VNU Journal of Science: Earth and Environmental Sciences, Vol. 30, No. 4 (2014) 49-63

Estimation of Groundwater Recharge of the Holocen Aquifer from Rainfall by RIB Method for Hưng Yên Province

Nguyễn Đức Rỡi*

Institute of Geological Sciences, VAST, 84 Chùa Láng, Hanoi, Vietnam

Received 10 October 2014
Revised 30 October 2014; Accepted 30 November 2014

Abstract: Estimation of groundwater recharge from rainfall is a key factor for determining groundwater resources in water development and management. The paper presents application of rainfall infiltration breakthrough (RIB) model method for groundwater Holocene aquifer recharge estimation for Hưng Yên province in the Red River Delta, Vietnam. Although monitoring Holocene aquifer water level (WL) data are from different hydrogelogical either nearly naturally undisturbed or groundwater disturbed abstraction conditions, the relationship between the groundwater level fluctuation and cumulative rainfall departure is of a good match. The groundwater monitoring wells of the national monitoring network have been used are QT119, QT129 and QT130. The fractions of cumulative rainfall departure are from 13% for monitoring well QT119, and 12%-16% for wells QT129 and QT130. For the basic case of specifice yield of 0.1, the rainfall recharge rates are from 427mm (34.1% of mean annual rainfall) in the monitoring well QT119 area to 527mm (38.1% of mean annual rainfall) the area of monitoring wells QT129 and QT130 area. This recharge rates already include the evapotranspiration from the groundwater, which may be more or less than 50% of the total recharge rate and other possible discharge. Therefore, the obtained effective recharge is lightly greater then the range of 15%-20% of rainfall which is commonly used by the Vietnam hydrogeologists.

Keywords: Red River Delta, Cumulative Rainfall Departure (CRD), Rainfall Infiltration Breakthrough (RIB), Groundwater Recharge, Pearson Correlation, Spearman Correlation.

1. Introduction

The demand of groundwater (GW) exploitation in Hung Yen province is growing to contribute to the water supply for social economic development of the province. In Hung Yen province currently there are 5 water supply systems for industrial zones with a total capacity of 51,600 m3/day; 5 systems for urban areas with a total capacity of 13,500 m3/day; 12 rural water supply system with a total capacity of 7,058m3/day, nearly 145,400 household Unicef-type groundwater wells with a total average abstraction rate of about 145,000m3/day, and hundreds of individual GW abstraction wells in the organizations and factories of the province. The total GW abstraction volume in the province is about

* Tel.: 84-913032963
Email: nguyenducroi01@yahoo.com.vn

267,000m3/day. It is expected that demand for water in the province up to 2020 is approximately 468,000m3/day, from which is about 456,000 m3/day of GW [1].

In order to have sustainable utilization of GW resources, it is needed to determine the compositions of its reserve components. One of the components of GW reserves is the dynamic reserve thanks to the rainwater recharge. With an annual rainfall of around 1,500mm to around 2,000mm in the province, and with the distribution of the top surface soil with permeability from medium (sand, silty sand) to the weak (silt, semipermeable clay) formations, the GW dynamic reserve from rainfall would be not small. But, what is the recharge value from the rainfall for the study area? Within this paper, an attempted application of rainfall infiltration breakthrough method (RIB) (X Sun et al., 2013) [2] to estimate rainfall recharge thanks to rainwater infiltration into Holocene aquifer in Hung Yen province through monitoring WL data in the monitoring GW boreholes is presented. Through the application results some discussions on the applicability of the method to the study area are made.

2. Hydrological conditions of the study area

There are the following Quaternary hydrogeological structure units from the top to bottom in the study area [3, 4, 5].

2.1. Semi-permeable layer (layer 1)

The first top semi-permeable layer consist of sediments of alluvial, marine and swamp, Thai Binh formation (amQ_2^3tb, mbQ_2^3tb) (thickness is 1.48÷7.0m) and upper Hai Hung formation ($Q_2^{1\text{-}2}hh_2$) (thickness is 0÷10.0m) of total thickness 2.0÷ 13.0m, in average 6.17m. The lithology is mainly clay and silts with hydraulic conductivity 0.000259÷ 0.00838m/day, in average 0.003m/day.

2.2. Holocene aquifer (qh) (layer 2)

This is the first aquifer from the ground surface and consists of lower Hai Hung formation $Q_2^{1\text{-}2}hh_1$ and Thai Binh alluvial formation (aQ_2^3tb). Aquifer *qh* has its distribution over the entire study area. The lithology of the aquifer is mainly sands, silty sands. This aquifer is a moderate rich aquifer, the boreholes in which have pumping rates 2÷2.2l/sec, unit pumping rates 0.2÷0.39l/sec/m. The aquifer transmissivity is 96.5÷355m^2/day. The water level (WL) depth is 1.12÷4.0m, in average 1.12 m, which is correspondingly 1.18÷8.22m (MSL), in average 297MSL. The annual maximal WL difference magnitude is 0.6÷ 0.84m. The water total dissolved solids (TDS) is 0.1÷1.79g/l, in average 0.56g/l. Water with TDS more than 1g/l is mainly distributed in east of Kim Dong district, east of An Thi district and Phan Sao commune in north Phu Cu district.

In some places the middle part of aquifer qh is a semi-permeable layer dividing the aquifer into upper Holocene (qh2) and lower Holocene aquifer (qh1).

2.3. Semi-permeable layer (layer 3)

The second semi-permeable layer consists of sediments of alluvial, marine and swamp, upper Vinh Phuc formation (amQ_1^3vp2), mainly clay, silty clay or sandy clay, in some places laterite, when wet it is soft plastic, when dry it is hard so this layer is very low permeable. The top of the layer is in the depth 6.5÷38.0m, the thickness is 1.0÷21.5m, in average 8.49m. The hydraulic conductivity 0.00026÷ 0.0639m/day, in average 0.0097m/day. This layer may be absent in some places.

2.4. Upper Pleistocene aquifer (qp2) (layer 4)

This is aquifer consists of lower Vinh Phuc formation ($Q_1^3 vp_1$) and has it is distributed over the entire study area. The aquifer consists of mainly alluvial fine sand on the top, medium sand in the middle, coarse sands and gravel in the lower parts. The depth of the top is from 13m to 49.6m, in average 24.73m; the depth of bottom is 19.5÷59.0m, in average 30.06m; the thickness is 1.0÷27.3m, in average 14.33m. This is low confined aquifer with WL depth 0.2÷4.2m, in average 1.8m, which is correspondingly 8.95÷-1.17m (MSL), in average 2.05MSL. The annual maximal WL difference magnitude is 1.8÷ 2.0m. The WL presently has declining tendency, from 1995 till 2007 had decreased more than 2m. This aquifer is a rich aquifer, the boreholes in which have pumping rates 1.8÷12l/sec, unit pumping rates 0.09÷0.95l/sec/m. The aquifer transmissivity is 350÷569m^2/day, and the aquifer storavity coefficient is 0.0001÷0.0002. The water TDS is 0.1÷2.16g/l, in average 0.46g/l. Water with TDS more than 1g/l is zonally distributed in Dong Thanh, Nhan La, Vu Xa, Luong Bang (Kim Dong district); Dang Le, Cam Ninh, Ho Tung Mau, Hong Van, Hong Quang (An Thi district); Nhat Tan, Ngo Quyen, Vuong town, Di Che, An Vien (Tien Lu district); Dinh Cao (Phu Cu district); Trung Nghia (Hung Yen city), and others.

2.5. Semi-permeable layer (layer 5)

This semi-permeable layer directly covers lower Pleistocene aquifer qp_1 and consists of sediments of mainly clay, silty clay or silty clay, upper Ha Noi formation ($amQ_1^{2-3}hn_2$). The top of the aquifer is in the depth 31.0÷59.0m, in average 40.43m, the thickness is 0÷19.8m, in average 7.2m. The hydraulic conductivity 0.00026÷0.0622m/day, in average 0.034m/day. This layer may be absent in some places which makes tight hydraulic connection between qp_2 and qp_1.

2.6. Lower Pleistocene aquifer (qp1) (layer 6)

This is aquifer consists of silica quartz gravels of Ha Noi formation (Q_1^{2-3} hn_1) within the whole study area. The depth of the top is from 31.2m to 66m, in average 48.0m; the depth of bottom is 67÷107m, in average 71m; the thickness is 13,5÷41m, in average 27m. The WL depth 0.13÷7.5m, in average 2.77m, which is correspondingly 4.30÷-3.64MSL, in average 0.72MSL. In Gia Lam district which is adjacent to Hung Yen province the WL depth is 7.55÷14.0m. The annual maximal WL difference magnitude is around 1.24m. This aquifer is a very rich aquifer, the boreholes in which have pumping rates 1.67÷126l/sec, unit pumping rates 5÷10l/sec/m and greater. The aquifer transmissivity is 1,426÷3,650m^2/day, in average 2,540m^2/day.

The hydrogeological section of the study area may be seen from the actual section of GW monitoring well QT119 as shown in Figure 1.

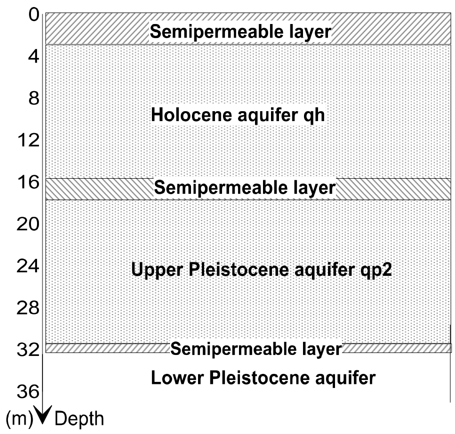

Figure 1. Hydrogeological section at monitoring well QT119.

2.7. Groundwater monitoring system in the study area

In Hung Yen province there are only three national groundwater monitoring systems, namely QT119, QT129 and QT130 [6] and as shown in Figure 2.

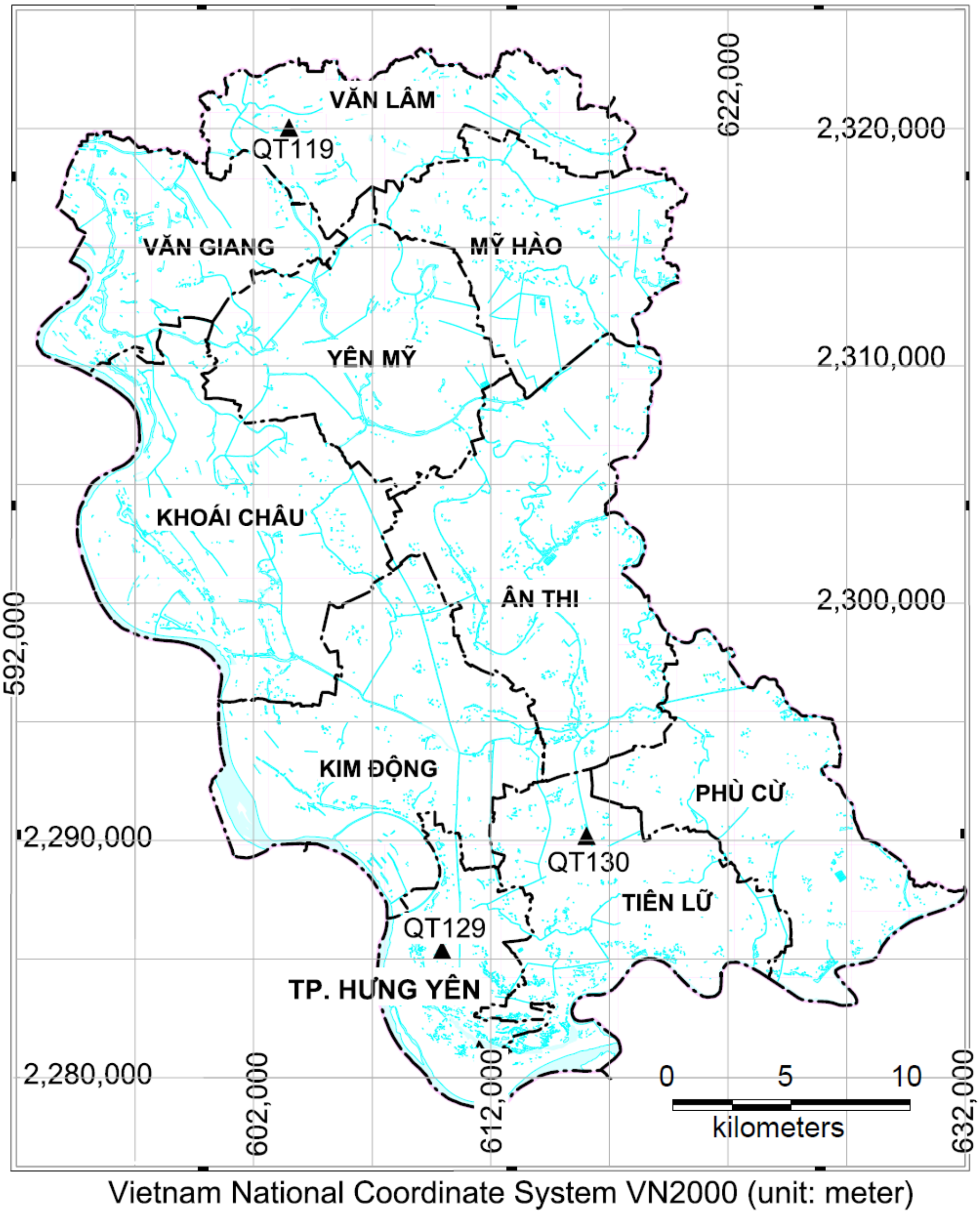

Figure 2. Map of locations of GW monitoring wells.

3. About recharge estimation methods

Recharge estimation is a difficult, sensitive and delicate problem and varies very much in accuracy and uncertainty. Authors Kinzelbach W. et al. in 2002 [7] in their survey work on the most common methods of recharge estimation have classified into the following groups with accuracy ratings in three classes, according to regional recharge estimates: 1) class 1: factor of 2 (two times larger or two times smaller than the true value); 2) class 2: factor of 5 (of the same order of magnitude); and 3) class 3: factor of 10 or more (with large errors likely).

The method to be applied in this work is the rainfall infiltration breakthrough-RIB (X Sun et all, 2013) [2] modified based on cumulative rainfall departure (CRD) method (Bredenkamp et al., 1995) [8] (Xu Y and Van Tonder, 2001) [9]. In accordance to Kinzelbach W. et al. [7], the CRD method has advantages in simplicity and error stabilization thanks to long time series, disadvantage in requirement of storage coefficient, of known discharge (including abstractions), and the accuracy class 2 to 3.

4. Rainfall infiltration breakthrough method (RIB)

4.1. Method description

The CRD and RIB methods utilize the relationship between water level fluctuations and the departure of rainfall from the mean rainfall of a preceding time. The RIB formula is defined as (X. Sun et al., 2013) [2]:

$$RIB(i)_m^n = r\left[\sum_{i=m}^{n} P_i - \left\{2 - \frac{1}{P_{av}(n-m)}\sum_{i=m}^{n} P_i\right\}\sum_{i=m}^{n} P_t\right] \quad (1)$$

(n=®, i−1, i−2, …N); (m=®, i–1, i–2, … M); m<n<I

where:

- *RIB(i)* is the cumulative recharge from rainfall event of m to n

- *N* is the total length of rainfall series.

- *r* is a fraction of cumulative rainfall departure

- P_i is the rainfall amount at ith time scale (daily, monthly or annually)

- P_{av} is the mean precipitation of the whole time series

- P_t is a threshold value representing the boundary conditions (P_t ranges from 0 to P_{av})

Value of P_t=0 represents a closed aquifer system, which means that the recharge at ith time scale only depends on preceding rainfall events from P_m to P_n; while value of P_t=P_{av} represents an open system, which means that the recharge at the ith time scale depends on the difference between the average rainfall of preceding rainfall events from P_m to P_n and the average rainfall of the whole time series. Both *r* and P_t values are determined during the simulation process.

It is assumed that groundwater recharge by the RIB method has a linear relationship with water level fluctuations under natural conditions. The relationship between natural rainfall and water level fluctuations can be described by Eq. (2):

$$\Delta h_i = \frac{1}{\mu} RIB(i)_m^n \quad (2)$$

where:

Δh_i is the water-level fluctuation, which is equal to the difference between the observed water level at ith time scale and the mean water level of the whole time series; a positive value represents an increase of water level while a negative value implies a decrease of water level.

- μ is the specific yield of the aquifer.

Equations (1) and (2) indicate that the water-level fluctuation at ith time scale (daily/monthly/annually) is affected by preceding rainfall events from P_m to P_n, with a weighting factor $\left\{2-\frac{1}{P_{av}(n-m)}\sum_{i=m}^{n}P_i\right\}$ that is a function of the moving average of a rainfall time series. It is not necessarily constant and may be positive or negative depending on whether or not the amount of rainfall during the period of interest exceeds the moving average rainfall. The scheme of the RIB model is shown in Figure 3.

In reality, the water level fluctuations result from many factors besides rainfall, including groundwater evapotranspiration, abstraction, base flow and water flow into/out of the aquifer, etc. The relationship between the RIB model and water level fluctuations can be expressed as:

$$\Delta h_i = \frac{1}{\mu} RIB(i)_m^n + \frac{1}{A\mu}\Delta Q \qquad (3)$$

ΔQ represents groundwater volume increase (decrease if the value is negative) resulting from evapotranspiration, abstraction, outflow, inflow and other activities over an area of A.

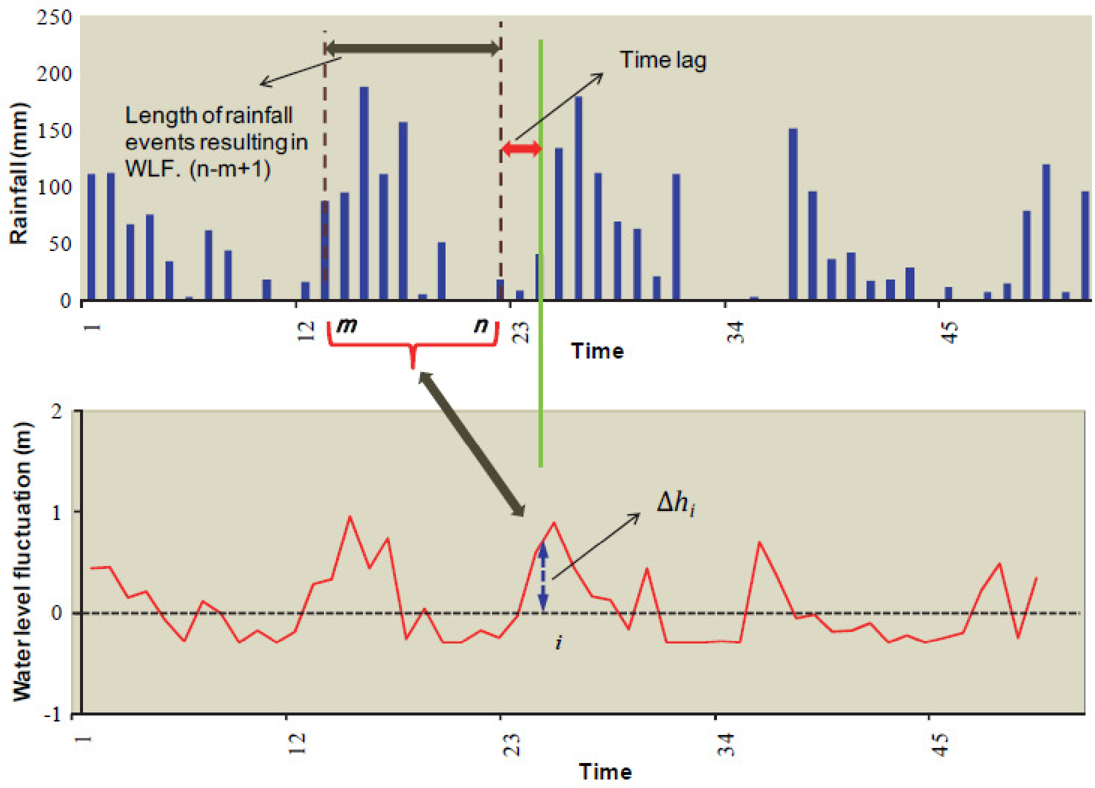

Figure 3. Scheme of the RIB process (X. Sun et al., 2013) [2].

The difference of contiguous departures should be regarded as recharge instead of using the departure from average. The groundwater level will rise if the difference is positive and vice versa; recharge at the ith time scale can be calculated as:

$$\mathrm{Re}(i) = RIB(i)_m^n - RIB(i)_{m'}^{n'} + \frac{1}{A}\Delta Q = \left[\Delta h(i) - \Delta h(i-1)\right]\mu + \frac{\Delta Q}{A} \quad (4)$$

$$\mathrm{Re}(1) = \Delta h(1)\mu + \frac{\Delta Q}{A} \quad (5)$$

$$T_{\mathrm{Re}} = \mathrm{Re}(1) + \sum_{i=2}^{n} \mathrm{Re}(i) \quad (6)$$

where: Re(1) is the recharge for the first time step; Re(i) represents the recharge estimate at the ith time, which could be daily, monthly or annually; T_{Re} is the sum of the recharge in mm for the whole time series. If the value of Re(i) becomes negative in Equations (4) and (5), no recharge on the ith time scale is assumed.

4.2. Assumed assumptions in the RIB application to the study area

As previous studies have given arguments on use of rainfall of longer than daily due to the fact that the effects of factors other than rainfall, i.e., evapotranspiration, atmospheric pressure and entrapped air, on water level fluctuations at short-term scales can be significant, and also shown that the recharge rates estimated at monthly scale are more realistic than those estimated at daily scale (X. Sun et al., 2013) [2]. Therefore, monthly rainfall data are used in this study, also because the monitoring groundwater level data are in monthly basis (recorded on the 15th of each month).

As it had been shown in paragraph 4.1, the needed input data are including specific yield, inflow and outflow etc. The specific yield of the Holocene aquifer determined in the hydrogeological survey is varying from 0.01 to more than 0.1 [3,4,5]. The common used value is 0.1. Therefore, the specific yield of 0.1 is used in the recharge estimation. Then, since the recharge in inversely proportional to the specific yield, the recharge is then re-estimated in accordance with specific yield.

Regarding the inflow and outflow, the monitoring wells Q119 and Q130 are located far from the population areas so that the man-made outflow may be eliminated. Regarding the natural inflow and outflow, these figures are impossible to be determined within this limited work. Therefore, the natural inflow and outflow is assumed to be implicit in the estimated recharge. This means that if the net inflow and outflow is known, then the actual recharge shall be the estimated recharge minus the net inflow and outflow. However, the recharge is to be estimated from the rainfall, while the area is large and the GW level is mostly effected by the rainfall recharge, then averagely over the whole area the inflow and outflow would most likely be balanced.

Regarding the lag time between rainfall event and recharge, the monitoring GW level had been recorded for the 15th day of each month and the monthly rainfall data are used, then the lag time of few days or even couple weeks would be negligible for this time scale.

4.3. RIB application to the study area

The obvious direct relationship between the water level of Holocene aquifer and rainfall can be visually felt from the graphs of water level and rainfall in the three monitoring well QT119, QT129 and QT130 as shown in the Figures 4-6 (4-QT119, 5-QT129 and 6-QT130).

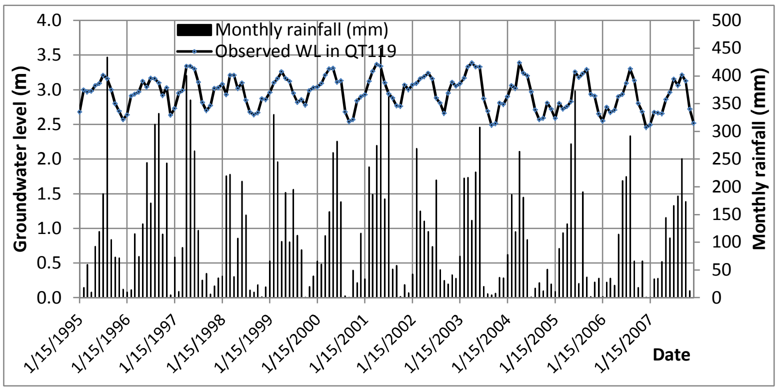

Figure 4. Monthly GW levels in the monitoring well *QT119* and rainfall.

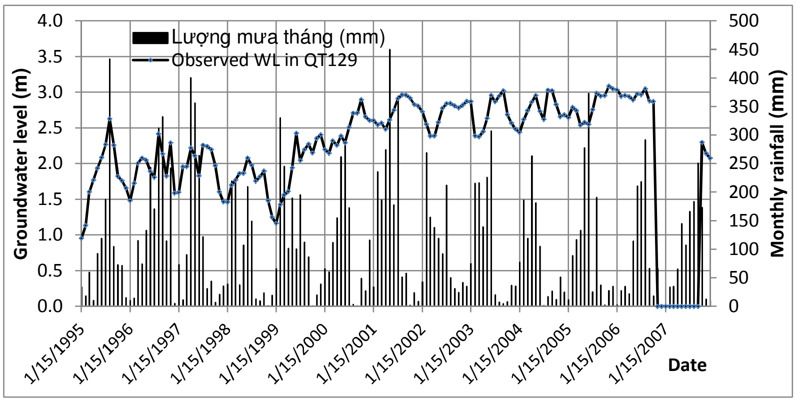

Figure 5. Monthly GW levels in the monitoring well *QT129* and rainfall.

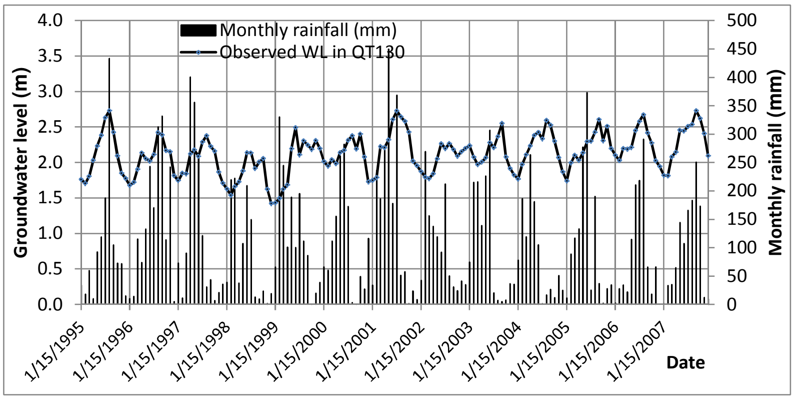

Figure 6. Monthly GW levels in the monitoring well *QT130* and rainfall.

Statistic analysis of the groundwater level in the observation wells and the monthly rainfall data during the study period have shown that between GW level and monthly rainfall is a strong correlation for monitoring well QT119 since the Pearson correlation coefficient is equal 0.654, while is a very poor correlation for well QT129 and QT130 (Table 1.)

Table 1. Pearson correlation coefficient ® between GW level and monthly rainfall

Monitoring well	QT119	QT129	QT130
Correlation coefficient *R*	0.654	0.017	0.209

After the application of RIB method with constant value *r* as the original metehod proposes, it had been observed that the observed WL and RID simulated WL are of good match for some years, while are of worse match for other years. Therefore, the change of *r* for each year would result in better match for the entire series. Therefore, the analysis of the recharge had been carried out in two alternatives:

- A constant of *r* (fraction of cumulative rainfall departure) is used as the RIB method specifies;

- A varying *r* over the analysis period, but constant over each year;

Besides, the values of parameter P_t representing the boundary conditions (P_t ranges from 0 to P_{av}) had been manually estimated. However, the best one is $P_t = P_{av}$ for all the three monitoring wells' areas, and the closer to zero the worse RIB simulated WL (Figure 8 shows the case of P_t=0.5P_{av} for monitoring well QT119).

Also, since the observed WL at QT129 has two distinguished parts: one is from 1995 to 1999, and another is from 2000 to Oct. 2006 (for from Nov 2006 till 2007 data are missing), the results of those two time periods are to be separately described.

The values of fraction of CRD *r* have been trial-and-error determined by visual better match between observed WL and RIB simulated WL and the values of correlation coefficient. The values of *r* in the RIB analysis of the three wells are given in Table 2 and the resulted RIB simulated WL are shown in the Figures 7-13 for both constant and varying fraction of CRD.

Table 2. Determined recharge values (1995-2007) by the RIB

Monitoring well	Time period	Constant fraction *r* (%)	Varying fraction *r* Min-Max (average) (%)
QT119	1995-2007	13	9-25 (16.26)
QT129	1995-1999	16	16-22 (20.00)
	2000-15.Oct.2006	12	9-18 (13.00)
QT130	1995-2007	15	11-30 (19.00)

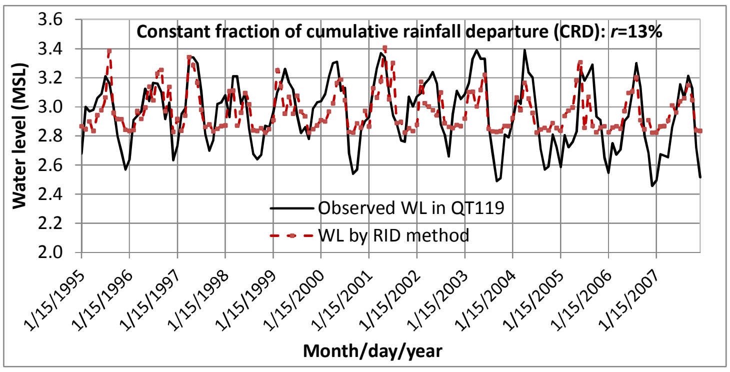

Figure 7. Observed and RIB simulated WL at well QT119: constant *r*.

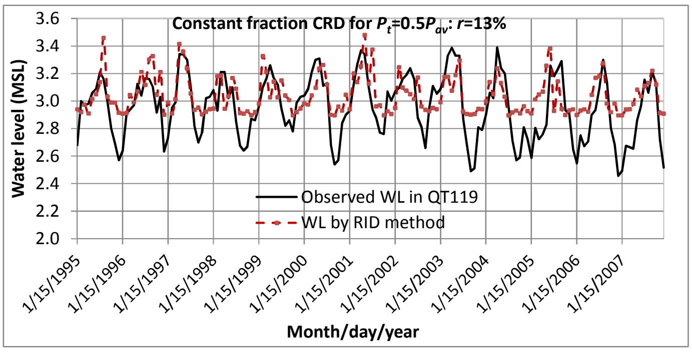

Figure 8. Observed and RIB simulated WL at well QT119: P_t=0.5P_{av}, constant r.

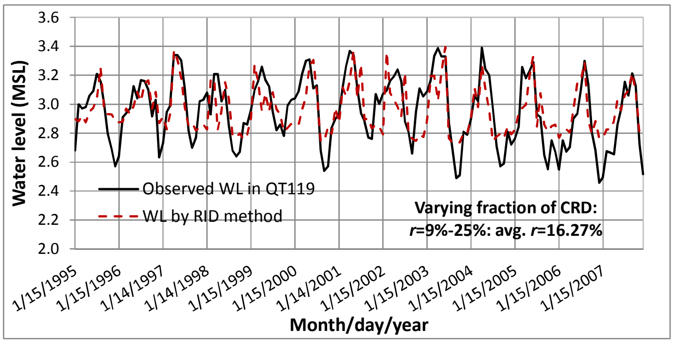

Figure 9. Observed and RIB simulated WL at well QT119: varying r.

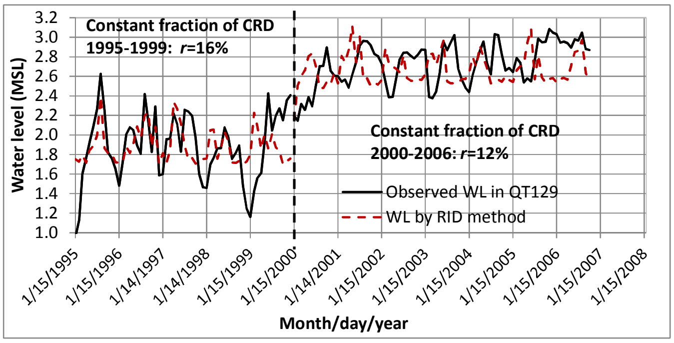

Figure 10. Observed and RIB simulated WL at well QT129: constant r.

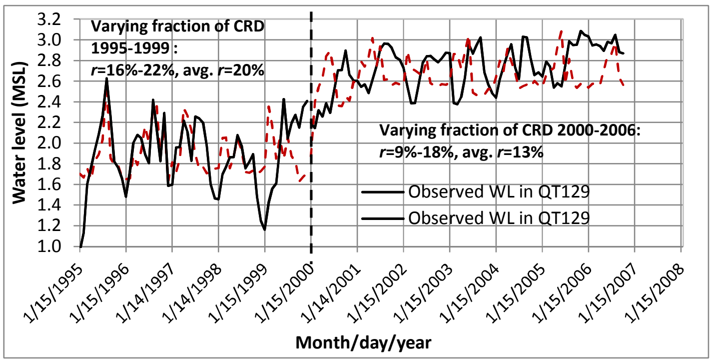

Figure 11. Observed and RIB simulated WL at well QT129: varying r.

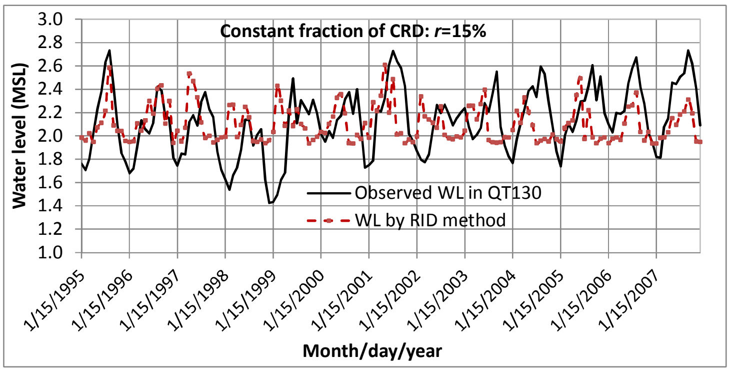

Figure 12. Observed and RIB simulated WL at well QT130: constant *r*.

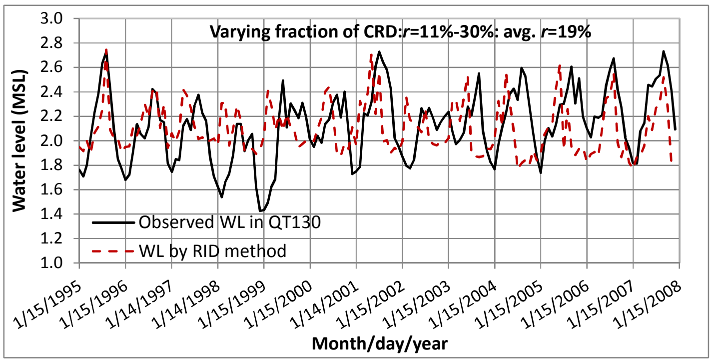

Figure 13. Observed and RIB simulated WL at well QT130: varying *r*.

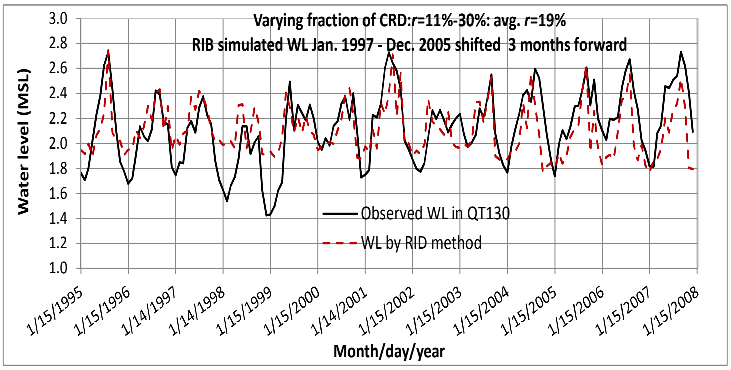

Figure 14. QT130: RIB simulated WL Jan. 1997-Dec. 2005 shifted 3months forwards.

Since the varying parameter *r* has given better match between the observed WL and RIB simulated WL, the results for varying *r* and threshold parameter $P_t=P_{av}$ are presented and discussed hereafter. In order to determine the degree of correlation between the observed GW levels and RIB-determined GWL levels the Spearman correlation coefficient have been determined as presented in Table 2. By the Spearman correlation criteria, the observed and RIB simulated WL are of strong correlation for QT119 and 129, while very poor correlation is for QT130.

From the graphs of the RIB simulated WL and observed WL for the three monitoring wells it may note the following. The RIB simulated WL is of better match with the rising WL, because during the rainy season the recharge is overwhelming any discharge. The over-estimated WL for after rainy season would be due to the improper assumption about the evapotranspiration, inflow and outflow etc. from the aquifer in the area. Since, there is no obvious shallow groundwater abstraction in the three monitoring wells' areas, the discharge from the aquifer would be dominating after the rainy season due to groundwater drainage to the lakes and rivers and evapotranspiration from the groundwater etc.

Regarding the monitoring well QT129 observed WL, during the period 1995-1999 the WL fluctuation magnitude is much greater than that of period 2000-Oct. 2006. Also, in January 2000 the WL sharply raised up and the fluctuation magnitude from that time became much smaller than before. This would be of some reasons causing the change of hydrogeological conditions due to man-made acivities, for example the fast urbanization of Hung Yen city around the monitoring well QT129 has caused such changes.

Regarding the monitoring well QT130 observed WL, the RIB simulated WL during Jan. 1995-Dec. 1996 and Jan. 2006-2007 are cyncronized with arlier WL. However in the period during Jan. 1997 - Dec. 2005 the RIB simulated WL is about 3 months arlier than the observed WL. This would be due to the error in dating the observed WL during the monitoring work. The simple forward shift of this period to 3 months had given much better correlation of Spearman's correlation coefficient of 0.656-0.658 and is shown in Table 2 and Figure 14.

The estimated recharge values have been estimated by the above-described equations 4-6 are given in Table 3, where the uncertainty of the recharge estimation in regards to the specific yield ranging from 0.06 to 1.2 was also presented.

Table 2. Spearman's correlation coefficient (R_s) between observed WL and RIB simulated WL

Borehole	QT119	QT129	QT130	QT130 (RIB simulated WL Jan. 1997-Dec. 2005 shifted 3months forwards)
Constant r	0.751	0.708	0.171	0.656
Variable r	0.730	0.712	0.164	0.658

Table 3. Determined recharge values (1995-2007) by the RIB method

Time period	T_{re} (mm)	Total rainfall (mm)	Percentage of rainfall (%)	Percentage of rainfall (%)		
μ=0.1				μ=0.06	μ=0.08	μ=0.12
QT119, QT130						
1995-2007	6,592	17,310	38.1	22.86	30.48	45.72
Mean annual	507	1,332				
		QT129				

1995-15.Oct.2006	5,480	16,060	34.1	20.46	27.28	40.92
Mean annual	427	1,251				
1995-1999	2,636	6,984	37.7	22.62	30.16	45.24
Mean annual	527	1,397				
2000-15.Oct.2006	2844	9,076	31.3	18.78	25.04	37.56
Mean annual	416	1,328				
Average mean annual	6,036	16,685	36.1	21.66	28.88	43.32

5. Discussions and concluding remarks

- GW level of the Holocene aquifer in the study area would obviously tightly related to the rainfall thanks to the permeable of semi-permeable surface ground soil layer and its not thick thickness. The Holocene aquifer level rise thanks to the below Pleistocene aquifer would be not present since at the present WL of Pleistocene aquifer is lower than the Holocene aquifer.

- The Holocene aquifer of the study area is better representing an open system from the RIB methodology's standpoint.

- Besides the strong relationship of Holocene aquifer WL with rainfall for which there is strong relationship between observed WL with RIB simulated WL as for well QT119, even though the Holocene aquifer level has very poor relationship with rainfall, the simulated WL by RIB may have very strong relationship with the observed WL as the analysis results of monitoring well QT129 show that the Spearman correlation coefficient is 0.708-0.712.

- The fractions of cumulative rainfall departure are from 13% for monitoring well QT119, and 12%-16% for wells QT129 and QT130. For the basic specific yield of 0.1, the rainfall recharge rates are from 427mm (34.1% of mean annual rainfall) in the monitoring well QT119 area to 527mm (38.1% of mean annual rainfall) the area of monitoring wells QT129 and QT130 area. This recharge rates already include the evapotranspiration from the groundwater, which may be more or less than 50% of the total recharge rate for the study area, as the results by Dang Huu On et al. (2007) [10]. Therefore, the obtained effective recharge is more or less in the range of 15%-20% of rainfall which is commonly used by the Vietnam hydrogeologists.

- The modification of use of varying fractions of CRD to the original proposed RIB method with constant *r*, makes insignificantly better Spearman correlation although visually the fluctuation of GW level rise looks better.

- The recharge values obtained by the RIB method would be the total rainfall recharge to GW that already includes the evapotranspiration from the GW. The estimation of the evapotranspiration from GW would be a challenging task for estimation true rainfall recharge to the GW.

Finally, as this method had been first time manually applied in climate condition other than arid and semi-arid, it is worthwhile to have more study and research on its applicability, the effect of the varying fractions of CRD etc. For avoiding any unnecessary discrepancies in application of RIB method, the observed WL data need carefully be checked for accuracy such that had been possible occurred to QT129 and QT130 (if such shortcomings actually had been happened). Accurate experimental areas would be the best conditions for such study and research, for which all the boundary conditions, rainfall events, transpiration, evapotranspiration, inflow and outflow, groundwater abstraction etc. need to be accurately identified and monitored.

References

[1] Nguyen Duc Roi, 2009. Report on groundwater resources utilization planning of Hung Yen province upto 2020. Hung Yen DoNRE (in Vietnamese).

[2] X Sun, Y Xu, NZ Jovanovic, E Kapangaziwiri, L Brendonck and RDH Bugan, 2013. Application of the rainfall infiltration breakthrough (RIB) model for groundwater recharge estimation in west coastal South Africa. ISSN 1816-7950 (On-line), Water SA Vol. 39 No. 2 April 2013.

[3] Chau Van Quynh, 1996. Report on groundwater exploitation exploration of Cam Giang- Hai Duong and My Van- Hung Yen area. Department of geology and mineral resources-MoNRE (in Vietnamese).

[4] Chau Van Quynh, Nguyen Thi Tam, 1998. Report on groundwater exploitation exploration of Hung Yen town. Department of geology and mineral resources-MoNRE (in Vietnamese).

[5] Phan Xuan Hai, 1984. Report on groundwater exploration of An Thi area-Hung Yen scale 1:50,000. Department of geology and mineral resources-MoNRE (in Vietnamese).

[6] Nguyen Thi Ha, 2010. Report on groundwater monitoring system of Hung Yen province. Hung Yen DoNRE (in Vietnamese).

[7] Kinzelbach W., Aeschbach W., Alberich C., Goni I.B., Beyerle U., Brunner P., Chiang W.-H., Rueedi J., and Zoellmann K., 2002. A Survey of Methods for Groundwater Recharge in Arid and Semi-arid regions. Early Warning and Assessment Report Series, UNEP/DEWA/RS.02-2. United Nations Environment Programme, Nairobi, Kenya. ISBN 92-80702131-3).

[8] Bredenkamp DB, Botha LJ, Van Tonder GJ and Van Rensburg HJ, 1995. Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity. WRC Report No. TT 73/95. Water Research Commission, Pretoria.

[9] XU Y and VAN TONDER GJ, 2001. Estimation of recharge using a revised CRD method. Water SA 27 (3) 341–344.

[10] Dang Huu On, Bach Ngoc Quang, Dao Van Quang, 2007. Determination of rainfall recharge to groundwater at Nhu Quynh groundwater balance polygon. Journal of Geology, No. 300/5-6/2007, pp. 50-56 (in Vietnamese).

Xác định đại lượng bổ cập nước mưa cho tầng chứa nước Holocen khu vực tỉnh Hưng Yên bằng phương pháp RIB

Nguyễn Đức Rỡi

Viện Địa chất, Viện Hàn lâm Khoa học và Công nghệ Việt Nam, 84 Chùa Láng, Hà Nội, Việt Nam

Tóm tắt: Xác định đại lượng bổ cập nước ngầm từ nước mưa là rất quan trọng trong đánh giá trữ lượng nước ngầm phục vụ khai thác và quản lý tài nguyên nước. Bài báo trình bày ứng dụng phương pháp đường cong mưa ngấm (RIB) để xác định đại lượng bổ cập nước ngầm từ nước mưa khu vực tỉnh Hưng Yên-đồng bằng sông Hồng. Mặc dù mực nước tầng chứa nước Holocen trong các lỗ khoan quan trắc ở các điều kiện động thái mực nước khác nhau, chẳng hạn gần như là động thái tự nhiên hoặc động thái phá hủy do khai thác, nhưng quan hệ giữa dao động mực nước và mưa cộng dồn xuất phát rất chặt chẽ. Tài liệu quan trắc mực nước được sử dụng là từ các lỗ khoan quan trắc trong mạng lưới quan trắc Quốc gia QT119, QT129 và QT130. Tỷ số mưa cộng dồn xuất phát xác định được có giá trị từ 13% đối với lỗ khoan QT119, 12%-16% đối với QT129 và QT130. Đối với trường hợp cơ bản có hệ số nhả nước trọng lực bằng 0,1 thì lượng nước mưa ngấm tổng cộng là từ 427mm (34.1% lượng mưa năm trung bình) đối với khu vực lỗ khoan QT119 đến 527mm (38.1% lượng mưa năm trung bình) đối với khu vực các lỗ khoan QT129 và QT130. Lượng nước mưa ngấm này bao hàm cả lượng bốc hơi nước từ nước ngầm, mà tổng lượng bốc hơi này cùng các thành phần thoát nước ngầm khác ở khu vực có thể chiếm khoảng trên dưới 50%. Vì vậy lượng nước mưa ngấm hiệu quả ở khu vực chiếm khoảng 15%-20% tổng lượng mưa, và nằm trong giới hạn giá trị mà các nhà địa chất thủy văn Việt Nam thường sử dụng.

Từ khóa: Đồng bằng sông Hồng; Mưa xuất phát cộng dồn (CRD); Đường cong mưa ngấm (RIB); Bổ cập nước ngầm: Tương quan Pearson; Tương quan Spearman.