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Identification of Flood Source Areas in Pahang River Basin, Peninsular Malaysia

Wan Nor Azmin Sulaiman, Heshmatpoor A., and Mohd Hafiz Rosli

Department of Environmental Science, Faculty of Environmental studies, University Putra Malaysia (UPM), 43400, UPM Serdang, Selangor, Malaysia

Abstract

The roles of upland watersheds in flood source contribution towards downstream areas in a river basin system are generally neglected in the inclusion of management strategy related to downstream flood management. In this study an assessment on the flood source area of Pahang river basin was attempted. The concept of unit flood response as an index of hydrologic response was used in identifying the flood source areas for the basin. The results indicated that among the 16 sub-basins of Pahang river basin, sub-basin of Sungai Pahang is ranked first in production of flood discharge while Sungai Perting sub-basin is ranked last in term of production of flood discharge. Comparison between maximum daily discharge of upper and lower segments of Pahang river basin indicated that up-stream watershed contributes significantly high and more flood (94.78%) than down-stream (5.22%). In addition, the upland watersheds were found to more efficient in producing surface runoff and send the floodwater to the lower receiving basin of Sungai Pahang. Considering that basin flood response is generally a nonlinear function of many factors, the sub-basins that are located nearest to and most distance from the basin outlet do not necessarily generate the highest and lowest contribution to the flood peak at the outlet. Similarly, sub-basins producing the highest or lowest absolute or specific discharge at their own outlet may not necessarily ranked first and last in flood index.

Keyword: Hydrological response unit; ranking; flood source are; Pahang river basin

1. Introduction

Recently, flooding is becoming one of the most significant natural hazard in Malaysia. There is a perception that land use-land cover change due to physical characteristics and intensive development as well as deforestation activities will results in increased flood frequency and severity. In this regards, numerous flood alleviation projects have been implemented throughout Malaysia. A successful flood control project must look beyond the damaged reaches by studying the contribution of headwater sub-basins to the flood magnitude at downstream locations. In order to accommodate this assessment, the hydrological response unit concept as a simple iterative simulation technique is introduced, whereby the contribution of each sub-basin unit to the flood peak response at downstream outlet can be disaggregated.

Although flood abatement attacks the flood problem at the source by seeking to prevent large flow downstream (Smith and Ward, 1998), the key to the success of these efforts is to identify and prioritize headwater areas with respect to flood generation at the outlet (Saghafian and Khosroshahi, 2005). The recognition of area(s) that contribute the flood problem at the main outlet of river basin in Pahang is the main issue to be addressed in this paper.

1.1. Study area

The selected study area, the Pahang Basin is located between longitude of 101° 30' E - 103° 30' E latitude 3° 00' N - 4° 45' N, is the largest river basin in Peninsular Malaysia. The climate of Pahang Basin generally is hot and wet, with an average annual rainfall between of 2,000 - 3,000 mm. Central Mountain Range bounds Pahang Basin along its western side while East Coast Range in the North-East. The main river in Pahang Basin is Pahang River, which flows for a length of 440 km and is the longest river in Peninsular Malaysia.

The digital elevation model (DEM) of the basin was prepared using GIS with 20 meter pixel size based on 1:50 000 topographic map. For this purpose of study, the Pahang Basin was divided into 16 sub-catchments. Besides that, some basin characteristic such as basin slope and length and others were also extracted using GIS. Table 1 provides information regarding the morphological characteristic of Pahang Basin adapted from previous study (Mohd Hafiz *et al*., 2008).

The shape of a basin could influences the shape of its characteristic flow hydrograph and for this study we used Graveliusûs index K_G, which is defined as the relation between the perimeter of the basin and that of a circle having a surface equal to that basin (McCuen, 1989).

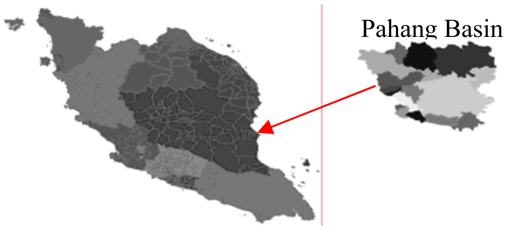

Figure 1. Pahang river basin in Peninsular Malaysia

2. Methodology

Attempting to reach the objective of this research is not straightforward, since the number of hydrometric stations and the available flood data measured at the stations are almost always insufficient for identifying the flood producing areas within the watersheds. This leads to take advantage of applying distributed simulation tools to conduct of flood source areas and the corresponding influential factors. Many researchers (e.g., Viessman *et al*., 1977; Mahdavi, 1999) have considered the effect of watershed characteristics on the peak discharge as corresponding influential factor. This spatial factor in large basin can solved through delineation into sub-area for distributed approach and call unit flood response (UFR). The flood source analysis may be conducted through the inspection of the change in absolute peak discharge value or, alternatively, the change in peak discharge divided by sub-basin area. These two indexes, specific peak discharge and unit flood response can be defined to prioritize sub-basins on the basis of the quantity of their contribution to the flood peak at the main basin outlet. The unit flood response approach can be defined according to the flood index to prioritize sub-basins on the basis of the quantity of their contribution to the flood peak at main river basin outlet (Saghafian *et al*., 2004):

$$FI_k = \{(Q_{o,all} - Q_{0,all-k})/ Q_{o,all}\} * 100 \quad (1)$$

$$fi_k = \{(Q_{o,all} - Q_{0,all-k})/ A_k\} \quad (2)$$

Where FI = gross flood index of K^{th} subwatershed (in percent); $Q_{o,all}$ = peak outlet discharge with all sub-watershed units present in the base simulation (m^3/s); $Q_{0,all-k}$ = peak outlet discharge without k^{th} sub-watershed removed (m^3/s); fi_k = specific flood index of K^{th} subwatershed (in $m^3/s/km^2$).

3. Results and Discussion

In this study it is hypothesized that the ranking of sub-basins units on the basis of their contribution at the main outlet, which receives spatially and temporally combined contributions from several units, resembles the ranking of sub-basins on the basis of the magnitude

Table 1. Characteristics of Pahang Basin

Sub basins	Area, A (km2)	Perimeter, [P] (km)	Basin Length, Lc] (km)	Basin Slope, *S*	Shape Index, KG	Circularity Ratio, FC
Jelai	2906.737	700.56	172.663	0.006	3.638	3.666
Serau	696.816	219.56	56.43	0.0014	2.329	1.149
Tanum	2013.576	364.08	112.936	0.0018	2.272	1.905
Tembeling	4176.142	584.56	195.661	0.011	2.533	3.059
Lipis	1408.08	349.12	111.209	0.0104	2.605	1.827
S.Pahang	6439.892	818.018	199.848	0.0004	2.854	2.876
Liang	264.368	114.8	39.219	0.0362	1.977	0.601
Tekai	1085.415	282.038	55.751	0.0201	2.397	1.476
Sempam	135.684	108.08	35.739	0.0336	2.598	0.566
Benus	308.2	135.24	46.88	0.0162	2.157	0.708
Kelau	636.394	247.48	72.368	0.018	2.747	1.295
Bentong	727.961	262.62	63.402	0.0025	2.725	1.374
Teriang	836.11	209.12	84.939	0.0007	2.025	1.094
Bera	883.536	284.32	89.81	0.0003	2.678	1.488
Perting	103.591	85.48	23.652	0.0338	2.352	0.447
Telemung	369.006	139.573	46.914	0.0179	2.034	0.73
			Total:	0.2104	39.922	24.258
			Average:	0.0117	2.495	1.516

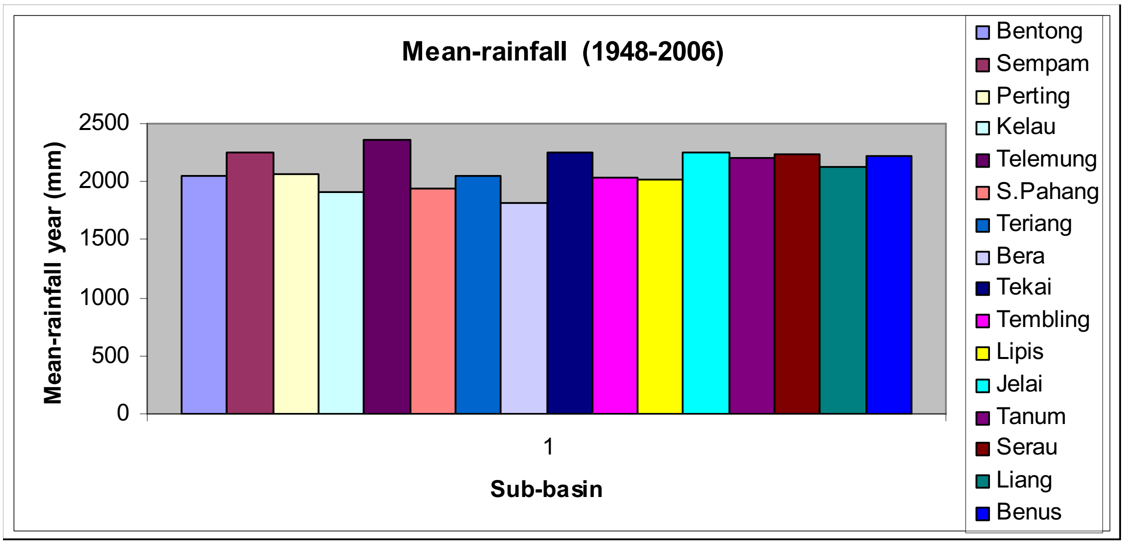

Figure 2. Maximum rainfall-monthly for each sub-basin of Pahang river basin

of peak discharge produced at the outlet of each unit. Further detailed model simulation study is still ongoing. Pahang river basin is considered for test of this hypothesis. Unit flood response (UFR) is the main approach to reach the objective of the study. Pahang basin is discreetized into 16 sub-basins as units flood response using GIS. Rainfall and runoff data was prepared for the relevant sub-basins and then the homogeneity of available data were tested by run-test method (Mahdavi, 1999). A record of rainfall and runoff representing basic year between 1973 until 2006 were chosen using bar graph technique and then missing data was calculated by using arithmetic mean and normal ratio method.

A relationship between elevation of stations and rainfall was established for the preparation of an isohyetal map. But, correlation coefficient between elevation and rainfall was low ($R^2 = 0.15$) and this equation couldn't help researchers to estimate rainfall on un-gauged sub-basins. This also means that the rainfall of the study area is not related to the topography. For this reason, rainfall of un-gauged sub-basins were estimated by using concept of central point of each sub-basin as mean condition point and cartesial axis method (Mahdavi, 1999). Fig. 2 and 3 shows the results of analysis of rainfall in Pahang river basin.

Then, the relation between maximum daily discharges and area of the sub-basins, and specific maximum daily discharge with area of the sub-basins were established based on available observed discharge data obtained for the six's Drainage and Irrigation Department gauging stations (SG.bentong at Jambatan Kuala Marong; Teriang at jambatan Api; Jelai at Jeram Bungor; Jelai at Kuala Medang; SG. Pahang at Sg. Yap; and SG. Pahang at Lubok Paku). These relationships are tabulated in Table 2. Discharge Data for un-gauge sub-basin were estimated by using equations in Table 2.

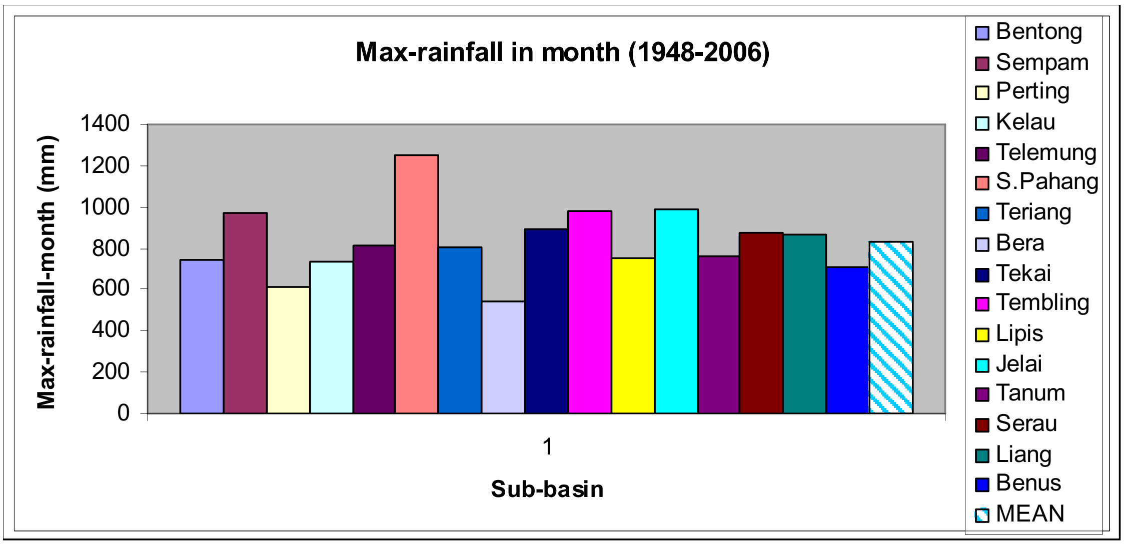

Figure 3. Mean of rainfall in each sub-basin of Pahang river basin

Table 2. Relationship between Q_{max} and Area

Relation between	Equation	R^2
Q_{max} [m^3/s] and Area [A, Km^2]	$Q_{max} = 9.3244\ (A)^{0.6569}$	0.957
Q_{max} /Area[$m^3/s.km^2$] and Area [A, Km^2]	$Q_{max}/A = 9.538\ (A)^{-0.3468}$	0.861

Table 3. Relationship between $Q_{max}\_ARI_{50}$ and Area

Relation between	Equation	R^2
$Q_{max}\_ARI_{50}$ [m^3/s] and Area [A, Km^2]	$Q_{max}\_ARI_{50} = 8.1363(A)^{0.6811}$	0.962
$Q_{max}\_ARI_{50}$ /Area[$m^3/s.km^2$] and Area [A, Km^2]	$Q_{max}\_ARI_{50}/A = 8.1362(A)^{-0.3189}$	0.848

In addition, maximum daily discharges of six stations were treated for statistical distribution using SMADA™ (version 6) software. Results indicated that all discharge data for the 6 stations followed the distribution of log Pearson type III. Relation between temporal maximum daily discharges for Average Recurrence Interval (ARI_50) of 6 selected stations and its drainage area was computed as indicated in Table 3. The key factor for the preparation of temporal discharge data in un-gauged sub-basin is drainage area. Therefore, discharge data for un-gauge sub-basin for ARI_50 were estimated by using equations in Table 3.

A ranking between sub-basins of Pahang river basin was derived by using index of specific maximum daily discharge [Q_{max}/Area]. In addition a ranking between sub-basins of Pahang river basin as units flood response was derived by using index of specific maximum daily discharge for 50 years average recurrence interval [$Q_{max}\_ARI_{50}$/Area].These two rankings were shown in Table 4.

Table 4. Ranking of sub-basins of Pahang based on specific maximum observed discharge ($Qmax\_ARI_{50}$)

Sub-basin	Area (km^2)	Qmax (m^3/s)	Qmax/area ($m^3/s.km^2$)	Priority ranking	$Qmax\_ARI_{50}$ (m^3/s)	Qmax/area-ARI_{50} ($m^3/s.km^2$)	Priority ranking
PERTING	103.59	198.5	1.91	1	179.23	1.73	1
SEMPAM	135.68	234.7	1.73	2	230.61	1.69	2
LIANG	264.36	363.7	1.37	4	363.23	1.37	4
BENUS	308.20	402.2	1.3	5	403.24	1.30	5
TELEMUNG	369.00	452.8	1.22	6	455.85	1.23	6
TERIANG	836.11	539.9	0.64	13	559.94	0.66	13
KELAU	636.39	628.6	0.98	7	660.75	1.03	7
BENTONG	727.96	707.5	0.97	8	724.11	0.99	8
BERA	883.53	803.5	0.9	9	826.22	0.93	9
TEKAI	1085.41	871.5	0.8	10	950.53	0.87	10
SERAU	696.81	980.6	1.4	3	1066.10	1.52	3
LIPIS	1408.08	992.2	0.7	11	1121.23	0.79	11
TANUM	2013.57	1380.3	0.68	12	1447.96	0.71	12
JELAI	2906.73	1756.8	0.6	14	1859.31	0.63	14
TEMBELING	4176.14	1988.3	0.47	15	2379.78	0.56	15
S.PAHANG	6439.89	2962.6	0.46	16	3196.34	0.49	16

Table 5. Priority ranking based on Flood Index (FI) for Pahang river basin

Sub-basin	$Qmax\_ARI_{50}$ (m^3/s)	Area without sub-basin (km^2)	Qmax-ARI without sub-basin (m^3/s) at main outlet	ΔQ m^3/s)	Flood index FI%	Priority Ranking Based on FI%
PERTING	179.23	22887.86	7581.48	23.35	0.307	16
SEMPAM	230.61	22855.77	7574.23	30.59	0.402	15
LIANG	363.23	22727.09	7545.16	59.66	0.784	14
BENUS	403.24	22683.25	7535.25	69.58	0.914	13
TELEMUNG	455.85	22622.45	7521.49	83.34	1.095	12
TERIANG	559.94	22155.34	7415.36	189.47	2.491	8
KELAU	660.75	22355.06	7460.82	144.01	1.893	11
BENTONG	724.11	22263.49	7439.99	164.83	2.167	9
BERA	826.22	22107.92	7404.54	200.28	2.633	7
TEKAI	950.53	21906.04	7358.42	246.40	3.240	6
SERAU	1066.10	22294.64	7447.08	157.75	2.074	10
LIPIS	1121.23	21583.37	7284.43	320.40	4.213	5
TANUM	1447.96	20977.88	7144.61	460.22	6.051	4
JELAI	1859.31	20084.72	6935.99	668.83	8.794	3
TEMBELING	2379.78	18815.31	6634.32	970.51	12.761	2
S.PAHANG	3196.34	16551.56	6079.64	1525.19	20.055	1
Main outlet	7604.83					

According to UFI method, each sub-basins of Pahang river basin was removed singly and estimated discharge (ARI_{50}) at main outlet was determined, respectively. The flood index (FI) for each sub-basin was obtained using UFI method. The flood source contribution (Priority) ranking was obtained by using FI index. Table 5 listed the flood source area ranking obtained for the respective sub-basins.

Based on its topographic characteristics, the Pahang river basin can be divided in general into two parts namely the upper (head area covering Sg.Tekai, Tembeling, Tanum, Serau, Jelai, Lipis, Liang, and Sempam sub-basins), and lower plain area covering S. pahang, Bera, Teriang, Telemung, Benus, Perting, Bentong, and Kelau sub-basins) it is clearly indicated that head area of the basin contributed more influence to production of flood flow than the lower plain-area of the basin.

Analysis of the flood discharge records for Pahang River basin at Sg.Yop gauging station which represent the upper sub-basins indicated that discharges produced are high and peakier flood (94.78%) than the lower section at Lubok Paku (5.22%). Table 6 indicated that Specific flood discharge at Sg.Yop section estimated equaling 0.48 m^3/s per unit area while it is 0.279 m^3/s per unit area for Lubuk Paku. In addition, the head basins of study area are more capable of sending more flood water to downstream receiving sub-basins (S.Pahang). Considering that basin flood response is generally a nonlinear function of many factors, the sub-basins that are the nearest to and most distance from the outlet do not necessarily generate the highest and lowest contribution to the flood peak at the outlet. Similarly, sub-basins producing the highest or lowest absolute or specific discharge at their own outlet may not necessarily rank first and last in flood index.

Table 6. Separation of drainage into upper and lower parts of Pahang river basin

	Sub-section	Area (km^2)	$Qmax\_ARI_{50}$ (m^3/s)	$Qmax\_ARI_{50}/area$ ($m^3/s.km^2$)	Ranking
1	Upper sub-basins of S.Pahang_	12686.5	6089.85	0.480	1
2	Lower sub-basins of S.pahang_	22990.9	6425.01	0.279	2

Comparison between source ranking based on specific discharge listed in Table 4 and Table 5 respectively, indicated that the two mode of ranking are the same. However, sub-basin one (S.Perting) with a flood index of 1.7 is more susceptible to a peaky flood and sub-basin sixteen (S.Pahang) with a flood index of 0.49 is in the lowest rank for production of flood per unit area. Comparison between Table 4 and Table 5 on peak flow indicates that S.Pahang and S.Perting are in first and last ranking respectively. This ranking is mainly contributed by drainage area as a common effect on peak flood.

4. Conclusion

Concept of unit flood response which was translated into two indexes namely peak flood and specific peak flood were used in this paper for decomposing the effect of sub-basin as unit on the flashing of flood at outlet of Pahang river basin. Results indicated that Sungai Pahang sub-basin is in last rank in term of production of specific flood water but rank first in term of flood discharge. In contrast, sub-basin of S.Perting is in the first rank in term of production of specific flood but in last rank in term of flood discharge. This results and discussion is greatly depended on area of the sub-basins and independent on other effect factors on flood. In dealing with flood control, generally the sub-basins with highest rank on flood contribution, the method of flood engineering practices could be implemented while for sub-basins with highest rank in specific flood discharge the mode of control may be more towards the bio-engineering practices. The results of such studies are quite helpful in flood control projects and assessment of flood characteristics of basins corresponding to best management practices. This finding is part of the more detailed on going study of Pahang river basin (Wan Nor Azmin *et al*., 2009).

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Correspondence to
Dr. Wan Nor Azmin Sulaiman
Department of Environmental Sciences,
Faculty of Environmental Studies,
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor,
Malaysia
Tel: (603)8946-6751
Fax: (603)8946-7463
E-mail: wannor@env.upm.edu.my