SAND-TRAPPED WATER RESERVOIRS: ALTERNATIVE TECHNOLOGIES FOR FRESHWATER AUGMENTATION IN REMOTE COMMUNITIES OF SOUTH AFRICA

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***Abstract*:** South Africa water resources are scarce in global terms with mean annual rainfall 50 per cent less than world average of 860 mm/a . On the other hand, increasing economy development and resulting contamination of water resources further reduced water availability. The conventional water resources (largely surface water) in the country have been fully exploited. So therefore, new methods are needed to make limited water resources available. High evaporative losses from surface storage, increasing costs of large dams and aridity conditions make development of unconventional sand water storage appealing for freshwater augmentation.

***Keywords*:** Rural water supply, groundwater, run-off storage, ephemeral river.

I. INTRODUCTION

In rural semi-arid areas, access to a sustainable and adequate supply of water is critical. Rural communities use water for a wide range of productive and domestic uses, all of which are important to their livelihoods.

South Africa is semi-arid and classified water-stressed country [1]. Freshwater is limited and in great demand as population increase. The demands for water at assured supply levels are far exceeded the capacity of some of the catchments to provide. With over 50% of South African's catchments considered to be over-allocated [6] the need to increase water resources in meeting growing water demand has been recongnised more than ever. As surface water resources become fully developed, groundwater development offers the only possible optional method for developing water resources [9]. However, in dry semi-arid regions, rural settlements with limited availability of surface water resources often depend on groundwater for all their water requirements and overexploitation of groundwater is usually experienced because of this. [1] considered contributing factors to slow rates of groundwater recharge as low rainfall combined with high rates of evaporation experienced in semi-arid regions.

Despite an increase in the number of options for water sources development, sand water storage development provides a potentially means in rural communities under arid conditions. This method, coupled with modern hydrological tools may supplement the other classical methods of water resources development and help to secure future water supply. The focus of this paper is therefore to present general overview of water resources in South Africa, describing unconventional method of groundwater storage which can be applied with low investment costs and offer good prospect for development.

II. OVERVIEW OF WATER RESOURCES

South Africa climate varies from semi-desert in the western part to subhumid along the eastern coast [2]. Western parts of the country are both arid and hot. Large areas are regularly subjected to series of prolonged dry periods that often broken by intense rainfall. South Africa has limited amount of rainfall a year with clear division between dry and rainy periods. Rainy period is often followed by a long dry period. The average annual rainfall is approximately 460 mm slightly less than half of the world average. The rainfall is irregular in both time and space. The total annual surface runoff of all rivers averages around 49 000 million m^3 which is less than half of the Zambezi's annual flow [2]. However, about 75per cent of runoff flow into the sea along the eastern and southern seaboards. The annual potential evapotranspiration is greater than the annual rainfall. A combination of high variable rainfall and runoff within the rain season and higher evaporation reduces river flow to low levels for most of the time and some are even without water during prolonged dry period. Sometimes unpredictable high flow is experienced resulting in soil erosion and large flash floods carrying large amounts of sediment loads [1]. Natural availability of water across the country is unevenly distributed [4]. Compared with other neighbouring countries, South Africa water resources are small, while groundwater often represents the most important and alternative source of water for towns and villages [10]. Rural/ remote communities at the heart of resources insecurity are more vulnerable to temporal and spatial variability. Many agricultural economies in rural areas are sustained by irrigation and contamination of available water resources by agro-chemical may further decreased water availability with growing difficulties of meeting basic human needs.

III. GROUNDWATER RESOURCES

Alluvial pools are a widespread occurrence under semi-arid conditions. Most of South Africa's rivers are ephemeral [3] with temporary surface flow that varies between seasons. The rivers flow for short periods following heavy rainfall and there are no navigable rivers [2]. Aquifer storage to hold part of the natural flow in seasonal rivers is essential with more than 60% of the river flow arising from only 20 % of the land [4]. The basic principle of aquifer storage is that, instead of storing water at the surface, water is stored subsurface. One of the advantages of subsurface storage is the loss of water due to evaporation is much less than that of surface reservoirs. Groundwater contributes a few of the total available water in rural areas of South African. According to [3] and [4], 60 to 90 per cent of rural areas depend on groundwater. Figure 1 shows groundwater exploitation in South Africa while Table 1 gives the breakdown of groundwater use. As a result, the groundwater resources have assumed great importance as the principal source of freshwater in this semi-arid area [3]. Aridity conditions are considered to create more incentive to develop subsurface water. Since dams for surface storage are increasingly difficult to build because of site limitations and unfavourable environmental, technical, and sustainability. Also, evaporation losses cause surface dams to be inefficient for long-term storage since it has to cope with changes in climate. Presently, over 2,000Mm^3 is lost each year through evaporation from surface storage reservoirs. This is estimated to about 7.5 per cent of total capacity in the country and nearly equal to the volume of water stored in the largest dams in South Africa [1]. While remote communities rely mostly on groundwater, there are strong signs of receding groundwater levels from recent studies over years [8]. Therefore, to ensure best stability in the use of groundwater, it is essential to undertake measures to increase groundwater recharge. Aquifer storage provides a potentially means for fulfilling such measures.

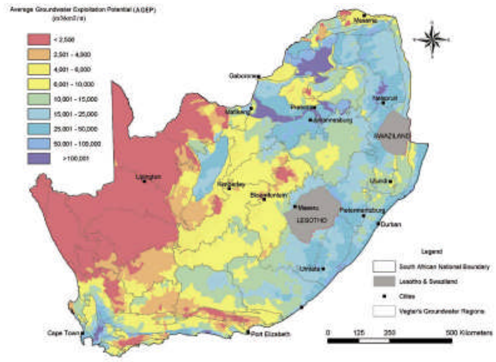

Fig. 1 Average groundwater exploitation for South Africa

TABLE: I

SOUTH AFRICA'S BREAKDOWN OF GROUNDWATER USE BY SECTORS

Water use sector	TOTAL WATER MM^3/YEAR	Per cent total
Urban use	70	3.9
Rural domestic	120	6.7
Stock-watering	100	5.6
Irrigation	1400	78.2
Mining and quarries	100	5.6
Total	1790	100

Source: Tewari and Kushwaha, 2008

IV. WATER HARVESTING AND ARTIFICIAL RECHARGE TO GROUNDWATER

The problem of water shortage in arid and semi-arid areas is not only because of uneven distribution and low rainfall throughout the season but also because of the untapped potential of excess runoff storage for use when needed. Harvesting of runoff water is a principle of collecting and using runoff from a catchment surface. Runoff water catchment technologies have only been used on a rudimentary level in South Africa. However, no significant impact in solving rural and urban water supplies problem have been made. Recharge to groundwater is not a new idea of runoff water harvesting but rather a new term employed to describe traditional as well as unconventional ways of groundwater storage. The storage techniques used in runoff harvesting can be classified as above-ground storage and artificial recharge to ground. The artificial recharge to groundwater aims at increase of groundwater reservoir by adapting the natural movement of surface water using suitable civil construction techniques. [9], described runoff harvesting through sand-trapped reservoir as in-stream adjustment of stream bed barricaded with weir of suitable size. Sand carried by heavy flows during the rains is deposited upstream of the weir and the reservoir is filled up overtime with sand. This forms artificial aquifer which is replenished each year during rain. The water stored in sediment below the ground surface can be used to recharge an aquifer or to raise groundwater levels of an aquifer thus making it accessible for abstraction. Sand-trapped water reservoir system is illustrated as shown in figure 2.

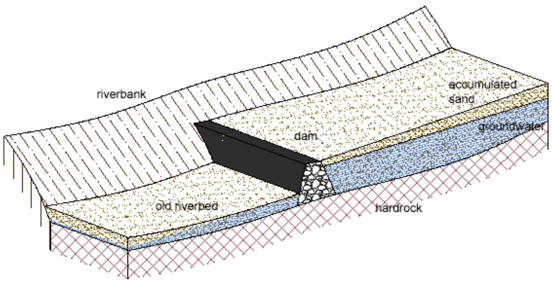

Figure 2. Schematic representation of a sand-storage dam.

Source: Quilis, R.O. et al. (2008)

V. AQUIFER STORAGE

Sand-trapped water reservoirs are indigenous methods where surface runoff is store in the ground by infiltration and resulting movement to underlying groundwater. Their main function normally is to store water for short or long-term periods in sand voids because of sediment deposition from alluvial channel in ephemeral rivers. Other objectives or side benefits include decrease of downstream erosion and protection from evaporation losses and subsequence quality improvement of the water during abstraction as it flows through vadose zones and aquifers. This soil-aquifer treatment or geopurification plays an important role in water reuse, especially where water purification cost is prohibitive in rural areas. Sand-trapped water reservoir is sustainable because with single flash floods reservoir can be brought to its full capacities. However, their design and functionality are based on topography of the catchment areas. [7] suggests an idea of subsurface water storage for South Africa as water conservation and storage for municipalities in response to the growing water scarcity.

VI. SUMMARY AND CONCLUSIONS

One of the 7th agenda of Millennium Development Goals (MDGs), as noted by [13], is decrease by half the proportion of people without sustainable access to basic water. South Africa is a signatory to MDGs with its mixture of developed and developing regions, about 9.7 million (20%) of the people do not have access to adequate water supply. Runoff harvesting technology is not prevalent in South Africa despite their potential for augmenting freshwater in the country. The application is mainly concentrated on roof catchment in the rural areas. The potential of application of runoff harvesting technology is high especially in the rural catchments falling within the deficit Water Management Area such as Limpopo Province. Runoff rainwater harvesting has the potential in this region to supply water to rural and even to peri-urban areas that conventional technologies cannot supply.

Sand-trapped water reservoirs described are possible means of increasing groundwater availability in the respective demand sectors and thus hold potential for research into their further understanding. Runoff water harvesting with specific reference to Sand-trapped water reservoir is selected. South Africa rural areas have a good share of sandy seasonal rivers that are prone to siltation an ideal condition for sand water storage application. Evaluation of alternative technologies for freshwater augmentation in Africa shows that despite the high effectiveness of sand water storage in augmenting freshwater in Africa, its extent of use has been limited to Kenya, Zimbabwe, Egypt, Libya, Tunisia and Algeria [14] Therefore, there is need to promote the technology also in South Africa. Although, improving water productivity by ensuring that water resources are reliable will need the right mix of manageable technologies and appropriate incentives. By linking groundwater sources to a water supply system that obtain from subsurface storages on ephemeral rivers, a major contribution can be made to increase alternative strategies available for water supply management.

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