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Groundwater governance for improving city water resilience in Cape Town, South Africa

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Until recently, Cape Town, South Africa's second largest city relied entirely on surface water for water supply. Low rainfall between 2015 and 2018 caused extreme water scarcity and water insecurity, even though the city is located on a number of significant aquifers. Water demand management measures instituted during the drought accelerated the transition to a decentralized, hybrid system. Groundwater played an important role in this transition, particularly for households, the bulk users of utility-supplied water. The current water governance and management is ill-equipped for the emergent hybrid system underpinned by an engineering approach that treats water narrowly as a resource for supply and use. This approach is problematic because it does not adequately consider water as one of multiple systems comprising the environment that supplies critical ecosystem services. Even though the City of Cape Town, as local government, effectively does not have a groundwater management role, its responsibilities for water and sanitation services, spatial planning, land-use management and environmental management all intersect with groundwater management. Significant water governance reform is therefore necessary for sustainable groundwater use and resilience in Cape Town and other South African cities.

KEYWORDS

water governance, groundwater, local government, Cape Town–South Africa, resilience

Introduction

Cape Town is located in Sub-Saharan Africa with unprecedented rates of urban growth creating significant challenges for spatial and utility service planners (Saghir and Santoro, 2018). Cape Town's own population growth is just under 2.57% but is expected to accelerate over the next 5 years with the addition of an estimated 400,000 residents to the current almost 4.7 million. Current service backlogs are expected to increase, exacerbating already constrained service provision. Whilst ongoing urban agglomeration in the global south presents opportunities for sustainable just transitions on the one hand, on the other, there is a heightened risk for those living in cities, particularly as climate change shocks and stresses increase in intensity and frequency. The unprecedented 1:590 year drought (City of Cape Town, 2019a) experienced between 2015 and 2018 that impacted the surface-dependent Western Cape Water Supply System (WCWSS) is a case in point. The National Department of Water and Sanitation (NDWS) as the regulator and raw water supplier, and the City of Cape Town (the water utility) introduced water restrictions as rainfall and dam levels dropped, in addition to a water conservation and demand management (WCDM) strategy–particularly focused on households who use 70% of the total water supply.

Cape Town is well-acquainted with drought. Water restrictions, coupled with WCDM has previously included small-scale groundwater use, first promoted in 2007 in the *Long-term Water Conservation and Water Demand Management Strategy* (City of Cape Town, 2007) and again in the Guidelines for the Installation of Alternative

Water Systems. The extent to which these documents encouraged uptake is unknown, but unsurprisingly, there were correlations between wellpoint and borehole registrations and Level 2 water restrictions during the twelve months between the end of 2004 and 2005 (Wright and Jacobs, 2016).

WCDM programmes' success limited the potential scope for further systems efficiencies in 2015. Daily usage nevertheless dropped by almost 50% (City of Cape Town, 2019a).

These dramatic reductions resulted in part from the adoption of alternative water[1] for non-potable uses, e.g., greywater for toilet flushing and the use of other water resources[2] such as groundwater for garden irrigation, which can account for up to 70% of a household's overall water usage.

As the drought progressed and "Day zero" became a potential scenario, households and businesses who could afford to, installed groundwater treatment systems to go "off grid" and self-supply both potable and non-potable water.

The water utility found itself in a difficult position. On the one hand, it required Capetonians to use water to generate sufficient tariffs to cross-subsidize poorer households, but on the other, resources were critically low. The added risk of household water treatment and associated health risks was a further reason the difficult decision was taken by the water utility to discourage groundwater treatment for domestic use[3], apart from large water users, e.g., businesses, who are permitted to treat groundwater to a potable standard *via* water services intermediary agreements[4] (City of Cape Town, 2010). Even though households are permitted to use groundwater for domestic purposes, those living in urban areas are required to receive water from the water utility, and it in turn controls access and use of non-utility supplied water. It follows that even if a household has a borehole, permission from the water utility is required for plumbing connections into a home and the borehole installation is subject to water utility inspection, regardless of the intended use.

Enforcing groundwater regulations is challenging in urban contexts. Its dispersed nature and general availability without the requirement for licensing is problematic, but secondary in impact to incoherent and ineffectual governance. The NDWS and water utility were poorly prepared for the unprecedented "boom" in well and borehole drilling. It created an entirely new crisis around information availability, mandates, regulations and procedures and enforcement. During this short crisis period it is likely that boreholes supplied groundwater for non-potable *and* domestic use. The extent of this household shift away from utility-supplied water is the subject of ongoing work at the water utility and is likely to be consistent with trends identified in the Africa Infrastructure Country Diagnostic Programme (Foster et al., 2020).

Regulatory uncertainty is rooted in national and local government responsibilities. Groundwater management precludes Schedule 1[5] (household) and General Authorisation[6] users, who until 2018, were not required to report on, or meter groundwater use (Wright and Jacobs, 2016). Despite the requirement for *borehole registration* for Schedule 1 use with both the water utility and NDWS, poor data management has exacerbated institutional and licensing transition failures stemming from a regime overhaul post-1994. The complete intended legal and institutional vision of that time has yet to be implemented, including for example the establishment of catchment management agencies (CMAs).

Measuring the extent of groundwater uptake is therefore difficult because the exact number of boreholes and wells, and abstraction rates is unknown[7]. Borehole ground-truthing by Wright and Jacobs (2016); Ramboll (2018) and more recently, the WWF (2021) however confirm that the number is greater than what is shown on the water utility or NDWS registers.

In the absence of accurate data, proxies such as income and property size have been used to determine borehole prevalence. Jacobs et al. (2011) estimate that between 2002 and 2003[8] (prior to specific water utility groundwater promotion) up to as many as 30% of homes with property areas >1,000 m^2 registered boreholes. Property size is an important indicator as there is often a correlation with property value (Hedden and Cilliers, 2014) and borehole affordability. Table 1 consolidates data and illustrates the exponential growth in boreholes between 2013 and 2019.

Large groundwater users, unlike Schedule 1 users who are required to register their borehole with NDWS and the water utility, must in addition to registration, procure a water use license before commencing abstraction activities. Water use license application processes have a 300-day timeline, but are known to take longer. For this reason, groundwater was a less viable option for large water users during the drought.

1 Alternative water includes groundwater, greywater, rainwater, swimming pool water, basement water, treated effluent and seawater.

2 Water resources are defined in the National Water Act (1998) and include groundwater, wetlands, rivers, stream, springs.

3 Domestic use is defined in the City of Cape Town (2010) as drinking, ablution and culinary purposes excluding toilets and urinals.

4 Water Service Intermediary Agreements were allow for supply of non-City water provided that it is supplementary or incidental to, for example a lease agreement. Appetite for these agreements is low and most will terminate in the near future, without the possibility for renewal.

5 Under Schedule 1 of the National Water Act water may be taken from water resources without a licence: For reasonable domestic use in that person's household, directly from any water resource to which that person has lawful access; For use on land owned or occupied by that person, for – Reasonable domestic use; Small gardening not for commercial purposes; and, The watering of animals (excluding feedlots) which graze on that land within the grazing capacity of that land.

6 A general authorization permits slightly larger groundwater use within set limits and conditions without a license, registration however required. It is permitted in certain catchments or aquifer systems and reduces 'red tape' by predetermining conditions for abstraction. In the event that groundwater use exceeds the limitations of the Schedule 1 Use and the General Authorisation, a Water Use License would be required via an application process and license issuance that includes conditions such as monitoring and reporting.

7 Detailed knowledge is limited to City-owned wellfields.

8 City water demand estimates between 2000 and indicate stable water demand, without and increase, despite population growth, urbanisation and nominal economic growth. While a correlation between the increase in boreholes by high water users and this phenomenon has not been directly established, it seems likely that it played a role.

TABLE 1 Summary of estimated boreholes (Kring, 2019).

Source	Number of boreholes	Total abstraction rate (Mm^3/a)
Wright (2013)	3,764	0.46
Ramboll (2018)	8,158	0.99
Jordan (2019)	26,000	3.16
Maximum theoretical abstraction DWAF (2018)		19.63

The water utility, like households and large water users, also explored alternative water sources. As an emergency response to the drought, initial explorations promoted expensive, small-scale desalination and not groundwater, despite previous bulk water supply success from the Atlantis Water Resource Management Scheme (AWRMS). Real and perceived water quality issues and management difficulties at the AWRMS may have influenced the City's initial decision against groundwater. Even though focus shifted to groundwater as the cost and technical implications of desalination became clearer, groundwater wellfields have only recently come online[9]. Going forward, groundwater has been included in the water utility's Water Strategy titled, *Our shared water future–Cape Town's Water Strategy* (the Water Strategy). By 2040, it will contribute 7% of total bulk water supply (City of Cape Town, 2019b).

Ensuring groundwater availability for bulk supply will however rely on data and management. Table 2 consolidates abstraction data from the literature and the water utility's City of Cape Town (2019b). Even though a water use license should create a level of certainty, in practice, monitoring is not undertaken and consequently, abstraction rates, particularly from the Cape Flats Aquifer are unknown, presenting the real risk of over-exploitation and resource degradation not uncommon in other African cities, e.g., Lusaka (Zambia), Mombasa (Kenya) and Douala (Cameroon) (Foster et al., 2020).

Water augmentation responses during the drought fundamentally changed Cape Town's centralized, bulk-dominated water system. Governing the emergent system–a hybrid with multiple scales, roleplayers and significant complexity–is a challenge because water governance is contradictory and does not sufficiently support this type of system.

Future role of groundwater in Cape Town

Once the 2015–2017 drought period came to an end, there were challenges in defining groundwater's future role in "normal" and drought scenarios. This section discusses three conceptual framings that connect to the need for urban resilience in the face of climate change; the importance of integrated water management (urban and natural) for resilience and groundwater sustainability; and the role of groundwater management in urban climate adaption.

City of Cape Town (2019b) includes aspects of resilience. Its vision is for a water sensitive city that "will actively facilitate the transition of Cape Town over time into a water sensitive city with diverse water resources, diversified infrastructure and one that makes optimal use of stormwater and urban waterways for the purpose of flood control, aquifer recharge, water reuse and recreation, based on sound ecological principles." Although the vision seeks to significantly improve water resilience, the role of non-City groundwater users in water supply and the City's role in groundwater management are not discussed.

"Resilience," a global philosophy and process, was gaining prominence at the time of the drought. It recognizes that urbanization, globalization, technological advancement and increasing economic and political instability exacerbated by climate change, expose cities because they are interconnected and dependent, to disruption from shocks and stresses. For this reason, a holistic, systems-thinking approach is needed that anticipates how stresses affect a city's ability to thrive and respond in moments of shock. "Urban" resilience therefore refers to the capacity of a city–individuals, communities, institutions, businesses and systems–to survive, adapt and thrive irrespective of the stresses and shocks they experience (City of Cape Town, 2019a).

Hybrid, decentralised water supply systems comprise systems that operate and are controlled at different scales by a variety of stakeholders who enable ongoing functioning and multiple water sources applied within a fit-for-purpose approach that prevents complete systems failure in the event of a shock or stress (Swilling, 2018). Groundwater, as highlighted during Cape Town's drought, is critical for water resilience because it provides system flexibility, adaptability, redundancy and natural buffering (Foster et al., 2020) that augments and protects the centralised potable water supply system.

The decentralised water system that emerged highlighted firstly, the importance of aquifers located within the city boundary that are separate from the WCWSS catchments located north-west of Cape Town (Figure 1), and secondly, the lack of monitoring and management of Cape Town's aquifers by the NDWS.

Increased domestic groundwater use, whilst beneficial for broader resilience, poses a threat to water utility infrastructure investments to improve water resilience because shifts to non-utility sources potentially reduce tariff incomes and present a challenge for investment recovery. It follows that whilst household groundwater use is important for water resilience, it may not be in the water utility's financial interests.

Conjunctive water management[10] is however in the City's interests because it optimises the urban water system controlled by the water utility. The AWRMS is an example that illustrates how integrated planning (spatial and water/sanitation systems) can manage the connections between surface water and urban systems. In Atlantis, stormwater collection and wastewater treatment are managed separately for industrial and residential areas. Separate treatment for different water qualities enables firstly, safe groundwater recharge by surface infiltration basins using both stormwater and treated effluent and secondly, saline intrusion management. Growing levels of informality and service planning challenges, particularly sanitation services, affect groundwater

9 Bulk supply from groundwater commenced from the Table Mountain Group in August 2020.

10 Conjunctive water management optimises urban (potable water, surface runoff and treated wastewater) and natural water systems (streams, rivers, springs, groundwater and wetlands) through holistic and integrated planning and management.

TABLE 2 Consolidation of groundwater abstraction volumes as per Ramboll (2018) and City of Cape Town (2019b).

Name	Storage	Managed aquifer recharge (MAR)	Estimate Mm^3/annum	City new water programme (NWP) -planned Mm^3/annum	Water use license (WUL)/schedule 1/general authorisation
All aquifers					
Ramboll (2018)		N/A	23		WUL
Ramboll (2018)			30		Schedule 1 (estimate)
Cape flats aquifer					
Department of Water and Sanitation (DWS) (2016)			9.1		
Ramboll (2018)			18		WUL
Phase 1 - 2020	100—150 ML	Yes		7.3	WUL
Phase 2 - 2021		Yes		9.1	WUL
Table mountain group aquifer					
Phase 1 – 2020		N/A		5.5	WUL
Phase 2 – 2022		N/A		5.5	WUL
Phase 3 – 2022		N/A		7.3	WUL
Atlantis					
Ramboll, 2018		Yes	5		
Atlantis - 2021		Yes		4	WUL

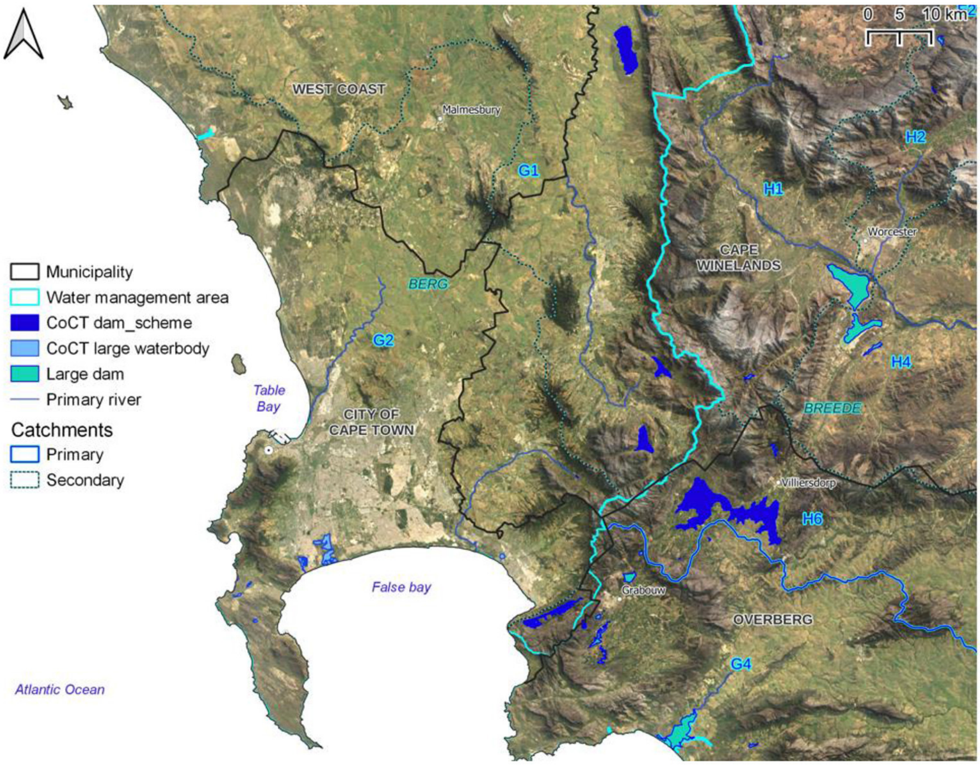

FIGURE 1
Map showing overlaps between water management areas, CMA areas and groundwater resources (specific to Cape Town's water supply); Source: Flugel (2021) from Faragher (2022). Cape Town is located within the Berg Catchment.

quality and increase treatment costs making it less viable for even non-potable uses. Heavily polluted stormwater from vehicle residues and ongoing power outages ("loadshedding") that cause pump station failures and sewer spills into rivers, wetlands and groundwater are further threats to groundwater quality. With the exception of energy, all these issues are within local government mandates.

The AWRMS is located in the Dassenberg Climate Corridor within the Ganzekraal Conservation Area and the Koeberg Nature Reserve (Cape Nature, 2019) that provide eco-services and amenity–and aquifer recharge. Nature reserves, public open spaces, wetlands, detention and retention areas and other undeveloped areas allow rainwater to infiltrate groundwater and therefore play an important role in groundwater recharge and quality. They also contribute towards liveability, biodiversity that supports and structures urban landscaping, providing recreation and amenity, heat amelioration, air quality improvement, and flood management. Considered in this way, aquifers are strategic assets for climate adaption and resilience beyond water supply, although their location underground protects water from trans-evaporation (International Association of Hydrogeologists, 2019) caused by climate change making them climate resilient, in addition to their climate adaption role.

Groundwater is an important part of water resilience, conjunctive water management and climate adaption and it is therefore important to understand governance as an enabler or inhibitor to groundwater inclusion in a hybrid, decentralised water supply system and importantly for cities, the potential role for local government.

Method

A desktop investigation was conducted to firstly identify governance issues that impede or support groundwater inclusion in a hybrid, decentralised water supply system; and secondly, identify the role of local government in groundwater management.

The issues identified through this process were reviewed for alignment and expansion against academic research papers, government reports, legislation, policy, strategy documents and other online sources. Interviews with relevant experts were conducted to verify and sense-check the review outcomes.

Results–towards a water resilient Cape Town

Governance is multi-dimensional comprising policy, legislation, institutional arrangements, strategies and plans, and management that results in infrastructure and services for households. Governance determines the structure, functioning and management of both natural and urban water systems; in addition to urban systems that affect water governance. This section considers the applicability of water governance for a hybrid, decentralised water supply system, and identifies issues and opportunities to determine if it is fit-for-purpose. Water governance includes policy, legislation and strategy; institutional arrangements; management and infrastructure.

Policy, legislation, strategy

Prior to colonisation and the introduction of Roman-Dutch law, water-use was regulated by customary rights (Kidd, 2017). At this time, water resources belonged to rural communities who used it for the common good as directed by traditional leaders. Colonial legislation emphasised private water rights linked to land ownership for use by the landowner (Lazarus, 1997). These rights were entrenched during the previous South African policy of Apartheid.

For example, the Water Act No.54 of 1956 (the Act) created groundwater categories–subterranean, public surplus and private water. "Subterranean water" was a special category of groundwater. The right to use and control this resource vested with the Minister. These subterranean government water control areas were subject to different allocation rules. "Public water," also subject to regulation, included groundwater and surface water. According to the Act, surface water would fall into one of two categories, either normal flow or surplus water. Despite groundwater's description as "public water" it became private water because it does not visibly flow and was therefore categorized as surplus water and was not directly regulated. Water pumped from boreholes was therefore private water and its use vested with the owner of the land upon which it was found (Lazarus, 1998; Kavin, 2000). The Act did not address the need for equitable access or groundwater resource management (Lazarus, 1997).

A legislative review commenced in 1994 in response to the shifting political landscape and led to the National Water Act No.36 of 1998 (NWA) wherein water is presented as a common good, de-coupled from land ownership. The implications of this were significant, particularly for South Africans living in rural areas who had limited, or no access to water. The NWA outlines institutional arrangements, roles and responsibilities for water resource management applicable to watercourses, surface water, estuaries and aquifers. In comparison, the Water Services Act No.108 of 1997 (WSA) was "new" legislation that enabled the devolvement of water and sanitation services (water services) to local authorities in turn created through other legislated processes towards the establishment of new, post-apartheid government structures. Even though the National Environmental Management Act No.108 of 1998 (January 1999) (NEMA) was promulgated after the WSA (November 1997) and NWA (August 1998), it is the overarching legislation. The natural water system is one of the ecological systems that comprise the environment that NEMA defines as:

"the surroundings within which humans exist and that are made up of—

(i) the land, water and atmosphere of the earth;
(ii) micro-organisms, plant and animal life;
(iii) any part or combination of (i) and (ii) and the interrelationships among and between them; and
(iv) the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and wellbeing"

Even though NEMA locates water within the environment, it is typically managed separately as per the NWA. The further division of water resource management (natural) and services (urban) contributes towards challenges starting with the delineation of catchments which is important because of the role that ecological integrity plays in surface and groundwater management.

Natural water systems are determined by surface water catchments that do not align with city boundaries. Emergent complexity therefore centres around the management of urban water resources located within local government areas. Who is responsible for catchment management? And resource management including abstraction and water quality monitoring; and aquifer protection and management? Technically, CMAs are responsible, but these are largely unformed, leaving management to NDWS regional offices.

Institutional complexity and potential conflicts of interest are inherent in this arrangement because it establishes the NDWS as the provider of strategic oversight, regulator and manager. Whilst the interim role may have been necessary at the outset of the new dispensation to enable the development of the desired institutional arrangements, the ongoing instability has particularly affected groundwater. The depth of these issues, in addition to the policy shortcomings in both water supply and resource management were highlighted during the drought.

Even though national level decision-makers' failure to lead and implement policies and strategies has been compounded by state capture and delayed governance maturation (SADC-GMI, 2019), given the contextual changes and evident short-comings, its appropriateness should be re-evaluated, particularly because it does not provide guidance for urban catchments that are modified by development and infrastructure.

Stormwater management and its role in integrated water management including groundwater, exemplifies these challenges. It is a proxy for "invisible" groundwater because of the direct, symbiotic relationship. As previously discussed, catchment management is a water resource management activity, but in the absence of a CMA, it falls to the NDWS. The water utility is however responsible for stormwater (surface water) management that incorporates rivers, wetlands and streams as "drainage" infrastructure. The two mandates are complementary, but differ. Catchment management is at a catchment scale inclusive of ecological considerations, water resource management and land-use and land management considerations, in contrast to the water utility's engineering-focused stormwater management that treats stormwater as waste and limits its role to ensuring drainage and flood prevention[11].

Until the drought, there had not been an urgent need to consider catchment management for supply because water supply is externalised to non-Cape Town catchments. This, combined with legislation and institutional separation appears to have negated the perceived importance of city-located groundwater resources and eroded the potential for integrated water management and urban water resources for use, thereby disincentivising urban water resource management.

Groundwater-specific policy is limited to a national level. It is inclusive of the *Policy and Strategy for Groundwater Quality Management in South Africa* (PSGQM) (Department of Water Affairs and Forestry, 2000); *Integrated Water Quality Management–Policies and Strategies for South Africa* (IWQM) (Department of Water and Sanitation, 2017) and the more recent *National Groundwater Strategy* (NGS) (Department of Water and Sanitation, 2017). These documents establish policy guidance, but offer limited local government direction, beyond 'local' action (National Department of Water and Sanitation, 2017) and are non-specific regarding implementation. For example, the PSGQM is comprehensive for water quality, but lacks detailed direction and guidance for groundwater abstraction and the control thereof (SADC-GMI, 2019) in addition to local government mandates within urban areas.

The IWQM establishes a framework for integrated groundwater management driven by water quality considerations. It further calls for stakeholders including government, civil society and the private sector to work together to develop a common vision for water quality management and joint approaches to solving complex catchment problems (Department of Environmental Affairs and Development Planning, 2018). Further policy development at a local government level is recommended, but progress appears modest towards the suggested systems-based, adaptive management approach. Local government policy analysis found that although groundwater-specific policy is only at a national level, the water utility has the highest aggregation of other related policy across multiple line departments, in addition to water and sanitation services. Groundwater resource management can therefore be effected through existing policy, e.g., environmental, urban development and urban systems. Groundwater for use is promoted for rural households or where it can contribute to domestic supply (bulk) in the *National Water Resource Strategy* (2) (Department of Water Affairs, 2013), the National Water and Sanitation Masterplan (Department of Water Sanitation Human Settlements, 2018) and the *National Groundwater Strategy* (NGS) (Department of Water and Sanitation (DWS), 2016). The latter emphasises a bottom-up approach with government and civil society jointly developing and managing groundwater resources with civil society acting as the champion and watchdog. The NGS sets out the long-term pathway for this system within the context of a groundwater governance framework. Guidance for managing systems' complexity particularly in urban areas; and direction on "local action" implementation (i.e., by local government) and urban household groundwater use–is lacking (Figure 2).

It is significant that the NWA and NGS do not define the role of groundwater in rapidly urbanising South African cities' water supply. It is unclear if a scenario inclusive of multiple boreholes in close proximity located in serviced areas and used for household purposes was considered in the policy conceptualisation given that urban households have the same access as rural households.

Domestic water users access groundwater directly from aquifers and circumvent formal processes and regulations. This use is currently un-measured and unmanaged (World Bank, 2021) because monitoring is largely voluntary, even though registration and abstraction reporting is a recent legal requirement (Department of Water and Sanitation, 2017). Data is consequently unavailable to determine the aggregated impact on aquifers. The focus on large water users therefore presents a challenge to establishing and managing an integrated, complex hybrid system

11 In addition to stormwater management, the City also manages the bulk groundwater wellfields.

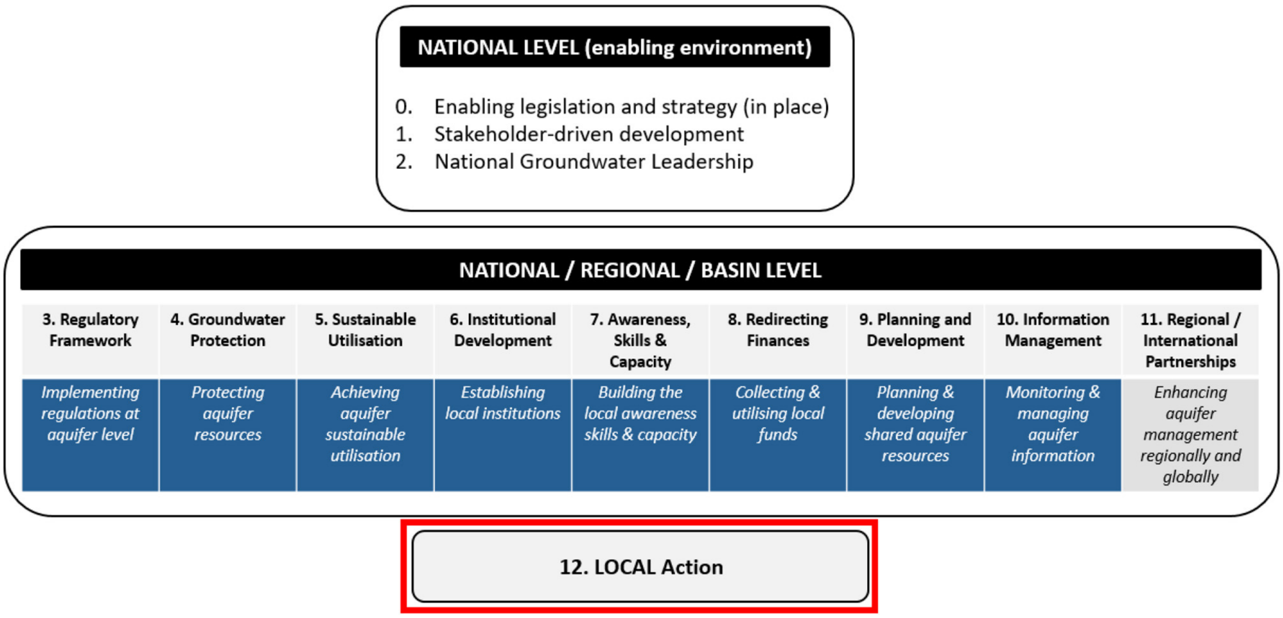

FIGURE 2
Groundwater Governance; Source: National Department of Water and Sanitation (2017) highlighting "local action".

comprised of large and smaller water users. This will leave both the water utility and private users vulnerable (World Bank, 2021), especially in the event of another water crisis where groundwater is seen as a last resort. Data unavailability is an outcome of the broader issues, which as discussed, are also systemic and governance-rooted.

Whereas, the legislative and institutional separation within water governance of resource management (outside urban areas) and water services (infrastructure in urban areas) may have been expedient for water services delivery to rural areas, the lack of nuance, appropriate governance and institutional implementation pose risks to urban groundwater sustainability and natural systems' health. Positively, it has enabled a desirable transition towards a hybrid, decentralised system, but the absence of data limits management–further compromising sustainability.

It follows that a change in context and system requires governance that responds to the new needs to support systems (natural and urban water systems) for sustainability and resilience. Changes that include combining the NWA and the WSA into a single legislation as recommended in the *National Water and Sanitation Masterplan* (Department of Water Sanitation Human Settlements, 2018) would enable greater natural and urban water cycle integration, integrated water resource management and conjunctive management. Changes to local government bylaw reforms, classification and processes for Schedule 1, General Authorisation, Licensing and Compulsory Licensing to enable administrative efficiency and effectiveness, would further improve management.

Governance challenges for this emerging system lie in the complexity that arises from the co-location of natural and urban water systems, which creates a variety of water types and interfaces not considered in existing governance and legislation; for example, basement water and brines. Cape Town's wastewater treatment works (WWTW) are not designed with complex water systems in mind; e.g., to treat high levels of brine or to cope with low flow levels. Increased household-level treatment of alternative water sources (groundwater and seawater) and incorrect disposal of brine from the treatment process during the drought added unplanned loads to WWTW and affected treatment processes[12]. Increased hybridisation must therefore consider the full water cycle, including wastewater reticulation and treatment. Designing and managing the water system (urban and natural) holistically as an integrated system inclusive of different urban water sources, such as treated effluent and surface water–can enable conjunctive management.

As previously discussed, the legislated separation of water resource management and services has implications for stormwater. "Basement water" is groundwater derived from basement dewatering and it is similarly affected. Defined as incidental to an activity (dewatering), it is in essence groundwater. The general authorisation guiding the disposal of dewatered water refers to mining and defines water found underground as "water that enters mine workings, basements, tunnels or other construction through seepage or runoff that does not refer to water found in an aquifer" (Department of Water Affairs, 2013). How this water differs to aquifer water is unclear. It is conceivable that non-aquifer water is used in mining activities, it is less evident how water from dewatering of basements, tunnels or other construction activities undertaken below ground is not groundwater. Officials in both the water utility and NDWS agree that basement water is

12 WWTW failures causing the discharge of incorrectly treated wastewater and damaged sewage reticulation pollutes groundwater resources and damages aquatic ecosystems. These issues have gained prominence and are now addressed in the City's Inland Water Quality Improvement Programme.

most likely to be aquifer water but suggest that it may be treated as waste on account of it having passed through a structure.

Basement water occurs across the city and until the drought was typically disposed of as wastewater into the stormwater system, as per the regulations. For this reason, it was not considered for use and integrated into potable and non-potable supply systems.

Conceptually, a basement is not dissimilar to a borehole, it is only the dominant function that differs. They nevertheless intercept aquifers and streams that traverse the city. The integration of basement water into urban supply systems optimises the resource that would otherwise be disposed of. Many of the buildings with basements are located in dense, urban environments and have limited landscaping and single water supply systems. Greatest optimisation has therefore relied upon treatment to potable quality and use *via* a WSI agreement, to avoid the need for a dual system. Had buildings been designed with dual systems[13], supply to toilets could have been accommodated without treatment because toilet water does not have a determined quality. Variable water qualities discharging into the wastewater system can however be an issue, because wastewater treatment works have design specifications that may not accommodate significant fluctuations, again emphasising the need for integrated water system planning and management for conjunctive use.

The designation of basement water as waste, whilst questionable, enables use, compared with groundwater (a water resource) that would trigger a water use licence application (WULA). The water utility was however willing to enter into a WSI agreement provided that a water use licence application had been made.

Since the drought, there has been a policy shift away from private water services providers and those who have been operating will be required to reconnect to the water utility supply when the WSI agreements conclude. In the absence of treatment and separate supply to toilets for flushing, landscaping is the only permissible use for untreated basement water. It is therefore likely that basement water, surplus to landscape irrigation requirements, will be disposed of. It follows that basement water treatment infrastructure, similar to groundwater treatment infrastructure, will become redundant.

For WSIs who invested in treatment plants and engaged in monitoring and testing contracts during the drought, this decision has been difficult. Financial sustainability of these systems is usually only reached after a few years and for some, this may not be achieved within the drought timeframe. Re-commissioning at a later date will also incur costs. Even though this decision does not affect domestic non-potable water users using groundwater, it nevertheless consolidates the water utility's role as water service provider and eliminates parts of the emergent hybrid, decentralised system. Understandably, the water utility's position has been affected by its obligation to recoup infrastructure investments necessitated by the drought. The loss of source and scale diversification is likely to reduce resilience and cause reputational damage amongst partners whose investment and support played an important part in the Cape Town's drought response.

This example illustrates the complexity of water governance that emerges in urban areas and the importance of considering governance across all scales, interrogating professional responsibility (architects, engineers, landscape architects), design standards and associated regulations and guidelines. Decisions taken during planning and design phases can affect a system's flexibility and adaptability and taking strategic decisions early in a project is therefore important to enabling groundwater use and recharge potential using sustainable urban drainage.

Institutions and management

Natural and urban water systems' integration requires management integration–especially of groundwater management priorities–horizontally and vertically within policy and institutional arrangements. This is inherently more complex and creates institutional complexity and multi-dimensional intersections between natural and urban water resources; and environmental and land-use management mandates–falling not only across spheres of government, but also internally between and within directorates and departments.

Policy, legislation and strategy are governance foundations. Their efficacy and impact is however dependent upon management and institutions for implementation. Organograms indicating management structures are therefore important tools for understanding implementation intent and should reflect an understanding of water systems and groundwater management complexity within urban catchments. To effect water resource management, local government institutional arrangements would need to consider broader management and co-ordination beyond the metro boundary; their urban catchment management role and water utility responsibilities for Schedule 1 and General Authorisation user management.

The NWA proposes institutional arrangements, supported by the WSA. Lack of implementation of for example CMAs has created difficulties leading to iterations that are intended to remedy, but further deviate from the original intent, creating other difficulties in the process. Key omissions are the overarching role of environmental management, municipal users, groundwater users, management partners, and inter-catchment co-ordination, particularly significant in the absence of CMAs, leaving this responsibility to NDWS and locking them into long-term roles originally intended to enable transition.

The interconnected nature of water is such that contextualisation within the water system (both urban and natural) and other contributing systems is critical to ensure overall coherence, connectivity and water health. The proposed institutional arrangements do not do this, nor do they reflect a systems approach.

Figure 3 illustrates the full scope of water resource and supply management in Cape Town including potable water users and groundwater users (licensed and unlicensed). Catchment management forums (CMF), provided for in the NWA, accommodate stakeholder involvement. The City established two CMFs–the Sand River and Hout Bay CMFs to support their work, although at this time their work does not include

13 Dual reticulation water supply is not a building compliance requirement and most toilets are therefore flushed with potable water.

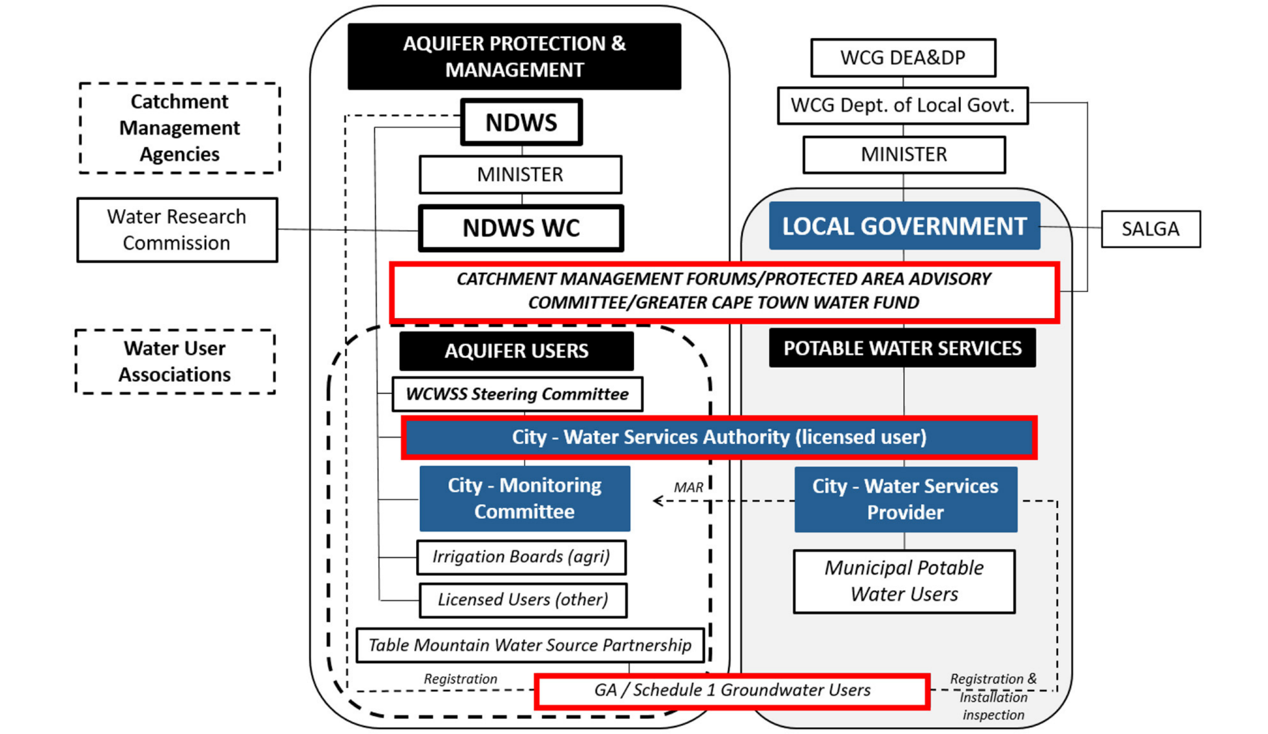

FIGURE 3
Current structure showing Institutional arrangements and partners for Cape Town's water system; SALGA refers to South African Local Government Association.

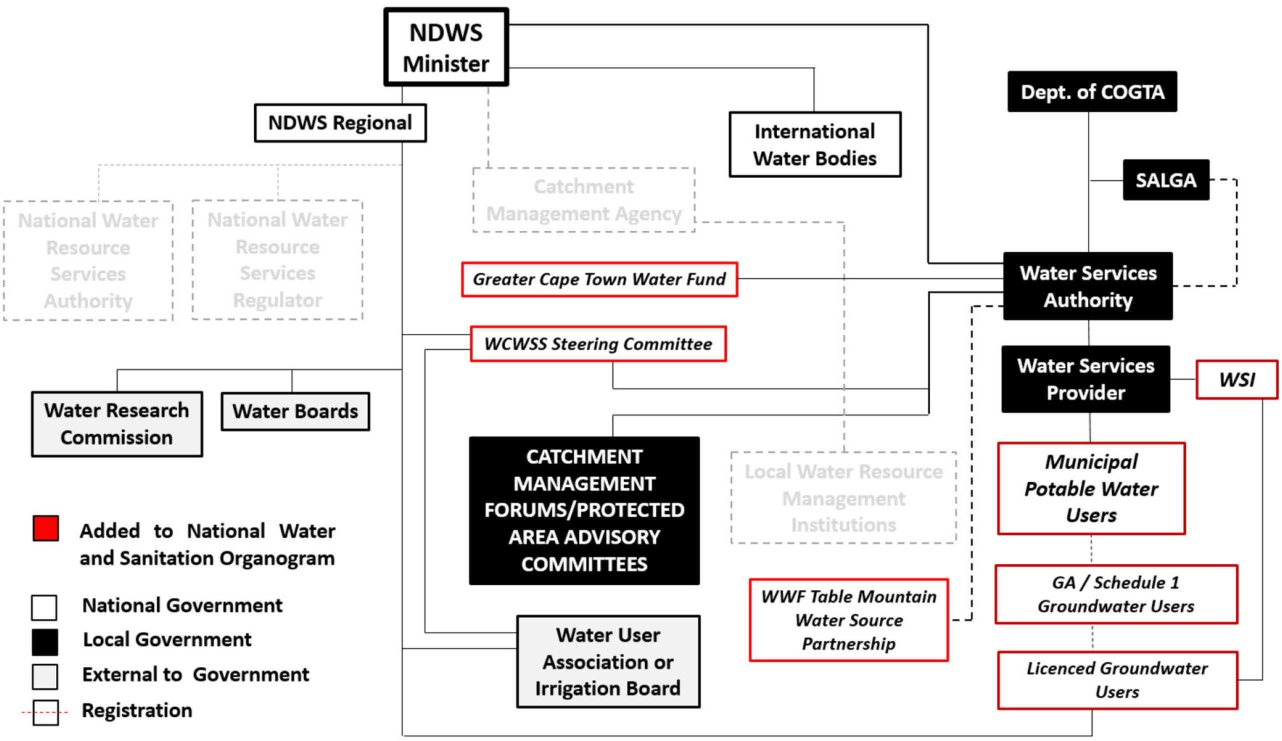

FIGURE 4
Water Management Institutional Status Quo for Cape Town illustrating overlaps between aquifer protection and management, aquifer users and potable water services; Source: Faragher (2022). Dept. of COGTA refers to the Department of Cooperative Governance and Traditional Affairs.

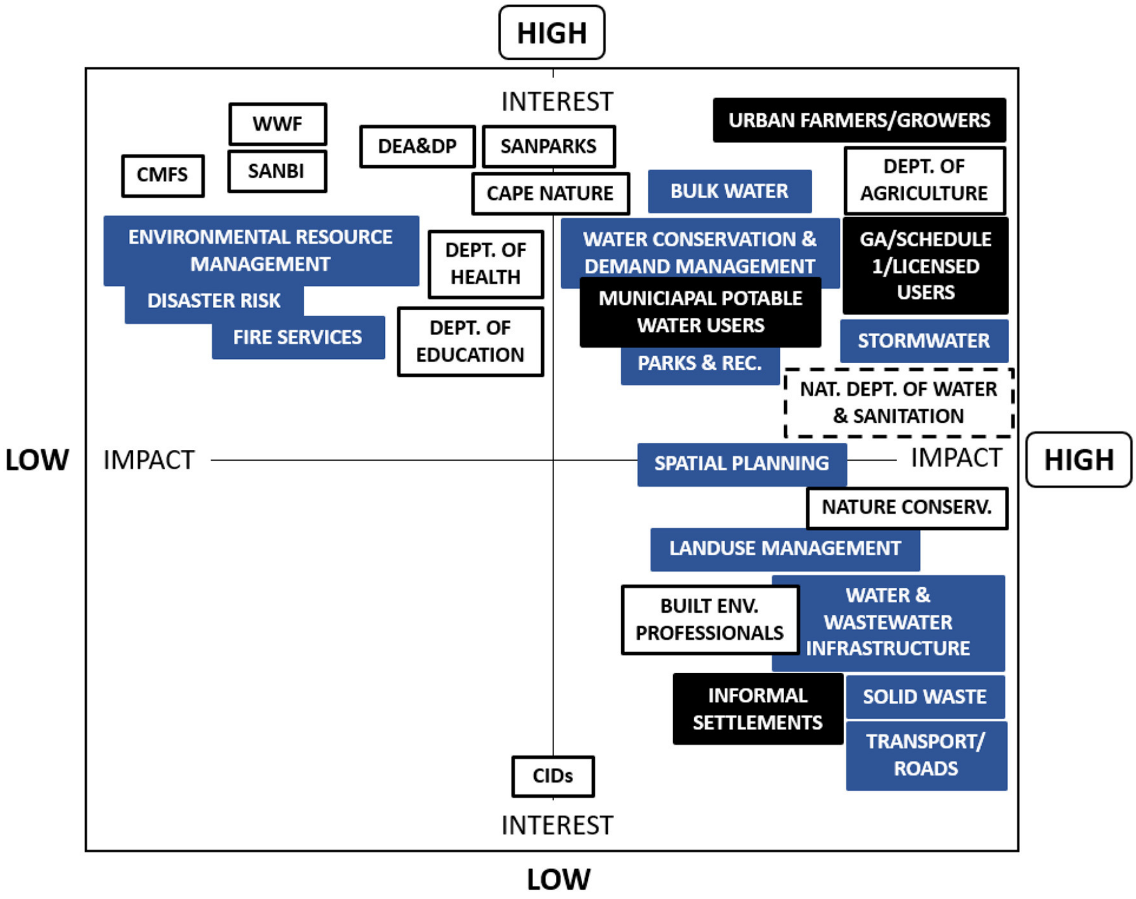

FIGURE 5
Stakeholder mapping adapted from National Department of Water and Sanitation (2017); Source: Faragher (2022).

groundwater user management but has the potential to. Other partners include the Greater Cape Town Water Fund and Table Mountain Water Source Partnership specifically for gathering groundwater data for monitoring.

Figure 4 illustrates aquifer protection and management, and aquifer users as a collection of institutions and activities alongside those associated with potable water services. This graphic arrangement allows for the identification of overlaps and illustrates how the City has assumed a NDWS role by supplying groundwater for bulk water supply. Similarly, Schedule 1 and general authorisation users who treat groundwater to potable quality (even though the City's Water Bylaw limits self-treatment) assume a local government water services role. This hybridisation–borne out of necessity in response to drought–is not contemplated in the legislation framework and is largely absent from the institutional framework, resulting in unforeseen roles and responsibilities. The source diversification and multi-scale supply generating these new roles and responsibilities are significant because it builds resilience and augments municipal, potable water supply, increasing municipal potable water availability (Wright, 2013; Kring, 2019).

As previously discussed, local government and therefore the water utility, are not responsible for groundwater management. The water utility's groundwater management role is defined in the water use licence conditions and is limited to their wellfields. This position however appears to be misaligned with the NGS and pre-existing governance. Nevertheless, investigations of local government mandates in relation to groundwater resource management found that many activities–because they are localised–lie within local government mandates (National Department of Water and Sanitation, 2017). The *Water and Sanitation Masterplan* (Department of Water Sanitation Human Settlements, 2018) supports this view and identifies the need for local water resource management institutions. The NGS further refers to local action. The *National Climate Change Response Policy* (National Department of Water and Sanitation, 2017) builds off the municipal obligations as identified in the Constitution and emboldens them to build and implement a comprehensive set of climate adaption measures in order to ensure the safety and sustainability of residents and the local environment within its boundaries. These measures would apply to groundwater governance and management because of its critical resilience role (Taylor et al., 2016).

Figure 5 maps groundwater stakeholders, including local government departments. It illustrates the importance of groundwater to bulk water, water conservation and demand management, parks and recreation and stormwater management. In contrast–spatial planning, land use management, water

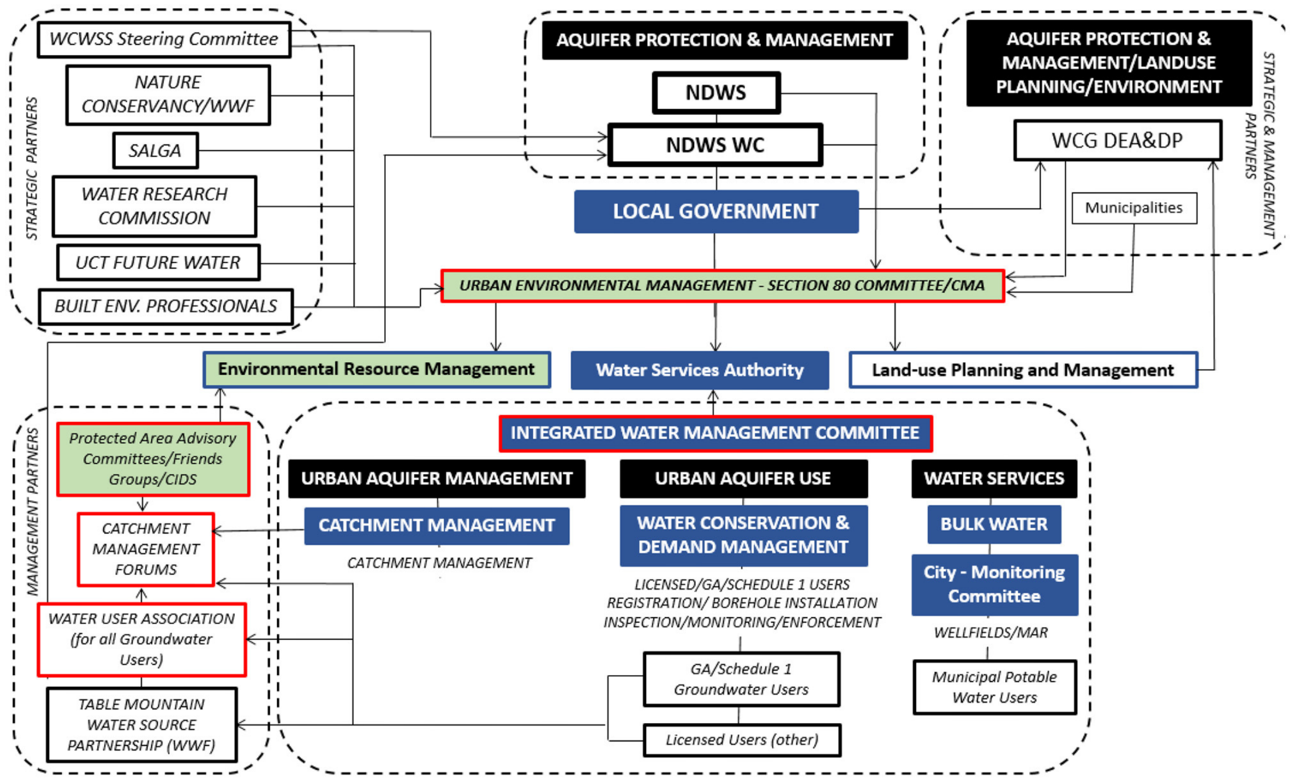

FIGURE 6
Proposed institutional arrangements; Source: Faragher (2022).

and wastewater infrastructure, solid waste management and transport/roads–that have a high impact on groundwater, are shown to have low interest because their contributing role to groundwater recharge and water quality is less relevant. City departments' activities typically occur separately, even though they may overlap or affect each other, adding further complexity to already complex systems made more so by development and infrastructure modifications.

Many of these activities and mandates are consistent with groundwater protection activities. Operationalising these mandates using an environmental approach through grey, blue and green infrastructure can affect improved surface and groundwater management.

An environmental approach considers the effects of decisions on all aspects of the environment, including people, when selecting the best practicable environmental option (Department of Environmental Affairs, 1998).

Groundwater management's success lies within the ecological functioning of blue-green systems and their integration with urban systems. An environmental approach using systems thinking, integrated transversally across multiple City departments responsible for both urban and natural systems, is thus best enabled for groundwater management. Because the DWS mandate is currently limited to water and sanitation services, it is suggested that the City Department of Environmental Management assume the leading role in managing groundwater *via* an Urban Environmental Management Committee (Figure 6). This is an option until such time as a CMA is established and even then, the City should lead because of the dominance of its mandates within the metropolitan area and localised proximity.

Groundwater protection

An environmental approach includes groundwater protection and management as described in the NGS. Protection is described as pollution prevention and remediation, both local government activities (Riemann et al., 2012) and includes protecting the aquifer from water quality deterioration, aquifer recharge reduction, and rehabilitation with respect to water quality. As previously discussed, the DWS currently conducts these activities only in relation to their wellfields. This section identifies alternative policy opportunities for groundwater management by local government in spatial planning, non-groundwater specific water policy, environmental and climate adaption policy and strategy.

Pollution prevention can be achieved through groundwater protection zones *via* spatial planning policy and regulations. These include the City's Integrated Development Plan (IDP) that outlines the City's 5-year priorities. The Metropolitan Spatial Development Plan (MSDF) and district plans direct and control land-use in support of these priorities regulated *via* the Development Management Scheme and Planning Bylaw. Groundwater protection is possible for undeveloped areas, but is more challenging within existing, developed areas. Detailed explorations that outline trade-offs are needed to guide the preparation of protection zones within developed areas and areas that have latent development rights.

Water-specific policy is prepared to support the IDP and the MSDF. It commences with the Water Strategy, Water Sector Plan and Water Services Development Plan (WSDP) that inform asset management and maintenance plans for water and wastewater infrastructure. The Urban Stormwater Impacts Policy; Floodplain and River Corridor Management Policy and the Stormwater Management By-Law (2005) are significant for effecting sustainable urban drainage and water quality objectives. They also have groundwater protection potential, but at present do not integrate the water cycle, support groundwater recharge/management or promote conjunctive water use. Overarching catchment policy is further needed that contextualises both surface and groundwater within the natural and urban environments for the further development of catchment management strategies and river corridor plans inclusive of groundwater protection and management. Whilst the policy framework is a necessary starting point, it must be supported by reporting. At present, rivers and wetland[14] reporting is *ad hoc*, focuses on water quality and does not include aquifers or water use, i.e., it is not integrated.

Even though groundwater management is largely lacking, Cape Town's aquifers have a level of protection because they are located beneath agricultural areas or nature reserves, such as the Philippi Horticulture Area, Table Mountain Nature Reserve and Koeberg Nature Reserve. Cape Town's Environmental Management Strategy; Environmental Management Programme; Biodiversity Strategy; Local Biodiversity Strategy and Action Plan; and Green Infrastructure Programme are therefore important for both groundwater protection and pollution prevention.

The connection between grey-blue-green systems and aquifer protection is not explicit in water governance because of the separation of 'water' from environmental and urban management. Conceptualising blue-green systems as integrated systems, foundational to groundwater management, shifts the emphasis from the systems' individual components towards the system as a whole, creating potential for systems' connectivity and improvements towards increased eco-service delivery needed for resilience, climate adaption and liveability. Using groundwater protection as a spatial structuring informant *via* groundwater protection zones in the metropolitan spatial development framework and district plans can direct spatial development decisions and inform design projects, whilst supplying resilience dividends. Groundwater recharge is however threatened by re-zonings for urban development and rapidly growing informal settlements, insufficient solid waste and sewage services, and infrastructure maintenance that cause pollution. The inclusion of groundwater protection zones for the Cape Flats Aquifer (CFA) in the City's current draft district plans, is however a significant step towards groundwater protection for the CFA wellfields but has limited value for other aquifers in developed areas. Integration of protection zones into development management processes and capacity-building for informed decision-making are necessary next steps towards deeper institutionalisation and operationalisation.

Groundwater (utilisation) management

A number of legislated reporting requirements offer other opportunities for a local government groundwater resource management role. The City is a Water Service Authority and must therefore prepare water services development plans (WSDPs). Water and sewage service reporting and planning forms the bulk of the City's WSDP. Current reporting is limited to bulk potable water supply and will include bulk groundwater. The Water Bylaw (City of Cape Town, 2010) requirement for written permission to use a non-City water source however indicates an interest in non-bulk sources. This data could be inputted to management processes. In addition, and possibly aligned to resource management is the requirement to provide details of existing and proposed water conservation, recycling[15] and environmental protection measures.

The City promotes an "aggressive approach to conservation as well as fast-tracking the exploitation of the most economical alternative sources such as groundwater" (Department of Water and Sanitation, 2017), consistent with the City's WCDM that promotes local boreholes for small consumers (City of Cape Town, 2007). It follows that because small consumer borehole use is part of the City's Water Conservation and Demand Management Strategy it would be included in WSDP reporting, as per the WSA. In addition to this reporting, the NGS proposes adjustments to Blue Drop[16] reporting to include a groundwater assessment as part of an overall strategy to improve local groundwater management. It follows that the water utility has a responsibility to report its own groundwater use–and General Authorisation and Schedule 1 users. Mechanisms for this reporting are available in the City's Amended City of Cape Town (2010) that requires borehole/wellpoint registration inclusive of installation details and an onsite inspection.

Schedule 1 and General Authorisation groundwater use is not contingent upon City-registration and despite the Water Bylaw requirements (2018), borehole data is still limited. Groundwater management shortfalls emerged strongly during the drought and led to the establishment of the Table Mountain Water Source Partnership, led by the WWF. Ongoing work includes borehole ground-thruthing and the establishment of a monitoring network.

14 The *Water Quality of Rivers and Open Water Bodies in the City of Cape Town* was completed in 2020 by Liz Day, Dean Ollis, Tumisho Ngobela and Nick Rivers-Moore.

15 Recycling refers to the use of treated effluent for potable and non-potable purposes. It is an important component of aquifer management and is used for recharge e.g., Atlantis Aquifer Management Scheme. Wastewater planning and management consequently has an integral role in conjunctive management for sustainable groundwater use.

16 Water service providers are required to undertake external Blue Drop reporting on an annual basis. The purpose of the reporting is to promote good practice in water service provision. Green Drop reporting similarly pertains to wastewater treatment works.

This work, combined with the City's hydro-census will establish a more reflective database of boreholes to enable management necessary for sustainable use.

Conclusion

While South Africa's water governance is location specific, Cape Town's challenges and adaptions during the 2015–2018 drought are likely to be of interest to other cities located in water scarce areas, as they explore water resilience options.

The city's transition to diverse sources and a decentralised, hybrid water system occurred out of necessity in response to the drought and groundwater played an important role, particularly for households. Greater knowledge of alternative water options, including groundwater, enabled the short-term shift to different water sources thereby meeting the WCDM strategy objectives and progressing Cape Town towards the longer-term strategic goal of water resilience and a water sensitive city. The system that emerged, comprised of multiple sources and users fulfilling overlapping roles, whilst ultimately desirable, is not considered in current conventional water governance.

The water system's appearance and operations are policy, legislation and strategy-derived. It is the outcome of a process undertaken within a context and consequently reflects decisions taken within a technical, budgetary and political context. South Africa's water governance is emblematic of this with the current paradigm strongly informed by the country's political history.

The conundrum the water utility faces, is that even though groundwater use is critical for WCDM, particularly during droughts, it is not beneficial to the water utility in non-drought times when water supply is adequate. These two competing interests are at the centre of local government ambivalence to groundwater and other alternative water sources. Irrespectively, managing groundwater is in the interests of local government to secure their own supply and enable ongoing non-potable domestic supply that augments potable supply.

In conclusion, even though the NDWS has been historically responsible for groundwater management, many non-water-specific City mandates overlap with groundwater management activities and responsibilities in addition to those applicable to water supply. A systems approach that considers water as a system integrated with other systems, importantly as a part of environmental systems, enabled the identification of strategic intervention areas and levers within existing City mandates, beyond those associated with water supply.

The systems approach furthermore highlighted the potential of groundwater to enable better water management throughout the water cycle and build broader systemic change and resilience, climate adaption, liveability and urban health. South Africa (and Cape Town's) water governance is however based on an engineering approach that treats water as a resource for supply, ill-equipping it to realise the future role of groundwater. Significant water governance reform is therefore necessary.

Author contributions

TF conducted the research and wrote the paper with support and editing by KC. All authors contributed to the article and approved the submitted version.

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TF is an official at the City of Cape Town. Her work during the drought included alternative water research that highlighted groundwater water governance issues. An opportunity arose in 2020 to focus more deliberately on groundwater governance and culminated in a report titled; *Sustainable Groundwater Management: A Framework for Local Government* (Faragher, 2022). The research conducted for this report was supervised by A/Prof Kirsty Carden as part of the MISTRA Urban Futures Writing Partnership and has formed the basis for this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Glossary

AWRMS Atlantis Water Resource Management Scheme
CFA Cape Flats Aquifer
City/CoCT City of Cape Town
CMA Catchment Management Agency
CMF Catchment Management Forum
Dept. COGTA Department of Cooperative Governance and Traditional Affairs
IDP Integrated Development Plan
IWQM *Integrated Water Quality Management Policy – Policies and Strategies for South Africa*
MSDF Metropolitan Spatial Development Framework
NEMA National Environmental Management Act
NDWS National Department of Water and Sanitation
NGS National Groundwater Strategy
NWA National Water Act
PSGQM *Policy and Strategy for Groundwater Quality Management in South Africa*
Water Utility City of Cape Town Water and Sanitation Department
WCDM Water Conservation and Demand Management
WCWSS Western Cape Water Supply System
WSA Water Services Act
WSDP Water Services Development Plan
WSI Water Services Intermediary
WULA Water Use Licence Application
WWTW Waste Water Treatment Works