*Aceh International Journal of Science and Technology, 2 (1): 8-16*
*April 2013*
*ISSN: 2088-9860*

**RESEARCH PAPER**

# Determining Groundwater Recharge from Stream Flow with Seasonal Recession Method

**[1*]Ichwana, [2]Zulkifli Nasution, [3]Sumono**

[1]Agricultural Engineering Department, Faculty of Agriculture, University of Syiah Kuala, Indonesia.
[2]Agroecotechnology Department, Faculty of Agriculture, University of Sumatera Utara, Indonesia;
[3]Agricultural Engineering Department, Faculty of Agriculture, University of Sumatera Utara, Indonesia.
*Corresponding author: ichwana_ramli@yahoo.co.id

**Abstract** - Volume of groundwater recharge showed a picture of a watershed to determine the flow instability due to the physical characteristics of the watershed and precipitation. Many methods had been constructed to understand the dynamic movement of water discharge. One of them was the analysis of the stream hydrograph with Seasonal Recession Method. Information about groundwater recharge condition at several sub watershed in Krueng Peusangan Watershed was really needed in management of watershed for sustainable water resources. The study aimed to determine groundwater recharge from stream flow with seasonal recession method was conducted in Krueng Peusangan watershed, Aceh Province, Indonesia. The results showed that the trend pattern of the stream hydrograph could be explained using the exponential function where the dots lowest discharge that is the end of the recession (y) than any period of time on stream hydrograph semi logarithmic (x). The pattern of results that occurred in the watershed of Krueng Peusangan: (A) Krueng Seumpo had a trend for $y = 9.2x^{-0.35}$, (B) Simpang Jaya for $y = 559.7x^{-0.5}$, (C) Beukah village for $y = 142x^{-0.32}$ , (D) Sub watershed of Lut Tawar (Wih Nareh) for $y = 1.3x^{-0.12}$ and (E) Sub watershed of Teupin Mane (Krueng Teumbo) for $y = 1.94x^{-0.42}$. It also showed that the location of A, B, C, E had a higher slope and a decreased recharge pattern compared to the location of D (sub watershed of Lut Tawar) that tended to flat. The volume of groundwater recharge that occurred in a region (A and D) increased while the other location was very volatile. Moreover, recharge instability occurred in Krueng Teumbo. Therefore, it needed a clear direction for land use and functions of forests, especially in the recharge area, in order to maintain the balance of the hydrological cycle, and the quantity of groundwater.

**Keywords**: groundwater recharge, seasonal recession method, base flow, stream flow, water resources

## Introduction

Watershed has an important role when it plays a better role in dampening fluctuations of runoff after precipitation and stabilize or maintains the flow in the dry season. Flow impairment caused by the utilization of water resources and land beyond its carrying capacity is seen from the suitability ratio of low flow to the total flow of the river (Djuwansah, 2006). Ground water conditions at a watershed are influenced by natural factors such as climate, geology, relief, soil, and vegetation, but there is still a connection to obscurity (Price *et al.*, 2011). However, in general, if the total annual precipitation increases. It is always offset by an increase in base flows, and the trend coefficient does not match with the recession of ground water as well (Sharma, 2010)

Understanding the contribution of groundwater in the river is very important in planning for water resources management, because the management of groundwater resources will cause problems of irregular disruption of the balance hydrological cycle and impact on groundwater contamination, the decline in ground water level (land subsidence) and seawater intrusion. Human impact on the landscape can change some or all of these factors, in turn, influence the timing and quantity of base flow. Understanding the base flow is very important, due to the water quality issues, water supply, and aquatic habitats. The base flow has been proven to be highly influenced by the characteristics of the watershed (Price, 2011; Lin, 2007)

Infiltration is one of the hydrological cycle components to provide an overview of a watershed conditions due to precipitation. A popular method by Meyboom (1961) was used to determine the volume of recharge with seasonal recession and the recession curve displacement method by Rorabaugh (1964). The method is a basic method used in the concept of river flow contributions from direct runoff and groundwater base flow (Hongbing, 2004). According to Price e*t al.* (2011), there is no proper standard in determining base flow. It is influenced by the availability of data and management purposes, which is ggenerally divided into four methods: event based statistics low flow, flow-duration curve statistics, metrics that express the proportion of base flow to total flow and base flow recession statistics. Welderufael, (2010) mentioned a multitude of methods have been developed which can be conveniently categorized into four basic approaches: graphical base flow separation, filtering algorithms, frequency analysis and recession analysis.

Several analytical expressions have also been developed to find a constant recession by using the solution of linear differential equations that govern the flow at the base aquifer. Recession constants describing the slope of the decline in stream flow following the dynamic movement of water in the basin fill (Rivera-Ramirez *et al.*, 2002). Accurate estimation of the groundwater recharge is very important as an indicator of the proper management of the groundwater system (Kyoochul, 2008). The aim of this research is to determine the volume of the watershed recharge in Krueng Peusangan for the upper, middle and lower region, based on the available data using the Base flow Recession Analysis. The base flow is assumed to fluctuate (ups and downs) and the river discharge has been representing the integration of the physical condition of watershed and precipitation.

## Materials and Methods

The study was conducted in the watershed of Krueng Peusangan which had 12 sub watersheds. Partly of the area lied within the administrative area of Central Aceh District on the upstream, in the middle of Bener Meuriah District, and Bireuen District downstream. Geographically, the watershed of Krueng Peusangan was in the top position (Upper) 5°16'34" NL - 96°27'12 "E, and the bottom (Lower) 4°30'38" N-97°02'40 " L, with an area of 2557.80 km$^2$. Precipitation data for the upstream and downstream areas were derived from Stations of Meteorology and Climatology of Lhokseumawe and Bebesan Takengon. Although Krueng Peusangan watershed consisted of 12 sub watershed. But they were available and operated only at (two) river water monitoring stations called Teumbo and Nareh Stations for the periode of 2008-2011. Whereas, three other stations were now no longer functioned so that the data which available was only from the year of 1987-1996.

While there were five observation posts of discharge point: (A) Kr. Seumpo (5°04'04" North Longitude (NL) and 96°42'46" East Longitude (EL) , (B) Kp. Simpang Jaya (05°07'04" NL and 96°40'54" EL) , (C) Ds. Beukah (05°10' NL and 96°48'04" EL) , (D) Wih Nareh ( 04°34'34.8" NL and 96°48'52.8"EL), and (E) Kr. Teumbo (04°59'6.9" NL and 96°4'46.6" EL) shown in Figure 1.

River flow was a sensitive parameter to the changes of watershed components. In this research, daily flow data was necessary to establish river flow hydrograph.The data was obtained from the equation that described the relationship between discharge with the water level. The data as used in this study were stream flow data issued by the Office of Water Resources and Headquarter of Krueng Aceh Watershed, Aceh Province (NAD).

The recharge volume of groundwater of Krueng Peusangan watershed would be determined by flow semi-logarithmic hydrograph, by analyzing the based flow recession that occurred every year from the hydrograph. To obtain semi-logarithmic hydrograph, the time component was plotted on the arithmetic scale, while the discharge components were placed on a logarithmic scale. Base flow recession lines were obtained by connecting the lowest discharged points on the hydrograph, which follows the trend line of decreased discharge in one period. Determination of the recession line refers to the criteria (a) base flow recession was the decline in groundwater discharge, so it should have followed the decline of curve hydrograph, (b) base flow on a hydrograph was the basis of the hydrograph, which was under the direct runoff, (c) the starting point of the recession was the lowest point at the beginning of the downward trend , while the end point of the recession was the lowest point at the end of the downward trend of discharge curve in a period of recession. (d) the line connecting the two points was the basic flow restrictor to direct runoff.

The idea of seasonal recession method by Meyboom, 1961 for the first was to identify one large recharge trend in a semi-logarithmic seasonal hydrograph over a 12 month period for two or more consecutive years. If the recession curve was plotted on the semilogarithmic paper, it would be a straight line. The assumption was that discharge of the stream during recession period, the line of recession trend would be entirely contributing groundwater. Then, the total ground water recharge was calculated by using the total volume of potential groundwater discharge at the beginning of the recession minus the volume of the potential ground water discharge left at the end of the recession. The total volume of potential base flow was the amount of ground water that flowed into the river during a period of recession complete (Meyboom, 1961 in Fetter, 2001). The total volume could be calculated using equation (1)

$$Q_{tp} = \frac{Q_0\, t_1}{2.3} \qquad \text{.................................(1)}$$

Where
Vtp = total volume of potential base flow (m$^3$)
$Q_0$ = discharge of baseflow at initial recession (m$^3$/sec)
$t_1$ = time required by the base flow to flow from Qo to 0,1Qo (sec)

The volume of residual potential base flow is the amount of base flow remaining at the end of a recession, which can be calculated by equation (2):

$$V_t = \frac{V_{tp}}{10^{t/t_1}} \text{....................................(2)}$$

Where
Vt = volume of the residual of potential base flow (m$^3$)
t = time required by the base flow to flow from the beginning and final recession (sec)

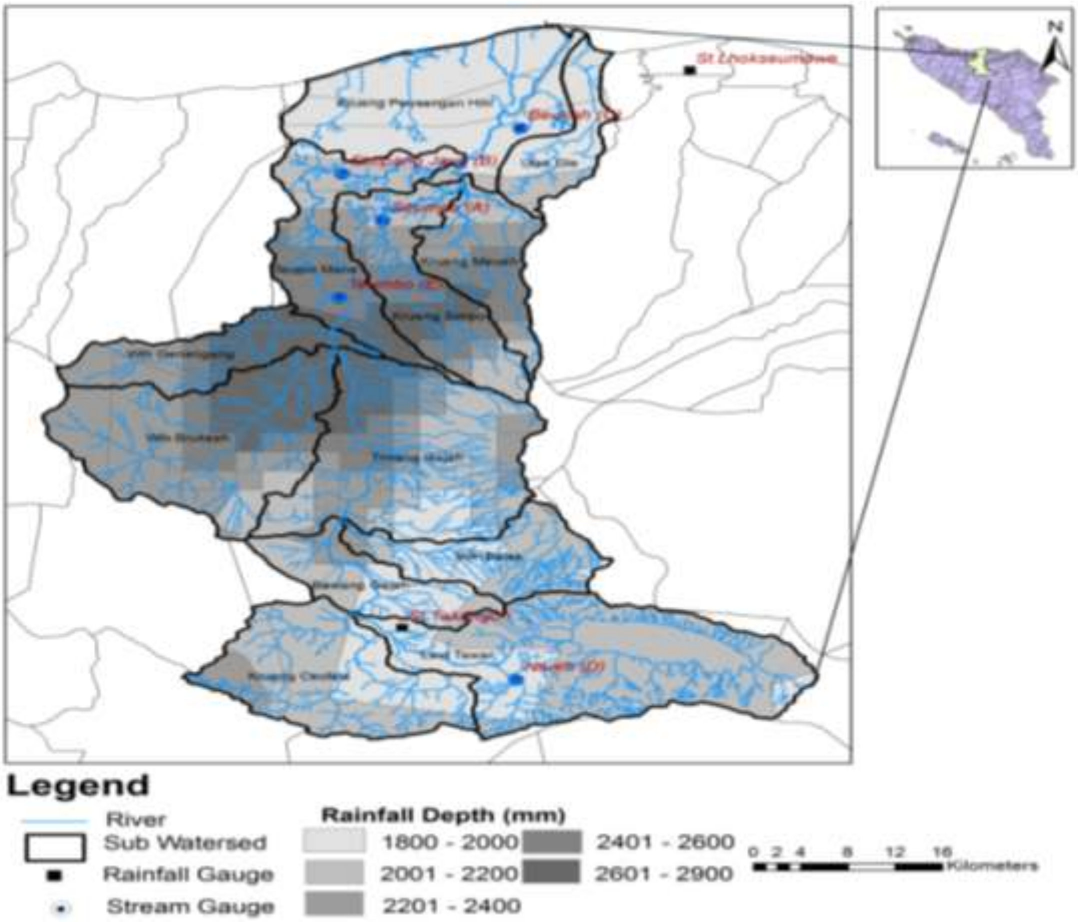


Figure 1. Krueng Peusangan watershed and the observation points of discharge

The amount of water that seeped into the ground water reservoir (volume absorption) which can be determined by calculating the difference between the total volumes of potential base flow recession year (n +1) with the volume of residual potential base flow from the end of the recession in the using equation (3):

$$V_r = V_{tp(n+1)} - V_{tn} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

Vr = volume of infiltration ($m^3$)

$V_{tp(n+1)}$ = total volume of potential baseflow from the recession at the $n^{th}$ year (n+1) ($m^3$)

$V_{t(n)}$ = volume of the rest potential baseflow from final recession at the $n^{th}$ year ($m^3$)

n = time (year-1, 2, 3, …n)

A large number of streams and rivers have base flow recessions of the simple exponential type, and these recede according to the equation (Martin, 1973)

$$Q_t = Q_o e^{-at} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where $Q_t$ is the discharge of the river at time t and $e^{-a}$ is a constant definiting the rate of recession. It is common practice to replace this baseflow recession constant $e^{-a}$ with k. Thus, equation (4) becomes

$$Q_t = Q_o k^t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Analysis of data to determine the volume of recharge of Krueng Peusangan Watershed made by connecting the end points of the base flow recession during the observation period for each sub-watershed. This curve would be created with the help of Microsoft Software Excel. The pattern of groundwater recharge condition changes was obtained by connecting the dots of lowest discharge (y) in which it was the end of the recession from every period to the time (x) on flow semi-logarithmic hydrograph . The lines that formed as a particular curve which followed the end of the recession flow fluctuation from each observations period. The pattern of recharges in a watershed could be explained using equation trendline through excel software . Trend was selected that had coefficient determination $R^2$ ranges from 0 to 1, which higher value indicating less error variance (Moriasi *et al.*, 2007).

$$R^2 = \frac{(n\Sigma xy - \Sigma x \Sigma y)^2}{(n\Sigma x^2 - (\Sigma x)^2)(n\Sigma y^2 - (\Sigma y)^2)} \quad \ldots\ldots\ldots\ldots(6)$$

## Results and Discussion

The process of infiltration into the soil was strongly influenced by rainfall and watershed characteristic form morphometry and morphological watershed. Morphological watershed was the information on the physical characteristics of the watershed were able to characterize the watershed include forms the watershed, watershed topography and drainage patterns. Meanwhile, quantitative morphometry of watershed stated that the network state river basins covering a total area, width, slope, stream order and density. The size of a watershed or sub watershed served as a container for the water flow of the surface water storage. The more extensive a sub-watershed, the more the amount of water that could be accommodated and the longer time required by rain to reach the outlet.

The shape of sub watershed of Krueng Peusangan (Table 1) was generally round-shaped indicating the shape and speed of discharge relatively small. This condition caused the travel time of water from the tributaries varied toward the center of the flow due to infiltration. But the opportunity to hone the ground water and soil material dispersing was greater, because Krueng Peusangan watershed was considered as a priority watersheds based on the Decree of the Minister of Forestry No. 328/MenHut-II/2009. The rehabilitation effort was very important to reduce the hazard of erosion and sedimentation that would occur if the watershed in critical condition allowed. The slope of the river varied for each tributary. Generally, slope of Krueng Peusangan watershed was 0.002% . The greater the speed of the flow, the risk of riverbank erosion and sedimentation increased.

Table 1. Morphology of Krueng Peusangan Watershed and Sub Watershed

| Watershed/Sub Watershed | Area ($km^2$) | Shape | Drainage Pattern | Elevation (m) | |
|---|---|---|---|---|---|
| | | | | Min | Max |
| Watershed | | | | | |
| Krueng Peusangan | 2557.80 | non rounded | Dendritic | - | 2,864.0 |
| Sub-Watershed | | | | | |
| Krueng Celala | 239.09 | rounded | Dendritic | 796.0 | 2,162.0 |
| Lut Tawar | 390.58 | non rounded | Dendritic | 804.0 | 2,572.0 |
| Wih Balek | 133.14 | non rounded | Paralel | 600.0 | 2,404.0 |
| Bawang Gajah | 115.35 | non rounded | Dendritic Rectangular | 590.0 | 2,022.0 |
| Timang Gajah | 358.59 | rounded | Dendritic | 246.0 | 2,864.0 |
| Wih Bruksah | 325.67 | rounded | Dendritic Rectangular | 240.0 | 2,727.0 |
| Wih Genengang | 128.17 | non rounded | Dendritic | 207.0 | 2,707.0 |
| Krueng Meueh | 122.56 | non rounded | Dendritic Rectangular | 22.0 | 1,375.0 |
| Krueng Seumpo | 179.82 | non rounded | Dendritic | 21.0 | 1,896.0 |
| Teupin Mane | 182.76 | non rounded | Dendritic | 17.0 | 1,158.0 |
| Krueng Peusangan Hilir | 292.18 | non rounded | Dendritic | - | 249.0 |
| Ulee Gle | 89.89 | non rounded | Dendritic | - | 168.0 |

Source: Headquarter of Krueng Aceh Watershed, 2010

Drainage density obtained for each sub-watershed was less than 1.74, which means that watershed of Krueng Peusangan had surface characteristic, such as bad surface drainage, a lot of standing water and the frequent of flood occurrence and a zone of sedimentation. The sub watershed which had higher drainage density would have a better hydrological conditions when compared to the watershed that had low drainage density. This was due to the increasing density of drainage, precipitation would spread evenly to the tributary - before entering the creeks and the main river water had a longer and more seep into the soil, that in turn would increase the availability of groundwater. The availability of water in a watershed was influenced by evapotranspiration as one of the parameters that need to be taken into account. The evapotranspiration calculation of Penman method used due to many involving climatic data such as the amount of temperature, humidity, duration of solar radiation, wind speed and number of rainy days.

In a watershed, there were different forms of land use with a variety of vegetation and the amount of evapotranspiration that differed from one vegetation with others. The amount of evapotranspiration that occurred in a watershed depended on each type of land use factors other than climate. In Figure 2 showed that the average precipitation at the observation stations.

Figure 2 showed that rainy season in October-December. It was determine the line of the river flow recessions taken from November. Ichwana *et al.* (2012) mentioned that characteristics of the location A, B, C and D had the in common the evapotranspiration for each location where the value was higher than location E. Precipitation data at the location of A, B, C, E was taken from Lhokseumawe station because of this area belongs o the the Middle and downstream area of the Krueng Peusangan Watershed. Whereas, the location of D was taken from Takengon station, in which this area belonged to the part of upstream Krueng Peusangan watershed. This explained by using Principal component analysis that showed the characteristic for the precipitation location are different in October, November, December and March between the upstream and downstream area.

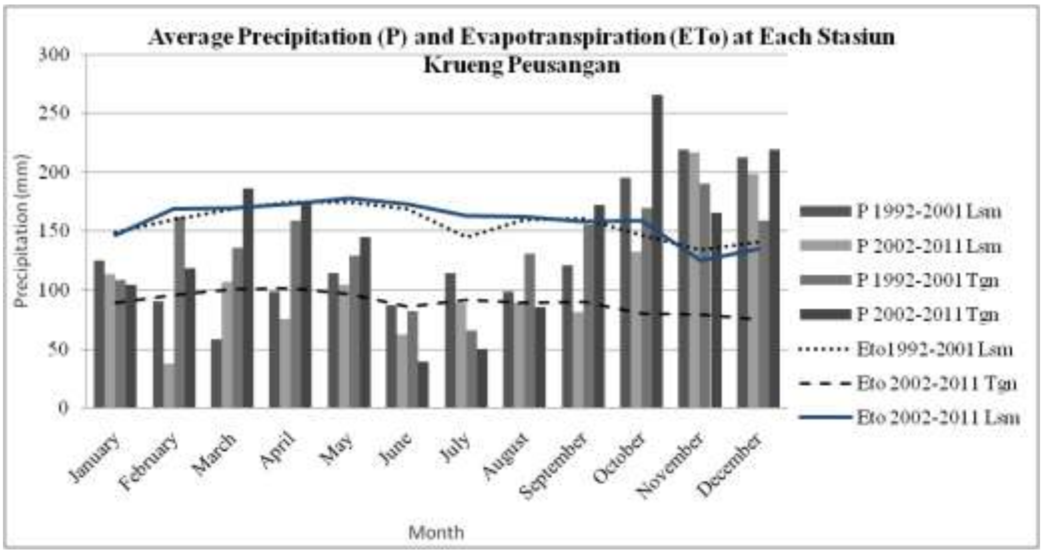


Figure 2.Precipitation and evapotranpiration at watershed of Krueng Peusangan

Average precipitation at station of Lhokseumawe (Lsm) in 2002 - 2011 period decreased by 17.12% from the average rainfall at station of Lhokseumawe (Lsm) for the period of 1992-2001. While the average precipitation at station of Takengon (Tgn) for the period of 2002-2011 increased by 4.67% of the average precipitation at station of Takengon (Tgn) in the period 1992-2001. Average evapotranspiration upstream (Takengon) decreased by 22.95% compared to the downstream in Lhokseumawe. From the analysis of precipitation in the past two decades showed indications of a decrease in rainfall that had already started to sense changes in the weather at locations upstream and downstream of Krueng Peusangan watershed. Evapotranspiration upstream (plateau) was lower than the lowlands (downstream) that affected the volume of recharge. Land development was related to the volume of surface water and ground water. Therefore, the infiltration was very important in development because of all types of development plan could reduce the impact on the hydrology (Brander, 2004).

Runoff occurred when precipitation rate exceeded the rate of infiltration into the soil. After infiltration reached the saturation rate, water began to fill the basin surface and once filled the basin surface, runoff would occur. In this study, the available discharge for watershed of Krueng Peusangan was the measurement point at (A) Krueng Seumpo (representing sub watershed of Seumpo (period 1993-1996), (B) Simpang Jaya village representing sub watershed of Krueng Celala, Lut Tawar, Wih Balek, Bawang Gajah, Timang Gajah, Wih Bruksah, Wih Genengen, and Teupin Mane (period 1988-1996) , (C) Beukah village was the downstream of watershed Krueng Peusangan (period 1987-1996), and (D) Wih Nareh representing sub watershed of Lut Tawar (period 2008-2011), (E) Krueng Teumbo representing sub watershed of Krueng Celala, Lut Tawar, Wih Balek, Bawang Gajah, Timang Gajah, Wih Bruksah, Wih Genengen (period 2008-2011)

. Figure 3 showed the pattern of groundwater recharge condition that occured at some point in Krueng Peusangan watershed. It is obtained by connecting the dots lowest discharge that is the end of the recession than any period of time on stream hydrograph semilogarithmic. The lines that form a particular form of the exponential curve following the end of the recession flow fluctuation of each period of observations at the study site. . The line produces a regression equation : (A) Krueng Seumpo, $y = 9.2x^{-0.35}$ with coefficient of determination ($R^2 = 1$), (B) Simpang Jaya $y = 559.7x^{-0.5}$ ($R^2 = 0.829$), (C) Beukah , $y = 142x^{-0.32}$; $R^2 = 1$, (D) sub watershed of Lut Tawar, $y = 1.3x^{-0.12}$; $R^2 = 0.941$, and (E) sub watershed Teupin Mane , $y = 1.94x^{-0.42}$. with $R^2 = 0.917$, That was showed a good relationship a variable dots lowest discharge recession with period of time observation. It also showed the location of A, B, C, E had a higher slope which decreased absorption pattern compared to watershed of Lut Tawar, while location of (D) tended to flat. In contrast to patterns of groundwater recharge in Krueng Aceh watershed, the results of analysis flow was conducted by connecting the lowest point from the end of recession at every period to the time on semi-logarithmic hydrograph at Krueng Seulimum and Darang Village for observation period of 1988-1996. The results formed polynomial curved pattern that tends to take place to negative direction (Ichwana *et al.*, 2011). Instability of recharge that occured will affect the amount of ground water reserves in the watershed (Fetter, 2001). Base flow recession was a function of topography, drainage patterns, soil type, geology of the watershed (Martin, 1973). Besides affected by rainfall and climatic conditions, the minimum discharge condition of a stream could not be separated from the influence of soil water reserves at a watershed. In the period of without rainfall (dry season), the discharge of ground water would flow into rivers and sustain river streams (Querner, 2001), so the reduction in the minimum discharge that occured in Krueng Peusangan watershed could be used as an indicator for the declining number of precipitation recharged into reserves and ground water in this area.

Lowest discharge was required to estimate low-flow index in the catchment area and the gauge was calculated by regression model regional and regional hydrological model. Lowest discharge was use to determine the low-flow season going. Thus, it was be used as indicators of watershed management (Engeland and Hisdal, 2009 ).

According to Asdak (1995) that fluctuations in ground water occurring naturally became a state of equilibrium. Ground water level would fluctuate widely because of two reasons; (1) the extraction of groundwater for human consumption, industry and agriculture, as well as the supply of ground water in catchment areas, and (2). the exchange of seasons. In line with the ongoing rainy season, ground water level would rise and reach the highest score at the end of the rainy season. Similarly, the state of the ground water level tended to decrease gradually when entering the dry season. In rivers that intersected groundwater level fluctuations would be more varied to follow fluctuations in river flow. During the dry season, the number and intensity of precipitation was very limited. Thus the river flow would come from groundwater of the catchment area around the river.

The flow of the river after the rain could be seen as the relationship between the physical watershed and runoff. Water storage could not be observed directly. It needed an approachment to provide water resource assessments. A research by Krakauer and Temimi ( 2011) mentioned that there was no significant variability in the recession timescale at a certain flow that correlated with climate and geomorphic variables, such as the ratio of mean stream flow to precipitation and soil to capacity water infiltration. Models recession curve approach to relate precipitation runoff and storage resources were also important to know how to increase groundwater recharge occurred in accordance with the climate. Therefore, it was necessary to maintain the balance of community participation to integrate in an effort for sustainable natural resource management (Cheinini *et al.*, 2008). Analysis of the flow of water from precipitation to river was necessary for optimal protection of surface and groundwater resources (Wenninger *et al.*, 2004). Understanding the runoff process was important to assess the impact of land use change and climate change in watershed hydrological response.

From the recession line from Figure 3, the base flow recharge volume for the five locations was calculated with seasonal recession method shown in Table 2. The location measurement at points B, C and E infiltration volume fluctuated widely and unstable. Point A and D showed that the catchment volume increased indicated that it was good. In the sub-watershed of Lut Tawar, the volume showed a decrease in infiltration after the maximum absorption of volume. From the charts, the discharge and trend lines were approximately equal in slope. If recession associated with precipitation, the location of rainfall has decreased by 16.127%. The average recession constant was found to be most strongly correlated with the catchment area. Large catchments experience flatter recession (smaller recession constants) which reflected the dampening of the recession response in large catchments (Rees, 2004).

Fluctuation of volume recharge that occurred influenced by precipitation for both locations. The absence of a long dry season in this basin was difficult to determine a definite trend of volume recharge. The negative sharp fluctuations of volume recharge obtained, indicated an unstable condition of the recharge area of sub watershed Teupin Mane at the measurement point to Teumbo (E). However, data for the next year was to be analyzed. For sub watershed of Teupin Mane area was dominated by Latosol soil (133.89%) Red-Yellow Podzolic (48.68%), and Andosol (0.19%) (Headquarter of Krueng Aceh Watershed, 2010), which was a type of soil with low absorption of water. In conditions with dry land farming and land cover mixture (68.72%) and secondary upland forest (22.81%) showed the forest which had been converted to agricultural land through logging forests for oil palm plantations. The reduced vegetation increased direct runoff during the rainy season. This caused the volume of infiltration basin in this area, experiencing extreme fluctuations (unstable).

The extreme fluctuations indicated the instability of absorption in the recharge area in this region. Sub watershed of Lut Tawar had varied soil types: Latosol, (40%), complex Podsolic and Litosol (35.7%), complex Podsolic Brown and Litosol (23.3%) and Andosol (1%) (BP DAS Krueng Aceh, 2010). The decreasing of absorption in this area was also due to the increasing in critical land (49.94%) and critical potential (22.6%). At this time, the greatest shrub extentention reached 45.55%, which was then followed by secondary upland forest (20.12%) and a mixture of dry land agriculture (10.9%).

Infiltration that occurred in a region was affected by a variety of factors, such as infiltration capacity, precipitation, climate, topography and geological structure. The variability of base flow comprehensive reflection of land use/cover changes (LUCC) and an important hydrological characteristic considered in maintaining sustainable development of an ecosystem (Lie, 2011). Land cover for secondary forests land decreased by 62.045%, dry land agriculture increased 103.93%, and shrub increased by 49.503% at the sub-watershed of Kr. Seumpo from 1990-2000. The location of Simpang Jaya (B) for period of 1990-2000, land cover for forest decreased 1.65% and dry land agriculture 42.67%. Land cover increased at rice field 7.96% and shrub 4.06% , human settlement increased 3.03%. Location Beukah (C) for period of 1990-2000, the forest has decreased 18.291%, settlement 12.102%, agriculture mixed upland 5.4% and shrub increased 16.4%. As for the sub watershed of Lut Tawar (D), land cover was changed for period of 2006-2011 in accordance with the discharge observations, the forest is decreased by 0.313%, dryland mix agriculture increased 0.195% and shrub increased 0.059% and location of Krueng Teumbo (E) forests decreased by 0.55% and shrub increased 0.78% for period of 2006-2011. From the description of the land use change, forest on the location of Lut Tawar (D) was not great, so the volume infiltration occured stable relatively. The forest at the location of Kr. Seumpo (A) decreased over 50%, but it was balanced by the increasing of dry land agriculture more than 100%. So, the volume of infiltration raises.

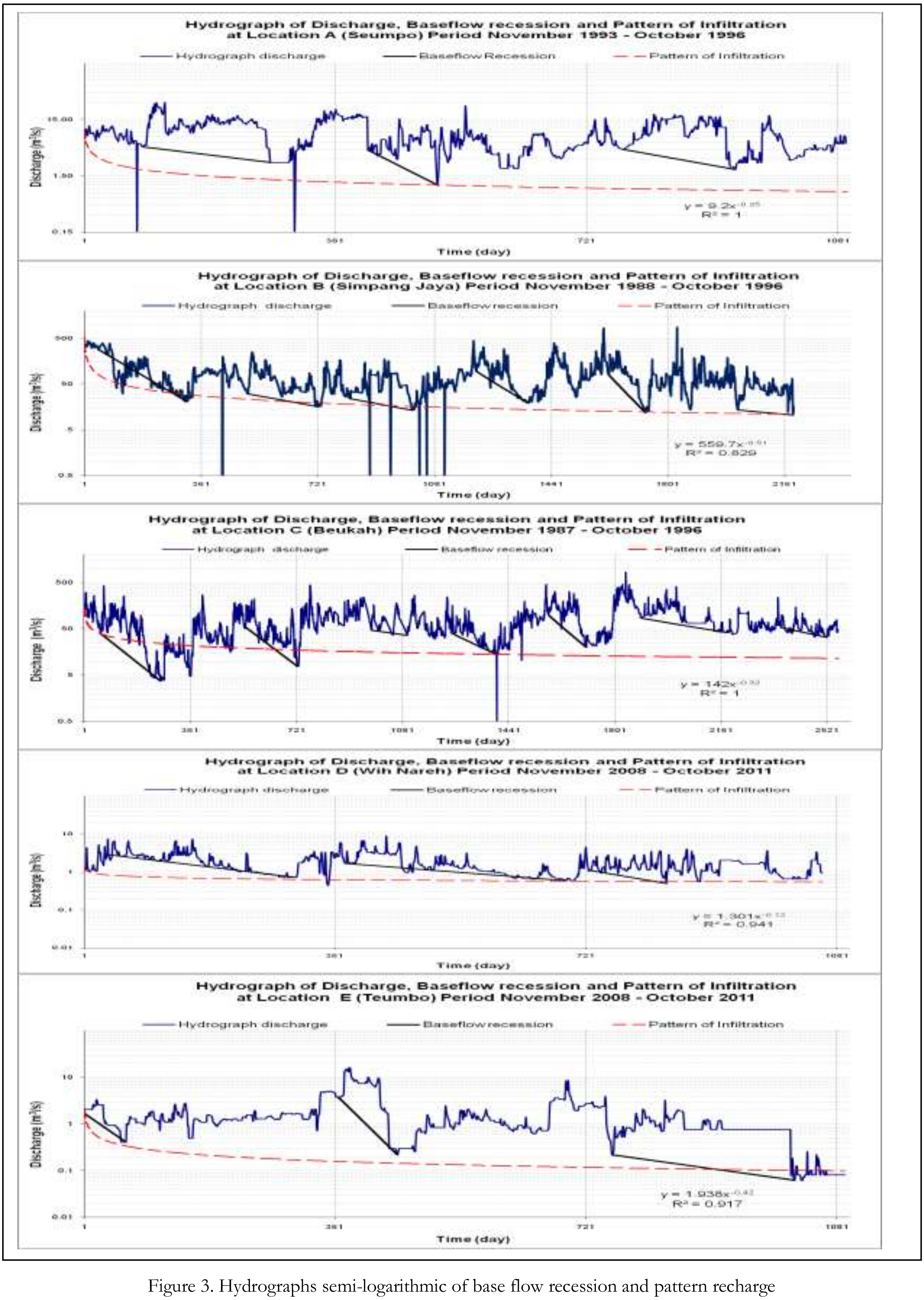


Figure 3. Hydrographs semi-logarithmic of base flow recession and pattern recharge

Table 2. Groundwater recharge with seasonal recession method at watershed of Krueng Peusangan

| Location | Period | Qo ($m^3/s$) | t1(s) | Vtp ($m^3$) | t (s) | t/t1 | Vt ($m^3$) | Vr($m^3$) |
|---|---|---|---|---|---|---|---|---|
| A | 1993/1994 | 4.90 | 67,526,434.1 | 144,154,257.1 | 15,811,200.0 | 0.2 | 84,077,379.8 | - |
| | 1994/1995 | 4.30 | 57,622,836.3 | 106,727,514.2 | 8,640,000.0 | 0.1 | 75,567,636.7 | 22,650,134.4 |
| | 1995/1996 | 4.40 | 69,673,106.3 | 134,499,387.7 | 13,910,400.0 | 0.2 | 84,931,334.6 | 58,931,751.1 |
| B | 1988/1989 | 285.00 | 19,737,695.0 | 2,445,757,857.3 | 23,587,200.0 | 1.2 | 156,091,875.2 | - |
| | 1989/1992 | 30.70 | 58,563,826.2 | 781,699,767.4 | 18,835,200.0 | 0.3 | 372,753,433.5 | 625,607,892.1 |
| | 1992/1993 | 23.90 | 105,533,648.9 | 1,096,632,264.3 | 16,675,200.0 | 0.2 | 762,171,399.2 | 723,878,830.8 |
| | 1993/1994 | 95.00 | 101,661,694.6 | 4,199,069,993.1 | 13,824,000.0 | 0.1 | 3,070,242,598.7 | 3,436,898,593.9 |
| | 1994/1995 | 80.50 | 91,724,897.3 | 3,210,371,406.0 | 9,849,600.0 | 0.1 | 2,507,109,545.8 | 140,128,807.3 |
| | 1995/1996 | 13.50 | 280,534,687.4 | 1,646,616,643.3 | 14,774,400.0 | 0.1 | 1,458,570,265.4 | -860,492,902.5 |
| C | 1987/1988 | 38.60 | 16,391,263.7 | 275,088,164.9 | 17,539,200.0 | 1.1 | 23,411,998.3 | - |
| | 1988/1989 | 53.00 | 7,720,272.4 | 177,901,928.7 | 15,292,800.0 | 2.0 | 1,859,164.9 | 154,489,930.4 |
| | 1989/1992 | 46.00 | 91,255,744.8 | 1,825,114,895.3 | 10,454,400.0 | 0.1 | 1,401,937,506.6 | 1,823,255,730.4 |
| | 1992/1993 | 40.20 | 109,027,772.5 | 1,905,615,850.1 | 13,305,600.0 | 0.1 | 1,438,787,732.8 | 503,678,343.5 |
| | 1993/1994 | 96.00 | 107,407,620.6 | 4,483,100,686.7 | 10,972,800.0 | 0.1 | 3,543,383,381.0 | 3,044,312,953.9 |
| | 1994/1995 | 85.30 | 186,575,438.8 | 6,919,515,185.4 | 25,228,800.0 | 0.1 | 5,068,218,105.5 | 3,376,131,804.4 |
| | 1995/1996 | 53.20 | 227,702,049.0 | 5,266,847,393.7 | 13,305,600.0 | 0.1 | 4,603,800,313.2 | 198,629,288.3 |
| D | 2008/2009 | 1.70 | 8,288,236.2 | 6,129,691.2 | 5,184,000.0 | 0.6 | 1,452,024.0 | - |
| | 2009/2010 | 3.77 | -17,311,100.3 | -28,390,204.5 | 7,344,000.0 | -0.4 | -75,405,840.6 | -29,842,228.5 |
| | 2010/2011 | 0.22 | -8,907,441.2 | -840,397.7 | 22,550,400.0 | -2.5 | -285,838,672.9 | 74,565,442.9 |
| E | 2008/2009 | 2.90 | 39,866,546.9 | 49,729,183.9 | 23,414,400.0 | 0.6 | 12,861,506.5 | - |
| | 2009/2010 | 1.70 | 80,618,914.8 | 58,290,980.6 | 27,388,800.0 | 0.3 | 26,660,584.9 | 45,429,474.1 |
| | 2010/2011 | 1.10 | 81,294,881.9 | 37,996,520.9 | 9,331,200.0 | 0.1 | 29,171,697.4 | 11,335,936.0 |

The conservation of an area index (Sabar, 2012) was used to demonstrate the ability of a region to absorb precipitation that felt into the surface soil. The process of infiltration could occur when there was an unsaturated zone between the ground level with the ground water. Therefore, the water infiltrated into the ground. The volume of recharge that contained in the watershed of Krueng Peusangan in middle region, fluctuated sharply. The condition of recharge volume was also influenced by the characteristics of the precipitation occurred in the region of this area. Conditions that occurred in both sub watersheds indicated that there had been an imbalance fluctuations of water seeped into the aquifer on the recharge area due to precipitation and high evapotranspiration in the lower-middle part of watershed of Krueng Peusangan.

To assess soil and water management and conservation in a comprehensive manner in a region, it needed the right approach. The ground water level tended to decrease gradually when entering the dry season. The assessment of available water resources in a variety of storage and moving along at different pathways in a watershed was essential for optimal use protection, and prediction of floods and low flows. In addition, understanding the runoff process was very important to assess the impact of changes in climate and hydrological response in land use of a watershed (Gonzales *et al.*, 2009).

## Conclusions

The pattern of absorption that occured in the watershed area of Krueng Peusangan: (A) Krueng Seumpo had a trend of $y = 9.2x^{-0.35}$, (B) Simpang Jaya village for $y = 559.7x^{-0.5}$, (C) Kr. Beukah for $y = 142x^{-0.32}$, (D) sub watershed Lut Tawar for $y = 1.3x^{-0.12}$ ,and (E) sub watershed of Teupin Mane for $y = 1.94x^{-0.42}$. It also showed the location of A, B, C, E had a higher slope which decreased absorption pattern compared to watershed of Lut Tawar, while location of (D) tended to flat. The location measurement at points B,C and E infiltration volume fluctuated widely and unstable. Point A and D showed that the catchment volume increased indicated that it was good. The volume of absorption that contained in the watershed of Krueng Peusangan midsection fluctuated sharply. The condition of absorption volume was also influenced by the characteristics of the rainfall occurred in the region of the area. Conditions that occured in both sub watersheds indicated that there had been an imbalance fluctuations of water seeped into the aquifer (groundwater catchment layer) on recharge area due to rainfall and high evapotranspiration in mid and downstream sections of Krueng Peusangan. Therefore, a clear direction needed for land use and functions of forests, especially in the recharge area to maintain the balance of the hydrological cycle and the quantity of groundwater properly.

## References

Asdak, C. (1995). Hidrologi dan pengelolaan daerah aliran sungai. Gajah Mada University Press, Yogyakarta.

Brander, R.E., Katherine, E., and Potter, K.W. (2004). Modeled impacts of development type on runoff volume and infiltration performance. Journal the American Water Resources Association, 40(4):961-969.

Cheinini, I., Benmammou, A., and Turki, M.M. (2008). Groundwater resources of a multi-layered aquiferous system in arid area: data analysis and water budgeting. International Journal of Environmental Science and Technology, (IJEST). 5(3) : 361-374.

Djuwansah, M.R. (2006). Aliran rendah sebagai indikator fungsi hidrologi daerah aliran sungai, Teknologi Indonesia, LIPI Press, 29(2): 11-21.

Engeland, K. and Hisdal, H. (2009). A Comparison of low flow estimate in ungauged catchments using regional Regression and the HBV model. Water Resources Management. 23 (12) : 2567-2586. Doi.10.1007/s11269-008-9397-7.

Fetter, C.W. (2001). Applied hydrogeology. 4th. ed. Prentice Hall Publishing Company.

Gonzales, A.L, Nonner, J., Heijkers, J., and Uhlenbrook, S. (2009). Comparison of different base flow separation methods in a lowland catchment. Hydrol. Earth Syst. Sci. 13, 2055–2068.

Rivera-Ramirez, H.D., Warner, G. S., and Scatena, F.N. (2002). Prediction of master recession curves and base flow recessions in The Liquillo Mountains of Puerto Rico. Journal of the American Water Resources Association, 38(3): 693-704.

Hongbing, S. (2004). Estimating the fate of precipitation from stream discharge: A case study in New Jersey. Bull. New Jersey Academy of Science, 49(2): 9-15.

Ichwana, Sumono, and Delvian. (2012). Karakteristik lokasi dan pola resapan: data, analisis dan respons, Rona Teknik Pertanian: Jurnal Ilmiah dan Penerapan Keteknikan Pertanian 5(2): 347-354.

Ichwana., Ferijal, T., and Nurba, D. (2011). Identifikasi perubahan kuantitatif resapan daerah aliran sungai Krueng Aceh dengan pendekatan analisis resesi aliran dasar , Seminar Nasional VII Penelitian masalah Lingkungan di Indonesia, ISSN 2088-4818: 401-414.

Krakauer, N.Y ., and Temimi, M. (2011). Stream recession curves and storage variability in small watersheds, Hydro. Earth Syst. Sci., 15: 2377–2389. Doi:10.5194/hess-15-2377-2011.

Kyoochul, H., Koh, D., Yum,B.Y., and Lee, K. (2008). Estimation of river stage effect on groundwater level, discharge, and bank storage and its application. Geosciences Journal 12 (2): 191-204. Doi: 10.1007/s12303-008-002-y.

Lei, Y.N., Zhang, X.P., Ma, Q., Sun, Y.P., Zhang, J.J., Fu, Y.L., and Xu, .P. (2011). Responses of base flow in Kure catchment to the LUCC on the Loess Plateau of China. 19th International Congress on Modelling and Simulation, Perth, Australia, 12–16 December 2011. http://mssanz.org.au/modsim.

Martin, G.N. (1973). Characterization of simple exponential base flow recessions. Journal of Hydrology, 12(1): 57-62.

Meyboom, P. 1961. Estimating groundwater recharge from stream hydrographs. Journal of Geophysical Research, 66: 1203-1214.

Moriasi, D.N. Arnold, , J.G., Van-Liew, M.W., Bingner, R.L., Harmel, R.D., and Veith, T.L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Jurnal American Society of Agricultural and Biological Engineers, 50(3): 885-900.

Price, K. (2011). Effects of watershed topography, soils, land use, and climate on base flow hydrology in humid regions: A review. Progress in Physical Geography, 35(4) 465-492.

Price, K., Jackson, C.R., Parker, A.J., Reitan, T., Dowd, J., and Cyterski, M. (2011) Effects of watershed land use and geomorphology on stream low flows during severe drought conditions in the southern Blue Ridge Mountains, GA and NC, USA Water Resources Research 47:W02516.

Querner, E.P. (2001). The Effects of human interventions on groundwater recharge. Paper in Impact of Human Activity on Groundwater Dinamics. Proceedings of Sixth IAHS Scientific Assembly, Maastricht, Netherland, IAHS Publ., 269: 59-66.

Rees, H.G., Holmes, M.G.R., Young, A.R., and Kansakar, S.R. (2004). Recession-based hydrological models for estimating low flows in ungauged catchments in the Himalayas, Journal Hydrology an Earth System Sciences 8(5): 891-902.

Rorabaugh, M. I. (1964). Estimating changes in bank storage and groundwater contribution to stream flow. International Association of Scientific Hydrology, 63: 432-441.

Sabar, A., and Plamonier, N. (2012). Tantangan pembangunan infrastruktur sumberdaya air berkelanjutan menghadapi perubahan iklim ikhwal urban metropolitan Jakarta. Prosiding Seminar Nasional Tantangan Pembangunan Berkelanjutan dan Perubahan Iklim di Indonesia, Medan, 2 Juni 2012: 65-85.

Sharma, A.N., Pereira, V., and Walter, M.T. (2010). Recession slope analysis coefficients, low flows, groundwater and precipitation responses for climate change studies, American Geophysical Union, AGU, Code: 2010AGUFM.H21G1154S.

Welderufael, W.A., and Woyessa, Y.E. (2010). Stream flow analysis and comparison of base flow separation methods case study the Modder River Basin. European Water, 31:3-12.

Wenninger, J., Uhrenbrook, S., Tilch, N., and Leibundgut, C. (2004). Experimental evidence of fast groundwater responses in a hillslope/floodplain area in the Black Forest Mountains, Germany. Hydrol. Processes, 18(17): 3305-3322.