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Alluvial aquifers in the Mzingwane catchment: Their distribution, properties, current usage and potential expansion

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Abstract

The Mzingwane River is a sand filled channel, with extensive alluvial aquifers distributed along its banks and bed in the lower catchment. LandSat TM imagery was used to identify alluvial deposits for potential groundwater resources for irrigation development. On the false colour composite band 3, band 4 and band 5 (FCC 345) the alluvial deposits stand out as white and dense actively growing vegetation stands out as green making it possible to mark out the lateral extent of the saturated alluvial plain deposits using the riverine fringe and vegetation . The alluvial aquifers form ribbon shaped aquifers extending along the channel and reaching over 20 km in length in some localities and are enhanced at lithological boundaries. These alluvial aquifers extend laterally outside the active channel, and individual alluvial aquifers have been measured with area ranging from 45 ha to 723 ha in the channels and 75 ha to 2196 ha on the plains. The alluvial aquifers are more pronounced in the Lower Mzingwane, where the slopes are gentler and allow for more sediment accumulation. Estimated water resources potential ranges between 175,000 m^3 and 5,430,000 m^3 in the channels and between 80,000 m^3 and 6,920,000 m^3 in the plains. Such a water resource potential can support irrigation ranging from 18 ha to 543 ha for channels alluvial aquifers and 8 ha to 692 ha for plain alluvial aquifers. Currently, some of these aquifers are being used to provide water for domestic use, livestock watering and dip tanks, commercial irrigation and market gardening. The water quality of the aquifers in general is fairly good due to regular recharge and flushing out of the aquifers by annual river flows and floodwater. Water salinity was found to increase significantly in the end of the dry season, and this effect was more pronounced in water abstracted from wells on the alluvial plains. During drought years, recharge is expected to be less and if the drought is extended water levels in the aquifers may drop substantially, increasing salinity problems.

Keywords: Alluvial aquifer; Irrigated agriculture; Remote sensing; Limpopo basin

1. Introduction

1.1. Alluvial aquifers

Alluvial deposits are common in southern Zimbabwe, occurring as sand filled ephemeral rivers. The Mzingwane River is one such sand filled channel, with extensive alluvial aquifers distributed along its banks on the lower catchment and is the major northern (left bank) tributary to the Limpopo River in Zimbabwe, contributing around a quarter of the run-off in the Limpopo River (Gorgens and Boroto, 1997). These alluvial aquifers already sustain commercial citrus irrigation schemes, and are considered to have groundwater potential to support significant additional irrigation development, using infiltration galleries and well point systems to exploit the resource (Owen, 2000).

The distribution of these aquifers is determined by the river gradient, geometry of channel, fluctuation of stream power as a function of decreasing discharge downstream

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due to evaporation and infiltration losses, and rates sediment input due to erosion (Richards, 1982). Alluvial deposits may be characterized by their position within the river valley, and occur as lateral accretion channel deposits, vertical accretion plains deposits, river terrace valley flat deposits and abandoned meander cut-off plain deposits (Owen, 1994). An enhancement of the thickness and area of alluvial aquifers is commonly observed associated with geological boundaries, and this enhancement occurs both upstream and downstream of the geological contact (Ekstrom et al., 1997; Beckman and Liberg, 1997). Such enhanced alluvial aquifers have been noted to have thickness of up to 20 m having a good water resource potential, e.g. Bwaemura Village aquifer has a potential capacity of 12,000 m^3/day, which could be used to develop 240 ha of irrigation (Owen, 2000). The lithologies on either sides of the geological contact will exhibit different degrees of resistance to fluvial erosion. The alluvium will accumulate over the less resistant lithology, regardless whether this lithology is upstream or downstream of the contact. However, the 3D geometry of the resultant alluvial deposits differ significantly dependant on which lithology is upstream and which is downstream (Owen, 2000).

The alluvial sediments have estimated hydraulic conductivity (K) values of between of 40 and 200 m/day based on the Hazen's (1911) method (the sand sieve analysis). Seepage losses have been noted to be insignificant and that the water will have moved 1.5 km downstream over a 300-day dry season (Nord, 1985). The evaporation losses from the channel sand decrease up to 1 m depth and then there is no further loss through evaporation. Yield ranges from 40 to 5200 m^3/day. The alluvial plain and channel deposits have specific yield values of between 5–7% and 15%, respectively (Owen, 1994; Nord, 1985; Wikner, 1980).

Recharge of the alluvial aquifers is generally excellent and is derived principally from river flow. Nord (1985) found that no river flow occurs until the channel aquifer is saturated and such full recharge normally occurs early in the rainy season. By contrast for lateral plains aquifers, recharge depends on the permeability of the aquifer, the distance from the channel and the duration of river flow (Owen, 1994). In Zimbabwe recharge is seasonal occurring in the rainy season (November–February) and aquifer losses due to evaporation, transpiration, vertical seepage losses to bedrock and downstream flows are all sources of aquifer losses during the dry season (April–October). Some alluvial aquifers may be recharged by dam releases during the dry season, such as the Zhove dam on the Mzingwane in southern Zimbabwe.

Evaporation losses from the channel sand beds are initially high, but decline as the water table declines to approximately 90 cm below the sand bed surface (Wipplinger, 1958). On the alluvial plains with finer grained soil, the evaporation extinction depth may be somewhat deeper, but it is transpiration from the thick lush forests that develop on the saturated alluvium under the riverine fringe that are likely to extract the most groundwater from the aquifers in the dry season.

The water quality is relatively good due to regular recharge and flushing out by flood waters and dam releases in the catchment (Owen, 1994; Owen, 2000). The salinity increases with distance from the channel and there is increase in salinity during the dry season mostly in the semi-arid parts of the catchment. Salinity has been noted to be a more general problem mostly in the plain deposits in the semi-arid areas of the area, which is the Lower Mzingwane (Moyo et al., 2005; Nare et al., 2005). Hoko (2005) reported conductivity levels of up to 9800 $\mu S\,cm^{-1}$ from shallow groundwater in Mwenezi district, immediately to the east of Lower Mzingwane.

Studies have shown that the groundwater in alluvial aquifers above granitic areas is of low salinity and that from basalts is of high salinity, e.g. conductivity of 520 $\mu\Omega\,cm^{-1}$ on granite compared to 1450 $\mu\Omega\,cm^{-1}$ on basalt, and sodium absorption ratio of 0.6 on granite compared to 2.3 on basalt (Owen, 1994).

In this paper, the distribution of alluvial aquifers in the Mzingwane Catchment will be identified and water resource potential calculated using data from the literature and satellite imagery identified alluvial aquifers extents. The current alluvial groundwater usage and possible irrigation potential will be analysed.

1.2. Study area

The Mzingwane Catchment is made up of the Mzingwane River and the Ncema, Inyakuni and Insiza tributaries (Fig. 1). The Mzingwane (Umzingwani) River rises near Bulawayo and flows south to the Limpopo, with Insiza as its major tributary. The Upper Mzingwane, Ncema, Inyakuni and Insiza Rivers are all dammed in the Esigodini area, and these dams supply the City of Bulawayo. The lower Insiza is dammed at Silalabuchwa and lower Mzingwane is dammed at Zhove, near Mazunga (Fig. 1). Generally, rainfall in the catchment is erratic and decreases from the north to the south, with annual rainfall at Esigodini ranging from 1200 to 200 mm over the last 70 years, and at Beitbridge from 500 to 50 mm for the same period. The land use in the Upper Mzingwane catchment is mainly commercial farming, private and resettlement land, while the Lower Mzingwane is mainly communal lands. The main settlements are Gwanda Town and Esibomvu, Esigodini, West Nicholson and Colleen Bawn. Commercial irrigated agriculture is a major water user in areas north of Gwanda, while in the southern parts of the catchment agriculture is mostly subsistence farming in the poverty stricken communal lands and extensive livestock management in the commercial areas (ZSG, 1998).

The northern half of the Mzingwane Catchment is underlain by crystalline granitic and gneissic rocks, with mineralised greenstone belts (Bulawayo, Gwanda and Filabusi Greenstone Belts) and intruded by various dolerite dykes and sills (Zimbabwe Geological Survey, 1994 and