THE CITY WATER RESILIENCE APPROACH

CITY CHARACTERISATION REPORT

JOHANNESBURG

EXECUTIVE SUMMARY

CONTEXT OF THE RESEARCH

City leaders in Africa face converging challenges: extending water and sanitation services for growing populations, managing watershed risks and competing water demands outside city jurisdiction, and designing for climate resilience. They are challenged to build urban water resilience, where communities have enough safe, reliable, and affordable water to survive and thrive through sustainable, adaptive, and resilient urban water systems. The recent COVID-19 crisis has highlighted the urgent need to close the urban services divide more than ever, given that the lack of access to essential services, including water, has exacerbated the challenge of responding effectively to the pandemic.

These converging challenges represent a significant threat to sustainable urbanization, but this moment of growth and development also presents an opportunity to "get water right." To ensure sustainable and equitable urbanization, cities must build resilience to water and climate risks. This will require overcoming underlying barriers to changing existing urban and water systems, such as knowledge and capacity gaps, siloed and uncoordinated planning (vertical and horizontal), and financial and technical bias toward rigid and centralized infrastructure. The World Resources Institute's (WRI) Urban Water Resilience (UWR) initiative works to help cities overcome water challenges through research to illuminate urban water resilience challenges and pathways, create partnerships with cities to enhance capacity and demonstrate solutions, and facilitate collective action to improve enabling environments. This initiative is being led by WRI Africa, WRI Ross Center for Sustainable Cities, the WRI Water Program and partners. Together, these programs and offices provide experience in creating accessible, equitable, healthy and resilient urban areas for people, businesses and the environment as well as working with businesses, governments and civil society to ensure a water-secure future by addressing water quantity, quality and governance challenges.

STRUCTURE OF THE REPORT

Chapter 1 introduces the context of the research by outlining the purpose of the Urban Water Resilience initiative in Africa, the use of the City Water Resilience Approach and the purpose of the City Characterisation Report. **Chapter 2** provides an overview of the City of Johannesburg including the location and topography, climate, urban development, population, economy, housing, access to basic services, standard of living and governance. The governance structure of the City of Johannesburg Metropolitan Municipality as well as the aspects specific to water governance are outlined in **Chapter 3**. **Chapter 4** frames the discussion around water resilience by discussing the urban water system. **Chapter 5** lists the key shocks and stresses that hamper resilience in the city as well as the vulnerabilities that prevent the city from mitigating threats. **Chapter 6** highlights the existing policies, projects and programmes that assist towards building resilience in the city. **Chapter 7** reflects on the alignment between the key CoJ initiatives and the Urban Water Resilience objectives and how existing efforts could be used in the application of the City Water Resilience Approach as well as identifying priority actions for implementation. Chapter 8 outlines the suggested way forward in scoping out the priority actions for implementations as well as the development of a resilience profile for the city of Johannesburg.

KEY FINDINGS

- The City of Johannesburg overall has a higher index of access to basic services such as housing, water, sanitation, electricity and refuse removal than the rest of South Africa however this is not the case for the informal settlements and marginalised areas located within the city. There is a significant gap between the affluent and impoverished population.
- With regards to water security, Johannesburg does not lie on a significant water source and is therefore reliant on neighbouring catchments for regional water supply and neighbouring country, Lesotho, for international water supply. Additionally, the city is reliant on surface water and alternative sources for water supply are largely unexplored.
- The City is prone to extreme growth pressures due to population growth and urbanisation as a result of being the largest economic hub in Africa which result in urban development. Urban development results in impervious areas which causes environmental degradation and flash flooding.
- There are a number of policies in place that aim to enhance the resilience of the city however there is a lack of on-the-ground action due to budget constraints and lack of institutional capacity.

NEXT STEPS

Considering the efforts that are already underway in the City of Johannesburg including the Water Security Strategy, Climate Action Plan and other plans and programmes, the aim of the Urban Water Resilience initiative is to build on existing efforts towards building water resilience in the City of Johannesburg. The Urban Water Resilience initiative going forward will therefore be implemented in two Phases:

Phase 1: Implementation of technical support for identified Water Security

Strategy Actions

Phase 1 consists of the Urban Water Resilience initiative supporting a maximum of two priority actions that align with the objectives of the UWR and aid in building water resilience in Johannesburg.

Phase 2: Initiating and advancing an urban water resilience agenda

There is a need to focus on building water resilience in the City of Johannesburg that includes and extends beyond water security. WRI and partners will continue to work collaboratively with CoJ towards initiating and advancing a city water resilience agenda using the City Water Resilience Approach to develop a resilience profile for the city.

FOREWORD

Johannesburg, home to approximately 4.4 million people, is South Africa's largest urban area. It is both the economic hub of South Africa and a significant economic player in the southern African region. The economic development opportunities of Johannesburg, however, continue to place the city under tremendous growth pressure as a result of high population growth, urbanization, and regional migration. With the expected population projected to increase by 45% and the city dependent on water sources in neighbouring catchments, the city faces the challenge of simultaneously improving reliability of water for existing population and planning for water security for future populations

At one point Johannesburg was considered to be the world's largest urban forest and was listed as one of the top ten greenest cities in the world. However, due to continued population growth and economic development this asset stands degraded and reduced. In addition, the city now faces a very uncertain future with climate change also threatening water security, resilience and liveability. Significant growth pressures, high inequality, pollution and environmental degradation, flash flooding, dilapidated infrastructure, delays in the development of new water infrastructure, fragmented governance, and limited financial capacity in the sector are all contributing to poor water resilience. Despite being a water stressed country with increasing risks due to climate change, Johannesburg's per capita domestic water use remains well above the global average with high rates of water loss.

These, and other shocks and stresses, affect the resilience of the city and the urban water system the city depends on to provide critical urban services, putting the livelihoods of its population, natural systems, and economy at risk.

There is an urgent need for the city to identify areas of opportunity for taking strategic actions, to improve project development and collaboration and to establish a baseline against which progress can be measured.

Since the beginning of 2022, the World Resources Institute (WRI), together with the City of Johannesburg's Environment & Infrastructure Services Department, and supported by the South African Cities Network, Zutari, Arup, The Resilience Shift, the Resilient Cities Network (R-Cities), and Department of Cooperative Governance and Traditional Affairs are working together to develop a better understanding of risks and vulnerabilities in Johannesburg's urban water system and to address them in a holistic manner.

As part of that work, this report provides an appraisal of the water context of Johannesburg. The appraisal includes its natural basin(s), maps key man-made and natural assets, governance processes of the urban water system, and interdependencies with other systems. The report assesses key water and urban policies, programs, plans underway and in development; and identifies development shocks and stresses to develop an analysis of existing urban water resilience challenges facing the city. In doing so, the report provides factors contributing to the resilience of the city water system and those increasing its vulnerability.

Following the report, the team has engaged key stakeholders to assess the city's urban water resilience according to the City Water Resilience Approach (CWRA) with the aim to develop a baseline. Based on the assessment, the team will further develop a Water Resilience Profile and Action Plan for the City of Johannesburg

to support and enhance the implementation of its Water Security Strategy while integrating a holistic resilience approach. Lastly, priority actions will be identified, and discrete technical assistance will be provided to advance those actions towards implementation.

This work is part of a multi-year Urban Water Resilience (UWR) Initiative, led by WRI along with partners in six African cities. In each city, the initiative undertakes baseline research and facilitates a structured, multi-stakeholder planning process to identify actions that address water-related shocks and stresses. Support for this initiative is provided by the Federal Ministry for Economic Cooperation and Development (BMZ).

On behalf of the project team and the project partners, we would like to thank the City of Johannesburg's Environment & Infrastructure Services Department and all City officials engaged in the planning process for the development of the Johannesburg City Characterization Report (CWRA-CCR).

ARUP

RESILIENT CITIES NETWORK

THE RESILIENCE SHIFT

WORLD RESOURCES INSTITUTE

ZUTARI IMPACT. ENGINEERED.

South African CitiesNetwork

Johannesburg is situated in a water scarce region and our current water consumption are not attuned to this reality. In addition, our city faces shocks and stresses that affect the resilience of the urban water system. Shocks and stresses influencing Johannesburg's water system include water security challenges, climate change, flooding, population growth, environmental degradation, aging infrastructure, and inequality. In order for us to tackle water security, it is important to better understand the shocks and stresses that places Johannesburg in a vulnerable position and implement suitable actions. In doing so, the City of Johannesburg's Environment & Infrastructure Services Department (EISD) completed its first Water Security Strategy to meet goals aligned with the City's long-term strategy. This strategy serves to develop a long-term vision and enable systemic change towards a water secure Johannesburg. Building on this on-going work, now developing the Implementation Plan, CoJ is strengthening the resilience component of its water system to withstand shocks and stresses.

It is in this context that our city, as represented by EISD, has partnered with the World Resources Institute (WRI) under the Urban Water Resilience (UWR) Initiative to complement the Water Security Strategy. Under the Urban Water Resilience Initiative, City of Johannesburg and WRI are working collaboratively with the objective to ensure that the implementation of the Water Security Strategy Implementation Plan takes advantage of resilience strategic planning through the integration of the City Water Resilience Approach (CWRA) to better plan for and manage related stresses and shocks to the water system.

As part of the CWRA, the Characterization report for the City has been developed with the aim to establish an in-depth water resilience profile of risks and vulnerabilities and identify areas of intervention to enhance the resilience of the urban water system in partnership with ARUP, Resilient Cities Network, South African Cities Network, City of Johannesburg, and WRI. Moreover, this intervention will help strengthen City of Johannesburg's capacity to build resilience in the city's water system and also to transform Johannesburg into a water-secured city. Therefore, for Johannesburg to achieve a water secure city given the various threats it faces, it must be on the road to enhance its resilience.

It is in this light that the City of Johannesburg stands ready to work with partners such as WRI, in building the city's water resilience.

MS NOMVULA MOFOKENG

Deputy Director: Environment & Infrastructure Services Department
City of Johannesburg

CONTENTS

ACRONYMS & ABBREVIATIONS

100RC	100 Resilient Cities
AMD	Acid Mine Drainage
BMZ	German Federal Ministry for Economic Cooperation and Development
CAP	Climate Action Plan
CBD	Central Business District
CMP	Catchment Management Plan
CoCT	City of Cape Town
COGTA	Department of Cooperative Governance and Traditional Affairs
CoJ	City of Johannesburg
CPF	Community Policing Forum
CRC	Cooperative Research Council
CSIR	Council for Scientific and Industrial Research
CSP	Cities Support Programme
CWRA	City Water Resilience Approach
CWRF	City Water Resilience Framework
DANIDA	Danish International Development Agency
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EISD	Environment and Infrastructure Services Department
GCRO	Gauteng City Region Observatory
GDARD	Gauteng Department of Agriculture and Rural Development
GDP	Gross Domestic Product
ICLEI	International Council for Local Environmental Initiatives
IVRS	Integrated Vaal River System
IWA	International Water Association
JMPD	Johannesburg Metropolitan Police Department
JPOMA	Johannesburg Property Owners and Managers Association
JPTC	Joint Permanent Technical Commission
JRA	Johannesburg Roads Agency
JW	Johannesburg Water
LHDA	Lesotho Highlands Development Authority
LHWC	Lesotho Highlands Water Commission
LHWP	Lesotho Highlands Water Project
NBI	National Business Initiative
NRW	Non-Revenue Water
NT	National Treasury
OECD	Organization for Economic Co-Operation and Development
PRV	Pressure Reducing Valve
R-Cities	Resilient Cities Network
RQO's	Resource Quality Objectives
RSA	Republic of South Africa
RW	Rand Water
SACN	South African Cities Network
SADC	Southern African Development Community
SIWI	Stockholm International Water Institute
StatsSa	Statistics South Africa
TCTA	Trans-Caledon Tunnel Authority
UCT	University of Cape Town
UJ	University of Johannesburg
UWR	Urban Water Resilience
WCWDM	Water Conservation and Water Demand Management
WITS	University of the Witwatersrand
WRC	Water Research Commission
WRI	World Resources Institute
WSCI	Water Sensitive Cities Index
WSS	Water Security Strategy
WUL	Water Use License

GLOSSARY

African Translated as "a native of Africa" in the modern sense, during the apartheid era it was synonymous with the term "bantu". (van der Waal, no date)

Apartheid Translated from the Afrikaans meaning 'apartness', apartheid was the ideology supported by the National Party (NP) government and was introduced in South Africa in 1948. Apartheid called for the separate development of the different racial groups in South Africa. (SAHO, no date)

Backyarding The process of building an informal settlement in the backyard of a formal structure with a formally laid out stand with access to basic services in a formal settlement.

Bantu Bantu refers to a major linguistic group in Africa, and more locally, to identify the sizeable group of Nguni languages spoken by many Africans in sub-Saharan Africa, and it identifies those Bantu-speakers who spoke that group of closely related languages which linguists divide into four categories: Nguni, Sotho-Tswana, Venda and Tsonga-speakers. Bantu speakers comprise more than a 100 million Negroid people who live in southern and central Africa, ranging from Nigeria and Uganda to South Africa, and who speak about 700 languages, including many dialects. From 1977, the term 'Bantu' was slowly replaced by 'black'. In the 1980s, South African universities changed their 'Bantu languages' departments to 'African languages. (van der Waal, no date)

Black The term is used in the South African context and as defined black refers to people with an African, Indian, and Coloured background. (Diversity Journal, 2013)

Coloured A racial group in South Africa comprising the descendants of the indigenous tribes of the Khoikhoi and the San people, a result of the interracial marriage between white settlers and African natives as well as Asian slaves brought from the dutch colonies in the eighteenth and nineteenth centuries. (Encyclopedia.com, 2018)

Ecosystem Services Ecosystem services are the benefits to society provided by ecosystems or ecological assets. (Schäffler et al., 2013)

Formal A formal urban settlement is structured and organised. Land parcels (plots or erven) make up a formal and permanent structure. A local council or district council controls development in these areas. Services such as water, electricity and refuse removal are provided and roads are formally planned and maintained by the council. This category includes suburbs and townships. (Statistics South Africa, 2001)

Green infrastructure Green infrastructure in this report refers to the interconnected set of natural and man-made ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing services and strategic functions in the same way as traditional 'hard' infrastructure. (Schäffler et al., 2013)

Indian A racial group in South Africa descended from indentured labourers who came to South Africa during the 1800 - 1900's from the British colony of India.

Informal Informal settlements occur on land which has not been surveyed or proclaimed as residential, and the structures are usually informal. They are usually found on the outskirts of towns or in pockets of 'infill' inside towns, or along railways and roads. Informal dwellings are makeshift structures not erected according to approved architectural plans. (Statistics South Africa, 2001)

Township Commonly understood to refer to the underdeveloped, usually (but not only) urban, residential areas that during Apartheid were reserved for non-whites (Africans, Coloureds and Indians) who lived near or worked in areas that were designated 'white only'. (Pernegger and Godehart, 2007)

White A White person is one who is in appearance obviously white - and not generally accepted as Coloured - or who is generally accepted as White - and is not obviously Non-White, provided that a person shall not be classified as a White person if one of his natural parents has been classified as a Coloured person or a Bantu. White people in South Africa were generally descended from the European settlers and classified as "White" as long as they did not have any ancestors who were of a different racial group. (Cortland, no date)

1 INTRODUCTION

City leaders in Africa face converging challenges: extending water and sanitation services for growing populations, managing watershed risks and competing water demands outside city jurisdiction, and designing for climate resilience. They are challenged to build urban water resilience, where communities have enough safe, reliable, and affordable water to survive and thrive through sustainable, adaptive, and resilient urban water systems. The recent COVID-19 crisis has highlighted the urgent need to close the urban services divide more than ever, given that the lack of access to essential services, including water, has exacerbated the challenge of responding effectively to the pandemic.

These converging challenges represent a significant threat to sustainable urbanization, but this moment of growth and development also presents an opportunity to "get water right". To ensure sustainable and equitable urbanization, cities must build resilience to water and climate risks. This will require overcoming underlying barriers to changing existing urban and water systems, such as knowledge and capacity gaps, siloed and uncoordinated planning (vertical and horizontal), and financial and technical bias toward rigid and centralized infrastructure. The World Resources Institute's (WRI) Urban Water Resilience (UWR) initiative works to help cities overcome water challenges through research to illuminate urban water resilience challenges and pathways, create partnerships with cities to enhance capacity and demonstrate solutions, and facilitate collective action to improve enabling environments. This initiative is being led by WRI Africa, WRI Ross Center for Sustainable Cities, the WRI Water Program and partners. Together, these programs and offices provide experience in creating accessible, equitable, healthy and resilient urban areas for people, businesses and the environment as well as working with businesses, governments and civil society to ensure a water-secure future by addressing water quantity, quality and governance challenges.

Johannesburg
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12.1 URBAN WATER RESILIENCE IN AFRICA (UWR)

WRI is undertaking a three-year program (2020-2022) to help advance urban water resilience in Africa. The initiative builds on WRI's strong water resources knowledge, globally recognized data and analytical capacities as well as the WRI Ross Center for Sustainable Cities' deep capacity and track record of helping 400+ cities globally tackle tough sustainability and equity challenges, including many cities in Africa. The overall objective of this work is to help cities address their water risks and vulnerabilities through research, technical assistance, knowledge sharing, and partnerships for collective action.

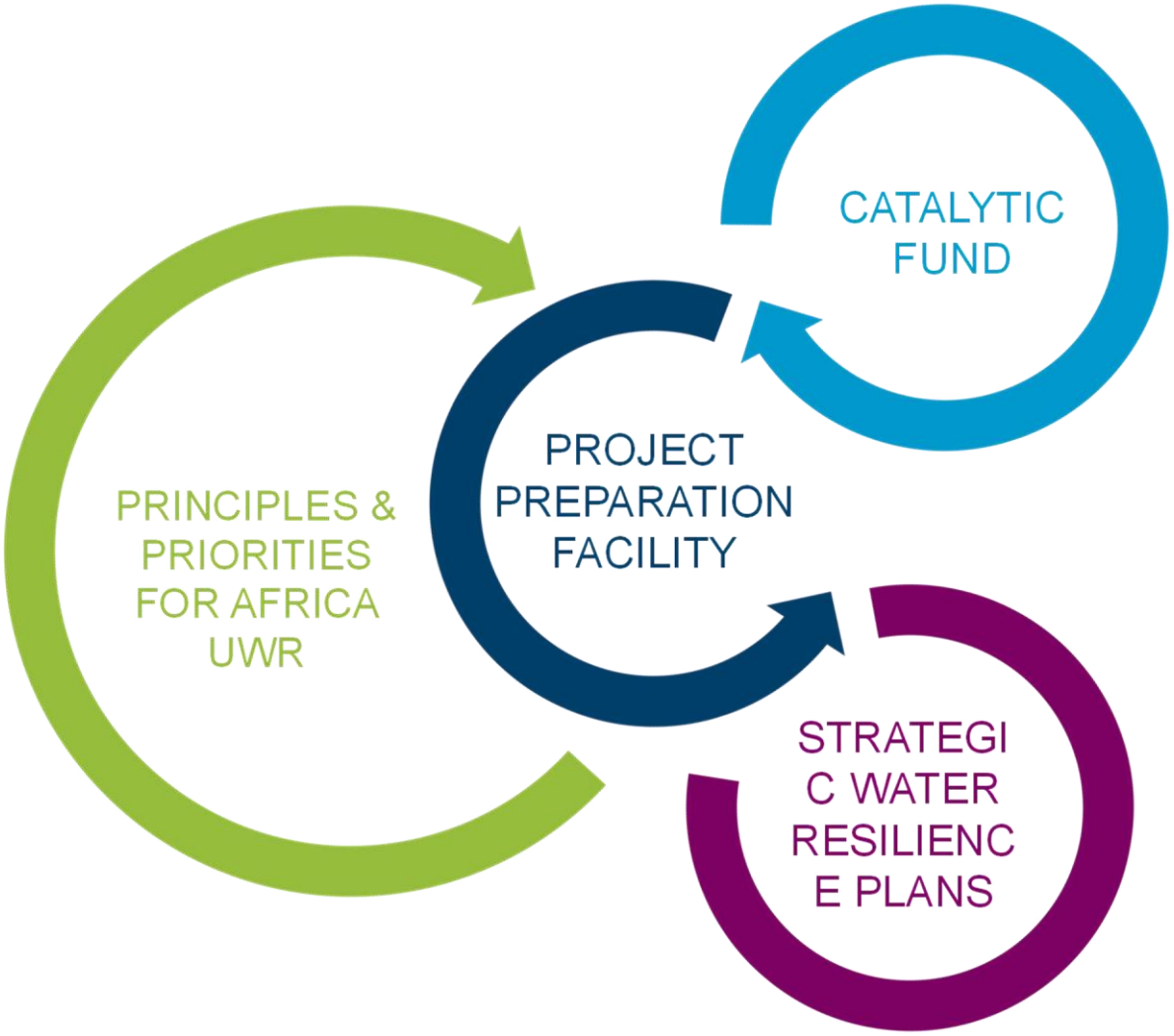
To this end, WRI and partners will work with city stakeholders to: map key water, climate and development risks facing a city; identify pathways for change (e.g., policy, planning, and governance interventions); set specific targets and owners for actions; catalyze implementation of priority actions through various capacity building initiatives, including providing technical assistance and supporting knowledge exchange; and soliciting commitments from regional and national stakeholders to create necessary enabling conditions (e.g., policy alignments and enhanced investment).

This work is made possible by a grant from the German Federal Ministry for Economic Cooperation and Development (BMZ). WRI envisions this effort as the foundation for a larger urban water resilience program in Africa, in partnership with other international, pan-African, and local partners.

WRI helps African cities build water resilience through three key components:

- Research to illuminate urban water resilience challenges and pathways: Research under the Urban Water Resilience initiative is enhancing awareness and understanding of urban planning, water resources management, governance, finance, and infrastructure design, with a focus on resilience for vulnerable populations.
- Partnerships with cities to enhance capacity and demonstrate pathways: WRI is partnering with a cohort of six cities and their regional and national governments, supporting cities to advance their water resilience agendas, providing technical assistance, and facilitating capacity building.
- Collective action to improve enabling environments: WRI is mobilizing collective action through engagement with key stakeholders, including regional governments, financial institutions, and research institutions.

The Urban Water Resilience (UWR) initiative is focused on six African Cities, namely: Kigali & Musanze in Rwanda; Addis Ababa & Dire Dawa in Ethiopia; and Johannesburg & Gqeberha in South Africa. This study is being implemented as part of the second component to develop partnerships with cities to enhance capacity and demonstrate pathways. In South Africa the UWR is being applied in collaboration with the South Africa Cities Network (SACN) in Johannesburg and Gqeberha. Zutari is providing technical support in both these cities. For Johannesburg, the WRI, SACN and Zutari will additionally be supported by Arup and the Resilient Cities Network (R-Cities) to develop an assessment of water resilience. This will be developed in close partnership with the city stakeholders using the City Water Resilience Approach (CWRA).



- A coalition that endorses a Practice Shift of new Priorities & Principles for UWR in Africa
- A fund that invests in low carbon resilient water solutions enhancing proof of concept for innovative solutions and financing in water
- Project design & structuring, feasibility studies, business models, bankable resilience projects, follow-on investment for implementation
- Developing strategic UWR plans at city-region scale, identifying a pipeline of opportunities; the RIGHT solutions, the RIGHT priorities

Figure 1.

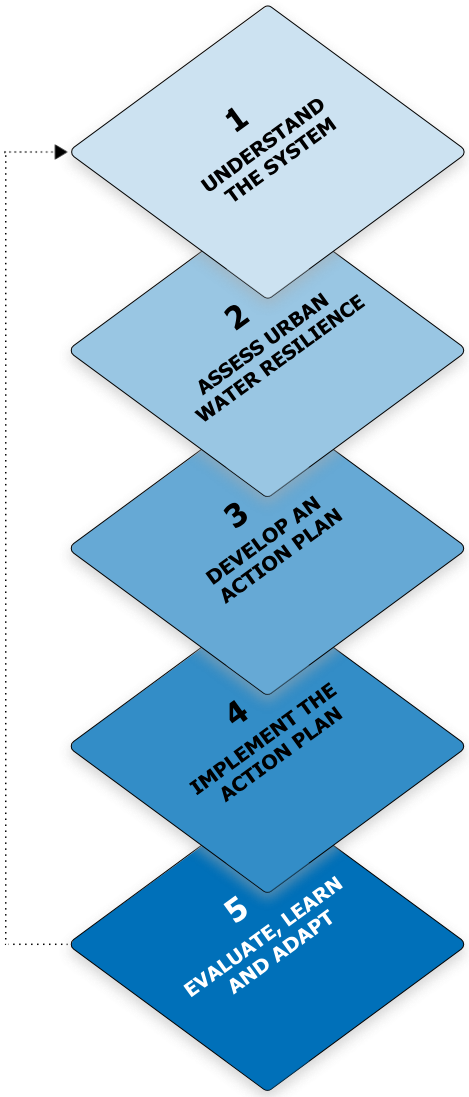
Overview of the outcomes of the key components of the WRI's Urban Water Resilience in Africa initiative

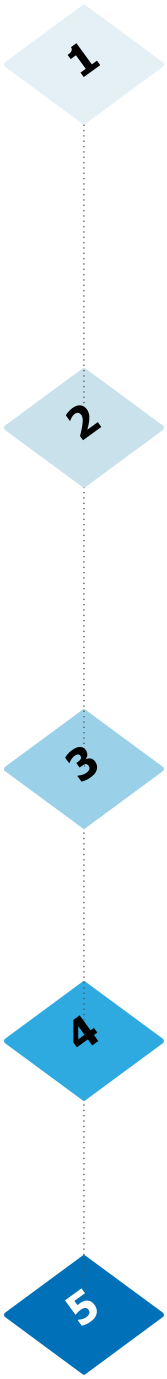
12.2 CITY WATER RESILIENCE APPROACH (CWRA)

The City Water Resilience Approach (CWRA) (Figure 2) responds to a demand for new approaches and tools that help cities grow their capacity to provide high quality water resources for all residents, and to protect them from water-related hazards. The CWRA process outlines a path for developing urban water resilience and provides a suite of tools to help cities identify, assess, take action to address and ultimately survive and thrive in the face of water-related shocks and stresses.

The CWRA is based on fieldwork and desk research, collaborative partnerships with subject matter experts, and direct engagement with city partners. The approach was developed through investigations in eight cities and consultation with over 700 individual stakeholders by Arup. They worked with the Stockholm International Water Institute (SIWI), 100 Resilient Cities (100RC), the Organization for Economic Co-Operation and Development (OECD), and in close collaboration with city partners from Cape Town, Amman, Mexico City, Greater Miami, and the Beaches, Hull, Rotterdam, Thessaloniki, and Greater Manchester. Each partner city confronts persistent water-related shocks or suffers chronic water-related stresses and is committed to co-creating water resilience approaches. The cities represent diverse geographies and face a range of shocks and stresses in various socio-political contexts.

The approach outlines five steps to guide partners through initial stakeholder engagement and baseline assessment, through action planning, implementation, and monitoring of new initiatives that build water resilience:





Step 1: Understand the system
The city's unique context is appraised to understand shocks and stresses, identify system interdependencies, engage local stakeholders to clarify gaps in information, and map key infrastructure and governance processes. This first step of the CWRA process results in the City Characterization Report that summarizes the results of this research. [this report]

Step 2: Assess urban water resilience
The city's current practices are assessed using the City Water Resilience Framework to identify areas of existing strength and weaknesses and establish a baseline against which progress is measured. This second step results in a City Water Resilience Profile, which summarizes the assessment process and outlines potential actions to build resilience.

Step 3: Develop an action plan
Based on the city assessment, an action plan is developed for realizing interventions that build water resilience. The action plan is based on a holistic evaluation of anticipated benefits and costs and prioritization of projects identified in the previous step.

Step 4: Implement the action plan
Actions agreed upon during the previous step are implemented according to best practices. In this step, the CWRA provides best practice guidance for how ongoing actions can be monitored to ensure objectives are met, and resources are used appropriately.

Step 5: Evaluate, learn and adapt
Implementation is evaluated. Adjustments are made to the implementation plan to account for new developments or changing circumstances in the city, and to align with updated objectives for the next period.

To guide cities through this process, the CWRA offers a suite of resources that target specific challenges identified by cities in their efforts to build water resilience:

OURWATER

OurWater is a digital tool that helps cities better understand the types of shocks and stresses they confront, their impact on natural and man-made infrastructural systems, and the interaction between key stakeholders involved in urban water management. The OurWater tool is used in Step 1 of the CWRA to map the infrastructure and governance arrangements that define the urban water system.

THE CITY WATER RESILIENCE FRAMEWORK (CWRF)

CWRF assesses a city's resilience to water-based shocks and stresses and allows the city to identify and prioritize future action. Understanding their resilience helps cities formulate a clear vision of what urban water resilience means to them, including what specific conditions must be in place to achieve this vision, what efforts will be required to build resilience, and what actors are involved. The CWRF is the primary tool used in Step 2 to assess urban water resilience and is the focal point for workshops conducted in the city. The UWR is being implemented in cities based on the City Water Resilience Approach (CWRA) that has been developed by Arup and the Resilience Shift. The CWRA and the main deliverables is shown below on the next page.

It is recognised that each city will be at a different stage in terms of water resilience. As a result, it may be necessary to adapt the above framework based on the local context and existing programs. Proposed adaptions are set as levels to ensure that a holistic set of indicators are used rather than ad hoc selection of indicators that might compromise the whole system view. The CWRA has been applied in the past to Cape Town, another South African city, and lessons learnt from the application of the approach in Cape Town will be considered in the application in Johannesburg where the contexts overlap.

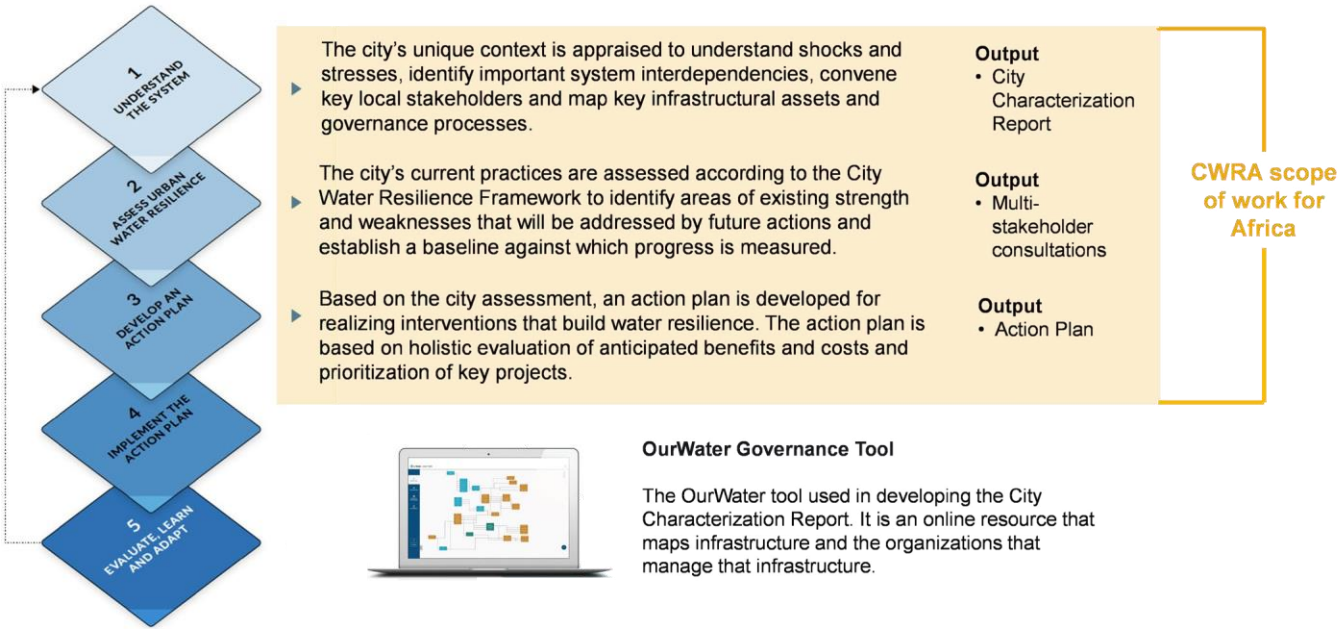


Figure 2.

Overview of the City Water Resilience Approach and its application for the AUWI

12.3 PURPOSE OF THE CITY CHARACTERISATION REPORT

The first step of the CWRA is to understand the local water system and the factors that contribute or detract from resilience described in this document, the City Characterization Report. This report details research undertaken in Johannesburg to:

1. Define the city water basins, the urban water system and its governance structure, and the interdependencies with other systems
2. Identify the factors impacting the resilience of the city's water system and those increasing its vulnerability

The data for this report was collected through extensive desktop research and the authors' collective experience working on water and urban issues in Johannesburg. This report aims to outline what has been done in the city to enable water resilience to date and use this information to adapt the application of the CWRA as is appropriate towards the development of a resilience profile which is the next step in the CWRA methodology.

Diepsloot River, Johannesburg
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2 OVERVIEW OF THE CITY OF JOHANNESBURG

Johannesburg, also known as the City of Gold, is the 'engine room' of South Africa and the SADC region and most advanced commercial city in Southern Africa (COGTA, 2020). Johannesburg has grown into a global cosmopolitan city with key connections to Southern Africa, Africa and the world (City of Johannesburg, 2016). The tertiary sector dominated economy of Johannesburg is vital to the country, as the single largest metropolitan contributor, contributing 16% nationally and 40% to Gauteng (COGTA, 2020).

The City of Johannesburg (CoJ) Metropolitan Municipality serves as the local governing entity and is the largest of the eight metros in South Africa. Johannesburg is home to approximately 5.6 million people, almost 10% of the population of South Africa covering an area of 1 644 square kilometres with a moderate population density of 3 425 per square kilometre.

Johannesburg is imprinted with the spatial inequalities left by the legacy of apartheid which affect not only the racial diversity in the city but also the socio-economic landscape making it the second most unequal society in the world with the stark contrasts between the northern affluent suburbs and its impoverished southern counterpart. As a major economic hub, the CoJ also suffers from high levels of in-migration and inequality with a large portion of the population living in informal settlements (19.1%) with limited to no access to basic services such as water supply, sanitation, electricity and refuse removal.

Johannesburg
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Being home to the world's largest urban forest, Johannesburg is one of the ten greenest cities in the world. However, the city has lost majority of its indigenous grasslands and is dominated by colonial imported alien invasive species. The green infrastructure of the city is under constant threat due to the extreme growth pressure faced by the city due to population growth and urbanisation from in-migration within South Africa and migration from other parts of Africa.

As a result of its topographic location, Johannesburg does not lie on a significant water source and is heavily reliant on water supply from the Integrated Vaal River System (IVRS) that is supplemented by the Lesotho Highlands Water Project (LHWP) from the neighbouring Kingdom of Lesotho. A failure to maintain wastewater treatment works for the CoJ and surrounding municipalities has contributed to serious pollution concerns in the urban rivers affecting many downstream users. Due to the economic significance of the city and the critical risk of water insecurity due to poor water management, supply reliance on an international entity, climate change impacts, urbanisation and population growth, Johannesburg is in need of building water resilience to ensure minimal disruption in the face of key shocks and stresses that impact the city.

2.1 LOCATION

Johannesburg is located within the province of Gauteng in South Africa (Figure 3 & 4). "Gauteng" means "place of gold" in the Sotho-Tswana languages due to the discovery of gold that led to the founding of the area. Gauteng is the smallest province in South Africa and accounts for only 1.5% of the land however it the most populous and wealthiest province and contains Tshwane, the administrative capital of the country. Gauteng is divided into three metropolitan municipalities: City of Johannesburg, City of Tshwane and City of Ekurhuleni; and two district municipalities which oversee local municipalities: Sedibeng (Emfuleni, Midvaal and Lesedi) and West Rand (Mogale City, Merafong City, Rand West City (culmination of Randfontein & Westonaria)).

Figure 3.
City of Johannesburg laocation (COGTA, 2020)

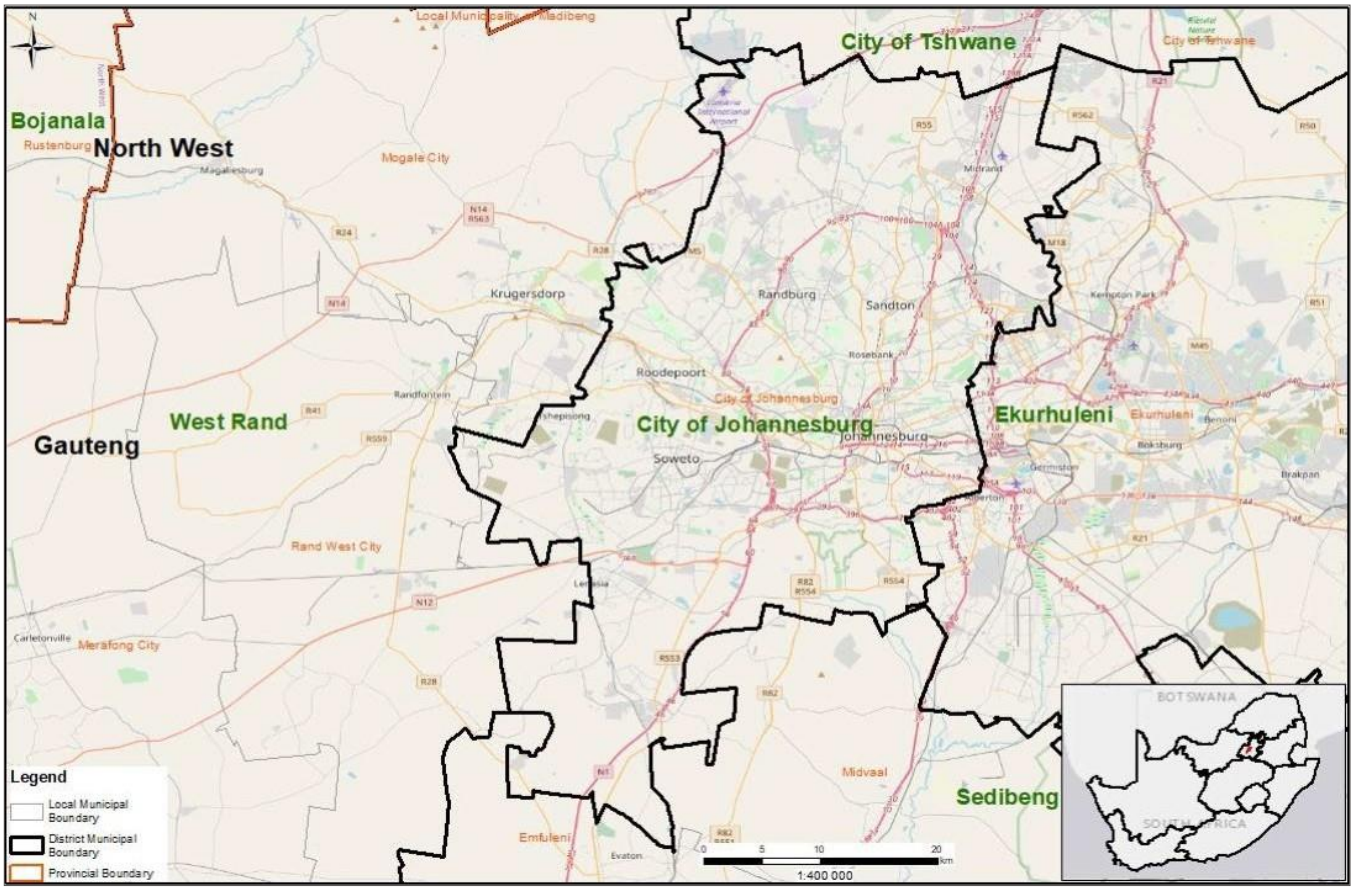
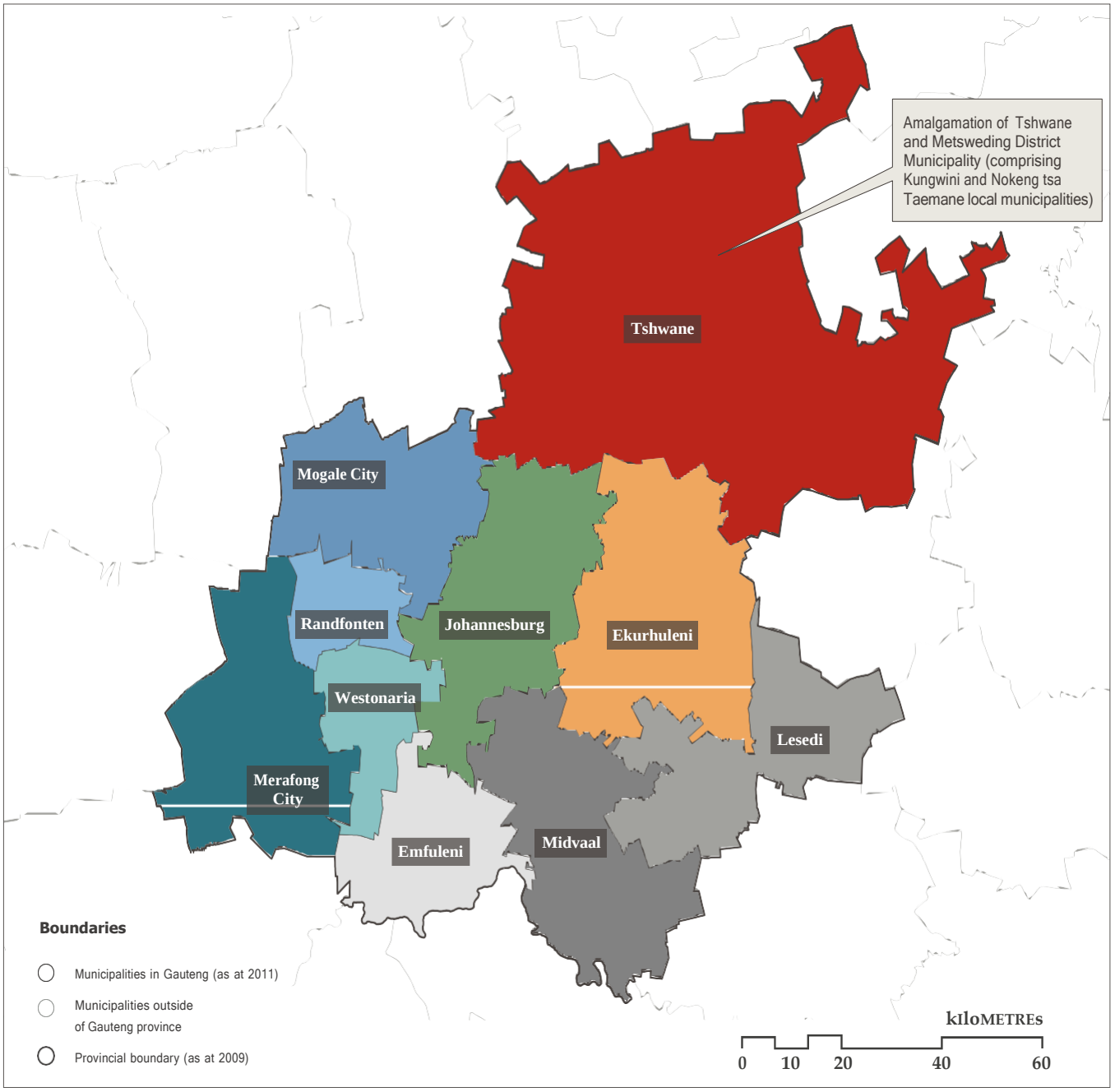


Figure 4.
Map of Gauteng Municipalities (Mkhize and Khanyile, 2020)



Data Source
MDB (2001) Local municipalities; StatsSA (2001) Provinces; MDB (2006) Local municipalities; MDB (2006) District municipalities; MDB (2009) Local municipalities; MDB (2009) District municipalities; MDB (2009) Provinces; MDB (2011) Local municipalities; MDB (2011) Provinces; IEC (2016) Local municipalities

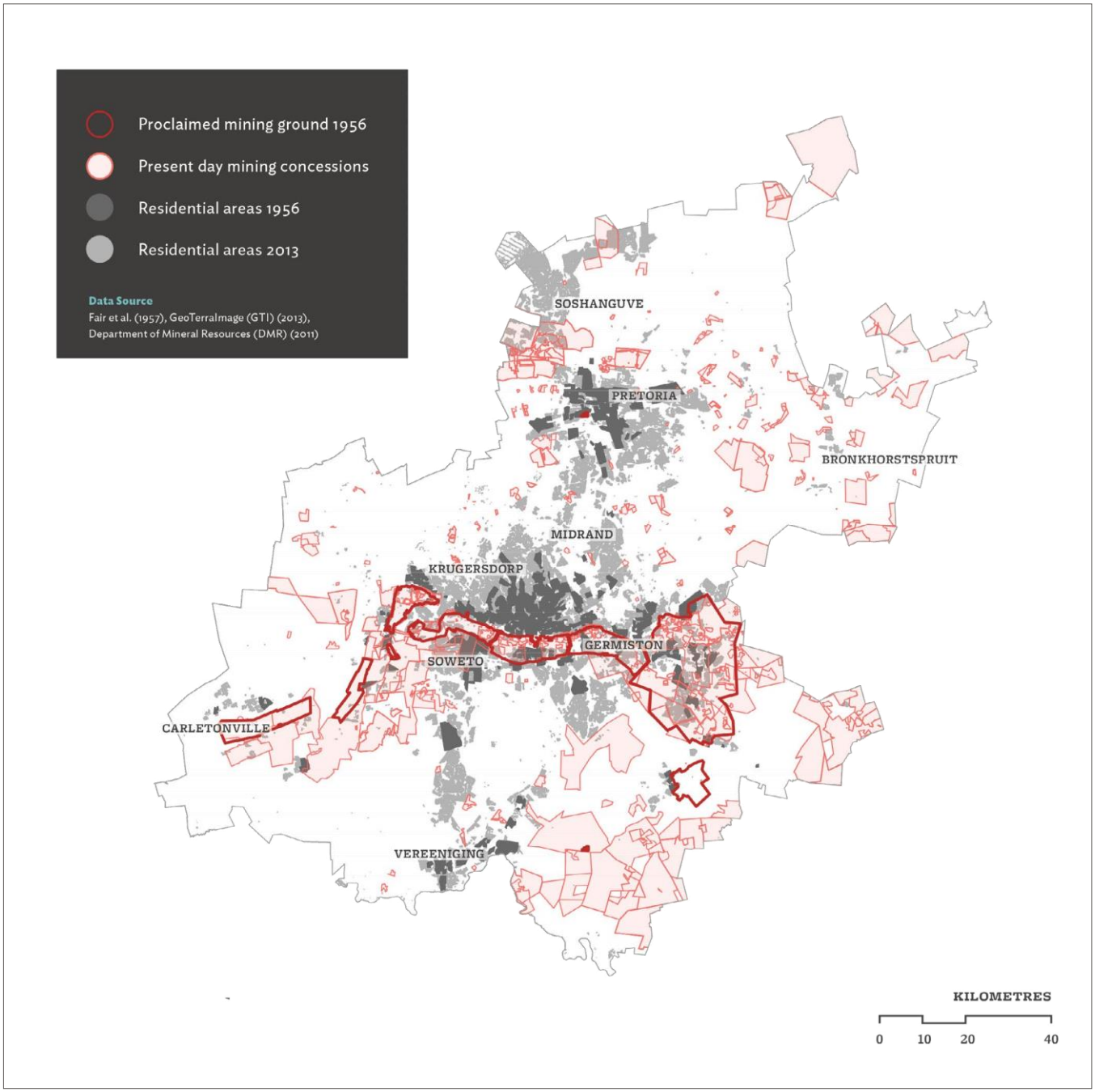
2.2 URBAN DEVELOPMENT

The discovery of gold in the territory of the Zuid Afrikaanse Republiek (ZAR) in 1886 led to the initial establishment of a mining camp that subsequently was subject to rapid urban development from prospective miners both domestically and internationally developing into the "Witwatersrand" of which includes the East Rand, Central Witwatersrand (Johannesburg, Germiston, Alberton, Kempton Park and Edenvale) and West Rand (Mubiwa and Annegarn, 2013). Through the enforcement of government levied compulsory cash taxes on all adult males, rural indigenous African males were forced to seek employment in the mining towns further expanding the population (Mubiwa and Annegarn, 2013). Transport infrastructure and land use-patterns were influenced by mining where towns subsequently developed along major transport routes (modern day Main Reef Road, the Soweto highway and the M2 highway) (Mubiwa and Annegarn, 2013). Between 1900-1910 there was substantial growth in residential suburbs to north of the Witwatersrand Ridge while all mining activities were concentrated on the southern slopes of the ridge (Figure 5). Prior to the introduction of apartheid there was colonial racial segregation planning focusing on separate development between races preventing certain races from purchasing land outside areas that had been designated for them (Native Urban Areas Act of 1923) (Mubiwa and Annegarn, 2013).

The second wave of northward expansion occurred in the late 1930s and post-World War II coinciding with the motor vehicle increasing the accessibility of the northern suburb residents working in the south. Without a public transport option to services these commuters, they became dependent on private vehicles for transport requiring the construction of a road network – a commute continuing to the present day resulting in the infamous traffic congestion of the city (Mubiwa and Annegarn, 2013). The mid 1940s to late 1950s witnessed significant growth in industrialisation and urbanisation bringing about the establishment of industrial towns with the State initiated interventions of the development of new steel and petrochemical industries to transform South Africa into a modern industrial economy (Mubiwa and Annegarn, 2013).
The land-use structure was fundamentally transformed with the advent of apartheid in 1948 when the Nationalist Party came into power and introduced discriminatory racial segregation (apartheid) legislation (e.g. the Bantu Urban Areas Consolidation Act 25 of 1945 and the Group Areas Act 41 of 1950) (Mubiwa and Annegarn, 2013). The implications were that "citizens were separated into so-called 'White', 'Bantu', 'Coloured' and 'Asian' precincts, separated by buffer strips of at least 100 m wide, or by distinct industrial or environmental buffer zones" (Mubiwa and Annegarn, 2013) and "non-white" citizens were forcibly moved from inner city suburbs to settlements established on urban peripheries, ultimately widening the spatial configuration of the region and increasing travel distances. It was during this period that Soweto (short for South Western Township) was established for "Bantu" citizens who were forcibly removed from Sophiatown to house low-income Afrikaans-speaking citizens (Mubiwa and Annegarn, 2013) (Figure 6).

Railway lines and a heavily subsidised a commuter bus-service (PUTCO) were established to the townships to maintain the provision of menial labour by "non-whites" (enforced by apartheid laws in the form of racially based job reservation Acts) that served the industrial and commercial economy. Additionally, road access to Black townships were inhibited to control the populations at roadblocks for security related purposes. Properties in townships were State owned and rent out at subsidized rates but not permitted to be owned. The lack of freedom of movement, home ownership, and insecurity of tenure deliberately stifled any normal processes of urban development creating townships into

Figure 5.
Development of human settlements and mining areas from 1956 to 2013 in Gauteng (Khanyile, 2016)



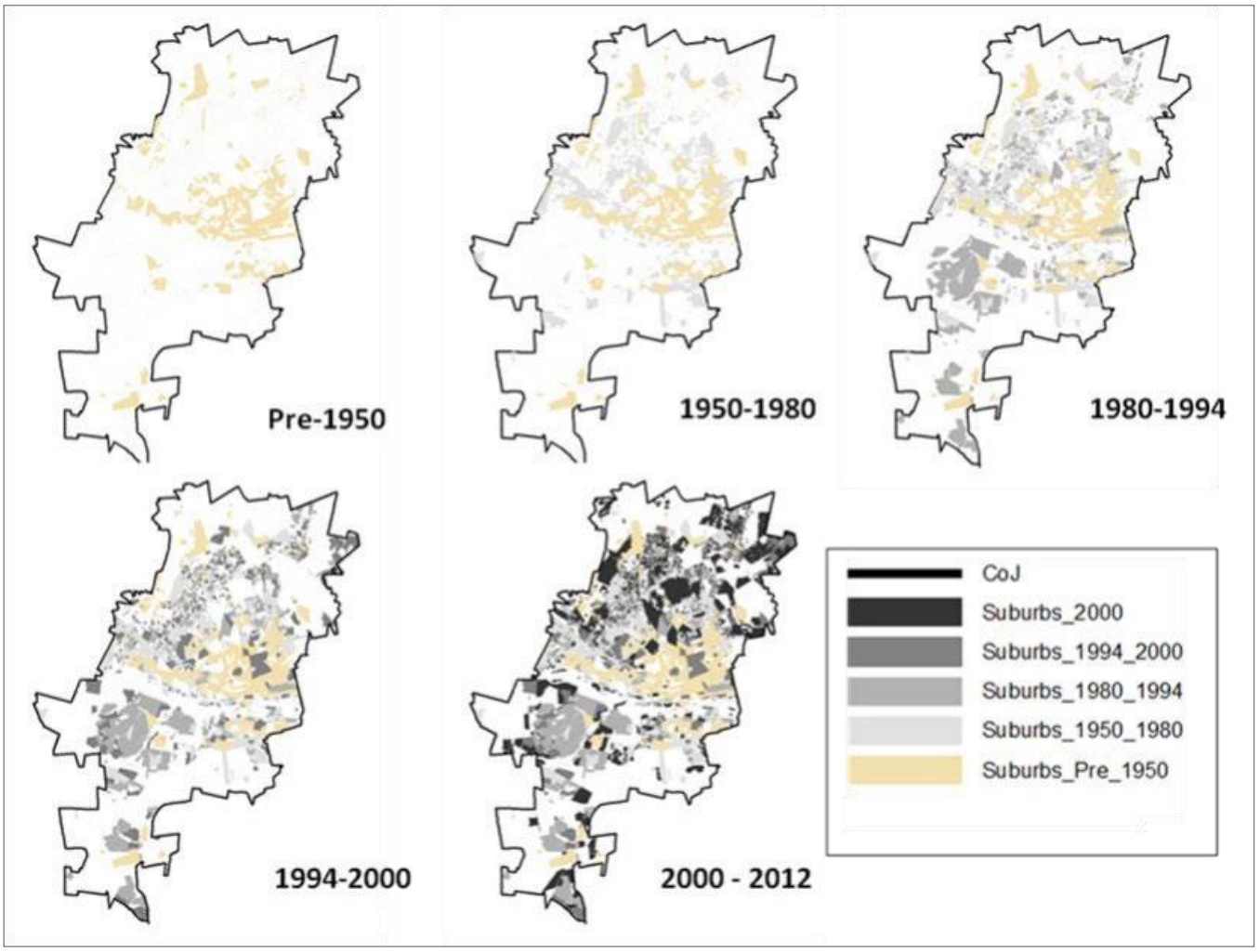


Figure 6.
Spatial pattern of growth of Johannesburg pre-1950 - 2012 (City of Johannesburg, 2016)

temporary residences for labour for the white-owned and controlled economy. Vigorous spatial planning and deliberate industrial policies in the 1960s resulted in an expansion of areas such as Soweto (Bantu), Lenasia (working class Indians) to further separate Black residential communities from the northern affluent white suburbs in pursuit of social and economic race-based segregation and establish isolated industrial parks in areas adjacent to designated 'Black homelands', promoting industrial growth using pools of cheap labour without attracting Blacks into the White urban centres. (Mubiwa and Annegarn, 2013)

The apartheid ideology based on the premise that Black citizens were not a permanent feature of urban life became unsustainable in the mid-eighties when the State was unable to keep up with the housing demand and attempted to transfer responsibility to the already incapacitated provincial and local government. The unfortunate legacy of apartheid and its segregationist regulations are embedded in the spatial footprint of the city with some aspects impossible to retrofit. Even after the democratic election and political transformation of 1994, the unsustainable and inefficient cityscape urban planning including the stark job-housing mismatch, fragmentation and spatial disconnection, urban sprawl and limiting densities, limited land-use diversity and pressure on the natural environment (City of Johannesburg, 2016) persists and continues to be a challenge in the transformation of South African cities into more egalitarian societies. (Mubiwa and Annegarn, 2013)

A significant rural-to-urban migration occurred by the Black population that was previously forcibly kept out of cities and towns with the repeal of the Group Areas Act in 1991 (and

other discriminatory legislation at South Africa's political dispensation in 1994). Although programmes were introduced to upgrade and integrate existing townships as well as redress previous discriminatory housing policies (under the Reconstruction and Development Programme (RDP)), the rate of construction has not matched the demand of the inward migration, natural population growth and the large influx of economic and political refugees from the rest of Africa resulting in numerous informal settlements cropping up without formal planning permissions or prior construction of essential infrastructure. (Mubiwa and Annegarn, 2013)

Present day Johannesburg is sub-divided into 7 Regions governed by the City of Johannesburg Metropolitan Municipality labelled from A-G (Figure 7) and characterised below (COGTA, 2020).

Region A (Diepsloot/Midrand) is located in the northern region of Johannesburg and links to the capital city of Tshwane. This region is the packaging and logistics hub for the city's distribution network houses the growing residential area of Midrand as well as the impoverished townships of Diepsloot and Ivory Park.

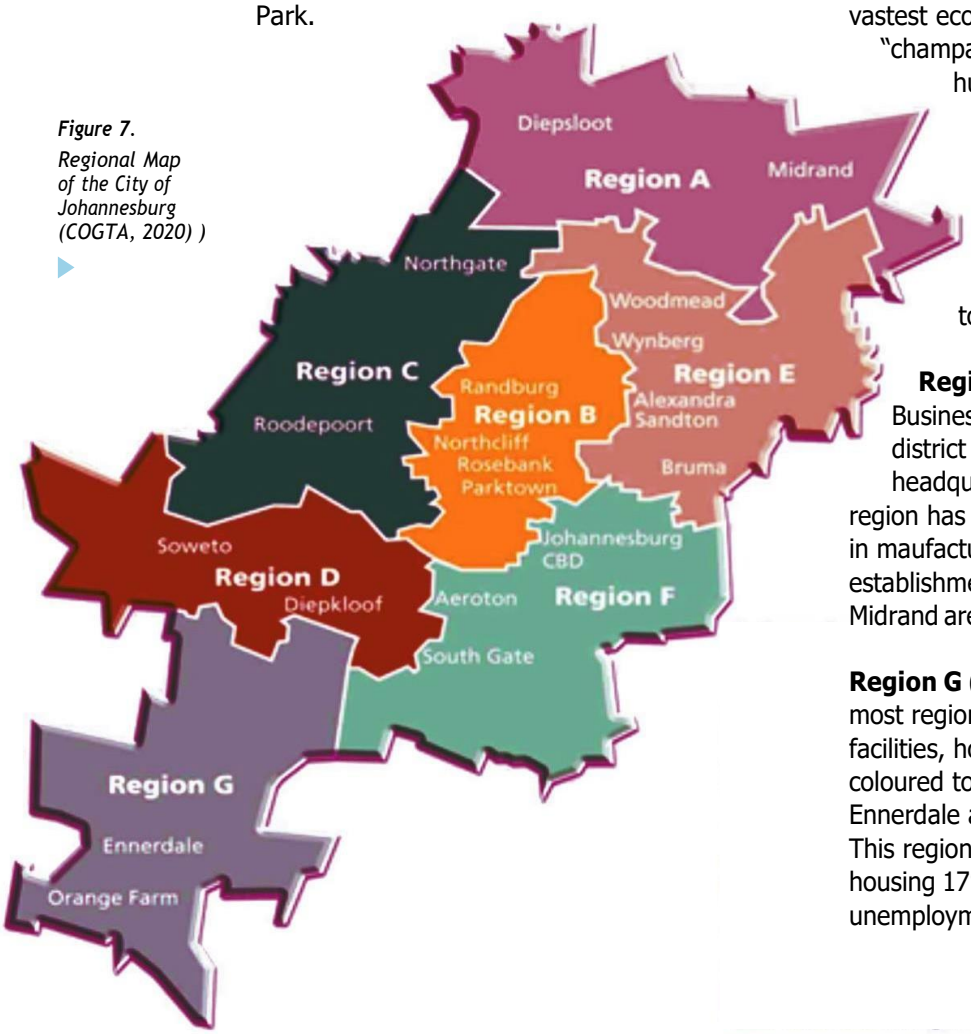


Figure 7. Regional Map of the City of Johannesburg (COGTA, 2020))

Region B (Northcliff/Randburg) is home to the affluent residential suburbs of Parktown, Randburg and Northcliff where some telecomunications and financial services companies are headquarted. The former coloured township of Riverlea is also within Region B.

Region C (Roodenpoort) is located to the west of the city and houses the industrial and warehousing areas as well as the impoverished township of Doornkop. In the apartheid era, this area served as a buffer between the affluent white areas and the concentration of black townships.

Region D (Greater Soweto) is home to the main cluster of black townships including South Africa's largest township, Soweto. This is the most populated part of the city with 24% of the city's population concentrated here however it also has the highest unemployment rate of 43%. This area is also largely industrial and used to formally house mining activities. There is also livestock and agricultural products that are produced here.

Region E (Sandton/Alexandra) houses the vastest economical disparity consisting of the "champagne north" that hosts the financial hub of Sandton with the richest square mile in Africa bordering the oldest and poorest township of Alexandra. This region hosts the Johannesburg Stock Exchange (JSE) contributes the most to the city's economy with finance, retail and warehousing core to the area.

Region F (Inner City) houses the Central Business District which is the financial district for the city with some bank headquarters and government offices. This region has been in decline due to a decline in maufacturing and the exit of JSE with the establishment of Sandton and the upcoming Midrand area.

Region G (Ennerdale/Orange Farm) is the south most region with small holdings and storage facilities, home to the middle income formerly coloured townships of Eldorado Park and Ennerdale and the Indian township of Lenasia. This region is the second most populated are housing 17% of the city's population with a 28% unemployment rate.

2.3 TOPOGRAPHY

Johannesburg is located on a plateau termed the "Highveld" at an elevation of 1,753m above sea level. The Central Business District is located in Region F on the "Witwatersrand" a ridge that falls to the north and the south. For the CoJ, water security has always been a challenge as it is the only major city in the world not located near a significant water source (CoJ, 2011).

In fact, it is situated on a watershed that separates two water catchment areas; the Crocodile River Catchment, housing the Limpopo River to the North that flows into the Indian Ocean and the Vaal River Catchment housing the Orange River towards the South that feeds the South Atlantic Ocean.

Figure 8a.
The water catchment areas In Gauteng (GCRO, 2018).

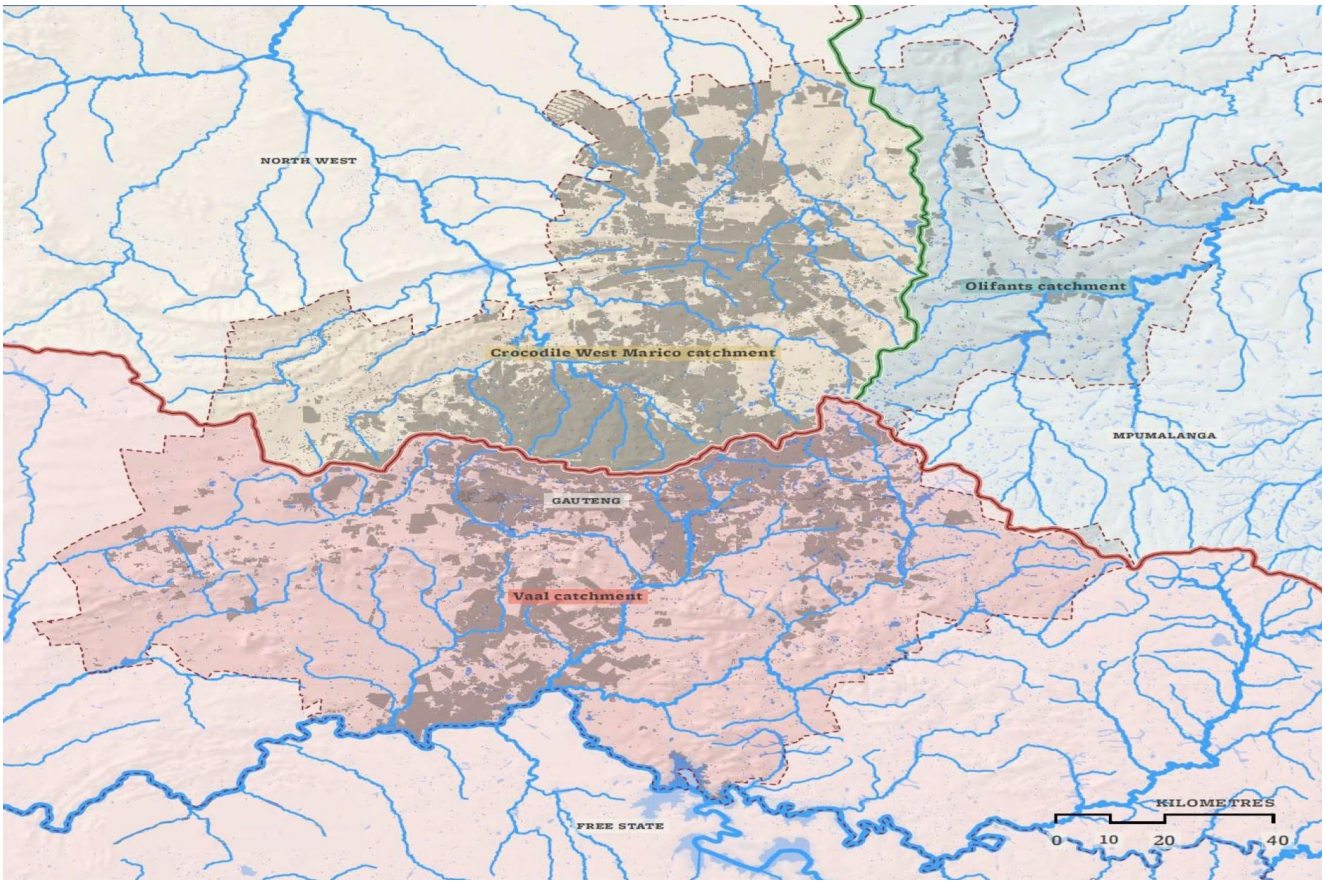
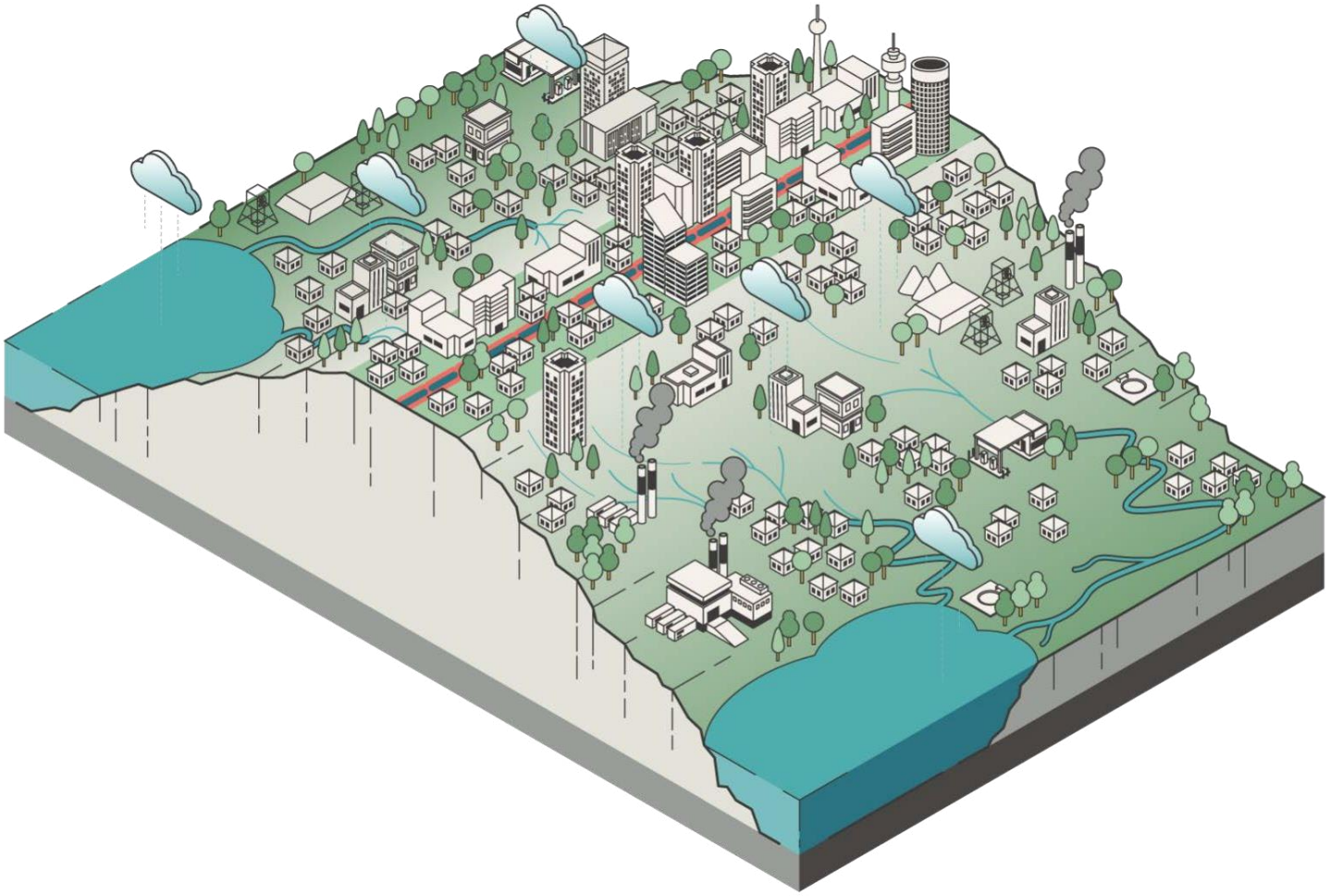


Figure 8b.

Illustration of the Witwatersrand mountain ridge showing the direction of surface water flow (GCRO, 2018).



2.4 GREEN INFRASTRUCTURE

Green Infrastructure is defined as "the interconnected set of natural and man-made ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing services and strategic functions in the same way as traditional 'hard' infrastructure." (Schäffler et al., 2013). There are numerous benefits to green infrastructure that result in providing urban services and improving public health in urban environments such as improved air quality and noise reduction, micro-climate regulation (heat-stress reduction), flood risk mitigation and storm surge protection, an increase in property values, provision of recreational spaces, water infiltration and supply, and improved food security with substantial evidence gathered in recent years highlighting that green spaces positively contribute to the liveability of urban environments and an improved quality of life for inhabitants (Culwick et al., 2019).

Prior to the gold-mining boom in Johannesburg, the Witwatersrand was characterised by savannah grassland, scattered bushveld, and some native woodland areas (Schäffler et al., 2013). Subsequently, the CoJ has become the world's largest urban forest, home to approximately 10 million trees (Schäffler et al., 2013) with a tree coverage of 23.6% (Treepedia, no date). Johannesburg's interesting and controversial ecological profile began with the tree-planting boom in the late 1800's for timber to support mining activities and to combat the effects of mining that resulted in poor quality air (Schäffler et al., 2013). Even though indigenous trees met the initial timber demand, private landowners and mining companies invested in large-scale non-indigenous timber plantations which included quick-growing species such as Eucalyptus, Black Wattle and Jacaranda from places like Australia that colonials were familiar with, fundamentally transforming the landscape of Johannesburg (Schäffler et al., 2013). The transformation of the landscape was further enhanced through the creation of nurseries and the Horticultural Training Centre at Zoo Lake, conducting experiments of mass tree planting, and giving residents trees for domestic use resulting in a variety of green spaces

Figure 9.
Mature tree coverage split between indigenous and non-natural (left) and mature tree coverage including all trees (right) (Schäffler et al., 2013)

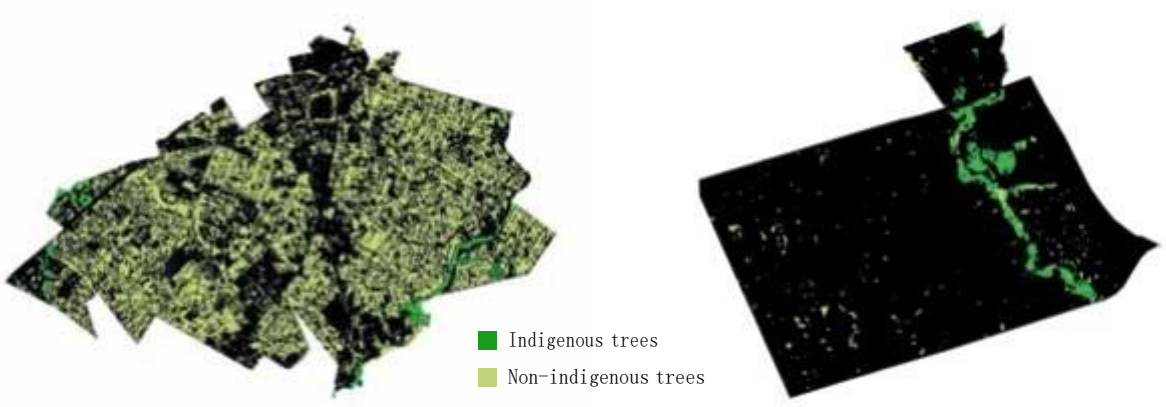


Figure 10.
Tree coverage for Bryanston (left) vs tree coverage in Alexandra (right) (Schäffler et al., 2013)

Tree-planting has its roots in the country's colonial and apartheid history being tied to political, socio-economic and ideological forces (Culwick et al., 2019) that resulted in an uneven distributed throughout the city with distinct differences in tree coverage between the affluent north (24.2% tree coverage) and its impoverished southern counterpart (6.7% tree coverage), also known as the "green divide" (Figure 9) (Schäffler et al., 2013). This divide is clearly demonstrated in Figure 10 below showing the significant non-indigenous tree coverage for Bryanston, a typical northern affluent suburb contrasted with the sparse indigenous vegetation in Alexandra, the city's poorest informal settlement.

There are a number of initiatives undertaken by City Parks to reduce ecological disparity and ideas of environmental justice by 'bridging the green divide' resulting from a 'legacy of inequality separating the wealthy north from the dusty south-west' by providing inclusive open spaces and serves all the people of the CoJ and to further their vision of being "Africa's leading green environment and cemetery management company" (Schäffler et al., 2013). These initiatives include environmental education and community participation programmes, such as Arbour Week, 200 000 Tree Planting Campaign, Extreme Park Makeover, Greening Soweto and Outdoor Gyms (Figure 11) (Schäffler et al., 2013).

Figure 11.
All trees and tree planting projects in the CoJ (Schäffler et al., 2013)

In Johannesburg, the total area classified as 'green open space' constitutes 9.7% of the total land area (approximately 15 970 ha) and includes 23 open space types such as parks, nature reserves, riverine areas, and road verges (Figure 12) (Schäffler et al., 2013). Region G (21.3%), Region C (16.3%) and Region F (16%) house the greater proportions of open space due to reduced developmental pressure and location (away from economic activity) whilst Region E (10.2%), Region A (11.1%) and Region B (11.7%) have the lower proportions of open space due to their central locations to economic activity and increased developmental pressure (Schäffler et al., 2013). The manmade or planted green space (gardens, golf courses, non-natural trees) prevails over the natural green space (thicket, bush veld, bush clumps, indigenous forest, shrub lands, degraded natural vegetation and natural land surface) (Schäffler et al., 2013) resulting in the indigenous vegetation dominated by alien invasives which can have potentially negative environmental implications such as very high water demands.

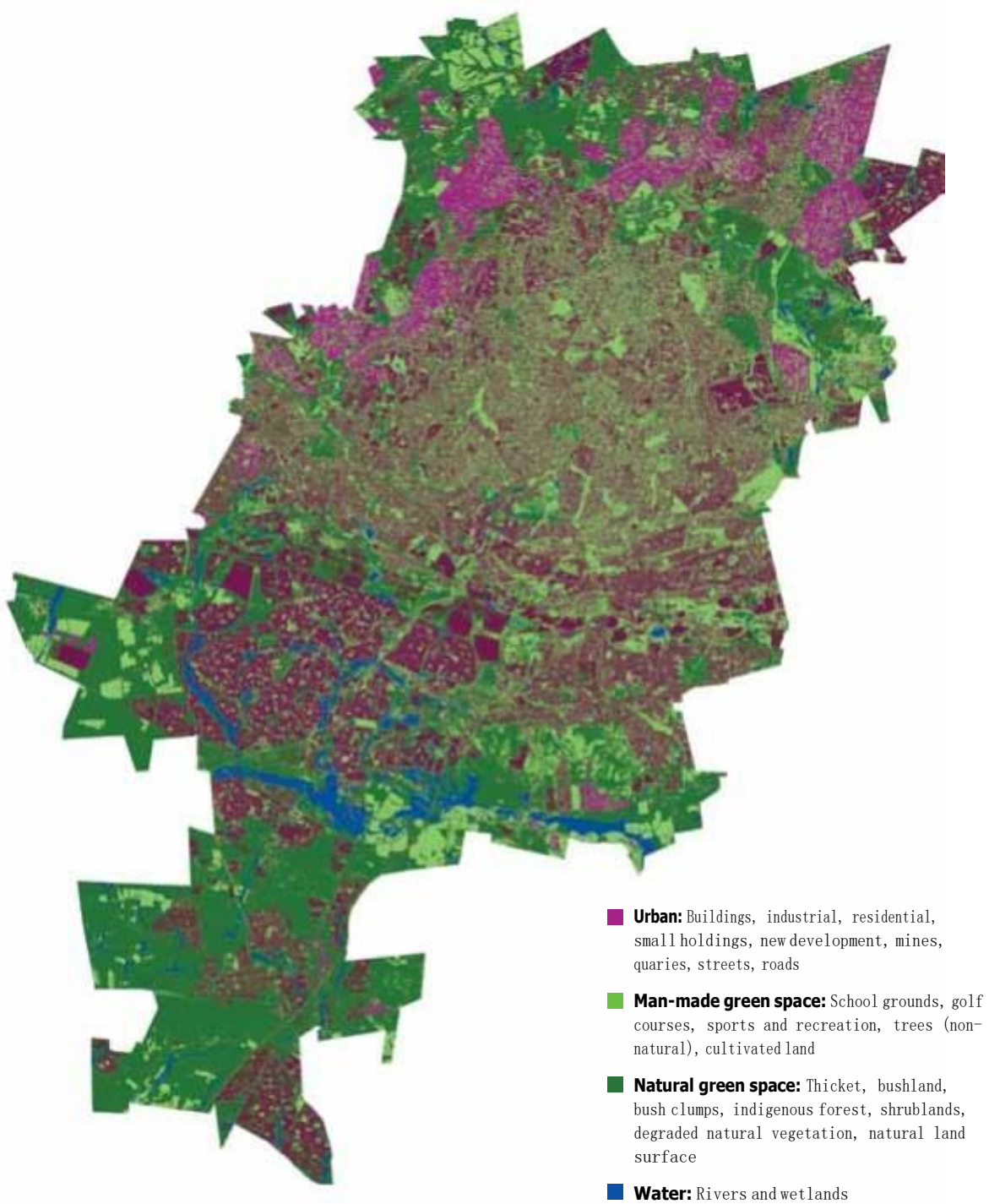


Figure 12. Overview of land cover classes in Johannesburg (Schäffler et al., 2013)

There are standards established to ensure consistency and certainty in urban green space planning in order to bridge the unequal access to urban parks and green spaces by ensuring sufficient access to green spaces and ecosystem services for all urban residents (Culwick et al., 2019), one of which include the standard of 2 ha of green space per 1 000 people in Johannesburg (Schäffler et al., 2013). Figure 13 shows the spatial distribution of Johannesburg City Parks and Zoo-owned land in 2017 (left) highlighting that parks are not equally distributed across the CoJ and are concentrated with the northern affluent suburbs as well as the southern suburbs where significant efforts have been made to green the city but the northern and southern most parts of the city have been neglected. Figure 13 also shows the Johannesburg standard for urban green space planning applied to the wards of the CoJ (right) highlighting that a very select number of wards in the city have sufficient access to green space particularly concentrated with the northern suburbs.

Figure 13.

Spatial distribution of parks across the CoJ (left) and wards above and below 2ha parks per 1000 individuals in the CoJ (right) (Culwick et al., 2019)

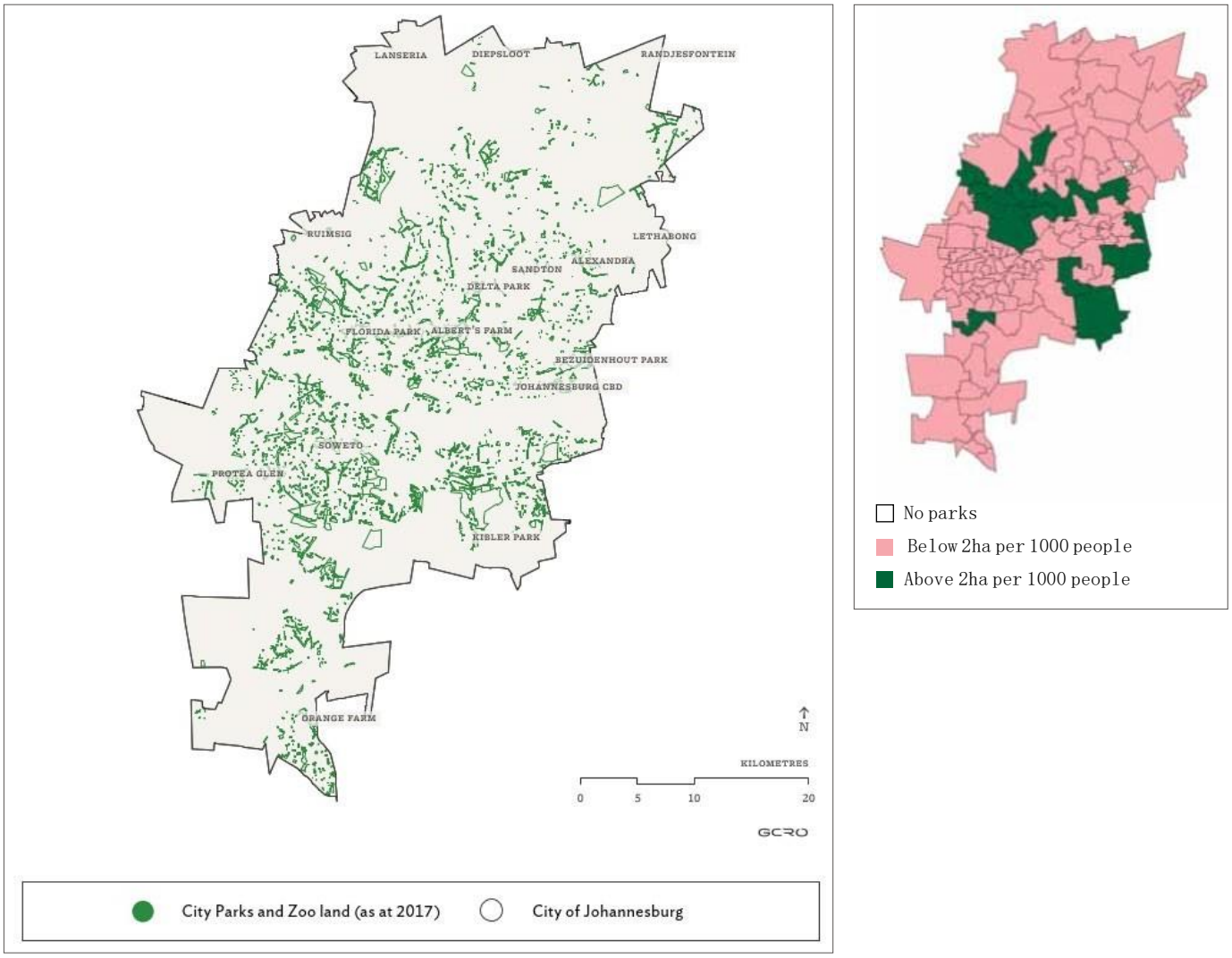
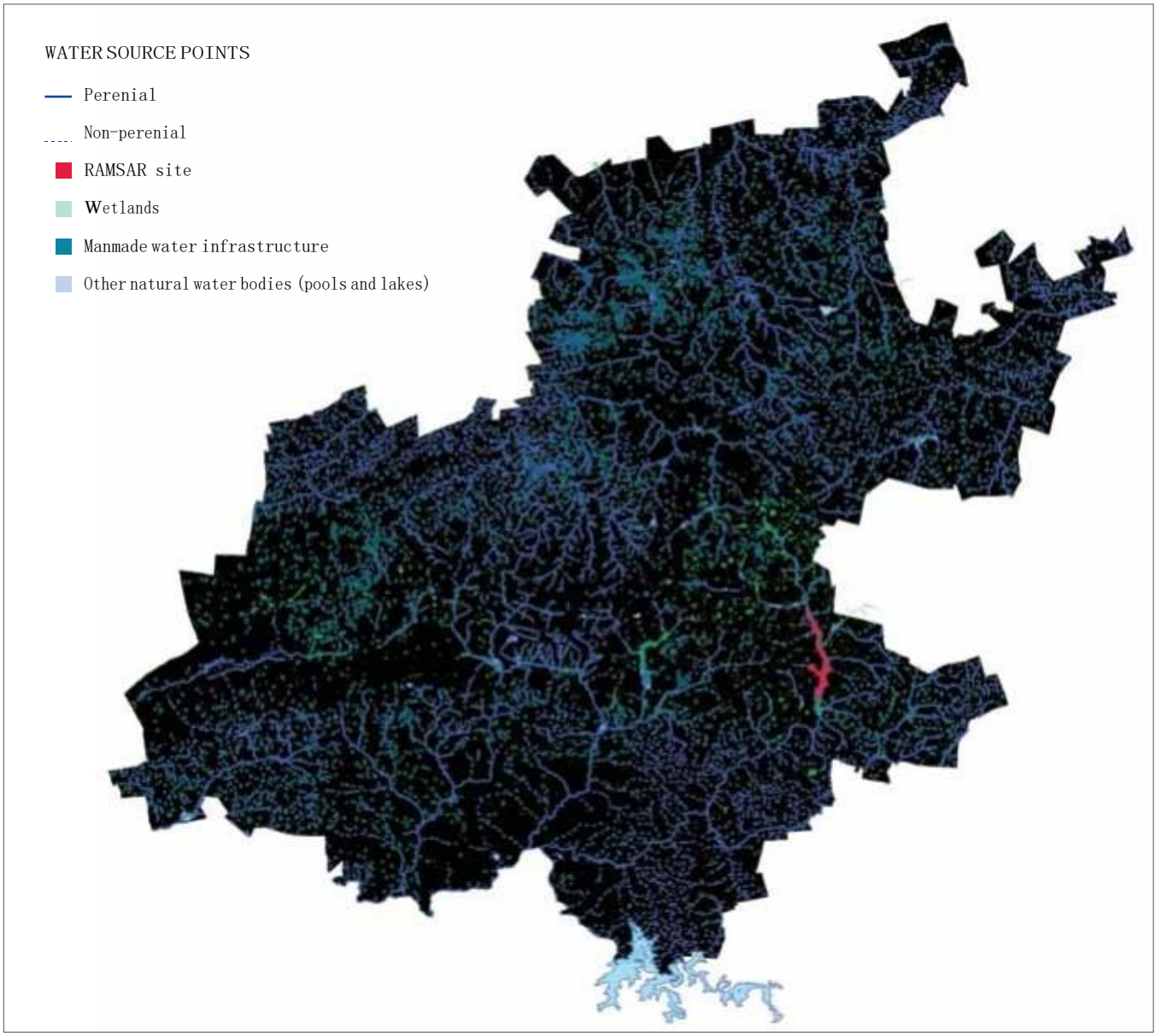


Figure 14 below highlights the hydrological network of Gauteng comprised of hydrological features that are critical to the functioning of ecological processes that benefit humans and the environment (Schäffler et al., 2013). Although South African water policies could be labelled as some of the most progressive in the world, Gauteng's hydrological network is subject to numerous challenges resulting from poor management of natural and man-made hydrological systems and poor implementation and enforcement of water legislation (Schäffler et al., 2013). Being located far from a significant water source, supply and quality dominate the challenges which also include degradation of water bodies, wetlands and various aquatic ecosystems as a result of development and abuse of water legislation (Schäffler et al., 2013). With the majority of its rivers being ranked between a D (large loss of habitat and basic ecosystem functions) to an F (near complete loss of habitat and destroyed ecosystem functions) and all of its 21 wetland types threatened with 13 being critically endangered Johannesburg grapples with poor riverine and wetland health (CoJ, 2021). Water quality is impacted by poor quality wastewater effluent discharges and sewer spills, illegal dumping, land use changes due to development, acid mine drainage (AMD), and pollution of feeder stream and water bodies by mine residue areas (MRAs), subsequently limiting reuse potential by affecting the health of the riverine and wetland systems, affecting the health of natural ecosystems and humans living within close proximity, as well as causing environmental problems for downstream water users (CoJ, 2021) (Schäffler et al., 2013).

Figure 14.
Hydrological networks in Gauteng (Schäffler et al., 2013)

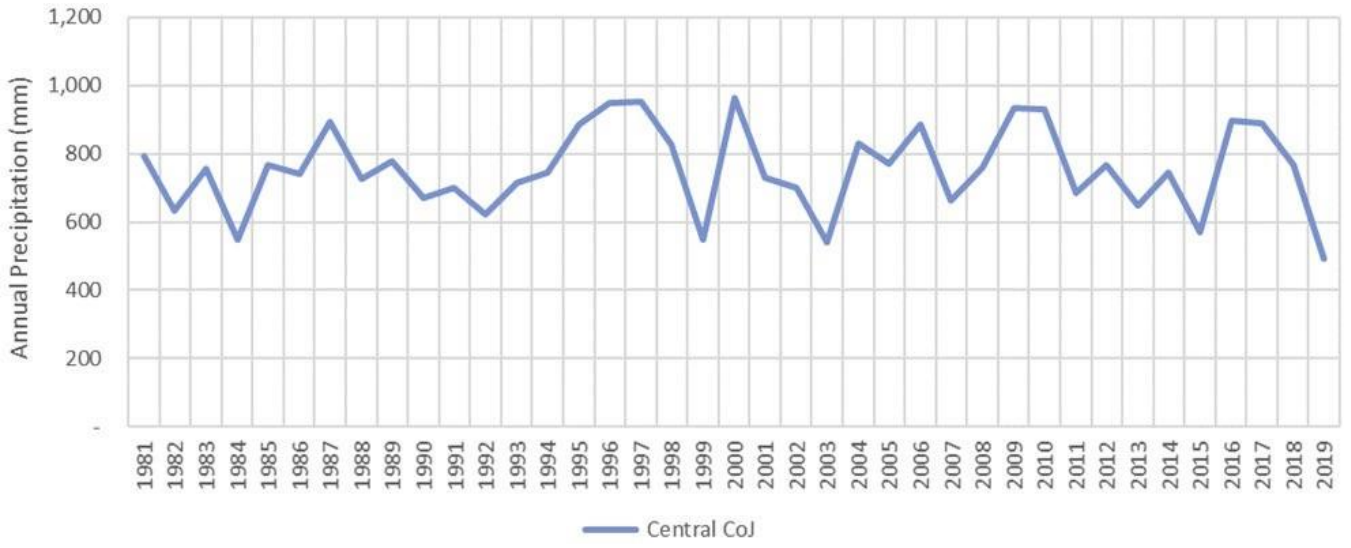


2.5 CLIMATE

The climate of Johannesburg can be described as sub-tropical with mild, sunny winters and warm sunny summers usually accompanied with afternoon thunderstorms. The average temperature ranges from 10°C in the winter to 21°C in the summer. The City is located on a plateau approximately 1,700m above sea level resulting in a climate altered by altitude. The rainfall season occurs during the summer months from October to March and amounts to approximately 700mm per year. (World Climate Guide, no date) The annual precipitation for Johannesburg from 1981 to 2019 is shown in Figure 15 below from where the periods of below than average rainfall can be observed, the latest period being from 2010 – 2016 where the city was subject to water restrictions due to the low dam levels in the Vaal.

With the City being located on a watershed away from any significant water source, the rainfall contributes to catchments in the north and south. With the highly built-up nature of the city making it largely impervious and the significant intensity of precipitation that occurs during thunderstorms, Johannesburg is prone to flash flooding, see 3.5 and 4.1 for more information.

Figure 15.
Annual precipitation for the CoJ (CoJ, 2020)2013)



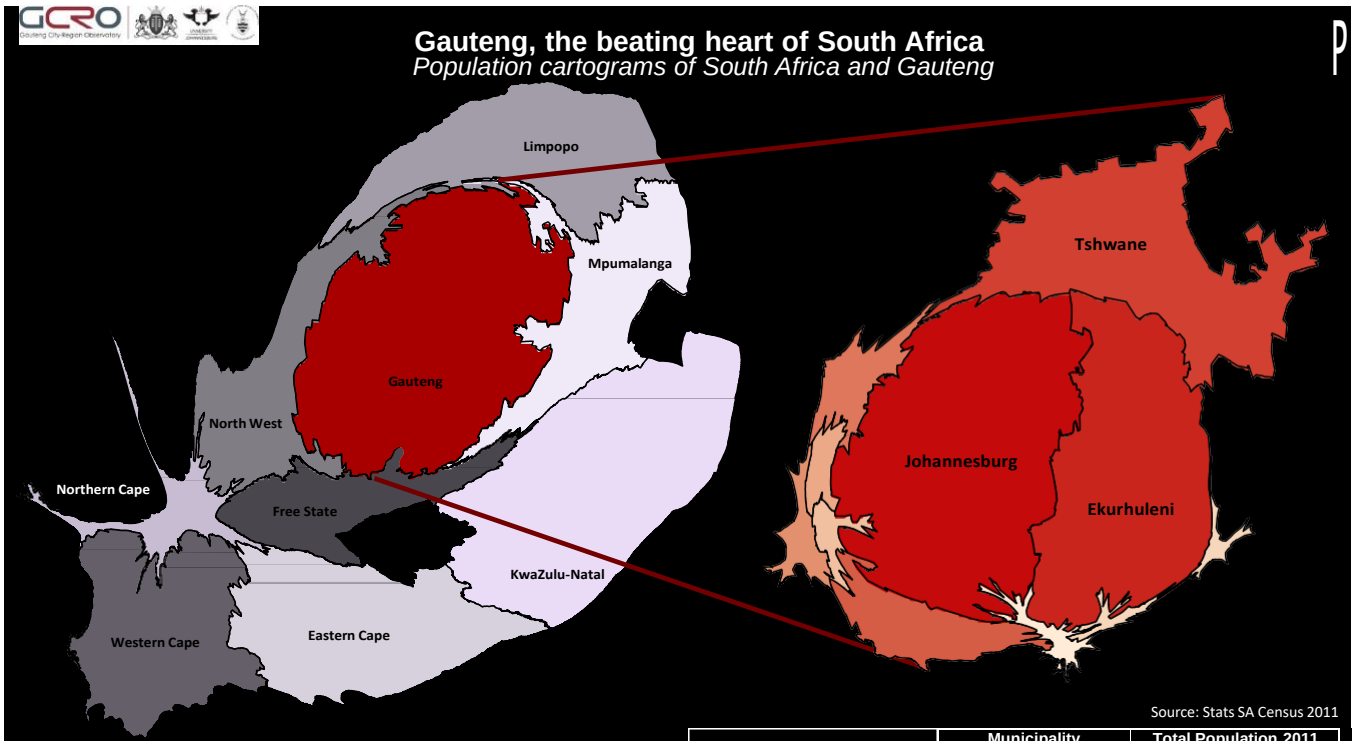
2.6 POPULATION

The CoJ services a population of 5,6 million, almost 10% of South Africa's population, the most populous city in Gauteng, the most populous province in South Africa (Figure 16). The gender split is approximately 49.9% male and 50.1% female with about 40% of the population within the young working age (25-44 years) category (COGTA, 2020).

Johannesburg has an extreme growth pressure indicating the expansion as a result of population growth and urbanisation which often conflicts with its environmental pressures to preserve the natural environment (Engelbrecht et al., 2019).

The population density for Gauteng is highest in Johannesburg (Figure 17) with concentrations highest in the CBD as well as the townships with informal settlements such as Soweto, Diepkloof, Alexandra, Ivory Park and Diepsloot (Figure 18).

Figure 16. *Population cartogram of South Africa & Gauteng (GCRO, 2013c)*



Province	Total Population 2011
Eastern Cape	6 562 053
Free State	2 745 590
Gauteng	12 272 263
KwaZulu-Natal	10 267 300
Limpopo	5 404 868
Mpumalanga	4 039 939
North West	3 509 953
Northern Cape	1 145 861
Western Cape	5 822 734

Municipality	Total Population 2011
City of Johannesburg	4 434 830
City of Tshwane	2 921 490
Ekurhuleni	3 178 470
Emfuleni	721 663
Lesedi	99 520
Merafong City	197 520
Midvaal	95 301
Mogale City	362 422
Randfontein	149 286
Westonaria	111 767

Klien Street, Johannesburg, © Media Club, Flickr

Figure 17.
Population density in Gauteng (GCRO, 2012c)

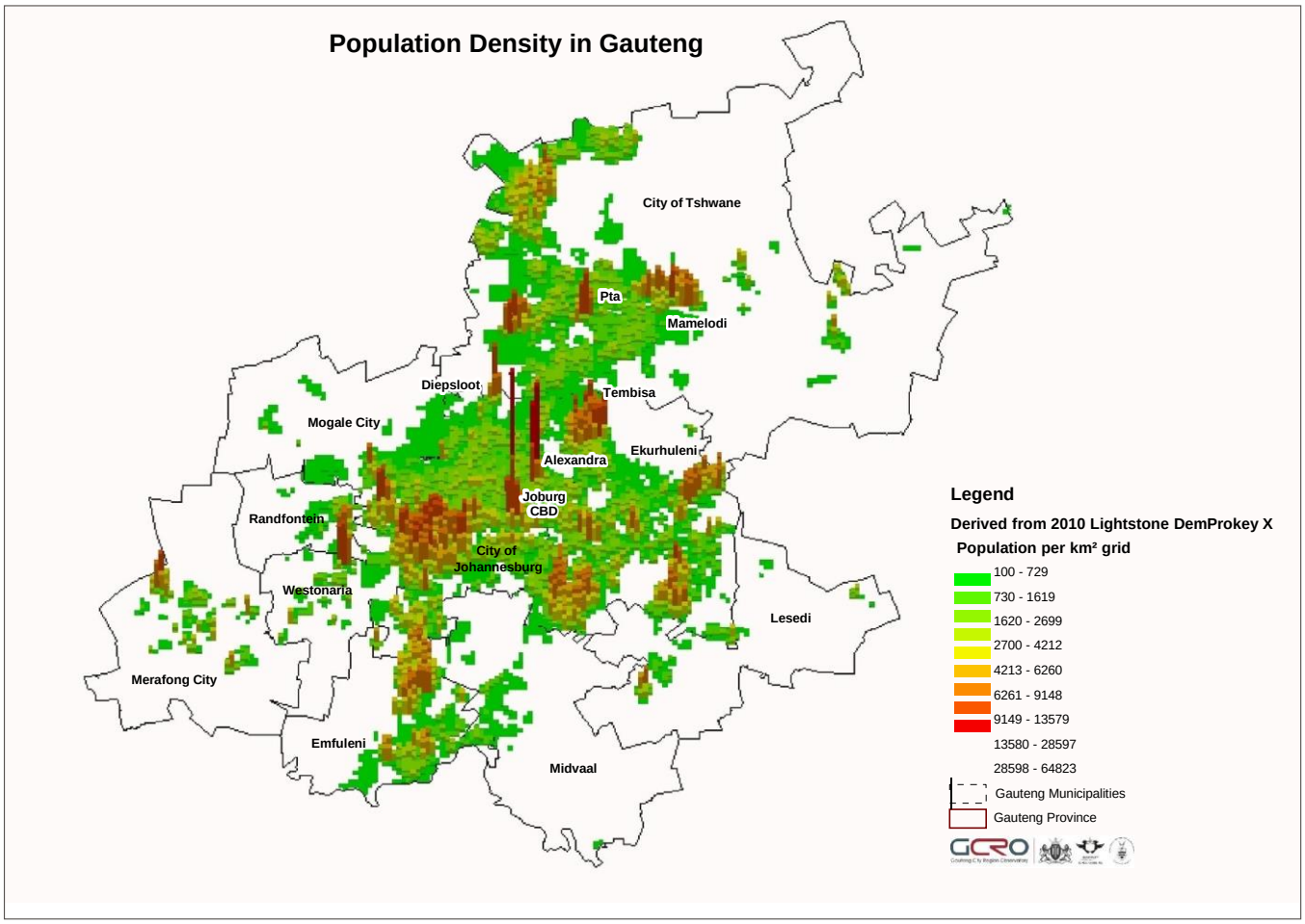
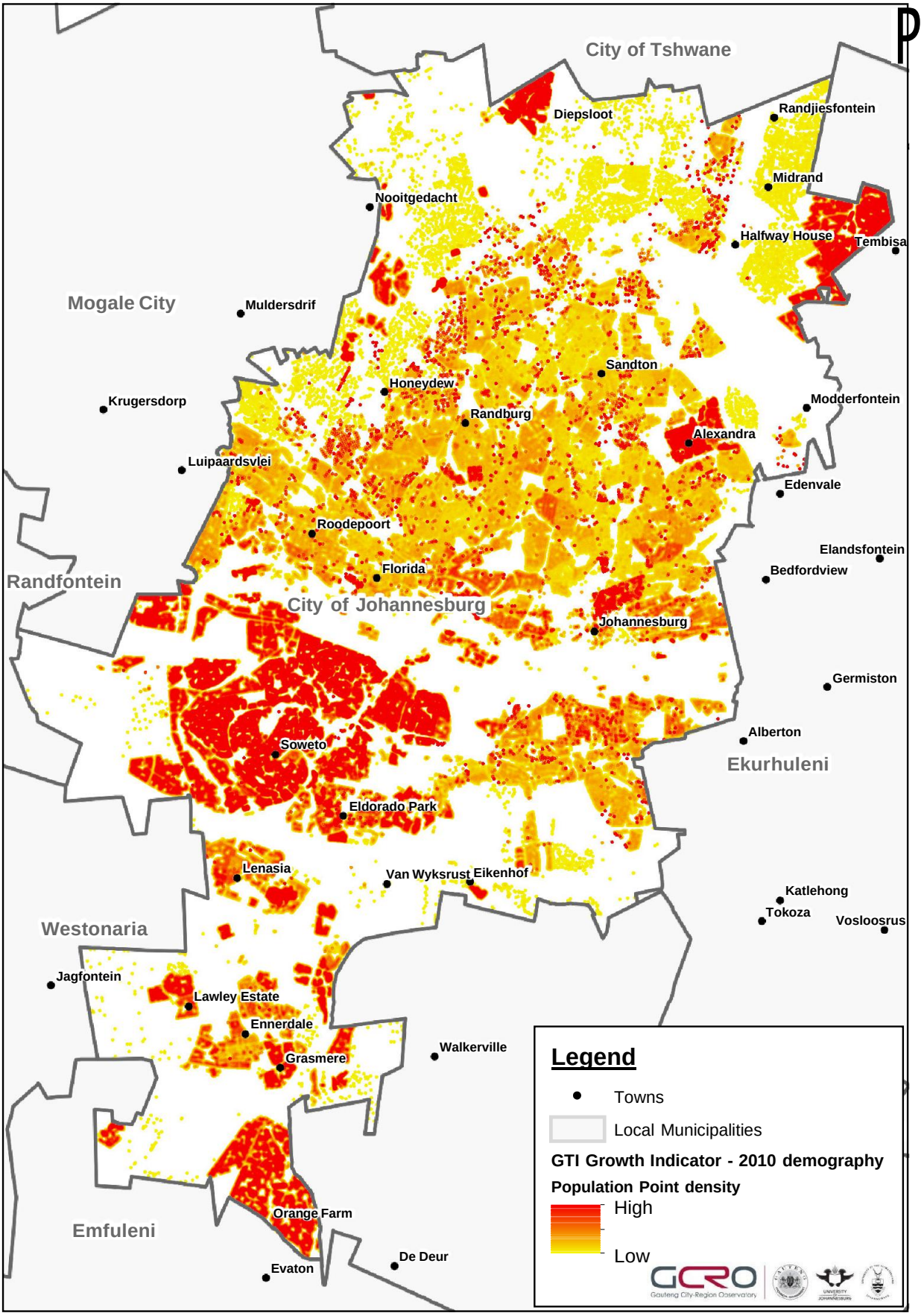


Figure 18.
2010 Population for the City of Johannesburg (Wray, 2011)



With regards to race, the city's population consists of 80.17% Black Africans (4.13 million), 9.79% White (504 000), 5.27% Coloured (272 000) and 4.76% Asian (245 000) people in 2018 (COGTA, 2020). The concentration of black people are still largely within the city's southern poorer areas with high unemployment rates (Soweto) and the concentration of white people are within the northern affluent suburbs (Sandton) (Figure 19). From 1996 to 2018, wards located in the core of Johannesburg have increased in racial diversity whereas wards located in the old township areas (apartheid era) and on the periphery of the city still display low levels of racial integration (Figure 20), these areas include Soweto, Alexandra, Ivory Park and Diepsloot which are still largely dominated by the black African race (Katumba, 2019).

Figure 19.
Gauteng population by race (GCRO, 2013b)

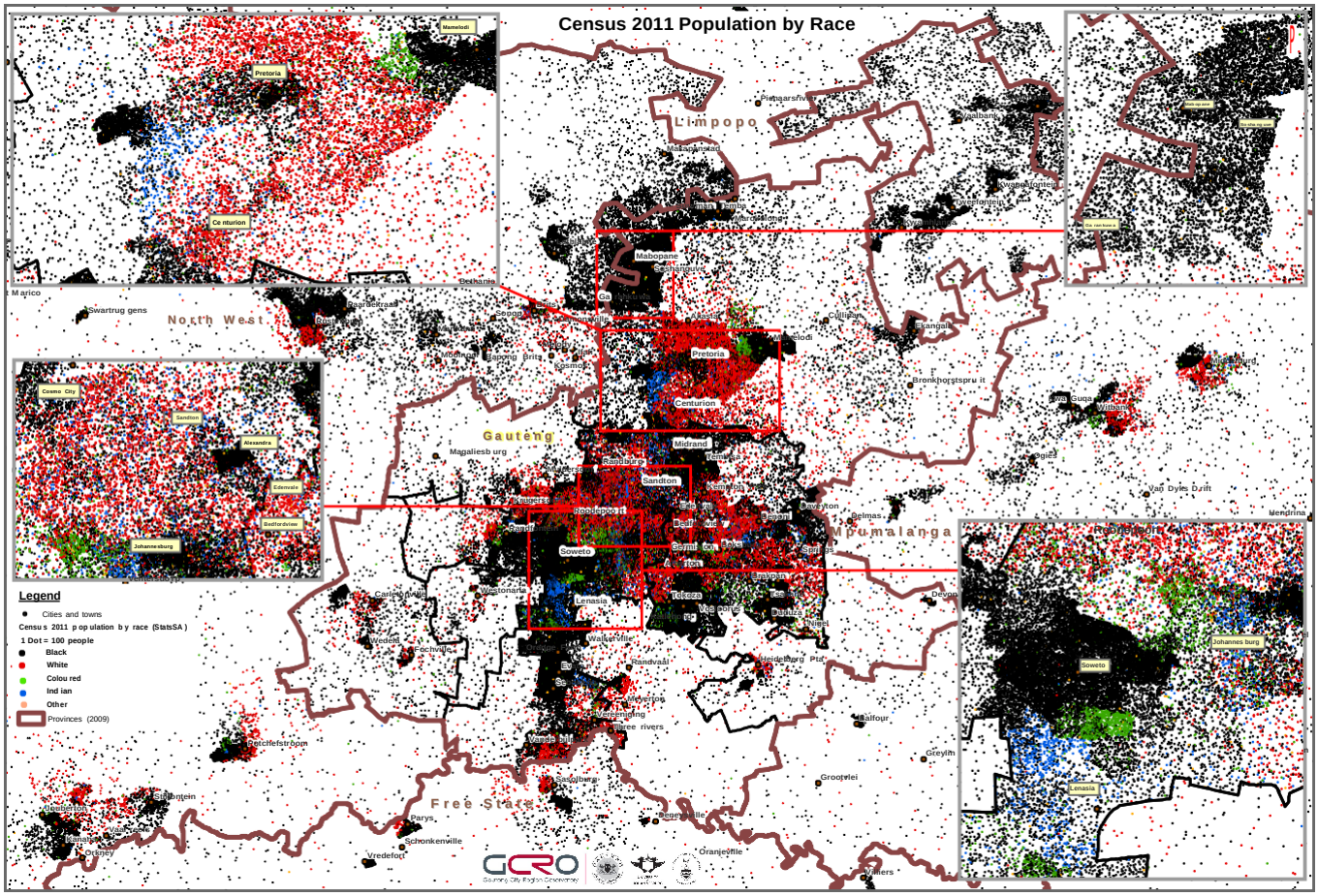


Figure 20a.
Racial diversity across Gauteng
1996 vs 2018 (Katumba, 2019)

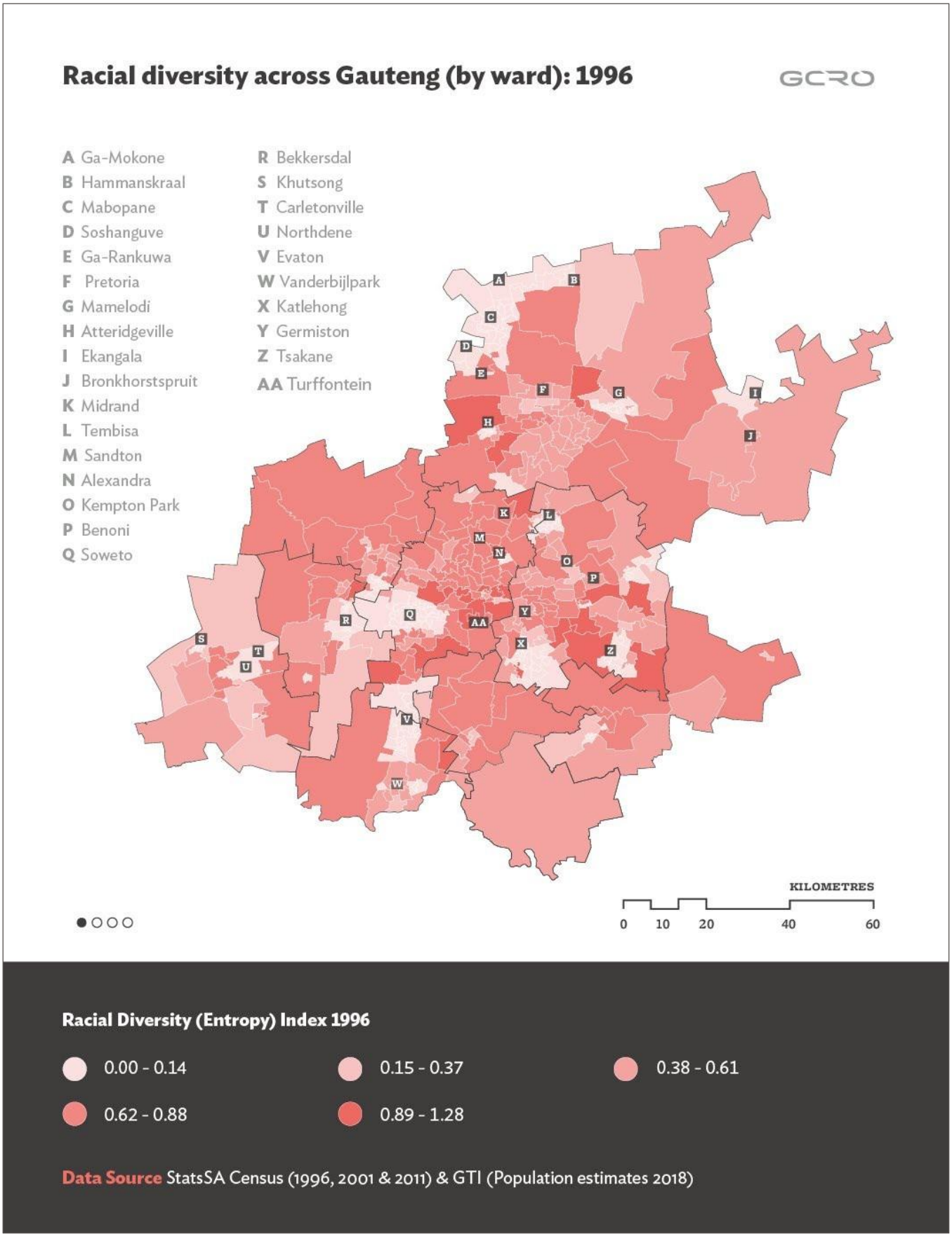
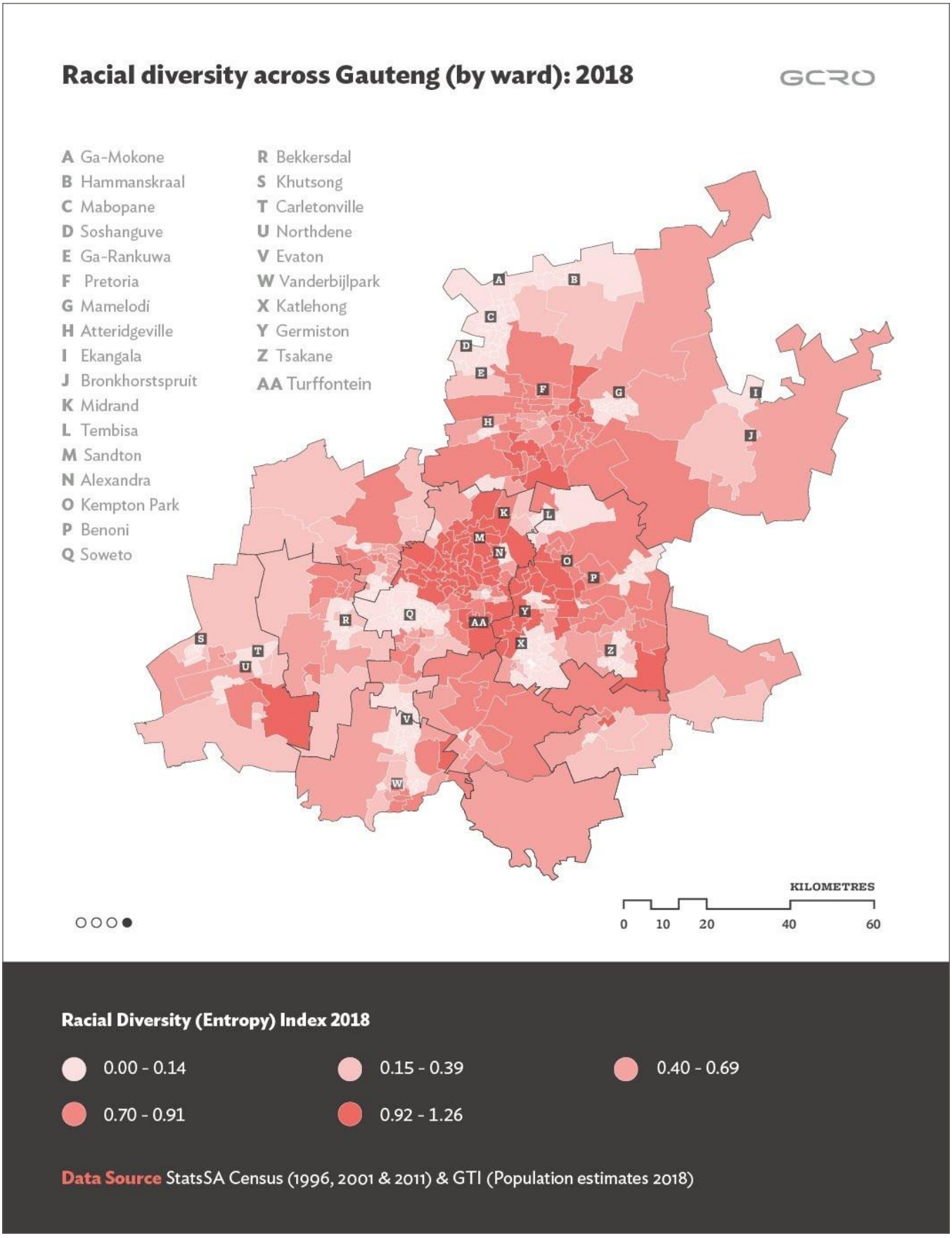


Figure 20b.
Racial diversity across Gauteng
1996 vs 2018 (Katumba, 2019)



2.7 ECONOMY

Johannesburg is the economic and logistics hub of South Africa with road, rail and air transport networks spreading to other parts of the country, Africa and the world (City of Johannesburg, 2016). From 1996 to 2013, the economic output of the city grew 92% outperforming the growth of South Africa as a whole at 70% (City of Johannesburg, 2016). Johannesburg is the largest single metropolitan contributor to the national economic product, contributing 16% nationally and 40% to Gauteng with a Its average Gross Domestic Product (GDP) has a growth rate of 2% per annum, above the national average GDP growth percentage (CoJ, no date).

The city's economic sectors comprise of the following: financial, real estate and business services (32%); wholesale and retail trade, catering and accommodation (16%); community, social and personal services (20%); manufacturing (16%); transport storage and communication (8%); construction contractors (4%); electricity, gas and water (2%); mining and quarrying (1%); and agriculture (<1%) (City of Johannesburg, 2016). The city has witnessed a decline in mining and manufacturing with the tertiary sector (trade, transport, finance and community services) now dominating the city's economy with 76% of the output and the finance sector showing the fastest growth from 1996 to 2013. The estimates for the contribution of the informal sector to the economy are between 7% and 13% (COGTA, 2020). The hotspots for economic activity within the city are the CBD and Sandton (Figure 21).

Of the economically active population, 52.6% are employed with 77% employed in the formal sector. Of these, 26.1% are employed in the finance sector, 22% are employed in the trade and retail sector and 17% in the community services sector which includes general government services (COGTA, 2020).

Although the average income per household is 57% higher than the rest of South Africa, starkly contrasting its economic contribution 8% of the population of Johannesburg have no income at all, 47% live on less than R40 000 per annum (approximately $7 a day in 2022) with 32.5% living below the lower poverty line, a youth unemployment rate estimated to be over 46.6%, and an unemployment rate at 26.5%, higher than the world average but lower than the national average of 35.3% (COGTA, 2020). Of the population living in poverty, 61.4% were categorised as Black African (COGTA, 2020).

This unequal income disparity is spatially aggregated where the northern suburbs (Sandton) is characterised as being affluent and the southern suburbs (Soweto) and informal settlements being the poorest (Figure 22). Region E & F (Inner City, Sandton & surrounds) contribute 50% of the economic output but only house 23% of the population contrasting with the south-western Regions D & G (Soweto to Orange Farm) contributing 13% but housing 41% of the population and reporting the highest poverty rates (City of Johannesburg, 2016).

Figure 21.

Economic activity across Gauteng (GCRO, 2011)

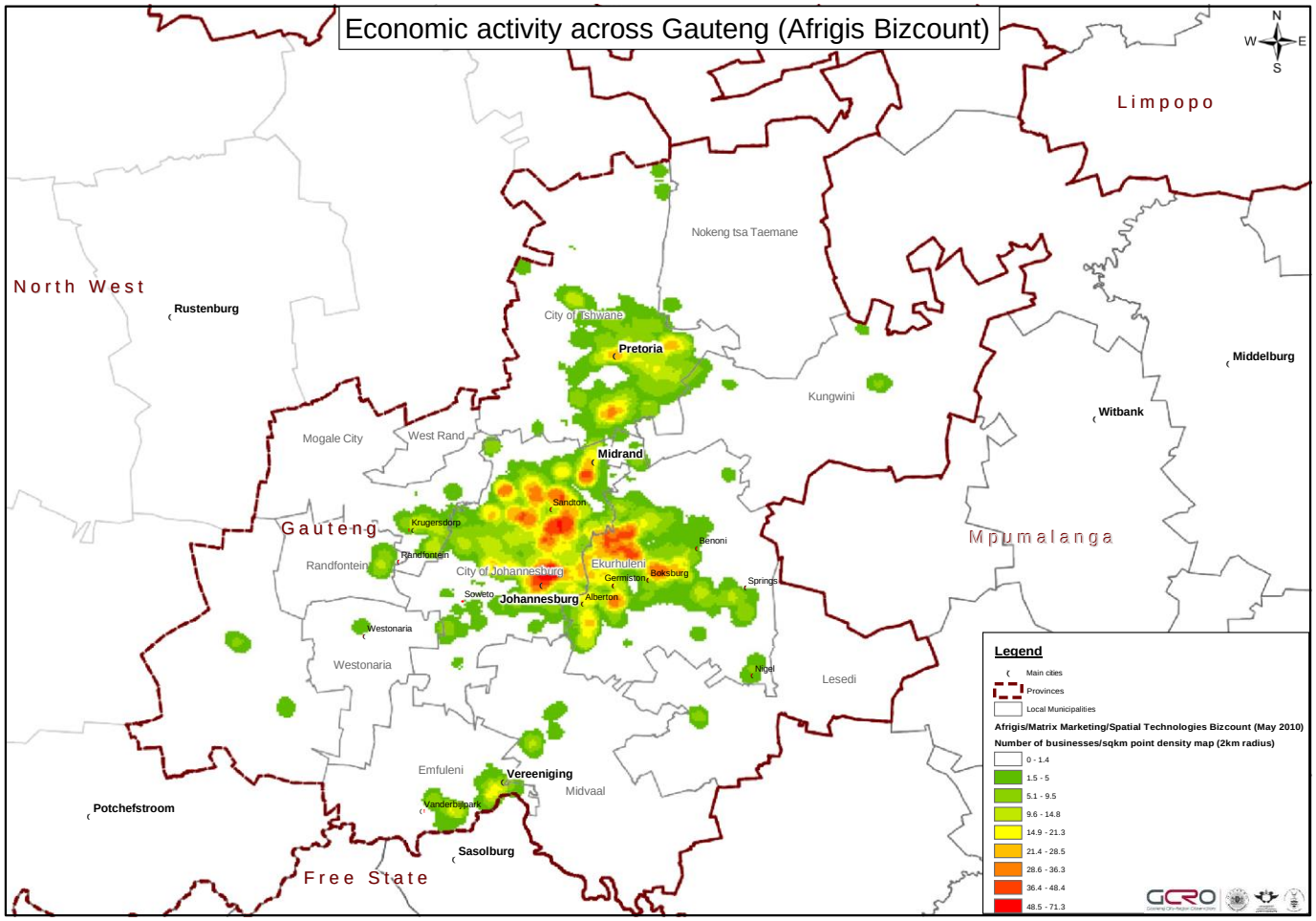
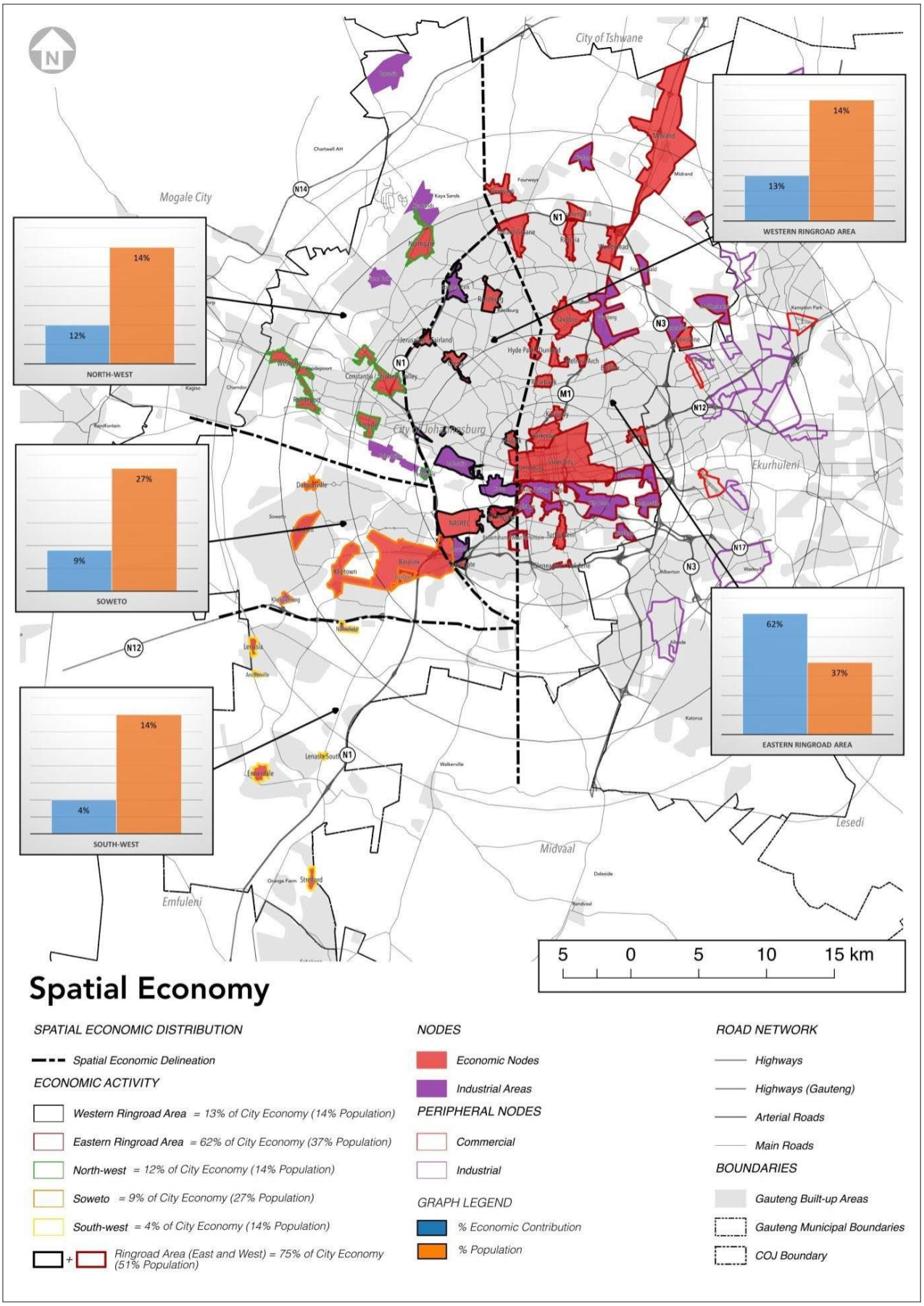


Figure 22.
Spatial Economic Distribution (City of Johannesburg, 2016)



2.8 HOUSING

There are approximately 1.8 million households in the city of Johannesburg with an average annual growth rate in the number of houses of 3.04%. However, with an average annual growth rate of 2.91% in total population, the average household size in the city is decreasing. This is also reflected in the number of individuals per household having decreased from 3.9 to 3.1 from 2008 to 2018.

Areas in the city of Johannesburg are split between formal and informal. The distinction between formal and informal areas was based on the definition by Statistics South Africa (StatsSA) which classifies settlement types according to the urban characteristics of the population and the degree of planned and unplanned development (Statistics South Africa, 2001).

For urban areas, the two broad settlement types are defined as follows:

- **Formal urban areas:** a formal urban settlement is structured and organised. Land parcels (plots or erven) make up a formal and permanent structure. A local council or district council controls development in these areas. Services such as water, electricity and refuse removal are provided and roads are formally planned and maintained by the council. This category includes suburbs and townships.
- **Informal urban areas:** informal settlements occur on land which has not been surveyed or proclaimed as residential, and the structures are usually informal. They are usually found on the outskirts of towns or in pockets of 'infill' inside towns, or along railways and roads. Informal dwellings are makeshift structures not erected according to approved architectural plans.

In the CoJ, 80.2% of the households are formal, 19.1% is informal and 0.7% live in other (South African Human Rights Commission, 2021). Informal settlements occur mostly on the periphery in the CoJ particularly in floodplains where development is illegal due to the flood hazard. Within the CoJ, informal settlements are found mainly in the townships of Soweto, Alexandra, Ivory Park and Diepsloot (Figure 23). Informal settlements coincide with a dense majority Black African population, high unemployment rates, low household incomes, and limited access to basic services.

In the post-apartheid era, the government made a concerted effort to resolve the housing crisis (informal settlements with lack of basic services) by constructing large-scale developments however these were located on the outskirts of towns far from economic and social opportunities resulting in high costs for the provision of bulk infrastructure and linking to town centres (South African Human Rights Commission, 2021). Subsequently there has been a shift in the government policy with the introduction of the National Upgrading Support Programme (NUSP) to support municipalities to implement in-situ upgrading of informal settlements to provide better living conditions and access to services in locations that have better access to economic opportunities (South African Human Rights Commission, 2021). Regardless of the progress of the NSUP since 2019 to conduct feasibility studies and develop plans, the implementation has been inconsistent and poor (South African Human Rights Commission, 2021).

2.9 ACCESS TO BASIC SERVICES

Provision of basic services in the City of Johannesburg is comparatively higher than the national total where the CoJ has an Index of Services Development at 0.87 which is higher than the national total of 0.75 (COGTA, 2020). The Index of Services Development measures access to formal housing, water, sanitation, electricity and refuse removal. Access to formal housing is at 75.1%, the lowest compared to the other basic service provision of water (99%), sanitation (93%) (Johannesburg Water, 2021), electricity (92.3%) and refuse removal (92.9%) (COGTA, 2020).

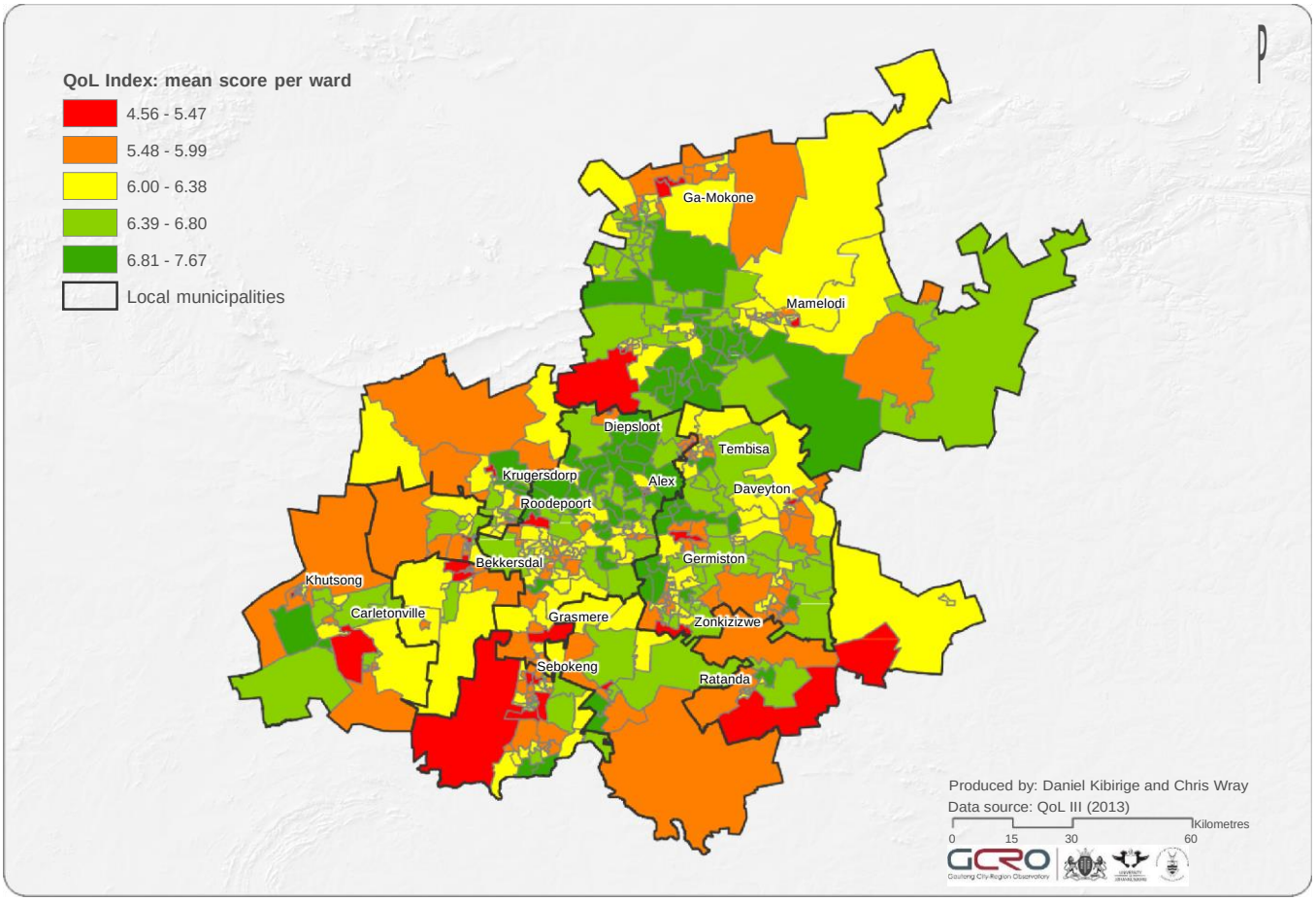
Access to water and sanitation is provided through piped water and water-borne sewerage informal households and standpipes, and VIP latrines and chemical toilets in informal settlements. Access to basic water and sanitation was at 99% and 93% respectively for the whole of the CoJ for 2020/2021. However, for informal settlements, access to basic water is at 96.09% against a target of 96.09% where 176 697 of the total 183 895 informal households have access; and access to basic sanitation is only 43.47% below the target of 45.19% with a total of 79 937 of the total 183 895 households in informal settlements having basic sanitation (Johannesburg Water, 2021). Johannesburg Water has an ongoing project called the "Marginalised Areas Programme" to track projects and progress within areas that were previously disadvantaged including areas of Ivory Park, Diepsloot, Alexandra, Orange Farm, Soweto, and all informal settlements where 40 projects to provide/upgrade water and sanitation infrastructure were implemented within marginalised areas in 2020/2021 (Johannesburg Water, 2021).

Water consumption per capita per day for 2020/2021 was at 268.23 l/c/d, less than 275.36 l/c/d in the previous year (2019/2020) (Johannesburg Water, 2021) but still significantly higher than the global average of 173 l/c/d (GCRO, 2018).

2.10 QUALITY OF LIFE

The Quality of Life index compiled by the Gauteng City Region Observatory (GCRO) includes 200 indicator questions combined into 10 dimensions of quality of life of which include work, socio-political, global, security, connectivity, community, family, dwelling, health and infrastructure. The 10 dimensions are measured out of a total score of 10 where 10 is the highest quality of life (Everatt, 2014). The Quality of Life was mapped on a ward scale due to the fact that there are regions within the city that are vastly contrasting. The results indicate that the highest quality of life exists in the more affluent northern suburbs and the lowest quality of life are concentrated in the former townships such as Alexandra (Region E), Diepsloot (Region A) and Ivory Park (Region A) (Figure 24). These findings confirm the resilience of apartheid inequalities, and the way they are woven into the spatial geography of the city-region (Everatt, 2014).

Figure 24.
Quality of Life index mean score per ward in Gauteng (Everatt, 2014)



3

GOVERNANCE

The Republic of South Africa (RSA) is a constitutional democracy with an independent judiciary and a three-tier governance system; the national, provincial and local levels defined as distinctive, interdependent and interrelated that have legislative and executive authority in their own spheres. The Gauteng Provincial Government is the provincial government that operates in the Gauteng region with the City of Johannesburg (CoJ) as the metropolitan municipality.

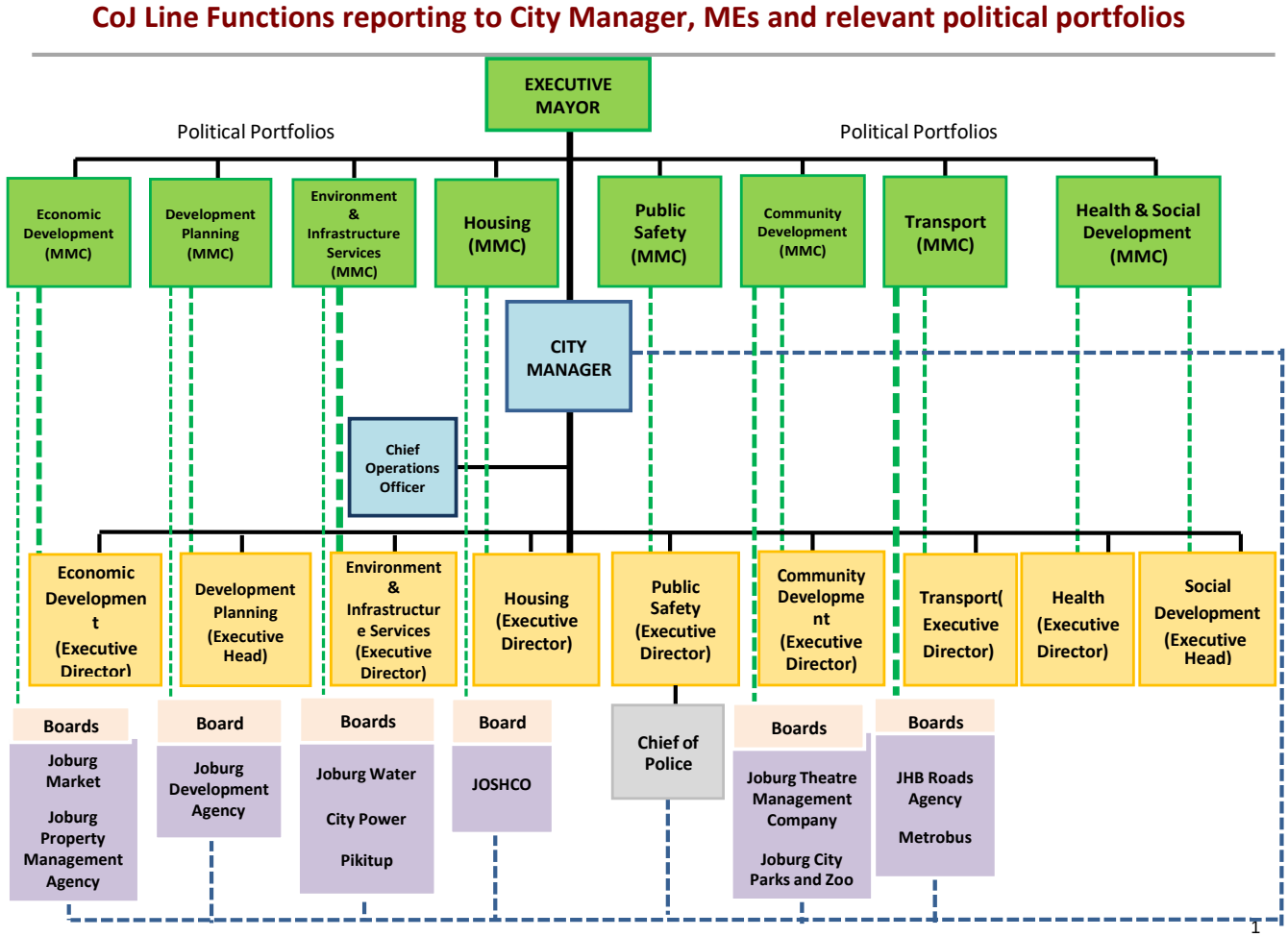
3.1 CITY OF JOHANNESBURG

The City of Johannesburg Metropolitan Municipality comprises the legislative arm (the council); executive arm (executive mayor and mayoral committee); and administrative arm.

3.1.1 LEGISLATIVE ARM

The council's primary role is to act as lawmaker which includes legislative, oversight and participatory roles. The oversight function includes receiving reports from the executive mayor and the mayoral committee. It is the responsibility of the council to approve by-laws, City policies, the Integrated Development Plan, tariffs for rates and service charges, and the City's budget. The council comprises 270 councillors representing various political parties and various structures of which include the following: the Speaker of Council, the Chief Whip of Council, Section 79 committees, Standing committees, Leader of Executive Business, and the Executive Mayor and Mayoral committee. The City of Johannesburg governs 7 Regions (A-G) each of whom have an appointed Regional Director. Regions are further broken down into wards of which each ward has an appointed Ward Councillor. The primary duty of ward councillors is to represent the needs and interests of their constituents and are responsible for building community involvement to ensure that public voices are heard. (City of Johannesburg, no date b)

Figure 25. Organogram of the CoJ (City of Johannesburg, no date b)



3.1.2 EXECUTIVE ARM

The purpose of the executive arm is to put into effects government laws and programmes and oversees the functioning of each political portfolio. The Executive Arm is run by the Executive Mayor with Members of the Mayoral Committee (MMC) responsible for each political portfolio. These portfolios include the following: Economic Development, Development Planning, Environment and Infrastructure Services, Housing, Public Safety, Community Development, Transport, and Health and Social Development (Figure 25). Each MMC has an Executive Director for the relevant portfolio reporting to them as well as the Board for any of the Municipal Owned Entities that may fall under that portfolio.

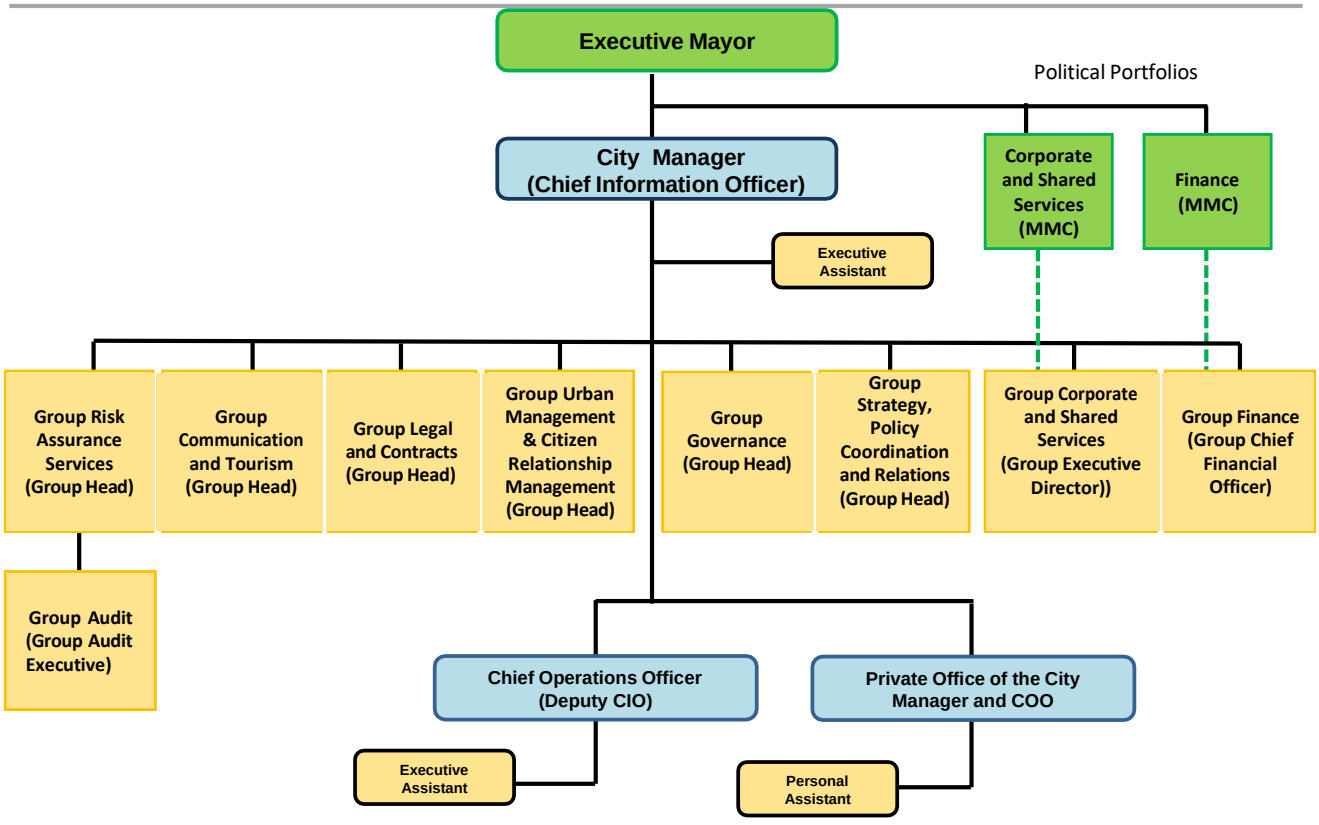
The City of Johannesburg owns the following entities (Figure 25): Joburg Market, Joburg Property Management Agency, Joburg Development Agency, Joburg Water, City Power, Pikitup, JOSHCO, Joburg Theatre Management Company, Joburg City Parks and Zoo, Joburg Roads Agency and Metrobus.

3.1.3 ADMINISTRATIVE ARM

The City Manager, also known as the Chief Information Officer, runs the administrative arm to drive outcomes and strategic priorities of the city (Figure 26). The City Manager is supported in the following areas (City of Johannesburg, no date a):

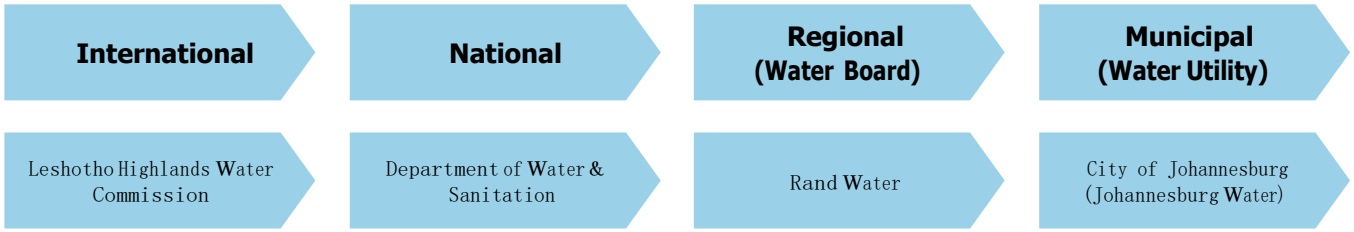
- Strategic Support: Includes content support, research and information provision, briefing notes, media management and stakeholder relations, international relations, IGR, advisory services, monitoring and evaluation support and assessments, etc.
- Executive Support: Includes support to the legislated and executive functions of the City Manager and delegated functions for example: document preparation and timely availability of documents for signature, prioritising of activities, governance support, etc.
- Personal and Administrative support: Support to the City Manager and delegated functions in terms of diary management, logistical support, correspondence management, records and document management, etc.

Figure 26. Organogram of the office of the City Manager (City of Johannesburg, no date a)



3.2 WATER GOVERNANCE

Figure 27.
Water Governance related to the CoJ



3.2.1 INTERNATIONAL GOVERNANCE

In 1986 the Kingdom of Lesotho and the Republic of South Africa signed a Treaty that established the Lesotho Highlands Water Project (LHWP) for the mutual benefit of the two countries with the purpose of providing water to South Africa and hydroelectric power to Lesotho (Lesotho Highlands Development Authority, no date). The Kingdom of Lesotho operates as an owner of the dams and the infrastructure located within Lesotho's borders. The Lesotho Highlands Water Commission (LHWC) (née Joint Permanent Technical Commission (JPTC)) consists of representatives from Lesotho and South Africa with a monitoring, advisory and approval function (Lesotho Highlands Development Authority, no date). The Trans-Caledon Tunnel Authority (TCTA), an agency owned by the South African Government mandated with financing and implementing bulk water infrastructure projects, reports to the LHWC with regards to operations and maintenance issues and is responsible for the delivery tunnel that transports water over the border (Lesotho Highlands Development Authority, no date). The Lesotho Highlands Development Authority (LHDA) reports to the LHWC and manages the part of the project that falls within Lesotho's borders including construction, operation and maintenance of dams, tunnels, power stations and infrastructure as well as secondary developments such as relocation, resettlement, compensation, supply of water to resettled villages, irrigation, fish hatcheries and tourism (Lesotho Highlands Development Authority, no date).

3.2.2 NATIONAL GOVERNANCE

According to the Constitution of South Africa 1996, "Everyone has the right to have access to sufficient food and water…(and) the state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights." (Republic of South Africa, 1996). Furthermore, the Water Services Act of 1997 (Republic of South Africa, 1997) provides for the rights of access to basic water supply and basic sanitation where the government has to ensure that water supply services and sanitation services are provided in a manner that is efficient, equitable and sustainable. This Act also provides for the gathering and the distribution of information in a national information system, the promotion of effective water resource management and conservation, the promotion of the interests of consumers and the broader goals of public policy. The National Government plays the role of custodian of the nation's water resources and has mandated this role to the Department of Water and Sanitation. The roles and responsibilities of the Department of Water and Sanitation include the following: National water resources planning & management including operation of the Integrated Vaal River System (IVRS) and Resource Quality Objectives (RQOs). The operation of the Integrated Vaal River System (IVRS) is strategically informed by the IVRS Reconciliation Strategy (DWS, 2021) which assists with decision making, long term water resource planning and water resource management.

Figure 28. Governance of the Lesotho Highlands Water Project (Lesotho Highlands Development Authority, no date)

3.2.3 REGIONAL GOVERNANCE

The Department of Water and Sanitation oversees 13 regional Water Boards who are responsible for providing bulk water services within their gazetted areas of operation. Water Boards are public entities established through the Water Services Act, Act 108 of 1997 with a main role to provide bulk potable and wastewater to water service institutions in their designated areas (South African Government, no date). The Minister of Water and Sanitation is a shareholder and executive authority for water boards and has the mandate to provide oversight management. The Water Board that is responsible for the bulk supply of water to Gauteng and surrounding areas is Rand Water, the largest bulk water board in Africa. Rand Water's distribution network includes large diameter pipelines, feeding 58 strategically located service reservoirs, with customers including metropolitan municipalities (one of which is the City of Johannesburg Metropolitan Municipality), local municipalities, and mines and industries in and around Gauteng, supplying, on average, 3.7 million litres of water daily. (Water and sanitation | South African Government, no date).

3.2.4 MUNICIPAL GOVERNANCE

The water board responsible for the Gauteng Province, Rand Water, supplies water to the water and sanitation utility responsible for the city of Johannesburg, Johannesburg Water, a state-owned enterprise of the CoJ, who is responsible for water supply and sanitation provision to the residents of Johannesburg (Rand Water, no date b). Johannesburg Water is also responsible for water quality and ensuring that water supply maintains potable water standards as well as wastewater treatment. Anything related to groundwater is also managed by Johannesburg Water. Johannesburg Water falls under the directorate of the CoJ Environment & Infrastructure Services Department's (EISD) Water Services Regulation & Policy Unit. The Johannesburg Roads Agency is responsible for stormwater management and serves as the custodian of stormwater infrastructure.

3.2.5 SUMMARY OF KEY STAKEHOLDERS

In terms of managing the urban water system for the CoJ, the key stakeholders and their responsibilities are show in Error! Reference source not found. and including the national Department of Water and Sanitation (DWS), Rand Water, Joburg Water, the City of Johannesburg Environment and Infrastructure Services Department (EISD) and Johannesburg Roads Agency (JRA).

Table 1.
Key role players & responsibilities

Key Player	Responsibility
Department of Water & Sanitation (DWS)	National water resources planning & management including operation of the Integrated Vaal River System (IVRS) and Resource Quality Objectives (RQOs).
Rand Water (RW)	Water Services Authority who serves as the bulk water supplier to Joburg Water
Joburg Water (JW)	Responsible for water supply & sanitation services for the CoJ and overseen by the CoJ EISD's Water Services Regulation and Policy Development unit.
CoJ – Environment & Infrastructure Services Department (EISD)	Responsible for Water Resources & Biodiversity including improved & protected water courses, water conservation, demand reduction, alternative sources, building a water sensitive city, adequately protected, and secured biological diversity, control of alien & invasive species, ecological functioning ecosystem, equitable provision of recreational open spaces. EISD are responsible for the development of the CoJ Climate Action Plan (CAP) and the development of the Water Security Strategy.
Johannesburg Roads Agency (JRA)	Custodian of stormwater infrastructure overseen by the CoJ Transport Department

Additionally, key stakeholders to consider are listed below:

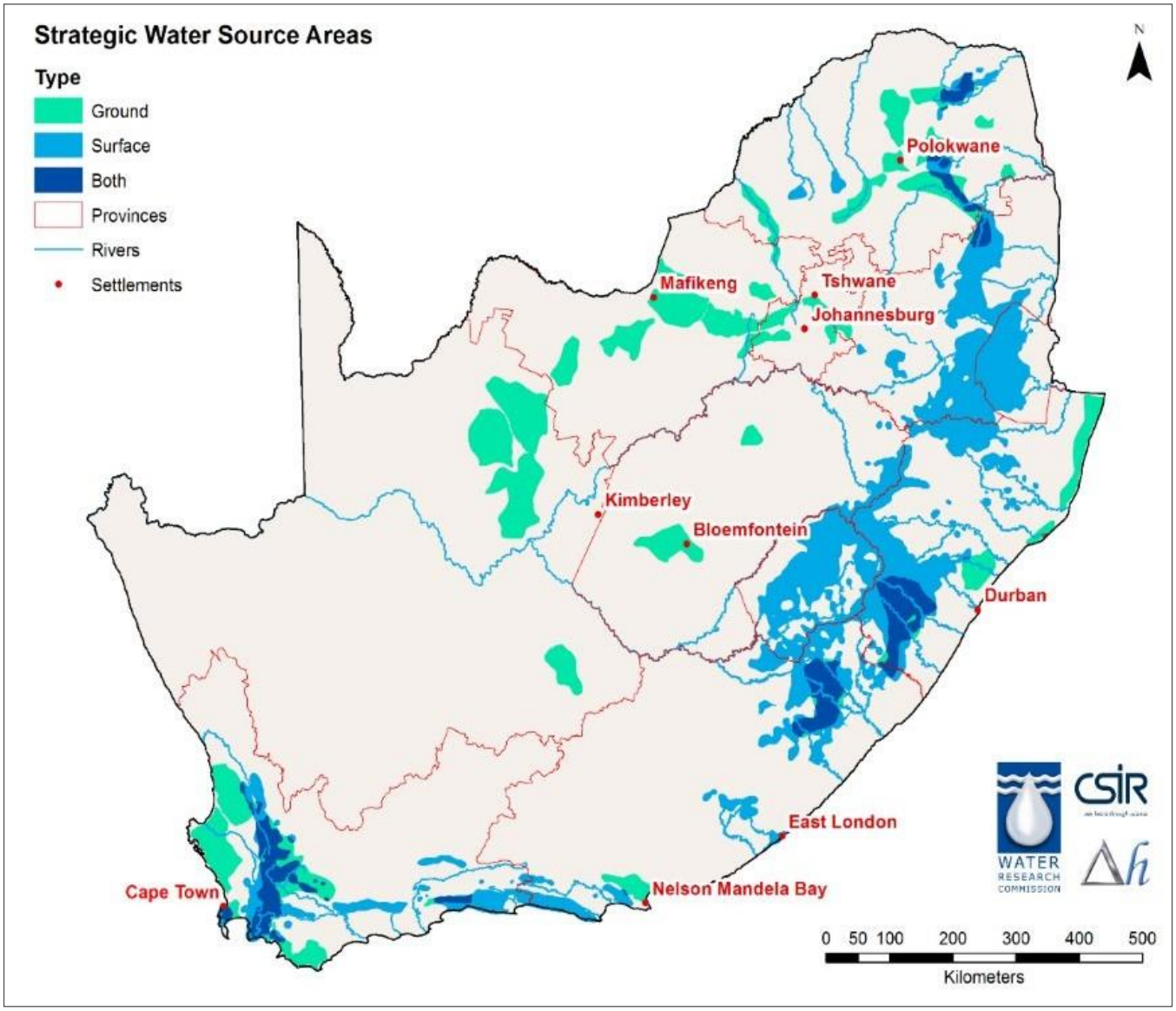
- South African Cities Network (SACN)
- Cities Support Programme (CSP) supported by National Treasury (NT)
- Gauteng Department of Agriculture & Rural Development (GDARD)
- Gauteng Department of Cooperative Governance & Traditional Affairs (COGTA)
- Gauteng City Region Observatory (GCRO)
- Department of Environmental Affairs (DEA)
- Water Research Commission (WRC)
- University of the Witwatersrand (WITS)
- University of Cape Town (UCT) & Future Water
- University of Johannesburg (UJ)
- ICLEI-Africa Local Governments for Sustainability
- Urban River Alliance (Fourth Element; AquaLinks, Eco-Pulse & Chris Brooker & Associates)
- Johannesburg Property Owners & Managers Association (JPOMA)
- National Business Initiative (NBI)

4

UNDERSTANDING JOHANNESBURG'S WATER SYSTEM

The City of Johannesburg was founded due to the discovery of gold and therefore is one of the only major cities in the world that is not located near a strategic water source. This is unlike other significantly populated areas in South Africa that either have access to surface water or groundwater within a relatively close proximity (Figure 29). The Gauteng Province is reliant on water supply from the Integrated Vaal River System (IVRS) operated by the National Department of Water and Sanitation. The IVRS is supplemented by the Lesotho Highlands Water Project (LHWP) that provides water to South Africa via its neighbouring country Lesotho who has abundant surface water (Figure 29). The water governance and water supply is explained in more detail in this section.

Figure 29.
Adapted version of strategic water sources in South Africa (David Le Maitre et al., 2019)



4.1 WATER SUPPLY

4.1.1 INTERNATIONAL WATER SUPPLY

Interest in the water potential of Lesotho began in the early 1950's due the abundance of the resource that the land-locked country could provide to augment South Africa's water supplies. After viability investigations, a Joint Technical Committee comprising experts from both countries began a full feasibility study in 1978 which was completed in April 1986. The Treaty was signed between the Kingdom of Lesotho and the Republic of South Africa on the 24th October 1986 in Maseru, Lesotho. The project was set out to benefit South Africa by providing water supply and Lesotho through the provision of hydroelectric power with South Africa covering the costs of the transfer of water and the compensation for the displacement of individuals and communities and Lesotho to finance the hydroelectric power component of the project.

The Lesotho Highlands Water Project comprises a number of phases (Lesotho Highlands Development Authority, no date):

Phase 1 supplies the Integrated Vaal River System (IVRS) with 780 million m3 annually (HLDA, 2019)

- Phase 1A began with the construction of the Katse Dam with a reservoir volume of 1950 million m³ which was completed in 1997 and water supply began in 1998 via the Katse Muela Transfer Tunnel 45 kilometres long.
- Phase 1B began with the construction of the Mohale Dam with a reservoir volume of 946.9 million m³ which was completed 2002 and supplied water via the Mohale Katse Tunnel (32 kilometres long)

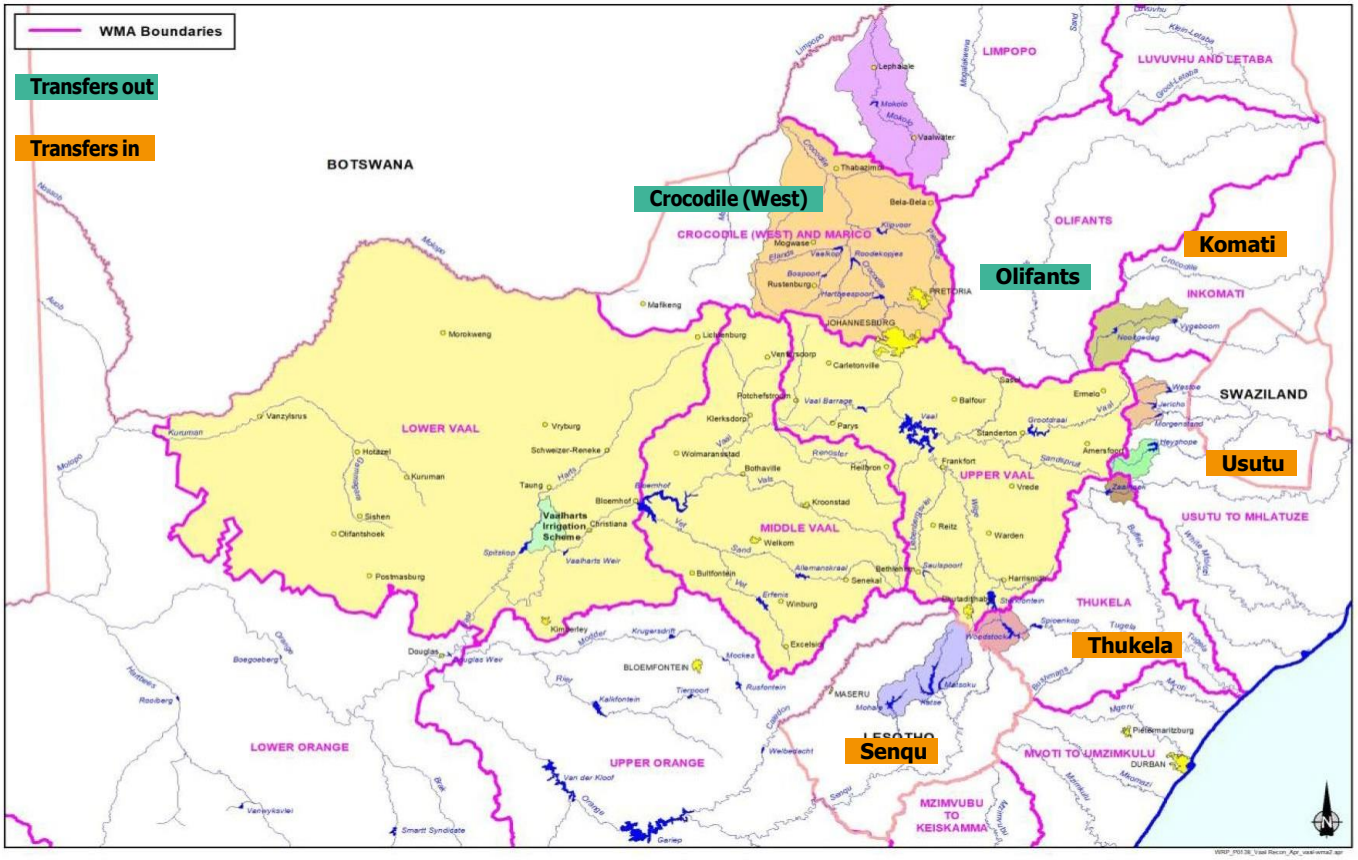
Phase 2 plans include the construction of Polihali Dam and a Polihali Katse Transfer Tunnel. Polihali Dam will create a reservoir on the Senqu and Khubelu rivers expected to contribute 490 million m³ per annum totalling 1270 million m³ per annum supplied to South Africa. The design commenced in 2017 and tender design water completed in 2020. The construction is expected to begin in 2022 with completion and commissioning expected in 2028. This delay in the implementation of Phase 2 of the LHWP presents a significant water security risk to the CoJ as a result of increasing water demand due to population growth & urbanisation, the significantly high percentages of non-revenue water and the relatively high consumption per capita per day compared to international standards (discussed in more details in the sections below).

4.1.2 REGIONAL WATER SUPPLY

The IVRS supplies water to South Africa's most densely populated and important economic centre, serving a population of more than 15 million people. Developments in this part of the country include power stations, mining industry (gold and platinum), petro-chemical industry and extensive urban sprawl. The core catchment consists of the Upper, Middle and Lower Vaal River Water Management Areas (WMAs) (Figure 30). However, this core area is linked to other WMAs via a complex arrangement of inter-basin transfers that include portions of the Komati, Usutu, Thukela, Senqu River (located in Lesotho) and Upper Orange (Riet-Modder River) catchments shown in Figure 30. The Crocodile West and Olifants catchments transfer water out of the system due to the nature of the topography.

Due to the highly intricate nature of the IVRS and the various inter-basin transfers that exist in the system, a complex set of operating rules has been developed that regulates when and how much water is transferred shown diagrammatically in Figure 31. The bulk water supply for the CoJ comes from the IVRS (Figure 31), particularly the Upper Vaal Water Management Area that is fed by the Vaal River and supplemented with the Usutu, Thukela and Senqu Water Management Areas (Figure 31). The system supplies water to 13 municipalities in Gauteng Province of which the CoJ is one. The water requirements in the area are therefore very important to sustain the economy of the country and the well-being of its people (DWS, 2020).

Figure 30.
Water Management Areas considered in the Integrated Vaal River System (DWS, 2021)



The IVRS supplies a total water demand of 3919 million m3/a (in 2019) of which 780 million m3/a (20%) is supplied by the Lesotho Highlands Water Project. The IVRS is managed by the Department of Water and Sanitation (DWS) and is responsible for supplying water to a range of sectors (Department of Water and Sanitation, 2021) (Figure 32):

- Urban Water (Rand Water, Midvaal Water Company, Sedibeng Water, and other towns)
- Agricultural (Vaalharts / Lower Vaal irrigation and other irrigation users)
- Industrial (ESKOM, SASOL, ArcelorMittal Steel)
- Ecological (Wetlands & Rivers)

Figure 32 shows the water requirements per sector for 2019 based on the actual use and the projected use for 2050. Although the total demand is expected to increase, the Urban Water and the Ecological water requirements are expected to grow faster than the Agricultural and Industrial sectors.

Rand Water is the largest water user in the IVRS with a total demand of 43.4% (in 2019) equivalent to 1700 million m3/a according to the latest update to the IVRS Reconciliation Study (Department of Water and Sanitation, 2021). This is expected to grow to a total demand of 53.8% (2615 million m3/a) by 2050 due to population growth and urbanisation for a high-growth demand scenario (Figure 33). (Department of Water and Sanitation, 2021).

Figure 31.
IVRS Actual Water Requirements for 2019 (left) and projected for 2050 (right) per sector

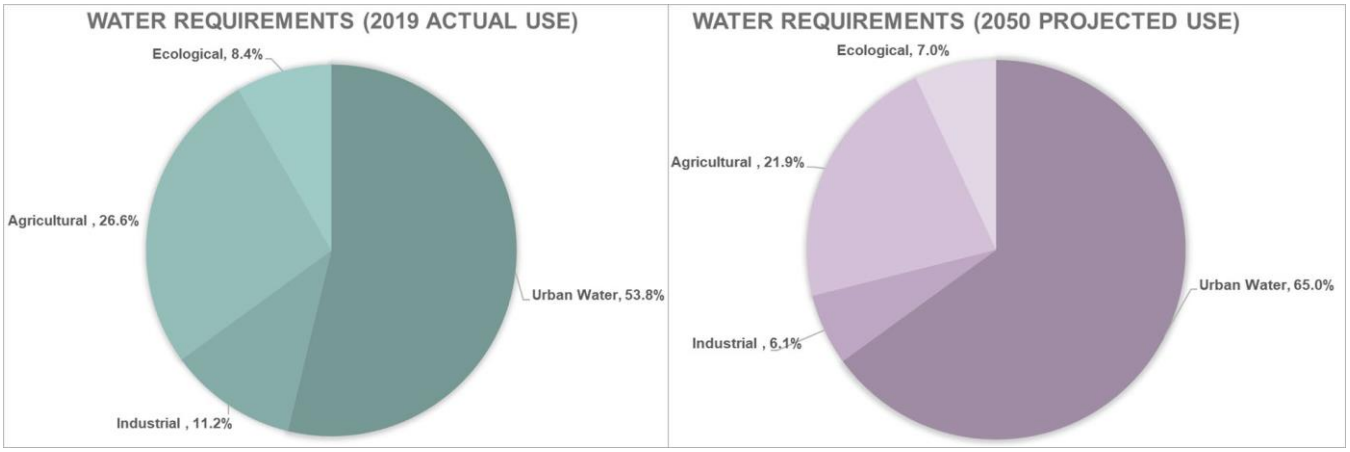


Figure 32.
IVRS Actual Water Requirements for 2019 (left) and projected for 2050 (right)

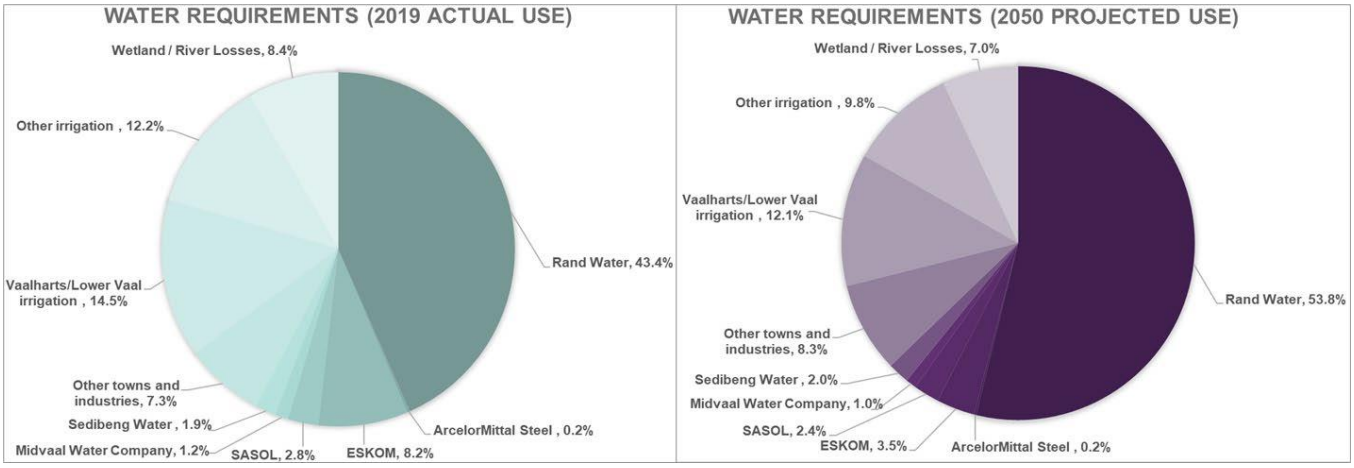


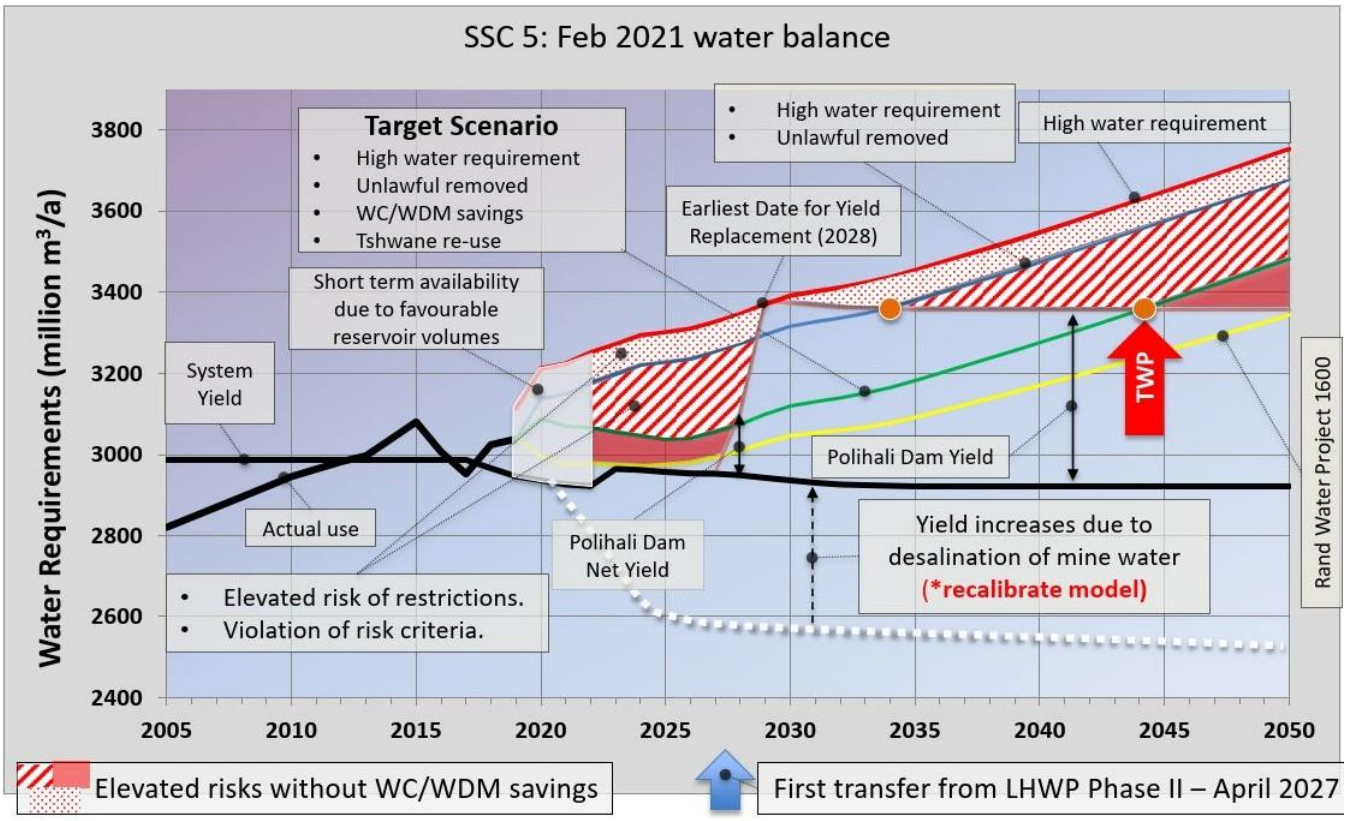
Table 2.
IVRS System demand for 2019 - 2050 (Department of Water and Sanitation, 2021)

Water users / planning years	2019	2020	2025	2030	2035	2040	2045	2050
Water requirements (million m³/a)								
Rand Water	1700	1816	1974	2113	2252	2367	2488	2615
ArcelorMittal Steel	9	9	10	10	10	10	10	10
ESKOM	322	301	246	214	170	170	170	170
SASOL	109	110	111	115	115	115	115	115
Midvaal Water Company	47	47	47	47	47	47	47	47
Sedibeng Water	74	75	80	83	86	88	92	96
Other towns and industries	287	291	311	330	342	360	380	402
Vaalharts/Lower Vaal irrigation	567	567	589	589	589	589	589	589
Other irrigation	477	477	477	477	477	477	477	477
Wetland / River Losses	328	329	330	331	333	334	336	339
Return Flows (million m3/a)								
Southern Gauteng (Rand Water)	453	484	525	558	595	625	657	690
Midvaal Water Company	1	1	1	1	1	1	1	1
Sedibeng Water	3	3	3	3	3	4	4	4
Other towns and industries	85	86	90	93	93	94	95	96
Irrigation	79	79	80	80	80	80	80	80
Mine dewatering	126	126	128	128	128	128	128	128
Increased urban runoff	112	113	121	129	139	150	163	178
Overall gross system demand	**3919**	**4022**	**4173**	**4309**	**4421**	**4557**	**4704**	**4859**
Overall net system demand	**3060**	**3130**	**3225**	**3316**	**3382**	**3476**	**3576**	**3681**

The IVRS Reconciliation Strategy Study Phase 1 (DWS, 2015) concluded that Water Conservation Water Demand Management (WCWDM) interventions were a crucial component to limiting the risk of drought restrictions until Phase 2 of the Lesotho Highlands Water Project (LHWP) comes online which at that stage was envisaged to be in 2024, when water from this scheme can be delivered to the Vaal Dam (Figure 34). The likely WCWDM measures would include the eradication of unlawful water use in the irrigation sector, desalination of mine water and re-use of water in Tshwane (Target Scenario in Figure 34). The 2015 IVRS water balance indicated an increased risk of water availability in the short-term. An appropriate preparedness plan for all sectors at all water supply levels needs to be put in place to ensure that consumption can be reduced in the event that a drought occurs, and so to prevent water supply failure from the system. To this end, a 3-year continuation study of the IVRS Reconciliation Study (Phase 2) was started in 2018 and has recently been finalised. The latest IVRS water balance is shown in Figure 34 below and based on the update water requirement projections, there is an elevated risk of restrictions without WC/WDM savings until the yield augmentation schemes are implemented.

The Phase 2 Reconciliation study developed an action plan in order to implement the interventions required to reduce the elevated risk of restrictions until planned infrastructure augmentation options come online. Due to various delays, the revised implementation date for the LHWP Phase 2 is estimated to be April 2027 but there is concern that the process may experience further delays which may have serious implications for the water balance of the IVRS. The second planned augmentation scheme is the Thukela Water Project which was supposed to follow the LHWP Phase 2 but updates to the hydrology and the feasibility studies will be required before this project can progress. The most recent reconciliation strategy for the Integrated Vaal River System highlights the elevated water security risks without Water Conservation and Water Demand Management (WCWDM) savings even after LHWP Phase 2 comes online (see Figure 34).

Figure 33.
Overall water balance for the IVRS highlighting elevated risk of restrictions (DWS, 2021)



RAND WATER

Rand Water, the largest bulk water board in Africa, is mandated to ensure bulk supply to Gauteng, parts of Mpumalanga, Free State and Northwest provinces, servicing approximately 19 million people of which 98% (1700 million m3/a) of its supply comes from the IVRS via the Lesotho Highlands Water Project (LHWP) (Water and sanitation | South African Government, no date) and the remainder is abstracted from underground sources at Zuurbekom.

Rand Water's distribution network includes over 3 056 kilometres of large diameter pipeline, feeding 58 strategically located service reservoirs. Its customers include metropolitan municipalities, local municipalities, mines and industries including Sasol & Eskom and it supplies, on average, 3 653 million litres of water to these customers daily (Figure 35). Rand Water is supplied with raw water from the IVRS by DWS, treats it to a potable standard for human consumption and then supplies it to municipalities, mines and industry. Municipalities then supply the water to consumers in their jurisdiction. Municipal customers account for 95% of the total water demand and the remainder is supplied directly to mining customers. Based on their current requirements, Rand Water's demand is greater than their current quota from the IVRS and therefore the system is expected to remain under pressure at least until Phase 2 of the Lesotho Highlands Water Scheme (LHWS) comes online. The implementation of successful water demand management projects need to show good results to sustain current to medium term water demands. As a result, Rand Water initiated Project 1600[1] in 2017 to provide guidance, support, and oversight to municipalities to reduce their collective demand to comply with 1600Mm3/a abstraction limit. Project 1600 aims to gather municipalities every quarter to assess their progress and review their water demand management strategies for the following quarter. During the 2020/2021 water planning year, Rand Water abstracted 1664 million m3 which is 3% higher than the target of Project 1600 however much-improved compared to previous years (Rand Water, 2021b).

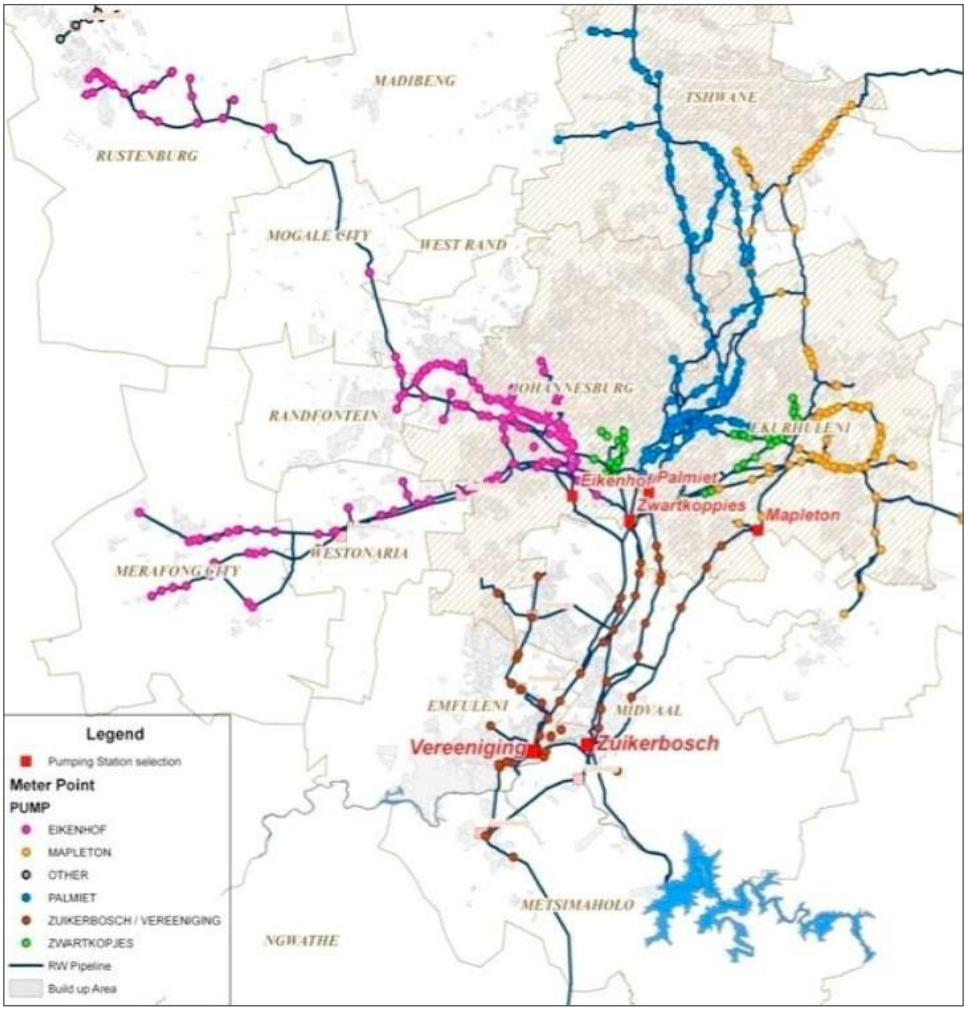


Figure 34. Rand Water areas of supply (Matlakala et al., 2019)

(1) Project 1600 is part of Rand Water's Water Conservation and Demand Management Strategy to comply with 1 600Mm3/ annum abstraction limit until Lesotho Highlands Scheme's additional water supply becomes available.

4.1.3 MUNICIPAL WATER SUPPLY

Johannesburg Water (JW) is an independent entity that is responsible for water and sanitation in the City of Johannesburg Metropolitan Municipality. JW purchases treated water from Rand Water and sells and distributes it to individual users in the Johannesburg network. It supplies 1.6 billion litres of potable water per day through a water distribution network of some 12,000 km, 127 reservoirs and water towers, and 37 water pump stations. JW operates in all seven regions of CoJ with ten network depots and six wastewater treatment plants. (JW, no date)

JW has a licenced water allocation of 1 322 Ml/d (483 million m3/a) from Rand Water (De Jager, 2019) but have been using more than their allowance over the last few years. In the 2019/20 financial year JW used ~1 616 Ml/d (~590 million m3/a) which is 23% more than their licenced water allocation (CoJ; JW, 2020; JW, 2020d). Despite being situated in a water scarce region, it has been observed that the CoJ current water use is not responsive to this reality (GCRO, 2018). Water demand in the CoJ is relatively high at 268 l/c/d compared to the global average of 173l/c/d (DWS, 2018; JW, 2020b). The CoJ water demand is also 23% above the Municipality's limit (as set by Project 1600) (JW, 2020d) which has resulted in JW struggling to manage the pressure on infrastructure in recent years (JW, 2020d, 2020b). The Municipality has also come close to serious droughts several times in the last decade (e.g. 2015 - 2017). While overuse of water is prevalent in the Municipality, there are also areas who do not have adequate or affordable access to water. This highlights the importance of equity in terms of achieving the objective of becoming a water sensitive city and improved quality of life for all.

The CoJ experiences intermittent interruptions to supply caused by pipe bursts, electricity / power supply interruptions, low pressure. Recently JW has been allocated a R3.3-billion multi-year capital budget for water and sewer pipe replacements, upgrades to the water storage infrastructure and the wastewater treatment works programme. The money will also be used for the repair and maintenance of obsolete infrastructure. About 10% of this allocation will be invested in more resilient infrastructure for earmarked reservoirs to ensure consistent supply to residents, businesses and hospitals in the area.

As reducing the overall water demand is a critical issue for JW compounded with the delay in LHWP Phase 2 and limitations on water abstraction licenses, the entity has also joined the Rand Water Project 1600. To comply with the allocation from the IVRS, the water demand needs to be reduced to 1300 Ml per day but was at 1 630 Ml per day for 2020/2021, increasing 1.80% percent from the previous year (Johannesburg Water, 2021).

Water demand is influenced by several variables, including illegal abstraction, leakages in ageing infrastructure, conservation efforts of users, economic and population growth and water quality issues in the system (JW, 2015, 2017, 2018, 2019, 2020d). JW's WCWDM strategy has implemented a range of actions such as pressure management, maintenance of ageing infrastructure, and continuous metering monitoring, among other actions (JW, 2015, 2017, 2018, 2019, 2020d). JW measures the volumes they supply into six main areas: Johannesburg Central, Soweto, Sandton, Randburg, Midrand, and Deep-South. This is useful for managing spikes in usage and identifying problem areas within their water supply system.

A major area for concern is Non-revenue Water[2] (NRW). JW reported that NRW amounts to 39.4% (commercial losses at 7.0%, unbilled authorised consumption at 14.3%, and physical losses at 18.1%) in 2020/2021 against the target of 32% up from 34.5% in 2019/20 (Johannesburg Water, 2021). NRW is categorised into 'unbilled authorised consumption', 'commercial losses' and 'physical losses'. The targeted actions to reduce commercial and physical losses have the greatest opportunity to save water. However, losses under unbilled authorised consumptions are more difficult to reduce, as this consumption includes water supplied to informal settlements, water used for emergency services and water used for the piped network maintenance, among other uses. Increases in NRW for 2020/2021 can be attributed to several causes including property leaks & leaking reservoirs in the Soweto Region; aging infrastructure and slow response times to burst pipes due to COVID-19 in the JohannesburgCentral Region; billing of the deemed customer category data showed that customers were billed flat rates of 20kl, 10kl or 6kl but actual consumption ranged from 50kl to 60kl impacting the Unbilled Authorised Consumption totally 4% of the NRW system input volume with affected areas located in Soweto, Orange Farm and Alexandra (Johannesburg Water, 2021).

NRW is incorporated in future planning for JW, as they believe that their infrastructure upgrade and renewal programme as well as their targeted pressure management plan will have a significant impact on reducing NRW values (JW, 2020d). According to the JW 2020/21 business plan, only 54% of Johannesburg's internal bulk water meters are operational. JW is working to have all meters 100% operational by the end of 2020/21. JW has identified priority areas from night flow analysis. These priority areas will have their water infrastructure surveyed towards mitigating leaks.

JW has also identified several pressure-reducing valve (PRV) zones where pressure management will be implemented towards reducing loss, infrastructure damage and water demand management. JW estimates 2300 Ml per annum is saved maintaining the current PRV zones and a further 2257 Ml per annum could be saved once the newly identified PRV zones are established.

(2) Non-revenue water includes all water supplied that is not paid for, including physical water losses through leaks in the distribution system, illegal connections, unbilled consumption and billed, but unpaid for water use (DWS, 2018)

4.2 WATER TREATMENT

Water treatment is the responsibility of Rand Water (RW) who treats bulk water from the IVRS and sells it to Joburg Water (JW). JW is then responsible for the distribution and sale of water to individual users. Water quality testing is performed by both RW (RW, 2021) and JW (JW, 2020a) who are expected to be fully compliant with the South African National Standards Drinking Water 241:2015 code. JW conducts daily water quality testing for microbiological and chemical analysis across a number of sampling points in its reticulation systems (Johannesburg Water, 2021), 2021).To ensure compliance, water quality is one of the strategic goals of JW and the latest report indicates a compliance target of 99.4% for 2019/2020 and 2020/2021 achieved as opposed to the SANS compliance target of 95% (Johannesburg Water, 2021).

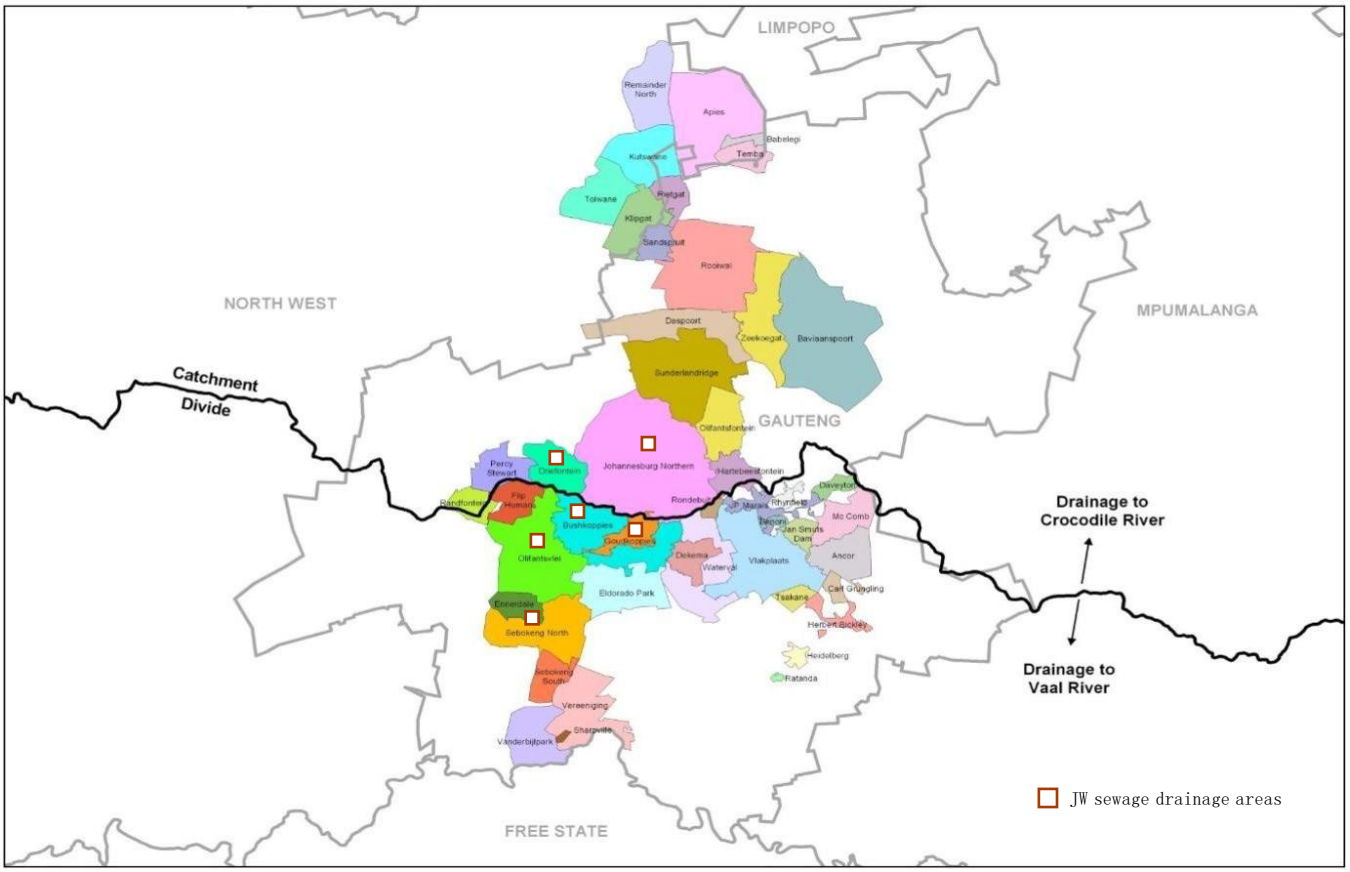
4.3 WASTE WATER TREATMENT

Joburg Water (JW) manages the collection, treatment and discharge of the wastewater for the whole of the City of Johannesburg including water-borne sewerage for formal households and VIP latrines and chemical toilets in informal settlements. JW operates and maintains a wastewater network including 11,000 km of reticulation and 38 sewer pump stations. JW treats 979 Ml/d of sewage at its six wastewater treatment works (WWTW) (Johannesburg Northern, Driefontein, Bushkoppies, Goudkoppies, Olifantsvlei, and Ennerdale) , which includes one of its biogas-to-energy pilot plants (Johannesburg Northern WWTW), where methane gas is converted to energy (Johannesburg Water, 2021).

JW's latest effluent compliance for its wastewater treatment works is 84.6% for 2020/2021 up from 79.9% the previous year (Johannesburg Water, 2021). It has been noted that prior to 2016 JW was reported to have higher than 90% compliance, which is the industry target (JW, 2018). However, the conditions of the Water Use Licence (WUL) has amended the regulatory framework to include more stringent water quality standards. As a result, the wastewater treatment works have been less compliant. This poor quality affects the city's riverine systems which in turn affects the ecological water supply required as well as any ecosystem functions that it supports. In addition to the direct impact that failing treatment plants might have on downstream water quality, it is also of concern for water security. This is particularly important along the Vaal River where significant and increasing volumes of water are required by downstream users and water quality needs to be kept at acceptable levels. Climate change will also increase risk as hotter temperatures impact the risk of

Figure 35.

Adapted from the Updated IVRS Reconciliation Study showing the Sewage Drainage Areas (SDA's) for Gauteng (Department of Water and Sanitation, 2021)



In the regional area, Rand Water has plans to expand its bulk sanitation services to municipalities recognising that some of the main polluters in the catchment are municipal sewage treatment plants and the discharge of poorly treated wastewater into river systems impacts raw water abstraction for water supply. Rand Water's Bulk Sanitation Services include the following: to extend Rand Water's catchment monitoring programme; to conduct assessments of the Sewage Treatment facilities in the catchment; to report on the findings; and to provide site-specific recommendations to the respective municipalities that guarantee effluent compliance with the general standards set by the Department of Water Affairs (Rand Water, no date a).

4.4 STORMWATER MANAGEMENT

Unlike other sources of water in the CoJ, the Johannesburg Roads Agency is the custodian of stormwater infrastructure in the city and responsible for stormwater management. In the CoJ, stormwater management has historically entailed diverting stormwater flows into piped stormwater drainage systems to remove the water as quickly as possible. In 2010, CoJ gazetted the stormwater management by-laws (CoJ, 2010) that required all new developments to manage and treat their stormwater on-site to ensure that new developments do not decrease the quality of stormwater nor increase the flood risk. This by-law began to enforce decentralised stormwater management, which in theory should reduce CoJ's stormwater operation and management costs as the stormwater management cost would be borne by the property owners or developers. The by-law was not being effectively enforced thus there was a need for a stormwater manual to provide guidance on how best to enforce the by-law. The CoJ have also drafted a Stormwater Design Manual (CoJ, 2019) that advocates for both efficient drainage and improved flood risk management along with the protection of the stormwater as a potential water supply source. The design manual sets principals that encourage holistic and collective stormwater management and planning across the city and the use of a combination of blue, green and grey infrastructure for improved water quality, eco-system function and flood protection.

In recent years, the CoJ has been experiencing more high intensity rainfall events overloading the city's stormwater system causing more frequent flooding in the city. The flooding occurs in low-lying areas which often is occupied by informal housing and/or low-income households such as Soweto, Alexandra and Diepsloot among others. Figure 37 highlights the hydrology of Gauteng. Rivers, dams, wetlands, and flood areas and flooding hotspots. In addition, flooding also impacts on water quality due to for example the flooding of sewerage networks and ponds. Figure 38 below highlights the stormwater related issues in the CoJ including the flood risk areas, institutional issues, infrastructure issues and water quality problem areas as well as opportunities for stormwater interventions.

In 2019, the Johannesburg Roads Agency (JRA) commissioned a feasibility study to investigate the benefits of regional stormwater management (Aurecon, 2019). The feasibility study recommended that the CoJ undertakes stormwater management and maintenance plans at a catchment level to assess a dual approach of decentralised and local as well as centralised regional stormwater management. This approach would also improve management of stormwater quality at source while allowing for better management of larger volumes of stormwater to reduce flooding (Aurecon, 2019).

Figure 36.

Hydrology of Gauteng (GCRO, 2012b)

Hydrology sources: Ekurhuleni Metropolitan Municipality Corporate GIS (2012); Johannesburg Roads Agency (2012); City of Tshwane Roads and Stormwater Division (2012); West Rand District Municipality (2012); Randfontein Local Municipality Development Planning (2012); Merafong City Planning and Environmental Management (2012)

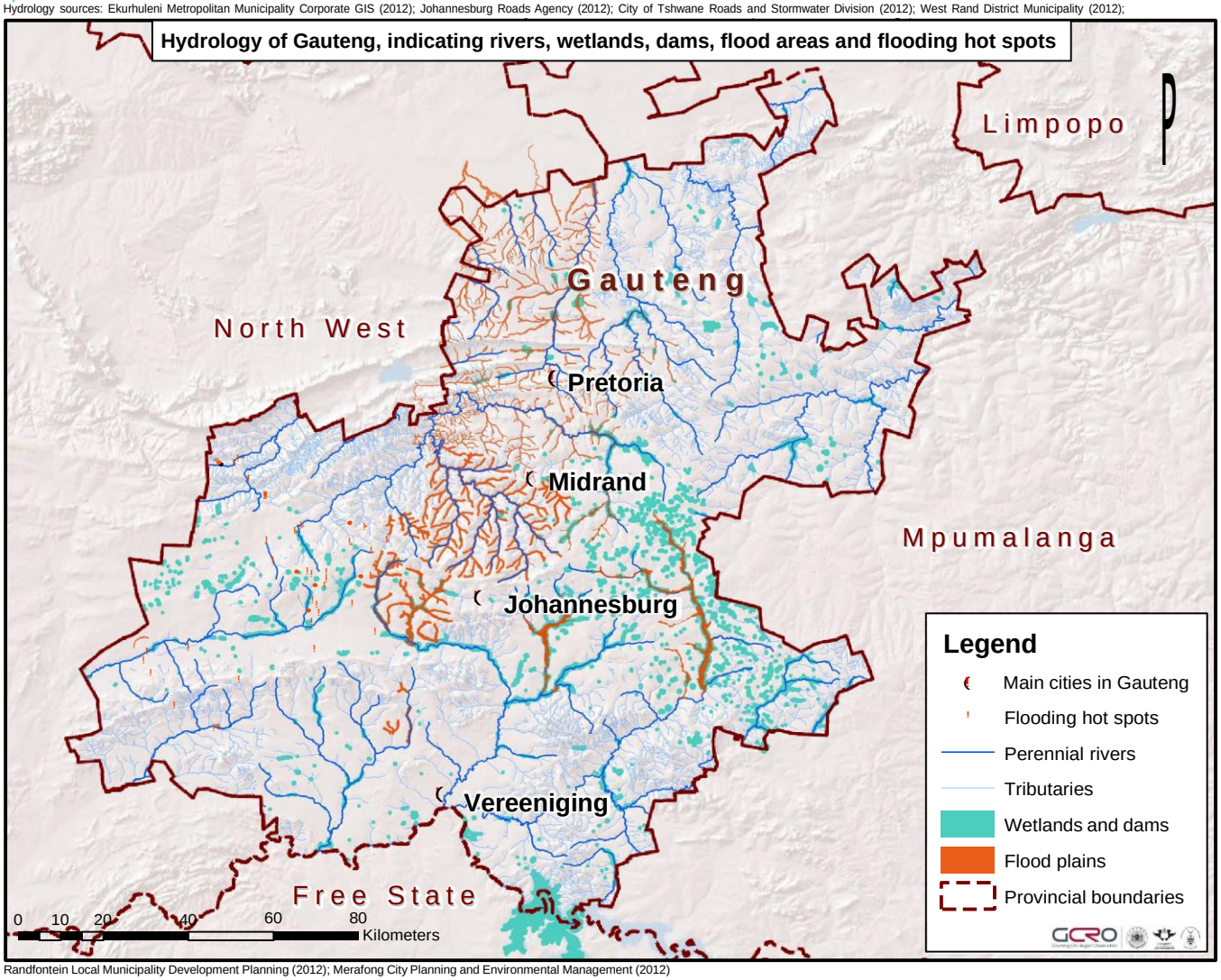
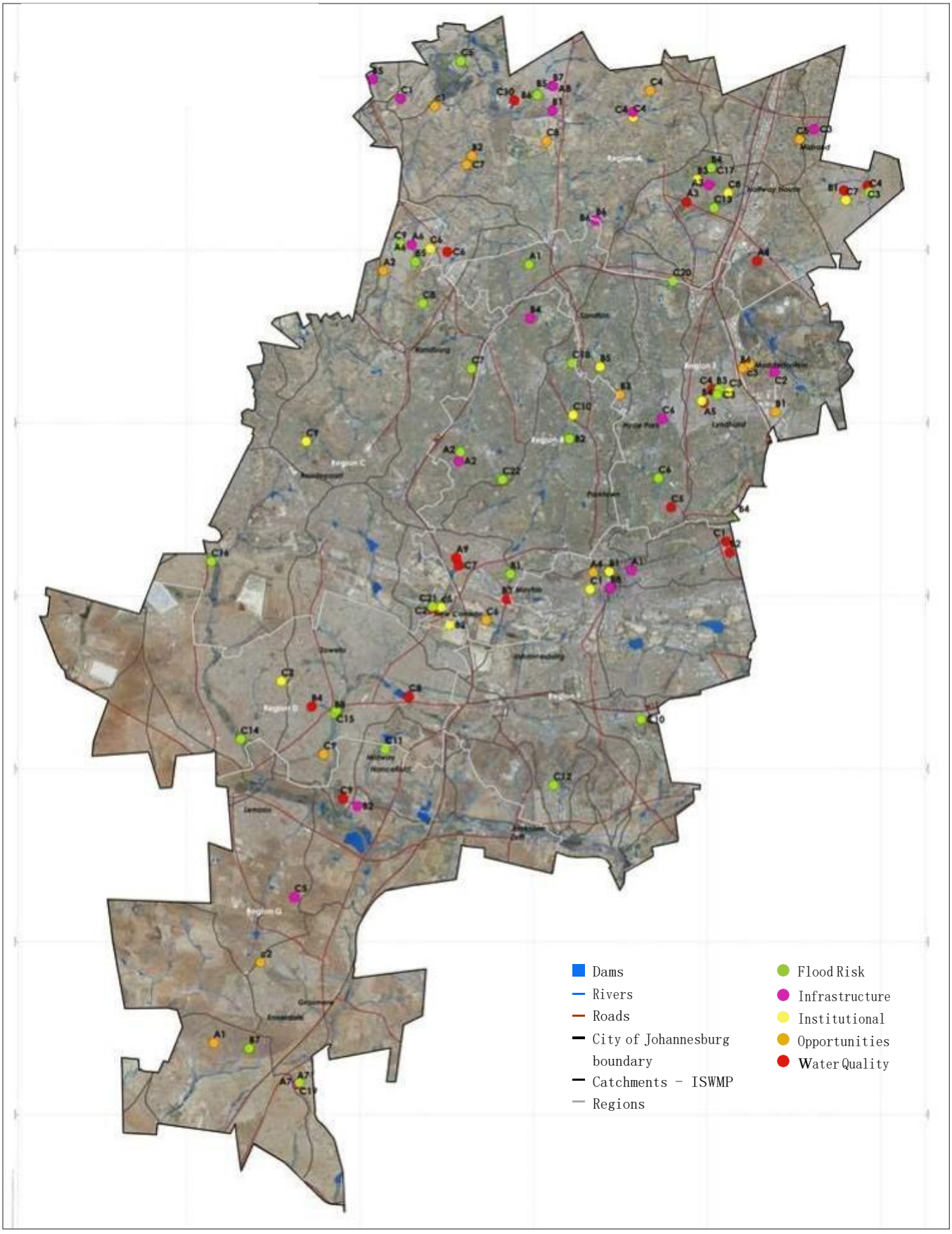


Figure 37.
Stormwater Management Issues and Opportunities within the CoJ (Cullis and Phillips, 2019a)



4.5 GROUNDWATER

The CoJ has various aquifers within its municipal boundaries and according to the Council of Geoscience (2016), the groundwater quality is generally good except in areas with close proximity to mines. The Council of Geoscience (2015) notes that part of the CoJ (13%) is underlain by dolomite rock, which is notorious for formation of sinkholes and subsidence and thus does not recommend large-scale groundwater abstraction within these areas. They subsequently recommended that groundwater abstraction could be an economically viable alternative resource for on-site and small-scale schemes (Council of Geoscience, 2016). However, where more extensive groundwater abstraction is unavoidable, the Council insists that detailed geohydrological investigations must be undertaken to ensure sustainability and health of the groundwater levels.

In 2019 and 2021, the CoJ commissioned a hydrogeological study to identify possible groundwater sources and borehole locations that could be used as an alternative water supply for communal swimming pools and parks irrigation within the City of Johannesburg. This study (Council of Geoscience, 2019, 2021) found that from 10 boreholes ~22 000m3/month could be abstracted sustainably to augment water supply to communal swimming pools and irrigate parks. This equates to ~1Ml/d which seems relatively insignificant compared to the current total water usage of 1616 Ml/d.

If these efforts are scaled up sustainably to include schools and other recreational fields and swimming pools and even some industrial supply needs, these efforts collectively would have a more significant influence by diversifying some of CoJ supply needs and ensuring some resilience to change. To ensure the sustainability of the resource, however, the report recommends water level monitoring at the boreholes, bi-annual water quality testing, and strict management of pumping rates.

4.6 WATER QUALITY

Water quality issues are mostly present on the outskirts of CoJ around newer established townships to the east and north (Ivory Park, Diepsloot, Alexandra) and the older townships of the south (Soweto) due to inadequate access to basic services like sanitation, refuse collection and stormwater drainage, there is a lack of formal infrastructure therefore refuse and wastewater from informal settlements find its way into the nearest river courses. Water quality issues are also present around the mining belt to the south and west of the CBD. Industrial pollution is also present in Bosmond to the west of Johannesburg CBD. The availability of water in the IVRS is directly impacted by water quality due to dilution release requirements from the Vaal Dam as a result of high salinity concentrations (DWS, 2021). According to the Municipal Strategic Self Assessments of Water Services Authorities in South Africa, the Wastewater/Environmental Safety & Regulatory Compliance of Gauteng is only 40% (DWS, 2019) however the CoJ's effluent compliance is 84.6% (Johannesburg Water, 2021). This indicates that there are surrounding municipalities who are struggling with being compliant and are impacting the water quality of river systems by depositing non-compliant effluent leading to environmental consequences that affect all who are in the catchment.

4.7 ALTERNATIVE SOURCES OF WATER

The CoJ, like most other cities in South Africa is completely reliant on surface water. However, alternative water supply options could be considered and should be developed as part of a more integrated and diversified water supply strategy for the CoJ. An understanding of how these alternatives supply options interact with the existing bulk water supply system is critical. Below is a short summary of alternative sources of water that have been identified for the CoJ.

4.7.1 RAINWATER HARVESTING

Rainwater harvesting is a decentralised and close-to-source solution of alternative water supply. Rainwater harvesting may not be a reliable, continuous source of water for Johannesburg, as the area is characterised by seasonal summer rainfall which would require large storage capacity to ensure continuous supply throughout the year. However, it can be used as a stormwater management tool through the use of Sustainable Drainage Systems[3] (SuDS), to reduce urban water runoff volumes helping to reduce flooding and prevent additional pollution from entering the river systems as well as additional benefits such as to health, well-being, and improved quality of local ecosystems. The CoJ commissioned a study that included the development of rainwater harvesting guidelines for the municipality and applying the guidelines at selected case-study sites. The study aimed to understand the plausibility of rainwater harvesting as a viable alternative water resource for the municipality. The case study sites included various user categories: a multi-dwelling residence, a stand-alone office block, a commercial building, and a school. The results showed that the non-residential categories with extensive roof collection and significant rainwater demand were financially viable. The residential case study was not financially viable due to the smaller collection area and lower rainwater demand (Ndiritu, Ilemobade and Kagoda, 2018).

4.7.2 TREATED EFFLUENT AND WATER RE-USE

Joburg Water (JW) is currently supplying treated effluent to a number of existing users including, Kelvin Power Station, Ruimsig Country Club, Steyn City and PPC. As part of JW's 2020/21 business plan, it intends to expand the supply of treated effluent to additional customers as an alternative water source (JW, 2020c). This supply could be an alternative water source for industries, commercial lawns, gardens, and managed aquifer recharge among other users. JW is also investigating returning treated effluent to be mixed with treated surface water to increase its potable water supply.

(3) Sustainable Drainage Systems are holistic drainage solutions designed to mimic natural water cycles which aims to manage the stormwater quantity and quality close to the source.

5

CHARACTERISING RESILIENCE

Resilience is characterised by the ability of a system to withstand shocks and stresses exerted upon it. Therefore, resilience is fundamentally dependent on how vulnerable a system is. The greater the vulnerability, the less the adaptive capacity, the greater the damage done as a result of shocks and stresses exerted on the system. This section explores the vulnerability of the City of Johannesburg and the key shocks and stresses that the city encounters.

5.1 UNDER LYING SETTLEMENT VULNERABILITY

This section explores the settlement vulnerability faced by the City of Johannesburg. Hazards exploit system vulnerabilities which results in failure. The less vulnerable a system is, the more resilient it will be in the face of shocks and stresses.

Vulnerability is defined as "The conditions or processes that are driven by different economic, social, physical and environmental factors and that have the potential to increase a system's exposure to the impact brought on by a hazard" according to the United Nations International Strategy for Disaster Reduction and adopted by the South African National Disaster Management Centre.

Figure 38.
Vulnerability for the greater Gauteng region

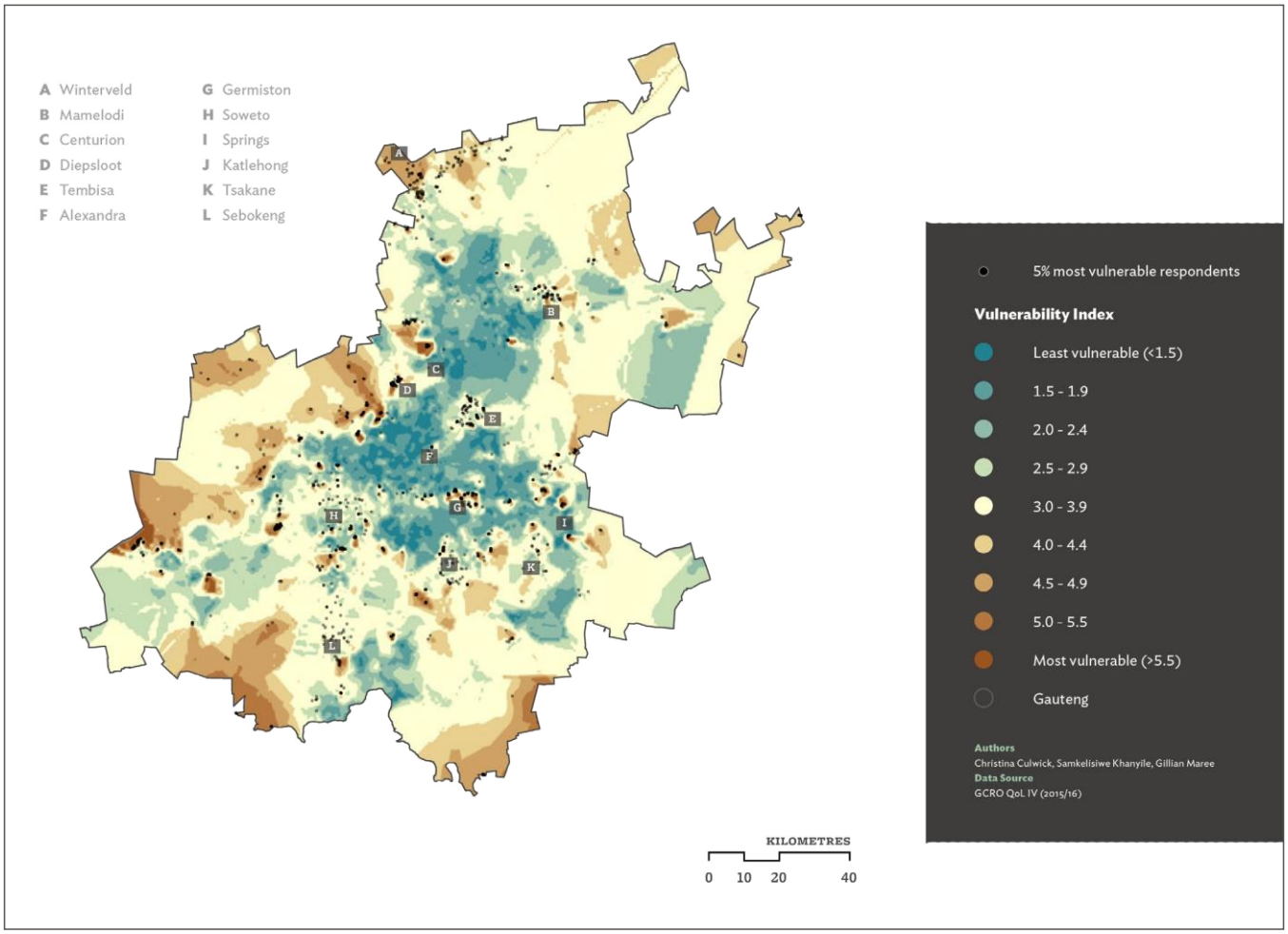
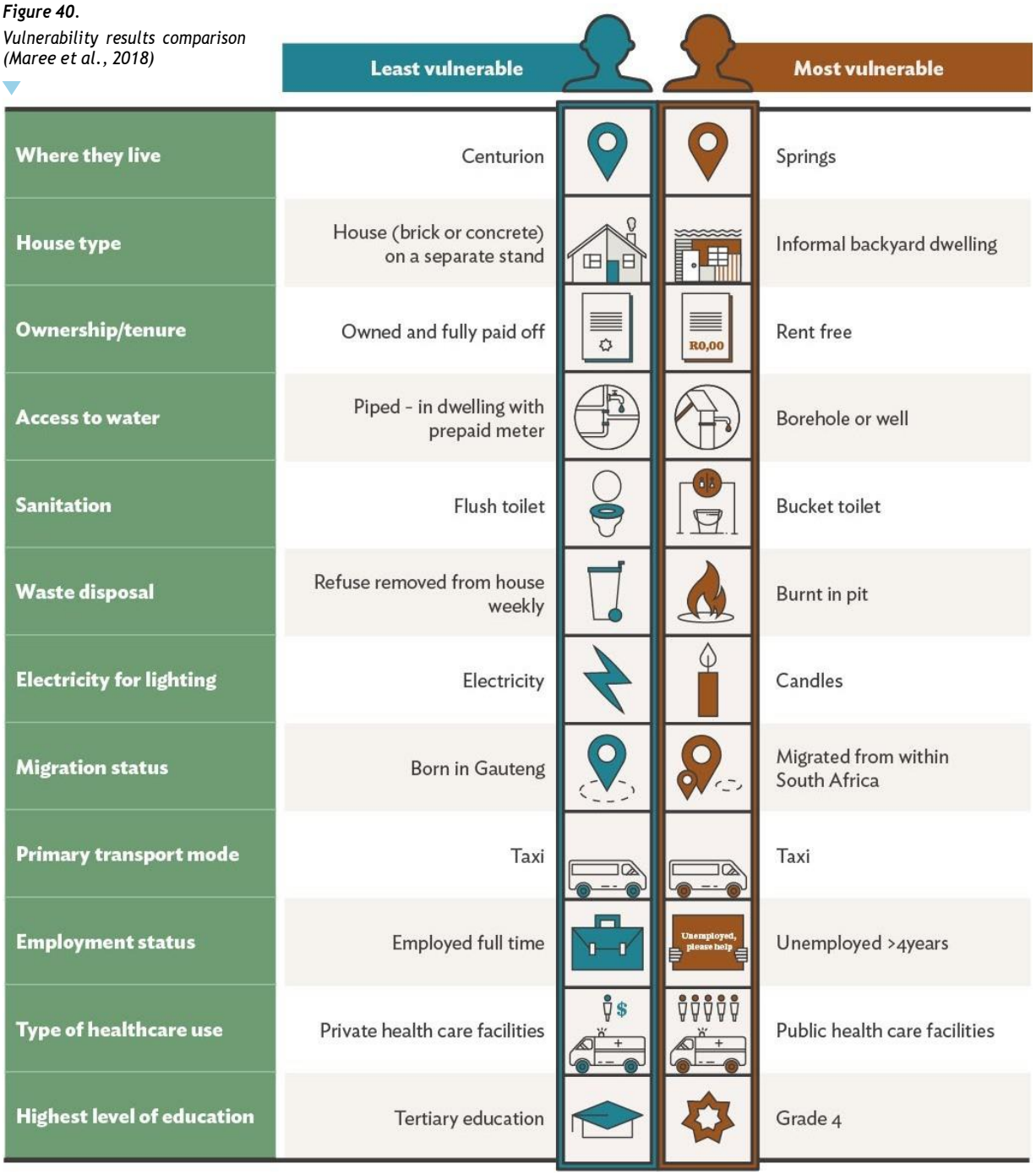


Figure 39.
Vulnerability Index Variables (Maree et al., 2018)

QoL IV (2015/16) variables used to construct the Vulnerability Index	
Dimensions	**Indicators**
Poverty & other risks	1. *Monthly household income less than R1600/month* 2. *Unemployed* 3. *Has not obtained Grade 9 equivalent* 4. *An adult in the household often or always goes hungry because not enough food is available* 5. *Agree that environmental factors have harmed respondent or their family*
Health	6. *Respondent has a disability* 7. *Health has been poor or very poor in past four weeks* 8. *Health status always affects work* 9. *Health status always affects usual social activities*
Dependency	10. *There are children in the household* 11. *Respondent is 60years or older*
Housing	12. *Live in informal dwelling* 13. *Live in one room & share with one or more households*
Services	14. *No access to a flush toilet* 15. *Water not piped into dwelling* 16. *Water is hardly ever or never clean* 17. *Does not have secure access to electricity* 18. *Refuse not removed from house* 19. *Dissatisfied with stormwater infrastructure or the area has none*
Communication & access	20. *Does not have access to the internet* 21. *Household does not have a working cell phone* 22. *Household does not have a working radio* 23. *Household does not have a working television* 24. *Household does not have a working car* 25. *Household does not have a working bicycle* 26. *Not in easy walking distance to transport*
Coping capacity	27. *Dissatisfied with emergency services where respondent lives* 28. *Respondent does not trust people in their community* 29. *Dissatisfied with time spent with family* 30. *Dissatisfied with friends* 31. *Dissatisfied with or not in a relationship* 32. *Respondent feels no one cares about people like them* 33. *Could not borrow any money in a health emergency* 34. *Respondent finds it difficult or impossible to save money* 35. *Not covered by any medical insurance*

The GCRO's fourth Quality of Life Survey (QoL IV 2015/16) was used to construct a Vulnerability Index of which the results are shown in Figure 39 using the following dimensions: Poverty & other risks, Health, Dependency, Housing, Services, Communication & access, and Coping Capacity; each of which are characterised by a range of indicators that are drawn from objective and subjective measures to obtain an overall sense of vulnerability (Figure 39) (Maree et al., 2018). Areas such as Soweto, Diepsloot, Ivory Park and Alexandra have high concentrations of vulnerability whereas areas such as Sandton contrastingly have the lowest vulnerabilities. In Johannesburg there is a mix of many high-vulnerable people living next to people with the least vulnerability such as Alexandra and Sandton or Houghton and Hillbrow showing the stark contrasts between the two different realities that characterises the city. The vulnerability results comparison in Figure 40 below provides key insights into what the lives of those who are categorised as most vulnerable look like compared to those who are least vulnerable. This is useful for comparing what the situation on the ground for each respondent is and the stark inequalities by looking at where they come from (born in Gauteng vs. migrated from another province); location and type of house that they live in (privately owned and fully off house on an independent stand vs. rented out informal backyard dwelling on another person's stand); access to services that they have (water is piped with a prepaid meter / flush toilet / weekly refuse removal / electricity / private healthcare vs. borehole or well / bucket toilet / refuse burnt in a pit / candles / public healthcare); level of education (tertiary vs. Grade 4); and employment status (full-time employed vs. unemployed for greater than 4 years resulting in a discouraged job seeker).

Figure 40.
Vulnerability results comparison (Maree et al., 2018)



The Green Book, a practical planning tool for adapting South African settlements to climate change, uses the following definitions to describe the four types of vulnerability (Le Roux, van Huyssteen, et al., 2019a):

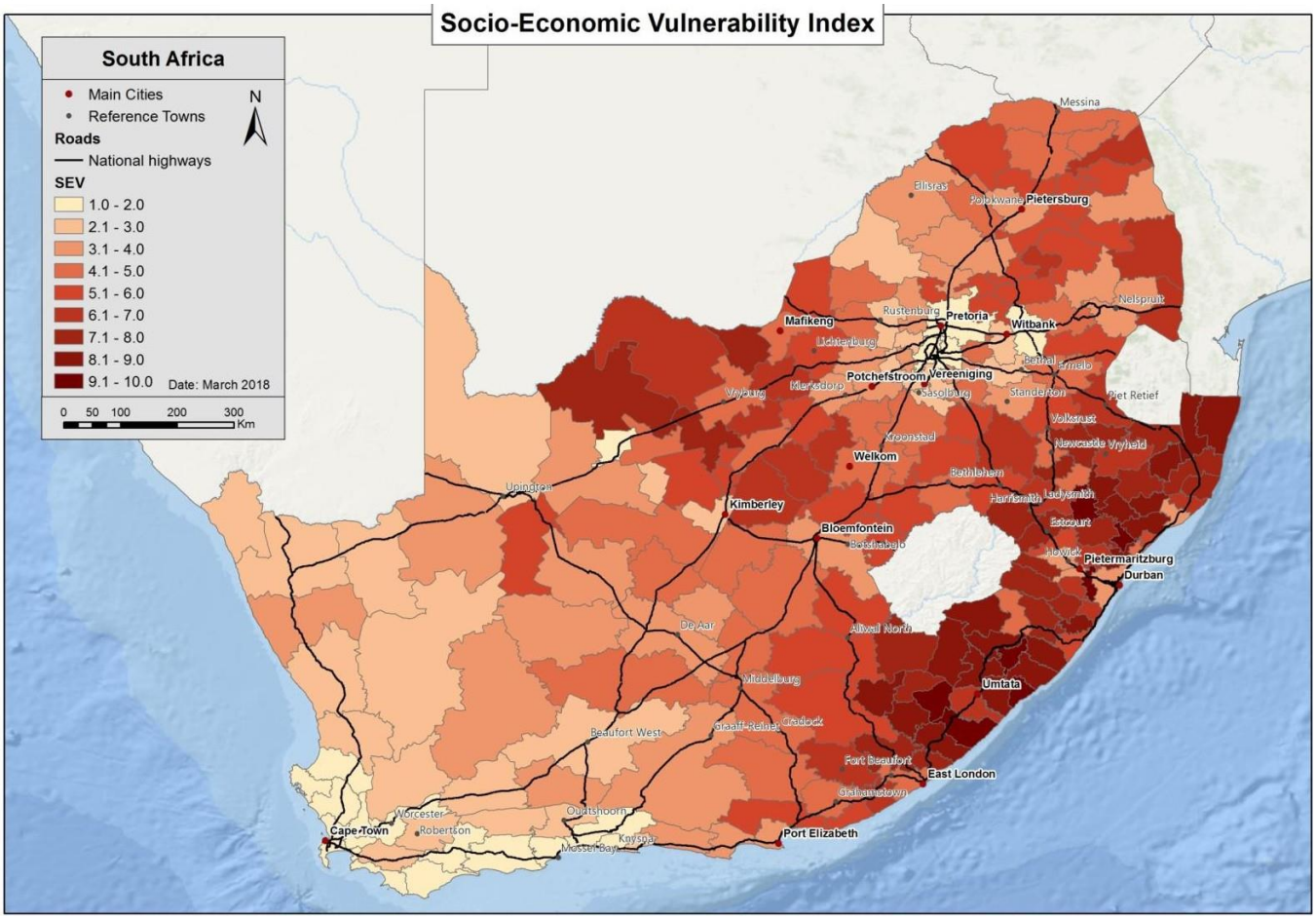
Socio-Economic Vulnerability Index

Social inequalities are the factors that shape and influence the susceptibility and coping mechanisms of communities. Indicators for social vulnerability attempt to consider the sensitivity to natural hazards of a population and the ability of the population to respond to and recover from the impacts caused by the natural hazard. This type is characterised by the following: household composition, income composition, education, mobility, health, access to basic services, access to social government services, political instability, and safety & security. The Socio-Economic Vulnerability Index for the CoJ is between 1.0-2.0 which is the least vulnerable category ranking the CoJ 6/213 in South Africa indicating that the Socio-Economic situation in Johannesburg is good overall (Figure 41).

Economic Vulnerability Index

The economic dimension of vulnerability can be described as the potential risks posed by hazards on economic assets and processes within the settlements and their municipalities. Potential hazards can be job losses, increased poverty and interruptions in business activities. Economic vulnerability includes the lack of diversity of a local economy and a dependency on declining sectors. Economic vulnerability also includes a focus on people living in poverty as they are inevitably more vulnerable to disasters and climate-related hazards because of a number of reasons, including that they often lack the necessary resources to build (and re-build) safe and secure homes, have limited or no access to insurance, and are often located in informal settlements with limited access to good quality basic services. Economic vulnerability is characterised by diversification, size of economy, labour force, GDP growth/decline pressure, and inequality. The Economic Vulnerability Index for the CoJ is between 1.0-2.0 which is the least vulnerable category ranking the CoJ 12/213 in South Africa indicating that the Economic situation in Johannesburg is good overall (Figure 42).

Figure 41. Socio-Economic Vulnerability Index for South Africa (Le Roux, van Huyssteen, et al., 2019b)



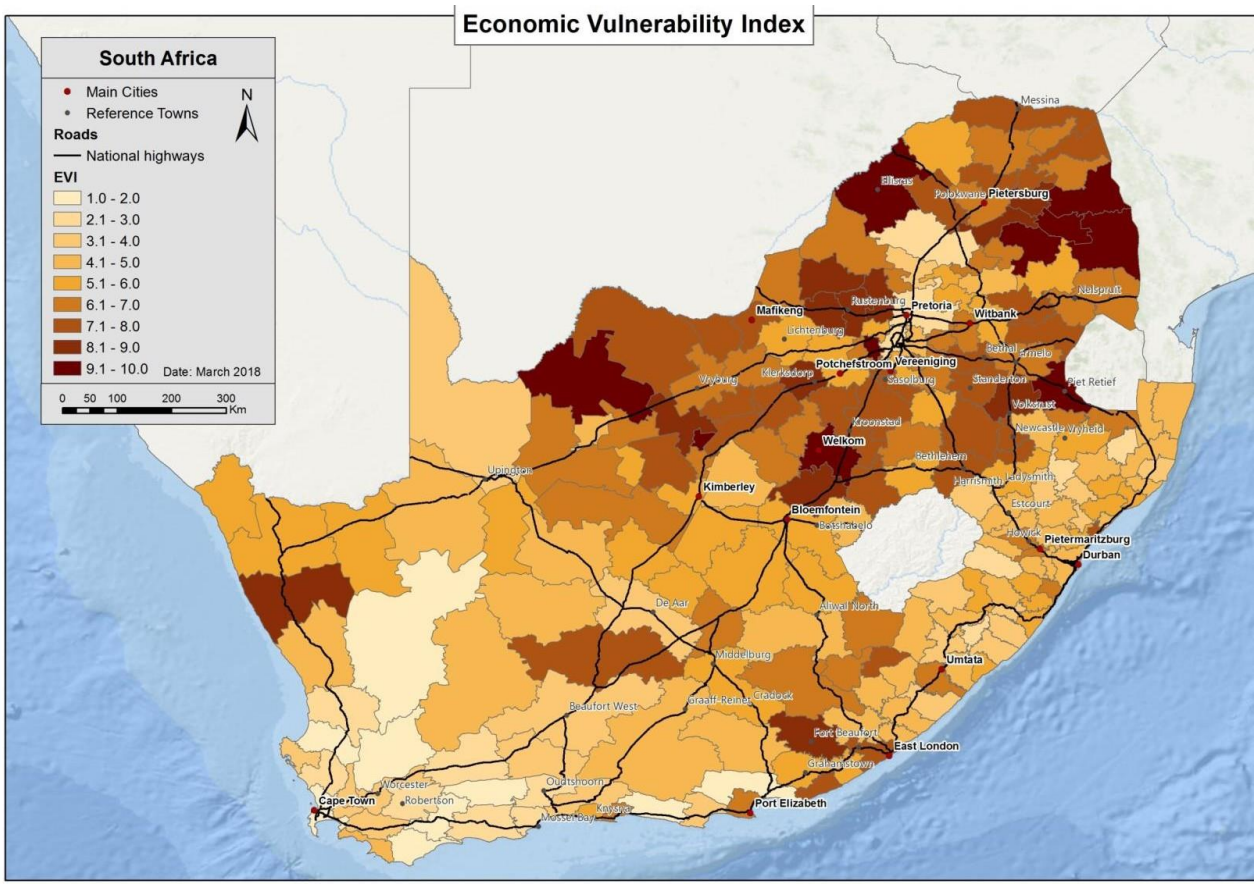


Figure 42.
Economic Vulnerability Index for South Africa (Le Roux, van Huyssteen, et al., 2019b)

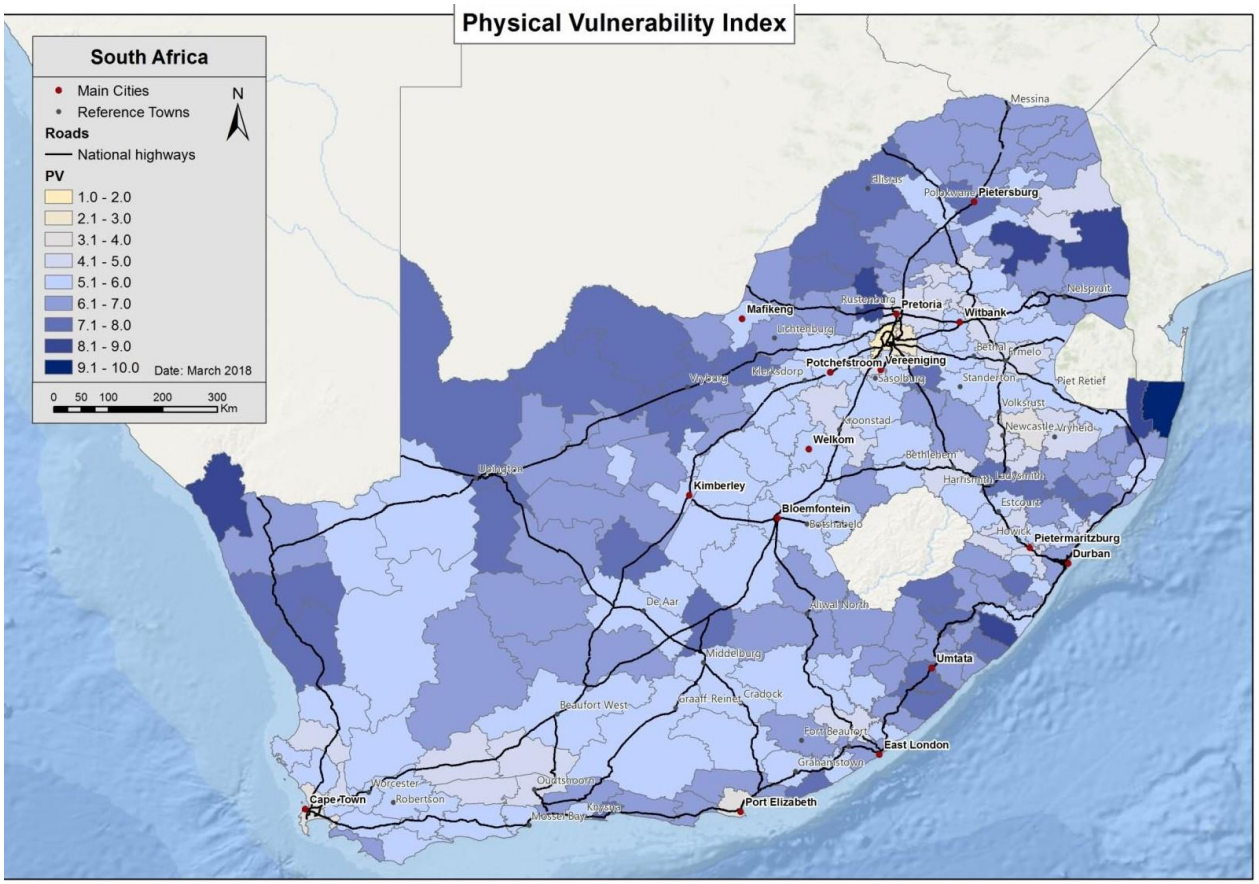


Figure 43.
Physical Vulnerability Index for South Africa (Le Roux, van Huyssteen, et al., 2019b)

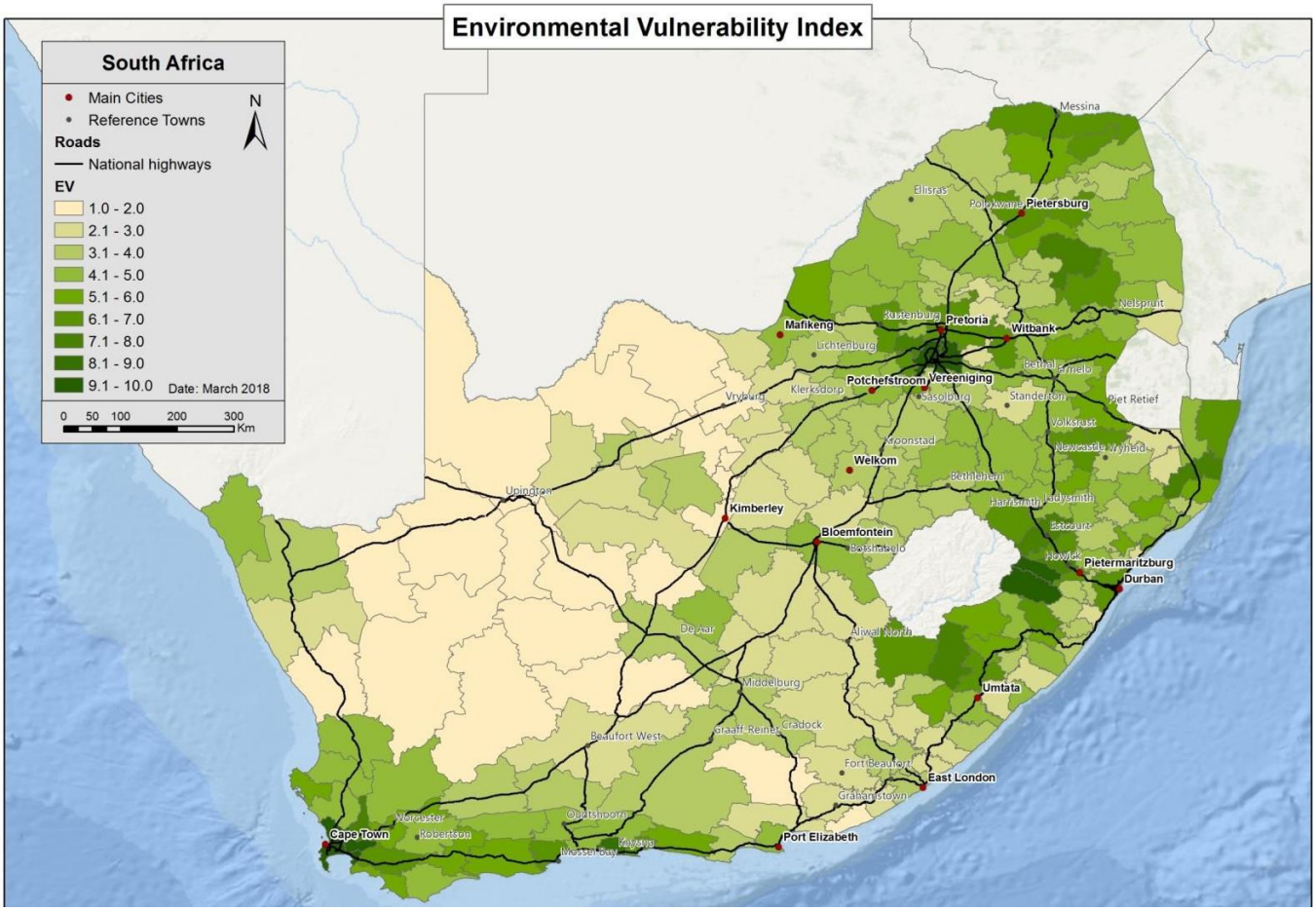
Physical Vulnerability Index

The physical dimension of vulnerability relates to the built environment, its fabric and built structures (buildings and infrastructure) and focuses mainly on the conditions that exist before a hazard occurs (exposed elements and their characteristics) and the expected degree of loss which results from the occurrence of a hazard of a given magnitude. Physical vulnerability is determined through assessing road infrastructure, housing type, maintenance of infrastructure, density, and accessibility within the local municipality. The CoJ is the least vulnerable in terms of the Physical Vulnerability Index compared to the rest of South Africa with a ranking of 1/213 (Figure 43).

Environmental Vulnerability Index

The environmental dimension of vulnerability can be defined as the vulnerability and risk to the natural environment and in the case of settlements the impacts on the ecological infrastructure on which such settlements are dependent. The environment that is at risk includes populations and communities of organisms, ecosystems, habitats, physical and biological processes such as reproduction, diversity, energy flows, ecological resilience and natural selection. In essence, it is considered to be the external conditions, factors and influences that affect and surround a settlement or community, including both human-built and natural elements. Environmental vulnerability is characterised by human influence on the environment, ecological infrastructure, water resources, health, and environmental governance. With a ranking of 209/213, the CoJ is one of the most vulnerable cities in South Africa in terms of the Environmental Vulnerability Index (Figure 44).

Figure 44.
Environmental Vulnerability Index for South Africa (Le Roux, van Huyssteen, et al., 2019b)



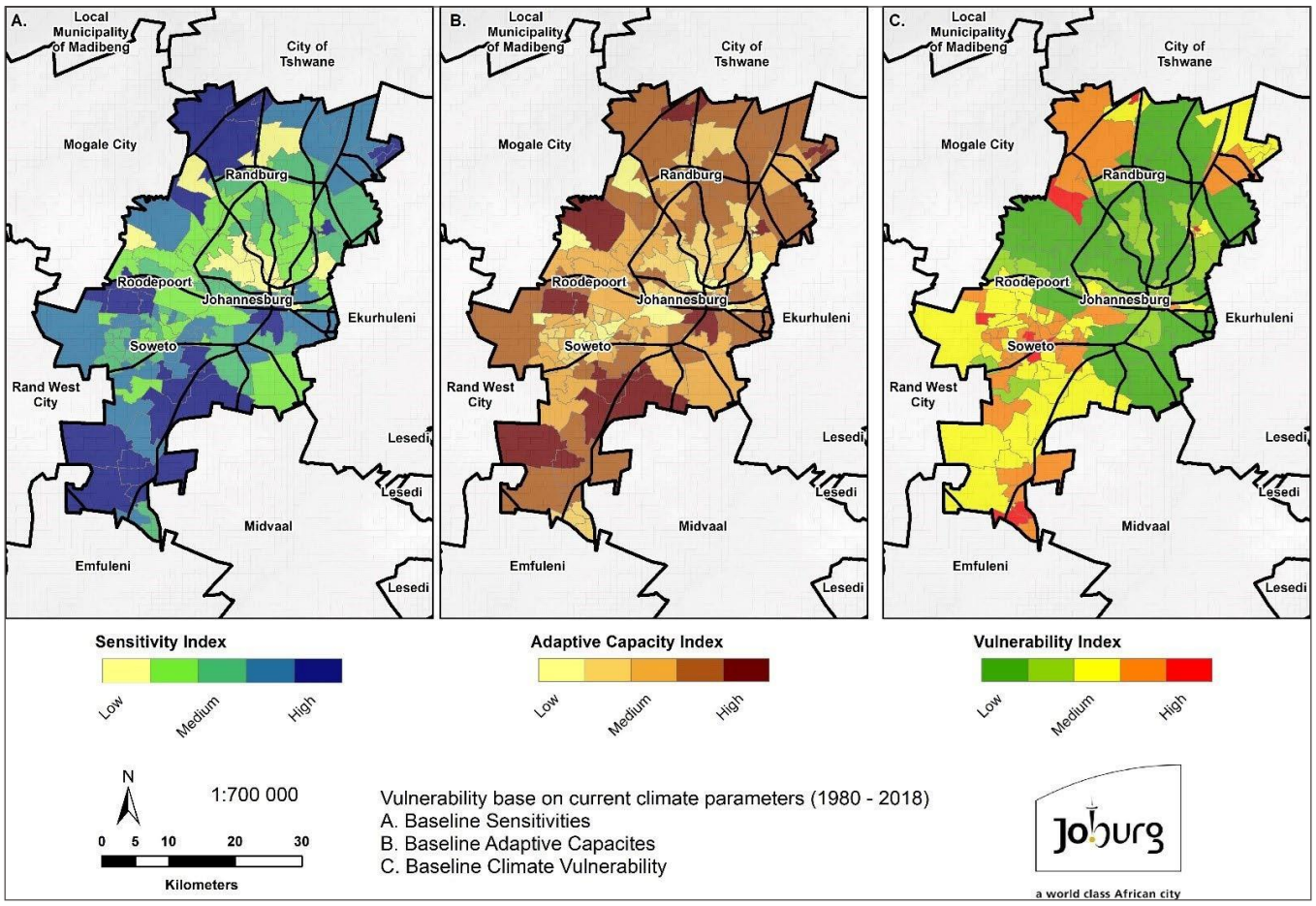
The CoJ is ranked on a municipal scale against the rest of the municipalities in South Africa according to the four indicators that determine local municipality vulnerability Error! Reference source not found. below. For the socio-economic, economic and physical vulnerabilities, the CoJ performs very well against the rest of South Africa maintaining a position in the top 5% of least vulnerable cities however the environmental vulnerability is by contrast exceptionally high (in the 2% of the most vulnerable cities in South Africa) indicating that the environment is severely degraded and seldom prioritised.

Table 3.
CoJ Municipality Ranking (Le Roux, van Huyssteen, et al., 2019b)

Type of Local Municipal Vulnerability	Country-wide Rating (/213)
Socio-Economic Vulnerability	6
Economic Vulnerability	12
Physical Vulnerability	1
Environmental Vulnerability	209

The Climate Action Plan further deduced what the vulnerability of the CoJ is based on current and project climate trends. The assessment was carried out by establishing the Sensitivity Index (A) that considered how exposed an areas is to a hazard and the Adaptive Capacity Index (B) that looked at how well an area is able to respond to a hazard (Figure 45) considering indicators linked to quality of life such as types of dwellings, access to services like clean water, and household income (City of Johannesburg, 2020a). The Sensitivity Index (A) and Adaptive Capacity Index (B) were combined to deduce the overall Vulnerability Index (C) (Figure 45). The areas that are higher in vulnerability correspond with the poorer informal settlements and the areas which are low in vulnerability coincide with the established affluent suburbs.

Figure 45.
Baseline sensitivity, adaptive capacity and climate vulnerability of the CoJ (City of Johannesburg, 2020a)



5.2 KEY STRESSES & SHOCKS

Through the review of existing studies, the following key shocks and stresses have been identified:

Stresses	Shocks
Poverty & Inequality	Failing infrastructure
Growth pressure	Energy disruption
Lack of basic service provision	Flooding
Climate change impacts	Theft & Vandalism
Water security challenges	COVID 19
Environmental degradation	

5.2.1 POVERTY & INEQUALITY

South Africa is known to be the most unequal society in the world (COGTA, 2020) initially associated with apartheid stemming from white supremacy but still continues to be a major issue almost three decades later. In a list of twenty of the most unequal cities, seven South African cities dominate with Johannesburg the second most unequal city in the world behind London (World Atlas, 2019). This is supported by the significantly high Gini coefficient that measures income inequality being at 0.624 for the City of Johannesburg (COGTA, 2020) driven by the fact that the wealthy have gotten richer at a faster rate than lower income groups (City of Johannesburg, 2016).

Although, the average income of Johannesburg is nearly double the rest of South Africa, 8% of the population have no income at all and 47% live on less than R40 000 per annum (approximately $7 a day in 2022) (COGTA, 2020). The percentage of people living in poverty in the City of Johannesburg was 45.57% in 2018 with the population group of people living in poverty being 61.4% Black African (COGTA, 2020). The mean income per ward is highlighted in Figure 46 below showing the disparity between the affluent north (Sandton) and impoverished south (Soweto). Of the economically active population, 52.6% are employed with unemployment being 26.5% in the city and youth unemployment estimated to be over 46.6%.

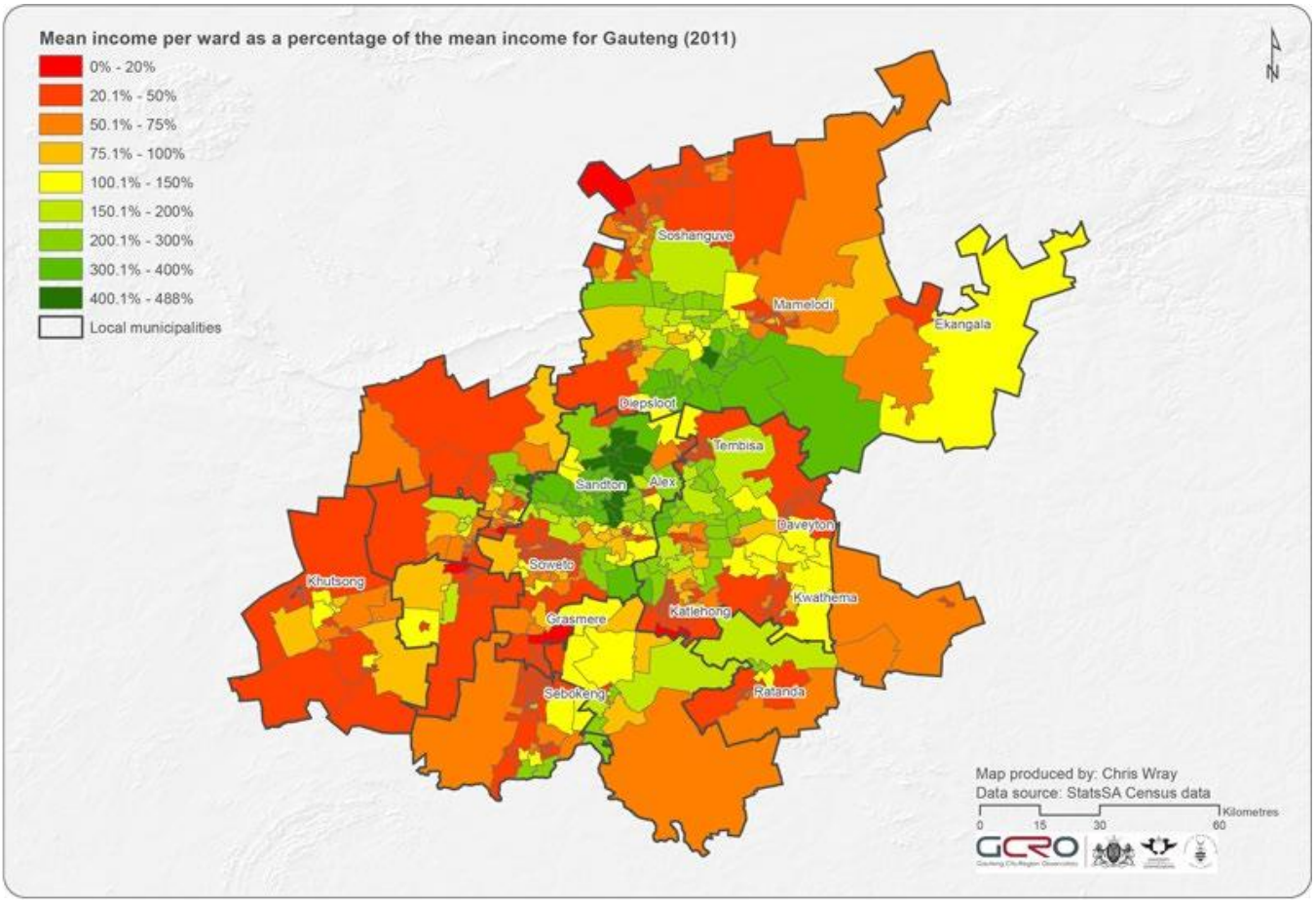


Figure 46.
Baseline sensitivity, adaptive capacity and climate vulnerability of the CoJ (City of Johannesburg, 2020a)

The Human Development Index (HDI) that constitutes indicators made up of life expectancy, education and per capita income indicates that in South Africa the HDI for whites in Gauteng has been historically much higher than other race groups due to the advantages given during apartheid and remains at 0.90 equivalent to Denmark (ranked 15 of all countries on the index) (Götz and Kibirige, 2014). Contrastingly, Africans have an index of 0.68 equivalent to El Salvador (ranked 107) however the HDI for non-whites (Africans, coloureds and Indians/ Asians) has risen significantly over the last two decades in the post-apartheid era reflecting dramatic improvements in income and education opportunities as reflected in the increase in the overall value for the City of Johannesburg, rising from 0.70 in 1996 to 0.75 in 2012 (Figure 47).

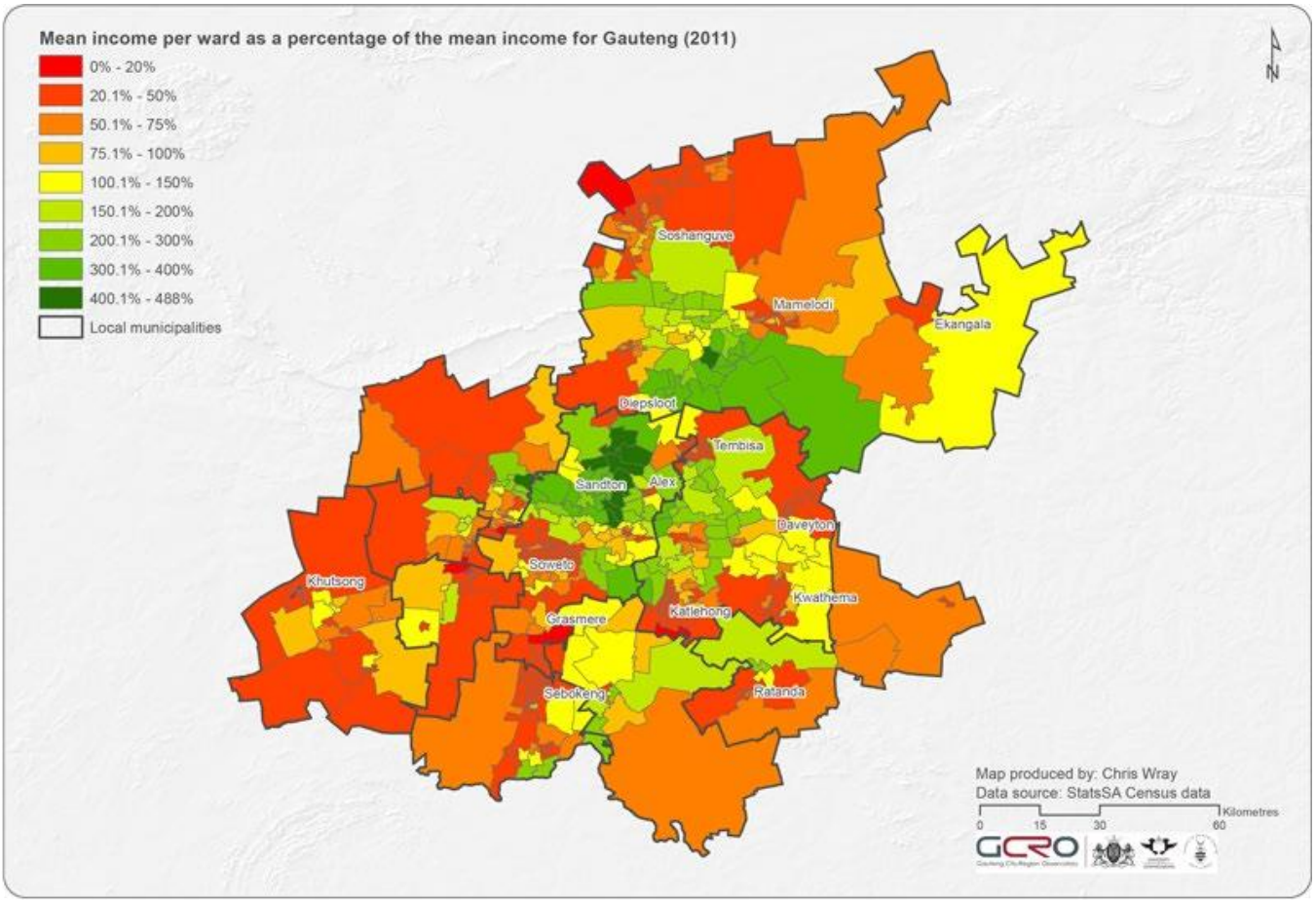


Figure 47.
Gauteng's HDI for 1996 & 2012 (Götz and Kibirige, 2014)

5.2.2 GROWTH PRESSURE

By 2050, the South African population is projected to increase by 23.6 million people with 62% of the growth projected to occur in the City Regions. Gauteng, Kwa-Zulu Natal and the Western Cape are expected to see the largest percentage increases in population growth. Gauteng being the smallest of the 9 provinces has the densest population distribution and is projected to experience an increase in South Africa's population from 23.6% to 27% by 2050, 99.9% of the population increase will occur in the Gauteng City Region. Johannesburg is the fastest growing district municipality in Gauteng. The city is projected to grow by 84% (an increase of 3.6 million people by 2050). For both medium and high growth scenarios, Johannesburg is greater than 60% from 2011 – 2050 and relatively extreme compared to the rest of South Africa as can be seen in Figure 48 below.

On a growth pressure scale that ranges from Extreme to Declining, the majority of the City of Johannesburg is expected to experience a high growth pressure (Figure 49). Growth creates opportunities to entrench principles of resilience into the design of South African cities, however without adequate planning and efficient management, growth will place enormous pressures on infrastructure and have critical implications for national and regional policies and inter-governmental prioritisation efforts.

Figure 48a.
Relative and absolute population change per District Municipality between 2011 and 2050 for the high growth scenario

Relative and absolute population change per District Municipality between 2011 and 2050 for the medium growth scenario

Figure 49. Population growth pressure for Johannesburg for 2050 (Le Roux, Arnold, et al., 2019)

KEY STRESSES

5.2.3 LACK OF BASIC SERVICE PROVISION IN INFORMAL SETTLEMENTS

Compared to the rest of South Africa, the provision of basic services such as access to piped water (98.8%), sanitation (96.4%) and electricity (92.3%) are relatively high. The issues with access to basic services is largely concentrated in informal settlements where less than half the households have access to basic sanitation and piped water is provided in the form of a standpipe. These issues are exacerbated by high population growth and urbanisation due to international and rural migration. (COGTA, 2020). Of the total number of households in Johannesburg, 19.1% live in informal settlements (South African Human Rights Commission, 2021). Even though JW provides communal potable water through communal taps and shared sanitation services, a backlog does still exist.

5.2.4 CLIMATE CHANGE IMPACTS

Climate Change Impacts water resilience through four main areas: Drought Tendency Risk, Wild-fires Risk, Heat Stress Risk; and Urban Flooding (Figure 50).

- **Drought Tendency Risk** - With an increase in drought tendency risk, water security is directly impacted. Drought tendency risk increases with an increase in average temperature, creating more arid conditions and increased variability in precipitation resulting in reduced annual precipitation.
- **Wild-fires Risk** - The risk of wild-fires is related to the drought tendency and the heat stress risk. With more arid conditions, hot days are a catalyst for wild fires starting and spreading. This poses a risk to infrastructure, the environment and people living in a city, decreasing liveability. A wild-fires risk also intensifies the need for fire suppressants to be constantly on-hand, therefore playing a role in water availability and storage.
- **Heat Stress Risk** - Heat Stress Risk is an increase in the number of hot days per year. As temperatures increase, so does water usage. This also impacts the likelihood of wild-fires.
- **Urban Flooding Risk** - Increased precipitation intensity results in an increased risk of urban flooding. If not appropriately planned and designed for, this has the potential to cause infrastructural damage and loss of life. Business continuity can potentially be interrupted as a result of people not being mobile during intense storms and communication breakdowns.

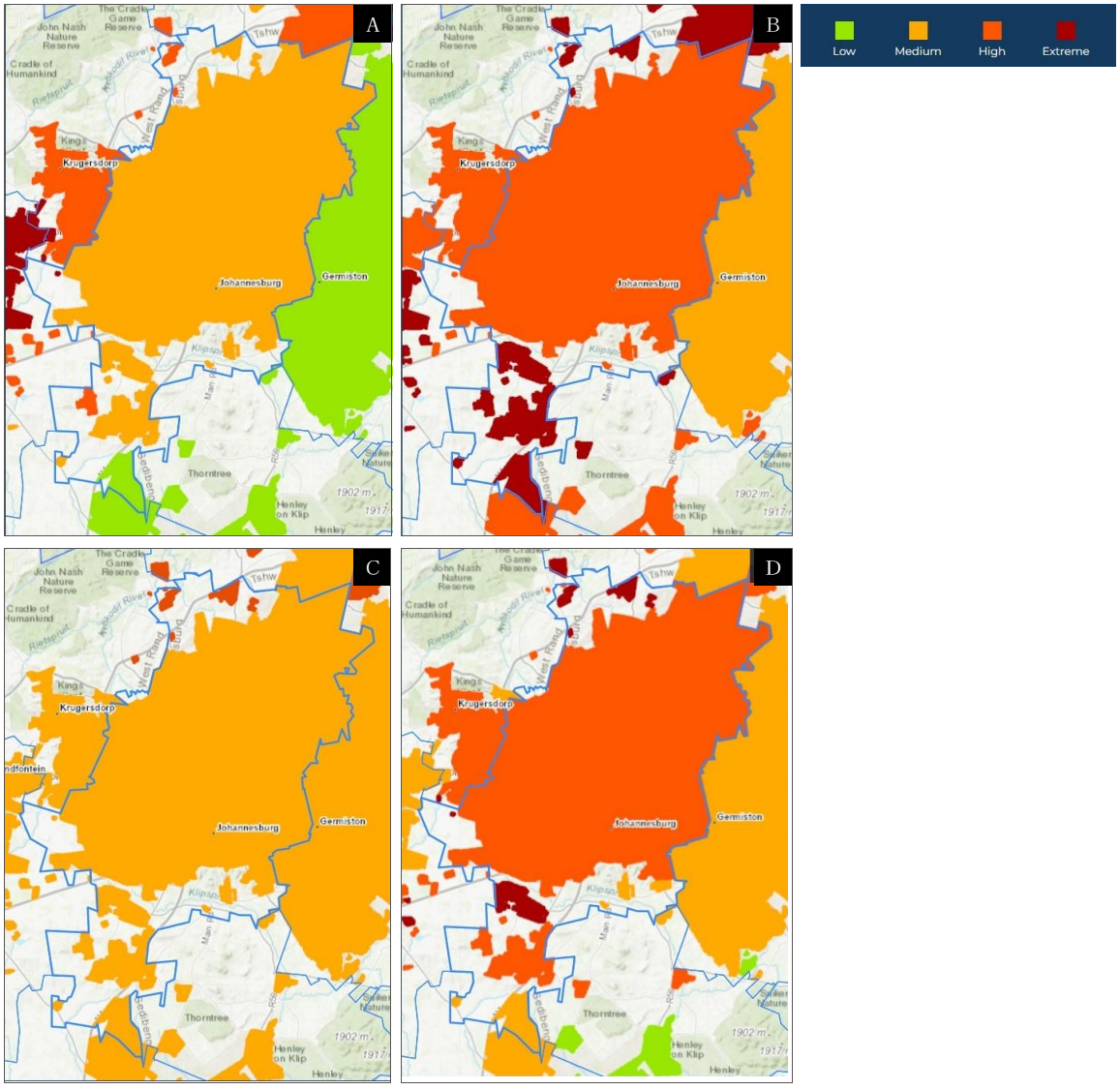


Figure 50. Projected climate change impacts on the CoJ (Engelbrecht et al., 2019)

A - Risk of increase in drought tendencies

B - Risk of increasein wild fires

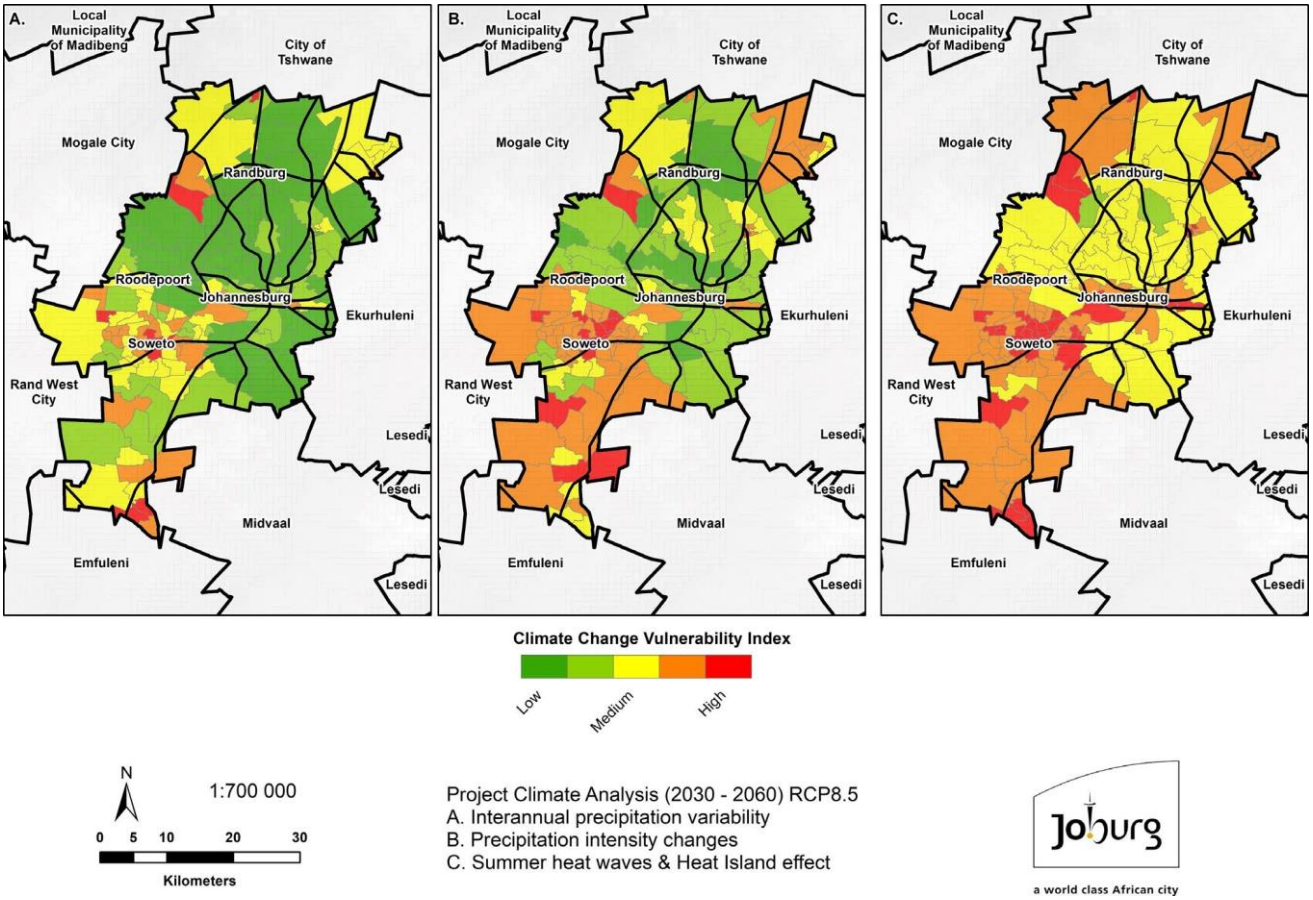
C - Risk of increase in heat stress

D - Risk of increase in urban flood

Johannesburg is expected to experience a moderate risk to drought tendency and heat stress and a high risk to wild-fires and urban flooding (Engelbrecht et al., 2019). Wild-fires is of particular concern because of the populated nature of the city and the lack of access to significant water sources. Urban flooding is already a major concern for the City of Johannesburg and is only expected to worsen under the impacts of climate change. The extreme growth pressures put further strain on the environment and further pressure to turn previous areas into impervious which would exacerbate flooding impacts.

Representative concertation pathways, also referred to as RCPs are a set of scenarios used by scientist to characterise the future climate change projections. Of the four, the best scenario is 2.6 and the worst scenario is 8.5. Error! Reference source not found. below breaks down the various areas in Johannesburg in terms of their climate vulnerability index scores per climate hazard for RCP 8.5. From the maps below, those who are most at risk include the informal settlements and less affluent areas such as townships, mainly Soweto in the south, Ivory Park (north-east), and Diepsloot (north-west).

Figure 51. RCP8.5 climate vulnerability index scores per climate hazard (City of Johannesburg, 2020a)



5.2.5 WATER SECURITY CHALLENGES

Johannesburg is extremely reliant on surface water with a high water demand per capita (Cullis and Phillips, 2019b). Johannesburg does not lie near a strategic water source (David Le Maitre et al., 2019) and is thus reliant on an international supplier, the Lesotho Highlands Water Project for water supply via the Integrated Vaal River System (DWS, 2021). Therefore, the delays in Phase 2 of the LHWP have significant impacts for the City of Johannesburg and would be substantially worse if a possible drought had to occur. Unlike other South African cities which rely on groundwater, groundwater as a source is largely unexplored in the city due to the water pollution caused by Acid Mine Drainage as well as the volatile dolomitic soil areas. Johannesburg is also known to have very high percentages of Non-Revenue water as a result of illegal connections as well as failing infrastructure that leads to leakages and pipe bursts. These aspects result in projections that the City of Johannesburg face an extreme future water supply vulnerability under a high growth scenario and RCP 8.5 climate change projections (Cullis and Phillips, 2019b).

There is also a risk of water supply being held "hostage" for the purpose of political leverage. In the case of Johannesburg, if this had to occur between South Africa and neighbouring country Lesotho, Johannesburg would be significantly impacted due to their heavy reliance on Lesotho for water supply. This could have far reaching consequences because Johannesburg is the economic hub of Africa.

5.2.6 ENVIRONMENTAL DEGRADATION

Urban development due to population growth and urbanisation has resulted in a significant loss of ecosystem services including resources required to sustain the province which have occurred unequally across Gauteng (Culwick et al., 2019) (Figure 52). Johannesburg is particularly built up (Figure 52 & Figure 53), however Diepsloot, Soweto and Alexandra (informal settlements) experience a significantly built up and low distribution of vegetation (Figure 54). There are plans and policies in place by the Gauteng Province to conserve and protect environmental infrastructure however this is constantly under pressure due to the growing need for development as a result of population growth and urbanisation. Johannesburg is prone to urban encroachment, development pressures on protected areas, previous development on the wetland areas, and poor air quality. The CoJ ranks within the world's ten greenest cities with a tree coverage of 23.6% (Treepedia, no date) however there is a clear "green" divide between the north of the city which is more affluent than it's less affluent southern counterpart.

Figure 52. *Gauteng Grey vs Green infrastructure (GCRO, 2012a)*

Figure 53.
Green & urban areas in Gauteng (GCRO, 2013a)

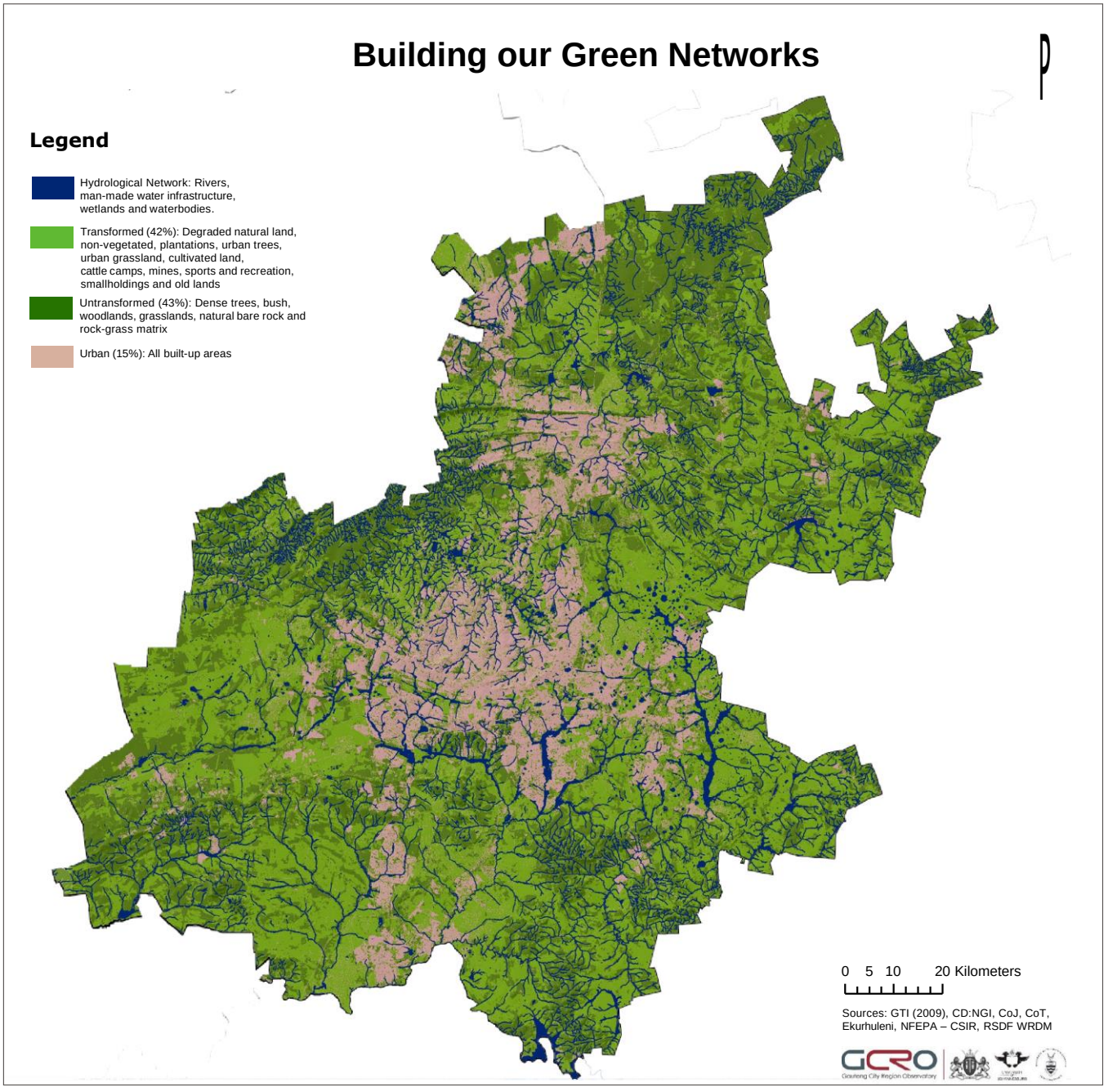
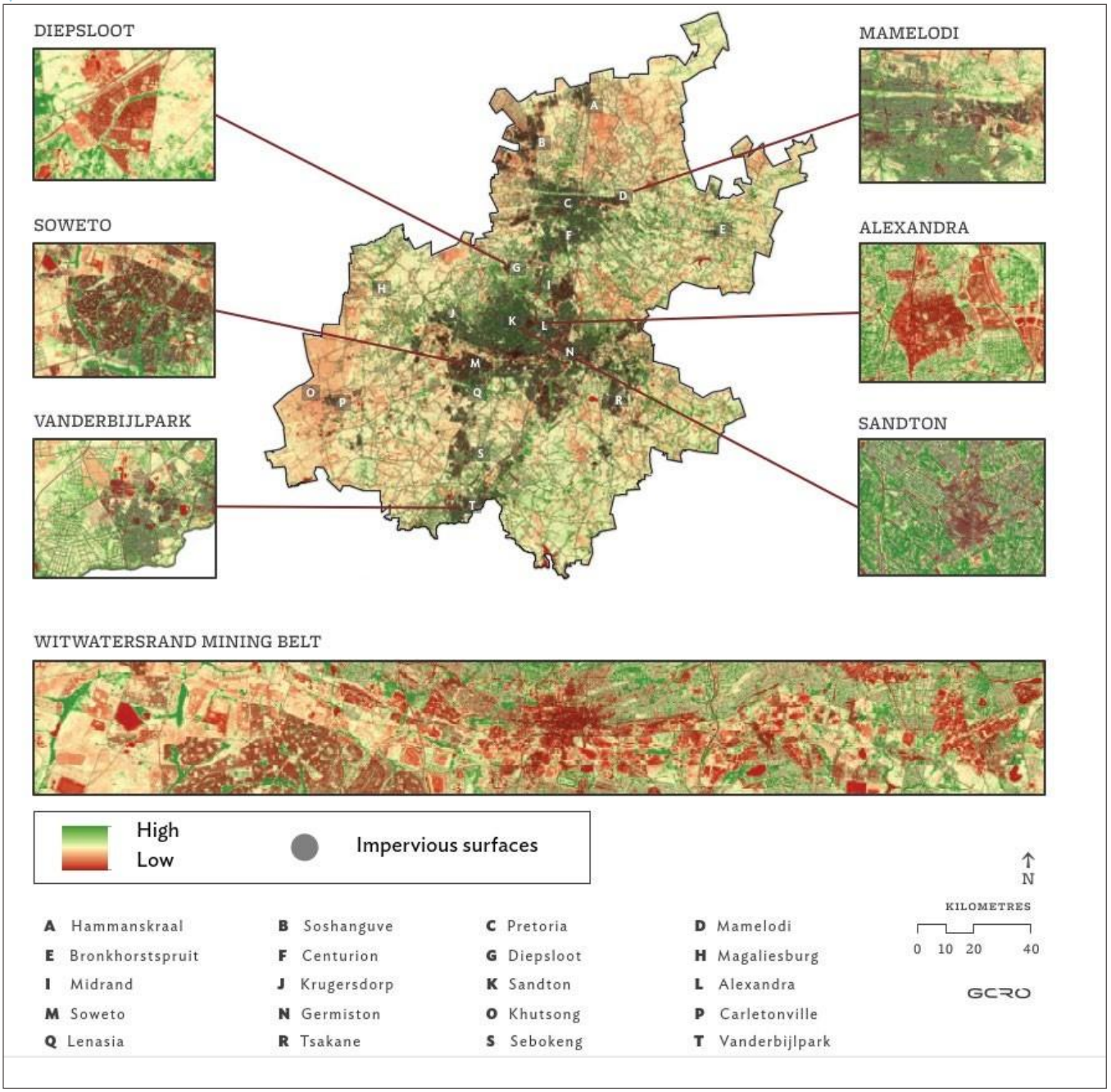


Figure 54.
Green vegetation distribution map of Gauteng (Culwick et al., 2019)



KEY SHOCKS

5.2.7 FAILING INFRASTRUCTURE

Infrastructure failure results from irregular replacement of ageing infrastructure and a lack of maintenance. Due to aging infrastructure water pipe bursts remain high at a rate of 368.23 per 100km of network length for 2020/2021 which was down from the previous year at 453.83 (Johannesburg Water, 2021). 84.20% of pipe bursts were repaired within 48 hours against a target of 95% Johannesburg Water is continuing to implement interventions to accelerate response time and 105km of water pipes were replaced against the annual target of 36km (Johannesburg Water, 2021). As a result of underfunding for infrastructure, JW currently has an infrastructure backlog of R20.4 billion, of which (Johannesburg Water, 2021). A general lack of maintenance is a common issue across South Africa as a result of budget constraints and institutional capacity.

5.2.8 ENERGY DISRUPTION

Water suppliers rely on Eskom to provide energy for pumping, distributing, water treatment and wastewater treatment. Electricity interruption like load shedding leads to a water supply interruption. When load shedding exceeds a duration of 4 hours, areas within the CoJ experience water shortages or reduced pressures due to the disruption in electricity required to pump water from the reservoir to the towers (City of Johannesburg, 2020b). Johannesburg Water is in the process of securing back-up generators to assist when outages are experienced however residents are urged to make alternative arrangements to secure a water supply (City of Johannesburg, 2020b). Additionally, there is also a probability of other events that cause disruptions to water supply. Recently (September 2021), as a result of a wild-fire, Eskom lost a critical power station which supplies power to a Rand Water Treatment Works, resulting in water supply to six of their customers being interrupted including the City of Johannesburg (Rand Water, 2021a). Although this is not a regular occurrence, in the past decade Eskom has been increasingly becoming less and less reliable as an electricity supplier.

5.2.9 FLOODING

With population growth and urbanisation that result in the densification of areas and increase in impervious surfaces coupled with the increasing effects of climate change, flooding has become a primary concern for the CoJ. Conventional stormwater design is primarily based on principles of conveyance where stormwater is treated as hazardous and the aim is to rid an area of stormwater as quickly as possible to prevent flooding. However, this design methodology results in an increase in flood peaks and contributes to poor water quality in rivers. Flooding and water quality are major issues for the CoJ especially for the less fortunate residents who suffer the most as they are unable to afford properties outside of the floodplains or in areas that have adequate stormwater infrastructure.

The CoJ's stormwater infrastructure is aged and there is a significant lack of maintenance due to capacity and budget limitations. This results in regular infrastructural failures especially during the summer rainy season which causes road and front yard flooding that hinders traffic and movement in some parts of the city but has far more extreme impacts in other low-income areas of the city where homes and possessions get washed away due to riverbanks bursting causing injuries and loss of life (Figure 55). Climate change is expected to moderately increase the number of extreme rainfall days with a high increase in the risk of urban floods (D Le Maitre et al., 2019). Climate change impacts coupled with the already detrimental state of stormwater infrastructure in the city and lack thereof, there is a need for building resilience into the stormwater system to prevent disastrous consequences.

Figure 55. Informal dwellings located along the river bank affected by flooding (Sapa, 2014)

5.2.10 THEFT & VANDALISM

Theft and vandalism of infrastructure causes a disruption to water supply. The theft of water infrastructure is a recurring issue and includes brass water meters that affects customers and causes pipe bursts. Metal infrastructure is often stolen to be resold at scrapyards. Johannesburg Water is combating this by replacing brass meters with plastic ones and establishing relationships with Community Policing Forums (CPFs) to assist with arresting culprits (Johannesburg Water, 2021). Vandalism of hydrants has been noticeably increasing by illegal car washers and homeless people in the Johannesburg CBD in order to access water. Illegal water connections also occur when there is a lack of basic service provision as in informal settlements and people need access to water or when illegal immigrants need access to water and do not qualify for access to service provision in South Africa. To combat this, Johannesburg Water is assisted by the Johannesburg Metropolitan Police Department (JMPD) to prevent vandalism of infrastructure and they will further consider a proposal made by the Department of Economic Development to legalise car washing in a controlled manner (Johannesburg Water, 2021).

5.2.11 COVID-19

The Council for Scientific and Industrial Research (CSIR) together with the Albert Luthuli Centre for Responsible Leadership developed a set of COVID-19 Vulnerability Indicators to identify vulnerabilities in communities and areas in need of targeted interventions (COGTA, 2020). The indicators comprise transmission potential which identify areas that prevent the practicing of social distancing and limit good hygiene practices and health susceptibility that identify where a large number of people would be susceptible due to age and underlying health conditions (COGTA, 2020). The mapping (Figure 56) shows that COVID-19 vulnerabilities are consistent with vulnerabilities such as poverty and unemployment, limited access to healthcare and population density resulting in the Southern region of Johannesburg where there is a concentration of informal settlements facing the highest levels of vulnerability as compared to its more affluent North.

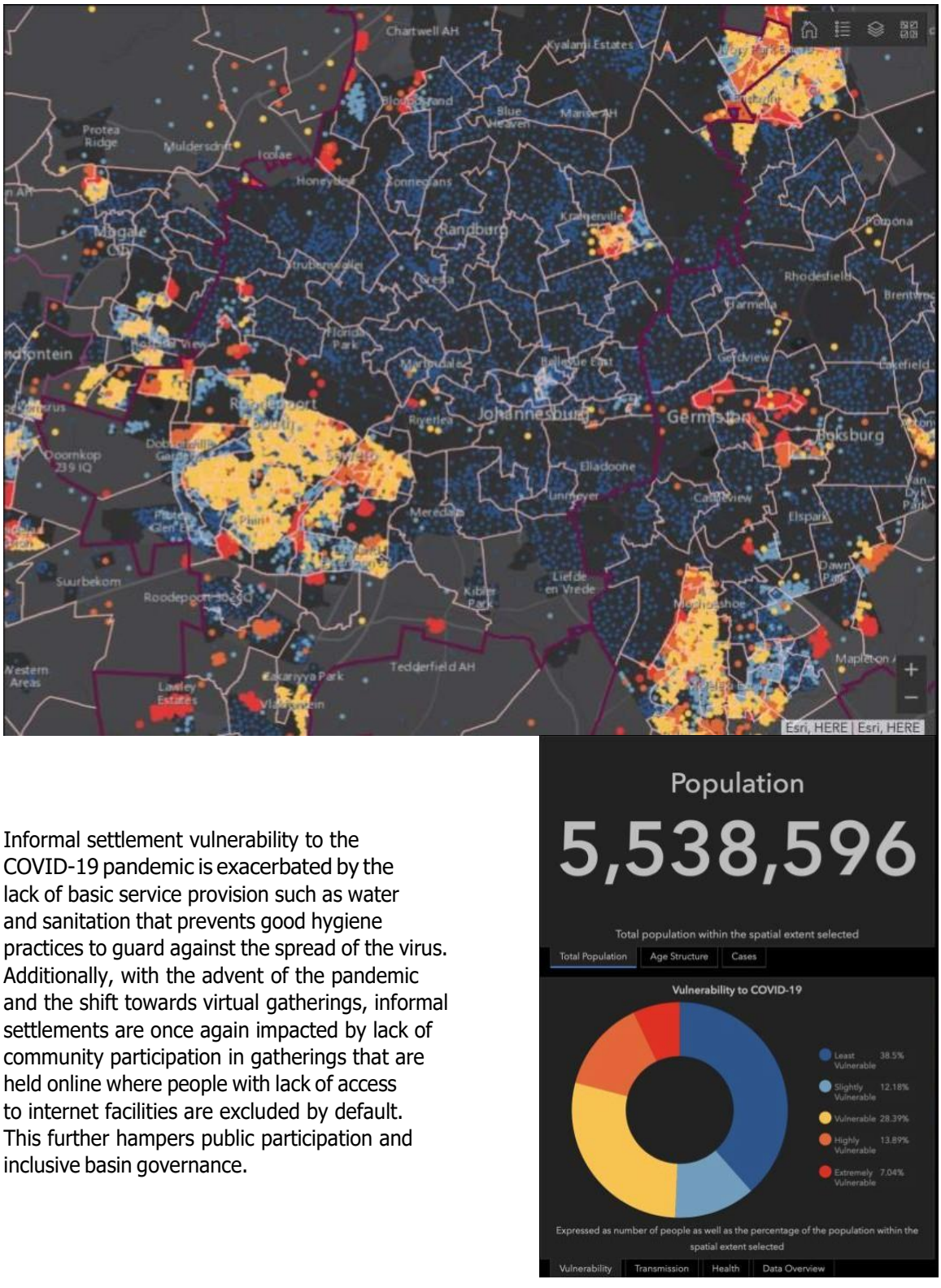


Figure 56. Mapping of COVID-19 vulnerability indicators (COGTA, 2020)

Informal settlement vulnerability to the COVID-19 pandemic is exacerbated by the lack of basic service provision such as water and sanitation that prevents good hygiene practices to guard against the spread of the virus. Additionally, with the advent of the pandemic and the shift towards virtual gatherings, informal settlements are once again impacted by lack of community participation in gatherings that are held online where people with lack of access to internet facilities are excluded by default. This further hampers public participation and inclusive basin governance.

6

KEY POLICIES, PROJECTS, PROGRAMMES & STRATEGIES

To ensure that ongoing programmes and projects relevant to this study are considered and built upon, key programmes relating to building resilience that are active in the CoJ are described below, including:

- Growth and Development Strategy – Joburg 2040
- Climate Action Plan (CAP)
- Water Security Strategy (WSS)
- Water Demand Management Programme
- Greening and Green Infrastructure Strategy
- IVRS Reconciliation Strategy
- Other water security and resilience programs

6.1 JOBURG 2040 – GROWTH AND DEVELOPMENT STRATEGY (CoJ, 2011)

To cope with drivers of uncertainty such as migration, globalisation, climate change, natural resource scarcity, technological innovation and inequality; the City of Johannesburg developed an aspirational Growth and Development Strategy that defines the type of society that the city of Johannesburg aspires to be by 2040 to build adaptive capacity, ensuring it is more resilient to change and more adept at seizing opportunities as they arise. The strategy outlines the following:

VISION

Johannesburg – a World Class African City of the Future – a vibrant, equitable African city, strengthened through its diversity; a city that provides real quality of life; a city that provides sustainability for all its citizens; a resilient and adaptive society." Joburg. My City – Our Future!

MISSION

The City of Johannesburg commits itself to pro-active delivery and the creation of a city environment in 2040 that is resilient, sustainable and liveable. It aims to achieve this through long-term 2040 plans, targeted programmes, services and enabling support that drives economic growth, optimal management of natural resources and the environment, the development of society and the individuals within it, and the practice and encouragement of sound governance, in all the City does.

PRINCIPLES

- **Principle 1:** Eradicating Poverty
- **Principle 2:** Building and growing an inclusive economy
- **Principle 3:** Building sustainable human settlements
- **Principle 4:** Ensuring resource security and environmental sustainability
- **Principle 5:** Achieving social inclusion through support – and enablement
- **Principle 6:** Promoting good governance

OUTCOMES

Outcome 1: Improved quality of life and development-driven resilience for all - The City envisages a future that presents significantly improved human and social development realities, through targeted focus on poverty reduction, food security, development initiatives that enable self-sustainability, improved health and life expectancy, and real social inclusivity. By 2040, the City aims to achieve substantially enhanced quality of life for all, with this outcome supported by the establishment of development-driven resilience.

Outcome 2: Provide a resilient, liveable, sustainable urban environment – underpinned by infrastructure supportive of a low-carbon economy. The City plans to lead in the establishment of sustainable and eco-efficient infrastructure solutions (e.g. housing, eco-mobility, energy, water, waste, sanitation and information and communications technology), to create a landscape that is liveable, environmentally resilient, sustainable, and supportive of low-carbon economy initiatives.

Outcome 3: An inclusive, job-intensive, resilient and competitive economy that harnesses the potential of citizens - The City of Johannesburg will focus on supporting the creation an even more competitive, 'smart' and resilient city economy, when measured in relation to national, continent and global performance. The City, will promote economic growth and sustainability through the meaningful mobilisation of all who work and live here, and through collaborating with others to build job-intensive long-term growth and prosperity, from which all can benefit.

Outcome 4: A high performing metropolitan government that pro-actively contributes to and builds a sustainable, socially inclusive, locally integrated and globally competitive Gauteng City Region - The City envisages a future where it will focus on driving a caring, responsive, efficient and progressive service delivery and developmental approach within the GCR and within its own metropolitan space, to enable both to reach their full potential as integrated and vibrant spaces. Additionally, the strategy includes long-term outputs which are the deliverables through which the City plans to achieve the desired outcomes and indicators which are measures through which the City plans to assess progress against its desired outcomes.

6.2 CLIMATE ACTION PLAN (CoJ, 2011)

Climate change projections indicate that the City of Johannesburg is expected to experience continued harmful impacts such as droughts and threats to water security, flooding, and heatwaves that pose a risk to human health. The CoJ has developed a climate action plan that aligns with the aims and targets of the Paris Agreement as well as the City's long-term strategy that makes provisions for a resilient, liveable, sustainable urban environment, compatible with a healthy natural environment and underpinned by infrastructure supportive of a low-carbon economy (CoJ, 2011). To enhance climate resilience and adapt to climate change impacts, the Climate Action Plan has a vision with two main goals, themes with targets for 2030 and 2050, actions and sub-actions.

VISION

Johannesburg – a World Class African City of the Future – a vibrant, equitable African city, strengthened through its diversity; a city that provides real quality of life; a city that provides sustainability for all its citizens; a resilient and adaptive society.

GOAL 1: NET-ZERO EMISSIONS BY 2050

Theme 1: Affordable Clean Energy

- By 2030, 35% of electricity consumed is generated from renewable energy sources.
- By 2050, all residents have access to safe, affordable and net-zero emissions energy.

Theme 2: Optimised Energy Efficiency in Buildings

- By 2030, new buildings operate at net-zero emissions. In addition, the City commits to only developing, owning and occupying assets with net-zero emissions operations.
- By 2050, all buildings operate at net-zero emissions.

Theme 3: Green Transport

- By 2030, 70% of commuters use public transport, walk or cycle.
- By 2050, 90% of commuters use public transport, walk or cycle and all residents have access to safe, affordable and net-zero-emissions transport.

Theme 4: Alternative Waste Management

- By 2030, per capita municipal solid waste generation has been reduced by at least 15%. The volume of municipal solid waste sent to landfill or incinerated has been reduced by at least by 50%, and at least 70% of waste is diverted away from landfill and incineration, compared to 2016.
- By 2050, 100% of solid waste is diverted from landfill and remaining methane emissions from waste are captured.

Theme 5: Improved Water Supply & Wastewater Treatment

- By 2030, a comprehensive review has been undertaken of the energy use by, potential energy savings and energy generation opportunities in the water and wastewater systems, and a Net- Zero-Energy programme has been developed.
- By 2050, net-zero emissions has been achieved in all water and wastewater systems, including water treatment, conveyance, supply, and wastewater treatment and disposal.

GOAL 2: A CLIMATE-RESILIENT CITY BY 2050

Theme 1: Water Security

- By 2030, 100% of residents have access to a reliable water supply and 96% have access to sanitation services. The city is fully water secure.
- By 2050, 25% of water supplied comes from alternative sources, average per capita water demand is reduced to 175 litres per day, water losses are reduced to below 20% and Blue Drop status is maintained above 95%.

Theme 2: Resilient Human Settlements

- By 2030, all households have access to safe, resilient, and affordable basic services.
- By 2050, 100% of the population is accommodated in affordable, resilient and low-carbon housing. All citizens have access to safe and sustainable open space, with tree cover of over 30%.

Theme 3: Flood & Drought Management

- By 2030, flood management is mainstreamed and improved across all sectors to minimise social, economic and environmental impacts of flooding.
- By 2030, fully functional early warning systems are in place for floods, droughts, fires and storms, and the response plans for floods and droughts have been updated.
- By 2050, no houses, offices, industries or critical infrastructure are located in high-flood risk areas and water supply and food systems are drought proof.

Theme 4: Resilient Infrastructure

- By 2030, all current backlogs of upgrades to urban stormwater infrastructure have been addressed and updated stormwater guidelines have been developed.
- By 2050, the City of Johannesburg has been transformed into a Water Sensitive City which incorporates Water Sensitive Urban Design (WSUD) into all aspects of urban planning.
- By 2050, the city has 30% green cover(including green roofs) for city and passive building cooling.

Theme 5: Healthy Communities

- By 2030, the City is compliant with the National Ambient Air Quality Standards (NAAQS) and aspires towards compliance with WHO standards.
- By 2030, the negative impacts of higher temperatures and heat waves on food security, human and environmental health have been reduced.
- By 2050, all communities enjoy clean air, are resilient to the health impacts of climate change and are food secure.

6.3 WATER SECURITY STRATEGY (CoJ, 2011)

To align with the 2040 Growth and Development Strategy, particularly Outcome 1 and Outcome 2 (CoJ, 2011), the CoJ EISD (Environment and Infrastructure Services Department) commissioned a Water Security Strategy to guide the City and its stakeholders to better manage the water system to support the vision of a liveable, resilient and sustainable urban environment that improves the quality of life for all. The process for the development of the Water Security Strategy included the following steps:

Desktop Research
A review of existing policies and strategies, municipal reports, feasibility studies, risk assessments, business plans, and annual reports to gain an initial understanding of the status quo of Johannesburg's urban water system.

Benchmarking exercise
The CoJ was benchmarked against the Cooperative Research Council's Water Sensitive Cities Index. This is further discussed in Appendix A.

Stakeholder interviews
Interviews were conducted with CoJ officials from various departments and municipal entities working within the urban water sector to validate findings of the benchmarking results and reflect on priorities.

Steering Committee Prioritisation Workshop
Drawing from the previous engagements, the steering committee of the CoJ EISD identified the strategic responses that form the basis of the strategy.

Broader Stakeholder Validation Workshop
The stakeholders working within the urban water sector including government officials, academia, practitioners, organisational users and household users were invited to comment on the appropriateness of the strategic responses and the key role players.

The draft CoJ Water Security Strategy comprises 7 goals with 16 strategic responses and 65 corresponding actions (Figure 57 below).

Figure 57. Water Security Strategy Goals and Strategic Responses (CoJ, 2021)

6.4 WATER DEMAND MANAGEMENT PROGRAM (Joburg Water)

The City of Johannesburg Water Conservation and Water Demand Management (WCWDM) Framework Strategy was developed in 2019 by assembling a range of departments across the municipality to discuss the water issues facing Johannesburg. The WCWDM Strategy also mapped out a comprehensive list of 58 interventions across five themes namely, (1) Water Resource Management, (2) Distribution Management, (3) Consumer Demand Management, (4) Social Awareness and Education and (5) Management and Institutional Aspects (De Jager, 2019).

6.5 GREENING AND GREEN INFRASTRUCTURE STRATEGY (CoJ & GCRO)

The Gauteng City Region Observatory was appointed by the CoJ EISD to develop a Greening and Green Infrastructure Strategy as part of their project 'Green assets and infrastructure' that examines the current state of green infrastructure in the Gauteng City Region. The project recognises the contribution that urban greening and green infrastructure makes to sustainability and quality of life in urban communities with the objective to influence government policy and demonstrate how GI can complement and improve more traditional infrastructure investments. The strategy considers the protection of the City's natural green infrastructure, promoting the enhancement and expansion of the City's natural assets, integrating urban ecology into City planning and design, harnessing opportunities for grey-green infrastructure solutions, and ensuring the implementation of greening measures. (Maree, 2017)

6.6 INTEGRATED VAAL RIVER SYSTEM RECONCILIATION STRATEGY

The Department of Water Sanitation commissioned a three-year study (2018 - 2020), titled "The Continuation of the Vaal River System Reconciliation Strategy Study (Phase 2)" due to the identification of several factors that could influence the original date of 2025 for the augmentation of the Vaal River System as suggested by previous water balance assessments. This study builds on previous studies completed including the original Strategy (2009) and the Phase 1 Continuation Study (2015). The purpose of this study is to reconcile the current and future water requirements with the available water resources by implementing appropriate interventions to increase the available water, conserve water through conservation and water demand management measures as well as improve the water quality in the river systems. (DWS, 2021)

6.7 OTHER WATER SECURITY AND RESILIENCE RELATED PROJECTS

There are several other water security and resilience related studies and projects that have been undertaken for the CoJ and the Gauteng region. I summary of some of these are given in Table 4.

Table 4.
Selection of other water security and resilience related projects in the CoJ and Gauteng

Project Name	Project Description	Responsible Agency	Date
Future Cities South Africa	UK Prosperity Fund Soweto Strategic Area Framework. To implement targeted interventions that support inclusive economic growth to enable sustainable urban development geared towards prosperity.	CoJ EISD	Ongoing
Upper Jukskei Catchment Management Plan (CMP)	To develop the hydrological component of a catchment pilot study for a sub-catchment of the Jukskei catchment within the CoJ.	CoJ EISD	Ongoing
Pathways to Water Resilient South African Cities	To identify opportunities for, and generate knowledge on, the physical and institutional integration of decentralised nature-based solutions into the urban water cycle to support and accelerate a transition towards water resilience in South African cities.	Danish International Development Agency (DANIDA)	Ongoing
Research on the use of SuDS in Gauteng	To research the feasibility of implementing Sustainable Drainage Systems (SuDS) in Gauteng for the management of stormwater, prevention of urban flooding and climate change mitigation.	Gauteng Department of Agriculture and Rural Development (GDARD)	02/2020
Regional Attenuation Feasibility Study	Feasibility study to assess the relevance and feasibility of increased regional attenuation for the purpose of stormwater management, harvesting and re-use.	CoJ Environment and Infrastructure Services Department (EISD) & Johannesburg Roads Agency (JRA)	06/2019

7

ALIGNING URBAN WATER RESILIENCE TO KEY COJ INITIATIVES

In order to establish a lasting relationship between the CoJ and the WRI, it is necessary to align the Urban Water Resilience initiative with existing efforts underway. This section therefore reflects on the resilience related work that has already been done in the City of Johannesburg, particularly the Water Security Strategy and Climate Action Plan and how those initiatives align to the CWRA and the broader objectives of the UWR initiative.

7.1 BROADER WATER RESILIENCE PERSPECTIVES

The Department of Water Sanitation commissioned a three-year study (2018 - 2020), titled "The Continuation of the Vaal River System Reconciliation Strategy Study (Phase 2)" due to the identification of several factors that could influence the original date of 2025 for the augmentation of the Vaal River System as suggested by previous water balance assessments. This study builds on previous studies completed including the original Strategy (2009) and the Phase 1 Continuation Study (2015). The purpose of this study is to reconcile the current and future water requirements with the available water resources by implementing appropriate interventions to increase the available water, conserve water through conservation and water demand management measures as well as improve the water quality in the river systems. (DWS, 2021)

7.2 CONSOLIDATING ACTIONS FOR IMPROVED WATER RESILIENCE

Previous studies including the CoJ Water Security Strategy (CoJ, 2021) and the Climate Action Plan (CoJ, 2020) contained a list of actions to be taken towards ensuring water security in city of Johannesburg. These actions were compiled and analysed against the goals of the City Water Resilience Framework (CWRF) to assess the extent to which the actions matched the CWRF.

From the analysis performed, 7 goals of the Water Security Strategy covered 11 goals of the CWRF in part (Figure 58), however Goal 12: Prosperous Communities was not covered by the Water Security Strategy at all. The Climate Action Plan, specifically the Theme: Resilient Human Settlements contained actions that corresponding in part to Goal 12 of the CWRF (Figure 59). The Water Security Strategy addresses 42 out of 57 actions of the CWRF and the Climate Action Plan addresses a further 6 goals. Of the remaining 9, 4 goals are partially addressed and 5 are not addressed at all:

Partially addressed goals:

- 2.3 Incorporation of social, environmental and economic costs and benefits into decision-making around water
- 8.2 Ensuring adequate human capacity for operations and implementation
- 8.5 Promotion of reliable supply chains for water infrastructure
- 12.2 Provision of sufficient water quality and quantity for industry and commerce

Goals not addressed:

- 5.5 Integrated planning with agriculture and food supply chains
- 6.1 Promotion of integrity in contracting and financial decision-making procedures
- 7.3 Ensuring adequate funds to government for disaster recovery
- 7.4 Ensuring adequate financial resources for recovery of households and businesses
- 12.4 Support for improved mobility through water-related transportation

This exercise assisted in determining which goals already have existing actions and which goals require actions to be further developed towards attaining the goal. This exercise is also useful in determining the stakeholders who should be considered for further engagement. The compilation of the actions against the CWRF goals forms the foundation for the action plan as part of the City Water Resilience Approach towards the identification of two-priority actions for implementation.

Figure 58.
Alignment of the CWRF goals and the CoJ Water Security Strategy Goals

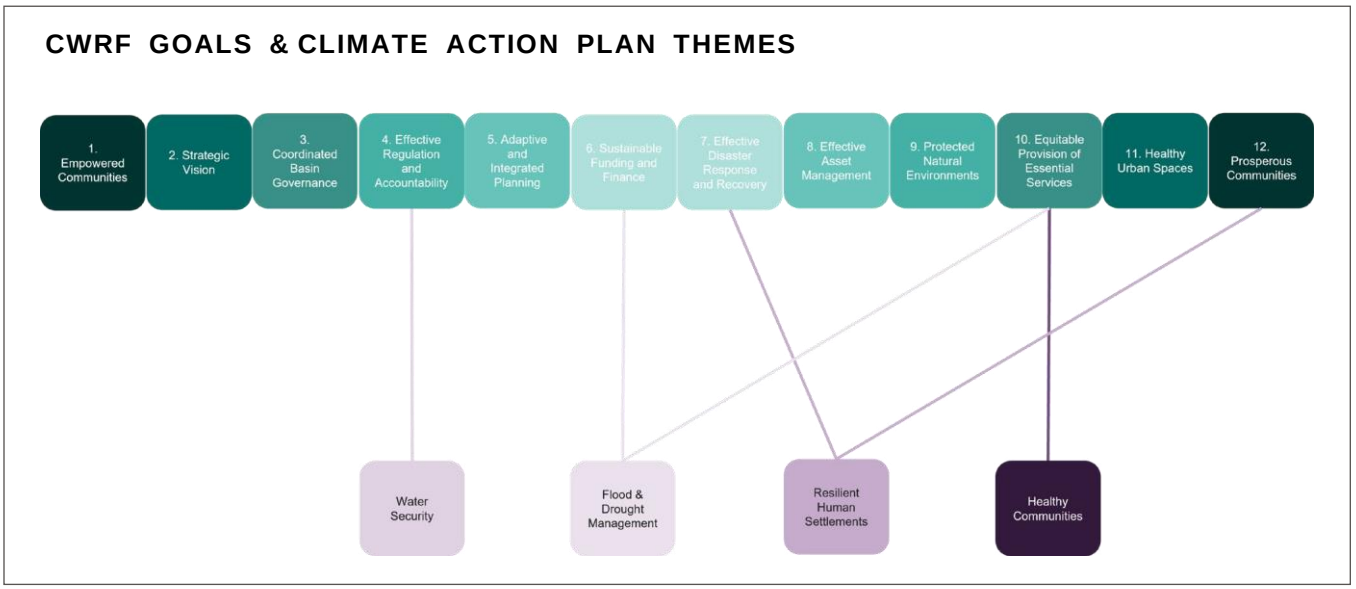


Figure 59.
Alignment of the CWRF Goals and Climate Action Plan Themes

7.3 PRELIMINARY IDENTIFICATION OF PRIORITISATION ACTIONS

The WRI has identified Assistance Action Areas as part of the Africa Urban Water Initiative, these action areas include Key System Goals and Cross Cutting Issues where the WRI offers support to cities:

Key System Goals

1. Enhancing spatial planning processes inside and/or outside of the city jurisdiction for improved water and climate resilience
2. Helping cities together with basin actors reduce future vulnerabilities to water and climate shocks and stressors through basin governance
3. Helping cities develop bankable/fundable project proposals to attract public and/or private sector funding

Cross Cutting Issues

1. Helping cities design for social equity & inclusion
2. Helping cities and basin actors mainstream nature-based solutions
3. Helping city and regional actors develop leadership skills for complex environments

The actions that were deemed critical in the Water Security Strategy refer to immediate action with a time frame of 0-2 years. The actions compiled from the CoJ Water Security Strategy and the Climate Action Plan that align with the goals of the CWRF were further filtered to analyse how these actions align with the WRI Assistance Action Areas. These actions were selected for analyses to coincide with the time-frame of the WRI Africa Urban Water Initiative. They were further filtered on the basis of ease of implementation based on "project readiness" – whether the action could be implemented immediately or whether it was dependent on a range of other actions and was a longer-term commitment. Of the actions that align with the CWRF, are critical to the CoJ Water Security Strategy, are deemed to have a "high" project readiness and align with at least one of the WRI Assistance Action Areas, the following list of 8 actions was compiled in Table 5 below. These actions are to be further prioritised to identify two priority actions for implementation that the WRI will support in the Africa Urban Water Initiative.

Table 5.
CoJ Water Security Strategy Actions identified for prioritisation

COJ WATER SECURITY STRATEGY ACTIONS
3.2 a) Create an oversight and compliance role, within the CoJ institutional arrangement, for stormwater management • Clearly define roles, responsibility and oversight for each aspect of stormwater management • Improve coordination and commuwnication where functions are held across various departments
4.2 a) Continuously monitor and update maps of existing high-value ecological water areas such as recharge and infiltration areas, water feeder areas, hydrological pathways, rivers, their banks and flood plains, among others
4.2 b) Ensure planning and development regulations and by-laws and the approval protocols and mechanisms align with water security and sustainable development goals that support sustainable water management • Develop a process and protocol document that equips development control and approval personal with data and knowledge to ensure applications are compliant with water sensitive principles and preserving water sensitive areas • Ensure land use change does not increase runoff, decrease recharge and/or cause flooding • Advocate for the use of sustainable urban drainage systems • Ensure development does not occur within high risk flood zones specially along rivers and water bodies where development must not influence the natural water systems and services • Ensure new developments and/or amendments and upgrades include the required percentage of green space as spatulated in the Johannesburg Spatial Development Framework 2040 and the CoJ Nodal Review Policy • Advocate to increase the required percentage of green space for new developments.
5.1 b) Advocate for and enable co-creation of knowledge by leveraging knowledge partnerships within the municipality and between municipal entities and outside stakeholders • E.g. Using students' work experience or projects to better understand water related problems or test solutions
6.1 a) Advocate for and actively participate in CoJ Environmental Awareness Forum on behalf of urban water system
6.2 a) Co-develop clear water values and a water vision to be shared across departments and water stakeholders engaging with the water sector, the urban water system and the water security strategy
7.1 a) Improve organisational integration • Investigate the viability of a water security task team versus an overseeing urban water system department • Advocate for a response person and/or team of people to manage and store the urban water system data in a data management system • Monitor, evaluate and adapt processes and intuitional arrangements in alinement with changing circumstances and new insights • Delineate roles and responsibilities especially where overlapping mandates exist and embed in practise • Ensure effective succession planning • Improve intra- and inter-departmental planning and risk management
7.3 a) Map finance flows for Johannesburg's water infrastructure and urban water system to understand the gaps and highlight the opportunities for funding maintenance and new development requirements.

8

THE WAY FORWARD

Considering the efforts that are already underway in the City of Johannesburg including the Water Security Strategy, Climate Action Plan and other plans and programmes, the aim of the Urban Water Resilience initiative is to build on existing efforts towards building water resilience in the City of Johannesburg. The Urban Water Resilience initiative going forward will therefore be implemented in two Phases:

PHASE 1:

IMPLEMENTATION OF TECHNICAL SUPPORT FOR IDENTIFIED WATER SECURITY

Strategy Actions

Phase 1 consists of the Urban Water Resilience initiative supporting a maximum of two priority actions that align with the objectives of the UWR and aid in building water resilience in Johannesburg. These two priority actions will be selected from the Water Security Strategy list of actions in conjunction with the CoJ Water Security Strategy Steering Committee. Once the two priority actions are identified, they will be scoped out and implementation assistance will be offered on behalf of the WRI for the period June - December 2022. A technical report detailing the two priority actions, the selection process, and implementation plan will be prepared.

PHASE 2:

INITIATING AND ADVANCING AN URBAN WATER RESILIENCE AGENDA

There is a need to focus on building water resilience in the City of Johannesburg that includes and extends beyond water security. WRI and partners will continue to work collaboratively with CoJ towards initiating and advancing a city water resilience agenda using the City Water Resilience Approach. The City Water Resilience Framework will be populated with data gathered through a desktop assessment as well as the Water Sensitive Cities Index which was previously populated where it is applicable and there is an overlap of indicators. The population of the CWRF will be followed by an interactive workshop with the stakeholders in the City of Johannesburg that offer resilience persepectives to validate the scores and provide a platform for discussion where concerns may be raised. This will be followed by a visioning workshop that will develop a water resilience vision for the future City of Johannesburg. The visioning workshop will also aid in identifying key areas for action. The resulting reports will consist of a Resilience Profile & Action Plan for the CoJ that will contribute to tackling the shocks & stresses that directly and indirectly impact the urban water system.

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APPENDIX A

A.1 COMPARISON OF THE WSCI AND THE CWRF

The Water Sensitive Cities Index (WSCI) developed by the Cooperative Research Council (CRC) was used to benchmark the city of Johannesburg to aid in the development of the Water Security Strategy. In order to build upon efforts already underway, the WSCI was compared to the City Water Resilience Framework to assess the extent to which goals overlapped and whether there were any gaps in the analysis. Following the brief overview and review of each identified framework, the individual indicators and benchmarking frameworks are assessed according to the IWA principles for a Water Wise City.

A.1.1 OVERVIEW OF THE CITY WATER RESILIENCE FRAMEWORK (CWRF)

The City Water Resilience Approach (CWRA) was developed by ARUP as part of the 100 Resilient Cities program and responds to a demand for new approaches and tools that help cities grow their capacity to provide high quality water resources for all residents, and to protect them from water-related hazards ("provide and protect") such as drought, flooding and contaminated water. The approach outlines a path for developing urban water resilience and provides a suite of tools to help cities survive and thrive in the face of water-related shocks and stresses. The CWRA approach has five steps to guide stakeholders through the process of building water resilience, which are:

1. Understand the system by identifying shocks and stresses, system interdependencies, stakeholders, and infrastructure and government processes.
2. Assess urban water resilience of the city at present by using the City Water Resilience Framework (CWRF) to identify strengths and weaknesses and establish a baseline against which progress can be measured.
3. Develop an action plan based on step 2 that identifies interventions that can develop water resilience within the city.
4. Implement the action plan according to best practices and monitor ongoing actions to ensure that objectives can be met and that resources are used effectively.
5. Evaluate, learn and adapt by making adjustments to the implementation plan to account for new developments and changing circumstances in the city, and to align with updated objectives for the next period.

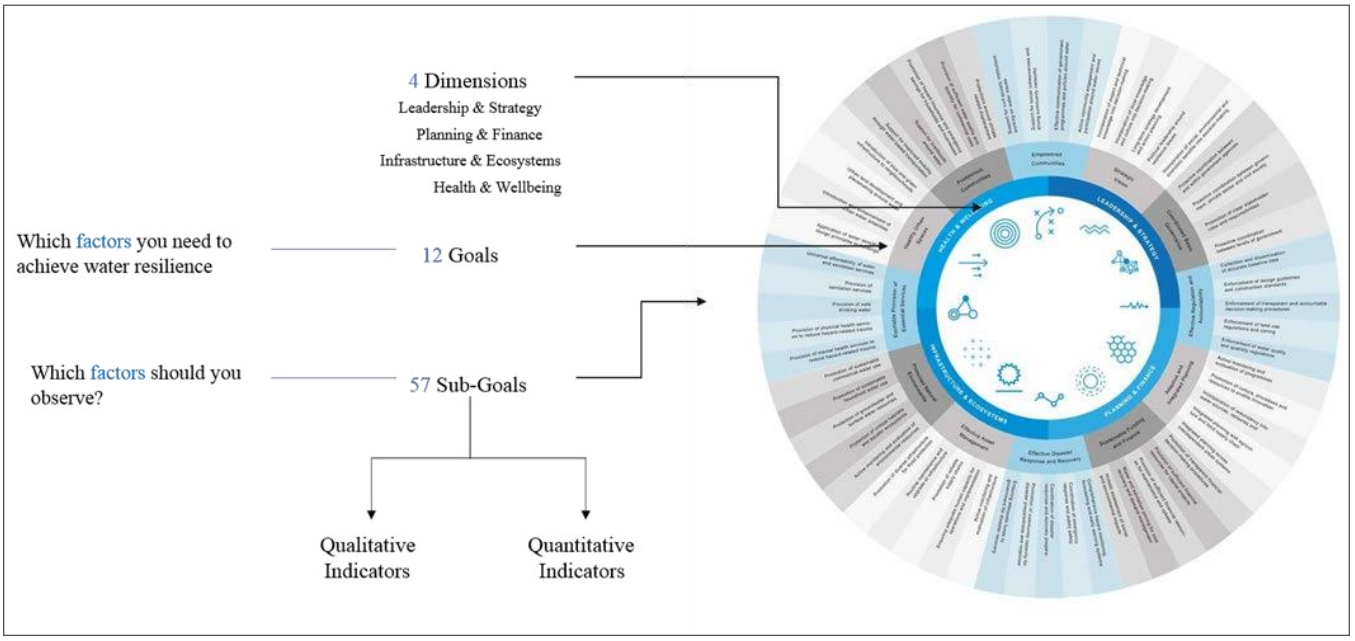


Figure 60.
Arup City Water Resilience Framework

The City Water Resilience Framework (CWRF) consists of four dimensions, 12 goals and 57 sub-goals (Figure 60). The 57 sub-goals, which are comprised of both qualitative and quantitative indicators, are scored on a scale of one to five (poor to optimal) through interactive roundtable discussions with workshop participants. Once the indicators are scored they are assigned a consensus score which considers the level of agreement of the participants.

The CWRF was applied to 13 cities globally thus far, including the City of Cape Town in South Africa and provided an assessment of water management and the factors that impact the system as shown in Figure 60Error! Reference source not found. (Arup, City of Cape Town and 100 Resilient Cities, 2019). The application of the CWRA built on other work initiated by the City and explored themes represented in the Water Strategy which aims to make Cape Town a WSC by 2040 (City of Cape Town, 2019). The Water Resilience Assessment Workshops engaged stakeholders from multiple sectors, and their responses to challenges were grouped according to four dimensions of resilience: Leadership and strategy, planning and finance, ecosystems and infrastructure, health and wellbeing.

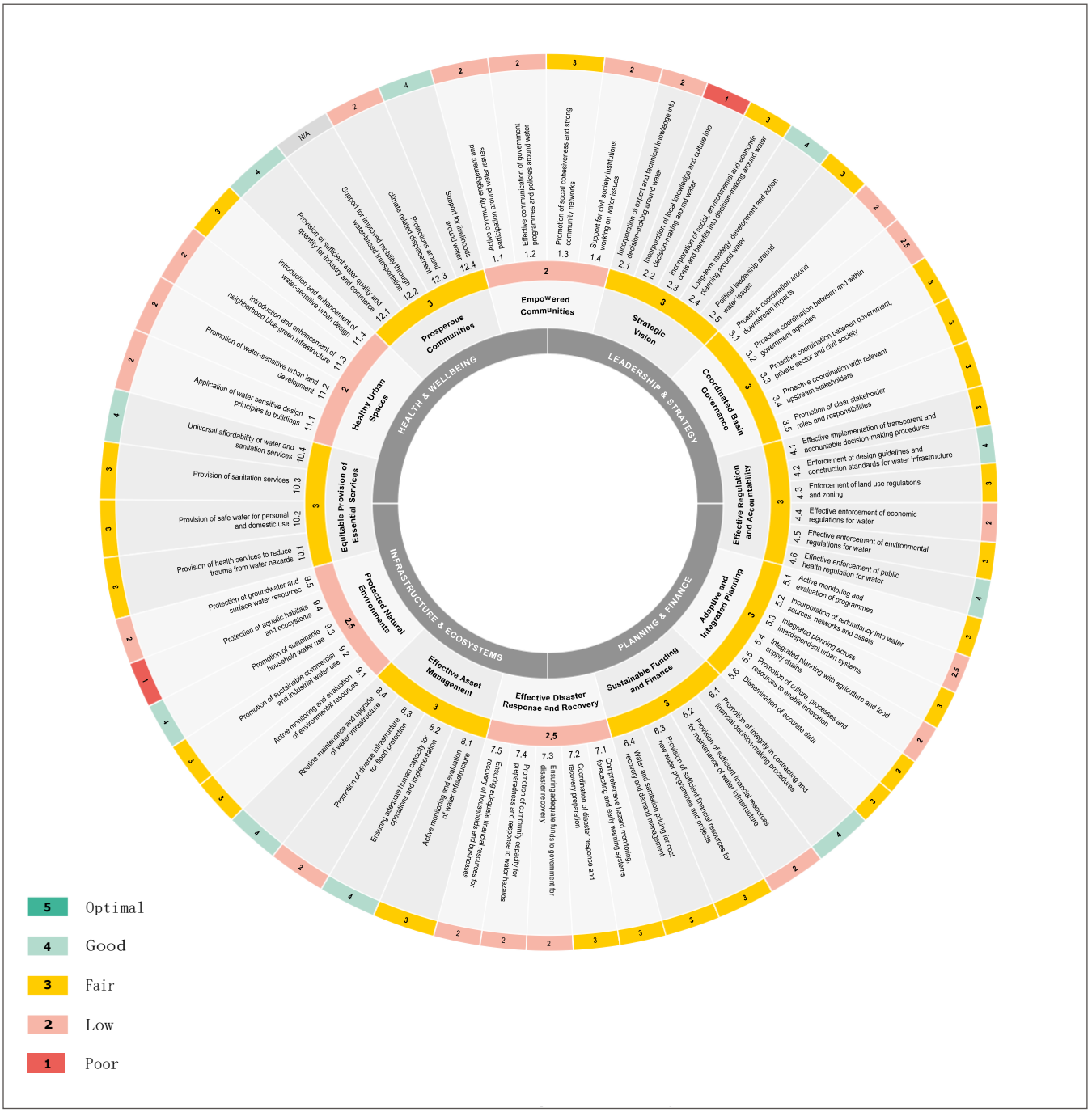


Figure 61.

Results from the Cape Town Water Resilience Assessment, qualitative scoring (Arup, City of Cape Town and 100 Resilient Cities, 2019)

A.1.2 APPLICATION OF THE WATER SENSITIVE CITIES INDEX (WSCI)

The WSCI was developed by the CRC and is a tool designed to benchmark a city's current performance against seven goals of a Water Sensitive City (WSC). The tool guides and coordinates stakeholders to drive their water sensitive city transition by establishing their understanding, motivation and capacity to do so. It also assists cities in navigating their journey to becoming water sensitive. The WSCI has been implemented in 12 cities in Australia and 3 cities internationally (Arup et al., 2019). The WSCI has also recently been adapted for application in South Africa by Zutari and applied to the City of Cape Town as well as the City of Johannesburg (CoJ) with recommendations for application in other African cities.

The seven goals of a WSC are both bio-physical and socio-political and are outlined in Figure 62.

The seven goals have 34 corresponding indicators (Figure 63) which are scored on a rating scale from one to five. The scoring process is performed through a collaborative workshop with participants from key stakeholders and organisations from across the water sector, such as local municipalities, NGOs, and government departments. The data from the scoring process is then entered into a web-based platform that can filter the results according to what is most useful for the user. The advantage of the web-based portal is that it allows comparison with other global cities and it can also be used as a reference point for future benchmarking which is recommended after a few years to measure progress.

Figure 62.
The seven goals of the Water Sensitive Cities Index

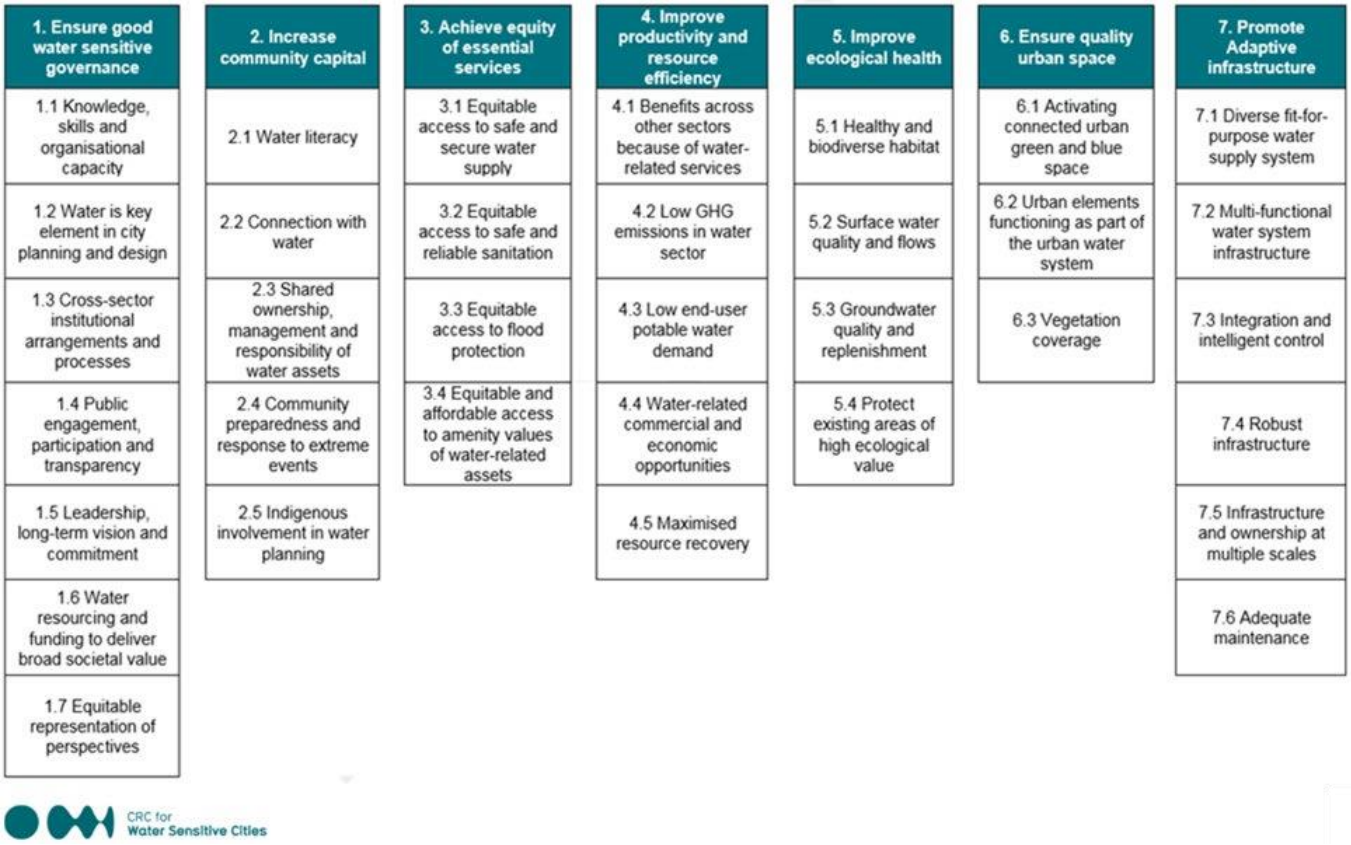


Figure 63. The Goals and Indicators of the Water Sensitive Cities Index

One of the strengths of the WSC benchmarking index is that the results can be viewed through several "lenses" that have been developed through applied research and trailed in a number of global cities and represent the many dimensions and interests associated with becoming a water sensitive city. The three primary analytical frameworks that are used to gain insight into the current state of a city's water sensitivity status and used to develop appropriate management responses, include the following:

1. The **City State Benchmark** classifies the city according to the six states of urban water systems according to the socio-political drivers of the Urban Water Management Transitions Framework

2. The **Principles of Water Sensitive Practices** to deliver water sensitive services:

- 2.1. Cities as Catchments provides resources at different scales in fit-for-purpose applications by understanding cities as catchments.
- 2.2. Ecological Services integrates urban water management into the urban landscape.
- 2.3. Water Sensitive Communities comprises citizens that are engaged in water-conscious behaviours that feel connected to their water environments and appreciate the value of water.

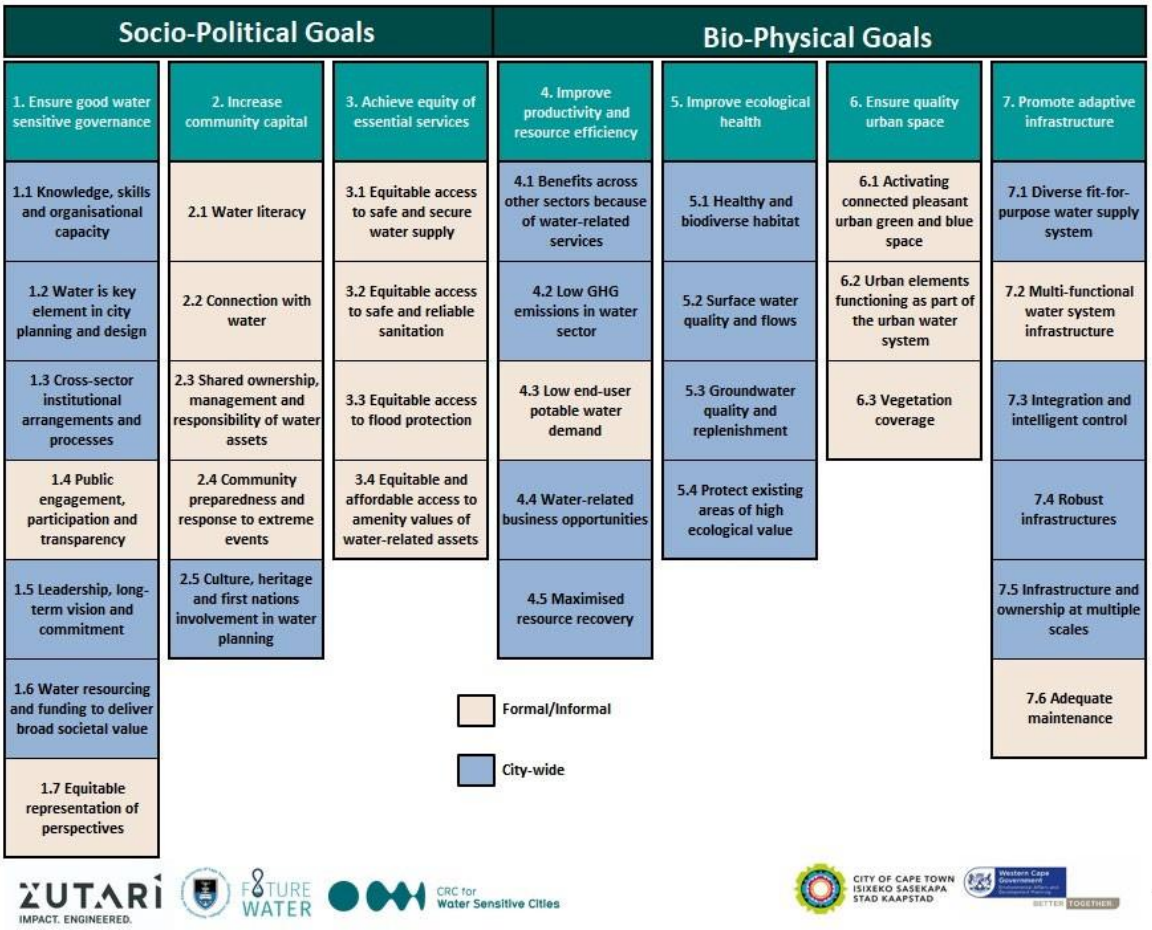
3. The **Water Sensitive City Outcomes** lens assesses the performance of the urban water system in terms of the key principles of resilience, sustainability, liveability, and productivity.

The results of the benchmarking process are presented in several formats such as those shown in Figure 64. This allows stakeholders and cities to understand where their city sits on the city-state continuum and where the strengths and weaknesses of the city lie. The footprint diagram (left) shows the overall scores for the seven goals which are based on the ratings of the 34 indicators. The circular diagram (middle) shows the percentage attainment that the city currently has in terms of the city-states in Figure 64. The bar graph (right) shows the WSC outcomes based on the filtered scores of the seven goals. Each of these outputs can then be viewed independently or compared with other cities on the CRC web-portal.

The CRCWSC Water Sensitive Cities Index (WSCI) benchmarking tool was recently refined to a South African context and applied to the City of Cape Town. The tool was used to identify in which city state of the Urban Water Management Framework Cape Town currently lies and how far they are from transitioning to a Water Sensitive City. 17 out of the 34 indicators were split for individual scoring based on formal and informal areas (Figure 65). Scoring was done by stakeholders that represented various expertise within the public and private sector. A level of confidence was added to the scoring to indicate how confident the overall group was about the score that they gave.

Figure 64.
Typical outputs of the WSC Index Framework Results

Figure 65.
Adaptation of the Water Sensitive Cities Index to the South African context (Zutari, 2020)

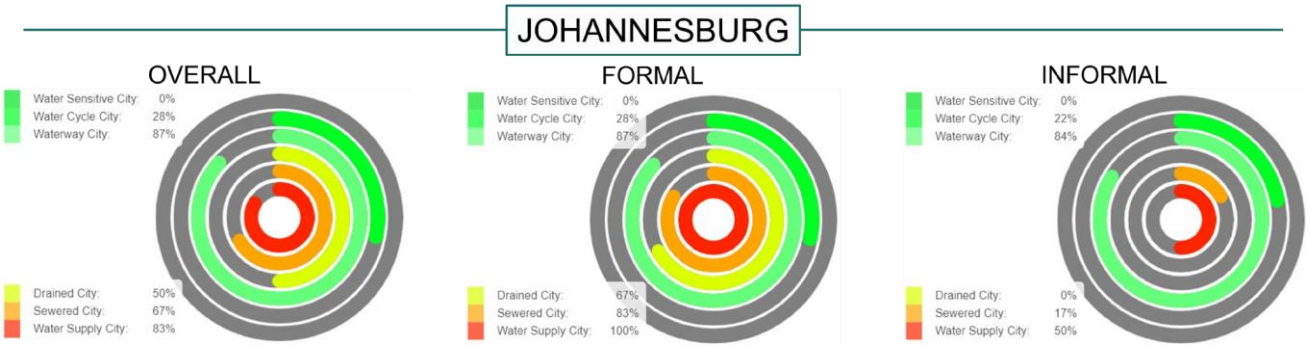


As part of the development of the development of the CoJ's Water Security Strategy, a benchmarking process was performed whereby the CoJ was benchmarked against a Water Sensitive City using the Cooperative Research Centre's Water Sensitive Cities Index (CRC WSCI). The results for the benchmarking are displayed below. The WSCI has 7 goals with a total of 34 indicators, each scored out of 5.

The process allowed for Johannesburg to be benchmarked against its informal areas, formal areas and city overall since diluting the formal areas with the informal areas would not give an accurate reflection of the city's performance. Johannesburg performed best in Goal 3: Achieve Equity of Essential Services and worst in Goal 7: Promote Adaptive Infrastructure.

Figure 66.
Indicators of the WSCI colour coded against the scoring scale (CoJ, 2021)

Figure 67.
Progress against city states for Johannesburg (CoJ, 2021)



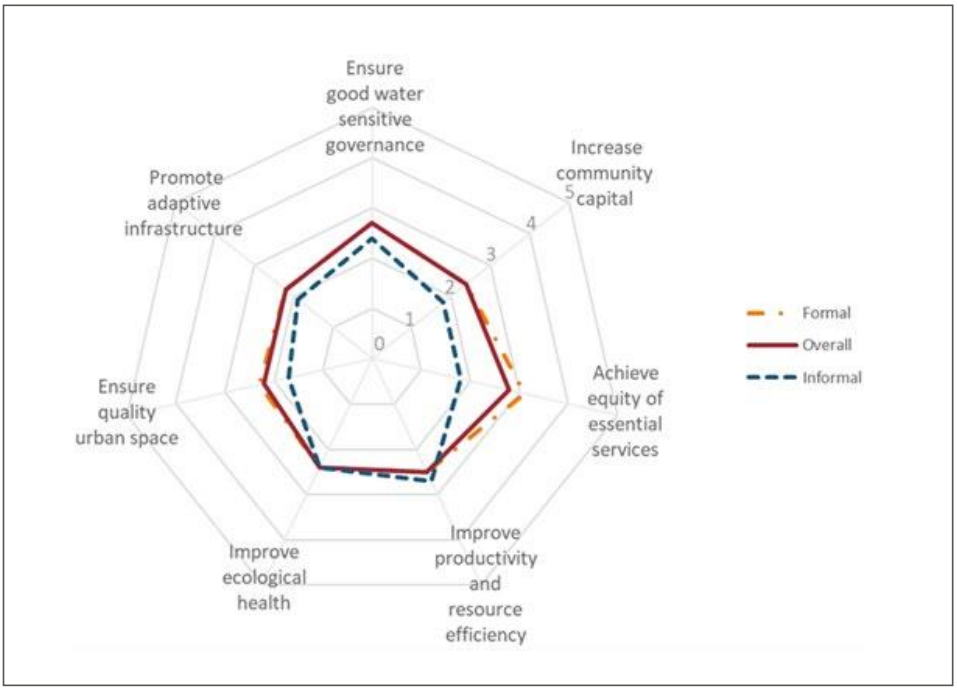


Figure 68. Progress against city states for Johannesburg (CoJ, 2021)

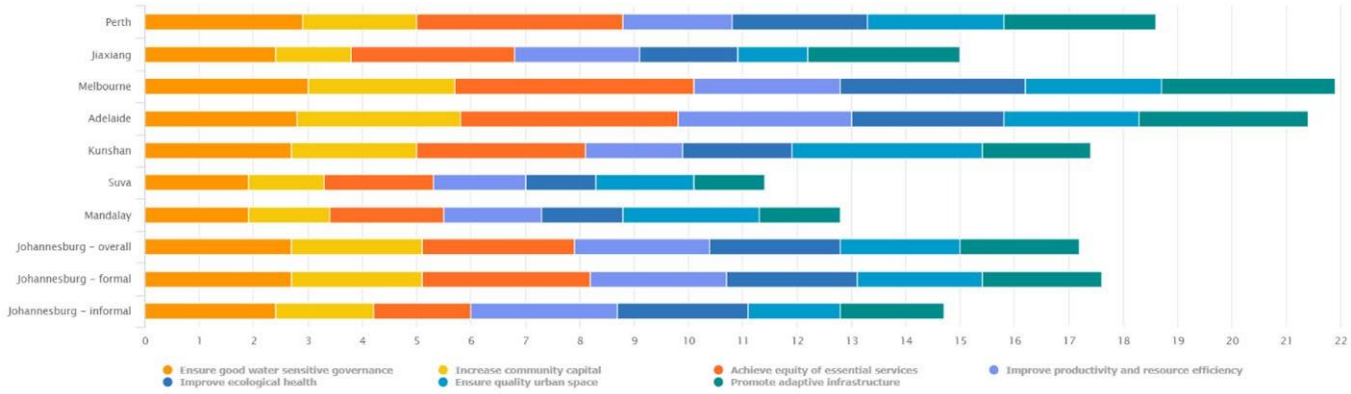


Figure 69. Johannesburg compared to other international cities using the WSCI (CoJ, 2021)

The formal areas results set has the highest average goal scores, followed by overall and then informal. Goal 3 'Achieve equity of essential services' and Goal 1 'Ensure good water sensitive governance' were the highest average goal scores for formal and overall. Given that the average goal scores for overall are comprised of a weighted average between formal and informal, there is close alignment between overall and formal. The three results sets achieved the same score for Goal 5 'Improve ecological health' and were closely matched for Goal 4 'Improve productivity and resource efficiency'. The informal areas scored well for Indicator 4.3 'Optimal End-User Potable Water Demand', although there was much debate about the meaning of this in terms of equity of access. Overall, the CoJ achieved average scores for each of the seven goals of a WSC with Goal 7 'Promote adaptive infrastructure' and Goal 6 'Ensure quality urban space' scoring the lowest. For the informal areas, Goal 2 'Increase community capital' and Goal 3 'Achieve equitable services' were very low.

Of significant concern for both formal and informal Areas was a lack of basic water literacy (i.e. understanding of where CoJ gets its water from and the role of urban stormwater management) as well as inadequate maintenance and funding for improved water use efficiency and water security.

A.1.3 COMPARISON OF FRAMEWORKS, INDICATORS AND GOALS

The benchmarking assessment tools described above were selected for their holistic and integrated approach to urban water systems, that is, their explicit linkages to the concepts of water sensitivity, resilience and sustainability. As such, the nature and number of indicators included in each tool generally reflect an integrated approach however, some tools provide a wider range of indicators and/or indicators of a wider scope to allow for an integrated approach. Each of the benchmarking frameworks have been assessed inError! Reference source not found. in terms of the key principles of a Water Wise City as defined by the International Water Association (IWA, 2017) which are shown in Figure 70.

The frameworks (CWRF & WSCI) both match the IWA's Principles for Water Wise Cities (Figure 70) however in some instances the CWRF matches the principles to a greater extent than the WSCI and in other cases visa versa. The WSCI sufficiently covers the following principles: Shared Vision, Knowledge & Capacity; and to a lesser extent meets Governance, Planning Tools and Implementation Tools compared to the CWRF. The CWRF sufficiently covers Shared Vision, Governance, Planning Tools and Implementation Tools and to a lesser extent than the WSCI covers Knowledge & Capacity.

The WSCI was rated for the formal and informal areas of Johannesburg after which a weighted average was applied to obtain an Overall city score. For the purpose of the comparison exercise the overall city ratings were used. The Water Sensitive Cities Index consists of 7 Goals and 34 Indicators. The Cities Water Resilience Framework consists of 4 Dimensions, 12 Goals, and 57 Sub-goals. The sub-goals are determined through a range of quantitative indicators (40) and qualitative indicators (62). The Water Sensitive Cities Index is a set of qualitative indicators, therefore for the purpose of comparing the two frameworks, only the qualitative indicators of the CWRF were compared to the qualitative indicators of the WSCI.

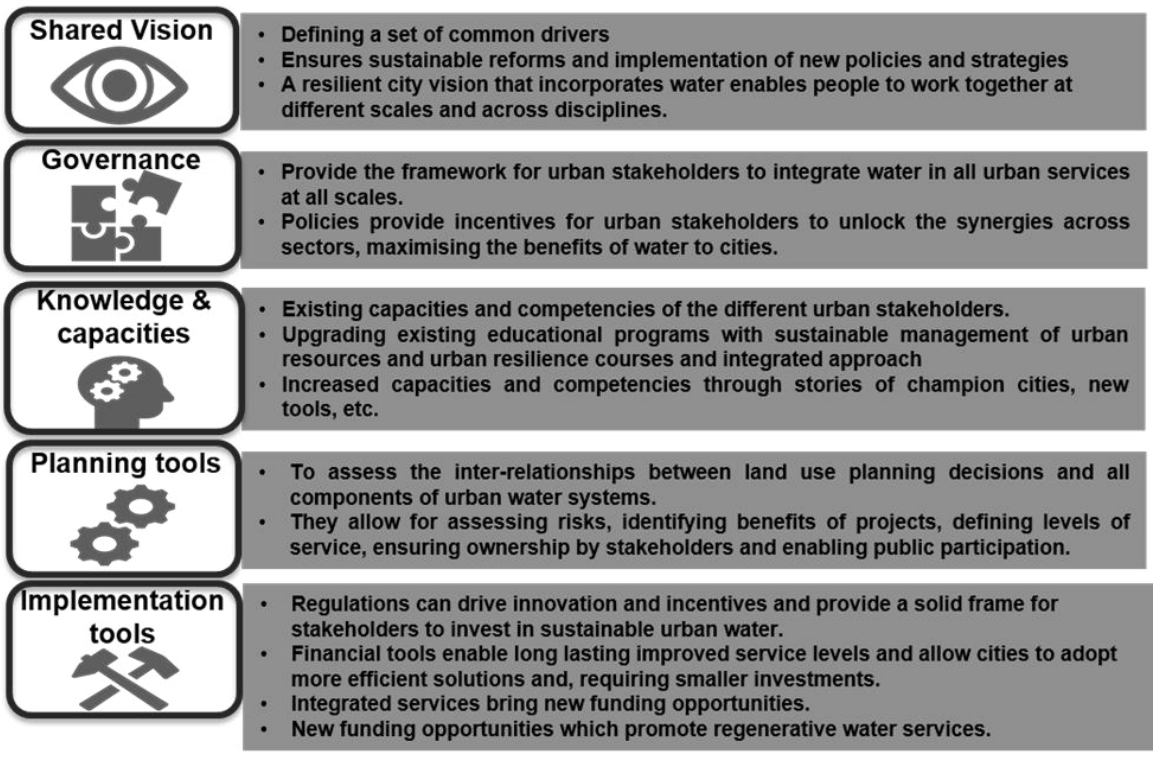
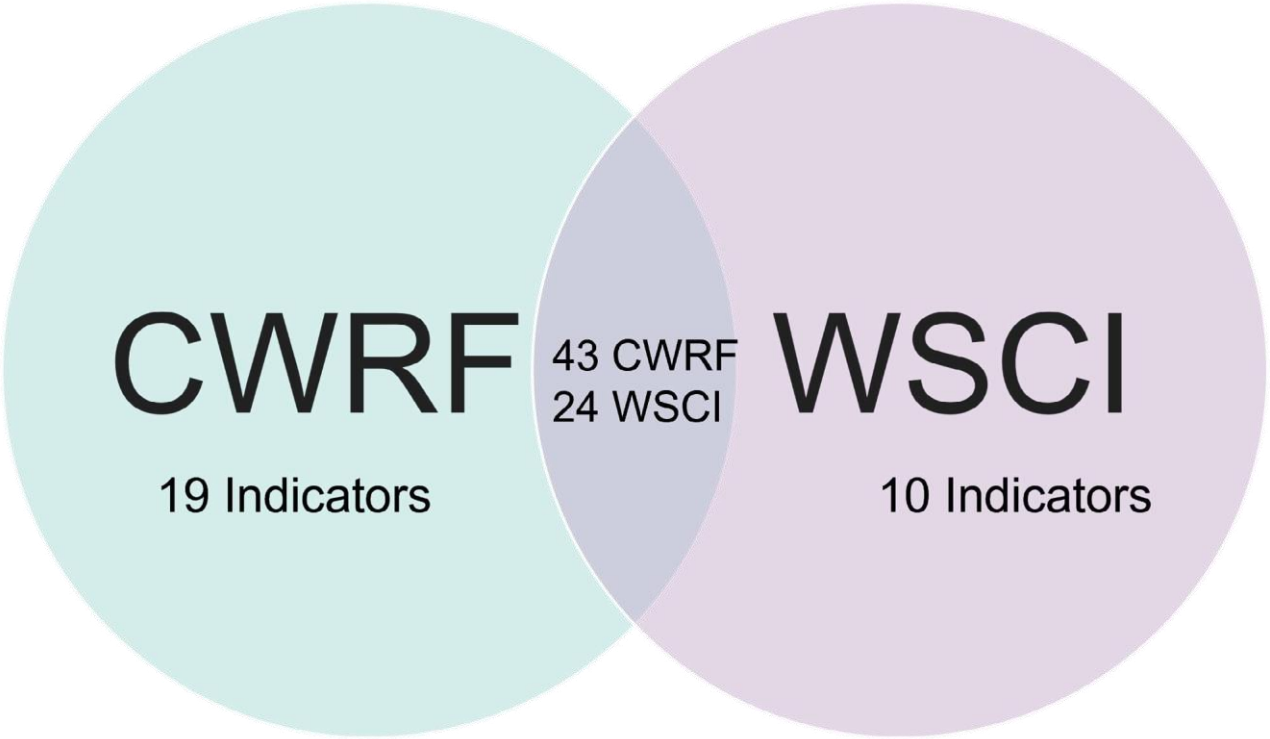


Figure 70. IWA's Principles for Water Wise Cities Building Blocks

Of the 62 qualitative indicators in the CWRF, 43 indicators overlap with 24 Indicators of the WSCI (Figure 71). The remaining 19 are to be determined through stakeholder engagement. The WSCI has been framed around 4 outcomes: Resilience, Liveability, Sustainability & Productivity. 19/34 align with resilience, 17/34 align with Liveability, 15/34 align with Sustainability and 13/34 align with the Productivity lens. There are 11 WSCI Indicators that do not overlap with the CWRF, of these 6 indicators have a resilience lens that refers to resilience as a whole extending beyond water resilience. Of the 19 CWRF indicators that do not overlap with the WSCI, the following goals were largely not covered: Goal 4: Effective Regulation and Accountability, Goal 6: Sustainable Funding and Finance and Goal 12: Prosperous Communities. These goals are largely related to funding, financing and the creation of resilient communities.

Figure 71.
Comparison of indicators between the CWRF and WSCI



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Holland.

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