Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025

FAO Otieno[1]* and GMM Ochieng[1]

[1]*Faculty of Engineering, Tshwane University of Technology, Private Bag X680, Pretoria 0001, South Africa*

Abstract

South Africa, currently categorised as water stressed country is forecasted to experience physical water scarcity by the year 2025 with an annual freshwater availability of less that 1 000 m^3 per capita. With the trends in population growth and its attributes and continuous pollution of the available water sources, there is bound to be increased pressure on the available water probably resulting in increased conflict over its allocation and a further stress on this resource leading to scarcity. Most countries in the world including South Africa have developed most of their water resources with very little scope for further expansion. This study attempted to establish possible solutions to this scenario. Possible solutions would be as follows. First is the demand management of the water through developing and or improving existing systems that improve water use efficiency in the various demand sectors thereby increasing access to more users and uses for a given volume of water. Second is identifying and developing alternative supply systems suitable for the various demand sectors in order to augment the conventional supply volumes. Third is the application of feasible, special management techniques to improve water quality to appropriate standards for particular uses in areas where natural poor quality water occurs. Fourth is the reallocation of some water from low benefit uses to higher benefit uses. Fifth is the possibility of water transfer from surplus areas to deficit area. A water management tool/model suitable for the various sectors of demand and suitable areas of application in each sector is envisaged as the output of this study. If found to be practicable, and eventually utilised, this model will have the potential to increase the water availability for the various sectors and avert possible conflicts in water allocation. The impact of this economically, socially and environmentally in South Africa and possible application in other water stressed countries with similar conditions will be significant.

Introduction

Sustainable water development and management is a critical component of development for all societies. Often, however, the geographic distribution of water resources does not correspond to the location of the demand centers. South Africa for example is a semi arid country (65% of the country) in which the average rainfall of 450mm/year is well below the world average of about 860mm/year. As a result, South Africa's water resources are in global terms, scarce and limited in extent (RSA, 2002). The country is currently categorised as water stressed with an annual fresh water availability of less than 1 700 m^3 per capita (the index for water stress). The current estimate by FAO is 1.154 m^3 per capita/year [2]. The International Water Management Institute (IWMI) (IWMI, 1996) estimates that in 2025 the country will be among the countries in the world that will experience a physical water scarcity scenario with an annual freshwater availability of less than 1000m^3 per capita (the index for water scarcity). The natural availability of water across the country is also uneven and this is compounded by a strong seasonality of rainfall. Currently eleven of the nineteen Water Management Areas (Catchment based) in the country are facing a water deficit where the requirements of water exceed its availability whilst a surplus still exists for the country as a whole. An analysis by the Department of Water Affairs and Forestry (DWAF) show that looking forward to 2025 several additional Water Management Areas (WMA) will be in a situation of water deficit even if further potential infrastructure development is factored in. the development of infrastructure is in itself an expensive option and therefore an efficient use of currently available water resources must be improved (RSA, 2002).

Often, it is not practical or economically viable for water to be transferred from areas of surplus to areas of deficit. The recently proposed First Edition National Water Resources Strategy (NWRS) (RSA, 2002) points out that such imbalance within the WMA will be addressed by the relevant catchment management strategies when they are developed. NWRS simply sets out the ways in which the RSA government aims to achieve integrated water resource management by way of describing the policies, strategies, plans and procedures by which this will be done.

Since such tool/model to address these imbalances at the catchment level is not in place yet, the aim of this study will be to make a contribution in realising the objectives of this strategy by applying known scientific knowledge and modeling techniques to develop a water management model/tool to address the imbalances in the deficit and near deficit WMA in South Africa. In this case, a representative deficit WMA(s) will be selected for study based on the level of development, agro climatic conditions, relative water scarcity, level of agricultural intensification and the degree of competition for water. This will be inline with the proposed NWRS objectives in fulfilling the National Water Act (RSA,1998) that seeks to equitably, efficiently and sustainably develop water resources in South Africa.

The model will look at the Potential Yield of the WMA, against the various water use sectors i.e. for domestic (including 'productive use' use), industrial, mining, agricultural and the environment need under normal (present) conditions. Optimisation techniques will then be applied to each use sector and the effect on the Yield analysed for the various optimisation levels (feasible both technologically and economically). An 'Augmented Yield' through intro-

This paper was originally presented at the 2004 Water Institute of South Africa (WISA) Biennial Conference, Cape Town, South Africa, 2-6 May 2004.
* To whom all correspondence should be addressed.
☎+2712 318-5120 ; fax:+2712 318-5568;
e-mail: otienofao@tut.ac.za

duction of less conventional sources will also be determined. This will then be balanced against the various use sectors under normal (present) conditions and optimised conditions. Variations of optimisation conditions under Potential and 'Augmented' Yield will then be analysed to obtain the most optimal abstraction from the yield that would be economically and technologically feasible. This would then form the basic tool/model for water resource management in the WMA. The parameterisation will be such that it is replicable in other WMA(s) and other regions out of South Africa with similar conditions.

Trends in water use/demand and general water situation in South Africa

Water demand projections in South Africa indicate an annual growth rate of 1.5% between 1990 and 2010 with 3.5% predicted for urban and industrial use and 1% for irrigation (*Review of Water Resources Statistics*). Despite the conventional demand sectors, a major but salient demand sector is the "productive uses" of water at household level and village-based enterprises. This sector is predicted to more than double the water supply volume and must be better recognised in order for rural water supply to become more demand responsive and sustainable (Moriarty, 2001; Natural Resources Institute). Water transfer from surplus to deficit areas is also increasing leading to reduced availability in the transfer area. With the increase in population coupled with increased human activities, the impact of organisations or individuals on the water quality in rivers, streams, groundwater and wetlands will make water unavailable through pollution. Deteriorating water quality is one of the major threats to South Africa's capability to provide sufficient water of appropriate quality to meet its needs and to ensure environmental sustainability (RSA, 2002). These conditions will put pressure on the already stressed water systems leading to a reduction in water availability, a situation likely to result in increase in conflicts over water allocation.

Many of the current patterns of water use are still characterised by inequality, inefficiency, and inadequacy (Mokgobe et al., 2001). As stated in the Proposed First Edition NWRS (RSA, 2002), with the current high degree of resource utilisation in the country, the efficiency of water use must be substantially improved. For instance irrigated agriculture represents close to 60% of the total water requirements in the country (RSA, 2002) (73% used in agriculture [8]: 54% of readily available water is used in irrigation, (WRC, 2002)). Yet, irrigation water use efficiency is estimated at 21% (*AQUASTAT Country Profiles)* while the direct contribution by agricultural sector to the GDP is only about 4 – 5% (IPTRID, 2000) (4.5%(RSA, 2002)). Worldwide studies of major cities in the world indicate that 35 – 50% of water supplied for domestic purposes is unaccounted for (Rosegrant et al., 2002). All these are pointers to a looming water crisis nationally, regionally and internationally.

To avert a looming crisis, especially in the already deficit and near deficit WMA, new storage projects, optional water management methods and design innovations will be important components to the solution. Unfortunately for South Africa, much of the readily available water resources in the deficit areas have been developed (IPTRID, 2000). In the Northern parts of the country (constituting eight out of nineteen WMAs), both surface and groundwater resources are nearly fully developed and utilised with little undeveloped resource potential remaining. Some over exploitation occur in localised areas. The reverse applies to the well-watered South-Eastern region of the country (constituting three out of nineteen WMAs) where there are still significant undeveloped and little used resources (RSA, 2002). However, as already mentioned, it might be impractical or economically unviable for water to be transferred from surplus to deficit WMAs. The prospects therefore of increasing new storage projects in the deficit WMAs might be minimal.

Possible solutions as envisaged in this study are as follows:

- Demand management of water in the respective WMA. This will be done through developing and or improving existing systems that improve water use efficiency in the various demand sectors. Examples would be identifying the "sinks" for the unaccounted for water in domestic supply and developing means of "sealing" such "sinks"; Cleaner production techniques in the industry or improving irrigation use efficiency by precision irrigation. In these ways, the same volume of water in the use sectors is made available for more users/uses.
- Developing alternative supply systems suitable for the various demand sectors in order to augment the conventional supply volumes e.g. use of marginal water and reuse of wastewater for irrigation, desalination, regional cooperation, rainwater management among others.
- In areas where natural poor quality water occurs, feasible, special management techniques may be applied to improve water quality to appropriate standards for particular uses.
- Reallocation of some water from low benefit uses to higher benefit uses over time. Most likely to be heavily impacted by this approach is the agricultural sector (irrigation). However, there is bound to be tension and conflict through this approach. This is because for instance, in South Africa, approximately 49% of the population lives in rural areas where agriculture is practiced. IPTRID (IPTRID, 2000) report shows that irrigated agriculture is of considerable importance in rural areas with opportunities for employment and food production for the families. The problem is compounded by the location of the country. Vast expanse of South Africa is considered arid and semi arid land with 65% of the country not receiving enough rainfall for successful dry land farming (<500 mm/year). Therefore irrigation is inevitable.

These approaches could be supported by a report from a study by (Rosegrant et al., 2002) for the 2020 Vision Initiative stating that expanding water supplies can help alleviate water scarcity, but the results of the study show that the most promising avenue is likely to be water management reforms, incentive policies, and investment in infrastructure and technology to enhance efficiency in the existing uses. For example in this report it is shown that feasible improvements in irrigation efficiency of basin scale irrigation water use can, on a global scale, compensate for irrigation reduction resulting from:

- the phasing out of groundwater overdraft worldwide;
- increased committed environmental flows;
- higher prices for agricultural water use (which themselves encourage investments in improved efficiency); and
- low irrigated area development.

It is also shown that improving irrigation water use efficiency is an effective way to increase water productivity and availability. Further, in the Proposed First Edition NWRS (RSA, 2002), it is reported through a study by DWAF that despite the increasing entries of competing uses of water, sufficient resources are available (considering the country as a whole) to meet all priority water requirements for the next 25 years provided they are managed well (management being the catch word).

Rationale

Models play an essential role in predicting outcomes ("what- if scenarios") and in understanding the possible consequences of interventions in important management objectives. It is widely acknowledged that water scarcity is nationally, regionally and locally varied. Therefore, a good water management policy involves planning at the watershed or basin level, and implementing at the local level. This fact is supported by the National Water Act (RSA,1998) that establishes the basis for management of water resources on a catchment basis (for equity, efficiency and sustainability). With all the complexities involved in development of models, it is important to borrow from existing basic techniques but the model must be tailored to specific countries and basins (in this case South Africa and WMAs). Each model varies based on the level of development, agro climatic conditions, relative water scarcity, level of agricultural intensification, and degree of competition for water. There is therefore need to adapt and develop tools to address complex water/environment problems, assist stakeholders in putting policy into action and to develop effective management strategies at the catchment level.

Study objectives

Broad objectives

The broad objectives of the study will be:

- To assess the water use practice in the key demand sectors aiming at establishing areas that require improvement or development to increase water use efficiency and the possibilities of their uptake
- Identify viable optional supply sources suitable for each demand sector aiming at assessing their impact on water availability in South Africa and possibilities of their development and uptake
- General assessment of the impact of the above measures on water availability in quality, quantity, the economic implications and environment in totality. Combining the findings from the above to work out an optimised management tool suited to each catchment / WMA and its characteristics (climate, land use, infrastructure etc)

Specific objectives

This will be handled under each broad objective.

Specific objectives for broad objective 1

- Assess the water withdrawal level versus the actual product (output) water consumption level in agricultural, domestic (including productive water use) and industrial sectors. The aim here is to establish the use efficiency. A case study approach on a selected representative WMA will be used.
- Assess the magnitude of evaporation from reservoirs as a freshwater user and further assess its effect on the water management model (in most cases, this component of water use is ignored whilst it contributes greatly to water losses. Its contribution is estimated to be more than the total of industrial and potable supply put together)
- Take stock of the quantity of water rendered unavailable through utilisation in the various sectors such as the quantity of water rendered unusable through pollution (from point and none point sources)
- Assess possible technological/engineering means of rehabilitating this quantity (in 3 above). Comparing costs of development and environmental effects if any.
- Do multi criteria analysis in selecting the best applicable options for each sector.

Specific objectives for broad objective 2

- For each demand sector identify feasible optional supply source based on the level of quality demanded by each sector, costs of application and technology level required (sustainability).
- Assess the quantity of conventional supply volumes augmented by each system
- Do multi criteria analysis in selecting the best applicable options for each sector

Specific objectives for broad objective 3

- From the multi criteria analyses establish the contribution of each best option on availability of water and its productivity.
- Combining the outcomes of specific objectives 2 and 3 above develop a water balance model accounting for all sectors including reservoir losses, unaccounted for water, water for productive uses and the environment itself. The water balance model should provide information on total available renewable water, optimised sector water use and use efficiencies and augmentation within the water cycle in the selected representative elementary catchment (case study) that can readily be replicated / reproduced for all the catchments / WMAs in this country.

Proposed study methods

Representative catchment / water management area (WMA)

This study will base its data collection and analysis on a catchment / WMA level. Therefore, the first and most important task will be the selection of a representative catchment based on the level of development, agro climatic conditions, relative water scarcity, level of agricultural intensification, and degree of competition for water. The conditions should be such that reproducivity of the model in other catchments/basins is possible.

Demand areas / sectors

Agricultural water use

The present irrigation practice(s) will be examined. The water use efficiency (s) for each practice will be determined by looking at the actual crop water requirement, actual quantity of water applied, quantity wasted (non consumptive), cost involved. Possible improvements on the existing systems or introduction of better/ alternative systems will be assessed based on the water use efficiency (s), costs and sustainability. The quantity and quality of water made available through improved use efficiency of the existing systems or alternative systems will be calculated based on the present and forecasted future irrigation needs.

Industrial water use

Major industries will be listed. The water withdrawal will be established. The production line water use and processes will be evaluated. Possible improvements on production process to improve on water use efficiency will be explored based on the economic and environmental draw offs. The quality and quantity of water made available through these improvements or alterations in the process or product will be calculated based on the present and future forecasted industrial development.

Domestic water use (including water for productive use)

Present conventional supply volumes (i.e. for drinking, cooking, washing and sanitation) will be established. Present productive use volumes will be established (especially for the rural community). Present use efficiency in both scenarios will be evaluated. The unaccounted for water will be determined. Possible means of improving use efficiency in both scenarios will be explored and ways to account for the unaccounted for water will be explored too. The volume saved from these means will be calculated based on the economic impacts, present and forecasted future demands.

Evaporation from reservoirs

Stock of all the present number of reservoirs will be taken and the volumes of water contained calculated. The quantity of water evaporated monthly/yearly will be calculated (using best suited model for the catchment). The quantity made unavailable each month/year for the various activities will thus be determined. This will be used in assessing the effect of reservoir evaporation on the water availability.

Environmental water demand

This is basically water for recreation, and for ecological balance. Present volumes and use trends, projected future volumes and use trends, use efficiency, and sustainable abstractions if any will be evaluated

Optional/alternative water supply sources

Use of marginal water and reuse of wastewater

Urban drainage water quality will be analysed. Possible treatment and possible use areas such as irrigation and other "productive use" use such as brick making will be explored. The effect of this on the stream water quality will be analysed. The impact on water availability will also be evaluated. 99.9% of wastewater flow is water with only 0.1% as solids. The best treatment strategies will be explored with the aim of making the wastewater reusable. Possible reduction of wastewater pollution in receiving waters will be explored aiming at reducing the water unavailability through wastewater pollution. The quantity that can be rehabilitated through these proposed/improved systems will be calculated based on the current and forecasted waste production levels. Evaluation of the costs and environmental effects will be done. The impact on water availability will be determined.

Rainwater management

The most critical management challenge is how to deal with the poor distribution of rainwater leading to short periods of too much water and flooding, and long periods of too little water. This study will explore the technologies, skills and capital resources required to overcome the poor and extreme distribution of water resources through storage and transfer mechanisms. The aim is to enhance access to water for agriculture, drinking and sanitation and environment. The approach will be to develop appropriate tools for enhancing the productivity of water in the following:

Rain fed Production: use will be made of well known soil and water conservation techniques (the principle requirement is the improvement of infiltration, water holding capacity).

Roof top Water harvesting: look at the best collection and storage design and the quantities that can be harvested in any given rainfall event. Potential quantities will be estimated from present and forecasted infrastructural development.

Field Water Harvesting: As cities spread outwards, encroaching into the rural areas and the rural areas become urbanised, conversion from predominantly vegetated land use to urban uses may result in tremendous reductions in watershed absorption capacity. This situation results in concentrated storm runoff characterised by shorter times of concentration, high flow velocities and sharp peak discharges that cause land degradation through erosion, floods downstream and heavy sediment loads in receiving waters such as streams, lakes etc. The increased volumes of runoff can be harnessed for useful purposes. In this study, assessment of infrastructural development will be done. Derivation of direct runoff hydrographs associated with historical infrastructural development will be done. Runoff plots will be used to establish soil-water relationships. Soil samples will be collected and analysed for relevant properties. Development and verification of a model for distributing and storing runoff to the unsaturated subsurface watershed components to meet agricultural water demand and storage of excess to meet domestic demand and agricultural demand through irrigation will be done. The model will be sensitive to downstream needs so as not to cause imbalance in water system (through hording).

Desalination

This is a capital - and energy intensive source of freshwater that would be out of reach of many rural communities and many developing countries' budgets. Ultra filtration technology was widely developed in South Africa to deal with the wide range of industrial and mining pollutants. Although there is great potential for augmenting South Africa's water supply by desalinating sea water and brackish groundwater, the cost are still prohibitive (3 – 4 times more expensive than conventional methods of obtaining freshwater (Eglal et al., 2000). As such, this state-of-the art technology has not yet applied to domestic water supply except in exceptional cases. In this study, its possible effect on water availability if implemented will be discussed.

Regional cooperation

Two or more countries share most river basins in Africa. Since this is a fairly political approach through signing of protocol and negotiated treaties, competition and conflict in water use generally emerge in the event of a breach of agreement leading to international tension. However, its possible contribution to water availability will be discussed.

Cloud seeding

In Africa region, South Africa is credited as one of the countries to be practicing cloud seeding technique as a form of unconventional water source (Eglal et al., 2000). The cost implications would also make it unsustainable. Its possible impact on water availability may be discussed.

Multi -criteria analysis (MCA)

Option selection will be done through MCA. This method looks at all the options in reference to purpose fulfillment, economic and environmental implications and social acceptance or priority. Weightings will be used.

Modelling

Model development will be based on known water balance evaluation techniques and optimisation methods.

The product/envisaged outcomes of the study

- The projected product of the study will be an integrated water resources management tool for both rural and urban catchments to optimally and efficiently utilise and develop water resources to avert a possible water crisis in South Africa and other related countries under similar conditions.
- The tool will incorporate both conventional and none conventional demand sectors.
- The developed tool will assist stakeholders in putting policy into action and to develop effective management strategies at the catchment level in line with the National Water Act (1998).

References

REPUBLIC OF SOUTH AFRICA (2002) *Proposed First Edition National Water Resource Strategy*.

REVIEW OF WATER RESOURCES STATISTICS BY COUNTRY. Viewed on http://www.fao.org/ag/agl/aglw/aquastat/water_res/south_africa/index.stm

INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI) (1996) World Water Demand and Supply, 1990 to 2025: Scenarios and Issues, Research Report 19.

REPUBLIC OF SOUTH AFRICA (1998) *National Water Act* (Act 36 of 1998).

MORIARTY P (2001) WATSAN and rural livelihoods approaches. Paper prepared for the 27th WEDC Conference, People and Systems for Water, Sanitation and Health, Lusaka, Zambia.

NATURAL RESOURCES INSTITUTE: *Our Work in Water Management, Viewed at http://www.nri.org*

MOKGOBE K, POLLARD S and BUTTERWORTH J (2001) Water resources and water supply for rural communities in the Sand River catchment, South Africa. Paper prepared for the 27th WEDC Conference, People and Systems for Water, Sanitation and Health, Lusaka, Zambia.

AQUASTAT COUNTRY PROFILES. Viewed on http://www.fao.org/ag/agl/aglw/aquastat/countries/south_africa/index.stm

WATER RESEARCH COMMISSION (2002) Technical Report 1999, Water Research Commission, Pretoria.

INTERNATIONAL PROGRAMME FOR TECHNOLOGY AND RESEARCH IN IRRIGATION AND DRAINAGE (IPTRID) (2000) Affordable Irrigation Technologies for Smallholders: Opportunities for Technology Adaptation and Capacity Building, Programme Formulation Report No. 6, The Republic of South Africa.

ROSEGRANT MW, CAI X and CLINE SA (2002) *Global Water Outlook to 2025. Averting an Impending Crisis*. A 2020 Vision for Food, Agriculture and the Environment Initiative", International Food Policy Research Institute, Washington, DC, USA; International Water Management Institute, Colombo, Sri Lanka,.

EGLAL R, RATHGEBER E and BROOKS DB (2000) Water Management in Africa and the Middle East: Challenges and Opportunities", Copyright 1999, 2000 © IDRC (International Development Research Centre).