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Reviewer C: Round 1
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Conflicts of interest: None declared

Does the manuscript fall within the scope of SAJS?
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Is the manuscript written in a style suitable for a non-specialist and is it of wider interest than to specialists alone?
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Are the methods described comprehensively?
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Do you believe somebody with more methodological expertise in the area of this study than you have needs to review this?
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If yes, can you suggest the type of expertise needed.
I cannot check the economics on this, though I didn't pick up glaring issues upon my brief read-through. I can only comment from an ecological perspective.
Are the interpretations and conclusions justified by the research results?
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Comments to the Author:

This is a fantastic contribution. I only have a couple of minor comments that I hope the authors can include, such as some missing relevant references, expressing the limitations of NIAPS and briefly listing the best practices that should be considered for IAP clearing, especially sustainable funding.

[See Appendix 1 for Reviewer C's comments made directly on the manuscript]

Author response to Reviewer C: Round 1

This is a fantastic contribution. I only have a couple of minor comments that I hope the authors can include, such as:

1. Some missing relevant references,
2. Expressing the limitations of NIAPS and,

Briefly listing the best practices that should be considered for IAP clearing, especially sustainable funding.

AUTHOR:

1. Added the following references:
   a. Rebelo et al. 2021
   b. Holden et al. (2022)
   c. Updated du Plessis et al. (2024), which is now published.
2. Noted NIAPs has its limitations and referred reader to Preston paper for more detail on this.
3. Have added to line 318 in discussion...."following best practice guidelines for IAP clearing".

Spelling error uMgeni?

AUTHOR: uMgeni and Mgeni are used interchangeably in the literature and reconciliation reports. "Mgeni" is used to describe the system, while "uMgeni" Water is the name of the water service provider.

Reviewer E: Round 1

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Viability of investing in ecological infrastructure in South Africa's water supply areas

Running head: Viability of investing in ecological infrastructure

Abstract

There is increasing understanding of the role that ecological infrastructure (EI) – natural ecosystems that provide important services and save on built infrastructure costs - can have in ensuring the security of water supply, particularly in water scarce areas. In general, however, there has been insufficient action to prevent or reverse the degradation of ecosystems in water supply areas. This becomes increasingly problematic as water demands grow and where rainfall is affected by climate change. In South Africa, one of the main threats to water supply is the proliferation of woody invasive alien plants (IAPs) which significantly reduce streamflow and water yields. This study analysed the viability of investing in EI through IAP clearing by comparing the costs and effects on water yields with those of planned built infrastructure interventions designed to meet increasing water demands in the medium to long term in all of South Africa's water supply areas. The estimated water savings achieved by clearing IAPs from catchment areas of existing bulk water infrastructure was approximately 24% of what would be gained by implementing all built infrastructure interventions by 2050. This suggests that IAP clearing be implemented ahead of built infrastructure interventions to delay these costs as well as to protect the existing built infrastructure investments.

Keywords: ecological infrastructure, invasive alien plants, water security, ecosystem health, cost-effectiveness analysis

Significance

- IAP clearing in South Africa's water supply systems could lead to a total estimated streamflow gain of 1595 million m^3 and a yield gain of 997 million m^3 by 2050, equivalent to a quarter of the yield gains through implementation of built infrastructure interventions over the same time period.
- IAP clearing was more cost-effective than built infrastructure interventions in all water supply systems, except one, the Orange River System.

- These findings add to the growing body of literature that advocates for EI investments to secure hydrological ecosystem services.

Introduction

Water security is becoming increasingly important globally, especially in regions that already experience water scarcity in relation to increasing human demands due to low or declining rainfall and/or inadequate water supply infrastructure (1). South Africa is a water scarce country where these problems are exacerbated by the degradation and pollution of its surface water catchment areas. Catchment degradation takes the form of invasion by woody alien plants, indigenous bush encroachment and the loss of vegetative cover (hereafter referred to as desertification), with the first two reducing stream flows and the latter increasing the rates of sedimentation in reservoirs.

As is the case in most parts of the world, water security in South Africa has been addressed almost entirely through the planning and construction of water supply infrastructure, including sophisticated interlinked systems of reservoirs and inter-basin transfer schemes (2). However, there is increasing evidence that it would be more efficient to integrate catchment conservation actions into water sector investment planning. Indeed, a large body of research has shown that reducing the extent of IAPs can have significant impacts on stream flow and reservoir yields in South Africa (3–6), and there is growing evidence of the benefits of addressing bush encroachment and desertification (7). Many studies have now shown that undertaking restoration and conservation measures in catchment areas not only has a positive return on investment and but can be cost-effective in meeting water security goals (8–12).

This kind of evidence has led to the idea of solving what were traditionally engineering problems using "nature-based solutions" (NbS) and is gaining traction globally. The idea came fairly late as the impacts of people on the environment only started to become apparent in the 1960s (13) and only reached the scales that attracted more widespread attention once their exponential trajectory started having measurable impacts at significant scales. In South Africa concerns about the impacts of catchment degradation on water supply started emerging after catchment degradation had become so widespread that the impacts on water supply were irrefutable, leading to the emergence of Working for Water (WfW) and other government funded land restoration programmes in the 1990s (14,15). Widespread problems of this nature that affect food and water security have led to the declaration of 2021-2030 as the "UN Decade on Ecosystem Restoration" to encourage global efforts towards restoring ecosystems (16) and signatories to the UNFCCC have agreed to work towards achieving Land Degradation Neutrality by 2030 to reverse or offset the extensive degradation that has taken place since 2000 (17).

missing critical literature here. see:

Rebelo et al. 2021 -Benefits of water-related EI investments

Holden et al. 2022 -Nature-based solutions in mountain catchments reduce impact of anthropogenic climate change on drought streamflow

Natural ecosystems of catchment areas that are critical in that their degradation would have significant impact on the cost of water supply can be referred to as "ecological infrastructure"

(EI), as they provide important services that reduce the costs of built infrastructure (10,18). In the context of water security, protecting these ecosystems helps to maintain the overall quantity and quality of stream flows and also helps to reduce the seasonal variability in flows (19–23). This saves on built infrastructure costs, such as water storage, flood mitigation measures and water treatment costs. Where water security is also threatened by climate change, the restoration and protection of EI can also be regarded as ecosystem-based adaptation (EbA).

There is a growing call for 'investing in EI' as a means to ensure the longevity and most efficient use of existing built infrastructure, towards securing a resilient, reliable water supply. Apart from addressing the primary goal of water security, EI investments also come with a range of co-benefits from securing non-hydrological services that benefit society (15).

The lack of investment in EI is often due to a lack of information (18,24). Indeed, there is little information on the extent to which investing in EI for water security is viable, and where such investments should be prioritised in South Africa. Decision-makers require sound evidence of the feasibility and likelihood of maximising return-on-investment for an intervention before they are willing to invest. To this end, our study aimed to determine the cost effectiveness of investing in the clearing and long-term control of IAPs to secure water supply in relation to that of planned built infrastructure for each of South Africa's main water supply systems that serve the country's major population centres, and how they vary in terms of their rainfall, IAP infestation and their plans for meeting future demands. Our analysis suggests that for nearly all water supply systems, such investments would be comparatively cost-effective and should be introduced ahead of costly engineering projects.

Data and Methods

Study area

The analysis was carried out for each of South Africa's eleven major water supply systems (WSSs). These systems include reservoirs (as well as the surface and underground water source areas), water treatment works and reticulation networks that are managed by water service providers (WSPs - semi-autonomous parastatal water boards or metropolitan municipalities in the case of City of Cape Town and Nelson Mandela Bay) to supply a defined set of urban and rural communities. These WSPs sell bulk water to municipalities or directly to water users, and are expected to invest in the management, maintenance and augmentation of these systems with some assistance from the national Department of Water and Sanitation (DWS).

Water supply systems are an appropriate unit of analysis since they are the scale at which South Africa's DWS undertakes its water supply infrastructure planning through 'reconciliation strategy studies'. These studies estimate the water demand trajectory and lay out plans for a series of (usually built) infrastructure investments to meet demands over time as they grow with the population. Within each water supply system, our focus was on the catchment areas of the main existing surface water supply reservoirs (large dams), as being the EI of interest.

Delineating dam catchment areas

The analysis was limited to catchment areas that currently feed bulk water supply dams. This scale was considered the most relevant and comparable to those of built infrastructure interventions.

A sub-dataset of South Africa's large dams was created using the South African National Committee on Large Dams (SANCOLD) 'South African Register of Large Dams' dataset (25) to include only large dams (wall height 5-15 m; capacity >3 million m^3) either owned and managed by the relevant WSPs or owned by DWS but managed by the relevant WSPs. Catchment areas of the large dams were then delineated using ArcGIS software's 'Watershed' tool (ArcMap version 10.4.1). Subsequently, the dam catchment areas were subdivided into quaternary catchment areas using the South African quaternary catchment data (26).

I think it would be appropriate to comment on the serious limitations of NIAPS here. Understanding these are the only data that can be used.

Extent of IAP coverage in catchment a

The National Invasive Alien Plant Survey (NIAPS) dataset (27) was used to estimate the extent of IAP coverage in each of the large dam catchment areas. This study focused on gums (*Eucalyptus spp*.), pines (*Pinus spp*.) and wattles (*Acacia spp*.) as the three most dominant, thirsty invaders in South Africa. A logistic population growth model (**Equation 1**) was applied to the NIAPS 2010 data to estimate current and future IAP coverage in 2022 and in 2050 in each quaternary catchment:

$$\frac{dp}{dt} = kP_{t-1}\left(1 - \frac{P_t}{K}\right) \qquad \textbf{Eq. 1}$$

whereby k is the growth rate, P is the population size, t is the relevant time step, and K is the carrying capacity. The carrying capacity was considered a measure of 'invadable land', or the land area suitably available for infestation. This was calculated per quaternary catchment using the South African National Land-Cover dataset (SANLC) 2020 (28). It was assumed that invadable area included all land that was not classified as "built-up", "cultivated", "mines and quarries", or "waterbodies". The spread of IAPs is largely determined by the rate at which the species under consideration can reproduce. The literature presents a wide range of spread rates for gums, pines and wattles, ranging from 2.6% per annum for wattle (29) to 15.6% per annum for pine (30). Therefore, a more general spread rate of 7.5% per annum was applied to all three types of IAP species to account for the broad range of spread rates found in the literature.

Cost-effectiveness analysis

Overview

To derive the costs of interventions for catchment restoration (i.e., IAP clearing), information was gathered from literature that addressed the spread of IAPs (5,7,31) and methods of calculating estimates of the cost to clear IAPs per hectare. Similarly, all information pertaining to built infrastructure interventions was retrieved from reports published by DWS, who provide access to reconciliation strategy studies for bulk water supply augmentation options for each water supply system in South Africa. These reports included relevant cost and yield information.

Unit reference values (URVs) can be used as a direct measure of the benefits derived from water resource interventions and are commonly used to assess the feasibility of projects in the water supply sector (32). This is done by calculating the cost per cubic meter of water over the lifetime of the project. URVs were used as a measure to compare the financial costs and benefits (additional water gain) derived from EI and built infrastructure interventions in this study. All analyses assumed that interventions would be implemented in 2022 and were evaluated up to 2050, assuming a 28-year project lifespan for IAP clearing and management.

Assessment of planned infrastructure development

Each of the study focus regions are depicted in **Figure.** number? To determine the planned sequence of infrastructure development per water supply system, each of the relevant reconciliation strategies were analysed. Only the interventions planned to take place between 2022 and 2050 were considered. Yield gains and URVs for each water supply option were then extracted directly from the reconciliation strategy reports. Where cost and URV information was not available for a given intervention, a representative URV based on the average of similar interventions in other water supply systems was used. Taking inflation into account, the URVs of each intervention were reported in 2022 Rands.

Costs of clearing IAPs

Cost estimates for clearing IAPs in South Africa were based on person-day estimates provided by the Working for Water (WfW) programme. Person-day estimates are derived from data collected over the lifespan of the WfW programme and are based on the costs to clear different groups and age classes of IAPs in riparian and landscape settings using different treatment methods over time (7). Regression models (**Table 1**) were used to calculate the person-day estimates required to clear one hectare of gum, pine and wattle. The cost to clear IAPs in 2022 was estimated to be R500/ha.

Based on the person-day estimates and the cost to clear one condensed hectare (c.ha) of infested land, the cost of initial and follow up clearing events for gums, pines and wattles was calculated for each relevant quaternary catchment. It was assumed that the first two follow up clearing events would take place in three-year intervals after the initial clear in 2022 and every six years thereafter until 2050. A discount rate of 8% was used to determine the present value of costs over the time period. Investment in clearing IAPs is considered inefficient at densities below 5% so a threshold was applied to the base year (2022) whereby all quaternary catchments with an IAP infestation of less than 5% were excluded from the cost model.

Calculating URV's for IAP clearing

The URV for securing water supply through clearing IAPs is derived by dividing the total present value of costs (PV_c) by the present value of water supplied (PV_w) as shown in **Equation 2**. The total PV_c to clear IAPs from an area is the sum of initial and follow up PV_c costs. The initial PV_c is the product of the number of person-days required to clear IAPs in the first year and the cost to clear one condensed hectare of infested land, while the PV_c of one follow up event is the product of the number of person-days required to clear IAPs in a follow up event and the cost to clear one condensed hectare of infested land.

$$URV\ (R/m^3) = \frac{PV_c}{PV_w} \qquad \textbf{Eq. 2}$$

The PV_w is based on the quantity of water gained if IAPs are removed from catchment areas by 2050. To determine this, estimates of streamflow reduction as a result of IAPs were extracted at the primary catchment level (5). A factor to represent the amount of water used by IAPs per unit area was calculated for all primary catchments and then applied to each relevant quaternary catchment. The gain in streamflow was then converted into a gain in yield by applying a ratio between water flow and yield based on Cullis et al. (33), who estimated changes in yield due to IAPs in all of South Africa's major water management areas. The relevant streamflow to yield ratio was applied to each quaternary catchment according to the water management area within which it is located. This was calculated for the period between 2022 and 2050 using **Equation 3**, where W_t is the quantity of water at year t, and r is the discount rate.

$$PV_w = \sum\left(\frac{W_t}{(1+r)^t}\right) \qquad \textbf{Eq. 3}$$

Results

Catchment areas

The dataset consisted of 64 quaternary catchments with a combined catchment area of approximately 230 500 km^2 (**Figure 2**). The Integrated Vaal River System has the largest catchment area covering 46.9% of this, and the Western Cape Water Supply System the smallest covering <1%.

Extent and spread of IAPs

IAP coverage in 2022 was estimated to be approximately 623 000 c.ha, which covered 2.7% of all catchment areas combined. By 2050, at a spread rate of 7.5%, it was estimated to quadruple to 2.5 million c.ha, or 10.9% of catchment areas, without clearing interventions. The Amatole WSS had the highest percentage area of IAP coverage in both 2022 (22%) and 2050 (58%; **Figure 3**). Conversely, the Orange River System was estimated to have the lowest percentage area of infestation in both 2022 (0.3%) and 2050 (1.6%).

Overall, gum and wattle were more prolific than pine in most water catchment areas. Wattle was shown to have the most drastic spread by 2050, having the highest average coverage (9.5%) between all three species. The Amatole WSS's high percentage of invaded area was dominated by wattle infestation, covering 29.3% of the water supply system's total catchment area by 2050.

Cost-effectiveness analysis

The Integrated Vaal River System was estimated to have the greatest number of condensed hectares infested with IAPs by 2050 (approximately 922 000 c.ha; **Table 2**), resulting in the highest PV_c to remove them (R4.7 billion), while the Luvuvhu-Letaba WSS had the lowest number of condensed hectares (approximately 25 000 c.ha), requiring the lowest allocation of investment for IAP removal (R71.8 million).

Across all 11 water supply systems considered, a total of 52 planned water supply projects were specified in the relevant reconciliation strategy studies between 2022 and 2050. Combined, planned built infrastructure interventions would result in yield gains of approximately 4 173 million m^3/a. On the other hand, the amount of water that could be gained by removing IAPs from bulk water supply catchment areas increased exponentially between 2022 and 2050, resulting in a streamflow increase of about 1 595 million m^3 and an increased yield of about 997 million m^3 (**Table 2**), equating to approximately 24% of the amount of water that could be gained through implementation of built infrastructure interventions in the same time frame.

When the URVs and yield gains of IAP clearing are compared with that of planned built infrastructure developments, it becomes clear that IAP clearing is a cost-effective intervention for securing water supply. IAP clearing was the most cost-effective water supply option for all water supply systems except for the Orange River System, which showed relatively low water gains for the associated URV (**Figure 4**). Overall, IAP clearing was the most cost-effective augmentation option.

The URVs for built infrastructure ranged from R0.48/m^3 for the new Vioolsdrift Dam augmentation project in the Orange River System (34) to R44.36/m^3 for the Zambezi River transfer scheme in the Crocodile West WSS (35), while the URVs for IAP clearing ranged from R0.79/m^3 for the Western Cape WSS to R7.18/m^3 for the Crocodile West WSS (**Table 3**). All URVs for IAP clearing were lower than that of built infrastructure interventions, except for the Orange River System which had low levels of IAP invasion and planned built infrastructure interventions that would produce a significant amount of water.

Discussion

There is growing awareness of the important role of both ecological and built infrastructure in achieving economic growth and development in terms of water security. However, degradation of EI is resulting in the loss of valuable hydrological ecosystem services that not only affect human well-being but also increase the costs of water supply. Investing in restoration and conservation of catchment areas can effectively support existing built infrastructure and delays the need for more expensive engineered solutions. This not only reduces costs over the long-term, but also generates a range of co-benefits. However, the potential of nature-based solutions to deliver on intended benefits continues to be questioned due to concerns over the lack of scientific evidence (36–38).

This study has shown that securing hydrological ecosystem services through catchment restoration is cost-effective and should be considered as a priority action for achieving water security in South Africa. Broadly, the yield gained (997 million m^3) from clearing IAPs from South Africa's key water supply areas equates to approximately 19% of the capacity of the Gariep Dam, the largest dam in South Africa. Of all the 11 water supply systems analysed, only IAP clearing in the Orange River System was less cost-effective than planned built infrastructure options. This can be explained by the low levels of estimated invasion in this water supply area, so removal of IAPs would not result in a significant gain in additional water when compared to the built alternatives which had significantly higher yields.

This study's findings concur with many other studies in South Africa that have shown that restoration measures can be cost-effective in securing hydrological ecosystem services. However, most of these have been conducted at a smaller scale, focusing on single quaternary catchments, and have compared URVs of IAP clearing usually with the URVs of dam construction. Clearing IAPs was found to be a cost-effective intervention in a quaternary catchment of the Olifants River with a URV of R1.44/m^3, which compared favourably with a URV of R2.93/m^3 for the De Hoop dam (39). In a comparison between the uMngeni and Baviaanskloof-Tsitsikamma catchment areas, uMngeni had more severe levels of degradation which consequently resulted in a higher URV for restoration of EI (R2.50/m^3) than the Baviaanskloof-Tsitsikamma (R1.17/m^3) (9). In two quaternary catchments in Northern Zululand, IAP clearing was more economical than raising the wall of Hazelmere Dam, with a URV of R2.50/m^3 compared to R3.67/m^3 (40).

Investing in catchment restoration should be regarded as an attractive opportunity as built augmentation options become progressively more expensive due to 1) the cheaper interventions being implemented first (41), and 2), more costly maintenance due to the impacts of catchment degradation which shortens the projected lifespan of reservoirs and related infrastructure (9). Furthermore, investing in EI has numerous co-benefits, such as biodiversity gains, wildlife and flood risk reduction, reduced sediment mobilisation and the potential for business opportunities through value added products processed from cleared IAP biomass (7,10,15,40,42,43).

Given that water service providers, as the main beneficiaries of catchment restoration, stand to gain significantly from improvements in catchment health through cost savings, their apparent low willingness to invest in EI is concerning. Indeed, only one of the eleven water supply systems have formally acknowledged and actively incorporated catchment restoration as a key intervention in their planning and budgeting for securing water in the long-term, i.e., as an intervention in the reconciliation water balance. IAP clearing is formerly included as a prioritised augmentation option in the Western Cape WSS reconciliation strategy (44). The net URV of R1.20/m^3 outlined in the reconciliation strategy is slightly higher than the URV of R0.79/m^3 estimated in this study, but still significantly lower than the range of URVs determined for built infrastructure augmentation options in the WSS (R2.57-18.77/m^3).

While other water reconciliation strategies, such as for the uMgeni WSS and Richards Bay WSS (45,46), acknowledge the importance of catchment restoration and the maintenance of EI, they did not quantify the additional yield that could be obtained from removing IAPs and do not explicitly account for it in reconciliation scenarios or water balances developed for the water supply system. The reason for this, stated in the KZN Coastal Reconciliation Strategy, is due to a “lack of quantifiable data” (45). In the Western Cape WSS there has been considerable research undertaken to assess the impact of IAPs on water supply which has provided the information needed to secure support and funding to undertake restoration activities in important water source areas. An outcome of this research has been the formation of the Greater Cape Town Water Fund (GCTWF), which since 2018, has successfully brought together and linked beneficiaries and stakeholders in pursuit of a common goal of securing water (47). The GCTWF operates at a large scale, focusing restoration efforts, particularly IAP clearing, in the catchments that feed the Western Cape WSS. These restoration efforts have been guided by scientific research that has determined priority areas for IAP clearing based on cost-effectiveness and return on investment (31,47). In developing the Business Case for the GCTWF, the URVs to clear IAPs ranged from R0.30/m^3 – R0.80/m^3 in the top seven priority sub-catchments (31). The URV for clearing IAPs in the Western Cape WSS determined in this study falls at the upper end of this range. The success of the GCTWF hinges on its ability as an independent entity to securely manage funds from multiple sources and undertake restoration activities effectively and efficiently. Recent research suggests that there is sufficient consumer surplus and potential to raise domestic water tariffs to cover the estimated costs required to restore catchment areas supplying water to some of these municipalities (48,49).

The results from this study provide evidence at scale that investing in EI is a cost-effective and worthwhile long-term option for all of South Africa’s water supply systems. However, given that state budgets remain the primary source of restoration funding in the country and are heavily constrained, catchment partnerships and water funds are most likely needed to succeed in leveraging the investment needed to restore these important catchments. The findings from this study provide useful information on the viability of EI for water security in South Africa.

Something about best practices could be mentioned here? e.g. inegrated, catchment approach, top to bottom, less dense to more dense, and critically here: the need for sustainability - funding for follow-ups

Conclusions

IAP clearing in catchment areas should be considered a formal intervention for securing future water supply alongside built infrastructure options in South Africa's water supply systems. IAP clearing would lead to a total estimated streamflow gain of 1595 million m^3 and a yield gain of 997 million m^3 by 2050, equivalent to a quarter of the yield gains through implementation of built infrastructure interventions over the same time period. The URVs for built infrastructure ranged from R0.48/m^3 to R44.36/m^3, while the URVs for IAP clearing ranged from R0.79/m^3 to R7.18/m^3. All URVs for IAP clearing were lower than that of built infrastructure interventions, except for just one water supply system, the Orange River System. These findings add to the growing body of literature that advocates for EI investments to secure hydrological ecosystem services by showing that such approaches can be more cost-effective than built infrastructure development options. The findings should be used to leverage and prioritise investments in EI in South Africa and to encourage the initiation of new partnerships and funds for priority catchment areas.

Competing interests

We have no competing interests to declare.

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Data available on request from authors.

Figures and tables

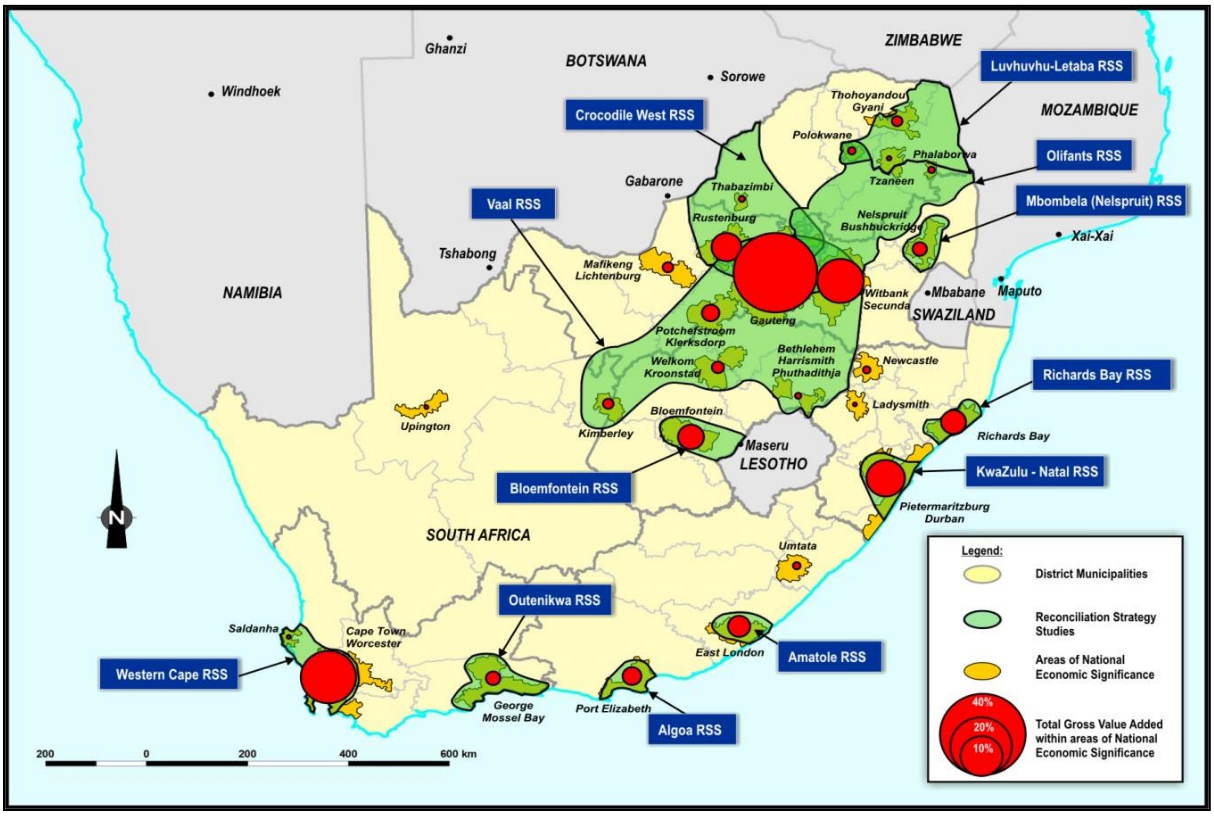


Figure 1. The regions and scales of the twelve reconciliation strategy studies (RSS) conducted and published by South Africa's Department of Water and Sanitation (50).

Table 1. Regression models used to calculate the number of person-days required to clear one hectare of gum, pine, and wattle species, where I_{ha} is the invadable hectares in the relevant quaternary catchment, and x is the average percentage density per pixel (31).

Species	**Initial clearing**	**Follow ups**
Gums (*Eucalyptus spp.*)	$\mathrm{I}_{ha}(2.4254e^{0.028x})$	$\mathrm{I}_{ha}(1.7074e^{0.1(0.028x)})$
Pines (*Pinus spp.*)	$\mathrm{I}_{ha}\ (2.0647e^{0.027x})$	$\mathrm{I}_{ha}(1.6161e^{0.1(0.027x)})$
Wattles (*Acacia spp.*)	$\mathrm{I}_{ha}\ (2.0057e^{0.028x})$	$\mathrm{I}_{ha}(0.2006e^{0.1(0.028x)})$

Spelling error: uMngeni?

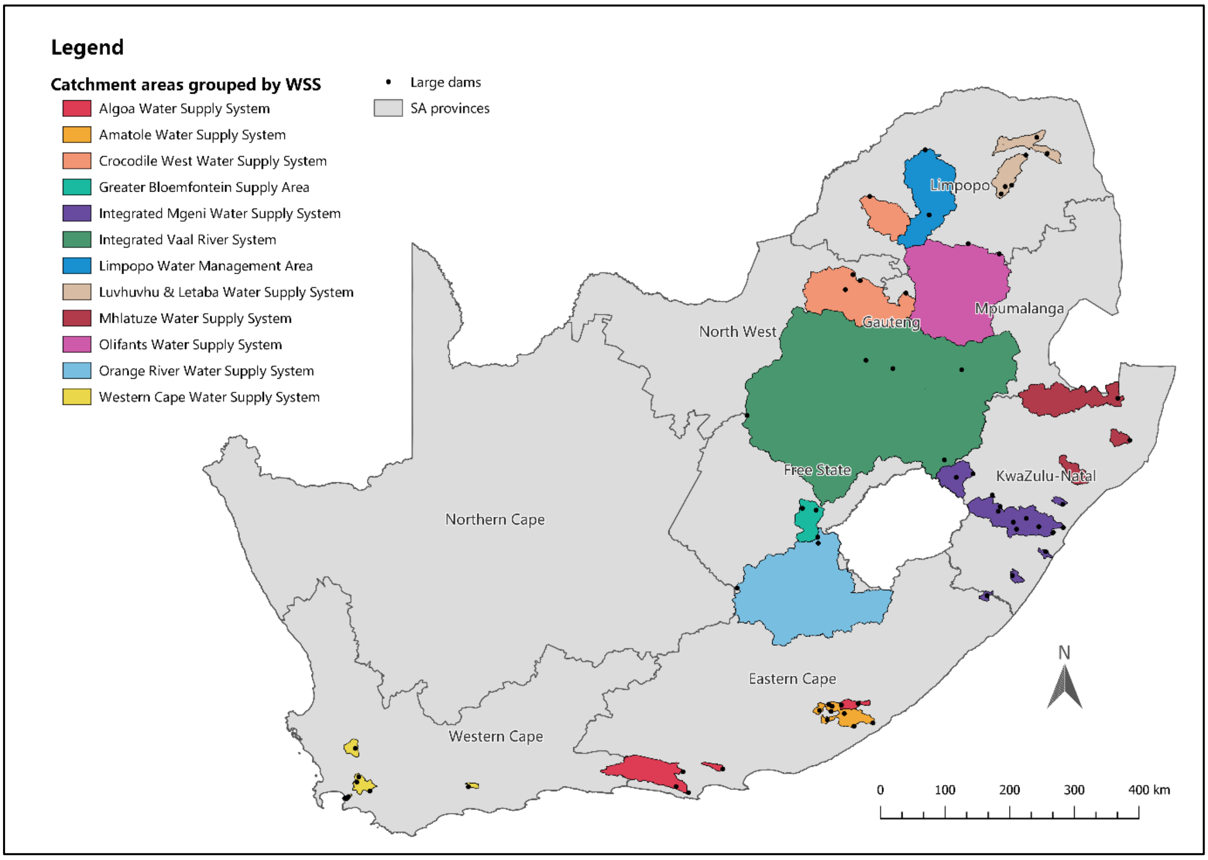


Figure 2. Spatial distribution of dam catchment areas (coloured by WSS) included in the IAP spread and cost-effectiveness analyses.

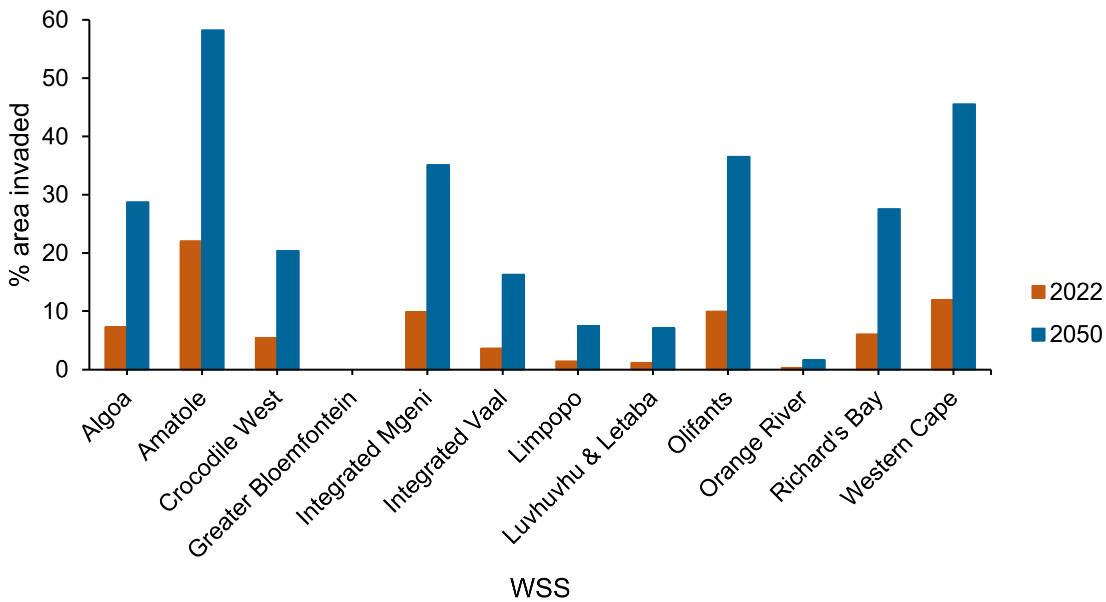
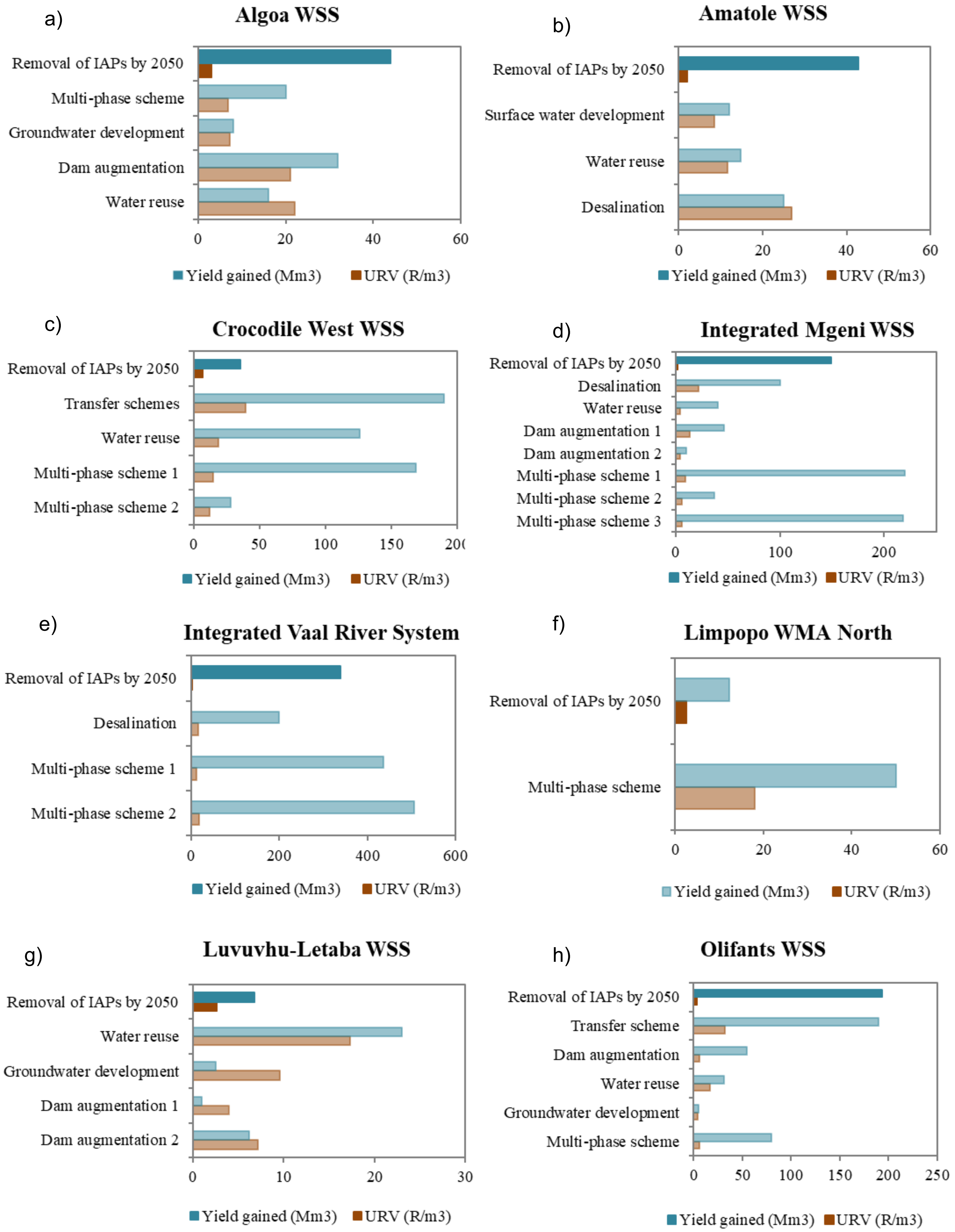


Figure 3. Present (2022) and future (2050) percentage area of IAPs in each water supply system.

Table 2. The total condensed hectares (c.ha) that would be infested in 2050 if no clearing was pursued, the water gained by 2050 with intervention and the present value (PV) in 2022 Rands of the investment required to clear IAPs in existing bulk water supply infrastructure catchment areas of each relevant water supply system between 2022 and 2050.

WSS	Area infested by 2050 without intervention (c.ha)	Increase in streamflow by 2050 with intervention (million m^3)	Increase in yield by 2050 with intervention (million m^3)	PV of clearing costs (R millions)
Algoa WSS	145 657	103.9	43.9	740.80
Amatole WSS	92 804	87.7	42.7	578.89
Crocodile West WSS	235 377	66.5	35.8	1 414.64
Integrated Mgeni WSS	227 610	303.9	148.9	1 231.66
Integrated Vaal River System	922 233	423.4	338.7	4 696.02
Limpopo WMA North	61 764	22.8	12.3	136.84
Luvuvhu-Letaba WSS	24 929	11.8	6.8	71.80
Olifants WSS	524 977	263.0	193.6	3 078.45
Orange River System	45 818	26.6	14.3	145.45
Richard’s Bay WSS	188 057	180.4	89.2	889.88
Western Cape WSS	46 326	105.4	71.0	325.93
Total	**2 515 554**	**1 595.4**	**997.1**	**13 310**


a)
Algoa WSS
Removal of IAPs by 2050
Multi-phase scheme
Groundwater development
Dam augmentation
Water reuse
0
20
40
60
Yield gained (Mm3)
URV (R/m3)
b)
Amatole WSS
Removal of IAPs by 2050
Surface water development
Water reuse
Desalination
0
20
40
60
Yield gained (Mm3)
URV (R/m3)
c)
Crocodile West WSS
Removal of IAPs by 2050
Transfer schemes
Water reuse
Multi-phase scheme 1
Multi-phase scheme 2
0
50
100
150
Yield gained (Mm3)
URV (R/m3)
d)
Integrated Mgeni WSS
Removal of IAPs by 2050
Desalination
Water reuse
Dam augmentation 1
Dam augmentation 2
Multi-phase scheme 1
Multi-phase scheme 2
Multi-phase scheme 3
0
100
200
Yield gained (Mm3)
URV (R/m3)
e)
Integrated Vaal River System
Removal of IAPs by 2050
Desalination
Multi-phase scheme 1
Multi-phase scheme 2
0
200
400
600
Yield gained (Mm3)
URV (R/m3)
f)
Limpopo WMA North
Removal of IAPs by 2050
Multi-phase scheme
0
20
40
60
Yield gained (Mm3)
URV (R/m3)
g)
Luvuvhu-Letaba WSS
Removal of IAPs by 2050
Water reuse
Groundwater development
Dam augmentation 1
Dam augmentation 2
0
10
20
30
Yield gained (Mm3)
URV (R/m3)
h)
Olifants WSS
Removal of IAPs by 2050
Transfer scheme
Dam augmentation
Water reuse
Groundwater development
Multi-phase scheme
0
50
100
150
200
250
Yield gained (Mm3)
URV (R/m3)

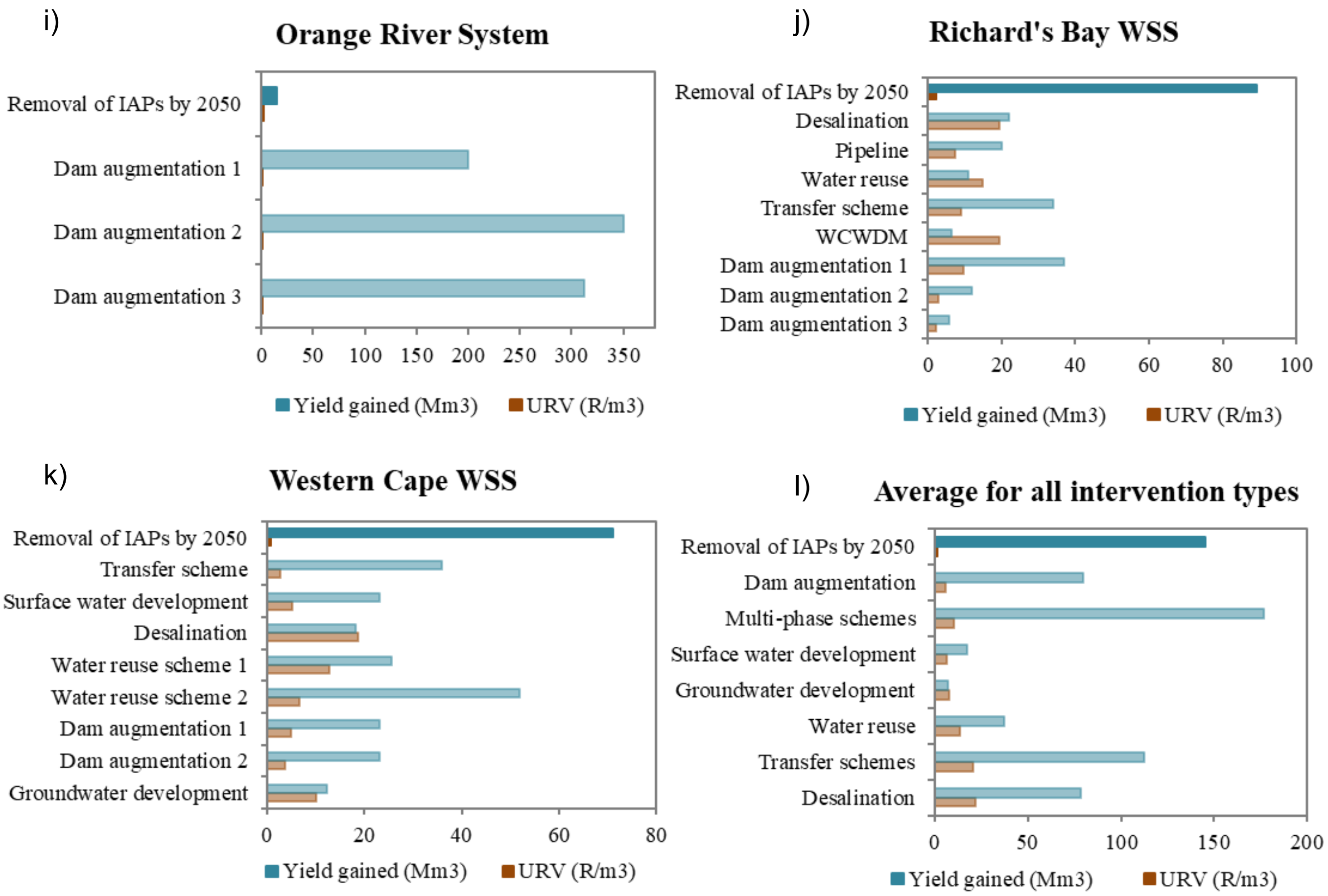


Figure 4. (a-l) Unit reference value (URV) and yield gained through implementation of interventions for each water supply system, and (**g**) the average URV and yield gained per intervention type across all water supply systems.

Table 3. A summary of the overall extent of IAPs (% IAP coverage) within each water supply system without intervention, as well as the unit reference values (URVs) associated with built infrastructure and IAP clearing. URVs are reported in 2022 Rands.

WSS	% IAPs		Range of Built Infrastructure URVs (R/m^3)	URV IAP clearing (R/m^3)
	2022	2050		
Algoa WSS	7.26	28.68	6.77 – 25.62	2.99
Amatole WSS	22.00	58.22	8.46 – 28.66	1.97
Crocodile West WSS	5.43	20.35	12.38 – 44.36	7.18
Integrated Mgeni WSS	9.84	35.12	4.54 – 21.91	1.43
Integrated Vaal River System	3.61	16.30	11.80 – 17.61	2.78
Limpopo WMA North	1.40	7.50	*17.95	2.53
Luvuvhu-Letaba WSS	1.14	7.10	**3.98 – 17.32	2.60
Olifants WSS	9.96	36.51	4.50 – 31.92	2.82
Orange River System	0.27	1.61	0.48 – 0.84	2.45
Richard’s Bay WSS	6.03	27.50	2.22 – 19.36	2.01
Western Cape WSS	11.97	45.49	2.57 – 18.77	0.79

*Only one planned built infrastructure intervention.

**Values based on the average URVs of similar projects due to deficient data.