Department of Facilities Management

STORM WATER MANAGEMENT AT THE UNIVERSITY OF PRETORIA

April

2023

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

EXECUTIVE SUMMARY

South Africa is one of the driest countries on earth. Water resources in South African cities and towns are under increasing pressure from population growth, climate change, extreme drought and waterway degradation. As a result, water consumption has increased to unsustainable per capita, and increasing amounts of technology and energy are used to provide water for human needs.

Rather than the traditional approach of managing urban water supply, storm water and wastewater separately, the University of Pretoria is moving to a more integrated approach and treating all three as a single resource by creating a closed-loop system where all water is used as effectively as possible.

This approach includes water demand management, where the water demand is reduced, and water recycling and reuse (where appropriate). Water is a critical utility for the University of Pretoria, accounting for approximately 15% of UP's annual utility budget. In addition to serving the daily domestic needs of more than 66 000 people, water is used for energy production, laboratory and research processes, dining services, restrooms and grounds maintenance for campuses with more than 1 039 970 m^2 net floor area.

Regarding its Water Management Policy, the University works towards strengthening a culture of water conservation and sustainable water use. The University of Pretoria strives to become a water-sensitive university that optimizes and integrates water resource management. As a result, UP staff and students will be more resilient, have better business continuity, and be able to live more comfortably. This document aims to align future water management initiatives with the University's Sustainability and Water Management policy and plan.

In many parts of the country, due to inadequate freshwater resources, more freshwater resources are needed to meet domestic, economic development, and environmental needs. When there is a low supply of clean water for drinking and sanitation, human health and productivity are negatively affected. Therefore, a primary constraint must be overcome to maintain a healthy ecosystem and a clean environment.

The Water Institute of UP is a unique academic institute that addresses many water issues, including water and agriculture, water and health, water and global change, water treatment and infrastructure, and water management. It emphasizes work across academic disciplines and faculties and takes a robust transdisciplinary approach to solve water challenges. The Department of Facilities Management as the custodian of the water reticulation and management of the University of Pretoria, can consider future endeavours with the Water Institute of UP to develop and research alternative water solutions in line with the Sustainable Development Goals.

The goal of transdisciplinary research and collaboration between the Water Institute of UP and the Department of Facility Management will be to undertake large-scale infrastructure projects, prioritizing water management projects to support the University's that aspiration to be a research-intensive university while promoting sustainability.

During 2021 (as part of the fifth cycle of infrastructure and efficiency funding received through DHET), major infrastructure modernization projects, including the completed water installations, were implemented. The water installations aim to mitigate the risk of supply disruptions in the Tshwane Municipality.

The University of Pretoria (UP) is committed to sustainable water stewardship and aspires to be an internationally recognized community of water-smart individuals committed to achieving a net zero water campus by 2050.

The UP Water Management Policy and Plan is a testament to this commitment and support to UP's Strategic Plan 2026 and Beyond, which emphasizes sustainability. The University commissioned the Water Management Policy and Plan in response to its drive towards transdisciplinary, collaborative, and impact-oriented research into implementing water-sensitive design principles.

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1. STRATEGIC INTENT

The sustainable water systems at the University of Pretoria aim to provide adequate water quantity and appropriate water quality for a given need without compromising the future ability to provide this capacity. This document will focus on sustainable water use at the University of Pretoria to ensure the university's business continuity. Examples include rainwater gardens, storm water retention to ensure optimal use in the gardens and the reuse of greywater where possible.

Sustainable water supply is a component of integrated water resources management that brings together multiple stakeholders with different viewpoints to determine how water should best be managed. In order to decide whether a water system is sustainable, various economic, social and environmental considerations must be taken into account.

Unfortunately, fresh surface water is limited and unevenly distributed worldwide and in South Africa. The very arid Gauteng area receives water from various regional dams, such as the Vaal Dam and imports water from the Orange River system through the Lesotho Highlands Water Project, notably the Katse Dam.

This document will aim to re-investigate and re-imagine the actions listed in the Water Management Plan and policy of the University of Pretoria. The Water Management Plan and Policy (2017) focused on developing long-term water saving strategies with no clear and obvious consideration of alternatives to municipal storm water dependency. Since then and more specifically since 2018, a need has arisen to investigate alternative storm water sources. The drought of 2018 forced universities to investigate alternative water sources to reduce the dependency on municipal water supplies and the following actions are proposed to achieve this goal:

- The University's overall needs and maintaining business continuity during periods of unprecedented low rainfall and water restrictions needs to be addressed;
- Reducing overall spending on water (a scarce natural resource) through appropriate investments;
- Providing a diverse, resilient and sustainable combination of water resources; and
- Mitigating the overall impact of runoff from UP on downstream water quality.

Failure to maintain business continuity during a drought or supply disruption would seriously disrupt academic activity. Moreover, a disruption in business continuity would jeopardise UP's reputation as the leading research-intensive University in Africa. To achieve these ambitious proposals in this document, UP must embark on an action plan that includes infrastructure upgrades, operational improvements, and student awareness programs. The University of Pretoria recognises its essential role as an anchor institution in the Hatfield CID. Implementing the Water Management Plan and policy will require significant resources and will take several years. The Water Management Plan and policy implementation have been driven by funding from the DHET, particularly for water conservation projects focused on alleviating water dependency in student residences at UP, where water use is highest.

Water is a precious resource, and the University of Pretoria has to be serious about re-imagining its use of the resource and the infrastructure used to reticulate water on the campuses. The fundamental basis of proper water management is that the University cannot manage what it does not measure and cannot measure if it does not know what to measure. Therefore, this includes consolidating infrastructure records and installing additional intelligent water meters to better understand water usage across the university campus. Secondly, the University has to monitor how water is being used, how much water is being lost to leaks, and demand fluctuations at a building level. These are required to inform better and direct infrastructure interventions. Finally, the University of Pretoria must understand and improve its water measurement. To this effect, the University already has leak detection monitors. However, the comprehensive monitoring and auditing of water utilisation on UP campuses need to be modernised by implementing automation initiatives.

Water monitoring remains tied to old analogue devices that cannot provide feedback at a scale and timeframe that helps users and operational managers. Therefore, a starting point for building a water-sensitive campus is to improve understanding of the water system and monitor future progress.

This document aims to provide a comprehensive strategy for water management as a long-term plan. The Department of Facilities Management has to develop an overarching strategy to carry out its broad aim for sustainable water management, consistent with a realistic budget. This plan aims to:

- Provide clear, realistic and achievable goals for improving water management at all campuses and a clear plan to achieve that goals;
- Provide a clear understanding of water resource services and use across all campuses, including identifying risks and opportunities;
- Define the Capex and Opex requirements of each water management program;
- Define the benefits of the water management program;
- Prioritise the water management program implementation and align these interventions with the expected Tshwane Municipality water management program;
- Assigning roles and responsibilities for each water management program and understanding the capacities of the role players within the different management roles;
- Establish a monitoring mechanism to monitor the implementation of water policies and actions to report on how each objective is being met.

(This report should be read in conjunction with the Water Management Policy [Rt 04/17] and Plan [Rt 05/17] attached as Annexure 1 Water Management Policy [Rt 04/17] and Annexure 2: Water Management Plan [Rt 05/17].

There are better ideas than investing in new water sources to supplement municipal supplies for the University. Adding complexity to the water system makes little sense before improvements can be made to the existing municipal supply system, based on the reasoning that interventions are costly. Investments in water-saving devices at the University of Pretoria have continued. The investments in water-saving devices include the installation of low-flow showerheads, dual-flush toilet systems and urinal control devices in existing buildings on campus.

Several deficiencies have been identified at UP, which pose ongoing challenges and require further attention:

- UP water meters - to ensure that the meters are operational and that the data recorded is correctly interpreted and used;
- Support from Tshwane Municipality – Tshwane City's guerrilla tactics, bureaucracy and incompetence have led to mass infrastructure failures and created significant challenges to day-to-day university operations;
- UP required much more determined efforts to meet its water needs and improve its dependency on the city of Tshwane Metropolitan Municipality's water supply.

2. WATER SOURCES

2.1 GROUNDWATER USE

South Africa is an arid country characterized by extreme climatic conditions and evaporation rates that often exceed precipitation. Groundwater is an essential water resource that contributes to the country's water security and universal access to water and sanitation. Groundwater accounts for more than 50% of global freshwater; therefore, it is vital for irrigation at the University of Pretoria. Approximately 64% of extracted groundwater is used for irrigation purposes. Awareness and better management of groundwater are required to ensure its sustainability. In order to promote sustainable use, the University of Pretoria should measure water quality and levels beyond the general legal requirements. The responsible use and management of groundwater entail collecting data on groundwater levels. Quality-management of groundwater use is not just beneficial to the aquifer but also makes business sense.

Sustainable groundwater use ensures that groundwater is available for future generations. In some cases, groundwater has been stored for many years, and while it can be considered a renewable resource, it can be depleted in the long term if not managed properly. Uncontrolled withdrawal and continued overexploitation of groundwater endanger the sustainability of the resource. The University of Pretoria should prevent this by installing a good monitoring and reporting platforms to measure water withdrawal from boreholes on its campuses.

Sustainable groundwater use requires effective management beyond monitoring groundwater abstraction volumes and incorporating groundwater levels and quality monitoring. Despite this, resources are often neglected when it comes to investment. With ongoing resource development and no control, the consequences include:

- Contamination and salinization of groundwater.
- Subsidence,
- Falling water tables, and
- Reduced groundwater contribution to groundwater-dependent ecosystems.

Storm water quality treatment must be undertaken with due consideration of the legislative requirements in the National Water Act. The enacted National Water Act (Act 36 of 1998) [NWA] provides the legal framework for effective and sustainable resource management. The NWA recognizes the following:

- Water resource management aims to achieve sustainable and equitable water use.
- Sustainability and equity are central guiding principles in protecting, using, developing, conserving and managing water resources.
- The need to protect the quality of water resources to ensure sustainability.

Groundwater can be a sustainable source of water supply if the total amount of water entering, exiting and stored in the system is conserved. Three main factors determine the source and amount of water flowing through a groundwater system are:

- Precipitation,
- Location of streams and other surface water bodies, and
- The evaporation rate, a sustainable abstraction or pumping capacity for groundwater, can not be generalized.

The NWA restricts water use's purpose, nature and extent and requires groundwater use to be monitored, measured, recorded and registered with the Competent Authority. Groundwater use requires a license unless it is listed as a:

- Schedule 1 water use,
- It is an existing lawful use (ELU),
- It is permitted with a general Authorization (GA) or if the need for a water use license (WUL) is waived.

(In the case of the University, the boreholes were drilled prior to 1998 when the NWA was enacted. Therefore the boreholes are defined as Existing Lawful Use).

Unsustainable groundwater use leads to declining water levels, reduced runoff and poor water quality, threatening the livelihood of UP's affected gardens and sports fields. Various practices of sustainable groundwater supply include changing rates or spatial patterns of groundwater extraction, increasing recharge of the groundwater system, reducing runoff from the groundwater system, and changing the volume of stored groundwater at different time scales.

A long-term vision is necessary for groundwater extraction, as the effects of its development can take years to become apparent. Integrating groundwater supply into an appropriate University Masterplan's planning and sustainable drainage systems are essential (Annexure 3: UP Masterplan 2022 - 2026). The unavailability of reliable data affects the confidence level of developed groundwater models that help predict safe abstraction rates under different climatic conditions and scenarios of water use, aquifer recharge and depletion.

2.2 RAINWATER HARVESTING

In natural environments, rainwater mostly evaporates, is absorbed by plants or soaks into the ground. Urban development dramatically changes these processes, clearing the land of vegetation and covering it with 'hard' or impervious surfaces that cannot let water through.

As a result, rainwater runs off these surfaces, through storm water drains and straight into waterways as polluted storm water in a short time. This changes the timing, speed and volume of water flows, affecting storm water management systems.

Water sensitive urban design (WSUD) uses better urban planning and design to reuse storm water, stopping it from reaching our waterways by mimicking the natural water cycle as closely as possible. The WSUD that will be discussed include a range of options:

Rainwater harvesting is a process that uses the direct collection of rainwater, typically from roofs, for additional on-site water use. Rainwater harvesting (RWH) can improve water supply in a water-restricted region like Gauteng, where the University of Pretoria is located. Although rainwater harvesting can technically meet global water needs given the Earth's surface area and rainfall, given a level of uncertainty (particularly in the face of climate change) and competing land-use applications, the solution may most practically complement sustainable water supply systems.

RWH is described as collecting rainwater for later use instead of letting it drain into storm water networks and sewer systems. It is commonly used in rural areas and on farms but is fast becoming an alternative method of using water sustainably. Traditional storm water infrastructure pollutes and discharges millions of cubic meters of water into watercourses and oceans every year. With minimal treatment, this water could be used to supplement the drinking water supply for secondary water uses such as toilet flushing and garden irrigation.

RWH has been used in South Africa for decades. However, it must still realize its full potential as unresolved challenges prevent widespread adoption. Improving the quantity and quality of water supply through RWH effectively increases available potable water for communities. For this document, the University of Pretoria will investigate augmenting available water resources (dependency on municipal water resources and water abstraction from boreholes) with RWH.

Collecting water from precipitation is one of the most sustainable sources of water supply as it has inherent barriers against the risk of overexploitation of surface and groundwater sources and directly provides potable quality. However, rainwater harvesting systems must be adequately designed and maintained to collect water efficiently, prevent contamination and use sustainable treatment systems if the water is contaminated.

There are two effective rainwater harvesting techniques.

1. Using surface runoff.
   With this process, rainwater runs off as surface runoff and can be stored for later use.
2. Groundwater recharge.
   Groundwater recharge is a hydrological process in which water flows from surface water into groundwater.

In South Africa, rainwater is typically collected from the roofs of buildings. It is then stored in tanks for later use. Therefore, it is proposed that RWH be combined with rain gardens (Sustainable Drainage System, swells and other sustainable solutions) to achieve the most optimal long-term solution.

Rainwater runoff from impervious surfaces (typically roofs) is passed through a coarse filter and collected in a storage facility (water tanks, sump, or reservoir). The water is then pumped on demand by a booster pump which feeds directly into the irrigation pipeline that provides water to various points in the gardens. Once the storage tank runs dry, water from the main line should be fed into the system. If this is done manually, it would require regular monitoring of the water level in the storage tank. An automated ball valve can also be used.

Alternatively a gravity fed system would eliminate any technical breakdowns. This water is then gravity fed into the specified application points in and around campus gardens. Gravity supply systems do not generally require electrical energy which saves on costs and means that supply can be maintained during power outages.

Many different systems for collecting and reusing rainwater are commercially available. The key element requirements for an effective storm water collection and reuse systems from roofs are:

- The strategic placement of gutters;
- A first flush trap and/or filter sock to catch leaves and other debris;
- A rainwater storage tank (tank, barrel or sump); leaf and organic debris deflectors;
- A means of getting the water to its point of use, preferably by gravity or otherwise, a pump and piping;
- An in-line filter and/or UV sanitizer if there is a risk of human contact; and
- An overflow system, preferably connected to another option in a Sustainable Drainage Systems (SuDS) treatment e.g. swells.

The advantages of a well-designed RWH systems are:

i) Optimal use of rainwater collection and reuse systems at the different UP campuses can significantly reduce potable water consumption;

ii) Collecting storm water runoff reduces the pollution load entering nearby watercourses;

iii) Collection and reuse of storm water runoff attenuates flood peaks; and

iv) A variety of rainwater storage tanks are commercially available in South Africa and are generally easy to install. Alternatively a RWH system can easily be incorporated with Sustainable Drainage Systems (SuDS).

The disadvantages of RWH systems are:

i. Water quality must be monitored and is generally such that the water can only be used for additional irrigation or landscaping purposes;

ii. Rainwater storage systems installed above ground can be unattractive. This can be incorporated into a sustainable drainage system that can soften the aesthetics of the system; and

iii. Currently, storm water reuse is relatively expensive, with the associated storm water tanks and mechanical systems representing the highest cost of the system.

Figure 1: Rain gardens connected to a rainwater harvesting (RWH) system

2.2.1 SUSTAINABLE DRAINAGE SYSTEMS (SUDS)

Traditional storm water management focuses primarily on volume management (flow management) by collecting runoff and directing it to the nearest watercourse. Unfortunately, the traditional storm water management methodologies have led to the erosion of natural channels and pollution, resulting in environmental degradation. Sustainable Drainage Systems (SuDS) offer an alternative approach by design to water volume management; water quality treatment; improved amenities; and the preservation of biodiversity. SuDS attempts to manage surface water drainage systems holistically per sustainable development principles and SDG 6 considerations.

Urban storm water should be considered part of the urban water cycle, a strategy increasingly referred to as Water Sensitive Urban Design (WSUD), with a storm water management component known as SuDS. SuDS offers an alternative to traditional drainage systems for managing drainage around and within properties and developments. These structures temporarily store water during storm events, reduce peak discharges, and reduce surface runoff. SuDS mimic the natural water management cycle by retaining water where it falls. SuDS are designed to manage storm water locally (as close as possible to its source), mimic natural drainage and promote its infiltration, attenuation and passive treatment.

SuDS seeks to manage surface drainage systems holistically, in line with the ideals of sustainable development. The aim is to design water quantity management, water quality treatment, improved facilities and biodiversity conservation. In this way, many of the negative environmental impacts of rainwater are mitigated, and some benefits can be realized.

SuDs reduce runoff volume from a given site by intercepting water and increasing storage while slowing infiltration. Storing water close to the source ensures that rainwater does not flow to another area and cause problems elsewhere. There are three types of drainage methods involved in source control. These methods are:

- interception,
- infiltration and
- water storage.

Figure 2: A typical example of a well-designed Sustainable Drainage Systems

It is essential to understand that SuDS generally consists of several options in a treatment plan for adequate storm water management. Adequate storm water management improves the system's efficiency and resilience. In other words, storm water is managed through a series of unit processes collectively known as a treatment plan. There are three critical stages in the treatment plan for storm water management, each using slightly different combinations of SuDS options to control storm water:

- Source controls manage storm water runoff as close to its source as possible, typically on-site. SuDS options include green roofs, rainwater harvesting, permeable pavements and soakaways.
- Local controls manage storm water runoff in the area, typically within road reserves. SuDS options include bio-retention areas, filter strips, infiltration trenches, sand filters and swales.
- Regional controls manage storm water runoff from several developments. SuDS options include constructed wetlands, detention ponds and retention ponds.

SuDS offer a range of ecosystem services which may benefit society. These include:

i. Regulated climate
ii. Water and air purification
iii. Regulated water supply
iv. Erosion and sediment control
v. Habitat functions
vi. Waste treatment
vii. Human health, well-being and cultural benefits

The benefits of a well-designed and implanted SuDS are:

- Flood risk management – reducing the risk of flooding from development.
- Water quality management – reducing the impact of diffuse pollution.
- Improving amenities and biodiversity – integrating green infrastructure with SuDS solutions can help create habitat, recreational and biodiversity areas.

2.2.1.1 SOAKAWAY SUDS

Typically, soakaways contain coarse aggregate or other porous media that gradually release storm water into the surrounding soil. They operate similarly to infiltration trenches but usually have a smaller area. These systems traditionally handle building runoff. Connecting multiple soakaways to drain an area as large as a parking lot or a road is possible. Modular cellular structures can be used as a more suitable 'backfill material' in these cases. The preferred soakaway system will be determined depending on the type of material used and the cross-section of the soakaway. Groundwater recharge and storm water treatment are relatively high with modular cellular structures. On the flip side, water racing through soakaways can cause groundwater contamination. Therefore, implementing adequate storm water pre-treatment upstream of the soakaway is essential. Using a system of soakaways, pollutants are removed through volatilisation, sedimentation, bio-degradation, and filtration.

Figure 3: An example of a Soakaway Sustainable Drainage Systems

The soakaway size depends on the porosity of the course aggregate or cellular material used to fill the excavated pit. It is emptied either by the percolation of the storm water directly into the underlying soil or via perforated drainage sub drains installed near the structure's base. Measures should be taken to prevent fine-grained material from entering the backfill portion of the system, especially during the construction and maintenance phases. Soakaways in fine-grained soils should be lined with a geo-textile to prevent fines migration into the coarser porous media. If required, a custom-designed oil and sediment collection compartment may also be constructed as a simple and effective pre-treatment device.

Soakaways are usually designed to store the entire volume from the design storm and be able to infiltrate at least half of this within 24 hrs to create additional capacity for the runoff from subsequent rainfall events. They usually serve areas less than 1000m^2, but groups of soakaways can help campuses as large as 100,000m^2. They can be between one and four metres in depth, although soakaways serving single residences are seldom more than 1.5 m in depth. They are often constructed using preformed polyethylene or precast concrete rings, 1-2.5 m in diameter. The lined excavation can be kept hollow, but a high voids fill material reduces the turbulence associated with high flow rates into the structure. Soakaways should be constructed at least 1.5 m above the groundwater table to prevent groundwater contamination from allowing for additional filtration.

The design life of soakaways is directly related to the frequency and quality of inspection and maintenance cycles. Routine inspections of the soakaway SuD will be easier and allow for greater accessibility to the backfill material if the flow entering into the soakaway is visible through an inspection opening. If rainwater is collected or received from surrounding areas such as parking lots and roadways, these areas should be swept regularly to prevent silt from entering the soakaway SuD. Part of the annual maintenance of a soakaway SuD is the replacement of the 'backfill material'. The University should consider the installation of oil and grit separators in the soakaway SuD treatment system to provide pre-treatment of storm water runoff where necessary. In some of the campuses where the soakaway SuDS will be implemented the storm water runoff is received from areas where storm water are polluted with high levels of hydrocarbons, heavy metals and/or Total Suspended Solids (TSS).

Soakaway SuDs are normally modular in nature and consist of geocellular structures. The size and design of the modular systems mean that it can be made to suit the specific landscaping requirements of any campus of the University.

The benefits of a well-designed and implanted Soakaway SuD are:

i. Infiltration systems that are regularly operated and maintained can have a design life of up to 20 years, after which the fill should be replaced;
ii. Infiltration significantly reduces both flow volume and rate; and
iii. Infiltration channels are particularly effective in removing particulate and suspended storm water runoff pollutants.

The disadvantages of Soakaway SuD systems are:

iv. Infiltration shall not be appropriate in areas where infiltration would adversely affect adjacent structural foundations or compromise existing drainage properties;
v. Seepage is generally confined to relatively small contiguous areas;
vi. Infiltrations do not work well when installed on steep slopes and in loose or unstable areas;
vii. Due to low infiltration rates, underground piping systems must be used when infiltration is implemented in very fine silt and clay layers; and
viii. Sedimentation within the collection chambers leads to a gradual reduction in storage capacity.

2.2.1.2 RAIN GARDENS

Raingardens are specially-designed garden beds that filter storm water runoff from surrounding areas or storm water pipes. Raingardens are also called bio-retention systems because they use soil, plants and microbes to biologically treat storm water. At its simplest, a rain garden is a shallow depression with absorbent but free-draining soil planted with vegetation that can withstand occasional transient flooding. Rain gardens can be combined with rainwater harvesting measures to help gardens deal with rainfall more effectively. In rain gardens, the soil and vegetation are free-draining, absorbent, and can withstand occasional flooding.

Rain gardens are an infiltration method that increases the amount of water entering the soil, thereby reducing runoff rates and surface water volume. Downspouts are often disconnected from the sewer system and diverted into the garden. These rain gardens are designed to also incorporate planters with water supply through downspouts on properties with limited space. Furthermore, rain gardens require no changes to the existing drainage system and can be installed virtually anywhere, providing significant benefits for surface water quality and habitat creation. A rain garden mimics the natural water retention of undeveloped land and reduces the amount of rainwater draining into drains. Low-level pollution can be treated with rain gardens.

Rain gardens typically absorb all the rainwater that flows into them, but excess water is diverted down existing drains when it fills up after significant rainfall events. These simple rain gardens require no redesign of the existing drainage systems and can be installed anywhere space permits. Other features that can be described as rain gardens include bio-retention strips, troughs, and specially designed tree cavities that can hold the often more polluted surface water that runs off roads and other paved surfaces. These features usually include layers of gravel, engineered floors, and perforated drains usually installed in the street.

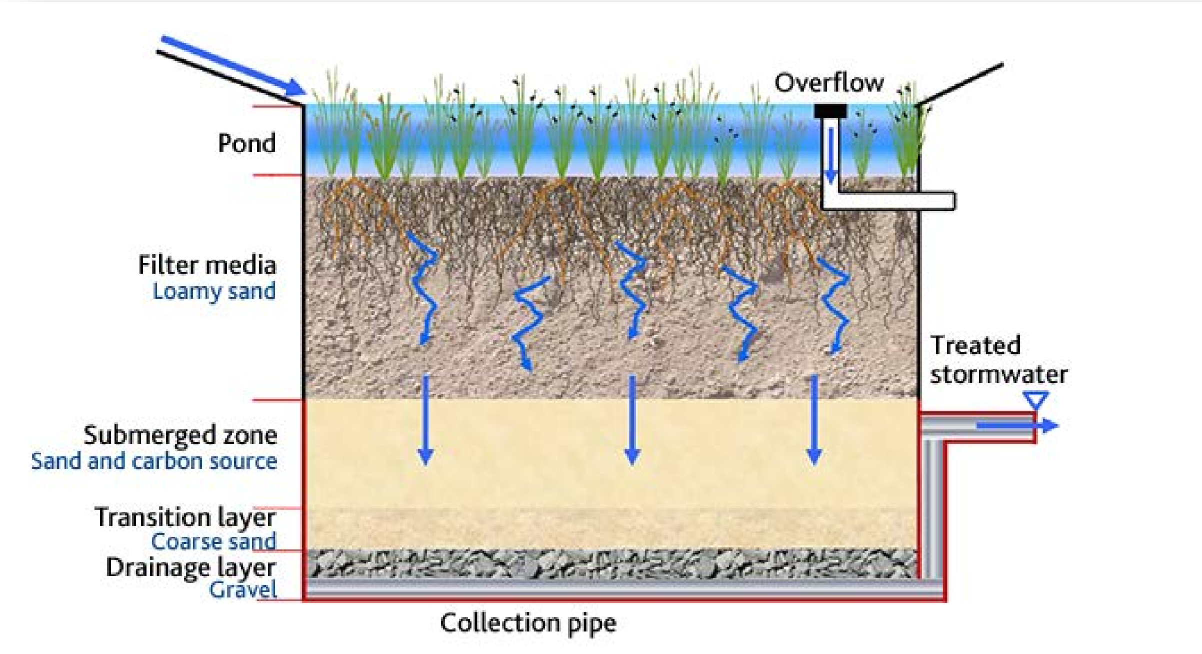

Figure 4: A simple explanation of how rain gardens function

Even when flooding does not occur, runoff can wash oil, heavy metals, and other pollutants into watercourses and damage the plants and animals that live in aquatic environments. Sealed surfaces can also cause problems in warm weather. When the sun shines, more heat is absorbed, resulting in hotter urban areas than the surrounding countryside, a phenomenon known as the Urban Heat Island Effect.

The purpose of rain gardens is to assist urban gardens in dealing more effectively with rainfall, but it also filters and clean runoff. Rain gardens can also be planted to attract wildlife and reduce maintenance costs, for example, where frequently mown lawns are replaced. Well-designed rain gardens can be easily combined with schemes to harvest rainwater. By increasing the amount of water entering the soil, rain gardens help to reduce the effects of drought and help vegetation to thrive without the need for irrigation.

Raingardens differ from normal gardens:

- Must be cleaned of rubbish and sediment that collects on the surface after it rains,
- Should not be fertilised or sprayed with herbicides, as the storm water should contain enough nutrients,
- Have a 200mm to 500mm space above them for water to collect and settle for a few hours, and
- Use a special soil such as loamy sand, called filter media that drains quickly and does not release nutrients into the storm water.

The many benefits of green infrastructure include the following:

- Reduced risk of a flood;
- Reduction in water pollution;
- Better health through stress reduction and more places to exercise;
- Space to relax and play;
- Habitat for wildlife and space for people to enjoy nature;
- Environmental education; and
- Local food production.

Figure 5: A formal design rain garden

2.2.1.3 SEDIMENT BASINS

Sediment basins are designed to trap and store sediment and debris. These basins work by slowing the water velocity, causing sedimentation of coarse and medium-sized sediments and associated nutrients. Sediment accumulates in the sediment basin and periodic removal (desilting) is required.

Sediment basins can be either permanent systems, or temporary measures to control sediment loss during high risk periods such as during tillage, land preparation, planting or harvesting.

A sediment basin is a temporary pond built on a construction site to capture eroded or disturbed soil that is washed off during rain storms and protect the water quality of a nearby stream, river, lake, or bay. The sediment-laden soil settles in the pond before the runoff is discharged. Sediment basins are typically used in areas larger than 20 000 m2 or more, with sufficient room. These ponds are often used with erosion controls and other sediment control practices. Sediment traps may be used on smaller campuses where a basin is not practical. Sediment basins are ponds with open water that capture coarse sediment and litter carried by storm water. They intercept storm water before it reaches the waterway, and slow it down to allow the coarse sediment to fall to the bottom.

In some sites, the sediment basin is modified to function as a permanent storm water management system for the complete site, either as a detention basin or a retention basin.

Sediment basins work in the following way:

- Water enters the sediment basin, slowing down to less than 0.5m/s – during this time the water level can temporarily rise by up to 350mm (called the extended detention depth).
- Gravity pulls the coarse and medium sediment to the bottom.
- The cleaner water stays at the top of the pond and flows through the outlet structure.

Sediment basins are used in catchments with high sediment loads, such as construction sites, to protect downstream treatments from sediment. Use a sediment basin:

- During development construction or on campuses where the storm water entering the campus is known to be of poor quality, and
- upstream of a wetland or raingarden.

Figure 6: A sediment basin

The many benefits of sediment ponds include the following

i. Sediment basins reduce ephemeral gully and gully erosion,
ii. Sediment basis are cost effective mechanisms to manage sediment in the storm water system,
iii. Sediment from the campuses can be trapped and reused,

iv. Moderates peak flows and slows velocity, reducing risk of flooding and erosion,
v. In some instances sediment basins can also be used for water capture and re-use,
vi. Remove coarse and medium sized sediments prior to run-off entering downstream treatment system/s, so that downstream systems are not smothered with sediment and can efficiently treat smaller-sized sediments, nutrients and pesticides, and
vii. Control flows entering downstream treatment systems by diverting high flows, protecting them from scour and resuspension.

Disadvantages of a sediment basin:
i. It requires regular maintenance to remove silt,
ii. Sediment basins effectively remove sediment down to only about medium-sized silt. Removing smaller particles—such as fine silt or clay—typically requires additional controls or practices,
iii. Standing water has the potential to cause the breeding of mosquitoes,
iv. The construction and proper functioning of sediment basins require adequate space and topography. Basins require large surface areas to facilitate the settling of sediment. The available area can limit the potential maximum size of sediment basins,
v. Install sediment basins only within the property or special easement limits, and where failure of the structure will not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities, and
vi. Sediment basins can attract children, and therefore can be very dangerous.

2.2.1.4 MANMADE WETLANDS

Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. Constructed wetlands or treatment wetlands are artificial wetlands that are used for treating organic, inorganic and excess nutrient contaminants in surface water.

Similar to natural wetlands, constructed wetlands also act as a bio-filter and/or can remove a range of pollutants (such as organic matter, nutrients, pathogens, heavy metals) from the water. Constructed wetlands are designed to remove water pollutants such as suspended solids, organic matter and nutrients (nitrogen and phosphorus). All types of pathogens (i.e., bacteria, viruses, protozoans and helminths) are expected to be removed to some extent in a constructed wetland. There are two main types of constructed wetlands: subsurface flow and surface flow. The planted vegetation plays an important role in contaminant removal. The filter bed, consisting usually of sand and gravel, has an equally important role to play. Some constructed wetlands may also serve as a habitat for native and migratory wildlife, although that is not their main purpose. Subsurface flow constructed wetlands are designed to have either horizontal flow or vertical flow of water through the gravel and sand bed. Vertical flow systems have a smaller space requirement than horizontal flow systems.

In natural wetlands, the flow in and out is a result of seasonal meteorological events and groundwater patterns. Conversely, in constructed wetlands, the hydraulic regime is strictly controlled by inlet distribution headers, outlet collection systems, water level-control devices and liners.

Wetlands must have one or more of the following three attributes:

- At least periodically, the land supports predominantly hydrophytes,
- The substrate is predominantly undrained hydric soil, and
- The substrate is saturated with water or covered by shallow water at some time during the growing season of each year.

The many benefits of wetlands include the following

i. Wetlands store our water to ensure supply during dry periods,
ii. Wetlands can prevent floods,
iii. Wetlands recharge ground water,
iv. Wetlands help to control erosion,
v. Wetlands provide shelter for juvenile fish, and
vi. Wetlands provide homes for animals and plants.

Disadvantages of manmade (artificial) wetland is:

i. The large land area required,
ii. The unpleasant odour that can be associated with certain types of effluent being treated,
iii. Constructed wetlands may not effectively treat some types of complex pollutants, and
iv. These systems also need more land than conventional systems. High land costs and lack of suitable land can make construction of large systems impractical.

Figure 7: A man-made wetland

2.2.1.5 SWALES

Swales are one of the most commonly used rainwater practices. They have been used along country roads and residential streets to divert runoff for years. Today, swallows not only transport rainwater, but also help treat runoff to reduce pollutants. Swales are shallow, wide, and grassed channels designed to store and/or transport runoff and remove debris. They can be used as conveyor structures to direct runoff to the next stage of the treatment train and can be designed to promote infiltration where soil and groundwater conditions permit. Dams and berms may also be installed across a swallow's river path to encourage sedimentation and infiltration.

Three types of swales provide different surface water management options:

- Standard Conveyor swale generally used to convey runoff from the drainage catchment to another stage of a SuDS system. The Standards Conveyor swale may be lined or unlined depending on suitability for infiltration.
- Improved Dry Pan Includes an underdrain filter bed of soil below the turf conveyor channel to accommodate different treatments and pumping capacities above the standard pan. The underdrain keeps the main channel dry except for major runoff events and prevents the channels from becoming waterlogged where the depression is on gentler slopes. A liner can also be installed in the underdrain when infiltration into the underlying soil is inappropriate.
- Wet Swales – When prolonged storm drain treatment procedures are required, the swales' feed channel can be stimulated to maintain marshy conditions by using liners to control infiltration or sitting in an area with a high water table. Settling promotion is enhanced by the use of dense vegetation, mostly grass, which promotes low flow velocities to trap particulate pollutants. In addition, barrages or berms may be installed over the swale channel to encourage settling and infiltration. As a result, swales effectively improve the water quality of the drain by removing sediment and particulate pollutants. Effectiveness is further enhanced in wet channels by creating persistent wetland conditions at the base of the channel.

Swales apply to a variety of situations. This type of storm water system is typically located alongside roads and replace traditional storm drains and drainage pipe systems. However, examples of depressions found in landscaped areas next to parking lots, next to fields and in other open spaces can also be seen. Swales are ideal for use as drainage systems on industrial sites as any contamination is visible and can be treated before it causes damage to the receiving watercourse.

The benefits of a well-designed and swales are:

i. Easy to integrate into landscaping
ii. Good removal of urban pollutants
iii. Reduces runoff rates and volumes
iv. Low capital costs
v. Maintenance can be integrated into general landscaping
vi. Pollution and clogs are visible and dealt with efficiently.

The disadvantages of swales are:

i. Not suitable for steep areas or areas with curb side parking

ii. Limited ability to use trees for landscaping
iii. Risk of clogging in connecting lines

Figure 8: Swales in landscaping design to manage storm water from

2.2.1.6 POROUS PAVING AND GARDENS

Permeable pavements refer to pavements designed to promote the infiltration of storm water through the surface into the subgrades and/or underlying strata. These pavements are also referred to as porous paving. Porous paving allows water to pass through it and filter back to the drains or into groundwater. There are many alternatives for the supporting surface material including:

- permeable concrete paving block (PCBP),
- brick paving,
- crushed stone,
- gravel,
- permeable or porous concrete and
- permeable or porous asphalt.

Porous paving is an alternative to conventional impermeable pavements, with many storm water management benefits. These surfaces allow water to percolate through to a sub-surface course, from where it either infiltrates to the soil or is filtered back to the drainage system. Porous paving can be used for a variety of water management objectives to:

- reduce peak storm water discharges from paved areas,
- increase groundwater recharge,
- improve storm water quality, and
- reduce the area of land dedicated solely to storm water management

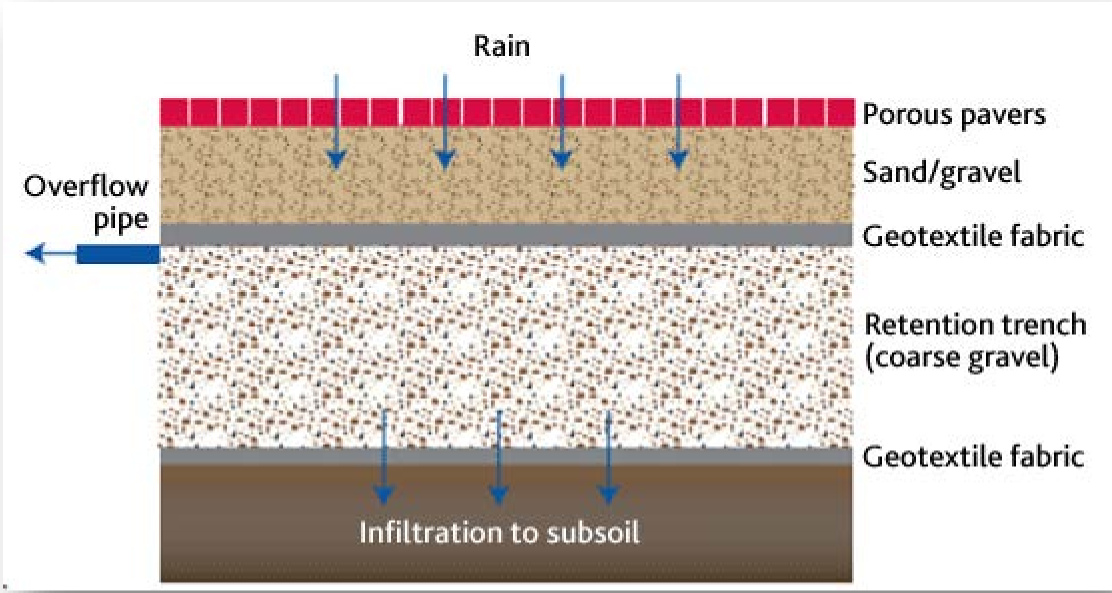

Figure 9: Porous paving layers

Permeable paving surfaces are suitable for pedestrians and vehicles and can be modified to support heavier loads. Permeable pavements are generally constructed on a bed of coarse gravel, which provides temporary storage and allows rainwater to drain into the underlying layer, thereby promoting the replenishment of the water table. Stored rainwater can be reused for typical gardens and lawns. Permeable walkways generally do not remove trash and other debris from storm water runoff because it is left on the surface. However, this provides an opportunity to collect it through sweeping. Permeable paving technologies can be designed to meet most charging specifications. Typical installations include:

- parking lots;
- private roads,
- loading areas; and
- cycle paths, walkways, terraces and around swimming pools.

Special care should be taken to protect the walkways from sediment deposition during construction, as permeable walkways tend to become clogged with particulate matter. Another problem is structural failure due to high wheel loads. The use of permeable pavement should ideally be limited to flat surfaces as high velocity rainwater from steep slopes cannot readily penetrate the pavement surface. A steep slope can also contribute to sediment deposition and clogging. Permeable Concrete Paving Blocks (PCBPs) are commonly used for high traffic areas. This would be preferable if the permeable coverings can be designed using a gradient filter in such a way that geotextiles can be dispensed with. The operation of water-permeable sidewalks depends to a large extent on good workmanship, especially when laying pavers. PCBPs should have even spacing between each paver and no protruding blocks.

The benefits of permeable pavements are:

i. Permeable pavements reduce storm water runoff rates and volumes from sealed areas;
ii. Permeable pavements increase the usable area on certain developments by, inter alia, using roads, driveways and car parks as rainwater drainage areas;
iii. Storm water runoff stored in permeable pavements can be used for replenishing the water table and for various household purposes;
iv. Lined permeable pavement systems may be used where foundation or soil conditions limit infiltration processes,
v. Retain pollutants close to source, and
vi. C.an appear more aesthetically pleasant than conventional drainage channels

The disadvantages of Permeable pavements systems are:

i. The implementation of permeable walkways is generally limited to sites with slopes less than 5%;
ii. Permeable walkways should not be built with backfill materials as these soils could fail when saturated;
iii. Permeable pavements are not normally suitable for heavy traffic and speeds in excess of about 50 km/h or for use by heavy vehicles and/or high point loads;
iv. If mishandled, there is a great potential for clogging by fine sediments, significantly reducing the effectiveness of the specified system; and
v. The pollutant removal capability of permeable pavements is lower than most other SuDS options.

Regular inspection and maintenance are recommended to ensure the long-term effectiveness of permeable pavements. The fine stone aggregate in the joints and slots of PCBPs should be replaced from time to time to prevent blockage. A typical maintenance procedure includes vacuum sweeping and/or high-pressure jet-washing of the surface every three months or four times yearly.
The following guidelines should be followed for reconstruction:

i. Remove the surface layering and laying courses;
ii. Remove the geotextile filtering layers;
iii. Inspect, remove, wash and replace sub-base if required;
iv. Renew or replace the geotextile layering; and
v. Renew the laying course and/or PCBPs.

That being said, many examples of permeable paving systems around the world are still functioning successfully with minimal maintenance after many years. The enormous infiltration capacity of the permeability ceiling systems is in many cases often designed for around ten times the infiltration capacity theoretically required for the design storm, so that significant clogging can be tolerated before the system fails. Gravel paving systems generally consist of individual aggregates without the addition of a binder. These systems are the simplest and least expensive permeable patches available. Gravel paving systems may require daily maintenance including raking, grading and re-levelling of their specified aggregate surfaces. They are most effectively used for parking lots and driveways where traffic volume and speed are relatively light. Rainwater that seeps through the porous paving should be caught and safely removed from the underlying layers. Permeable pavements have the aesthetic advantage of being designed to blend in with the surrounding urban landscape.

Figure 10: Permeable pavements and parking areas

2.2.1.7 GRASS DRAINAGE CHANNELS

A grass-lined channel is a graded, vegetated channel that collects and conveys storm water while encouraging infiltration into the ground. Vegetation lining the channel slows down the concentrated flow.

Grass drainage channels are traditional overgrown open channels designed to convey water quality rather than treat it. Drainage channels provide limited removal of contaminants through grass or other vegetation filtration, sedimentation, biological activity in the grass/soil media, and little infiltration when underlying soils are permeable. However, their main function is to provide erosion-free transport, typically up to 10-year frequency design flow. Grass drainage channels are typically trapezoidal, triangular or parabolic in shape and are designed based on peak flow rate rather than a water quality volume approach.

Drainage channels are commonly installed in highway and street drainage systems. However, they can also be used in place of traditional curb and gutter drainage systems at the University campuses to improve contaminant removal and achieve limited groundwater recharge and runoff volume reduction. Grass drainage channels are treatment systems with a longer hydraulic residence time than drainage canals. The removal mechanisms are sedimentation and gravity separation rather than filtration.

The benefits of grass drainage channels are:

i. Provides pre-treatment if used as the first part of a storm water treatment system.
ii. Open drainage system aids maintenance
iii. Accepts sheet or pipe flow
iv. Compatible with LID design measures.
v. Little or no entrapment hazard for amphibians or other small animals

The disadvantages of grass drainage channels are:

i. Short retention time does not allow for full gravity separation. These systems provide limited pollutant removal.
ii. Require more maintenance than traditional curb and gutter drainage systems.
iii. May be impractical in areas with very flat grades, steep topography, or poorly drained soils.
iv. Limited bio-filtration provided by grass lining.
v. Cannot alone achieve 80% TSS removal.
vi. Must be designed carefully to achieve low flow rates for Water Quality Volume purposes (<1.0 fps).
vii. Mosquito control considerations.

Grass drainage channels convey and treat rainwater. Properly designed grass drainage channels are ideal when used alongside roadways or parking lots where runoff from impervious surfaces can be channelled into the channel via the film flow. When implementing these retention systems, consideration should be given to supplementing them with green filter strips with a slight gradient or a gravel screen for stratified flow. Make the pitch as flat as possible. This increases hydraulic residence time (HRT), allows gravity separation of solids and maximizes sediment removal. Install control dams to further increase HRT. Design grass drainage channels to maximize contact with vegetation and ground surface to promote greater gravitational separation of solids during the storm associated with the water quality event.

Figure 11: A grass drainage channel

2.3 RE-USE WATER

There is not enough water in South Africa to sustain life. Municipalities must develop safe, unconventional solutions to meet population and economic needs. It achieves this while alleviating safety concerns and dispelling preconceived misconceptions about wastewater reuse. By 2030, urban water demands will exceed supply, making clean water supply one of the University's biggest challenges. Climate change is projected to decrease rainfall in South Africa in the next few decades. The country receives less than 50% of global precipitation. Drought conditions in Cape Town in 2018 sparked calls to improve water security in response to “Day Zero”. Other cities were also motivated to avoid a similar scenario. With the 2018 drought, the University of Pretoria realized its responsibility as a water custodian.

Greywater reuse reduces the amount of freshwater needed to supply a household and the amount of wastewater entering the sewer or septic systems. The use of grey water for irrigation alone can result in water savings of about 12 to 65%. If the University can re-use water from sinks, showers, baths, washing machines or dishwashers for irrigation purposes in the landscaping environment during dry seasons it can relieve the pressure and dependency on municipal water.

Water reuse offers positive environmental benefits, specifically for the water environment, by protecting aquatic ecosystems. This reduces the demand for water from a natural source and reduces the risk of polluting natural waters by using reclaimed water. This results in less wastewater discharge. Water reuse must therefore be evaluated in the context of other water supply and water augmentation options. This includes environmental impacts, carbon footprint, ecological footprint, and energy usage.

The Millennium Declaration, signed by 147 heads of state in September 2000, established a comprehensive global framework to support concerted efforts towards poverty reduction and sustainable development. The Declaration led to the eight Millennium Development Goals (MDGs).
Goal 7of the Millennium Development Goals (MDGs) stated “Ensure environmental sustainability”. Safely using wastewater, black water[1], and greywater[2] contributes to less pressure on freshwater resources and reduces health risks for downstream communities. Improved water management, including pollution control and water conservation, is critical to maintaining ecosystem integrity.

The SDGs expanded its scope to 17 goals from the eight goals in the MDGs, which covers universal goals on fighting inequalities.
Goal 6 of the Sustainable Development Goals stipulates that governments and nations should ensure access to water and sanitation for all. Access to safe water, sanitation and hygiene is the most basic human need for health and well-being.

Water reclamation refers to the process of reusing wastewater. This process will allow the University to reuse water after treating it with appropriate treatment methods to return it to its original clear,

[1] Black water: black water is any waste from toilets or urinals.
[2] Grey water: wastewater that has been used for washing, laundering, bathing or showering. wastewater

safe state. Before water can be reused, a level of treatment is almost always needed. The level of treatment and the residual products following from this treatment vary according to the technology applied and the purpose or use of the reusable water. This can vary from simply disinfection to the complication of the removal of salts and gasses associated with some of the treatment processes. The proper disposal and treatment of concentrate and residuals will be needed if non-destructive processes are used. Managing salinity is also important. Therefore, the following actions are recommended:

- Identify the need for additional treatment (a regulatory framework is needed to manage concentrate).
- Define the proper disposal.

- Understand public health considerations.
- Consider cost issues.

Water reclaimed from human use can also be used as a sustainable water source. Using it can reduce additional pressure on surface and groundwater resources. There are centralized and decentralized systems, including greywater recycling systems and microporous membranes. Reclaimed water must be treated to provide the appropriate quality for a given application (irrigation, industry use, etc.). Wastewater reclamation may seem more viable because it requires less energy, but public acceptance of this option can sometimes pose significant challenges. However, studies show that people are less accepting of reclaimed water for drinking and personal uses such as washing. However, they are more accepting of it for outdoor irrigation and sewer reticulation. The University faces another aspect to consider: contamination and human health risks. This risk must be managed to ensure all risks are eliminated before implementation.

For the purposes of the document four definitions need more clarification:

1. Reclaimed water: Water reclamation is the process of converting municipal wastewater or industrial wastewater into water that can be reused for a variety of purposes. Types of reuse include: urban reuse, agricultural reuse, environmental reuse, industrial reuse, planned potable reuse, de facto wastewater reuse.
2. Grey water: Greywater refers to domestic wastewater generated in households or office buildings from streams without fecal contamination, i.e., all streams except for the wastewater from toilets. Sources of greywater include sinks, showers, baths, washing machines or dishwashers.
3. Black water: lack water refers to domestic wastewater generated in households with fecal contamination, therefore wastewater specifically from toilets.
4. Recycled water: Water generated from sewage, greywater or storm water systems and treated to a standard that is appropriate for its intended use. (In industry, recycled water can relate to cooling water recycling where there is minimum treatment)

The National water resources strategy (NSWR) of South Africa indicates that water reuse is one of the important strategies to balance availability of water in future. The Department of Water and Sanitation has provided a national water reuse strategy, but what is lacking is a guideline for municipal engineers when implementing reclamation and reuse projects. A proper guideline is required to ensure compliance to legislative requirements. Annexure D of the National water resources strategy -

2 document sets the vision for the implementation of water reuse in South Africa. The NSWR recognizes the important role that good information plays in supporting sound decisions, and as such states the three aspects to be considered, which are;

- Educating users with respect to the benefits and acceptance of water reuse;
- Providing people who are considering water reuse with clear guidelines on how to implement water reuse projects; and
- Provide sound methodology in the evaluation of options to balance water requirements and supply.

Reuse has become an attractive option for water augmentation due to improvement in efficiency of treatment processes, reduced costs, and the fact that this water source is readily available and in close proximity to the point of application.

The following actions are important to consider with the construction of a water reclamation plant:

- planning,
- implementation,
- operation,
- maintenance, and
- management of water reclamation and reuse schemes.

Water reclamation and reuse projects incorporate more advanced treatment processes and technologies compared to conventional surface water project. Water reclamation plants will fail if it is not based on sound scientific and engineering knowledge and principles related to the reuse and recycling of wastewater for a variety of potable and non-potable uses.

There is a considerable potential to expand the use of treated wastewater for irrigation purposes in South Africa. This can be researched and implemented at the University of Pretoria's Miertjie le Roux campus (a training and research feed mill facility of the University).

The benefits of water reclamation are:

i. Reclaimed water from treated wastewater is nutrient-rich;
ii. There is a constant flow of grey water available;
iii. Grey water use manages water demand and creates water resilliance;
iv. Alleviates financial demands of municipal water dependency;
v. When utilized to irrigate agricultural land, this water reduces the need for fertilizer to support crop development.
vi. The reservation of the reclaimed water (grey water) for non-priority purposes,
vii. Improving water security and sustainability for future generations to come.

The disadvantages of water reclamation are:

i. Lack of regulation;

ii. Not all water reclamation systems are created equal – proper investigation of available systems to ensure the installation of the best technology available;
iii. Recycled water can be dangerous if not treated properly;
iv. Difficult public acceptance, and
v. The presence of new pollutants

2.4. WATER PURIFICATION PLANT

Commercial water treatment systems treats large volumes of water at high flow rates. The type of water treatment used in such systems depend largely on the desired purity level of the final water composition. Commercial water purification systems are widely used to meet the high water purification needs of healthcare facilities, laboratories, residences, manufacturing facilities, schools, restaurants and other high water consumption organizations that need improved water quality.

Because each water purification plant removes a specific type of contaminant, none can be relied on to remove all contaminants to the levels required for critical applications. A well-designed water purification system combines purification technologies to achieve the final water quality. Each water purification plant must be used appropriately to optimize its particular removal capabilities.

The advantages of a water purification plant would be:

i. Municipal water supplies are often unreliable, with unplanned downtime and variable water quality.
ii. Installing a water treatment system protects the University from rising water costs and guarantees water quality.
iii. The University can improve its ecological sustainability and relieve the strained municipal water supply.
iv. Removes dissolved inorganics effectively.
v. Relatively inexpensive initial capital investment.

The disadvantages of a water purification plant would be:

i. A water purification plant does not effectively remove particles, pyrogens or bacteria.
ii. DI beds can generate resin particles and culture bacteria.
iii. High operating costs over long-term.
iv. Genetic impact of hormones released on water can have a very negative impact on the University's reputation.

The first step is pre-treatment equipment specifically designed to remove contaminants from the feed water. Pre-treatment removes contaminants that may affect downstream purification equipment, especially reverse osmosis (RO) systems. Examples of pre-treatment are carbon filters (or tanks) for chlorine removal, particulate filters for sediment/silt/particulate removal, and softening agents to neutralize minerals that cause "hard" water.

The following purification step is Reverse Osmosis (RO). RO removes 90 - 99% of all the contaminants found in water. It is the heart of any well-designed water purification system because it effectively removes many impurities.

However, the tight porosity of the RO membrane limits its flow rate. Therefore, a storage container collects water from the system and distributes it to other points-of-use, such as polishing systems.

Polishing systems purify pre-treated water, such as RO water, by removing residual trace contaminants. Polishing elevates the quality of pre-treated water to "Type I" or "ultrapure" water.

A polishing system is designed to remove residual traces of impurities from water already pre-treated by some other means (such as reverse osmosis or deionization). Treating raw tap water using such a system would quickly exhaust its capacity and affect final quality.

A typical polishing system may consist of activated carbon, mixed-bed deionization, organic scavenging mixtures, and 0.22 µm final filtration. Designs can also be enhanced with ultrafiltration, ultraviolet oxidation, or other features for specific applications.

This combination of purification technologies and proper pretreatment will produce water that is virtually free of ionic, organic, and microbial contamination.

Water treatment methods commonly used in commercial water purification systems consist of:

2.4.1. REVERSE OSMOSIS

Water softeners remove calcium and magnesium from water through ion exchange. As hard water enters the mineral tank, it flows through a bed of spherical resin beads. These plastic beads, mostly polystyrene, are charged with sodium ions. Resin beads are anions, meaning they have a negative charge. The minerals calcium and magnesium have a positive charge, making them cations. Because opposite charges attract, the negative charge on the minerals is attracted to the positive charge on the resin beads. As hard water flows through the resin, the beads grab the mineral ions and remove them from the water. When the beads capture the mineral ion, the sodium ion is released. The resin column removes all hardness from the water as it flows through the mineral tank, and softened water flows into your home.

Water softening is achieved by adding chemicals that form insoluble precipitates or by ion exchange. Water treatment removes calcium, magnesium and other metal cations from hard water. Soft water extends plumbing life by reducing or eliminating lime scale build-up in pipes and fittings. Water softening is usually achieved by adding lime softening or ion exchange resins but is increasingly performed using nano-filtration technology or reverse osmosis membranes. The most common means of removing hardness from water are ion exchange resin or reverse osmosis. Other approaches include precipitation methods and sequestration through chelating agents. Lime softening is a process of adding lime to hard water to soften it. It has several advantages over the ion exchange process but is mainly suitable for commercial treatment applications.

A water softener consists of three components: a control valve, a mineral tank and a brine tank. These three work together to remove minerals from hard water, monitor water flow, and regularly clean the system through a regeneration process.

The water softener regeneration cycles flood the resin beads with a highly concentrated brine solution, washing away the hardness minerals and draining them out of the system. The resin beads are recharged and primed to eliminate the hardness minerals again. Resin beads are extremely durable and can effectively soften your water for twenty years or more. Water softeners are regenerated using one of two methods: co-current or counter current regeneration (also known as down flow brine and up flow brine).

2.4.2. DEIONIZATION

Among all common water filtration methods, the process used for removing all dissolved salts from water is called deionization. Deionization requires water to flow through two ion exchange materials to remove all salt content.

Demineralization and deionization are used interchangeably in the industry. While demineralization is generally better understood, deionization is especially relevant.

The passage of water through the first exchange material removes calcium and magnesium ions just as in the normal softening process. Unlike home equipment, deionization units also remove all other positive metallic ions in the process. The positive metallic ions that have been removed are replaced with hydrogen ions instead of sodium ions.

Water that has been deionized is also referred to as demineralized water. The process of deionization involves the use of ion exchange resins specially manufactured to remove mineral ions. Deionization results in ultrapure water, similar to that obtained from distillation because most contaminants are dissolved salts.

2.5. RECOMMENDATIONS

The University of Pretoria realises the need to review the Water Management Policy and programme based on continuous improvement of operations and strive to meet sustainability goals. The University works towards strengthening a culture of water conservation and sustainable water use. Furthermore it strives to become a water-sensitive University that optimizes and integrates water resource management.

The following recommendations for storm water management should be noted:

a. Collecting and updating storm water and sewage pipeline data maps,

b. Do a leak detection test of storm and sewer pipelines,
c. Address storm water drains where services are run through the drains to save space,
d. This negatively affects the efficiency as the capacity of the drain is no longer sufficient to deal with rain events and runoff from rain events, and
e. Equipped storm water drains with meters to measure water quality and volume.

Arising from the report the following recommendations for borehole use on all campuses should be noted:

a) Borehole water should be used exclusively for irrigation purposes to ensure the sustainability of the resource.
b) The boreholes should be equipped with meters to measure water quality.
c) Collecting data on groundwater levels using meters.
d) Regular water sampling of borehole water to test the quality of the groundwater.
e) Installation of a good monitoring and reporting platform to measure water withdrawal from boreholes on its campuses.
f) A registered and renowned Geohydrological engineering company should be appointed to undertake a drainage area study of all the campuses.
g) During extreme water shortages, all irrigation on the campuses should be stopped and domestic water restrictions are to be implemented to insure that the boreholes do not completely run dry.

The following recommendations for rainwater harvesting on all campuses should be noted:

a) The size of the storage tank,
b) The size of the campus,
c) The location of the storage tank should not be too close to the lecture buildings,
d) The size of the roofs,
e) The volume of water that is intended to be captured off the roofs,
f) The drainage pipes and pumps that would be connected to the system, and
g) The total cost of the system from installation to maintenance.

The following recommendations for rain gardens on all campuses should be noted:

a) Rain gardens should be a minimum of 5 meters from building structures to prevent seepage into the foundations,
b) Locate the rain garden outside of a tree’s drip line to avoid cutting roots,
c) Do not place a rain garden near a septic system,
d) Keep the rain garden away from utility lines. Before installing the rain garden infrastructure the utility locations’ should be marked.
e) Do not place a rain garden in a spot where water pools after a storm. Puddled water is a sign of slow soil infiltration,
f) Do not build a rain garden in soil that has a high water table, and

g) Since a rain garden surface must be flat, the amount of grading required during construction increases with slope. Rain gardens should not be built on land with a slope greater than 15%.

The following recommendations for grey water re-use should be noted:

a) Careful analysis of the local by-laws for the use of grey water. It is suggested that the University obtains a legal opinion prior to the installations of systems,
b) The management and use of grey water can pose significant risks, specifically in terms of the potential health and environmental hazards from chemical and microbiological contaminants and diseases depending on the source of the grey water, the treatment process and the use for which it will be adopted,
c) Grey water should not be used for drinking or cooking purposes,
d) Washing and cleaning of pavements, especially those draining to storm water systems,
e) Irrigating gardens during or immediately after a rainfall event,
f) Irrigating the sports fields,
g) The use of eco-friendly or neutral cleaning,
h) Water from kitchens, cleaning cloths and brushes used for painting should not be used. Preferably only use “low risk” grey water.
i) Store warm water in a holding tank to cool down and use within 24 hours. The holding tank should be classified as a septic tank and the water stored I this tank should only be used for irrigation purposes,
j) Grey water should only be used in locations where groundwater is at least 1,5m below the surface,
k) Surface accumulation of grey water should be avoided,
l) Grey water should not be allowed to leave the boundaries of the campus,
m) The grass landscapes (sports fields) should not be irrigated with grey water to avoid any possible infections,
n) Label pipes that are used to reticulate grey water clearly to eliminate confusion between grey water and potable water pipes, and
o) Never use hosing, spraying or misting methods when irrigating with grey water.

The following recommendations for operational procedures impact on storm water should be noted:

a) HVAC maintenance should not wash air conditioner filters on roofs where the water decants into storm water drains,
b) The cleaning of equipment (Industrial Hygiene and cleaning) should be restricted to sewer drains,
c) The sewer drains should be clearly marked so that staff would know where they can dispose of contaminated water,
d) New projects will be providing slop hoppers to the staff and contractors to dispose of dirty water, and
e) Monitoring and inspection of sewer lines to ensure that the discharging of dirty water into the sewer system can negatively impact on the WWTW and the solids settle down in the P-traps, harden and block the pipes.