CITY OF HARARE

HARARE WATER DEPARTMENT

CLIMATE RESELIENCE WATER SUPPLY PLAN

2022-2050

|Main Report December 2022

Dutch Water Operators

CRWSP-2050 | COH/HWD | UNICEF | Vei.BV

Acknowledgements

Bringing this Climate Resilience Water Supply Plan to life required strong collaborations and generous support. We are deeply grateful to the Embassy of Sweden, UNICEF, and Vei.BV for their invaluable financial contributions. The dedicated professionals from the City of Harare departments, including our policy makers, deserve special recognition for their unwavering cooperation and expertise. We also extend our heartfelt thanks to our external stakeholders – local institutions of higher learning, government departments, local authorities, and NGOs – whose thoughtful input enriched the drafting process.

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EXECUTIVE SUMMARY

Climate change stands as a monumental challenge of the 21st century, casting a long shadow over the sustainability of water resources. Extreme weather events, once considered outliers, are becoming increasingly common place, disrupting the delicate balance of the water cycle. Anthropogenic activities, primarily the rampant emission of greenhouse gases, have acted as the primary catalyst for this global crisis, leading not only to Climate change but also to the deterioration of water quality and a devastating decline in biodiversity. It is now irrefutable that fresh drinking water is not an infinite bounty, but a finite and intensely vulnerable resource. Yet, Climate change, exacerbated by human actions, is steadily eroding our water security. This poses a direct threat to the fundamental human right to safe drinking water and sanitation, jeopardizing not only basic survival but also the prospects for sustainable development across the globe as enshrined in Sustainable Development Goal 6.

Faced with the looming threat of Climate change 's impact on water resources, the City of Harare (COH), Harare Water Department (HWD) partnered with Vei.BV, and UNICEF to develop a comprehensive Climate Resilience Water Supply Plan (CRWSP) – charting a roadmap for secure water access until 2050. The CRWSP delves into the projected effects of Climate change on Harare's water supply, taking into account the anticipated future water demand. Through meticulous baseline studies, the plan analyses existing and potential water sources, aiming to strike a delicate balance between supply and demand over the next three decades.

The CRWSP hinges on three core pillars: identifying promising new water sources to meet future demand, accurately estimating the available resources from all sources, and aligning projected water demand with available resources, securing long-term water security for Harare in a changing climate. By consolidating these goals, the CRWSP provides the Harare Water Department with a unified roadmap for navigating the challenges of Climate change and ensuring water for its present and future residents.

Therefore, the CRWSP sets out the following specific objectives.

(i) To Undertake a Comprehensive analysis of the COH water resources system.

(ii) To identify the specific Climate change impacts on the current and future water supply.

(iii) To propose short, medium & long-term adaptation measures to mitigate the identified impacts.

(iv) To provide a roadmap for the implementation, monitoring and evaluation of the adaption measures.

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ABBREVIATIONS

CCKP	Climate change knowledge portal
CMIP6	Coupled Model Inter-comparison Project Phase 6
COH	City of Harare
CRWSP-2050	Climate Resilience Water Supply Plan
HWD	Harare Water Department
MIPs	Model Inter-comparison Projects
MJ	Morton Jaffrey water treatment works
NRW	Non Revenue water
IPCC	Intergovernmental Panel on Climate change
IWRM	Integrated water resources management
PE	Prince Edward Water treatment works
RCPs	Representative Concentration Pathways
SD	Standard deviation from the mean
SSP	Shared Socioeconomic Pathways
UMSC	Upper Manyame Sub Catchment
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
UNFCCC	United Nations Framework Convention on Climate change
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

GLOSSARY

Adaptation is defined by the UNFCCC as “an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”. There are several kinds of adaptation: anticipatory, reactive, private, public, autonomous and planned. Adaptation measures include prevention, tolerance, sharing of losses, changes in activities or of location and restoration.

Anthropogenic is an effect caused or resulting from human activity.

Climate is a composite measure of the average pattern of variation in temperature, humidity, precipitation, wind, atmospheric pressure, sunshine, atmospheric particle counts and other meteorological variables in a region over a long period of time (usually 30 years).

Climate change according to the UNFCCC means “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. This differs from the IPCC usage where Climate change refers to “a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or a result of human activity”

Climate risk means a risk resulting from Climate change and affecting natural and human systems and regions. It is a combination of the probability of an event and its negative consequences. A societal element is said to be at risk when it is exposed to hazards and is likely to be adversely affected by the impact of those hazards when they occur.

Climate variability is the way climatic parameters fluctuate during a few years to a few decades above or below a long term average-value. Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic external forcing.

Climatic hazard is any event or change in climate, such as a single extreme event that exceeds a critical temperature threshold or a complex combination of changes involving variables and/or resulting in multiple impacts. It is an extreme climatic/weather event causing harm and damage to people, property, infrastructure and land-uses. It includes not only the direct impacts of the climate/weather event itself by also other indirect hazards triggered by that event. A climatic hazard may be slow (like sea level rise) instead of sudden and severe or may be benign in today’s world and become hazardous in a new, different climate regime.

The I**PCC** is the intergovernmental body of the United Nations (UN) tasked with regularly assessing the science related to the Earth’s changing climate and determining the state of knowledge related to Climate change.

Model Inter-comparison Projects (MIPs) are sets of experiments and simulations designed to test and compare specific aspects of climate models.

Redundancy Spare capacity is built into the system to account for disruptions and surges in demand. It also involves multiple ways of fulfilling a need or function.

Representative Concentration Pathways (RCPs), which are plausible future scenarios of anthropogenic forcing spanning a range from a low emission scenario characterized by active mitigation (RCP 2.6), through two intermediate scenarios (RCP 4.5 and RCP6.0), to a high emission scenario (RCP 8.5).

Resilience according to IPCC is “the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization and the capacity to adapt to stress and change". Simply, it is the ability to survive, recover from and even thrive in changing climatic conditions. It includes the ability to understand the potential impacts and to take appropriate action before, during and after a particular event, such as major flooding or prolonged drought, to minimize negative effects and maintain the ability to respond to changing conditions including unpredictable conditions.

Resourcefulness: Citizens and institutions are aware of climate risks, able to adapt to shocks and stresses and can quickly respond to a changing environment.

Robustness: Urban physical assets are designed, constructed and maintained in anticipation of high-impact climate events.

Scenario is a sequence of events, course of events, chain of events especially when imagined. It is an account or synopsis of a possible course of action or events, a description of what could possibly happen.

Sustainability was defined in 1987, by the UN Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Vulnerability according to IPCC is "the degree to which a system is susceptible to and unable to cope with, adverse effects of Climate change including climate variability and extremes". Vulnerability is a function of the character, magnitude and rate of Climate change and variation to which a system is exposed, its sensitivity and adaptive capacity.

1 INTRODUCTION

1.1 Call for action

Climate change is being experienced across Zimbabwe, affecting water supply, health, agriculture, housing, safety, and livelihoods. Zimbabwe experiences climate change, in the form of extreme weather events, whole Communities are being uprooted by relentless droughts and floods, proving the shifting climate's destructive force. In particular, the spectre of famine and water insecurity looms large, threatening to swell the ranks of "climate refugees" in cities like Harare. This influx will inevitably strain the city's already overburdened resources, especially its limited water reserves. The emissions causing this crisis originate worldwide however, developing nations like Zimbabwe bear the brunt of its consequences. Despite ranking among the 100 least-emitting countries, Zimbabwe, along with its fellow developing nations, contribute a mere 3% to global emissions. In stark contrast, the top ten emitters, mostly developed nations, generate a staggering 68%[1]. This disparity highlights a crucial dilemma i.e., while everyone must contribute to climate action, nations like Zimbabwe face the unenviable task of adapting to a crisis they barely contribute to. The City of Harare (COH) has taken a proactive stance, acknowledging that water supply will be the most vulnerable aspect of service delivery under the intensifying grip of Climate change. Working in collaboration with development partners, the COH has embarked on developing a comprehensive Climate Resilience Water Supply Plan (CRWSP). This ambitious plan lays out a roadmap for securing Harare's water in the future, outlining interventions to tackle the challenges posed by a changing climate. The CRWSP aims to create a climate-proof water supply system for Harare, safeguarding the city's present and future residents. While the path ahead requires dedication and collective effort, initiatives like the CRWSP offer a beacon of hope in the face of a formidable challenge. Formulation of the CRWSP falls in line with Zimbabwe’s National development strategy which prioritizes disaster preparedness[2] and the National Climate Change Response Strategy which emphasizes sustainable water management under changing climatic conditions[3].

1.2 Purpose and Scope of the plan

The purpose of the Climate Resilience Water Supply Plan is to ensure that the City of Harare continues to provide safe and reliable potable water to its customers, even in the face of the challenges posed by climate change. The Plan is a critical tool that will help mobilize and direct a transition towards climate-smart operations. The scope focuses on locating, estimating, and balancing water demand and water availability through 2050. Baseline studies were conducted to establish population trends, climate variability, water quantity, quality, and demand as related to the city of Harare. After establishing the baseline status, reasonable assumptions were then made about what the future might hold, and projections were made up to 2050 considering the anticipated changes in climate.

1.3 Rationale for the plan

Climate change is already impacting water resources in Zimbabwe. Frequent and intense droughts, coupled with erratic rainfall patterns are making it increasingly difficult to ensure a reliable water supply for the citizens of towns and cities in the country[4]. Rapid population growth further strains these already limited resources, as aging and obsolete water infrastructure struggles to keep pace with demand. Many of the treatment plants, networks, and aging pipes are in need of urgent repair or replacement, leaving citizens vulnerable to water shortages and contamination. Developing a long-term CRWSP for Harare is both urgent and crucial, in ensuring proactive measures, promoting long-term sustainability, and safeguarding Harare's water security for generations to come.

1 https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters
2 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC203781/
3 https://faolex.fao.org/docs/pdf/zim169511.pdf
4 https://documents.worldbank.org/curated/en/925611468329355687/pdf/937310WP0Box380babwe000Issues0Paper.pdf

2 STRATEGIC DIRECTION, TARGETS AND PROPOSED ADAPTATION MEASURES

2.1 The Strategic direction

The City of Harare Climate Resilience Water Supply Plan (CRWSP) is based on three strategic directions and from each of the strategic directions, targets have been set;

Strategic Direction 1. DIVERSIFYING AND SECURING WATER SOURCES

Mitigate the impact of climate change by finding alternative water sources and ensuring long-term sustainability.

Target.1 Achieve at least 90% treatment and operational efficiency for all existing Wastewater Treatment Works (WWTWs) by 31 December 20230.

Target.2 Increase total water availability by at least 10% through policies that promote the conjunctive use of surface water and other sources (Groundwater, rainwater harvesting, Grey water reuse) by 31 December 2035.

Target.3 The Kunzvi - Musami water supply schemes to be online by 31 December 2035.

Strategic Direction 2. IMPROVING WATER USE EFFICIENCY AND REDUCING DEMAND

Reduce water losses and promote conservation through infrastructure upgrades and behavioural changes.

Target.4 NRW Reduction to at most 30% by 31 December 2030.

Target.5 Implement policies that enforce the use of water-efficient technologies by 31 December 2030.

Target.6 Achieve at least 10% reduction in per capita water consumption through public awareness campaigns by 31 December 2025.

Strategic Direction 3. ENHANCING SYSTEM RESILIENCE

Target.7 Achieve 100% treatment and operational efficiency for the existing Water Treatment Works (WTWs) by 31 December 2025.

Target.8 Extension of water and sanitation services to at least 90% of all uncovered areas by 31 December 2040

2.2 Adaptation measures

From the set targets, Adaptation measures are proposed for the short, medium, and long term. Furthermore, these are divided into active measures to be implemented or initiated by the city of Harare water department, and passive measures to be implemented by other actors.

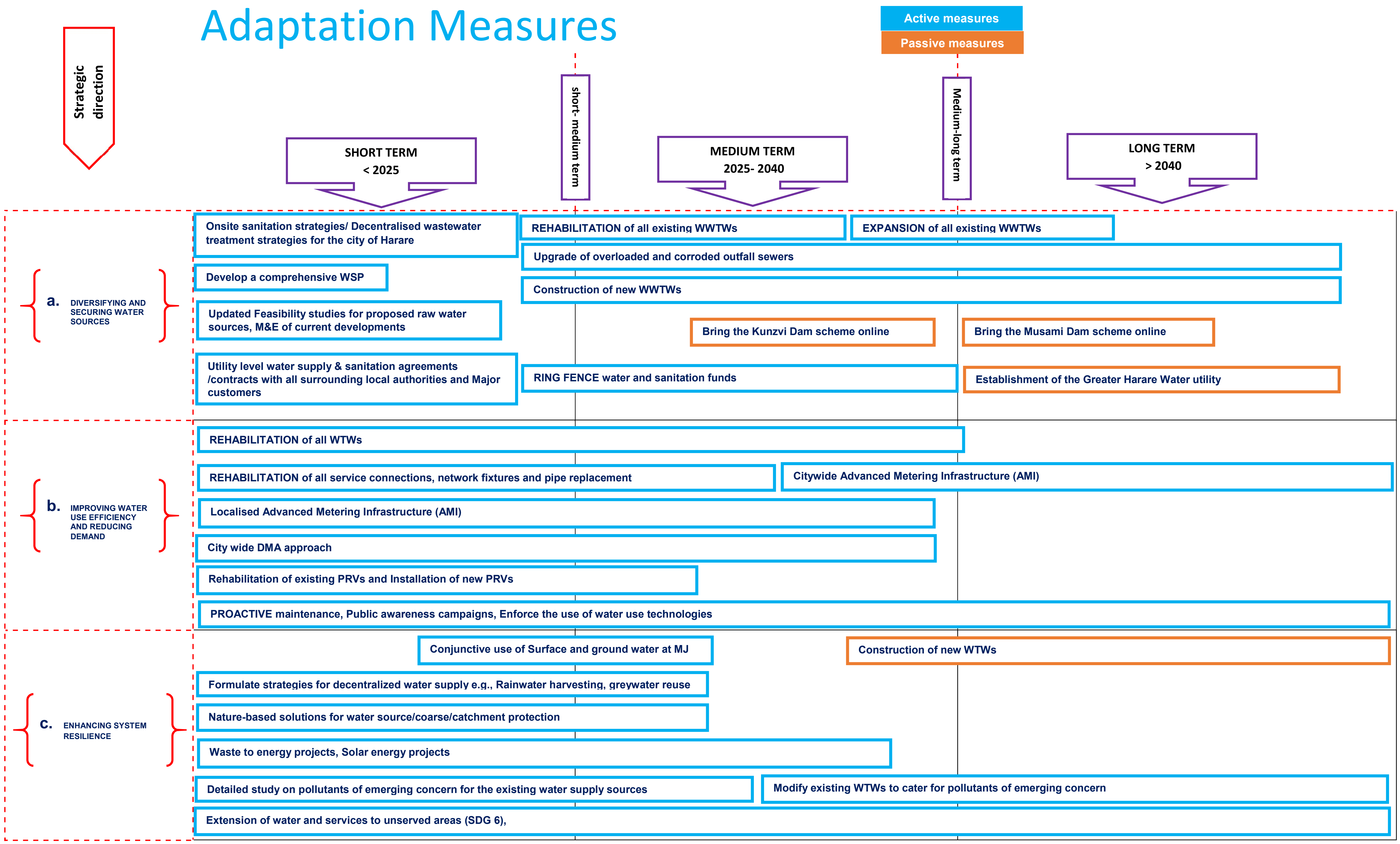
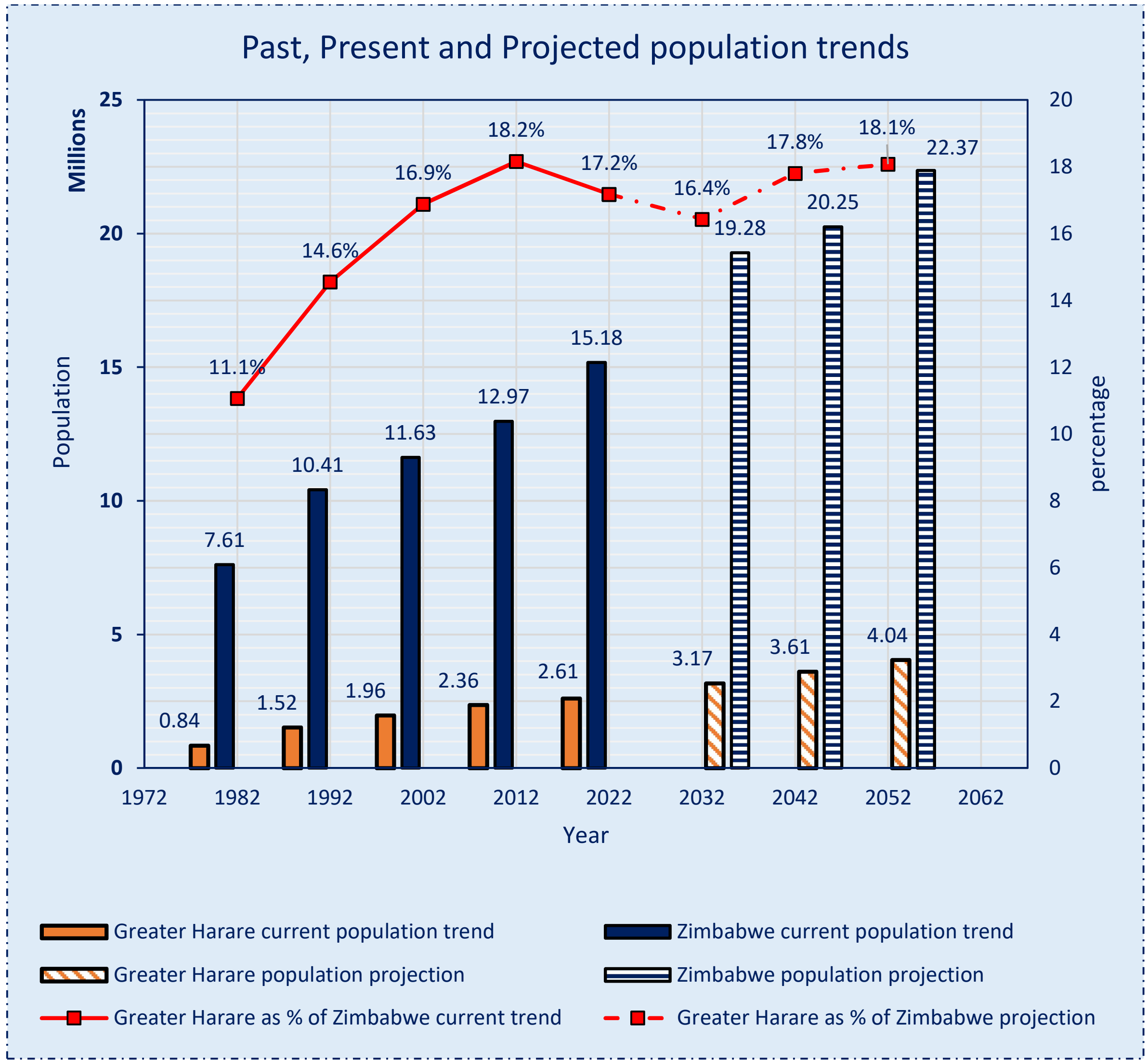


Figure 1: An Illustration of the proposed adaptation measures

3 VULNERABILITY ASSESSMENT (THROUGH BASELINE ASSESSMENT AND CLIMATE PROJECTIONS)

3.1 Population and water demand projections

Potable water supply is meant to satisfy anthropogenic activity. As a result, population trends are a key driver of water demand. Population censuses are conducted every 10 years in Zimbabwe, so population data is readily available[5]. For the development of the CRWSP, this data was used to project population trends up to 2050. The population was disaggregated according to housing categories (i.e., High, medium and low density), and the respective water demands were assigned to each housing type. The overall water demand was then calculated. The following graphs illustrate the past, present, and future projected trends for population, water production, and water demand in the greater Harare area.



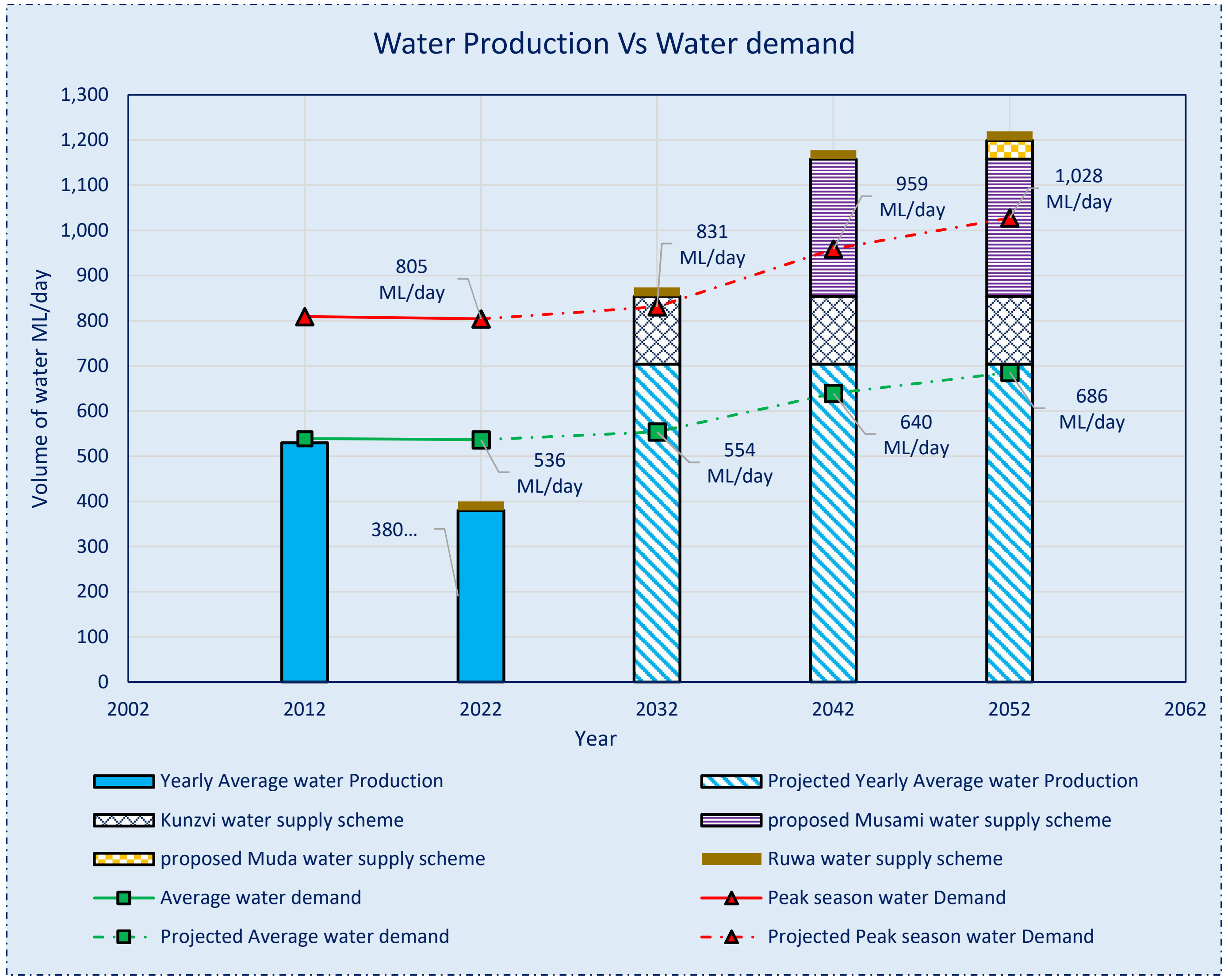


Figure 2: *Population Projections, Water Production Vs Water demand Projections*

From the available data and the projection methodology used, it is anticipated that the population of the Greater Harare area will peak at approximately 4 million residents in 2050 (Figure 2)[6]. This is a conservative estimate, considering that population dynamics can shift suddenly due to unforeseen events, such as socio-economic developments, pandemics, or wars. However, for the purposes of making an inference of the water demand into the future, the projects are expected to reasonably give a safe estimate of the water demand, such that all future requirements may be catered for. Therefore, it is anticipated that the average water demand in 2050 will be around 686 million litres per day (ML/day), while the peak water demand will be around 1028 ML/day. From the water production statistics for the year 2022, it can be observed that the average water production for the year, which was around 380 ML/day, was much lower than the average demand of 536 ML/day, let alone the peak water demand of 805 ML/day. It can also be observed that assuming that all the water treatment works (WTWs) have been optimized by 2032, operating at full capacity, at peak water demand, the greater Harare area will still have a water deficit. Therefore, in the short term, it is critical that all the WTWs are rehabilitated to operate at full capacity, and in the medium to long term, all the proposed new water supply schemes should be online.

5 https://zimbabwe.opendataforafrica.org/anjlptc/2022-population-housing-census-preliminary

6 https://documents.worldbank.org/en/publication/documents-reports/documentdetail/982261468196754920/main-report

3.2 Analysis of the COH Water Resources System

3.2.1 Surface water

The Greater Harare area sits on its catchment, sourcing its water from surface water reservoirs, namely Lake Chivero and Lake Manyame, which are downstream of the main catchment. From a water quantity perspective, this is an ideal setup, as the city can recycle wastewater for reuse. However, from a water quality perspective, this poses a risk to the quality of the water in the water supply reservoirs. Anthropogenic activities on the main catchment are the major threat to the environmental stability and water supply in the catchment. This is due to the production and discharge of pollutants onto watercourses, groundwater over-utilisation, deforestation, soil erosion, improper solid waste management, and poor agricultural and land practices.

The City of Harare is also wetland country, and the current estimated extent of wetlands is approximately 20,000 hectares, or 22% of the overall area of the city (Figure 3). These are crucial for water filtration and purification however, there has been degradation and destruction of sensitive ecosystems, including the massive invasion and construction on wetlands by both formal and informal development[7]. It is also worth noting that all the outfall sewer lines in the city are located on streams and in the proximity of wetlands (Figure 8). Considering the challenge of aging infrastructure, most of the outfall sewers are spilling into the environment. There is also no instance of an engineered system for the management of either solid waste or storm water. The aforementioned issues are being exacerbated by rapid population growth, rapid urbanization, illegal land occupations, human displacement and resettlement, as well as Climate change. This has had profound and direct impacts on water supply, sanitation, food security, and the economy in general.

The water-related challenges are expected to increase with the adverse effects of Climate change, which has deviated the local climate from its natural variability and increased the occurrence of extreme weather events. Rapid urban population growth has also caused a mismatch between service provision and demand. As a result, it has been the environment that fills the gap, such as groundwater abstractions in instances where there is no water supply, wetlands invasion in instances where there is demand for land, slums due to the housing deficit, and garbage dumps due to improper solid waste management. The overall result has been the overall degradation of the environment, including water quality deterioration.

The design capacities of the main water supply reservoirs are as follows: 480.23 million cubic meters for Lake Manyame and 247.18 million cubic meters for Lake Chivero. There are also two upstream dams, Harava and Seke dams, with a combined capacity of 12.5 million cubic meters. Bathymetric surveys conducted for Lake Chivero in 2021 and Lake Manyame in 2022 show that both reservoirs are still within the 10% threshold in terms of volume reduction (Figure 3, Appendix). The total estimated 4% risk yield of the Chivero-Manyame system with allowance for upstream and downstream commitments is approximately 436 million litres per day. Allowing for upstream commitments only, the 4% risk yield is 478 million litres per day. The 10% risk yield with upstream commitments only is estimated to be 478 million litres per day[8]. The safe yield of the reservoirs is clearly much lower than the current average demand, let alone the projected demand. This is risky for a large city such as Harare. Therefore, there is a need to develop new water reservoirs and production facilities in other catchments.

7 https://www.auditorgeneral.gov.zw/vacancy/category/1-special-audited-reports?download=44:value-for-money-audit-report-on-protection-of-wetlands-by-ema-2021&start=20
8https://documents1.worldbank.org/curated/en/925611468329355687/pdf/937310WP0Box380babwe000Issues0Paper.pdf

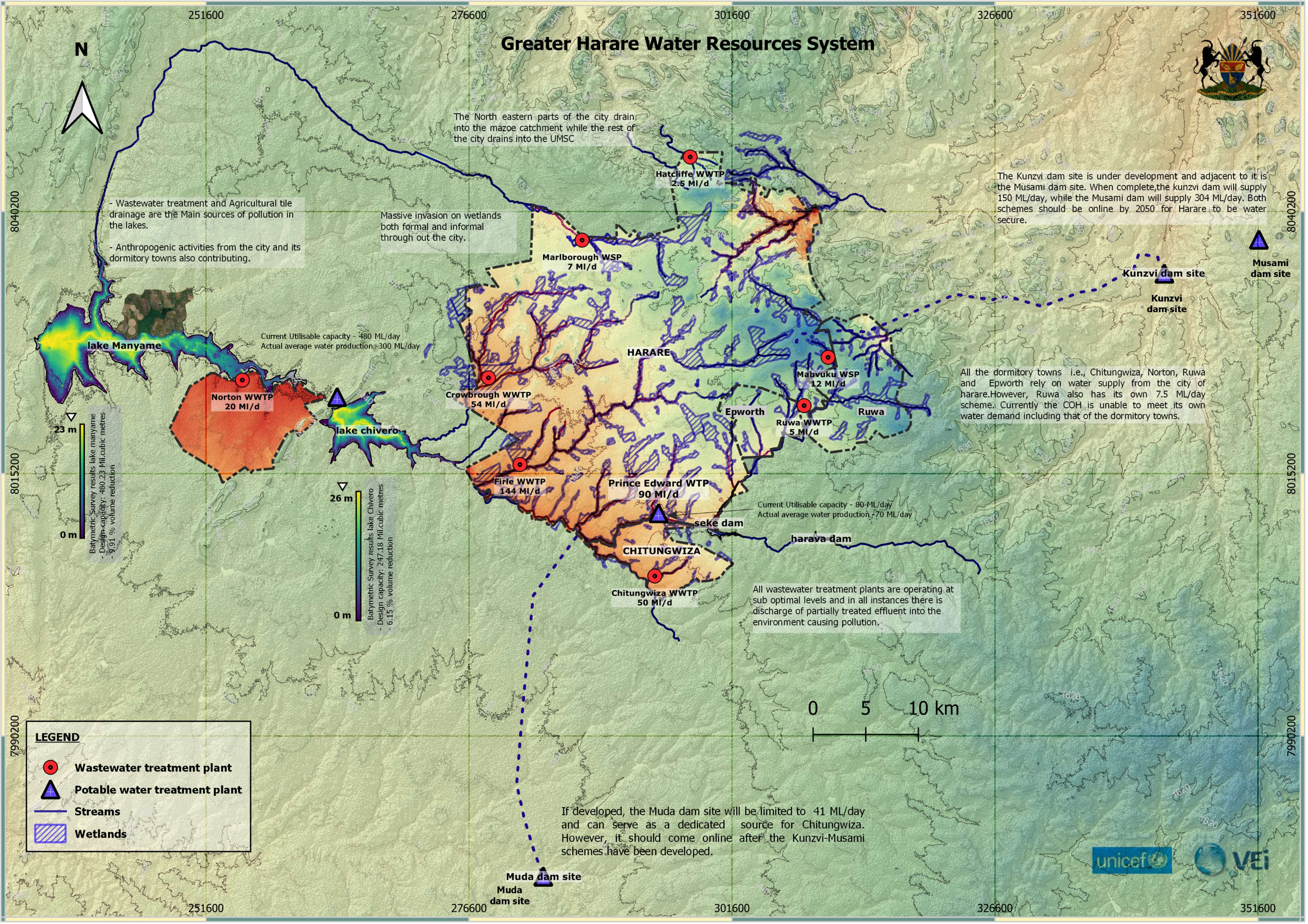


Figure 3: *Greater Harare surface water resources system*

3.2.2 Groundwater

Groundwater in the greater Harare area, and everywhere else, is a finite and vulnerable resource and the ability to store and transmit groundwater depends on the geological formations present in a specific area. Figure 4 is a simplified geological map of greater Harare, and as can be seen, the geological makeup across the city is highly variable. All rocks in the area are of either igneous or metamorphic origin. This makes most of the rocks massive and crystalline, meaning they can be classified as "hard rocks." In their natural state, these rocks are impervious and unable to store water in a primary sense.

Granitic rocks are the most abundant type, stretching from the northeast to the southwest of the area. These rocks vary in age, ranging from older gneissic rocks to younger granites. They have poor groundwater potential due to a lack of primary permeability and porosity. These rocks cover the largest part of the greater Harare area. Therefore, in most areas of the city, groundwater comes from secondary structures such as faults, fractures, and regoliths. Groundwater potential under such conditions is invariably related to the amount of rainfall, fracture pattern distribution, and regolith development. Borehole depths in areas containing gneisses and granites range from 30-50 meters. Groundwater levels range from 5-30 meters and are mostly less than 20 meters deep. Yields are equally variable, ranging from 0.1-0.2 liters per second. Values outside these ranges may occur depending on the prevailing hydrogeological conditions.

A small number of dolerite dykes occur in the Upper Manyame Sub-Catchment and are more or less parallel to the Great Dyke. The doleritic intrusions are easily traced in the field as they form streaks of red soils and sometimes accompanying ridges with black weathering, rounded boulders, and support a lot of vegetation[9]. Most aquifers in the city of Harare are unconfined, meaning they are open to the elements. As a consequence, the available groundwater is superficially stored. This storage is referred to as "secondary porosity." The groundwater storage depends on the degree of fracturing and weathering that the bedrock has undergone.

The majority of Greater Harare has moderate groundwater potential due to the geology[10]. However, this hasn't deterred over-utilization of the resource. Estimates suggest there are over 10,000, with some figures as high as 75,000, functional boreholes in Harare alone. This collective abstraction has a significant impact, manifested in seasonal drawdown, reduced water deliveries, and borehole failure. These problems are further compounded during drought cycles or years with poor rainfall distribution. Considering Climate change is causing a deviation of rainfall patterns from natural variability, the status of groundwater in Harare is expected to worsen.

There have been various initiatives that aim at the conjunctive use of surface and groundwater however, a major challenge with using groundwater as an alternative water source is that the exact amount of water stored is unknown. Most indications for the greater Harare area point to the fact that groundwater is being over-utilized. Regulations should be strictly enforced to ensure the registration of all consultants, drillers, and service providers. This will promote responsible practices in all aspects of groundwater management, crucial for sustaining this vital resource. Research conducted using the GRACE satellite mission, determined that the greater Harare area has seen an overall decrease in groundwater levels as a result of uncontrolled groundwater abstractions[11].

9 https://www.sciencedirect.com/science/article/abs/pii/S0167289496800133

10 https://www.sciencedirect.com/science/article/abs/pii/S1474706517301055

11 R. van Dijk, F. van 't Klooster, J. Mc Gregor, L. Schuurman, I. StreefkerkManyame Catchment: A Risk Assessment

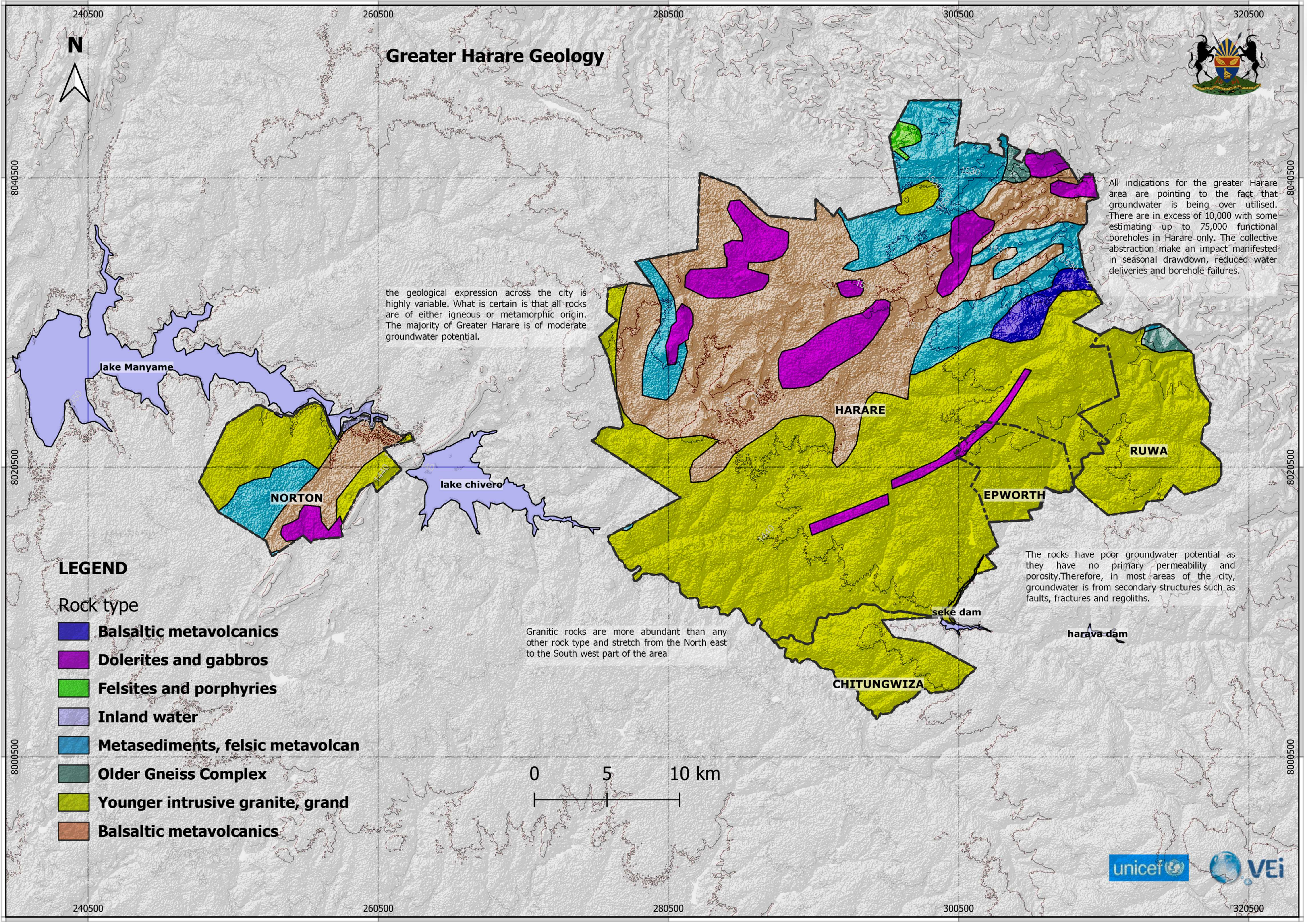


Figure 4: *Greater Harare geology*

3.2.3 Surface water quality

The Upper Manyame Sub Catchment (UMSC), where the greater Harare area lies is one of the most extensively studied areas in Zimbabwe in terms of water quality dynamics. The following are abstracts from such research, highlighting the status of ambient water quality in the catchment including management issues.

A case study by Magadza (2008), illustrated a number of management issues for Lake Chivero. The lake is downstream to the COH and its dormitory towns (Figure 3). Historically, the lake became hypereutrophic about fifteen years after its filling. Restoration measures were then taken to restore the lake. Proper investment, management of infrastructure and nutrient removal resulted in the improvement of the trophic state of the lake to mesotrophic in the 1970s. From 1980 onwards there was a surge in urban population. Inflow diminished, resulting in the reduction of flushing of the lake. As the population grew, wastewater return flows into the lake increased relative to the precipitation runoff inflow. Currently, wastewater return flows are the main inflow into the lake during the dry season. These developments, in the context of inadequate investment in wastewater treatment facilities, poor infrastructure maintenance, low operating capital and poor governance, have resulted in the lake reverting to a hypereutrophic state, and now poses health and water security risk[12].

Research conducted by Tendaupenyu (2012), to investigate Nutrient limitation on phytoplankton growth in the UMSC reservoirs indicated nitrogen to be the primary limiting nutrient in Lake Manyame, Harava Dam and Seke Dam. No nutrient was found to be limiting growth in Lake Chivero, instead, light was implicated to be the limiting factor in the lake. Harava Dam and Seke Dam showed signs of enrichment, relative to the levels established in 1977. This was attributed to sewage discharge from expanding urban settlements. Lake Chivero has relatively remained the same, serving as a nutrient trap, shielding the reservoirs downstream. Lake Manyame, Seke Dam and Harava Dam were concluded to be mesotrophic, and Lake Chivero eutrophic. This was the status of the reservoirs in 2012 however, presently all the reservoirs are showing signs of being eutrophic[13].

Due to the vulnerability of the UMSC water resources to anthropogenic activities, alternative management models for the reduction of pollution have been proposed. An example is research that was conducted by Nyarumbu & Magadza (2016). They determined the applicability of the Planning and Management Model of Lakes and Reservoirs (PAMOLARE) for predicting and managing changes in lake trophic status. Using lake Chivero as a case study, three scenarios were analysed. These were; the use of the existing management system, the use of natural wetlands and the use of a combination of efficient wastewater treatment and wetlands. The trophic status of Lake Chivero was evaluated by analysing different Physico-chemical variables from the lake's major and minor tributaries. The results indicated that Lake Chivero was hypereutrophic, with a mean phosphorus concentration of 2.77 mg/L and a mean nitrogen concentration of 3.21 mg/L. The phosphorus contribution from non-point sources was estimated to be about 493 tonnes per annum compared to 634 tonnes per annum from point sources. About 40,000 ha of wetlands would have the capacity to remove up to 80,000 tonnes of phosphorus and about 99,700 tonnes of nitrogen per annum. The phosphorus in the lake water could decrease from 2.77 to 0.22 mg L^{-1} over 6.5 years. Nitrogen levels in the lake water also could decrease from 3.16 to 3.06 mg L^{-1} over 4 years. The notable trends indicated that the model could be used as a tool for planning the management of Lake Chivero[14].

12 https://www.researchgate.net/publication/227851662_Lake_Chivero_A_management_case_study

13 https://www.ajol.info/index.php/wsa/article/view/73315

14https://www.researchgate.net/publication/283312012_Using_the_Planning_and_Management_Model_of_Lakes_and_Reservoirs_PAMOLARE_as_a_tool_for_planning_the_rehabilitation_of_Lake_Chivero_Zimbabwe

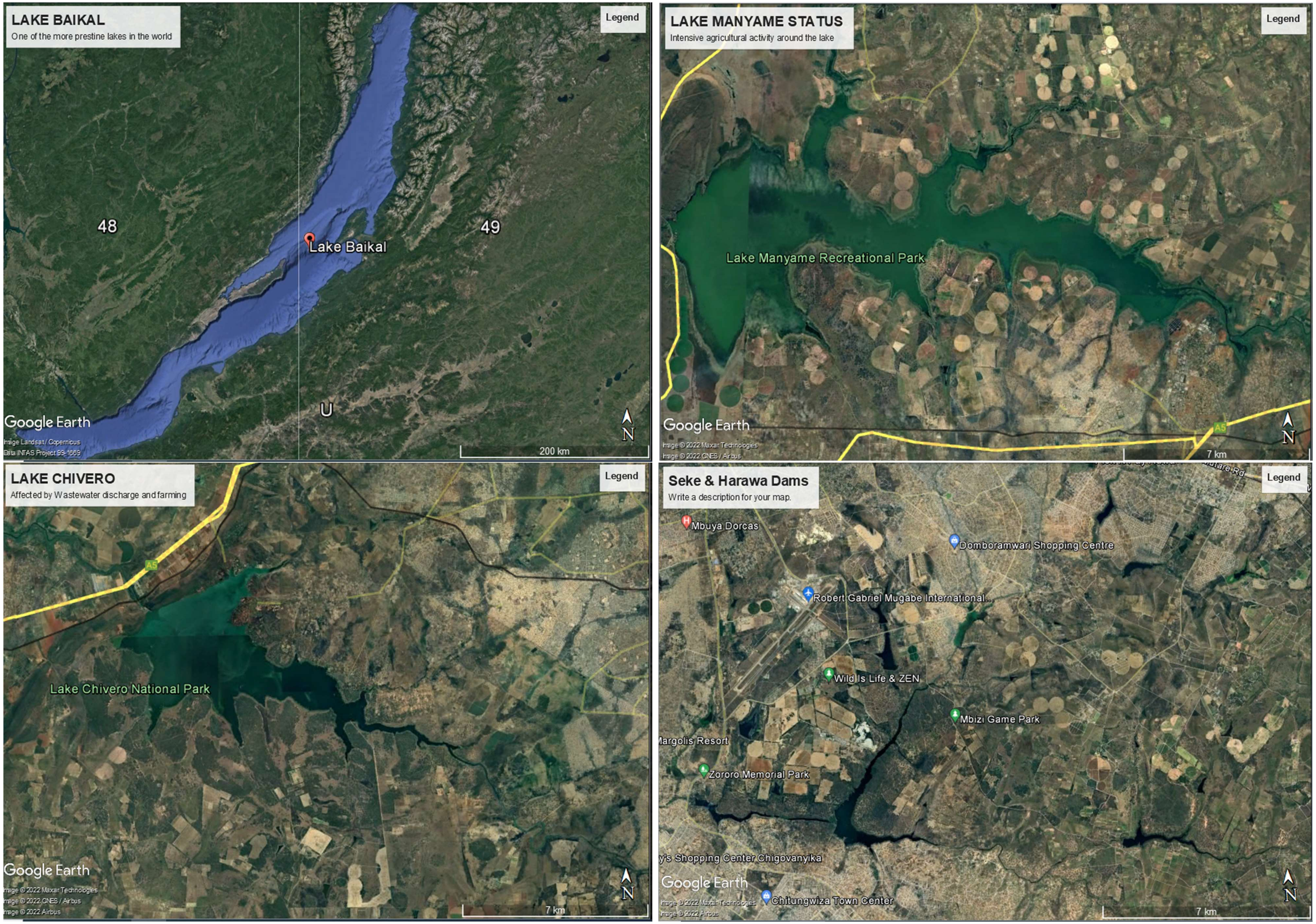


Figure 5: *An illustration of the eutrophication in the COH water supply reservoirs*

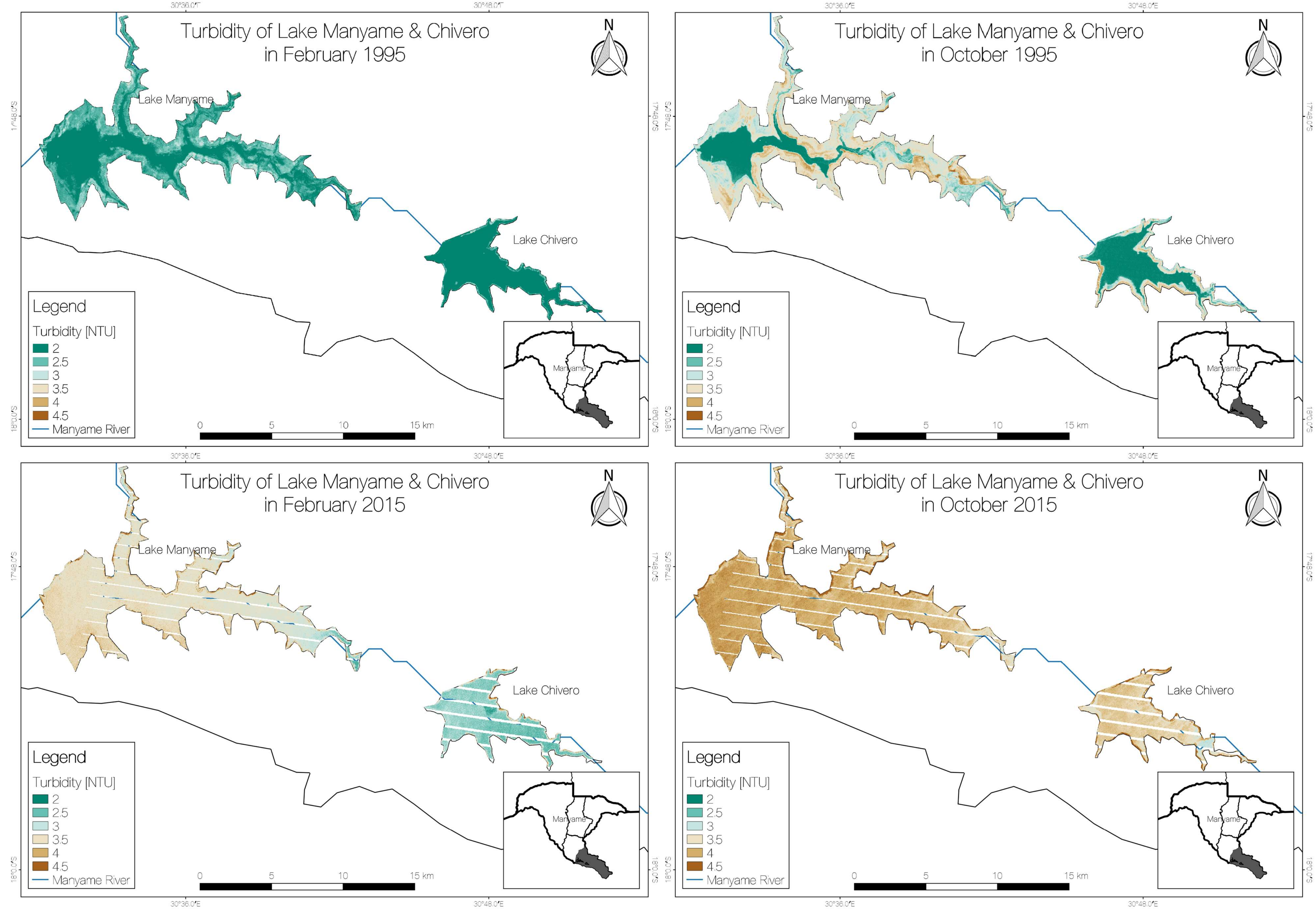


Figure 6: *An illustration of the deterioration of water quality in the main water supply reservoirs*[15]

15 R. van Dijk, F. van 't Klooster, J. Mc Gregor, L. Schuurman, I. StreefkerkManyame Catchment: A Risk Assessment (COH-WWX HARARE Project)

3.2.4 Demographic and land use change developments

The entirety of the greater Harare area, has experienced rapid population growth and urbanisation from the late 90s to the present. The four major towns i.e., Harare, Chitungwiza, Norton and Ruwa, have increased in population, without corresponding extension of infrastructure and services. The city of Harare experienced population growth from 310,000 people in 1961 to around 1.7 million in 2012[16]. According to van Dijk et al. (2019)[17], a significant increase of roughly 70% in urban areas was observed in the period between 1995 to 2015 in the greater Harare area. In the same period, the rapid urbanisation resulted in the reduction of vegetation and tree cover in the area. The dynamics are illustrated in Figure 7. Urbanization of the greater Harare area continues, with plans in place to merge the city of Harare and its dormitory towns into a single metropolitan area.

Historically, a key development that had a major impact on the demographic and land use patterns in the greater Harare area was the land reform program of Zimbabwe in the year 2000. The program further accelerated urbanization, in the process outpacing the provision of services which included accommodation, water, solid waste and wastewater collection. The dilapidation of infrastructure triggered other challenges such as water loss and contamination, resulting in low water availability, poor water quality and risk to public health. The fast pace of urbanization also coincided with the economic decline that was experienced in Zimbabwe after the year 2000, resulting in low levels of employment and an increase in urban poverty and crime. As a result of these developments, in most urban centres there is evidence of poor spatial planning through the emergence of illegal settlements thus worsening environmental degradation and service delivery. In addition, there is unwillingness to pay rates by urban citizens and the effectiveness of the water sector reforms in terms of policy, legal, institutional and practice issues still remain as a gap within the water sector.

It is also important to note that due to the housing deficit in the greater Harare area, according to Dialogue on Shelter (2014), there are more than 60 informal settlements in and around Harare[18]. The peri-urban areas of all town centres have experienced expansion in recent years due to informal settlements e.g., in Epworth, Hatcliffe and Whitecliff, Harare south and west. There has also been a lot of development in the affluent suburbs of the city mainly in the North-eastern side of the city. What is common is that the aforementioned developments are creating more demand on the already limited infrastructure. As a result, there has been a mismatch between the expansion of the city and the extension of water, sanitation and other services. Most areas in the peripheries of the city i.e., Low-medium density properties and informal settlements are heavily reliant on decentralised services e.g., ground water, onsite sanitation systems and solid west dumps.

The most important socio-economic activities in the greater Harare area range from industrial manufacturing, engineering, farming, recreation and tourism. Regulation of these Anthropogenic activities remain as a major Gap in the greater Harare area. As a result, there has been a sharp deterioration in the natural environment in the area. Examples are the aforementioned invasion of wetlands by both formal and informal developments, the production and discharge of pollutants into the environment especially sewage, solid waste. All this has had a profound effect on the city's water supply in particular water quality and increased demand on an increasingly scarce resource.

16 https://www.zimstat.co.zw/wp-content/uploads/publications/Population/population/census-2012-national-report.pdf

17 R. van Dijk, F. van 't Klooster, J. Mc Gregor, L. Schuurman, I. StreefkerkManyame Catchment: A Risk Assessment (COH-WWX HARARE Project)

18 https://www.iied.org/sites/default/files/pdfs/migrate/G03861.pdf

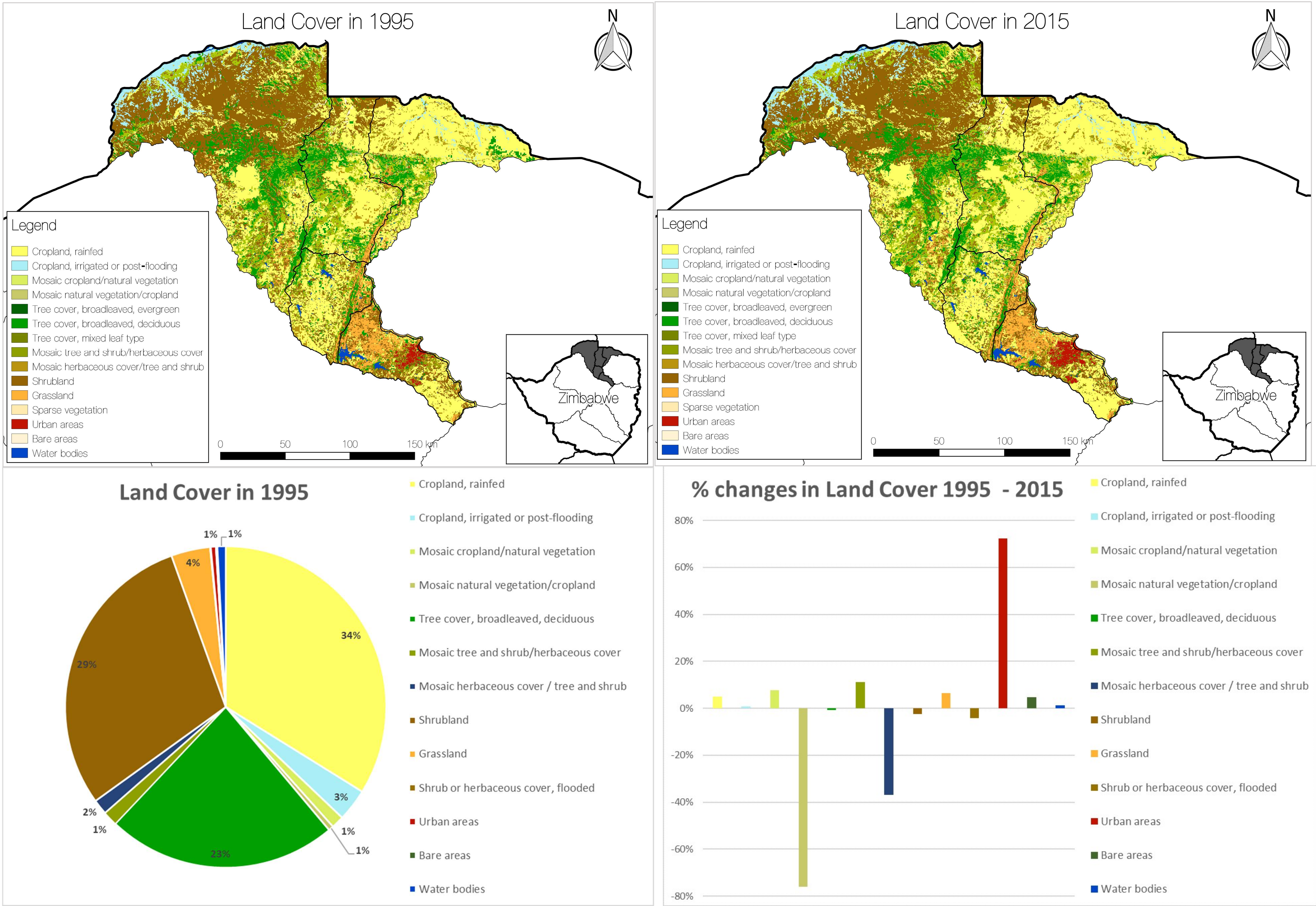


Figure 7: *Land use- land cover Changes for the UMSC from 1995-2015*[19]

19 R. van Dijk, F. van 't Klooster, J. Mc Gregor, L. Schuurman, I. StreefkerkManyame Catchment: A Risk Assessment (COH-WWX HARARE Project)

3.3 Analysis of COH Water Supply Scheme

3.3.1 Water production

The Harare water supply scheme consists of two major water treatment works (WTWs), with a combined design output of 704 ML/day. Morton Jaffray (MJ) WTWs, supplied with raw water from lake Manyame and lake Chivero, has a design capacity of 614 ML/day. Prince Edward (PE) WTWs, supplied with raw water from Seke and Harava dams, has a design capacity of 90 ML/day. The present combined utilisable capacity of the WTWs is limited to 480 ML/day, while the actual combined water production for the year 2022 was 380 ML/day (Figure 2). Due to the poor water quality in the main water supply reservoirs, eight water treatment chemicals are required for potable water production in an energy intensive treatment regime. Therefore, the cost of water production is high, and the situation is often made worse by supply chain issues and plant breakdowns. Consequently, the average water production is usually lower than the utilisable capacity of the plants which in turn is lower than the average/peak water demand (Figure 2). The average chemical cost before energy and other operational costs for the year 2022 was USD $ 1,252,301.57. The cost is very high, making the water treatment regime unsustainable.

3.3.2 Distribution Network

The Harare water supply scheme provides treated water to Greater Harare area. The supply area includes neighbouring municipalities and government facilities. The scheme consists of 16 treated water pumping stations, 27 reservoir sites, over 5,400 km of transmission and distribution pipelines and over 200,000 service connections. Generally; the water transmission and distribution system is in different stages of dilapidation with many portions requiring upgrade and/or replacement. All reservoir sites need major repairs and upgrades e.g., the installation of float valves to curtail massive water losses. Most of the isolation valves are in a bad shape rusty and leaking. The valve chambers are generally in poor condition, damaged and in some instances filled with dirt. Based on the operation and experience of the Harare Water Department (HWD), most network appurtenant fittings and structures must be repaired/ replaced. The service connections are heavily corroded and incrusted. This is expected, given that most connections have been in service for over 40 years. Most of the leakages in the network occur on these lines. The unfortunate part is that currently the HWD is in reactive maintenance mode due to scarcity of funds which means proper attendance to faults within the distribution network is a major challenge let alone the replacement or upgrade of the system. As a result, The NRW is around 60%, of which around 25% are physical losses.

3.3.3 District Metering System

The City of Harare used to have a comprehensive metering system in operation. Bulk water meters and flow meters were installed to measure weekly flows at outlets/inlets of reservoirs and pumping stations as well as flows in the main supply pipes transferring water into individual supply areas of the city. There were 145 district meters installed in the water supply system. Out of 145 meters, 11 bulk meters used to be read by the Chitungwiza Council. The remaining 134 meters were under the control of the water workshop of the COH. The district metering system is no longer functional because (a) the meters are not working, and (b) there have been interconnections among district metering areas (DMAs) and areas that are not metered. Efforts are underway to restore the old district metering together with comprehensive NRW studies. The map in Figure 8 shows the spatial location of the main facilities in the water supply scheme. A detailed Water and Sanitation investment plan for the Greater Harare area is available and can be referred to for a more comprehensive analysis of the water supply of the greater Harare area including the required investment[20].

20 https://documents.worldbank.org/en/publication/documents-reports/documentdetail/982261468196754920/main-report

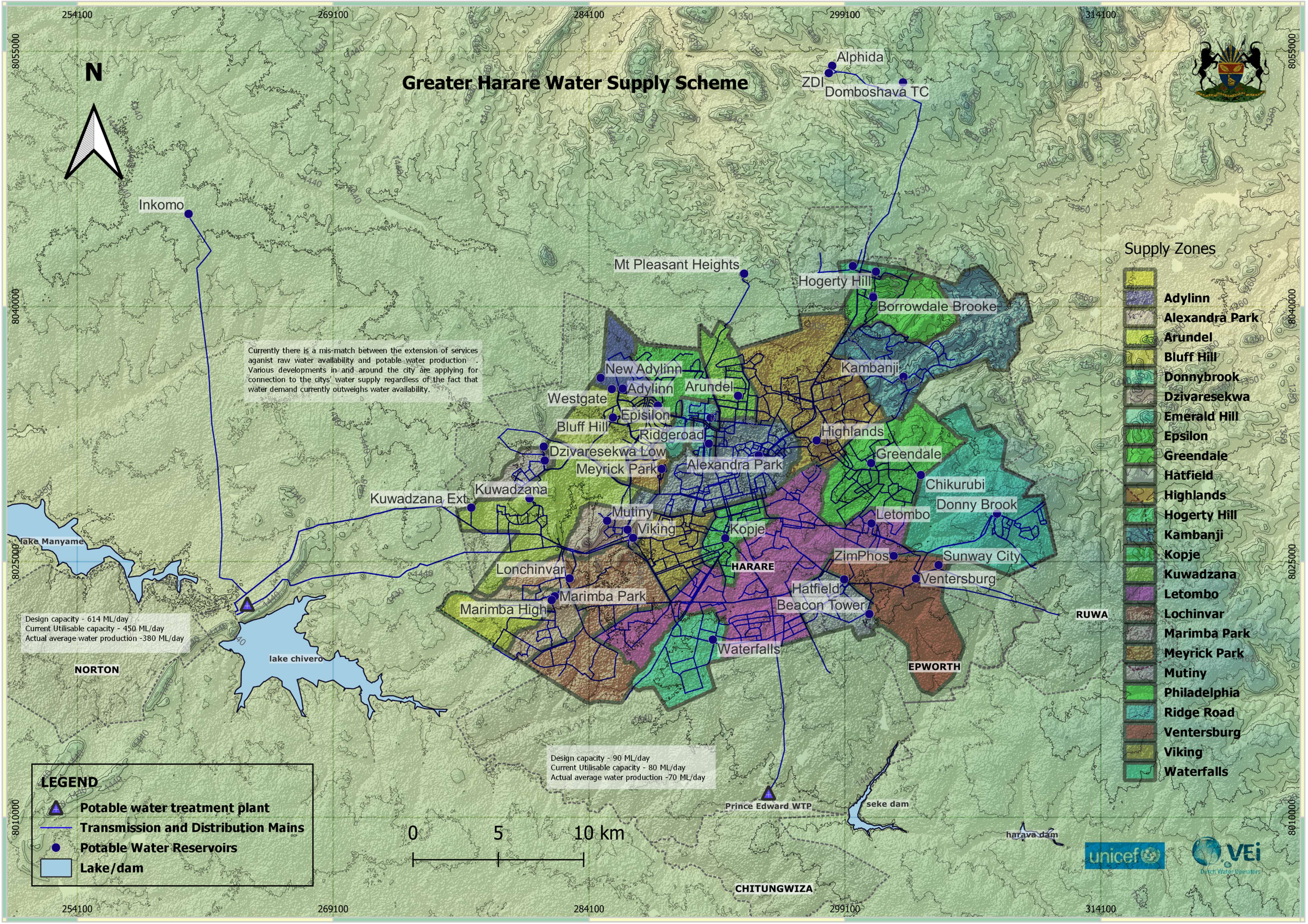


Figure 8: *Greater Harare water supply Scheme*

3.4 Analysis of the COH Sanitation System

Sewage flows by gravity therefore, the city of Harare is divided into five sewer catchment areas according to the drainage patterns of the city. The catchment areas are; Firle, Crowborough, Harare east, Harare North and the Harare southern incorporated areas (SIA). There is also the minor Budiriro Catchment Area. The design treatment capacities of the wastewater treatment works (WWTW) is as follows; Firle WWTW 144 ML/day, Crowbrough 54 ML/day, Donnybrook waste water Stabilisation Ponds 12 ML/day, Marlborough wastewater Stabilisation Ponds 7 ML/day and Hatcliffe WWTW 2,5 ML/day. Currently all the sewerage infrastructure is overloaded in terms of collection, conveyance and treatment.

Sewage collection, conveyance and treatment for the Harare east, Harare North and the Harare southern incorporated areas (SIA) catchment areas is of concern. Currently these areas have sparse sewerage provision and include large unsewered areas into which the city is expanding. Collected sewage in these areas is, (with the exception of Chitungwiza) treated in many dispersed small stabilization ponds which are generally functioning poorly. The current situation in these catchment areas is that the bulk of the sewage is discharged into the nearby water course and tributaries partially treated or untreated. The water treatment works extract water downstream of this increasingly polluted catchment and as highlighted in the previous section, water pollution is at the core of the water supply challenges for the greater Harare area.

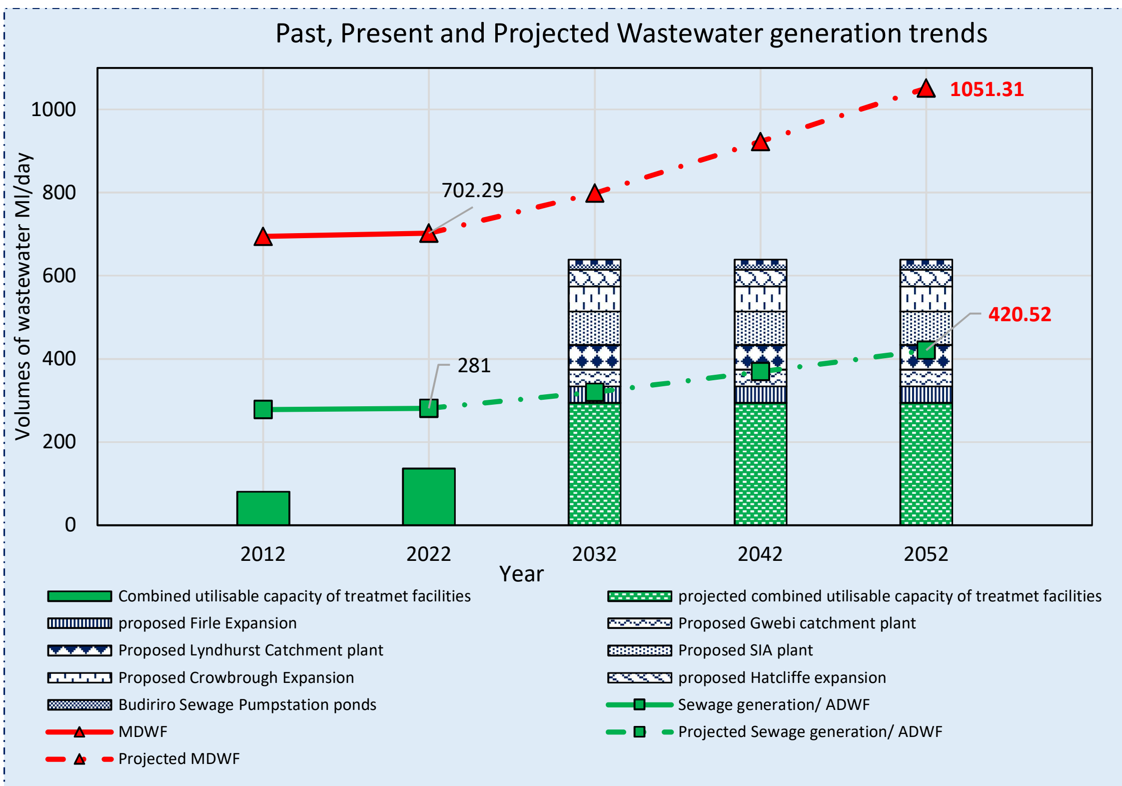


Figure 9*: Greater Harare wastewater flow and generation projections*

Figure 9 is an illustration of the current sanitation status in the greater Harare area. It is unfortunate that for the longest period wastewater treatment has always come short of the wastewater generation and if this is not rectified, as early as 2032 wastewater generation and the subsequent pollution would have doubled causing further deterioration of water quality in the area.

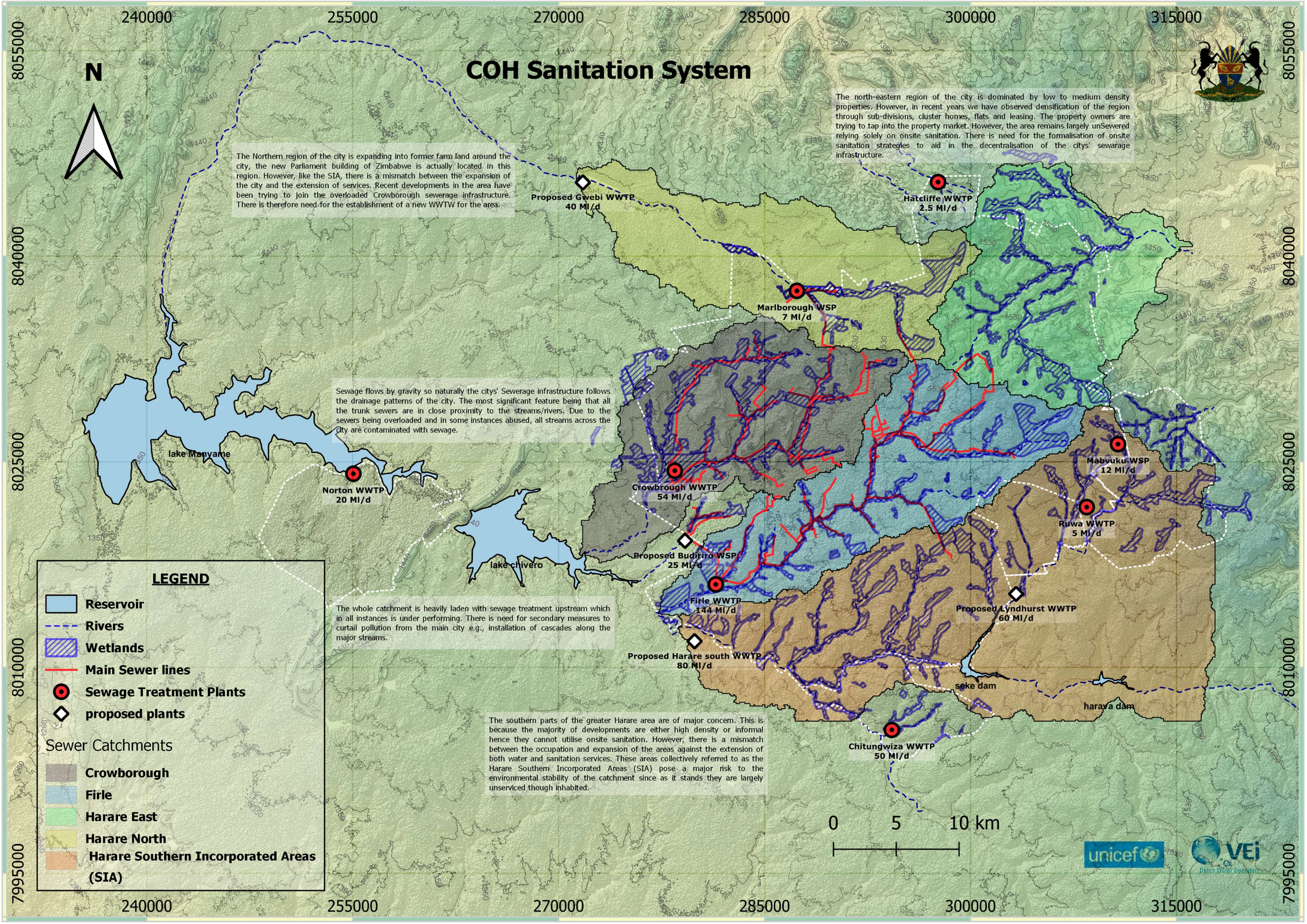


Figure 10: *Greater Harare sanitation situation*

3.5 Climate and Climate change in the Greater Harare area

3.5.1 Climate of Greater Harare

The Greater Harare area has a subtropical highland climate with an average annual temperature of 18°C, which is rather low for the tropics. This may be due to its high altitude (1,490 m) and the prevalence of a cool south-easterly airflow. The area experiences three main seasons: a warm, wet season from November to March/April (rainy season); a cool, dry season from May to August (winter); and a hot, dry season in September/October. In the coldest month of July, the average daily temperature ranges from about 7°C to 20°C, while in the hottest month (October), it ranges from about 13°C to 28°C. The area is characterised by relatively high to moderate rainfall around 826 mm/year while the Mean Annual Runoff (MAR) of the area tends to vary following the seasonal rainfall trend.

The observed trend has been a gradual increase in the average temperature and a decrease in annual precipitation. The frequency, duration and intensity of extreme events i.e., drought and floods has increased to an extent where the distribution of both the average temperature and precipitation have shifted, becoming less spread and concentrated on extreme values. In particular, there is uneven distribution of rainfall over the wet seasons. The chronological distribution of precipitation has shifted into isolated dry periods and intense rainfall events such that when averaged overtime as shown in Figure13, it would appear that there is an increase in precipitation. However, the manner in which the rainfall is being received gives the impression of a perched scenario the intensity and duration of dry periods has increased. These observations have been made for both the greater Harare area and the country of Zimbabwe at large[21].

3.5.2 Target scenarios for climate projections

The Climate projections for the Greater Harare area as presented on the World Bank's Climate change knowledge portal (CCKP) have been adopted for the development of the CRWSP-2050. The portal offers a complete suite of indicators for in-depth analysis into future climate scenarios and potential risks due to Climate change. The projections are derived from the Coupled Model Inter-comparison Project Phase 6 (CMIP6) which is an integrated framework within which a number of individual Model Inter-comparison Projects (MIPs) are organized. Each individual MIP lays out an experimental design aimed at improving the understanding of; (i) important physical processes in the climate system; or (ii) the response of the climate system to external drivers such as increasing greenhouse gases. CMIP6 comprises of 23 individual MIPs and for the scenarios, the models feature new state-of-the-art Shared Socioeconomic Pathways (SSPs). SSPs are meant to provide insight into future climates based on defined emissions, mitigation efforts, and development paths. The SSPs were designed to work in combination with an updated version of the RCPs. Figure 11 shows the relationship between the SSPs and the RCPs and the five SSP scenarios are defined as follows;

- SSP1 Sustainability - Taking the green road (low challenges to mitigation and adaptation)
- SSP2 Middle of the road - (medium challenges to mitigation and adaptation)
- SSP3 Regional rivalry - A rocky road (high challenges to mitigation and adaptation
- SSP4 Inequality - A road divided (low challenges to mitigation, high challenges to adaptation)
- SSP5 Fossil-fuelled development - Taking the highway (high challenges to mitigation, low challenges to adaptation)

21 https://climateknowledgeportal.worldbank.org/country/zimbabwe/climate-data-historical

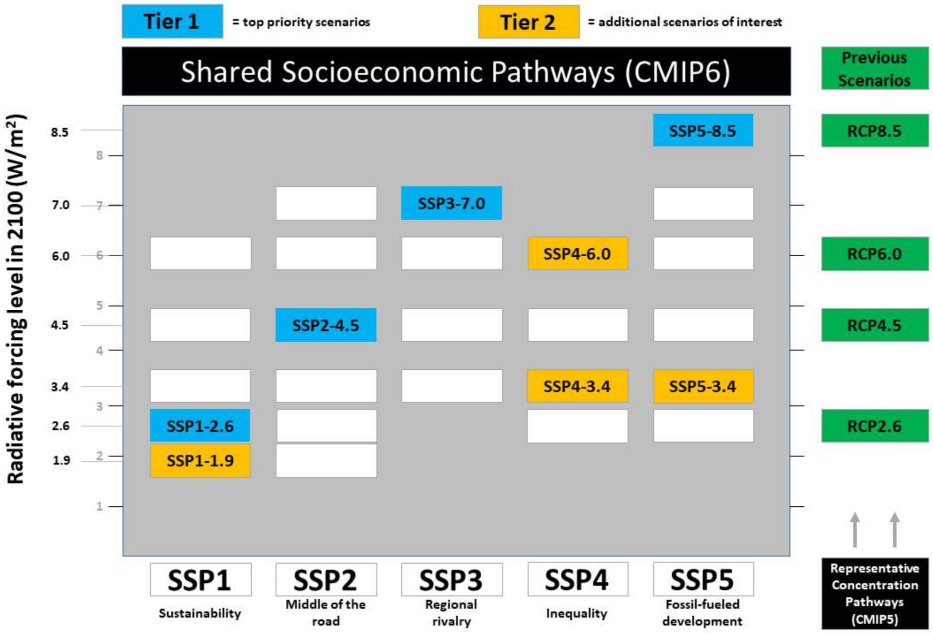


Figure 11: Relationship between the SSPs and RCPs

The climate Indicators were investigated as a multi-model ensemble instead of individual models. This was done because Multi-model ensembles represent the range and distribution of the most plausible projected outcomes of the change in the climate system for a selected SSP, while Individual models can have substantial bias. Having laid out the foundations for the climate projections, the following section will explain the anticipated Climate change effects in the greater Harare area and the country as a whole.

3.5.3 Climate projections for Zimbabwe and the COH

It can be observed that for all of the modelled top priority Scenarios, the projected trends for average temperature in Harare and Zimbabwe as a whole are already departing from the natural variability, with an overall increase in the average temperature for both the COH and the country being anticipated (Figure 14). However, At the low-end i.e., SSP1, the anticipated departure of temperature trends from natural variability and the subsequent rise in temperature will be less significant and in all instances it is anticipated that the rise in temperature will be less than 1 ^{0} C for this trajectory. At the high-end i.e., SSP5, the anticipated departure of temperature trends from natural variability and the subsequent rise in temperature will be much more significant and it is anticipated that there will be a gradual rise in temperature, with an anticipated rise of about 2 ^{0}C by the year 2050 and a peak rise of about 5 ^{0} C is anticipated by the year 2100 for this trajectory.

In terms of rainfall, the projected trend for average precipitation in Harare and Zimbabwe is are gradual departure from the natural variability. However, the amount of precipitation received will vary depending on the modelled scenario/ followed trajectory. At the low-end i.e., SSP1, it is anticipated that the precipitation trends for both the country and the city of Harare will closely follow the observed natural variability however, with an average increase in precipitation over time. At the high-end i.e., SSP5, there will be an overall departure of the rainfall trends from natural variability with an average decrease in the precipitation received over time.

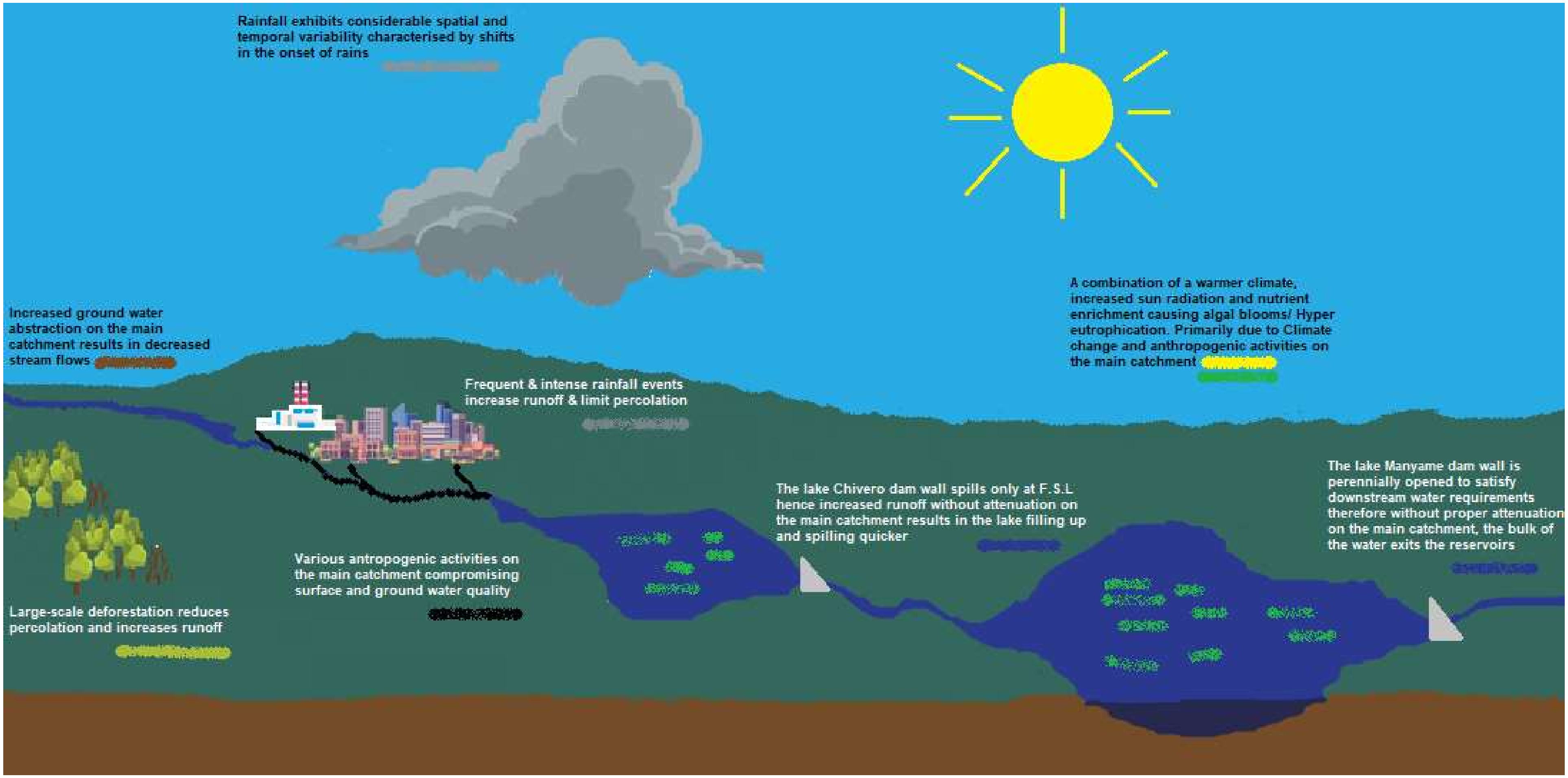


Figure 12: Schematic of the greater Harare water resources system issues.

3.5.1 Observed historic temperature Trends for Zimbabwe and the city of Harare

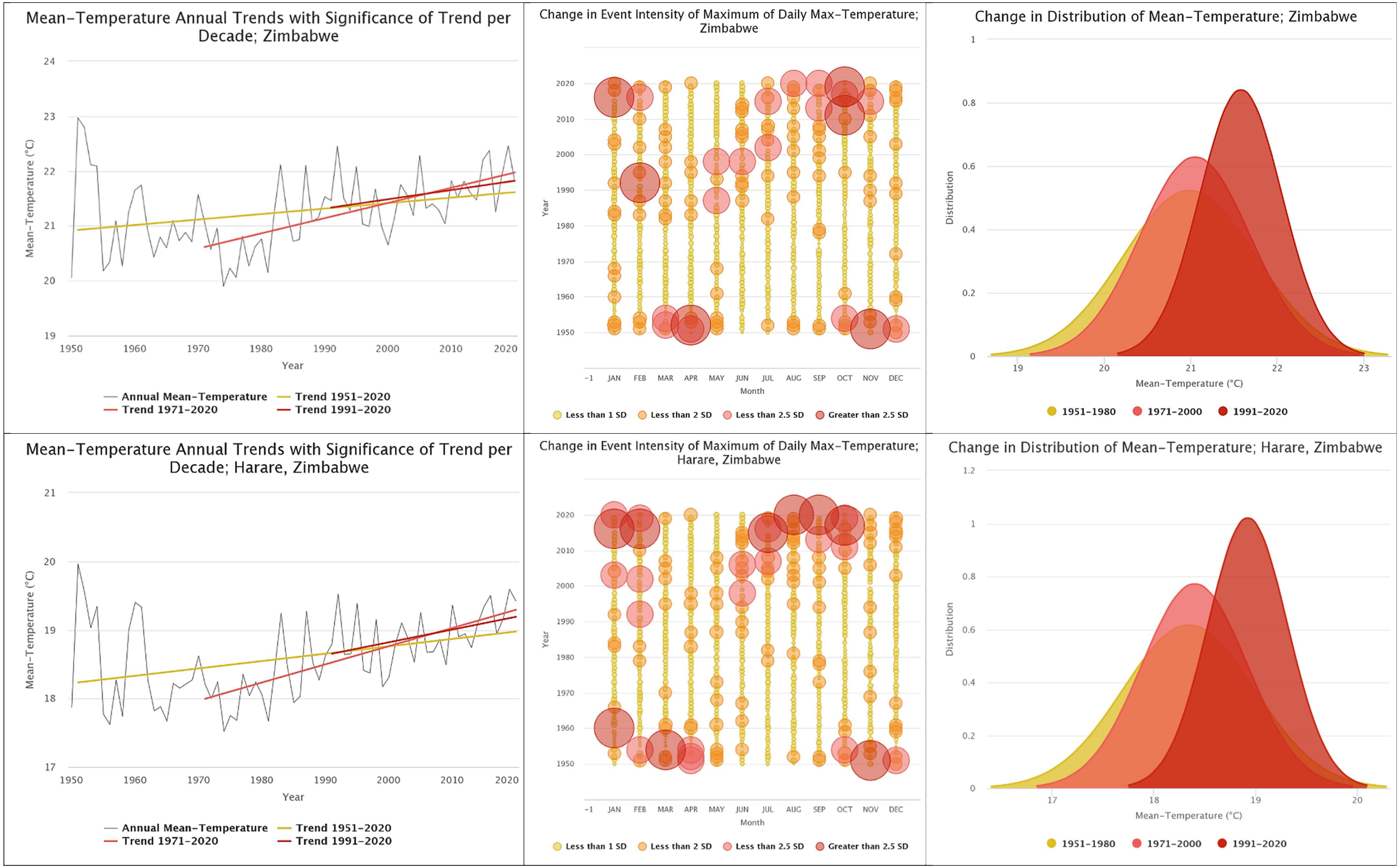


Figure 13: Historic temperature Trends for Zimbabwe and the city of Harare

3.5.2 Observed historic Precipitation Trends for Zimbabwe and the city of Harare

Figure 14: Precipitation Trends for Zimbabwe and the city of Harare

3.5.3 Projected climate variability Trends for Zimbabwe and the city of Harare

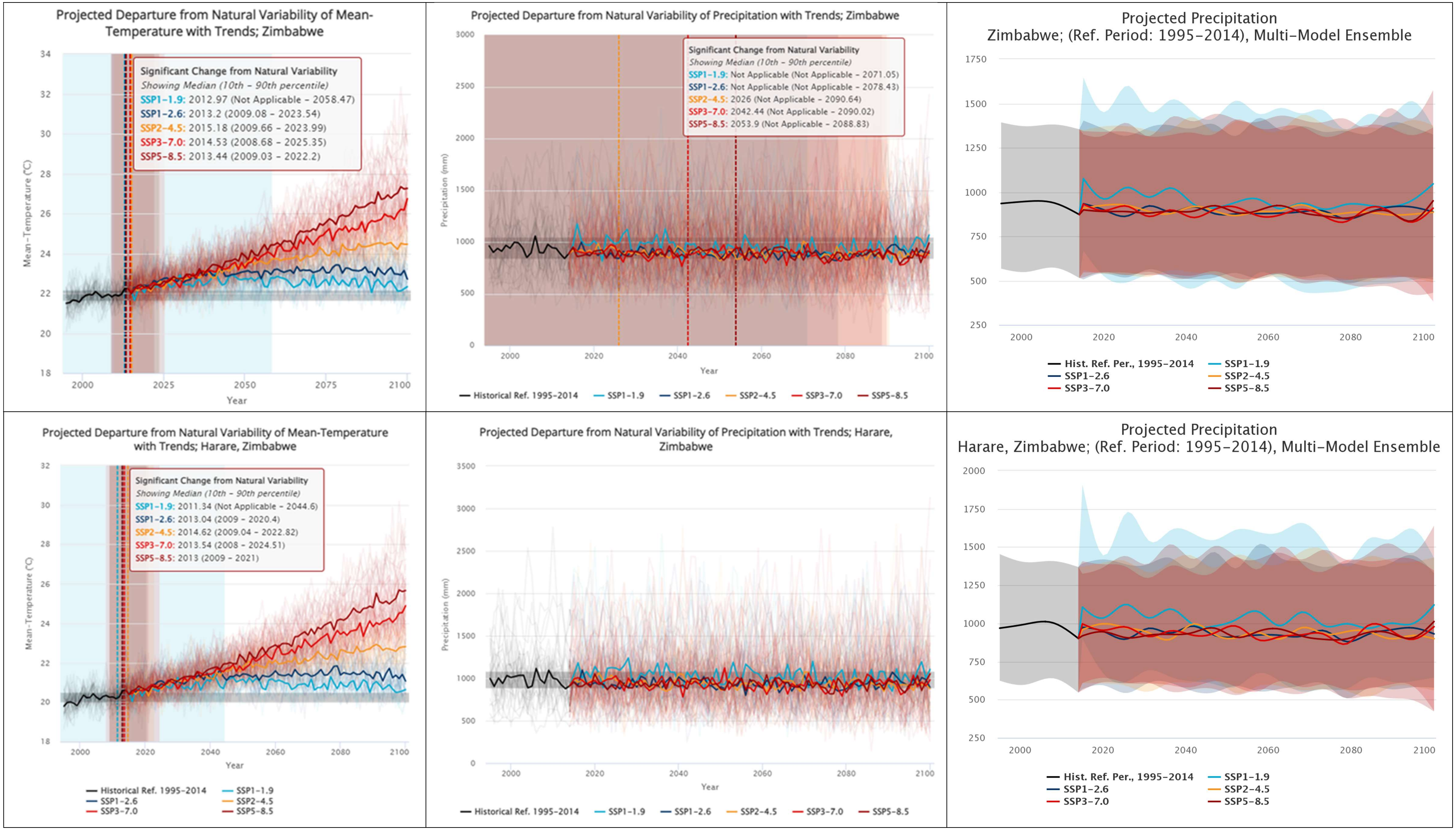


Figure 15: *Projected Climate Trends for Zimbabwe and the city of Harare*

4 HAZARD IDENTIFICATION

4.1 The Anticipated effects of Climate Change in Harare

Based on projections and historical data, Harare is likely to face several climate threats in the coming decades.

a) Increased Droughts:

Historical data: Harare experiences a seasonal drought period, available data suggest these periods are becoming longer and intense. The city is also facing more intense rainfall deficits associated with climate patterns like the positive Indian Ocean Dipole/Zonal Mode (IODZM), worsening dry conditions[22] [23] [24].

Projections: Reduced rainfall and higher temperatures are expected to lead to drier conditions, impacting water quantity through increased evaporation rates and water quality due to a combination of Reduced Dilution, Algal Blooms, changes in water chemistry and increased mobilization of contaminants [25] [26].

b) Flooding:

Historical data: Harare has been experiencing flooding events, particularly in low-lying areas[27].

Projections: Intense rainfall events, even within shorter rainy seasons, could lead to flash floods[28]. This will impact water quality due to a combination of Increased erosion and runoff, Overflow of sewer systems and shortened settling time.

c) Extreme Weather Events and the associated Increased Variability

Historical data: Harare experiences occasional heatwaves and thunderstorms.

Projections: Heatwaves are expected to become frequent and severe. Changes in weather patterns could also lead to more frequent and intense storms with high winds, hail, and lightning. Erratic weather patterns are anticipated, with periods of intense rain followed by long dry spells. This unpredictability will make it difficult for water managers to plan and allocate resources effectively.

d) Combined effects:

The combined impacts of drought and heatwaves are anticipated to exacerbate water scarcity and negatively affect agricultural productivity this will lead to the indirect effect of rural to urban migration resulting in increased demand for resources in urban areas including water.

22 https://climatechange.umaine.edu/2023/07/24/climate-migration-in-zimbabwe/

23 https://www.mdpi.com/2071-1050/12/3/752

24 https://www.waterworld.com/water-utility-management/article/14211783/floodings-impact-on-public-water-supplies

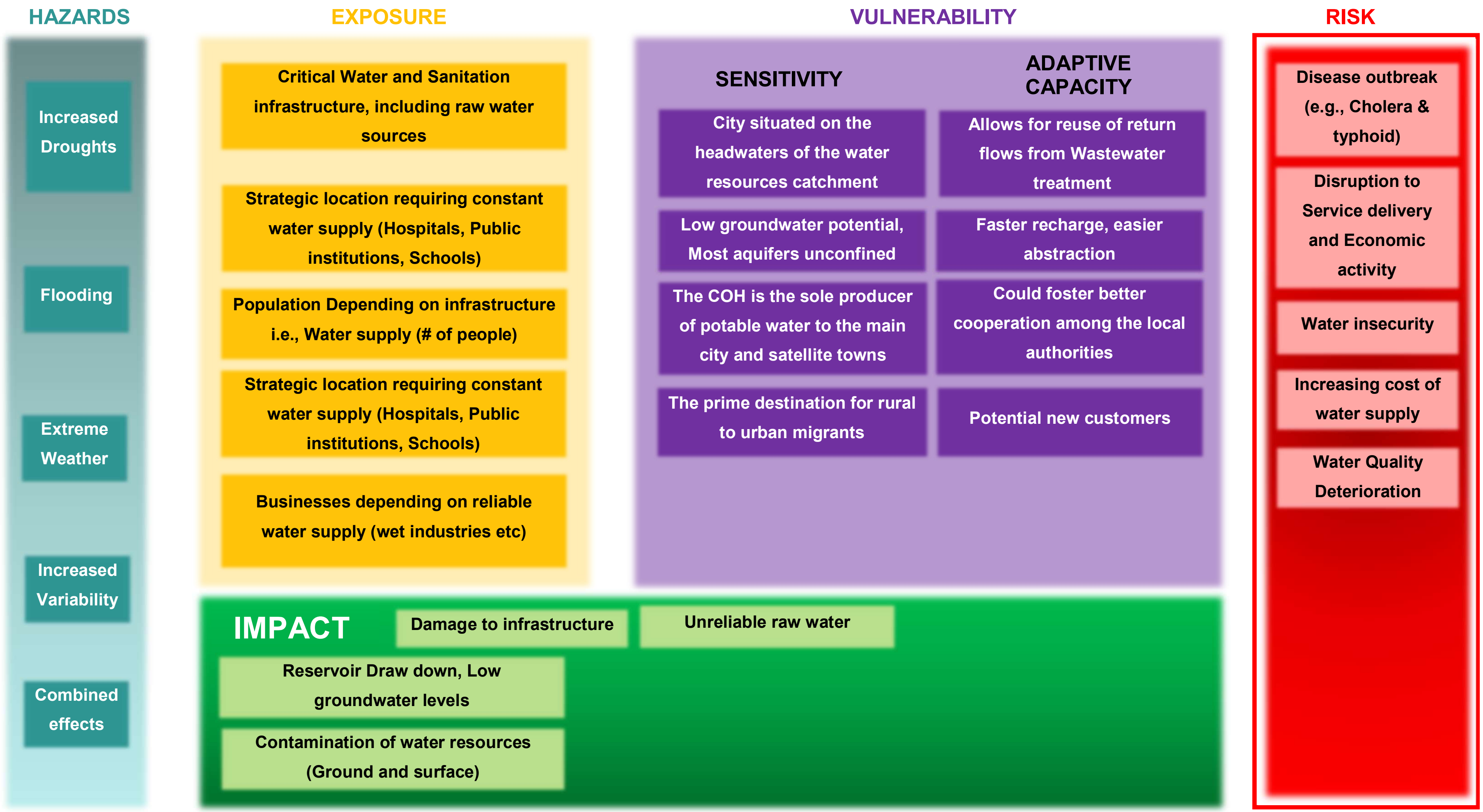
25 https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2469

26 https://climateknowledgeportal.worldbank.org/country/zimbabwe/climate-data-projections

27 https://youtu.be/WuyZAZq0_wc

28 https://repository.lboro.ac.uk/articles/thesis/Hydrodynamic_simulation_of_rainfall-induced_flooding_in_cities_of_low-_and_middle-income_countries_A_case_study_of_Harare/20348037

RISK ASSESSMENT



4.2 Community Vulnerability Assessment

Engage with local communities to understand their specific vulnerabilities and existing coping mechanisms related to water security.

Low density

Medium Density

High density

Peri - Urban

An interesting analogy to the situation with precipitation in the greater Harare area is a situation whereby a person (representative of the city's catchment), receives all their rations for a week a single day (representative of intense precipitation), and is then required to utilise the rations the very same day (representative of runoff). However, the capacity of the person to utilise the rations is finite (representative of the storage capacity of the water supply reservoirs). The only option would be to share the excess with other individuals (representative of other catchments). Consequently, when asked if the person received their rations for the week it will seem as if they received their fair share However, the distribution of the ration does not allow them to fully enjoy. Hence they suffer for most of the time. Such is the situation with precipitation in the greater Harare area and the country as a whole.

5 Challenges, Problems and Opportunities

5.1 Analysis of challenges and problems

The city of Harare is faced with a difficult, complex, but solvable set of challenges in its ambition to insure a climate resilient water supply. The current attitude of the city council on Climate change issues indicates a positive move towards well-established practices and important initiatives that include the development of an overall urban resilience plan that covers all aspects of service delivery. However, there are also multiple areas for improvement and the COH as the capital city of Zimbabwe needs to be more advanced in its transition to climate smart operations, providing an example of good practice that the rest of the nation can draw from. In defining the problems and challenges being faced by the city in terms of its water supply, the key difference between challenges and problems in the context of this plan is that; while challenges are demanding tasks that the water utility are trying to overcome, problems are those aspects of water supply that are difficult to deal with or understand that hinder water supply and security. Therefore, from the analysis presented from sections 3 to 5 above, the key challenges and problems being faced by the City of Harare as related to water supply are as follows;

5.1.1 Challenges

- Water source protection
- Active maintenance
- Revenue collection efficiency
- NRW reduction
- Low Customer confidence
- low operating capital
- Extension of services
- Hyper inflationary economy

5.1.2 Problems

- Climate change
- Rapid population growth
- Water contaminants of emerging concern
- Non-payment culture
- Low Coordination of the water sector
- Low investment in water supply infrastructure

5.1.3 Opportunities

The setup of the City of Harare water resources system, in particular the arrangement of the catchment, provides a unique opportunity for wastewater recycling provided the wastewater treatment facilities are optimised. This is because all water in the city is of endogenous precipitation and flow and it all ends up impounded downstream in the major water supply reservoirs. So in terms of water quantity the system is self-sufficient and sustainable without input from other catchments. Also to consider are the opportunities related to the efforts to mitigate and adapt to Climate change , such as operational efficiencies and cost savings, the adoption of low-emission energy sources, the development of new products and services and access to new sources of funding. Overall, the low-carbon transition process creates opportunities for efficiency, innovation and growth.

As it stands the city's wastewater treatment operations are not optimised key issues to consider being methano-genesis; the generation and release of nitrous oxide; and the nutrient enrichment of the water supply reservoirs. Methane and nitrous oxide are potent greenhouse gases having far more warming potential than carbon dioxide. The nutrient enrichment in the water reservoirs is causing the hyper eutrophication of the water supply reservoirs driving up water treatment and production cost. A holistic approach is therefore required in water supply and sanitation, starting with a conscious realisation that potable water supply and sanitation for the city of Harare are directly linked and one aspect cannot function without the other.

6 IMPLEMENTATION OF THE COH CLIMATE RESILIENCE WATER SUPPLY PLAN

6.1 Key elements of success

(i) **Policy and environmental management leadership;** For the COH this role lies with the Environmental Management Committee (EMC) of the city council of Harare. The EMC are to drive the transformation towards climate smart operations and accelerate the mainstreaming of environmental sustainability management at all levels of the Organization.

(ii) **Targeting high impact Climate resilience actions;** as reflected in the planned targets, which are in areas of operation that have significant potential for improving water quality and quantity as identified in the analysis conducted in the Plan's development.

(iii) **Investment in the form of additional resources;** in order to achieve the planned targets, improved environmental management and unlocking long-term operational efficiencies, the city will require significant investments;

- Intensifying existing efforts and scaling up existing, known solutions will lean heavily on the city's current budget and structures. However, the city requires additional funding to accelerate the implementation of novel, climate smart and high return on investment solutions.

- The application of innovative interventions will require sustained investment on research and development, something which is currently lacking in the organisation.

(iv) Implementing the city's Climate resilience strategy up to 2050 will also necessitate **Dedicated capacity and Specialized expertise, for training and change management** to encourage and drive a culture of sustainability and shift behaviours throughout the Organization. This should be both in the form of long term and temporary dedicated capacity.

(v) **Outreach and communication**; we need to catalyse action and change the organizational culture, through an effective communication strategy. The international focus on the climate crisis and, at National scale and the existing environmental management efforts worldwide have highlighted the importance of communication to drive action, create alliances, and change the everyday behaviours necessary to support sustainability initiatives. Communication and strategic outreach will be necessary to engage the citizenry, development partners, and all the other stakeholders in an on-going dialogue from the inception of the Plan to the achievement of its targets

6.2 Approach

Track 1 – Through **Intensification** the COH is to build on existing system capacity but reinforced and supported by some additional dedicated implementation capacity. The focus would be on behavioural and managerial changes, water demand management, energy efficiency, the use of proven sustainable solutions where possible and water source protection. The core funding for this would be the annual operating budgets of the city with a more systematic emphasis on prioritizing high impact projects. However, the Plan cannot mobilize to the required scale without additional seed funding from either internal or external resource mobilization.

Track 2 – Innovation would be a major new effort focused on the conception of novel and better solutions to tackle the water and sanitation crisis in the city. Key interventions include support for research and development and the formulation of new climate smart operating procedures and adjust to new challenges in water supply and sanitation.

Track 3 – Internal and external outreach. The key to the success of the proposed operational and institutional change lies in the active involvement of the COH staff, policy makers, citizens and the participation from all stakeholders. Implementation of the Plan will require proactive measures to move beyond information sharing into substantive and true joint efforts, both within the COH departments and with the rest of the water sector stakeholders and partners.

6.3 The implementation team

In order to respond to the climate emergency and make rapid response, a dedicated team will be required to focus on the implementation of the Climate Resilience Water Supply Plan. The team will need to be multi-functional with expertise in the following areas:

Policy, Strategic Planning, Monitoring and Evaluation; in order to align climate resilience interventions with the city's policy priorities while developing an actionable work plan and continuously review progress to sustain a results-oriented approach that will maximize impact.

Engineering and information technology; building on existing in-house expertise, to support the entities for the rapid implementation of the Plan, including expertise in Water resources engineering, town planning, water and sanitation, civil and environmental engineering as well as capacity building experience to deliver projects with local partners for the benefit of the city.

6.4 Monitoring and Evaluation Framework

GOAL: WASTEWATER CONVEYANCE AND TREATMENT OPTIMISATION (*Sustainability*)										
Targets/ Outcome/ Output/ Activities	INDICATOR	DEFINITION	Means of verification/ Source of data	Unit	BASELINE What is the current value?	TARGET What is the target value?	DATA SOURCE How will it be measured?	Reporting FREQUENCY How often will it be measured?	RESPONSIBLE Who will measure it?	REPORTING

Target 1: Wastewater Treatment Efficiency	Percentage of treated wastewater meeting discharge standards	- Regulatory reports from Environmental Protection Agency (EPA) - Independent audits	%		(Establish current baseline through data collection)	90%	EPA reports, Audit reports	Quarterly reports	Quarterly	Water Treatment Authority	Public reports, Board meetings
Target 2: Increase Water Availability	Percentage increase in total water available for the city	- Water production and consumption data	%		(Establish current baseline through data collection)	10%	Water Authority records	Quarterly reports	Quarterly	Water Authority	Public reports, Board meetings
Target 3: Kunzvi-Musami Completion	Online status of water supply schemes	- Official commissioning reports - Independent verification of functionality	Operational (Yes/No)		Not operational	Operational	Water Authority reports, Independent verification reports	Annual reports	Annual	Water Authority, Construction Contractor	Public reports, Board meetings
Target 4: NRW Reduction	Percentage of water lost in distribution network (Non-Revenue Water)	- Water production and consumption data - Leak detection and repair reports	%		(Establish current baseline through data collection)	30% or less	Water Authority records	Quarterly reports	Quarterly	Water Authority	Public reports, Board meetings

Target 5: Water-Efficient Technologies	Percentage of public buildings using water-efficient technologies	- Inventory of public buildings with water-efficient technologies	%		0%	50%	Water Authority records, Building inspections	Annual reports	Annual	Water Authority, Public Works Department	Public reports, Board meetings
Target 6: Per Capita Water Consumption Reduction	Percentage reduction in average water consumption per person	- Household water consumption data	%		(Establish current baseline through data collection)	10%	Water Authority records	Annual reports	Annual	Water Authority	Public reports, Board meetings
Target 7: Water Treatment Efficiency	Percentage of treated water meeting drinking water standards	- Regulatory reports from health authorities - Independent water quality testing	%		(Establish current baseline through data collection)	100%	Health Department reports, Water quality test reports	Quarterly reports	Quarterly	Water Treatment Authority	Public reports, Board meetings
Target 8: Service Extension Coverage	Percentage of population with access to water and sanitation services	- Household surveys - Geographical mapping of serviced areas	%		(Establish current baseline through data collection)	90%	Water Authority records, Demographic surveys	Annual reports	Annual	Water Authority	Public reports, Board meetings

INDICATOR	DEFINITION	MEANS OF VERIFICATION	UNIT	BASELINE	TARGET	DATA SOURCE	REPORTING	FREQUENCY	RESPONSIBLE	REPORTING
Improved Water Security	Reduced vulnerability to water shortages	- Water availability data - Frequency of water rationing	Qualitative (Improved/ Not Improved)	High vulnerability	Improved	Water Authority reports, Public surveys	Annual reports	Annual	Water Authority	Public reports, Board meetings
Sustainable Water Management Practices	Increased adoption of water-saving practices	- Water consumption data - Public surveys on water	Qualitative (Increased/ Not Increased)	Low adoption	Increased	Water Authority records,	Annual reports	Annual	Water Authority	Public reports, Board meetings

		conservation awareness				Public surveys				

Upgraded Wastewater Treatment Plants	Number of upgraded wastewater treatment plants	- Construction completion reports	Number	(Identify existing number of plants)	As per Target 1	Construction reports	Quarterly reports	Quarterly	Water Treatment Authority	Public reports, Board meetings
Developed Water Resources	Volume of water from new sources	- Data on operational water sources and capacities	Cubic meters (m3)	Existing sources only	As per Target 2	Water Authority records	Quarterly reports	Quarterly	Water Authority	Public reports, Board meetings
Implemented Water-Efficient Technologies	Number of public buildings with water-efficient technologies	- Inventory of public buildings with water-efficient technologies	Number	0	As per Target 5	Water Authority records, Building inspections	Annual reports	Annual	Water Authority, Public Works Department	Public reports, Board meetings
Public Awareness Campaigns	Number of public awareness campaigns conducted	- Campaign reports								

(M&E Framework Still under development !!)

7 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

(i) A Comprehensive analysis of the city of Harare's water resources system was carried out that included baseline studies for gathering data in terms of water quality, water quantity, population and climate dynamics.

(ii) Specific Climate change and population growth impacts on the current and future water supply were then identified as guided by the baseline studies. This was achieved by making reasonable assumptions in terms of the future of the city in terms of both the population growth and Climate change.

(iii) Key Strategic directions were then formulated from which specific targets were devised. From the set Targets, Adaptation measures were proposed for the short, medium, and long term each with detailed interventions together with some preliminary costs with the overall aim of making the city's water supply more resilient to the effects of Climate change.

(iv) A roadmap for the implementation of the plan including a robust monitoring and evaluation framework for the proposed adaption measures was then put in place.

7.2 Conclusions

The following conclusions were drawn in formulation of the plan;

(i) Bathymetric studies in the main water supply reservoirs showed that the design capacity of the lakes is still within the 10% threshold in terms of loss of storage.

(ii) From the available data and the projection methodology used, it is anticipated that the population of the Greater Harare area will peak at approximately 4 million residents by the year 2050. Based on the population projections, it is anticipated that the average water demand in 2050 will be around 686 ML/day while the peak water demand will be around 1028 ML/day.

(iii) All indications are that uncontrolled anthropogenic activities on the main catchment are the major cause of the deplorable water quality in the water supply reservoirs and constitute a threat to the water security in the future. Wastewater treatment in particular is the major cause of water pollution in the city and proper treatment provides a unique opportunity for making the city's water operations more sustainable.

(iv) All the infrastructure for both water and sanitation is in a dilapidated state requiring massive investment for the city is to provide safe water and sanitation for its citizens. Climate resilience would entail first reaching acceptable, proper service levels and only after that will the city of Harare be able to build the extra capacity to adapt to Climate change. But this will entail huge financial investment which the city is struggling to raise by itself or attract from external sources. According to the world bank, Water providers that collect less than 70% of their allotted tariffs, or have non-revenue water rates greater than 40%, are simply not financially viable or creditworthy. They rarely attract sorely needed public and such is the case with the city of Harare.

(v) Cost analysis: While efficient, some targets like upgrading wastewater treatment plants (Target 1) and water-efficient technologies (Target 5) might require significant investment. Exploring funding options and cost-benefit analysis would be beneficial.

(vi) Sustainability of new resources (Target 2): While exploring alternative sources like rainwater harvesting is positive, ensuring their long-term sustainability, especially considering potential climate change impacts, is important.

(vii) Enforcement mechanisms: The plan doesn't mention how water use reduction (Target 6) or Non-Revenue Water (NRW) reduction (Target 4) will be enforced. Implementing regulations or incentive programs could be explored.

(viii) Equity considerations: Extending services (Target 8) is crucial, but ensuring affordability and equitable access for low-income communities needs to be addressed.