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Management of Water Resources in South Africa: A Systematic Review

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Abstract

Water is a vital resource for human survival, economic development, and environmental sustainability. It is essential to agriculture, energy production, public health, and biodiversity preservation. Efficient water management is even more important in areas that are prone to scarcity. This paper presents a systematic review of the management of water resources in South Africa, a country characterized by significant water scarcity challenges compounded by its socio-economic and ecological needs. South Africa's limited freshwater resources are under extreme stress due to its semi-arid climate, unequal rainfall distribution, expanding population, and industrial needs. The nation's water security has also been made more difficult by historical injustices, climatic fluctuations, and decaying infrastructure. Through a systematic review of 60 scholarly articles published between 2011 and 2025 in the Web of Science database, this study discusses the historical context of water management in South Africa, including the legacy of apartheid-era policies and their impact on access to water. It also examines current management practices, governance structures involving national and local authorities, the role of key institutions such as the Department of Water and Sanitation (DWS), climate change impact on water availability, population growth and urbanization, inequality and access, and challenges in South Africa's water resources management (WRM). In particular, this review highlights the integration of scientific water quality and biostability assessment into the Integrated Water Resources Management (IWRM) framework in order to produce actionable insights that enhance resilience, sustainability, and equity in WRM. Furthermore, it explores future strategies for sustainable WRM, emphasizing the importance of IWRM, community participation, technological innovation, and climate change adaptation. Through this comprehensive analysis, the paper aims to contribute to a deeper understanding of the complexities and opportunities in ensuring water security for all South Africans.

Keywords: water resources management; water quality and biostability; environmental sustainability; population; stakeholder; economy; South Africa

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1. Introduction

Water resources are critical for South Africa's economic, social, and environmental sustainability, serving as a foundation for agriculture, industry, energy production, and daily human needs [1–5]. As a water-scarce country with highly variable rainfall and frequent droughts, South Africa faces significant challenges in meeting the growing demands of its population and economy [1–3]. Reliable water supplies are essential in agriculture, one of the biggest water consumers, in order to maintain rural livelihoods and food security.

Similar to this, sectors like manufacturing, mining, and the energy sector, particularly hydropower, all depend on a steady supply of water to function [1,2]. A review of the social and local dynamics in South Africa's water-energy-food nexus by Khofi et al. (2025) [1] examines the interconnectedness of water, energy, and food resources in South Africa. Their findings highlight the need for a holistic and context-sensitive approach to address the challenges within this nexus, particularly in marginalized communities. Another study by Nkosi et al. (2021) [2] on the impact of land management on South African's water resources expresses that despite the country's best efforts in ensuring the protection and sustainable use of water resources, the water quality has been compromised in most parts of the country, thus affecting water availability. Therefore, the increase in water demand with development presents the need for better integrated strategic approaches and a change in behaviour towards water resources and land management.

Urban areas are experiencing increasing pressure due to population growth and urbanization, further straining already limited resources [6]. Efficient management and equitable distribution of water are therefore essential not only to support economic growth but also to reduce poverty, promote social equity, and enhance resilience to climate change [6,7]. Long-term sustainability will depend on integrated water resource management, investment in infrastructure, innovation in water-saving technologies, and inclusive governance that involves all stakeholders [7]. A study by Yu et al. (2024) [7] explored the ecological, social, and economic effects of urbanization on the urban critical zone. Their findings indicate that urbanization exerts considerable pressure on the urban critical zone by affecting its interfaces, leading to profound changes in ecosystem structure, processes, and functions [7]. The study also highlights the need for an integrated approach through sustainable urban planning and investment in green infrastructure to ensure the health and resilience of both natural environments and human societies for the healthy urban critical zone [7]. Knowing that the urban critical zone refers to the near-surface environment in urban areas where complex interactions occur between the atmosphere, land surface, water, living organisms, and human infrastructure, shaping the sustainability and function of cities [7].

The history of water management in South Africa is deeply intertwined with the country's political, social, and economic development, shaped significantly by the legacy of apartheid and its policies of racial segregation and inequality [8–10]. The Apartheid (1948 to 1994) in South Africa was the racial segregation under the all-white government of South Africa, which dictated that non-white South Africans (a majority of the population) were required to live in separate areas from whites and use separate public facilities. It also involved the separation of people based on racial classification and the unequal distribution of rights and resources [11]. Under colonial and apartheid rule, water rights were largely controlled by the state and white landowners, with black communities systematically excluded from access to adequate water infrastructure and services [11]. Water was managed primarily for the benefit of commercial agriculture, mining, and urban white populations, while rural and peri-urban black communities often relied on inadequate or informal water sources [9–11]. For instance, a study by Adeyeye et al. (2020) [9] explores the challenges of water access in the rural and peri-urban communities in South Africa. Their results express that the sustainability development goals and activities need to redefine water access targets and associated metrics against the urban-urban bias, a tendency to prioritize urban areas over rural ones in policy-making and progress evaluation, by ensuring that the minimum benchmark should be universal access to safe water in rural areas [9]. Similarly, a study by Mthiyane et al. (2022) [10] explores the negative consequences of rural-urban migration within the KwaDukuza municipality. Their findings highlight how the influx of people from rural areas to KwaDukuza strains resources, leads to environmental degradation, and aggravates existing service delivery challenges. Another study

by Kaziboni (2024) examines how colonial and apartheid policies in South Africa created "invented water scarcity," where access to water was deliberately restricted for black communities [11]. The results highlight how these policies, based on racial discrimination, aggravated existing socio-economic inequalities and established power imbalances related to water management [11].

Moreover, after the democratic transition in 1994, the new government sought to reform water governance by enshrining the right to water in the Constitution and introducing progressive legislation such as the National Water Act of 1998 [12–14]. By establishing water as a national resource to be managed in the public interest, this Act signalled a paradigm shift and promoted efficiency, sustainability, and equity [12]. However, a study by Jegede and Shikwambane (2021) [12] on "water Apartheid" and the significance of human rights highlights the ongoing inequality in access to water resources, particularly for marginalized communities. Their findings contradict the human rights principles of equality and non-discrimination, as enshrined in the South African constitution and international law. Affirmative action is proposed as a necessary measure to address these inequalities and ensure that all citizens have access to basic water services [12]. By placing a higher priority on environmental preservation and fundamental human requirements, the new government sought to right historical wrongs and underlined the necessity of integrating water resource management. However, in spite of these changes, the legacy of inequality endures, and issues like deteriorating infrastructure, corruption, climate change, and rising demand continue to put pressure on South Africa's water governance [14,15]. Tewari (2009) [14] analysed the evolution of water rights in South Africa over three and a half centuries, starting from 1652. His study highlighted the transition from a system largely based on riparian rights to one that emphasizes public ownership and management of water resources [14]. Similarly, a study by Bablin (2021) [15] on South Africa's water history reveals a legacy of inequality rooted in its colonial and apartheid past, with significant shifts occurring after the end of apartheid. It further expressed that the country has made progress in extending water services to previously disadvantaged communities, but persistent inequalities and challenges remain [15]. These challenges are aggravated by factors like climate change, population growth, and inadequate infrastructure [15].

2. Methods

A systematic literature review was carried out to find, combine, and assess information to answer the study topic on the current status of Water Resources Management (WRM) in South Africa, and the key challenges faced. This section outlines the procedures used to find and assess literature about sustainable water management in South Africa.

2.1. Data Collection

The data collection and analysis strategy used in the review was based on Nightingale (2009) because it provides a structured and rigorous approach to synthesizing research, minimizing bias, and offering a comprehensive overview of a specific topic [16]. Considering its prestigious and multidisciplinary nature, it is regarded as part of the scientific database Web of Science (WoS) (Salisbury, L., 2009) [17]. The following keywords were used in the WoS literature search: "water resources management", "water quality and biostability", "environmental sustainability", and "South Africa".

2.2. Data Extraction

After taking into consideration the inclusion criteria, there were 60 articles in total. A Master document contained the information gleaned from the chosen articles, including titles, authors, year, and major themes. After reading the filtered material in its entirety,

notes were taken and arranged in a master document. The notes were arranged according to pertinent subjects such as participation of stakeholders in water management in South Africa, current water management in South Africa, and the challenges of managing water resources in South Africa, including climate change, inequality and access, water quality and biostability, water usage and allocation, growth and urbanization, economic factors, technological innovations, and more are a few examples. Studies were included based on the following criteria:

- Only studies published in the English language were included
- Only studies relevant to South Africa were selected
- Only studies that address aspects of WRM in were selected

Given the critical and multifaceted nature of water scarcity in South Africa, it was therefore essential to focus on high-quality, relevant literature that directly informs WRM within this context. In this systematic review, studies were excluded based on the following criteria:

- Geographical irrelevance: research not focused on South Africa or lacking significant relevance to the South African context was excluded to ensure the review remains regionally grounded.
- Non-management focus: studies that did not address aspects of water resource management were omitted.
- Inadequate methodological rigor: articles lacking a clear methodology, including anecdotal reports, editorials, or opinion pieces, were excluded to maintain the scientific integrity of the review.
- Language: only studies published in English were included, due to limitations in translation capacity and to ensure accurate interpretation of findings.
- Redundancy: duplicates or studies presenting identical data without additional insights were excluded to avoid redundancy.

3. Dimensions of Analysis

3.1. Stakeholders' Participation and South Africa's Current Water Management

South Africa is facing significant challenges when it comes to water management [1]. Current management practices and governance structures in water management in South Africa involve a complex interplay between national and local authorities, aiming to ensure the equitable and sustainable distribution of water resources [1,18,19]. At the national level, the DWS sets the overarching policies, regulatory frameworks, and strategic planning initiatives [18–20]. These include Integration Water Resources Management (IWRM) approaches, catchment management strategies, and compliance monitoring. Local authorities, such as municipalities and water service providers, are responsible for implementing these policies on the ground, including the delivery of water and sanitation services, maintenance of infrastructure, and local-level planning. The Catchment Management Agencies (CMAs) also play a vital role in bridging the gap between national oversight and local action by managing water resources within specific hydrological boundaries [7–20]. A study by the Water Research Commission (WRC) (2016) [20] aimed to benchmark South Africa's WRM against other countries, specifically assessing how effectively South Africa manages its water resources and identifying potential areas for improvement. The goal was to gain insights and inform future strategies for water management in South Africa by learning from the approaches of other nations [20]. Despite this structured approach, challenges such as poor coordination, inadequate funding, aging infrastructure, and capacity constraints often hinder the effective implementation of water governance, calling for stronger collaboration, accountability mechanisms, and investment in technical capacity across all levels of govern-

ment [1,18,19]. Therefore, the National Water Resources Strategy 3 (NWRS-3) (2022) [18] sets out the strategy to ensure that water resources are protected, used, developed, managed, and controlled sustainably and equitably. Similarly, the NWRS-3 (2023) [19] outlines the importance of water conservation and water demand management (WC/WDM) in ensuring South Africa's water security. Figure 1 presents the map showing South African water management areas (WMAs) [19].

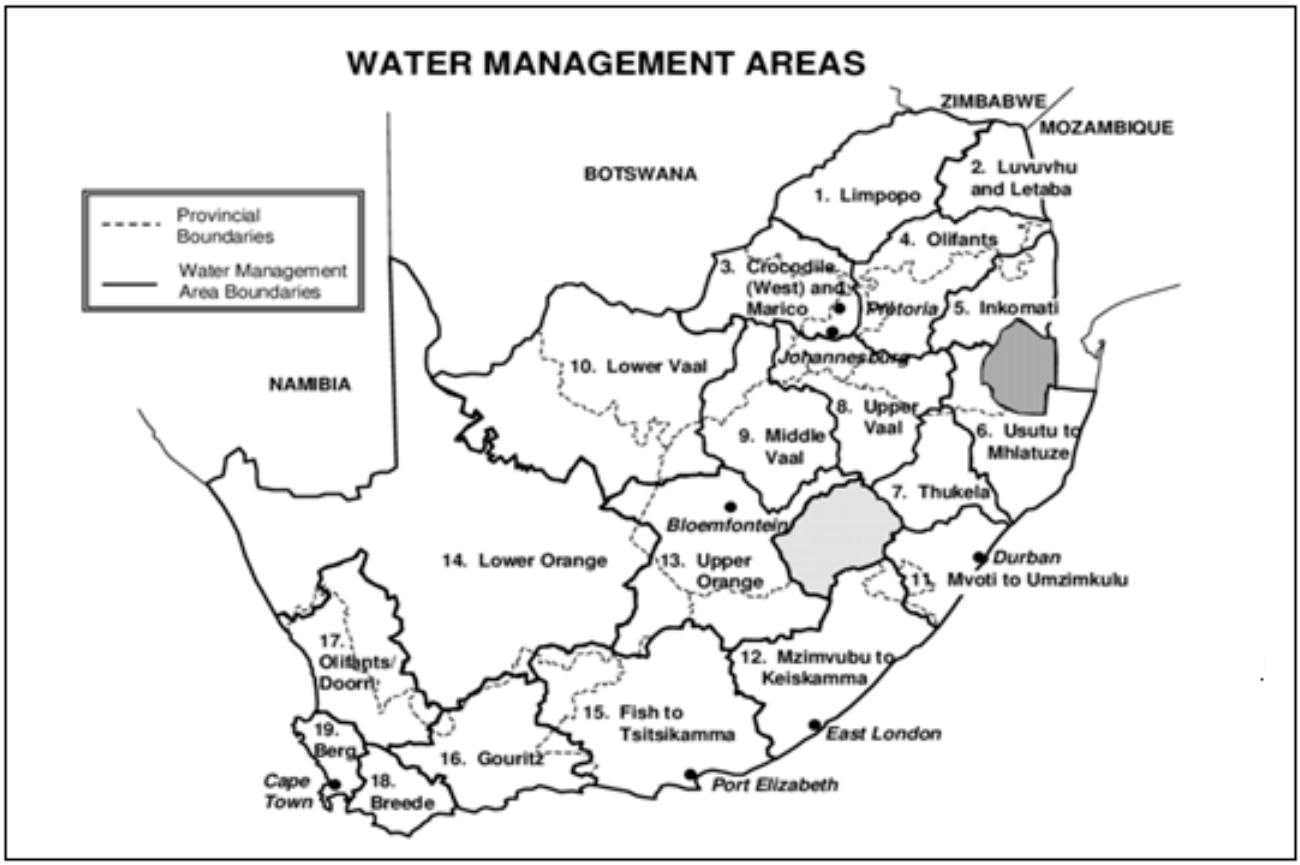


Figure 1. Map showing South African water management areas (WMAs) (Reproduced from Department of Water and Sanitation, 2023, [19]).

3.2. South Africa's Water Resource Scarcity and Unequal Distribution

South Africa is facing significant challenges when it comes to water resources, with both scarcity and unequal distribution being critical issues [1–21]. The nation is regarded as one of the driest in the world, and factors like population increase, industrial demand, and climate change are putting more and more strain on its water supplies. Igamba (2022) [22] highlighted the ongoing water crisis in South Africa, emphasizing the severity of the situation and describing it as a looming threat. His findings showed that, although there is adequate rainfall in some parts of South Africa, especially along the eastern and southern coasts, there are persistent water shortages in the western and interior regions [22,23]. This unequal distribution means that large portions of the population, especially in arid areas, struggle to access reliable and clean water [23,24]. A major industry in South Africa, agriculture is also severely damaged; farmers must contend with less water available for irrigation, which has an influence on food production and financial stability. In addition, the issues are made worse by outdated infrastructure, water pollution, and ineffective management, underscoring the urgent need for more equitable and sustainable solutions to guarantee water security nationwide [23,24]. Whereas, Adom et al. (2023) [24] assessed the social and economic implications on water security in the Nation Mandela Bay Metropolitan

Municipality, Eastern Cape of South Africa. Their findings established that water shortage is portrayed as a standalone issue without linking it to social and economic challenges. Their study, therefore, recommends a multidimensional approach to tackling the problem of accessibility, taking into consideration the social and economic needs of the population.

3.3. Water Usage and Allocation in South Africa

Despite the existence of a comprehensive framework intended to manage water allocation and usage in South Africa, significant challenges persist in effectively balancing the competing demands of agriculture, industry, forestry, environment, and domestic consumption, while ensuring the sustainability of the country's water supply [20–25]. The National Water Act of 1998 plays a pivotal role in this process by setting out regulations for equitable and efficient water distribution [20]. Water in South Africa is considered a public resource, and its allocation is managed by the Department of Water and Sanitation (DWS), which oversees the distribution to ensure that all sectors have access to the necessary amounts [18,19,21]. Since Agriculture uses the most water, it is strictly regulated to encourage more effective irrigation techniques and cut down on water waste. Urban consumption and industrial use are likewise strictly regulated, with policies in place to discourage excessive water extraction from bodies of water and to promote water reuse in specific industries [19–21]. However, challenges persist, such as the over-extraction of groundwater in some areas, which can lead to long-term sustainability issues, and the impact of pollution, which can limit the availability of clean water [25,26]. Schreiner (2013) [27] investigated the challenges in implementing South Africa's National Water Act. The findings highlight the gap between the Act's ambitious goals and the reality of its implementation, particularly regarding water use licensing and institutional capacity. His study expressed that the allocation process must also consider the needs of marginalized communities, particularly in rural areas, where access to water can be limited or inconsistent [27]. Effective WRM in South Africa consequently requires balancing these competing demands while promoting conservation, addressing inequities, and adapting to climate variability [25–27]. Another study by Jack et al. (2023) [26] aimed to bridge knowledge gaps in the three pillars of sustainability. The results showed that the Water-Energy-Food nexus's influence on water management, water pricing efficiency, and user willingness to pay. Figure 2 provides an illustration of water allocation and usage in South Africa.

Water use among racial groups in South Africa is deeply influenced by the country's historical context of apartheid, which created considerable disparities in access to resources, including water [28,29]. During apartheid, white communities were prioritized in the development of water infrastructure, resulting in reliable and abundant water access for urban white populations, while black communities, particularly in rural areas and informal settlements, were systematically marginalized and left with inadequate or no water services [28]. Although post-apartheid policies have aimed to redress these inequalities, significant disparities persist. Wealthier, predominantly white households often have access to private water sources, water-efficient appliances, and consistent municipal supply, enabling higher per capita water use [28,29]. In contrast, many black South Africans still face limited access, relying on communal taps, boreholes, or water tankers, especially in underdeveloped areas [29,30]. This disproportion not only reflects broader socioeconomic divides but also contributes to unequal water consumption patterns across racial groups [28]. In order to attain water equity, these structural inequities must be addressed by focused infrastructure investment, community involvement, and legislative changes that give historically underserved communities top priority [28–30]. Francis (2025) [29] analyses water as a social justice in South Africa, where inequalities in access to freshwater persist despite political and legal transformations. His findings highlight the ongoing

challenges in achieving equitable water access despite progressive legislation, particularly in the context of South Africa's history of water apartheid. Another study by Molobela and Sinha (2011) [30] on the management of water resources in South Africa demonstrated that in South Africa, almost everyone is affected by the mismanagement of water resources, hence those living in poor areas are the most affected as they do not have access to potable water and proper sanitation.

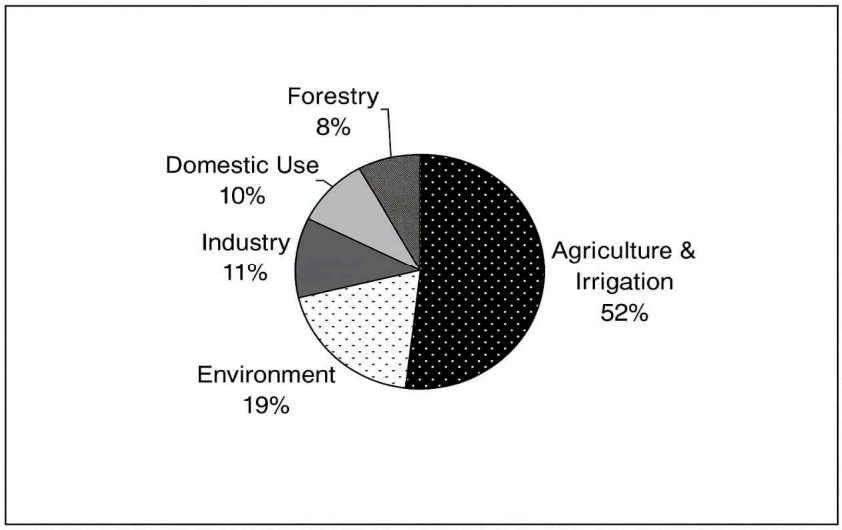


Figure 2. Water allocation and usage in South Africa (Reproduced from Itumeleng, P.M. and Pramod, S., 2011, [30]).

3.4. Climate Change Effects on Water Availability

South Africa faces water stress due to its semi-arid climate and uneven rainfall distribution, and faces growing pressure on water availability and management as a result of climate change. [31,32]. More frequent and severe droughts are being caused by rising temperatures and changing rainfall patterns, especially in the interior and western regions. This is lowering the amount of surface water available in reservoirs, dams, and rivers. At the same time, floods, another extreme weather event, are occurring more frequently, polluting water sources and causing damage to water infrastructure [31]. Groundwater recharge is also declining due to both climate variability and over-extraction, especially in rural areas that rely heavily on boreholes. These changes are placing increasing pressure on South Africa's aged and often poorly maintained water infrastructure, while exacerbating existing inequalities in water access between urban and rural communities [31]. Water quality is further threatened by pollution, reduced river flow, and inadequate wastewater treatment during heavy rainfall events [32]. The growing competition for limited water resources between households, agriculture, industry, and the environment highlights the urgent need for integrated and climate-resilient water management strategies [32]. This includes improved governance, investment in alternative water sources such as desalination and water reuse, promotion of water-efficient technologies, and restoration of natural ecosystems to support long-term sustainability of water supply in the face of a changing climate [31,32]. Adom et al. (2022) [31] examine the threats climate change poses to water and food security in South Africa. Their study highlights the interconnectedness of water and food systems, particularly through the Food Energy Water (FEW) Nexus, and emphasises the need for adaptation strategies in response to climate variability and change. Another study by Edokpayi et al. (2020) [32] on the influence of global climate change on water resources in South Africa indicates that both increases and reductions in water resource availability are associated with climate change (floods and drought) in different parts of

South Africa. Figure 3 shows the April-May-June 2025 global prediction for total rainfall probabilities in South Africa.

3.5. Urbanization and Population Growth

Urbanization and population growth in South Africa have placed significant pressure on the country's already limited water resources, complicating effective water management [10,33–35]. The need for clean water for residential, commercial, and agricultural use rises sharply as the urban population grows, especially in places like Johannesburg, Cape Town, and Durban [33–35]. This expansion frequently outpaces the development and maintenance of water infrastructure, leading to frequent service interruptions, water losses from leaks, and overwhelmed wastewater treatment systems [10]. Informal settlements, which frequently lack proper sanitation, contribute to the pollution of rivers and groundwater, further degrading water quality [34]. A study by Chitong (2020) [34] explores how urbanization and associated factors create different levels of water scarcity in African cities. Their findings highlight that while physical water scarcity exists, human and social factors play a significant role in aggravating water challenges. Furthermore, the Urban expansion also reduces natural recharge areas due to increased paved surfaces, heightening the risk of flooding and decreasing groundwater replenishment [35]. Combined with the impacts of climate change, such as prolonged droughts and unpredictable rainfall, these challenges make water resources more vulnerable and harder to manage sustainably. As a result, WRM in South Africa must navigate the complex interactions of growing demand, deteriorating infrastructure, environmental degradation, and governance limitations to ensure equitable and long-term access to water for all citizens [36,37].

3.6. Economic Aspects

Economic factors play a major role in the challenges facing WRM in South Africa, influencing both the availability and sustainability of water services [38,39]. One of the primary issues is insufficient funding for water infrastructure development and maintenance [3–26]. Many municipalities, particularly in under-resourced areas, struggle with limited budgets and poor financial management, leading to deteriorating infrastructure, high water losses, and service delivery backlogs [38]. A significant obstacle that is frequently postponed because of conflicting national goals and a lack of public funding is the expensive cost of modernizing deteriorating water systems, such as pipelines, dams, and wastewater treatment facilities [39]. Additionally, non-payment of water tariffs by households and institutions undermines the financial viability of water utilities, creating a cycle of underfunding and service deterioration [38,39]. In rural and poor urban areas, affordability remains a key issue, with many communities unable to pay for water, even when it is available [38]. Tshona et al. (2024) [38] investigated the inadequate water provision in rural communities. Their findings reveal that ageing infrastructure, ineffective governance structures, limited financial resources, and uneven distribution of water resources exacerbate the problem. The water sector also suffers from limited private sector involvement due to perceived risks and low returns on investment [39]. Economic inequality further intensifies these challenges, as wealthier areas can subsidize water infrastructure improvements, while poorer communities remain marginalized [3,26,38,39]. A study by Dinar (2024) [39] on the role of economic and modelling approaches in water resource management reveals that given the increased complexity of the water and environmental interactions, models applied to address water resource management challenges have to take into consideration the physical environment (soil, plant, and human interaction). Overall, financial limitations significantly restrict South Africa's capacity to make investments in cutting-edge, effective, and just water resource management systems.

3.7. Water Quality and Biostability

Water quality and biostability play a crucial role in the effective management of water resources in South Africa, a country facing significant water scarcity and pollution challenges [2–40]. Poor water quality, often resulting from industrial discharge, agricultural runoff, and inadequate wastewater treatment, compromises the safety and usability of water for domestic, agricultural, and industrial purposes [40]. Bwapwa (2018) [40] reviews the main issues causing water quality deterioration and water scarcity in South Africa. His study highlights that raw water quality deterioration and scarcity are primarily caused by human activities and physical factors. Biostability, which refers to the ability of water to maintain low microbial regrowth during distribution, is vital to ensure that treated water remains safe until it reaches end users [41]. Prest et al. (2016) [41] reviewed the existing knowledge on biological stability controlling factors and how these factors are affected by drinking water production and distribution. Their study indicated that the production and distribution of biologically stable drinking water should be a non-negotiable goal for water utilities with the perspective of providing the same water quality to consumers as produced at the treatment facility. Their study also indicated that this can only be achieved by adequate monitoring and control of microbial processes during water treatment and distribution [41]. In South Africa, managing these factors is particularly important due to the reliance on limited and often stressed freshwater sources, such as rivers and dams [2–40]. Water Services Authorities (WSAs) in South Africa are mandated to conduct daily, weekly, fortnightly, and monthly testing of various kinds to test the quality of water supplies to citizens [2–40]. The Water Service Acts (Act No. 108 of 1197) require the creation and maintenance of a national information system and the keeping of an eye on the operations of all water service organizations [40]. The department has adopted the Integrated Regulatory Information System (IRIS) to monitor drinking water quality [40]. High-quality, biostable water reduces the need for additional chemical treatments, lowers health risks, and minimizes infrastructure degradation, such as biofilm formation in pipelines [40,41]. Therefore, incorporating rigorous water quality monitoring and strategies to enhance biostability is essential for sustainable water resource management, supporting both environmental health and socio-economic development in the region.

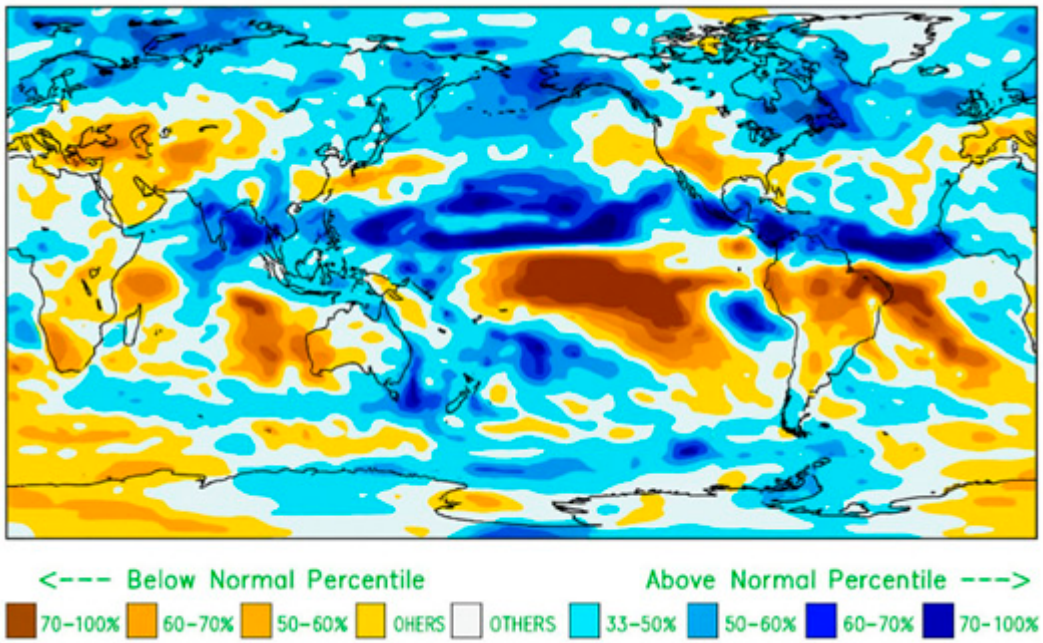


Figure 3. April-May-June, 2025 global prediction for total rainfall probabilities (Reproduced from the monthly State of Water Bulletin, March 2025, [41]).

3.8. Technological Innovations

Technological innovations are playing an increasingly important role in enhancing WRM in South Africa, offering solutions to address the country's persistent water challenges such as scarcity, pollution, and infrastructure inefficiencies [42–44]. One key innovation is the use of smart water management systems, which include real-time monitoring sensors, data analytics, and automated control systems to detect leaks, monitor water quality, and optimize distribution [45,46]. A study by Takhumova and Goncharova (2025) [44] explores innovative approaches to water resource management in achieving sustainable development goals. Their findings underscore the importance of interdisciplinary strategies that combine technological innovation with robust policy support and active community engagement. [44] These technologies help municipalities reduce water losses and improve efficiency, particularly in urban areas where deteriorating infrastructure leads to high levels of non-revenue water [44–46]. Desalination plants have also been introduced in coastal regions like the Western Cape to diversify water sources, especially during drought periods. Water recycling and reuse technologies are gaining traction as well, enabling treated wastewater to be reused for agriculture, industrial processes, and even potable supply under strict conditions [46]. In agriculture, precision irrigation systems using GPS and soil moisture sensors are helping farmers optimize water use and increase crop yields with less water [46]. Additionally, mobile apps and digital platforms are being used to engage communities, report service issues, and raise awareness about conservation [43–46]. Despite these advances, the widespread adoption of technology in South Africa is still limited by funding constraints and capacity gaps, particularly in rural and under-resourced municipalities [44–46]. However, continued investment in technological innovation, alongside policy support and skills development, is essential for building a resilient and sustainable water management system.

4. Challenges in South Africa's WRM

a. Funding and resource allocation

Challenges related to funding and resource allocation significantly hinder the implementation of effective WRM strategies in South Africa [38,47–49]. Limited financial resources, especially at the municipal and local government levels, often result in underinvestment in critical water infrastructure such as treatment plants, pipelines, and reservoirs [47,48]. This lack of funding affects both the maintenance of existing systems and the development of new projects needed to address growing demand and climate-related pressures [48]. Ruiters and Echendu (2022) [48] investigated the economic costs and investment challenges of water infrastructure in South Africa. Their results indicate that several reforms and measures are needed in each of the five categories of potential inefficiencies and scenarios that could lead to better or improved efficiency in the water infrastructure under-maintenance and capital investment challenges, distribution, losses and non-revenue water (NRW), water use tariff models, and affordability and revenue collection and management. Many municipalities struggle with poor revenue collection, mismanagement of funds, and inefficiencies in budgeting processes, which further exacerbate the problem [47–49]. Additionally, the allocation of resources is often unequal, with rural and disadvantaged communities receiving less investment, deepening inequalities in access to safe and reliable water [47,48]. The high costs associated with upgrading infrastructure, implementing advanced technologies, and ensuring compliance with water quality standards require long-term financial planning and innovative funding models, such as public-private partnerships and donor support [47–49]. Ruiters (2013) [49] examines various funding models for water infrastructure in South Africa, emphasizing the need for innovative approaches to address the country's significant infrastructure backlog and

ensure sustainable water service delivery. Without addressing these financial constraints, the country's ability to deliver sustainable, equitable, and climate-resilient water services remains severely limited.

b. Policy implementation gaps

Effective management of South Africa's water resources is severely obstructed by policy implementation gaps, even though the nation has comprehensive and progressive water laws, as previously mentioned [50–52]. While these policies emphasize equitable access, sustainability, and public participation, there is often a disconnect between policy formulation and practical execution on the ground [51,52]. Factors contributing to this gap include limited institutional capacity, bureaucratic inefficiencies, lack of coordination among different spheres of government, and insufficient funding to support policy-driven initiatives [50,51]. Scopetsa (2020) [50] investigated the challenges facing the implementation of public policies in South Africa since the dawn of democracy. His findings showed that there are numerous challenges in the implementation of policies including the governments' inability to involve the public in policy planning, formation, and implementation, the public's failure to follow public policies, the exclusion of people's cultural and value systems, a lack of trust in leadership, insufficient capacity, bureaucratic systems, setting unrealistic goals, and corruption. Many water management institutions, such as CMAs, face delays in establishment or lack the resources to function effectively [17–27]. Furthermore, enforcement of water use regulations and pollution controls is inconsistent, with many offenders going unpenalized due to weak monitoring and compliance systems [51,52]. Adom and Simatele (2021) [52] investigated the effectiveness of public policies and programs in addressing water security in post-apartheid South Africa, specifically focusing on the period after 1994. Their findings highlight both the advancements made in water distribution and the persistent challenges, including inadequate infrastructure, unequal access, and governance issues. Corruption and political interference further complicate implementation efforts, undermining public trust and accountability. Bridging the policy implementation gap requires strengthening institutional capacity, enhancing inter-agency collaboration, improving transparency, and ensuring that national water strategies are backed by adequate financial and human resources to translate policy intentions into tangible outcomes [51,52].

c. Education and capacity building

Education and capacity building challenges present a significant barrier to effective WRM in South Africa [53–55]. While national policies recognize the importance of building human and institutional capacity, implementation remains inconsistent, particularly at the local and community levels where skills shortages are most critical [53]. Mpu and Adu (2021) [53] explore the difficulties faced in implementing inclusive education in South Africa. Their study highlights issues such as overcrowded classrooms, insufficient training for educators, and a lack of knowledge and skills among teachers regarding inclusive practices. Many municipalities and water management institutions lack adequately trained personnel to plan, implement, and monitor WRM programs effectively [54,55]. Technical expertise in areas such as hydrology, water quality monitoring, infrastructure maintenance, and climate adaptation is limited, leading to inefficiencies and poor decision-making [55]. Additionally, the education system has not sufficiently addressed the growing demand for specialized training in water-related fields, resulting in a skills inconsistency in the sector [53,54]. Public awareness and community engagement in water conservation and management are also retarded by a lack of targeted educational campaigns and outreach, especially in rural and marginalized communities [56,57]. As a result, many citizens are not equipped to participate meaningfully in decision-making or adopt sustainable water

practices [57]. Bazaanah (2023) [57] investigated community participation in water and sanitation service delivery: An empirical case of Mantsopa Municipality, South Africa. His results indicated that community involvement can enhance service delivery and improve resident satisfaction. Overall, addressing these challenges requires a coordinated effort to invest in water education at all levels, from primary schools to higher education institutions, and to develop continuous professional development programs for practitioners, while also empowering communities through inclusive and accessible capacity-building initiatives [58–60].

5. Conclusions

This review has examined the current state of WRM in South Africa, highlighting the complex and interrelated challenges that hinder sustainable and equitable water governance. It emphasises how institutional fragmentation, socio-political dynamics, infrastructural limitations, and environmental pressures, particularly climate change and growing water scarcity, collectively obstruct effective WRM in South Africa. Despite the existence of a structured policy and governance framework, implementation remains weak due to poor coordination, inadequate funding, aging infrastructure, and capacity constraints. These systemic issues are further aggravated by rapid urbanization and population growth, which intensify pressure on already limited water resources.

This review recognises that the lasting impacts of apartheid still influence disparities in water access and distribution. Addressing this requires inclusive stakeholder participation, particularly from historically marginalized communities, to ensure that water management initiatives are socially just and broadly supported. To move toward a more resilient and sustainable water future, South Africa must adopt integrated approaches that combine technological innovation, adaptive governance, and skills development. Conventional management models are no longer sufficient in the face of escalating climate risks and infrastructural decline. A shift toward collaborative, accountable, and forward-thinking water governance, supported by strong political will and strategic investment, is essential for overcoming the persistent barriers to effective WRM.

Integrating scientific water quality and biostability assessment into the IWRM framework is essential for producing actionable insights that enhance resilience, sustainability, and equity in WRM. By systematically incorporating data-driven evaluations of water quality and microbial stability, decision-makers can better anticipate and mitigate contamination risks, optimize treatment processes, and ensure the long-term safety and availability of water supplies.

6. Policy Recommendations

To address the complex challenges identified in the review and support sustainable, equitable, and resilient WRM in South Africa, the following key policy recommendations have been identified:

- A key priority should be expanding community participation in decision-making processes, ensuring that the voices of historically marginalized groups are heard and considered in water planning and governance.
- Equally important should be investment in educational programs and capacity-building initiatives to equip individuals and institutions with the skills and knowledge needed for sustainable WRM.
- Technological advancements must be leveraged to improve water quality monitoring, data collection, and real-time management, enabling more responsive and informed decision-making.

In addition, climate-resilient strategies such as diversifying water sources, protecting natural ecosystems, and enhancing drought readiness are crucial for ensuring long-term water security. Building a more efficient and just water management system also requires strengthening institutional structures, enhancing interagency coordination, and encouraging accountability and openness. When combined, these tactics provide a rigorous approach to safeguard South Africa's water future in a setting that is becoming more unpredictable.

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References

1. Khofi, L.; Manderson, L.; Reid, M.; Moyer, E. A review of the social and local dynamic in South Africa's ware energy food nexus. *J. Environ. Manag.* **2025**, *380*, 124938. [CrossRef]
2. Nkosi, M.; Mathivha, F.I.; Odiyo, J.O. Impact of land management of water resources a south African's context. *Sustainability* **2021**, *13*, 701. [CrossRef]
3. Afuye, G.A.; Majahana, J.M.; Kalumba, A.M.; Zhou, L.; Mazingo, S.P. Drought Disasters, Vulnerability, Severity, Preparedness and Response to the Water Sector: A Comprehensive Model Approach for Water Governance and Policy in South Africa. *Prog. Disaster Sci.* **2025**, *26*, 100417.
4. Richards, K.A.; Mulala, D.S. Overcoming systematic and institutional challenges in policy implementation in South Africa's water sector. *Sustain. Water Resour. Manag.* **2024**, *10*, 69.
5. Makanda, K.; Nzama, S.; Kanyerere, T. Assessing the role of water resources protection practice for sustainable water resources management: A Review. *Water* **2022**, *14*, 3153. [CrossRef]
6. Kuddus, M.A.; Tynan, E.; McBryde, E. Urbanization: A problem for the rich and the poor? *Public Health Rev.* **2020**, *41*, 1. [CrossRef]
7. Yu, P.; Wei, Y.; Ma, L.; Wang, B.; Yung, E.; Chem, Y. Urbanization and the urban critical zone. *Earth Crit. Zone* **2024**, *1*, 100011. [CrossRef]
8. Turok, I.; Barel-Saladin, J. Is urbanisation in South Africa on a sustainable trajectory? *Dev. S. Afr.* **2014**, *31*, 675–691. [CrossRef]
9. Adeyeye, K.; Gibbert, J.; Chakwizira, J. Water marginality in rural and peri-urban communities. *J. Clean. Prod.* **2020**, *273*, 122594. [CrossRef]
10. Mthiyane, D.B.; Wissink, H.; Chiwawa, N. The impact of rural-urban migration in South Africa: A case of KwaDukuza municipality. *J. Local Gov. Res. Innov.* **2022**, *3*, a56. [CrossRef]
11. Kaziboni, A. Exclusion and invented water scarcity: A historical perspective from colonialism to apartheid in South Africa. *Water Hist.* **2024**, *16*, 45–63. [CrossRef]
12. Jegede, A.O.; Shikwambane, P. Water "Apartheid" and the significance of human rights principles of affirmative action in South Africa. *Water* **2021**, *13*, 1104. [CrossRef]

13. Tarantino, R. South African Rights and Legacies of Apartheid. In *BSV Honors Program Theses and Projects*; Bridgewater State University: Bridgewater, MA, USA, 2019; Item 402.
14. Tewari, D.D. A detailed analysis of evolution of water rights in South Africa: An account of three and a half centuries from 1652 AD to present. *Water SA* **2009**, *35*, 693–710. [CrossRef]
15. Bablin, E. Foundation and change of water Inequality in South Africa: South African Water History. In *The Proceedings of Great Day 2020*; Milne Library: New York, NY, USA, 2021.
16. Nightingale, A. A guide to systematic literature reviews. *Surgery* **2009**, *27*, 381–384. [CrossRef]
17. Salisbury, L. Web of Science and Scopus: A comparative review of content and searching capabilities. *Charlest. Advis.* **2009**, *1*, 5–18.
18. Department of Water and Sanitation. Review of the National Water Resources Strategy. *Gov. Gaz.* **2022**, *3*, 2327.
19. Department of Water and Sanitation. *Update of National and Sectoral Water Conservation and Water Demand Management Strategies 2023*; WP 11390; Department of Water and Sanitation: Pretoria, South Africa, 2023.
20. Water Research Commission. *A Comparison of the South African Approach to Water Resources Management and Planning with International Countries*; WRC Report No. KU 341/15; Water Research Commission: Pretoria, South Africa, 2016.
21. Germanie, V.; Van der Walt, K. South Africa's Water Crisis—An Interdisciplinary Approach. *Natl. Water Sanit. Master Plan* **2018**, *58*, 483–500.
22. Igamba, J. Water Crisis in South Africa. Greenpeace International [Internet]. 2022. Available online: https://www.greenpeace.org/africa/en/blogs/51757/water-crisis-in-south-africa/. (accessed on 20 June 2025).
23. Water Research Commission. *The Water Energy Nexus in the Context of Climate Change: Investigating Trade-Offs Between Water Use Efficiency and Renewable Energy Options for South Africa*; WRC Report Number 2239/1/15; Water Research Commission: Pretoria, South Africa, 2016.
24. Adom, R.K.; Simatele, M.D.; Reid, M. Assessing the social and economic implications on water security in the Nelson Mandela Bay Metropolitan Municipality, Eastern Cape of South Africa. *J. Water Health* **2023**, *21*, 939–955. [CrossRef]
25. Msibi, M.I.; Dlamini, P.Z. *Water Allocation Reform in South Africa: History, Processes and Prospects for Future Implementation*; WRC Report No. 1855/1/11; Water Research Commission: Pretoria, South Africa, 2011.
26. Jack, O.; Marin, C.; Tilak, G.; Laura, B.M. A systematic literature review of sustainable water management in South Africa. *Sustain. Water Resour. Manag.* **2023**, *10*, 162.
27. Schreiner, B. View point: Why has the South African's National Water Act been so difficult to implement? *Water Altern.* **2013**, *6*, 239–245.
28. Hydrosoft Institute. *Decolonising Water Access and Allocation: A Renewed to Address Persistent Inequalities in the Water Sector*; WRC Report No 2858/1/21; Water Research Commission: Pretoria, South Africa, 2021.
29. Francis, R. *Water Justice in South Africa: Natural Resources Policy at the Intersection of Human Rights, Economics, and Political Power*; Bepress Legal Repository: Berkeley, CA, USA, 2025.
30. Molobela, I.P.; Sinha, P. Management of water resources in South Africa: A review. *Afr. J. Environ. Sci. Technol.* **2011**, *5*, 993–1002. [CrossRef]
31. Adom, R.K.; Simatele, M.D.; Reid, M. The threats of climate change on water and food security in South Africa. *Am. J. Environ. Clim.* **2022**, *1*, 73–91. [CrossRef]
32. Edokpayi, J.N.; Makungu, R.; Mathivha, F.; Nkuna, T.R. Influence of global clime change on water resources in South Africa: Toward an adaptive management approach. In *Water Conservation and Wastewater Treatment in BRICS Nations*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 83–115.
33. Carden, K.; Armitage, N.P. Assessing urban water sustainability in South Africa-not just performance measurement. *Water SA* **2013**, *39*, 345–350. [CrossRef]
34. Chitong, H. Urbanization and the water challenges in Africa: Mapping out orders of water scarcity. *Afr. Stud.* **2020**, *79*, 1–20.
35. Turok, I. South Africa's tortured urbanization and the complications of reconstruction. In *Urban Growth in Emerging Economics*; Routledge: London, UK, 2014; Volume 1, pp. 143–190.
36. Cole, M.J.; Bailey, R.; Cullis, J.; New, M.G. Spatial inequality in water access and water use in South Africa. *Water Policy* **2017**, *20*, 2017111. [CrossRef]
37. Mpongwana, Z.; Shumba, K.; Bracking, S. Reflections on rural household water insecurity: Evidence from Goboti and Khubui in the Eastern Cape and Limpopo provinces, South Africa. *Afr. J. Inter/Multidiscip. Stud.* **2022**, *4*, 217–233. [CrossRef]
38. Tshona, S.S.; Lungisa, S.; Mgweba, L. Thirsting for solutions: Unpacking inadequate water provision in rural communities. *Afr. Public Serv. Deliv. Perform. Rev.* **2024**, *13*, a873. [CrossRef]
39. Dinar, A. Challenge to water resources management: The role of Economic and modelling approaches. *Water* **2024**, *16*, 610. [CrossRef]
40. Bwapwa, J.K. Review on main issues causing deterioration of water quality and water scarcity: Case study of South Africa. *Environ. Manag. Sustain. Dev.* **2018**, *7*, 14. [CrossRef]

41. Prest, E.I.; Hammes, F.; Mark van Loosdrecht, C.M.; Vrouwenvelder, J.S. Biological stability of drinking water: Controlling factors, methods, and challenges. *Front. Microbiol.* **2016**, *7*, 45. [CrossRef]
42. Okello, C.; Githoora, Y.W.; Sithole, S.; Owuor, M. Nature-based solutions for water resource management in Africa's arid and semi-arid lands (ASALs): A systematic review of existing interventions. *Nat.-Base Solut.* **2025**, *6*, 100172. [CrossRef]
43. Onyena, A.P.; Sam, K. The blue revolution: Sustainable water management for a thirsty world. *Discov. Sustain.* **2025**, *6*, 63. [CrossRef]
44. Takhumova, O.; Goncharova, M. Innovative approaches to water resources management in achieving sustainable development goals. *E35 Web Conf.* **2025**, *614*, 04019. [CrossRef]
45. Patience, M.; Stuart, W.; Deborah, C.; Milanthi, J.; Javier, M.S.; Chris, D. In water quality and management in Africa: Toward developing an African water quality program (AWAQ). *Int. Water Manag. Inst. (IWMI)* **2024**, *208*, 52.
46. Boularbah, S.; Elkhoumso, W.; Bourziza, R. Treated waste water reuse in Agriculture: An overview. *E35 Web Conf.* **2024**, *429*, 05002. [CrossRef]
47. Malaza, M.; Mabunda, A. Challenges of integrated water resources management in the Western Cape Province, South Africa. *J. Water Resour. Ocean Sci.* **2019**, *2*, 9. [CrossRef]
48. Ruiters, C.; Echendu, J.A. Economic costs and investment challenges of water infrastructure in South Africa. *Infrastruct. Asset Manag.* **2022**, *9*, 194–206. [CrossRef]
49. Ruiters, C. Funding models for financing water infrastructure in South Africa: Framework and critical analysis of alternatives. *Water SA* **2013**, *39*, 313–326. [CrossRef]
50. Scopetsa, T. Challenges facing the implementation of public policies in South Africa since the dawn of democracy. *Educor Multidiscip. J.* **2020**, *4*, 141.
51. Mackay, H.M.; Rogers, K.H.; Roux, D.J. Implementing the South African water policy: Holding the vision while exploring an uncharted mountain. *Water SA* **2004**, *29*, 4. [CrossRef]
52. Adam, R.K.; Simatele, M.D. Analysis of public policies and programmes toward water security in post policies and programmes towards water security in post-apartheid South Africa. *Water Policy* **2021**, *23*, 503–520. [CrossRef]
53. Mpu, Y.; Adu, E.O. The challenges of inclusive education and its implementation in schools: The South African perspectives. *Perspect. Educ.* **2021**, *39*, 225–238. [CrossRef]
54. Donolwe, D.; Bomman, J. The challenges of realising inclusive education in South Africa. *South Afr. J. Educ.* **2014**, *34*, 2076–3433. [CrossRef]
55. Jardinez, M.J. The advantages and challenges of inclusive education: Striving for equity in the classroom. *J. Educ.* **2024**, *12*, 57–65. [CrossRef]
56. Merci, M. Empowering communities for sustainable water management: Insights from Justdiggit and the Paani foundation. *E53 Web Conf.* **2024**, *550*, 01042.
57. Bazaanah, P.; Nthama, M.L. Community participation in water and sanitation service delivery: An empirical case of Mantsopa Municipality, South Africa. *Big Data Water Resour. Eng. (BDWRE)* **2023**, *4*, 16–26. [CrossRef]
58. Joshua, R.; Nokulunga, B.; Hulisani, M.; Mirrander, N.; Judy, R. *National State of Water Report*; Department of Water and Sanitation, SA: Pretoria, South Africa, 2023.
59. Department of Water and Sanitation. South Africa. *National Water Resource Strategy III*; Department of Water and Sanitation: Pretoria, South Africa, 2023.
60. Savenije, H.H.G. *Water Resources Management Concepts and Tools*; Lecture Notes; WERM011/96; International Institute for Infrastructure, Hydraulic and Environmental Engineering: Delft, The Netherlands, 1996.

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