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Estimation of Groundwater Recharge Response from Rainfall Events in a Semi-Arid Fractured Aquifer: Case Study of Quaternary Catchment A91H, Limpopo Province, South Africa

By

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Abstract

Groundwater recharge estimation at regional and local scale remains a major challenge especially in arid and semi-arid areas where recharge is difficult to quantify because of uncertainties of hydraulic parameters and lack of historical data. This study estimated groundwater recharge response to rainfall events in a semi-arid fractured aquifer. Recharge was estimated using Chloride Mass Balance (CMB) and Extended model for Aquifer Recharge and soil moisture Transport through unsaturated Hardrock (EARTH) methods. The CMB method estimated recharge by incorporating the ratio of average chloride content in rainfall (including dry and wet deposition) to that of groundwater of the entire study area. The EARTH part of the model used for recharge estimation in this study is SATFLOW, which computes groundwater level with the estimated recharge from the percolation zone and rainfall. Groundwater chemistry data was acquired from the Department of Water and Sanitation (DWS) and Global Project Management consultants, while additional groundwater samples were also collected to fill-in the identified gaps. These together with rainfall samples were sent to Council for Geoscience laboratory for geochemical analysis. Long term rainfall and groundwater levels data were acquired from South Africa Weather Services and DWS, respectively. Using CMB method, recharge rate was calculated both at regional and local scales. The results calculated at a local scale were integrated using 3D Analyst Tool in ArcGIS software to develop a recharge distribution map of the entire area. Sixty percent of the groundwater levels data for 5 boreholes was used for EARTH model calibration while the remaining 40% was used for validation. The model performance was evaluated using coefficient of determination (R^2), correlation coefficient (R), Root Mean Square Error (RMSE) and Mean Square Error (MSE). Three different soil types were identified and these include clay loam, sandy loam and sandy clay. The specific yield values for these soil types are 0.0 - 0.198%, 0.052 – 0.28% and 0.03 – 0.12% for clay loam, sandy loam and sandy clay, respectively. Regional recharge rates of 3.3 mm/a (equivalent to 0.5% of 656 mm/a MAP) and 30.1 mm/a (equivalent to 4.6% of 656 mm/a MAP) were calculated using rainfall chloride concentrations of 0.1 and 0.9 mg/L, respectively. The estimated local recharge rates ranged from 2.2–78.7 mm/a (0.34-11.9%) and 0.24-8.75 mm/a (0.04-1.3%) using rainfall chloride concentrations of 0.9 and 0.1 mg/L, respectively. The average recharge rate estimated using EARTH model is 6.12% of the MAP (40.1 mm/a). CMB results were found to fall within the same range with those obtained from other

studies within the vicinity of the study area. The results of EARTH model and CMB method were found to be comparable. The computed R^2, R, RMSE and MSE ranged from 0.5-0.88, 0.68-0.94, 0.05-0.34, 0.16-3.16, and 0.50-0.79, 0.71-0.89, 0.07-0.68, 0.15-8.78 for calibration and validation, respectively. This showed reasonable and acceptable model performance. The study found that there is an average response of groundwater levels during rainfall events, which is likely to be due to lack of preferential flows between surface water and groundwater systems. This has resulted in an average relationship between estimated and observed groundwater levels during rainfall season. The study has recommended that more boreholes be drilled in the study area when using EARTH model to estimate recharge in order to improve on the recharge distribution across the study area. It is also important to use other recharge estimation methods which are suitable for fractured aquifer system in future as this will assist on the comparison of the results of current study with those of other methods and improve on reliability.