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GREEN
INFRASTRUCTURE

URBAN WATER MANAGEMENT FRAMEWORK FOR PAARDEN EILAND,CAPE TOWN

Dissertation presented as part fulfilment of the degree of
Masters of City and Regional Planning
In the School of Architecture, Planning and Geomatics
University of Cape Town
October 2015

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Acknowledgements

First and foremost I would like to give thanks to my Lord and Saviour for guiding me through this process as well as blessing me with the opportunity of being a part of such great programme, which as the potential to influence and improve the urban environments we live in.

Secondly, I would like to thank my friends and family for their unwavering support and constant encouragement to do my best, not just through this process but throughout my university career.

I would also like to thank my supervisor Nancy Odendaal for her expertise, direction and invaluable advice, as well as Tania Katzschner for being an inspiration and for playing an influential role in my choice of dissertation topic.

NSFAF for awarding me a study loan and much needed financial assistance that made it possible for me to continue with the MCRP programme.

Pierre Roux from the City of Cape Town's Catchment, Stormwater, and River Management branch, for providing the necessary Paarden Eiland stormwater data and referrals.

“Just as we must carefully plan for and invest in our capital infrastructure — our roads, bridges and waterlines, we must invest in our environmental or green infrastructure — our forests, wetlands, stream and rivers . . . Just as we must carefully plan for and invest in our human infrastructure — education, health service, care for the elderly and disabled — we must also invest in our green infrastructure.” — Maryland Governor Paris Glendening January 1999

Abstract

Cities in South Africa are currently experiencing rapid urbanisation, especially Cape Town. Infrastructure development has long been a critical component with a large amount of money invested in the development of hard infrastructure. However, in light of excessive stormwater runoff, the increased deterioration of surface water resources, degraded water quality, and the rapid progression of climate change around the global, many cities including Cape Town have progressed towards more sustainable forms of infrastructure development. Discourse surrounding sustainable development often encourages the improvement of the quality of urban areas without compromising the carrying capacity of ecosystems. This is a fairly new model in South Africa, which challenges the underlying principles of conventional infrastructural design and management. There is particularly an enthusiastic interest in the promotion of green infrastructure as a water sensitive design strategy in the management of stormwater and surface water.

Presently, drainage systems for urban areas in Cape Town are constructed using principles of hard infrastructure, which often consist of complex man-made networks of underground tunnels and pipes that gather and direct stormwater runoff towards a surface waterbody. However, the extensive development of drainage infrastructure has led to increased stormwater runoff volumes, flooding, and flows. Urban stormwater runoff is known to be one of main sources of pollution and degradation of waterbodies, which has in turn resulted in the degradation of other environmental assets. Therefore, the planning, design, and implementation of infrastructural solutions there is a need to move towards a more sustainable and water sensitive model, in order to remediate these problems. Green infrastructure in this respect offers an opportunity to better manage both stormwater and surface water in a more holistic, cost-effective, efficient and ecological sound manner. The main objective of green infrastructure urban water management is to mimicking the natural hydrological cycle through various stormwater management interventions, in order to achieve what conventional drainage systems currently do and beyond their existing capacity.

This dissertation uses Paarden Eiland as a case study and experimental project site in order to assess and investigate how green infrastructure can be utilised to effectively manage stormwater runoff and surface water within a heavily developed urban area. It explores the potential benefits this method of management provides in comparison to a conventional infrastructural approach of management. This study also highlights some of the critical issues and barriers that urban practitioners need to take into account when implementing such systems. A green infrastructure urban water management framework and conceptual layout are presented in order to demonstrate potential green infrastructure tools and strategies that may be used in retrofitting heavily developed areas, as well as provide guidance on how spatial planning can be utilised as a tool in the planning, design, and implementation of green infrastructure as well as in overcoming identified financial, technical, and institutional barriers.

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Abbreviations and Acronyms

BMP– Best Management Practices

BRT– Bus Rapid Transit

CBD– Central Business District

CFR– Cape Floristic Region

CMA– Catchment Management Area

CoCT– City of Cape Town

CSIR- Council for Scientific and Industrial Research

DEAT- Department of Environmental Affairs and Tourism

DWAF– Department of Water Affairs and Forestry

ECAMP– Economic Areas Management Programme

EIA– Environmental Impact Assessment

EP– Environmental Programmes

EPA– United States Environmental Protection Agency

GIS– Geographical Information Systems

IDP– Integrated Development Plans

IPCC–Intergovernmental Panel on Climate Change

JCP– Johannesburg City Parks

JMOSS– Joburg Metropolitan Open Space System
LID– Low Impact Design

LUPA– Land Use Planning Act (3 of 2014)

NEMA– National Environmental Management Act (19 of 1998)

NGO– Non-governmental Organisations

NMT– Non-motorised Transport

OCED– Organisation for Economic Co-operation and Development

PAWC– Provincial Administration of Western Cape

PPP– Public Private Partnership

PSDF– Western Cape Provincial Spatial Development Framework

SDF– Spatial Development Framework

SLIP– Stormwater Land Identification Project

SPLUMA– Spatial Planning and Land Use Management Act (16 of 2013)

STATSA– Statistic South Africa

SUD– Sustainable Urban Drainage

UNEP– United Nations Environment Programme

USA/US– United States of America

WERF– Water Environment Research Foundation

WCIF– Western Cape Infrastructure Framework

WSUD– Water Sensitive Urban Design

CHAPTER ONE

1. Introduction

1.1 Context and Purpose of Study

*"We forget that the water cycle and the life cycle are one" (*Cousteau, 2007)

"In the end, all water is stormwater" (Parker, 2013)

Municipal governments are under massive pressure to provide services and infrastructure to expanding populations in an economically responsible, environmentally conscious and socially orientated manner (Hammitt, 2010), especially in the Global South. However, the conventional methods and approaches towards the provision of stormwater/grey infrastructure have proven that they are not meeting the fundamental pillars or criteria of sustainability-economy, equity, and environment (ibid.). Grey/hard infrastructure is often a complex man-made network of underground tunnels and pipes that are meant to gather and direct stormwater runoff towards a surface water body (ibid.). Grey infrastructure tends to incur high capital and maintenance costs, with which cities are struggling to keep up amidst the growing and existing demands. Governments are taking on enormous debt to maintain and expand grey infrastructure, and will continue to incur debt as populations grow, if they continue with business as usual.

Besides the high cost of grey infrastructure, urban stormwater runoff is one of main sources of pollution and degradation to all types of water bodies (Droguett, 2011), and is one of the main challenges facing drainage services for the City of Cape Town (CoCT) (City of Cape Town, 2014). Stormwater urban runoff is known to be non-point source pollution, which is largely associated with two constituents (Droguett, 2011). These constituents are defined to be:

- increased volume and velocity of runoff; and
- the concentration of pollutants/contaminants within the runoff.

As the runoff flows across the urban landscape, it tends to cause erosion, the widening of channels and the downcutting of streams (ibid.). It also tends to pick up and transport a variety of anthropogenic and natural pollutants, then depositing them into surface water such as wetlands/vleis, rivers, coastal waters, and groundwater resources (ibid.). This then leads to increased contamination within water sources, changes in hydrology, as well as water properties, in turn causing habitat degradation, biodiversity loss, human health risks/threats, and changes in ecological responses.

The increase in urbanisation has led to the increase of the quantity of pollutants carried into surface water. Certain features of the urban environments such as impervious surfaces often cause the runoff to contain a variety of materials and pollutants such as sediment, oil, and toxic chemicals from pesticides, motor vehicles, and so forth (US EPA, 2014a). Impervious surfaces are also known to increase the amount of stormwater runoff, where it is approximately 16 times higher than that of undisturbed natural land (Carlet, 2014). In addition, an increase in stormwater runoff and discharge may result in the overloading of sewers and pipes, therefore changing and negatively affecting water quality, which affects day-to-day urban activities (Droguett, 2011) as well as the natural environment.

The City of Cape Town has a widespread network of wetlands and rivers, which fulfil various ecological, recreational, and infrastructural functions (Nel, Parker and Silbernagl, 2013). They are an important part of the natural landscape, and encourage as well as provide economic and recreational opportunities, health benefits, natural hazard regulation, urban resilience, and other ecosystem services (Nel et al., 2013). According, to the Department of Water Affairs (DWA), over the past few decades many of Cape Town's watercourses and surface water have been negatively affected by pollution, where 69% of the vleis or wetlands and 42% of the rivers have poor to bad water quality (CoCT, 2008). Additionally, the Western Cape, in which the Cape Town is located, is currently experiencing a limitation in water resources, which have become increasingly stressed due to a steady increase in water demand and the deterioration of water quality in surface waterbodies (Western Cape Government, 2012). The effects of climate change will place even further stress on limited water resources. Therefore, management and discharge of water from urban systems as well as grey infrastructure, play a major role in ensuring water sustainability and feasible management of this essential resource.

As we move towards the future, with the existing water protection goals, fiscal limitations, cynical abuse of water legislation, and grey infrastructure there is a great need to move towards alternatives for hard infrastructure and management techniques that combine tried and true grey infrastructure with green infrastructure practices and approaches that are both cost-effective and reduce runoff into existing sewer systems and surface water (Odefey, Detwiler et al., 2012).

According to Benedict and McMahon (2006), a green infrastructure approach is different from conventional and traditional methods/approaches to conservation and urban development, because it looks at conservation and protection concurrently with land development and infrastructure planning. Traditional methods and approaches for conservation, urban development, as well as the provision of infrastructure are usually done in isolation of each other. However, a green infrastructure approach provides a framework for conservation, development, and spatial planning, which recognises the need to prioritise conservation opportunities and plan urban development in a way that optimises the use of land to meet the needs of both society as well as nature (Benedict and McMahon, 2006), through which ecological systems, green spaces as well as other landscape features provide certain services in the same way as traditional 'hard' infrastructure (Schäffler, Otto, et al., 2013).

Therefore, this dissertation analyses current key spatial planning and urban water management policies regarding stormwater and surface water management, as well as grey infrastructure for Paarden Eiland, Cape

Town, in order to provide sustainable strategies and recommendations for urban water management and spatial planning with regards to the provision of green infrastructure. This dissertation also explores the current state of urban drainage systems in Paarden Eiland, Cape Town and draws on theory and techniques (both local and international) from ecological resilience theory, green infrastructure and water management theory, as well as theory around water sensitive urbanism and planning. Ultimately, this dissertation is a hybrid which includes a framework that focuses primarily on green infrastructure urban water management techniques and approaches and the integration of spatial planning into the provision of green infrastructure, as well as a conceptual layout that represents the basic spatial characteristics of green infrastructure urban water management practices is provided.

The above informs the design of a green infrastructure framework and conceptual layout for Paarden Eiland, Cape Town (Blaauwberg District), which demonstrates the spatial components of this approach for the purpose of this dissertation.

Paarden Eiland serves as a pilot/experimental project site that assists in providing a better understanding of green infrastructure as an effective management approach for stormwater and surface water within the City, and will hopefully form a platform for additional green infrastructure research within a South Africa context. The development of a framework and conceptual layout for Paarden Eiland is meant to set a precedent for more effective and sustainable urban water management practices, as well as innovative design. With regards to planners, the conceptual layout and framework illustrates how a green infrastructure approach can support broad planning goals pertinent to sustainable development, the protection of important natural assets, and economic development.

1.2 Philosophical Underpinnings of the Study

Water is increasingly at the foreground of global policy change, management, and planning (Grafton and Hussey, 2011). Water is a critical issue worldwide and there are growing concerns about water as a renewable resource and its availability for both users as well as ecosystem health (ibid.). Therefore, municipalities and practitioners need to gain a sound understanding of key issues and the policy setting underpinning urban water management and its infrastructure (ibid.). Hence, the unsustainable use and management of urban water and its systems need to be transformed.

The philosophy that underpins this dissertation is that that water affects every facet of life, it connects and supports the functioning of the natural environment, society, and the economy, therefore there needs to be a move towards more water-sensitive urbanism and design in terms of infrastructure and other elements that make up the urban environment.

The discharge and treatment of stormwater may no longer be considered in isolation to the planning and design of an urban area (Wong, 2000). The management of not only stormwater but also surface water needs to be acknowledged at all stages of spatial planning and urban design processes, in order to ensure that the planning, architecture, and the infrastructure of a site is created in such a manner that it is sympathetic to the stormwater treatment systems as well as the natural environment (ibid.).

This can be achieved through the concept of green infrastructure as a water-sensitive urban design strategy for sustainable stormwater and surface water management.

'The future of stormwater has arrived, and that future is green.' (Wise, 2007)

This concept is based on landscape design and consists of formulating development plans that integrate multiple sustainable stormwater management objectives and techniques as well as the involvement of pro-active processes that recognises the opportunities of spatial planning, urban design, and grey infrastructure to be intrinsically connected (Wong, 2000). This concept provides a basis for a holistic approach in terms of managing both surface water as well as stormwater, by using techniques that are able to deliver and provide a wide range of beneficial outcomes on both a local and a regional scale (ibid.). The integration of spatial planning and the use of best management practices aid in achieving the objectives of water sustainability as well as sustainable drainage systems for urban areas (ibid.). The selection of best management practices involves a critical assessment made within and of a variety of disciplines such as engineering, landscape architecture, and ecology, in order to account for site specific characteristics and limitations (ibid.).

Connectivity is the key to making a green infrastructure concept work in reality (Benedict and McMahon, 2006). Green infrastructure includes both natural and restored ecosystems and elements, which together form a network or system of hubs, sites, and links (ibid.). Hubs can range from managed preserves, publicly owned land, to municipal parks (ibid.). Hubs function as anchors for green infrastructure networks (ibid.). Sites are usually local areas and are characterised as smaller than hubs (ibid.). Sites usually function as nature-based recreation areas (ibid.). Links are characterised as floodplains and greenbelts, and tend to tie the system together and are extremely important in maintaining critical ecological processes (ibid.).

The idea of planning and designing a city in a manner that preserves and works with natural systems is extremely pertinent for urban water management, because it assists in striking a balance between environmental health and urban development. This approach provides the opportunity to manage the natural environment holistically as well as provide sustainable livelihoods, where water systems as well as other ecological systems are treated and used in a mindful and cautious manner, whilst creating urban environments that are conducive to economic growth, social inclusivity, and urban development.

1.3 Scope of Study and Geographical Area

The scope of this dissertation is limited to the management of stormwater and surface water as well as the relevant grey infrastructure. While this study recognises the importance of the management of all water systems, man-made as well as natural, to allow for optimal ecological function and environmental health, the primary focus of this research will be on sustainable stormwater and surface water management and grey infrastructure in Cape Town, through the use of green infrastructure.

The focus area for this dissertation is Paarden Eiland, Cape Town, which is a large industrial area strategically located near the Blastrite Cape Town Harbour site, with rail and bus routes, but more importantly it is located approximately at the confluence of the Salt and Black Rivers, which eventually drain out into Table Bay. Paarden Eiland is also situated in close proximity Zoarvlei; refer to Figure 1.

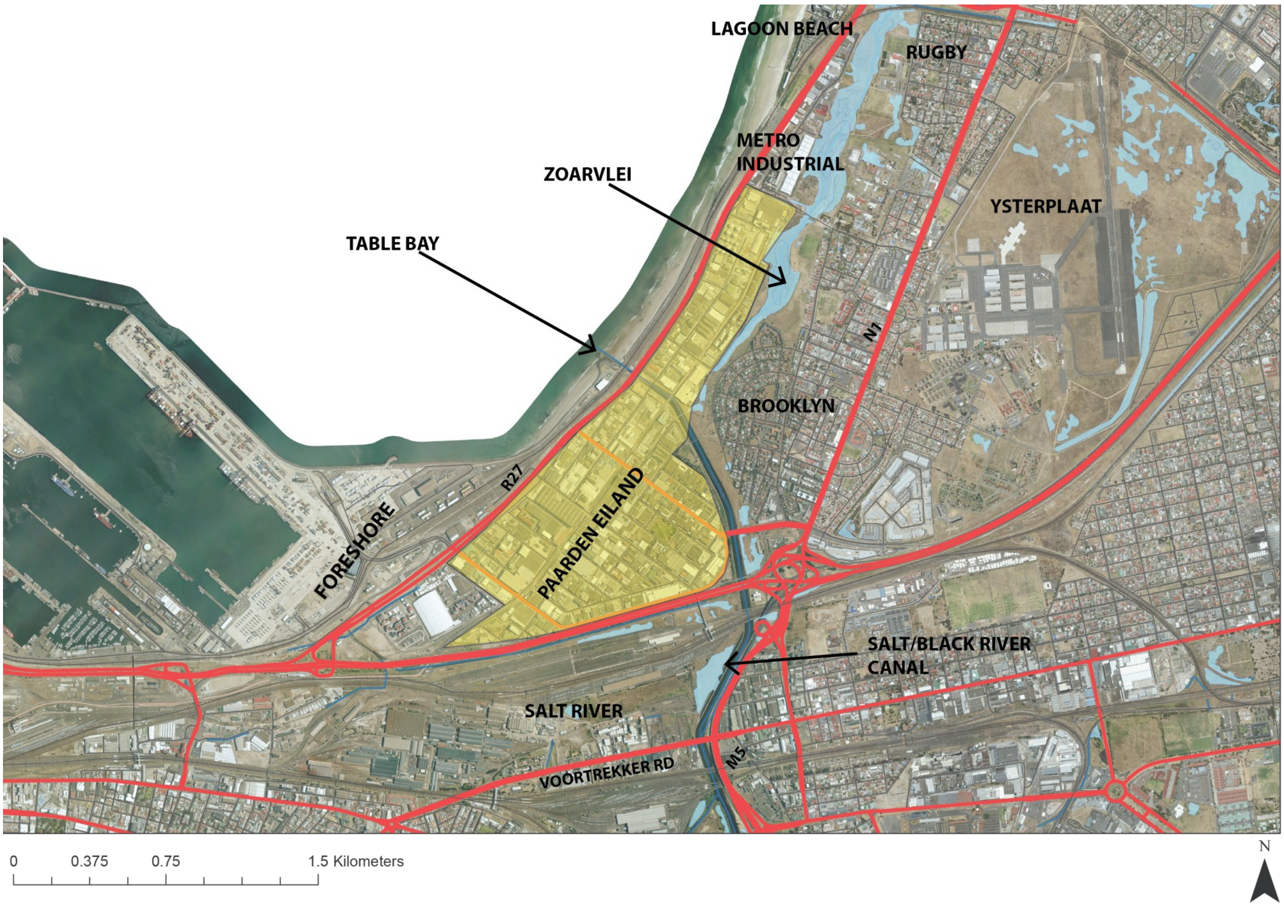


Figure 1: Map of Paarden Eiland Industrial Area and Surroundings (Source: Author, GIS Technical Library, University of Cape Town, 2011)

The City of Cape Town (2012a) has spear-headed the necessary process to grant Paarden Eiland voluntary conservation area status, with specific reference to the Zoarvlei. The site has been greatly affected and degraded due to extensive development; however, it still holds ecological value and is part of Cape Town's ecological infrastructure (CoCT, 2012a). Stormwater from Paarden Eiland has had a massive impact on the Zoarvlei as well as the Salt and Black Rivers, as stormwater being expelled into to these systems has greatly affected the quality of water (Holtzhausen, 2012). It is therefore essential that stormwater is treated or cleaned before entering the Atlantic Ocean via Table Bay, which would have its own set of repercussions for marine life and the natural environment.

This site is an interesting site to employ and retrofit green infrastructure urban water management techniques to demonstrate ecological and water-sensitive planning and design within an a heavily developed industrial area, which has ecological value for greater Cape Town. This is a good example of how green infrastructure can be used within a heavily developed area that has issues pertaining to stormwater and surface water management. Figure 2 below is a basic illustration of how green infrastructure can be used to improve urban metabolisms.

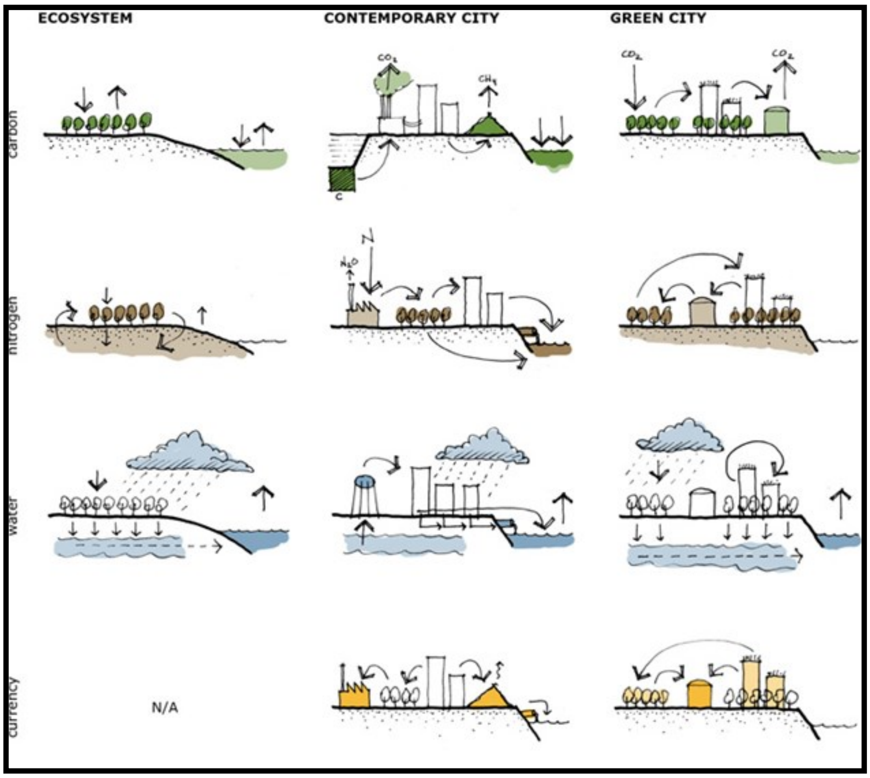


Figure 2: Improvement of Urban Metabolism through Green Infrastructure (Source:http://www.carlsterner.com/research/2010_toward_the_green_city.shtml)

The development of green infrastructure within Paarden Eiland is both a cost-effective as well as a resilient approach to urban water management and grey infrastructure, which will enhance the City of Cape Town's conservation efforts. This will help enhance urban resilience towards climate change and create sustainable living, whilst delivering other environmental, social, and economic benefits (US EPA/United States Environmental Protection Agency, 2014b).

This scale allows for a more realistic view and approach to investigating and researching the provision of green infrastructure urban water management techniques and approaches in terms of stormwater and surface water, given the time limit of the dissertation as well as the objective to further incorporate and collaborate various sectors, academics, and experts found in spatial planning, urban design, landscape architecture, civil engineering, urban water management, and relevant departments within South African government.

1.4 Key Definitions

The following section comprises a review of the main concepts as well as key definitions underlying this study. More detailed definitions may also be included in the relevant sections to come.

Bio-engineering

Biological application of engineering principles/structure (UC Berkeley, 2015).

Ecosystem services

The notion of ecosystem services has been created to aid our understanding of the human use and management of natural resources. Therefore, ecosystem services are benefits that society receives from ecological assets and ecosystems (Schäffler et al., 2013).

Global North

Refers to developed countries primarily located in the Northern Hemisphere.

Global South

Refers to developing countries primarily located in the Southern Hemisphere.

Green infrastructure

For the purpose of this dissertation, green infrastructure is a set of interconnected natural and man-made ecological systems, green spaces and other landscape features (Schäffler et al., 2013). These features together form an infrastructure network which delivers services and strategic functions in the same manner as that of conventional 'hard' infrastructure (ibid.).

In terms of stormwater and surface water management, green infrastructure refers to management techniques and technologies that utilise, improve, and mimic the natural hydrological cycle's processes of evapotranspiration, infiltration, and reuse (Tian, 2011).

Green infrastructure is often associated with blue infrastructure (Blue-green infrastructure). Blue infrastructure is primarily the utilisation of proprietary small footprint highly efficient devices that are often installed and retrofitted within existing collection systems (Hydro International, 2015).

Grey/hard infrastructure

Traditional grey infrastructure consists of engineered delivery networks that are hierarchically structured (Wolf, 2003). These networks deliver a range of services and goods to populations within cities. These infrastructure networks and systems require massive capital investment to build and maintain, and are usually single-use occupiers of large areas of urban land (ibid.).

Non-point source pollution

Non-point source pollution often results from land runoff, atmospheric deposition, precipitation, drainage, hydrologic alteration or seepage (US EPA, 2014a). Non-point source pollution is one of the leading causes of water quality problems in urban settings/environments (ibid.).

Retrofitting

The process of modification or installation of alternative stormwater management mechanisms or approaches in an existing developed area in order to achieve best management of stormwater (Vice, 2011).

Sustainability

Sustainability has various definitions. However, for the purpose of this dissertation, it is the creation and maintenance of conditions under which humans and nature can co-exist in productive unison, in order to fulfil social, environmental, economic and other requirements of both present and future generations (US EPA, 2014b).

1.5 Research Questions

This section will highlight a number of key themes and questions that will be examined throughout this dissertation and that are related to a number of debates around green infrastructure development. These questions will be centred on understanding and defining green infrastructure in general, exploring the potential role of spatial planning in the provision of green infrastructure in Cape Town, with specific reference to Paarden Eiland, and the potential value of green infrastructure in urban water management. This will be done through critical engagement of both local and international literature and case studies, in order to evaluate the appropriateness of this context.

Questions to be answered throughout this dissertation are as follows:

Primary Questions

Green infrastructure and heavily developed/ industrial areas:

- How does green infrastructure provide innovative and effective solutions for managing stormwater and surface water through the remediation of industrial and heavily developed areas within a city, such as Cape Town?

Secondary Questions

Green infrastructure and spatial planning:

- What should the role of planning be in the provision of green infrastructure and urban water management?

Green infrastructure and urban water management:

- How is green infrastructure different from current/conventional water management strategies and practices within Cape Town?
- What is the potential value and implication of green infrastructure with regards urban water management in comparison to the traditional hard infrastructure methods of managing stormwater and sur-

face water?

1.6 Structure of Study

The structure of this dissertation is guided by both primary and secondary research questions, and is presented throughout the dissertations via a series of chapters.

Chapter Two: This dissertation starts with a literature review of relevant international as well as local literature on ecological planning, water-sensitive urbanism, green infrastructure and urban water management, and the use of spatial planning as a tool within a green infrastructure water management approach. The literature review provides the understanding and context of current theoretical discourse, in order to gain a deeper insight into the topic of green infrastructure and water management, and the potential role of spatial planning in its provision. This helps create an appropriate structure in which to locate the contextual analysis of both Paarden Eiland and the City of Cape Town.

Chapter Three: The literature review is followed by a precedents chapter, whereby international and local precedent is assessed in order to gain a better understanding of how green infrastructure urban water management practices can be employed in a successful and effective manner.

Chapter Four: This chapter involves the evaluation of the methods and techniques of investigation utilised in the composition of a green infrastructure framework and conceptual layout for Paarden Eiland.

Chapter Five: This chapter deals with an in-depth contextual analysis of the current state of Cape Town's grey infrastructure and key issues and priorities pertaining to surface water and stormwater. The chapter also contains an analysis and a review of relevant policy and legislation related to the Cape Town's management and regulation of stormwater and surface water.

This analysis guides the development of both the green infrastructure urban water management framework and conceptual layout for Paarden Eiland.

Chapter Six: This chapter includes the site analysis of Paarden Eiland in order to determine the appropriate green infrastructure stormwater and surface water guiding principles and strategies for particularly heavily developed, industrialised areas. This chapter also includes the conceptual layout and framework for Paarden Eiland.

Chapter Seven: This chapter outlines final implementation recommendations, reflects on the process and lessons learnt, and concludes the study. This chapter also briefly highlights areas of future research that have surfaced during this study as opportunities to expand this field of research.

Within these chapters, international and local literature is revisited in order to identify appropriate precedent, management, planning, and implementation practices, which benefit infrastructure planning and design, and urban water management in Cape Town, with particular reference to Paarden Eiland.

1.7 Conclusion

Water plays an important role in the continued survival and existence of life on earth. The uncertainty of water as a renewable resource, due to the increase in demand, environmental degradation, mismanagement, and climate change, means this valuable resource is under immense stress and pressure.

Therefore, the re-engineering/bio-engineering of infrastructure networks for resource productivity within rapidly developing cities such as Cape Town may find sources of resilience within the use of green infrastructure approaches and techniques (Schäffler and Swilling, 2013). This adds to research on water-sensitive urban design and spatial planning, which presents an opportunity for including a green infrastructure approach into urban water management as well as spatial planning.

Introducing the value of ecosystem services provided by green infrastructure into the matrices of traditional grey infrastructure choices and budget decision-making standards is extremely important (ibid.) if cities are to manage stormwater as well as surface water in a more sustainable manner.

CHAPTER TWO

2. Literature Review

2.1 Introduction

The water service sector is facing a number of challenges in delivering quality service in terms of managing stormwater as well as surface water in Cape Town (Pithey, 2007). The high capital costs of upsizing, upgrading, and building new grey infrastructure in order to meet a growing demand is putting a major strain on local government (Howe, Mukheibir. and Gallet, 2013). This together with the looming reality of climate change and the increase in water resource insecurity and vulnerability (Ziervogel and Zermoglio, 2009), will mean that spatial planners, decisions-makers, along with other relevant stakeholders will need to adopt a new way of thinking and managing urban water resources and systems.

One response to the interlocking challenge of vulnerability with regards to urban water systems, overall environmental degradation, and climate change has been to move towards the concept of ecosystem services (Scott, Collier et al., 2013), in order to achieve both ecological and urban resilience. According to Scott et al. (2013), the ecosystem service approach in the last twenty years has been widely researched and promoted as a mechanism to address the conservation of natural assets such as urban surface water bodies and even more recently, an approach to grapple with climate change mitigation and adaptation. Smith and Maltby (2003) state that the ecosystem service approach is a noteworthy theoretical approach in terms of planning for complex systems such as urban water systems, because it provides a framework that holistically looks at ecosystems in decision-making, and when valuing the ecosystem services provided. The concept of ecosystem services has been deemed by many to be the last best hope for mainstreaming conservation, sustainable urban water management, and socio-ecological resilience (Daily, Polasky et al., 2009) However operationalising the concept has proved to be a major challenge, especially for spatial planning (Scott et al., 2013).

An extensive body of literature emerged in the last decade advocating the shift from land-use planning a regulatory approach, towards spatial planning, whereby the role of planning and the planner was re-established to one of an integrator, co-ordinator, and mediator of spatial dimensions of wider policy streams through partnerships and negotiated governance (ibid.). Although sustainability has been central to many spatial planning debates, the emergence of spatial planning has largely been influenced and driven by market competitiveness, which seeks to re-position regions in a Global North's economic space (ibid.). However, faced with mismanagement of water infrastructure and urban water systems, growing environmental risks, and water resources insecurities, this dissertation argues for a need to fully embed an ecosystems as well as a socio-ecological resilience approach into spatial planning, "proposing the notion of an ecological turn in planning" (Scott et al., 2013:3) and urban water management.

This literature review, strives to investigate potential avenues for planning to deliver ecological sound outcomes for stormwater and surface water management, through investigating the interactions between an ecosystem approach and spatial planning frameworks. In particular, the investigations of emerging literature around green infrastructure as a water-sensitive urban design strategy for sustainable stormwater and surface water management. Spatial planning has the potential to contribute towards the transition to a more resilient urban environment, in order to better cope with stormwater and surface water problems and other environmental risks. The theory and application of green infrastructure is now being advocated as a means to enhance sustainable stormwater and surface water management via spatial planning and urban design.

This literature review will also serve as a starting point to identify and document theories and case studies where innovative and institutional mechanisms have been used and established to overcome the challenges of moving towards green infrastructure urban water management as well as integrating spatial planning within this approach and framework.

This chapter includes an investigation of the general approach to stormwater drainage systems and the hydrological shortcomings that are created by conventional stormwater and surface water management strategies. This aids in establishing an argument for moving away from conventional stormwater and surface water management towards a more ecological, urban water-sensitive, green infrastructure model of design and management. Therefore, this chapter examines and assesses how to adapt hard infrastructure to climate change as well as the examination of more holistic approaches to planning and designing for urban water systems such as ecological planning and water-sensitive urban design. This assessment leads to the investigation of green infrastructure as a new paradigm in which stormwater and surface water may be managed in more effective and sustainable manner. This chapter also identifies potential barriers for implementing green infrastructure urban water management, green infrastructure design implications for urbanism, as well as the use of spatial planning as a tool in the provision of green infrastructure.

2.2 Urban Water Cycle

No place bears a resemblance to the water cycle and flow of an urban area. It has straight and conventional flows over impervious surfaces and through concrete pipes. Streams are channelised, even disappearing into concrete underground networks and magically reappearing. Stormwater rapidly washes the city clean, carrying away dirt from the streets and sidewalks, forming a concoction of chemicals from buildings and other surfaces.

Man-made systems then carry off and partially cleanse human waste, so it does not build up in the city. Rivers bulge with sediment and a myriad pollutants are often squeezed through the city, sometimes even causing mass flooding, which cleans out the accumulated toxins from industrial areas and deposits it into surface waterbodies (Adapted from Forman, 2014:149).

There are five major areas in which global water is distributed: sea and ice, subsurface, land surface, and the atmosphere (Forman, 2014). Lakes and rivers make up approximately 2% of the liquid water on land, and the other 97% is subsurface water (ground water) (ibid.).

Urban areas are also a part of the global water cycle; however, they tend to have various distinctive flows, in comparison to entirely natural areas (ibid.). Urban areas are often characterised by hydrological budgets of inflows and outflows (Forman, 2014). A very small amount of water is either cycled or recycled within an urban area, often done by a network of pumps and pipes (ibid.).

The urban hydrological cycle is characterised by atmospheric water vapour cooling which falls as precipitation (ibid.). Buildings, roads, and other urban structures often interrupt precipitation, therefore it tends immediately to evaporate back into the atmosphere (ibid.). Some of the remaining water then infiltrates into cracked hard surfaces and soil present in open spaces as well as vegetated patches (ibid.). This water is then usually absorbed by roots and transported throughout the plant (ibid.). On the one hand, the unique combination of transpiring plants and evaporation off of structures creates evapotranspiration (ibid.). Evapotranspiration is directly proportionate to the amount of vegetation cover present within a particular area (Berthier, Dupont et al., 2006).

On the other hand, water that is no absorbed within the soil ends up as subsurface flow or groundwater (Forman, 2014). However, in the case of a high rainfall event surface water/runoff tends to be drained into stormwater drainage systems, which eventually empty out in to surface waterbodies (ibid.)

Forman (2014) states that most distinctive features of the urban water cycles is that of:

- Extensive impervious surfaces;
- Other targets for the supplement of piped-in water; and
- Stormwater drainage systems.

All the above features play a significant role in accelerating water flow into local surface waterbodies (ibid.).

2.3 General Approach to Stormwater Drainage Systems

A conventional drainage network consists of a minor and a major drainage system (Parkinson and Mark, 2005). The minor drainage system is a piped system that conveys stormwater runoff from smaller more frequent storm events, whilst the major drainage system is designed to carry stormwater runoff from more severe storm events (Arisz and Burrell, 2006). The main purpose of a major drainage system is to capture and convey stormwater runoff when the minor drainage system's capacity has been exceeded. This system generally consists of rivers, open channels, detention/retention ponds, and roadways (ibid.). Due to economic constraints of many local governments the hydraulic capacity of the minor drainage systems is often limited and during extreme rainfall events this system tends to overflow into streets and roadways (ibid.).

Other important design elements for conventional drainage systems consist of stormwater runoff being routed through a separate or combined drainage system. Separate drainage systems are made up of two drainage networks, where the one is designed for surface water runoff and the other is for dry weather flow of urban wastewater (Parkinson and Mark, 2005). The surface water runoff is often drained through a storm sewer network and discharged into a surface waterbody, without any form of treatment (ibid.). This is a particular problem in most developing countries, where the construction of separate drainage systems is expensive, therefore the stormwater drainage system is often built without any provision for wastewater (ibid.). Therefore, wastewater and stormwater are combined and transported through one system into a surface waterbody, without the necessary treatment.

A combined drainage system tends to have a mixture of domestic, industrial and commercial wastewater during drier weather conditions, and during wetter conditions it acts a flooding mechanism for stormwater runoff (Parkinson and Mark, 2005). Figure 3 shows a basic design of a typical stormwater drainage system.

These conventional drainage systems/elements are supposed to take into account the natural flow paths of drainage during storm events of different magnitudes (Parkinson and Mark, 2005). However, most stormwater drainage designs tend to neglect the critical role that natural drainage routes have on the drainage of runoff as well as the mitigation of flooding in urban environments (ibid.).

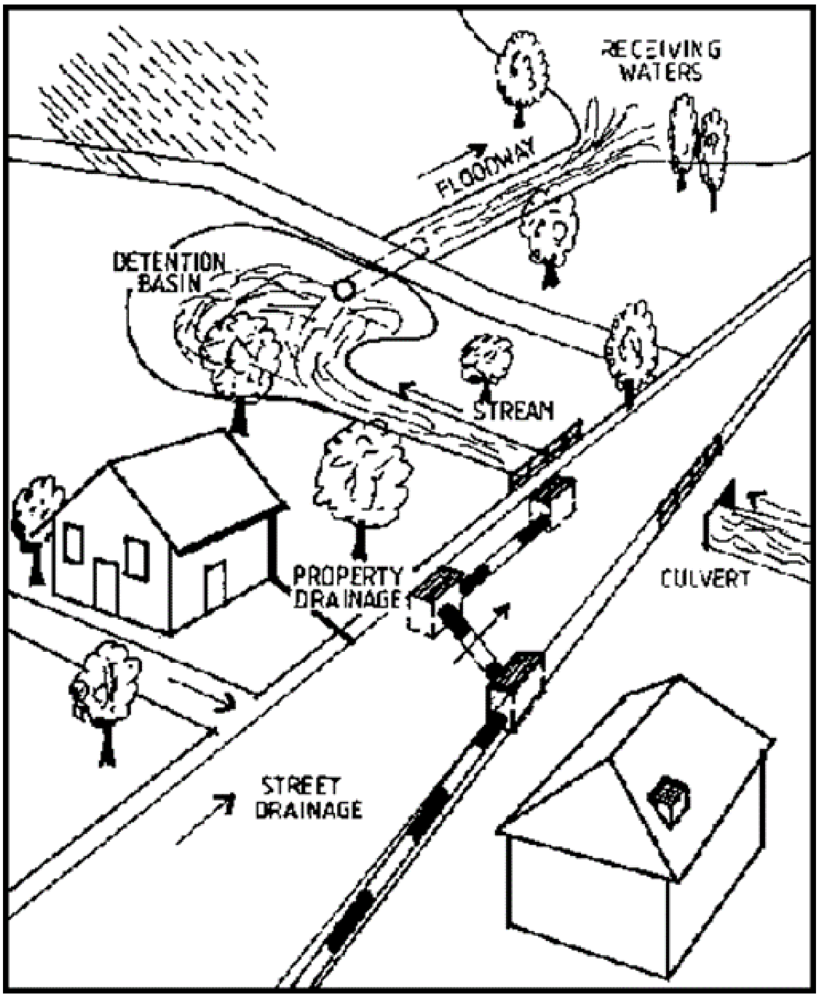


Figure 3:Typical Stormwater Drainage System (Source: http://www.nzdl.org/gsdlmod?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL1.233&d=HASH4ea1eceaacd252591bdaf1.1&gt=2)

2.3.1 Hydrological Shortcomings of Conventional Urban Stormwater and Surface Water Management

Urbanisation is a key demographical trend of the 21st century (Parkinson and Mark, 2005). Global urban populations are estimated to rise to approximately 4.9 billion, by 2030 (ibid.). Therefore, there are a number of considerations that need to be taken into account in terms of this growth:

- The majority of this growth will be focused in towns and cities, this is especially true for developing countries such as South Africa and transitional economies

- In terms of developing countries most of this growth will most probably be unplanned, with communities and private developers exploiting the weak regulatory capacity of local authorities, especially outside municipal boundaries (Parkinson and Mark, 2005.).

In this instance the construction of buildings in and around vital floodplains and natural drainage paths is almost certain (Parkinson and Mark, 2005.). This will result in stormwater problems being worsened in many circumstances, due to the downstream constrictions cause by unregulated development (ibid.). Many cities and towns lack effective and efficient stormwater drainage systems, coupled with inappropriate planning that will alter the natural flow of watercourses (ibid.). The services that are provisioned by these natural watercourse and surface waterbodies are often neglected and underappreciated during the development of urban areas. Watercourses and surface waterbodies are often destroyed, drained, or channelised to allow for development (ibid.).

Economic development also plays a major role in the implications of urban hydrology and stormwater management (Parkinson and Mark, 2005). For example, the increase in car usage and other forms of road transportation leads to a significant increase in impervious surfaces, and can constitute up to 70% of impervious surfaces in countries which are heavily developed (Wong, Breen and Lloyd, 2000). This is especially evident in industrialised areas and countries (Parkinson and Mark, 2005). A higher proportion of stormwater contaminates are associated with transport-related impervious surfaces. Runoff from transport-related impervious surfaces regularly show elevated concentrations of suspended solids and related contaminants such as zinc, copper, and lead, as well as other contaminants associated to microbiological pollution often caused by the flooding of sanitation systems (ibid.). The discharge of pathogenic bacteria and other micro-organisms can result in health implications (ibid.). Figure 4 is an illustration of the temporal and spatial extent of urban water quality problems

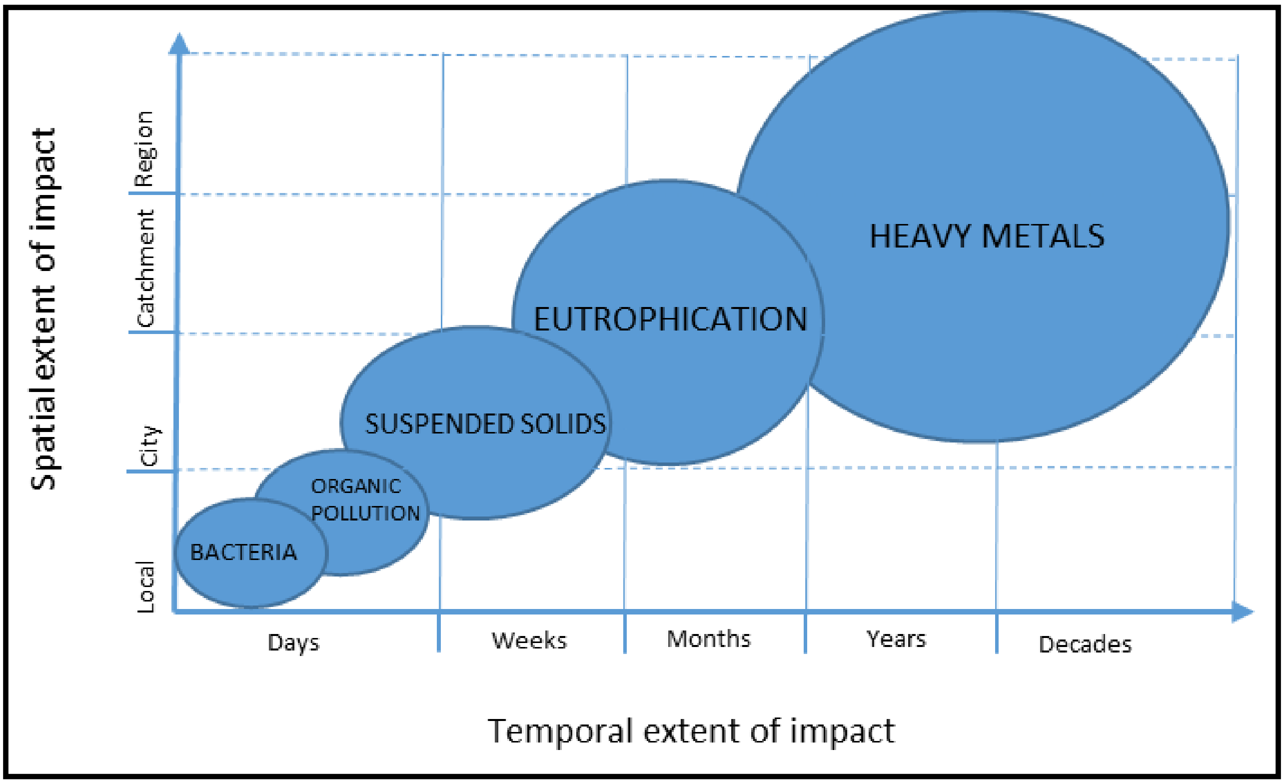


Figure 4: Temporal and Spatial extent of Urban Water Quality Problems (Adapted from: Parkinson and Mark, 2005)

The densification of urban areas, often results in a dramatic increase of impermeable surfaces, due to paving and roofs (Parkinson and Mark, 2005.). This leads to changes in runoff patterns, which affect the magnitude and frequency of flooding. Figure 5 illustrates the effects of urbanisation on stormwater runoff.

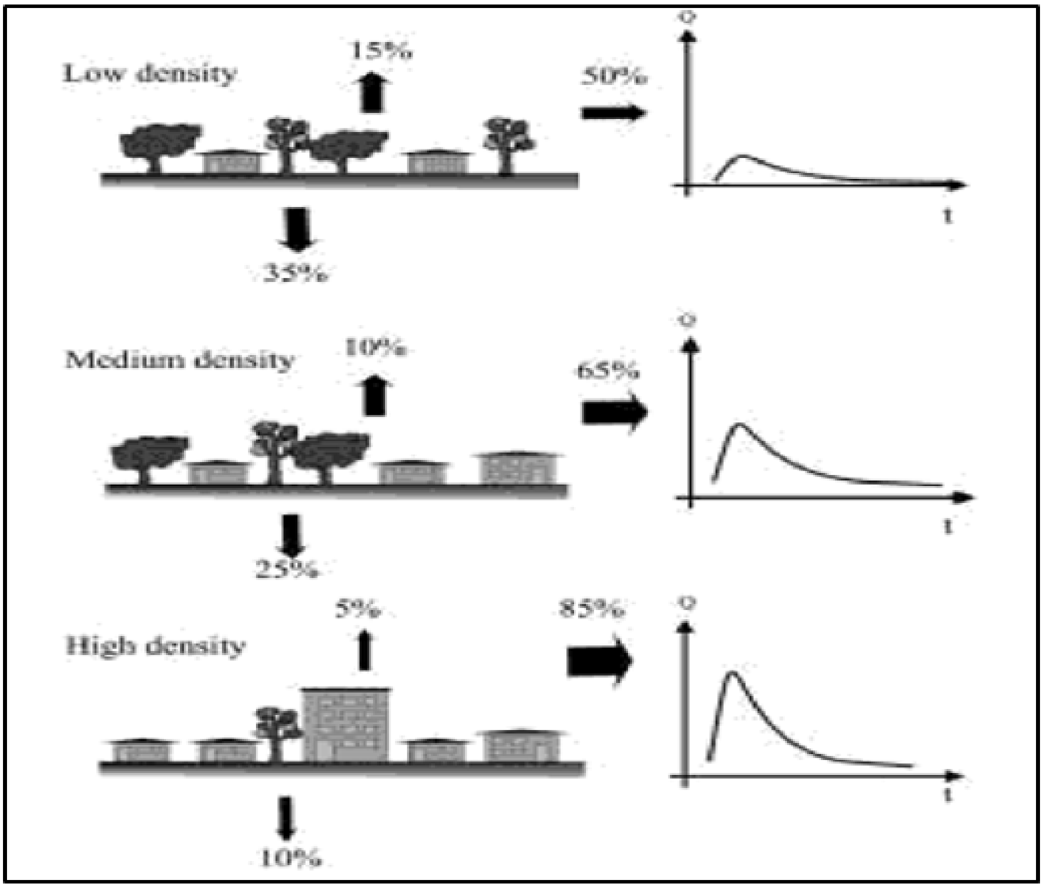


Figure 5: Effects of Urbanisation on Stormwater Runoff (Source: Parkinson and Mark, 2005)

Conventional forms of stormwater management in terms of environmental protection are a failure, because they do not tackle all of the changes of the flow regimes produced by conventional stormwater drainage. (Burns, Fletcher et al., 2011). Burns et al. (2011) argue that there are two forms of stormwater management currently in place:

1. Drainage-efficiency focused stormwater drainage; and

2. Pollutant-load-reduction focused stormwater drainage.

The drainage-efficiency approach was initially implemented to manage flood risk, by routing stormwater runoff into the nearest surface waterbody (Burns et al., 2011). This systems was developed to effectively transport rainfall events that are large enough to induce impervious runoff (usually > 1mm/day), but small enough that they do not reach the system's design capacity (ibid.).

During the 1990s stormwater runoff was predominately being managed for drainage-efficiency; however, this approached was later considered a major threat to regionally important coastal embayments, due to increased loads of pollutants, largely nitrogen carried by stormwater (Burns et al., 2011). Figure 6 lists environmental impacts from pollutants found in stormwater runoff in receiving surface water. Ongoing recognition that stormwater runoff as cause for environmental degradation has led to revision of stormwater management objectives, and the introduction of reducing pollutant loads within stormwater while reducing peak flows (ibid.). Many management strategies emerged as a need to reduce pollutant loads such as Low Impact Design (emerged in the United States of America) and Sustainable Urban Drainage (emerged in New Zealand) (ibid.).

These strategies have been successful to a certain extent; however, only a limited number of studies have documented the effectiveness of these approaches in restoring and protecting the ecological integrity of urban waterbodies (Burns et al., 2011.). Although there has been a recent advance towards reducing pollutant loads and peak flow rates, there is still a need for more comprehensive and holistic approach that includes the aim to restore and protect ecologically vital elements (ibid.). Otherwise, successfully restoring and protecting urban waterbodies is unlikely.

Pollutant	Source	Environmental impact
Oxygen demanding materials	Vegetation, excreta and other organic matter.	Depletion of dissolved oxygen concentration, which kills aquatic flora and fauna (fish and macro-invertebrates) and changes the composition of the species in the aquatic system. Odours and toxic gases form in anaerobic conditions.
Inorganic compounds of nitrogen and phosphorus	Fertilisers, detergents, vegetation, animal and human urine, sewer overflows and leaks, septic tank discharges.	In high concentrations, ammonia and nitrate are toxic. Nitrification of ammonia micro-organisms consumes dissolved oxygen. Nutrient enrichment (eutrophication) causes excessive weed and algae growth blocks sunlight, which affects photosynthesis and causes oxygen depletion.
Oils, greases and gasoline	Roads, parking areas, garages and petrol stations (spillages and leakages of engine oil), and industry. Vegetable oils from food processing and preparation.	Pollution of drinking water supplies and impacts on recreational use of waters. Reduction of oxygen transfer at the water surface. Carcinogenic compounds may cause tumours and mutations in certain species of fish.
Heavy metals, pesticides, herbicides and hydrocarbons	Industrial and commercial areas. Leachate from landfill sites and improper disposal of household chemicals.	Toxic to aquatic organisms and accumulate in the food chain impairing drinking water sources and human health. Many of these toxins accumulate in the sediments of streams and lakes.
Suspended solids, sediments and dissolved solids.	Erosion from construction sites, exposed soils, street runoff and stream banks.	Sediment particles transport other pollutants that are attached to their surfaces. Sediments interfere with photosynthesis, respiration, growth and reproduction, and deposited sediments reduce the transfer of oxygen into underlying surfaces.
Higher water temperatures	Increase in water temperature as runoff flows over impervious surfaces (asphalt, concrete, etc.).	Reduced capacity of water to store dissolved oxygen. Impact on aquatic species that are sensitive to temperature.
Trash and debris	Domestic and commercial refuse, construction waste and various types of vegetation.	Blockages and constrictions to drainage channels, aesthetic loss and reduction in recreational value.

Figure 6: Environmental Impacts of Pollutants from Stormwater Runoff in Surface Water (Source: Parkinson and Mark, 2005)

Flooding and pollution-based issues related to urban runoff are common to many places around the globe. However, the conversion of land in order to accommodate sewer/drainage infrastructure is another major problem associated with the management of stormwater as well as urban growth.

Land conversion typically involves the use of undeveloped land to accommodate development (Burchell and Mukherji, 2003). This conversion of land includes capital improvements required by growth, and involves the expansion of both roads and drainage/sewer facilities (ibid.). This encompasses the development of land, which often encroaches onto important agricultural and environmentally sensitive land, through the construction of roads, pavements, and large amounts of drainage/sewer infrastructure (ibid.), consequently contributing to urban sprawl and negative fiscal effects on local municipalities. This, in turn, influences the management of stormwater and surface water in urban areas as well as the magnitude of urban runoff.

These problems are a particular challenge to developing countries such as South Africa, because urban drainage systems are often associated with numerous issues linked to institutional arrangements (Parkinson and Mark, 2005). A significant institutional problem associated to drainage, is that there is no clear constituency, till a major problem occurs (ibid.). It is only after a large-scale flooding event that investments are made to repair and enhance infrastructure (ibid.)

A key problem in developing countries is that there is not enough control and regulation over new developments, due to the weaknesses in the administrational and planning systems (Parkinson and Mark, 2005.). Planning authorities and regulatory organisations tend to lack resources to create and implement effective solutions for managing runoff and mitigating flooding events (ibid.). Another problem is linked to a lack of co-ordination between different organisations and governmental departments (ibid.). Stormwater drainage and protection facilities are part of a larger environmental system, therefore urban flooding is not bound by local administrative boundaries (ibid.). This leads to an ineffective alignment between administration and hydrological boundaries (ibid.). Drainage systems are widely affected by the lack of appropriate planning and management.

The limited ability of relevant officials, professionals, and departments to collaborate with each other enables the continued support for institutional silos and inertia within stormwater and surface water management. Furthermore, this approach to planning often requires substantial investments with a limited variety of traditional technologies (Howe et al.,2013). The management of urban water systems tends to be fragmented, where the design, construction, and operation of infrastructure is carried out in isolation from each other (ibid.). In addition, short-term conventional solutions are often chosen with very little consideration for long-term impacts on the hydrological system (ibid.). Silo thinking creates institutional mismatching, which tends to lead to fragmented institutional responsibilities that do not coincide with scale and the specific context of urban water resources (Özçevik, Brebbia and Sener, 2015). This in turn results in legal inconsistencies and the disregard for externalities (ibid.). As a consequence, current issues are exacerbated rather than mitigated.

2.4 Adapting Infrastructure to Climate Change

The urban environment has very unique set of biophysical characteristics in relation to rural areas (Gill, Handley et al., 2007). These characteristics include an altered energy exchange and changes in hydrology (ibid.). Such changes are due to the conversion of undeveloped land and altered surface cover, which has resulted in less vegetated areas that then leads to the decrease of evaporative cooling and the increase in impermeable surfaces, which in turn leads to an increase in surface runoff after a rainfall event (ibid.). This alters the hydrological cycle. Consequently, in the face of climate change these distinctive features will be amplified.

Climate change has already had far-reaching impacts on infrastructure and is able to put operation and reliability of hard infrastructure at risk (European Commission, 2013). The most likely predicated threats to hard infrastructure consist of: damage and destruction caused by extreme weather events, coastal flooding, changes in water availability and cycle, and inundation from sea-level rise (ibid.). These threats may not impact hard infrastructure directly, but could possibly limit physical access and services (ibid.).

The need for future infrastructural investment to accommodate the projected growth and expansion of urban centres will increase immensely in the coming decades (European Commission, 2013). Climate change might have little effect on altering the demand for infrastructure, but it will increase the cost of infrastructure in general, and will most certainly affect where infrastructure is built and placed, how it is designed, as well as operated (ibid.). There will also be a need for additional infrastructure committed to climate protection, such as flood protection and enhanced sea defenses, interconnection in water supply, and the retrofitting of existing infrastructure to improve resilience against climate change (ibid.).

Stormwater infrastructure in particular is designed based on an underlying assumption that the probability distribution of precipitation event extremes are statistically stationary in their nature (Rosenberg, Keys et al., 2010). “This assumption is called into question by climate change, resulting in uncertainty about the future performance of systems constructed under this paradigm” (Rosenberg et al., 2010:1), which tends to be inflexible to change. The Intergovernmental Panel on Climate Change (IPCC) (2007) states that there is an approximately 90% chance that the frequency of heavy rainfall events will be increased in the 21st century, therefore increasing stormwater runoff by as much as 10% to 40%. The increase in stormwater runoff entering surface waterbodies could result in increased peak flows, causing erosion, a decrease in natural stream stability, and will impact the overall ecology of surface waterbodies. The capacity of stormwater facilities influences economic activities as well as society, therefore the mismanagement or lack of adaption of stormwater infrastructure could potentially result in the disabling of key economic and societal assets (Rosenberg et al., 2010).

Hence, making stormwater infrastructure “resilient to climate change is an important and early adoption challenge” (European Union, 2013:5). This will require sophisticated decision-making and a multi-disciplinary approach. Addressing climate threats in the investment and operating decisions can open up new opportunities in terms of looking at alterative and cost-effective ways of planning, designing, and managing infrastructure (ibid.). Adopting infrastructure to climate change provides the opportunity to move towards the use of ecological infrastructure, to mitigate some of the risks and impacts associated with climate change.

2.5 Introduction to Ecological Planning and Urban Ecology

"Ecology has come of Age" (Lister, 2010). In the past two decades, designers and planners have become increasingly interested in the science and concept of living systems, both as an instrument and a metaphor (ibid.). From a large, operational, and performative sense of landscape design for brownfields and neglected sites to the design of smaller scale projects such as city parks (ibid.), ecology is now a key part of the vocabulary and language of the contemporary urban environment and landscape (ibid.).

In a formal sense, ecology is a branch of biological sciences; it is the study of complex relationships between organisms/species and their environments (Lister, 2010).The 'environment' here is understood by ecologists as the physical environment governed by air, water, and soil (Forman, 2014). More broadly, ecology is frequently used as a metaphor to describe the relationship between humans and their various constructed environments, from political-economic to social-cultural (ibid.). The shape and form of our physical environmental changes are dictated by the political-economic and social-cultural forces of globalisation, capitalism, decentralisation, and post-industrialisation of the contemporary metropolitan region, and have reshaped the paradigm and notion of ecology (ibid.).

In the context of the rise of ecology as a science, and a strategy within, the increasing confluence of the landscape/natural environment and urbanism has highlighted the changing role of ecology in planning and design of urban environments.

In the 1960s ecology as a discipline was propelled to the frontline, due to the environmental crisis that was suddenly being realised (Forman, 2014). Ecology was emphasised as a key subject both for understanding and solving the problem of environmental degradation. Professional societies and journals on the topic of ecology were founded in 1912/1915, and a modern ecology was born highlighting ecosystem, theoretical, systems ecology, and community (ibid.). Many sub-specialties evolved from this concept, including the recent development of landscape ecology, urban ecology, and conservation biology (ibid.). The diversity of ecological sciences naturally developed variations in defining ecology (ibid.). However, despite all these variations with the science of ecology, all types of ecological sciences prescribed to one shared notion and definition, that it is 'the interaction of organisms (including humans) with the natural environment' (Forman, 2014).

In the 1990s and 2000s, urbanisation and global climate change further catapulted environmentalism and ecology to the forefront as a solution to societal and environmental problems (ibid.). Within this, the infant concept of urban ecology has been growing as a solution to both societal and environmental problems.

2.5.1 Ecological Planning

Sustainable development is a widely accepted strategic framework in making decisions about future land-use development and activity (Opdam, Steingröver and Rooij, 2006). However, the incorporation of ecological sustainability is not well established in both spatial and landscape planning (ibid.). The inclusion of ecological principals in spatial planning and landscape planning is a recent progression (ibid.). According to Steiner (2011) ecological planning is defined as the use of biophysical and socio-cultural information and knowledge to suggest appropriate opportunities and constraints, for decision-making about the use of current and future landscapes.

Sustainable land-use development requires that spatial planning along with landscape planning aim for “a condition of stability in physical and social systems achieved by accommodation the needs of the present without compromising the ability of future generations to meet their needs” (Opdam et al., 2006:323). This suggests that decision-making about future land-use development must achieve a balance between cultural, ecological, and economic functions, so that current and future prime resources are not depleted and destroyed. Opdam et al. (2006) state that the landscape as a geographical unit is distinguished by the specific pattern of ecosystem types, which are formed by the human, geographically and ecologically induced forces. Therefore, the landscape is regarded as a unit of physical planning (ibid.). Hence, planning and sustainable development of landscapes requires that:

- the landscape structure encourages ecological, economic, and social process; so that the natural environment can deliver goods and services well into the future;
- the landscape is flexible to change, without compromising key resources;
- relevant stakeholders are involved in the decision-making of landscapes and land-use functions and patterns (Opdam et al., 2006).

A key factor amongst many in obtaining ecological sustainability is the spatial cohesion of ecosystem networks (Opdam et al., 2006). This is one of the main reasons for the knowledge gap between ecology and planning (ibid.). However, solving this problem is well beyond the scope of this dissertation.

2.6 Introduction to Water-sensitive Urbanism and Design

Water-sensitive Urban Design (WSUD) is an integrated water management framework that incorporates low impact design (LID), water conservation and restoration, water quality management, and urban ecology (Donofrio, Kuhn et al., 2009). WSUD is increasingly becoming a significant component in creating and implementing sustainable planning in urban areas around the world, as well as contribute to adequately preventing flood events and protecting water quality (ibid.). Urban water management has been one of the greatest challenges of the 21st century (ibid.). WSUD provides key approaches to resolving certain dilemmas associated with urban water management.

The concept of WSUD emerged in Australia around the 1990s, from the realisation that conventional methods of managing urban water systems degrade the state of aquatic resources (Donofrio et al., 2009), with water being a growing problem globally. In many cities water is seen as critical to the delivery of water sensitivity design by employing a transdisciplinary approach to urban water management that aims to holistically consider the environment, social, and economic consequences and opportunities of water management strategies (Ashley, Lundy et al., 2013). WSUD considers urban surface runoff as a resource rather than a liability (ibid.). Urban designers, architects, and spatial planners have recently recognised the value of water and green infrastructure in the urban landscapes as a significant component of multi-functional land-use and climate change adaption (ibid.). "There is a now a major opportunity to provide water, drainage, and associated services" (Ashley et al., 2013:66). This can be done by connecting water with other urban services (ibid.).

There has been a significant change in the way in which surface water is expected to be managed, with an increasing preference for SUDs (Ashley et al., 2013). However, surface water is only on component of the urban water cycle, therefore a comprehensible and whole-system approach for management is now a feasible option (ibid.).

The notion of water sensitivity allows for the identification of the most viable options for managing urban water systems and water quality (Ashley et al., 2013). Urban areas need to be water sensitivity to urban design, place-making, and liveability by potentially moving towards sustainable urban water management (ibid.). WSUD includes the management and protection of the natural environment into spatial planning and urban design. This integrates engineering and ecological professions that are related to protecting urban water resources (ibid.).

WSUD is a concept beyond stormwater management (ibid.). Its pursues maximising the opportunities for living and manipulating the supply, use, reuse, and management of wastewater, in order to enhance and support human health by reducing the impacts of urbanisation on the water cycle as well as the natural environment (ibid.). Figure 7 is an illustration of WSUD, the interactions between the urban environment and the urban water cycle.

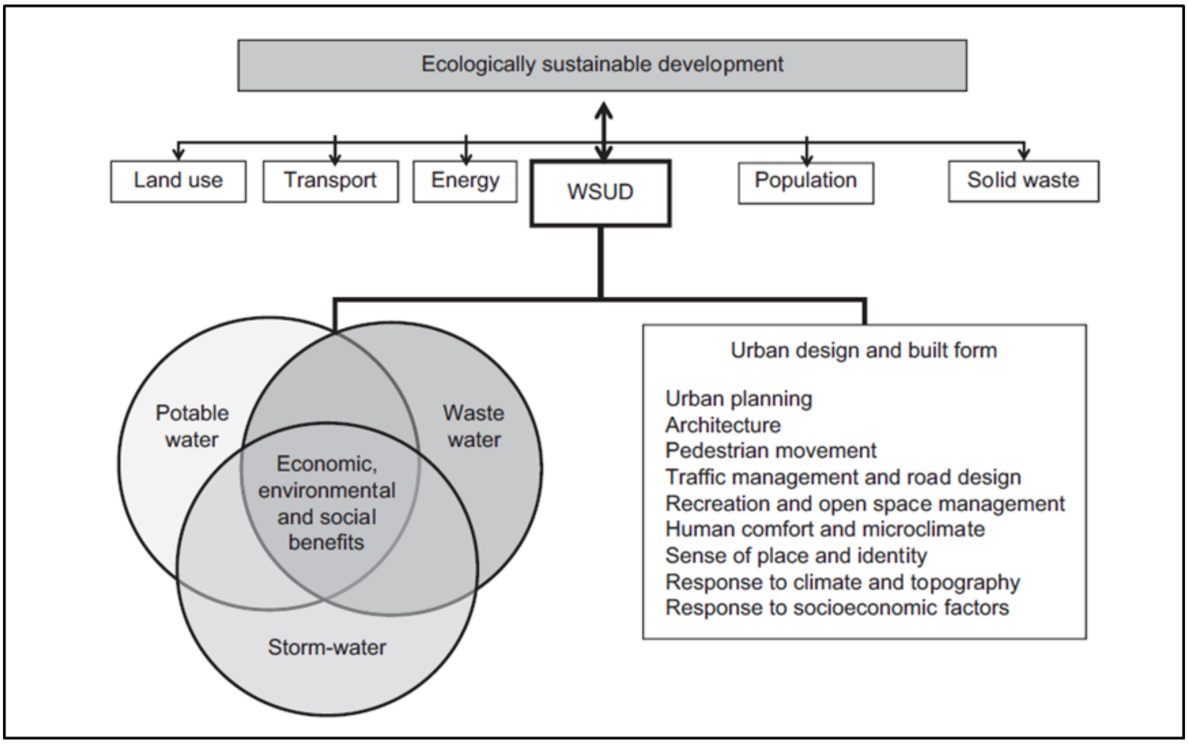


Figure 7: WSUD: Interaction between the Urban Environment and the Urban Water Cycle (Source: Ashley et al., 2013)

The principles of the WSUD are applied, in order to make the most of opportunities to manage the urban water cycle by delivering multi-functionality and appropriate urban design as well as spatial planning (Ashley et al., 2013). Figure 8 depicts key principles of WSUD.

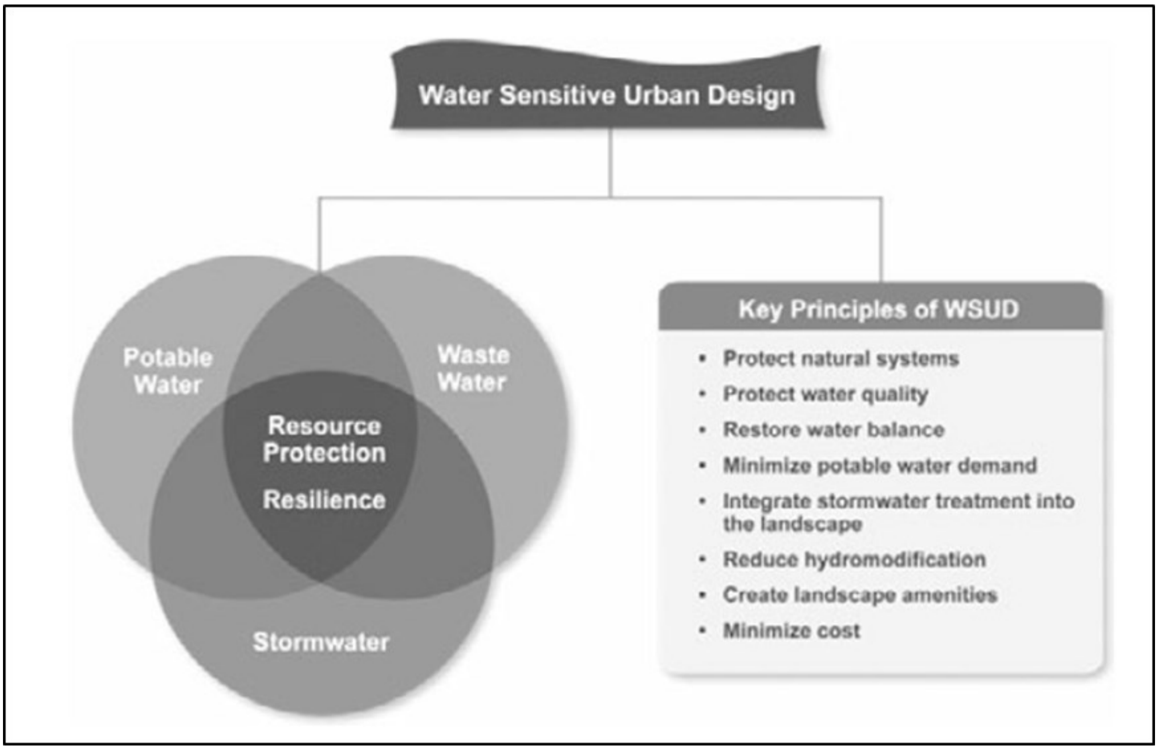


Figure 8: Key Principles of WSUD (Source: Donofrio et al., 2009)

WSUD offers a basis for key design elements such as site design, planning, stormwater management, water quality treatment, and water conservation (Donofrio et al., 2009).

2.7 Green Infrastructure and Urban Water Management as a New Paradigm

"The rise in green infrastructure research has coincided with the reassessment of what landscapes should be in terms of form and function" (Mell, 2008:69). The definition and meaning of green infrastructure is constantly changing and evolving in meaning (Austin, 2014). Austin (2014) states that fundamentally, green infrastructure is a continuous network of green spaces and corridors which are planned and managed to support healthy ecosystem function. Green infrastructure provides the opportunity to mitigate pollution, recreation, generate economic value, and urban structure that benefits not only humans but also the natural environment (ibid.). Green infrastructure is primarily the conversion from a grey infrastructure model to a more sustainable and eco-friendly model. Organisational co-operation, multi-functionality, policy, and planning integration are all notions that underpin the rise of green infrastructure, but are also extremely vital developments in planning policy as a whole (Mell, 2008). Therefore, what needs to be truly addressed at this moment in time is how green infrastructure as a theory and as a landscape management tool can be appropriately mainstreamed into planning practice as well as stormwater and surface water management.

Green infrastructure is a fairly new term, although the concept is not (Benedict and McMahon, 2006). The notion of green infrastructure is rooted in the studies of land and the relationship between man and nature, which began millions of years ago with the first hominid. The field of green infrastructure is a mixture of different theories, ideas, research, and conclusions from ecology, engineering, development planning, and nature conservation (ibid.). “Green infrastructure gains its strength from its interdisciplinary roots” (Benedict and McMahon, 2006:23), and therefore has the ability to promote a variety of benefits. This approach is meant to help determine the best way to use and develop land whilst supporting and enhancing existing natural processes as well as fulfilling infrastructure and recreational needs of the urban populations (ibid.). The above notion has had a long association with green infrastructure research and practice dating back to its early use in the 1990s.

The first large-scale attempt to integrate green infrastructure into urban planning and design occurred in Maryland, USA during the 1990s (Benedict and McMahon, 2006). This was a response to the growing interest and research around addressing the complexities that are presented by sustainable development and land conversion (ibid.). Both conservationists and planners recognised that preserving nature in isolated pockets and parcels was not working in promoting ecological resilience and integrity (ibid.). Natural areas need to be linked at a regional and landscape scale, in order to fully enhance and protect biodiversity and ecosystem services (ibid.). Maryland ran a state-wide greenways planning initiative, which led to state-wide ecological analysis and green infrastructure mapping (ibid.). During the 1990s, the state of Florida carried out a major green infrastructure initiative, by commissioning a state-wide greenways system (ibid.). This initiative was meant to connect existing and proposed conservation lands, trails, private lands, and urban open space (ibid.), in an attempt to reconnect the city to the biosphere. These two initiatives sparked a growing number of regions and communities to start to undertake green infrastructure planning, design, and implementation efforts around the world (ibid.)

2.7.1 Current Green Infrastructure Research and Practice

Current research around green infrastructure can be broadly divided into two groupings; theoretical research and practical application (Mell, 2008). The theoretical research is broadly based on the underlying concepts drawn from the historical work of Frederick L. Olmstad and Ebenezer Howard, and are contextualised within modern-day landscape planning (ibid.). Both Olmstad and Howard were fundamental in developing green infrastructure thinking, they were among the first to explore the interrelationship between ecological capacity and social opportunity of a given area (ibid.). This idea is present and evident in landscape planning. The ideas of multi-functionality, practice integration, and the importance of understanding landscape form and function are also heavily emphasised in landscape planning as well as in green infrastructure research (ibid.).

Various researchers from a number of academic institutions have created a few important pieces of practice -led green infrastructure research, which illustrate the practical benefits of green infrastructure to both social and ecological populations around the globe (Mell, 2008). The conversion of these theoretical ideas into practical landscape management practices is therefore a significant area of research that needs to be well addressed, otherwise the important teachings and values proposed by authors such as Benedict and

McMahon, Austin, and many others could be lost in translation. Figure 9 highlights green infrastructure concepts and ideas as well as an array of documents that reinforce the importance of green infrastructure.

Elements of Green Infrastructure	Authors
Assessibility	Countryside Agency and Groundwork (2005); Gallent et al. (2004); Hidding and Tenuissen (2002)
Concept and a resource	Davies et al. (2006); Benedict and McMahon (2006)
Connectivity and networks	TEP (2005); Benedict and McMahon (2002); TCPA (2004); Williamson (2003); Countryside Agency (2006)
Integration of different cross-boundary people, places and policies	TEP (2005); TCPA (2004); Weber, Sloan and Wolf (2006); Countryside Agency (2006)
Scale (GI size, political, physical landscapes)	TEP (2005); TCPA (2004); Countryside Agency (2006)
Multiple benefits	TEP (2005); Benedict and McMahon (2002); ODPM (2003); Williamson (2003); Lindsey et al. (2001); Countryside Agency (2006)
Multi-functionality	TEP (2005); ODPM (2003); TCPA (2005); Gobster and Westphal (2004); Countryside Agency (2006); Davies et al. (2006)
* TEP is an environmental consultancy firm based in the northwest of England.	

Figure 9: Green Infrastructure Research (Source: Mell, 2008)

However, the documents listed in Figure 9, amongst others, tend to focus primarily on a particular element of green infrastructure, rather than presenting the nuances and understandings found between theoretical and practitioner-based research (Mell, 2008). Only a few researchers worldwide have attempted to bridge this gap (ibid.). There is a great need to further combine broad concepts of form, space, and function within green infrastructure research about practical implementation and delivery ideas/strategies (Ahern, 2007). Examples of integrating green infrastructure concepts and research into adaptive planning do exist (Mell, 2008). This has been seen in green infrastructure projects that use water resources to mitigate climate change (Ahern, 2007).

Green infrastructure thinking has been significantly shaped by the role of water in both the urban and natural environment, and has led researchers to debating a potential sub-category of blue-green infrastructure (Ahern, 2007). Climate change is one of the most important and discussed issue by planners and developers, therefore green infrastructure thinking has promoted the value of mitigating climate change through sustainable design of residential and large scale infrastructure development (Mell, 2008). Environmental design plays a vital role in green infrastructure thinking (ibid.). This is evident in the design concept of SUDS (sustainable urban drainage systems), which help with controlling water surges by providing reservoirs in order to store, filter and release rainfall and stormwater during surges in urban water systems (ibid.). SUDS as green infrastructure are able to help mitigate adverse climatic conditions, by conveying and retaining water in the built environment, in a similar way to that of a natural system (ibid.).

The constituents of green infrastructure are able to contribute to ecosystem health in numerous ways (Tzoulas, Korpela et al., 2007). Green infrastructure contributes to the conservation of biological diversity, by providing the opportunity to increase vegetation cover (natural, semi-natural, and artificial) in urban and peri-urban settings (ibid.). Additionally, green infrastructure may provide a physical foundation for ecological networks, in order to appropriately maintain the integrity of habitat systems (ibid.). The creation of ecological networks has been encouraged as a means of mitigating ecological impacts and habitat fragmentation (ibid.). This approach is meant to increase diversity within ecosystems, in terms of genes, species, and habitats (ibid.). Diversity is indeed one of the most significant indicators of ecosystem health (ibid.), therefore an important element of restoring and protecting the natural environment. The importance of diversity is proven by the clear fact that species-rich heterogeneous habitats tend to more resilient than homogeneous habitats. Ecosystems that are considered to be species-rich also tend to have higher yields of productivity than simpler ecosystems (Naeem, Chair et al., 1999). Therefore, a green infrastructure approach could potentially influence urban ecosystem health, by adding to ecological resilience, productivity, and organization (Tzoulas et al., 2007).

2.7.2 Green Infrastructure and Managing Stormwater and Surface Water in Urban Areas

The concept of green infrastructure was developed from the principles of ecological planning (Youngquist, 2009), in order to align economic, and social development with environmental protection. Even though green infrastructure presents possible social, economic, and environmental benefits, cities have been hesitant and slow to implement green infrastructure for the management of stormwater and urban surface water, especially in developing countries.

The need for cities to manage stormwater increase as development continues to alter the natural landscape and local hydrological patterns, converting naturally permeable land into impervious surfaces (Hammitt, 2010). Developing a pocket of land by only 10% has proven to change dramatically the hydrology of that particular area (ibid.). A typical city has been known to generate surface runoff that is five times higher than that of a natural area of the same size, resulting in bursts of high runoff discharge (ibid.). A city without any form of stormwater infrastructure will result in stormwater runoff pooling in low-lying areas, uncontrolled flooding events, property damage, and habitat destruction (ibid.).

However, green infrastructure provides the opportunity to reduce the probability of the each of the above risks, by restoring and maintaining a site's natural hydrological patterns, whilst allowing for development to occur (Hammitt, 2010.). The role of green infrastructure in stormwater and surface water management, is, however, highly dependent on a variety of variables such as location, assessed need, existing resources base, and governance structures (Mell, 2012a). Therefore, there is no standardised process for the application of green infrastructure. Location context is extremely important in the application of different green infrastructure typologies and solutions, in order to ensure that intervention does not impact the landscape in a negative manner (ibid.).

The section below will give a summarised overview of key urban water management issues that can be appropriately addressed by green infrastructure.

Water Supply Regulation

The functioning of economic, industrial, social, ecological activity is dependent on water supply. Therefore, water is a precondition to any environment, built or natural. Urban areas often use grey infrastructure as means for the provision of water to supply large populations with water. However, water originates from a broader network of ecosystems, making nature the foundation of water provision.

Hydrological processes characteristic of the urban environment that affect the water cycle such as runoff and infiltration, can be mitigated through the use of green infrastructure interventions that will maintain and enhance water supply by increasing and maintaining clean water supply through increasing infiltration and storage capacities of wetlands and soils, as well as increasing the recharge of aquifers.

Water Quality Regulation

Water pollution from non-point sources is one of the major problems, in terms of urban water management. The main sources of non-point pollution runoff are agricultural lands and industrial areas. Water drainage infrastructure is often the solution used to capture polluted runoff; however, this runoff is often diverted into urban surface water systems. Green infrastructure provides an alternative service to water purification by trapping and filtering pollutants.

Moderation of Flood Events

Floods are a common and costly occurrence in urban areas. Conventional flooding management techniques involve heavily engineered solutions. However, engineered solutions often provide a false sense of security, especially if coupled with inappropriate land-use activity and management.

Green infrastructure is a great way to moderate the velocity of flooding by increasing the ability of the landscape to store and convey floodwaters. Forest/vegetation and wetlands are a great means of using the natural ability of ecosystems in retaining and slowing down surface runoff.

Urban Stormwater Runoff

Stormwater runoff is one of the main causes of waterway degradation and habitat loss. Stormwater tends to flush pollutants from surrounding areas into watercourses and systems, and can sometimes lead to the overflow of combined sewers. Conventional solutions to this problem involve expanding water-drainage infrastructure that can sometimes aggravate the problem itself. Green infrastructure reduces the risk of sewer overflow and contamination of watercourses and systems, by aiding infiltration and storage of stormwater runoff.

Figure 10 is a summary of green infrastructure solutions relevant to urban water resources issues and management.

Water management issue (Primary service to be provided)		Green Infrastructure solution	Location: Watershed	Location: Floodplain	Location: Urban	Location: Coastal	Corresponding Grey Infrastructure solution (at the primary service level)
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	x				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		x			
		Wetlands restoration/conservation	x	x	x		
		Constructing wetlands	x	x	x		
		Water harvesting*	x	x	x		
		Green spaces (bioretention and infiltration)			x		
		Permeable pavements*			x		
Water quality regulation	Water purification	Re/afforestation and forest conservation	x				Water treatment plant
		Riparian buffers		x			
		Reconnecting rivers to floodplains		x			
		Wetlands restoration/conservation	x	x	x		
		Constructing wetlands	x	x	x		
		Green spaces (bioretention and infiltration)			x		
		Permeable pavements*			x		
	Erosion control	Re/afforestation and forest conservation	x				Reinforcement of slopes
		Riparian buffers		x			
		Reconnecting rivers to floodplains		x			
	Biological control	Re/afforestation and forest conservation	x				Water treatment plant
		Riparian buffers		x			
		Reconnecting rivers to floodplains		x			
		Wetlands restoration/conservation	x	x	x		
		Constructing wetlands	x	x	x		
	Water temperature control	Re/afforestation and forest conservation	x				Dams
		Riparian buffers		x			
		Reconnecting rivers to floodplains		x			
		Wetlands restoration/conservation	x	x	x		
		Constructing wetlands	x	x	x		
		Green spaces (shading of water ways)			x		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	x				Dams and levees
		Riparian buffers		x			
		Reconnecting rivers to floodplains		x			
		Wetlands restoration/conservation	x	x	x		
		Constructing wetlands	x	x	x		
		Establishing flood bypasses		x			
	Urban stormwater runoff	Green roofs			x		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			x		
		Water harvesting*	x	x	x		
		Permeable pavements*			x		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				x	Sea walls
		Protecting/restoring reefs (coral/oyster)				x	

Figure 10: Green Infrastructure Solutions for Urban Water Problem., Solutions marked with '' consist of built ('grey') elements that interact with natural features (Source: UNEP, 2014)*

2.7.3 Most Common Examples of Green Infrastructure Solutions Relevant to Stormwater and Surface Water Management

Riparian Buffers

Riparian buffers are vegetated strips that are positioned adjacent to watercourses and systems, which provide protection to aquatic environments from the impacts of surrounding areas (Enanga, Shivoga et al., 2010). Riparian buffers can be used to maintain water quality by trapping sediments and filtering pollutants such as nitrogen phosphorous, via biological and physical-chemical processes (ibid.).

During flooding riparian vegetation tends to slow down runoff as well as reduce peak flow, by absorbing excess water.

Wetland Restoration, Construction and Protection

The restoration of wetlands that have been damaged by human activities such as draining can prevent further loss of ecological value (UNEP, 2014). Wetlands provide meaningful ecological support in terms of water treatment, flood control, and water supply (ibid.). Wetlands tend to be a cost-competitive and sustainable alternative for regulating and maintaining water quality, through their ability to filter effluent and absorb pollutants. Microorganisms found in the soil and vegetation associated with wetlands, help break down waste as well as eliminate pathogens (ibid.).

Wetlands are also able to store large quantities of water and release it gradually; this plays a vital role in the natural regulation of water quantity in events of draught and flooding (UNEP, 2014).

Wetlands can also be artificially constructed, mimicking the hydrological processes of natural wetlands (UNEP, 2014).

Green Roofs

Green roofing is a method of building roofs that are fully or partially covered with vegetation (UNEP, 2014). Green roofs can be designed with additional drainage nets and/or irrigation systems (Foster, Lowe et al., 2011). Green roofs are able to function as an essential part in water quantity regulation, by reducing stormwater runoff and the overburdening of sewers (ibid.). They later release stored runoff via evapotranspiration (ibid.). Annual stormwater runoff can be reduced by approximately 50% to 60%, through water retention provided by green roofing (ibid.)

Green Spaces

Green spaces comprise areas that are partially or completely covered by vegetation, in order to create a basis for bioretention and infiltration (UNEP, 2014). Green spaces are most relevant to urban areas, because they provide a means for regulating stormwater runoff in the presence of impervious surfaces (ibid.). Within the concept of green spaces, there are two green infrastructure solutions that have fairly similar benefits but somewhat different functions:

- Rain gardens: these are depressions developed in the landscape to infiltrate and filter stormwater runoff (ibid.). They consist of vegetation as well as sometimes an underdrain (ibid.).

  Rain gardens are specifically developed to deal with large rainfall events and high concentrations of nutrients often found in stormwater runoff (ibid.). Their preferred placement is at the bottom of slope, so that they are able to collect rainwater and stormwater effectively (ibid.).

- Bioswales are a landscape technique that consists of a drainage course, sloped sides, and vegetation/ compost in the middle (ibid.). Bioswales are meant to redirect and filter out pollutants (ibid.). The key difference between bioswales and rain gardens is that bioswales are primarily meant to transport water from one place to another, whilst removing silt and other pollutants (ibid.). Bioswales have a high tolerance for wet conditions and can be installed near or next to paved areas (ibid.).

Permeable Paving

Permeable paving is made from materials that cater for infiltration, filtration, and groundwater recharge (UNEP, 2014). The materials used in manufacturing permeable paving are often made out of coarse particles, in order to enhance permeability (ibid.).

Permeable paving is usually installed with two layers: the first being finer sediment, which filters out pollutants, and the second a gravel that conveys and stores water (UNEP, 2014). Permeable paving aids in reducing groundwater and soil contamination, as well as stormwater runoff by approximately 70% to 90% (Foster, Lowe et al., 2011).

2.8 Barriers for Implementing Green Infrastructure Urban Water Management

Despite the increasing interest and acknowledgement that green infrastructure can be implemented to manage both stormwater and surface water in urban areas in a holistic manner, the process of adoption worldwide has been relatively slow (Tian, 2011). Even though some cities have enacted stormwater regulations and policies that promote green infrastructure solutions, more often than not cities use green infrastructure as an experiment in new development rather than implementing citywide solutions (ibid.).

Removing implementation barriers for green infrastructure will allow cities to employ large-scale plans that are cost-effective (Hammitt, 2010). Barriers that are commonly identified tend to be barriers related to institutional capacity, technical application, and financial constraints.

2.8.1 Institutional Barriers

Fragmented Regulatory Framework

A fragmented regulatory framework is characterised by inconstancies within policies (Tian, 2011). Implementation requirements on a local level tend to give rise to inconstancies within stormwater policies across jurisdictions, rather than managing stormwater throughout a watershed (ibid.). This makes it extremely difficult for polices to implemented effectively. There is also a massive lack of green infrastructure reinforcement within local governmental ordinances and development standards (ibid.).

Regulations around the management of current stormwater and surface water management tend to discourage and minimise the potential benefits that green infrastructure presents (Tian, 2011). This slows down the process of implementing green infrastructure projects. State policies and regulations also still do not fully encourage the management of stormwater and surface water via the use of green infrastructure (ibid.).

The lack of inter-jurisdictional communication and planning is another major problem. Stormwater is often managed by various government entities within a watershed, and more often than not, these entities do not work collaboratively as stormwater management is usually a low priority on local government’s agenda (ibid.).

Resistance to Change

Although local governments have acknowledged that green infrastructure is a potential tool to holistically manage stormwater and surface water, the primary barrier is still resistance within local government (Hammitt, 2010). This resistance is embedded in governmental officials religiously following past practices to fulfil infrastructural priorities (ibid.). The reason behind this is that many existing officials have their expertise based on well-established conventional hard infrastructure methods (ibid.).

Another barrier is the uncertainty governments have around how to apply green infrastructure techniques to the management of stormwater and surface water (Hammitt, 2010). Engineers, on the other hand, are slowly getting to grips with techniques to implement green infrastructure project (ibid.). However, uncertainty still remains, because the concept and practice of green infrastructure is still relatively new (ibid.). Consequently, the lack of design standards creates a barrier of acceptance (ibid.).

2.8.2 Technical Barriers

Lack of Performance and Cost Data

Since green infrastructure approaches are fairly new, officials and practitioners have limited experience and familiarity (Tian, 2011). Therefore, there is an evident lack of performance and cost data, in comparison to conventional hard infrastructure approaches (ibid.). Conventional stormwater management is often centralised and a heavily engineering-based approach, whilst green infrastructure is applied to developments that vary in scope and landscape features (ibid.). The decentralised nature of green infrastructure makes data collection exceptionally difficult, which makes local governments hesitant to start adopting and implementing green infrastructure into stormwater and surface water management (ibid.).

Lack of Design and Maintenance Standards

Conventional hard infrastructure is well-established, with standardised design manuals, lacking, however, in green infrastructure (Tian, 2011). Unstandardised green infrastructure techniques create a barrier to widespread implementation, because designers and maintenance officials are unable to pick applicable approaches and practices from an established manual, which creates hesitation (ibid.).

Insufficient Expertise and Knowledge in Government

The application of green infrastructure is new and a complicated approach that requires extensive knowledge from several disciplines (Tian, 2011). Engineers and other relevant practitioners tend to lack expertise beyond their intended field (ibid.), so the possibility of appropriate implementation of green infrastructure is highly unlikely. Green infrastructure implementation also requires strong political leadership to successfully advocate for a change in stormwater and surface water management approaches (Hammitt, 2010), without which the likelihood of green infrastructure being integrated into policies and planning systems is slim.

2.8.3 Financial Barriers

Lack of Sufficient Funding

Governments are currently facing the challenge of financial constraints in implementing a green infrastructure approach to managing stormwater and surface water in urban areas (Tian, 2011). The financial barrier is a significant challenge for municipalities. Although one of the benefits of implementing green infrastructure is that it is cost-effective long-term, the initial cost might be too high for municipalities to even consider moving from conventional methods of stormwater and surface water management (ibid.). The municipalities that have started to adopt a green infrastructure approach have been faced with budget limitations in terms of building institutional capacity, training existing staff, employing relevant consultants, and developing new programmes (ibid.).

Lack of Incentive-based Policies

Municipalities have not adequately employed incentive-based policies to encourage green infrastructure stormwater and surface water management techniques (Tian, 2011.). Therefore, there lacks of creative and innovative incentive-based programmes that encourage the move towards green infrastructure to the wider public (ibid.).

However, the use of both international and local case studies will allow for an in-depth and multi-faceted exploration of complexities associated with implementation. Case studies are a useful evaluation tool when comes to implementing a fairly recently developed concept such as green infrastructure in a new setting such as Cape Town. The use of case studies will shed light on the complexities of implementation and potential lessons learned. This, in turn, will help guide cities that are considering employing green infrastructure, in what to expect and what to avoid in order to minimise or avoid implementation issues.

2.9 Green Infrastructure Planning and Design

2.9.1 Green Infrastructure and Possible Implications for Urbanism and Design

With the reality of climate change, rapidly growing urban centres, and extensive environmental degradation around the globe, it is evident that there is a great need for more adaptive urban infrastructure within cities (Peng, 2011). This especially true for coastal cities such as Cape Town, that might be subjected to sea level rise and stormwater surges (ibid.). This then provides the potential for green infrastructure to supplement current civil engineering solutions and conventional infrastructural systems (ibid.). This in itself will have implications for both urbanism as well as the design of stormwater infrastructure.

Landscape and urban ecology provide a complex way of understanding and shaping environments (Steiner, 2011). “In its Dutch origin, ‘landschap’ meant to adapt cultural and natural processes to create new territory” (Steiner, 2011:333). This notion is, to some extent, embedded in the concept of green infrastructure planning, design, and management, as well as the development of urban sustainability. Ecosystem understanding and city design provide the unique possibility of moving towards a new type of urbanism called Landscape Urbanism.

Landscape urbanism emerged approximately a decade ago (Waldheim, 2010) and has evolved from design theory within both landscape architecture and architecture itself (Steiner, 2011). The emergence of landscape urbanism came about as a critique of the inability of conventional urban design strategies to cope with global environmental degradation that was mainly caused by industrialisation (Waldheim, 2010). This type of urbanism provides the opportunity to use cultural and natural processes inform the design and organisation of urban form (Steiner, 2011). The basic principle of landscape urbanism is that the landscape or natural environment should be the fundamental building block to city design, since it is the fundamental building block to life and to the survival of mankind. Unlike traditional forms of urbanism that are commonly structured around infrastructure, commercial, and residential development. These traditional structuring elements are often associated with economic development, therefore tend to again preference. The approach of landscape urbanism involves the understanding of large-scale systems, in order to inform and structure development proposals in a way that engages and integrates both ecological and social dynamics (ibid.). This thinking is reflected in urban sustainability theory and practice, and is demonstrated in Figure 11.

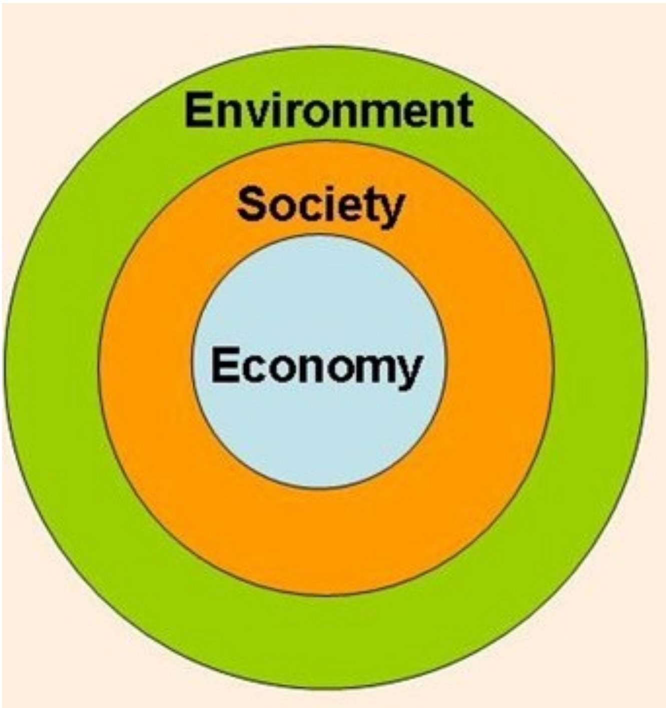


Figure 11: Basic Sustainability Sphere (Source: https://sustainabilityjeff.wordpress.com/2011/01/)

One of the earliest attempts at employing landscape urbanism was McHarg's plan for the Woodlands in Texas, which successful utilised stormwater drainage systems to structure the master plan, therefore making water the fundamental structuring element (ibid.). This involved protecting hydrological corridors, in order to form green ribbons that would weave through the urban fabric of the Woodlands (ibid.). McHarg the author of "Design with Nature", with the help of his team laid the foundation for dealing with urban sprawl and associated developmental challenges in a sustainable manner (The Woodlands, 2015).

Alternative ideas about city design and planning are extremely important in this day and age, because current urbanisation trends pose substantial social and environmental challenges (Steiner, 2011). As the global population grows, the percentage of those residing in large city regions will increase. The consequences of continuing to develop as in the past will exacerbate water and air pollution, as well as the loss of valuable habitats and agricultural land (ibid.). Therefore, early forms of landscape urbanism such as McHarg's Woodlands Master Plan are an example and opportunity to design with nature, in order to improve the quality and resilience of cities, society, and the natural environment.

The response to environmental and societal challenges should – and most likely will – influence the field of city design.

2.9.2 The Use of Spatial Planning Systems as a Tool within Green Infrastructure Planning

The management of an urban landscape is a process filled with challenges and conflicting agendas (Mell, 2011). There is the apparent need of government, often articulated through policy – the *obligation* – to provide adequate housing and efficient transportation infrastructure, and to support economic development, in order to secure and promote the prosperity of a city's economy (ibid.). This has directly led to the trade-off between economic needs and the management of valuable ecological resources (ibid.). Ecological resources and their fundamental needs in urban environments tend to be sidelined or even disregarded, because of the lack of informed valuations of resources, both financially as well as socially (ibid.). Therefore, it is only sensible that over the past decade, the fragmentation related to urban environments be addressed through the development of green infrastructure approaches (ibid.). Green infrastructure planning and techniques have brought developers, planners, ecologists, and architects together, in order to form a holistic and functional framework in which the ecology of urban environments is thoroughly understood (ibid.).

Green infrastructure has been debated and reviewed as being a solution to the demanding needs of both the built and natural environment within theory, policy, and practice (Mell, 2011). The concept of connected ecological networks to maintain the ecological integrity of the landscape is embedded in green infrastructure thinking and planning. This idea has been drawn from conservation biology and landscape ecology principles, and has been a fundamental driver for sustainable stormwater and surface water management through green infrastructure approaches. This provides alternatives to conventional grey infrastructure solutions. The overarching reason for employing and implementing green infrastructure is its adaptive capacity to tackle current urban challenges in a more sustainable and holistic manner (ibid.).

However, Davies et al. (2006) warn planners and practitioners about planning for green infrastructure. Planners and relevant practitioners have to have a comprehensive understanding of environmental systems and the multi-functional benefits they pose, as well as the understanding of environmental, social, and economic challenges related to achieving sustainable development within urban areas (ibid.), which are primarily decimated by market-competitiveness in order to plan appropriately for green infrastructure. If development is to move towards the creation of high-quality environments, it extremely crucial that planners understand all of the overarching influences involved (Mell, 2011). Subsequently, knowledge and expertise need to be communicated appropriately through planning policy, in order to provide a framework which planners, engineers, practitioners, and developers can utilise effectively (ibid.). Therefore, it is extremely important that the planning system in South Africa be utilised as a vital component in the development of green infrastructure, by integrating it into planning and policy (ibid.). The development and design of high quality green spaces needs to be aligned with statutory planning regulations, and planners need to be able to ensure this by engaging with effective planning methods and thoughtful design (Nicholson-Lord, 2003). However, for any of this to be possible, especially in a developing country context, green infrastructure planning needs to have the same importance as other infrastructure planning systems (Benedict and McMahon, 2006) – hence the need for a greater level of co-operative planning at all scales (local, regional, and national) (ibid.).

In developing countries such as South Africa, there has been an attempt to utilise spatial planning as a guide to infrastructure planning (Todes, 2008). This attempt arose as an alternative to master planning, in order to address the reasonably unsuccessful and poor capacity of local governments in employing appropriate infrastructure (ibid.). This as mentioned before is largely due to the institutional silos. Therefore, spatial planning provides an invaluable opportunity to lift silo thinking (Haughton, Allmendinger et al., 2010) not just in South African governance systems, but also in civil engineering as well as policy making. Spatial planning is increasingly becoming a multi-faceted profession, whereby spatial planners are able to work with the dynamic nature of scales and tend to engage in a wide-range of practices in order to produce a variety of appropriate long-term solutions that balance socio-economic and environmental needs for a particular area/space. Spatial planning is often seen as a means of knitting together a diverse range of issues, solutions, and actors across different scales in an effort to create cities that are sustainable and just.

As a result the provision of green infrastructure urban water management practices requires the steadfast support of spatial planning, in order to achieve the sustainable management of urban water resources in Cape Town.

2.9.2.1 Planning Tools in Support of Green Infrastructure

Land acquisition has been the common and most effective way to implement green infrastructure as well as to conserve ecologically valuable land within growing cities (Austin, 2014). However, other planning tools should be utilised (ibid.). Austin (2014) states that there are various planning techniques that can be applied to the provision of green infrastructure and conservation that are cheaper than the process of land acquisition. Based on Austin's theory on planning and design process, the following are the planning techniques recommended to integrate spatial planning as a tool in the implementing green infrastructure in a developing country (also applicable to the provision of green infrastructure urban water management).

Comprehensive Planning, Zoning, and Ordinances

Zoning as a planning tool in the long term is not the most sustainable approach, because the current zoning scheme protects existing land uses rather than accommodating for future land uses. Zoning is also susceptible to political and economic misuse (different agendas), and tends to be inflexible when it comes to creating long-term and system-wide green infrastructure. However, zoning as a physical planning tool has the potential to aid in the effective planning and implementation of green infrastructure and protect ecological valuable resources. Zoning can be made more flexible and effective by establishing temporary zones in expectation of unspecified land-use. This method aids in avoiding conflicting land-uses and creates appropriate taxation rates that do not speculate future commercial or residential development and value.

Comprehensive plans and planning are a step in the right direction, although currently they lack authority and clout to implement green infrastructure principles and objectives. Subdivision and development ordinances are an effective way in which green infrastructure objectives articulated in a comprehensive plan or a more flexible zoning scheme can create positive long-term results. If comprehensive plans and zoning do not move towards a more flexible and sustainable model, then effectively implementing green infrastructure will be extremely difficult, especially in a developing country context.

An example of this is reducing the residential densities per acre on a section of land by downzoning (Benedict and McMahon, 2006). Downzoning is a technique that can be used to protect and conserve green infrastructure elements (ibid.). However, landowners tend to object to downzoning, because of the fear of a loss in property value (ibid.). Conversely, research has proven that, when used in combination with a comprehensive plan in terms of economically and ecological valuable land, downzoning can stabilise land value, while promoting environmental conservation as well as reducing sprawl (ibid.).

Resource Protection and Conservation Subdivision Ordinances

Natural resource protection ordinances that are often reflected in subdivision and development ordinances are truly just development restrictions. Nevertheless, there is still the potential for these ordinances to support green infrastructure plans, by protecting wetlands, riparian buffers, steep slopes, and ecological corridors. Conservation subdivision ordinances used to conserve open spaces can be a vital tool in implementing green infrastructure, if consistent with green infrastructure plans and objectives.

An example of this is clustering development, which is a conservation design that is currently a lucrative option for developers, which fulfils the desire of certain residents to live in aesthetically appealing neighbourhoods with ample green open space (Benedict and McMahon, 2006). This approach places residential developments in less sensitive areas, whilst conserving and protecting landscape features (ibid.). Clustering often preserves approximately 50% to 90% of the existing natural land (ibid.).

Incentives and Technical Assistance

Tax incentives and technical assistance for private landowners are usually valuable tools to promote the expansion of the endeavours that land acquisition and development rights put in place. Monetary compensation to landowners tends to help in enabling and encouraging landowners to restore and protect natural landscapes. This has become a common practice in the United States, where tax incentives are offered by any level of governance to promote a desired land use.

An example of a tax incentive is some states in the US allowing for income tax credits and deductions to reduce a landowner's income tax burden, by issuing credits for conservation practices employed by a landowner (Benedict and McMahon, 2006). This is most appropriate at a local scale for green infrastructure initiatives (ibid.).

2.10 Conclusion

Cities are constantly facing the pressures of stormwater regulation, surface water management, financial constraints, and the shortcomings of grey infrastructure. In response to this, municipalities and other relevant bodies are quickly realising that green infrastructure, as an effective and flexible approach to mitigating the limitations of conventional grey infrastructure solutions in terms of stormwater and surface water management, is a truly viable option and might be our last best hope at achieving ecological and urban resilience.

However, there are still a few institutional, technical, and financial barriers that need to addressed, in order to put in place effective strategies that can be used by municipalities to overcome these barriers, before green infrastructure stormwater and surface water management techniques can be employed successfully. The use of precedents will aid in establishing certain norms and standards for green infrastructure implementation practices that will potentially help in minimising or avoiding implementation issues

CHAPTER THREE

3. Precedents Analysis

3.1 Introduction

This chapter investigates the interaction between sustainability and green infrastructure innovation, in terms of managing stormwater and surface water in urban areas. The analysis and review of green infrastructure case studies will help gain in-depth insight into the practicalities as well as the design elements of employing green infrastructure and integrating spatial planning into its provision.

A qualitative approach was employed in this chapter, in order to “cover contextual or complex multivariate dimensions of the phenomenon” (Dangelico and Pujari, 2010: 473) of green infrastructure stormwater and surface water management techniques and practices.

The reason behind choosing Stockholm and Portland as case studies was to look at successful international precedent and comprehensive green infrastructure programmes that shows the benefits of green infrastructure stormwater and surface water management techniques employed and planning context. This will aid in establishing guiding principles that will help design the Paarden Eiland Conceptual Layout and Framework. Consequently, this chapter also looks at Johannesburg as a case study, to illustrate that developing countries are starting to shift their thinking about service-delivery, and are moving towards considering green infrastructure as a viable option to addressing hard infrastructure issues related to urban areas.

The use of case studies proves to be particularly useful when studying emerging innovations, evaluating initiatives, and informing design and policies.

3.2 Stockholm, Sweden

The city of Stockholm has made a fairly successful attempt at implementing green infrastructure at a regional scale with a hierarchical habitats and green wedges for local species, and public transportation networks (Austin, 2014). On a more local scale, mixed-use districts have employed green spaces in order to appropriately manage stormwater and to provide holistic urban habitat (ibid.). This has been successfully implemented in the district of Hammarby Sjöstad (ibid.).

Hammarby Sjöstad, Stockholm, Sweden:

Hammarby Sjöstad is a brownfield district in Stockholm, which is being developed into a sustainable neighbourhood (Gaffney, Huang et al., 2007). Hammarby Sjöstad was primarily an industrial waterfront that had a reputation of being run-down and polluted in the 1990s, and is currently being redeveloped (redevelopment began in 1996) (ibid.). The main focus of the redevelopment of this site was to build a sustainable community that was twice as efficient and effective as a conventional urban neighbourhood and community (ibid.).

The model used to achieve sustainability in Hammarby Sjöstad is known as the Hammarby Model, shown in Figure 12 (ibid.). It attempts to create a balance between nature and the urban environment, by using the concept of closed-loop urban metabolism (ibid.). This model is meant to bring about a balance and unification between energy, water, and waster infrastructure (ibid.). Hammarby Sjöstad is therefore considered a great example of how ecological features and the urban environment can work together, through comprehensive planning (Beatley, 2004).

For the purpose of this dissertation, there will be a primary focus on how Hammarby Sjöstad manages its stormwater through the use of green infrastructure and the planning context behind implementation.

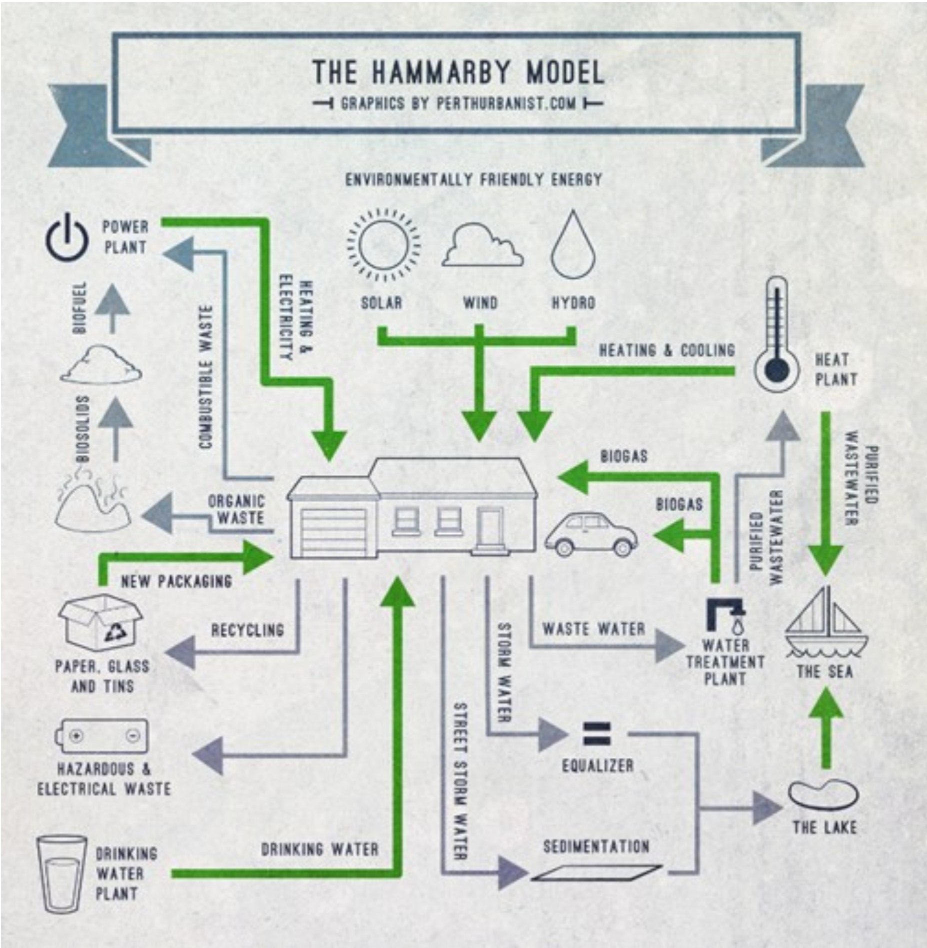


Figure 12: Hammerby Model of Closed-Loop Urban Metabolism (Source:https://www.pinterest.com/pin/515240013592410544/)

3.2.1 Stormwater Treatment in Hammarby Sjöstad

Stormwater treatment and management is a critical part of green infrastructure, and in Hammarby Sjöstad stormwater management and treatment is exceptionally well-developed and diverse in its nature (Austin, 2014). Hammarby Sjöstad currently utilises eight various treatment pathways for stormwater management and treatment (ibid.). This includes filters, swales, infiltration, oil and grit separators, ponds, open channels, wastewater treatment plants which direct water into surface water after being treated, and engineered soils for better infiltration (ibid.). Therefore, stormwater tends to be managed in three ways:

1. Some of the stormwater is treated separately from actual wastewater via wastewater treatment plants.
2. Other portions of the stormwater are treated by different landscape features.
3. If a residential area has less than 800 motorised vehicles per day, then stormwater is directly discharged

into the nearest surface waterbody.

However, the no-treatment scenario contributes about 1712 kg of suspended solids to the Hammarby Lake every year, whilst the landscape and vault treatment techniques contribute up to approximately 256 kg to 638 kg per year, depending on the efficiency of the different treatment systems (Austin, 2014.). Regrettably, the lake still remains heavily polluted with heavy metals, even after 15 years of improvement and enhancement (ibid.).

In Hammarby Sjöstad, they have constructed an infiltration trench in the centre of the street (ibid.). The trench is approximately 4.5 m wide and 0.762 m deep, it is wrapped in filter fabric and covered with about 0.4064 m of topsoil (ibid.). It treats stormwater from the street and surrounding parking lots (ibid.). The trench is able to hold a two-year storm event as well as the ten-year storm event up to 27 minutes before it overflows (ibid.). Infiltration trenches are able to have a high water-quality performance, reducing a majority of pollutants found in stormwater (ibid.). Trees are often planted in the centre of the trench as well as the surrounding areas, by including a soil buffer (ibid.). Trees are also planted on the sidewalks to receive rainfall and stormwater runoff.

The original industrial site's water quality feature has been retained (Austin, 2014.). It consists of a shallow bench at the edge of Hammarby Lake and contains dense *Phragmites,* a native reed (ibid.). This wetland treats and stops stormwater runoff from reaching any new development (ibid.).

On the northern edge of the lake, there is a vital stormwater runoff treatment system, which receives stormwater runoff from 1.2 ha of urban streets (Austin, 2014.). Before the runoff enters, it is pre-treated so that oil and water are separated, and large particles are captured (ibid.). The runoff then flows into a sedimentation pond that is surrounded on both sides with a planted gabion (ibid.). Once sediments have settled at the bottom of the pond, the runoff flows gradually through a constructed wetland (ibid.). The runoff is then directed through stepped wetlands, so that runoff has maximum contact with soil, substrate and vegetation (ibid.). This helps remove hydrocarbons, pathogenic bacteria, and nitrates (ibid.).

To gain maximum efficiency and effectiveness in dealing with stormwater, it is necessary to have a mixed design to management.

3.2.2 Planning Context

The Environmental Programme (EP) was introduced in 1997; however, the planning process for Hammarby Sjöstad had already begun in 1999 (Goel, 2013; The Young Foundation, 2009). The main motive behind the EP was to establish a district that was twice as efficient as a conventional district within today's urban environment (Goel, 2013). According to Goel (2013), the programme's success was highlighted by the six fundamental objectives listed below:

1. Land use: The transformation of old brownfield sites into pleasant residential areas with aesthetically pleasing parks and public open spaces, through sanitary redevelopment and recycling

2. Energy: The use of renewable energy, biogas, and the re-use of waste for heat combined with mechanisms for efficient energy consumptions within buildings
3. Water and sewage: Both input and output processes should be as clean and efficient as possible, coupled with new technology for water saving and treatment, as well as sewage treatment
4. Waste: Implementation of practical systems that sort material and recycle energy whenever possible
5. Transportation: Efficient public transportation coupled with the development of attractive non-motorised vehicle paths such as cycle and pedestrian paths, in order to decrease car usage
6. Building materials: Environmentally friendly.

For each of the above objectives there is a detailed implementation and design plan, embedded in the Hammarby Model (Goel, 2013).

3.3 Portland, Oregon, US

Portland, Oregon is often referred to as one of the best examples for green infrastructure stormwater management (United States Environmental Protection Agency/EPA, 2010), with multiple policies and programmes promoting green infrastructure stormwater management that have gone through several iterations over time to make these policies and programmes successful and well-established (ibid.). Today, Portland has one of the most comprehensive and developed green infrastructure programmes in the US (ibid.). The city of Portland has taken the initiative to implement a city-wide programme and invested approximately $9 million into green infrastructure, in order to save ratepayers $224 million in maintenance and repair costs for combined sewer overflow (ibid.). The array of programmes and policies is a testament that Portland considers stormwater as a resource rather than a problem that needs to be removed as quickly as possible (ibid.). They have moved beyond the ‘out of sight, out of mind’ mentality.

3.3.1 Stormwater Management and Treatment in Portland, Oregon

Technologies and initiatives used in Portland vary, therefore this section will focus on the most successful.

Green roofs/Eco-roofs: A majority of Portland’s buildings have incorporated vegetated roof systems, which help reduce runoff, provide better air quality, and enhance habitats (Water Environment Research Foundation/WERF, 2009). Developers proposing any new development within the Central City are able to gain floor area bonuses if they install eco-roofing (ibid.). This provides incentive for developers to incorporate green infrastructure techniques within the design of a new development. Figure 13 illustrates the concept of vegetated roofs.

In addition, Portland has adopted a policy that requires all City bureaus to integrate green building practices into all City-owned facilities, both existing and new (Water Environment Research Foundation/WERF, 2009).

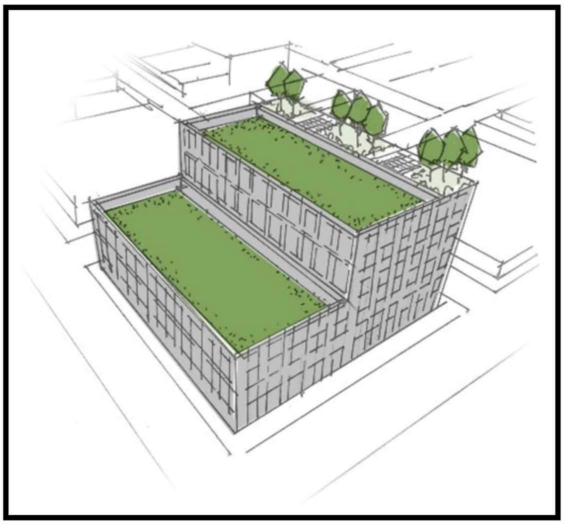


Figure 13: Eco-roof Concept (Source: http://www.teufellandscape.com/blog/solutions)

Green streets: Portland has retrofitted most of streets with landscaped swales, planter strips, curb extensions, pervious paving, and street trees, in order to help divert and infiltrate stormwater runoff (Water Environment Research Foundation/WERF, 2009) Portland adopted a cross-bureau policy called the Portland Green Streets Program in 2007 (United States Environmental Protection Agency/EPA, 2010). This policy facilitates the integration of green street facilities into both public and private development (ibid.). Green streets allow for in-flow control to mitigate combined sewer overflows, sewer backups, and other hard infrastructure insufficiencies, as well as ecosystem health (Water Environment Research Foundation/ WERF, 2009).

The SW 12th Ave is an initiative steered by the Portland State University Campus, which won the American Society of Landscape Architects Design Awards in 2006 (Water Environment Research Foundation/ WERF, 2009). The project was completed in 2005, and consisted of four stormwater planters arranged in a sequence, which capture and treat stormwater runoff from approximately 743 m² of street surface (ibid.). Stormwater runoff is meant to enter the first planter through a channel cut into the curb (ibid.). Depending on runoff flow, water is able to pond up to 6 inches in depth, promoting infiltration as well as biological treatment of pollutants (ibid.). If the capacity of the first planter is reached, then runoff will leave the first planter and enter the second, and will be directed into subsequent planters (ibid.) (see Figure 14).

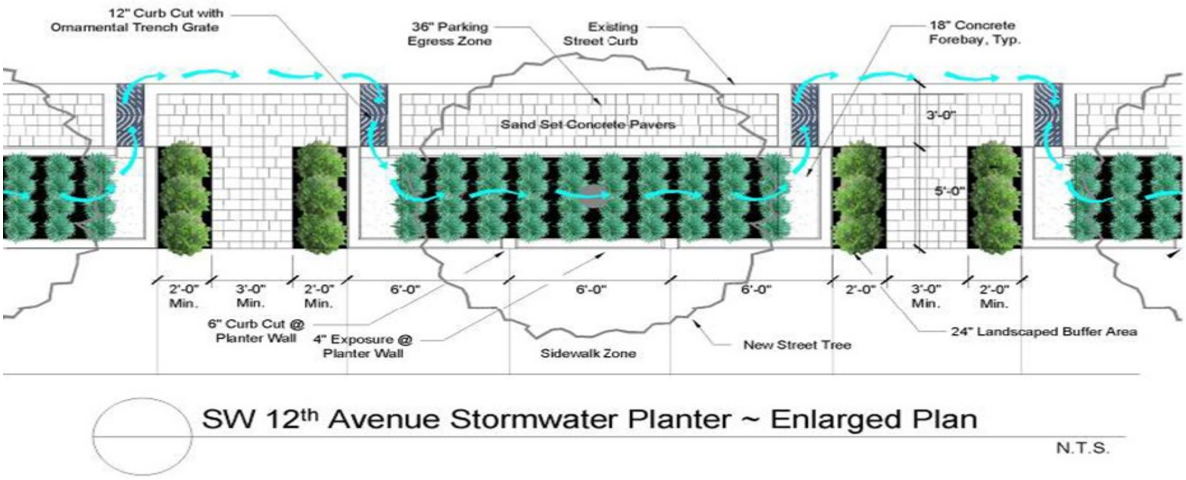


Figure 14: SW 12th Ave Stormwater Planter Plan (Source: Hoyer et al., 2011)

Sustainable stormwater monitoring: The Sustainable Stormwater Management Program monitors and reports the results of a variety of projects throughout the City of Portland (Water Environment Research Foundation/WERF, 2009). This data is used to quantify benefits of sustainable stormwater management practices (ibid.). This helps in improving design and function of existing and future projects, as well as lowering maintenance costs by tracking performance and tackling maintenance issues as soon as they arise (ibid.).

3.3.2 Planning Context

Portland has created innovative stormwater regulations as well as a hierarchy of mandatory requirements for both public and private development (Hoyer, Dickhaut et al., 2011). Currently, the Portland Stormwater Management Code and Manual (as cited in Hoyer et al.) outlines certain requirements such as:

- Any development consisting of over 46.5 m^2 of impervious paving as well as properties that are proposing stormwater discharge off-site, need to comply with pollution reduction and flow control requirements (United States Environmental Protection Agency/EPA, 2010);
- All existing and future projects need to meet the Destination/Disposal requirements; this includes designing a hierarchical system that mimics natural hydrological conditions through on-site infiltration.

The City of Portland is a great example of integrative planning, where ideas for decentralised stormwater management were incorporated into urban development goals (Hoyer et al., 2011). They implemented a highly effective strategy to use decentralised green infrastructure methods to lower the pressure on grey/ hard infrastructure, whilst restoring the local water cycle, meeting open space planning objectives, and responding to local community’s needs (ibid.). Innovative public outreach programmes have contributed significantly to the success of implementing green infrastructure methods to manage stormwater (ibid.). Ultimately, Portland’s policies and programmes in terms of stormwater management through green infrastructure methods, as well as the active participation of residents, has played a major role in establishing Portland as one of the most sustainable cities in the US (ibid.).

3.4 Johannesburg, South Africa

With this case study, a green infrastructure plan has not been implemented yet. However, Johannesburg as well as Pretoria have been considering moving towards green infrastructure, to manage many of their urban problems, including the management of stormwater and surface water. Even though nothing has been implemented yet, this is a good example of how developing countries are starting to consider the shift away from the traditional way of carrying out urban planning programmes, towards more ecological sound urban planning methods. Johannesburg is currently considering investing in green infrastructure as a service delivery option (Schäffler et al., 2013).

The City of Johannesburg recognises that infrastructure development is crucial for addressing service-delivery issues that are currently being experienced in Johannesburg, as well as for encouraging spatial re-structuring and integration (City of Johannesburg, 2015). Therefore, it is high up on the City of Johannesburg's agenda to invest in service infrastructure (ibid.). However, the City of Johannesburg is currently characterised by ageing infrastructure, massive backlogs, and capacity constraints (ibid.). The City of Johannesburg intends budgeting and spending approximately R110 billion over the next 10 years, for the provision of infrastructure (ibid.). Maintenance expenditure of existing infrastructure will be increased from 2.5% to approximately 7% of the City's annual budget (ibid.). The City of Johannesburg recognises that there needs to be a better and more cost-effective way to deliver services, whilst maintaining ecological integrity and expanding access to all residents (ibid.). Therefore, they have allocated more than 50% of their operating budget towards funding sustainable services and strategic infrastructure (ibid.). The overarching reason for doing so, is the fear of the effect of climate change on Johannesburg as a city in general, therefore they are trying to build urban resilience as a result (ibid.).

The City of Johannesburg is beginning to engage with concepts of resilience and sustainability in terms of infrastructure planning (City of Johannesburg, 2015). These concepts are embedded in green infrastructure thinking and planning. The City of Johannesburg is actively looking at ecological/green infrastructure as a means of improving microclimates, managing urban drainage systems, recharging groundwater, and preventing as well as mitigating flooding (ibid.)

3.4.1 Water Quality Management Initiative

The Johannesburg region has been experiencing major challenges associated with water quality. As a response to this, the city has launched an initiative to create an urban forest, whereby city trees and "ecological networks provide a set of ecosystem services that uniquely showcase the potential of green infrastructure" (Schäffler and Swilling, 2013: 249).

Firstly, this proposed urban forest could potentially address the recently discovered ecological crisis of acid mine water from old dormant mines entering sewer systems, wastewater treatment plants, groundwater, surface water, and flooding underground infrastructure (Schäffler and Swilling, 2013). This phenomenon is known as acid mine drainage, and occurs when highly acidic polluted water, which contains unsafe levels of salts and heavy metals, enters water systems and renders the water unusable unless treated (ibid.). Treating water that has been affected by acid mine drainage is an extremely intensive and costly process (ibid.). However, planting certain types of trees and shrubs that treat heavy pollutants within the urban forest, can serve as a pollutant sink (ibid.).

Lastly, the urban forest has the potential to regulate water flow as well as stormwater runoff and pollutants, by intercepting and reducing stormwater runoff (ibid.) whilst treating pollutants found in stormwater. This is a crucial function, because Johannesburg regularly experiences intense Highveld thunderstorms, and replacing natural drainage systems with hard infrastructure has resulted in the increase of hazardous flash floods (ibid.).

3.4.2 Planning Context: Current Plans and Visions

In the Gauteng City Region, the groundwork for investing in the region's ecological assets has been laid (Schäffler et al., 2013). There is a strong sense of protecting natural resources and a number of policies that focus on conservation targets have been put in place (ibid.), predominately for the protection of indigenous plant species. With regards to Johannesburg, a formal mandate has been put in place to appropriately manage and conserve green spaces within the city (ibid.). The municipal entity that deals with this is known as Johannesburg City Parks (JCP), which was mandated through the Department of Environment and Infrastructure Services, under the Environmental Planning and Management branch (ibid.). The JCP also consists of other agencies, where some are private as well as part of Non-governmental Organisations (NGOs) (ibid.). These agencies have and continue to play a vital role in the City Parks active tree-planting programmes (ibid.).

The City of Johannesburg has interpreted a greening mandate via various ecologically progressive policies and frameworks (Schäffler et al., 2013). Some of these are mandatory in terms of national legislation such as the Biodiversity Act (10 of 2004), which requires local and district municipalities to develop a Bioregional Plan that is in line with Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs) (ibid.). Consequently, in the light of these mandatory obligations, the City of Johannesburg has created a set of specific policies and frameworks that summarises the framing of its green mandate (ibid.). An example of this is the development of the Joburg Metropolitan Open Space System (JMOSS), in 2002 (City of Johannesburg, 2002). JMOSS is meant to guide the planning and management of green open spaces within the city. JMOSS is a comprehensive policy framework for the management, protection and enhancement of open space areas (ibid.).

Beyond the greening initiatives undertaken by JCP, the Department of Environment and Infrastructure Services has recognised the potential of using green infrastructure to manage stormwater (Schäffler et al., 2013). Johannesburg Roads Agency is responsible for the management of roads and stormwater, and has recently received pilot training from an organisation called SWITCH (ibid.). SWITCH is an action-research programme that is co-founded by the European Union, and consists of a cross-disciplinary team that encourages the appropriate management of stormwater, whist maintaining the natural water balance (ibid.).

However, the interventions proposed by SWITCH have yet to be seen to in Johannesburg (Schäffler et al., 2013). It is evident that even though alternatives to managing stormwater are being considered, there are still a number of challenges associated with effectively implementing decentralised green infrastructure methods and practices in Johannesburg.

While there has been some indication that officials understand the potential benefits of moving away from grey/hard infrastructure towards green infrastructure, “there has been limited realisation of the concept in plans and practice” (Schäffler et al., 2013: 68).

3.5 Green Infrastructure Principles

Green infrastructure projects around the globe tend to be based on common green infrastructure principles, which are based on Benedict and McMahon's work (2006) as well as the above precedent. The following principles will help provide a framework for the sustainable use of urban land, in order to benefit society, nature, and the economy, as well as guide and inform the design of the Paarden Eiland green infrastructure urban water management framework and conceptual layout at a later stage in this dissertation.

These principles are meant to be a benchmark for integrating green infrastructure approaches into existing planning activities and to reinforce existing protection efforts of ecological valuable systems and land, as well as form a basis for establishing context specific principles for Paarden Eiland's green infrastructure urban water framework:

1. Connectivity is crucial.
2. Context is important.
3. Green infrastructure should be based on solid science and spatial planning theory and practice.
4. Green infrastructure should function as a framework for environmental protection and urban development.
5. Green infrastructure design and planning before development.
6. Green infrastructure is vital public investment and should have sufficient funds allocated to it.
7. Green infrastructure benefits both nature and society.
8. Green infrastructure involves diverse stakeholders.
9. Green infrastructure requires long-term planning, monitoring, and commitment.

3.6 Conclusion

A number of foundations have been established in terms of planning and implementing green infrastructure globally. Progressive institutional structures and bold conversation targets have created a productive and active policy setting. The case studies used have illustrated that green infrastructure, if appropriately planned and implemented, can be extremely beneficial socially, economically, and environmentally in order to build both ecological and urban resilience. Most of the agendas shown in the case studies above take place via the increase of city trees and vegetation, the use of SUDs, greening urban streets, the use of open channels, and the treatment of pollutants through waste-water treatment plants, in the attempt to manage stormwater as well as surface water. The mixture of landscape and engineering design elements helps make green infrastructure strategies more effective. While these techniques and methods have proven to work effectively and efficiently in Stockholm and Portland, it is evident that mainstreaming green infrastructure planning has its challenges, especially in the context of cities within developing countries such as Johannesburg. This shows that it is pertinent that there is activism from both governments as well as the public, so that the implementation of decentralised green infrastructure and relevant policy frameworks are successful. Both the government and the public need to be entirely invested in moving away from conventional grey/hard infrastructure towards green infrastructure, for any major change to occur in thinking as well as reality.

The case studies used demonstrate that there is an opportunity for cities around the world to situate themselves in a diverse ecological and institutional setting. The integration of various disciplines/knowledge in dealing with the challenges associated with managing green assets and stormwater is a critical step in developing a city-wide approach to employing appropriate green infrastructure urban water management techniques.

CHAPTER FOUR

4. Methodology

4.1 Introduction

Given the contemporary nature of green infrastructure research and given that this dissertation is of a hybrid nature, it is only appropriate that a range of research methods and techniques be used to create a robust evidence base for this dissertation. This chapter outlines the methods and techniques used to answer both the main as well as subsidiary research questions established in Chapter One. The first section of this chapter involves understanding and describing the applied research methods, specifically a mixed methods approach which includes a case study approach. This is then followed by a discussion of research techniques employed, such as open-ended discussions with relevant professionals and officials, mapping, analysis of current ecosystem services data in Paarden Eiland, discourse analysis, and a desktop study. The limitations of these methods and techniques have been covered in this chapter, in order to address any gaps that have arisen within the research process. The final section of this chapter discusses the ethical considerations and concerns regarding this study, and concludes with the research limitation experienced during this study.

4.2 Research Methods

The rationale behind using a mixed methods approach to data collection and research is to use both qualitative and quantitative data to direct analysis undertaken, in order to produce relevant and appropriate recommendations that will be made in later chapters. A combined approach assists in understanding the concept of green infrastructure, its utilisation in policy and practice, as well as the holistic and perpetual understanding of landscapes to a greater extent than just using a single method. The methods used aim to present quantitative and qualitative results that provide greater understanding and depth to the discussions presented throughout this dissertation.

4.2.1 Introduction to Mixed Methods Approach

According to Flyvbjerg (2006), the distinct separation that is often seen in literature and research between quantitative and qualitative methods can be limiting. In most cases the combination between the two methods tends to be best (ibid.). Each research method answers specific types of questions while not being suitable to answer other types, and therefore it is best to combine quantitative and qualitative methods (Thomas, 2003). Figure 15 illustrates the framework for mixed methods approach .

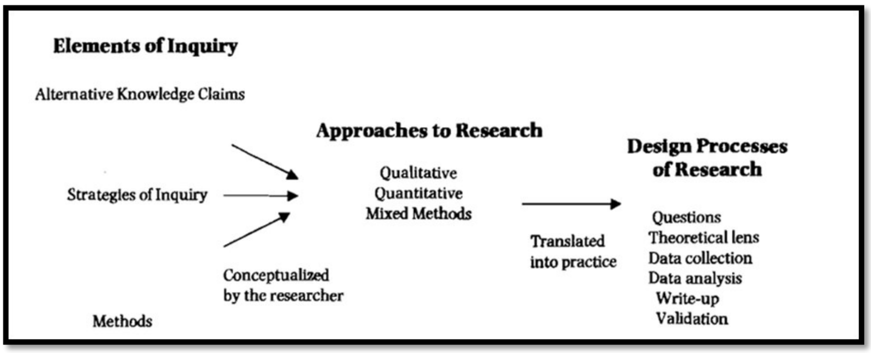


Figure 15: Methods Leading to Approaches and the Design Process (Creswell, 2003)

Researchers have recognised that all methods have limitations, therefore biases are inherent in any single method; however, using a mixed method approach could potentially help neutralise biases of other methods through using one method to inform another (Creswell, 2003). This might involve using quantitative methods in which concepts and theories are tested, followed up with a qualitative method engaging with a comprehensive exploration of a few cases or individuals (ibid.). Figure 16 shows qualitative, quantitative, and mixed methods procedures.

Quantitative Research Methods	*Qualitative Research Methods*	*Mixed Methods Research Methods*
Predetermined	Emerging methods	Both predetermined and emerging methods
Instrument based questions	Open-ended questions	Both open- and closed-ended questions
Performance data, attitude data, observational data, and census data	Interview data, observation data, document data, and audiovisual data	Multiple forms of data drawing on all possibilities
Statistical analysis	Text and image analysis	Statistical and text analysis

Figure 16: Quantitative, Qualitative, and Mixed Methods Procedures (Creswell, 2003)

4.2.1.1 Qualitative

With regards to this research, the analysis of documents can often be used in conjunction with other qualitative research methods by means of triangulation (this is an amalgamation of methods in the study of the same phenomenon) (Bowen, 2009). This involves drawing on various sources of evidence, and seeks to substantiate the research by using multiple data sources and methods (ibid.). This is extremely useful when investigating and researching the potential of using green infrastructure as a mechanism to reduce stormwater and surface water problems in Paarden Eiland, and the greater Cape Town region. The use of a multiple documents (international and local) on green infrastructure will help build a confluence of evidence, which will in turn help breed credibility of this study. A variety of documents can really aid a researcher in uncovering meaning, to develop a greater understanding, and to gain relevant insight into the research problem (ibid.).

The basis for document analysis lies in its role in methodological and data triangulation, documents have a great deal of value in case study research, as well as can be a useful standalone method for specific forms of qualitative research (Bowen, 2009).

4.2.1.2 Quantitative

The use of quantitative research methods/techniques plays a crucial role in developing a fairly standard conceptual framework for green infrastructure systems and practices as well as norms that are compatible and possibly transferable to the rest of South Africa. Quantitative research tends to produce measurements and analyses that are easily replicable and generalisable (Thomas, 2003).

However, there are a few limitations to using qualitative and quantitative research methods on their own. Qualitative analysis limitations are that knowledge produced is difficult to generalise and replicate if necessary, and challenging to use when making quantitative predictions. The limitations associated with quantitative analysis are that a researcher's theories used might not reflect local communities' understandings, as well as the possibility of being susceptible to systematic error and random errors. Therefore, it is only appropriate that a combination of both is used.

4.2.2 Case Study Method

As a research method the case study approach is used in various situations, in order to contribute to our knowledge of a particular phenomenon (Yin, 2003). The case study research method is often preferred when research is focused on a contemporary phenomenon within a real-life setting (ibid.). It allows for researchers to maintain the significant and holistic characteristics of real-life events, "such as individual life cycles, organizational and managerial processes, neighbourhood changes, international relations, and maturation of industries" (Yin, 2003: 2).

If designed and executed appropriately, a detailed case study can contribute to theoretical development (Duminy, Andreasen et al., 2014). This particularly important in a Global South urban context, a case study approach will help test relevance and applicability of Global North ideas, in order to develop contextual knowledge that allows the Global South to situate itself in global urban theory (ibid.). This is particularly important when looking at employing green infrastructure stormwater and surface water management techniques in a Global South city such as Cape Town, when this approach, practice and concept has been developed in the Global North context (ibid.). A case study approach has the potential to produce highly contextualised knowledge of power relations, interests, and day to day practices that support planning processes (ibid.), therefore encouraging a nuanced understanding of green infrastructure stormwater and surface water management techniques from a practice perspective, in order to stimulate the creation of policy and interventive recommendations (ibid.).

According to Bracken (1981), the case study approach is appropriate when analysing policy, although it poses some limitations. The most obvious limitation is that of developing appropriate theory around the topic/policy being analysed. Bracken (1981) believes that the requirement fundamental to the case study approach is developing various systematic frameworks, which allows for a more general input when regarding knowledge around urban policy. When dealing with case studies, other research methods may be employed. However, a clear and direct conceptual framework is crucial when dealing with the dynamic environments subjected to both policy and autonomous influences (Bracken, 1981).

In consideration of the research question, the use of Paarden Eiland as an experimental case study area was vital in designing a conceptual framework with regards to identifying key policy variables and the political dimensions specific to Cape Town, which in turn helped in identifying how to appropriately integrate green infrastructure with respect to urban water management into spatial planning, management and governance. The choice of case study area also provided insight into the issues of a green infrastructure approach as well as an opportunity to create context-specific and value-driven knowledge (Flyvbjerg, 2011).

The case study method also disclosed a varied set of factors that interact with each other in order to produce unique environmental, social, and economic features characteristic of Paarden Eiland, which were useful for obtaining a deeper insight into the developmental factors of Paarden Eiland.

The rationale behind selecting specific case studies helped to reflect strong and positive examples of the research topic of interest (Yin, 2003). "This rationale fits replication logic well, because your overall investigation may then try to determine whether similar casual events within each case produced these positive outcomes" (Yin, 2003:13).

There are, however, limitations to this approach. The limitation that often occurs is that of biases, where the researcher creates bias towards justifying their hypothesis (Yin, 2003). Considering the possibility of these biases, care will be taken in this matter, and findings that might contradict the hypothesis will be included.

Case studies have the ability to reveal successfully some of the complexities of real-life situations; however, they tend to have a problem in appropriately representing them (Hodkinson and Hodkinson, 2001). It is sometimes difficult to present a realistic picture of complexities in writing, because writing often tends communicate these complexities in a linear form (ibid.). This is a result of the general format of writing where it has a beginning, middle, and an end (ibid.). There are often various ways in which to present the same set of problems in approach and emphasis (ibid.), therefore, making the findings of research based on the case study method difficult to summarise (ibid.).

The case study approach is often involves the use of multiple sources of evidence to reduce limitations that might occur (Duminy et al., 2014), therefore a mixed methods approach enhances the investigation of surface water and stormwater issues as well as the benefits of green infrastructure in this regard (ibid.).

4.2.3 Research Techniques and Analytical Tools

This section discusses the research techniques and analytical tools used. Both qualitative and quantitative research techniques were employed. These techniques include drawing mainly on secondary sources of research. Open-ended discussions, as well as prior documentation/journals have been utilised on a quantitative level, whilst mapping, modelling and analysis of current data on ecosystems with specific reference to water bodies as well as water infrastructure in Paarden Eiland have been performed on a quantitative basis. These techniques have been important in terms of answering the main and subsidiary research questions of this study, each contributing a distinctive aspect of information. A variety of research techniques aided in developing a holistic and comprehensive investigation of the study area (Paarden Eiland). Research undertaken was predominately qualitative information; however, quantitative data has been vital to the research process as well. Quantitative data has been very useful in substantiating qualitative research findings, and at the same time qualitative data has strengthened the overall argument of this dissertation. The research techniques used for this study include open-ended discussions, desktop research, mapping and observations, spatial data analysis, data analysis, and policy discourse review.

4.2.3.1 Secondary Data

The research for this study was done with the use of secondary sources, which has mainly been completed through the literature review (refer to Chapter Two). Secondary data can be simply defined as information produced by other researchers and scholars. If secondary research and data analysis is undertaken diligently, it can provide an effective way of gaining a broad understanding of research questions presented (McCaston, 2005). The information collected has been extremely helpful in revealing the relationship between green infrastructure and the appropriate management of stormwater and surface water.

Mapping and Observations

In terms of this dissertation, this research technique has had a particular focus on mapping as a tool for analysis. This has helped in spatially locating the analysis, in order to recognise certain constraints, overlapping concerns, and opportunities in the area. This has been critical in forming a spatial representation, which in turn informed the research outcome of the green infrastructure urban water management framework for Paarden Eiland and conceptual layout. This has also aided in the prioritisation of certain green infrastructure types.

Open-ended Email Discussion

This research technique provided for a more comprehensive understanding of the research topic through open-ended discussions with relevant academics and government officials, allowing for the freedom of opinion. This permitted the participants' responses to be used directly in the dissertation for a more well-versed response to the topic at hand.

However, this technique can be limiting, because it is time-consuming and is susceptible to the participant's personal biases. Therefore, the use of other research techniques helped neutralise some of these biases.

Desktop Research

The desktop study done included a collation, evaluation, and integration of project-relevant information and was used for the preliminary assessment of the site's conditions and conceptual design. This technique was also used to undertake a literature review to understand different theoretical standpoints from scholars on the topic of the use of green infrastructure to successfully manage stormwater and surface water within urban areas.

The advantage of using this technique is that a substantial amount of information can be assessed. However, the disadvantage is that it may contain some personal biases. This was mitigated by having discussions with academics and supervisor, in order to guarantee a thorough justification for the response to the research.

Policy Discourse Review/Document Analysis

Policy discourse review and analysis is an effective way to consider development policy (Gasper and *Apthorpe*, 1996). This facilitated the understanding the political and regulatory frameworks that are important to the management of stormwater and surface water in Cape Town, and more specifically Paarden Eiland. The review involved the assessment of predominately local policies, as well as national and provincial policies focused on legislation directed towards stormwater and surface water management.

A policy discourse review "uncovers the role of bureaucratic modes of organization, managerial, and implementation practices" (Jacobs, 2006:40). Understanding bureaucratic roles is important when trying to mainstream green infrastructure urban water management techniques.

Spatial Data Analysis

Spatial data and its analysis have aided researchers and decision-makers in dealing with a variety of urban challenges (Hsiang, 2011). Spatial data analysis provided information on Paarden Eiland and facilitated the understanding of spatial patterns and attributes of this location. With regards to Paarden Eiland, the current land-uses, surface water and stormwater data, as well as hard infrastructure data were significant in determining appropriate green infrastructure stormwater and surface water management techniques.

Data Analysis

When data was collected, the interpretation of the data occurred. The analysis of this data involved the reuse of both qualitative and quantitative evidence through investigating, categorising, formulating, and testing of the data. A mixed methods approach facilitated the explanatory interpretations of green infrastructure water management techniques.

4.3 Ethical Considerations

The most prominent issues concerning ethics in research were that when conducting the research, participants and third parties were not harmed, their rights were not violated, and participants were not put in any dangerous situations.

However, due to the low-risk nature of this project, all information was treated in a careful and conscientious manner. Therefore, no rights were infringed upon and confidentiality of participants was guaranteed.

4.4 Limitations of Research

A number of limitations were encountered during this study, the key ones being the following:

- Time constraints of producing a comprehensive dissertation meant that research was limited to stormwater and surface water management issues and green infrastructure solutions for a particular site (Paarden Eiland), rather than city-wide/nation-wide analysis and implementation,
- A limited amount of written information on the study area, resulted in analysing a large amount of spatial data and district-related documents to substantiate the argument of moving towards green infrastructure urban water management.
- The limitation of successful green infrastructure stormwater and surface water Global South case studies and documentation meant that the lessons learnt and information used was limited to mainly a Global North perspective.
- The scope of the dissertation itself, site-specific settings such as runoff rates, frequency, and water quality were unable to be sampled or tested in order to confirm information obtained from secondary sources.
- Due to the scope of the dissertation, the development of a master plan for the site was not possible; however, in order to accommodate this a conceptual layout and framework was developed.

4.5 Conclusion

This chapter outlines both the research methods and techniques utilised for the purpose of this study. A mixed methods approach as well as the case study method was selected for this study and various research techniques were used to answer the main and subsidiary questions. The chapter was concluded with the ethical considerations that will be carried out as well as the limitation experience throughout the research process.

CHAPTER FIVE

5. Contextual Analysis

5.1 Introduction

Currently, approximately 54% of the world's population lives in urban areas, and this amount is predicted to increase to about 66% in 2050 (United Nations, 2014). This landmark indicates a significant turning point that has radically affected water and land environments. Meeting water supply, water demand, and flooding needs while conserving natural resources is an enormous challenge. Increasingly, cities are being designed for adaptability and resilience to the impacts of urban densification, population densification, and climate change. Responding to these issues requires a major shift in the way to design, plan, and build cities around the world and manage surface water resources as well as stormwater. Therefore, this makes this study particularly important, in order to secure a more water-sensitive future.

The research undertaken in the literature review has laid out the theoretical foundation of this dissertation. This chapter sets out the contextual analysis of Cape Town, in order to comprehend the current state and trends of stormwater quality, quantity, and surface water management. As this study is focused on the role of spatial planning as a tool in providing green infrastructure stormwater and surface water management, this analysis is translated through the utilisation of maps and site plans. It depends on the data collection of a variety of national, provincial, and municipal documents with academic research.

The City of Cape Town's vision is for "effective stormwater management with safe and healthy rivers" (CoCT, 2001:15). To elaborate on this, the following level of stormwater and surface water management envisaged for greater Cape Town (CoCT, 2001:16) is to:

"Minimise flooding of property and improving and maintaining the health of our rivers, wetlands, and vleis through integrated catchment management for the benefit of the people of the CCT"(City of Cape Town).

This chapter will provide an indication of whether this vision is being upheld and indicates the concerns and shortcomings of current stormwater and surface water management in Cape Town. In order to appropriately locate this study, this chapter will provide an overview of the relevant national, provincial, and municipal policies, strategies as well as spatial informants, and the management of stormwater and surface water within these tiers of government. The chapter continues to evaluate the bio-physical, socio-economic, and infrastructural context of Cape Town.

The chapter will led to the investigation of the specific context of Paarden Eiland, with regards to stormwater management and its effect on surrounding surface waterbodies. Consequently, the opportunities and constraints of stormwater and surface water will be identified in order to compose a list of key issues and priorities for Paarden Eiland.

This chapter concludes with a representation of these key issues and priorities, as well as opportunities and constraints to use as a basis for intervention in the following chapters.

5.2 Current Policies and Strategies: National, Provincial, and Municipal Government

Within the framework of the Constitution, the following legislation applies.

5.2.1 National and Provincial Government Legislation

In terms of national government the relevant documents in terms of managing stormwater and surface water throughout the country include the Constitution:

The National Water Act (36 of 1998)

This act covers the fundamental goal of managing water resources for the benefit of all users, and the protection of water quality in order to ensure the sustainability of the nation's water resources through integrated management (CoCT, 2015a). This act places responsibility on local authorities for the protection of water resources and requires the stormwater quality control of private and public land in terms of urban water management (Vice, 2011). However, nothing in this piece of legislation relates to then sustainable and integrated management of water resources (ibid.).

The National Environmental Management Act (NEMA) (19 of 1998)

This act establishes guiding principles for the protection and management of the natural environment and aids decision-making with regards to matters affecting the natural environment. It also promotes cooperative governance (CoCT, 2015a.). NEMA places responsibility on developers in order to prevent any destructive practices that will have a negative impact on the natural environment (Vice, 2011). This act also emphasises the importance of sustainable developmental practices and has established principles that promote urban sustainability (ibid.). These principles largely underpin the fundamental philosophy of green infrastructure urban water management as well as overall environmental protection.

Disaster Management Act (Act 57 of 2002)

This act concentrates on preventing or reducing the risk of disasters, mitigating the severity of disasters and any emergency, through establishing swift and effective responses to disasters and post-disaster recovery (Government Gazette, 2003). This act forms the basis for adaptive planning and management of urban water resources.

SANS 10400-R: Stormwater Disposal

The SANs 10400-R is currently a draft publication of national regulation which relates to stormwater management (Vice, 2011). However, this document still relies heavily on conventional drainage practices and has no reference to more sustainable and effective ways in which stormwater may be managed.

Western Cape Planning and Development Act (7 of 1999)

This act is a guideline and parameter for planning and sustainable development, where provincial and regional interests are involved. This includes environmental protection and land development management (CoCT, 2015a).

Land Use Planning Act (LUPA) (3 of 2014)

This act makes provision for provincial spatial development frameworks that provide minimum standards and the effective co-ordination of spatial development frameworks (CoCT, 2015a).

Other policy frameworks that influence the management of stormwater and surface water include on a national level are the Department of Water Affairs and Forestry's (DWAF) white papers linked to water law, water supply, and sanitation, as well as the Department of Environment and Tourism's (DEAT) integrated environmental management procedures (CSIR Building and Construction Technology, 2009). While these might not be completely obligatory, they do influence planning and the management of stormwater and surface water.

Other provincial policies, strategies, plans, and guidelines that are relevant to stormwater and surface water management include the Western Cape Infrastructure Frameworks (WCIF), Western Cape Provincial Spatial Development Framework (PSDF), and the Sustainable Water Management Plan.

5.2.2 Local/Municipal Government (City of Cape Town)

The following legislation, policies, and guidelines are the most influential in terms of implementing green infrastructure urban water management practices in Paarden Eiland.

Sector Specific Legislation

By-law for Stormwater Management and Related Matters (2005)

This by-law was enacted in order to regulate stormwater management in Cape Town as well as to regulate activities that might negatively affect development, operation, or maintenance of stormwater systems. This piece of legislation also specifies penalties for stormwater-related offenses (Vice, 2011).

Related Legislation

Spatial Planning and Land Use Management Act (SPLUMA) (16 of 2013)

This allows for the provision of provincial spatial development frameworks, in order to provide for minimum standards for the efficient coordination of spatial development frameworks. This act also provides the norms and standards for effective municipal development management and regulates provincial development management. SPLUMA, is broadly a guiding framework for land-use planning in Cape Town (CoCT, 2015a).

Related Policies and Projects

Policy for Control of Development near Watercourses (City of Cape Town, 2002)

This policy provides a framework for the management and control of development near watercourses, in order to reduce potential flooding, while conserving the natural environment (CoCT, 2002).

Stormwater Land Identification Project (SLIP)

SLIP is a set of GIS plans covering the entire Catchment Management Area (CMA), which detects all erven impacted by stormwater issues (CoCT, 2002).

City of Cape Town Management of Urban Stormwater Impacts Policy

This is the most progressive stormwater management policy in the country. It fully encourages the use of Water-sensitive Urban Design principles and sustainable urban drainage practices. This policy fundamentally targets the improvement of stormwater quality discharged from urban development (Vice, 2011);

Floodplain and River Corridor Management Policy

This policy is supplementary to the City of Cape Town's Management of Urban Stormwater Impacts Policy (Vice, 2011). This policy is not directly associated to the management of stormwater; however, it takes into account the importance of managing watercourses in an effective and sustainable manner and recognises the value of using stormwater as a resource (ibid.). In addition, this policy also states that:

"Watercourses and wetlands are public resources which have the remarkable potential to stimulate local economies and to break down political, social and economic barriers if managed and used with this goal in mind." (Roads and Stormwater Department, 2009). These socio-economic benefits mentioned to a large degree are the same as the benefits achievable through the application of green infrastructure.

Integrated Metropolitan Environmental Policy (IMEP) (2001)

This policy forms a basis for a succession of programmes and strategies to ensure that the principles of sustainability are adhered to (CoCT, 2003).

Other relevant municipal documents that indirectly affect the management of stormwater in the City of Cape Town consist of the Integrated Development Plan (IDP) 2013/2014, Cape Town Spatial Development Framework (CTSDF), City of Cape Town Water Services Development Plan, and other sector-specific policies pertaining to urban stormwater management.

Most of the national, provincial and local legislation and guidelines presented herein have influenced either the planning, implementation or management of the Paarden Eiland's current stormwater management system.

5.3 Review and Implications of Stormwater Legislation and Policies

Legislation and policies have a direct influence on institutional framework (Parkinson and Mark, 2005). Therefore, stormwater and surface water legislation and policies tend to determine the government's role and responsibility in provide appropriate stormwater services as well as properly regulating and managing stormwater. The manner in which policies and legislation is formulated determines the modes of operation, which will directly and indirectly encourage improved efficiency (ibid.).

Cape Town's water systems have been shaped and dramatically transformed by political and legislative influences over the past few centuries. The conventional and accepted approaches to managing stormwater and surface water have been the norm since the 17th century and have resulted in the significant deterioration of urban water systems (Haskins, 2012a).

However, stormwater management, in particular in Cape Town, is gradually moving towards a green revolution, in order to keep up with global awareness and sustainability trends (Haskins, 2012a). This movement is compatible with South Africa's National Water Act (36 of 1998).

This approach has currently been formalised in the Catchment, Stormwater, and River Management Strategy (Haskins, 2012a). This strategy is reinforced by the Stormwater By-law, which provides for the regulation of stormwater management in Cape Town. The management of urban stormwater impacts in Cape Town has presented principles of Water-sensitive Design and Sustainable Urban Drainage.

However, despite the recent planning and legal strategies presented, many of Cape Town's valuable natural water systems have been degraded and lost (Snaddon and Day, 2009). Consequently, water quality and wetlands in Cape Town also continue to deteriorate (Haskins, 2012a).

5.3.1 Review of Policies, Legislation, and Guiding Documents

From the analysis of Cape Town's various policies, plans and documents with regards to stormwater and surface water, it is evident that these documents acknowledge the effect of stormwater on the natural environment, urban landscape, and the societal health. Therefore, interventions are usually focused around mitigating flooding and excessive stormwater runoff via the use and expansion of hard infrastructure.

Several key points can be drawn from the analysis of these documents. Firstly, a majority of these documents tend to have a predominately anthropogenic view of managing water resources in general, and tend to focus on the environment as merely an afterthought, rather than as the primary concern. These documents are primarily focused on the consumption and supply of drinking water, and casually touch on the issue of stormwater. Stormwater in this regard, is seen as a nuisance rather than a resource that could potentially be recycled and reused, therefore the main objective of many of these policies documents is to remove stormwater via hard infrastructure and divert it into the nearest surface waterbodies in effective and swift manner. Secondly, various principles and guidelines are utilised within these documents; however, there are three overarching principles that appear throughout and across these documents: equity, equality, and sustainability. These three principles are meant to ensure that resources are conserved and protected to benefit current and future generations. This approach, therefore, looks at the relationship of urban water systems and the urban landscape in fragmented manner, hence oversimplifying the role of the urban water cycle in sustaining both urban and natural landscapes.

In the face of climate change, parts of South Africa such as Cape Town will become drier and hotter, therefore many of the documents analysed mention the importance of conserving natural systems, which act as buffer systems and promote urban resilience, especially with regards to water systems. The fear and uncertainty of climate change and the realisation that urbanism has contributed to global environmental degradation, has driven South African governments into considering Water-sensitive Urban Design (WSUD) as a mechanism to deal with the potential of a looming country-wide water crisis. The Management of Urban Stormwater Impacts Policy in particular states that,

"In order to reduce impacts of urban stormwater systems on receiving waters, all stormwater management systems shall be planned and designed in accordance with best practice criteria and guidelines laid down by Council, to support Water-sensitive Urban Design principles" (Roads and Stormwater Department, 2009).

This a prime example of governments in South Africa starting to reconsider the way in which stormwater is currently being managed, in order to move towards more ecologically sound management techniques. However, large-scale and centralised infrastructure projects are still being emphasised and implemented (Cameron, 2014). This approach has led to the inflexibility and vulnerability of infrastructure to changing urban environments and to climate change, and will continue if approaches to infrastructural projects are not done different manner, therefore perpetuating the problem already at hand.

Furthermore, there is concern noted that the foremost documents that currently guide development and the change in urban water systems in Cape Town, either have no mention of stormwater management or vaguely touch on the issue. Both the Western Cape Infrastructure Framework (2013), Integrated Metropolitan Environmental Policy (2011), as well as the Western Cape Provincial Spatial Development Framework (2013) make no mention of potential strategies for improving the management stormwater in Cape Town, whilst the Cape Town Spatial Development Framework (2012) vaguely mentions the need to appropriately management stormwater in terms of recreational spaces that are located near rivers and coastal areas. However, Cape Town's Integrated Development Plan (2013) mentions stormwater, but only with regards to the analysis of stormwater infrastructural networks, identifying areas which need stormwater infrastructure upgrades, and some of the strategies and programmes that the City of Cape Town is considering implementing better management of stormwater. Even though the IDP evaluates stormwater management in Cape Town, it is still predominately based on hard infrastructural issues and solutions. None of the above documents that are meant to direct development and investment in Cape Town have any form of spatial representation of analysis or intervention for stormwater in Cape Town. The strategies and programmes proposed for stormwater management in the IDP are not appropriately translated into the City's SDF, so in this regard these documents do not correctly align or speak to each other.

There is also still a strong sectoral approach to managing stormwater and implementing interventions, which lie predominately within the Roads and Stormwater Department, even though stormwater problems directly or indirectly affect other local government departments. Lastly, the documents analysed tend to have a capitalistic view on the provision of infrastructure, and propose interventions to replace or extend hard infrastructure in order to boost economic development. However, the reality of South Africa as a whole is that a majority of the population still depends on the provision of free services, mainly due to the high level of inequality as well as unemployment rates experienced throughout the country. This in turn leads to the costly expansion and upgrading of hard infrastructure, which tends to result in immense financial pressures for local municipalities that are already pretty much underfunded.

As discussed in the literature review, the management of stormwater and surface water resources needs to move from conventional hard infrastructural solutions towards more sustainable, ecologically sound and cost-effective management techniques. This transition is a complex one and requires a holistic and comprehensive understanding of urban water systems and how they influence the urban landscape. Therefore, the improvement of co-ordination between relevant departments and the spheres of governance, as well as the alignment of projects and strategies, both spatially and institutionally, are key to a successful transition towards more sustainable ways of managing urban water systems.

5.4 The City of Cape Town: Contextual and Urban Water Systems Analysis

This section provides an overview of the bio-physical socio-economic setting as well as trends of Cape Town. This overview will provide a greater understanding of how urban activities influence urban water systems and the hydrological cycle. The main objective of this section is to present a qualitative and quantitative basis of research, in order to understand the context-setting in which Paarden Eiland is situated.

5.4.1 Bio-physical Analysis

Cape Town is located in the Western Cape, South Africa, and has a spectacular setting in the sense that it is located at the south-western tip of Africa, so cre-ating a unique atmosphere for the establishment of natural systems. The municipal area covers approximately 2461 km² (StatSA, 2011). This setting has encouraged the rich biodiversity within the Cape Floral Kingdom, the world heritage site of Table Mountain, and the beaches on the Indian and Atlantic Ocean coastlines. Cape Town is host to a variety of endemic floral and faunal species and a landscape that accommodates for diverse networks of rivers and wetlands. All of these aspects provide the natural infrastructure that functions to support the city. This has resulted in Cape Town being officially identified as a global biodiversity hotspot (CoCT, 2011). Therefore, this places an international responsibility on the tiers of government to ensure the adequate conservation and protection of the natural environment (ibid.).

Climatic Conditions

Cape Town experiences a Mediterranean climate with average rainfall ranging between 500 mm to 1400 mm around the Cape Peninsula's mountains (Tadross and Johnston, 2012). Cape Town has several microclimates; hence some parts of the city will tend to receive significantly more rainfall than others (World Weather Online, 2015). This results in wetter weather around Table Mountain Range and with drier weather conditions on the Cape Flats (Cameron, 2014). The rainfall is fundamentally brought in by the northwesterly wind, the prevailing winter wind. Rainfall often occurs in winter between April and September when the temperature and the evapotranspiration rate are at their minimum (Tadross and Johnston, 2012). However, in summer (November to March) the evapotranspiration rate is much higher than rainfall, therefore creating drier climatic conditions during this time period (ibid.). Cape Town also experiences summer temperatures that peak in February with a monthly average of approximately 26.9ºC (ibid.). Winter temperatures are the lowest in July, with an average maximum of about 17.7ºC and minimum of 9.1ºC (ibid.). Figure 17 illustrates the daily climatology of rainfall with reference to evapotranspiration, and minimum and maximum temperatures experienced in Cape Town.

These climatic conditions have a significant impact on the ecological functioning of Cape Town's natural systems by enabling of floral and faunal species to flourish, the recharge of groundwater, as well as rainfall being captured and transported throughout river and wetland systems.

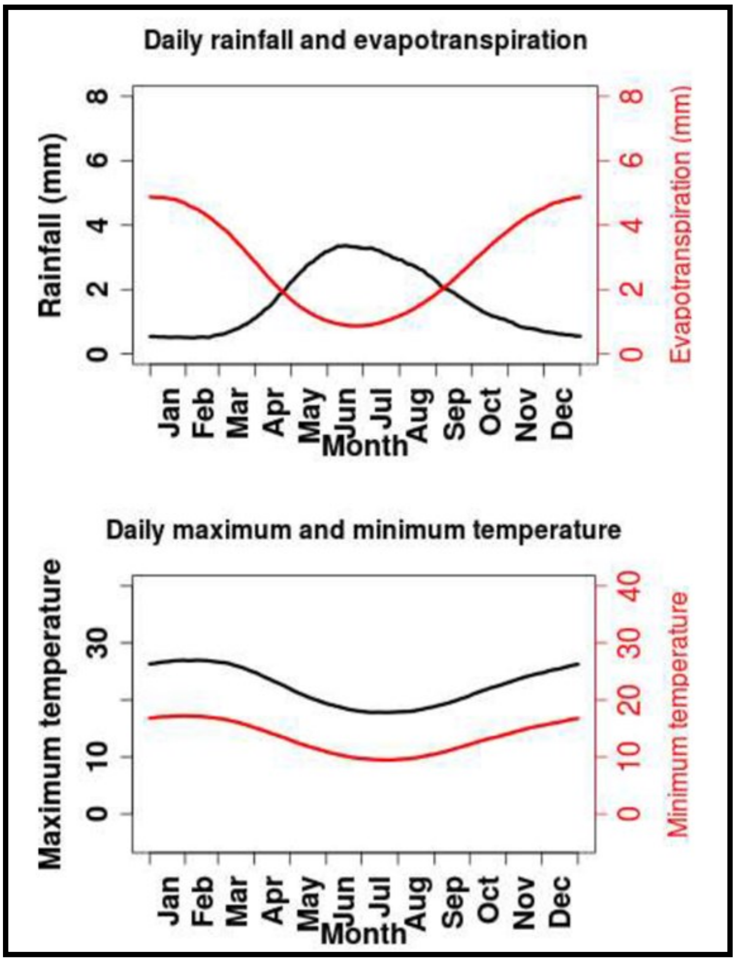


Figure 17: Daily Rainfall (mm day-1) with Reference to Evapotranspiration Rates (mm day-1) (top) at Cape Town and minimum and maximum temperatures (°C) (bottom) (Source: Tadross and Johnston, 2012).

However, Global Climate Modelling projections suggest that climate change is expected to have a significant impacts on South Africa, more specifically on the Western Cape (Tadross and Johnston, 2012). These impacts include general warming, the disruption of conventional rainfall patterns, and the increased frequency of extreme weather events such as drought and flash flooding (ibid.), so affecting both Cape Town's natural and urban environment. It is therefore imperative that the City of Cape Town include the potential impacts of climate change in policy-making and planning processes (ibid.), as well as retrofit the urban environment to better cope with potential vulnerabilities of communities and infrastructure.

Biodiversity

Cape Town is situated within one of the world's six plant kingdoms, known as the Cape Floristic Region (CFR) (CoCT, 2012b). The CFR has been identified as the smallest and most biologically diverse plant kingdom in the world (ibid.). It has the highest proportion of endemic species, with over 70% of approximately 9600 plant species that are unique to South Africa only (ibid.). However, the CFR is known as one of the world's 25 most threatened ecosystems (ibid.).

"Cape Town's natural and endemic vegetation types, and the floral and faunal biodiversity they support, are under severe threat." (State of the Environment Report, 2012b).

Approximately 60% of the initial extent of Cape Town's indigenous vegetation has been lost, this phenomenon is particularly severe within in the lowlands (CoCT, 2012b). Lowlands are often subjected to urban development, because they are easily accessible in comparison to mountainous areas. Of these vegetation types a large number have been lost, in particular the Cape Flats Dune Strandveld (52% has been lost), Cape Flats Sand Fynbos (84%), and Swartland Shale Renosterveld (91%) (ibid.).

The loss of vegetation types and the degradation of ecosystems within Cape Town have had a detrimental effect on ecological functioning of natural systems as a whole, due to the interconnectedness and interdependencies of ecosystems, hence impacting the hydrological cycle as well. See Figure 18 and 19, which illustrate Cape Town's biodiversity network as well as conservation status.

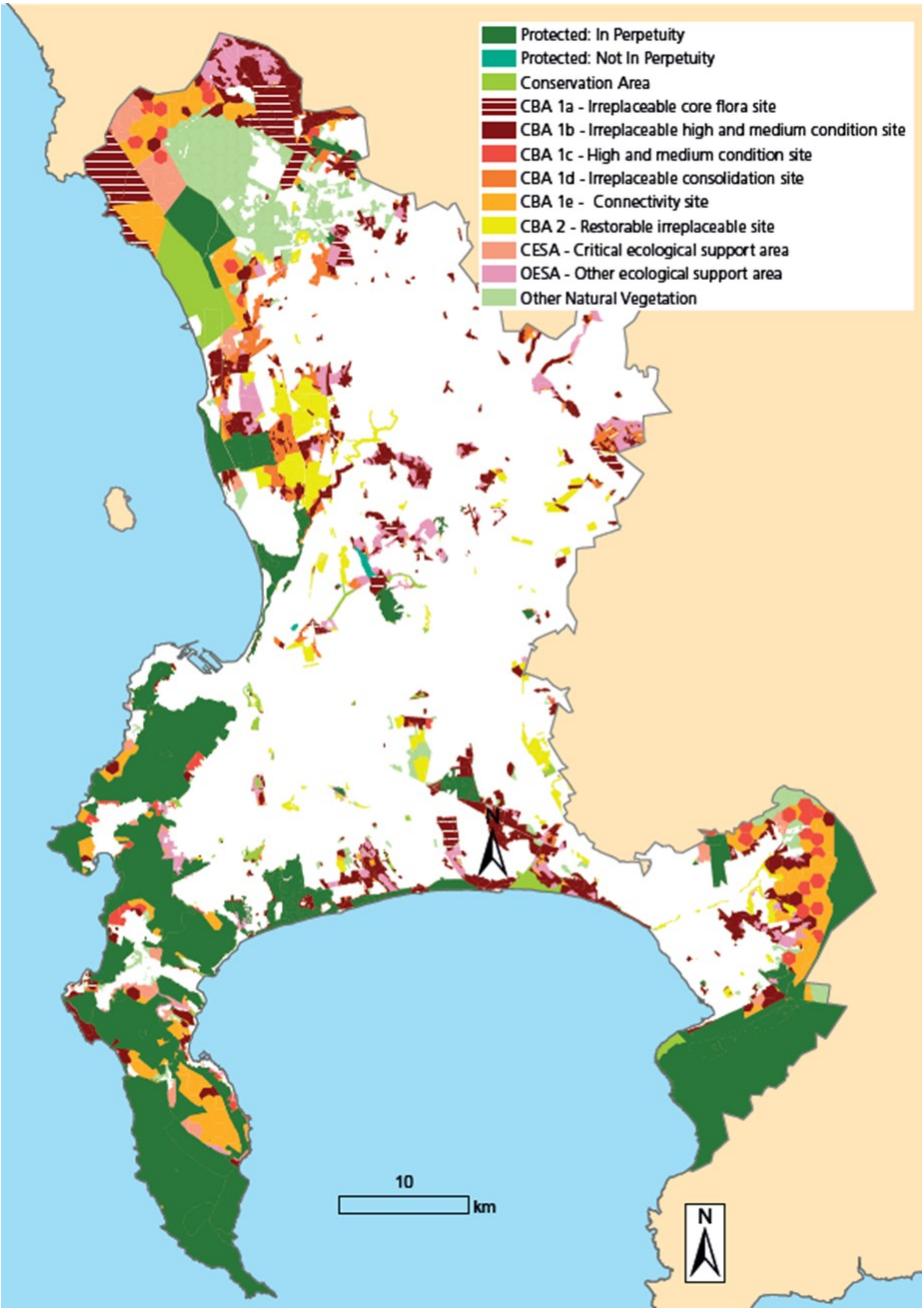


Figure 18: Biodiversity Status (Source: CoCT, 2012b)

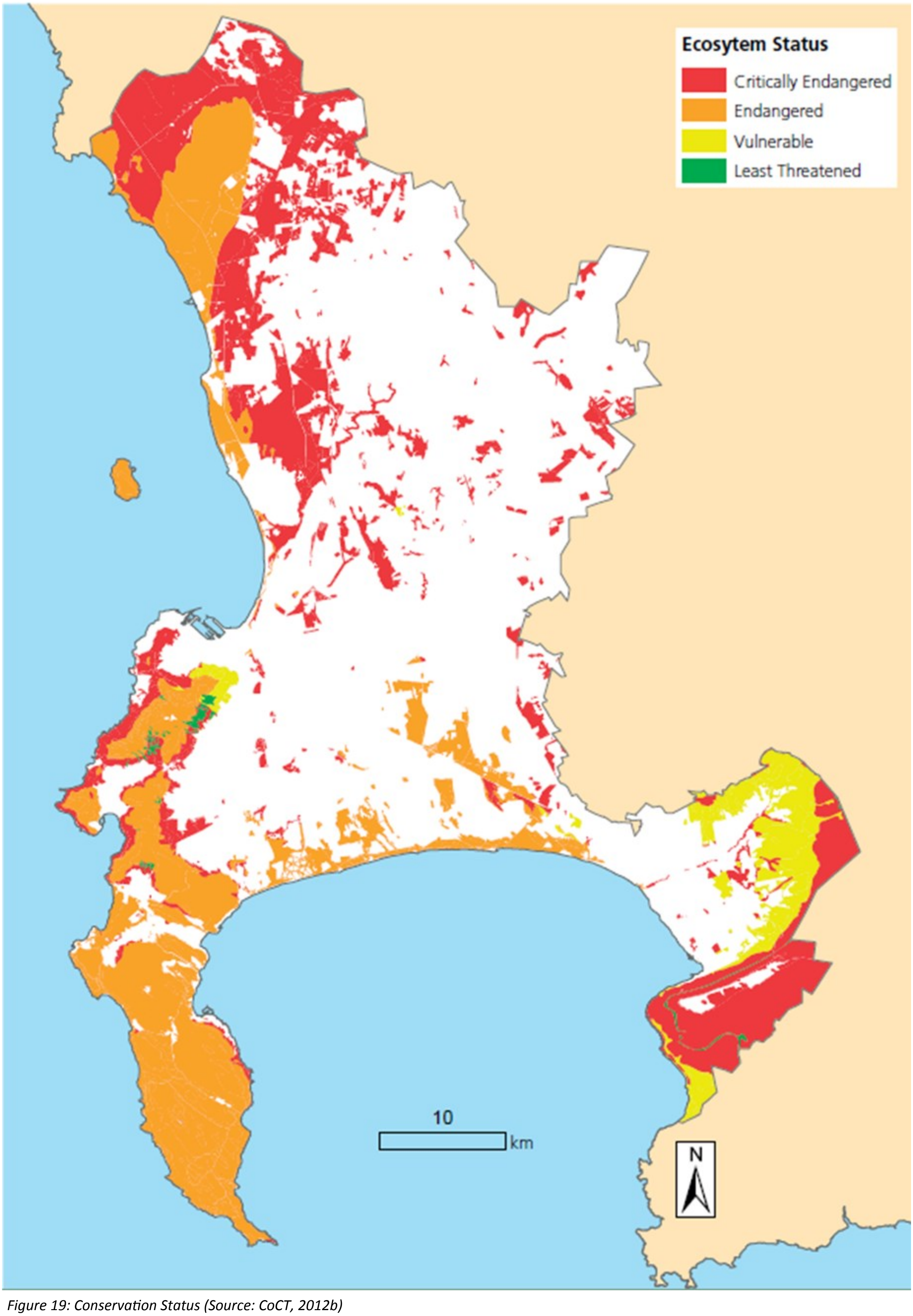


Figure 19: Conservation Status (Source: CoCT, 2012b)

Urban Water Systems – Freshwater Quality:

Cape Town consists of an extensive network of rivers and wetlands. These freshwater systems deliver a dual function, by providing important habitat conditions for the survival of flora and fauna as well as natural infrastructure for the management, treatment, and transportation of stormwater and treated wastewater (CoCT, 2012b). Cape Town's stormwater infrastructure interfaces directly with receiving coastal and freshwater environments (ibid.). The continuous pollution (organic and inorganic) and littering of stormwater and freshwater systems poses a great threat not only to public health, but also to biodiversity. The main sources of pollution of Cape Town's freshwater systems is contaminated stormwater and untreated wastewater effluent (ibid.).

The City of Cape Town uses phosphorous concentration data from samples taken from freshwater ecosystems, as a measurement proxy of ecological condition or trophic state (degree of nutrient enrichment) of these systems (CoCT, 2012b)

Phosphorous is a common key pollutant within urban environments (CoCT, 2012b). High levels of phosphorous within in freshwater systems results in the process of eutrophication (see Figure 20). This leads to the degradation of these systems, through the increased concentrations of toxic ammonia and the reduction in oxygen levels (ibid.). Figure 21, is a guide to the acceptable levels of phosphate.

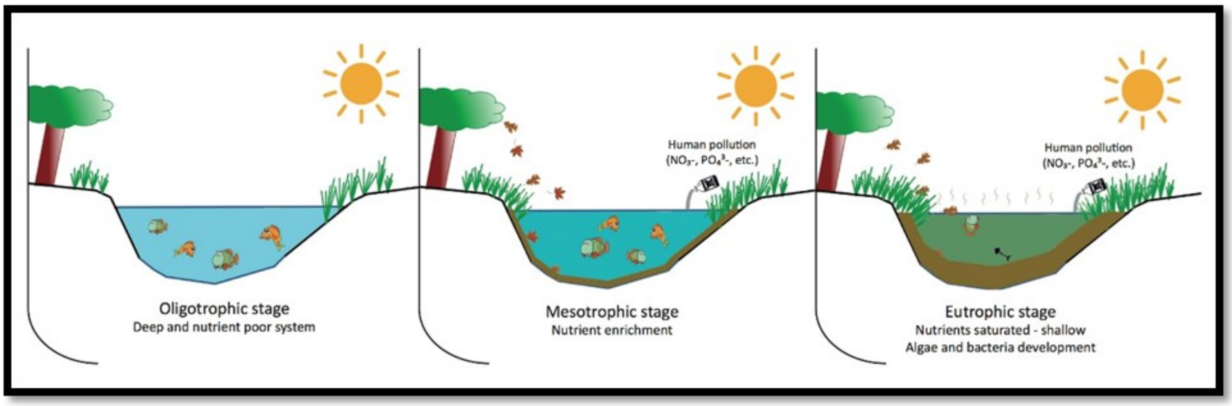


Figure 20: Eutrophication Process and Stages (Source:http://www.aquagreen-tech.com/en/presentation/the-eutrophication.html)

Trophic Tendency	Total Phosphate (mg/ℓ)	"State" and typical conditions
Oligotrophic Very low nutrient level	< 0. 005	**"Excellent"** Usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or blue-green algae.
Mesotrophic Moderate nutrient level	0.005- 0.025	**"Good"** Usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic.
Eutrophic High nutrient level	0.025 - 0.125	**"Fair" to "Poor"** Usually low levels of species diversity; usually highly productive systems, with nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species which are toxic to humans, wildlife and livestock.
	0.125 - 0.25	
Hypertrophic Excessive nutrient level	> 0.25	**"Bad"** Usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to humans, wildlife and livestock.

Figure 21: Categories of Trophic States (Source: CoCT, 2012b)

There have been a few significant improvements in both water quality and ecosystem health in a number of the City's wetlands and rivers during the 2010/11 in comparison to the 2008/9 hydrological year (CoCT, 2012b). Although it is not always clear on the exact causes of improvement in a particular year, it is evident that the Cape Town's freshwater systems are starting to benefit from increased management and attention (ibid.). However, the poor water quality of many of the city's freshwater systems remains of serious concern (ibid.).

Between October 2010 and September 2011, approximately 10 out of 14 rivers and nine out of 13 wetlands were categorised as eutrophic and hypertrophic, therefore indicating poor to acute ecosystem health (CoCT, 2012b). Only three rivers and one wetland were categorised as mesotrophic, indicating average ecosystem health (ibid.). However, none of Cape Town's freshwater systems have been classified as oligotrophic (ibid.). Hence, demonstrating that eutrophication in these systems is a long-term and severe problem.

5.4.2 Cape Town's Trends, Policy Linkages, and Policy Reponses to Improve the Management of Freshwater Systems

Trend and target

Trend: There have been some significant improvements in river and wetland health since the previous reporting period (2008/9). However, progress is still required in order to meet the IMEP targets in 2014.

Target: IMEP Environmental Agenda 2009-2014 Target: half of rivers and half of vleis must achieve 80% target compliance with the public health recreational guideline.

Current: Overall, water quality in rivers remains poor, and is not on track to meet the targets. Water quality in wetlands has improved; currently, just over half of wetland ecosystems meet the public health guideline for water quality, thus meeting the IMEP 2014 target.

Policy Linkages

IDP: Strategic Focus Area 3 - The Caring City

MDG Goal 7: Target 9 – Integrate the principles of sustainable development with country policies and programmes, and reverse the loss of environmental resources.

Urban Environmental Accords: Action 21 – Municipal wastewater management guidelines; and reduce the volume of untreated wastewater discharges by 10% in seven years, through the expanded use of recycled water, and the implementation of a sustainable urban watershed planning process, which includes participants of all affected communities, and is based on sound economic, social and environmental principles.

IMEP Environmental Agenda 2009-2014: Target 7 – River Health.

Catchment, Stormwater and River Management Strategy: Aims to safeguard human health, protect natural aquatic environments and improve recreational water quality.

By-law relating to Stormwater Management: Provides for regulation of stormwater management and regulates activities which may have an impact on the city's stormwater system and natural receiving water systems.

Policy Responses

The Council has incorporated the concept of Water-Sensitive Urban Design in its Spatial Development Framework, and approved a stormwater policy entitled 'Management of Urban Stormwater Impacts' (2009)[25]. This policy requires that developers introduce measures for the management of stormwater quality and quantity on-site, so that impacts on receiving waters such as rivers, wetlands and the near-shore coastal environment may be reduced. This requires widespread support and commitment by many role players in both government and civil society, in order to achieve real improvements in the state of receiving aquatic environments over the long term.

Within the Cape Town area the pressure to develop is significant, and requires careful management to avoid developing in high-flood-risk areas, to protect the environmental integrity of adjacent aquatic resources, and to ensure that permitted development enhances the aesthetics and character of adjacent rivers and wetlands. A second stormwater policy, titled 'Floodplain and River Corridor Management' (2009), tackles these issues and promotes an approach for dealing with development proposals within and adjacent to flood-prone areas and aquatic ecosystems and their buffers.[26]

Since their approval in 2009, the requirements of both these policies have been applied to all new development applications in Cape Town, whether at the basic assessment, scoping, EIA or building plan submission stage. It is anticipated that effective implementation of Water Sensitive Urban Design and Sustainable Urban Drainage Systems, and ensuring aquatic ecosystems are managed or rehabilitated so that their functional integrity is maintained, may increase the resilience of urbanised catchments to climate change impacts.

Figure 22: Summary of City of Cape Town's Trends, Policy Linkages, and Policy Reponses to Improve the Management of Freshwater Systems (Sources: CoCT, 2012b)

5.5 Concerns and Implications of Current Stormwater and Surface Water Management in Cape Town, South Africa

Management of stormwater in urban areas in South Africa such as Cape Town have focused and continue to focus on collecting runoff and channeling it into the nearest watercourse and surface water (Armitage, Vice et al., 2013). This has resulted in prioritising the quantity of stormwater drainage, with little or no consideration for the preservation of the natural environment (ibid.). The impact of poor water quality on South African watercourses is increasingly being highlighted by the media, academics, and other professional bodies (Fisher-Jeffes and Armitage, 2013). There has been a major focus on the failure of sewage systems in many reports, due to the distressing nature of its pollution, and the ability to identify who is responsible due to the point-source character of sewage pollution (ibid.). However, stormwater pollution in general diffuses, therefore making it extremely difficult to attribute responsibility (ibid.).

The City of Cape Town (CoCT), documented in its State of Environment Report that polluted stormwater is a major contributor to the deteriorating water quality of respective surface water/watercourses as well as surrounding habitats (Fisher-Jeffes and Armitage, 2013). It also contributes to the collapse of sewage systems treatment works that have become overloaded, with stormwater entering into the sewer network (ibid.).

"The water cycle is one of the most critical processes to supporting life on this planet, and fresh waters are central to all aspects of our lives. Historically, urbanisation has led to the loss and degradation of wetlands, rivers, and groundwater resources through pollution, resource depletion, and construction within natural flood plains. "(Woods-Ballard, Kellagher et al., 2007)

The development of urban areas has reduced the natural permeability attributes of land by substituting free draining surfaces with impermeable surfaces such as roads, roofs, and paved areas that are often drained by hard infrastructure (Armitage *et al.*, 2013). Development also results in a general loss of vegetation, which reduces stormwater buffering through interception storage, ponding, and evapotranspiration (ibid.). During development subsoil strata often gets compacted, which leads to a reduction in infiltration potential (ibid.).

Traditional drainage systems are usually focused on decreasing flooding and tend to largely ignore the preservation and enhancement of water quality and the associated aspects of amenity and biodiversity (Armitage *et al.*, 2013). This often has severe impacts on flooding in terms of the wider catchment, and ignores the potential to use stormwater as a resource (ibid.). Figure 23 is a basic illustration of typical pre and post-development states in terms of the traditional method of managing stormwater.

In South Africa, surface runoff accounts for 9% of the total precipitation process, whilst the other 91% either evaporates or infiltrates (Winter, 2010). The conversion ratio of rainfall to runoff for the whole country is among the lowest on the globe, in comparison to the global average of approximately 35% (ibid.). Surface water resources for the City of Cape Town represent about 440.5 Mm^3/year, which is 97% of the total yield (ibid.).

Cape Town currently has a formalised stormwater drainage network, comprised of 535 km of drainage, 1 573 gullies, 844 manholes, 30 flushing tanks, 100 overflows from sewage systems (Haskins, 2012a). The stormwater reticulation system has expanded as a direct response to the rapid population growth and the expansion of Cape Town's urban footprint (ibid.). The 1904s and '60s were a period of extensive stormwater engineering, involving the realignment of the Liesbeek and Salt Rivers, the construction of several canals, detention ponds, and the upgrading of drainage systems as a bid to mitigate the impacts of flooding in a rapidly growing city (ibid.). Stormwater runoff patterns in Cape Town are typical of that of most developed cities – reduced infiltration, increased runoff rates, volumes and flood events (ibid.).

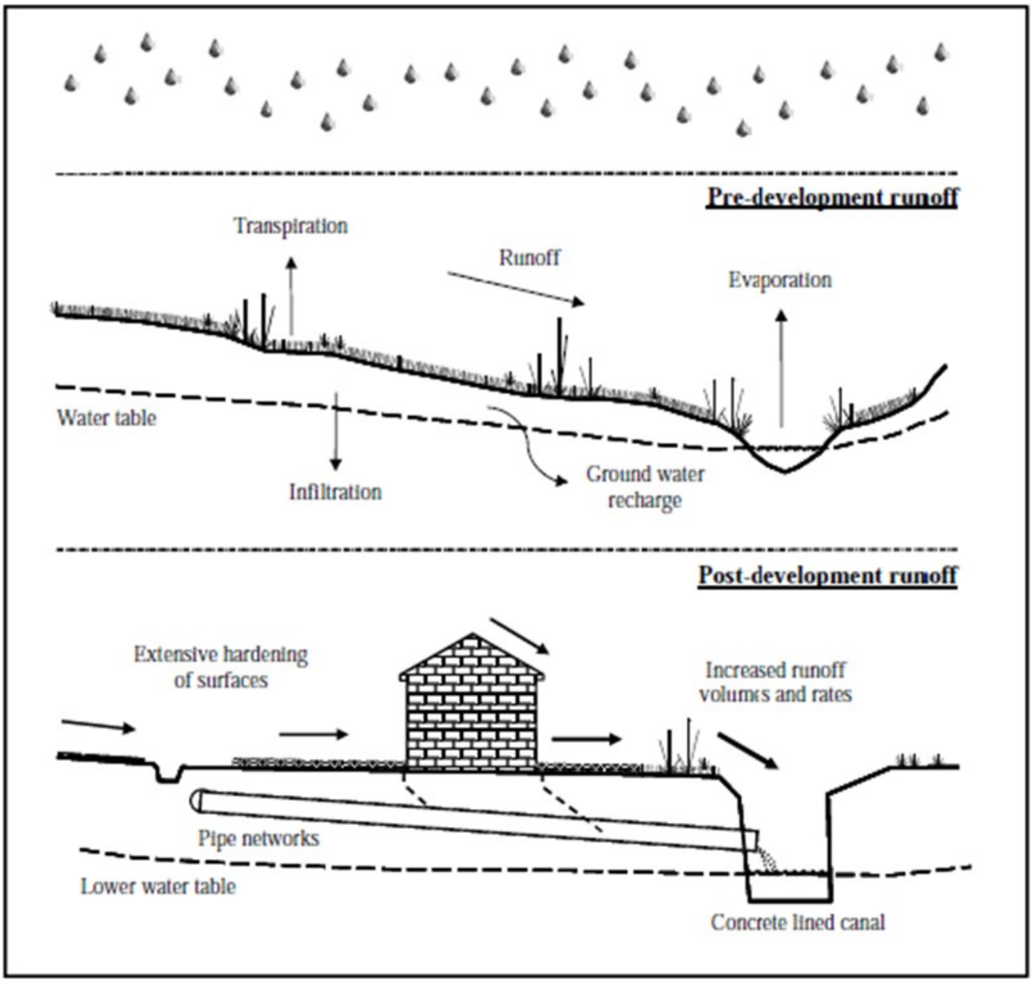


Figure 23: Pre- and Post-Development Scenarios of the Traditional Method of Managing Stormwater (Source: Armitage et al., 2013)

The urban water cycle in Cape Town as well as the rest of South Africa is currently being managed in a fragmented manner. The inadequate integration of stormwater management and the management of other forms of urban water has resulted in municipalities all across South Africa employing unholistic approaches to managing all urban water systems (Fisher-Jeffes and Armitage, 2012). Therefore, stormwater management ends up being ineffective and inefficient, with those responsible for it operating often being under massive budgetary constraints (ibid.). Stormwater is usually managed as a flood hazard and disposed of as fast as possible (ibid.). This approach of management focuses primarily on managing quantity rather than quality.

South African municipalities are constitutionally obliged to provide a safe and healthy environment, while assuring economic development and the provision of services in a sustainable manner (Fisher-Jeffes and Armitage, 2012). The management of stormwater is falling short of these objectives; this is partly due to the fact that stormwater management is incredibly underfunded. Municipal infrastructure requires extensive re-investment and maintenance capital. According to Fisher-Jeffes and Armitage (2012), current municipal replacement cost of infrastructure is approximately R723 billion for all South African municipalities and the depreciated replacement cost is approximately R385 billion.

The problem of underfunding stormwater management is not unique to South Africa; however, the circumstances in South Africa are particularly bad. Funding for stormwater management mainly comes from general municipal rates, and competition with other pressing issues frequently leads to stormwater management being extremely underfunded, sometimes receiving only a tenth of what is needed to manage stormwater quantity (Fisher-Jeffes and Armitage, 2012). This makes it incredibly difficult for municipalities to meet their obligations with respects to stormwater quality management, which leads to the degradation of the natural environment and its ecosystem services (Oelofse, 2011). Municipalities need to start investing in a more sustainable stormwater management approaches. It is no longer possible to solve stormwater, surface water, and infrastructural problems with concrete pipes (Winter, 2010).

5.6 Industrial Stormwater Management

The importance of appropriate stormwater management in industrial sites has been recognised globally, because contaminates within stormwater discharge tend to be higher in industrial areas than other land-uses (Fenelon, 2010).

Activities that often take place at industrial facilities, such as material handling and storage, are usually exposed to the weather. Therefore, the runoff generated through rainfall events tends to come into contact with these activities, picking up pollutants and transporting them to a nearest storm drainage system or directly to a river, lake, or coastal water (United States Environmental Protection Agency, 2015).

Contaminates such as copper and zinc are usually found in industrial stormwater discharge and accumulate in freshwater and estuarine sediments, causing biodiversity loss as well as if ingested by aquatic animals/organisms enter the food chain (United States Environmental Protection Agency, 2015). Therefore, it is extremely important that improving stormwater runoff is a key priority for cities, in order to properly protect and ensure that harbours or ports as well as waterways are conserved for future generations (Fenelon, 2010).

The wetlands and river systems present in surrounding areas around Paarden Eiland receive stormwater from various suburbs in Cape Town, therefore it is important that the right management measures are put in place to protect vital biodiversity areas within the Blaauwberg District, the surface water surrounding Paarden Eiland, as well as the coastal waters of Table Bay (Atlantic Ocean). All these environmental elements are important to the ecological functioning of the greater Cape Town region.

5.7 Conclusion

A number of foundations have been established in terms of planning and implementing green infrastructure globally. Progressive institutional structures and bold conversation targets have created a productive and active policy setting. The case studies used have illustrated that green infrastructure, if appropriately planned and implemented can be extremely beneficial socially, economically, and environmentally in order to build both ecological and urban resilience. Most of the agendas shown in the case studies evaluated take place via the increase of city trees and vegetation, the use of SUDs, greening urban streets, the use of open channels, and the treatment of pollutants through wastewater treatment plants, in the attempt to manage stormwater as well as surface water. The mixture of landscape and engineering design elements help make green infrastructure strategies more effective. While these techniques and methods have proven to work effectively and efficiently in Stockholm and Portland, it is evident that mainstreaming green infrastructure planning has its challenges, especially in the context of cities within developing countries such as Johannesburg. This shows that it is pertinent that there is activism from both governments as well as the public, so that the implementation of decentralised green infrastructure and relevant policy frameworks are successful. Both the government and the public need to be entirely invested in moving away from conventional grey/hard infrastructure towards green infrastructure, for any major change to occur in thinking as well as in reality.

The case studies used demonstrate that there is an opportunity for cities around the world to situate themselves in a diverse ecological and institutional setting. The integration of various disciplines/knowledge in dealing with the challenges associated with managing green assets and stormwater is a critical step in developing a city-wide approach to employing appropriate green infrastructure urban water management techniques.

CHAPTER SIX

6. Green Infrastructure Framework for Paarden Eiland, South Africa

6.1 Introduction

The purpose of this chapter is to present an investigation of Paarden Eiland's stormwater and surface water management, to gain greater insight into Cape Town's current stormwater and surface water management. Paarden Eiland could potentially be a great example of how not only an industrial area, but also an area that is heavily developed (very little of its own natural infrastructure) can be retrofitted with green infrastructure to better manage both stormwater runoff as well as receiving surface water systems in the area.

This chapter begins with a district analysis of Blaauwberg, in order to gain an in-depth overview of the district contextual setting in which Paarden Eiland is located, so gaining an understanding of the greater bio-physical and socio-economic setting in which Paarden Eiland's natural and hydrological systems/networks are situated and connected to that influence stormwater runoff and surface water conditions.

This chapter will also include a site analysis for Paarden Eiland and its surrounding areas. This will help reflect on the existing course of stormwater runoff and the state of surface waterbodies in the area. The site analysis process will look at some of the main features that should be considered, in order to identify potential and existing constraints as well as opportunities. These features include geology, hydrology, biodiversity, existing and surrounding development (land-use), transport and movement systems, existing stormwater infrastructure, and spatial opportunities and constraints. The identification and analysis of these features will be utilised to develop a site analysis plan that will later inform the design process for Paarden Eiland's green infrastructure framework. The site analysis also helps map out certain informants that have implications for stormwater management.

This chapter then moves onto the development of a conceptual framework and layout. The conceptual framework establishes spatial and green infrastructure objectives as well as guiding principles, whilst the conceptual layout focuses on the general concept for Paarden Eiland's layout, which takes into account both the legal and physical features of the site as established through the site analysis process. Once the planning phase has established a comprehensive a green infrastructure framework for the appropriate management of stormwater and surface water within Paarden Eiland will be developed.

6.2 District Analysis

As the spatial focus area is Paarden Eiland, this section provides an in-depth overview of the bio-physical and socio-economic trends, in order to better understand the local biological, anthropogenic, and industrial influences on surface water systems within the area. This analysis will help guide strategic green infrastructural intervention.

6.2.1 Socio-economic Analysis

The Paarden Eiland local area within the Blaauwberg District incorporates the residential suburbs of

Milnerton South, Lagoon Beach, Woodbridge Island, Rugby, Brooklyn/Ysterplaat, and the industrial suburbs of Metro Industrial and Paarden Eiland (CoCT, 2013). The residential areas are a mixture of income groups, although the area is predominately low-density residential (ibid.). The industrial areas consist of large industrial buildings as well as newly re-developed offices and showrooms; however, these industrial areas still to some degree suffer from urban blight and stagnation (ibid.).

The industrial area of Paarden Eiland plays a significant role in supporting the Port and its functions for the greater Cape Town (CoCT, 2013). Forty percent of the industrial area's businesses are directly linked to the Port (ibid.). This makes Paarden Eiland a strategic location, which has therefore resulted in the increase of land values that are three times higher than any other industrial suburb or land in Cape Town (ibid). Figure 24 illustrates the spatial development plan for Blaauwberg as a district.

6.2.2 Bio-physical Analysis

It is important to note that Paarden Eiland is located in the Table Bay District along the coastline. However, Paarden Eiland falls predominately within the Blaauwberg District; therefore, in terms of analysing the bio-physical attributes and conditions of Paarden Eiland, it is necessary to look at the bio-physical trends of the Blaauwberg District in order to have a holistic and comprehensive understanding of water systems and other environmental assets. It is important to recognise that the natural systems located near Paarden Eiland are connected to a larger ecological network, which is located throughout the district.

This area has a number of significant environmental features which include a coastline along the Atlantic Ocean, tracts of threatened vegetation types and conservation areas, along with number of locally important rivers, wetlands, and estuaries (CoCT, 2009).

Biodiversity Status (Blaauwberg District)

The Blaauwberg District has some if the most significant unpreserved lowland sites within the CFR, therefore identified as a conservation priority (CoCT, 2012c). This district also has the remaining tracts of two of South Africa's rarest vegetation types (Sand Fynbos and Renosterveld) (ibid.). Sand Fynbos and Renosterveld are high in species diversity as well as have the highest occurrence of vulnerable and Red List plant species, as well as several faunal species (ibid.). The district's biodiversity is under immense treat from rapid development and the overexploitation of water resources (ibid.).

Hydrological Status (Blaauwberg District)

The degradation and pollution of wetlands, rivers, and groundwater systems within Blaauwberg District is a critical issue (CoCT, 2012c). Several of the rivers in the district, in particular the Diep River, have lost most of their natural riparian habitat and environmental functioning (ibid.).

The Diep River Estuary, also known as the Milnerton Lagoon, is directly upstream of its mouth at Zoarvlei. The rivers in the area have been degraded by pollution created by urban stormwater runoff, treated effluent, and new as well as existing industrial areas (CoCT, 2012c).

Under natural conditions, the Zoarvlei wetland was once part of a larger system of estuarine wetlands connected to the coastal marshes of both the Black/Salt River and the Diep River (Haskins, 2012b). However, at present the Zoarvlei has become an isolated wetland system, fed by groundwater intrusions and stormwater (ibid.).

The Zoarvlei functions as a perennially saturated to inundated freshwater coastal lake, and consists of two other seasonal lakes (Haskins, 2012b). The vlei primarily receives stormwater from the residential areas of Rugby, Brooklyn, and Ysterplaat, as well as surrounding industrial areas. Stormwater from Century City also crosses the vlei before entering and exiting into Table Bay (ibid.). The degradation of inland water systems has affected coastal deposition and sedimentation processes (CoCT, 2012c).

The main causes and sources of the pollution of surface water, according to the Blaauwberg District Environmental Management Framework (2011), include:

- Insufficient service provision, which often tends to lead to contaminated stormwater
- Polluted runoff from industrial and agricultural areas
- Sewer overflows

Illegal dumping into stormwater and sewer systems.

6.2.3 Blaauwberg District Spatial Development Framework Provisions for Stormwater Management and Associated Issues

The stormwater challenges associated with the district are largely related to the poor maintenance of wastewater ingress, which is caused by illegal dumping into the stormwater system (CoCT, 2012c). Therefore, it is important that new developments within the district follow the City of Cape Town's Urban Stormwater Impacts Policy, which encourages the use of best practice measures in managing both quantity and quality of stormwater (ibid.). These best practice measures also provide an opportunity to retrofit existing developed areas (ibid.).

Currently, the Diep River and Rietvlei are known to be the main drainage systems for the Blaauwberg District, and a stormwater management plan has been prepared for predominately the central areas of the district (CoCT, 2011). This management plan includes providing a decentralised stormwater treatment at the source, in order to minimise the impacts of runoff on these systems (ibid.). The management plan also proposes that stormwater from the north-western areas of central Blaauwberg be diverted westwards towards the north of Big Bay, in order to discharge stormwater into the Atlantic Ocean (ibid.).

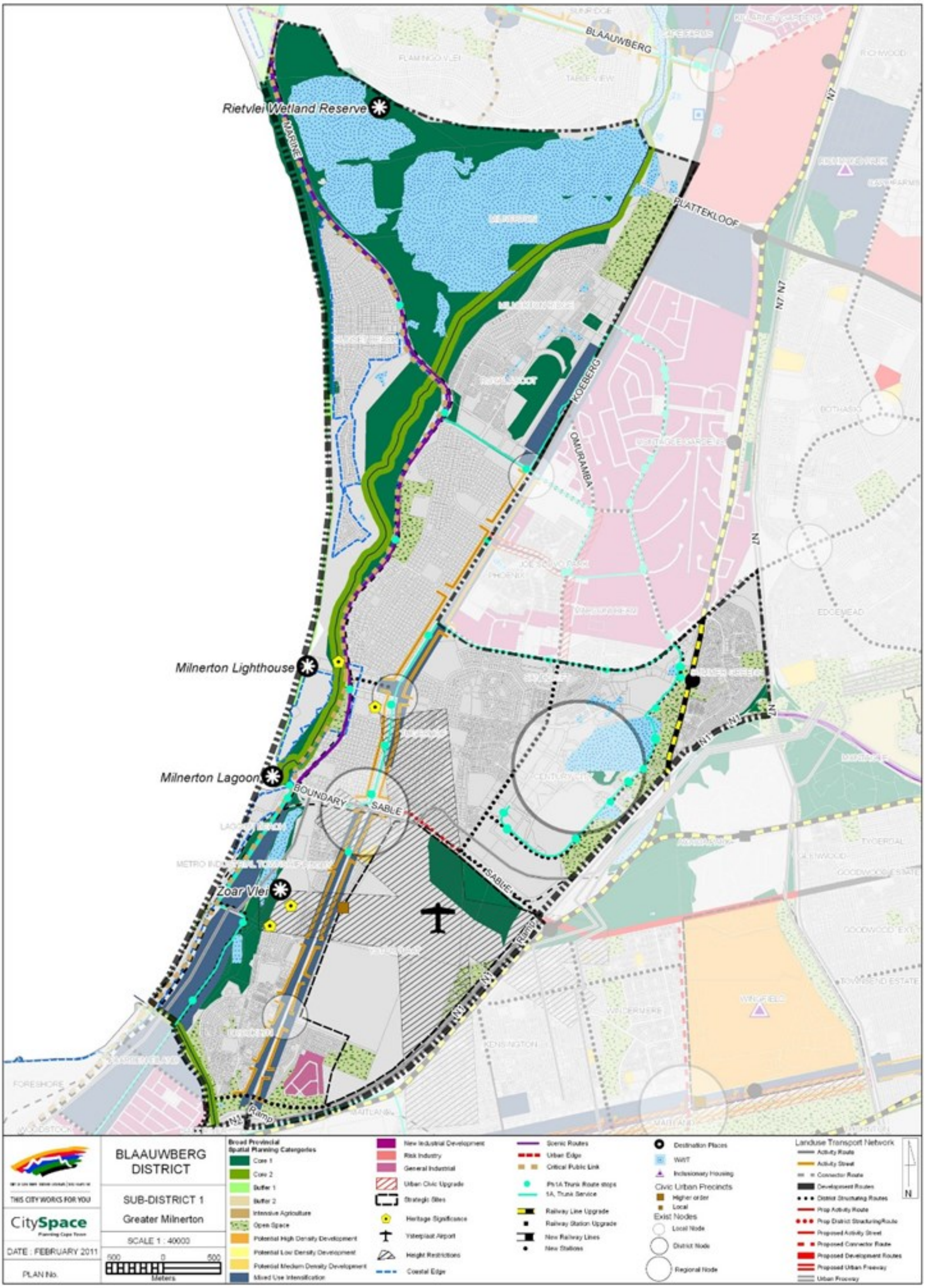


Figure 24: Blaauwberg District Plan (Source: https://www.capetown.gov.za/en/sdf/PublishingImages/Blaauwberg_Apr2011/Subdistrict%201_s.jpg)

6.3 Site Analysis

Paarden Eiland was strongly promoted and proclaimed as an industrial area around 1935 (Serif, 2015). Currently, it consists of smaller scale manufacturing and industrial activity, as well as some commercial activity (ibid.). Therefore, smaller-scale factories are being established in this area (ibid.), unlike industrial areas such as Epping and Maitland that operate on a much larger scale of industrial activity. The area has gone through a number of evolutions from initially being just wild veld towards evolving into an agricultural area, industry, commercial and retail, and now hosting various entertainment sectors (ibid.). This evolution has occurred over approximately the past 350 years, and is an indication that Paarden Eiland holds great economic value to greater Cape Town (ibid.).

Besides the economic value that Paarden Eiland holds for greater Cape Town, there have been some issues identified in the area. These include environmental degradation of particularly surface water, flooding, ageing water infrastructure, excess stormwater runoff into surface water and Table Bay, poor NMT (non-motorised transport) and pedestrian facilities and routes, and the degradation of existing developments. The City of Cape Town has currently established a local area development framework for Paarden Eiland and the surrounding areas, in order to promote the regeneration of the area. The City of Cape plans on focusing on transit-oriented development between Marine Drive and Koeberg Road and the identification of improvement opportunities for the public environment, in order to achieve a quality environment for the study area (CoCT, 2014). This in turn provides an opportunity to introduce green infrastructure as a means of appropriately managing stormwater and surface water, as well as beautifying the area to provide a better quality environment for residents and business owners with the area.

Table 1: Paarden Eiland's Location and Demographic Profile (Source: Cape Town Census data (2011) & Ecamp (2013))

PAARDEN EILAND'S LOCATION PROFILE		
SIZE	Warehousing	Very Large
	Light Industry & Workshops	Large
	Conventional Industry	Very Large
	Retail	Very Small
ROOM FOR GROWTH	Future Industrial Bulk	Low
	Extent of Vacant Land	Constrained
ACCESS	Public Transport Connectivity	Low
	Distance from Regional Market Nodes	Very Well Located
	Distance from freight Corridors & Gateways	Very Well Located
INFRASTRUCTURE	Water Reticulation	Low Risk
	Sewer	Low Risk
	Stormwater (flooding and Sea Level Rise)	High Risk
PAARDEN EILAND'S DEMOGRAPHIC PROFILE (2011 CENSUS DATA)		
Population		11
Area		1152.09 HA
Unemployment		0

Biodiversity

In the past, the area of Paarden Eiland was known for its highly diverse biodiversity. After the extensive industrial development in the area much of this biodiversity was lost. However, even after decades of development in the area, the City of Cape Town still recognises that this area still holds environmental significance, and is in the process of securing environmental protection status for Paarden Eiland's water and wetland systems (CoCT, 2015b). Figure 2 below, illustrates that the Paarden Eiland is located within a biodiversity network, which is currently predominately critically endangered due to pollution, degradation, and encroaching development.. Paarden Eiland's main wetland system known as the Zoarvlei as the figure below indicates is protected in perpetuity, which means that it has National, Provincial, and Municipal significance .

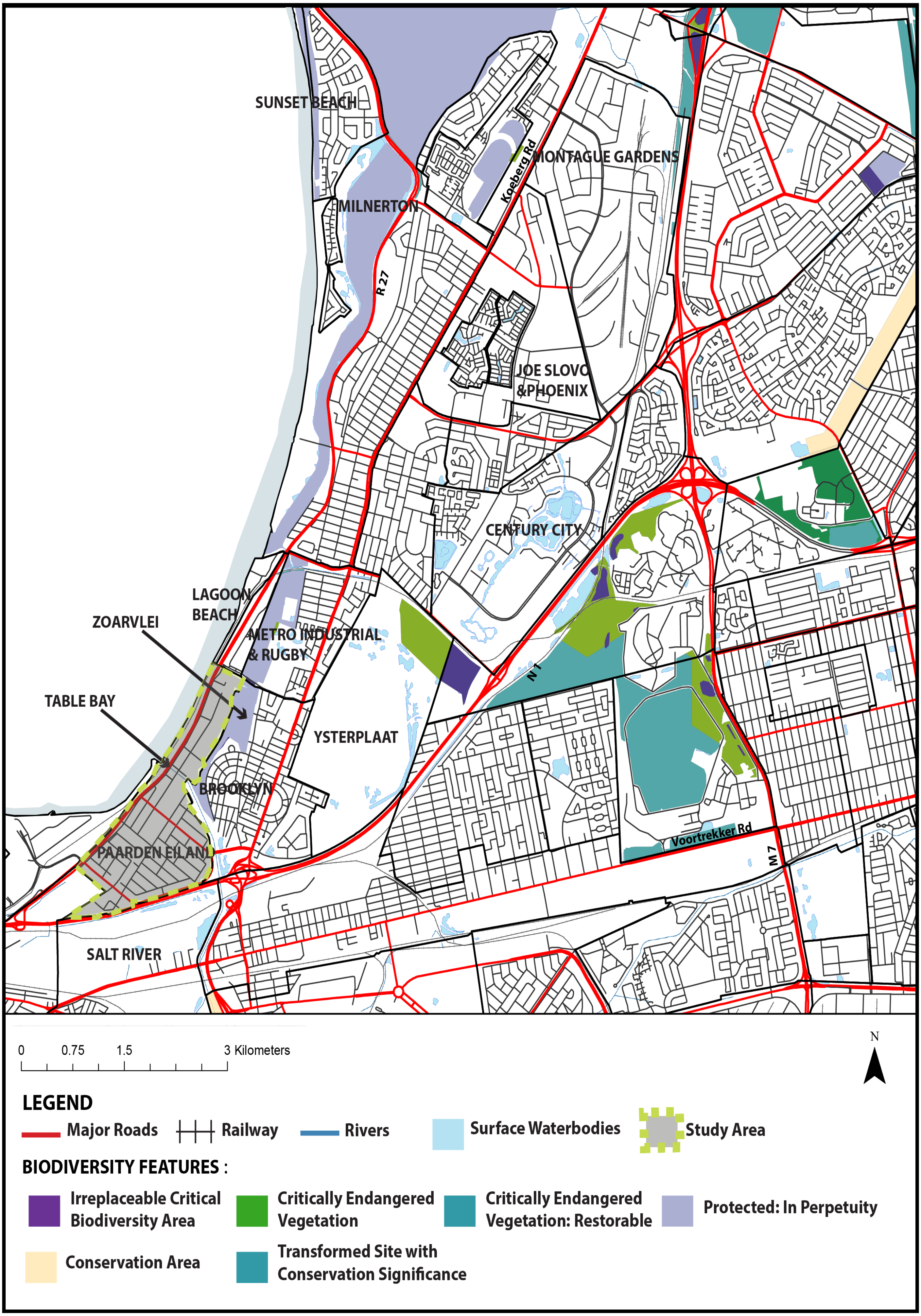


Figure 25: Biodiversity Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Hydrology

River, wetland, and groundwater systems in proximity to Paarden Eiland tend to be fairly degraded, polluted, and their natural habitat compromised. This is due to polluted stormwater runoff and effluent entering surface water systems, as well as illegal dumping, resulting in poor water quality. Figure 26 below helps give an indication of the extent of existing wetlands in the area and the effects of development on these systems. A fairly large number of the wetlands present in the area are classified as isolated, meaning they are not linked to each other in a holistic network but are scattered and fragmented across the landscape. This eventually compromises the functioning of the hydrological cycle and the ability of these systems to act as buffers for flooding. The figure also shows that area in which Paarden Eiland is located is extremely susceptible to flooding events. Flooding in turn has negative implications for existing properties, infrastructure, and societal health.

The groundwater in the area is classified as being one of the most vulnerable in Cape Town, according to Figure 27, which is a cause for concern in a region that is experiencing water scarcity.

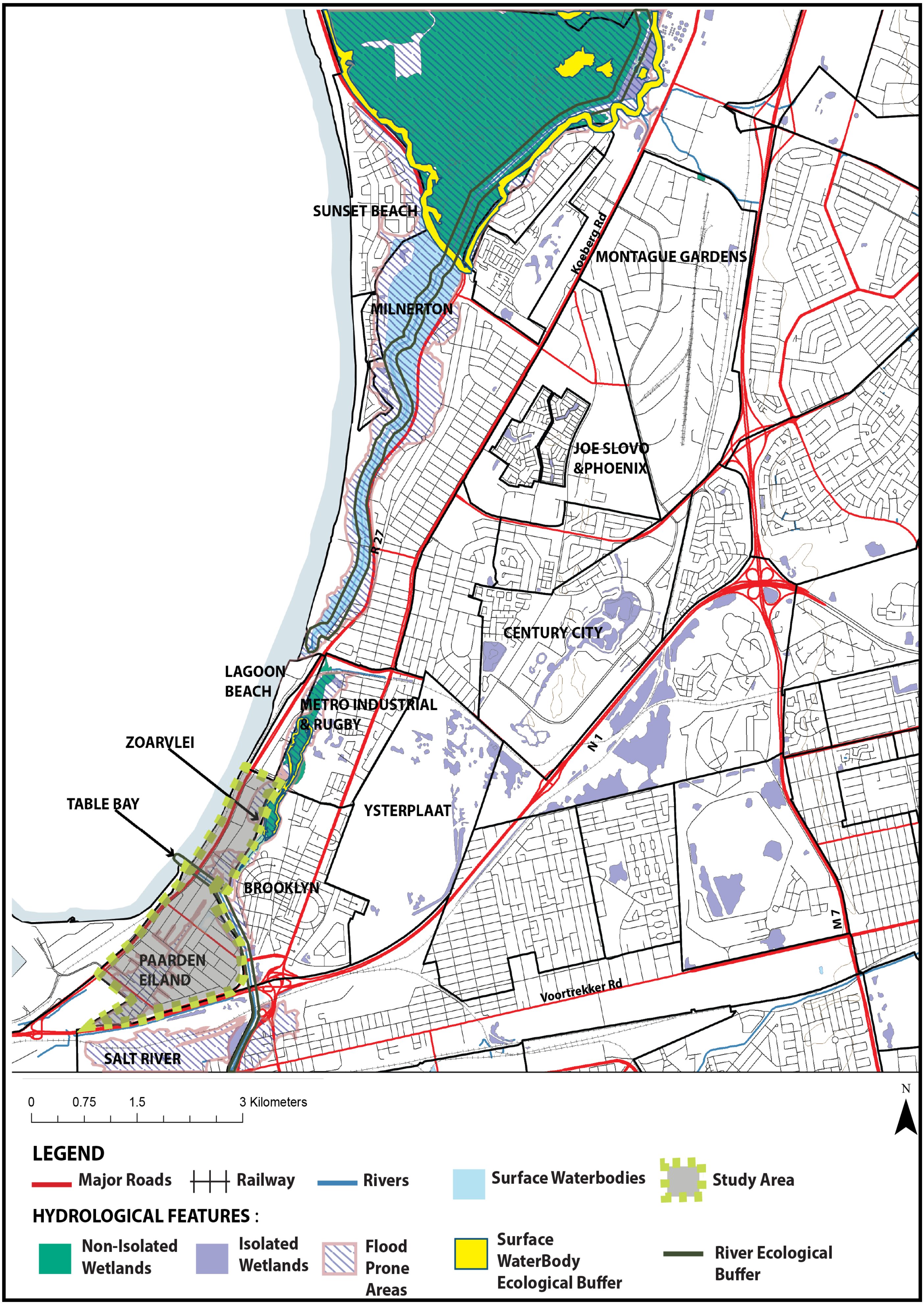


Figure 26: Hydrological Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

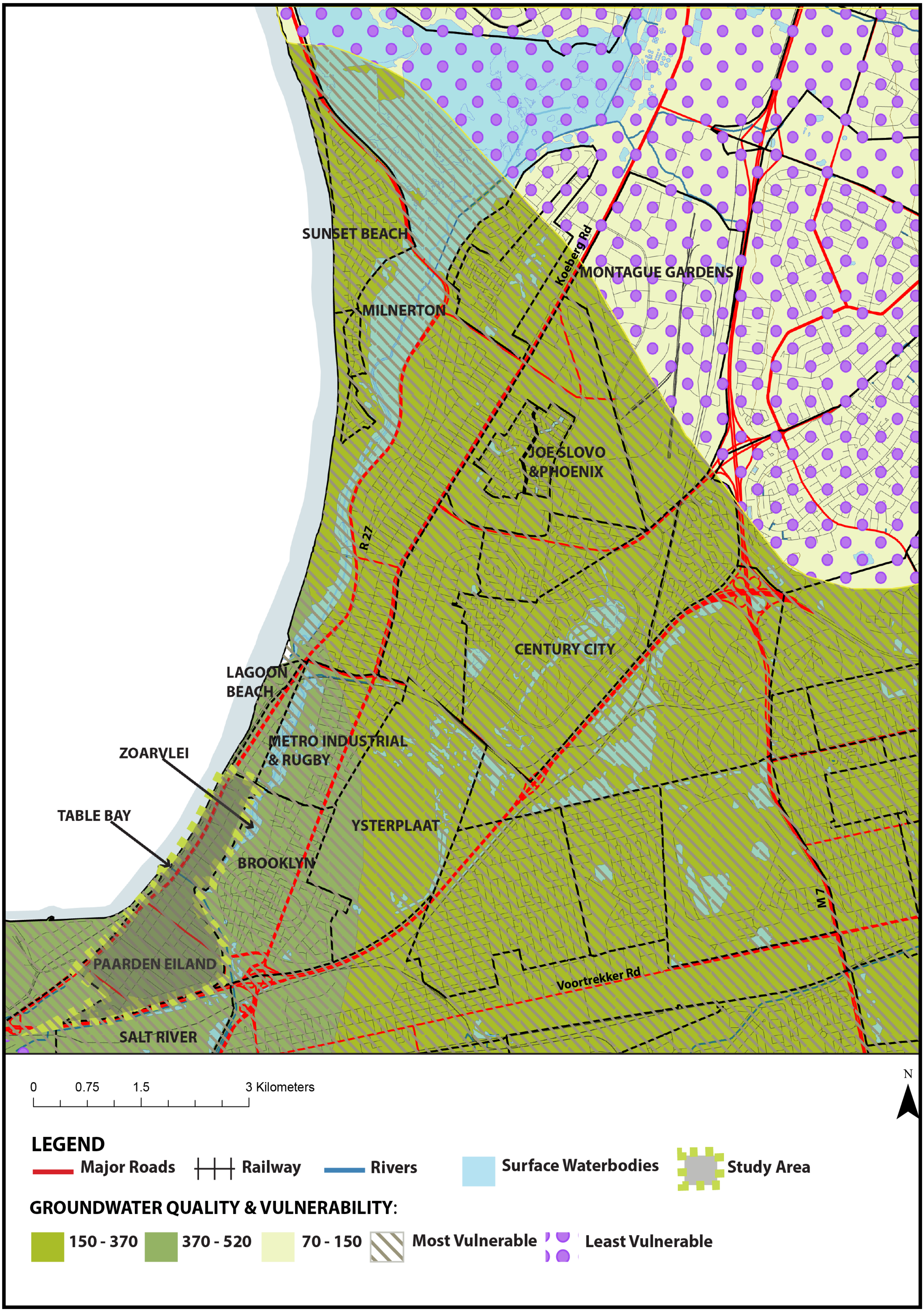


Figure 27: Groundwater Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Geology and Vegetation

The geology of a site has a great impact on the functioning of hydrological systems as well as the ability of biodiversity to thrive. Podzolic soils are known to be forested soils that are often found on sandy deposits and occur in areas with a mean annual precipitation of 700mm (Encyclopaedia Britannica, 2015). Soils with a strong texture contrast are commonly widespread and are predominately well suited for agriculture (State of Victoria, 2015), whilst soils with limited pedological development are a result of human activity developed through the extensive modification of original soil horizons (Chesworth, 2008). The impact of development on soils often results in the restriction of soil in terms of its capacity to hold water, causes erosion, reduces infiltration and groundwater recharge. Paarden Eiland according to the Figure 28 below consists of predominately soils that are Podzolic.

In Figure 28 we are able to see the extent of endemic vegetation species such as the Cape Flats Dune Strandveld which is currently under major threat, with very little of this species still remaining in the area.

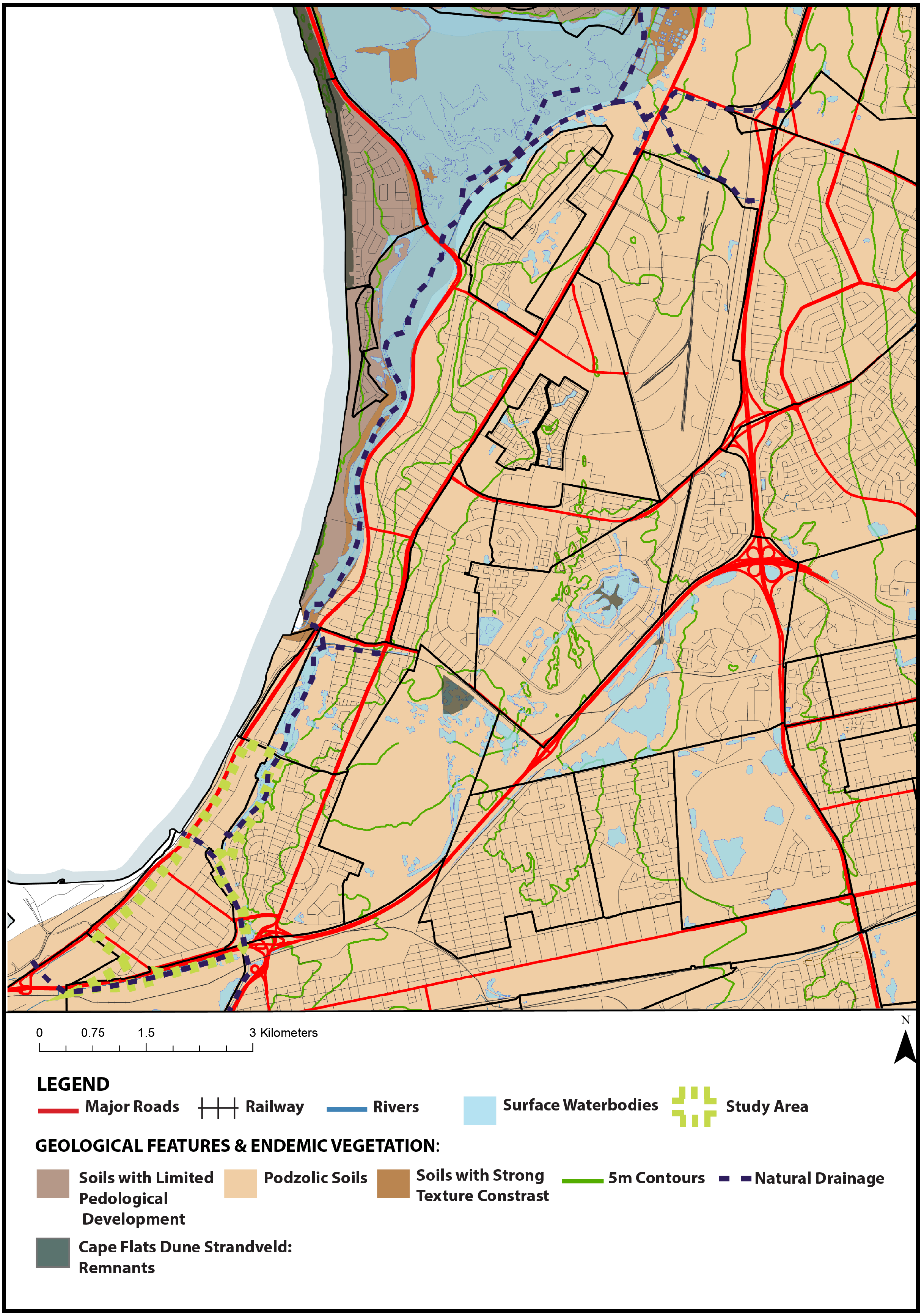


Figure 28: Geological and Vegetation Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Stormwater Infrastructure

The City of Cape Town has recently noted in the Milnerton South – Paarden Eiland Local Area Spatial Development Framework (2013), that the Zoarvlei should be deepened in order to increase stormwater capacity. This is due to the fact that stormwater infrastructure in the area is ageing and its capacity for dealing with stormwater runoff is fairly low (Ecamp, 2013). This poses a high risk of flooding, especially because Paarden Eiland is located in a flood-prone zone. Figure 29 below illustrates the current stormwater infrastructure system in place, which fits the conventional model of developing stormwater infrastructure.

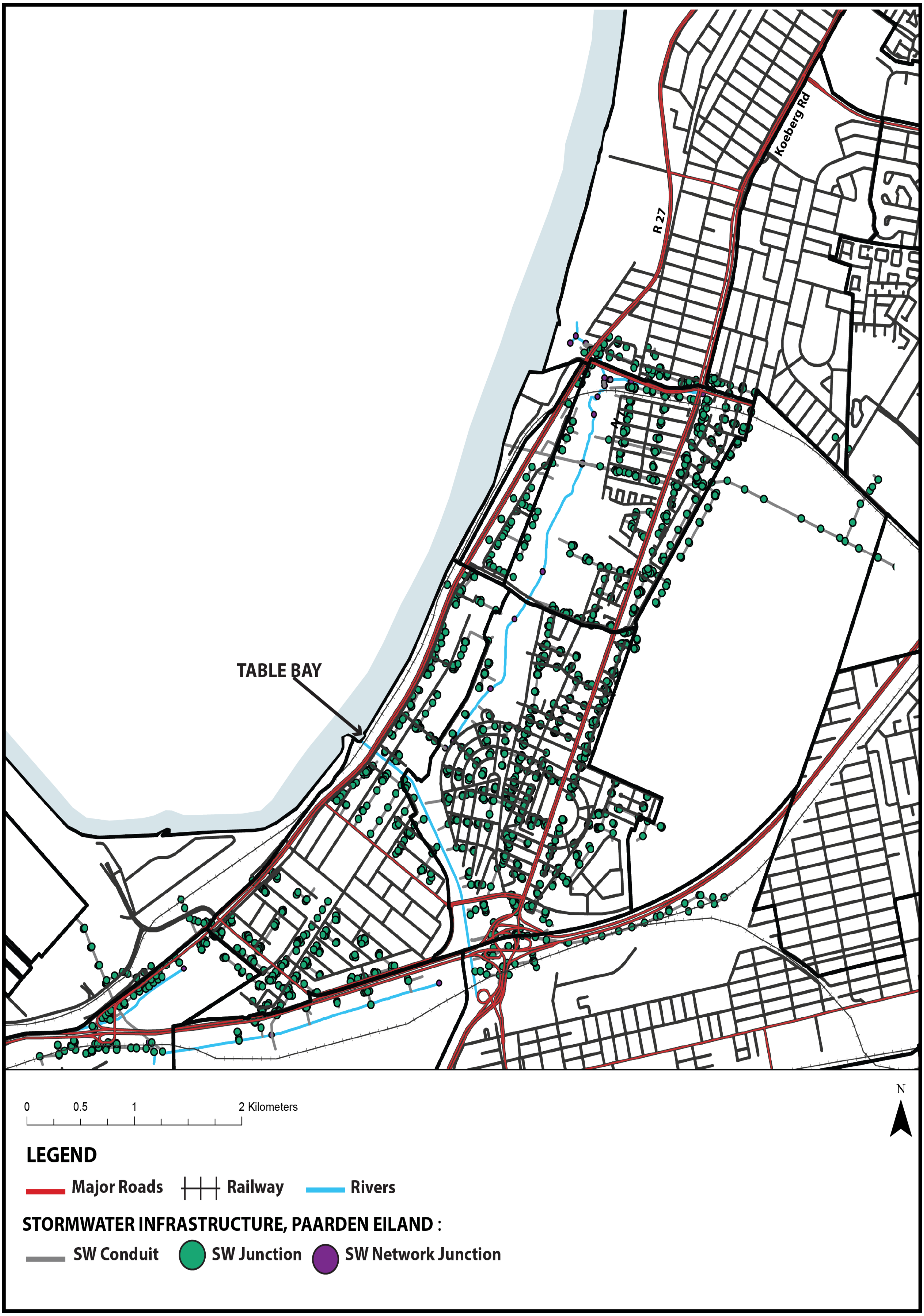


Figure 29:Stormwater Infrastructure Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Transport and Movement Network

Paarden Eiland is situated within the N1 corridor, which connects to the Port, other large industrial and development areas, as well as to the Cape Town CDB. The N1 corridor encompasses Voortrekker Road, the R27 and M7, as well as Koeberg Road. This area is known to have very high levels of freight, passenger rail, commuter, tourist, and business as well as recreational traffic movement (Frieslaar and Jones, 2006).

The area is serviced by public transport in the form of BRT buses, regular buses, taxis, and passenger rail. The transport pattern displayed in Figure 30 below, indicates a linkage of main transport routes that connect the site to the Cape Town CBD, Bellville/Tygerberg, and large commercial developments such as Century City. Overall, the site is nestled within a well-established transport and movement network, providing a fairly good connectivity to the rest of Cape Town. However, it lacks well-established NMT and pedestrian walkways and routes.

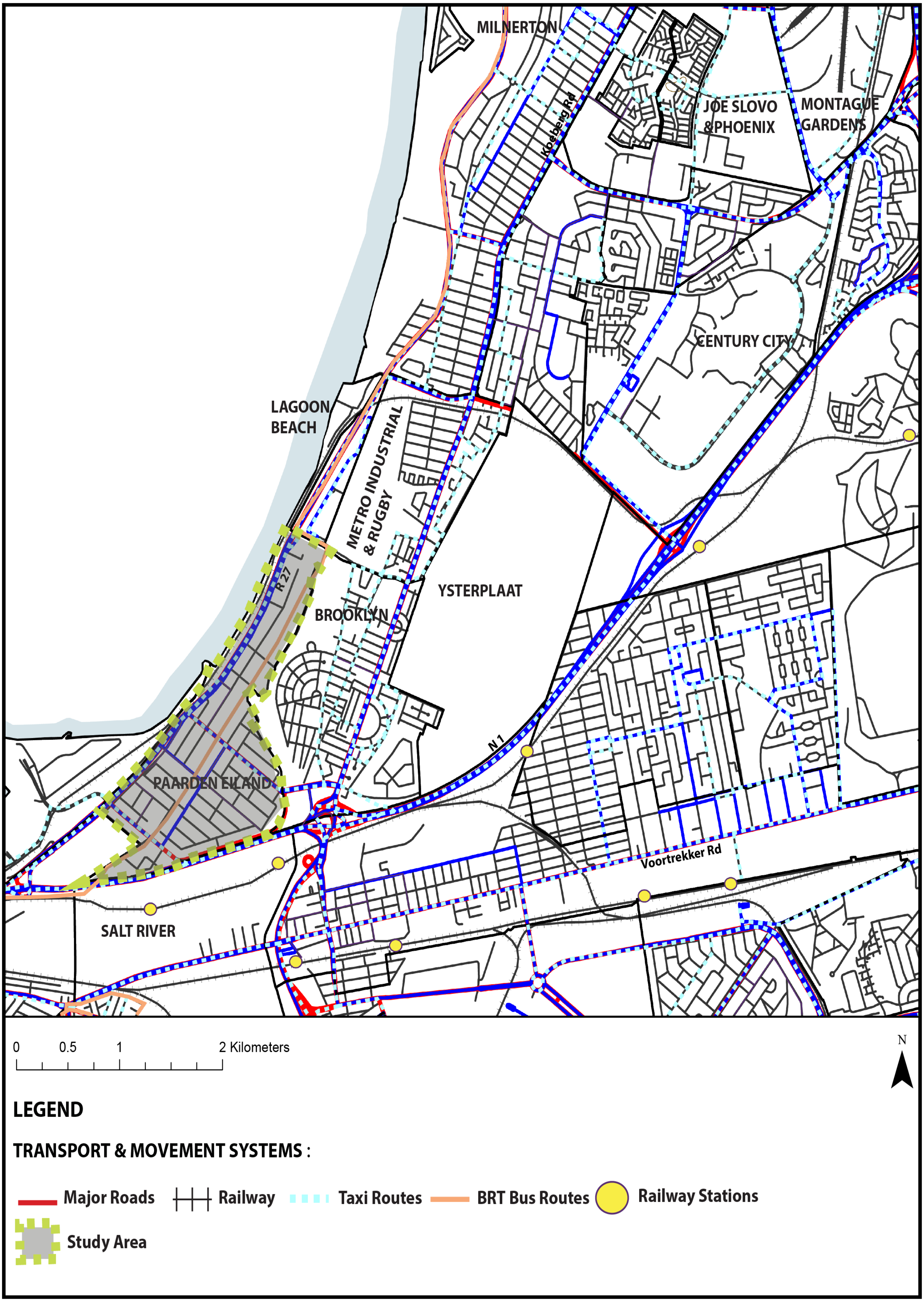


Figure 30: Transport and Movement Network Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Land use

Paarden Eiland is predominately classified as an industrial and commercial area, which is surrounded by residential areas and mixed-use precincts such as Brooklyn, (see Figure 31). Land use to a certain extent influences the types and concentration of pollutants found in stormwater runoff. Industrial sites such as Paarden Eiland tend to have higher concentrations of zinc and copper in stormwater runoff than other land-use, this poses significant implications for surface water systems receiving high concentrations of these pollutants (refer to Chapter Five: Contextual Analysis).

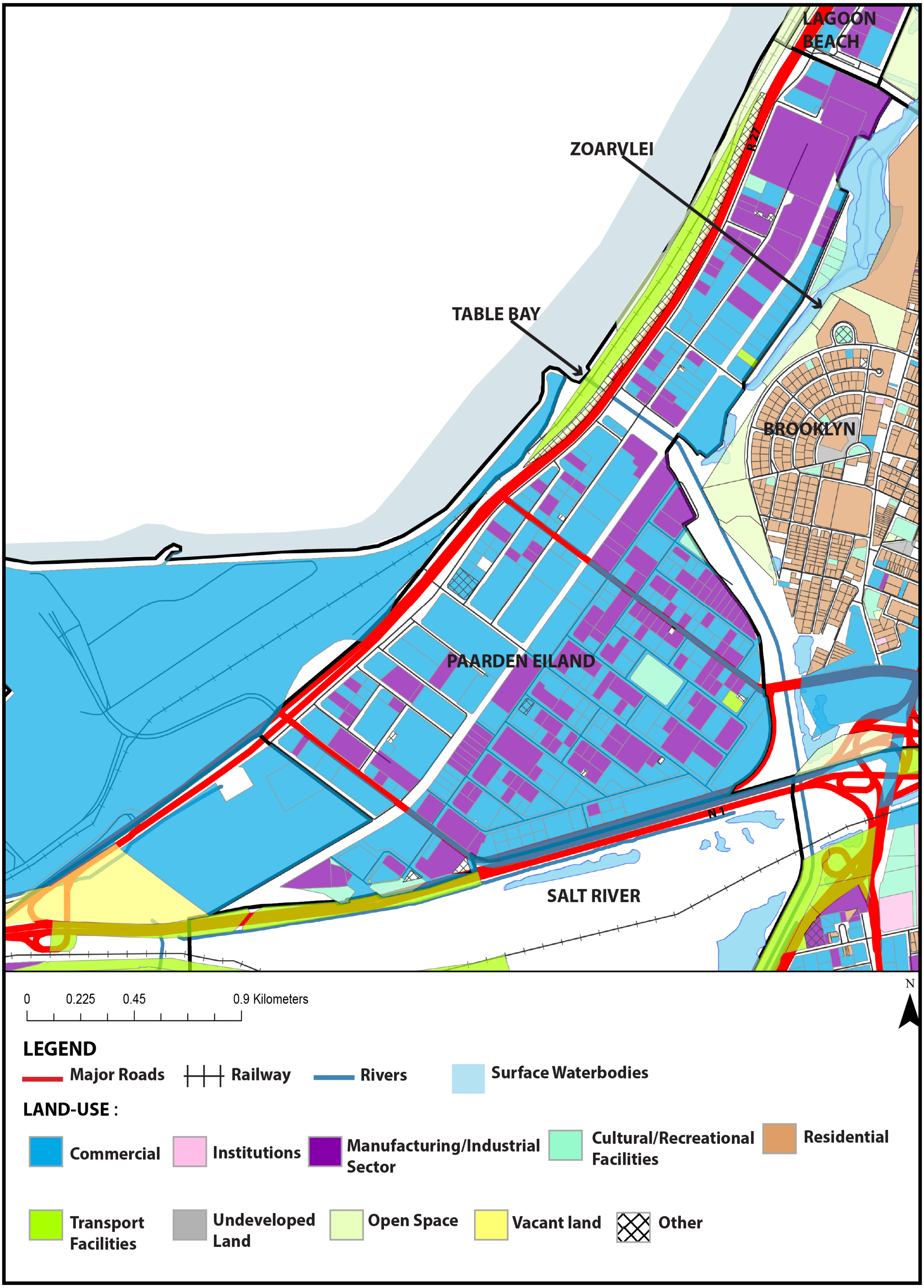


Figure 31: Land-use Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

Opportunities and Constraints

The identification of opportunities and constraints presented in Figures 32 and 33 will help dictate to what extent different green infrastructure stormwater management design elements will be feasible in terms of retrofitting and incorporating green infrastructure into the site. Spatial opportunities in this respect tend to provide ecological elements that will aid in developing ecological sound stormwater management design options, in order to minimise or neutralise constraints identified.

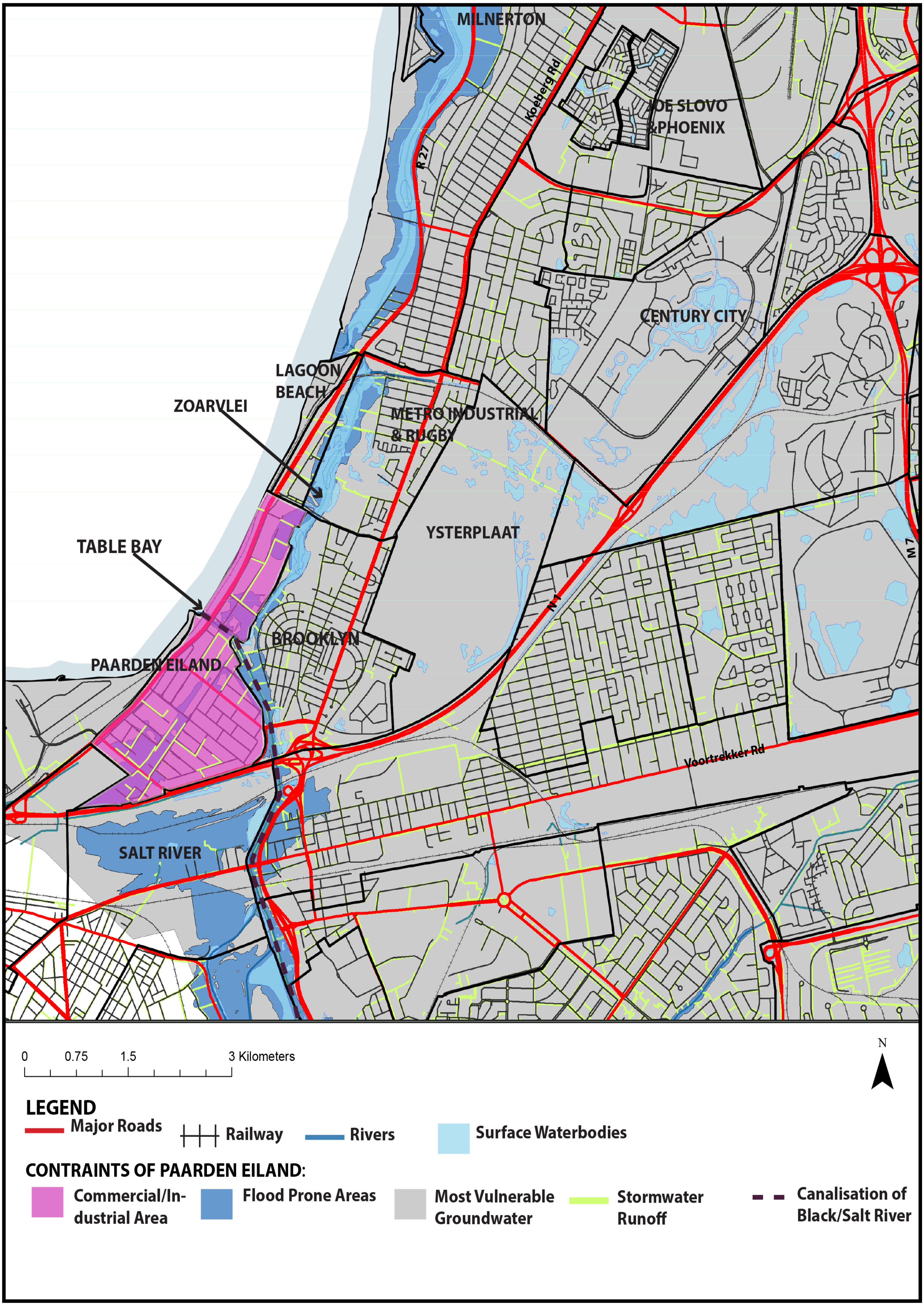


Figure 32: Constraints Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

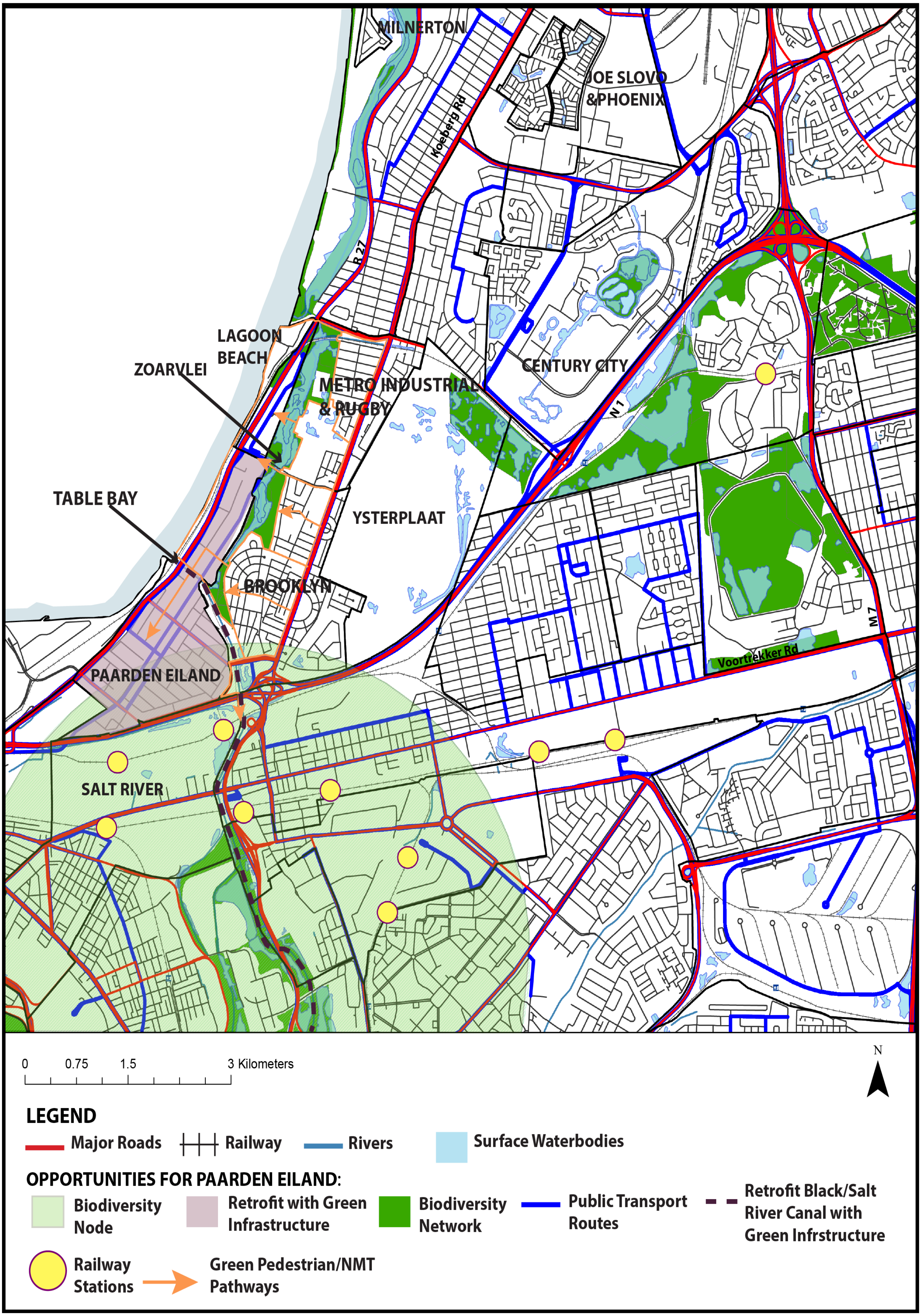


Figure 33: Opportunities Map (Source: Author, GIS Technical Library, University of Cape Town, 2011)

6.4 Conceptual Framework

Ecological urbanism first emerged as a term in 1999 in Miguel Ruano's book *Ecourbanismo* (Hagan, 2015a); it is has re-emerged as an approach and framework for inter-disciplinary urban planning and design. Ecological Urbanism aims to create artificial ecosystems within cities, in order to bridge urban design and ecology (Hagan, 2015b). The concept of green infrastructure is embedded in ecological and sustainable urbanism and provides a framework for addressing challenges such as climate change, infrastructural costs and failures, and the appropriate management of the natural environment, in order to fulfil the human need for an environment that is healthy and safe.

This framework uses ecological insights in order to design cities and sites that are resilient and sustainable in terms of the economy, the environment, and society. South Africa has recently started considering the benefits of ecological planning and green infrastructure, and some of this thinking has been translated into certain policies. However, the attempt to do so thus far has been minimal and fragmented, due to the continued dominance of old approaches to spatial and infrastructure planning, and a lack of cross-sectoral integration and collaboration (The Sustainability Institute, 2009). The conceptual layout and framework should therefore ensure that an ecological/green infrastructure approach underpins interventions in the area. The area should be designed to create a built environment that supports sustainable social, economic and environmental contexts (ibid.), with particular emphasis placed on efforts to overcome the mismanagement of or lack of appropriate management of surface water systems and stormwater.

6.4.1 Guiding Principles

The following principles will inform the overall direction for the Paarden Eiland Framework. Various principles are identified in order to formulate a sustainable and appropriate approach to managing stormwater and surface water through green infrastructure. These principles may be applied to new developments as well as urban renewal/regeneration projects. These principles do not represent comprehensive theory, but illustrate some basic characteristics of employing green infrastructure urban water management techniques. The principles formulated are based on some of the guiding principles established in Chapter Four.

Flood Risk Management and Climate Change Adaption:

The use of green spaces and networks to manage storm flows and help free up storage capacities of existing hard infrastructure to reduce the risk of damage to urban property and vulnerable regeneration areas (TEP, 2008). This also aids in establishing and enhancing the integrity of ecological corridors and distinctive landscapes, in order to appropriately adjust to climate change (ibid.).

An Ecological Framework:

The creation of green spaces to sustain and enhance existing biodiversity through forming habitat networks (ibid.).

A Sustainable Movement Network:

The establishment of multi-user routes for recreation and commuting (ibid.); pedestrian-centred routes in and around urban areas, in order to enable access throughout a site as well as to the natural environment (ibid.).

Sense of Place:

The creation of distinctive and vibrant landscapes, and the encouragement of utilising and appreciating the natural and built heritage of rivers, canals, wetlands, parks, and architecture (ibid.).

River and Canal Corridor:

The improvement of waterways and water quality, which will provide an opportunity for leisure, economic benefits, the enhancement of biodiversity, and the mitigation of excessive stormwater runoff and flooding.

Supporting Urban Regeneration:

Accessible, safe, clean, and quality natural infrastructure that will provide both economic and community benefits to all sectors (ibid.). This is particularly important in areas of deprivation and transformation (ibid.).

6.4.2 Strategies

Cape Town's current stormwater and surface water management consists of a complex array of constructed infrastructure and some natural features, which have various diverse functions (CoCT, 2002b). This approach to managing stormwater and surface water is widely recognised as having many negative impacts on the natural drainage of an area as well as on the development itself (ibid.). Therefore, the strategies considered illustrate a greater cognisance of natural drainage patterns and systems in terms of developing green infrastructure techniques for the management of stormwater and surface water management. (To see how these strategies have been employed in reality please see Chapter Four)

1. Minimise the risk of flooding: This is one of the primary strategies for Paarden Eiland, which is considered a flood-prone area. The mitigation of flooding may be achieved through mimicking pre-development responses to storm events.
2. Protect receiving waterbodies: It should be noted that receiving surface waterbodies are not necessarily the system in which stormwater is directly discharged, but can be other natural systems situated further downstream within the catchment (CoCT, 2002b). In this regard, stormwater runoff affects not only Zoarvlei, but also other waterways such as the Black and Salt Rivers, the Diep River Estuary, and coastal waters of the Atlantic. Therefore, there is a great need to design and implement stormwater

management systems that will primarily improve freshwater systems, and in turn improve coastal waters through the use of green infrastructure systems that mimic natural drainage conditions

3. Promote multi-functional use of stormwater management systems: Resources such as land and water systems are increasingly becoming scarce, especially in an area such as Paarden Eiland that is predominately developed. Therefore, stormwater may provide opportunities for multi-functionality such as parks, recreation, sport, and maintenance efficiency.
4. Retrofit built-up areas: Retrofitting Paarden Eiland with green infrastructure provides an opportunity to re-establish lost links, in order to create new linkages to improve strategic green networks located within the Blaauwberg District as well as greater Cape Town. This is especially important when it comes to the isolated wetlands, the diminishing extent of the Cape Dune Strandveld vegetation species, as well as the canalisation of the Black/Salt Rivers. Green infrastructure poses significant possibilities for industrial areas, brownfield sites, and proposed areas of urban regeneration (The Scottish Government, 2011). Retrofitting green spaces around buildings and within streets in Paarden Eiland, which have been lost due to development can alleviate flooding risks (ibid.).
5. Development of Sustainable Environments: Sustainable stormwater and surface water management systems can be implemented in Paarden Eiland, in order to minimise maintenance requirements and maximise local authority funding (ibid.). Environment policies that promote indigenous planting programmes will help reduce long-term maintenance requirements for green infrastructure implemented in Paarden Eiland.

6.5 Conceptual Layout

The following conceptual layout was developed to demonstrate and evaluate tools and design elements that support environmental sustainability efforts of a green infrastructure approach. This concept was created to identify the level of green infrastructure required at local area scale and a predominately developed area, in order to improve stormwater runoff and the management of surface water. This builds upon the site analysis done earlier in this chapter.

6.5.1 Green Infrastructure Network Concept

A significant part of green infrastructure research is identifying ecological networks (Wickham, Riitters, Wade, and Vogt, 2010). According to Benedict and McMahon's research there two fundamental components to ecological networks-hubs and links. A set of hubs connected to links represents an ecological network that can be utilised to inform both development as well as conservation (Wickham et al., 2010). Figure 34, demonstrates a green infrastructure concept of hubs and links for Paarden Eiland.

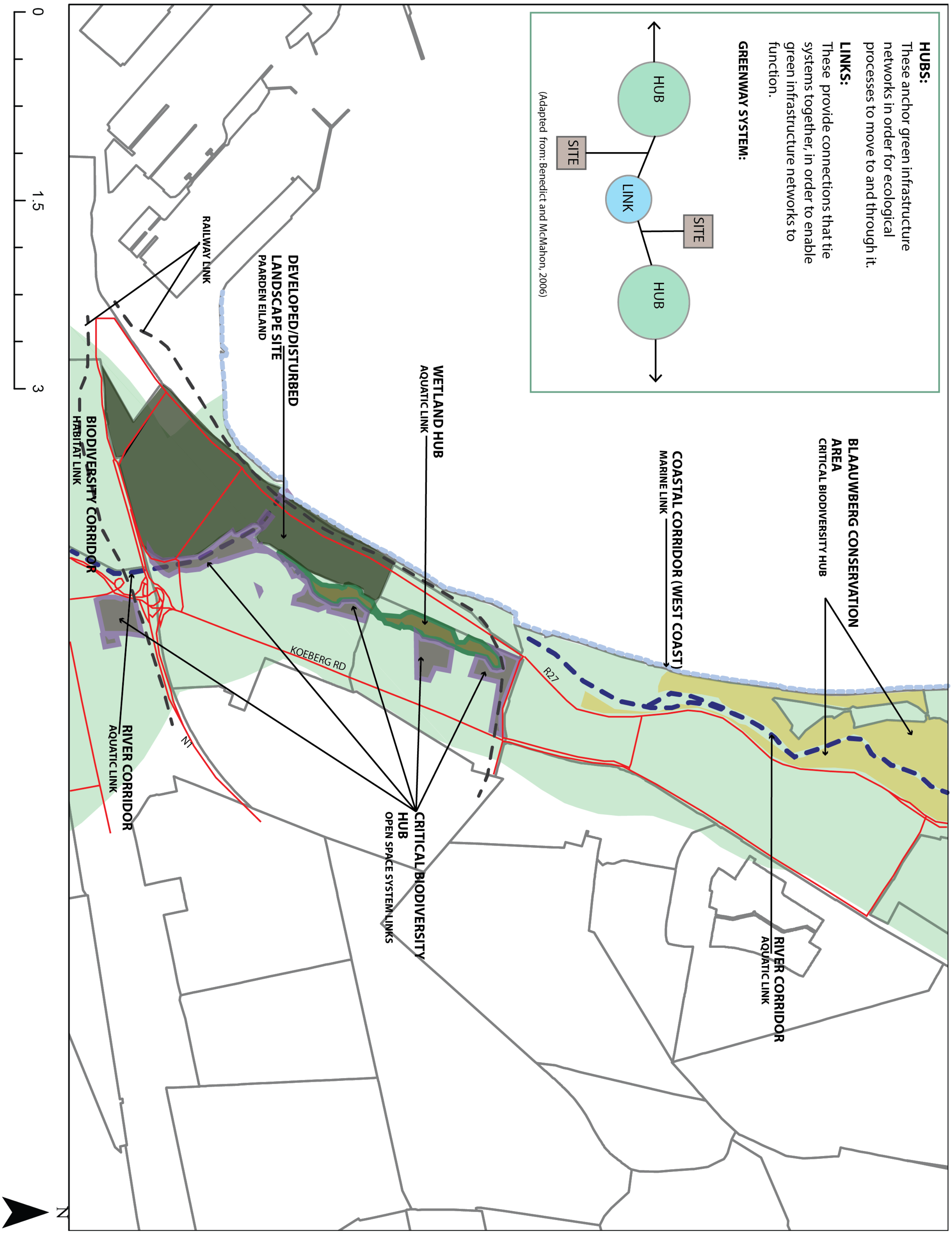
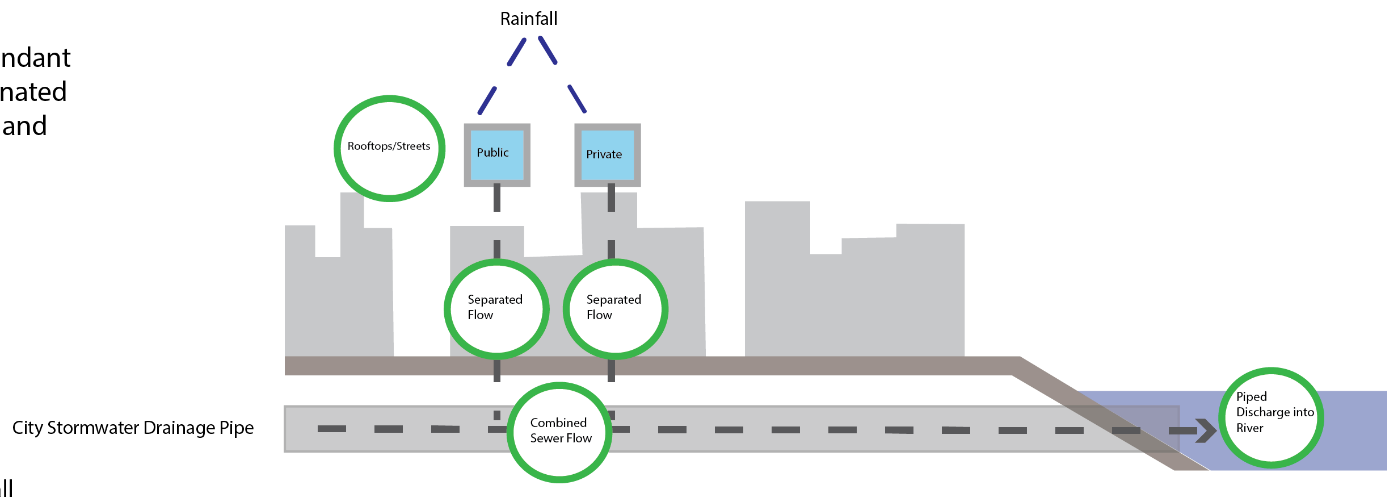


Figure 34: Green Infrastructure Concept of Hubs and Links for Paarden Eiland Based on Benedict and McMahon's Theory (Source: Author, 2015)

6.5.2 Green Infrastructure Concept

The green infrastructure concept focuses on demonstrating a green infrastructure surface conveyance system, in which green infrastructure can be used as a structuring element within a site in order to influence runoff patterns for the effective management of stormwater and surface water. Figure 36, shows a simple illustration of a green infrastructure conveyance system versus a traditional hard infrastructure conveyance system.

Conventional System:
Traditional stormwater management requires redundant piped infrastructure systems that transect contaminated agents, hence increasing construction, permitting, and maintenance costs (EPA, 2013)



Concept for Green Infrastructure Stormwater Management:
A system that operates on a mixed public and private green infrastructure system that uses surface conveyance to reduce comtaminants and integrate green infrastructure stormwater and surface water management within developments/sites. (EPA, 2013)

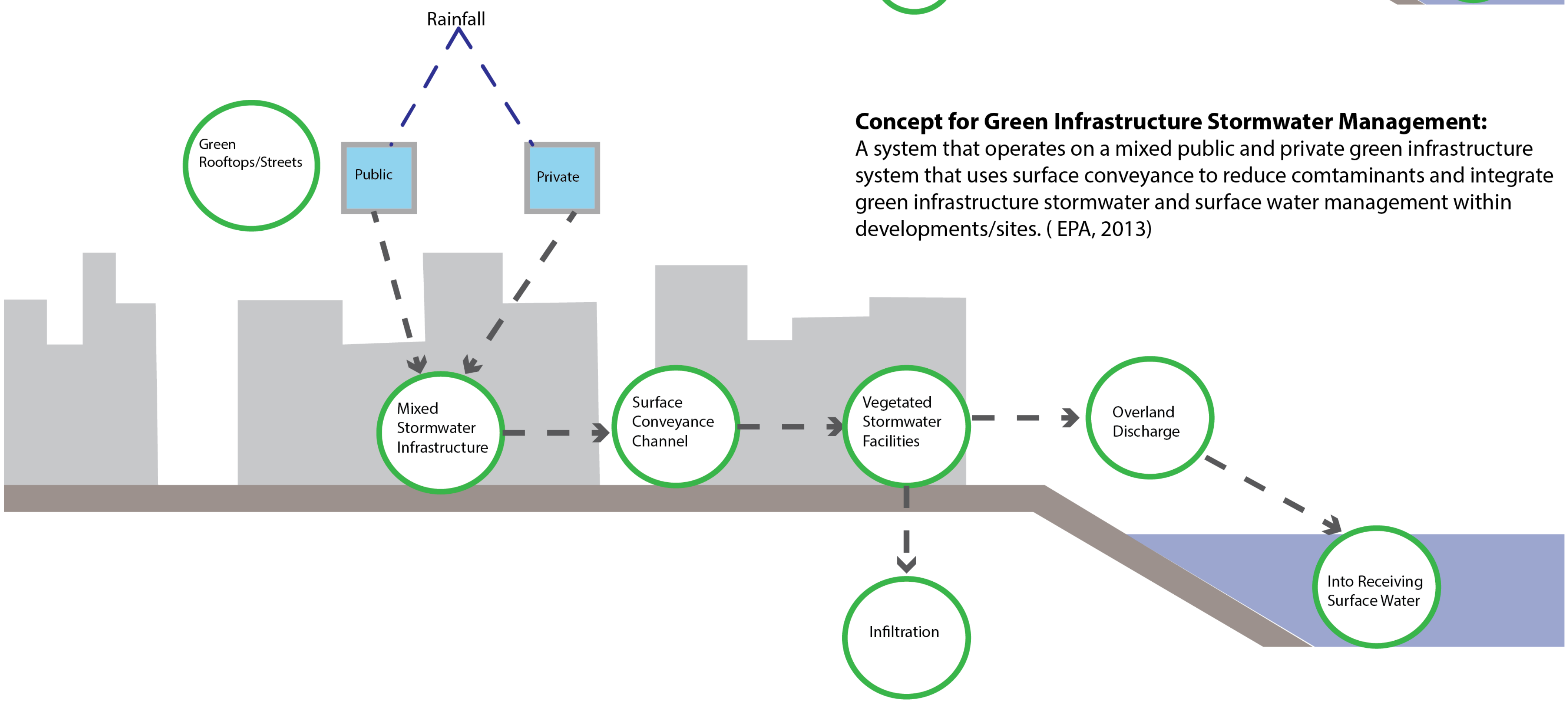
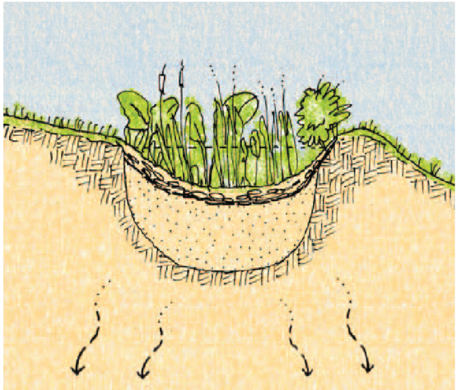


Figure 35: Green Infrastructure Concept (Adapted From: EPA, 2013)

6.6 Basic Green Infrastructure Urban Water Management Toolkit for the Conceptual Layout and Design of Paarden Eiland

A green infrastructure urban water management guiding toolkit will help with the selection of certain green infrastructure stormwater and surface water management techniques and mechanisms that are suitable for an area such as Paarden Eiland. This will help in creating an urban environment that has a unique sense of place, as well as create a sustainable environment that encourages the appropriate management of both stormwater and surface water. Figure 37, shows key green infrastructure tools that may be implemented to mitigate flooding and reduce contaminants related to stormwater runoff, and Figure 38 illustrates green infrastructure potential for Paarden Eiland.

BIO-RENTION/CURB-SIDE PLANTER



PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	● ⊗	●
Nutrients	◓	Peak Flow Reduction:
Organics	●	◓
Litter	◓ ⊗	
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

A stormwater facility that depends on vegetation and/either indigenous soils/bio-engineered soils to capture, infiltrate, and transpire water, as well as remove runoff pollutants

SETTING

- Can be used in a variety of urban settings such as office/commercial storefronts, parking lots, and parks.
- Can easily be integrated into retrofitting existing developments.

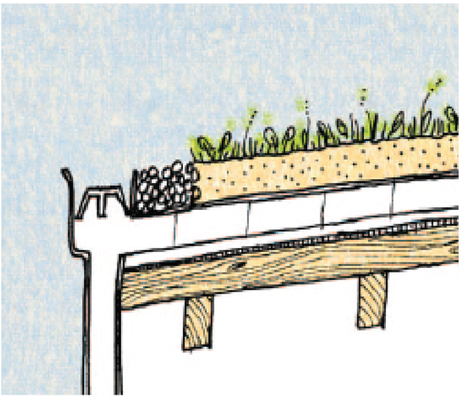
BENEFITS

- Inexpensive and simple to install.
- Improves water and air quality.
- Increases permeability of surfaces within highly developed areas.
- Provides aesthetic amenities.
- Facilitates groundwater recharge.

LIMITATIONS

- Requires a fairly flat site.

VEGETATED/ECO ROOFS



PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	●	◓
Nutrients	●	Peak Flow Reduction:
Organics	●	◓
Litter	○	
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

Improve runoff quality by filtering pollutants, through direct plant uptake. Engineered soils absorb rainfall and release it gradually. Vegetated/Eco roofs require a growing medium, subsurface drainage pipes, and waterproof membrane to protect roof structure

SETTING

- Commonly installed on commercial, multistorey, and idustrial structures.
- Can be used on newly constructed roofs or when re-roofing existing buildings.

BENEFITS

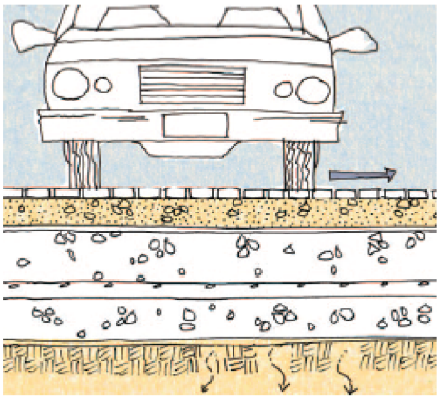
- Extends roofs life.
- Lowers temperature of stormwater to maintain appropriate temperature for aquatic life.
- Creates habitats and increases biodiversity.
- Provides aesthetic amenities.

LIMITATIONS

- May require additional structural support.
- May require irrigation systems to maintain vegetation during drier season (depending on vegetation types used)

● HIGH ◓ MODERATE ○ LOW ⊗ REQUIRES PRE-TREATMENT

PERMEABLE PAVING



PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	● ⊗	●
Nutrients	○	
Organics	◓	**Peak Flow Reduction:**
Litter	○ ⊗	◓
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

Porous load-bearing surface that temporarily stores runoff in an underlying layer, until it infiltrates into soil below. infiltration rates depend on design, installation, and maintenance. Common materials used include porpous asphalt, pervious concrete, interlocking block pavers, and platic grid systems.

SETTING

- Areas with low-speed travel and light-medium loads such as parking lots, low-traffic streets, and NMT/pedestrian pathways.
- Soil infiltration rates, depth of groundwater and bedrock, and adjacent land-use should be assessed prior to installation.
- Off-site sediments and pollutants should be directed away from permeable surfaces.
- Minimum setback is approximately 3m

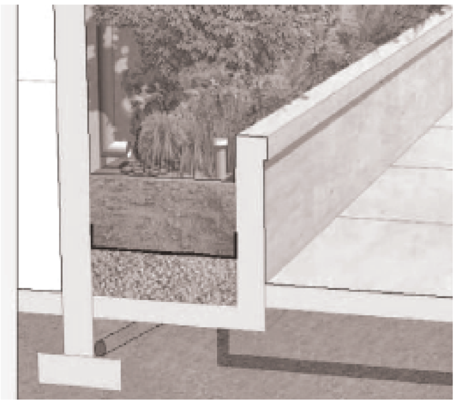
BENEFITS

- Reduces runoff volume and attenuates peak flows.
- Improves water quality.
- Facilitates groundwater recharge.

LIMITATIONS

- Limited to paved areas with slow traffic.
- Difficult in compacted soils (slows infiltration rates).
- Depth of groundwater must be 1.2m.

FLOW-THROUGH/ STORMWATER PLANTER



PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	● ⊗	◓
Nutrients	◓	
Organics	●	**Peak Flow Reduction:**
Litter	○ ⊗	◓
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

Structurally landscaped planters that collect stormwater and filter out pollutants. Slowly releases stormwater into sewer system.

SETTING

- Appropriate for sites with developmental constraints.
- Excess stormwater collects in perforated pipes below the flow-through planter and drains to an appropriate discharge point.
- Commonly located adjacent to streets where runoff is directed for treatment before entering catchment basin.

BENEFITS

- Serves various benefits such as dention, reduction of physical/chemical/microbial pollutants.
- Reduces erosion potential.
- Ehances aesthetic and habitat value

LIMITATIONS

- None.

● HIGH ◓ MODERATE ○ LOW ⊗ REQUIRES PRE-TREATMENT

CONSTRUCTED WETLANDS

PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	● ⊗	◓
Nutrients	◓	Peak Flow Reduction:
Organics	●	●
Litter	○ ⊗	
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

Man-made wetland design that collects and purifies stormwater through microbial transformation, pplant uptake, and adsorption. Beneficial in terms of flood control and water quality improvement.

SETTING

- Site should be fairly flat.
- Can recieve drainage from upstream.

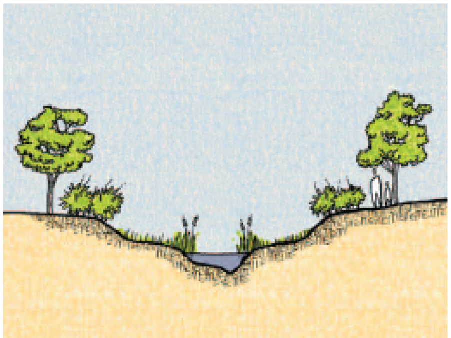
BENEFITS

- Removes stormwater pollutants.
- Reduces peak flow and runoff volume.
- Attractive landscape feature.
- Provides valuable wetland habitat.
- Size and dimensions are customizable.

LIMITATIONS

- Requires a fairly large area.

BIO-ENGINEERING OF RIVER/STREAM SYSTEMS



PERFORMANCE

Pollutant Removal:		Volume Reduction:
Sedimentation	●	●
Nutrients	●	Peak Flow Reduction:
Organics	●	●
Litter	○ ⊗	
Heavy Metals	●	
Oil/Grease	●	

DESCRIPTION

Bio-engineering mechanisms can be used to restore rivers and streams that have been previously buried in underground culverts and pipes, as well as canalised. These mechanisms tend to decrease demand on treatment facilities and ehance the local area.

SETTING

- Suited in river/stream paths and systems.
- Can be located transversely to existing open spaces.

BENEFITS

- Improves water quality.
- Improves urban hydrology.
- Replaces deteriorating culverts.
- Restores degraded river/stream systems that are canalised.
- Creates habitats and increases biodiversity.

LIMITATIONS

- High installation costs.
- High maintenance costs, in comprison to the above mentioned mech-anisms.
- Benefits might be lost if only fragmented segments are bio-engi-neered.

● HIGH ◓ MODERATE ○ LOW ⊗ REQUIRES PRE-TREATMENT

Figure 36: Green Infrastructure Toolkit (Adapted From: San Francisco Public Utilities Commission, 2013)

GREEN INFRASTRUCTURE POTENTIAL FOR PAARDEN EILAND

CURRENT STATE OF PAARDEN EILAND: **GREEN INFRASTRUCTURE POTENTIAL:**

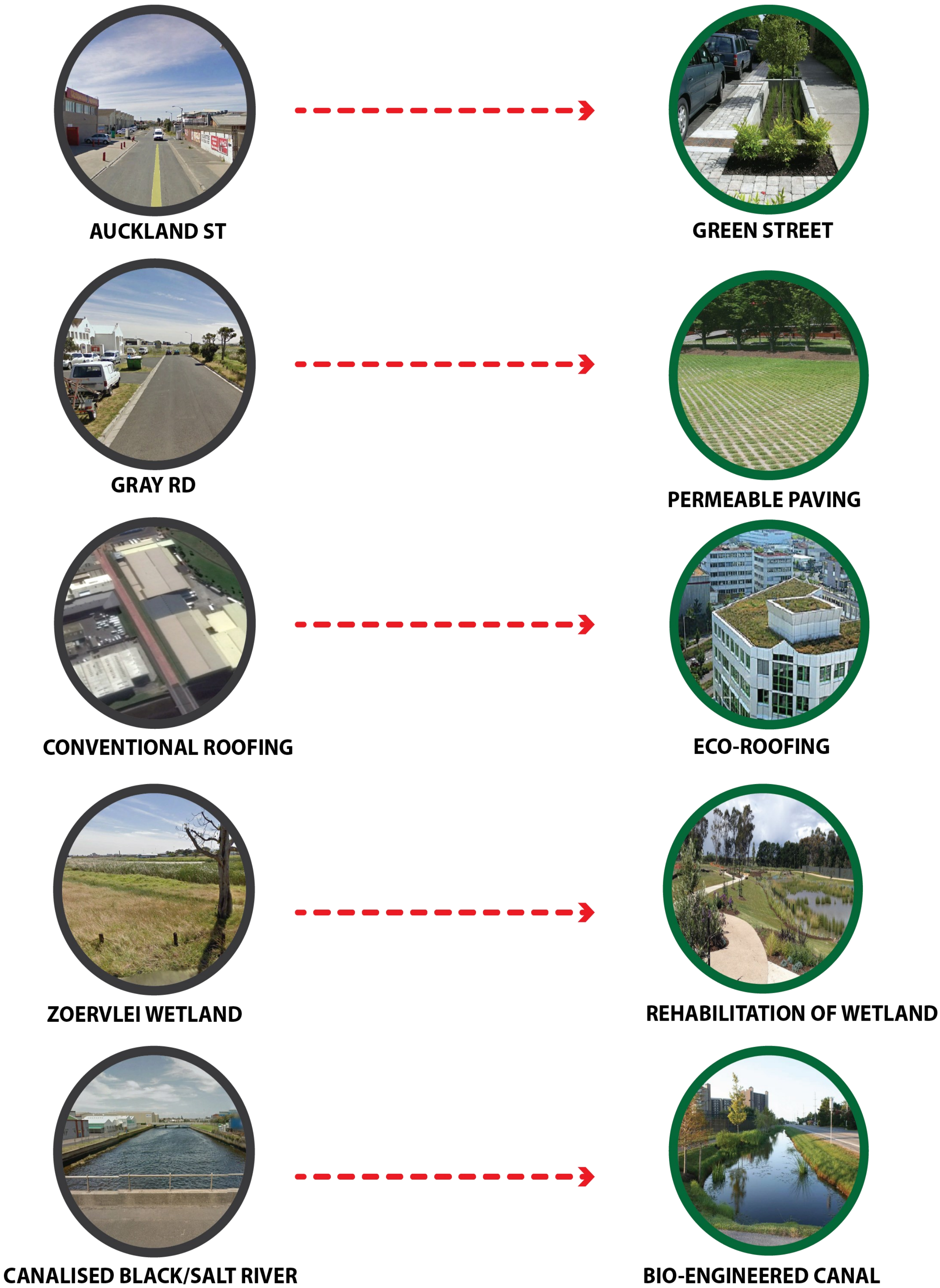


Figure 37: Green Infrastructure Potential for Paarden Eiland (Source: Author, 2015; Google Earth, 2015)

6.7 Land Cover Breakdown

The land cover break down for Paarden Eiland simply shows that the area is predominately built up, with a fairly small amount of natural land left. See Figure 38.

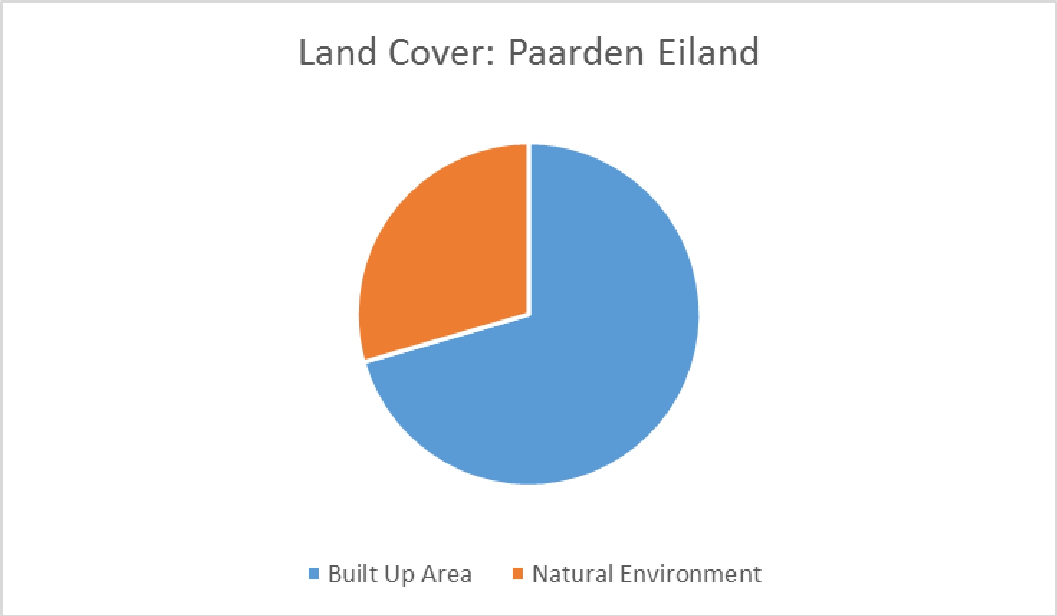


Figure 38: Land Cover Breakdown (Author, GIS Technical Library, University of Cape Town, 2011)

6.8 Current Zoning

The map below (Figure 39) shows the current zoning scheme for Paarden Eiland.

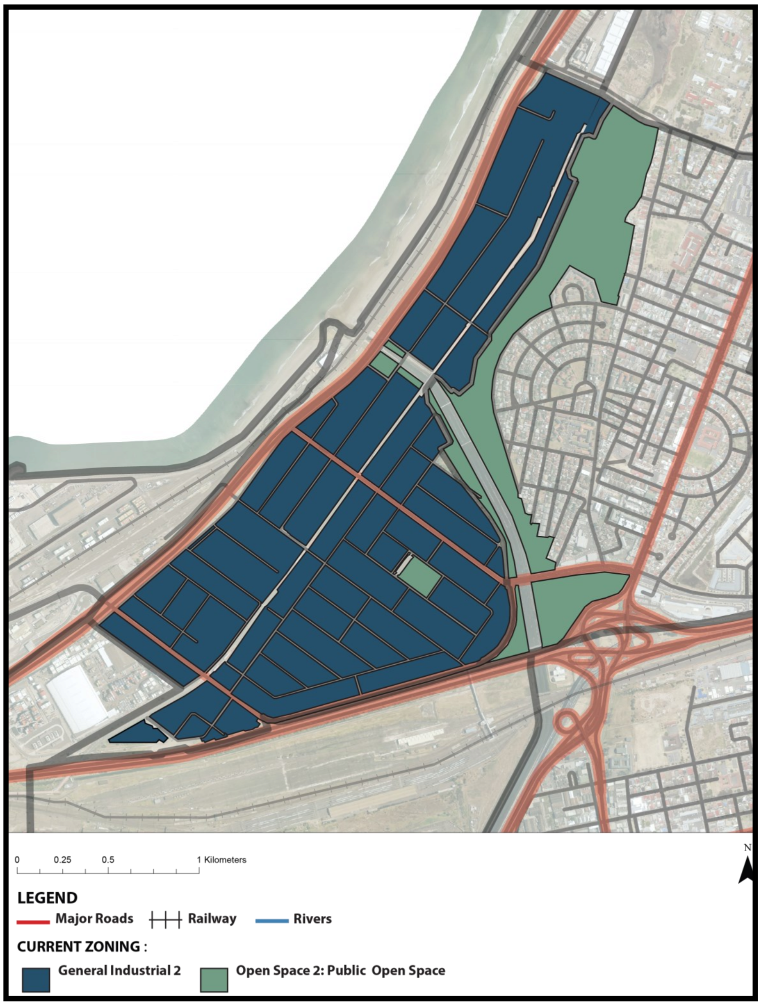


Figure *39: Current Zoning for Paarden Eiland Land Cover Breakdown (Source: Author, Cape Town City Map Viewer, 2015)*

6.9 Paarden Eiland Conceptual Layout

The conceptual layout translates the guiding principles established in the previous section, into a set of technical layout planning guidelines. The conceptual layout illustrates specific zones (grey, blue, and green) and their ability to process stormwater throughout the site. It is important to note that these zones should work in an integrated and interconnected manner, in order for green infrastructure to function at its optimal capacity.

This strategic approach allows for detention, infiltration, and retention to work co-operatively/holistically in order to improve both stormwater and surface water management through the employment of green infrastructure in the most suitable areas of the site. It is important to recognise that existing traditional stormwater infrastructure should be integrated and work in conjunction with green infrastructure strategies for the appropriate management of urban water systems. Figure 40, illustrates the green infrastructure conceptual layout for Paarden Eiland. Figure 41 shows a green infrastructure few discharge concepts for the different zones, as well as Figure 42 shows green infrastructure precedent for Paarden Eiland.

Detention Zone:

The zone focuses on the use of above ground green infrastructure detention systems with infiltration capacity that provide temporary storage as well as the creation of green streets.

Infiltration Zone:

This zone provides the opportunity to use green infrastructure that is effective with regards to the infiltration of stormwater runoff. This zone may include the development of vegetated bioswales, infiltration planters, permeable paving, and the planting of stormwater vegetation.

Retention Zone:

The Salt/Black river canal as well as the Zoarvlei currently receives stormwater. In terms of the canal this system receives stormwater runoff from surrounding roads, parking lots, as well as pavements. The Zoarvlei currently formally receives stormwater from the surrounding areas. Therefore, this is the reason why the two systems were chosen to form part of the retention zone.

The rehabilitation of the Zoarvlei as well as the use bio-engineering mechanisms for the canal, will help improve the ecological health of both systems and as a result will improve their stormwater retention capacity.

Other interventions proposed within this conceptual layout were guided and align with the current Milnerton South-Paarden Eiland Local Area Development Framework.

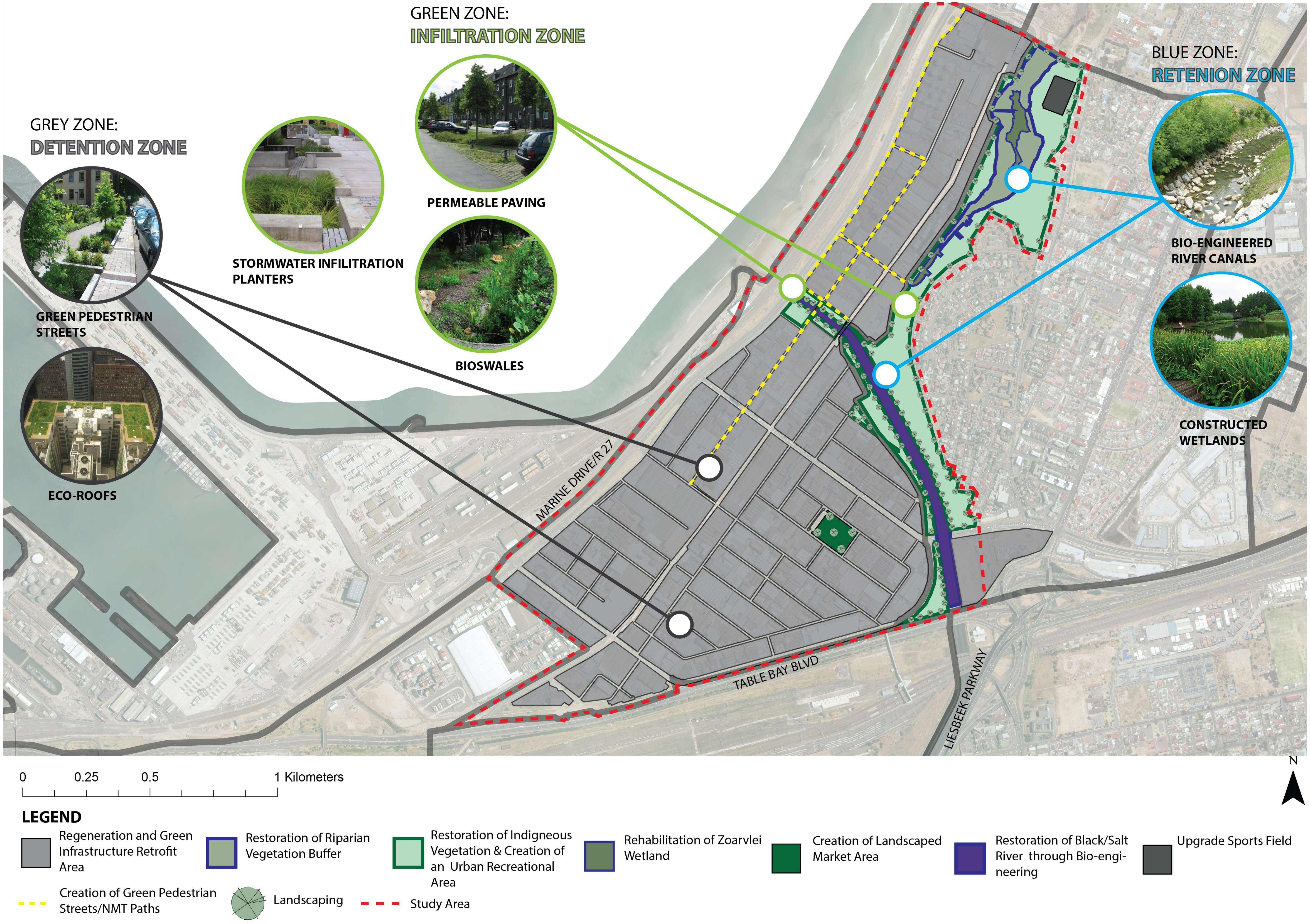


Figure 40: Green Infrastructure Conceptual Layout Land Cover Breakdown (Source: Author, 2015)

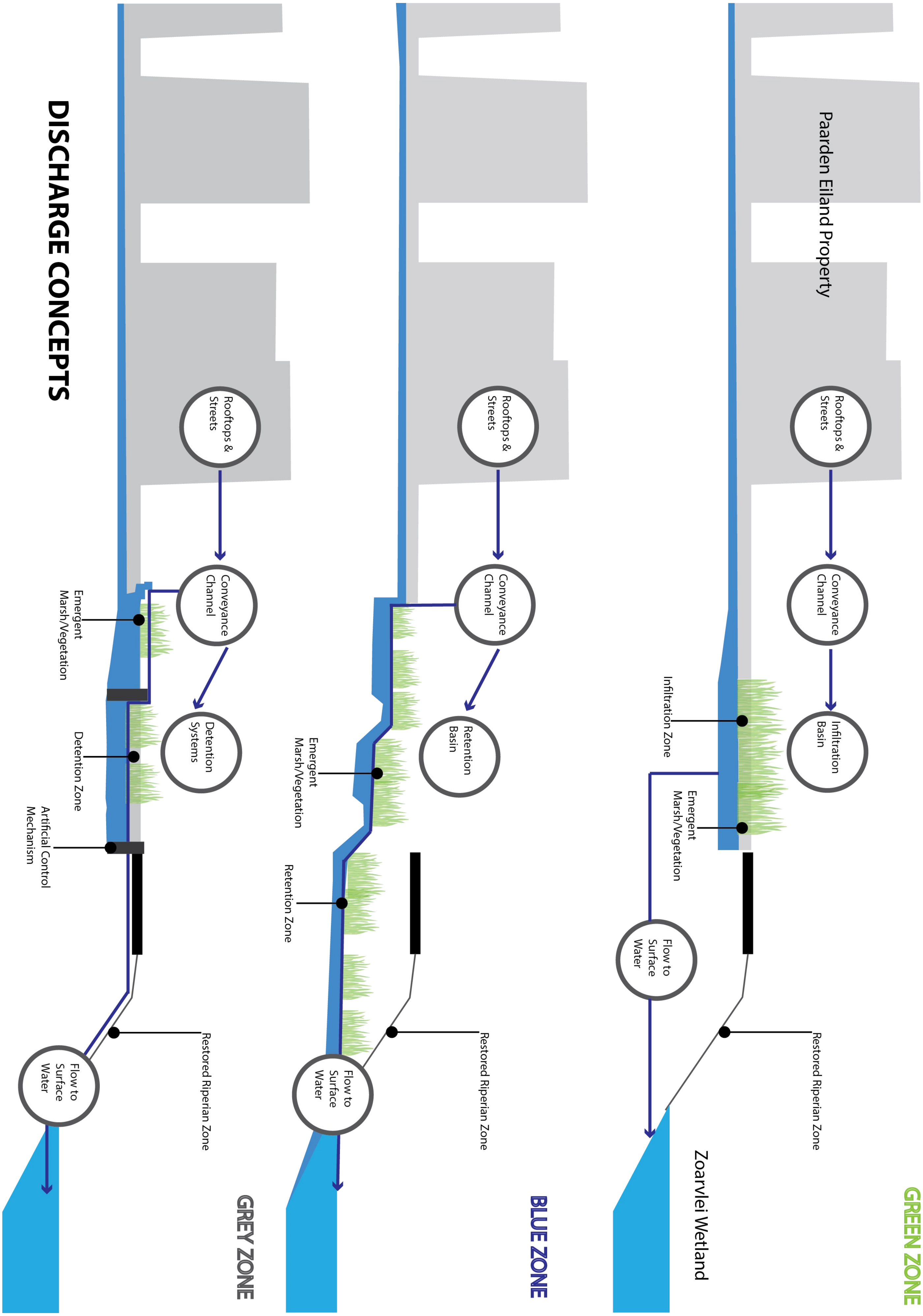
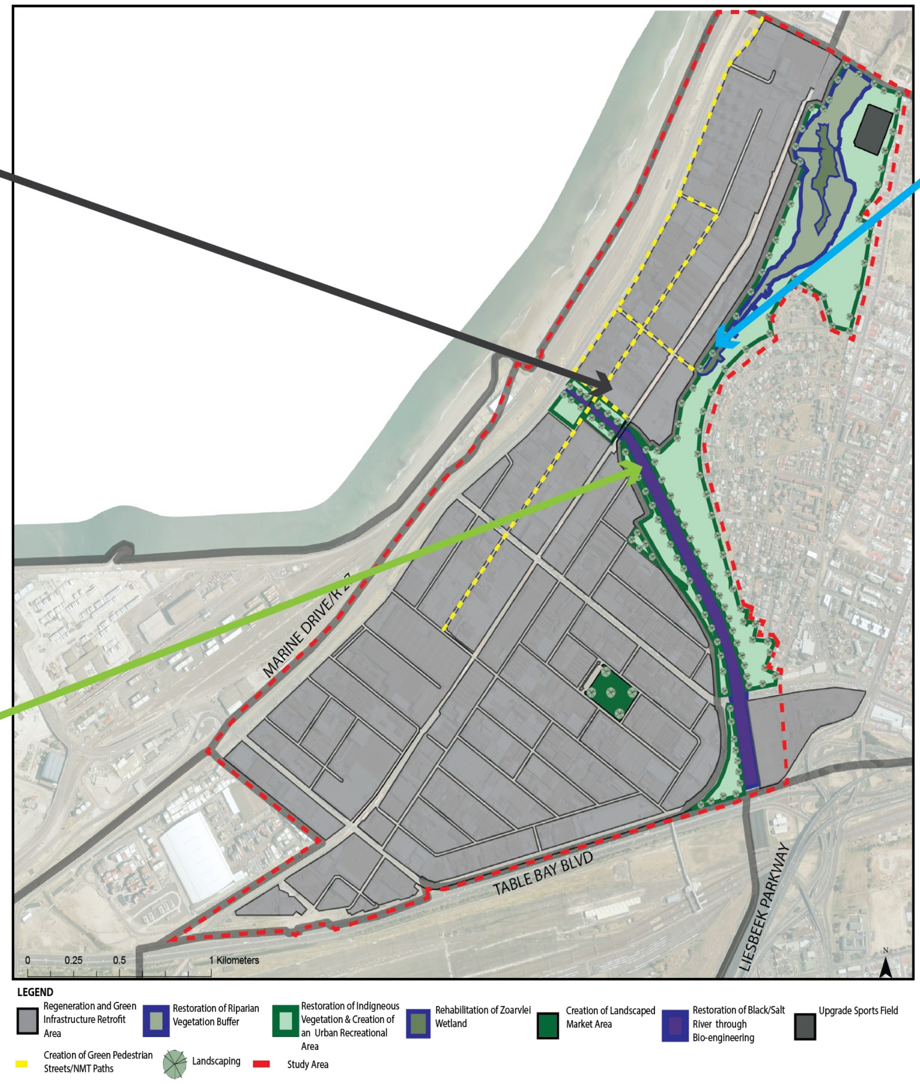
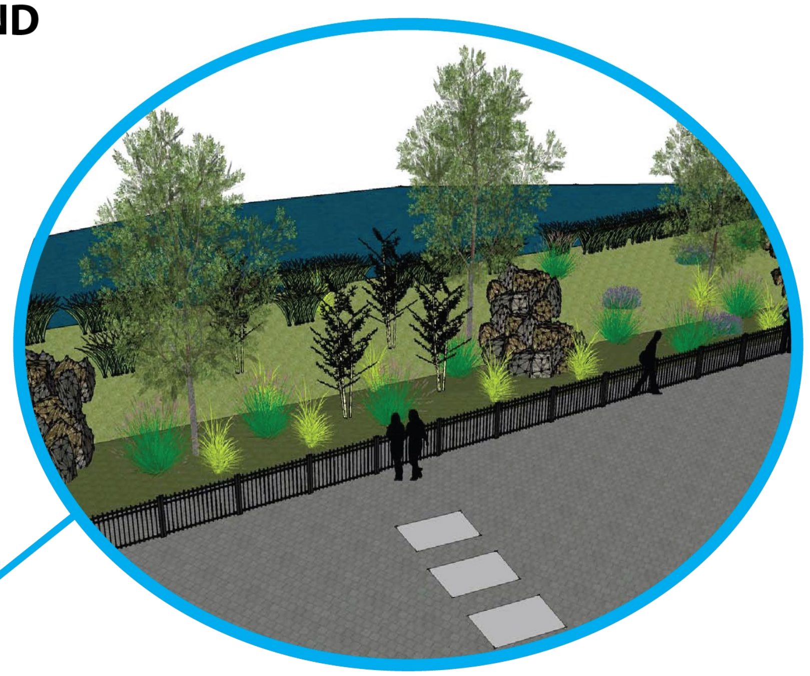


Figure 41: Green Infrastructure Discharge Concepts for Zones (Adapted from: EPA, 2013)

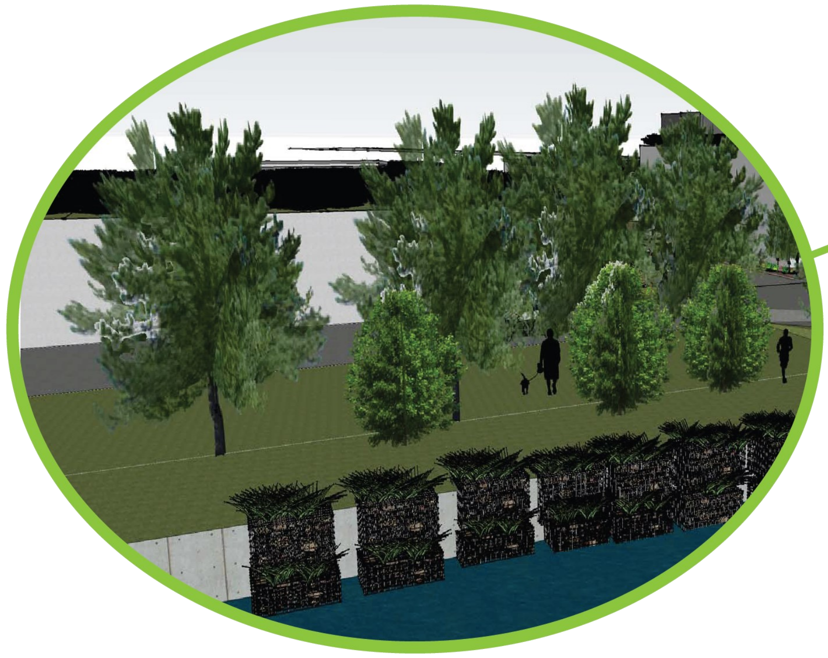
GREEN INFRASTRUCTURE PRECEDENT FOR PAARDEN EILAND

DETENTION STRATEGY FOR AUCKLAND ST. :
Due to extensive development within Paarden Eiland (compaction of soil over time), this zone is likely incable of effective infiltration, therefore limiting the types of green infrastructure that can be used. However, green streets and eco-roofs and above ground green infrastructure practices will help transform impervious surfaces into landscaped green spaces that are able to capture stormwater runoff, reduce flow rates, and volume. Therefore, reducing/mitigating flooding and damange to property.





INFILTRATION STRATEGY FOR GRAY RD. :
Soils within this zone are more capable of effective infilration of stormwater runoff. Therefore, the construction of a vegetated bioswale and the planting of indigneous vegetation that is able to filter stormwater, is more appropriate for this zone. Vegetated bioswales act as buffer strips and use land flow as well as gentle slopes to convey stormwater runoff/flow towards surface waterbodies such as Zoarvlei. These systems also protect water systems from erosive storm events.



RETENTION STRATEGY FOR SALT/BLACK RIVER CANAL:
Bio-engineering of the canal through the use of vegetated gabions provides the opportunity to harness the inhernt qaulity and functionality of natural systems such as the Salt/Black River system. In order to collect/retain and remove contaminants from stormwater runoff from streets, roadways, and parking lots.

SOME EXAMPLES OF INDIGENOUS VEGETATION FOR GREEN INFRASTRUCTURE TYPES		
Common Name	Soil Types	Comments
Waterblommetjie	Pool	Winter-growing floating plant.
Blue Water Lily	Pool	Summer-growing floating plant.
Water Parsnip	N/A	Grows along streams and is able to cope with high nutrient loads.
Skeekbiesie	Sand	Grows near rivers and vleis, it is evergreen, and acts as a buffer plant.
Vleibiesie	Sand and Clay	Fast growing, is able to be relocated, handles inundation year round, and drought.
Sea Rose	N/A	Short-lived, however has deep roots that aid infiltration.
Searsia (Rhus) angustifolia	Sand	Common fynbos, riparian shrub/tree.
Rooikanol	Sand	Good for areas that are wet seasonally.
Honeysuckle	Sand	Grows along streams and damp slopes.

(Source: Catchment, Stormwater, & River Management Branch, 2011)

Figure 42: Green Infrastructure Precedent for Paarden Eiland (Source: Author, 2015)

Table 2: Conceptual Layout Proposal and Key Interventions (Author, 2015)

CONCEPTUAL LAYOUT PROPOSAL			
CONCEPT	The establishment of green infrastructure to improve stormwater and surface water management.		
PURPOSE	To improve stormwater and surface water quality and quantity, in order to create a sustainable and water sensitive industrial/commercial site.		
KEY INTERVENTIONS		**STRATEGY ALIGNMENT**	**IMPLEMENTATION TIME FRAME**
GREY ZONE	• The establishment of a detention zone for stormwater within Paarden Eiland's built-up area through above-ground green infrastructure (e.g. eco-roofs and green streets) to reduce stormwater runoff during storm events.	**1,4,5**	**Long-Term**
GREEN ZONE	• Creation of an infiltration zone to provide the best opportunity to infiltrate stormwater via using vegetated best management practices (BMPs) and permeable surfaces (e.g. bio-swales, permeable paving, and stormwater infiltration planters). • Incremental implementation of these BMPs will provide cumulative benefits for stormwater management of Paarden Eiland and the Zoarvlei Wetland.	**1,2,4,5**	**Long-Term**
BLUE ZONE	• Development of a blue zone for stormwater retention. A central focus on the Zoarvlei and the Black/ Salt Rivers. • The use of certain BMPs (constructed wetlands, bio-engineered river canals, and sub-surface storage) is recommended in these areas. • The utilisation of public amenities such as the sports field on Wemyss Street and the development area of Paarden Eiland form a contiguous corridor for stormwater. • The construction of wetlands in the area could aid in re-connecting Zoarvlei to other isolated wetlands in an attempt to restore it to its natural state.	**1,2,3,5**	**Long-Term**
ACCESS,CIRCULATION,PARKING	• The establishment of green pedestrian/NMT paths on Auckland Street, President Kruger Street, and along Vrystaat Road, Service Road, and Acteon Road. • Link pedestrian/NMT routes to both the blue and green zone, to foster recreational and tourist activity.	**3,4,5**	**Short-Term**
PUBLIC SPACES & LANDSCAPING	• Restoration of the Zoarvlei, Black/Salt Rivers, riparian vegetation to improve water quality, habitats, and increase local biodiversity. • Restoration of local vegetation and creation of urban recreational area to increase community interest and biodiversity. • Upgrading the sports field on Wemyss Street, for an attractive public amenity. • Creation of landscaped market area between Lowes Stoft Street and Bloemfontein Street for small scale local economic and recreational activities.	**1,2,3,5**	**Short-Term**
INFRASTRUCTURE	• Upgrading and linking existing stormwater infrastructure with green infrastructure, to improve stormwater runoff quality and quantity. This will also aid in mitigating flooding risks. • Implementation of green infrastructure throughout the site.	**1,2,3,4,5**	**Medium-Term**
Long-Term = 5 years Medium-Term= 2-4 years Short-Term= 1-2 years			

This framework and layout provides an overarching conceptual construct that may be utilised to educate developers, residents and business owners about green infrastructure urban water management practices. It may also be used to help guide future redevelopment and development within Cape Town.

6.10 Conclusion

Paarden Eiland plays a significant role to the Blaauwberg District and greater Cape Town, due to its strategic location, its supporting role to the Port, its role as a commercial/industrial node, and its natural setting within Cape Town's biodiversity corridor. It therefore has both economic and ecological value to greater Cape Town.

However, after the analysis of the site a few significant issues were identified: the degradation of surface water (Zoarvlei as well as the Black/Salt Rivers), aging water infrastructure, and excessive stormwater run-off. These issues tend to greatly increase the flooding risk, pollution of urban water systems, habitat loss, and biodiversity loss within an area. Therefore, the City of Cape Town has put Paarden Eiland on its urban regeneration and conservation agenda.

This provided the opportunity to introduce green infrastructure thinking and tools as a means not only to manage stormwater appropriately and protect surface water in order to improve water quality and quantity, but to also create a sustainable urban environment. The conceptual framework designed for Paarden Eiland is therefore based on ecological insights in terms of design and the use of green infrastructure tools and mechanisms. This leads to the development of a conceptual layout for the area, where zones were created to maximise the management of stormwater in particular through the use of green infrastructure. These zones consisted of a detention zone (grey zone), infiltration zone (green zone), and a retention zone (blue zone). These zones, along with other key interventions, were established by using the guiding principles and strategies formed within this chapter, in order to create a strategic and context-based approach to maximise capital benefits of investment and to achieve the objectives established in a holistic manner.

The framework established may be used as an example and a guide to educate the greater Cape Town community, developers, and business owners about opportunities that green infrastructure water management practices provide to urban regeneration initiatives and future development, in terms of managing stormwater and surface water in a cost-effective and sustainable manner.

CHAPTER SEVEN

7. Implementation and Recommendations Framework, and Conclusion

7.1 Introduction

Green infrastructure urban water management design is primarily a spatial vision of a desired future for a particular site or city. However, making this vision a reality can be challenging, due to the complex nature of hydrological systems, and the availability of resources and tools. Therefore, it is important to "move seamlessly from planning to on-ground results" (Benedict and McMahon, 2005:149). This means taking the first step to implement the project in the very first place. Solutions to complex problems such as managing stormwater and surface water in urban areas necessitate change in mindsets, practices, and design.

The fundamental aim of green infrastructure planning is to identify, protect, and provide long-term management solutions, in order to support natural functioning of ecological systems while still providing economic and societal benefits. Green infrastructure urban water management practices provide many mechanisms and tools that can be used to achieve the most appropriate solutions in terms of managing stormwater and surface water, as seen in Chapter Four and Chapter Six.

Therefore, this chapter initially explores a potential implementation strategy for the conceptual layout proposed for Paarden Eiland. This will help inform and establish recommendations for developing a green infrastructure integrated stormwater and surface water management framework.

This chapter then progresses onto recommendations for overcoming implementation barriers, research findings, personal reflections, and future research areas. These sections are informed by all the chapters established in this dissertation. In addition, this chapter will end by concluding the dissertation.

7.2 Potential Implementation Strategy for the Conceptual Layout Proposal for Paarden Eiland

The conceptual layout proposal is meant to help guide future decision making on stormwater and surface water challenges in Cape Town. The implementation of identified strategies provides an opportunity to improve stormwater and surface water quality as well as ecological health. Therefore, this section will provide some important ways in which these strategies may be implemented to achieve the desired spatial vision for Paarden Eiland, in terms of employing green infrastructure urban water management techniques.

7.2.1 Stakeholder Involvement:

Green infrastructure planning with regards to stormwater and surface water management will influence the development and management of urban water resources and its implementation will have implications for the public, local governments, and developers in the form of both opportunities and possible constraints (Comhar, 2010). Therefore, green infrastructure planning should be informed to a certain extent by stakeholder engagement (ibid.). Stakeholder involvement has the potential of playing a determining role in the success of green infrastructure projects throughout Cape Town (Naumann, Davis et al., 2011). The Table 3 below, illustrates the relevant stakeholders, in terms of employing green infrastructure within Paarden Eiland for the management of stormwater and surface water.

Table 3: Potential Stakeholders that Impact the Implementation and Management of Green Infrastructure Stormwater and Surface Water Projects (Source: CoCT, 2002b & Naumann et al., 2011)

STAKEHOLDERS	POTENTIAL ROLE
Dept. of Water Affairs & Forestry (DWARF)	• Management and control of water resources with regards of the National Water Act.
Provincial Administration of the Western Cape (PAWC)	• The control of activities that may have a negative effect on the natural environment, with regards to the Environmental Conservation Act.
Academic & Related Institutions	• Further related research and education.
NGOs (Non-governmental organisations)	• Advise and monitor activities of service.
Private Organisations	• The provision of funds through donations and sponsorships. • Technical implementation through sub-contracting jobs.
Planning Authorities (such as City of Cape Town's Catchment, Stormwater and River Management, and Roads and Stormwater Dept.)	• Support project design based on ecological data and existing spatial plans. • Integration of green infrastructure into spatial plans.
Local Communities	• Able to act as consultants and informants during the project development and implementation phase. • May assist in post-implementation maintenance.

Stakeholder engagement provides the prospect for establishing public-private partnerships (PPPs). PPPs are extremely applicable and important within this context (Naumann et al., 2011). PPPs provide the opportunity to use innovative instruments as a means to leverage the City of Cape Town's finances and pursuing new avenues for combining private and public funding/finances. PPPs provide the opportunity to engage with the private sector and enhance the public sector's contribution to green infrastructure implementation (ibid.).

7.2.2 Relevant Legal and Policy Considerations

When implementing green infrastructure with regards to appropriately managing stormwater and surface water, relevant authorities and organisations need to take into account legislation and policies related to the management of urban drainage systems during the planning phase. In terms of implementing green infrastructure within Paarden Eiland, municipal level (City of Cape Town) legislation and policy were taken into account. Figure 43 below lists relevant municipal stormwater management legislation and policies.

RELEVANT LEGAL AND POLICY CONSIDERATIONS

- Proposed by-law for stormwater management and related matters.
- Policy for control of development near watercourses.
- Stormwater land Identification Project.
- Zoning Schemes.

Figure 43: Cape Town's Policies and Legislation Related to Urban Drainage Management (Adapted From: Vice, 2011)

7.2.3 Planning Instruments

Planning instruments help better manage resourcing requirements through the use of formal and/or regular mechanisms for implementation. This assists in achieving appropriate planning outcomes, the adoption of suitable best management practices approaches, the reduction of potential procedural failures, and the alignment of governmental agencies, developers, and community interests. Table 4, lists a few mechanisms that may be used to effectively implement green infrastructure urban water management within Paarden Eiland.

Table 4: Potential Planning Tool for Implementing Green Infrastructure Stormwater and Surface Water Management for Paarden Eiland (Source: Author, 2015)

MECHANISMS FOR IMPLEMENTATION			
Project Name	**Action**	**Role-players**	**Time Frame**
Overlay Zones	• Council may prepare any overlay zone as provided for in the zoning scheme.	Land-use Management (City of Cape Town)	Short-Term
Urban Design Master Plan	• Appoint consultants to develop and finalise urban design master plan for the site/precinct.	Spatial Planners, Urban Designers, and Landscape Architects.	Short-Term
Integrated Infrastructure Master Plan	• Appoint consultants to develop and finalise an integrated infrastructure master plan that includes green infrastructure the site/precinct.	Spatial Planners, Landscape Architects, Civil Engineers, Ecologists, and Environmentalists	Short-Term
EIA Study of Site	• Appoint consultants to undertake a comprehensive and thorough EIA that will inform the master plan for the site/ precinct.	Environmental Resource Management	Short-Term

7.3 Directives for Ongoing Monitoring for Elements Utilised in the Conceptual Layout

Pilot monitoring directives serve as a foundational element of an adaptive management approach to implementing green infrastructure (Bloomberg and Strickland, 2012). These can be used to guide future planning, design, and construction endeavours (ibid.). Table 5 below, gives an indication of types of measuring tools and methods that could be used for monitoring green infrastructure features identified and utilised in the Paarden Eiland conceptual layout.

Table 5: Monitoring/Measuring Tools for Green Infrastructure Elements Use within the Conceptual Layout (Source: Author, 2015)

GREEN INFRASTRUCTURE FEATURES	MEASURING/MONITORING TOOLS AND METHODS
Eco-Roofs	• Instrumented flumes located near drainage outlets on the eco-roof. This monitors runoff flow rates and volume. • Analysis of runoff samples of selected storms, in order to monitor the concentration of dissolved and suspended pollutants. • Data logging weather stations suited on the eco-roof can monitor performance and conditions.
Permeable Paving	• End-to-end/open-innovation geospatial sensor network, which can be connected to a common router for real time location and data. This measures volume of stormwater runoff and infiltration rates. • Hydrography analysis. • Inspection of surfaces for structural degradation based photo documentation and field inspection logs.
Stormwater Infiltration Planters	• Continuous flow monitoring and flow testing to monitor peak flows and volume.
Bioswales	• Electromagnetic flow metres connected to data logger to measure flow and infiltration rates. • Hydrograph analysis.
Constructed Wetlands	• Fixed weir at an outlet provides a simple means of measuring flow and collecting samples. • Surface water sampling stations located at accessible points of an inlet and outlet, in order to monitor pollution and water quality. • Photo documentation and written observations from field reports.
Bio-engineered Canals	• Automated monitoring connected to two-way wireless communication measures water levels and flow. This system can initiate alarms and report changing conditions. • Analysis of water samples to measure pollution rates and concentrations. • Photo documentation and written observations from field reports.
Green Streets	• Continuous flow monitoring and flow testing to monitor peak flows and volume. • Photo documentation and written observations from field reports.

In order to have effective maintenance and monitoring of green infrastructure elements implemented, it is extremely important to establish maintenance and monitoring programmes. These programmes should evaluate the effectiveness of green infrastructure stormwater elements in terms of hydrological conditions, sewer hydraulics, groundwater levels, receiving water conditions, and overall water quality (Philadelphia Water Department, 2014). There should also be a programme created to monitor maintenance and monitoring plans, to assess the effectiveness of monitoring tools and methods used, in order to make appropriate adaptive improvements over time (ibid.).

7.4 Recommendations for Developing a Green Infrastructure Integrated Stormwater and Surface Water Management Framework

A green infrastructure integrated stormwater and surface water management framework incorporates principles of green infrastructure and integrated water resource management in order to create solutions to urban water challenges. This section describes how these principles may be employed to runoff control and flood mitigation strategies.

In light of the extensive degradation of urban water resources caused by stormwater runoff joint with the impacts of flooding, and inadequate drainage of runoff has led to the critique of traditional approaches to the design and operation of current urban drainage systems (Parkinson and Mark, 2005). Therefore, there is a need for a more comprehensive and appropriate framework in which stormwater and surface water is managed.

The fundamental aim of this framework is to overcome the various water-related issues that arise in urban environments as a result of uncoordinated, inefficient use, and the abuse of urban water resources., through the development of coherent and comprehensive policies and legal instruments for the co-ordination and regulation of activities that affect the distribution, availability, and quality of urban water resources (Parkinson and Mark, 2005). This framework may be utilised within the context of an urban catchment and provides an approach towards planning and designing of stormwater and surface water management strategies, which takes into account environmental sustainability, economic efficiency, and social equity (ibid.).

A green infrastructure integrated stormwater and surface water management framework should include short, medium-, and long-term objectives for stormwater and surface water management strategies. Short-term objectives should establish priorities for runoff control, flood protection, and pollution mitigation strategies (Parkinson and Mark, 2005). Medium-term objectives should put a greater emphasis on the development and implementation of water quality improvements, the preservation of the urban hydrological cycle, and water resource conservation (ibid.). Long-term objectives should focus primarily on the conservation and preservation of natural assets and the amenity value of urban water resources (ibid.). Table 6, shows a few fundamental short-term, medium-term, and long-term objectives for managing stormwater and surface water in a sustainable manner.

Therefore, fundamentally these objectives are meant to broaden conventional stormwater and surface water management techniques towards planning and designing urban drainage systems that are multi-functional as well as that integrate existing natural drainage systems in order to encourage habitat protection and recreational activities (Parkinson and Mark, 2005).

Table 6: Objectives for Green Infrastructure Stormwater and Surface Water Management Strategies (Source: Parkinson and Mark, 2005)

SHORT-TERM OBJECTIVES	
Flood Protection	• Prevent structural damage to infrastructure and properties. • Mitigate flooding hazards. • Reduce disruptions and risks to human life.
Environment Health Protection	• Mitigate the degradation of ecological integrity.
MEDIUM-TERM OBJECTIVES	
Pollution Prevention, Mitigation, and Control	• Preserve and enhance receiving surface water ecosystems. • Protect water quality through minimising the discharge of pollutants into the natural environment.
Water Conservation	• Restoration of natural surface water and groundwater re-charge. • Promote the re-use of stormwater.
Preservation of Hydrological Cycle	• Reduce developmental and engineering modifications to natural surface water. • Promote the replication of natural drainage patterns (pre-development conditions) in the development and implementation of stormwater infrastructure.
LONG-TERM OBJECTIVES	
Amenity	• Integrate urban drainage into landscape design and adopt green infrastructure principles to create a sustainable environment. • Promote land and water based recreational activities.
Habitat Protection	• Protection of local biodiversity through the preservation and restoration of natural habitats.
Resource Conservation	• Minimise the destruction of natural assets during the development and operation of drainage infrastructure.

In response to the issues related to current stormwater and surface water management, certain fundamental components have been identified that form the basis of green infrastructure stormwater and surface water management strategies, which meet the objectives identified.

1. **Green Infrastructure Network Design and Catchment Planning**

The initial step in designing a green infrastructure network design and catchment planning to select both natural and man-made features that should be included within the master plan, and that will be catalytic to managing stormwater and surface water management as well as enhancing the natural environment (Benedict and McMahon, 2005). This step should also include network design and catchment planning goals and objectives that guide the decisions made during the design process.

Working landscapes and resources-based industries such as eco-tourism, recreation, forestry, and agriculture provide the opportunity to be included in green infrastructure networks, and help identify habitats and other natural features that are key in protecting water quality and quantity, as well as are key in protecting national biodiversity hotspots (Benedict and McMahon, 2005). The economic value of these assets should also be assessed and considered (ibid.).

The second step should be, identifying landscape types within the study area as well as gathering and processing data on features that characterise those landscapes (ibid.). This identification process provides a rationale for deciding what resource features are to be included and connected within a green infrastructure network and catchment area (ibid.). Data should be collected at the scale that is appropriate for the project type, and should be as current as possible (ibid.). Natural resource features can be simply categorised into priority ecological areas, significant ecological areas, and other ecological landscape features.

The third step is to set priorities for conservation and protection. This step requires an ecological assessment of the study area to be undertaken, in order to make sure that the goals set are met (Benedict and McMahon, 2005). Ecological value of the whole network system and individual features should be considered. Consequently, a risk assessment will help determine the areas that are vulnerable to development, degradation, of fragmentation (ibid.). Assessments should also include existing institutional arrangements that affect land use and the management of networks (ibid.).

The last step and possibly the most significant step in successfully developing green infrastructure management strategies, is establishing a multi-disciplinary design team and a leadership/review team that will determine who should be involved at what stage of the design process (Benedict and McMahon, 2005). The political context and the availability of resources should be considered. It is also critical that an appropriate review team be established to review the preliminary design to make sure that the design meets the goals and objectives set as well as that the information used is accurate (ibid.). The leadership/review team plays an important role in public participation meetings, at which the design is reviewed by communities affected. The results gathered through the review process should be corroborated and feedback should be established. The review process may demonstrate how inputs from relevant stakeholders can have a positive impact on the design process (ibid.)

2. **Integration of Conventional and Green Infrastructure and Services**

Integrating green and hard infrastructure requires governmental bodies to play a facilitating role in empowering change, education, and innovation among residents and developers (Hostetler, Allen et al., 2011). Planners in particular are able to help shape policies that will impact the design and management of proposed and existing developments that are situated near important ecologically important assets (ibid.). While there is no best policy at the moment in South Africa to achieve this, there are various key interventions/mechanisms that can collectively have an impact on maintain the functionality of urban natural assets and corridors (ibid.).

The first mechanism is the implementation of systems thinking where planners and researchers must expand the geographical scales of conservation efforts and move beyond the protection of individual places, in order to embrace and protect whole ecosystems. Lastly, removing regulatory barriers to green infrastructure design and management practices (Hostetler et al., 2011). Regulatory measures and tools need to be updated in order to encourage innovation and implementation of sustainable practices (ibid.). This can be achieved through governmental bodies engaging in incentive-based polices where: a) governments openly involve stakeholders to aid in creating incentive-based policies, b) creating educational and marketing campaigns in order to build awareness among communities, built environment professional and the general public, and c) local governments need to establish clear communication with/and cooperation between regulators and planners (ibid.). The feedback and reflection from stakeholders is extremely important in successfully implementing and integrating green infrastructure into hard infrastructure and services.

3. **Stakeholder Participation and Partnerships**

As highlighted in the above section, the management of urban water resources and other natural assets in an integrated and holistic manner requires the involvement of stakeholders who have an interest in its allocation, usage, disposal, and re-use (Parkinson and Mark, 2005). Through the involvement of stakeholders in the planning and design process, the management of stormwater and surface water resources may be assigned to the most appropriate stakeholder at the lowest suitable level possible (ibid.). In theory, this should assist in promoting local ownership and subsequently increase responsibility (ibid.). Vested interests, a lack of appropriate and co-ordinated incentives, and a lack of governmental support are some of the issues encountered in the decision-making, planning, and implementation phase (ibid.). Therefore, local authorities need to take into account local stakeholder demands, while concurrently meeting conservation and legislative/policies obligations (ibid.). Figure 44, shows some basic measures that are necessary in creating an effective green infrastructure urban water management strategy.

General Steps for Creating a Green Infrastructure Urban Water Management Strategy

1. Form a group of stakeholders.
2. Perform an inventory of natural resources.
3. Identify measurable, outcome-based goals and strategies for achieving them.
4. Evaluate options for meeting goals and objectives.
5. Select and implement appropriate management option.
6. Monitor the outcomes of management options, to select most appropriate management scenario.
7. Use monitoring outcomes to update and refine management strategies.

Figure 44: Basic Steps needed to create a green Infrastructure Management Strategy (Adapted From: Benedict and McMahon, 2005)

7.5 Planning Process and Improvement Options

7.51 Policy and Institutional Framework Development

The choice of green infrastructure urban water strategies should go beyond conservation and climate change adaption agendas, and should emphasis other social, economic, and environmental benefits (OECD, 2012). Therefore, aligning policy goals and exploring potential synergies and co-benefits is important in developing coherent and cost-effective policies (ibid.). Green infrastructure urban water management strategies should be designed in such a manner that they take into account various policy criteria, and be aligned with economic and infrastructure planning, in order to enhance and advance policy in a more cohesive and strategic manner (ibid.).

Sector policies are particularly important in shaping green infrastructure investment and implementation. A key objective would be to systematically integrate green infrastructure into sector policies, as well as making sure that these policies are aligned across the different tiers of government and stakeholders.

Policies for Stormwater Runoff Control and Flood Mitigation

Policies related to stormwater runoff control should be related to interventions and instruments that meet stormwater and surface water objectives established earlier in chapters.

Policies for flood mitigation and risk management should recognise that protection of all residents and developments at all times is impossible, therefore policies need to be based on a realistic assessment of risk. The emphasis of policies for runoff control and flood mitigation needs to shift from one of an emergency response towards an emphasis of risk management/reduction (Parkinson and Mark, 2005).

7.5.2 Spatial Planning

The planning process can be defined in terms of a greater number of stages and phases, but there are essentially three stages that are illustrated in Figure 45 (Parkinson and Mark, 2005). Each of the stages that are established in the planning process should involve an iterative process.

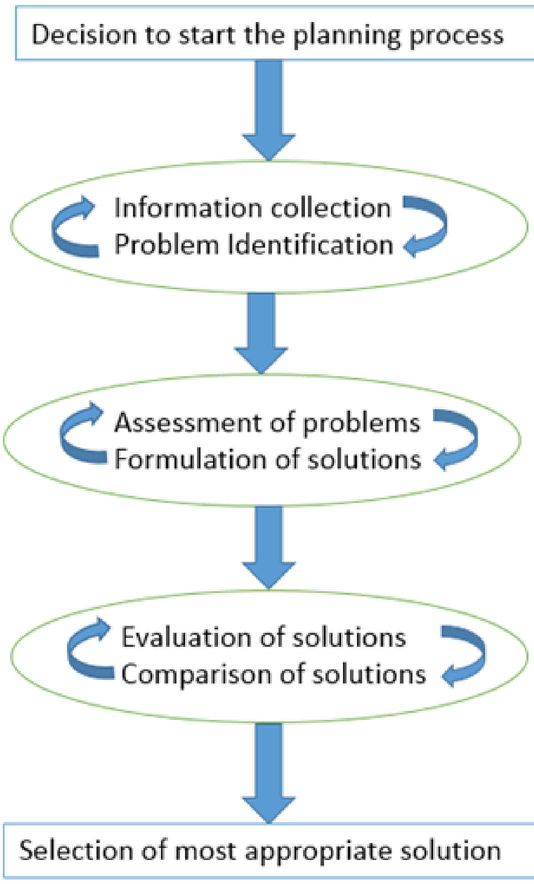


Figure 45: Stages in the Planning Process (Source: Parkinson and Mark, 2005)

In terms of issues related to existing drainage systems, it is very rare that there is a one fits all solution. Therefore, the planning process should establish a range of potential solutions that depend on the concerns and priorities identified (Parkinson and Mark, 2005). Hence, the planning process can be quite complex involving a variety of groups, organisations, and individuals who have different interests and perceptions (ibid.). Therefore, the final plan tends to often require trade-offs between competing goals and objectives related to numerous qualitative and quantitative aspects of urban stormwater and surface water management. Decisions made in the planning process influence the way in which the plan is implemented and there is no exception with regards to the implementation of green infrastructure stormwater and surface water management practices and strategies. Therefore, the planning process is extremely critical in establishing green infrastructure urban water management strategies as well as in implementing them.

The proposed solutions identified during the planning process need to be evaluated according to certain criteria, which will then give an indication of each proposed solutions positive and potential negative impacts. Based on the results a number of alternatives can be compared in order to identify which option offers the most sustainable and cost-effective solution. According to Parkinson and Mark (2005) there are two basic methods involved in the evaluation and comparison of alternatives:

- Quantitative assessment
- Qualitative assessment

With regards to Paarden Eiland, the comparison of green infrastructure urban water management strategies and conventional hard infrastructure strategies, the incorporation and implementation of green infrastructure practices to manage stormwater and surface water is the more cost-effective and sustainable approach. It is important to note that the planning process for green infrastructure requires rigorous technical evaluation and comparisons within its own field to develop appropriate and context-specific green infrastructure urban water management tools and techniques for a particular site or area.

7.6 Overall Recommendations for Creating a Green Infrastructure Integrated Stormwater and Surface Water Framework

An integrated framework should be established in order to integrate green infrastructure projects and design into stormwater and surface water management. This is considered as an adaptive management approach that offers solutions to management challenges caused by increasingly complexity of managing urban water systems and the uncertainty of the frequency and magnitude climate change impacts. Therefore, an outline of a proposed six-step integrated framework has been established and is illustrated below, which has been adapted from Beaucamp, Adamowski et al.'s (2011) work.

1. **Inventory:** This step should be the initial starting point, in order to understand and define the existing situation of a particular site. This includes review and analysis of socio-economic, demographic, bio-physical, land-uses, transportation networks, and major facilities.

2. **Hydrological and Hydraulics Assessment:** Green infrastructure practices and mechanisms can be used to mimic the design and functions of conventional infrastructure. Therefore, it is important to define stormwater and surface water issues and water quality objectives based on green infrastructure principles. It is important to also gain an understanding of the hydraulics of surface water.
3. **Integrated Management Practices:** Water-sensitive urban design and low- impact design area approaches that may help in maintaining on-site water quality and quantity, and can be utilised to reduce stormwater issues and impacts. Therefore, an assessment of the availability of surface water and potential surface water resources is required. This assessment includes the identification of pollution sources and evaluating pollution control requirements for the protection of surface water resources and other natural assets. The quantity and quality of stormwater also needs to be examined.
4. **Spatial Planning:** This stage requires that a site analysis be performed in order to develop a conceptual plan/layout as well as an implementation strategy. This process should be multi-disciplinary and relevant professionals should be consulted during this stage. This stage also includes the planning of land-uses, transportation networks, and major facilities.
5. **Consultation:** A public information process and programme that involves planners, developers and other relevant stakeholders, in order to inform and gain feedback from the public. This process assists in appropriately reviewing the proposed project.
6. **Master Plan:** The preparation a green infrastructure integrated stormwater and surface water infrastructure plan. This process requires a feasibility study as well as the establishment of alternatives, which should be evaluated under technical, environmental, financial, and socio-economic considerations. Finally, an initial implementation and monitoring plan needs to be put in place and it should adhere to funding availability and sustainability/green infrastructure principles.

7.7 Recommendations for Overcoming Implementation Barriers

Recommendations established, were informed by the review of green infrastructure stormwater management related journals, articles, and government publications, which provided some solutions to addressing the barriers identified in the Chapter Two (The literature review).

7.7.1 Institutional Barriers Solutions

Fragmented Regulatory Framework

The different tiers of government and local governing jurisdictions should work in conjunction with each other, in order to develop co-ordinated and comprehensive stormwater and surface water management plan. This could possibly aid in removing barriers as well as inconsistencies to implement green infrastructure stormwater management practices. These barriers and inconsistencies exist due to fragmented and un-coordinated management.

Interdepartmental co-ordination is also required in order to undertake, identify, and reduce the inconsistencies between different policies and regulations (Tian, 2011). Besides, the integrated collaboration between levels government and departments, it is necessary to form partnerships and consult with other relevant professionals.

Resistance to Change:

Diverging from well-established engineering practices towards green infrastructure is often regarded as taking a risk and requires support from relevant stakeholders such as planners, officials, engineers, developers, and the greater public (Hammitt, 2010). Governmental support is key and should be the initial step in building a support base for green infrastructure urban water management practices, because the government tends to be a determining factor in the level/degree of which green infrastructure practices are employed in order to manage stormwater and surface water systems.

Technical support and assistance can play a key role in helping reduce the resistance to change. Technical support allows for the development of the correct understanding and perception of the benefits of green infrastructure urban water management practices can offer. This approach will enhance education and hopefully reduce scepticism and build confidence.

7.7.2 Technical Barrier Solutions

Lack of Performance and Cost Data

Performance and cost data of green infrastructure stormwater and surface water management is a significant component to conducting a cost-benefit analysis, which will help justify the cost-effectiveness and feasibility of green infrastructure. This can be done by evaluating and comparing different green infrastructure urban water management plans as well as developing small-scale local pilot projects. These local pilot projects should be monitored in order to gain local data to justify implementing green infrastructure practices to management stormwater runoff and surface water on a much larger scale.

Lack of Design and Maintenance Standards

The creation of performance standards and maintenance guidelines through the establishment of a manual for common green infrastructure techniques, and appropriate monitoring and maintenance practices. These standards should be tried and tested to promote predictability and reliability. Demonstrating that green infrastructure performance can be monitored and measured will show that green technologies can be reliable.

Insufficient Expertise and Knowledge in Government

Building expertise can be achieved by recruiting experts in the field of green infrastructure or related fields, or establishing training programmes for current employees. The formation of a partnership between local universities and government can assist in increasing research, education, and training opportunities.

7.7.3 Financial Barrier Solutions

Lack of Sufficient Funding

The establishment of stormwater fees could be utilised in creating a revenue stream for operational and maintenance costs of green infrastructure projects that management stormwater and surface water. Cost-sharing between governments and the private sector can assist in implementing green infrastructure projects on a city-wide scale.

Lack of Incentive-Based Policies

There are numerous incentive-based programmes available. The most common incentives tend to be discounted stormwater fees, grants and rebates, development incentives, and award/recognition programmes (Tian, 2011). The provision of such incentives provide an opportunity to reduce stormwater fees as well as construction and installation costs when incorporating green infrastructure into stormwater and surface water management efforts.

7.8 Research Findings

The fundamental advantage of green infrastructure to planning is that it can assist in delivering other/ alternative national, regional, and local policy objectives, not just related to green space conservation (RTPI, 2013). In terms of stormwater and surface water regulations and policy, green infrastructure provides a sustainable and alternative means of achieving better stormwater and surface water management. However, the challenge is guaranteeing that green infrastructure is able to provide functions that meet a variety of planning objectives. This requires comprehensive design, planning, and management, and success is highly dependent on a shared understanding between planners, developers, and other relevant stakeholders.

Since the inception of spatial planning, green infrastructure has played a significant role, but only in terms of conservation efforts. Natural systems have often been considered in a fragmented manner, therefore overlooking the multiple benefits of green infrastructure networks. This approach to managing natural systems has led to the accelerated degradation of urban water systems and biodiversity. Nevertheless, green infrastructure urban water management practices are a growing theme in governmental agendas around the world.

Therefore, with government recognition and support the importance for planners to understand and implement green infrastructure urban water management practices and approaches has never been greater (RTPI, 2013) especially with regards to the looming reality of global climate change impacts.

7.9 Areas of Future Research

Due to the limited scope of this dissertation/study, an extension of green infrastructure research should be done through further research. There are a few areas of further research that are necessary to advance and boost the green infrastructure stormwater and surface water management approach and argument, and further justify the integration green infrastructure into stormwater and surface water management practices especially in developing countries such as South Africa.

Areas identified for further research include systematically evaluating early benefits, long-term performance and effectiveness, as well as economic feasibility of green infrastructure stormwater practices in highly urbanised areas and industrial sites that lack existing natural systems that filter stormwater runoff pollutants and mitigate flooding.

Further investigating of the legality of governing stormwater and surface water decentralised green infrastructure practices, and ownership rights to green infrastructure once structures have been implemented. It is also recommended that research on re-use options for stormwater and related treatment methods should be advanced.

Informal settlements are a prominent feature of many developing countries such as South Africa's urban landscape, and with the interconnectedness of urban water systems, it would be valuable if further research was to be done on how to incorporate and implement green infrastructure interventions within the complex landscapes and context of informal settlements. This type of research would add significant value to the planning of service provision in areas of informality, and would assist in making a step forward in fulfilling the social inclusive criteria of sustainable development.

7.10 Reflections

This research has hopefully made a positive impact in terms of researching and shedding light on green infrastructure alternatives for managing stormwater and surface water as well as retrofitting an industrial and heavily developed area. This dissertation experience has been meaningful and extremely enlightening with regards to understanding and recognising the importance of appropriately managing stormwater and surface water, in terms of creating a sustainable urban environment.

This research process involved an extensive examination and review of literature, government publications (both local and international), journals, articles, and informal discussions with academic staff and a few officials.

Throughout this process, I experienced barriers in terms of the availability of written information on Paarden Eiland's current stormwater practices and issues. However, with the use of current GIS data and a few written documents, it has been possible to develop an argument for retrofitting Paarden Eiland with green infrastructure in order to address stormwater and surface water issues experienced in the area. This dissertation was heavily based on literature and theory, therefore having distinctive findings has been challenging.

I am fairly well acquainted with geographical area/setting of the site. Therefore, previously held information/knowledge, attitudes, and values may have impacted the research process and findings. Other limitations have been noted in Chapter Four.

7.11 Conclusion

This study confirms that green infrastructure in terms of managing stormwater and surface water provides a variety of benefits and promotes the advancement towards sustainable neighbourhoods, sites, and cities in comparison to conventional hard infrastructure practices, especially in the face of climate change. The approach of using ecological/green systems to inform design and planning has been around for decades, albeit just under different names such as ecological/landscape urbanism and has proven its relevance in planning and design.

However, even the greenest cities have battle with institutional, technical, and financial barriers associated with mainstreaming and implementing green infrastructure stormwater and surface water practices. This is often due to a lack of knowledge and understanding as well as a hesitation to move away from conventional practices both within governments and the general public. Nevertheless, with all the rhetoric around sustainable development, this is the right time for green infrastructure to take precedency in spatial planning, urban design, and engineering.

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Table 7: Municipal Policy Review

MUNICIPAL SPHERE OF GOVERNMENT									
Strategy/Plan/ Policy/ Legislation	By-law for Stormwater Management and Related Matters	Policy for Control of Development near Watercourses	Stormwater Land Identification Project	City of Cape Town Management of Urban Stormwater Impacts Policy	Floodplain and River Corridor Management Policy	Integrated Metropolitan Environmental Policy	Integrated Development Plan	Cape Town Spatial Development Framework	City of Cape Town Water Services Development Plan
Year	2005	2002	N/A	2009	2009	2001	2013/2014	2012	2013/2014
Aim	-To regulate stormwater management in Cape Town, as well as activities that may negatively impact the development, operation, and maintenance of stormwater systems.	-A framework to control development near watercourses, in order to reduce potential flooding damages, as well as protect and enhance the environment.	- Identifies all erven in the CMA impacted by stormwater issues. - To warn planners, developers, development control officers and anyone else involved in land use management of the stormwater implications of erven.	-Appropriately manage urban water bodies that are valuable resources in terms of providing environmental and recreational services, which require protection and enhancement.	-To sustain the aquatic ecology of the city, as an essential element in restoring the urban fabric of the city, through providing both recreational and socio-economic opportunities to communities.	- Creates basis for a series of strategies and programmes to ensure that the fundamental principles and approaches to sustainable development.	- An approach to plan future development in particular areas.	- The creation of a sustainable and equitable city.	-The eradication of basic services backlog, whilst reducing the impact on the water quality of urban surface water
Key Principles	-Prohibit illegal discharges. -Protect stormwater systems. -Prevent flooding risks. -Limit pollution incidents.	-To facilitate development in order to: * Guarantee effective functioning of stormwater systems without creating or worsening flooding risks. *Protect and restore the functioning of natural floodplains. *Mitigate/reduce adverse impacts on natural ecosystems. *reduce costly disaster management efforts.	- For plans to indicate: * Known flood prone areas demarcated by a flood line. * Flood prone rivers and canals. *Existing stormwater detention ponds, vleis and open water bodies. *Planned detention ponds.	-Reducing the impact of flooding on urban areas and regional economies. -Protect human health, natural water systems, and improve and maintain water quality.	-Reducing the impact of flooding on urban areas and regional economies. -Protect human health, natural water systems, and improve and maintain water quality.	-An open, participatory approach in the planning of proposals. -Consideration of alternatives options -Mitigation of negative impacts and enhancement positive aspects of proposals.	-The effective use of scarce resources. -To speed up service delivery. -Attract supplementary funding. -To overcome the apartheid legacy. -Promote co-ordination between the different tiers of government.	-Key principles derive from National legislation, in particular the Development Facilitation Act (67 of 1995)	- Optimise operations of water infrastructure. -Financial viability. -Infrastructure stability. -Operational resilience. -Community sustainability. -Water resources management.
Stormwater / Surface Water Management	- Regulate stormwater management practices in Cape Town.	-Applicable to the defined categories established for development near watercourses, whether man-made or natural, within the City of Cape Town.	-Identifies stormwater impacts and issues.	-Intended to reduce the detrimental impacts of stormwater runoff from developed areas by introducing Water Sensitive Urban Design principles to urban planning and stormwater management in the Cape Town.	- Advocates for a merit based approach when dealing with proposals within and adjacent to flood prone areas and environmental buffers. In addition, socio-economic considerations are also introduced whereby any permitted development will take cognizance of the presence of the watercourse / wetland and thereby holistically enhance the urban fabric of the area. - improving and maintaining recreational water quality.	- Assists in fulfilling the City's commitment to ensure that the quality of coastal, marine and inland waters is for the maintenance of biodiversity and the protection of human health.	-Formulation of strategies for stormwater infrastructure provision and management.	- The Cape Town SDF, states under its design guidelines for recreational spaces near rivers and within coastal zones, that there should be a promotion of multi-purpose use of stormwater detention/ retention ponds.	- Reports information for the previous five years and projects future requirements for water infrastructure, in order to inform future development.
Spatial Representation	No	No	No (plans have not yet been released to the public)	No	No	No	No	None stormwater management interventions)	Yes

The Valuation of Cape Town's Ecosystems

The valuation of Cape Town's ecosystems is a powerful tool/technique for assessing the potential monetary value of environmental assets within the City, which are often regarded as free. The valuation process will assist in building a shared understanding of the importance and value of natural assets, and will hopefully build a foundation and argument for future efforts to better secure, protect, and maintain these assets in a holistic manner.

Table 8: Cape Town's Ecosystem Valuation (Source: http://urbis.iclei.org/project/cape%20town%20case%20study, 2015)

VALUATION OF CAPE TOWN'S ECOSYSTEM SERVICES BASED ON THE URBIS INTIATIVE		
THEME	ESTIMATED VALUE PER ANNUM	METHOD
Tourism	US$ 137 million	Based on the revenue generated by visitors coming into Cape Town as a result of the attraction to Cape Town's natural features.
Recreation	US$ 58 to 70 million	Local recreational values, based on benefits transferred from previous valuation studies done on recreational assets.
Global Importance of Biodiversity	US$ 32 million	Based on donor funding received for conservation.
Natural Hazard Regulation	US$ 650 000 to 8.6 million	Based on estimates of the cost of damages avoided due to natural buffering for hazards such as wildfires, flooding, and storm surges.
Water Purification and Waste Treatment	US$ 8.5 to 9.9 million	Base on the minimum restoration costs required for a wetland to function normally and avoid ecosystem collapse.
***Based on the Millennium Ecosystem Assessment (2005) * All values are based on 2007 data *Study based in US$**		

Table 9: Summary of Valuations Studies for Cape Town's Natural Areas (Source: de Wit et al., 2009)

SUMMARY OF VALUATION STUDIES FOR CAPE TOWN'S NATURAL AREAS					
NATURAL FEATURES		RAND/ HECTARE		AVERAGE VALUE: MILLION (2007 data)	METHOD
HECTARES		MIN	MAX		
Mountain Fynbos	3 912	1 165	7 081	16.1	CVM
Lowland Fynbos	291	1 165	7 081	1.2	CVM
Wetlands	4 626	2 533	75 159	179.7	HP & CVM
Beaches	-	-	-	54.4	TCM
Parks	1 962	3181	104 239	105.4	HP & CVM
Sports fields	260.4	19 563	36 570	7.3	HP & CVM
Agriculture	3 265.9	937	57 684	95.7	HP
***Estimations based in South African Rands * TCM-Travel Cost Model, HP- Hedonic Pricing, CVM- Contingent Valuation Model**					

Even though we live in an age where every activity and object is immediately given a monetary value. This process is extremely important when it comes to understanding the value of something. However, it is extremely important that we learn to understand and account for intangible and unquantifiable value of green infrastructure/natural systems, because realistically one cannot really put a monetary price on the services that nature provides. These systems are invaluable.

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook**(available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Palmira, Ndeshihala de Almeida
Department		Architecture, Planning and Geomatics
Preferred email address of applicant:		dlmpal001@myuct.ac.za
If a Student	Your Degree: e.g., MSc, PhD, etc.,	Masters
	Name of Supervisor (if supervised):	Nancy Odendaal/ Tania Katzschner
If this is a researchcontract, indicate the source of funding/sponsorship		No
Project Title		Green Infrastructure Water Management Framework for Paarden Eiland, Cape Town.

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Palmira, Ndeshihala de Almeida		**22 Jun 2015**

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Nancy Odendaal(Tania Katzschner)		**22 Jun 2015**
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (Including Honours).	Vanessa Watson		**22 Jun 2015**
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G. Sithole Click here to enter text.		22 /07/2015 Click here to enter a date.

EBE Faculty: Assessment of Ethics in Research Projects (Rev2)

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee: submit to Ms Zulpha Geyer (Zulpha.Geyer@uct.ac.za; Chem Eng Building, Ph 021 650 4791).
NB: A copy of this signed form must be included with the thesis/dissertation/report when it is submitted for examination

This form must only be completed once the most recent revision EBE EiR Handbook has been read.

Name of Principal Researcher/Student: Palmira, Ndeshihala de Almeida Department: School of Architecture, Planning and Geomatics

Preferred email address of the applicant: dlmpal001@myuct.ac.za

If a Student: Degree: Masters Supervisor: Nancy Odendaal

If a Research Contract indicate source of funding/sponsorship:

Research Project Title: Green Infrastructure Water Management Framework for Paarden Eiland

Overview of ethics issues in your research project:

Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)?	YES	NO
Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2.	YES	NO
Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3.	YES	NO
Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4.	YES	NO

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate. Ensure that you refer to the EiR Handbook to assist you in completing the documentation requirements for this form.

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

	Full name and signature	Date
Principal Researcher/Student:	Palmira. Ndeshihala de Almeida	22/06/2015

This application is approved by:

Supervisor (if applicable):	Nancy Odendaal (Tania Katzschner)	22/06/2015
HOD (or delegated nominee): *Final authority for all assessments with NO to all questions and for all undergraduate research.*	Vanessa Watson	22/06/2015
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.		

ADDENDUM 2: To be completed if you answered YES to Question 2:

It is assumed that you have read the UCT Code for Research involving Human Subjects (available at http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf) in order to be able to answer the questions in this addendum.

2.1 Does the research discriminate against participation by individuals, or differentiate between participants, on the grounds of gender, race or ethnic group, age range, religion, income, handicap, illness or any similar classification?	YES	NO
2.2 Does the research require the participation of socially or physically vulnerable people (children, aged, disabled, etc) or legally restricted groups?	YES	NO
2.3 Will you not be able to secure the informed consent of all participants in the research? (In the case of children, will you not be able to obtain the consent of their guardians or parents?)	YES	NO
2.4 Will any confidential data be collected or will identifiable records of individuals be kept?	YES	NO
2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?	YES	NO
2.6 Are there any foreseeable risks of physical, psychological or social harm to participants that might occur in the course of the research?	YES	NO
2.7 Does the research include making payments or giving gifts to any participants?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

ADDENDUM 3: To be completed if you answered YES to Question 3:

3.1 Is the community expected to make decisions for, during or based on the research?	YES	NO
3.2 At the end of the research will any economic or social process be terminated or left unsupported, or equipment or facilities used in the research be recovered from the participants or community?	YES	NO
3.3 Will any service be provided at a level below the generally accepted standards?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

ADDENDUM 4: To be completed if you answered YES to Question 4

4.1 Is there any existing or potential conflict of interest between a research sponsor, academic supervisor, other researchers or participants?	YES	NO
4.2 Will information that reveals the identity of participants be supplied to a research sponsor, other than with the permission of the individuals?	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

SCHOOL OF ARCHITECTURE, PLANNING AND GEOMATICS
University of Cape Town
Private Bag x3, Rondebosch 7701
Centlivres Building
Email: Janine.Meyer@uct.ac.za Tel: 27 21 6502359

UNIVERSITY OF CAPE TOWN

June 2015

STATEMENT TO BE READ OUT TO AN INTERVIEWEE BY A STUDENT ABOUT TO UNDERTAKE AN INTERVIEW FOR THE PURPOSES OF A MASTERS DISSERTATION, AS A REQUEST FOR PERMISSION FOR THE NAME AND/OR IDENTITY OF THE INTERVIEWEE TO BE REVEALED IN THE DISSERTATION

A copy of the form can be given to the respondent if they request it.

MY NAME IS PALMIRA, NDESHIHALA DE ALMEIDA AND I AM STUDYING A MASTERS IN CITY AND REGIONAL PLANNING AT THE UNIVERSITY OF CAPE TOWN.

I AM DOING RESEARCH ON GREEN INFRASTRUCTURE WATER MANAGEMENT TECHNIQUES FOR PAARDEN EILAND, CAPE TOWN AS PART OF MY MASTERS DISSERTATION AND I WOULD LIKE TO ASK YOU SOME QUESTIONS TO HELP ME WITH MY RESEARCH.

I WOULD LIKE TO USE YOUR NAME, DESIGNATION AND POSSIBLY DIRECT QUOTES IN MY DISSERTATION AS A SOURCE OF INFORMATION. PLEASE INDICATE YES OR NO BELOW TO GIVE OR WITHOLD YOUR PERMISSION FOR ME TO DO THIS.

YES I GIVE PERMISSION FOR YOU TO USE MY NAME / DESIGNATION / WORDS IN YOUR DISSERTATION ☐

NO I DO NOT GIVE PERMISSION FOR YOU TO USE MY NAME / DESIGNATION /WORDS IN YOUR DISSERTATION ☐

IF YOU WANT TO END THE INTERVIEW AT ANY POINT YOU ARE FREE TO DO SO.

MY SUPERVISOR IS NANCY ODENDAAL AND HIS/HER CONTACT DETAILS ARE: Nancy.odendaal@uct.ac.za

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Signature and designation (interviewee)	Signature of student

This form is to be completed with your name and topic and submitted with your ethics form