

Estimation of recharge using a revised CRD method

Y Xu^{1*} and GJ van Tonder²

¹ Department of Water Affairs and Forestry, Pretoria

² Institute for Groundwater Studies, University of the Free State, Bloemfontein

Abstract

The cumulative rainfall departure (CRD) method, based on the water-balance principle, is often used for mimicking of water level fluctuations. Because of its simplicity and minimal requirement of spatial data, the CRD method has been applied widely for estimating either effective recharge or aquifer storativity, and consequently gained a focus in South Africa. This paper critically reviews this method and proposes expanded algorithm. Validation of the method under typical South African conditions is discussed based on model-generated and known cases. The study is aided with a user-friendly Excel program called Recharge Estimation Model in Excel (REME).

Introduction

Background

Hydrogeologists often compare rainfall and groundwater levels for estimation of groundwater recharge. The reader may refer to Wenzel (1936), Sophocleous (1991) and Wu et al. (1996).

In South Africa Bredenkamp et al. (1995) applied the CRD method in dolomitic aquifers and promoted the method through their publication entitled “*Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity*”. Their approach is based on the premise that equilibrium conditions develop in an aquifer over time, i.e. average rate of losses equating to average rate of recharge of the system.

They clearly showed that natural groundwater level fluctuation is related to that of the departure of rainfall from the mean rainfall of the preceding time. If the departure is positive, the water level will rise and vice versa. However, it can be demonstrated that as long as there is a surplus of recharge over discharge of an aquifer, even though the departure is negative, the natural water level may continue to rise.

Purpose

The purpose of this paper is to revisit the existing method and to improve the algorithm to accommodate a wide variety of circumstances. Following improvement of the algorithm a user-friendly tool could be developed for groundwater practitioners. Such a need was identified by the Department of Water Affairs and Forestry, which sponsored a project aimed at promoting the effective use of simple yet powerful methods for recharge estimation. This paper summarises some results of this project.

* To whom all correspondence should be addressed.
New address: Department of Earth Sciences, University of The Western Cape, Private Bag x17, Bellville 7535, South Africa
☎ (021) 959-2223; fax (021) 959-2438; e-mail: yxu@uwc.ac.za
Received 6 July 2000; accepted in revised form 3 April 2001.

Theory

Groundwater balance

Assuming an aquifer of area (A) receiving recharge from rainfall (Q_R) with production boreholes (Q_p) tapping the aquifer and with natural outflow (Q_{out}), a simple water balance equation for a given time interval i can be written as follows:

$$Q_{Ri} = Q_{pi} + Q_{outi} + \Delta h_i AS \quad (i = 1, 2, 3 \dots N) \quad (1)$$

where Δh_i is water level change and S aquifer storativity (specific yield). If Q_{Ri} is averaged over such a time interval where Δh_i is zero, the system may be treated as in equilibrium. This is, however, seldom the case in reality.

If Q_{pi} is a constant rate, aquifer storage ($\Delta h_i AS$) adjusts to accommodate for net balance between Q_{Ri} and Q_{outi} . This adjustment of the storage would be reflected in piezometric surface or water level change in boreholes. The cause-effect relationship between rainfall oscillation and water-level fluctuation is effectively represented by the correlation between the CRD and water level fluctuation.

Recharge formulae

Bredenkamp formula

Bredenkamp et al. (1995) defined CRD as follows:

$${}_{av}^i CRD_i = \sum_{n=1}^i R_n - \kappa \sum_{n=1}^i R_{av} \quad (i = 0, 1, 2, 3, \dots N) \quad (2)$$

where R is rainfall amount with subscript “ i ” indicating the i -th month, “ av ” the average and $\kappa = 1 + (Q_p + Q_{out}) / (AR_{av})$. $\kappa = 1$ indicates that pumping does not occur and $\kappa > 1$ if pumping and/or natural outflow takes place.

It is assumed that a CRD has a linear relationship with a monthly water level change. Bredenkamp et al. (1995) derived

$$\Delta h_i = (r/S) \cdot ({}_{av}^i CRD_i) \quad (i = 0, 1, 2, 3, \dots N) \quad (3)$$

where r is a percentage of the CRD which results in recharge from rainfall.