

## EFFECTS OF WATERSHED TOPOGRAPHY AND LAND USE ON BASEFLOW HYDROLOGY IN UPSTREAM KOMERING SOUTH SUMATERA, INDONESIA

\* Rosmalinda Permatasari<sup>1</sup>, Arwin Sabar<sup>2</sup>, Dantje Kardana Natakusumah<sup>3</sup> and Hazairin Samaulah<sup>4</sup>

<sup>1,4</sup>Faculty of Engineering, University of Tridinanti Palembang, Indonesia; <sup>2,3</sup> Bandung Institute of Technology, Indonesia

\*Corresponding Author, Received: 20 Oct. 2018, Revised: 11 Dec. 2018, Accepted: 05 Jan. 2019

**ABSTRACT:** The characteristic hydrology of a watershed is playing a major role in ensuring water resource availability. Rainfall and runoff responses in catchment area are part of the hydrology cycles. There are several factors to determine the characteristic of hydrology at the watershed, i.e. geological, region, soil and land cover. The existence of water resources is very substantial for surroundings. The rapid development in various sectors leads to water demands increase. Optimum utilization of water resources is needed in the sustainability of water resources or the need for integrated water resources management. The consequence of development is land use change, resulting in changes inflow characteristics, flood during the wet season and drought or discharge decrease in the dry season. Many studies associate higher watershed land cover with lower baseflows, attributed to high evapotranspiration rates, while other studies indicate increased baseflow with higher watershed land cover due to higher infiltration and recharge of subsurface storage. Adaptation and mitigation efforts are required to anticipate changes in the flow characteristics. The factors are key controls on base flow through their influence on infiltration, catchment and subsurface storage properties. This review underscores the need for more research that multiple aspects of the watershed system in explaining base flow. The result of average base flow and total flow ratio during 40 years (1971-2010) is 0.296 and the class of the hydrologic function as a BF / TF ratio value which indicated very poorly hydrologic function of upstream Komering, although in certain hydrologic function was still in the good category.

*Keywords: Hydrology, Base flow, Catchment, Upstream, Climate, Watershed*

### 1. INTRODUCTION

Streamflow can be divided into quick flow and baseflow. Quickflow is normally from surface runoff, while baseflow is from shallow and deep groundwater. In equatorial inland areas, such as Upper Komering, baseflow becomes an important water source to support water availability, ecosystem and economic development in the region. Typically, baseflow is not very sensitive to rainfall but more associated with the discharge from groundwater. Baseflow is influenced by natural factors such as climate, geology, relief, soils, and vegetation. Human impacts on the landscape may modify some or all of these factors, in turn affecting baseflow timing and quantity. [1]-[2]-[3]-[4].

Change in land cover and land use influences the runoff characteristics of a drainage basin to a large extent, which in turn, affects the surface and groundwater availability of the area [1]-[2]-[3]-[4]. Water availability in an area depends very much on how rainfall over the area is divided into various components such as surface runoff, interflow, groundwater recharge etc [5]-[6]-[7]. Streamflow can be divided into the quick flow and base flow. Quick flow is normally from surface runoff, while base flow is from shallow and deep groundwater. In equatorial

regions, such as Upper Komering, South Sumatera, the base flow becomes an important water source to support ecosystem and economic development in the region. Typically, base flow is not very sensitive to rainfall but more associated with the discharge from groundwater [8].

Degradation of the hydrological function is caused by exploitation of water and land resources exceeding their bearing capacity. It is often associated with the disaster in water resources, such as floods, landslides, droughts, and forest fires. A hydrologic function of watersheds is the role of the region in responding to rainfall and its flow to the surface. A watershed has a proper hydrologic function if its role in reducing runoff surge fluctuations caused by rainfall can further stabilize availability of flow during the dry season. Hydrological functions of an area are determined by several factors such as geological factor, regional, soil type and land cover. The flow and surface water quality produced can only be effectively measured in a stream at the regional watershed boundary [9]-[10].

Understanding the groundwater to stream flows is very important in the planning of water resources management. The direct flow is primarily the direct response of a rainfall event and includes the overland flow (runoff) and the lateral flow in the soil profile

also known as interflow. The base flow is a component of the stream flow which is discharged from the natural storage of aquifers [11].

This study have objectives: (1) To estimate baseflow quantity and baseflow index (BFI) of the Upper Komering, South Sumatera Indonesia and to identify the effect of watershed topography and land use on baseflow hydrology; (3) To determine the response of baseflow to climate change in the region through partial correlation and regression analyses on precipitation, baseflow and seasonal variations.

## 2. MATERIALS AND METHODS

The methodology used to develop regression models for baseflow estimation in this study entails the following steps are: 1) Development of a database to compile streamflow and physical characteristics of watersheds; 2) Baseflow separation and determination of baseflow index using a recursive digital filter technique for baseflow separation. This step involved partitioning of streamflow time series data into direct runoff and baseflow; 3) Validation of regression equations. Generally, hydrologic models.

### 2.1 Study Area

The study was conducted in the upstream Komering watershed, South Sumatera Province, Indonesia. Water discharge data analyzed were measured at The Perjaya (Martapura) headwork by the Department of Central River Region VIII. The upstream Komering watershed an area of about 4260 km<sup>2</sup>. The temperate humid climate 28.40 – 32.20 C, humidity 80% and ratio sunshine 29%. Rainfall pattern of Komering watershed follows as an equatorial zone. An average annual rainfall for 40 years from three stations Banding Agung, Muara Dua dan Martapura in upstream Komering 2602.08 mm/year , wet season or monthly rainfall peaks in year during October-May and dry season or lower during June-September [12]-[13]-[14] and the area's climate is equatorial region and it's present in Figure 1.

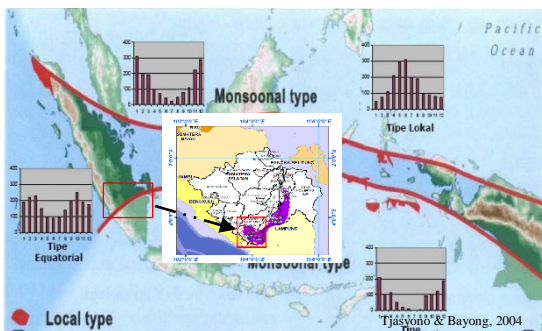


Fig. 1 The location of study area

The baseflow variability required data on the general condition of the upstream Komering watershed. General conditions of data were collected which associated to the variability of base flow, including land use, geology, water resources infrastructure and watershed meteorological conditions.

### 2.2 Data Processing

Variability of baseflow values were calculated from discharge rational model equation, as follow [14]:

$$Q = c (PA) + b \quad (1)$$

where Q is discharged in m<sup>3</sup>/sec, c is runoff coefficient, P is rainfall, A is an area in Ha and b is base flow.

Frequency-duration analysis, known as a flow duration curve, was another method used to analyze the characteristics of stream flow. The flow duration curve is constructed from flow data and is computed as follow [11]-[15]-[16]-[17]-[18]:

$$P(X_m) = \frac{m}{N+1} \quad (2)$$

where,

P = the probability of a given flow that will be equaled

m = the rank number when daily or monthly flows are arranged in descending order

n = the total number of observations

A stream discharge values at P = 50% (Q<sub>50</sub>) is taken as the median stream flow. Stream flows greater than Q<sub>50</sub> are taken as low flow rates [11]-[15]-[16]-[17]-[18].

A representation of sustained conditions, as opposed to extremes and events, is the baseflow index (BFI), which is the proportion of baseflow to total streamflow over a continuous period of record. The BFI is one of the most important low flow indexes, which is the long-term ratio of baseflow volume to total streamflow volume and affected by a number of climatic and topographic factors. Therefore, it can be used to analyze the correlation between baseflow and climate factors. BFI is calculated as a ratio between baseflow volume and total streamflow volume for a time period. Range value of base flow and total (BF/TF) ratio, as well as analysis of the physical condition of Komering watershed, can be used as a reference for the classification of hydrological functions. The base flow index respectively, as follows [10]-[19]-[20]-[21]:

$$BFI = \frac{BF}{TF} \quad (3)$$

where,

BFI = Base flow index

BF = Base flow values

TF = Total flow values

### 3. RESULTS AND DISCUSSIONS

Study area falls under equatorial rain climate region with the average rainfall 2,728.50 mm / year, and the lowest rainfall occurred in July. Water resources at upstream watershed are original from Muara Dua, the confluence of the Saka and Selabung Rivers, with each catchment areas of 1,070 km<sup>2</sup> and 1,230 km<sup>2</sup>. Selabung River upstream of Ranau Lake has a catchment area of 508 km<sup>2</sup> while at its downstream there is Perjaya headwork. The total catchment area of the upstream watershed is 5,169.74 Km<sup>2</sup>. Komerling watershed is dominated by swampland systems, making it vulnerable to flooding [13].

The river flow pattern is influenced by rock type and topography of Komerling watershed. Subsurface topography, in addition to surface relief, exerts a strong influence on water storage and throughflow pathways, and thus influences baseflow. Limestone and shale rocks are typical at the basin. The basin has two different forms of flow patterns, moderate and moderate-fine rectangular dendritics. The flow pattern affects the efficiency of the drainage system and hydrographic characteristics. Land use changes are the factors that affect changes in the hydrologic function [22]. Table 1 and Figure 2 are present land use of the study area.

Table 1 Land use in upstream Komerling, 2005

No.	Land use	Area (Ha)
1	Reeds	-
2	Thicket	166,824.858
3	Shrub	-
4	Lake	12,440.171
5	Denude forest	82,030.817
6	Village/settlement	18,065.790
7	Mixed farms	23,763.092
8	Smallholder plantations	223,714.106
9	Swamp	147,420.221
10	Paddy field	167,594.918
11	Moor	81,859.053
	Total	923,713.026

As the current study aims to assess how the change in land use and land cover in the last few decades affected the runoff characteristics of the area. Land use particularly for agricultural. In upstream basin at Belintang area is one of the largest agricultural production in South Sumatera. In order to assist the provincial government, therefore, irrigation project

development supported by the existences of Ranau Lake Regularly and Perjaya headwork was carried out.

The ratio of base flow and total flow (BF/TF) is as one indicator of the hydrologic functions of a watershed which is the role of the catch area responding to falling rainfall and surface runoff. The watershed category includes a good classification when it can reduce the surge in surface runoff fluctuations due to rainfall, stabilize the flow rate and ensure the sustainability of water availability [5]-[9]-[10]. Table 2 is present base flow and total flow ratio in upstream Komerling.

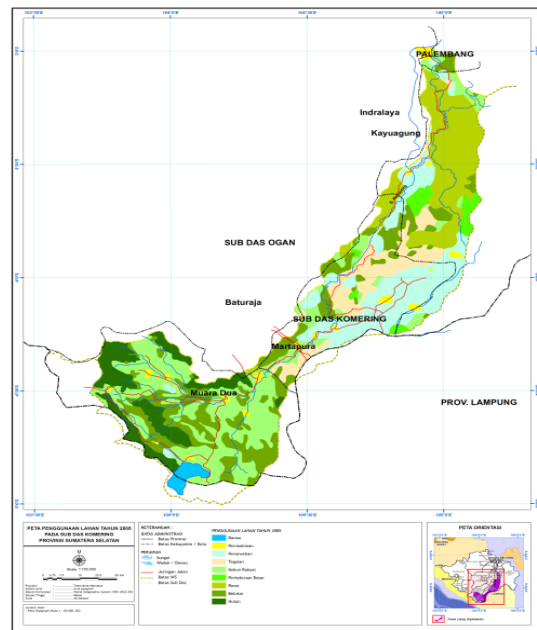


Fig. 2 The land use of the study area

Table 2 Base flow and total flow (BF/TF) ratio

Years	BFI	Years	BFI	Years	BFI
1971	0.160	1985	0.385	1999	0.306
1972	0.089	1986	0.343	2000	0.733
1973	0.399	1987	0.025	2001	0.528
1974	0.651	1988	0.528	2002	0.014
1975	0.301	1989	0.336	2003	0.519
1976	0.205	1990	0.456	2004	0.014
1977	0.318	1991	0.456	2005	0.008
1978	0.274	1992	0.315	2006	0.020
1979	0.244	1993	0.447	2007	0.042
1980	0.033	1994	0.182	2008	0.240
1981	0.585	1995	0.483	2009	0.094
1982	0.489	1996	0.386	2010	0.004
1983	0.329	1997	0.159		
1984	0.565	1998	0.158		

Range value of BF / TF ratio, as well as analysis of the physical condition of Komerling watershed, can be used as a reference for the classification of

hydrological functions. The criteria explained the bearing capacity of Komerung watershed as a water reservoir and also as a reference to evaluate the degradation level or accomplishment of watershed reservation. According to Table 2 the result of average base flow and total flow ratio during 40 years (1971-2010) is 0.296. Table 3 described the class of the hydrologic function as a BF / TF ratio value which indicated very poorly hydrology function of Komerung watershed, although in certain hydrologic function was still in the good category.

Table 3 Hydrology function classification [23], [24]

Hydrology function classification	BF/TF
Very good	>0,9
Good	0,7-0,9
Moderate	0,5-0,7
Poor	0,5-0,3
Very poorly	<0,3

Furthermore, the determination of the classification needs further analysis by reviewing the carrying capacity of watersheds in water availability and level of watershed damage. Land use change and watershed management affect the occurrence of erosion, sedimentation and ultimately affect water quality. In general, the occurrence of erosion is determined by climate factors, especially rain intensity, topography, soil, and rock characteristics, vegetation cover and land use and on the system of relationship between rain and surface flow is considered the only factor change and other factors can be as fixed variable [1]-[2]-[3]-[4]-[25]-[26].

Land cover is a fixed factor that is easily disturbed by human activities. The occurrence of erosion occurs due to changes in land use that lead to degradation of watershed quality. The distribution and classification of erosion levels in the Komerung DAS are presented in Table 4 and Figure 3.

Table 4. Erosion classification

Erosion classification	Area (Ha)	(%)	Legend
Very slightly	78.008,7	8,487	Light yellow
Slight	194.559,7	21,166	Yellow
Moderate	209.321,7	22,772	Gold
Serious	292.690,4	31,842	Light brown
Very seriously	144.623,0	15,734	Brown
Total	919.203,536	100	

The result of the distribution of erosion base on Figure 3 the upstream Komerung has been dominated serious erosion classification. If associated with the results of data processing increased runoff with an increase in the value of runoff coefficient, the decline in base flow value and the occurrence of discharge extremity, it can be concluded there has been a change of hydrological regime. Figure 4 is presented a trend of runoff coefficient (C) and base flow upstream Komerung Watershed.

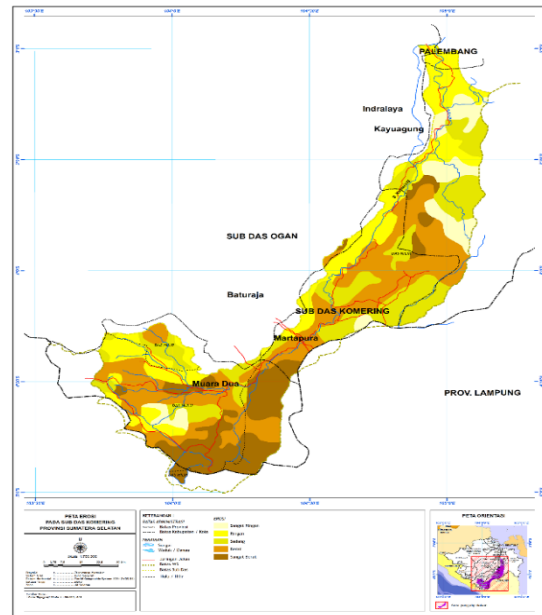


Fig. 3 Erosion classification in upstream Komerung

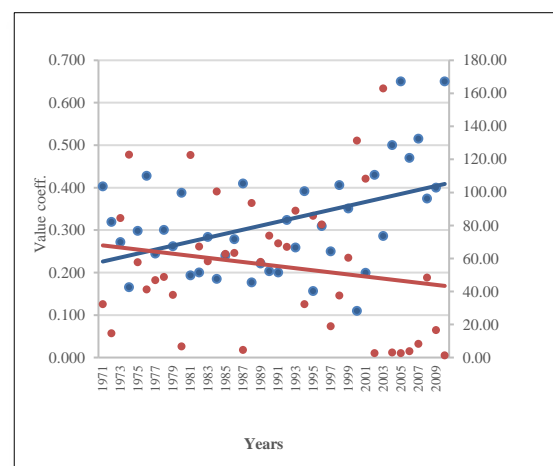


Fig. 4 Trend of runoff coeff. (C) and base flow upstream Komerung

Land use has an effect on the hydrological function of watershed especially affect runoff and base flow value. Base on Figure 2 land use due to human activities such as agricultural land (rice fields) and plantations contribute to large runoff.

#### 4. CONCLUSIONS

This paper has presented a regional regression approach to predict the BFI index at ungauged sites. Understanding land use and climate change will affect base flow quantity, in the context of watershed geomorphology, will aid watershed managers and stream in the protection of adequate water supply for human need and habitat availability in the stream. The choice of a particular baseflow separation technique, which has resulted to be the less stable procedure for the investigated area, seems not to be extremely relevant to the presented analysis.

The responses of runoff and base flow to climatic factors are different. Precipitation has a great impact on runoff, whereas temperature has a great impact on base flow. Land use changes have an impact on reducing the absorption capacity, especially in view of the proportion of changes in the agricultural area in the Upper Komerling Watershed and increasing the rate of surface runoff.

#### 5. ACKNOWLEDGMENTS

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