Post Flash Flood Hydrological Investigation

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In past decade, the occurrences of flooding and flash flood have been increasing over the lower northern part of Thailand. Flash floods typically result from intense rainfall rates that occur in individual thunderstorms, and often cause land sliding over the mountainous area. The study was undertaken for post flooding investigation over the flooded area of Uttaradit after the big flash flood in 2006. By coupling the data from field investigation and information from satellite images the changes of land use and watershed characteristics was then analyzed

1. Introduction

Flooding potential is one of critical factor for a hydraulic structure design. [1] To estimate flood discharge, flood elevation and flood volume, the watershed characteristics should be identified. The watershed characteristics depend on the physical properties of watershed area. If there are the changes in topography over the area due to the occurring of flash flood with landslide, the watershed physical parameters are deformed. In past decade, the flash floods have been often occurred over the lower northern part of Thailand which increases the vulnerability to floods. In year 2006, there was a severe flash flood over this part of country, covering the area of Uttaradit, Phrae, Sukothai and Nan provinces. Over the mountainous area of Uttaradit, not only flash flood but also landslide occurred which caused a lot of damages for both lives and assets. The event of this big flash flood also altered the topography of the area. As the watershed functions dominate the hydrological parameters, the objective of this study was set to post investigate the watershed characteristics after 2006 flash flood at Uttaradit. Using the satellite images, and obtained relevant data from Land development department, the topography and land covering of the watershed prior to and after flash flood was then analyzed. Daily rainfall from 4 stations close to the studied watershed was also analyzed to investigate the return period of rainfall.

2. Studied area

Considering the regularly flooded and also faced the flash flood with landslide in 2006, the watershed of Huai Nam Rit in Tha Pla district, Uttaradit province of Thailand was selected to study. The daily rainfall data from 4 stations of Thailand meteorological department (TMD) were also analyzed in this study. Figure 1 shows the location of studied watershed and Figure 2 shows the location of the 4 studied rainfall stations.

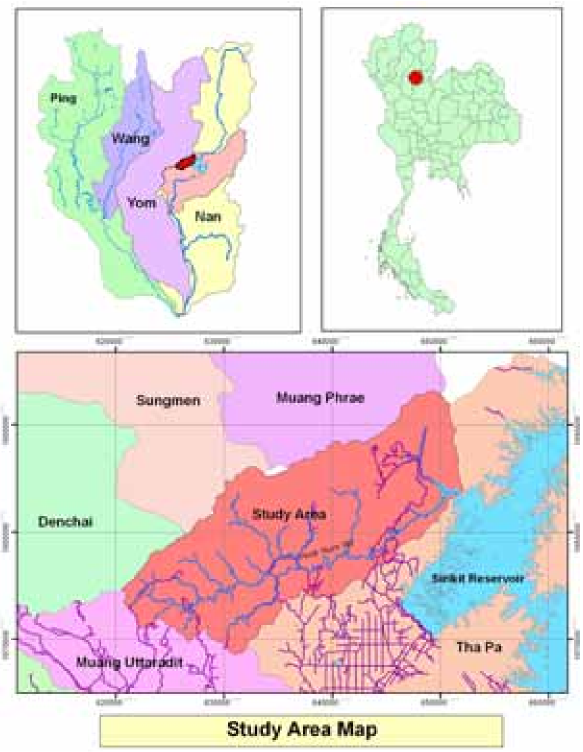

Figure 1 The studied watershed

3. Watershed characteristics

The physical characteristics of watershed include drainage area, watershed length, watershed slope and watershed shape. [1] [2] [3]

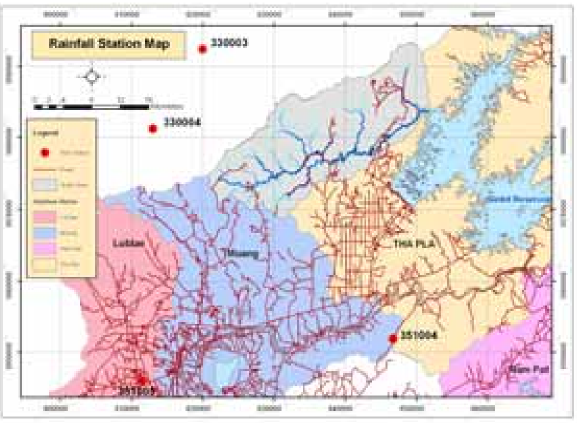

Figure 2 Location of 4 studied rainfall stations

The watershed parameters that reflect factor for a hydraulic structure design includes basin shape indices, channel geomorphology and physical hydrological parameters. The studied basin shape indices are: Shape Factor (L_l) [3]; Circularity Ratio (F_C) [3]; Lemniscate ratio (K) [4]; Basin circularity (c) [5]; Form factor (F) [6] and Basin Elongation (E). [7] These typical basin shape indices can be computed as follow:

(1) Shape Factor (L_l):

$$L_l = (L \times L_{ca})^{0.3} \quad (1)$$

(2) Circularity ratio (F_c):

$$F_c = \frac{P}{(4\pi A)^{0.5}} \quad (2)$$

(3) Lemniscate ratio (K):

$$K = \frac{L^2 \pi}{4A} \quad (3)$$

(4) Basin circularity (c)

$$c = \frac{4\pi A}{P^2} \quad (4)$$

(5) Form factor (F)

$$F = \frac{A}{L^2} \quad (5)$$

(6) Basin Elongation (E)

$$E = \frac{2\sqrt{A}}{L\sqrt{\pi}} \quad (6)$$

Where L is the length of the watershed ; L_{ca} is length to the center of watershed area ; P is the perimeter of the watershed and A is the area of the watershed.

The channel geomorphologic parameters that were analyzed in this study comprise of Channel Length [3], Channel slope [3], Drainage Density [2] and Bifurcation ratio [6]. The parameters of Drainage Density and Bifurcation ratio can be given by:

Drainage Density, $$D = \frac{L_t}{A} \quad (7)$$

Bifurcation Ratio, $$R_b = \frac{N_i}{N_{i+1}} \quad (8)$$

Where L_t is the total Length of stream channels in the watershed; A is watershed area; N_i is number of stream at any order and N_{i+1}= number of stream of the next highest order.

The studied physical hydrological parameters are Runoff Curve Number (CN) [8] and Time of Concentration (t_C). Three equations were utilized to obtain Time of Concentration as follow:

(1) US Bureau of reclamation equation [9]

$$t_C = 60\left(\frac{11.9L^3}{H}\right)^{0.385} \quad (9)$$

(2) Kirpich's equation [10]

$$t_C = 0.0078L^{0.77}S^{0.385} \quad (10)$$

(3) Barnsby's equation [10]

$$t_C = \frac{21.3L}{A^{0.1}S^{0.2}} \quad (11)$$

Where L is length of channel; H is the elevation difference between upstream and downstream point and S is average watershed slope.

4. Studied process

The process of study comprises of rainfall analysis, GIS based watershed map development and the watershed characteristics analysis. The daily rainfall records of 1976-2006 from 4 studied stations were analyzed for statistical characteristics. The series of daily, 2, 3, 4 and 5 day accumulated rainfall which exceed than mean values were then generated to analyze for rainfall at various return period of occurrences. The spatial patterns of rainfall in each return period were then constructed. The details of rainfall analysis process are shown in Figure 3.

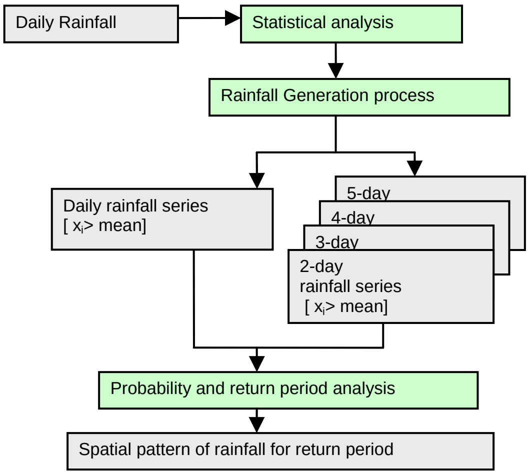

Figure 3 Rainfall Analysis Process

In order to compare the watershed identification between prior to and after flooding, the GIS based watershed map of these 2 periods were then developed with ARCGIS. Using ERDAS, the satellite images from year 2002 and 2007 were analyzed for landuse of before and after flooding. The soil covering type data obtained from Land Development department were also utilized in the process of CN evaluation. The process of GIS based watershed map development is shown in Figure 4.

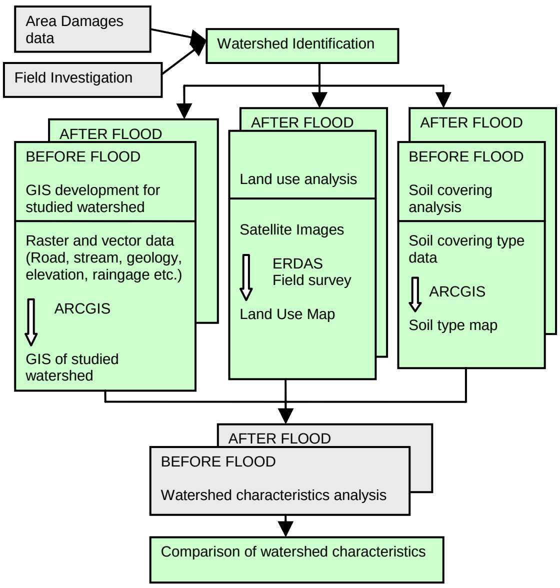

Figure 4 GIS based watershed development

The watershed characteristics were then considered by basin shape indices, channel geomorphology and physical hydrological parameters.

5. Results and Discussion

5.1. *Rainfall Analysis*

The maximum daily, 2-day, 3-day, 4-day and 5-day accumulated rainfall were analyzed for rainfall occurrences at several return periods as shown in Figure 5. Table 1 shows 2006 maximum daily and 2-5 day accumulated rainfall compared the records of 1976-2006. Determining the results of rainfall analysis and location of station, it is found that rainfall obtained from 351005 differed from the other stations, which means that 351005 is not the appropriate point to detect the rainfall for the studied basin. In 2006, which the event of flash flood with landslide occurred over the studied basin, the return periods of occurrences of 2-5 days accumulated rainfall are very large. Therefore, the further study should be done to analyze the accumulated rainfall as a significant factor of flash flood with landslide.

Table 1 Comparing 2006 rainfall with maximum and mean of records (1976-2006)

	Daily rainfall	Accumulated rainfall			
		2-day	3-day	4-day	5-day
Station 330003					
Mean	90.8	123.1	135.9	151.1	164.4
Maximum	212.0	265.7	265.7	305.9	393.8
2006 max. rainfall	118.4	201.9	208.5	231.6	235.9
Return period, yr	294	491	400	390	318
Station 330004					
Mean	91.9	122.9	145.1	160.7	172.3
Maximum	150.0	223.0	310.0	345.0	363.0
2006 max. rainfall	123.0	220.0	248.0	268.0	293.0
Return period, yr	401	1993	2347	1596	1379
Station 351004					
Mean	85.1	113.7	125.1	143.0	155.4
Maximum	161.2	201.3	201.3	230.4	230.4
2006 max. rainfall	141.8	201.3	201.3	230.4	230.4
Return period, yr	453	2324	2000	1068	1016
Station 351005					
Mean	115.5	152.2	180.0	194.7	210.5
Maximum	198.0	252.6	286.1	318.2	381.8
2006 max. rainfall	52.5	80.4	96.6	114.1	129.4
Return period, yr	12	17	15	17	17

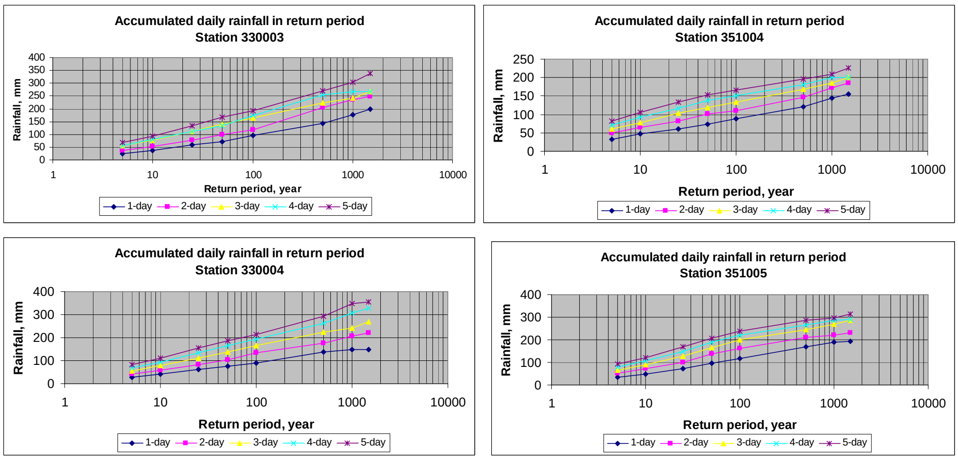

Figure 5 Return period of occurrences for daily rainfall of 4 studied stations

5.2. *Watershed Identification*

GIS based watershed was developed to analyze the different of characteristic between before and after flooding. The Soil type map of the studied basin was developed from the data obtained from Land Development Department, shown in Figure 6. Figure 7 demonstrates the stream order analysis of the study. Applying the satellite images of 2002 and 2007 with the ERDAS and ARCGIS, the land use map of before and after flooding were constructed as shown in Figure 8. Comparing between before and after flooding, the open forest of the area decrease from 44.27% to 24.62% whereas the dense forest shows slightly increase from 16.69% to 23.66%.

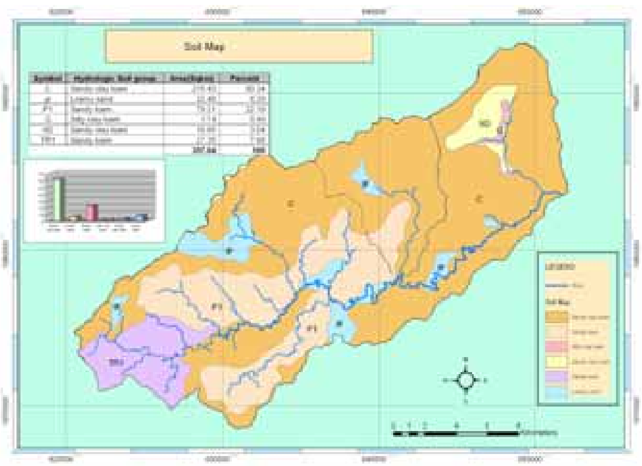

Figure 6 Soil Type map of the basin

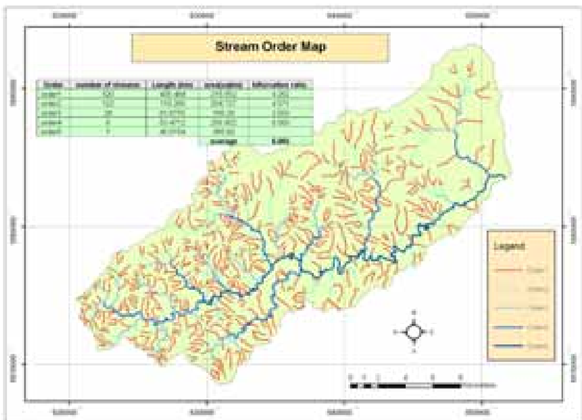

Figure 7 Stream order analysis

.Coupling these developed maps with the topography of the watershed the physical hydrological parameters were then analyzed. Table 2, Table 3 and Table 4 show the results of Basin shape indices, channel geomorphology and physical hydrological parameters, respectively. It is found that after flooding most of basin shape indices and physical hydrological parameters are changed, which means that the flooding potential of the watershed is also altered. Considering the channel geomorphology, there are changes in channel length and channel slope but the drainage density and bifurcation ratio are constant.

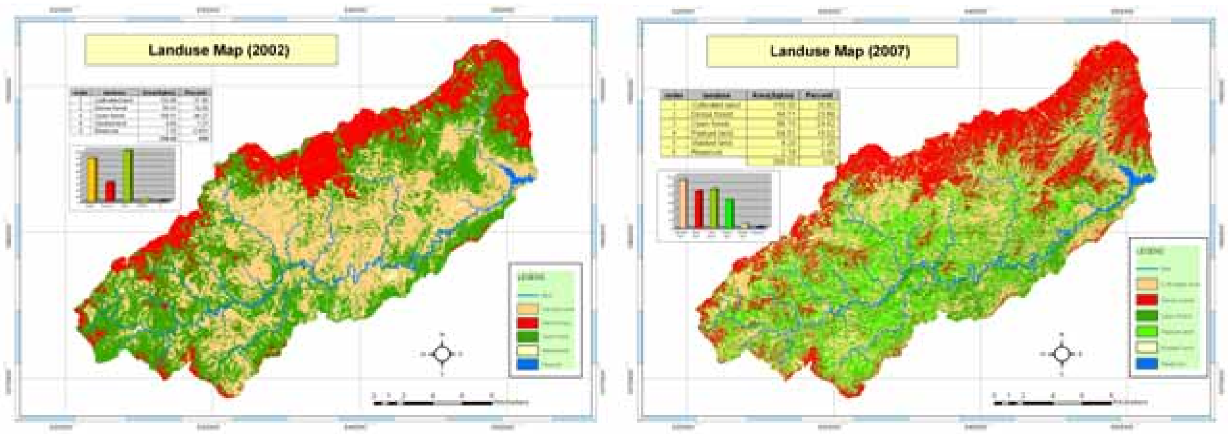

Figure 7 Landuse analysis for 2002 and 2007

Table 2 Basin shape indices

Basin shape Index	Before Flooding	After Flooding
1. Shape Factor (L_l)	6.987	6.953
2. Circularity ratio (F_c)	1.518	1.518
3. Lemniscate ratio (K)	6.889	6.666
4. Basin circularity (c)	0.434	0.434
5. Form factor *(F)*	0.114	0.118
6. Basin Elongation *(E)*	0.381	0.387

Table 3Channel geomorphology

Channel Index	Before Flooding	After Flooding
1. Channel Length, mile	33.892	33.326
2. Channel slope,%	0.678	0.689
3. Drainage Density	3.235	3.235
4. Bifurcation ratio	5.083	5.083

6. Conclusions

As the flooding potential of watershed depends on the watershed characteristics, it is necessary to analyze these watershed properties for the hydraulic structure design. In general, the watershed characteristics can be identified by basin shape indices, channel geomorphology and physical hydrological parameters. Flooding and flash flood with landslide is the important factor on changes in the topography of the area, which cause the deformation of watershed physical characteristics.

Table 4 Physical hydrological parameters

Curve Number (CN)			Time of Concentration (t_c)		
Antecedent moisture classes (AMC) Group	Before Flooding	After Flooding	Equation	Before Flooding	After Flooding
I	63	60	- US Bureau of Reclamation	10.04	9.85
II	80	78	- Kirpich	9.87	9.68
III	90	89	- Barnsby	8.13	7.97

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