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# Base flow index evaluation for Yom River, Thailand

Kanokporn Sawatpru
Master student, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Thailand 40002. E-mail: kanokporncp@gmail.com
Supasit Konyai
Asistant Professor, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Thailand 40002. E-mail: supako@kku.ac.th
Khanittha Chaibandita
Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Thailand 40002. E-mail: k.chaibun@gmail.com

**Abstract**
The most controversial river in Thailand is the Yom River. It has not been modified by large dam because of several valuable natural resources. Therefore the river is flooded in rainy season and very low flow in dry season. The low flow causes drought which is much more serious than flooding. The Yom River Basin management is only way to circumvent the low flow problem by studying base flow index (BFI). Base flow analyses for 8 gauging stations along the river were performed by 2 techniques i.e. graphical and modified U.K. Institute of Hydrology (MIH). The mean BFI results from graphical and MIH are 0.37 (0.05) and 0.45 (0.12). The result from graphical is more reasonable due to its lower standard deviation. BFI values from MIH vary with watershed area which may result from the using of fixing value of N-day at 10. Solution for this problem is ongoing in this study.
**Keyword:** Base flow index, Graphical method, Low flow, MIH method

## 1. Introduction

Yom River is one of the 4 main tributaries of the greater Chao Phraya River of Thailand. The river originates from mountainous further north of the country and joins the Nan just at the boundary between northern and central parts of Thailand. The Yom is almost the only river in Thailand that has not been perturbed by large dams. It is often flooded in rainy season and very low flow in the dry season. It has been often threaten to be dammed by politicians and the Government but without success for a long time. Yom river basin possesses of several rare natural resources e.g. golden teak forests and wild animals [1]. The native occupants fight for conserving their ecology. For the last decades, drought and low flow in the Yom has been intensified by shallow groundwater abstraction for dry season rice growing and urban expansion [2]. The frequent extreme low flow of the river has destroyed its ecology which is very fragile [3]. Therefore, the Yom River management plan and strict regulation must be urgently laid out. One important component to do these is the base flow study. Hydraulically we divide river flow into two parts i.e. quick flow and base flow. The quick flow results from precipitation that creating surface runoff from the catchment. Whereas, the base flow is the result of groundwater and other delayed flow that feed to the river [4]. The base flow is very important mechanism to sustain stream flow [5] in the Yom during dry season which is almost without rainfall for 6 months [6].

The quantity of base flow can be estimated from the total stream flow by base flow separation methods. Two main categories of the methods has been employed i.e. manual or graphical methods and programming methods. The manual methods are subjective and tedious but can be very accurate for the experience persons [7]. There are several programming methods each has its pro and con [8]. Base flow index (BFI), always used in low flow study, is the ratio of base flow to stream flow which can be daily, monthly, or annually. It is one of the most essential for planning and operating river basin management [9].

The objective of this study is to evaluate and analyze the spatial variation of BFI of the Yom River Basin. We compared both types of methods, graphical and programming. For graphical one, Matlab computer language was used for graphing and calculating. The modified UK Institute of Hydrology was chosen for programming methods.

## 2. Materials and methods

### 2.1 The study area

We chose the Yom River for base flow study because it has been one of the most controversial river in Thailand. Kaeng Suae Ten dam has been proposed since 1991 [10]. but cannot continue to be built until now (2013). There is no large dam in the Yom River Basin therefore the dry season flow depends on base flow only. The river is 735 km long stretching from mountainous North to low land Central Plain. It originates from Khun Yuom Peak (elevation at 1916 m) of Phi Pannam range in Pong District, Phayao Province. Its source elevation is about 360 m. A.M.S.L. It flows in direction North to South parallel with the others 3 i.e. Ping, Wang, and Nan. The Yom joins the Nan at Chumsang District of Nakorn Swan at elevation of 28 m. A.M.S.L. The tributaries are short and swift e.g. Pong, Ngao, Ngim, Sin, Mok, and Kam Mi Rivers. The mean annual runoff is 40.1 $m^3$/s at Srisatchanalai, Sukhothai Province and 103 $m^3$/s at Nakhon Sawan.

The Yom River Basin is long and narrow from N 15° 45’ 35’’ to 19° 25’ 24’’ and E 99° 16’ 34’’ to 100° 40’ 51’’ (Figure 1). The watershed area is 23618 $km^2$. There is no significant natural lake, just only a few reservoirs e.g. Mae Mok Reservoir (96 MCM) and Tha Pare Reservoir (68 MCM). The Basin is always divided into 2 parts, the Upper Yom and the Lower Yom Basins, at about the mid distance between Phrae and Sukhothai. The upper basin is mostly mountainous with 51 % of forest, including the only large teak forest, and 49 % of agriculture and urban areas [11]. The lower basin is floodplain and very suitable for cultivation. The land use is therefore mostly agriculture and urban area and only 26 % is forest [12]. In brief, the Yom basin is covered by agriculture in majority follows by forest, urban, and water body, respectively. Petchprayoon et al. [6] found that forest area had been shrinking from 11943 $km^2$ to 11644 $km^2$ in 16 years from 1990 to 2006 and agricultural from 12987 to 12978 $km^2$, while urban increased from 210 to 488 $km^2$ and water body area from 43 to 75 $km^2$. Their study also found that the trends of long term daily discharge of the river at six gauging stations are increasing while precipitation trends of the watershed are constant. Since their results based on high flow, we suspected that base flow should have been decreasing due to decrease of forest and agricultural areas and increase in urban area.

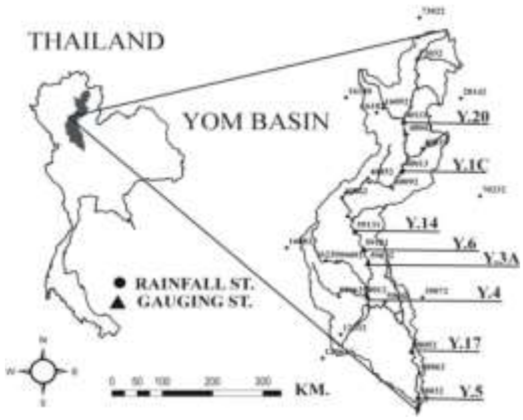



**Figure 1.** Study area on Yom River basin in North Thailand

According to Koppen-Geiger classification, the Yom River Basin belongs to Aw or sub-humid savanna climate type, which can be characterized as 6 months of rainy season and another 6 months for dry season. Average annual rainfall is 1087.8 mm with 955.4 mm falls in May to October which is 88% of annual rainfall. August is the month of highest rainfall and December is the lowest. Monthly rainfall distribution shows bimodal characteristic with a small drought period in June. The mean annual pan evaporation is 1747.3 mm with the highest month is April and the lowest is December. Mean temperature is 26.7 C with monthly value is shown in Figure 2.

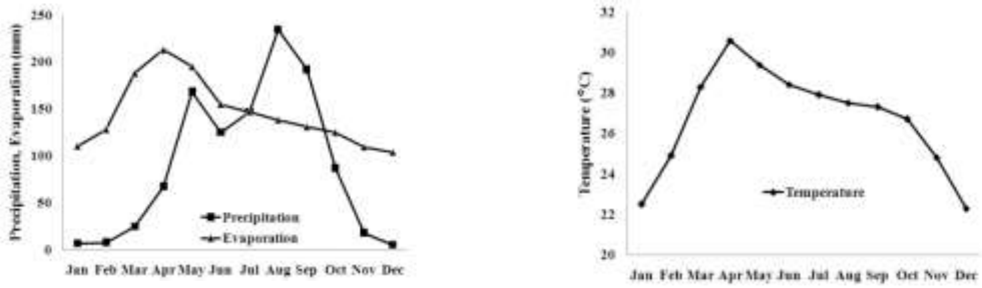



**Figure 2**. Average monthly temperature, precipitation and evaporation.

## 2.2 Baseflow analysis and baseflow index

The river flow can be classified into 2 principal components i.e. quick flow and base flow. When precipitation arrives on ground surface one portion flows on the surface (surface flow), some flows through and along the surface (interflow), and other seeps to groundwater aquifer (groundwater flow). The surface flow and a part of interflow feed the river as quick flow, while groundwater and delay part of interflow feed as base flow. The separation of river flow into quick flow and base flow, or sometime called base flow analysis, cannot be perfectly performed because the river flow is rather complex. The separation is however extremely necessary for river basin management, e.g. for this paper we want to know spatial variation of base flow and then the base flow index.

Base flow analysis can be classified into 2 main types i.e. manually and computer programming [13]. Manual or graphical methods are classical and usually apply for separating just one flood hydrograph to obtain direct runoff hydrograph or quick flow hydrograph for deriving unit hydrograph. The manual method is tedious, time consuming and may not be consistent. However when coupling manual with the help of computer, it can work very fast and render good result.In this study, we use both types of methods. For graphical method, we applied a computer language, Matlab, for plotting the complete series daily hydrograph and then computing the base flow and the base flow index. Matlab is an excellent programming language for both graphing and calculating e.g. see Lindfield and Penny. First, we plotted complete series of hydrograph of average daily flow. Then we used the assignment function "ginput" to mark the turning points, usually the lowest discharge. When we use the statement [X, Y] = ginput in the Matlab script all turning point coordinates are input into X, Y coordinates. They are ready for base flow volume calculation. During marking the turning points, the hydrograph can be enlarged at a specific period to get better vision. Base flow volume can be computed by Simson's rule or trapezoidal rule. This can be easily performed from the stored turning point data by Matlab e.g. using the function trapz or simp1 [14]. The total river flow volume can also be calculated in the same manner. The base flow index is obtained from the ratio of base flow volume to the river flow volume.

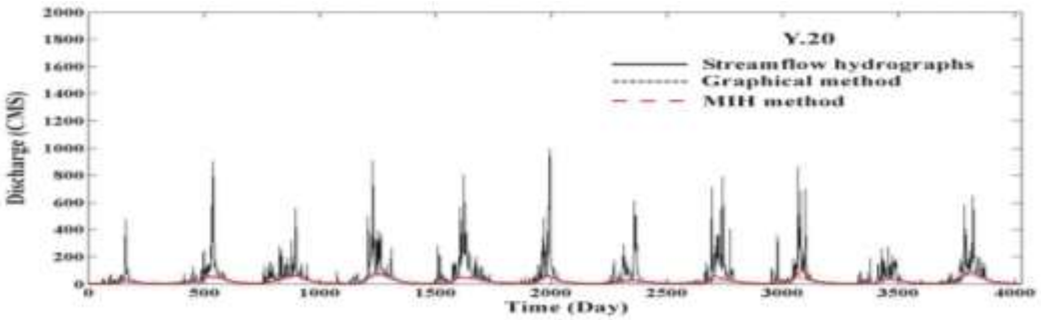
Computer programs using for base flow index are of two techniques i.e. recursive digital filter technique and smooth minima separation technique. The recursive digital filter technique derived from signal processing algorithm, by separating a low-frequency base flow signal from the high-frequency quick flow signal [15]. This technique was accepted, modified, and applied by several workers e.g. Nathan et al. [16], Lacey and Grayson [17], and Zhang, et al. [18]. The smooth minima technique originated from Institute of Hydrology so-call United Kingdom Institute of Hydrology (UKIH) method [19]. The procedure is simple and straight forward. From complete series of mean daily river flow hydrograph, the data are divided into 5-day (5 values) non-overlapping blocks from the first day to the last day, if the last block has less than 5 days it can be neglected. The smallest flow is spotted from each block now we obtain a series of minimum flows. Each minimum flow is multiplied by 0.9 then compares to the adjacent minimum values. If it is smaller than both adjacent values, then it becomes a turning point. By connecting the turning points, we obtain baseflow hydrograph. Even though the UKIH method is so popular and used in many works, e.g. Gustard et al. [20], Bloomfield, et al. [21] and Yang, et al. [5], it has been modified to render better values. Piggott, et al. modified the method to deal with the starting point and when the turning point higher than the stream flow [22]. Gregor (2012) modified the fix values of 5 days and the factor 0.9 to be any suitable values. In this study, we employ the modified method of Gregor (2012) (MIH, modified Institute of Hydrology) [23]. By comparing MIH to the graphical method we obtained 10-day block period and factor of 0.9 were the most suitable.

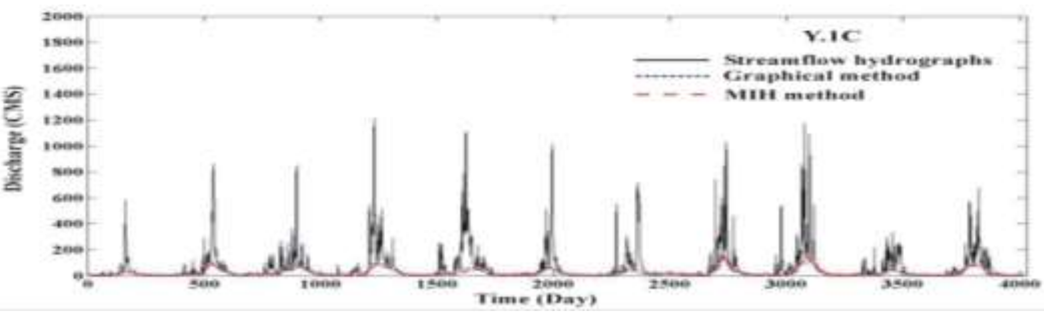
## 2. Results and discussion

The average base flow indices of 8 gauging stations from graphical and MIH methods are compared in Table 1. The base flow delineated lines from both methods are shown with river flow hydrographs in Figure 3. The average values of BFI are 0.37 and 0.45 for graphical and MIH methods respectively with standard deviations of 0.05 and 0.12 respectively. The average values show that MIH method gives over estimation of BFI about 20 %. The standard deviations also show that graphical method is more consistent than MIH method. The choice of N-day period and the multiply factor in this study are 10 and 0.9 respectively. This values have been tested with the graphical method with the best results. The true values of base flow cannot be actually known because of the complexity of the river flow system [8]. Several works were used the graphical method to be standard for other methods to compare [24, 25]. BFI values from MIH method seem to vary with the watershed areas as in Figure 4. This can be the effect of the fix value of 10-day block period. The N value may varies with the size of watershed area. The graphical method is though subjective but it can be easily fixed to avoid unreasonable points. The standard deviation of BFI from the graphical method is much lower than that of MIH means that graphical is more consistent and preferable.

**Table 1.** Summary of the total flow, base flow and BFI using different methods.

| Gauging Station | Year | Watershed Area ($km^2$) | Average annual rainfall (mm) | Total flow (mm) | Graphical method | | MIH method | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Base flow (mm) | BFI | Base flow (mm) | BFI |
| Y.20 | 1998-2008 | 5410.00 | 1170.00 | 3125.30 | 1056.03 | 0.34 | 1172.68 | 0.38 |
| Y.1C | 1998-2008 | 7624.00 | 1173.00 | 2938.84 | 950.56 | 0.32 | 992.95 | 0.34 |
| Y.14 | 1998-2008 | 12131.00 | 1132.59 | 2623.51 | 818.94 | 0.31 | 1010.14 | 0.39 |
| Y.6 | 1998-2008 | 12658.00 | 1213.70 | 2700.41 | 879.40 | 0.33 | 1029.78 | 0.38 |
| Y.3A | 1998-2008 | 13583.00 | 1194.30 | 2807.91 | 931.20 | 0.33 | 1057.21 | 0.38 |
| Y.4 | 1990-1997 | 17731.00 | 1177.42 | 733.57 | 267.94 | 0.37 | 367.75 | 0.50 |
| Y.17 | 1998-2005 | 21415.00 | 1175.56 | 1437.02 | 669.72 | 0.47 | 988.28 | 0.69 |
| Y.5 | 1991-1997 | 22344.00 | 1170.78 | 1177.14 | 431.61 | 0.37 | 617.21 | 0.52 |



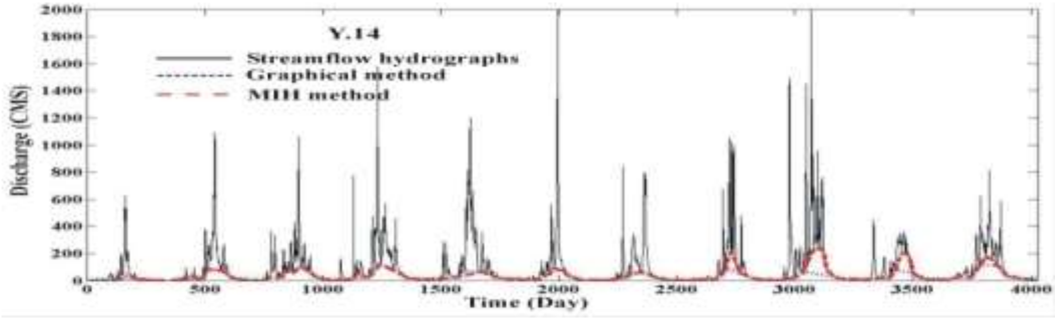
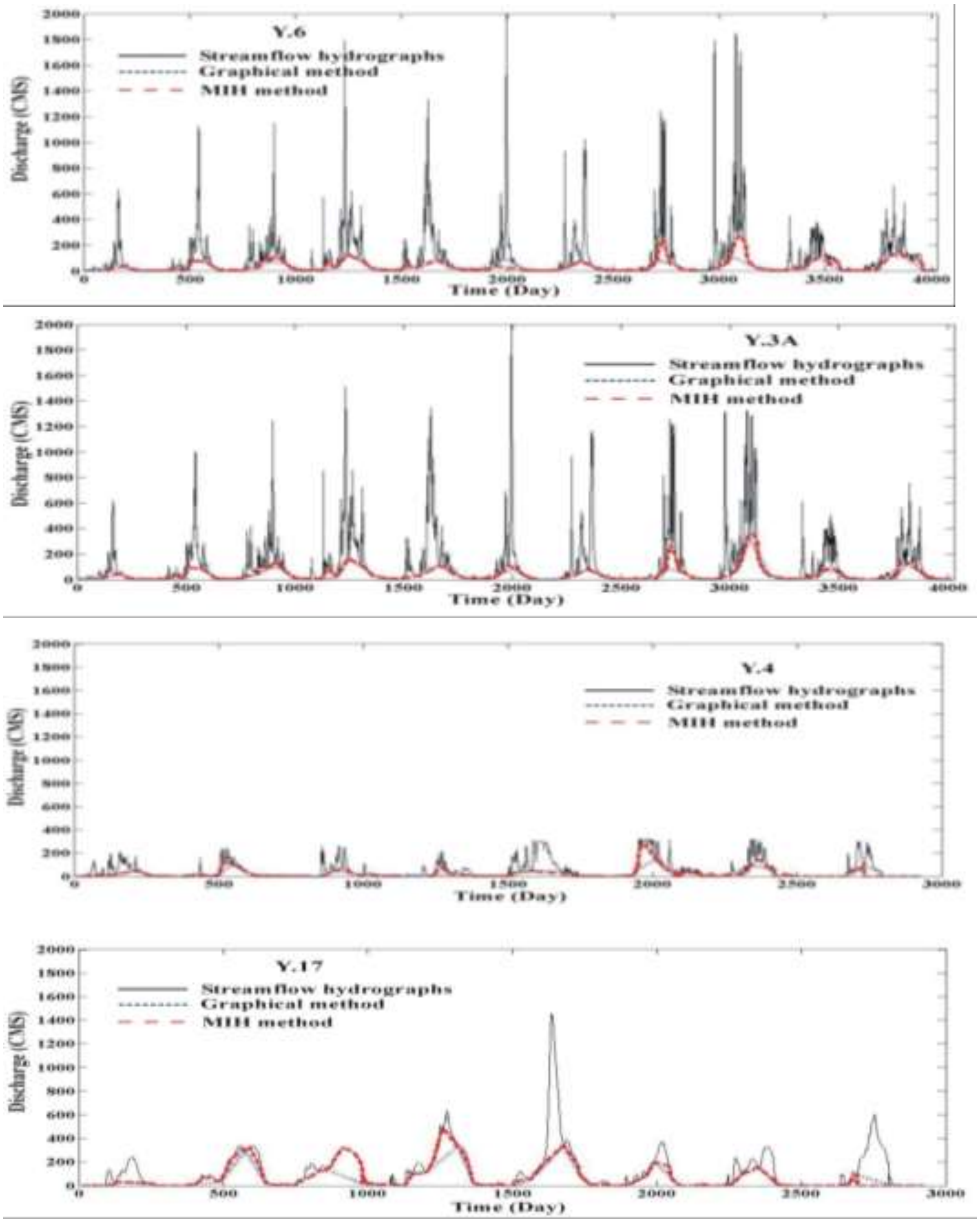



**Figure 3.** Base flow and streamflow hydrographs



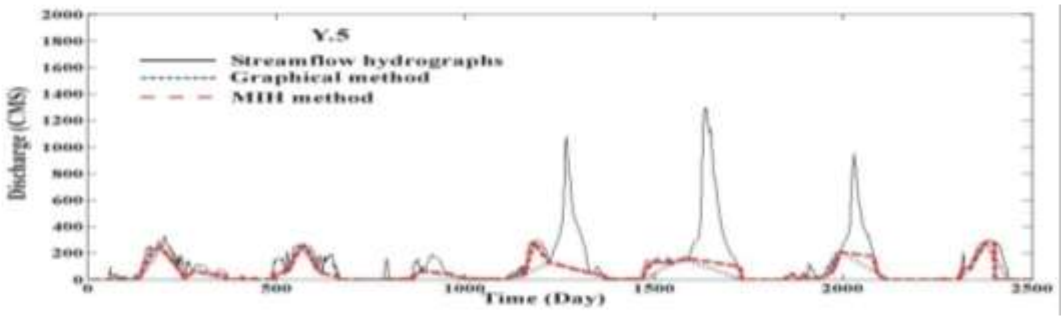



**Figure 3**(cont'd). Base flow and streamflow hydrographs

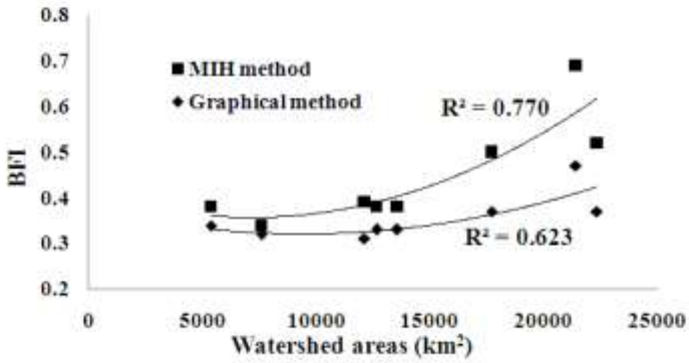



**Figure 4.** BFI values vary with the watershed areas

## 3. Conclusion

The serious problem of drought in the Yom River can be solved only by river basin management to increase and regulate the base flow. This can be done by BFI study. The mean daily flow data from 8 gauging stations along the Yom were used for base flow analyses. We compared 2 techniques for analyses, i.e. graphical and modified Institute of Hydrology techniques. The 2 techniques gave the mean values of BFI as 0.37 (0.05) and 0.45 (0.12) respectively. The standard deviation of the graphical method of 0.05 shows that it is more consistent than the MIH method. The BFI values from MIH method seems to vary with the size of watershed area. This may be the result of fixing value of N-day in the calculation. This skeptical point shall be found out in the near future.

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