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Research paper

Investment models for the water infrastructure value chain in South Africa: investment measures, needs and priorities

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South Africa has a serious backlog in investment for the development and management of water infrastructure. This study aimed to assess the investment measures, needs and priorities for water infrastructure (engineering realities) through the following objectives: (i) the measurement of water infrastructure investments which demonstrate the budgets required; (ii) understanding the current water infrastructure investment needs and priorities, including benefits and limitations; and (iii) the principles and characteristics for alternative and/or innovative measures, sources and/or models for water infrastructure investments and the envisaged effects. The range innovative of investment models for water infrastructure needs in South Africa are wide, i.e., 15 models were identified depending on the project type and overall transaction costs. The existing public provision model continues to characterise much of the water infrastructure investment in South Africa. The research determined investments in strategic water infrastructure systems over more than 20 years (1998/99–2019/20). The correlations between the three investment measures (as share of GDP) were generally negative and not significant, except for between GFCF(GG) + PPI and GFCFCE) + PPI, which was highly significant. Total water infrastructure investments constituted only 0.35–0.74% of GDP for the last ca. 20 years and 3.97–14.35% of total infrastructure investments. The results identified under-investment estimated at 54.023 billion ZAR for the medium-term expenditure framework (MTEF) period of 3 years.

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INTRODUCTION

South Africa is facing many significant engineering, economic and investment (funding and financing) challenges in relation to its water infrastructure value chain, both at resource level and in the provision of water services (DWAF, 2004, 2007, 2008; WB, 2010; DWA, 2013; Ruiters, 2013, 2020; Ruiters and Amadi-Echendu, 2020, 2022; AfDB, 2018; DWS, 2018). Water management institutions which have served South Africa well in decades past now appear unable or ill-equipped to cope with the current water infrastructure planning and service delivery challenges. The sustainability of the water infrastructure value chain is also at risk due to poorly maintained, poorly operated and often ill-equipped infrastructure, general under-pricing of water uses across the water infrastructure value chain, and the deteriorating quality of wastewater and sanitation services in many municipalities (DWS, 2018; DCoG, 2021). Thus, South Africa acknowledges water as a strategic resource under threat and requiring more astute development and management (DWA, 2013; WEF, 2018; DWS, 2018).

The public sector has predominantly funded water infrastructure in South Africa, a paradigm which assumes the state has adequate capacity to either finance, develop and/or operate water infrastructure. As this is not currently the case, there is now promotion of the primacy of private finance, with the appropriate pricing mechanisms providing incentives and signals for water infrastructure investments, i.e., private market model. However, these approaches have not succeeded in generating the flow of appropriate investments to adequately meet water infrastructure needs in South Africa.

Addressing the water infrastructure backlogs and deficient capability warrants immediate attention if South Africa is to build upon, and secure, economic growth and productivity gains. The first task is to overcome the highly visible and well-documented backlog in existing water infrastructure. The second task is to establish new, forward-looking, and resilient institutional frameworks to facilitate timely water infrastructure investments by integrating the full range of strategic planning, management and technical expertise. The framework for water infrastructure investment models must be designed to meet the challenges presented by the current and growing imbalances that exist between water supply and demand (DWA, 2013; NPC, 2013; PICC, 2013; DWS, 2018; DCoG, 2021; DPWI, 2022).

This research studied the key determining factors that have contributed to successful investments in the water infrastructure value chain of South Africa over the past 20 years. However, in the post–1994 period of South Africa, there have been growing demands on water infrastructure. The investment measures, needs and priorities for water infrastructure (engineering realities) development and management were assessed using the following research objectives:

- The measurement of water infrastructure investments, which demonstrate the budgets required
- Understanding the current water infrastructure investment needs and priorities, including benefits and limitations
- The principles and characteristics for alternative and/or innovative measures, sources and/or models for water infrastructure investments and the envisaged effects

METHODS

Data collection

Primary data were collected through quantitative and qualitative methods through the purposive sampling method (Creswell, 2013; Ruiters, 2020). Data were collected in the period 2016–2020 (Ruiters, 2020), from public sector institutions, private sector institutions, multilateral financial institutions (MFIs), water management institutions or regulatory agencies/institutions, local government, technical assistance providers, and official development assistance (ODA); the sample size included 425 interviews. Secondary data were collected from reports relating to water infrastructure needs and funding in South Africa from case studies, annual reports, databases, research reports, theses, etc., for the past 20 years, i.e., analysis for water infrastructure investments for 1998/99–2019/20 including by the private sector (Table 1). Revenue streams, local debt, expenditure, etc., relative to funding for water infrastructure, were reviewed.

Data analysis

Financial analysis of the water infrastructure value chain

Financial analyses for the water infrastructure value chain included capital investments such as: (i) investment (capital) needs: (ii) planning for financing the costs, i.e., funding the sources; and (iii) budgets required for operations and maintenance (cf. Goodman and Hastak, 2006; OECD, 2010a; WB, 2010; Tyson, 2018; Hahm, 2019; Rozenberg and Fay, 2019; Verougstraete, 2019; Ruiters and Amadi-Echendu, 2019, 2020, 2022).

Investment and capital stock data from 1998/99 – 2019/20 were used for the following measurements (Table 1):

(i) **Measure 1: Budget spending on water infrastructure plus PPI or Budget + PPI** – total water infrastructure (budget expenditure and private participation in water infrastructure (PPI) for water infrastructure investment (both new and maintenance) were included, i.e., national programmes, sub-national programmes, water agencies and utilities/boards (SOEs) and actual and/or planned (needs).

(ii) **Measure 2: General government GFCF plus PPI or GFCF + PPI** – adding private sector investment as part of the share of GDP and GFCF(GG) gave the value of GFCF(GG) +PPI, i.e. total water infrastructure.

(iii) **Measure 3**: GFCF on construction excluding buildings or GFCF(CE) – mainly civil engineering works, measure of water infrastructure investment but can either over- or under-estimate actual investments.

Statistical analysis

Regression models were used to analyse relationship between investment (funding and financial) regression variables (dependent variable) or response y that depends on k-independent variables with the determination of r as the (Pearson product-moment) correlation coefficient (Gioia et al., 2012; Creswell, 2013). Simple regression was used to determine the relationship between single regression variable x and response variable y for the constitution of the investment's correlation matrix as a measure of association between two measurement variables.

Table 1. Data sources, availability and coverage for water infrastructure investments and alternative measures of water infrastructure investment for the sampled period 1998/99–2019/20 in South Africa

Measurement	Sources	Description	Covered Items	Items not covered
1. Budget spending on water infrastructure (NRF)	Budget offfice and public finance (NRF) (NT, 2019a, 2019b, 2019c).	Capital expenditure in water infrastructure made by government. Infrastructure investment by state-owned-enterprises (SOEs) using budget transfers.	Capital expenditure by government in chosen infrastructure, e.g., water infrastructure.	Capital spending by SOEs using self-raised funds are typically not covered in budget data.
2. Gross fixed capital formation for general government GFCF (GG)[1]	National accounts (cf. Stats SA, 2007, 2018, 2019). Investment and capital stock dataset (IMF, 2015).	Public investment by general government – national and sub-national governments (i.e. provincial and municipalities). GFCF(GG) has frequently been used as a proxy for public infrastructure investments (cf. Wagenvoort, 2010; Gonzalez-Alegre et al., 2008).	Government investments in fixed assets (both infrastructure and non-infrastructure).	Infrastructure investment by SOEs is not included.
3. GFCF on construction excluding buildings or GFCF(CE)[2] – mainly civil engineering works	National accounts (cf. Stats SA, 2006, 2007, 2018, 2019). Investment and capital stock dataset (IMF, 2015).	Investments in water infrastructure construction other than buildings.	Infrastructure investments by government in water infrastructure structures.	Buildings, machinery, and equipment in (water) infrastructure projects are excluded to avoid over-estimation.
4. Private participation in water infrastructure (PPI)	World Bank PPI Project database (WB, 2019). National Treasury and DBSA available databases (cf. DBSA, 2009, 2019; NT, 2019a, 2019b, 2019c). Investment and capital stock dataset (IMF, 2015).	Investments in water projects that are owned or managed by private sector companies with at least 20% private participation in the project contract.	Some private investments with information from publicly available sources (e.g. commercial news databases, publications, government reports, multilateral development agencies). Water infrastructure projects reaching financial closure after 1994.	Private water infrastructure investments without publicly available information is not included in the PPI project database and in the study. Projects with divestiture and cancelled projects may be covered by the databases but are excluded to avoid over-estimating private water infrastructure investment.

Note: NRF = National Revenue Fund, Republic of South Africa; Stats SA = Statistics South Africa; NT = National Treasury, Republic of South Africa; DBSA = Development Bank of Southern Africa; [1]GFCF(GG) = macro-economic aggregate following national accounting standards, covering total general government investment on fixed assets, i.e. buildings, civil engineering, machinery, equipment, intellectual property, weapon systems, etc. (UN, 2006); [2]GFCF(CE) = macro-aggregate from GFCF classification of types of assets following national accounting standards and mainly includes civil engineering (UN, 2006).

The Fisher's least significant difference (LSD) method was used for the k-sample analysis to detect differences in the frequency distribution of the measurement investment variables for $k \geq 3$ populations based on random samples from each population (Gioia et al., 2012; Creswell, 2013). The populations were classified by the criterion that if no difference was detected between a pair of means, they were put in the same group, while if difference was detected, they were put in a different group.

Statistical data transformation techniques were used. This was the application of a deterministic mathematical function to each point in the dataset so that the data appeared more closely to meet statistical inference assumptions, i.e., a replacement that changes the shape of a distribution or relationship (Gioia et al., 2012; Creswell, 2013). The research data was log $10(x + 1)$ and arcsine$\sqrt{x}$ transformed, i.e. each data point zj was replaced with the transformed value $yj = f(zj)$, where f is a function.

RESULTS AND DISCUSSION

Measuring sustainable water infrastructure systems

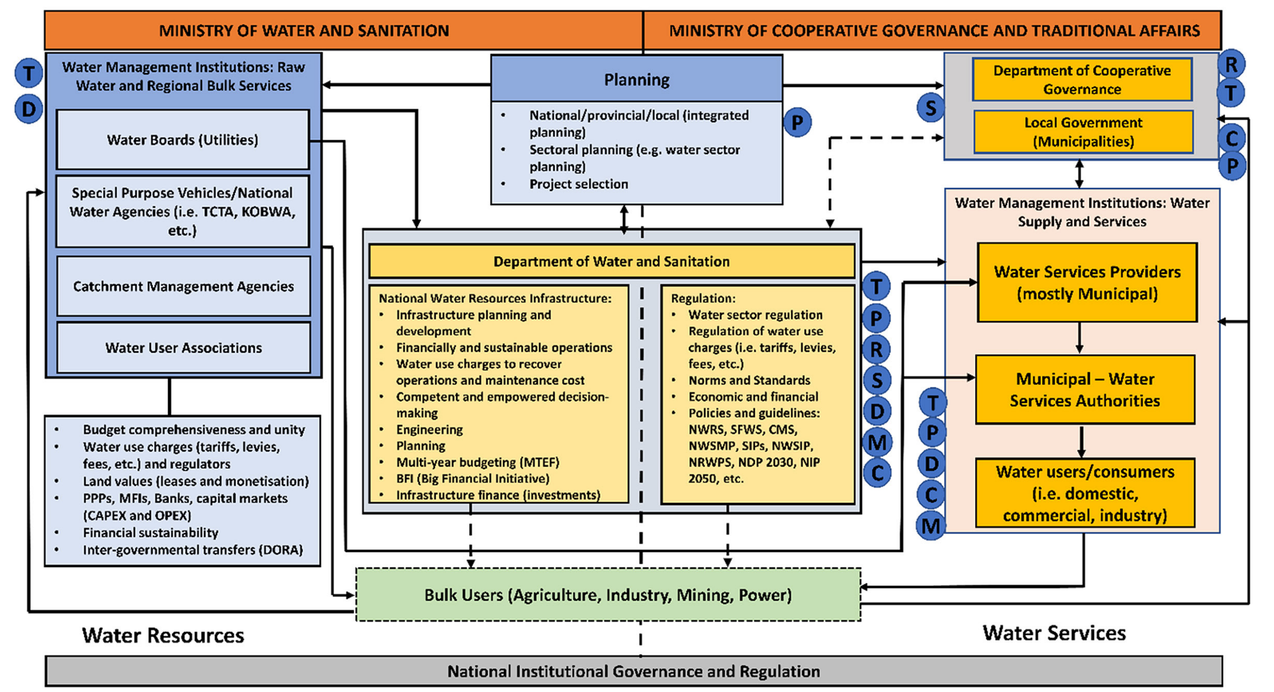
Conceptual framework model of water infrastructure value chain investments

The conceptual framework addresses water infrastructure value chain investment models in South Africa for ensuring water security and availability in specific water management areas (catchments) (Figs 1 and 2). The inter-relationship of the components in the water value chain determines the implementation environment and structure of the water infrastructure investment models, i.e., barriers, challenges, and financing and funding solutions (Fig. 2). The situation varies depending on what water management area is under investigation and what performance areas are addressed by a specific water management institution. In the country's more vulnerable catchments, i.e. Vaal, Marico-Crocodile (East), Berg, Mhlatuze, Umgeni, Thukela, Limpopo, Amatola, Algoa, Olifants, Usutu, etc., mega water infrastructure projects are planned and being implemented as measures to ensure water security and availability. Furthermore, it is essential to recover costs, maintain financial viability and to sustain water supply. To achieve these principles, suitable water-use charges and/or tariffs must be set by water management institutions involved in the water infrastructure value chain (Fig. 3).

Investment models for water infrastructure needs

This analysis outlines the capital requirements needed to address funding gaps within the entire water sector value chain in South Africa. The findings are contained in a single integrated investment planning model, the National Water Infrastructure Investment Financing Facility (NWIIFF), which includes water infrastructure and the financial flows in the water infrastructure value chain, regardless of who is responsible for the water infrastructure and who finances it (Fig. 4).

The results identified possible combinations of investment models that can be used with different financing instruments (Table 2; Fig. 5) (Head, 2006; Ruiters, 2013; Ehlers, 2014; Ruiters and Matji, 2015, 2016, 2017; Financial Innovation Lab, 2016a, 2016b; ADB, 2017; Amis et al., 2017; Ruiters and Amadi-Echendu, 2019, 2020, 2022). Amongst the projects examined, it was possible to detect investment models as described in Table 2 and Figs 4–6. Depending upon the purpose and nature of the water infrastructure and the institutional option, a spectrum of financing instruments can be used, and these disparate sources of finance can be grouped into broad categories: (i) official development assistance (ODA); (ii) concessionary finance; (iii) debt finance; (iv) equity finance; (v) reserves (water management institutions); and (vi) public sector finance (Table 2; Figs 4–6).



Note: T = tariff, P = integrated planning, R = regulation, S = strategy and policy development, C = coordination, D = development; M = management; CMS = catchment management strategy; DORA = Division of Revenue Act; KOBWA = Komati Water Basin Authority; MFI = multi-lateral financial institution; NRWPS = National Raw Water Pricing Strategy; NWRS = National Water Resource Strategy; NWSMP = National Water and Sanitation Master Plan; NWSIP = National Water Services Improvement Plan; PPP = public-private partnership; SFWS = Strategic Framework for Water Services; SPV = special purpose vehicle; TCTA = Trans-Caledon Water Authority

Figure 1. The conceptual hierarchical water infrastructure value chain framework/ecosystem for the development and management of, and investment in, water infrastructure in South Africa

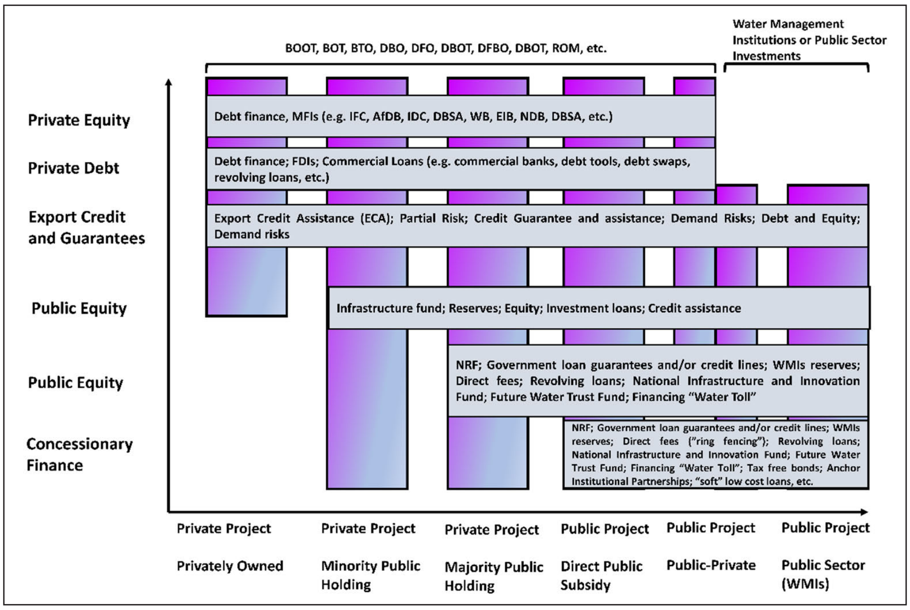


Figure 2. The spectrum of financing instruments used for the funding and financing of water infrastructure (after: Head, 2006; OECD, 2014; DWA, 2013; DWS, 2018)

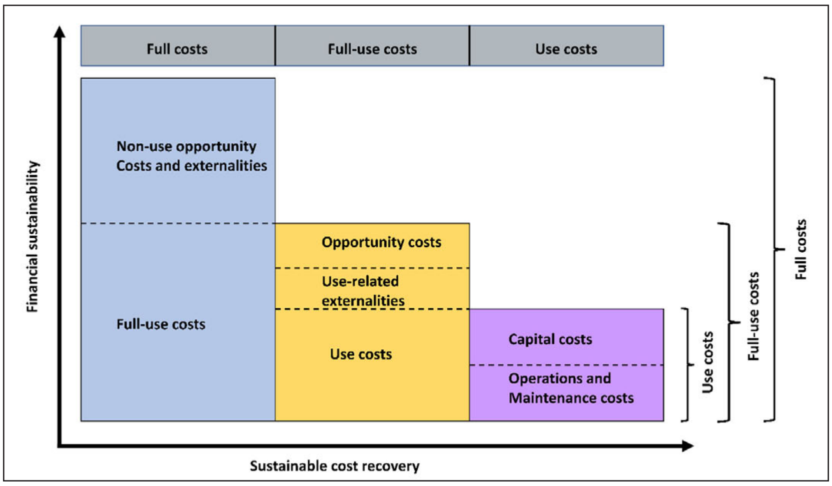


Figure 3. The costs in the water infrastructure value chain for financial sustainability and sustainable cost recovery for water infrastructure development and management in South Africa (after: Sadoff et al., 2003)

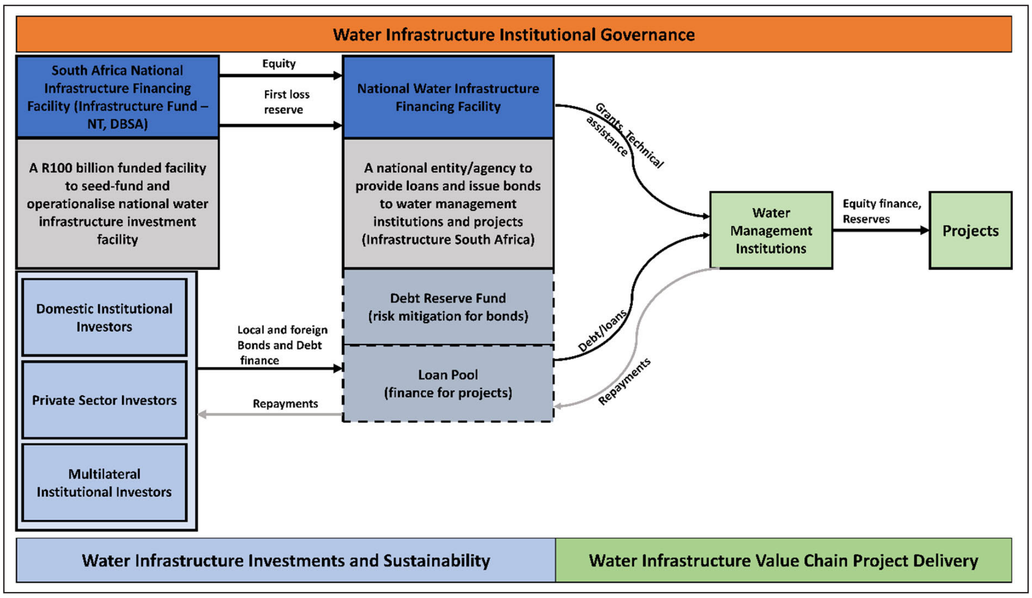


Figure 4. Overview and proposed national water infrastructure investment facility concept for South Africa's water infrastructure value chain (after: Global Innovation Lab for Climate Finance, 2016)

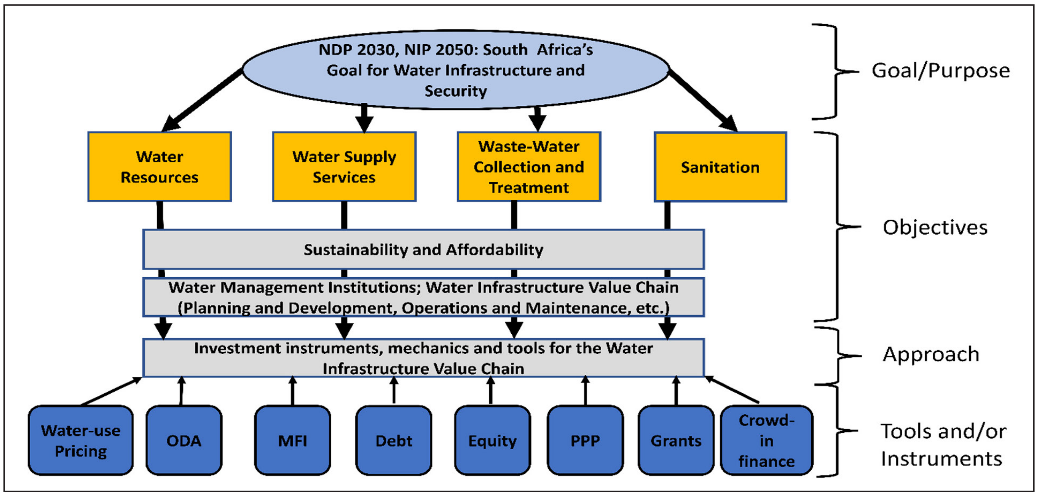


Figure 5. A new conceptual framework model for investments in water infrastructure in South Africa

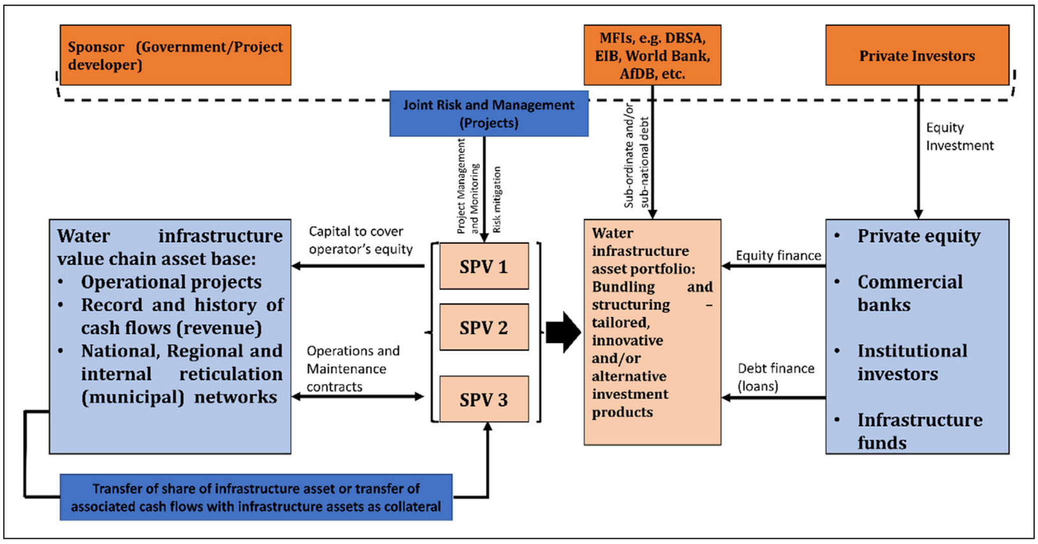


Figure 6. 'Balance sheet off-loading or leverage' for existing water infrastructure assets for the 'free-up' of investments for new water infrastructure (after: Ackermann, 2015)

Table 2. Types and use of innovative investment models with principles, criteria and characteristics for the water infrastructure value chain in South Africa

Framework type of investment models	Principles	Financial structure and characteristics
Model 1: Official development assistance (ODA), i.e. new or greenfield projects.	Oversees and manages water infrastructure projects at various levels. Official development assistance (ODA) in concessionary financing provided by a broad spectrum of international financing institutions. Effective governance, national policies, self-reinforcing, and robustness of water infrastructure development and management. Aligned organizational, company or institutional goals.	Future 'Central Water Infrastructure Fund' or National Infrastructure Innovation and Finance Fund. Concessionary finance, soft funds, grant funding and other philanthropic sources, e.g. ODA, philanthropic funds, etc.
Model 2: Ring-fenced special purpose vehicle (SPV), i.e. new or greenfield, operations and maintenance, and expanded investment projects.	SPVs (e.g. TCTA or NWRIA, KOBWA, DBSA, etc.) can maintain a strong presence in the commercial paper market and are able to secure funding at competitive prices. Leveraging of a strong balance sheet. SPV housing dedicated water infrastructure cashflows. Assist in overcoming weaknesses in the current selection of infrastructure projects. The economic use of water is charged at the full cost. The payment of a capital unit charge (CUC) to repay the off-budget loan funding. Effective governance, national policies, self-reinforcing, and robustness of water infrastructure development and management. Aligned organizational, company or institutional goals.	'Ring-fenced' water management institutions generating enough revenue for water infrastructure needs as set by the water pricing strategy (DWAF, 2007), i.e., full-cost recovery reflective (water user/usage-based charges and tariffs model). The individual limit is set internally from time to time when markets are suitable to move from one instrument to the other. Derived value of water to finance expansion, betterment (upgrading), operations and maintenance. Capital markets to finance water infrastructure needs, particularly local bond markets and/or institutional investors, e.g., pension funds, insurance companies, etc., as would be natural sources of long-term financing for water infrastructure. Having revolving funds and co-funding ('blended finance') for awarding loans for a variety of water infrastructure needs.
Model 3: Public-private partnership (PPP) with equity, i.e. new or greenfield, operations and maintenance, and expanded investment projects (NT, 2000).	The use of an institutional framework is essential in including the private sector for the implementation of water infrastructure projects. Effective governance, self-reinforcing, and robustness of water infrastructure development and management. Aligned organizational, company or institutional goals.	Investment instruments/tools: private funding, resource benefits, equity source, anchor institutional partnerships. Concession arrangements for the injection of necessary capital and management resources into the water infrastructure value chain. Sufficient revenue streams (water use pricing), appropriate contracting models, and parameters. Contracting private companies for certain services leads further to development and operating water infrastructure facilities (BOT, BOO, ROM, etc.). Provide a concession to a private company to run the facility over a certain time.

Table 2 continued. Types and use of innovative investment models with principles, criteria and characteristics for the water infrastructure value chain in South Africa

Framework type of investment models	Principles	Financial structure and characteristics
Model 4: Private market, i.e. new or greenfield, operations and maintenance, and expanded investment projects.	Private sector transactions occurred with most having been lease contracts (or *affermage*), management contracts and/or concessions. A well-structured privatisation model could be part of the water infrastructure solutions. Effective governance, self-reinforcing, and robustness of water infrastructure development and management. Aligned organizational, company or institutional goals.	Many investment instruments/tools are available and based on the BOOT model. Finance charettes is a process that normally employs an advisory panel of finance, planning and engineering experts, as well as public officials, for providing investment solutions. Commercial paper programme and funds could be raised in advance until the specific need for funding arises. Equity sources are more expensive than loans because equity holders are prepared to assume some risk in return for higher rewards, i.e.. return on equity 15% to 20% or more depending on the risk. Foreign direct investments from multinational companies. Concessionary finance in the form of grants, soft loans, carbon credits, etc., provided by bilateral donors, multi-lateral finance institutions (MFIs), etc.
Model 5: Alliancing	Under this model, the public and private sectors agree to jointly design, develop, and finance projects. They can work together to build, maintain, and operate water infrastructure.	Long-term funding sought from the commercial markets, i.e., commercial lending, equity (private), equity finance (public) and own finance (reserves). Water tariff model – revenues from the sale of bulk water. Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees).
Model 6: Bundling	Contracting with one partner to provide several small-scale projects to reduce the length of the procurement process as well as transaction costs.	Private investment (off-budget), i.e., commercial lending, micro-finance, equity finance (public and private). Water tariff model – revenues from the sale of bulk water. Own finance (reserves, private and concessionary). Concessionary finance from MFIs.
Model 7: Competitive partnerships	Private partners are selected, in competition with each other, to deliver different aspects of a project. Reallocate projects among partners at later stages, depending on performance. Public sector can also use costs and quality of other partners output as a benchmark for partners.	Private investment (off-budget), i.e., equity (private), private finance. Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees) Water tariff model – revenues from the sale of bulk water. Own finance (reserves).
Model 8: Incremental partnerships	Public sector can commission work packages incrementally and reserves the right to use alternative or new partners if suitable. Public sector contracts with private partners, in which certain elements/components of the work can be called off or stopped, if deemed unproductive and/or non-performance.	Private investment (off-budget), i.e., equity (private), private finance (off-budget). Water tariff model – revenues from the sale of bulk water. Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees) Own finance (reserves).
Model 9: Integrator	Public sector appoints a private sector partner to manage the project implementation. Arranges the necessary delivery functions and payment(s) according to overall outcomes, with penalties for late delivery, cost overruns, poor quality, etc. A less direct role in service provision and is barred from being directly involved in project delivery. Achieving best value for the public sector.	Private investment (off-budget), equity (private), private finance (off-budget). Water tariff model – revenues from the sale of bulk water. Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees). Own finance (reserves) and equity finance (public).
Model 10: Joint venture	A joint venture company is set up with majority owned by a private sector partner. Public sector selects a private partner through competitive bidding process, i.e., bids to carry out specific work packages. Phases are commissioned by the public sector partner (strategic partner), using the first phase as a benchmark, quality control and determine the appropriateness of future costs (e.g. transaction costs)	Private investment (off-budget), i.e., private finance (off-budget), equity (private). Water tariff model – revenues from the sale of bulk raw water. Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees). Funding sourced from the local financial markets and local MFI. Own finance (reserves) and equity finance (public).
Model 11: Divestiture	Public sector transfers all or part of the assets to the private sector. Certain conditions are normally included on the sale/transfer. An attractive asset base on public balance sheet for divesting.	Private investment (off-budget), i.e., equity (private), private finance (off-budget). Water tariff model – revenues from the sale of bulk raw water.
Model 12: Asset care and management (operations and maintenance) (Management contract or lease/ affermage) (OECD, 2009, 2010a, 2010b, 2013)	The responsibility for operating and maintaining existing assets, commercial (undertaking new investments) and management responsibilities are passed on to the operator. The risk transfer from the contracting authority to the operator can be significant but depends on the contract details and the determination of the operator's remuneration. The tariff adjustment rules govern or apply to the water use pricing (tariff, charges, fees) and adjustments.	Private investment (off-budget), i.e., equity, private finance. Water tariff model – revenues from the sale of bulk water. Export credits (ECAs) and credit enhancement facilities (guarantees) Funding sourced from the local financial markets and MFIs. Own finance (reserves) and equity finance (public).
Model 13: The regulated asset base (RAB) model (Meany and Hope, 2012).	The RAB model covers three elements: • Depreciation of the RAB over time, i.e., return of capital invested. • A return to investors based on the value of the RAB, i.e. return on capital invested. • The forecast level of operating expenditure (OPEX).	Most effective means of overcoming the time-inconsistency problem and should have investment benefits. Equity risk is effectively borne by taxpayers. Investments are protected, thus removing a substantial amount of investment risk. Significant financing, cost savings and cost regulation. Potentially allow the public sector to tap into capital markets. Embedded in the Regulated Price Index (RPI-X) framework and thus increase the RAB-backed assets. RAB model is relatively more flexible than PPP contracts. Strong incentives for efficiency in the delivery of investments (CapEx) and operating and maintenance costs (OpEx).
Model 14: Water infrastructure asset recycling (Samans and Drexler, 2017).	The public sector could redirect capital investments towards their most critical infrastructure needs using several innovative mechanisms, i.e., temporary-partial ownership, align different levels of government, setting up infrastructure funds to protect capital transfer and transparency. This includes infrastructure sectors with supportive regulation for privatization; an attractive asset base on public balance sheet for divesting; independent and capable infrastructure agency; well-developed infrastructure plan; and sufficient awareness and support from the population.	Private investment (off-budget), i.e. equity (private), private finance (off-budget). Water tariff model – revenues from the sale of bulk water Own finance (reserves) and equity finance (public). Concessionary finance from MFIs. Export credits (ECAs) and credit enhancement facilities (guarantees). A dedicated infrastructure fund.
Model 15: Green funds and/or carbon credits	Innovative financing mobilising large-scale private or concessionary finance from local or international bond markets for the water sector. Mobilise private finance with public funding and international investors to forge efficient partnerships and help bridge the investment, infrastructure, and sustainability gaps to enable a robust pipeline of economic water infrastructure to be built. State-owned entities/enterprises where the intention would be to refinance projects with capital investments and revenue streams.	Concessionary finance from MFIs. Private investment and water tariff scheme/model (off-budget), i.e., equity (private), private finance (off-budget). Export credits (ECAs) and credit enhancement facilities (guarantees).

Note: DBSA = Development Bank of Southern Africa; DWS = Department of Water and Sanitation; KOBWA = Komati Basin Water Authority; NWRIA = National Water Resource Infrastructure Agency; SPV = special purpose vehicle; TCTA = Trans-Caledon Tunnel Authority

Measuring water infrastructure value chain investments

Three alternative measures for water infrastructure value chain investment computations are proposed which combine the four data sources (Tables 1 and 3). Figures 7 and 8 provide these measures and include the benefits and limitations.

How do the Budget + PPI investment estimates compare with other measures? The Budget + PPI measure was generally low, as expected, based on the dataset for 1998/99–2019/20 (Fig. 7; Table 3). The differences were significant between the various investment measures. However, the divergence was only significant between Budget + PPI (total water infrastructure) and other water infrastructure sub-groups. Total water infrastructure investments constituted only 0.35–0.74% of GDP for the past approx. 20 years and 3.97–14.36% of total infrastructure investments. At the same time, the correlations between the three investment measures (as share of GDP) were generally negative (sub-groups) and not significant, except for between GFCF(GG) + PPI and GFCFCE) + PPI which was highly significant.

Furthermore, there was a fair degree of consistency between the physical measures of total water infrastructure investment and GFCF(GG) + PPI for the available time-series data set (Fig. 8). The regression result shows a statistically non-significant correlation between the physical infrastructure measure and accumulated per capita GFCF(GG). However, measuring infrastructure investment is complicated by the limited availability of high-quality data (Rozenberg and Fay, 2019). Among the various measures of infrastructure investment, GFCF(GG) is often used to analyse public infrastructure investment due to its relatively wide availability across countries and over time (Rozenberg and Fay, 2019). The Fisher's least significant difference (ANOVA) of LSD = 0.937, $F_{0.05,\,147,\,6} = 426.67$ and $P < 0.001$ indicate that the means of the investment variables are significantly different, with the means of GFCF(GG) + PPI, GFCF(CE) + PPI and total infrastructure greater than the total water infrastructure (Budget + PPI) and sub-groups. But the means for variables are indistinguishable from one another, except for the water infrastructure subgroups.

Comparing the alternative measures, and considering the distribution of GFCF(GG) and GFCF(CE) measures (Figs 7 and 8), suggests the following groups, based on the extent of infrastructure investments:

(i) **Invest substantially for GFCF(GG) + PPI**, with consistency or non-significant difference for GFCG(GG) + PPI for the past approx. 20 years as % of GDP, i.e., annual average of 18.50% (SD = ±2.14) and was approx. 489.14 billion ZAR/a (SD = ±285.42)

(ii) **High increase for GFCF(CE) + PPI**, with infrastructure investment rate increasing from 10.625% to 191.82% , an annual average of 86.73% (SD = ±66.97) and was ~611.46 billion ZAR/a (SD = ±637.98).

Table 3. The correlation matrix, *v* = 20, for the investment variables (parameters) for sustainable water infrastructure development and management in South Africa for the financial period 1998/99–2019/20

Investment parameters	Water services authorities	Water utilities/boards	DWS (water infrastructure)	Total investment
Water services authorities	–			
Water utilities/boards	0.980^NS	–		
DWS (water infrastructure)	0.963**	0.936*	–	
Total investment	0.991***	0.980***	0.986***	–

****P < 0.001; **P < 0.01; *P < 0.05; NS = 'not significant'*

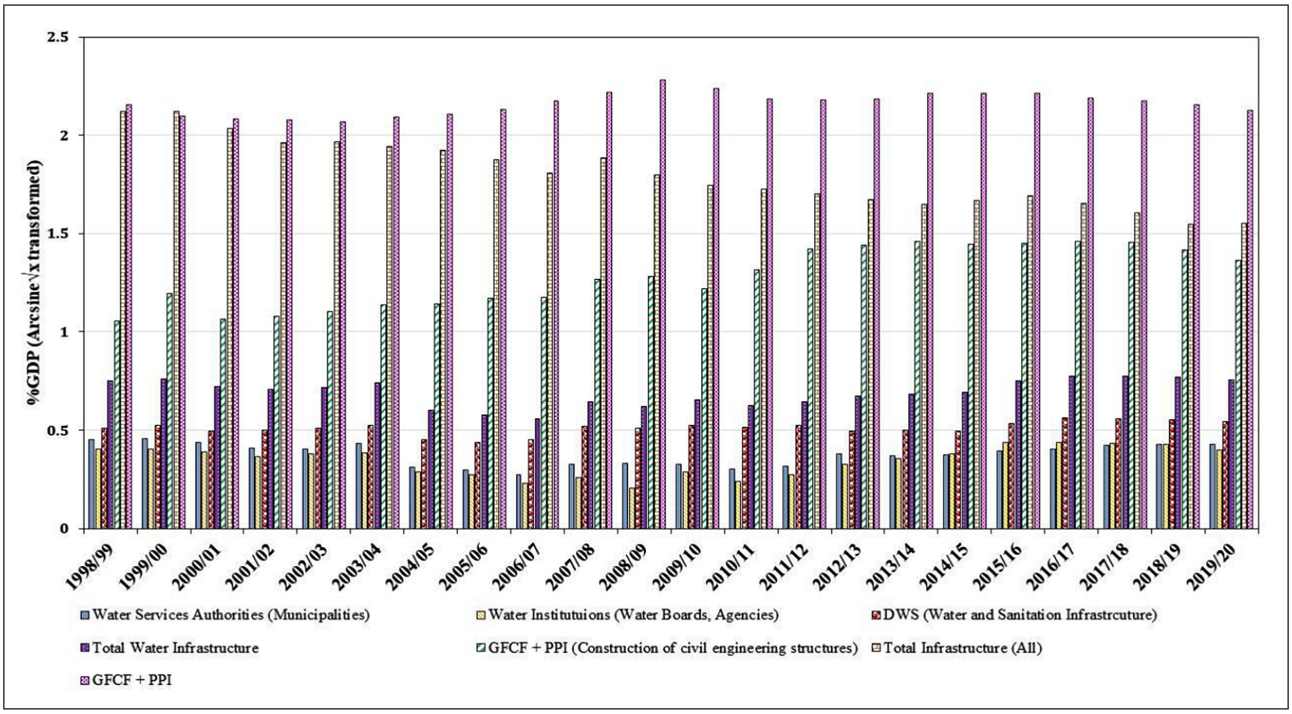


Figure 7. Water infrastructure investment rate for the past 20 years (arcsine√x transformed), 1998/99–2019/20, in South Africa

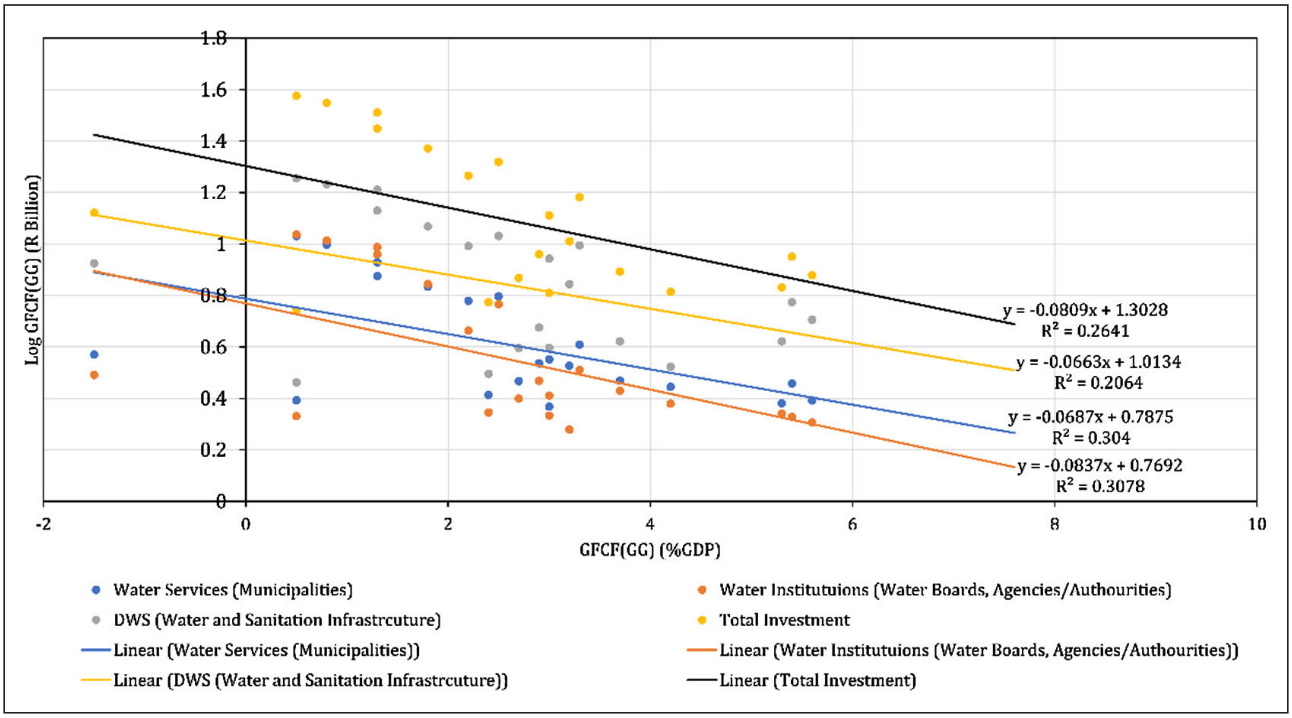


Figure 8. Relationship between total water infrastructure and accumulated real GFCF(GG) per capita for the time-period 1998/99–2019/20 in South Africa

Investment sources and water infrastructure investment needs

The current MTEF (2019/20 to 2021/22) funding estimates that allocation to water infrastructure is about 293.558 billion ZAR (Fig. 9; Table 4). The funding made available will not be adequate to meet all the project requirements of the water infrastructure value chain. It is therefore necessary to develop appropriate models/mechanisms to enable the prioritisation of projects that should be funded. Municipalities own revenues for water use tariffs were growing strongly over the research period, i.e., 32.48 billion ZAR for water supply and 13.44 billion ZAR for sanitation, i.e. ~18.6% per annum, and constitute ~28% of municipal revenue and cross-subsidises other services (Table 4). Municipalities are generally required to allocate approximately 5–12% of their annual operating budgets for rehabilitation and maintenance. The overriding principle is always to apply revenues to fund ongoing operational requirements, reduce debt (current and future) and thus minimize future finance costs (Table 4).

The national backlogs in water infrastructure are estimated to be approximately 54.023 billion ZAR, i.e., new capital projects, rehabilitation and maintenance programmes (Table 5; Fig. 10) (Stats SA, 2012, 2018, 2019; SAICE, 2017; DWS, 2018; NT, 2019a, 2019b, 2019c; DCoG, 2021). However, the medium- to long-term consequences of underspending on operations (repairs) and maintenance include: (i) deteriorating reliability and quality of services; (ii) move to more expensive crisis maintenance, rather than planned maintenance; (iii) increasing the future cost of maintenance and refurbishment; (iv) shortening the useful life of assets, necessitating earlier replacement, i.e., high capital costs; and (v) the influence of costs on water use charge calculations and models

Water infrastructure value chain priorities

The build-up cost of water use before any subsidies are applied, was estimated, and presented in Table 6 and Fig. 3. It is based on an estimated 3.9 billion m^3 of water used per annum in 2019/2020 and indicates that every water user would pay the full cost of 11.25 ZAR/m^3 (Table 6). This is made up of the cost of the distribution water infrastructure system, bulk water infrastructure supply system, water resources development systems and catchment management charges at the point of abstraction. As there are 'technical' losses through the system, primarily in the distribution system, for every m^3 of water abstracted and treated, with attendant costs, only an assumed 95% of this water reaches the water treatment works. Of every m^3 treated and transferred through a bulk water infrastructure network, only an estimated 60% reaches the end water user/customer. NRW or water losses, estimated at around 41.4%, need to be taken into consideration when developing water tariffs which are charged at each stage of the process to cover costs (Lambert, 2003; Ruiters, 2013; DWS, 2018; Ruiters and Amadi-Echendu, 2020, 2022).

Potable water infrastructure systems

The results from the investment strategy exemplified that there is no need for additional operating grant finance for the above (Table 6) (NT, 2019b). Income from the combination of the transfer and water use tariffs, which can, and should, be raised from end users of water and sanitation services, would be sufficient.

Non-potable water

It is accepted that the promotion of irrigated agriculture and support for emerging farmers is a high priority (Table 6). However, part of the investment plan is that any financial support should be focused on capital finance interventions and not on operating subsidies. The non-potable water cost at 2.53 ZAR/m^3 is unlikely to be affordable to most farmers and is far higher than current tariffs charged for irrigation water (Table 6).

Financing water conservation and demand management

The research results indicated that the proposed investment plan will have implications with regard to water infrastructure programmes (Table 6), e.g., funding commitments of 0.89 billion ZAR/a are required for urban and/or metropolitan municipalities.

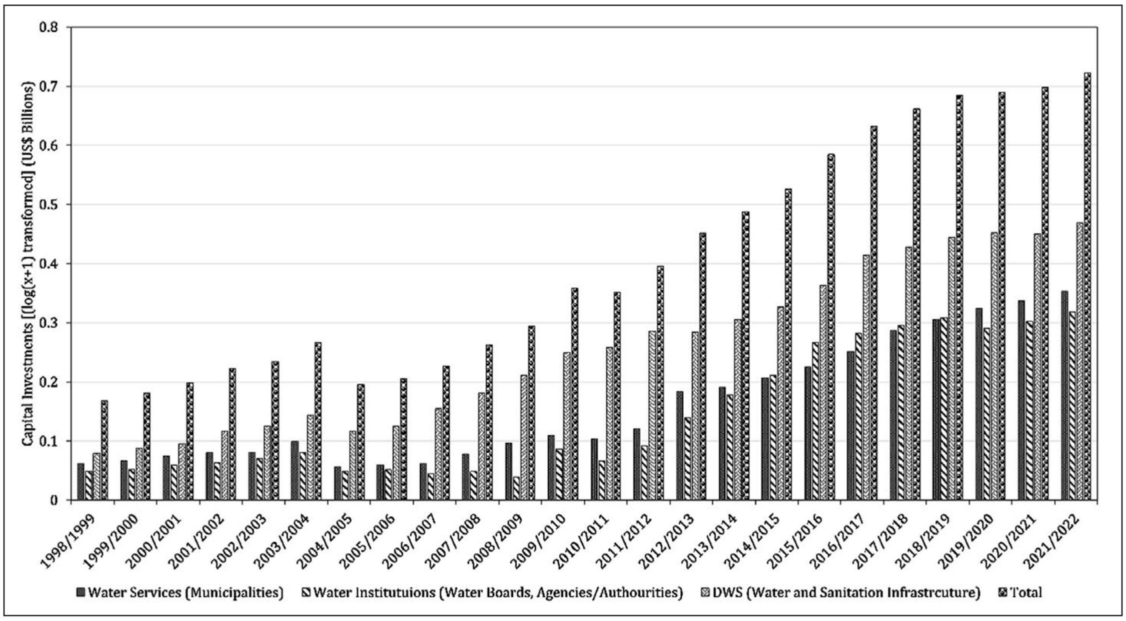


Figure 9. Water infrastructure investment in the past 20 years and the current MTEF (2019/20 – 2021/22) in South Africa

Table 4. Current MTEF (2019/20 to 2021/22) funding estimates allocation to water sector infrastructure

Water institutions	2019/20 (billion ZAR)	2020/21 (billion ZAR)	2021/22 (billion ZAR)	MTEF total (billion ZAR)
Department of Water and Sanitation	28.102	28.565	30.553	87.221
Department of Water and Sanitation: Water Trading Entity	12.785	14.140	15.639	42.564
Local government: regional bulk infrastructure	2.066	2.180	2.344	6.590
Local government: water services infrastructure	3.669	3.871	4.161	11.701
Trans-Caledon Tunnel Authority (TCTA)	11.069	6.903	10.801	28.773
Water Research Commission	0.318	0.347	0.378	1.043
Amatola Water	1.453	1.628	1.855	4.936
Bloem Water	1.669	1.769	1.875	5.313
Lepelle Northern	2.149	2.191	2.349	6.689
Magalies Water	3.926	4.245	4.589	12.760
Mhlathuze Water	1.568	1.676	1.792	5.036
Overberg Water	0.153	0.169	0.187	0.509
Rand Water	13.120	14.543	16.133	43.796
Sedibeng Water	8.288	8.958	9.683	26.929
Umgeni Water	2.980	3.302	3.417	9.699
Total water infrastructure estimates	**93.315**	**94.487**	**105.756**	**293.558**
Total public infrastructure estimates	**276.1**	**283.3**	**305.1**	**864.5**
Total % water infrastructure of public infrastructure estimates	**33.80**	**33.35**	**34.66**	**33.96**

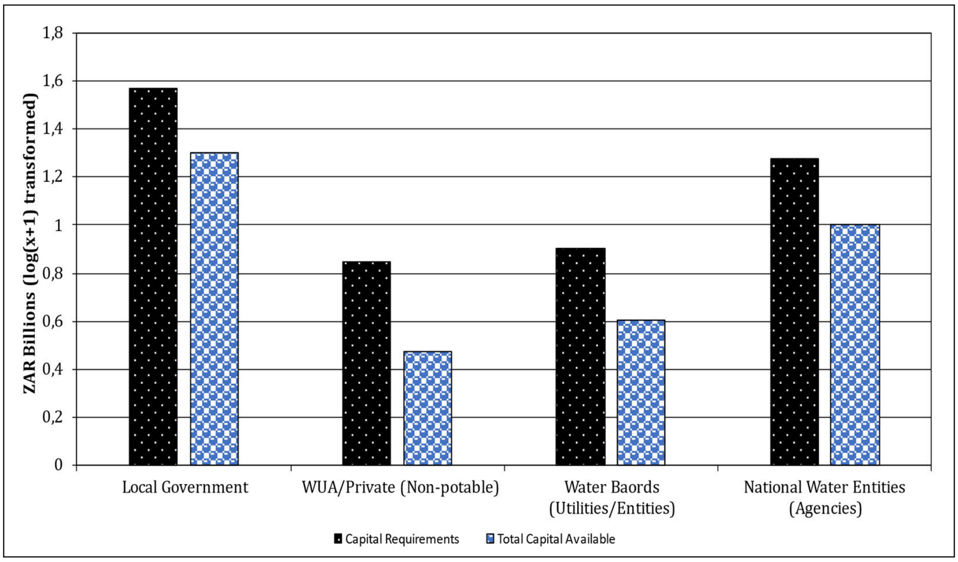


Figure 10. Capital finance gap [ZAR billions log(x+1) transformed] for water infrastructure investment (funding and financing) in South Africa

Table 5. Capital finance gap requirements per water management institution in the investment strategy for the water infrastructure value chain in South Africa

Water infrastructure investment requirements	Local government (billion ZAR)	WUA/Private – non-potable (billion ZAR)	Water boards (billion ZAR)	National entities (billion ZAR)	Totals (billion ZAR)
Capital requirement (per year over next 10 years)	57.857	8.766	9.882	30.124	**106.469**
Current capital available	30.761	3.506	4.782	13.070	**52.438**
Current gap	27.095	5.260	5.100	17.054	**54.023**
Proposed interventions (brought in over 5 years):					
Increase in debt finance by national entities				7.969	**7.969**
Increase in DWS budget				9.085	**9.085**
Increased own source funding from water boards			2.391		**2.391**
RBIG grant funding to water boards			2.710		**2.710**
Increased funding for non-potable distribution systems		1.594			**1.594**
New funding allocation for local water resources infrastructure	1.753				**1.753**
RBIG funding for regional infrastructure owned by municipalities	2.072				**2.072**
Increased 'own source' funding from municipalities	2.869				**2.869**
Private sector financing through build-operate-transfer (BOT)	3.188				**3.188**
Funding of local infrastructure by water boards	0.800				**0.8**
Increase in MG funding (water services portion)	11.954				**11.954**
Total increase in funding	**22.633**	**1.594**	**5.100**	**17.054**	**46.381**
Remaining gap	**4.463**	**3.666**	**0.0**		**7.650**

Table 6. Estimated operating and maintenance ZAR/m^3 and cost reflective tariffs, supplied from water infrastructure in South Africa

Water infrastructure component	Operation and maintenance cost (ZAR/kL)	Water infrastructure component cost (Total ZAR/kL used)
Water: internal	1.91	2.55
Connector: potable	2.31	1.59
Connector: non-potable	1.56	0.48
Bulk schemes	5.10	5.26
WR: potable	0.99	1.05
WR: non-potable	0.97	0.32
Total: potable	**10.31**	**11.25**
Total: non-potable	**2.53**	**0.80**

Costs of financing of operations and maintenance and analysis

Considering the water infrastructure value chain, the operating and maintenance cost breakdown, as an average for the country, was calculated and provided in Table 6. The addition of finance charges and any surplus applied by the water management institution providing the water infrastructure and associated service would add approximately 20% to the overall cost. The average cost of potable water infrastructure in South Africa is 10.31 ZAR/m^3 before any subsidies are applied, and for non-potable water it is 2.53 ZAR/m^3 (Table 6).

CONCLUSION

The results illustrate the availability of resources in South African for water infrastructure investments, indicating that innovative and alternative delivery models, tools and instruments are required to address: (i) significant mismatch between the estimated capital required to develop or rehabilitate the water infrastructure necessary for the provision of basic services and the current available capital budgets; (ii) for the immediate future, operating budgets for operating requirements. However, economically weaker municipalities would not be able to accommodate the operating requirements from rolling out services to poor communities; (iii) eradicating the capital and rehabilitation backlog; and (iv) adjusting the minimum standards in a manner that reduces capital and operating costs.

Water infrastructure investment, including closing the circle between public and private-sector capital, is proposed and required. Although some of these investment models partially fund South Africa's water infrastructure value chain, the link between costs and use is not well established. The investment models could play a greater role in meeting the investment needs of South Africa's water infrastructure and raise revenues to support sustainable water infrastructure. Reinforcing the relationship could create stable investment vehicles that do not depend solely on general tax revenues, i.e., national revenue fund. If there is the intention to proceed on the tenet that water infrastructure is an essential part of the nation's capital infrastructure providing for socio-economic and environmental development, then there should be investment models for water infrastructure needs in place. Combining the models and addressing the regulatory environment would depend on the institutional structure and governance, financial markets, and political climate. If the water infrastructure is classified as an essential part of a nation's capital infrastructure producing goods for public benefits, then investment models should be favourable alternatives for obtaining capital financing. These models can be consolidated to create a water infrastructure investment pool and/or (water) infrastructure trust fund. From this pool and/or trust fund, suitable model(s) can be selected for water infrastructure financing based on the implementation environment.

Some of the challenges or complex issues in the water infrastructure value chain in South Africa include pricing, access, public policy and regulation, risk-sharing, procurement processes, and governance. These have arisen as key challenges that will influence whether private provision of water infrastructure can grow as a viable new model in South Africa. The provision of investment is an essential ingredient of the overall strategy for water infrastructure. If it is not to be forthcoming then many risks, liabilities and actions could flow forth. The finance available should be used to augment and facilitate, in the most economic manner, development, rehabilitation and refurbishment, which have the highest economic benefit, first and then be used for future investment. If the total capacity to obtain finance is not available, there is a risk that the water infrastructure value chain will continue to deteriorate from its existing poor level, with consequences of failure to supply as well as an impact on water quality. If water tariffs are not tapered rapidly to a reasonable economic level with explicit subsidies and water (social) pricing as inherent ingredients, the operations and maintenance may continue to decline and stagnate with profound consequences.

In conclusion, tax revenues from the public sector continue to be the main source of the water infrastructure value chain investments. Innovative and/or alternative models are presented to address water infrastructure needs and backlogs. Prioritisation and sequencing of the capital project portfolio is required to ensure that the most critical projects are given enough emphasis, with priority consideration given to projects critical for socio-economic development.

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