Quantitative Analysis of Groundwater Flow in Ilorin, Nigeria

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Abstract

Groundwater is a principal component of the hydrologic cycle. Groundwater flow was determined for a well located in Ilorin (Longitude 40 35'E, Latitude 80 30'N), capital of Kwara State, Nigeria. The wet season in Ilorin is from March to October while the dry season is from November to February. Peak rainfall events occur between June and September. Groundwater flow was estimated at approximately 1 week (7 days) interval and flow statistics determined for 2007, 2008 and 2009. Mean groundwater flows (l/day) were 88.18, 81.05 and 79.10 for 2007, 2008 and 2009, respectively with corresponding coefficients of variation 0.43, 0.43 and 0.36. Mean monthly groundwater flows were also computed. March had the lowest values for the three years – 42.45 l/day, 39.52 l/day and 35.89 l/day for 2007, 2008 and 2009, respectively.

Keywords: Groundwater, Aquifer.

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1. Introduction

Groundwater flow is a major component of the hydrologic cycle (Rodda et al., 1993), which describes the cyclic movement of water from water bodies through the atmosphere, to the earth and back to the water bodies through overland and underground flows   (Figure 1). Since solar radiation, the driving force for the cycle, varies with seasons of the year and latitude, the intensity and frequency of the cycle depend on climate.

An aquifer (Moench, 1996, 1997; Sophocleus, 2002) is a geologic formation with features that allow significant quantities of water to be stored and transmitted. The aquifer may be confined or unconfined, depending on the absence or presence of a water table which is the static level of water penetrating the zone of saturation. An artesian or confined aquifer is overlain by an impermeable layer while an unconfined aquifer is overlain by a permeable stratum that allows water to percolate to the water table.

Factors affecting groundwater movement are geologic, hydrologic and meteorologic in nature (Beven and Germann, 1982; Betts et al., 2005), the driving force being the hydraulic gradient which is the difference in head between the recharge and discharge areas, divided by the length of the flow path. Groundwater flow rate in response to a given hydraulic gradient depends on the hydraulic conductivity of the aquifer (Vukovic and Soro, 1992; Alayamani and Sen, 1993; Springer et al., 1999; Schroder et al., 2008). Groundwater flow is expressed by Darcy's law (McWhorter and Sunda, 1977; Moench, 1996, 1997).

Groundwater, in most cases, is safer and more reliable for use than surface water. Thus; in most parts of the world, groundwater serves as a major source of water supply. The main objective of this work was to quantify groundwater flow, to enhance water supply planning.
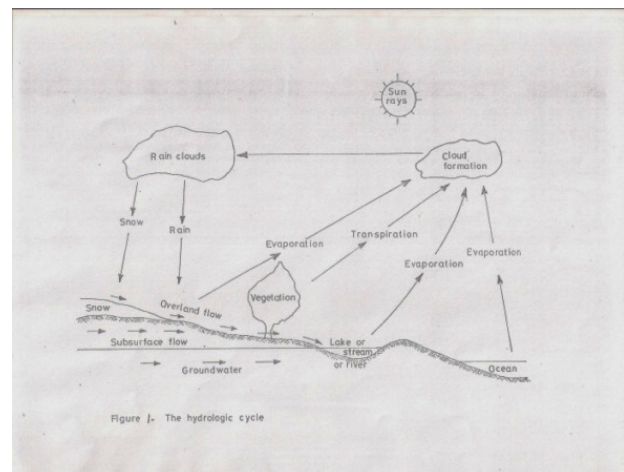

Fig. 1. Cyclic movement of water

2. Methodology

The study well is located in Ilorin (Longitude 40 35'E, Latitude 80 30'N), capital of Kwara State of Nigeria. The town, located in the Southern Guinea Savannah ecological zone of Nigeria, experiences two seasons: wet season from March to October and dry season, from November to February. Heaviest rainfall occurs between June and September. A summary of climatic conditions in Ilorin is as follows (Oyegun, 1983; Akintola, 1986): Mean monthly temperature varies from about 250C to about 290C. The relative humidity varies from about 70% in the dry months to about 80% in the wet months. The mean annual rainfall is

about 1222 mm. The soils have been classified as belonging to the order of alfisols – Tropeptic Haplustalf (Soil Survey Staff, 1975), with sandy loam to gravelly sandy loam on the surface, and sandy clay loam to clay loam in the subsoil.

Water in the well was pumped at approximately 1 week (7 days) interval and the volume of groundwater (Vg) for the period determimed from the well geometry, thus:

$$V_g = \frac{\pi d^2}{4} \Delta h = \frac{\pi d^2}{4} (h_2 - h_1) \tag{1}$$

where:

d = well diameter = 0.93 m
Δh = change in water level
h1 = initial water level (before pumping)
h2 = final water level (after pumping)

The groundwater flow (Qg) was determined as the groundwater volume (Vg) divided by the time of flow (tg); i.e.,

$$Q_g = \frac{V_g}{t_g} \tag{2}$$

3. Results and discussion

The groundwater flow statistics for the study well are shown in Table 1. For 2007; the groundwater flow ranged from 36.91 l/day to 164.70 l/day. The minimum flow occurred on April 2nd 2007 (Julian day 92) while the maximum flow occurred on July 28, 2007 (Julian day 209). The mean groundwater flow for 2007 was 88.18 l/day, and standard deviation of flow, 37.74 l/day. Thus, the coefficient of variation (Cv) was 0.43. For 2008; the flow ranged from 34.97 l/day (March 22nd) to 151.88 l/day (October 4) with mean flow of 81.05 l/day and standard deviation, 34.82 l/day (Cv = 0.43). For 2009; the flow ranged from 29.68 l/day (April 11) to 127.78 l/day (September 26) with mean flow of 79.10 l/day and standard deviation, 28.21 l/day (Cv = 0.36).

Table 1. Groundwater flow statistics for the study well

	2007	2008	2009
Minimum flow (l/day)	36.91	34.97	29.68
Date	April 2nd 2007	March 22nd 2008	April 11, 2009
Julian day	92	82	101
Maximum flow (l/day)	164.70	151.88	127.78
Date	July 28, 2007	Oct. 4, 2008	Sept. 26, 2009
Julian day	209	278	269

Mean groundwater flow (l/day)	88.18	81.05	79.10
Standard Deviation of flow (l/day)	37.74	34.82	28.21
Coefficient of Variation (Cv)	0.43	0.43	0.36

The monthly mean groundwater flows for the study well are shown in Table 2. For 2007; the flows ranged from 42.45 l/day (March) to 141.99 l/day (September); and for 2008; from 39.52 l/day (March) to 139.55 l/day (August). The monthly mean flows ranged from 35.89 l/day (March) to 121.50 l/day (September) for 2009. These results are compatible with basic hydrologic principles since rainfall plays dominant role in groundwater recharge. Peak rainfall events in the study area occur between June and September. These results are useful in water supply planning. Thus March is the most-likely month that other sources of water supply might be needed – to augment the groundwater supply.

Table 2. Monthly mean groundwater flows for the study well

Month	Mean Groundwater Flow (l/day)		
	2007	2008	2009
January	72.55	57.58	48.92
February	53.73	45.01	42.80
March	42.45	39.52	35.89
April	43.89	59.35	51.00
May	75.75	57.91	75.43
June	106.77	61.41	86.58
July	120.80	103.31	83.87
August	117.17	139.55	108.39
September	141.99	119.15	121.50
October	130.60	126.80	103.48
November	99.35	77.87	94.50
December	67.43	58.14	68.22

4. Summary and conclusions

Groundwater is a principal component of the hydrologic cycle. Groundwater flow was estimated at approximately 1 week (7 days) interval. Flow statistics were determined for 2007, 2008 and 2009. For 2008; the minimum flow was 34.97 l/day and occurred on March 22nd (Julian day 82) while the maximum flow was 151.88 l/day and occurred on October 4 (Julian day 278). The coefficient of variation was 0.43. Monthly mean groundwater flows were also computed. March had the lowest values for the three years which implies that other sources of water supply are most likely to be needed in March, to supplement the groundwater supply. These results are useful in water supply planning.

References

1. Akintola, J. O. 1986. Rainfall distribution in Nigeria. 1892 – 1983. Impact Publishers, Ibadan.
2. Alayamani, M. S. and Z. Sen. 1993. Determination of hydraulic conductivity from complete grain-size distribution curves. Groundwater. 31(4): 551 – 555.
3. Betts, A. K.; J. H. Ball; P. Viterbo; A. Dai and J. A. Marengo. 2005. Hydrometeorology of the Amazon. J. Hydrometeorology. 6: 764 – 774.
4. Beven, K. And P. Germann. 1982. Macropores and water flow in soils. Water Resources Research. 18: 1311 – 1325.
5. McWhorter, D. B. And D. K. Sunda. 1977. Groundwater Hydrology and Hydraulics. Water Resources Publications. Fort Collins, Colorado.
6. Moench, A. F. 1996. Flow to a well in a water-table aquifer – An improved Laplace transform solution. Groundwater. 34(4): 593 – 596.
7. Moench, A. F. 1997. Flow to a well of finite diameter in a homogenous, anisotropic water-table aquifer. Water Resources Research. 33(6): 1397 – 1407.
8. Oyegun, R. 1983. Water Resources in Kwara State, Nigeria. Matanmi & Sons Printing & Publication Co., Ilorin.

9. Rodda, J. C.; S. A. Pieyns; N. S. Sehmi and G. Matthews. 1993. Towards a world hydrologic cycle. J. Hydrological Sciences. 38(5): 373 – 378.

10. Schroder, Tom; Mathieu Javaux; Jan Vanderborght; Bernd Korfgen and Harry Vereecken. 2008. Effect of local soil hydraulic conductivity drop using a three-dimensional root water uptake model. Vadose Zone Journal. 7: 1089 – 1098.

11. Soil Survey Staff. 1975. Soil Taxonomy: A basic system of classification for making and interpreting soil surveys. US Government Printing Office, Washington, D. C.

12. Sophocleus, Marios. 2002. Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal. 10: 52 – 67.

13. Springer, A. E.; W. D. Petroutson and B. A. Semmens. 1999. Spatial and temporal variability of hydraulic conductivity in active reattachment bars of the Colorado River, Grand Canyon. Groundwater. 37(3):338 – 344.

14. Vukovic, M. And A. Soro. 1992. Determination of hydraulic conductivity of porous media from grain-size composition. Water Resources Publications. Littleton, Colorado.