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Review

Assessing the Role of Water Resources Protection Practice for Sustainable Water Resources Management: A Review

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Abstract: Water resource protection is central to sustainable water supply management for human wellbeing and for the ecological ecosystem to flourish. This review paper focuses on highlighting the role of groundwater and surface water protection practice to improve their sustainable utilization in South Africa. Using an integrative approach, this paper initially reflects on the history of water resources utilization, and it examines what is understood by the term "water resources protection". This review paper then continues by providing an analysis of the current practice at global and local levels. The study found evidence of water resource utilization in the ancient times with limited challenges despite unavailability of regulation mechanisms. However, in recent times water resource availability challenges linked to water availability and water quality deterioration are evident globally despite having policies and regulation in place. Based on the findings of the study, a novel conceptual results-oriented policy monitoring framework is proposed, and it was distinctively designed to address challenges identified in practice in the South African context. The framework is configured on (1) the vision of the catchment protection and sustainable use, (2) water resources protection practices, (3) the state of water resources, and (4) policy evaluation and review processes as the key elements to drive success in policy implementation and monitoring practice. Therefore, this paper provides a foundation for results-oriented policy monitoring for water resources protection to improve sustainable water resources utilization in the country. The proposed framework can be considered as a reference guide that can be used to monitor policy practice for water resources protection by following a result-oriented monitoring approach

Keywords: conceptual framework; policy implementation; resource-directed measures; results oriented monitoring; water resources protection

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1. Introduction

Water resources protection is described as an activity encompassing resource and habitat protection such as securing of resource, and instream flow rights. It involves progressive reduction in discharge, emissions, and losses of pollutants, to ensure long-term protection of available water resources and aquatic ecosystems [1,2]. Although water resources protection and water resource management are often used interchangeable in practice, water resources protection focuses on measures put in place such as prevention and control of water pollution [3]. On the other hand, water resources management emphasizes on enabling policy and regulating the environment, institutional roles and responsibilities, and management instruments as prerequisites to deploying water resources to support social and economic development while ensuring sustainability of the resource [4].

Globally, surface water and groundwater resources are regarded as one of the most essential material resources necessary for human survival and development [5]. Furthermore, these resources are considered as central to natural environment sustainability and ecological ecosystem evolution. It has been pointed out that the conditions of water resources at

one place can determine the local ecological environment [6]. The role of ecological ecosystems in social wellbeing such as provision of goods and services is well-documented [7]. It is in this regard that water resources protection is considered as central to socio-economic development and ecological ecosystem sustainability.

Such an argument is supported by [8] who noted that water resources are currently facing variable and unpredictable challenges globally that are mainly manifested in different aspects. It is acknowledged that water resources are an irreplaceable element of the ecological ecosystem and natural environment, which requires protection for sustainable utilization [6]. In the case of groundwater, protection measures require understanding of hydrologic characteristics of groundwater systems such as the scale, hydraulic conductivities, and effective porosities for predicting contaminant transportation [9]. Sustainable utilization of groundwater resources requires understanding of how much groundwater is available in a system, and in such practice aquifer recharge becomes a critical hydrologic parameter for consideration. As pointed out by [10], understanding of groundwater recharge assists in the conceptualization of aquifers for effective management and sustainable withdrawals. Furthermore, sustainability and availability of groundwater resources requires understanding of aquifer properties linked to groundwater pollution. Such understanding is central to the development of feasible methods that can be used to predict and track chemical concentration movement along saturated and unsaturated zones at a local, regional, and national level. For example, [11] showed that it is possible to predict regional scale loading of nitrate at the water table, a revelation which is critical for groundwater resources management. Similarly, understanding of hydrologic dynamics of groundwater is critical for ecological ecosystem sustainability and protection. For example, evolution of groundwater nitrate concentrations and nitrate loading from intensive agricultural activities can cause significant challenges in aquatic ecosystems in cases where groundwater discharges into surface water [12].

The vulnerability of both surface water and groundwater resources to pollution and over exploitation warrants adoption of water resources management approaches that seek to balance between their protection and sustainable utilization. It has been argued that such approaches should consider river basins as "natural" units and logical units for water management [13]. Water vulnerability to climate change has dire consequences on socio-economic development. For instance, when water resources vulnerability was assessed in Nigeria, climate change was identified as one of the factors having a negative impact on water resources, giving a compromise in terms of meeting future demand [14]. In South Africa, influence of climate change on water resources has been reported to cause constraints of water resources availability, and a negative impact on economic development, livelihoods, and progress towards attainment of SDGs [15]. Such challenges require strategies and tools for mitigating potential negative impacts imposed by climate change, and it is encouraging that relevant tools are made available for measuring water resource vulnerability due to environmental and anthropogenic factors [16]. Furthermore, tools for assessing the vulnerability of water resources in China have been developed [17]. For example, [18] developed a Vulnerability Scoping Diagram (VSD) framework and System Dynamics (SDs) model as a tool for water resource vulnerability in the Pearl River Delta network in the city of Zhongshan.

Policy relevant approaches have been considered as critical in water resources protection. For example, a research study conducted in the United States of America (Florida) investigated forest conservation for ecosystem service provision as an effective strategy for protecting water resources and increasing public welfare. Using a web-based choice experiment survey, the study found that forest/water protection programs provide an annual average of USD 154–230 million in clean water benefits, and a significant portion of that value was associated with the policy process. The findings of this study suggests that policy interventions provide relevant solutions for water resource protection [19].

Although policies for water resources protection are critical in mitigating water resource challenges [20], but if such policies are not appropriately implemented or if the implementation processed are delayed, their intended purpose are likely to be compromised. For example, development of policies that regulate the environmental quality of the waters in Chile have advanced significantly; however, it has taken the country about 22 years to implement such policies and thus, at present, water quality problems and challenges remain a major challenge in the country [21]. It has been argued that several advances and reforms of Chile's institutional and legal framework for water management have fallen short of what is needed to address the issues that Chile faces in its current phase of development. Hence the adoption of an integrated water resources management approach has been recommended as a priority so that Chile can face its current and future water management [21].

It has been argued that it is a necessary to monitor and report the impacts of water policies on water scarcity and resources management [22]. Results-oriented policy monitoring is seen as an appropriate approach for monitoring policy implementation practice to assess policy impacts. It is argued that the approach moves beyond an emphasis on inputs and outputs to a greater focus on outcomes and impacts of policy practice [23]. In this regard, several studies have been undertaken to assess policy impact on sustainable water resources utilization. For instance, in the United States of America (USA) changes in access to free drinking water in California public schools after implementation of the 2010 Federal and State school water policies was investigated [24]. The findings of the study indicated that there were significant increases in public schools meeting the criteria for excellence in free drinking water access after school water policies were implemented.

Locally, South Africa is considered among the 30 driest countries in the world receiving an average rainfall of about 450 mm per year compared with the global average of 860 mm per year; in this regard the country can be considered as a water-scarce country [25].

Water resource challenges linked to water availability are well-recognized and documented in the country, where water shortage is considered in the country as a mixture of many factors such as low rainfall, fast growing population, and high evaporation rates [26]. Climate variability has been reported to cause drought conditions which affect groundwater resources leading to high demand for water supply, resulting in overexploitation of aquifers [27]. For example, [28] demonstrated how drought conditions have affected groundwater resources in the Karoo, as a result the area was deemed suitable for managed aquifer recharge. Water resources challenges linked to water quality deterioration, which pose a threat to freshwater resources accessibility in the country, have been reported [29]. For example, several studies on watercourses have reported a decline on quality due to the ongoing pollution caused by urbanization, mining, industry, power generation, afforestation, and agriculture; therefore, with water scarcity and water pollution challenges experienced there is a crucial need to achieve a more sustainable management of the world's water resources [30,31]. Arsenic (As), Lead (Pb), and persistent organic pollutants (POPs) have been reported as the main critical pollutants in both surface water and groundwater in the country [32,33]. Concerns related to groundwater pollution as a result of unconventional gas exploration have also been reported. For example, shallow groundwater is the main source of potable water in the karoo; as a result, proposed shale gas exploration in the semi-arid karoo has experienced some challenges [34]. Ref. [35] noted that due to risk associated with shale gas exploration, adaptive management tools are critical for groundwater resource protection prior to initiation of the exploration process.

This paper initially reflects on the history of water resources utilization, and it examines what is understood by the term "water resources protection". It continues to provide an analysis of the current practice in water resources protection at global and local levels. Finally, by drawing on the findings of the review, a novel conceptual results-oriented policy monitoring framework is proposed, that is distinctively designed to address challenges of water resources protection practice in the South African context.

Therefore, the aim of this review paper is to provide a foundation for results-oriented policy monitoring for water resources protection to improve water resources protection practices and sustainable water resources utilization in the country. In order for the aim to be achieved the following objectives were formulated: (a) explore the concept of water resource protection focusing on water resource occurrence and utilization, (b) undertake a literature review on water resource protection to understand its application in policy practice globally and in South Africa, and (c) propose a feasible conceptual framework in order to improve water resource protection practice in South Africa.

2. Methodological Approach

The information presented in this paper is based on a review of the relevant literature. By summarizing and extracting critical information from key research in the water resources protection, water resources, and policy practice discipline, we establish the current state of knowledge on water resources protection in policy practice discipline. For instance, we first contextualize water resources protection by briefly reflecting on the history of water resources utilization (Section 3.1), then we define what water resources protection is (Section 3.2). Then we present a brief review on the current practice for water resources protection at the global level (Section 4), then we present legislative framework for water resources protection (Section 5.1), strategies for water resources protection (Section 5.2), and we provide highlights on the outcomes of resource-directed measures studies (Section 5.3) in the context of South Africa. Finally, we use the findings of the review to facilitate the development of a proposed results-oriented policy monitoring for water resources protection in the SA context. The illustration of the methodological approach followed in the study is presented in Figure 1. In this review, search terms related to the paper's title were entered into the EBSCOhost, Web of Science, Science Direct, Emerald, JSTOR, ProQuest, and Springer. Furthermore, grey literature sources such as Google Scholar, and online sources of State Departments reports were included in the literature review process. This approach was deemed necessary to remove biasness from the selection of academic and grey literature for inclusion in the compilation of this manuscript.

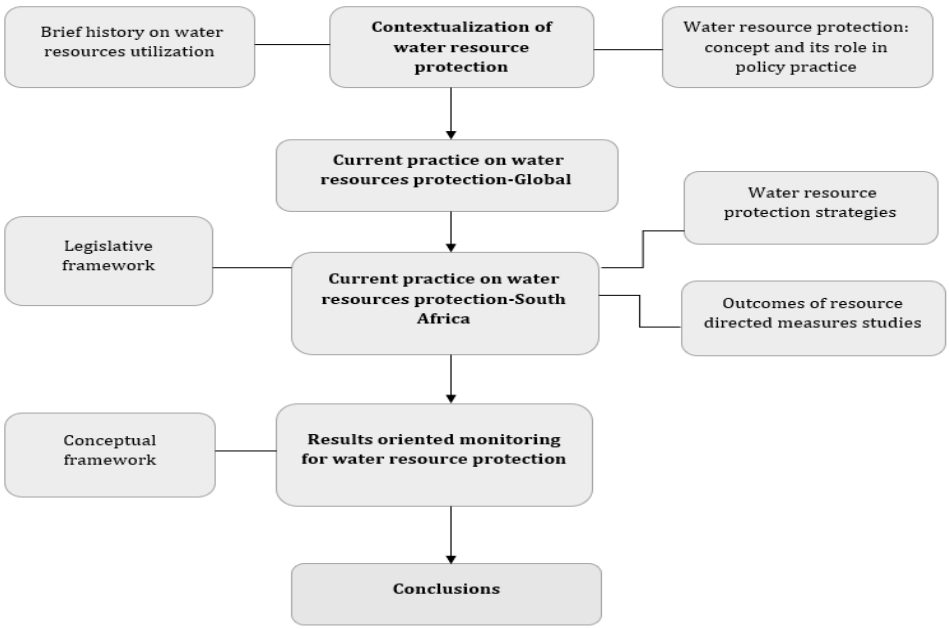

Figure 1. Research approach (Methodology).

3. Contextualization of Water Resources Protection

In this section we reflect briefly on the history of water resources utilization, and we also tried to define the concept of water resources protection and its application in policy practice. Such a reflection is critical in the contextualization of water resources protection.

3.1. Brief History on Water Resources Utilization

Water represents almost three-quarters of the earth surface with only less than three percent of this water being characterized as freshwater, and unfortunately it is unequally distributed in humanized spaces [36]. However, despite accumulation of a minor portion of the earth's surface, water resources are arguably indispensable to life [37]. It has been reported that approximately 50,000 years ago modern man were constantly on the move, and ancient villages, towns, and cities were built near freshwater sources such as rivers, springs, and lakes [38,39].

Sedentary agricultural life facilitated the construction of villages, cities, and eventually states, all of which were highly dependent on water, and [38] noted that this new type of livelihood spread everywhere, and the population began to expand tremendously, which created a brand-new relation between humans and water. Such revelation testifies to the importance and safety of surface and groundwater as a water source, particularly springs and wells. It has been documented that the 1900s was a period of extensive population growth when the total world population crossed the threshold of 1 billion people for the first time while the urban population increased 13-fold, and industrial production increased 40-fold [38,40]. This evidence is supported by [37] who noted that several changes occurred during the Industrial era of this period which was crucial for the use of water resources because of the competition between different activities needing water. Ref. [41] noted that the period of up to 1914 was a period of emergence of modern water industry with explosion of discrete interests due to unplanned, and unregulated water resources development.

Water used in large quantities formed part of a civilized way of life, with an average of 2 to 3 dams being commissioned each day in the 1900s [42]. Unfortunately, the health problems associated with water pollution became evident where industrial growth produced new waste streams in water [43]. For example, it has been reported that the Cuyahoga River in Ohio caught fire several times because of oil slicks and flammable industrial waste dumped into it [44]. Ref. [45] argued that water pollution was not new in the nineteenth century. The study argued that in the United States of America, water quality deterioration can be dated far back as in the Second World War, a period during which water pollution became an interstate problem where the United States of America had to solve their conflicts over the pollution of interstate waters by litigating in the Supreme Court of the United States of America [45]. Nevertheless, it is argued that the rise of civilization has always been linked to the successful management of water. Chemists started to work on problems of water quality in nineteenth century, most notable in Britain [42,46].

Refs. [47,48] warned about the unpleasant consequences of over exuberant growth. Likewise, [49] cited in [50] warned that "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years". For instance, the exploitation of water resources increased sharply between 1975 and 1995 but little change was apparent in the way water resources were managed up until the mid-1990s [51]. Consequently, the finite and indispensable nature of freshwater also came to the fore during the first decade of the twenty-first century [50]. Furthermore, due to unprecedented urbanization, climate change, which places enormous pressure on water availability and its security, freshwater pollution, depletion, and its protection is a global striking challenge of our time in the twenty-first century [52–54]. Therefore, it has been argued that efficient utilization and protection of such limited natural resource is critical for water supply and for life sustainability [55,56].

3.2. Water Resources Protection: The Concept and Its Role in Policy Practice

In this section, we present an overview of water resources protection in policy practice. Through literature examination, we provide a definition of water resource protection, and we reflect on various concepts as they are applicable in water resources protection practice, such as water resource types, applicable methods, settings, and level of application.

3.2.1. Defining Water Resources Protection

The word protection means an action of safeguarding from unwanted changes [57]. Some authors argue that precise meaning of the word protection can mean very different things to different people, contending that there are many forms and conceptions such as child protection, data protection, and environmental protection, just to name the few examples [58–60]. Therefore, water resources protection can be understood as an act of preventing unwanted changes to water resources, their constituents, and their associated ecosystems to sustain or improve their state. Although the terms water resources protection and water resources management are often used interchangeably, these terms do not necessarily mean same thing. Ref. [61] states that protection of water resources is associated with prevention of inappropriate for water resources utilization caused by water pollution and destruction, the sum of the law, administration, economy, technology, education, and other measures. Water resource management includes the construction such as dams and other storage projects to conserve water during the wet seasons for later use, and it takes the form of cooperative legal agreements negotiated over many years between neighboring states or countries to share scarce water resources [62].

3.2.2. Landscape Settings for Water Resources Protection

Consideration of landscape settings is critical in water resources protection practice, as it informs characteristics of water resources that exist in such environments and required protection measures. For example, the hydrology of mountainous terrain is known to be characterized by highly variable precipitation and water movement over and through steep land slopes [63]. As a results of the remoteness of water resources found in mountainous terrains, some of the commonly used methods for water resources protection cannot be sufficiently applied. For instance, use of satellite measurements of precipitation in mountainous terrains have been recommended due to limited availability of in situ measurements in such areas [64].

Karst terrains offer a different nature of water resources occurrence compared with mountainous terrains, [9,63] noted that karst terrains are characterized by closed surface depressions of various sizes and shapes known as sinkholes, an underground drainage network that consists of solution openings that range in size from enlarged cracks in the rock to large caves. Water recharge into an aquifer within the karst terrain environment is highly variable over time and space [65]. Furthermore, daily transpiration in karst terrain environments is significantly correlated to the air temperature and water vapor pressure deficit, a critical information in the understanding of vegetation water depletion and the underlying mechanisms for eco-hydrological processes and fragile ecological environment protection [66].

Throughout history humans have relied heavily on natural riverine environments which are highly productive, dynamic, diverse ecosystems [67]. However, heavy reliance on riverine environments may pose a threat to the water resources availability. For instance, hotspots of food-related river environment degradation have been reported in Australia, Pakistan, South Africa, and Spain [68]. This agrees with [69] who reported that South Africa is highly dependent on surface water, and a result, surface water resources are under great stress in some parts of the country, and water resources protection intervention is required.

3.2.3. Methods for Water Resources Protection

Activities such as use, development, conservation, management, and control are important in terms of water resource monitoring and possible impacts towards water resources protection [70], and therefore they are instituted to improve the state of water resources for the benefit of all. Rivers are the most used water source on account of their accessibility and availability [71], and this has directed some rivers towards non-natural flow regimes resulting in compromised quantity or volume of water required to maintain river health in a particular state [72,73]. To effectively manage such systems a

better quantitative understanding of hydrologic processes governing their behavior and availability is important.

Surface water levels have been used as a hydrological variable for quantifying the temporal river flow regime [74–76]. Ref. [77] applied the ICES at Release 33 GLA14 data to analyze water level variation in the Xinjiang's lakes and reservoirs in China from 2003 to 2009.

The results of the study showed that climatic conditions contribute to rising water levels in lakes in mountainous areas, especially for lakes that are recharged by snow and glacial melting, while for lakes in oases, the water levels are affected by a combination of human activity and climate change, and the water levels of reservoirs are mainly affected by human activity [77]. Ref. [78] used hydrological characterization methods to investigate flow regime in the Ethiopian Rivers. When the base flow index (BFI) was applied, it showed an incremental trend with ephemeral, intermittent, and perennial streams, whereas the number of mean zero flow days ratio (ZFI) and coefficient of variation (CV) showed a decreasing trend with the same type of flow regimes [78]. The findings of the study formed the basis for further understanding of the eco-hydrological processes of the river basins in Ethiopia.

Undoubtedly, surface water levels and river flow regimes are critical variables for assessing water resources for their sustainability and protection. Moreover, river water levels and flow regimes have a direct effect on stream water quality through assimilative capacity and dilution flow [79].

Water quality assessment methods are critical in water resources protection when such methods are used to investigate land-use influence on water resources quality. Such investigations enable prioritization of water resources management areas requiring interventions and effective mitigation strategies which are pivotal in the realization of community well-being and ecosystem health [80–82]. For example, river water quality measured with biological, water chemistry, and habitat indicators was analyzed to assess areas requiring water-quality management and land-use planning in the Little Miami River watershed [83]. The study found that the water biotic quality did not degrade significantly in the vicinity of the wastewater treatment plants, but significant lower water quality was found in areas downstream from high human impact areas where urban land dominated or near point pollution sources [83].

Water resources modelling techniques have been used in water resources protection practice to assess the impact of land-use activities on groundwater availability and recharge [10–12]. For instance, reduction in infiltration, which affects the groundwater recharge and storage has been linked with the increase in urbanization, and land-use change has been reported as a major factor affecting the groundwater system [84,85]. Using an empirical land-use projection model (Conversion of Land-use and its Effects (Dyna-CLUE)) and a hydrological model (Soil and Water Assessment Tool (SWAT)), [86] investigated the impacts of change in land-use patterns on the quantity of groundwater recharge in the Ho Chi Minh City, Vietnam. The results showed an increase in the observed groundwater recharge in the far future of low urbanization by 10% and a reduction of 30% and 52% in annual average groundwater recharge was observed in the far future of medium urbanization and high urbanization, respectively, which is an indication that change in built-up area has a significant effect on the groundwater recharge in the study area.

3.2.4. Level of Application for Water Resources Protection

Water is the basis for human life; its exploitation in various scales [87] requires varying water resources protection approaches. For example, at an international level, shared water resources require water resources protection practice within the framework of international water laws and agreements. Such practice requires competencies and skills for implementing the broad range of water resources protection activities in transboundary basins [88]. Ref. [89] argued that declining availability of existing water resources, water shortage crises, and lack of familiarity with international water laws and different principles in the use

of globally shared water resources may lead to tensions, conflicts, and disputes between cross-border water resources countries.

The regional scale of water resources protection pertains to activities undertaken with a state at a level higher than local using national policies. It is a scale where most policies and strategies are designed to guide water resources protection practice with a country. For example, in South Africa the National Water Resources Strategy 2 (NWRS-2) provides a direction on how the nations scarce water resources should be used and protected [90]. Although in general national polices are developed to guide use and protection of water resources, use of water resources and their impact happens at a local level; before water resources challenges become imminent at regional levels, such challenges first emerged at a local level. Therefore, localized water resources protection and management is pivotal to the sustainable use of water resources, where local government, and local communities plays a critical role in such practice [91].

This argument is supported by [92] who noted a need to develop a novel type of methodology which connects Pan-European data to the local scale in the field of water resources protection and management.

4. Current Practice on Water Resources Protection-Global Context

Over the years, there has been a brewing pressure on policy developers and water resource managers to develop and implement intervention strategies to mitigate environmental, water resources, and social impacts. This has motivated policy implementers and researchers to identify ways to better implement policies and strategies for effective protection of water resources [93–95]. Water resources challenges linked to ineffective policy intervention have been reported in Central Europe with a growing concern that the Water Framework Directive (WFD), which is a pioneering piece of legislation that aims to protect and enhance aquatic ecosystems and promote sustainable water use across Europe, would not be able to assist in achieving the objective of good status or higher in all EU waters by 2027 [96]. For example, devastating drought events have been reported in the areas of Western and Central Europe such Poland and Germany which has led to diminished spring discharges at a percentage between 4% and 52% [97]. Ref. [98] reported that despite extensive legislation that has been developed by the European Union to protect drinking water resources from agricultural pollution, the achievement of water quality objectives is an ongoing challenge throughout Europe. Complexities and inconsistencies of European legislation for drinking water resources protection have been cited as hampering efforts to achieve water quality objectives, and a new type of integrated management has been recommended for consideration in water protection decision making [98,99].

In Bangladesh, groundwater depth and groundwater-level deficit (drought) has been reported to be continuously increasing [100], and the decline has been linked with urbanization; as a result groundwater extraction in many locations has become unsustainable with predicted catastrophic events such as earthquakes, subsidence, and pollution being highly possible [101]. Due to current challenges related to stream low flows experienced in several countries, recommendations have been made on complementary management for high flows that occur early in the growing season with maintenance of adequate base flows to maintain ecosystem functioning in the face of hydrologic alterations induced by climate change and human water demand [102]. In terms of groundwater availability, intervention measures such as artificial recharge to the aquifers and water-saving technologies have been recommended to prevent groundwater mining as policy intervention measure [103]. In China the functions of water ecosystem of the Hainan province have been reported as degrading in the past few years, with the environmental quality of the water being inadequate. As a result, recommendations have been put forward for China's water ecological environment protection strategy to comprehensively consider the connection between space development and protection [104].

In the African context, challenges associated with water quality deterioration, river flow regime, and ineffective policy practice towards water utilization have been reported.

These challenges together with other many factors contribute to an increasing gap between water availability and demand in Africa [105]. Prior research indicates that watershed basins in Africa are prone to management challenges which may results in conflicts if not properly managed. For examples, a case study undertaken in the Nile River Basin on the roles and challenges faced in managing watersheds revealed that there is a sluggishness in the implementation of a coordinated planning and development program which leads to unsustainable utilization of water resources [106]. The author associated the challenge with a lack of coordination and detailed effective collaboration among some of the major players such as the Nile Basin Initiative and other development partners. The observation connotes that those policies developed for protection and management of water resources would not be good enough to curtail existing challenges if there are no existing plans put in place to implement policies, and in cases where there is a lack of policy implementation plans, conflict may arise.

In Nigeria, in the north central region, there are no apparent reported water challenges, which is due to water availability in water resource systems which is higher than the present use within the spatial location of rivers which also enables enough supply to all sections of the states in the region [107]. However, [108] reported that access to water within the Ado-Odo and Ogun State is mostly limited to the private sources because of the level of water quality and accessibility.

Water quality degradation has been found mostly in Lagos, Rivers, Kano, and Kaduna where most industries are located, and a need for water resource protection measures such as prosecution of water resources polluters by the Federal Ministry of Environment has been recommended [109]. Ref. [110] provided an indication that despite huge water resources in Nigeria, water resource development activities have not been efficient with the phenomenal population growth, and the researcher recommended policy reform in the country.

The Southern African Development Communities (SADCs) issues related to policy implementation and governance have been reported. For instance, in Malawi, water challenges linked with governance issues have been reported with indications that water supply and sanitation services are confined to urban populations due to governance administrative challenges [111]. A study by [112] indicated inconsistencies in the proportion of households that satisfy Malawi versus the United Nations and World Health Organization minimum water-access standards. A combination of factors including increased water demand, poor communication between stakeholders, and weak regulation and enforcement have been reported as challenges being experienced in Namibia, and as a result development of more robust and resilient strategies has been recommended [113].

Ref. [114] reported that groundwater use for irrigation has increased above the sustainable safe yield for the aquifers in the Grootfontein Tsumeb-Otavi Subterranean Water Control Area (GTO-WCA). The study proposed specific management solutions such as amendment of the legislation and policies to ensure that the management of karst aquifers in the country including the allocation of abstraction quotas [114]. Such reported challenges call for reinforcement of existing policies and improvement on their implementation. While water scarcity and water quality deterioration seem to be common in many African countries [115,116], policy-related challenges are also apparent. For example, lack of water resource protection practices for sustainable water supply has been identified amongst other factors as a driving factor for the experienced challenges especially in the Sub-Saharan African countries [117]. This is an indication that solutions on water resource challenges should not only focus on water quality and availability, but also on other aspects such as water governance and policy implementation [107].

The prevalent water resources challenges warrant policy interventions that seek to develop suitably comprehensive plans and institutional arrangements for sustainable water resources use and protection over time. Policy interventions that are beneficial to society are critical in the identification of the most effective ways of managing water resources in response to existing challenges [20]. Water resources protection policies are prevalent

around the world to alleviate global challenges such as water quality deterioration and water scarcity [118]. However, water resource protection for sustainable utilization goes beyond "mere" policy development and implementation, in that it also requires monitoring of such practice to assess policy impact. Therefore, it is necessary to monitor and report the impacts of water policies on water scarcity and resources protection [22]. For instance, when the 2010 the Federal and State school water policies were assessed for their impact on free drinking water access in California public schools, the study found that there were significant increases in public schools meeting the criteria for excellence in free drinking water access [24]. Contrary to the case of the USA, when the extended producer responsibility policy to reduce marine plastic debris in Canada was assessed for its impact on reduction in shoreline pollution levels, the study showed no reduction in pollution levels [119]. The observation suggested that the extended producer responsibility policy was ineffective in reducing plastic pollution in marine environments. Such findings suggest that policy interventions may not always provide desired outcomes, thus the need to assess policy effectiveness using the results monitoring approach.

5. Current Practice on Water Resources Protection-Local Context

In this section we reflect on water resources protection practices in South Africa by reviewing existing policies, strategies, and regulatory tools that are known to drive water resources protection. We focus on the legislative frameworks, water resources protection strategies, and outcomes of resource-directed measures studies.

5.1. Legislative Framework

In the local context, water resources protection in South Africa (SA) is enshrined in chapter 3 of the National Water Act (NWA) (Act 36 of 1998). While water source protection may be generally considered as measures designed to protect individual water sources, in the South African context water resources protection is fundamentally related to the use, development, conservation, management, and control of all water resources to achieve sustainable and equitable development for current and future generations [120,121]. The analysis from the collected data indicates that several policies and strategies for water resources protection are available in SA (Table 1).

Table 1. Illustration of key policy documents on water resources protection in South Africa.

Document	Promulgation Year	Context
White paper on water policy of 1997 (NWP, 1997)	1997	The White paper on water policy was developed in 1997, and it outlines the direction to be provided to the development of water law and water management systems.
National Water Act (Act 36 of 1998), (NWA, 1998)	1998	The purpose of the NWA (1998) is to ensure that the nation's water resources are protected, used, developed, conserved, managed, and controlled in ways which consider promotion of the efficient, sustainable, and beneficial use of water in the public interest.
National Regulation Number 810 of 2010		Regulation number 810 of 2010 outlines definitions, procedure for determining different classes of water resources, procedure for determining the reserve, and procedure for determining resource quality objectives.
National Water Resource Strategy of 2013 (NWRS, 2013)	2013	The strategy recognizes resource-directed measures as the approach adopted to protect water resources as per the NWA, as outlined in chapter 5 of the document.
National Groundwater Strategy, 2nd Edition (NGS, 2016)	2016	National Groundwater Strategy ensures that legislation such as the NWA is implemented successfully, especially when the aspect of groundwater is considered in terms of resource protection and sustainable utilization.

Refs. [90,122,123] form a consortium of policies fundamentally linked to water resources protection. The White paper on water policy was developed in 1997, and it outlines the direction to be provided to the development of water law and water management systems [122]. Its objective is to set out the policy of the government for the management of both quality and quantity of the country's scarce water resources. Principles of equity, efficiency, and sustainability are laid in [122] upon which the [121] is founded. The purpose of [121] is to ensure that the nation's water resources are protected, used, developed, conserved, managed, and controlled in ways which take into account amongst other factors: promoting equitable access to water; redressing the results of past racial and sex discrimination; promoting the efficient, sustainable, and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity and; meeting international obligations [121]. The Act is widely regarded as one of the most progressive and enabling pieces of environmental legislation globally [124]. Ref. [90] sets out how water is protected, used, developed, conserved, managed, and controlled sustainably and equitably. It recognizes resource-directed measures as the approach adopted to protect water resources as per [121], as outlined in chapter 5 of [90]. Ref. [123] ensures that legislation such as the NWA is implemented successfully, especially when the aspect of groundwater is considered in terms of resource protection and sustainable utilization.

5.2. Water Resources Protection Strategies

Water resources protection strategies are critical in the implementation of water resources protection policies. Water allocation schedules intended to specify, among other things, the quantities allocated to individual water users. Preparation of these schedules requires that water resources should be assessed in terms of their classes linked to the degree of change from their pre-development state.

In this context, the water resource reserve should be determined to quantify the amount of water to be reserved for basic human needs and ecological ecosystem sustainability before any water-use allocation is concluded. Furthermore, resource quality objectives (RQOs) should be determined to inform conditions that should be attached to water-use licenses. Therefore, RDMs are used as strategies to implement national policies towards protection of water resources. In this context water resources protection does not necessarily mean simple protection of water resources from land-use impacts, but it pursues to promote fair allocation of water resources to support economic developments while ecosystem protection and social benefits from such resources are ensured.

The authors of [121] define water resources protection strategies as resource-directed measures. Resource-directed measures (RDMs) consist of three components, namely, (1) water resource classification, (2) water resource reserve determination, and (3) resource quality objectives. Regulation number 810 of 2010, outlines definitions, procedure for determining different classes of water resources, procedure for determining the reserve, and procedure for determining resource quality objectives; allows to establish a set of qualitative relationships that specify how different levels of water resource use; ecosystem conditions; and ecosystem goods and services affect economic value and social wellbeing [125]. In terms of classification of significant water resource, the Regulation is used to classify water resources into Class I, Class II, and Class III depending on the extent of use of the water resource, by following the 7-step procedure outlined in the Regulation 810. In terms of water resource reserve determination, the reserve is determined for each water resource class by following the 8-step procedure outlined in the Regulation 810. Resource quality objectives are determined for each water resource class by following the 7-step procedure also outlined in the Regulation 810. Therefore, RDMs studies are undertaken by following prescribed procedures as outlined in the water resource classification system [126].

5.3. Outcomes of Resource-Directed Measures Studies

To date, several RDM studies have been conducted and concluded to ensure that practical policy implementation for water resources protection in the country is realized. The outcomes of such studies have been prescribed in the gazette (legalized) after undergoing extensive public scrutiny. In this context, outcomes of RDM studies are legally binding to authorities and water resources managers responsible for their implementation at catchment level. Implementation of RDM outcomes at catchment level facilitates policy practice at a localized scale where such practice has a direct impact on water resources utilization. Due to uncertainty associated with knowing how water resource systems would respond to the management actions, adaptive management is considered as a suitable approach for policy implementation towards water resources protection. South Africa is currently categorized as a chronic water-scarce country (500–1000 m^3/person/annum) and moving towards absolute water scarcity (500 m^3/person/annum) [127], hence the application of adaptive management in water resources protection becomes critical.

Ref. [128] assessed the role of self-organization and multi-scale feedbacks for learning and responsiveness in the Letaba and Crocodile catchments. The study found that factors of adaptive management such as good efforts to self-organize and functional feedbacks becomes limited when processes are confined to a local scale, which constrains learning and transformation at a wider scale. Such findings indicate that for adaptive management to be effective in water resources management, adaptive management frameworks must consider linkages between localized and regional water resources management practice, thus optimizing on impact and results driven policy assessment. Despite tremendous work by [128], application of adaptive management in the context of water resources protection, especially for results orientated policy monitoring is not fully addressed in South Africa. For instance, monitoring of RDM results would provide key information to establish compliance or non-compliance with established numerical limits, but it is not clear what to do in cases on non-compliance. Furthermore, it is not clear how to assess credibility of the RDM outcomes whether they are achievable, reliable, or not.

6. Results-Oriented Monitoring for Water Resources Protection

Without overlooking the remarkable stride made towards water resources protection globally and locally, evaluation of policy implementation for water resources protection to assess its effectiveness in addressing water resources challenges has been limited in practice.

Policy implementation towards water resources protection needs to show results or needs to have impact for reinforcement or need to address the desired goal or address the identified problems. Results-based monitoring has the capability to address identified problems linked to water resources protection and sustainable utilization because the focus is on the results of implementing the policy rather than the process of implementing the policy. Results-oriented policy monitoring is seen as an appropriate approach for monitoring policy implementation practice. It is argued that the approach moves beyond an emphasis on inputs and outputs to a greater focus on outcomes and impacts of policy practice [23]. For example, in China, key infrastructure projects were investigated for their results delivery [129]. The investigation found that many projects fail to deliver the expected benefits because the realization of results and benefits post-completion has not been effectively managed. The study argued that such problems can be addressed by adopting a results-based monitoring.

6.1. Conceptual Framework

South Africa's national water policies and legislation fully subscribe to protecting and managing the natural resource base of economic and social development as stated in the [121,130]. Water resource assessment in South Africa over the last 60 years has become more and more complex due to growth in land use, and deterioration in water quality [131]. Therefore, it is essential that water resource protection strategies such as resource-directed measures and results derived from undertaking such studies are prioritized for monitoring

to ensure that policy implementation for water resources protection is realized, and to show the impact of implementing such policies. Based on the findings of the review work in this paper, a conceptual results-oriented policy monitoring framework is proposed (Figure 2). The proposed framework explains features necessary for supporting results-oriented monitoring for water resources protection in the South African context. The framework includes features such as policy development, implementation, monitoring, reporting, and review. However, the framework is configured into four key features, namely (1) vision for water resources protection and sustainable use, (2) water resources protection practices, (3) state of water resources, (4) and policy evaluation and review processes, which are discussed in more detail in the following sections. The framework is intended to be considered as a reference guide that can be used to monitor policy practice for water resources protection by following a result-oriented monitoring approach.

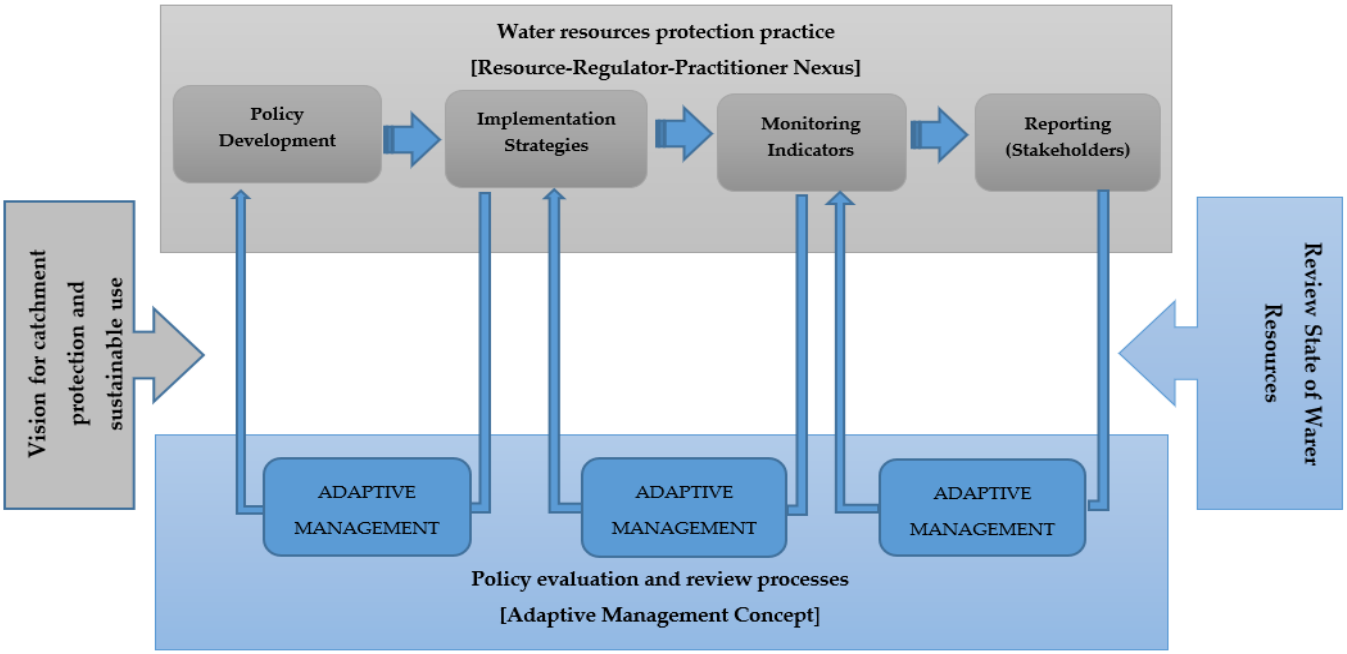

Figure 2. Conceptual framework for water resources protection using results-oriented monitoring.

6.1.1. Vision for Catchment Protection and Sustainable Use

This is the first key component of the framework which provides direction for whatever action is necessary to achieve vision of water resources. According to [132], stakeholders and decisionmakers often develop visions of the ideal-type future in response to societal challenges. Without a vision and clearly defined societal objectives, management of water resources to the needs for society as well as protection of environmental integrity, and ecological ecosystems sustainability would be compromised. Therefore, the framework begins by defining the problem. In the case of our study, we define vision as protection of water resources to achieve sustainable use of water for the benefit of all users including aquatic ecosystems. In the context of water resources protection in South Africa, this vision is entrenched in the National Water Act of the country.

6.1.2. Water Resources Protection Practices

Water resources protection practice is a critical process for the realization of the established vision within the context of the proposed conceptual framework. The process is started by developing appropriate policies, and relevant policy implementation strategies. Indicators for compliance monitoring are determined and reporting on the state of water resources completes the process. Water resources protection of a particular catchment considers the current state of the water resource and defined ecological, societal, and economic

aspects that are dependent on the resource, and therefore the practice requires application of the resource–regulator–practitioner nexus. The nexus is advocated by polycentric governance (decentralized activities) which is characterized by responsibilities of various actors in water governance (shared responsibilities) where decisions are taken all levels/scales from local through national to international [133,134].

6.1.3. State of Water Resources

The state of water resources is the third key feature of the proposed framework. Human satisfaction, protection measures, and diagnosis carried out by physical, chemical, and biological characteristics provides an indication of a water resource state [135]. In this process, data generated from monitoring and information derived from such data are presented to the stakeholders and policy implementors on the state of water resources. The established state of water resources provides clues about changes brought by water resources protection activities and provides an indication of the effectiveness of policies developed and implemented to effect state of water resources. Accordingly, decisions are made based on the state of water resources to ensure that availability and demand for water are met, and the vision of the society is accomplished. Such decisions may necessitate review of policies, strategies, processes, and programs designed for water resources protection.

6.1.4. Policy Evaluation and Review Processes

The last key feature of the framework is policy evaluation and review processes. In this process, policy evaluation is applied at each stage of the process, and it becomes part of water resources protection processes where intermediate outcomes are evaluated and immediate actions taken to remedy situation. Policy implementation towards water resources protection needs to show results or needs to impact reinforcement or needs to address the desired goal or address the identified problems. Results-oriented monitoring has the capability to address identified problems linked to water resources protection and sustainable utilization because the focus is on the results of implementing the policy rather than the process of implementing the policy. The critical aspect of results-oriented monitoring is that shortcomings in policy practice are corrected in near real time using adaptive management practice. The authors of [136] argue that adaptive management is an iterative process in which practitioners test hypotheses and adjust behavior, decisions, and actions based on experience and actual changes.

7. Conclusions

Water resources protection plays a critical role in policy practice to mitigate water resources challenges and in mitigating social wellbeing. Such practice is central to sustainable water supply management for human wellbeing and for the ecological ecosystem to flourish. Appropriate implementation and monitoring of water resources protection practice has received much attention on the international agenda. Approaches such as results-oriented policy monitoring are seen as appropriate methodologies for monitoring policy implementation practice to assess policy impacts. It is argued that the approach moves beyond an emphasis on inputs and outputs to a greater focus on outcomes and impacts of policy practice. In this paper a review of literature in the subject of water resources protection was undertaken, and the review focused on both groundwater and surface water. The review reflected on the concept of water resources protection and provided insight on how such a concept is applied in policy practice globally, and locally. The review revealed that although much has been performed in terms of policy implementation for water resources protection, some challenges linked to policy monitoring are evident.

A conceptual framework was presented that can be used to facilitate the application of results-oriented policy monitoring for water resources protection in the South African context. This framework considers the vision for water resources protection and sustainable use, water resources protection practices, the state of water resources and policy evaluation,

and review processes as the key elements to drive success in policy monitoring for water resources protection practice. The proposed the framework can be considered as a reference guide that can be used to monitor policy practice for water resources protection by following a result-oriented monitoring approach.

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