FRAMEWORK FOR INTEGRATING GREEN INFRASTRUCTURE INTO FORMAL URBAN ASSET MANAGEMENT SYSTEMS

Report

to the Water Research Commission

by

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EXECUTIVE SUMMARY

Urban riparian systems (i.e., wetlands, rivers, associated ecosystems) are extremely valuable natural assets that provide a wide range of economic benefits to residents of urban areas. These economic benefits have been explored through numerous studies, including a Water Research Commission study (WRC Report No. TT 726/17) which provided evidence-based analysis of socio-ecological systems with the purpose of analysing relationships between the degraded water resources and socio-economic development and human wellbeing in the Apies-Pienaar's River system. In spite of increasing awareness of the role and importance and economic value of green infrastructure, few, if any, formal institutional arrangements, and specifically economic policy instruments, exist which formalise and/or internalise decision-making around these assets into day-to-day economic decision-making.

The reason for this is a lack of a financial business case for investing in urban green infrastructure. A financial business case requires a positive benefit – cost ratio, where the benefits result from additional revenue streams generated.

In this study we investigate the potential of using municipal asset management systems as a mechanism for institutionalising such financial net benefits within municipal accounting systems, and thus creating incentives for investing into green infrastructure.

Integrating green infrastructure into municipal accounting systems would trigger a set of formal asset management activities that are currently lacking in the field of green infrastructure asset management. These activities include formal asset identification and valuation; regular condition assessments; and asset investment planning. Moreover, the process requires identification of revenue generation and cost savings associated with these green assets.

The aims of this study were therefore as follows:

- Review and consolidation of ecological valuation studies that represent realistic linkages with urban economies and asset planning structures.
- Make a case for the value of urban green infrastructure against existing trends of urban degradation and resulting risks, trajectories of change, future loss of benefits and the relevance to the National Water Act and Sustainable Development Goal 6.
- Exploration and review of existing asset management systems and outline opportunities for integration with concepts of green infrastructure and ecosystem services valuations.
- Conduct a critical review of the receiving environment and institutional readiness for implementation of proposed opportunities and potential risks of implementation
- Demonstrate the integrating indicators of urban green infrastructure into an existing formal urban asset management structure. The City of Tshwane was used as a case study.

Firstly, a literature review was conducted to make a case for the value of urban green infrastructure against existing trends of urban degradation and resulting risks, trajectories of change and, future loss of benefits. This involved analysing studies of ecological valuation that represent realistic linkages with urban economies and

asset planning structures. The analysis demonstrated that a well-functioning urban green infrastructure in a municipal area provides the following benefits:

- Opportunities for recreation and physical activity: has benefits to human health and psychological well-being for residents
- Enhance revenue: Translate to increased property values which in turn result in increased municipal rates income to a municipality
- Waste treatment and assimilation services: wetland systems provide an example of green infrastructure that can reduce pollutant loads in river systems
- Water regulation services: urban river systems play a role in moderating and regulating the timing and intensity of water flow, and this has benefits for stormwater drainage and sediment/erosion regulation
- Direct economic benefits to households, through creation of green jobs and lower utility expenses

To be able to integrate green infrastructure into asset management systems, it was important to review existing asset management systems utilized in South Africa and internationally and an outline of opportunities for integration with concepts of green infrastructure and ecosystem services valuations. The analysis demonstrated that asset management in the public sector involves the strategic planning, acquisition, use, and disposal of assets to maximize their service delivery potential and minimize risks and costs. In South Africa, the regulatory framework for asset management is guided by the Constitution, the Municipal Systems Act (MSA), and the Municipal Finance Management Act (MFMA). These regulations mandate municipalities to manage assets in a financially and environmentally sustainable manner.

The steps for integrating green infrastructure into a municipality's asset management system were then developed, and they included:

1. Asset delineation: The geographical boundaries of each green infrastructure component were delineated using desktop studies and ground truthing. Attribute data was collected for each wetland and mapped across the catchment. Attributes refer to the specific properties of an asset component, such as type, size, class, condition, location, and identity.
2. Asset classification: The assets were then classified based on their function, asset type, or a combination of the two.
3. Valuation of the asset: Valuation of the green infrastructure asset was based on the financial benefits the municipality derives from the asset.
4. Integration into the asset register: The asset was then integrated into the municipal's asset management system.

As municipalities are to implement this framework, it was important to assess institutional readiness of a municipality. The assessment was done by adopting and modifying a framework developed by the Organization of Economic Cooperation and Development (OECD, 2019), which was initially developed to determine institutional capacity for the development of and adherence to coherent policies that prioritise global Sustainable Development Goals (SDGs). This framework consists of four pillars, namely:

- Pillar 1: Institutional capacity and skill
- Pillar 2: Country practices and support
- Pillar 3: Data availability and tools
- Pillar 4: Partnerships and peer-learning.

The assessment showed municipalities do have available tools, frameworks and standards required for integration analysis. While municipalities may have competent multidisciplinary staff, additional technical capacity and budget are needed, particularly for the economic valuation of natural assets. Collaborative efforts with partners such as SANBI and DFFE can provide support towards a successful implementation.

To demonstrate the integration of green infrastructure into municipal asset management, City of Tshwane Metropolitan Municipality (MM) was selected as a case study. The study area covered a portion of quaternary A23A (i.e., Moreleta spruit River and Pienaar's River) of Limpopo Water Management Area (WMA). This case study delineated the various ecological assets such as the Colbyn Valley Wetland, Roodeplaat Dam, Moretele River, and Hartbeespruit River into management units. This process involved desk top analysis such as the use of both ArcGIS and QGIS and field verifications. The results from field (ground truthing) and literature resulted in an understanding of the assets current ecological status within the city of Tshwane and significant pressures from urban development.

The study area was delineated into six management units. Five of the management units had Present Ecological State (PES) category "E". This was due to deep stream incisions, bank destabilization, pollution and alien invasive species. Due to moderate modification on the channel, effective conservation and management efforts from the Friends of Colbyn organization and the community around Colbyn valley wetland, the Colbyn wetland system was the only management unit with an improved, though still poor condition (i.e., protected wetland with PES category D).

Based on the condition of the management units, mitigation options necessary to improve the conditions were then explored, together with their associated costs. The overall mitigation options required along the wetlands and rivers included several measures such as clearing alien vegetation to enhance biodiversity and reduce fire risks, building and maintain gabion infrastructure, re-vegetate, and building of retention ponds and pollution controls, to improve water quality. The estimated cost for the necessary restoration and management measures is approximately R12.2 million per year. The Net Present Value (NPV) of the total costs is R104 million discounted over a 20-year period.

To develop financial business case, a cost-benefit analysis assessment was conducted on asset's financial benefits for their preservation. The financial benefits included the following assessments:

- Water treatment cost savings: The City of Tshwane has three key Water Treatment Works (WTW) – Roodeplaat (25 MLD), Wallmansthal (11.6 MLD), and Klipdrift (29.9 MLD) that abstract water from the Roodeplaat Dam. These plants, due to deteriorating water quality, have resulted in using treatment technology that incur substantial costs for chemicals and electricity. The total annual costs for chemicals and electricity for these plants are around R35.6 million. However, by improving the quality of water through wetland rehabilitation, these operational costs could be reduced, by using a slow settling treatment method, leading to less energy-intensive treatment processes and lower chemical usage. By reducing the energy and chemical costs required for treatment the CoT could save approx. R13.2 million per year. The total NPV of these benefits is R73.9 million over a 20-year discounting period.

- Stormwater cost savings: It was assumed that the useful life of these stormwater assets could be extended by 20 years if the management units were restored to a well-functioning state. This would reduce the annual depreciation expense that goes into the CoT income statement. This reduction in the depreciation expense is around R55,000 per year. The total NPV of these benefits is approx. R330 000 over a 20-year discounting period.
- Property rates revenue generation: The case study revealed that properties near green belts could increase by 23% and enjoy higher market rates due to their scenic value, aesthetic appeal, and enhanced safety from flood mitigation provided by the wetlands. This in turn could result in increased property tax income for the City of Tshwane. The additional revenue from property rates is around R24.2 million per year. The total NPV of these benefits is approx. R115 million over a 20-year discounting period.

Comparing the NPV of the financial benefits to the NPV of the total costs, the financial analysis showed that the NPV of the financial benefits significantly outweighs the cost of mitigation. The NPV of the financial benefits is R189 million while the NPV of the total costs is R104 million. Thus, the benefit-cost (BC) ratio is 1.8. The Colbyn Wetlands, being the largest of the management units, has an NPV for the financial benefits of R57.5 million compared to a mitigation cost of R20.0 million, resulting in a BC ratio of 2.87.

The analysis from the case study provided insights to provide a guideline on how other municipalities can be able to implement this integration through drafting a guideline. The guideline lays out steps in which must be taken to ease the integration of the assets into an urban municipal management system.

Integrating green infrastructure into the municipal's asset management system is a transformative approach towards fostering sustainable urban development. By valuing and managing natural assets alongside traditional infrastructure, municipalities can strengthen its resilience to environmental challenges, enhance biodiversity, and improve the overall quality of life for its residents. This initiative not only aligns with cities of the future, global sustainability goals but also paves the way for a more harmonious relationship between urban environments and the natural world. However, to advance this initiative, it is essential to secure additional technical capacity and budget for the economic valuation of natural assets, ensuring their accurate integration into asset management practices. Strengthening partnerships with key stakeholders will be crucial for leveraging expertise and resources, while continuous development and refinement of the integration framework will foster adaptability and effectiveness. Additionally, a robust monitoring and evaluation system should be established to track the implementation process, enabling continuous improvement.

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ACRONYMS & ABBREVIATIONS

BC	Benefit-Cost
CARA	The Conservation of Agricultural Resources Act 43 of 1983
CMA	Catchment Management Agency
CMS	Catchment management Strategy
CoT	City of Tshwane
CVB	Channelled Valley bottom
DAF	Dissolved Air Flotation
DBSA	Development Bank of South Africa
DFFE	Department of Forestry, Fisheries and the Environment
DWS	Department of Water and Sanitation
E-BASES	evidence-based analysis of socio-ecological systems
EI4WS	Ecological Infrastructure for Water Security
EI	Ecological Importance
EIA	Environmental Impact Assessments
EIS	Ecological Importance and Sensitivity
ES	Ecosystem Services
FBIS	Freshwater Biodiversity Information System
GCRO	Gauteng City-Region Observatory
GCTWF	Greater Cape Town Water Fund
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIAMA	Government Immovable Asset Management Act
GIS	Geographic Information System
GRAP	Generally Recognised Accounting Practice
ICLEI	International Council for Local Environmental Initiatives
IDP	Integrated Development Plan
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs

IUDF	Integrated Urban Development Framework
LGCAMG	Local Government Capital Asset Management Guideline
LID	Low Impact Development
MEA	Millennium Ecosystem Assessment
MFMA	Municipal Finance Management Act
MLD	Mega litres per day
MM	Metropolitan Municipality
MSA	Municipal Systems Act
N.D.	No Date
NCAS	Green infrastructure Accounting System
NCAVES	Green infrastructure Accounting and Valuation of Ecosystem Services
NEMA	National Environmental Management Act
NHRA	Natural Heritage Resources Act
NPV	Net Present Value
NRM	Natural Resource Management
NT	National Treasury
NWM:5	National Wetland Map 5
NWRS	National Water Resource Strategy
OECD	Organization of Economic Cooperation and Development
PES	Present Ecological State
PM	Particular Matter
PPE	Property, Plant & Equipment
SA	South Africa
SABIF	South African Biodiversity Information Facility
SALGA	South African Local Government Association
SANBI	South African National Biodiversity Institute
SANSA	South African National Space Agency
SDG	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting

SNA	System of National Accounts
STATS SA	Statistics South Africa
SUDS	Sustainable Urban Drainage Systems
UKZN	University of Kwa-Zulu Natal
UN	United Nations
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
Wet-Health	Wetland Health
WMA	Water Management Area
WRC	Water Research Commission
WSUD	Water Sensitive Urban Design
WTW	Water Treatment Work
WULA	Water Use License Applications
WWTW	Wastewater Treatment Work

1 BACKGROUND

1.1 INTRODUCTION

A well-maintained green infrastructure provides extensive environmental, social and economic benefits to a variety of communities and economies on a global scale. The value of green infrastructure in providing these ecosystem services has, furthermore, been vigorously demonstrated and quantified and there is ever growing recognition of their importance to human well-being at multiple scales. It is clear that healthy ecosystems contribute significantly to national and local socio- economic wellbeing.

In spite of increasing awareness of the role and importance of green infrastructure, few if any formal institutional arrangements, and specifically economic policy instruments, exist which formalise and/or internalise decision-making around these assets into day-to-day economic decision-making. This is a major issue within South Africa with urban ecosystems especially, being placed under increasing pressure from ever increasing land use intensities and activities. The intent to manage the ecological degradation by environmental authorities is evident however existing regulatory and command and control instruments fail to fully prevent such degradation and environmental impacts remain an economic externality.

The “public good” nature of ecosystems results in any money spent on environmental compliance to be seen as a compliance cost or expense, not necessarily an investment. In best cases, such expenditure may be viewed as social responsibility expenditure. Furthermore, a healthy ecosystem is often viewed as a trade-off with economic development. The assessment of trade-offs evidently falling short of considering the cost of loss of ecosystem services, cost of rehabilitation or mitigation, cost of compensatory infrastructure needing ongoing and expensive management (like Wastewater Treatment Works etc.) and therefore the true socio-economic cost of environmental degradation, again, remains an economic externality. In the short term this is often felt by poorer communities who are especially dependent on ecosystem services, however over time impacts accumulates to have large direct impacts on the greater economy. In other words, the greater socio-economic cost of development through the loss of ecosystem services, is not effectively integrated into decision making processes.

There is a need to identify and explore innovative alternative ways of internalising these externalities into the way we do business and develop our economy.

As urban ecosystems are generally located on municipal land, this project investigates a municipal asset management system, as a very specific economic policy instrument, as such an institutionalisation mechanism for urban or municipal water-related green infrastructure.

The municipal management system provides important information required for the effective management of the assets as well as the detail of the figures disclosed in the annual financial statements. This system enables the municipality to maintain sufficient, appropriate audit evidence. It stores information on each asset, which includes amongst others the cost price, date acquired, location, asset condition and expected lifespan. It can also include information on current replacement costs. This project therefore explores if the structure of existing municipal asset management systems can accommodate green infrastructure, as defined by existing green infrastructure delineation systems.

1.2 PROJECT AIMS

The aims of this study are therefore as follows:

1. Review and consolidation of ecological valuation studies that represent realistic linkages with urban economies and asset planning structures;
2. Make a case for the value of urban green infrastructure against existing trends of urban degradation and resulting risks, trajectories of change, future loss of benefits and the relevance to the National Water Act and Sustainable Development Goal 6;
3. Exploration and review of existing asset management systems and outline opportunities for integration with concepts of green infrastructure and ecosystem services valuations;
4. Conduct a critical review of the receiving environment and institutional readiness for implementation of proposed opportunities and potential risks of implementation; and
5. Demonstrate the integrating indicators of urban green infrastructure into an existing formal urban asset management structure.

The output of the project is to develop and demonstrate a framework from where the urban green infrastructure can be integrated into an existing formal urban asset management structure. This outcome will highlight opportunities for practical integration of the value of green infrastructure into formal planning and established management systems.

2 MAKING THE CASE FOR URBAN GREEN INFRASTRUCTURE

Green infrastructure is the nature-based equivalent of built or hard infrastructure which includes features such as wetlands, rivers and other watercourses, forests, and even entire catchments. Much like hard or built infrastructure, green infrastructure can be seen as an asset (balance sheet item) and the delivery of ecosystem services can be described as the annual rent received from the asset (income statement items). Municipalities in SA can manage their green infrastructure in a manner that may maximise benefits. This includes financial benefits to the municipal entity and economic benefits to its residents and beyond.

2.1 Studies that Link Benefits and Urban Green Infrastructure

The most common way of linking green infrastructure to the economy is via the Ecosystem Services (ES) that are obtained from them. ES, according to the Millennium Ecosystem Assessment (MEA) (2003), are all of the social, ecological, and economic advantages that people can derive from nature. These services include both intangible (such as cultural or health benefits) and biophysical (such as water, food, and fiber) advantages. The System of Environmental-Economic Accounting (SEEA), developed by the United Nations, is a statistical framework for gathering data about habitats and landscapes, calculating the ecosystem services they provide, monitoring asset changes, and connecting this data to economic and other human activity. The linking uses an ecosystem asset account, a type of financial (monetary) account that keeps track of data on the stocks and changes in ecosystem assets.

The ES framework provided by the MEA was used in a study by Crafford and Hassan (2014), which used the ideas of ecosystem composition, structure, and function to formulate and demonstrate production functions that connect green infrastructure and biodiversity to the economy through the use of a case study. As it employs the understanding of ecosystem functioning and processes to determine the value of supporting and regulating services, this method can be utilized as a valuation strategy for ES.

The WRC has completed a study that explored and evaluated such benefits and demonstrated causality between green infrastructure and economic benefits to residents. The project explored the field of 'evidence-based analysis of socio-ecological systems' (E-BASES), with the purpose of analysing relationships between the degraded water resources and socio-economic development and human wellbeing in the Apies-Pienaars river system (Maila et al., 2018). The study evaluated the causal relationship between green infrastructure and those who gain from ESs in the Apies-Pienaar River system. By demonstrating how households benefit from riverine systems as well as using a tourism cost analysis that showed that the condition of the riverine system has an effect on, for instance, the number of fish caught and bird-watching trips. Additionally, the study connected green infrastructure to the economy by demonstrating that there is a positive relationship between property values and river proximity, with homes that are close to the river being worth more than those that are further away from it.

Such benefits are not only recognised in South Africa (SA). A report by the United States EPA (2017) on the health advantages of green infrastructure, which claimed that the natural habitats provided by green infrastructure generate areas for recreation and also boost social capital, supports all of these findings. In addition, the survey noted that green infrastructure lowers municipal water usage and cooling expenses while costing less than traditional grey infrastructure. The survey also discovered that green infrastructure has been proven to raise nearby property values, which is advantageous for both business owners and residential owners.

The benefits of urban green infrastructure investment not only accrue to residents of municipalities but also holds direct financial benefits to municipalities. An ES appraisal of the Groenkloof Nature Reserve (GNR) / Fountains Valley system, where an environmental and resource economic analysis was done, provided additional support for these conclusions (Prime Africa, 2014). The resource rent, which is a portion of the city's overall income from pro-rata water sales, gate fee revenue, and pro-rata property rates favourably impacted by proximity to the system, was the primary benefit indicator considered in this study. The discovered advantages were then valued using this metric. A resource rent of R0.5–1.5 million was obtained from the entrance gate fees. More than R150 million in additional rates revenue (accruing to the City) was attributable to increased property values from properties that were located 500 meters or less from urban green infrastructure.

It is evident from the aforementioned advantages that green infrastructure benefits both residents (economic benefits) and municipalities (financial benefits), hence it is crucial to protect these infrastructures by halting environmental degradation.

2.2 Benefits of Urban Green Infrastructure

Some of the benefits of well-functioning urban green infrastructure in a municipal area may broadly be classified as follows:

- Providing opportunities for recreation and physical activity: has benefits to human health and psychological well-being for residents, but can also translate to increased property values which in turn result in increased municipal rates income to a municipality.
- Providing waste treatment and assimilation services: wetland systems provide an example of green infrastructure that can reduce pollutant loads in river systems.
- Providing water regulation services: urban river systems play a role in moderating and regulating the timing and intensity of water flow, and this has benefits for stormwater drainage and sediment/erosion regulation
- Fostering a sense of community identity and well-being.
- Provides, in some cases, direct economic benefits to households.

Examples of these benefits are described in more detail below.

2.2.1 Reduction of Air Pollution

Green infrastructure can have a favourable effect on air quality. Ammonia, carbon dioxide, nitrogen oxide, ozone, and Particulate Matter (PM) can all be reduced from the air by vegetation (Molla, 2015). Depending on the species, the age of the tree, and the planting strategy, different trees have different capacities for absorbing pollution. Trees and other vegetation have been shown in various studies to be effective in capturing particulate matter. Most of the particulate matter is found in urban areas because there are so many motorized vehicles there (Molla, 2015; Xu et al., 2021). Well-kept turf grass in these settings shields or protects the soil and traps the particles preventing the atmospheric release of dangerous pollutants like sulphur dioxide, ozone and other pollutants.

Green roofs may also play a role in air pollution removal, particularly regarding PM reduction and intensive or semi-intensive green roofs have been found to be most effective. They can be used to supplement the use of urban trees for air pollution control. In Montreal in Canada, it was found that green roofs covered with dwarf mountain pine (*Pinus mugo* var. *pumilio* (Haenke) Zenari), on buildings that were heated with wood, were able to remove 4 g/m^2 PM_{10} (i.e., PM of 10 microns or less) and 1.5g/m^2 $PM_{2.5}$ (i.e., PM of 2.5 microns or less) over a year (Wróblewska and Jeong, 2021).

Living walls or green walls can also play a role in mitigating air pollution. Weerakkody et al (2018) found in a study of living walls (20 plant species) along a busy traffic street in Stoke-on-Trent in the UK that the walls were able to remove promising amounts of PM (Wróblewska and Jeong, 2021). To be most effective, the design and positioning of the walls is important.

The beneficial effect of vegetation and trees in an open area is dependent on weather conditions, wind flows, pollution concentration and the type, location and quality of the vegetation (Wentworth, 2017). The design or configuration of street trees or other vegetation is important as an ill-planned configuration may lead to deterioration of air quality compared to not having trees. Studies have found that hedges of 1.5m to 2.5m planted along similar roads can improve air quality (Wentworth, 2017).

2.2.2 Climate Regulation

To mitigate some of the negative effects of climate change in our urban environment, green infrastructure can be quite helpful. Depending on the location, kind, and severity of climate change, it is assisting people who live in towns and cities in adapting to it. Green infrastructure serves as insulation throughout the winter and provides shade, cooling, and wind blocking. A crucial component of urban climate change adaptation measures has been highlighted as trees (Molla, 2015).

Climate change impacts such as flooding and the heat-island effects may be effectively alleviated through green infrastructure, such as trees, vegetation, green roofs etc. Green infrastructure such as parks reduces the urban runoff and enables rainfall to soak into the underlying soil and above-ground surface water management features such as swales can channel, slow and store the water and control the rate at which it enters sewers and watercourses (Wentworth, 2017). An excellent example of how green infrastructure is being used as a solution to respond to climate-change-induced changes in rainfall, flooding and heat waves is found in the city of Rotterdam in the Netherlands. The city is below sea-level and particularly vulnerable to climate change rises in sea and river levels. An enormous park known as Dakpark was completed in 2014 on the top of a shopping centre lying above a dyke in Delfshaven. This roof park stretches for over a kilometre and contains a vegetable garden, open fields and a park with trees and shrubs. The park has an integrated dyke for flood defence and provides all the benefits of green roofs including absorbing rainwater runoff, decreasing heat and providing a park for recreational activities (GCA, 2021).

2.2.3 Water Regulation

Green infrastructure can play an important role in providing water regulation by decreasing the hardened surface area and improving permeable stretches (porous pavement, meadows and forests for example) and by protecting wildlife (by creating a suitable habitat) in urban areas. Planting of absorbent gardens, roadside plantings, vegetated roofs and other measures can assist in capturing rainfall runoff from hard city surfaces, filter and reduce stormwater. Rainwater can thus permeate the soil and gradually make its way to the aquifers and reservoirs. Additionally, plant or tree roots serve as a natural filter that limits the amount of sediment and other contaminants that enter reservoirs or other water sources.

Many cities in the world use green infrastructure to help capture stormwater runoff that would otherwise overwhelm the storm sewer systems in the city. One such example is in New York City in the USA where Brooklyn Bridge Park (85 acres) serves to provide recreational space and respite from the city space but also serves to capture stormwater overflow and urban runoff from the city streets. In China in Shenzhen, they have pioneered a low-impact development model for stormwater management. The sports centre in the city has been equipped with a green roof, rain gardens and permeable pavement and can capture more than 60 percent of the annual rainfall.

2.2.4 Noise Reduction

Xu et al (2021) addresses the function of vegetation in the absorption and insulation of noise, while urban greening has a certain commonality when it comes to noise attenuation, it provides traffic and street noise abatements. Green living roofs and walls can provide an effective sound level reduction in urban environments and designs can be made for new buildings but also retrofitted to existing buildings. This can have the added benefit of reducing the building energy needs and reducing air and noise pollution. In Singapore a green living wall has been used for the facade of one of the airport terminal buildings for effectively reducing noise levels (Dimitrijević et al. 2017). Important factors affecting the sound absorption and sound propagation properties and should be considered when considering designs, includes configuration of the green infrastructure system, the substrate thickness and vegetation layer (Dimitrijević et al. 2017).

Planting of buffers to noise consisting of trees and shrubs can result in a reduction of five to ten decibels (particularly sharp tones) for every 30m width of woodland, thereby reducing the noise to the human ear by about 50% (Forest Research, 2022). The choice of tree species for urban areas and the design of the green space is important for successful screening of noise.

2.2.5 Energy Use Reduction

Trees may help cool the air and lessen the amount of heat that reaches and is absorbed by buildings by providing shade when they are strategically positioned. This can lower the amount of energy required to cool buildings during warm weather. Particularly in regions with chilly winters, trees minimize wind spread, which can significantly affect the amount of energy required for heating. Trees emit water into the atmosphere, lowering the ambient temperature and reducing the need for building energy (CNT, 2010).

Green roofs significantly reduce the amount of energy required to keep building temperatures at comfortable levels throughout the year by insulating against excessive losses during colder months and heat absorption in hotter months of the year. In a study in Toronto, Canada two extensive green roofing systems in the city were found to be more thermally efficient in summer compared to winter months reducing heat flow by 70 to 90% in summer and by 10 to 30% in winter (Liu & Baskaran, 2005). The roof with a thicker growing medium served well for reducing heat gain in summer through increased insulation, evaporative cooling and thermal mass, however in winter when frozen the insulation was greatly reduced (Liu & Baskaran, 2005).

2.2.6 Economic Benefits of Green Infrastructure

The development of new recreational and leisure options is made possible by investments in green infrastructure, which also boosts the economies of forestry, agriculture, and public services (Molla, 2015). It boosts property prices, creates green jobs, and lowers infrastructure and utility expenses.

Several studies on the economic benefits of green spaces have found that people are willing to pay more for a residential property close to a green space as green spaces tend to create a favourable image for a place, boost retail sales, attract tourism, enhance investments within an area, and create favourable working spaces that encourage employment (Cilliers et al. 2013). There are studies that have shown that there is an increase in property values that are closer to green spaces which in turn results in increased local authority incomes through higher taxes and land values (Cilliers et al. 2013). Green spaces may also result in costs savings such as spatial planning, maintenance, energy consumption, CO_2 emissions and stormwater costs (Cilliers et al. 2013).

3 INTEGRATION OF GREEN INFRASTRUCTURE INTO ASSET MANAGEMENT

This chapter provides information related to understanding of the current asset management system utilised in municipalities and in particular CoT, by understanding the regulatory framework, the asset management process and the accounting requirements for managing assets. This is followed by how green infrastructure is envisioned to be integrated into asset management.

3.1 SOUTH AFRICAN MUNICIPAL ASSET MANAGEMENT FRAMEWORKS

In South Africa, the public sector holds vast portfolios of assets such as roads, transportation facilities, energy, water and telecommunications infrastructure, hospitals, schools, prisons, cultural facilities, nature reserves and military assets, and movable assets. These assets are essential for economic growth, poverty alleviation, the country's economic competitiveness, social upliftment and inclusion and, overall, our collective quality of life (NT, 2021). As such, asset management is seen as being central to providing required services in a cost-effective, efficient, and transparent manner.

In accounting, an asset is defined as a resource controlled by the department because of past events from which future economic benefits or service potential is expected to flow to the department (NT, 2021). Furthermore, assets can be tangible, intangible, financial or non-financial in nature. Within the public sector accounting environment, an item will only be recorded/recognized as an asset if the following two conditions are met 1) It is probable that future economic benefits or service potential will flow to the entity as a result of past events and 2) the cost or fair value of the item can be measured reliably.

With regards to value, we can generally differentiate between two types of assets i.e., 1) Assets that are used to deliver goods and services in furtherance of a department's objectives, but which do not directly generate net cash inflows are those typically embodying service potential and 2) Assets that are used to generate net cash inflows are typically described as those embodying future economic potential (NT, 2021). For this definition, value is measured in financial terms.

Another important aspect to consider is ownership. Whilst ownership is certainly a strong indicator, an entity must be able to control the use of the item and be entitled to its future economic benefits or service potential, for it to be recorded/recognized as an asset (NT, 2021).

In terms of the regulatory framework there are three key pieces of legislation that govern the management of assets:

1. The Constitution of the Republic of South Africa, 1996. The Constitution's prime mandate for Local Government is that services are provided in a sustainable manner (Section 152).
2. Municipal Systems Act (MSA), 2000. The MSA in sections 4(2)(d) states that a municipality has the duty to strive to ensure that municipal services are provided to the local community in a financially and environmentally sustainable manner.

3. Municipal Finance Management Act (MFMA), 2003. Section 63 of the MFMA states specific duties in respect of asset management, i.e., the safeguarding and maintenance of assets, valuation in accordance with Generally Recognised Accounting Practice (GRAP), maintaining a system of internal control over assets and keeping an asset register. Each municipal manager must ensure that the provisions of S63 are implemented.

Several documents provide guidance for the management of these assets and include the following:

- The Guidelines for Infrastructure Asset Management in Local Government 2006 – 2009 developed by the Department for Provincial and Local Government (Optional);
- The Local Government Capital Asset Management Guideline by National Treasury (Optional);
- Government Immovable Asset Management Act (GIAMA) (Statutory);
- SANS 55000 series of standards (Optional);
- Maintenance management standard by the Department of Public Works and the Construction Industry and Development Board (Optional); and
- Framework for Infrastructure Delivery and Procurement Management (Optional).

The GIAMA is the only statutory document which municipalities are required to follow, while the other documents may be used to provide further guidance.

3.2 ASSET MANAGEMENT PROCESS

The overall framework for the management of assets is referred to as the asset management process and is defined as the process of decision-making, planning and control over the acquisition, use, safeguarding and disposal of assets to maximise their service delivery potential and benefits, and to minimise their risks and costs over their entire life (NT, 2021).

The Integrated Development Plan (IDP) is usually a five-year plan which the local government is required to compile to plan the development needs of the municipality. Projects identified within the IDP are linked to municipal budget planning. Thus, to compile a good IDP and ensure the development goals of the municipality are achieved, it is necessary that the municipality provides accurate information on its assets. The asset management process can thus be thought of as the link between the asset register and the IDP (Figure 3-1). The process uses the asset registers to make plans for those assets and thus make effective use of assets controlled by the municipality. The asset management system should provide information to be used in compiling the IDP. The principal components of the process are the asset register and IDP.

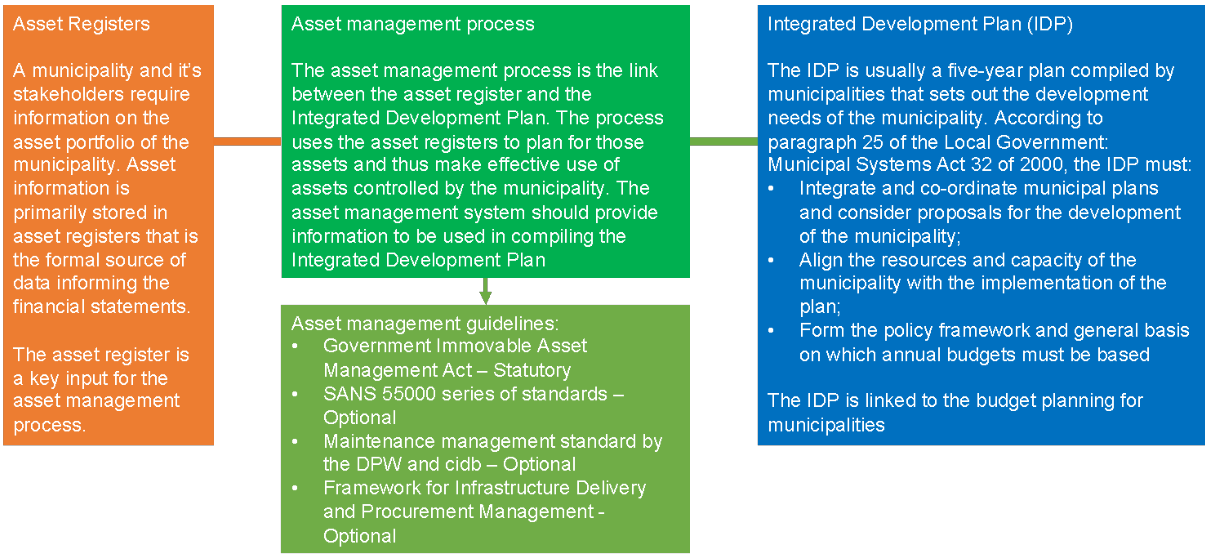

Figure 3-1. The asset management process

3.2.1 The asset register

The asset register is a complete and accurate database of the assets that are under the control of a municipality and that is regularly updated and validated. An adequate asset register is integral to effective asset management. It is the basis of an asset management information system and should contain relevant data beyond that required for financial reporting (NT, 2008).

The asset register provides important information required for the effective management of the assets as well as the detail of the figures disclosed in the annual financial statements. This register enables the municipality to maintain sufficient, appropriate audit evidence. It stores information on each asset, which includes amongst others the cost price, date acquired, location, asset condition and expected lifespan. It can also include information on current replacement costs. All assets owned and controlled by an entity must be recorded in an asset register, regardless of the funding source or value thereof. All disposed assets must be excluded (NT, 2008).

According to the Local Government Capital Asset Management Guideline (LGCAMG) (NT, 2008), the type of data required in an asset register should include information on the following aspects:

- Identification & Location - What and where is this asset and whom does it serve?
- Accountability - Who is accountable and how it is being safeguarded?
- Performance – What is its intended and actual level of service?
- Accounting – How is it accounted for? This should include a valuation basis and depreciation parameters.
- Management & Risk – How is it managed? How critical is it? This should include some maintenance, engineering and operational data and may be summarised from sub-systems.

- Acquisition and disposal – Transactional source (Audit Trail).

3.2.2 Accounting framework requirements for assets

The accounting and reporting principles governing capital assets are covered in more detail in standard-specific guidelines and should be referred to in conjunction with the LGCAMG (NT, 2008). Examples of accounting standards that cover assets are:

- Generally Recognized Accounting Practice (GRAP) 17 on Property, Plant & Equipment (PPE)
- GRAP 16 on Investment Properties
- GRAP 102 on Intangible Assets
- GRAP 100 on Non-current Assets Held for Sale and Discontinued Operations
- GRAP 101 on Agricultural Activities
- IAS 36 on Impairment of Assets.

Since asset registers are important in municipal planning and ultimately inform the IDP, there is justification for green infrastructure to be integrated into asset registers. However, these kinds of assets need to meet the accounting definition and recognition criteria. It is, therefore, necessary to review the accounting requirements for assets and how they apply to green infrastructure.

Municipalities are required by the MFMA to apply the standards of GRAP. To meet The GRAP accounting requirements assets need to be subjected to the following criteria: 1) meet the definition of an asset, 2) determine the applicable accounting standard and 3) meet the recognition criteria of the applicable standard. The requirements are discussed in more detail below:

1. **Meet the definition of an asset:** The Conceptual Framework for General Purpose Financial Reporting defines an asset as “a resource presently controlled by the entity as a result of a past event.” A resource is an item with service potential or the ability to generate economic benefits. Green infrastructure is thus a resource as it provides services to the public and generates economic benefits for the public and financial benefits for the municipality. Green infrastructure is also controlled by the municipality as the municipality is responsible for its management and operation.
2. **Determine the applicable accounting standard:** The accounting standard applicable to green infrastructure is determined by the nature of the asset. Green infrastructure is the nature-based equivalent of built or hard infrastructure. GRAP 17 Property, Plant and Equipment generally applies to infrastructure assets. Property, Plant and Equipment (PPE) are defined as tangible assets that are held for use in the production or supply of goods or services, for rental to others, or for administrative purposes; and are expected to be used during more than one reporting period. Green infrastructure is tangible assets that are used by municipalities to supply goods and services and are used for longer than a year. Green infrastructure thus meets the definition criteria for PPE.

3. **Meet the recognition criteria of the applicable standard:** Next, green infrastructure needs to meet the recognition criteria in GRAP 17. The recognition criteria states that the cost of an item of property, plant and equipment shall be recognised as an asset if, and only if a) it is probable that future economic benefits or service potential associated with the item will flow to the entity; and b) the cost or fair value of the item can be measured reliably. Green infrastructure can generate economic benefits for the municipality, which are showcased further in this report. Green infrastructure are natural assets, assets that weren't constructed. As these assets arose as a result of non-exchange transactions, they don't have an acquisition cost. Thus, the fair value measurement of these assets is more suitable. The fair value of natural assets is difficult to determine and are usually valued based on the ecosystem services they provide. However, recent frameworks have been established that provide methods for reliable valuation of natural assets, such as The System of Environmental Economic Accounting (SEEA) and Wealth Accounting and the Valuation of Ecosystem Services (WAVES) for example. Thus, green infrastructure meets the recognition criteria of GRAP 17.

3.3 INTEGRATING GREEN INFRASTRUCTURE INTO ASSET MANAGEMENT

The main question around integrating green infrastructure into the formal asset register of the City of Tshwane is what information should be included. To answer this, we followed the Local Government Capital Asset Management Guideline published by the National Treasury (NT, 2008). This ensures the information included can be easily integrated with current asset registers and meets National Treasury guidelines. The information gathered and organised into a formal asset register is described in the following sections.

3.3.1 Identification & location

This refers to information on what the asset is and where it is located. For this information on the asset class, the asset number, asset description, the suburb that each management unit is located in, the latitude and longitude coordinates of each management unit as well as an assigned Geographical Information System (GIS) code has been included. The asset class, asset number and the GIS code would be assigned by the municipality. The remaining information could be populated from GIS data.

3.3.2 Accountability

Accountability refers to information around who is accountable for the asset regarding oversight and management. For this information on the department responsible for the green infrastructure assets, any restrictions on the assets and the ownership of the assets have been included. It was assumed that the Environmental and Agriculture Management department within the municipality would be responsible for the assets. It was also not possible to identify any restrictions on the assets. Thorough analysis was done to identify land parcels that fall within the delineated management units. A list of the individual land parcels was made, and these were searched using the property valuation database within the City of Tshwane. Thus, it was possible to identify who the owners are. Based on this analysis, it can be said that ownership of these green infrastructure assets would fall under the City of Tshwane.

3.3.3 Performance

Information on an asset's performance history includes whether the asset is performing as intended and what its level of service is. For the purpose of green infrastructure information around the size of each management unit (its area in hectares) and its present ecological status was included. The present ecological status provides users of the asset register with information on each management unit's level of service.

3.3.4 Accounting

This relates to information around how an asset is accounted for, such as what valuation basis is used, namely historical cost or fair value, or how the asset is depreciated i.e. straight-line depreciation, reducing balance or units of production. The assets identified for inclusion in the case study are special as these assets typically have infinite useful lives and are typically transferred to the municipality. Thus, consideration had to be given to what valuation basis was used and what other information to include. As such, the information included under this section relates to the funding source for the maintenance of each management unit, the last date the asset was valued and the Net Present Value (NPV) of the financial benefits.

Municipalities are required by the Municipal Finance Management Act 56 of 2003 to apply the standards of GRAP. The valuation basis selected for the green infrastructure assets is the "Entity-specific value" defined in GRAP 17 as "the present value or service potential of the benefits an entity expects to arise from the continuing use of an asset and from its disposal at the end of its useful life or expects to incur when settling a liability." As such, using the "Entity-specific value" as a means of valuing green infrastructure aligns with accounting principles.

3.3.5 Management and risk

Information to be included under this category relates to how the asset is managed, including what maintenance is required. For the green infrastructure assets, information around the mitigation interventions required (which would represent maintenance), the cost of mitigation and the financial cost benefit ratio is included. The financial cost benefit ratio was given to show the ecological assets potential which helps in prioritization and risk management in the municipality. The financial cost benefit ratio is calculated as the value of the benefits divided by the value of the cost of mitigation.

3.3.6 Asset register

A formal asset register for green infrastructure was developed for the City of Tshwane municipality (see Section 5.8). Information from this asset register can be easily integrated with other asset registers within the municipality and allows for formal integration with the municipality's asset management process.

4 EVALUATING INSTITUTIONAL READINESS FOR SUCCESSFUL PROJECT IMPLEMENTATION

4.1 FRAMEWORK FOR ASSESSING INSTITUTIONAL READINESS

To successfully integrate green infrastructure into asset management systems, it is crucial to ensure that all necessary systemic requirements for implementation are in place. This review aims to assess the institutional readiness of the City of Tshwane and municipalities in general, evaluating its capacity, policies, and processes to effectively include green infrastructure (for the scope of this project, wetlands) in its asset register. The assessment was done by adopting and modifying a framework developed by The Organization of Economic Cooperation and Development (OECD, 2019), which was initially developed to determine institutional capacity for the development of- and adherence to coherent policies that prioritise global Sustainable Development Goals (SDGs). This framework consists of four pillars, namely:

1. Pillar 1: Institutional capacity and skill
2. Pillar 2: Country practices and support
3. Pillar 3: Data availability and tools
4. Pillar 4: Partnerships and peer-learning

Considering these pillars, our central hypothesis is that the current structure of municipal asset management systems can integrate green infrastructure as defined by existing green infrastructure delineation systems. Each pillar is elaborated upon below.

4.2 PILLAR 1: INSTITUTIONAL CAPACITY AND SKILLS

4.2.1 Research Capacity and Skill

The South African government's commitment to prioritising research as part of its national agenda has resulted in the development of several administrative mechanisms, innovations, and ground-breaking discoveries through its collaborations with academia and industry (see South Africa's National Research and Development Strategy, 2002). Many of the resources developed because of these collaborations will likely be useful at different points throughout the life cycle of this project. Examples of such include the National Water Act of 1998, which provides a clear definition for wetlands ("land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which in normal circumstances supports or would support vegetation typically adapted to life in saturated soil") in addition to serving as a comprehensive legislative framework for the management, protection, and sustainable use of water resources throughout the country. Research institutions such as

SANBI have also developed detailed descriptions of different wetland types (e.g., rivers, unchanneled valley bottoms, meandering flood plains, depressional pans etc.) and a hierarchical wetland classification system. In addition to this, the distribution, condition, and level of protection of South African wetlands have been determined through multiple studies (e.g., Rivers-Moore, 2012; Adeeyo, 2022). Furthermore, experts across multiple disciplines acknowledge the direct and indirect, environmental, social, and financial benefits of investing in green infrastructure such as wetlands and the impact they can have on the well-being of municipalities (e.g., water purification, flood control, recreation; Miguez, 2017).

4.2.2 Policy and Regulations

The South African government has developed several administrative mechanisms, structures and processes that prioritise the environment and, by extension, can also prioritise green infrastructure. For example, the country has the National Environmental Management Act 107 of 1998 (NEMA), the principal environmental statute. Additionally, there are several Specific Environmental Management Acts (e.g., National Water Act, 36 of 1998, National Environmental Management: Biodiversity Act, 10 of 2004, and the National Environmental Management: Protected Areas Act, 57 of 2003) which govern commercial activities that have a bearing on natural resources and the environment (Bowmans Guide to Environmental Law in South Africa). Below is a list of legislation that may be relevant to, and thus govern the project.

i. The National Environmental Management Act, 1998 (NEMA)

ii. The National Water Act 36 of 1998 (NWA)

iii. The Conservation of Agricultural Resources Act 43 of 1983 (CARA)- A legislative framework that aims to ensure long-term productivity and sustainability of agricultural lands by addressing various aspects related to conservation and management.

iv. The National Forests Act 84 of 1998 (NFA)- A legislative framework for forest conservation and sustainable utilisation. With a specific emphasis on promoting biodiversity and supporting the socioeconomic well-being of local communities.

v. The Natural Heritage Resources Act 25 0f 1999 (NHRA)- A legislative framework that safeguards landscapes, geological features, and cultural sites, ensuring their availability for future generations.

vi. The National Environmental Management: Biodiversity Act 10 of 2004 (Biodiversity Act)- a legislative framework that prioritises the equitable sharing of benefits derived from the country’s biodiversity.

vii. The National Environmental Management: Protected Areas Act 57 of 2003 (Protected Areas Act)- a legal framework for the establishment, management, and protection of South Africa’s protected areas.

viii. The Mountain Catchments Areas Act 62 of 1970- a legal framework for the management of water resources in mountainous catchment areas, ensuring the availability of clean and sufficient water supply for purposes including agriculture, domestic use, and industrial activity.

ix. The Municipal Systems Act, 2000 (MSA)- a legal framework that aims to promote good governance, accountability, transparency, and effective service delivery at the local government level.

x. The Municipal Finance Management Act, 2003 (MFMA)- a legislative framework for municipalities' financial management and accountability, seeks to promote just financial governance, transparency, and effective financial management practices at the local governmental level.

xi. The Government Immoveable Asset Management Act 19 of 2007 (GIAMA)- a legal framework for the effective management, utilisation and disposal of government properties and land.

xii. The Integrated Urban Development Framework (IUDF) is a policy initiative to guide urban development, promoting inclusive, sustainable, and resilient cities and towns.

4.2.3 Availability of Financial Resources

Finances are likely the most significant barrier to the full realisation of green infrastructure as an asset. In 2012, Giordano reported that the demand for financing nationwide ecosystem-based management interventions was estimated to be six times more than the resources availed by the Natural Resource Management (NRM) programmes that were investing in green infrastructure rehabilitation and enhancement projects. The demand is likely even greater since the country’s economy has taken major knocks (Lenoke, 2017; Mabunga, 2021) and more environmental degradation has taken place since then (Mani, 2021). The costs associated with incorporating green infrastructure, such as wetlands, into asset management systems can be substantial. This includes conducting assessments, mapping, monitoring, and implementing appropriate management strategies. Unfortunately, limited financial resources often result in a lack of skilled personnel, technical equipment, and resources necessary to conduct comprehensive assessments and implement sustainable management practices, which in turn hinders the effective integration of green infrastructure into asset management systems. Furthermore, insufficient financial support can undermine the capacity to address ongoing maintenance and monitoring needs, thus compromising the effectiveness and longevity of the incorporated green infrastructure.

To address this challenge, innovative funding mechanisms, public-private partnerships, and sustainable financing models should be explored. Increased investment in green infrastructure should be considered not only for its environmental benefits but also for its potential to improve the general public’s quality of life while generating economic returns in the form of ecotourism and ecosystem services. Additionally, raising awareness and advocating for the value of green infrastructure among decision-makers and the public can help foster a greater understanding of the need for financial resources in this domain. The following are different parties that play integral roles in green infrastructure funding mechanisms (as stated by Pasquini, 2019).

4.2.3.1 Government

The government plays the lead role in optimising investment in green infrastructure. It does this either by directly investing public funds into the restoration, maintenance, or conservation of green infrastructure (if this infrastructure is located on communal land) or by providing subsidies and incentives to encourage the contribution of other investors; and creating regulations which indirectly necessitate their investment.

4.2.3.2 The Private Sector

The private sector can invest in green infrastructure for several reasons. For example, an organisation can do so to reduce and manage risk when green infrastructure is directly tied to the success of its business. This can be in the form of a company indirectly investing in green infrastructure by collaborating with an insurance company to reduce their exposure to flood or fire risk and, in other cases, a company or an entire sector may look to secure the ecosystem services that play an integral role in their supply chain or product development. This sector can also incorporate green infrastructure investment into its corporate social responsibility initiatives to contribute to the stability of its surrounding communities. However, to a large extent, this sector only contributes to natural green infrastructure to adhere to governmental regulations and to receive operational licences, suggesting that green infrastructure is not its major priority.

4.2.3.3 The Landowner

Through the case study demonstration, it was highlighted as a significant barrier which is the inability for the municipality to invest in green infrastructure that lies on privately owned land.

Land ownership in South Africa is a complex and sensitive issue shaped by the country's history, particularly the legacy of colonialism and apartheid, which resulted in significant disparities in land ownership. South Africa has different types of land ownership, namely the private ownership in which the land is owned by individuals, corporations, or other private entities, the state-owned land in which the land is owned and managed by the government, including public infrastructure and conservation areas. Lastly, the Communal Land which the land is held in trust by the government for communities, often managed according to traditional practices.

Privately owned land poses a unique challenge for municipal investment in green infrastructure. Ecological assets such as wetlands, rivers, and green spaces often span both public and private territories. Without the ability to manage and invest in these privately owned sections, the effectiveness of green infrastructure can be severely compromised. This limitation hinders the municipal’s ability to maintain, rehabilitate, and protect essential ecosystems services that benefit the broader catchment.

Like the private sector, the government has also set regulations that require landowners to contribute to the maintenance of green infrastructure within their property. The type of intervention from the landowner is determined by the required management of the green infrastructure, and their ability to undertake such action or inaction.

Incentives

Incentive programs are the structured use of rewards and recognition to motivate desired behaviour from a specific group of people. In the context of environmental management, incentives refer to a diverse set of strategies and policies designed to encourage individuals, businesses, and communities to adopt environmentally friendly behaviours and practices. These incentives can take various forms, including financial rewards, regulatory measures, and behavioural nudges, aimed at promoting sustainable actions and reducing environmental harm. By providing motivation and rewards for environmentally responsible actions, these incentives help steer societies towards more sustainable development pathways. They serve as powerful tools for driving innovation, fostering conservation efforts, and mitigating the negative impacts of human activities on the planet.

Tax Rebates and Reductions: Offering tax incentives to landowners who maintain or restore green infrastructure on their property. This can be done by having municipalities incentivising green infrastructure by providing tax rebates and reductions to landowners who actively preserve or rehabilitate these elements on their properties. The procedure includes establishing clear eligibility criteria, including the specification of the many types of green infrastructure that qualify (e.g., green roofs, rain gardens) and the establishment of design and maintenance standards. Landowners can obtain incentives by submitting full project plans and supporting documents. Municipal authorities validate these applications through preliminary inspections, and permitted projects are granted tax refunds or reductions that are determined by their size and category.

In addition, municipalities may carry out regular checks and enforce the obligation for landowners to maintain and submit maintenance records and annual performance reports in order to guarantee adherence and efficiency. Using monitoring tools and performance measurements allows for the continuous tracking of the long-term advantages of the green infrastructure. Failure to comply may lead to the withdrawal of incentives or imposition of penalties, whereas outreach initiatives, workshops, and technical help aid landowners in effectively implementing and sustaining their projects.

4.2.3.4 Civil Society

Civil society is also encouraged to play a role in implementing and supporting investment in green infrastructure where appropriate. Civil society can bring expertise around innovation, demonstrating and facilitating collaboration, supporting capacity development, and monitoring and evaluation. Citizen scientists can play a huge role in ensuring a healthy green infrastructure through monitoring the health status of rivers and wetlands, Citizen science is growing in popularity not only in SA, but globally. This is mainly due to lack of data, as the mandated Government departments continue to struggle to collect data and manage resources in a sustainable manner.

In 2018, WRC conducted a study that developed citizen science water resource monitoring tools and communities of practice for South Africa, Africa and the world (WRC Project No.TT/763). The project has developed a wide range of tools (e.g., aquatic biomonitoring tools, wetland assessment tool, estuary tool, spring tool, etc) and documented many approaches and interventions which can be used by communities to improve water resource management within the region. The project has also developed a new, electronic, “virtual” toolbox on the internet, and this can be added to, as and when new tools emerge, or current tools are further refined or developed.

4.3 PILLAR 2: COUNTRY PRACTICES AND SUPPORT

In the South African context, seeing green infrastructure as a valuable asset is not only hindered by the lack of awareness and understanding among decision-makers and asset managers but it is further delayed by poor governance and business practices (e.g. issuing licences illegally, accepting bribes, and carrying out business practices that undermine the regulatory system; Sundström, 2013). Another factor contributing to the weak enforcement of these laws and regulations is confusion as to where the environmental management function lies. This results in local authorities referring matters to national or provincial departments because the broad-scale planning approaches linked to sustainable development are not well translated to the level of local government tasked with implementation (Cilliers, 2019). Fortunately, South Africa has interventions aimed at promoting environmental compliance, enforcing regulations, and holding accountable those who fail to adhere to the established standards. These include:

4.3.1 Environmental law enforcement

These are specialised units within law enforcement agencies such as the South African Police Service's Environmental Crime Investigation Unit. These units are tasked with investigating environmental crimes, gathering evidence, and working closely with other stakeholders to enforce environmental laws and regulations.

4.3.2 Regulatory Compliance and Monitoring

The government, through the Department of Forestry, Fisheries and the Environment (DFFE) and Department of Water and Sanitation (DWS), and other regulatory bodies, conducts regular inspections and monitoring to ensure compliance with environmental regulations. This involves assessing industrial facilities, waste management practices, and other activities that may impact the environment. Non-compliance can lead to penalties, fines, or legal actions.

4.3.3 Environmental Impact Assessment

This process is a key tool for managing the potential environmental impacts of development projects. It assesses the potential impacts, identifies mitigation measures, and ensures compliance with environmental regulations before project approval.

4.3.4 Legal Framework and Penalties

Penalties for environmental violations can range from fines to imprisonment, depending on the severity of the offence. The legal system ensures that individuals or entities found guilty of environmental violations face the appropriate consequences.

4.3.5 Collaboration among Stakeholders

Partnerships between various stakeholders including industry, civil society organizations, and communities formed to develop shared goals, promote compliance, and foster sustainable practices. Such alliances can improve the effectiveness of monitoring, enforcement, and remediation efforts.

Shared responsibilities between Government entities such as DFFE, DWS, Catchment Management Agencies (CMAs), Water boards, and municipalities can enhance the management of green infrastructure. For instance, the Government entities can provide technical and financial support for water-related projects, to non-government organizations, research institution and universities, community-based organization and private consulting companies. The DFFE can offer expertise in biodiversity and ecosystem services, while CMAs fulfils their mandate on looking after the green infrastructure. Municipalities, being closest to the urban populace, can ensure that local green infrastructure projects meet community needs and are well-maintained.

4.4 PILLAR 3: DATA ANALYSIS AND TOOLS

Multiple frameworks, guidelines and data-based tools have either been developed by- or made available to South African governmental and research organisations over the years. These tools provide valuable information for assessing the extent and condition of ecological assets and supporting informed decision-making. More specific to this project, these tools are likely to play an integral role in successfully integrating wetlands into the City of Tshwane’s asset management systems.

4.4.1 Tools for Asset Delineation and Classification

4.4.1.1 Manual for the Identification and Delineation of Wetlands and Riparian Areas

The country has widely accepted standardised methodologies for identifying and delineating wetlands. These methods were primarily developed by the Department of Water and Forestry which produced a manual for the identification and delineation of wetlands and riparian areas in 2005 (which is being updated).

4.4.2 Tools for Asset Valuation

Green infrastructure valuation tools provide a standardised, systematic and comparable way to measure and report the stocks and flows of green infrastructure in the country (SANBI, 2021; Stats SA, 2021). Assigning economic values to green infrastructure can help various stakeholders better understand the trade-offs associated with different land use options and make informed choices that integrate environmental considerations into planning and development processes. The appropriate valuation of green infrastructure would, therefore, play an integral role in green infrastructure being formally recognised as an asset and linking it to the country’s System of National Accounts (SNA).

Various tools and frameworks exist to assess the ecosystem services provided by the green infrastructure. These tools quantify the value of ecosystem services, such as carbon sequestration, water purification, and recreational opportunities. Examples include the green infrastructure Accounting System (NCAS) and the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) tool (Sharp et al., 2015) and the (WRC Report No. K5/2737, Wet-Ecoservices, Version: 2.)

4.4.2.1 Examples of Past Projects

South African entities such as SANBI and Stats SA have experience developing several national accounts. These include a NCAVES (Green infrastructure Accounting and Valuation of Ecosystem Services) project that employed the SEEA framework and led to the development of several national accounts in collaboration with the DFFE. These include:

i. Land and Terrestrial Ecosystem Accounts, 1990 to 2014. Published by Stats SA in December 2020 as the first account in the Green infrastructure Series.

ii. Accounts for Protected Areas, 1900 to 2020. Published in October 2021 and the second account in the Green infrastructure Series

iii. Accounts for Species: Cycads, 1970 to 2010.

iv. Accounts for Species: Rhinos, 1970 to 2017.

v. Land Accounts for Metropolitan Municipalities, 2005-2011. This pilot accounts for ecosystem services and asset value for KwaZulu-Natal.

vi. Sub-national Water Resource accounts, 2015-2021. Piloted water resource accounts for Mooi and uMngeni catchments in KwaZulu- Natal Province and Breede in the Western Cape Province.

4.4.2.2 Financial Auditing of Green Infrastructure

Although it is possible to test for the existence of green infrastructure assets, the complexity lies in assessing the value of these assets. This is because, in most cases, there is no actual purchase price or market value attached to these green infrastructure assets which makes determining the historical cost or fair value of these assets difficult. However, recent frameworks have been established that provide methods for reliable valuation of natural assets. The System of Environmental Economic Accounting (SEEA) and Wealth Accounting and the Valuation of Ecosystem Services (WAVES) are two frameworks that have developed standardised processes for green infrastructure accounting. In addition to these frameworks, there are various published reviews and discussions on methods for valuing ecosystem services, one such report is The Economics of Biodiversity: The Dasgupta Review, published in 2021.

The Auditor General includes guidelines for auditing capital assets in the public sector. However, it would be useful to explore the potential for the Auditor General to incorporate green infrastructure guidance and green infrastructure valuation methodologies into their audit guidelines. Integrating green infrastructure into the asset management system can help with maintaining an audit trail for these assets.

4.4.3 Data Sources and Analysis Tools

South Africa (and the City of Tshwane (CoT)) has access to various data and analysis tools that can aid in the identification, delineation, and classification of green infrastructure. Many of these were likely used by multiple institutions that conducted research resulting in a significant collection of environmental (i.e. wetland) spatial data. Some of the key resources available in South African institutions/ organisations include:

4.4.3.1 Geographic Information Systems (GIS)

GIS technology enables the integration and analysis of spatial data related to green infrastructure. It allows for the visualization, mapping, and spatial analysis of various environmental parameters, such as land cover, hydrology, and biodiversity. Examples of widely used GIS platforms include ArcGIS and QGIS.

4.4.3.2 Remote Sensing Data

Remote sensing techniques, including satellite imagery and aerial photography, provide valuable data for identifying and monitoring green infrastructure. Remote sensing data can assist in mapping land cover, vegetation indices, water resources, and other relevant parameters. This satellite imagery and remote sensing data is provided by South African National Space Agency (SANSA), as well as by the recently completed WRC Report:C2020/2021-00427.

4.4.3.3 National Wetland Inventory

The DFFE has developed a National Wetland Inventory that provides valuable data on the location and extent of wetlands in South Africa (Water SA 46(1) 66–79 / Jan 2020). It helps in identifying and delineating wetland areas for conservation and management purposes. Another wetland mapping (NWM:5) tool is provided in the WRC Report: K5/2546, which shows the distribution of inland wetland ecosystem types across South Africa and includes estuaries and the extent of some rivers.

4.4.3.4 Biodiversity Databases

South Africa benefits from comprehensive biodiversity databases that contain species distribution records, conservation statuses, and habitat preferences. The South African National Biodiversity Institute (SANBI) manages platforms such as the South African Biodiversity Information Facility (SABIF), Freshwater Biodiversity Information System (FBIS, 2023) and the Red List of South African Plants.

4.4.3.5 National Vegetation Database

The South African National Vegetation Database is a comprehensive resource that provides information on the country's vegetation types, vegetation mapping units, and associated plant species. It aids in the classification and assessment of green infrastructure related to vegetation. (S Afr J Sci. 2012;108(1/2) (WRC, 2015; WRC, 2019).

4.5 PILLAR 4: PARTNERSHIP AND PEER LEARNING

Considering the financial and implementation-related challenges that the CoT is likely to face in carrying out this project successfully, it is evident that it would gain numerous benefits from partnering with other institutions. These collaborative partnerships would enhance the city's capacity to effectively manage and utilize its natural resources for sustainable development by bringing more experts to the table who can provide valuable insights and methodologies to assess and manage CoT's green infrastructure more effectively. The collaboration will also increase resource availability, not only in a monetary sense (through the pooling of financial and technical resources) but also in providing access to comprehensive and up-to-date datasets and monitoring and valuation information. Partnering with institutions experienced in green infrastructure management can also support the development and enhancement of policy and planning frameworks in Tshwane, helping in aligning the city's asset management strategies with national and international best practices and ensuring consistency and coherence in decision-making processes. Partnering with other entities successfully could also attract additional stakeholders and enlarge the platform for knowledge exchange, joint research, collective advocacy and amplifying the CoT's influence in green infrastructure management. Below are organisations that the CoT could potentially partner with.

4.5.1 The South African National Biodiversity Institute (SANBI)

In addition to offering a wealth of expertise, SANBI could provide municipalities with access to extensive databases related to ecosystems that fall within the city's boundaries. Additionally, SANBI can provide technical assistance during the assessment and valuation phases and building initiatives that can enhance the knowledge and skills of the municipality's asset management teams. The municipality would also benefit from SANBI's experience in public awareness and education campaigns. These would raise awareness among citizens, stakeholders, and local communities, fostering public support and ensuring the longevity of the incorporated green infrastructure.

SANBI is currently implementing Global Environmental Facility (GEF) funded Ecological Infrastructure for Water Security (EI4WS) project in partnership with the Department of Environmental, Forestry and Fisheries (DFFE) and the Development Bank of South Africa (DBSA). The project aims to develop policy and capacity incentives for mainstreaming biodiversity and ecosystem values into national, regional and local development policy and finance.

The Nature Conservancy (TNC) launched the Greater Cape Town Water Fund (GCTWF), and work began to ensure the city has the water it needs for its citizens, businesses, and the economically important agricultural sector. TNC has helped establish more than 40 water funds worldwide since 2001, and there are more than 15 water funds in Africa in various stages of development. CoT could benefit from these types of initiatives.

4.5.2 The International Council for Local Environmental Initiatives (ICLEI) and Gauteng City-Region Observatory (GCRO)

ICLEI and GCRO can provide the municipalities with technical guidance and tools such as frameworks, methodologies and best practices for assessing, valuing and effectively incorporating green infrastructure considerations into its asset management systems (Bobbins et.al, 2019). These networks can also provide policy support and advocacy, ensuring that the municipality's asset management policies meet global standards. This collaboration could also give access to more funding opportunities by providing guidance on grant applications and sharing information on available financial mechanisms for sustainable asset management projects.

4.5.3 Government Departments

The mandate of the DWS as set out in the National Water Act (1998), is to ensure that the country's water resources are protected, managed, used, developed, conserved, and controlled by regulating and supporting the delivery of effective water supply that is critical for delivering on the people's right to have access to sufficient food and water, growing the economy and eradicating poverty.

CMAs are responsible for water resources management in their Water Management Area (WMA). Thus, the purpose of CMAs is the delegation of water resource management to a catchment level, within the framework of the National Water Resource Strategy:3 (DWS, 2022) of the Department. The CMA achieves this through developing and implementing a Catchment Management Strategy (CMS). The CMS provides the framework for management of water resources in a WMA.

This partnership would enable the CoT to leverage the department's technical expertise, policy support, data sharing, and capacity-building initiatives. These government institutions would be able to support the CoT in establishing/ maintaining monitoring and evaluation mechanisms for assessing the health and status of green infrastructure through joint monitoring programs, data collection initiatives and evaluation frameworks. The department could also provide guidance on applying for available grants, funding programs, and funding mechanisms for sustainable asset management projects.

4.1 STAKEHOLDER ENGAGEMENT WITH CITY OF TSWHANE

As this framework is to be utilised by municipalities, extensive consultation with CoT throughout the project was done, to better understand practicality of integrating green infrastructure into municipal asset management system. This was done through several meetings and a dissemination workshop. The discussion indicated that CoT have technical skills and tools to implement this framework, although an awareness on financial benefits for implementing the framework is limited. The aim is then to utilise the outcome of this work as a demonstration to CoT decision makers, and beyond CoT. The discussions assisted in developing the framework/guideline as shown in chapter 6 of this report.

4.2 SUMMARY

To conclude, many of the systems necessary for the successful integration of green infrastructure into CoT's register (and others) are already in place. South Africa has the required environmental compliance interventions, and the tools and frameworks for wetland delineation, restoration, health assessment, and economic valuation are available, along with GRAP standards for asset management. There is also the opportunity for collaboration with entities like SANBI, ICLEI, and gov depts such as DWS, DFFE, Stats-SA could help mitigate capacity and budgetary challenges. However, potential challenges include the need for additional technical capacity (skills) and budget to manage the increased workload. While CoT has competent multidisciplinary staff for wetland delineation and evaluation, the specialist capacity for economic valuation, essential for meeting GRAP standards, is lacking. Budget constraints further complicate project implementation.

The challenge of investing in green infrastructure on privately owned land is multifaceted, involving intricate legal, historical, and procedural hurdles. Effective management of these challenges is crucial to ensure the successful implementation and sustainability of green infrastructure projects that benefit the entire municipality. The CoT’s overall readiness to implement the project is given in Table 4-1 below:

Table 4-1. A summary analysis of CoT's readiness to implement the integration of green infrastructure into the asset management system

Pillar	Analysis	Readiness
Institutional capacity and skills	To implement the green infrastructure asset register, the CoT would require additional technical capacity and budget to effectively cope with the additional workload. Capacity and budget constraints are discussed briefly: 1. The CoT has a competent, multidisciplinary staff which would be able to delineate and evaluate the health of a wetland and then incorporate these wetlands into the current asset management system. However, the valuation of the wetland would require specialist capacity, which is currently not available in-house. Assigning economic value to the wetland would be required to meet the GRAP accounting standards of assets management systems to which all municipalities subscribe and would be vital to ensure that green infrastructure assets are incorporated. 2. Budget allocations for additional capacity are unlikely to be available due to the current financial constraints facing the CoT.	Lack of environmental economic valuation capacity and budget are likely to be major constraints to implement the project successfully.
Country practices and support	South Africa has interventions aimed at promoting environmental compliance, enforcing regulations, and holding accountable those who fail to adhere to the established standards.	It is unlikely that this would be a barrier to implementation.
Data availability and tools	The analysis show that there are, 1. Tools for wetland delineation, restoration and health/condition determination 2. Frameworks and tools for economic valuation of natural resources. 3. Standards for asset management i.e., GRAP	The availability of tools, frameworks and standards would allow the CoT to implement the project.
Partnerships and peer learning	Taking into consideration the capacity and budget constraints faced by the CoT, collaboration with the both the government and private sectors could be a potential solution for implementation. Partners such as SANBI, ICLEI, GCRO, DWS, Water boards and DFFE could provide the necessary support required.	Collaboration with partners could assist in allying capacity and budgetary constraints.

5 CASE STUDY: CITY OF TSHWANE METROPOLITAN MUNICIPALITY

5.1 OVERVIEW

This chapter demonstrates how to integrate green infrastructure into formal urban asset management systems through a case study in Tshwane Metropolitan Municipality. It outlines a step-by-step approach, starting with the identification and delineation of ecological assets. The process continues with classifying these assets based on their impact and ecological status, followed by a financial valuation that evaluates both their benefits to the municipality and the costs of their maintenance.

The study area in the City of Tshwane MM is in quaternary A23A within the Apies-Pienaar's tertiary catchment A23 of Limpopo Water Management Area (WMA), as shown in Figure 5-1. The quaternary catchment includes the A23A-01072 portion of the Hartbeesspruit in its entirety, and the downstream portion of A23A-01074 which is the Moretele River, both joining Moreletaspruit in Pretoria East before flowing into the Roodeplaat Dam. As a result of high urban pressures, these tributaries are in poor condition.

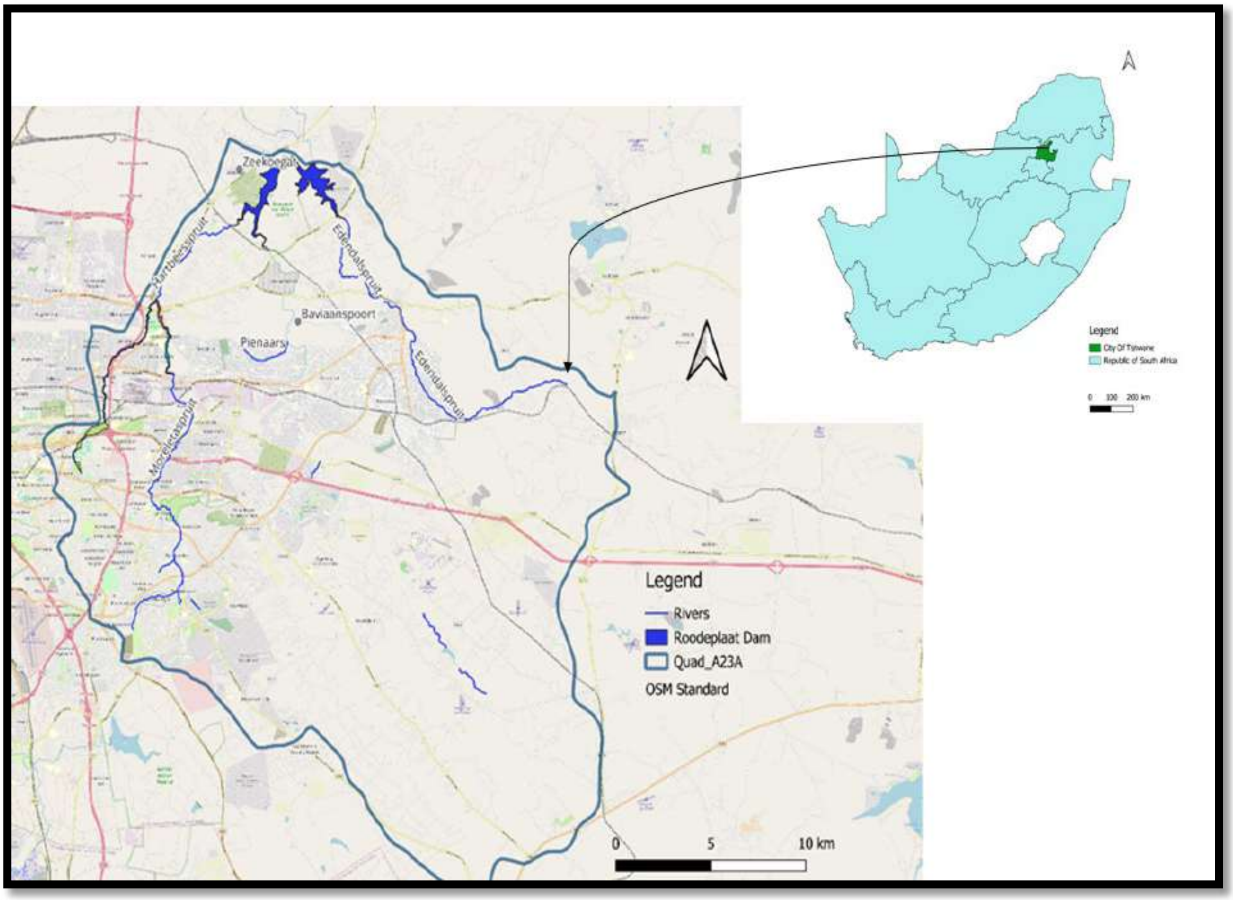

Figure 5-1. The location of the City of Tshwane in the Republic of South Africa and the quaternary A23A as the study area

5.2 THE CONDITION OF THE AREA

The Roodeplaat Dam, located approximately 24 km northeast of Pretoria, is a critical water resource supplying potable water to the provinces of Gauteng, Northwest, and Limpopo. It receives water from three significant tributaries: the Pienaar's, Edendalespruit, and Hartbeesspruit Rivers. The catchment areas include urban, agricultural, and natural land uses, presenting distinct challenges for land and water management (Mthembu et al., 2019). Poorly treated domestic wastewater and diffuse nutrient loading from agriculture and informal settlements threaten these water resources by altering ecosystem functions and reducing water quality (Nemutamvuni et al., 2020). Despite its importance, the Roodeplaat Dam suffers from high levels of eutrophication, algae, and water hyacinths, which degrade its biophysical integrity (Maruapula, 2020). The dam also faces pollution from aged and poorly maintained wastewater treatment works (WWTWs) such as the Baviaanspoort and Zeekoegat facilities as shown in Figure 5-2 (Edokpayi et al., 2015; Mnyango et al., 2022).

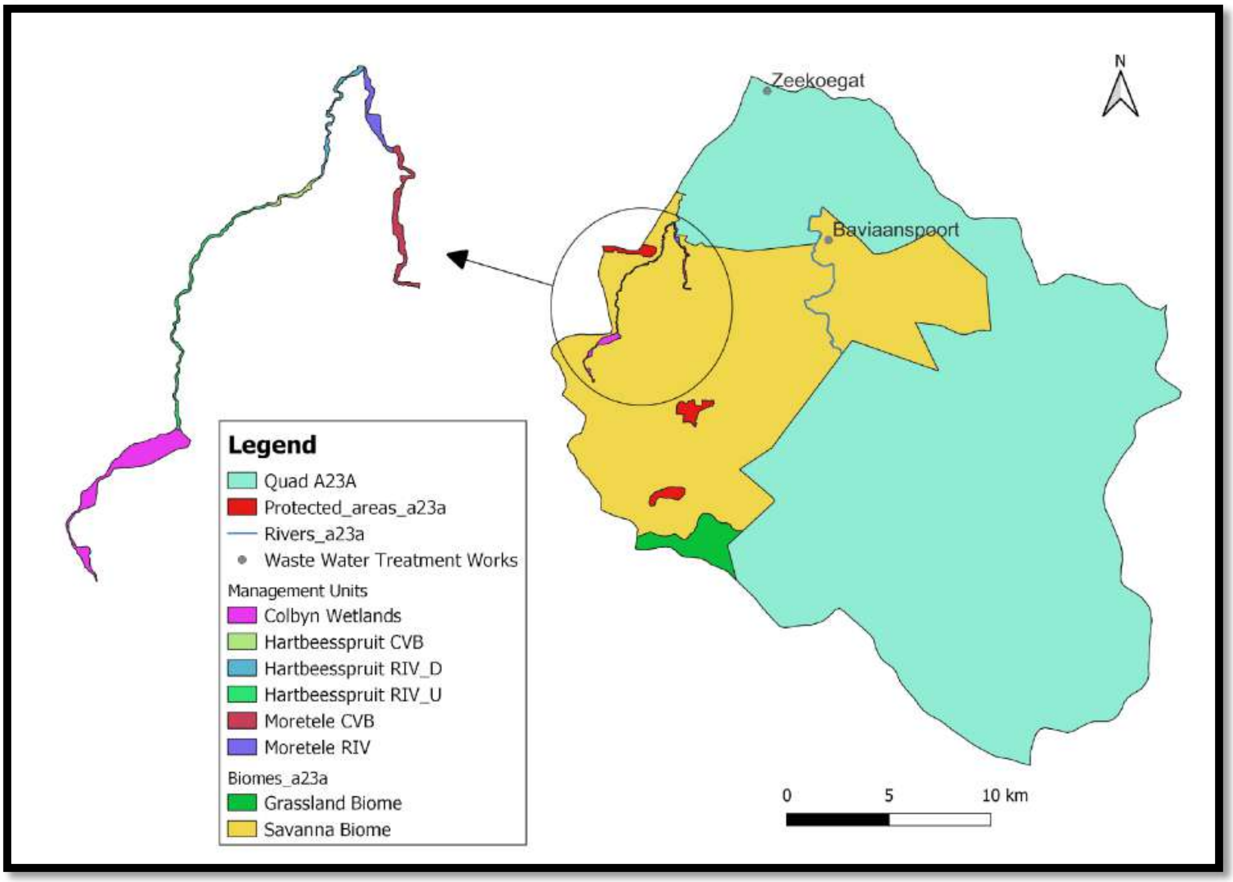

Figure 5-2. Study area showing Wastewater Treatment Works

The Colbyn Valley Wetland is a critical ecological resource (GI), comprising a 4.68-hectare peatland area (Delport, 2016). It offers essential ecosystem services such as water purification, flood and erosion mitigation, and carbon sequestration (Helson, 2012). However, the wetland faces degradation from urban expansion and historical agricultural use, including drainage ditches and irrigation trenches (Sherwill, 2015). Despite being designated as a conservation area, the wetland is threatened by potential land use changes for development projects (Nemutamvuni et al., 2020). The wetland remains crucial for local water supply and recreational activities and is a designated Critical Biodiversity Area (Nemutamvuni et al., 2020).

The Pienaar’s River, known as the Moretele River in Mamelodi, flows through informal settlements with poor sanitation, turning into a dumping site due to lack of service delivery. The river serves as a migration passageway for indigenous fauna and provides recreational and aesthetic value. However, the river's health is compromised by population density, industrialization, and commercialization, leading to pollution, habitat degradation, and alien vegetation intrusion.

The Hartbeespruit River, plays a fundamental role in water supply, ecological sustainability, and urban development in Pretoria (Smith et al., 2017). This riverine system provides habitats for diverse flora and fauna, supporting aquatic life and biodiversity. However, urbanization and human activities threaten the river with pollution and habitat degradation, affecting water quality. Despite these challenges, the river is utilized for recreational activities such as birdwatching and trekking.

5.2.1 CLASSIFICATION OF THE PRESENT ECOLOGICAL STATUS OF MANAGEMENT

EcoClassification as shown in Table 5-1, the term used for Ecological Classification, refers to the determination and categorisation of the Present Ecological State (PES) of various biophysical attributes of rivers compared to the natural or close to natural reference condition. The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river.

Ecological Importance (EI) of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological Sensitivity (ES) refers to the system’s ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience) (Resh et al. 1988; Milner 1994). Ecological Importance and Sensitivity (EIS) provides a guideline for the determination of the ecological management class. When EIS is high or very high, the ecological aim should therefore be to improve the condition of the river. However, the causes related to a particular PES should also be considered to determine if improvement is realistic and attainable. This relates to whether the problems in the catchment can be addressed and mitigated. If the EIS evaluated as moderate or low, the ecological aim should be to maintain the river in its PES. Ecological Categories A to D can be recommended as future states depending on the EIS and PES. Ecological Categories E and F PES are regarded as ecologically unacceptable, and remediation is needed (Kleynhans, 2007).

Table 5-1: Ecological categories for Eco-Status components (modified from Kleynhans 1996 & Kleynhans 1999).

Ecological Category	Description	Impact Score
A	Unmodified, natural	0-0.9
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	1-1.9
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	2-3.9
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	4-5.9
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	6-7.9
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible	8-10

Moretele River and Hartbeesspruit River have been seriously modified and both have been assessed as ecological category “E” (DWS, 2014). Both have a low Ecological Importance (EI), and moderate Ecological Sensitivity (ES) (DWS, 2014).

A summary of the PES, EI and ES is shown for the Moretele River in Table 5-2, and the Harbeesspruit in Table 5-3 respectively (DWS, 2014).

Table 5-2: Summary of the PES, EI and ES for the Moretele River (A23A-01074; DWS, 2014).

PRESENT ECOLOGICAL STATE		ECOLOGICAL IMPORTANCE				ECOLOGICAL SENSITIVITY	
INSTREAM HABITAT CONTINUITY MOD	LARGE	FISH Species/Sub quat reach (SQ)	6.00	INVERT TAXA/SQ	34.00	FISH PHYS-CHEM SENS DESCRIPTION	MODERATE
RIP/WETLAND ZONE CONTINUITY MOD	LARGE	FISH: AVERAGE CONFIDENCE	4.33	INVERT AVERAGE CONFIDENCE	4.47	FISH NO-FLOW SENSITIVITY DESCRIPTION	HIGH
POTENTIAL INSTREAM HABITAT MOD ACT.	SERIOUS	FISH REPRESENTIVITY PER SECONDARY: CLASS	LOW	INVERT REPRESENTIVITY PER SECONDARY, CLASS	MODERATE	INVERT PHYS-CHEM SENS DESCRIPTION	MODERATE
RIPARIAN-WETLAND ZONE MOD	SERIOUS	FISH REPRESENTIVITY PER SECONDARY: CLASS	LOW	INVERT RARITY PER SECONDARY: CLASS	HIGH	INVERTS VELOCITY SENSITIVITY	VERY HIGH
POTENTIAL FLOW MOD ACT.	SERIOUS	FISH RARITY PER SECONDARY: CLASS	VERY HIGH	ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING	LOW	RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) INTOLERANCE WATER LEVEL/FLOW CHANGES DESCRIPTION	LOW
POTENTIAL PHYSICO-CHEMICAL MOD ACTIVITIES	SERIOUS	ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING	LOW	HABITAT DIVERSITY CLASS	LOW	STREAM SIZE SENSITIVITY TO MODIFIED FLOW/WATER LEVEL CHANGES DESCRIPTION	LOW
		RIPARIAN-WETLAND NATURAL VEG RATING BASED ON % NATURAL VEG IN 500m (100%=5)	LOW	HABITAT SIZE (LENGTH) CLASS	LOW	RIPARIAN-WETLAND VEG INTOLERANCE TO WATER LEVEL CHANGES DESCRIPTION	**LOW**
		RIPARIAN-WETLAND NATURAL VEG IMPORTANCE BASED ON EXPERT RATING	LOW	INSTREAM MIGRATION LINK CLASS	MODERATE		
				RIPARIAN-WETLAND ZONE MIGRATION LINK	MODERATE		
				RIPARIAN-WETLAND ZONE HABITAT INTEGRITY CLASS	LOW		
				INSTREAM HABITAT INTEGRITY CLASS	LOW		

Table 5-3: Summary of the PES, EI and ES for the Hartbeesspruit (A23A-01072; DWS, 2014).

PRESENT ECOLOGICAL STATE		ECOLOGICAL IMPORTANCE				ECOLOGICAL SENSITIVITY	
INSTREAM HABITAT CONTINUITY MOD	LARGE	**FISH Species/Sub quat reach (SQ)**	3.00	**INVERT TAXA/SQ**	33.00	**FISH PHYS-CHEM SENS DESCRIPTION**	LOW
RIP/WETLAND ZONE CONTINUITY MOD	SERIOUS	**FISH: AVERAGE CONFIDENCE**	1.00	**INVERT AVERAGE CONFIDENCE**	2.70	**FISH NO-FLOW SENSITIVITY DESCRIPTION**	MODERATE
POTENTIAL INSTREAM HABITAT MOD ACT.	SERIOUS	**FISH REPRESENTIVITY PER SECONDARY: CLASS**	VERY LOW	**INVERT REPRESENTIVITY PER SECONDARY, CLASS**	MODERATE	**INVERT PHYS-CHEM SENS DESCRIPTION**	MODERATE
RIPARIAN-WETLAND ZONE MOD	SERIOUS	**FISH REPRESENTIVITY PER SECONDARY: CLASS**	VERY LOW	**INVERT RARITY PER SECONDARY: CLASS**	MODERATE	**INVERTS VELOCITY SENSITIVITY**	VERY HIGH
POTENTIAL FLOW MOD ACT.	SERIOUS	**FISH RARITY PER SECONDARY: CLASS**	VERY LOW	**ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING**	LOW	**RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) INTOLERANCE WATER LEVEL/FLOW CHANGES DESCRIPTION**	LOW
POTENTIAL PHYSICO-CHEMICAL MOD ACTIVITIES	SERIOUS	**ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING**	LOW	**HABITAT DIVERSITY CLASS**	VERY LOW	**STREAM SIZE SENSITIVITY TO MODIFIED FLOW/WATER LEVEL CHANGES DESCRIPTION**	LOW
		RIPARIAN-WETLAND NATURAL VEG RATING BASED ON % NATURAL VEG IN 500m (100%=5)	LOW	**HABITAT SIZE (LENGTH) CLASS**	VERY LOW	**RIPARIAN-WETLAND VEG INTOLERANCE TO WATER LEVEL CHANGES DESCRIPTION**	**HIGH**
		RIPARIAN-WETLAND NATURAL VEG IMPORTANCE BASED ON EXPERT RATING	HIGH	**INSTREAM MIGRATION LINK CLASS**	MODERATE		
				RIPARIAN-WETLAND ZONE MIGRATION LINK	LOW		
				RIPARIAN-WETLAND ZONE HABITAT INTEGRITY CLASS	LOW		
				INSTREAM HABITAT INTEGRITY CLASS	LOW		

5.3 DELINEATION OF THE STUDY AREA

5.3.1 Approach

The delineation of wetlands was essential for efficient management and conservation purposes of the green infrastructure. It promotes precise implementation of strategies that cater to specific ecological and hydrological requirements, guaranteeing optimal resource allocation and improved monitoring.

A South African, standardized methodology for identifying and delineating wetlands that is widely accepted and implemented, primarily developed by the Department of Water and Forestry was used (DWAF,2008). The key manual was initially produced in 2005 (currently being updated), outlines comprehensive methods using four main indicators to identify wetland types:

1. **Landscape Position:** This involves identifying regions where wetlands are typically found based on the feature's location in the landscape.
2. **Soil Form:** The presence of soil types that are associated with wetlands is used as a significant indicator.
3. **Species Composition:** Wetlands are identified by the presence of plant species that predominantly occur in wetland environments.
4. **Redoximorphic Features:** These are morphological characteristics in soils that appear due to prolonged periods of moisture, indicating the presence of a water table.

While both identification and delineation are crucial, delineation takes precedence during formal assessments such as Environmental Impact Assessments (EIA) and Water Use License Applications (WULA). Precise boundaries are required to map and designate wetlands as sensitive areas. For wetland delineation, the guideline proposes the following features:

1. **Redoximorphic Features:** Used as a proxy for indicating the depth of the water table.
2. **Presence and Position of Wetland Vegetation:** Different regions of the legally defined wetland zones are occupied by obligate and facultative species.

5.3.2 Delineation method

Desktop Analysis and ground truthing: This included the HGM unit and condition. Attribute data were extracted for Hartbeespruit river and mapped using the 1:500 000 Rivers GIS data layer (DWAF, 2006). Attributes refer to the specific properties of an asset component, such as type, size, class, condition, location, and identity. Attribute data for the Colbyn Valley Wetland was extracted from the SANBI, NBA, 2018 National Wetland Map 5 GIS data layer (Van Deventer et al. 2018). The Hartbeespruit river was divided into five sections (A, B, C, D & E) based on the GEO-ZONES the river passes through towards the Roodeplaat Dam.

5.4 DELINEATION OF MANAGEMENT UNITS

The study designated a total of six management units, with three of them classified as riverine wetlands and the remaining three classified as Channelled Valley Bottom (CVB) wetlands (see Figure 5-3). The delineation of these areas was determined according to criteria such as land use, ecosystem services, water resource management, floodplain management, and biodiversity conservation. Furthermore, these concepts will be elaborated upon in subsequent sections and then employed in the asset register.

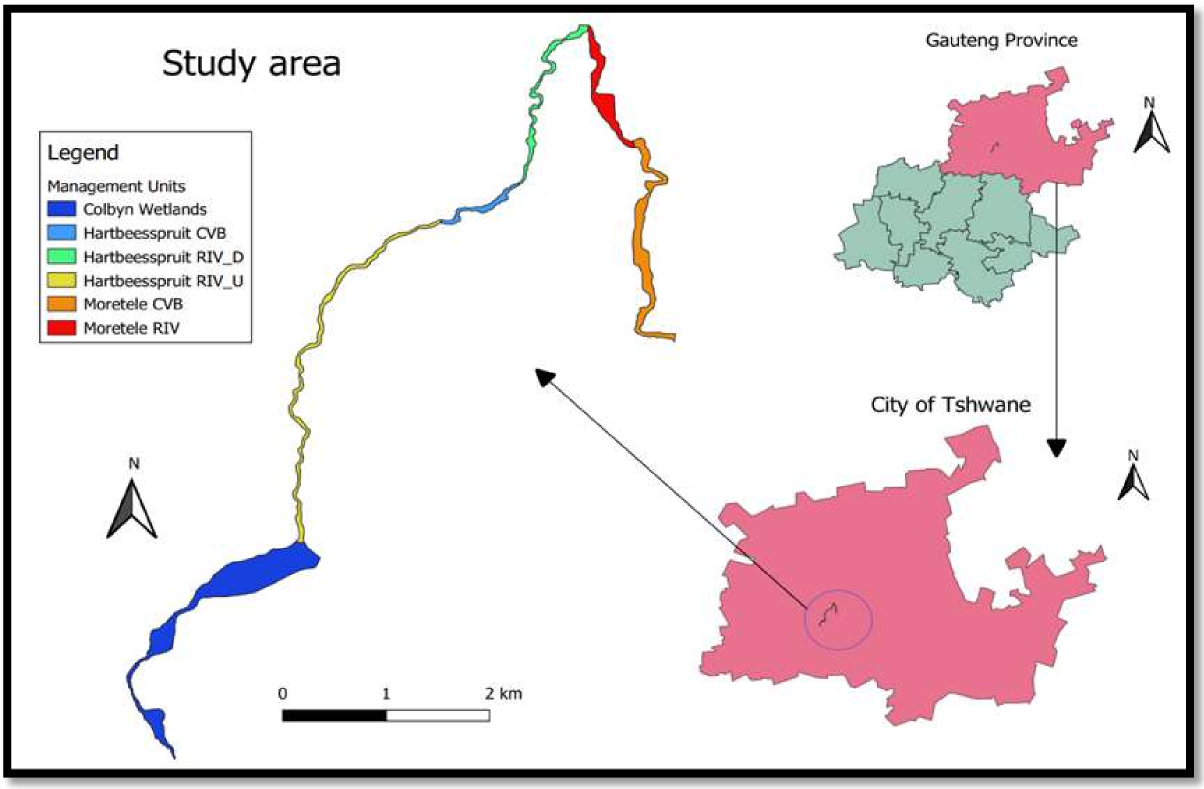

Figure 5-3. Map showing the management units along the Hartbeesspruit and Moretele rivers within the study area

The overall approach was to quantify the impacts of both human activities, urban development and clearly visible impacts on the stream's health. This process considered the assessment of the spatial extent of the impact of individual activities/occurrences. Then separately assessed the intensity of impact of each activity in the affected area. The extent and intensity were therefore combined to determine an overall magnitude of impact.

Table 5-4. The extent to which the ecological asset functionality is impacted

Management Unit	Impact Category	Conditions	Impact on Management units	Impact Score Range	Present Ecological State
Colbyn Wetlands	**Largely modified**	Channel incision in the Colbyn wetlands, wildfire and dumping	**Critical:** Channel incision	**4-5.9**	**D**
			Serious: Vegetation removal		
			Moderate: Alien species		
Hartbeesspruit Channelled Valley Bottom	**Seriously modified**	Wildfires, dumping, bank destabilisation, vegetation removal and alien plant species	**Critical:** Runoff/effluent: Urban areas, Urbanization	**6-7.9**	**E**
			Serious: Algal growth, Bed and Channel disturbance, Increased flows, Vegetation removal		
			Moderate: Canalization, Low water crossings, Small (farm) dams, Erosion, Roads		
Hartbeesspruit Riverine_D	**Seriously modified**	Stream incision, alien species, vegetation removal, bank destabilisation,	**Critical:** Runoff/effluent: Urban areas, Urbanization	**6-7.9**	**E**
			Serious: Algal growth, Bed and Channel disturbance, Increased flows, Vegetation removal		
			Moderate: Canalization, Low water crossings, Small (farm) dams, Roads,		

Management Unit	Impact Category	Conditions	Impact on Management units	Impact Score Range	Present Ecological State
Hartbeesspruit Riverine_U	**Seriously modified**	Stream incision, alien species, vegetation removal, bank destabilisation,	**Critical:** Runoff/effluent: Urban areas, Urbanization **Serious:** Algal growth, Bed and Channel disturbance, Increased flows, Vegetation removal **Moderate:** Canalization, Low water crossings, Small (farm) dams, Roads,	**6-7.9**	**E**
Moretele Channelled Valley Bottom	**Seriously modified**	Wildfires, dumping, bank destabilisation, vegetation removal and alien plant species	**Critical:** Runoff/effluent: Urban areas, Urbanization **Serious:** Algal growth, Bed and Channel disturbance, Increased flows, Vegetation removal **Moderate:** Canalization, Low water crossings, Small (farm) dams, Erosion, Roads	**6-7.9**	**E**
Moretele Riverine	**Seriously modified**	Stream incision, alien species, vegetation removal, bank destabilisation,	**Critical:** Channel incision **Serious:** Vegetation removal **Moderate:** Alien species	**6-7.9**	**E**

5.5 THE COST OF MITIGATION AND REQUIRED INTEVENTIONS

This section provides a comprehensive analysis of the rehabilitation options and associated costs for managing various wetland and riverine systems within the City of Tshwane. The costs will be part of the integration into asset management register and the prioritized management units have been evaluated in terms of interventions required to enhance their ecological functions and the ecosystem services they provide.

5.5.1 Mitigation options for the management units

The management units were prioritised in terms of improving the system and enhancing ecosystem services provided by the stretch.

5.5.1.1 Colbyn Valley Wetland

Suggested mitigation options and interventions required to improve from D to C in the Colbyn Wetland system include:

- Maintenance of gabion infrastructure – which is required to control erosion and prevent further channel incision.
- Monitoring – to ensure ongoing oversight and management of the system.
- Measurement weirs – installation of weirs is required to assist with monitoring and gathering data.
- Retention ponds – required to manage the delivery of stormwater to the system and promote a more naturalised hydrological regime.
- Pollution control measures– this will assist with the purification function of the wetland.
- Fire breaks – required to prevent damage to the system and provides protection for surrounding infrastructure.
- Maintenance – required to maintain the ecological integrity of the system.
- Birding infrastructure – this will enhance the aesthetic and recreational services provided by the systems.

5.5.1.2 Hartebeespruit _CVB

Suggested mitigation options and interventions required include:

- Gabion infrastructure – to provide structural support, preventing the collapse of banks due to water flow and the erosive forces of currents. This is particularly important in this area since it is prone to soil erosion and the natural vegetation is insufficient for stabilization.
- Re-vegetation – to contribute to the overall resilience of wetland ecosystems in the face of climate change. Native plants are often better adapted to local environmental conditions, making the

ecosystem more robust and resistant to changes. It also restores natural processes and provides bank stabilisation while improving infiltration and reducing surface runoffs.

- Maintenance - required to maintain the ecological integrity of the system.
- Measurement weirs - installation of weirs is required to assist with monitoring and gathering data.
- Monitoring - to ensure ongoing oversight and management of the system.

5.5.1.3 Haertebeespruit Riverine U & D

Suggested mitigation options and interventions required include:

- Clearing alien vegetation – to restore more natural vegetation structure and improve biodiversity in the area. To prevent fire risks and water resource depletion.
- Measurement weirs – installation of a weir is required to assist with monitoring and gathering data.
- Monitoring – to ensure ongoing oversight and management of the system.
- Maintenance – required to maintain the ecological integrity of the system.
- Gabion infrastructure – to prevent incision and control erosion. To also control the channel lining

5.5.1.4 Moretele CVB

Suggested mitigation options and interventions required include:

- Gabion infrastructure – to control and possibly reverse incision.
- Re-vegetation – to restore natural processes and provide bank stabilisation. For flood control, soil erosion prevention, carbon sequestration and water quality improvement.
- Maintenance – required to maintain the ecological integrity of the system.
- Measurement weirs – installation of weirs is required to assist with monitoring and gathering data.
- Monitoring – to ensure ongoing oversight and management of the system.

5.5.1.5 Moretele Riverine

Suggested mitigation options and interventions required include:

- Clearing alien vegetation – to restore more natural vegetation structure and improve biodiversity in the area. To reduce fire breaks since some alien species are highly flammable and to reduce water resource depletion since some alien species have high water requirements.
- Measurement weirs – installation of a weir is required to assist with monitoring and gathering data.
- Monitoring – to ensure ongoing oversight and management of the system.

- Maintenance – required to maintain the ecological integrity of the system.
- Gabion infrastructure – to prevent incision and control erosion.

5.5.2 Methodology for assessing EC of improvements

Expert opinion / knowledge was used, together with metrics in the DWS PES-EI-ES model (DWS, 2014; currently being updated), based on perceived improvements emanating from suggested interventions and the new, altered score has been listed as the “Ecological State achievable with interventions” (Table 5-5). The following interventions were related to the following metric changes:

- Removal of invasive alien plants species (which includes Eucalyptus, Weeping willow, Poplar, Wattle, Syringa, Tipu trees, Spanish reeds) – improves both the “riparian zone continuity modification” and the “riparian zone modification” metrics by 1 (one) point e.g. from 4 to 3.
- Buffering / managing delivery of storm water to the system (such as retention ponds) will promote more naturalised hydrological regime, particularly from headwater stream environment that delivers water to the wetland system – improves the “flow modification” by 1 (one) point.
- Prevent vegetation removal and / or bank destabilisation by surrounding land-use activities – improves the “riparian zone modification” metrics by 1 (one) point if the metric is already 3 or worse.
- Maintain / install stormwater pollution structures, (i.e., sediment trap), to – improves the “Potential physico-chemical modification” metric by 1 (one) point.

Table 5-5: Ecological state achievable with interventions per management unit

Management Unit	Present Ecological State	Ecological state achievable with interventions
Colbyn Wetland	**D**	**C**
Hartbeesspruit Channelled Valley Bottom	**E**	**D**
Hartbeesspruit Riverine_D	**E**	**D**
Hartbeesspruit Riverine_U	**E**	**D**
Moretele Channelled Valley Bottom	**E**	**D**
Moretele Riverine	**E**	**D**

5.5.3 Cost of Mitigation

Each of the mitigation options set out above were costed to determine the total cost of mitigation for each management unit in present value (2023) terms. Cost information was obtained from van Zyl, et al. (2004) who studied the costs and benefits of urban river and wetland rehabilitation projects in the City of Cape Town. These costs include capital costs such as gabion infrastructure, measurement weirs and earthworks to name a few as well as annual costs. In that study the annual costs were discounted to a present value over 30 years.

To cost the mitigation options in this study, the capital costs from van Zyl, et al. (2004) were inflated at an annual rate of inflation of 4.98% from 2004 to 2023 to arrive at the cost in 2023 terms. The present value of the annual costs in van Zyl, et al. (2004) were first translated into an annual amount and then inflated at the annual rate of inflation to arrive at the annual cost in 2023 terms. This methodology was used for the costing of items such as gabion infrastructure and the maintenance of gabion infrastructure, the cost of measurement weirs, the cost of site clearance and maintenance costs. Maintenance costs would be incurred annually and includes general expenses, site clearing, landscaping and waste collection as well as some contingencies and provisional expenses. The maintenance cost for the Colbyn Wetland system includes the cost of maintaining the retention ponds.

Monitoring costs would also be incurred annually and includes costs for managerial oversight, specialised programme subscriptions, administration costs and other services required such as site visits. These costs were sourced from discussions with organisations, such as Birdlife, who implement wetland rehabilitation projects. The cost of clearing alien vegetation was also sourced from discussions with these organisations and these costs are usually incurred for 3 – 5 years.

The cost for retention ponds were sourced from available literature, such as the Minnesota Stormwater Manual in the USA specifically the section on ponds, as well as costs relating to ponds for the treatment of water thus providing a range of costs. A reasonable cost within this range was then selected for the cost of the retention pond for the Colbyn Wetland system. The cost of pollution and waste control measures were sourced from available research, namely a report on current technologies for waste capture in river systems authored by the Benioff Ocean Initiative in 2021 (Benioff Ocean Initiative, 2021). A range of different technologies were analysed and the average cost of these was used and adjusted to 2023 terms.

The cost for the birding infrastructure was sourced from a publication by SANParks regarding the construction of a bird hide in the West Coast National Park (SANParks Honorary Rangers, 2023). The re-vegetation cost was determined by taking the estimated portion of the management unit that will undergo re-vegetation (in square meters) and multiplying that by the unit cost (R/m^2). The estimated portion that will undergo re-vegetation represents the portion of the entire management unit that will experience replanting of native vegetation. This was determined from a Working for Wetlands rehabilitation plan for wetlands in Mpumalanga (SANBI, 2014). This plan included the total area of the wetland, the area of re-vegetation and the unit cost per square meter. From this the average portion of a wetland experiencing re-vegetation could be derived as a percentage of the total wetland area. This average portion was multiplied by the size of the management unit to determine the area being revegetated in square meters. This was multiplied by the unit cost in 2023 terms to determine the total cost of re-vegetation.

The cost of rehabilitating all the management units is around R12.2 million per year. The total costs for each management unit were discounted over a 20-year period at 11.75% to arrive at a Net Present Value (NPV) for the costs. The 11.75% was used as a discount rate because we are discounting financial costs, and that rate represents current money market rates. The NPV of the total cost of mitigation (cost to implement mitigation options described above) for each management unit is indicated in Table 5-6. These values will go into the proposed asset register for the City of Tshwane MM.

Table 5-6. NPV of total cost of mitigation for each management unit

Management Unit	NPV of cost of mitigation over 20-year period
Colbyn Wetlands	R20,051,058
Hartbeesspruit Channelled Valley Bottom	R12,808,609
Hartbeesspruit Riverine_ D	R12,318,476
Hartbeesspruit Riverine_ U	R23,693,908
Moretele Channelled Valley Bottom	R20,092,197
Moretele Riverine	R15,701,457
Total	R104,665,705

5.6 FINANCIAL BENEFITS TO CITY OF TSHWANE MM

It is well understood that wetlands and green infrastructure provide ecosystem service benefits, but they can also provide financial benefits. It is important to note that only financial amounts should be included in the asset register as this asset register will be used in part of the generation of the financial statements for the municipality. Thorough analysis was done on the potential for the green infrastructure considered in the case study to provide financial benefits for the City of Tshwane. While there are upfront and annual costs associated with wetland conservation, and rehabilitation, the long-term benefits often outweigh these expenses. It was determined that the conservation, and rehabilitation of the green infrastructure can provide the following financial benefits to City of Tshwane Metropolitan Municipality:

- Water purification – Healthy-functioning wetlands and serve as natural water purifiers by employing a range of mechanisms. Acting as effective filters, wetlands facilitate the settling of suspended particles and sediments, reducing turbidity in water. They play a crucial role in nutrient removal, particularly nitrogen and phosphorus, preventing these substances from reaching downstream. Wetland vegetation and microbial communities contribute to the uptake, transformation, and decomposition of pollutants, while wetland soil acts as a sink for various contaminants. Additionally, wetlands serve as buffers, slowing down and capturing runoff, allowing for the natural settling of pollutants. The combined actions of filtration, nutrient regulation, microbial activity, and pollutant retention underscore the vital role of wetlands in purifying water and sustaining healthy aquatic ecosystems. This ultimately saves costs for the treatment plant. This was demonstrated through a rehabilitation of Zaalklap wetland in Mpumalanga Province (WRC Report No. 2230/2/16).

- Storm water management:
  - Well-functioning wetlands are integral to effective stormwater management through their natural processes. Acting as sponges, wetlands absorb and store excess rainwater during storms, preventing immediate downstream flooding. They play a crucial role in slowing down the release of water, acting as natural buffers against sudden surges. By stabilizing soil and reducing erosion, wetland vegetation helps mitigate the impacts of stormwater runoff. This can prevent wear and tear on surrounding stormwater infrastructure assets. Thus, extending the useful life of these stormwater assets.
  - Riverine areas provide critical ecosystem services, including: surface water supply, flood reduction, regulation of dry season flows, erosion and sedimentation reduction, food production, water quality maintenance, solid waste capture, diversity of habitats and conservation, maintenance of transport access (Business Case for Durban's TRMP, 2021). eThekwini Municipality's Sihlanzimvelo Stream Cleaning Programme has demonstrated that riverine management on municipal land can reduce damage to municipal road culverts and create many job opportunities in the city's most vulnerable communities.
- Property rates – Properties near wetlands often enjoy higher market rates due to several factors. The scenic value and aesthetic appeal of wetland surroundings make such properties attractive to buyers seeking visually pleasing environments. Additionally, the recreational opportunities provided by wetlands, coupled with their rich biodiversity and ecological value, contribute to a sense of environmental connection, which is increasingly valued in real estate. The role of wetlands in flood mitigation and water regulation adds a layer of safety and resilience, potentially making these properties more appealing. Hence, if wetlands are to be rehabilitated and conserved, the municipality will benefit from the increased rates from high-value property.

5.6.1 Water purification in three water treatment plants

International studies (Waly et al.,2022 and Stefanakis, 2019) have outlined the usefulness of wetlands in water treatment and energy costs reduction. However, a study conducted by Almuktar, et al. (2018) concluded that wetlands were the one of the most suitable in terms of pollutant removal and have advantages due to both low maintenance costs and required energy. In this case, the Roodeplaat, Wallmansthal and Klipdrift WTWs were chosen to demonstrate water purification benefits because the WTWs abstract water from the Roodeplaat dam. These plants are directly affected by the deteriorating water quality of the dam. However, without wetland restoration to improve water quality before abstraction, the costs of treatment are likely to be higher due to the intensified challenges associated with the deteriorating condition of the Roodeplaat Dam.

A conventional treatment process of drinking water has six stages as shown in Figure 5-4. Depending on the quality of water abstracted, the type of treatment technologies and the amount of chemicals used will differ.

Wetland restoration is vital for enhancing water quality, resulting in substantial cost reductions in the operation of water treatment facilities. This is notably evident in the areas of sedimentation, dissolved air flotation (DAF) components, and chemical treatment and energy use. The hypothesis is explained below.

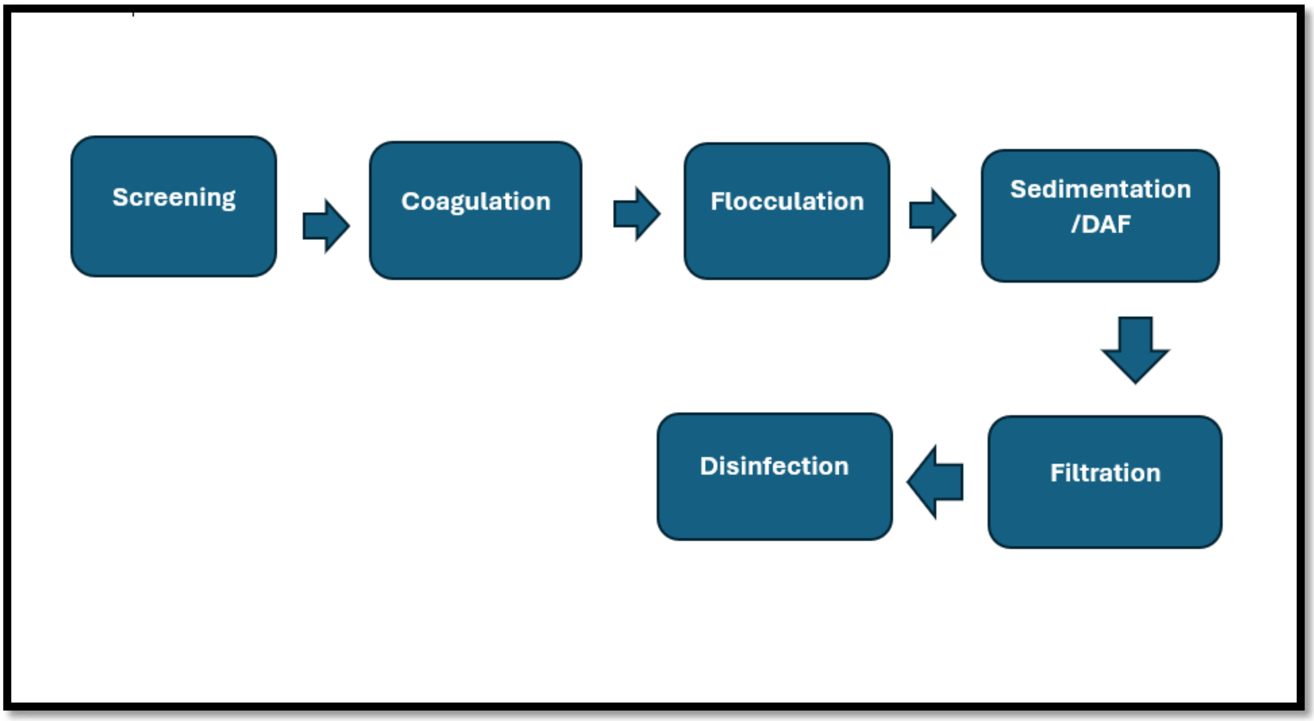

Figure 5-4. Typical example of convectional water treatment plant

Chemical costs

Wetlands act as natural filters, trapping sediments and suspended particles as water passes through the vegetation and soil. By restoring wetlands, there will be a reduction in the amount of sediment entering water sources. This can minimize the need for extensive sedimentation processes in water treatment plants, lowering flocculants (i.e., chemical cost) and maintenance costs.

Electricity costs

Wetlands are effective at removing excess nutrients, such as nitrogen and phosphorus, from the water. Excessive nutrient levels can lead to issues like eutrophication, requiring additional treatment processes in water treatment plants. Wetlands can help control algal growth through nutrient uptake and competition for sunlight. For example, a study conducted by Trepel (2010) assessed the cost-effectiveness of the water purification function of wetlands for environmental planning. Ecological complexity had proven that wetlands are more cost-effective than active treatment such as reverse osmosis for water purification. The study restored healthy aquatic ecosystems by rehabilitating a peatland after 2.1 billion euros were spent on a wastewater treatment plant that didn't have much of an effect on nitrogen. Based on an economic study of the results, the costs range from 70 to 100 € for a 1 kg drop in the P load (Trepel,2010). Furthermore, the model calculations revealed that restoring marshes to improve water quality will costs between 1 and 50 € for every kg of nitrogen that is kept in the soil over a 10-year period. Hence, the argument that wetland rehabilitation and protection is a more cost-effective way to lower nutrient loads.

In the city of Tshwane MM, the WTWs abstracting water from Roodeplaat Dam use DAF systems instead of a slow settling tank, due to an algae problem. The DAF system requires more energy than slow settling tank, to generate and release dissolved air for flotation. When water quality is improved through wetland restoration, the energy requirements for DAF processes will be reduced and less energy-intense sedimentation treatment technology will be utilised.

5.6.1.1 *Chemical and electricity cost reduction due to improved wetlands*

The cost reduction came as a result of rehabilitating all wetlands in all management units, so that cleaner water flows through the system eventually reaching the dam. The cost centre from the city of Tshwane MM and Magalies Water Board 2022 database were used to predict the current usage of chemical and electricity expenses associated with the purification of water in three water treatment plants from the City of Tshwane abstracting water from the Roodeplaat Dam.

The treatment costs (i.e., chemical and energy costs) of the three plants were compared with Rietvlei plant, which utilises less energy-intensive treatment technology due to settling tank treatment method, as shown in the table below.

Table 5-7:Treatment cost of water treatment plants (CoT, 2023)

Water Treatment Works	Operating Capacity (MLD)	Chemical cost	Energy cost	Total
Klipdrift	29.91	R3,826,747	R13,759,167	17,585,914
Wallmansthal	11.6	R1,026,738	R7,446,512	8,473,250
Roodeplaat	25	R898,074	R4,851,089	5,749,163
Rietvlei	40	R1,007,563	R 2,787,871	3,795,434

5.6.1.2 *Water treatment savings due to wetland rehabilitation*

The cost savings represent the energy and chemical costs only. The Rietvlei WTW was used as a reference for estimating the annual savings for chemical and electricity costs, that would occur if wetland rehabilitation were to take place. Based on the information in the table above, the chemical and energy cost for Rietvlei is R3 795 434/ annum for 40 MLD. This is then calculated as R94,885.85/MLD

If we then allocate the above cost per MLD, to WTW abstracting water from the Roodeplat dam, the annual chemical and energy cost would then be:

- Klipdrift WTW: R2,838,035.77 for 29 MLD

- Wallmansthal WTW: R1,100,675.86 for 11.6 MLD
- Roodeplaat WTW: 2,372,146.25 for 25 MLD

The above costs represent the annual costs the WTW would incur if the management units were rehabilitated to PES category D This would result in the following savings for the WTW:

Klipdrit WTW: R14,747,877

Wallmansthal WTW: R7,372,573

Roodeplaat WTW: R3,377,016

Total: R25,497,466

Although the river, upstream of Rietvlei Dam has PES category D (DWS, 2014), recent effort by CoT and NPOs, to improve the condition around the Rietvlei Dam were taken into consideration. Hence a condition factor was considered and is assumed to be 60%, to reflect a more realistic scenario. The condition factor was applied to the annual saving amounts above. The annual savings attributable to each management unit is calculated as follows:

$$TASMU = \left((TS \times CF) \div SMU\right) \times MU$$

Where,

TASMU: Total annual saving attributable to management unit

TS: Total annual saving

CF: Condition Factor

SMU: Total hectares of all the management units

MU: Hectares of individual management unit

The total annual savings is multiplied by the condition factor, and then divided by the total hectares of all the management units. This gives a rand per hectare amount for the total annual saving. The rand per hectare amount was then multiplied by the size of each individual management unit to determine the total annual savings attributable to each individual management unit.

The water treatment cost savings due to rehabilitation of all the management units would result in a cost saving of R13.2 million per year. The total NPV of these benefits is R73.9 million over a 20-year discounting period.

5.6.2 Property rates

Aesthetic and recreational factors stemming from improved green infrastructure can influence the valuations of nearby properties, with several studies showing the existence of this relationship (Crompton, 2004; Mansfield et al., 2005; Maila, et al, (K5/2272).

The calculation process and results for each of the six management units are indicated in the following table:

Table 5-8: Property rates per management unit

	Unit	Colbyn Wetlands	Hartbeesspruit Channelled Valley Bottom	Hartbeesspruit Riverine_D	Hartbeesspruit Riverine_U	Moretele Channelled Valley Bottom	Moretele Riverine
Total rates earned by City of Tshwane (A)	R'million/a	8,574	8,574	8,574	8,574	8,574	8,574
Total value of property (B)	R'million	558,070	558,070	558,070	558,070	558,070	558,070
Current rate earned per Rand property value (C = A ÷ B)	R/R	0.015364	0.015364	0.015364	0.015364	0.015364	0.015364
Number of properties within 500m of management unit (D)	#	957	747	241	2,538	1,135	147
Average value of property within area (E)	R	1,640,000	875,000	1,185,000	1,160,000	1,023,000	2,650,000
Current value of properties within 500m of management unit (F = D × E)	R'million	1,569	653	285	2,944	1,161	389
Property valuation increase (G)	%	23%	23%	23%	23%	23%	23%
New value of properties within 500m of management unit (H = (F × (1 + G))	R'million	1,922	800	349	3,606	1,422	477
Marginal increase in property values (I = H – F)	R'million	353	147	64	662	261	87
Additional property rates earned (C × I)	R/a	5,425,418	2,259,467	987,217	10,177,170	4,013,737	1,346,606

An explanation of the items listed in the above table follows:

- The total rates earned by the City of Tshwane: This value was obtained from the most recent financial census by Stats SA, being 2022.
- Total value of property: Prime Africa Consult completed a study in 2015 which was a valuation of the ecosystem services provided by the Groenkloof Nature Reserve (Fountains Valley) in the City of Tshwane. The total value of property in 2015 was indicated in this study (Prime Africa Consult, 2014). For the purposes of this study, the value of property in the City of Tshwane in 2015 was adjusted to 2023 levels using the Residential Property Price indices published by StatsSA.
- Current rate earned per rand property value: This value is calculated by taking the total rates earned and dividing it by the total value of property.
- Number of properties within 500m of management unit: A GIS analysis was conducted around the study area. Land parcel data, from GIS Departments at the City of Tshwane, was used together with a layer created of the six management units. A buffer was created around the management units of approximately 500m either side of the management units. Then, only land parcel data falling within the buffer were selected. From this data extracted we were able to perform a count of the number of properties within 500 meters of each of the six management units.
- Average value of property within the area: The average value of properties within 500m of each management unit was calculated based on searches done on property values from the City of Tshwane's Property Valuations database. Using the land parcel data, we were able to determine the GIS key for the properties and search for them on the property valuations database and get the value.
- Current value of properties within 500m of management unit: The average value of properties was applied to the total number of properties within 500m of each management unit to arrive at a current total value of properties within 500m of each management unit.
- Property valuation increase: The value of properties close to a rehabilitated wetland can increase by between 15% - 30%, based on real estate agents that were surveyed (van Zyl et al., 2004). Thus, an average of the range was used, which amount to 23%.
- New value of properties within 500m of management unit: For each management unit, the current total value of properties within 500m of the management unit were increased by 23% (current value x (1+23%) = new value). This represents the increased value from rehabilitation of the management unit.
- Marginal increase in property values: The marginal value was then calculated as the difference between the increased value and the current total value.
- Additional property rates earned: The rate earned per rand property value was applied to the marginal value to calculate the additional property rates earned by the City of Tshwane due to rehabilitation of the management unit.

The additional revenue from property rates is around R24.2 million per year. The total NPV of these benefits is approximately R115 million over a 20-year discounting period.

5.6.3 Stormwater Management

Rehabilitation of the six management units can extend the useful life of stormwater assets around those management units. A GIS analysis was done to identify stormwater assets in proximity to the management units. The cost of these stormwater assets was then determined and reflected in 2023 terms. Next, it was assumed that the useful life of these stormwater assets could be extended by 20 years if the management units were restored to a well-functioning state. This would reduce the annual depreciation expense that would go in the CoT income statement. This annual depreciation saving was then calculated as a rand per hectare amount. The rand per hectare amount was then multiplied by the hectares of each management unit to determine the total annual depreciation saving attributable to each management unit.

The calculation process and results relating to stormwater assets for each of the six management units are indicated in the following table:

Table 5-9: Stormwater infrastructure savings per management unit

	Unit	Colbyn Wetlands	Hartbeesspruit Channelled Valley Bottom	Hartbeesspruit Riverine_D	Hartbeesspruit Riverine_U	Moretele Channelled Valley Bottom	Moretele Riverine
Annual depreciation saving	R/a	54,509	54,509	54,509	54,509	54,509	54,509
Total size of management units combined	Ha	120.74					
Saving per hectare	R/Ha	451	451	451	451	451	451
Size of individual unit	Ha	55.00	4.76	9.28	16.84	21.64	13.22
Cost saving attributable to unit	R/a	24,829	2,149	4,189	7,603	9,770	5,969

The total size of management units combined is the total of each management unit summed up. It is used to calculate the depreciation saving per hectare. The size of the individual unit is the area of the individual management unit. This is used to calculate the depreciation saving attributable to each management unit.

The total reduction in the depreciation expense is around R55,000 per year. The total NPV of these benefits is approximately R330 000 over a 20-year discounting period.

5.7 RESULTS OF FINANCIAL BENEFITS

For each management unit, the total financial benefits were discounted over a 20-year period at an 11.75% discount rate to arrive at a NPV for the financial benefits. Wetlands International is a global not-for-profit organisation dedicated to conservation and restoration of wetlands. Since 2000 they have completed over 30 wetland restoration projects in 17 countries across four continents. They aspire to implement long-term projects, intending to be involved in projects for 20 years or more (Blanco & Yellachich, 2023). Therefore, a 20-year time frame was used because it represents a likely project life and a likely wetland rehabilitation project time frame. The 11.75% was used as a discount rate because we are discounting financial benefits, and that rate represents current money market rates. Note that the financial benefits don’t accrue immediately, some rehabilitation interventions would need to be implemented first and then the financial benefits would start to materialise over time. For each management unit it was assumed that the financial benefits would start flowing from 2026/2027 (year 3 out of the 20-year period), while interventions would start being implemented as early as 2023/2024 (year 1 out of the 20-year period).

The NPV of the financial benefits for each management unit is presented in Table 5-10. Each management unit would form a separate line in the asset register with the values in the table going into the proposed asset register for the City of Tshwane.

Table 5-10. NPV of financial benefits for each management unit

Management Unit	Original PES category	Improved PES category	Total annual financial benefits	Total annual cost of rehabilitation	NPV of financial benefits over 20-year period	NPV rehabilitation cost over 20-year period	Benefit-cost ratio
Colbyn Wetlands	D	C	R10,550,000	R2,600,000	R57,552,974	R20,051,058	2.870
Hartbeesspruit Channelled Valley Bottom	E	D	R2,579,000	R1,477,000	R15,109,019	R12,808,609	1.180
Hartbeesspruit Riverine_D	E	D	R2,000,000	R1,452,000	R12,272,037	R12,318,476	0.996
Hartbeesspruit Riverine_U	E	D	R10,472,000	R2,693,000	R57,065,848	R23,693,908	2.408
Moretele Channelled	E	D	R5,752,000	R2,445,000	R31,348,768	R20,092,197	1.560

Valley Bottom							
Moretele Riverine	E	D	R2,725,000	R1,601,000	R15,969,330	R15,701,457	1.017
Total			R34,078,000	R12,268,000	R189,317,976	R104,665,705	1.809

5.8 FORMAL ASSETS REGISTER FOR INTEGRATION OF GREEN INFRASTRUCTURE

The table below is a formal asset register for green infrastructure developed for the City of Tshwane municipality. Information from this asset register can be easily integrated with other asset registers within the municipality and allows for formal integration with the municipality's asset management process.

Table 5-11. Formal asset register for urban green infrastructure

Identification & Location				Accountability		Performance		Accounting			Management & Risk			
Asset Class	**Asset No.**	**Asset Description**	**Suburb**	**Responsible Department**	**Ownership**	**Area size**	**Present ecological status**	**Funding Source**	**Last date of valuation**	**Value of benefits**	**Mitigation options required**	**Ecological state achievable with interventions**	**Cost of mitigation**	**Financial cost-benefit ratio**
PPE - INFRA - WATER - ECOLOGICAL	20230	Colbyn Wetlands	Colbyn	Environmental and Agriculture Management	City of Tshwane	55.00	D	Fiscal	30/11/2023	R57,552,974	Maintenance of gabion infrastructure, Monitoring, Measurement weirs, Retention ponds, Pollution control measures, Fire breaks, Maintenance, Birding infrastructure	C	R20,051,058	2.870
	20231	Hartbeesspruit Channelled Valley Bottom	Bergtuin	Environmental and Agriculture Management	City of Tshwane	4.76	E	Fiscal	30/11/2023	R15,109,019	Gabion infrastructure, Re-vegetation, Maintenance, Measurement weirs, Monitoring	D	R12,808,609	1.180
	20232	Hartbeesspruit Riverine_D	Derdepoort 326-Jr	Environmental and Agriculture Management	City of Tshwane	9.28	E	Fiscal	30/11/2023	R12,272,037	Clearing alien vegetation, Measurement weirs, Monitoring,	D	R12,318,476	0.996

Identification & Location				**Accountability**		**Performance**		**Accounting**			**Management & Risk**			
											Maintenance, Gabion infrastructure			
	20233	Hartbeesspruit Riverine_U	Kilner Park/East Lynne	Environmental and Agriculture Management	City of Tshwane	16.84	E	Fiscal	30/11/2023	R57,065,848	Clearing alien vegetation, Measurement weirs, Monitoring, Maintenance, Gabion infrastructure	D	R23,693,908	2.408
	20234	Moretele Channelled Valley Bottom	Derdepoortpark	Environmental and Agriculture Management	City of Tshwane	21.64	E	Fiscal	30/11/2023	R31,348,768	Gabion infrastructure, Re-vegetation, Maintenance, Measurement weirs, Monitoring	D	R20,092,197	1.560
	20235	Moretele Riverine	Derdepoortpark	Environmental and Agriculture Management	City of Tshwane	13.22	E	Fiscal	30/11/2023	R15,969,330	Clearing alien vegetation, Measurement weirs, Monitoring, Maintenance, Gabion infrastructure	D	R15,701,457	1.017

6 CONCLUSIONS & RECOMMENDATIONS

Ecosystems provide extensive environmental, social and economic benefits to a variety of communities and economies on a global scale. The value of ecosystems has been vigorously demonstrated and quantified and there is ever growing recognition of their importance to human well-being at multiple scales. In spite of increasing awareness of the role and importance of green infrastructure, few if any formal institutional arrangements, and specifically economic policy instruments, exist which formalise and/or internalise decision-making around these assets into day-to-day economic decision-making.

In this assignment, we investigated a municipal asset management system, as a very specific economic policy instrument, as such an institutionalisation mechanism for urban or municipal water-related green infrastructure. The investigation included:

- Making the case for urban green infrastructure
- Framework of integrating green infrastructure into municipal asset management
- Institutional readiness to assess factors that might hinder the implementation
- Demonstrating the integration at the hand of a case study, located within the City of Tshwane Metropolitan Municipality

The analysis of linking green infrastructure to economic benefits to the municipality showed that people are willing to pay more for a residential property close to a green space as green spaces tend to create a favourable image for a place, boost retail sales, attract tourism, enhance investments within an area, and create favourable working spaces that encourage employment. Green spaces may also result in costs savings such as spatial planning, maintenance, energy consumption, CO_2 emissions and stormwater costs.

The analysis on municipal asset management system showed that by following GRAP accounting system, green infrastructure as an asset, can be integrated into an existing municipal asset register. The demonstration study also managed to demonstrate that the information from the asset register can be easily integrated with other asset registers within the municipality and allows for formal integration with the municipality's asset management process.

The case study showed that having an improved green infrastructure could provide the following financial benefits:

- Less chemical and energy costs for water treatment
- Extended life span on stormwater infrastructure
- Increased property rates

The case study managed to provide evidence in determining cost benefit analysis through assessing rehabilitation cost versus financial benefits directly to the municipality. This is a crucial component in developing a financial business case on urban green infrastructure rehabilitation.

Guidelines for implementing the integration of green infrastructure was then developed as shown in Table 6-1 which includes step by step procedures required for the assessment, as well as roles and reasonability per task. The guideline was done with the analysis of:

- Institutional readiness (chapter 4)
- Consultation with CoT (section 4.1)
- Insights from case study demonstration (chapter 5)

The investigation showed that although municipalities do have the capability to implement this tool, three key challenges remain.

- Municipality would only be able to rehabilitate green infrastructure on land under their ownership. Although Section 73(2)(b) of NEMBA states that 'A person who is the owner of land on which a listed invasive species occurs, must take steps to control and eradicate the listed invasive species and to prevent it from spreading, there still exist an institutional gap, or alternatively, a lack of financial incentives for private landowners to maintain their green infrastructure and interventions beyond invasive species clearing. Finally, the financial benefits identified and analysed in this study, accrues after a time lag, and therefore do not provide an immediate measurable return.
- The difficulty of integrating green infrastructure into municipal asset management system, as the Auditor General do not currently have explicit guidelines on how to incorporate green infrastructure assets and neither does exist formal green infrastructure valuation methodologies.
- Finally, the financial benefits identified and analysed in this study, accrues after a time lag, and therefore do not provide an immediate measurable return. However, with interventions such as re-vegetation bank stabilization, and gabion structures, flow and sediment control benefits could be seen

For further work, it is therefore recommended that these challenges be further explored, as they hold the key to the successful implementation of the framework. The framework must also be tested with several Metros to gain acceptance by SALGA.

Table 6-1. Guidelines for integrating green infrastructure into municipal asset management system

No.	Task/Action	Purpose	Procedures	Roles and responsibilities within municipalities	Resources and capabilities	Supporting Government departments/Institutions
1	Baseline assessment of green infrastructure	Understand where the green infrastructure falls within the municipality and the areas and people the green infrastructure benefits.	• Map out the green infrastructure within the municipality. • Identify the areas, communities, and people that the green infrastructure serves.	• GIS Department: To map out the green infrastructure • Water and sanitation department • Environmental department • Stormwater department:	• GIS software • GIS data • GIS experts	• DFFE • SANBI
2	Delineation and classification of ecological assets	To identify, classify and categorise ecological assets	• Use the standardised methodologies for identifying and delineating ecological assets. • Determine the present ecological status of the ecological assets and recommend ecological management category.	• GIS Department: • Environmental department	• Ecologists • Manual for the Identification and Delineation of Wetlands and Riparian Areas • WET-Health	• SANBI • DWS • DFFE
3	Identify mitigation options	To identify specific interventions required to improve or maintain the present ecological status of the ecological assets	• Undertake field visits to the areas where the ecological assets lie. • Design mitigation interventions that would improve or maintain the present ecological status.	• Environmental departments: • Water and sanitation departments:	• Engineering experts• Ecological rehabilitation experts • GIS data • GIS experts	• CMA (Through their CMS)

No.	Task/Action	Purpose	Procedures	Roles and responsibilities within municipalities	Resources and capabilities	Supporting Government departments/Institutions
4	Cost the mitigation options	To understand the investment required to restore and maintain the ecological assets	• Cost the mitigation interventions designed.	• Finance department • Water and sanitation department	• Engineering experts • Quantity surveyors • Ecological rehabilitation experts • GIS data • Cost information	•
5	Asset valuation	To identify and value the financial benefits associated with the green infrastructure and determine the net financial benefit i.e. after costs, for the purpose of valuing the assets for asset register integration	• Identify the financial benefits associated with the green infrastructure. • Value the financial benefits. • Bring the cost of the mitigation options into the valuation. • Calculate the net benefits i.e. after cost of mitigation. • Discount the net benefits to present value terms to determine the value of the asset.	• Finance department within the municipality and resource economist experts: To identify the possible benefits associated with the ecological assets. • Finance department: Required to value the financial benefits and determine the value of the asset.	• Financial skills • Resource economics skills	•
6	Integration of green infrastructure into formal municipal asset registers	To develop a comprehensive record of green infrastructure assets. This record could be an green infrastructure asset register on its own within the municipality or the green infrastructure assets could be brought in as individual	• Assign unique identifiers to the ecological assets for their record in the asset register. This would include the "Asset Class", "Asset Number", "Asset Description", location data such as suburb and coordinates• Define the responsibilities for the	• Finance department: Required to integrate into asset management systems.	• Financial skills • Accounting skills • Accounting software	•

No.	Task/Action	Purpose	Procedures	Roles and responsibilities within municipalities	Resources and capabilities	Supporting Government departments/Institutions
		assets into the existing municipal asset register.	maintenance and management of each asset. • Establish performance indicators to monitor the health and functionality of the assets. • Note down that "Entity-specific value" as defined in Grap 17 is the best valuation basis applied to the asset. • Develop a risk management strategy for the ecological assets. • Integrate all this information into the existing municipal asset register or create a new asset register for green infrastructure.			

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