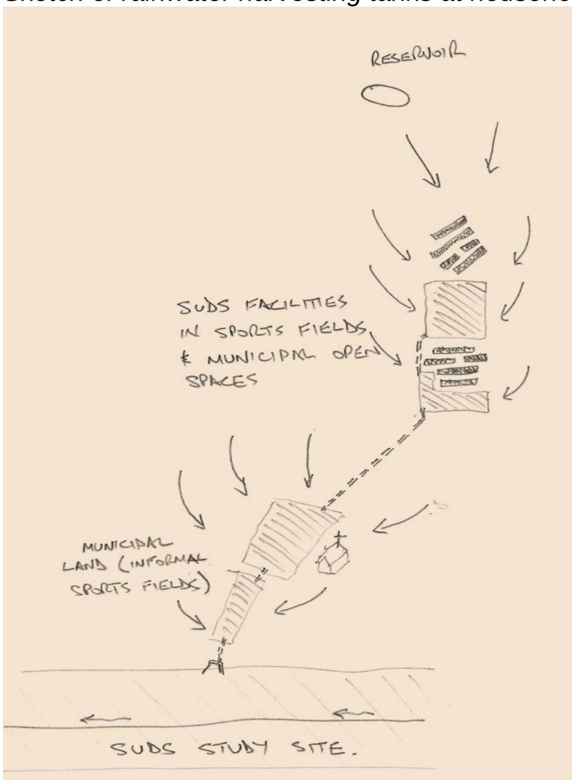
NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
Stuart Dunsmore (SD)	Fourth Element (Consultant)	Team leader	stuart@fourthelement.co.za
Tumi Pharumele (TP)	West Rand District Municipality	Disaster Management	ipharumele@wrdm.gov.za

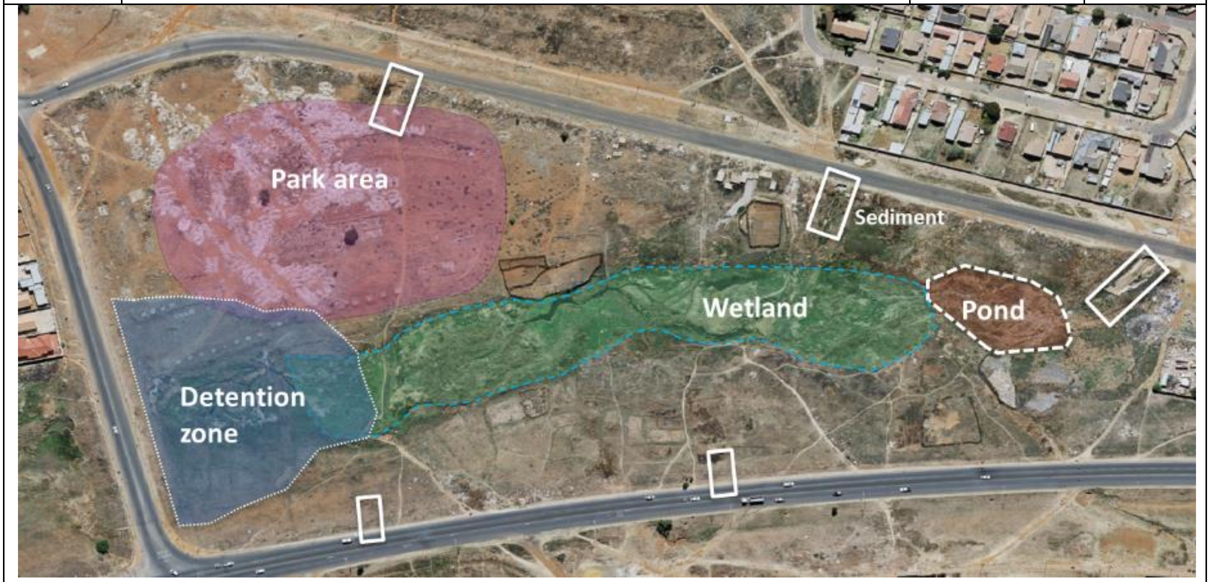
Apologies received

NAME	ORGANISATION	POSITION / DEPARTMENT	EMAIL
Basani Ndindani	GDARD	Environmental Policy, Planning and Coordination: Director	Basani.Ndindani@gauteng.gov.za;
Gail Andrews	Rand Water	Approached because of Rand Water Pipeline through site	gandrews@randwater.co.za
Marc Leroy	GDARD	GIS and data management expert	Marc.leroy@gauteng.gov.za
Molebatsi Jeremiah Jim	Mogale City	Ward 11 Councillor	21721659@sbs.ac.za
Michael Stadler	Mogale City	Roads and Stormwater	michael.stadler@mogalecity.gov.za
Nico Britz	Mogale City	Roads and Stormwater	johan.britz@mogalecity.gov.za
Gail Andrews and Samantha Stelli	Rand Water	Approached because of Rand Water Pipeline through site	sstelli@randwater.co.za
Susan Stoffberg	West Rand District Municipality	Environmental Manager	susanenvironment@gmail.com

When it is known explicitly who gave the input, initials indicate this in left column. For convenience of reading and follow up, the discussions are not written in chronological order but in an order that make sense for follow up.

Input by	Action item / Notes of the meeting	Respon-sibility	Date
SdT & RT	**1. Welcome**		
	Stephan du Toit welcomed all on behalf of Mogale City and Rina Taviv welcomed all who were present on behalf of GDARD		
MdG	**2. Objective and Introductions**		
	Marieke de Groen outlined the objectives of the workshop and explained that as a research project this project would not come with funding for implementation but rather derive lessons from the case study. She then gave everyone the opportunity to introduce themselves.		
NN	**3. Outline of the Objectives and Scope of the Study**		
	Ndivhudza Nengovhela outlined the objectives of the project and explained the scope of the study. She also provided an update on where the project was at the time, what deliverables had been completed and which ones were in progress.		
MdG & SD	**4. Presentation and 5. Workshop session**		
	Marieke de Groen gave a presentation introducing Sustainable Urban Drainage Systems, explained what they are, how the treatment train works and showed examples of SuDS around		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	Gauteng. Stuart Dunsmore explained the study area and kind of SuDS measures that are being investigated. For the upstream catchment rainwater harvesting at individual household level, and peak storage at sport fields were considered. For the area along the R41, sediment traps, a stormwater pond for irrigation, and a detention pond were considered. The report on the discussion is grouped around the upstream and the wetland area downstream, rather than in the chronological order of the meeting, for convenience of follow up.  *Sketch of rainwater harvesting tanks at household level*  *Sketch of SuDS facilities in Sportfields and municipal open spaces*		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
 *Sketch of measures at Wetland Study Site*			
HM	**Ash dumping site (Wetland Study Site)** The area of the Itsose recycling centre and surroundings is an old ash dumping site.		
HM	**Blockages by litter and rubble dumping (Wetland Study Site)** Harry Moiloa stated that there are tonnes of rubble lying upstream from the Itsose recycling centre that have been dumped during the mall redevelopment and block the culvert, together with litter. This results in stagnant water of bad quality on the other side of Geba Street. This presents a health hazard for people in the area and especially children who play in the water after rains. His recycling centre gets flooded often which sometimes forces him to close for 2 days. Harry Moiloa has been bringing this to the attention of the local and provincial authorities without getting a satisfactory response.		
HM, PT & RT	**Solid waste management (General)** Harry Moiloa asked who were responsible for managing the management of illegal dumping and implementing the law became a point of discussion. Patricia Tshitema responded that metro municipalities have Green Scorpions who are specially trained to deal with Environmental Impact issues but this is not the case for smaller municipalities. It would help if Green Scorpion programmes would be effectively implemented in smaller municipalities with assistance of the Province. Stuart Dunsmore emphasized that indeed solid waste management is also important for stormwater management. (See further illegal dumping and litter collection below.)		
HM	**New development without EIA (General)** Harry Moiloa mentioned that there is also a plan to build a church in the area upstream of the Itsose recycling centre, but there does not seem an Environmental Impact Assessment process started.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
SdT & SD	**Harvesting from pond** **(Wetland Study Site)** Stephan du Toit enquired about the possibility of how the pond could be used for harvesting purposes. Stuart Dunsmore responded that in the current suggested system, the pond is located as high as possible in the study site to enable gravity feed of water to irrigate the food gardens. However, this will limit the volume that can be harvested. Locating the pond lower in the study site (closer to the Wonderfonteinspruit) will increase the harvest potential, but will require pumping to get the water back up to the food gardens.		
SdT	**Treatment train necessary** **(Wetland Study Site & Upstream)** Stephan du Toit remarked that the low flow percentage reductions from the proposed SuDS measures is a clear indication that mitigation measures in the catchment are required to help with stormwater attenuation and improve the efficiency of the SuDS measures in the site. SD agreed, saying the principle of SuDS is to start treatment at source ("where the rain falls"). This reduces the flow and pollution loading in the lower parts of the catchment. If SuDS is only implemented in the lower parts then the size of the SuDS required for treatment is often too large (and expensive) to build. Rina Taviv asked about estimated peak reduction, but Stuart explained that MUSIC model doesn't calculate peak reduction.		
SdT & SD	**Sediment loads** **(Upstream area, impact on Wetland Study Site)** Stephan asked about whether the sediment loads from the sidewalks have been taken into consideration when setting up the SuDS model. Stuart Dunsmore responded by stating that the sediments loads used are based on data for residential areas from international research. The data is not specific to sidewalks, streets of roofs, but from the general land cover in a residential area. There is very limited data available in South Africa on pollutant loading and this is one of the gaps identified for the design of SuDS in South Africa. Therefore, the MUSIC model uses default values for a Mixed-use residential area.		
KN	**Wonderfonteinspruit river clean-up campaign** **(Bigger catchment)** Koogan Naidoo stated that there is a river-clean up campaign between GDARD and Mogale City to clean up the Wonderfonteinspruit. The programme started on the 18th February 2019. Service Providers are tasked with providing equipment and transporting the waste that has been collected. The service providers are required to keep records of everything that they provide and collect.		
MM & AM	**Illegal dumping** **(General)** Moipone Mangope remarked that the community should be made aware of illegal dumping and that they should be educated about sensitive areas. Azwindini Mutele remarked that people should be discouraged from illegal dumping and meetings should be held to raise awareness.		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
HM & RT SD	Harry Moila asked about the deterrents for illegal dumping with impunity. Rina Taviv responded that the by-laws and waste management should be the deterrents for illegal dumping. Municipalities do not need green scorpion training to deal with illegal dumping, they need trucks and the capacity within the municipality in terms of human and financial resources. The implementation of SuDS needs to also address illegal dumping because the performance of SuDS facilities becomes hampered with the presence of solid waste Stuart Dunsmore added that the issue of maintenance and illegal dumping should be addressed with the implementation of SuDS.		
 HM	**Litter collection** **(General)** Harry Moiloa stated that there are individuals who are serious about recycling and collect at their premises for two weeks, after which garbage collectors of Itsose recycling centre collect. Itsose also provides schools and other collectors with bags for recycling that allows the practice of source separation. The rate of recycling is quite high, for everything with value.		
 PM MdG RT NN	**Rainwater harvesting** **(Upstream catchment)** Pontsho Modise stated that schools need time to educate children before they can implement rainwater harvesting systems. The schools currently do not irrigate their sports fields but they have toilets and they often have issues with water supply, where water can be cut for up to four hours a time. Since the current water supply is unreliable, the question was posed how the participants assessed the risk of harvested rainwater used for consumption. It was confirmed this was indeed a risk, but the group thought this could be solved by proper instructions. Rina Taviv mentioned that a Water Research Commission (WRC) project, developed a kit for the treatment of water and that the recommendations made to harvest rainwater should be accompanied by suggestions on the treatment of that water if it is used for drinking. Ndivhudza Nengovhela suggested that Pontsho Modise contact the Cooperative Governance and Traditional Affairs (COGTA) that encourages rainwater harvesting by donating tanks to schools.NN will provide contact details.	NN	
 AM & HM MdG, AM, HM	**Food gardens** **(Wetland Study Site)** Azwindini Mutele is in favour of agriculture and stated that there are approximately between 4-5 people with plots on the SuDS site. Do the fields require irrigation? According to the locals in the workshop knowledge, the fields do not require irrigation for the crops currently grown, but maybe it would create the opportunity for some winter vegetables.		
	Reuse of sediment from sediment traps **(Wetland Study Site)**		

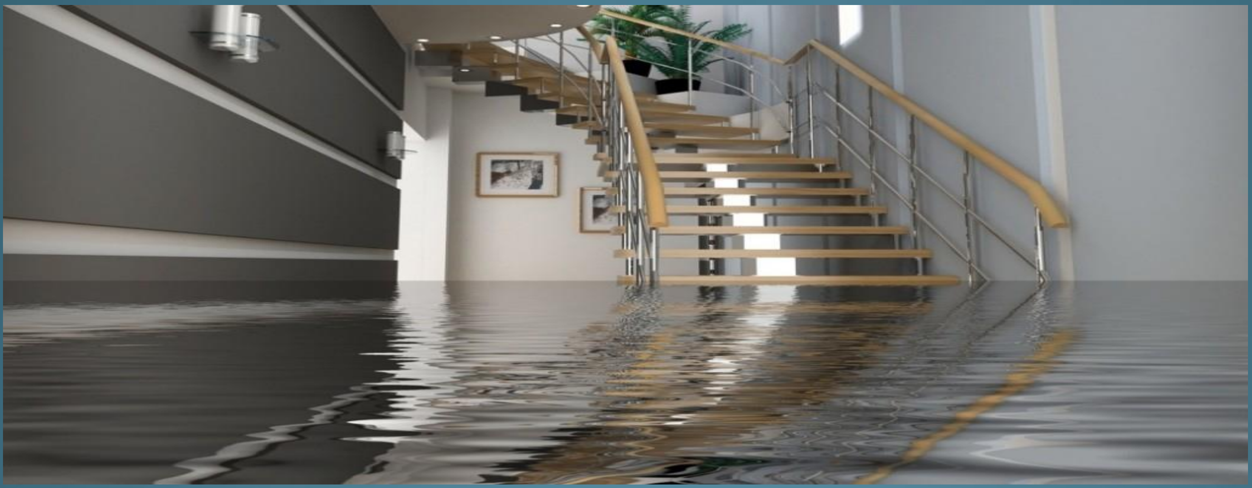
Input by	Action item / Notes of the meeting	Respon-sibility	Date
RT, SD	Rina Taviv suggested that the sediment traps might also serve as an opportunity to harvest and re-use the sediment. Stuart Dunsmore responded that recycling sediment could be an important opportunity, for example for building material (coarse sediment) or composting (finer sediment). It would depend on whether the sediment is contaminated in any way. Regular testing of sediment would be required.		
PT RT & PT SdT	**Safety in open spaces (General)** Patricia Tshitema remarked that safety is a very important issue to consider when planning SuDS. Safety measures such as fencing off areas (at least 1.8 m high) to prevent access should be considered to prevent children from accessing certain areas that may be unsafe for them. In terms of areas that provide recreational activities with SuDS employed, the SuDS must be designed in a manner that is safe and does not pose safety hazards. Rina Taviv stated that there are lessons to be learned from GDARD who are establishing parks. Patricia Tshitema stated that the GDARD parks initiatives in Westrand prove the point that safety is not considered and the projects fail after two years because they expect the municipality to take over the operations and maintenance of the projects, but the municipalities lack the capacity to do so. Stephan du Toit pointed out that ponds pose the risk of drowning and that the design should be based on gentle slopes and low depths. Otherwise, the areas must be secured using fences.		
SdT PT & SdT RT & PT RT	**Creation of Park Areas and Public Spaces (General)** Stephan du Toit stated that SuDS presents an opportunity for informal soccer fields to be formalised through the construction of SuDS. Patricia Tshitema confirmed that there is a need for parks in the area however it is not a priority and it would need to be in the plans for future parks developments in the Spatial Development Framework. Stephan du Toit added that there are no developed parks within a 2.8 km radius therefore there is a need for parks in the area. Rina Taviv stated that it is crucial for the creation of green spaces to mitigate the effects of climate change. With climate change, there is an anticipation for extreme heat waves and especially in township areas where people might not be able to afford air conditioners, green spaces would assist in reducing the heat effects. Patricia Tshitema added that even just the creation of green belts would make a difference Rina Taviv suggested that schools in the neighbourhood could partner with the municipality to look after parks. There could be programmes where school kids could be disciplined by cleaning up litter in parks.		
SdT	**Detention Zone (Wetland Study Site)**		

Input by	Action item / Notes of the meeting	Respon-sibility	Date
BK	The detention zone should not compromise the integrity of the roads infrastructure. The peak flows of the last years have never been so high that there was any attenuation, as the culvert capacity was higher than the flows. The West Rand District Municipality Disaster Management department had not had any complaints on flooding downstream of the culverts, where the houses seem to be in the flood risk zone.		
SdT	**Park area (Wetland Study Site)** Stephan du Toit informed the group that Kagiso Extension 9, that is currently part of the study site with the idea of making a park area there, is planned to be developed into a residential area.		
SdT	**On stakeholders involved in the site (Wetland Study Site)** Stephan du Toit remarked that there are potential role-players who are not at the workshop and could add value and serve as potential beneficiaries such as Rand Water who has sumps that flush into the stream and the company with petrol pipes that run parallel to the road. (After note: Rand Water had apologized for not attending this workshop.)		
	Closing comments:		
KN PT GH CS SD HM	Koogan Naidoo suggested that the SuDS plan should be aligned to the Spatial Development Framework, the Transport Plan for Mogale City and make use of the mapping of wetlands for the West Rand District Municipality. Patricia Tshitema emphasized the safety aspect of SuDS, suggested that job creation around communities should be a top priority in the recommendations for SuDS, and mentioned that the workshop made her realize how much SuDS require an integrated approach with several departments and parties working together. Gabisile Hlongwane mentioned that the land-use recommendations and illegal dumping is an element of poverty because people intentionally dump in order to create employment and get the municipality to hire them to clean up. Caroline Sithi recommended that SuDS be enforced in the development for township authorisations. Stuart Dunsmore added that the maintenance of SuDS systems offers the ideal opportunity for job creation. Harry Moiloa remarked that people need to change their “What’s in it for me” mindset.	Consultant	
NB	**5. Action Points** Neggie Bakwunye presented the summary of actions to be completed subsequently:		
	Koogan Naidoo to contact persons of the following: • Spatial Development Framework: Caliphornia (Local Economic Development) 081-3395737	KN	DONE

Input by	Action item / Notes of the meeting	Respon-sibility	Date
	• Roads and Transport Plan: Michael Stadler 082-3343542 • GDARD Wetland Clean Up campaign 071-2464959		
	Harry Moiloa to engage separately with the consultants about the rubble and illegal dumping on site, directly after the workshop.	HM	DONE
	Patricia Tshitema to investigate the relevant safety aspects and park requirements which might be relevant for consideration of SuDS in Kagiso and sent her findings to the consultants.	PT	
	The consultants to check on the rainwater treatment kit, developed with WRC funding.	Consultant	
NN	**6. Closure**		
	Ndivhudza Nengovhela concluded the meeting by thanking all for being present and contributing to the meeting.		
	The meeting closed at 13h00, followed by lunch		

ANNEXURE H: The Investigation of Basements and Rooftop Survey in selected Buildings of the Inner-City of Johannesburg Metropolitan Municipality

Report by GDARD.



ANALYSIS REPORT:

THE INVESTIGATION OF BASEMENTS AND ROOFTOP SURVEY IN SELECTED BUILDINGS OF THE INNER-CITY OF JOHANNESBURG METROPOLITAN MUNICIPALITY

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
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Drafted by: Neggie Bakwunye; Dakalo Phaswa; Ndivhudza Nengovhela; Rina Taviv and Basani Ndindani

<u>**Table of contents**</u>

1. Purpose

The purpose of this report is to present findings of the study that was undertaken with the aim of investigating basements and rooftops in selected buildings of the inner-city of Johannesburg Metropolitan Municipality. This report will not only be shared with GDARD officials and external stakeholders but is also presented as an annexure to the Sustainable Drainage Systems (SuDS) Implementation Manual for the Research on the use of SuDS in Gauteng Province.

2. Background and objectives

This study resulted from the observation made during a site visit to the Johannesburg CBD by the project management team of the Research on the Use of Sustainable Drainage Systems in Gauteng Province's Project. The SuDS project is currently conducted by the Environmental Policy, Planning and Coordination (EPPC) directorate, with the help from the appointed consultants (Fourth Element Consulting (Pty) Ltd. The SuDS project focuses on three identified study areas, which are Bonaero Park-Atlasville, Ekurhuleni Metropolitan Municipality, Kagiso in Mogale City and the catchment area that drains to the Robinson Canal in the Central Business District (CBD) of Johannesburg Metropolitan Municipality with focus on the Kopanong Precinct. Site visits were conducted in each study area, hence from the CBD site visit, it was noted that many buildings engage in dewatering practices in their basements on a regular basis.

It was hoped that the findings of this study could help in gaining knowledge of the amount of water pumped from basins and whether this water is reused and whether it is currently drained on the stormwater drainage systems. This is useful information to (1) understand the impact on the stormwater system and (2) to quantify if this pumped water could be an alternative water source, in particular because the project investigates the possibility of green roofs or bio-retention areas in the CBD, and these might need irrigation at least during the years of establishment, dependent on their design. There are discussions currently ongoing for reuse of the pumped water, not necessarily for SuDS, as discussed with Johannesburg Inner City Partnership (JICP) and Wouldn't It Be Cool (WIBC) – a company helping to establish entrepreneurs. The findings of this research will also be made available to them for that purpose.

It was agreed that information on the roof tops would be useful, for a better understanding of whether different types of green roofs would be possible (depending on access to roof, safety, roof cover, strength of roof) and what areas they could cover. In the CBD the WIBC is introducing urban agriculture entrepreneurs who use hydroponics farming, the alternative of this kind of agriculture, which has less structural requirements and is not a SuDS system, as it does not influence stormwater. By looking at properties of the roof such as the type of roof, surface area, accessibility and boundary walls, the research could also benefit WIBC, and rooftop greenhouses could be considered for suitable roofs in preference over SuDS green roofs.

In light of the above, the Research and Development unit embarked on a study that aimed at investigating the basements and rooftops in selected buildings of the inner-city of Johannesburg Metropolitan Municipality, with assistance from the Fourth Element Consultancy Team as a skills transfer project for Dakalo Phaswa, intern at the Research and Development Unit.

3. Activities

The activities of the study included the following:

- List the government and private owned buildings selected for this survey.
- Collect data and analyse existing dewatering measures in place.
- Enter the data into a database, including spatial details for further analysis.
- Collect data on type and accessibility of roof tops.
- Collect data on the amount/volume of water pumped from basements.
- Determine the opportunities for rooftop buildings for urban agriculture.

4. Methodology

This section focuses on the approaches used to collect, analyse and validate the data utilised for the study. Below is the explanation of the approaches deployed:

4.1 Data Collection

The survey method was used as the main tool for data collection in the study. Questionnaires were designed to collect relevant information and distributed to the targeted stakeholders. The questionnaire used is attached (see Appendix 1).

In ensuring that the questionnaires reached the stakeholders and completed, walk-ins were done to different Gauteng Provincial Department buildings (such as Gauteng Department of Sport, Arts and Culture; Gauteng Department of Education; Gauteng Treasury etc.) to hand over the questionnaire. They were followed up with telephone calls and emails. Other buildings that contributed to the study include: Sci-bono, Bank City, Anglo American and South Point and others. The Johannesburg Inner City Partnership assisted with the distribution of questionnaires to the property owners through emails. Follow-up through phone calls and emails was done by the project team.

In total, questionnaires from 19 buildings were received. An additional 27 buildings had information on Assessment reports done by Gauteng Department of Infrastructure Development (GDID) and the others had information on water seepage received from City of Johannesburg Metropolitan Municipality.

Further, the Kopanong feasibility assessment was consulted. The Kopanong feasibility assessment of the GDID included Cost & Benefits Analysis for 4 clusters of buildings in CBD. The estimated capital costs (expressed as Net Present Value for a 22 years period) per cluster of R1 222M to R2 296M are higher than current costs. Unfortunately, to cut the costs it was decided to not implement green star rating for existing buildings (only for 2 new ones). The operation and maintenance costs did not include cost of water, electricity, etc. The storm water options were not considered in the Cost & Benefits Analysis.

The investigation by Johannesburg Metropolitan Municipality by Council for Geosciences in 2017 (entitled “Investigation of groundwater occurrence within the inner city and its surrounding areas") showed that there are many areas where leakages from water and sewage reticulation systems or old infrastructures systems causing water seepage into basements. There are some areas in which the occurrence is related to rain water and the seepage takes place only during rainy seasons. This may be related to rising water table (level) during rain or direct seepage of rainwater into the building. The investigation focused on groundwater and explained that "*The occurrence of groundwater can be characterized into three broad groups: near surface occurrence within the weathered profile; occurrence within fractures, dykes and shear zones; and occurrence within dissolution cavities in the dolomites. In some parts, randomly oriented left lateral strike slip faults with minor occurrence of right lateral strike slip faults with the associated weathered and sheared zones can potentially act as a conduit for accelerated groundwater flow.* ". The boreholes were drilled and water levels and water quality were measured at 9 locations. Water levels varied between 2.95m to 17.7m deep while water quality was good at most of the sites. The main pollutants of concern were nitrate and Faecal Coliforms, which are indicators of sewage pollution. The water seepage rate analysis could not be conducted due to the access problem. The study recommended further monitoring, but have not provided any specific suggestions for groundwater use.

4.2 Data analysis

The data from the completed questionnaires has been consolidated into an excel spreadsheet for the purpose of analysis (see Appendix 2). The questionnaire contained questions such as the levels of the basement, dewatering practices, re-use of water from basements, types and access to roofs, etc.

5. Findings

This section of the report presents findings of the study conducted. This is done by discussing the findings of the basement areas and later discussing the roof tops of the buildings used in the study. Work done in relation to each topic that is being discussed is acknowledged and possible uses of both the water pumped out of the basements and rooftops are explained.

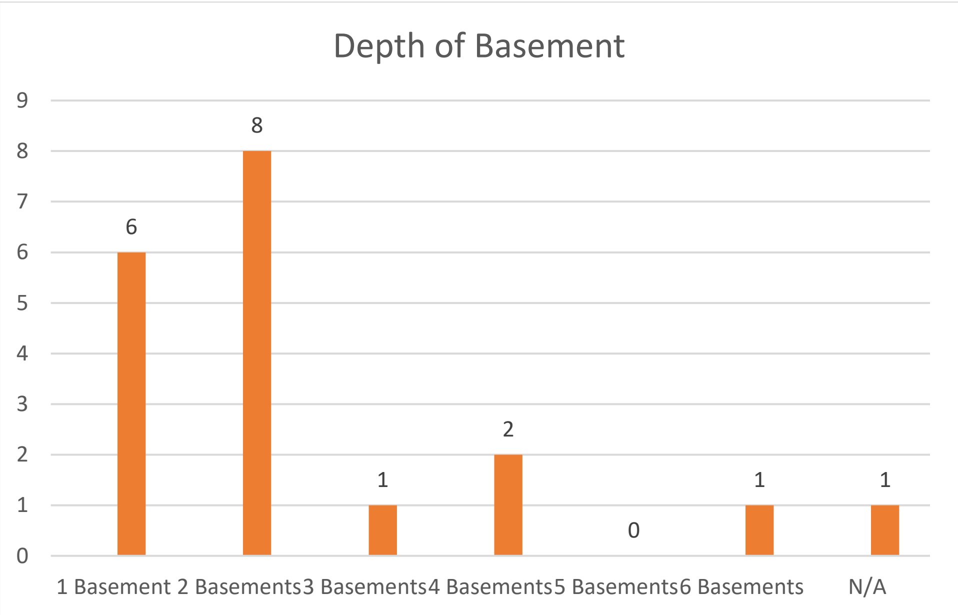
5.1 Basements

5.1.1 Presence of basement area

The graph below indicates that 18 buildings have basement area with only one building is without basement area. The building without basement area still included part of the study since it contained data that was used for rooftop analysis.

5.1.2 Depth of basement

The graph below shows the depth of the basements present in the buildings. The majority of the buildings have 1 to 2 levels of basement. The respondents indicated generally that they practice dewatering from basement 1 up to basement 4. Other respondents didn't specify the depth of their basements, but mentioned that they do have basement areas present, hence the graph below has an unspecified (N/A) column.

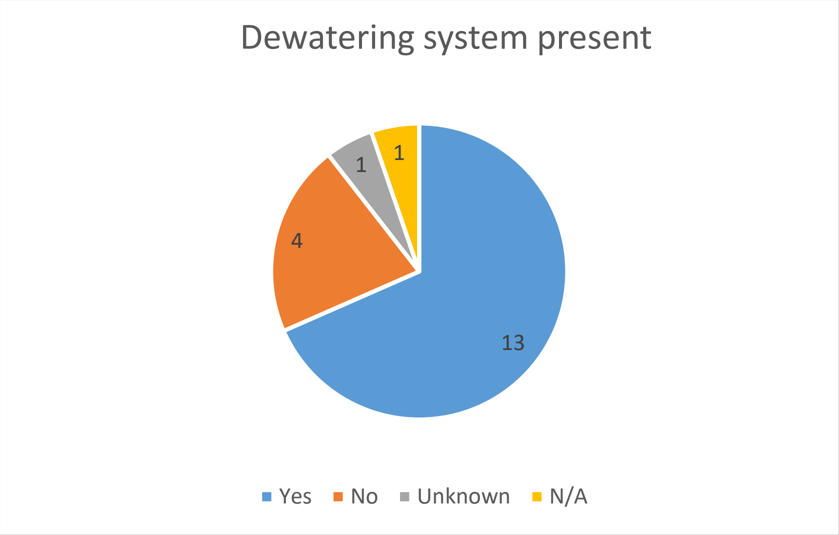


Graph 1: Depth of basement

5.1.3 Dewatering system in the basements

The graph below indicates the number of buildings with dewatering systems, with almost all the buildings having dewatering systems available.

From the 19 questionnaires submitted, 13 buildings indicated that they do have dewatering systems, whereas 4 of the buildings indicated that they don't have dewatering systems, with one building that has specified as unknown and the other one with no basement at all, hence the response is not applicable (N/A).



Graph 2: Dewatering system in the basements

5.2 Water

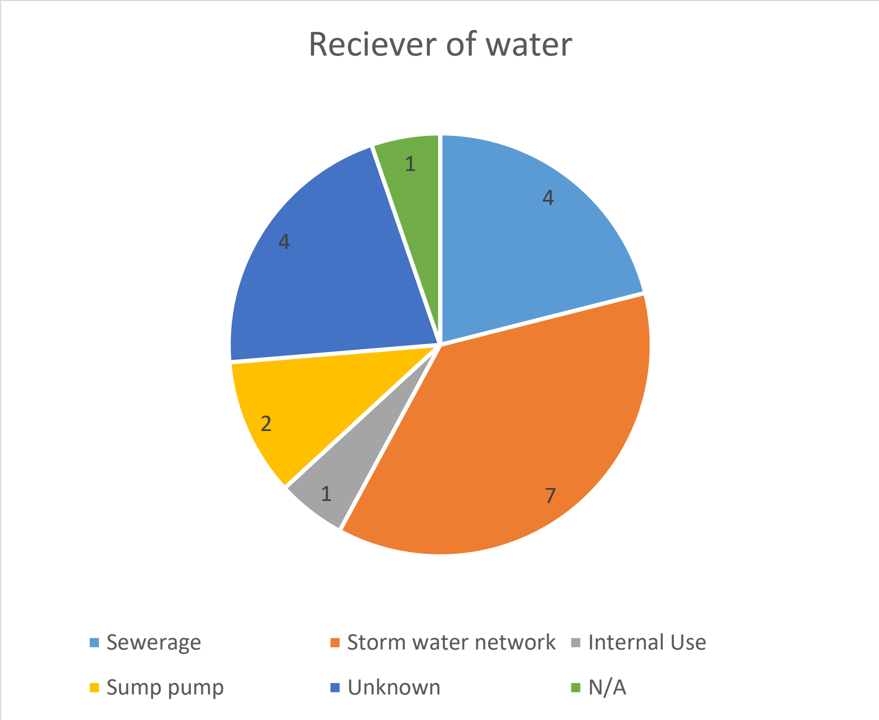
The graphs below illustrate the usage of water and also indicate as to whether the measurement of water quality is being conducted, and also look at where is this water being directed to. They also provide information on how buildings re-use their groundwater if it being re-used and also specify what is the water being re-used for.

5.2.1 Measurement of water quality conducted

It is noted that none of the buildings know the water quality of the water pumped from the basements. Interest has however been shown with regards to having tests done to measure the water quality.

5.2.2 Where is the water being directed to?

From the findings, 7 buildings indicated that they directed their water to the stormwater network, 4 directed them to sewerage, 6 did not know where the water goes to (4 indicated as such and 2 stated from sump pump), the remaining direct it either for internal use or not applicable, since there is no basement.



Graph 3: Where is the water being directed to?

5.3 Water re-use

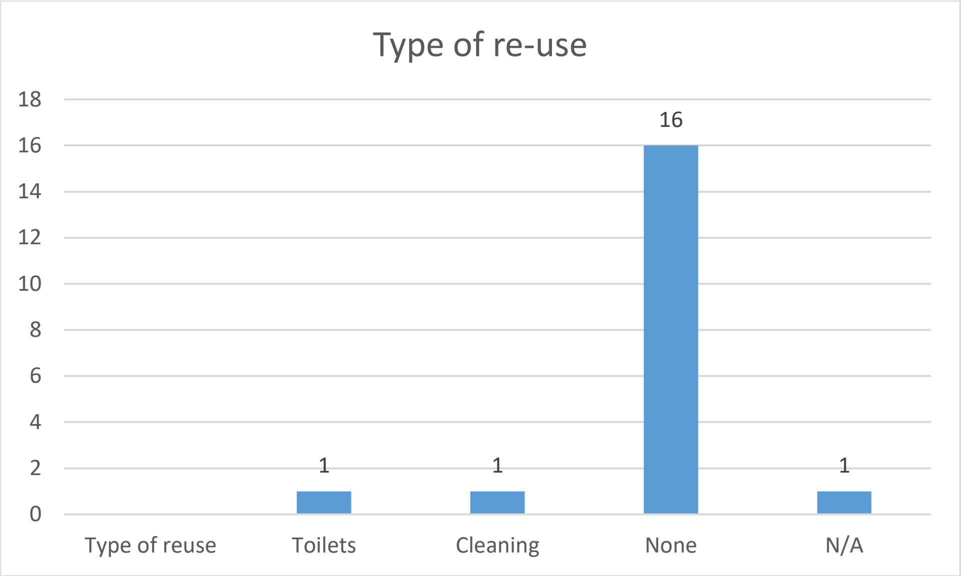
5.3.1 Is the water re-used

Even though water is pumped out of the basement of the buildings that the study was conducted in, the majority of the respondents stated that they do not re-use their water. The water pumped out is regarded as waste water, although it could be considered for re-use.

All of the buildings that practice dewatering are directing their water to stormwater or sewerage with exclusion of FNB Bank City, where they are using some of their water for fountains and external cleaning. For some buildings it was answered that the water is pumped to a sump, but that is a temporarily storage facility and does not clarify where the water is going to afterwards.

5.3.2 Type of re-use

The graph below shows that the majority of the buildings don't re-use their water, hence it supports finding above that the water is not being re-used but treated as a waste element. This is important for the study since it indicates the potential of harvesting the water, which will improve water security and reduce the burden in the stormwater network.



Graph 4: Type of water re-use

5.4 Pumps

The graph below mainly looks at the operation of the pumps in these buildings. However, there seems to be insufficient data concerning pumps. The questionnaire asked for the volume of water pumped, capacity of the pump and the usage of the pumps that are used. All buildings for which the survey was conducted did not provide any data with regard to the volume of water pumped.

5.4.1 Volume of water pumped

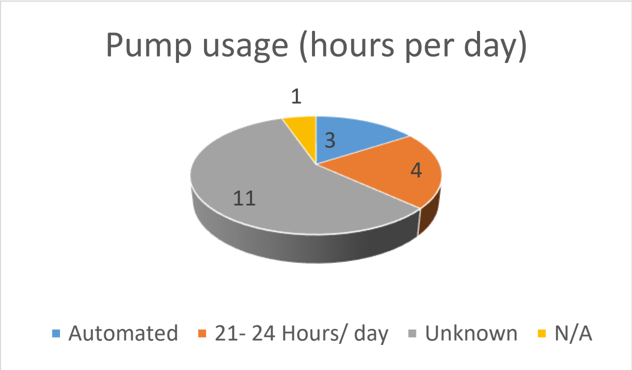
From the answers provided it was deduced that the amount of water pumped out of the basements is unknown and in some cases unspecified. Such shows that there is lack of interest in the water that is being pumped out, hence education and awareness of how the water can be re-used can play a vital role and positively influence the amount of money spent when purchasing water.

5.4.2 Capacity of pump

Majority of the buildings stated that they are not aware of the capacity of the pump, even though they are aware of the presence of the pump and that the pump is frequently being used since they experience basement flooding. One response stated that pump capacity is $140m^3/h$, while another said it is 1000 kpa.

5.4.3 Pump operating hours

The usage of the pump is also not presented in the questionnaires by majority of the buildings. This is followed by almost quarter the number of buildings saying that they operate their pumps between 21 and 24 hours.



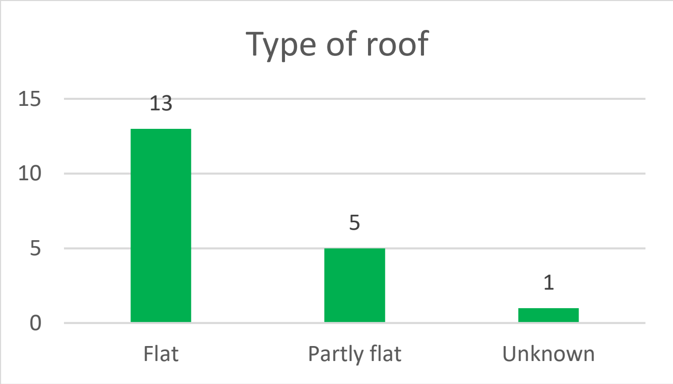
Graph 5: Pump Usage

5.5 Analysis of roof data

The graphs below illustrated how the roof tops, for which questionnaires were received, are structured. The graph below clarifies information with regard to the type of roof, can the roof be walked on, boundaries of the roof, accessibility of the roof and the surface of the roof. This data will also be beneficial to stakeholders dealing with urban agriculture, such as Wouldn't It Be Cool (WIBC) which is one of the organisations that is practising urban agriculture within the Johannesburg Metropolitan Municipality in the inner-city.

5.5.1 Type of roof

Chalatse (2003) suggests that the usability of urban and suburban roofing for existing and new houses based on the gradient / slope of the roof, materials used, etc. hence in quest to find out possible uses of the roof for urban agriculture, the type of roof questions were asked. The findings reveal that the majority of the roofs have a flat structure. Therefore, there is a possibility of using the roof for green roofs or rooftop agriculture, etc. However, there is one respondent who indicated that they are not aware of their roof type.



Graph 6: Type of roof

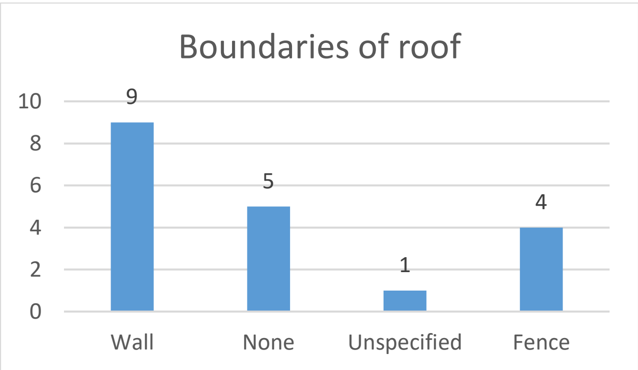
5.5.2 Accessibility to roof

The ability of the roof to be walked on was another important element of the study because for any secondary activity such as roof top gardens, there'll be a need to walk on the structure. All buildings involved in the study, with one exception, indicated that the roof can be walked on.

Accessibility of the roof was also an important component to study since it influences whether a building roof can be used or not. For all but one of the buildings there is an accessible roof, and stairs are there for access.

5.5.3 Boundaries on the roof

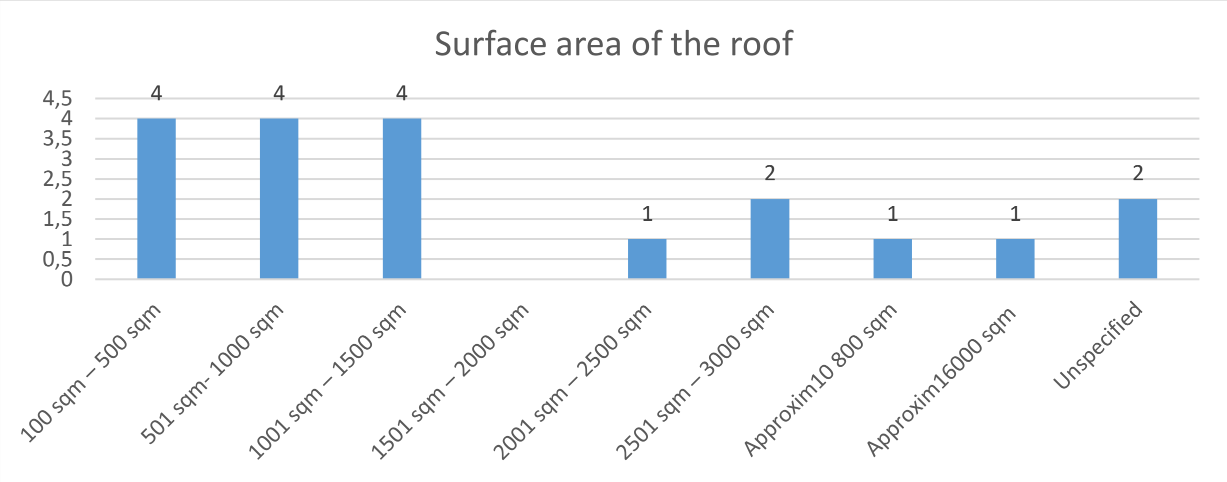
Most of the buildings indicated that they have wall boundaries. The remaining buildings either had none, a fence or didn't specify. Boundaries are important to note since they can serve as safety measure for roof activities and in some specific cases can retain the rain water for sometime.



Graph 7: Boundaries of roof

5.5.4 Surface area of the roof

Most of the buildings indicated that they have roof sizes between 100sqm – 1500 sqm. Important to note with that there are buildings with larger sizes up to 16000sqm. This will allow the possibility of having more than one activity carried out on the roof.



Graph 8: Surface area of the roof

6. Conclusions

The majority of the sample of 19 buildings have basements from which water is pumped (13 out of 19), but amounts of water are generally unknown. For many of the buildings it is unknown where this water is pumped to, but some pump to the stormwater system (7 out of 19) and surprisingly some are reported to pump to the sewerage system (4 out of 19). There would thus be potential for using the pumped water more effectively. Currently of the buildings consulted only FNB is having re-use on site. For none of the buildings tests are carried out on water quality. For most buildings it was confirmed that the research team would be welcome to take samples (see Appendix 2 with all results).

The roofs of the buildings are generally well accessible and most have flat area. Therefore most of the buildings are technically suitable for green roofs, if structural strength is confirmed, or alternatively for roof top farming.

7. Recommendations

This investigation did not yet do analysis on the combined answers in one questionnaire, but these are quite simple to derive from the full database of answers in Appendix 1. For example, if there is interest to develop a green roof, then it could be checked if the same building has already excess water it pumps from the basement that can be diverted to be used for irrigation. Such analysis only makes sense for locations that are seriously considered either as green roof or for bio retention (not so high pumping head, similar to current stormwater or sewerage system).

The ability for reusing the water pumped out from basements for irrigation and urban agriculture should be explored further. Such an exploration would benefit from an additional survey for every building where dewatering is practiced, to measure how much is pumped and to possibly suggest the savings on the cost of water should the water be used.

Education and awareness with facility management of the buildings would be needed for consideration of the water pumped as an additional source of water.

It is recommended that further studies be conducted on the water quality of the pumped water. This will influence the use of the water and has the potential to tell a story of whether the water that is pumped out from the basement is from the aquifers (ground water), leaking pipes or just rainwater seepage.

As for the roofs, for interested facility managers / property owners, the recommendation would be to consider contacting WIBC for the possibility of agricultural farming on their roof. The consideration for green roofs would also need further considerations by managers/ property owners, further defining the objectives of such a green roof apart from stormwater management. This survey did not make an attempt to ask for structural capacity of the roofs, which would be an important design input as well.

8. References

1. Chalatse, Keketso (2003) C beam environmental roof. MTech study Cape Technikon.

2. Ecolife dictionary. Accessed on July 2019, from: http://www.ecolife.com/define/grey-water.html

3. Karabo Mashabela (2015), “Onsite greywater reuse as a water conservation method: A case study of Lepelle-Nkumpi local municipality, Limpopo province of South Africa”. Accessed on July 2019, from: http://ulspace.ul.ac.za/bitstream/handle/10386/1645/mashabela_k_2015.pdf?sequence=1&isAllowed=y

9. Appendix 1: Questionnaire

Project GDARD: Research on the Use of Sustainable Urban Drainage Systems in Gauteng Province, Case Study CBD Johannesburg (Oct 2018-Sept 2019)			
Kindly reply to DAKALO.PHASWA@gauteng.gov.za, with cc to support@aqualinks.co.za			
Kindly reply before 8 May 2019, your cooperation is appreciated.			
Questionnaire for buildings in Inner City			
Questions	Unit	Answers	Contact details to get further information
General			
Building Street Address			
Building Name (if available)			
Building Owner (if available)			
Latitude (if available)	Lat		
Longitude (if available)	Long		
Respondent Name			
Email			
Phone nr			
Erfnr			
Basement			

Does your building have a basement area?	**Yes / No / Do not know**		
If Yes above, then kindly answer the following questions:			
Do you have a dewatering system for your basement/foundation? (removal of groundwater seeping into the basement)	**Yes / No / Do not know**		
What is the depth of the basement?	**m or nr of parking levels underground**		
Where is this water directed to?	**Sewerage/Storm water network and, or Internal Use of water or Do Not Know**		
Do you monitor the water quality of the groundwater that is being removed? (if so, can you provide more information on the water quality or give permission to take a sample)	**Yes, as follows or No, or No but you are welcome to come and take samples.**		
If the water is reused, what is it reused for?	**E.g. watering of gardens, toilet, cleaning of garages etc. Please be as specific as possible on amounts of water used.**		
What is the volume of water pumped per day? (If seasonal differences please indicate)	**m^3/day**		
If Question 7 is not known, then maybe 8 and 9 are known:			

What is the capacity of the pump?	**m^3/hour or l/s**		
How many hours a day is the pump switched on for? (If seasonal differences please indicate)	**hours/day**		
ROOF			
Is the roof flat?	**Yes / No / Do not know**		
Can the roof be walked on?	**Yes / No / Do not know**		
Does it have a fence / wall around it?	**Yes / No / Do not know**		
Is the roof easily accessible? (Staircase)	**Yes / No / Do not know**		
What is the surface area of the roof (approximately)?	**m^2**		
THANK YOU!			

10. Appendix 2: Data Collected

10.1 Basement Data

Name of Building	Building Street Address	Basement area present	Depth of basement (i.e number of parking levels underground)	Dewatering system present	Measurement of water quality conducted	Volume of water pumped	Capacity of the pump
Sci-bono.	Corner Helen Joseph and Miriam Makeba street, Newtown, Johannesburg.	Yes	2 Basements	Yes	Welcome to take samples	Unknown	Unknown
Periousia (PTY) Ltd	90 Albertina Sisulu & Cnr Harrison Street	Yes	1 Basement	No	No	Unknown	Unknown
45 Main Street	45 Main Street	Yes	2 Basements	Yes	No	Unknown	Unknown
44 Main Street	44 Main Street	Yes	1 Basement	No	No	Unknown	Unknown
47 Main Street	47 Main Street	Yes	1 Basement	No	No	Unknown	Unknown
55 Marshall Street	55 Marshall Street	Yes	6 Basements	Yes	No	Unknown	Unknown
42 Marshall Street	42 Marshall Street	Yes	2 Basements	No	No	Unknown	Unknown
BankCity	c/o Kerk And Simmonds	Yes	4 Basements	Yes	Welcome to take samples	Unknown	Unknown
Surrey House	35 Rissik Street	Yes	4 Basements	Yes	Welcome to take samples	Unknown	Unknown
Imumba House	75/77 Fox Street	Yes	3 Basements	Unknown	No	Unknown	1000 kpa
Diamond house	35 Melle street	Yes	2 Basements	Yes	No	Unknown	Unknown

Name of Building	Building Street Address	Basement area present	Depth of basement (i.e number of parking levels underground)	Dewatering system present	Measurement of water quality conducted	Volume of water pumped	Capacity of the pump
Phumelela House	99 Simonds street	No	No	N/A	N/A	N/A	N/A
Epozini	66 De Korte	Yes	2 Basements	Yes	Welcome to take samples	Unspecified	Unspecified
Argon	87 Juta Street	Yes	2 Basements	Yes	Welcome to take samples	Unspecified	Unspecified
Mvelelo	19 Melle Street	Yes	2 Basements	Yes	Welcome to take samples	Unspecified	Unspecified
Van der stel place	20 Melle Street	Yes	2 Basements	Yes	No	Unknown	Unspecified
46 De korte	46 De Korte	Yes	1 Basement	Yes	Welcome to take samples	Unspecified	Unspecified
Black Burn	77 Juta Street	Yes	1 Basement	Yes	Welcome to take samples	Unspecified	Unspecified
Norvic House	91 De korte Street	Yes	1 Basement	Yes	Welcome to take samples	Unspecified	Unspecified

10.2 Receiver of Water, Water Reuse, Hours of pumping

Name of Building	Building Street Address	**Receiver of water**	**Water reused (yes/no)**	**Type of re use**	**Pump usage (hours per day)**
Sci-bono.	Corner Helen Joseph and Miriam Makeba street.	Sewerage	No	None	Automated
Periousia (PTY) Ltd	90 Albertina Sisulu & Cnr Harrison Street	Unknown	No	None	Unknown
45 Main Street	45 Main Street	Sump pump	No	None	Automated
44 Main Street	44 Main Street	Unknown	Unknown	None	Unknown
47 Main Street	47 Main Street	Unknown	Unknown	None	Unknown
55 Marshall Street	55 Marshall Street	Sump pump	No	None	Automated
42 Marshall Street	42 Marshall Street	Unknown	No	None	Unknown
BankCity	c/o Kerk And Simmonds	Internal Use	Yes	Cleaning	Unknown
Surrey House	35 Rissik Street	Storm water network	No	Toilets	Unknown
Imumba House	75/77 Fox Street	Sewerage	No	None	21- 24 Hours/ day
Diamond house	35 Melle street	Storm water network	No	None	Unknown
Phumelela House	99 Simonds street	N/A	N/A	N/A	N/A
Epozini	66 De Korte	Storm water network	No	None	Unknown
Argon	87 Juta Street	Sewerage	No	None	Unknown
Mvelelo	19 Melle Street	Sewerage	No	None	Unknown
Van der stel place	20 Melle Street	Storm water network	No	None	Unknown
46 De korte	46 De Korte	Storm water network	No	None	21- 24 Hours/ day
Black Burn	77 Juta Street	Storm water network	No	None	21- 24 Hours/ day
Norvic House	91 De korte Street	Storm water network	No	None	21- 24 Hours/ day

10.3 Rooftops

Name of Building	Building Street Address	Type of roof (e.g flat)	can the roof be walked on?	Boundaries on roof	Accessibility of roof e.g. Staircase
Sci-bono.	Corner Helen Joseph and Miriam Makeba street.	Partly flat	Yes	None	Stairs
Periousia (PTY) Ltd	90 Albertina Sisulu & Cnr Harrison Street	Unknown	No	None	Other
45 Main Street	45 Main Street	Flat	Yes	Wall	Stairs
44 Main Street	44 Main Street	Partly flat	Yes	Wall	Stairs
47 Main Street	47 Main Street	Partly flat	Yes	Wall	Stairs
55 Marshall Street	55 Marshall Street	Partly flat	Yes	Wall	Stairs
42 Marshall Street	42 Marshall Street	Partly flat	Yes	Wall	Stairs
BankCity	c/o Kerk And Simmonds	flat	Yes	Unspecified	Stairs
Surrey House	35 Rissik Street	flat	Yes	Wall	Stairs
Imumba House	75/77 Fox Street	flat	Yes	Wall	Stairs
Diamond house	35 Melle street	Flat	Yes	Wall	Stairs
Phumelela House	99 Simonds street	Flat	Yes	Fence	Stairs
Epozini	66 De Korte	Flat	Yes	None	Stairs
Argon	87 Juta Street	Flat	Yes	Wall	Stairs
Mvelelo	19 Melle Street	Flat	Yes	Fence	Stairs
Van der stel place	20 Melle Street	Flat	Yes	Fence	Stairs
46 De korte	46 De Korte	Flat	Yes	None	Stairs
Black Burn	77 Juta Street	Flat	Yes	None	Stairs
Norvic House	91 De korte Street	Flat	Yes	Fence	Stairs