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Areal Rainfall Reduction Factor and Areal Flood Peak Reduction Factor for Upper Chao Phraya River Basin

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ABSTRACT

This research work consists of the study of areal rainfall reduction factor (ARF) for the upper Chao Phraya river basin from maximum rainfall depth–area–return period relationship, and the study of areal flood peak reduction factor from flood peak–area–return period relation. For maximum rainfall depth, considered duration is from 1 to 7 days, and for variation of areal rainfall reduction and areal flood peak reduction factors, considered return period is from 2 to 10,000 years. The data used in this study were annual maximum rainfall depth for duration of 1 to 7 days, and daily rainfall data. In the analysis, 35 subbasins located throughout the upper Chao Phraya river basin were selected as representative. The catchment areas of these subbasins vary from 30.23 to 12,866.00 square kilometers and watershed parameters were measured. Regarding to the study result of areal rainfall reduction factor varies from 100 percentage for the point rainfall of any duration to 43.81, 48.83, 52.58, 53.63, 54.92, 55.15 and 55.67 percentage for area of 13,000 square kilometers and for duration of 1, 2, 3, 4, 5, 6 and 7 days, respectively.

Key words: areal rainfall reduction factor, flood peak reduction factor, maximum rainfall, flood hydrograph, upper Chao Phraya river basin

INTRODUCTION

Many water resources development projects have implemented in upper Chao Phraya river basin, one for agriculture, other for mitigation flooding and so on. Design flood peak hydrograph in development area was needed for so-called projects. Nevertheless, design flood peak hydrograph that required from rainfall data, may be uncertained, because the study on areal rainfall reduction factor was insufficient and was not cover all over upper Chao Phraya river basin. Therefore the analysis of areal rainfall reduction factor and areal flood peak reduction factor by comparing both annual maximum rainfall depth and daily rainfall of the basin should conduct so as to acquire an appropriate factor for design flood peak hydrograph of this basin.

Upper Chao Phraya river basin has a catchment area about 89,422 sq.km. approximately 17.5% of overall area of Thailand. This basin is comprised of five subbasins; Ping, Wang, Yom, Nan, Sakae Krang and part of Chao Phraya between Nakhon Sawan province throughout Chao Phraya dam in Chainat province (Figure 1). The study of areal rainfall reduction factor has not been investigated yet in this basin. Therefore, this study is necessary for design flood peak hydrograph appropriate.

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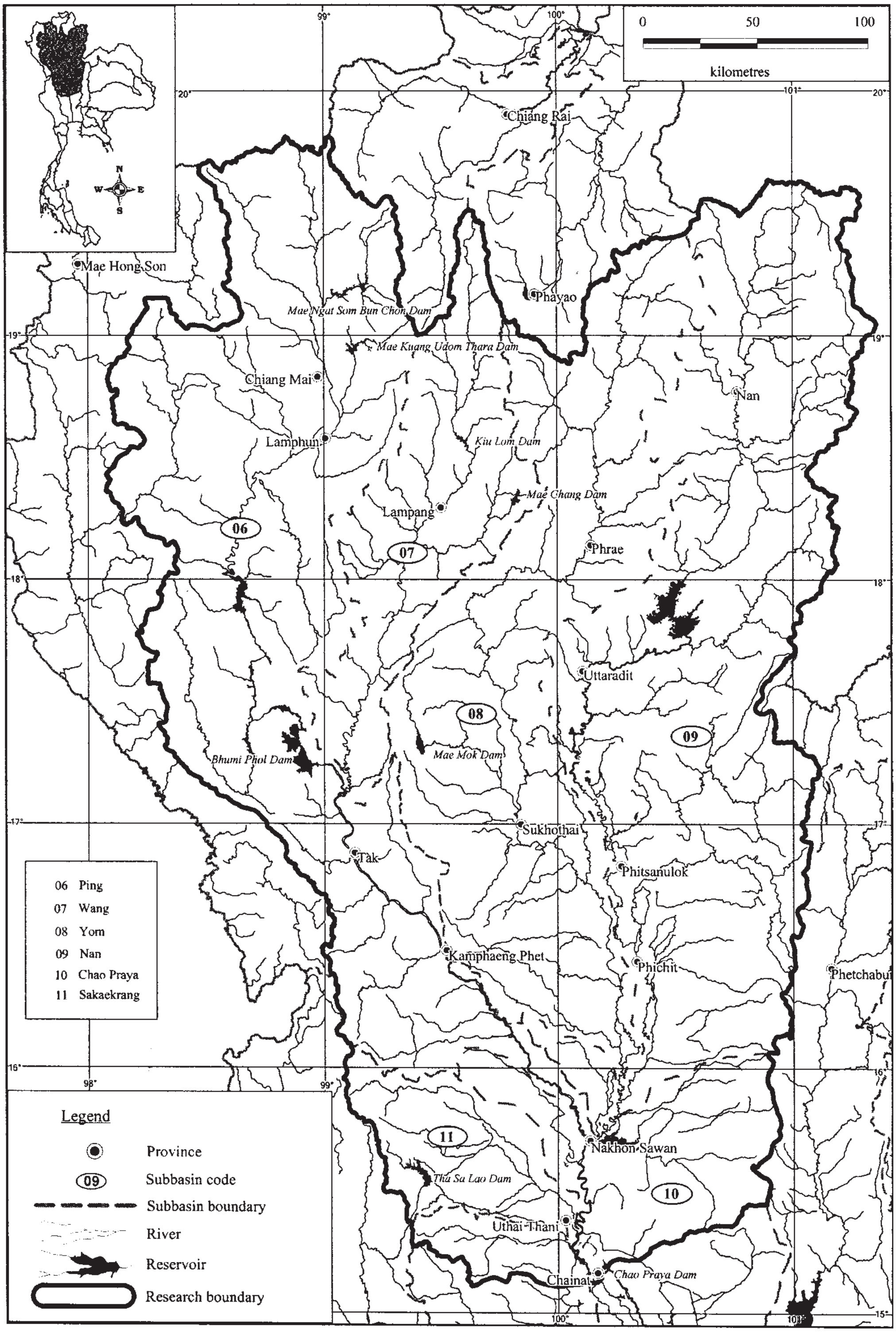

Figure 1 upper Chao Phraya river basin.

MATERIALS AND METHODS

Representative basin selection

This study was carried out in the upper Chao Phraya river basin. The selection of subbasin was conducted by considering physical condition as following:

1) Selected the representative basin from every subbasin of upper Chao Phraya river basin (Ping, Wang, Yom, Nan, Sakaekrang and Chao Phraya).

2) Representative basin have to cover all over upper Chao Phraya river basin, catchment area more than 70 percentage of upper Chao Phraya river basin.

3) Representative basin have different size so as to represent different catchment area, catchment area between 30 sq.km. and 12,866 sq.km.

By this selection, 35 subbasin were chosen which comprised of one representative from Ping river basin, five from Wang river basin, seven from Yom river basin, nine from Nan river basin, four from Sakae Krang river basin and one from Chao Phraya river basin.

Data collection

Data was collected from;

1) Daily rainfall data of 198 raingauges in upper Chao Phraya and nearby basins between 2512 B.E. and 2542 B.E. (31 years).

2) Annual maximum rainfall depth for duration of 1, 2, 3, 4, 5, 6, and 7 days of 198 raingauges in upper Chao Phraya and nearby basins between 2512 B.E. and 2542 B.E. (31 years).

3) Data which measurement and calculate from 1:50,000 map scale include of size of catchment area, lengths of main channel from outlet to the most remote divide (L), and lengths along main channel from outlet to point nearest to watershed centroid (L_c), and the average channel slope (S).

Areal rainfall reduction factor analysis

The study of areal rainfall reduction factor is a proportion of maximum rainfall depth from daily rainfall and maximum rainfall depth from annual maximum rainfall depth at different return period as shown in following equations:

$$ARF = 100 \times R_{TD} / R_{TY} \quad (1)$$

When ARF = Areal rainfall reduction factor

R_{TD} = Maximum rainfall depth from daily rainfall at different return period

R_{TY} = Maximum rainfall depth from annual maximum rainfall at different return period

1. Maximum rainfall depth analysis from daily rainfall at different return period (R_{TD})

1) Selecting an index raingauges station and calculating the daily rainfall at an index raingauges station of each basin for duration of 1, 2, 3, 4, 5, 6 and 7 days, between 2512 B.E to 2542 B.E. (31 years). Daily rainfall that was chosen from the same day (same storm) of every index raingauges station in representative basin and came from the storm at duration of 1, 2, 3, 4, 5, 6 and 7 days which has provided highly average rainfall depth of each representative basin in each year.

2) Areal distribution analysis of maximum daily rainfall depth of index raingauges station for representative basin between 2512 B.E. to 2542 B.E. by Thiessen average. These will provide a high average maximum rainfall depth of representative basin for duration of 1, 2, 3, 4, 5, 6 and 7 days in the so-called years.

3) Frequency analysis of the average maximum rainfall depth of representative basin at duration of 1, 2, 3, 4, 5, 6 and 7 days in the so-called years by Gumbel distribution. These will provide a maximum rainfall depth of representative basin from daily rainfall at different return period (R_{TD}).

2. Maximum rainfall depth analysis from annual maximum rainfall depth at different return period (R_{TY})

1) Selecting an index raingauges station for calculating average of maximum rainfall depth of each basin have had to be the same station as calculate from daily rainfall.

2) Frequency analysis of annual maximum rainfall depth for duration of 1, 2, 3, 4, 5, 6 and 7 days of each index station is by Gumbel distribution. These will provide maximum rainfall depth for duration of 1, 2, 3, 4, 5, 6 and 7 days at different return period.

3) Areal distribution analysis of maximum rainfall depth at different return period is by Thiessen average. These will provide maximum rainfall depth of representative basin from annual maximum rainfall depth at different return period (R_{TY}).

Then, compute areal rainfall reduction factor in each duration at different return period in every representative basin from equation (1), and compute relation between areal rainfall reduction factor and catchment area for each considered rainfall duration with regression equation in the form ARF = a – b lnA

Areal flood peak reduction factor analysis

The study of areal flood peak reduction factor is a proportion of flood peak hydrograph from daily rainfall and flood peak hydrograph from annual maximum rainfall depth at different return period. Step of analysis was show as following;

1. Unit hydrograph analysis for representative basin

1) Collecting watershed parameters of representative basin were measured, then calculated for duration of rainfall by assume time of concentration that gained from the equation:

$$T_C = (0.87\ L^3/H)^{0.385} \qquad (2)$$

When L = Lengths of longest watercourse, km.

H = Elevation difference between divide and outlet, m.

Then calculated unit hydrograph parameter by correlating peak discharge (q_p), basin lag (t_p), and the rainfall duration (t_r) of each representative basin from the equation (Tantitheravit, 1987).

$$t_p = 1.89533(LL_c / \sqrt{S}\,)^{0.17263}\ ;\ q_p / A = 1.36404\ (t_p)^{-0.62414} \qquad (3)$$

2) Calculating the unit hydrograph of each representative basin by using the unit hydrograph parameter from the first step and dimensionless unit hydrograph of subbasins in upper Chao Phraya river basin (Taesombat, 2001).

2. Flood peak hydrograph analysis at different return period

1) Dividing storm duration equally with a unit hydrograph duration both for maximum rainfall depth from daily rainfall at different return period (R_{TD}) and maximum rainfall depth from annual maximum rainfall depth at different return period (R_{TY}) of representative basin. Then, reducing rainfall with rainfall loss rate (Taesombat, 2001). Then, compute storm rainfall and rearrange their sequents which has duration as same as a unit hydrograph from representative basin.

2) The maximum rainfall excess was used with a unit hydrograph from representative basin so as to acquire direct runoff of representative from daily rainfall and from the annual maximum rainfall depth at different return period.

3) Considering the correlation of base flow (Q_B) and flood peak (Q_P) in regression equation (Taesombat, 2001). This provided base flow of representative basin. Then, gathering it with direct runoff to provide flood peak hydrograph of representative basin at different return period from daily rainfall and annual maximum rainfall depth respectively.

Then calculating areal flood peak reduction factor by calculate proportion of flood peak hydrograph from daily rainfall and flood peak hydrograph from annual maximum rainfall depth at different return period by considering proportion of flood peak discharge (Q_P), correlating areal flood peak reduction factor and catchment area by regression equation in the form AFF = a – b lnA

RESULTS AND DISCUSSION

Areal rainfall reduction factor analysis

The finding of areal rainfall reduction factor analysis of upper Chao Phraya river basin at a return period of 2 to 10,000 years at duration of 1 to 7 days was shown in regression equation, which demonstrated correlation of rainfall reduction factor value and catchment area (Table 1). And shown comparison graph of areal rainfall reduction factor among return period of 2 to 10,000 years in several duration in Figure 2. The calculation of areal rainfall reduction factor was done in the catchment area between 30.23 sq.km. and 12,866.00 sq.km. The finding shown that rainfall reduction factor value at different return period is 100 percentage while catchment area is zero (point rainfall). And it would reduce when the catchment area increased. The rainfall reduction factor value have had similar value in the small catchment area, but when the catchment area increased, the rainfall reduction factor have had higher different, the rainfall reduction factor at return period of 2 and 10,000 years have different vary from 13 to 19 percentage at duration 1 to 7 days. The areal rainfall reduction factor value has been reduced maximum at 10,000 years return period. It means that rainfall reduction factor value will reduce when a return period of storm and a catchment area increase.

Areal flood peak reduction factor analysis

The finding of areal flood peak reduction factor analysis of upper Chao Phraya river basin at a return period of 2 to 10,000 years was shown in regression equation, which demonstrated correlation of flood peak reduction factor value and catchment area (Table 2). And Figure 3 shows the comparison graph of areal flood peak reduction factor among return period of 2 to 10,000 years in several duration. The finding shown that flood peak reduction factor value at different return period reduced from 100 percentage while catchment area is zero. And it would reduce when catchment area increased. The flood peak reduction factor value have had similar value in the small catchment area. When catchment area increased, flood peak reduction factor have had higher different. The areal flood peak reduction factor value has been reduced maximum at 10,000 years return period. It means that flood peak reduction factor value will reduce when return period of storm and catchment area increase.

The comparison of areal rainfall reduction factor and areal flood peak reduction factor

The comparison of areal rainfall reduction factor in different of storm duration and areal flood peak reduction factor at the duration of 7 days was done at 10,000 years return period (Figure 4).

The finding shown that, rainfall reduction factor and flood peak reduction factor have had similar value in small catchment area. But in an increased catchment area, flood peak reduction factor will reduce more than the rainfall reduction factor at the duration of 2 days but less than rainfall reduction factor at the duration of 1 day, the catchment area was 13,000 sq.km value of flood peak reduction factor was 47.76 percentage and value of rainfall reduction factor at the duration of 1 day and 2 days was 43.81 and 48.83 percentage. It means that rainfall reduction factor and flood peak reduction factor value consistency reduce when a return period of storm and a catchment area increase.

The comparison of the result and studied storm

The comparison of areal rainfall reduction factor in duration of 3 days and former studied storm which investigated storm in the northeast and the north parts of Thailand (Sukklam, 1990) and which investigate storm in upper Chi and upper Mun basin (Teartrakoon, 1992) was shown in Figure 5.

The finding shown that value of areal rainfall

Table 1 Empirical equation which demonstrated correlation of areal rainfall reduction factor and catchment area of upper Chao Phraya river basin for duration of 1 to 7 days.

Duration (days)	Return Period (years)	Empirical Equation	R.	Duration (days)	Empirical Equation	R.	Duration (days)	Empirical Equation	R.	Duration (days)	Empirical Equation	R.
1	2	ARF = 112.37 - 5.84 lnA	0.688	2	ARF = 110.13 - 4.73 lnA	0.652	3	ARF = 108.04 - 4.10 lnA	0.593	4	ARF = 105.95 - 3.65 lnA	0.545
	5	ARF = 116.93 - 6.84 lnA	0.756		ARF = 116.57 - 6.03 lnA	0.787		ARF = 112.85 - 5.22 lnA	0.741		ARF = 111.70 - 4.90 lnA	0.707
	10	ARF = 118.65 - 7.23 lnA	0.757		ARF = 119.26 - 6.57 lnA	0.807		ARF = 114.68 - 5.67 lnA	0.760		ARF = 114.05 - 5.42 lnA	0.731
	20	ARF = 119.74 - 7.50 lnA	0.749		ARF = 121.10 - 6.95 lnA	0.812		ARF = 116.00 - 6.00 lnA	0.762		ARF = 115.72 - 5.80 lnA	0.735
	25	ARF = 120.02 - 7.56 lnA	0.747		ARF = 121.53 - 7.05 lnA	0.812		ARF = 116.32 - 6.08 lnA	0.761		ARF = 116.16 - 5.90 lnA	0.735
	50	ARF = 120.81 - 7.75 lnA	0.739		ARF = 122.79 - 7.31 lnA	0.810		ARF = 117.16 - 6.30 lnA	0.754		ARF = 117.34 - 6.17 lnA	0.732
	100	ARF = 121.41 - 7.89 lnA	0.732		ARF = 123.80 - 7.52 lnA	0.807		ARF = 117.86 - 6.49 lnA	0.748		ARF = 118.27 - 6.38 lnA	0.727
	200	ARF = 121.84 - 8.01 lnA	0.725		ARF = 124.61 - 7.70 lnA	0.804		ARF = 118.42 - 6.64 lnA	0.742		ARF = 119.01 - 6.56 lnA	0.721
	500	ARF = 122.41 - 8.14 lnA	0.717		ARF = 125.50 - 7.89 lnA	0.799		ARF = 118.99 - 6.79 lnA	0.734		ARF = 119.84 - 6.75 lnA	0.714
	1,000	ARF = 122.72 - 8.22 lnA	0.713		ARF = 126.06 - 8.00 lnA	0.796		ARF = 119.34 - 6.89 lnA	0.728		ARF = 120.35 - 6.87 lnA	0.710
	10,000	ARF = 123.46 - 8.41 lnA	0.700		ARF = 127.39 - 8.29 lnA	0.788		ARF = 120.19 - 7.14 lnA	0.713		ARF = 121.63 - 7.18 lnA	0.698
5	2	ARF = 104.76 - 3.36 lnA	0.514	6	ARF = 103.45 - 3.09 lnA	0.503	7	ARF = 104.26 - 3.12 lnA	0.498			
	5	ARF = 110.89 - 4.65 lnA	0.679		ARF = 110.63 - 4.52 lnA	0.689		ARF = 112.56 - 4.67 lnA	0.679			
	10	ARF = 113.47 - 5.20 lnA	0.705		ARF = 113.68 - 5.14 lnA	0.718		ARF = 116.11 - 5.33 lnA	0.709			
	20	ARF = 115.35 - 5.60 lnA	0.711		ARF = 115.88 - 5.58 lnA	0.725		ARF = 118.73 - 5.82 lnA	0.717			
	25	ARF = 115.83 - 5.71 lnA	0.711		ARF = 116.45 - 5.70 lnA	0.726		ARF = 119.45 - 5.96 lnA	0.718			
	50	ARF = 117.18 - 6.00 lnA	0.709		ARF = 118.05 - 6.03 lnA	0.724		ARF = 121.36 - 6.32 lnA	0.719			
	100	ARF = 118.21 - 6.23 lnA	0.706		ARF = 119.32 - 6.29 lnA	0.721		ARF = 122.90 - 6.61 lnA	0.721			
	200	ARF = 119.09 - 6.42 lnA	0.702		ARF = 120.40 - 6.51 lnA	0.718		ARF = 124.19 - 6.85 lnA	0.715			
	500	ARF = 120.06 - 6.63 lnA	0.696		ARF = 121.59 - 6.75 lnA	0.713		ARF = 125.60 - 7.12 lnA	0.711			
	1,000	ARF = 120.67 - 6.77 lnA	0.693		ARF = 122.32 - 6.90 lnA	0.710		ARF = 126.51 - 7.29 lnA	0.709			
	10,000	ARF = 122.14 - 7.10 lnA	0.681		ARF = 124.14 - 7.28 lnA	0.700		ARF = 128.77 - 7.72 lnA	0.702			

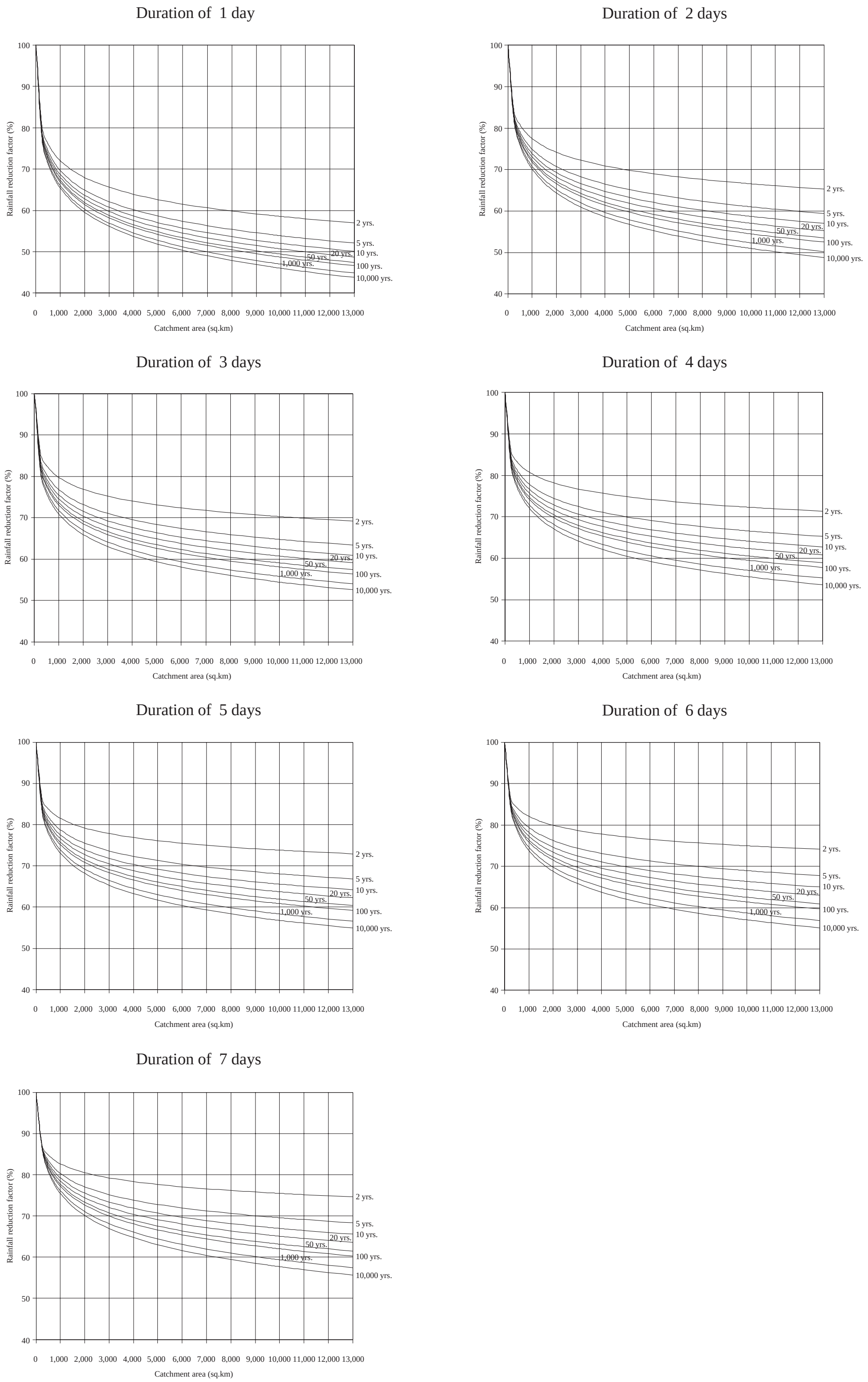

Figure 2 Comparison of graphs of areal rainfall reduction factor at different return period.

Table 2 Empirical equation which demonstrated correlation of flood peak reduction factor and catchment area of upper Chao Phraya river basin.

Return period (years)	Empirical equation	R.
2	AFF = 106.85 - 4.73 lnA	0.609
5	AFF = 112.01 - 5.84 lnA	0.727
10	AFF = 114.05 - 6.28 lnA	0.742
20	AFF = 115.39 - 6.59 lnA	0.741
25	AFF = 115.73 - 6.67 lnA	0.740
50	AFF = 116.71 - 6.89 lnA	0.735
100	AFF = 117.45 - 7.05 lnA	0.729
200	AFF = 117.94 - 7.18 lnA	0.723
500	AFF = 118.57 - 7.32 lnA	0.717
1,000	AFF = 118.94 - 7.41 lnA	0.712
10,000	AFF = 119.59 - 7.58 lnA	0.696

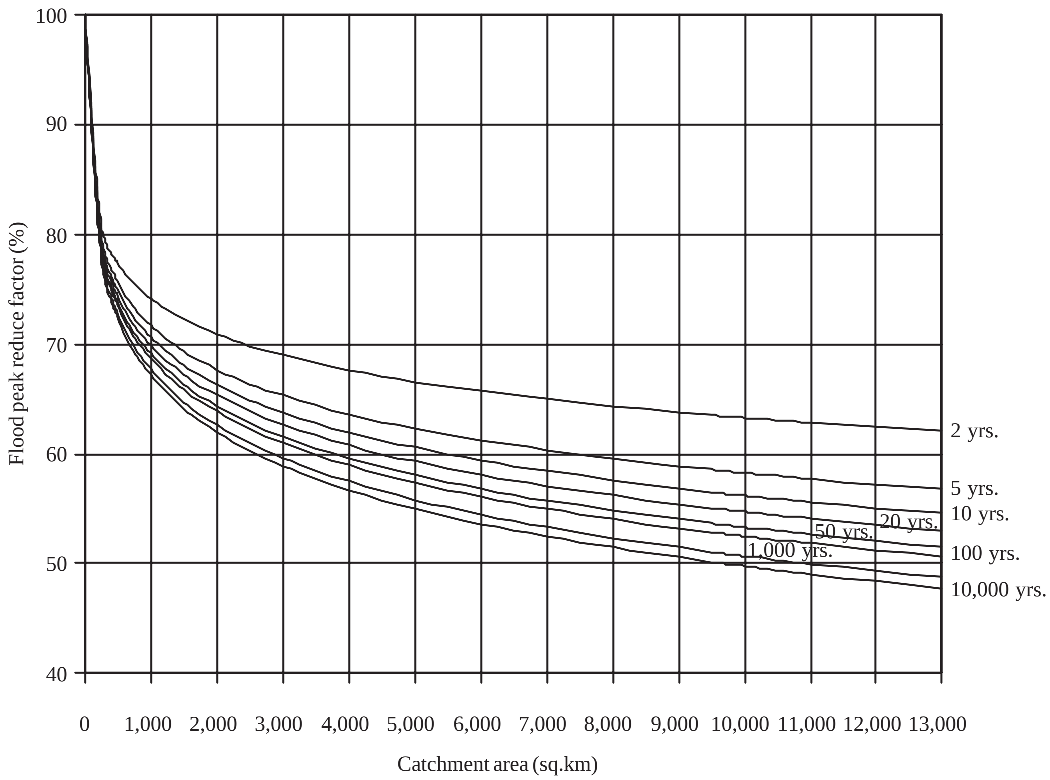

Figure 3 Comparison of graphs of areal flood peak reduction factor at different return period.

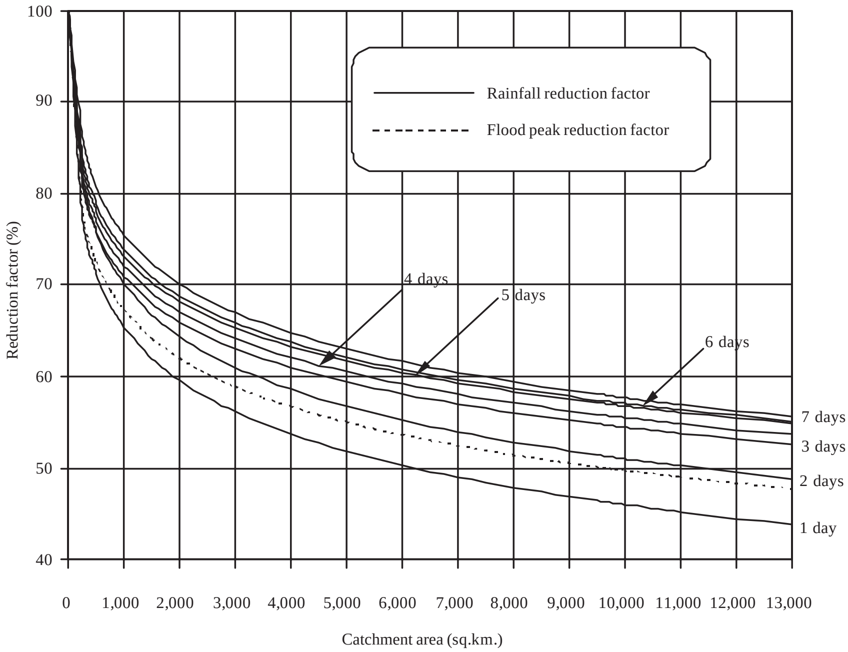

Figure 4 Comparison of graphs of areal rainfall reduction factor and areal flood peak reduction factor at 10,000 years return period.

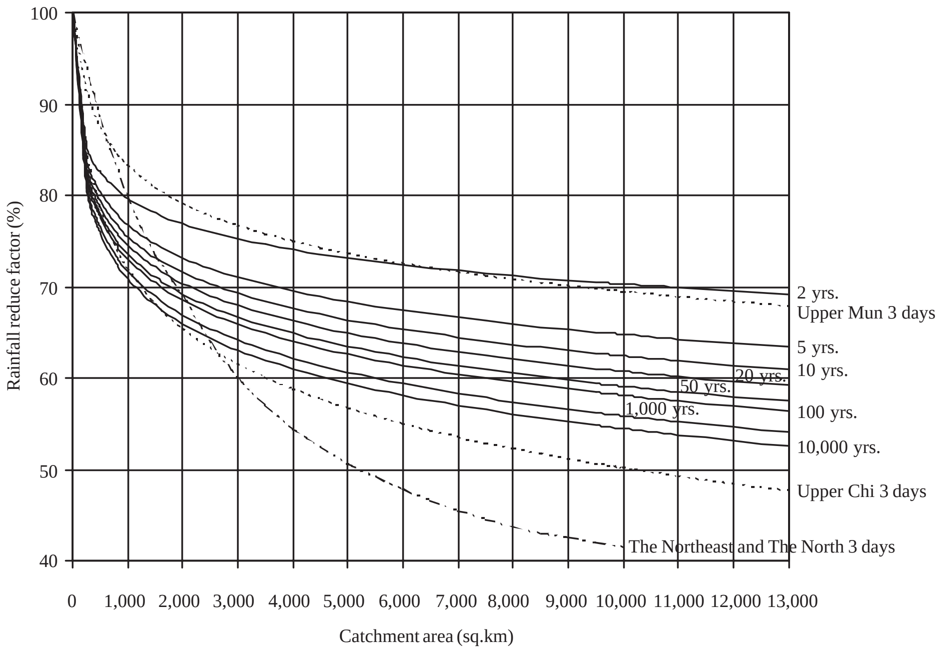

Figure 5 Comparison of graphs of areal rainfall reduction factor in duration of 3 days at different return period of this study and studied storm in Thailand.

reduction factor in duration of 3 days of this study was less than areal rainfall reduction factor of upper Mun river basin, except in 2 years return period for catchment area of 6,500-13,00 sq.km., value of areal rainfall reduction factor from this study was higher than areal rainfall reduction factor of upper Mun river basin, value of areal rainfall reduction factor of upper Chi river basin was less than areal rainfall reduction factor of this study at all return period. Value of areal rainfall reduction factor of the northeast and the north parts of Thailand was higher than value of areal rainfall reduction factor from this study when catchment area did not exceed 2,500 sq.km. But when catchment area increased more than 2,500 sq.km, value of areal rainfall reduction factor from this study was higher than value of areal rainfall reduction factor of the northeast and the north parts of Thailand. By the catchment area of 13,000 sq.km, value of areal rainfall reduction factor of upper Mun river basin was 67.93 percentage, value of areal rainfall reduction factor of upper Chi river basin was 47.67 percentage, and value of areal rainfall reduction factor of the northeast and the north parts of Thailand was 41.50 percentage.

Regarding to the study result is benefit for design flood hydrograph of water resources development project in Thailand have proper and appropriate for the physical condition.

CONCLUSION

The areal rainfall reduction factor and areal flood peak reduction factor were studied from daily rainfall data was concluded as following:

The relation between areal rainfall reduction factor and catchment area for each considered rainfall duration with regression equation in the form ARF = a – b lnA, the corresponding correlation coefficient is varied from 0.50 and 0.81 which lies within acceptable standard level. It is also encountered from analysis result, at 10,000 years return period, areal rainfall reduction factor varies from 100 percentage for the point rainfall for any duration to 43.81, 48.83, 52.58, 53.63, 54.92, 55.15 and 55.67 percentage for area of 13,000 sq.km. and for duration of 1, 2, 3, 4, 5, 6 and 7 days, respectively.

The relation between areal flood peak reduction factor and catchment area for each considered at different return period with regression equation in the form AFF = a – b lnA, corresponding correlation coefficient is varied from 0.60 and 0.74 which lies within acceptable standard level. It is also encountered from the analysis result, areal rainfall reduction factor varies from 100 percentage to 62.04, 56.73, 54.54, 53.00, 52.58, 51.49, 50.62, 49.94, 49.20, 48.72 and 47.75 percentage for area of 13,000 sq.km. and for return period of 2, 5, 10, 20, 25, 50, 100, 500, 1,000 and 10,000 years, respectively.

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