การวิเคราะห์อุทกภัยและพื้นที่เสี่ยงต่อการเกิดอุทกภัยบริเวณ อำเภอเมือง จังหวัดชุมพร

นางสาว ปราณี เจริญยิ่ง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาวิทยาศาสตร์สภาวะแวดล้อม สหสาขาวิชาวิทยาศาสตร์สภาวะแวดล้อม
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2542

ISBN 974-334-727-5

FLOOD ANALYSIS AND FLOOD PRONE AREAS IN AMPHOE MUANG, CHUMPHON PROVINCE

Miss Pranee Charoenying

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Science

Inter-Department of Environmental Science
Graduate School
Chulalongkorn University

Academic Year 1999
ISBN 974-334-727-5

Thesis Title	FLOOD ANALYSIS AND FLOOD PRONE AREAS IN AMPHOE MUANG, CHUMPHON PROVINCE
By	Miss Pranee Charoenying
Program	Inter-Department of Environmental Science
Thesis Advisor	Associate Professor Chaiyudh Khantaprab, Ph.D.
Thesis Co-Advisor	Assistant Professor Thavivongse Sriburi, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

....Dean of Graduate School

(Professor Suchada Kiranandana, Ph.D.)

THESIS COMMITTEE

....Chairman

(Assistant Professor Pipat Patanaponpaiboon, Ph.D.)

....Thesis Advisor

(Associate Professor Chaiyudh Khantaprab, Ph.D.)

....Thesis Co-Advisor

(Assistant Professor Thavivongse Sriburi, Ph.D.)

....Member

(Sunya Sarapirome, Ph.D.)

ปราณี เจริญยิ่ง : การวิเคราะห์อุทกภัยและพื้นที่เสี่ยงต่อการเกิดอุทกภัยบริเวณ อำเภอเมือง จังหวัดชุมพร (FLOOD ANALYSIS AND FLOOD PRONE AREAS IN AMPHOE MUANG, CHUMPHON PROVINCE) อ. ที่ปรึกษา : รศ. ดร. ชัยยุทธ ขันทปราบ, อ. ที่ปรึกษาร่วม : ผศ. ดร. ทวีวงศ์ ศรีบุรี; 94 หน้า.
ISBN 974-334-727-5

การวิเคราะห์อุทกภัยเชิงสถิติโดยมีตัวแปรทางอุทกภัยเป็นปัจจัยที่นำมาวิเคราะห์ด้วยวิธีสมการสหสัมพันธ์ถดถอย พบว่าปัจจัยสำคัญที่ทำให้เกิดอุทกภัยในพื้นที่ลุ่มน้ำชุมพร คือ การเกิดฝนตกหนักเนื่องมาจากพายุโซนร้อน นอกจากนี้จากการศึกษา HEC-1 model พบว่า การเปลี่ยนแปลงค่าของช่วงระยะเวลาที่ฝนตกจนกระทั่งปริมาณน้ำท่าสูงสุด (lag time) และระดับน้ำท่าสูงสุด เป็นผลมาจากการเปลี่ยนแปลงการใช้ที่ดิน และการขยายตัวของเมือง การเปลี่ยนแปลงการใช้ที่ดินไม่เพียงแต่ที่จะทำให้ปริมาณน้ำท่าเพิ่มขึ้นภายหลังฝนตก นอกจากนี้ยังมีผลทำให้ช่วงระยะเวลาที่ฝนตกจนกระทั่งปริมาณน้ำท่าสูงสุดลดลง ปริมาณน้ำและระดับน้ำสูงสุดเพิ่มขึ้น

การวิเคราะห์ความถี่ของปริมาณน้ำฝนและอุทกภัย โดยการประมาณค่าพารามิเตอร์ ด้วยวิธีการโมเมนต์ของกัมเบล เพื่อหาคาบย้อนพินิจที่ 2 5 15 25 และ 100 ปี นำผลที่ได้ไปใช้ในการประเมินพื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจในเวลาต่างๆ พบว่าพื้นที่ที่เสี่ยงต่อการเกิดอุทกภัยครอบคลุมพื้นที่ตำบล หาดพันไกร บางรัก นาชะอัง วังใหม่ วังไผ่ นาทุ่ง ท่าตะเภา บ้านนา ขุนกระทิง ตากแดด บางหมาก ท่ายาง ปากน้ำ ทุ่งคา วิสัยเหนือ และ หาดทรายรี ในบริเวณอำเภอเมือง จังหวัดชุมพร พื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจ 2 ปีครอบคลุมพื้นที่ 184 ตารางกิโลเมตร พื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจ 5 ปีครอบคลุมพื้นที่ 212 ตารางกิโลเมตร พื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจ 15 ปีครอบคลุมพื้นที่ 244 ตารางกิโลเมตร พื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจ 25 ปีครอบคลุมพื้นที่ 253 ตารางกิโลเมตร และ พื้นที่เสี่ยงต่อการเกิดอุทกภัยที่คาบย้อนพินิจ 100 ปีครอบคลุมพื้นที่ 269 ตารางกิโลเมตร คิดเทียบเป็นเปอร์เซ็นต์กับพื้นที่ทั้งหมดของอำเภอเมืองมีค่าเท่ากับ 23.19 เปอร์เซ็นต์ 26.66 เปอร์เซ็นต์ 30.74 เปอร์เซ็นต์, 31.89 เปอร์เซ็นต์, และ 33.92 เปอร์เซ็นต์ ตามลำดับ ซึ่งพื้นที่เสี่ยงต่อการเกิดอุทกภัยในคาบย้อนพินิจต่างๆกัน เป็นส่วนสำคัญในการนำมาใช้เป็นข้อมูลสำหรับการวางแผนและการจัดการอุทกภัยในบริเวณอำเภอเมือง จังหวัดชุมพร

สหสาขา ....วิชาวิทยาศาสตร์สภาวะแวดล้อม..ลายมือชื่อนิสิต..
สาขาวิชา.......วิทยาศาสตร์สภาวะแวดล้อม ......ลายมือชื่ออาจารย์ที่ปรึกษา..........................
ปีการศึกษา..............2542.........................ลายมือชื่ออาจารย์ที่ปรึกษาร่วม....................

4072305423 : MAJOR IN INTER-DEPARTMENT OF ENVIRONMENTAL SCIENCE
KEY WORD : FLOOD FREQUENCY ANALYSIS / FLOOD PRONE AREAS
PRANEE CHAROENYING : FLOOD ANALYSIS AND FLOOD PRONE AREAS IN AMPHOE MUANG, CHUMPHON PROVINCE. THESIS ADVISOR : ASSOC. PROF. CHAIYUDH KHANTAPRAB, Ph.D. THESIS CO-ADVISOR : ASSIST. PROF. THAVIVONGSE SRIBURI, Ph.D. 94 pp. ISBN 974-334-727-5

The flood statistical analyses are used for delineation of several flooding factors by means of multiple regression and correlation equations. The results of flood statistical analysis in the Chumphon basin is primarily caused by heavy rainfall of tropical storm. Furthermore, the HEC-1 model, showing the variation in lag time and flood peaks, reveals various levels of land use pattern and urban development. The land use changing not only promotes the increase volume of discharge after heavy rainfall, but also shortens the lag time and increase the flood peak and river stage.

The rainfall and flood frequency analyses have been carried out using the method of moment of parameter estimation for Gumbel Probability Distribution for the designed of 2, 5, 15, 25, and 100 years return periods. The flood prone areas are estimated from various designed flood events. The results indicate that large part of the flood prone areas are in the western part of khlong Tha Taphao. The location of flood prone areas of different of return periods cover numerous Tumbons of Hat Phan Ktar, Bang luk, Na Cha-ang, Wang Mai, Wang Phai, Na Thung, Tha Taphao, Ban Na, Khun Krathlng, Tak Daet, Bang Mak, Tha Yang, Pak Num, Thung Kha, Visai Nua, and Hat Sai Ree in Amphoe Muang. The flood prone areas of 2 years return period is about 184 square killometres, 5 years return period is about 212 square killometres, 15 years return period is about 244 square killometres, 25 years return period is about 253 square killometres, and 100 years return period is about 269 square killometres. The flood prone areas of 2, 5, 15, 25, and 100 years return periods cover 23.19%, 26.66%, 30.74%, 31.89%, and 33.92% of the total area of Apmhoe Muang, respectively.

The flood prone areas of different return periods are critically important for the planning and management of the flood disaster in Amphoe Muang, Chumphon province.

สหสาขา......วิชาวิทยาศาสตร์สภาวะแวดล้อม...ลายมือชื่อนิสิต..
สาขาวิชา......วิทยาศาสตร์สภาวะแวดล้อม......ลายมือชื่ออาจารย์ที่ปรึกษา..........................
ปีการศึกษา..............2542........................ลายมือชื่ออาจารย์ที่ปรึกษาร่วม......................

ACKNOWLEDGEMENTS

This thesis certainly would not have been accomplished without the encouragement and support of many people. First at all, the author would like to take this opportunity to acknowledge her advisor, Associate Professor Chaiyudh Khantaprab, Ph.D., and her co-advisor, Assistant Professor Thavivongse Sriburi, Ph.D. for the dedicated guidance, encouragement, suggestions and friendly discussions. Thank is extended to Assistant Professor Pipat Patanaponpaiboon, Ph.D. the Director of Inter-Department of Environmental Science for his kind assistance and as the chairman of thesis committee. Grateful acknowledgement is extended to Dr. Sunya Sarapirome for his valuable suggestions as a member of thesis committee. The author would like to express her appreciation to the following government agencies, namely, the Pollution Control Department, the Department of Land Development, the Thailand Remote Sensing Center of the Office of the National Research Council of Thailand, the Meteorological Department and the Royal Irrigation Department for their supporting data and information. Special thanks are extended to the Geology Department, Faculty of Science, Chulalongkorn University for the support of GIS software.

Thanks are also extended to the Shell Centenary Scholarship Fund and the Graduate School for the financial support and encouragement.

Finally, the author wishes to dedicate this thesis to the author's parents and aunt, who are always providing inspiration, support and encouragement throughout the course of study.

CONTENTS

Page

CONTENTS (continue)

LIST OF TABLES

Table Page

LIST OF TABLES (continue)

Table Page

LIST OF FIGURES

Figure Page

LIST OF FIGURES (continue)

Figure Page

CHAPTER I

INTRODUCTION

The main cause of a flood disaster in tropical area is the heavy rainfall during the monsoon season. However, there are other factors that increase the severity of flood such as the low relief of the flood plain area, deforestation of the watershed area, poor drainage, and land use change. Rapid development of urbanization as a result of increasing population, migration and human settlement leads to the reduction of natural retention storage, filling up of canal and overpumping of groundwater hence, reduces the drainage efficiency. Thus, flooding problems have the tendency to be prolonged and deteriorated.

Flood damage has been generally increasing each year and can be categorized as direct and indirect. Direct damages are those caused by the physical contact with floodwaters , whilst indirect damages are those consequent to direct losses. The damages result in loss of lives, property and production as well as affecting activities involved in the flooded area . Large and long duration of flooding can be considered as the economic loss. Flood affects directly to the people in terms of health impairment , risk of life and mental depression.

1.1 Statement of the problem.

The Chumphon basin had been among one of the most serious flooded areas in the southern part of Thailand. In this area, flooding occurs every year causing a lot of damage to the social and economic development. In 1989, the so-called "Gay" typhoon passed through Amphoe Muang in Chumphon province situated at the downstream of Chumphon basin was severely flooded. During this period the runoff and the flood volume reached the peak and the flood was longest. However, in 1997 the flood caused by "Zita" typhoon was somehow brought higher volume than that in 1989. The flood level went up to as high as 4-5 metres above the mean sea level (MSL) for more than 6 days. Constructions, agricultural and poultry-farm land were seriously damaged and some people were killed. The cost of damages were more than five thousand millions baht.

1.2 The study area.

The study area lies in the vicinity of Amphoe Muang, Chumphon province between the lattitude 10-15-00 N. to 11-20-00 N., and longitude 98-45-00 E. to 99-30-00 E., covering an area of approximately 794 square kilometres. The main rivers passing through the study area are khlong Tha Taphao and khlong Chumphon which eventually discharge directly to the Gulf of Thailand. (Figure1.1)

1.3 Objectives.

The objectives of this study are :

(1) To understand the geographic setting of the area used to be flooded in the past,

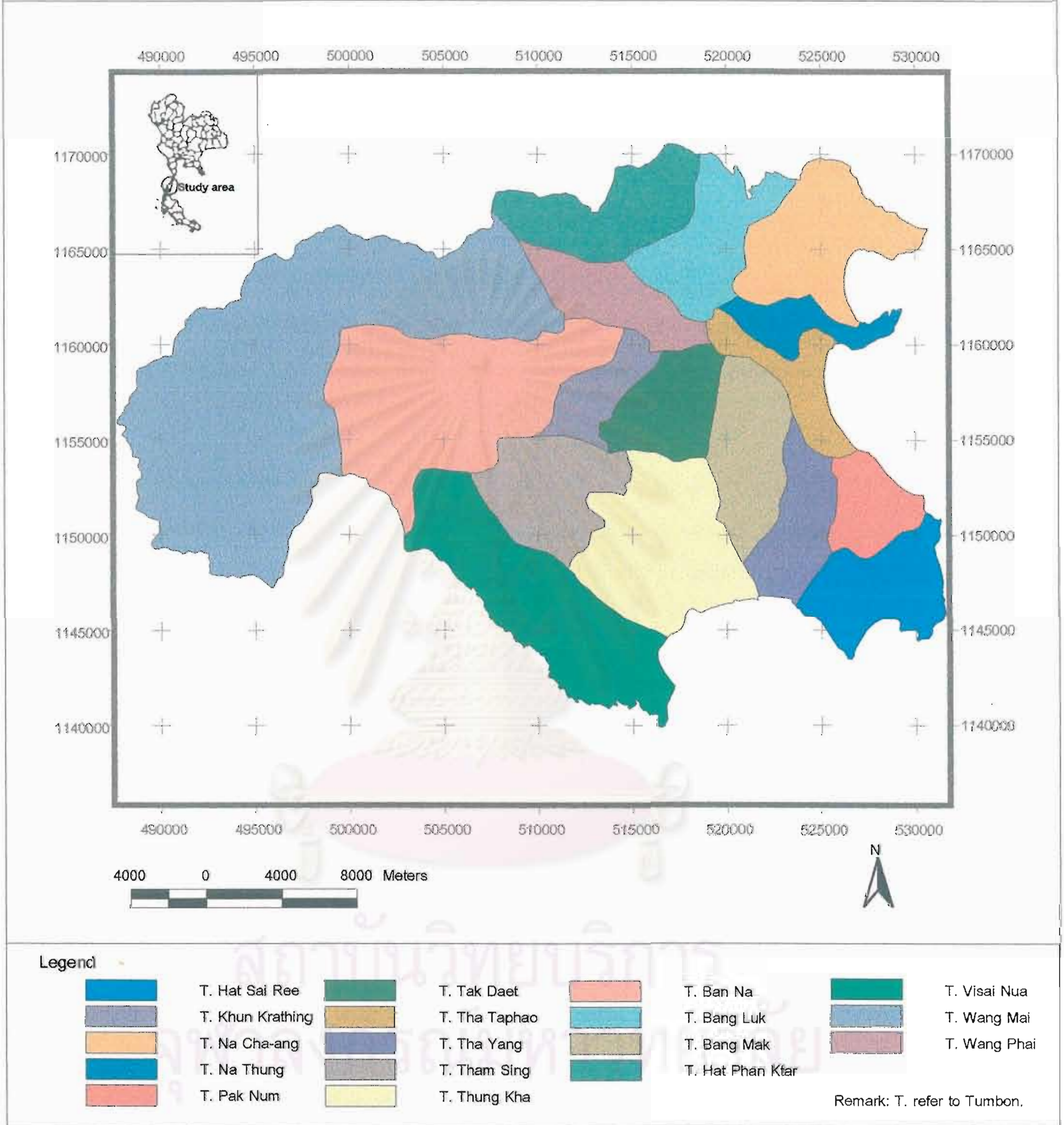
(2) To analyze the causes of flooding, evaluating the damages from flood, and

(3) To identify the flood prone area in Amphoe Muang , Chumphon province.

1.4 Scope of work.

The data and information regarding the topography, landform, existing landuse pattern, population as well as the general socio-economic condition of the study area will be primarily assessed in order to serve as the background of the present study. Besides, the historical records of flood and flood damages are acquired as much as possible. After that, the flood analysis will be conducted using the hydro-meteorological, namely , rainfall, water stage and discharge data available. The velocity of runoff, which has the implications on the lag time and discharge, is not included in this analysis so that the final flood risk assessment is accordingly identified and presented as flood prone map.

Map showing boundary of Amphoe Muang and the location of Tumbons in Amphoe Muang, Chumphon province.



Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.

Inter-Department of Environmental Science, Master of Science in Environmental Science.

Graduate School, Chulalongkorn University.

Figure 1.1 The boundary of Amphoe Muang and the location of Tumbons in Amphoe Muang, Chumphon province.

1.5 Previous works.

Chatrchareonmitr (1977) simulated the in main channel and floodplain flow of the Chao Phraya river. Method of node and branch was used for main channel flow computation while the level model developed earlier by Tingsanchali (1975) was used for the flood plain. Both models were linked together through weir equation of over bank spillage. The combination of explicit and implicit scheme was used in the numerical solution which had improved the numerical stability.

Hosking *et al.* (1984) concluded that the General Extreme Value (GEV) distribution with Probability Weighted Moment (PWM) method of parameters estimation yielded significantly better results in flood frequency analysis. He recommended the PWM method because of its fast and straight forward computations.

Arora and Singh (1986) have estimated the Extreme Value type 1 (Gumbel) probability distribution by methods of moments, maximum likelihood, probability weighted moment, mixed moments, least squares and incomplete means of Montecarlo samples. They concluded that probability weighted moment (PWM) method without doubt is the superior method resulting in less bias, least standard deviation and higher efficiency estimates.

Chubpisan and Srivittina (1986) suggested that the landuse are changed by human activities. Different pattern of landuse has different of runoff coefficients, such as, business zone is higher than those of the industrail zone and residential zone . Urbanization is increased by human activities but at the same moment the infiltration is reduced, and the impervious area is increased .

Veerapun (1986) and Savedpravitkun (1995) concluded that the main cause of flood in Nakornsitummarat province and Phedburi downstream basin areas are resulted from the depression that heavy rainfall increased runoff and breached occur in flood embankment in the river.

Luveera *et al.* (1987) suggested that the protection of flood and solution to the flood problem can be conducted through the flood analysis using collected data such as hydrology data, meteorology data, topography, geography, surrouding environment of stream and landuse planning.

ESCAP (1988) prepared the Manual and Guidelines for Flood Risk Analysis and Mapping aiming at officers of the Typhoon Committee Members, who were in charge of flood loss prevention, understood the techniques on flood risk analysis and mapping. The Manual and Guidelines describes the related techniques of three approaches of the flood risk analysis, namely, geomorphological approach, past flood approach and hydrological and hydraulic approach, in detail together with their advantages and limitations. The Manual and Guidelines also included the application results in the Upper Klang river basin in Malaysia and the Easthern Suburban Bangkok in Thailand, both of which were selected demonstration pilot areas. Furthermore, an actual example of flood risk map in Japan was included.

Nkemdirim and Kendrick (1996) suggested that the Hydrologic Engineering Center (HEC-1) model can be used to construct synthetic hydrographs for isolated interior urban floods. Flood peak and lag time were very well preserved in simulated flows. Total volume was not adequately expressed. Lag time varied inversely with both urban development and storm intensity. Peak discharge varied with storm intensity, but this variability was well defined only at very high urbanization levels. An 175 % increase in storm intensity produced a change of about 15% in peak discharge. Claims for flood damage correlated well with estimated of peak flow and lag time combined. Other measures of flood experience also correlated with the two features. Within the range of storms utilized, urban development factors consistently outranked storm intensity as a determining factor in flood damage.

Office of the Environmental Policy and Planing (1996) have estimated the flood risk map of eastern , western , and central part of Thailand using the GIS. Parameter estimation are the topography, geography, hydrology, meteorology, and landuse. The results lead to the determination and classification of two types of flood area. They are flash flood area in Chantaburi basin in eastern part, and all basins in western part. The other is "land-locked" flood area in Prachinburi basin and Bangprakong basin.

Office of the Environmental Policy and Planing and Forest Department (1996) have studied the flood prone area in Northeast basin of Northeastern part of Thailand using the GIS. The results lead to the determination and classification of flood area. They are two types of flooded area. One type is slow runoff in the flood plain and "land-locked" flood area. Flood hazard degree is categorized into four levels consisting of no hazard flooding, low hazard flooding, moderate hazard flooding, and high hazard flooding.

Tungtum and Yuvananon (1996) studied the impact of landuse change , volume and characteristics of runoff flowing in Pasak basin. Parameter estimation can be done by runoff data , rainfall data and forest areas in 1982-1990 . Data has been analysed by multiple linear regession equation. They found that correlation between runoff and rainfall were linear. It is noted that the forest areas were changed by human activities and the runoff in the wet season of upstream area has increased but the overall ronoff in this basin has not changed. This finding is significant and the management of the basin is accordingly required.

Kanchanaharn (1997) studied the application of flood plain mapping and risk assessment by the intergration of fused multisensor remote sensing derived information within a GIS. Landsat TM and ERSSAR data could be used to extract open water flooded over a three-year periods of October 1993, 1995 and 1996 for flood area and landuse classification. The study area is located in the central part of Thailand, mainly focused on Chao Phraya and Tha Chin basin. It includes most parts of Nonthaburi, Samut Prakarn, Samut Sakorn, west part of Bangkok, east part of Nakhon Prathum, and south part of Phathum Thani. She found that two types of flooded area could be identified. They are : (1) Flood occurring from water discharge combining with local rainfall and high tide as obviously seen in the northern part of the study area (Nakhonprathom , Pathumthani and Nonthaburi) In this case, the high risk area occopied 10.91 % of overall area . (2) flood occurring from the high tide (almost without affect from local rainfall or water discharge from the north of Thailand) which was obviously found in the southern part of the study area. It was found that high risk area occupied 17.62% of overall area.

Kawinpoomstan (1997) studied the flood risk mapping of the Yom river basin in Phrae and Sukhothai areas, Thailand. The objective of this study is to develop the flood risk map using the hydrological and hydraulic approach in estimating the changes in the flood plain inundution for different return period floods. It was found that at Amphoe Muang, Phrae the duration of flooding varies from 17 days (10-yr design flood) to 40 day (100-yr design flood) and the maximum depth is 0.80-2.13 m. above the average bank elevation. Amphoe Muang ,Sukhothai the duration of flooding varies from 31 day (2-yr design flood) to 87 day (100-yr design flood) and the maximum depth is 0.70-0.96 m. above the average bank elevation.

Thongsuk (1997) concluded that areas of Pha Nakhon Si Ayutthaya province are lowland with an average elevation of 3-6 meters above the mean sea level and that the areas which are frequently flooded are along the river bank. Factors related to floods using flood occurrence as dependent high runoff and population. It is found that a return period of 5,20 and 100 years showed that 34.75 , 38.72 , 20.71 and 5.82 percent of the province area were classified as high, moderate, low and no risk areas, respcetively. Flood areas include the Sena municipal area, Amphoe Maha Rat, Amphoe Ban Phraek, Tha Rua municipal area, Tha luang municipal area, areas surrounding the urban island and areas along major rivers.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

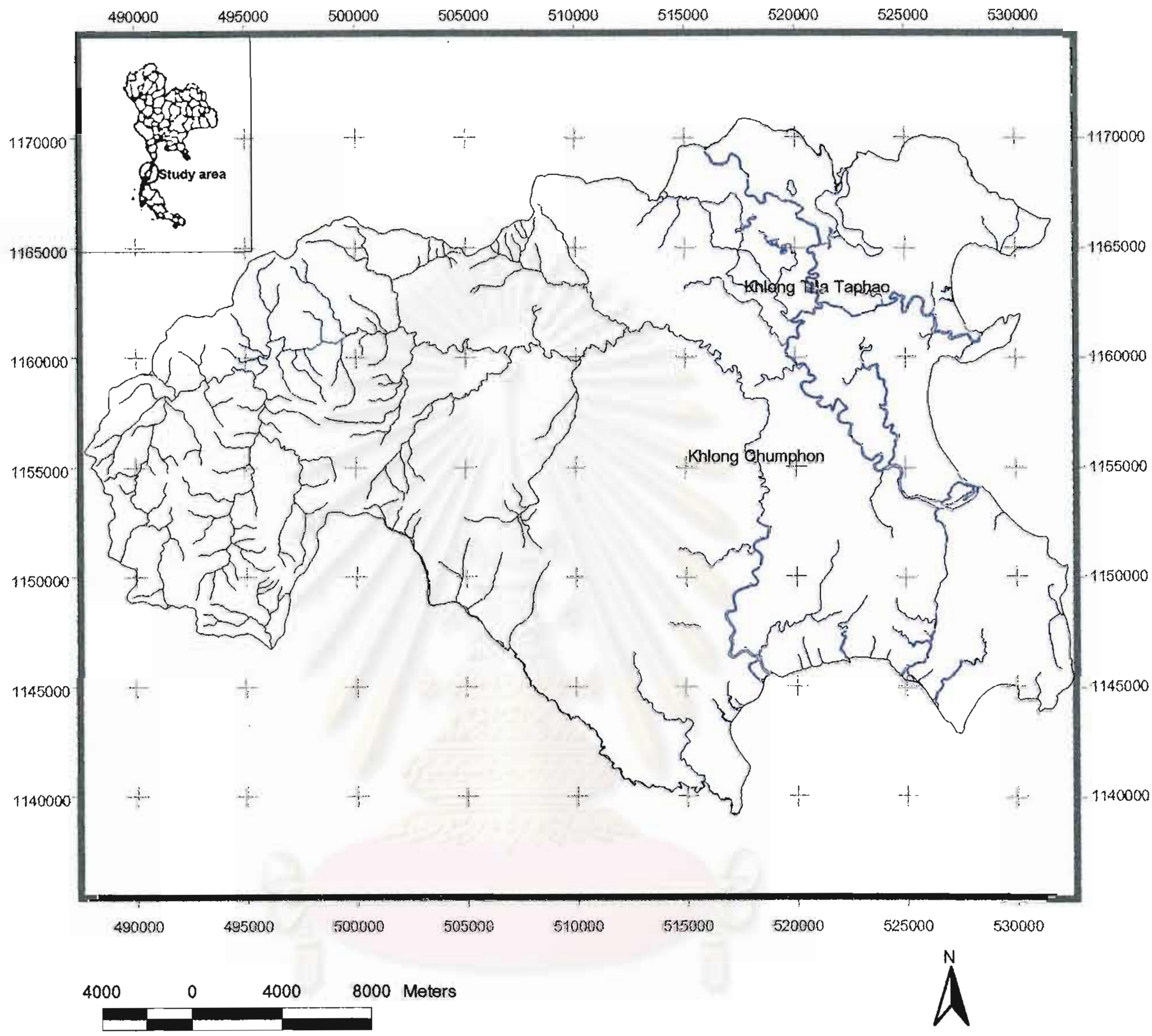
2.1 Geographical setting.

2.1.1 Location and topography.

The study area is located in the southern part of Thailand, mainly confined to the area of the Chumphon basin in Chumphon province. The total area is approximately 794 square kilometres, lies between latitude 10-15-00 N – 11-20-00 N and longitude 98-45-00 E – 99-30-00 E. Figure 2.1 shows location of the study area. Khlong Tha Taphao and khlong Chumphon are the main rivers in this area. Khlong Tha Taphao is combined by tributaries of khlong Rap Ro and khlong Tha Sae. It passes Amphoe Muang, Chumphon province and discharges directly into the Gulf of Thailand. It is about 39 kilometres long and a watershed area occupies about 2,227 square kilometres.

Khlong Chumphon is a relatively small river, located in the southwestern of Chumphon province. The river originates from mountain in the southwest near Ranong province. It flows from west to east and discharges into the Gulf of Thailand at Ban Banghai. The total length of about 61 kilometres and the cacthment area is about 449 square kilometres. The area of the Chumphon basin covers 3 Amphoes of Chumphon province, namely, Amphoe Pathui, Amphoe Tha Sae, and Amphoe Muang, consisting of Rap Ro, Tha Sae, Tha Taphao, and khlong Chumphon watersheds. Figure 2.2 shows location of the Chumphon basin in this area. Chumphon province is topographically high mountainous area in the west, namely, Thanowsri range with the elevation of about 200-600 metres (MSL). The central part of the east Chumphon province is low land of undulating terrain and flood plain with elevation of 100-200 metres (MSL). It is an important agricultural area. The urban and suburban areas are mainly in the flood plain and are bisected by a dense network of khlongs. In the far east is the coastal zone with wide beaches of gentle slope.

Map showing the boundary of Amphoe Muang and stream network.



Legend

Stream network

Boundary of Amphoe Muang

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter- Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 2.1 The boundary of Amphoe Muang and stream network.

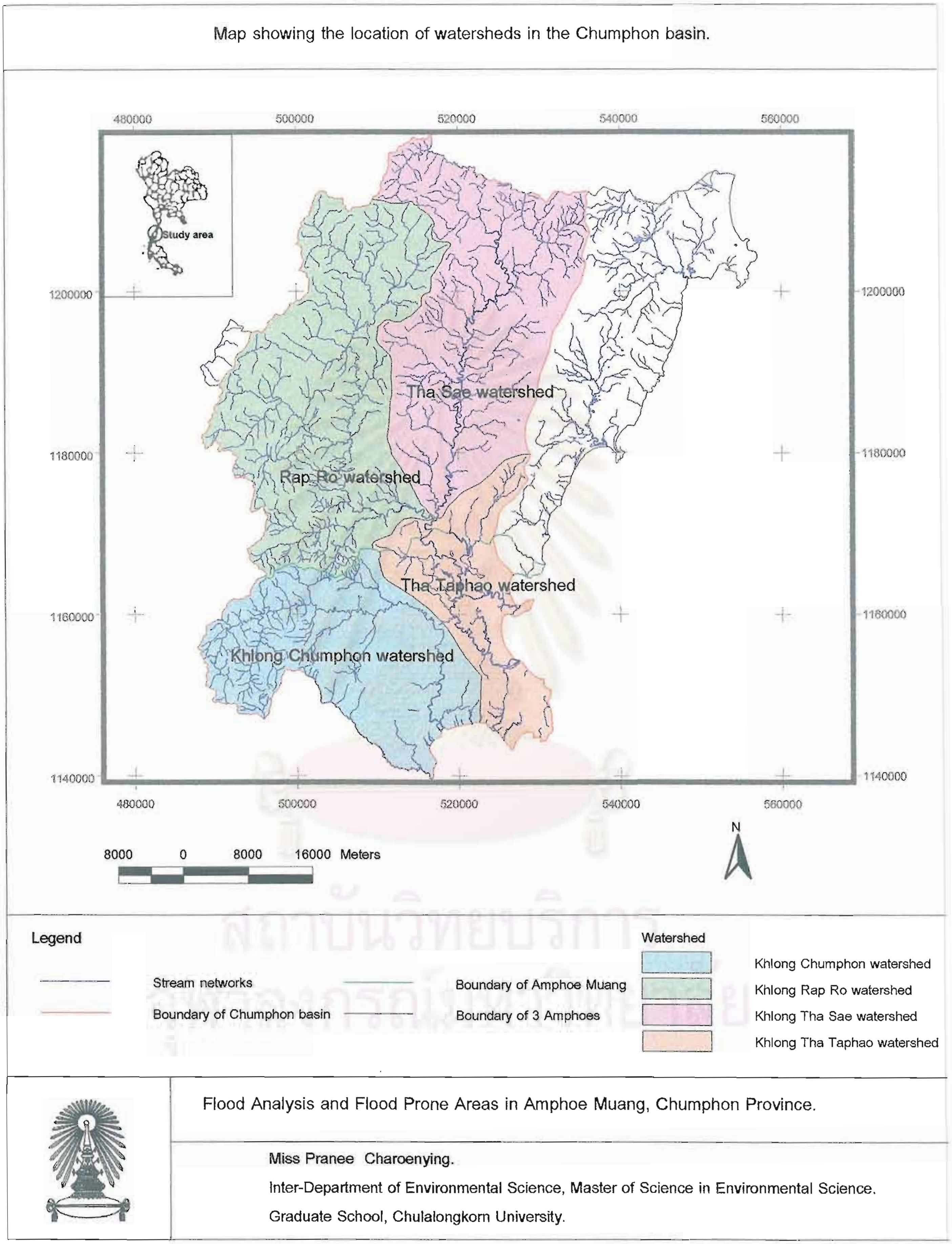


Figure 2.2 The location of watersheds in the Chumphon basin.

2.1.2 Land use and land cover.

The study of land use and land cover in the Chumphon basin, covering 3 Amphoes consist of Amphoe Muang, Amphoe Tha Sae, and Amphoe Pathui are identified into 9 classes using the interpretation of Landsat-5 (TM) in the scale 1:50,000 of 1988, 1993, and 1998. The available bands from Landsat-5 (TM) are band 2, band 3, and band 4. The present land use and land cover pattern of the study area is for agriculture purposes, such as, paddy field, tree crops land, field crops land, orchard, shrimp farm, deteriorated and forest land. Land use and land cover changing from 1988-1998 shown decreasing of forest land, orchard land, paddy land, field crops land, and mangrove forest land and increasing of deteriorated forest land, tree crops, shrimp farm, and residential land and others. However, the implication of the expanding social and economic development has resulted in the conversion of primary agricultural lands and forest areas into industrial and urban residential uses, namely, housing, road networks, and factories, etc. The result leads to the reduction of natural retention storage, infiltration and increasing of impervious areas. Thus, trend of flood problems in this area has been increasing. Land use and land cover maps show in Figure 2.3 – 2.5 and in Table 2.1 shows land use and land cover in 3 Amphoes, Chumphon province and Table 2.2 shows land use and land cover in Amphoe Muang, Chumphon province.

Table 2.1 Land use and land cover of 3 Amphoes, Chumphon province of 1988, 1993, and 1998.

Classification of land use and land cover	Land use and land cover in 3 Amphoe, Chumphon province.					
	1988		1993		1998	
	Areas (km^2)	Percentage	Areas (km^2)	Percentage	Areas (km^2)	Percentage
1. Forest land	865.36	28.55	728.35	24.03	697.54	23.01
2. Deteriorated forest land	190.74	6.29	308.36	10.17	318.74	10.52
3. Orchard	1206.02	39.79	584.56	19.29	997.13	32.90
4. Paddy field	145.01	4.78	74.51	2.46	28.45	0.94
5. Tree crops land	292.95	9.67	134.15	4.43	676.52	22.32
6. Field crops land	228.99	7.55	1051.16	34.68	136.94	4.52
7. Mangrove forest land	39.98	1.32	37.91	1.25	21.95	0.72
8. Shrimp farm	33.88	1.12	68.14	2.25	52.82	1.74
9. Residential land and others	28.11	0.93	43.81	1.45	101.08	3.33

Source: Satellite Image of Landsat-5 (TM) in 1988, 1993, and 1998 from the Thailand Remote Sensing Center, the Office of the National Research Council of Thailand.

Table 2.2 Land use and land cover of Amphoe Muang, Chumphon province of 1988, 1993, and 1998.

Classification of land use and land cover	Land use and land cover in Amphoe Muang					
	1988		1993		1998	
	Areas (km^2)	Percentage	Areas (km^2)	Percentage	Areas (km^2)	Percentage
1. Forest land	246.27	30.99	218.00	27.43	251.09	31.60
2. Orchard	324.90	40.89	124.63	15.68	354.50	44.61
3. Paddy field	30.39	3.82	18.96	2.39	24.58	3.09
4. Tree crops land	2.56	0.32	4.60	0.58	4.85	0.61
5. Field crops land	134.95	16.98	309.46	38.94	8.86	1.11
6. Mangrove forest land	21.71	2.73	37.91	4.77	18.29	2.30
7. Shrimp farm	33.88	4.26	59.39	7.47	52.82	6.65
8. Residential land and others	-	-	21.72	2.73	79.68	10.03

Source: Satellite Image of Landsat-5 (TM) in 1988, 1993, and 1998 from the Thailand Remote Sensing Center, the Office of the National Research Council of Thailand.

2.1.3 Climate.

The study area has a tropical climate. Northeast monsoon occurs during the period from October to February, bringing rain to the southern part of Thailand, including the study area, whereas, during May to October of each year, humid Southwest monsoon from the Indian Ocean will again passes this area. Pressure depressions occur in the South China sea, causing a lot of rain to be swept over to the study area, during November to December of each year (Figure 2.6). Furthermore, Bengol cyclone often occurs from Bengol Bay, during May. As a result, two seasons are distinguishable: The hot and rainy season from Northeast monsoon extends during February to April and southwest monsoon extends during May to October. Thus, the area has rainfall throughout the whole year and the temperature does not fluctuate drastically.

The climatic condition of Chumphon province in 30 years period showed in Table 2.3 and Figure 2.7.

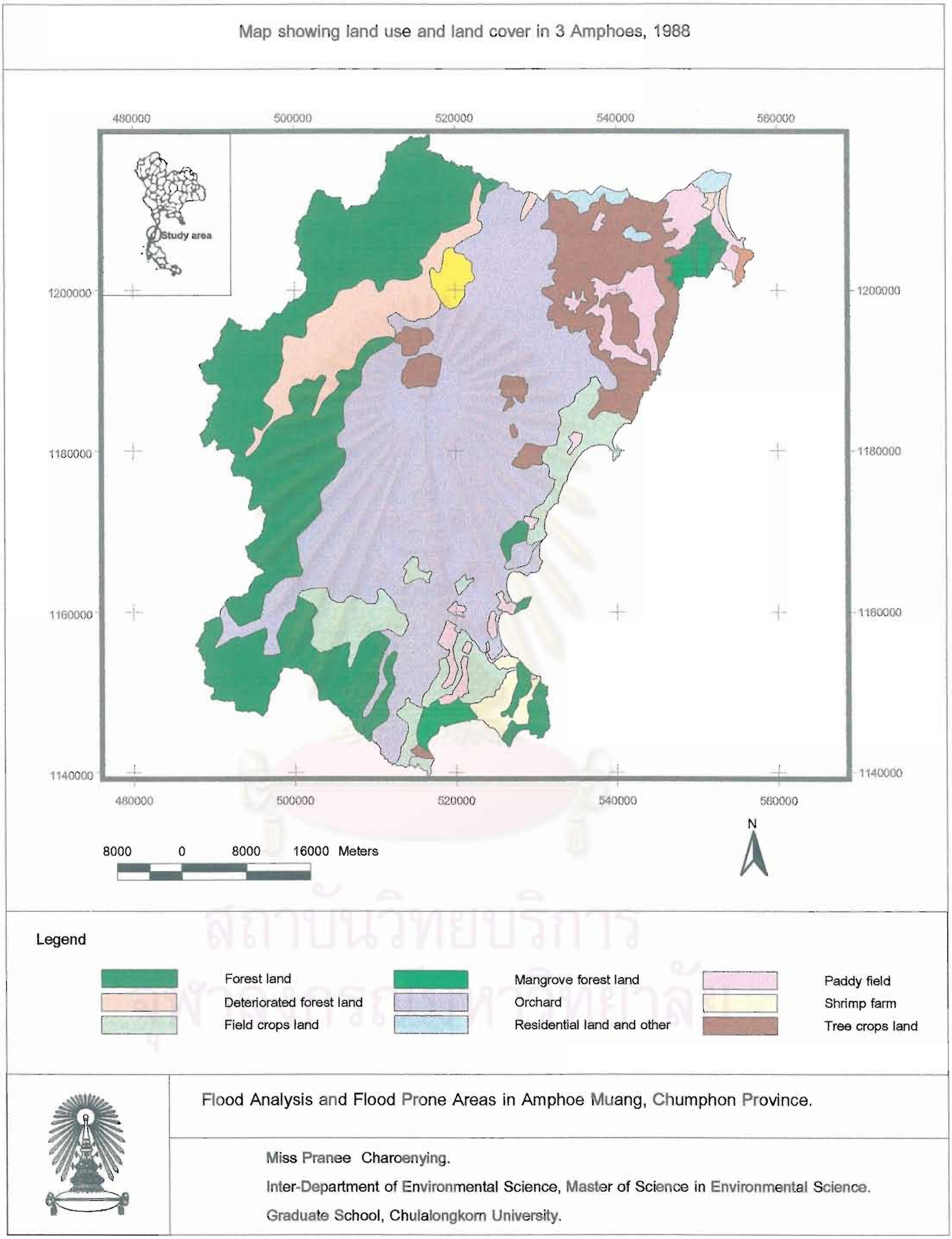
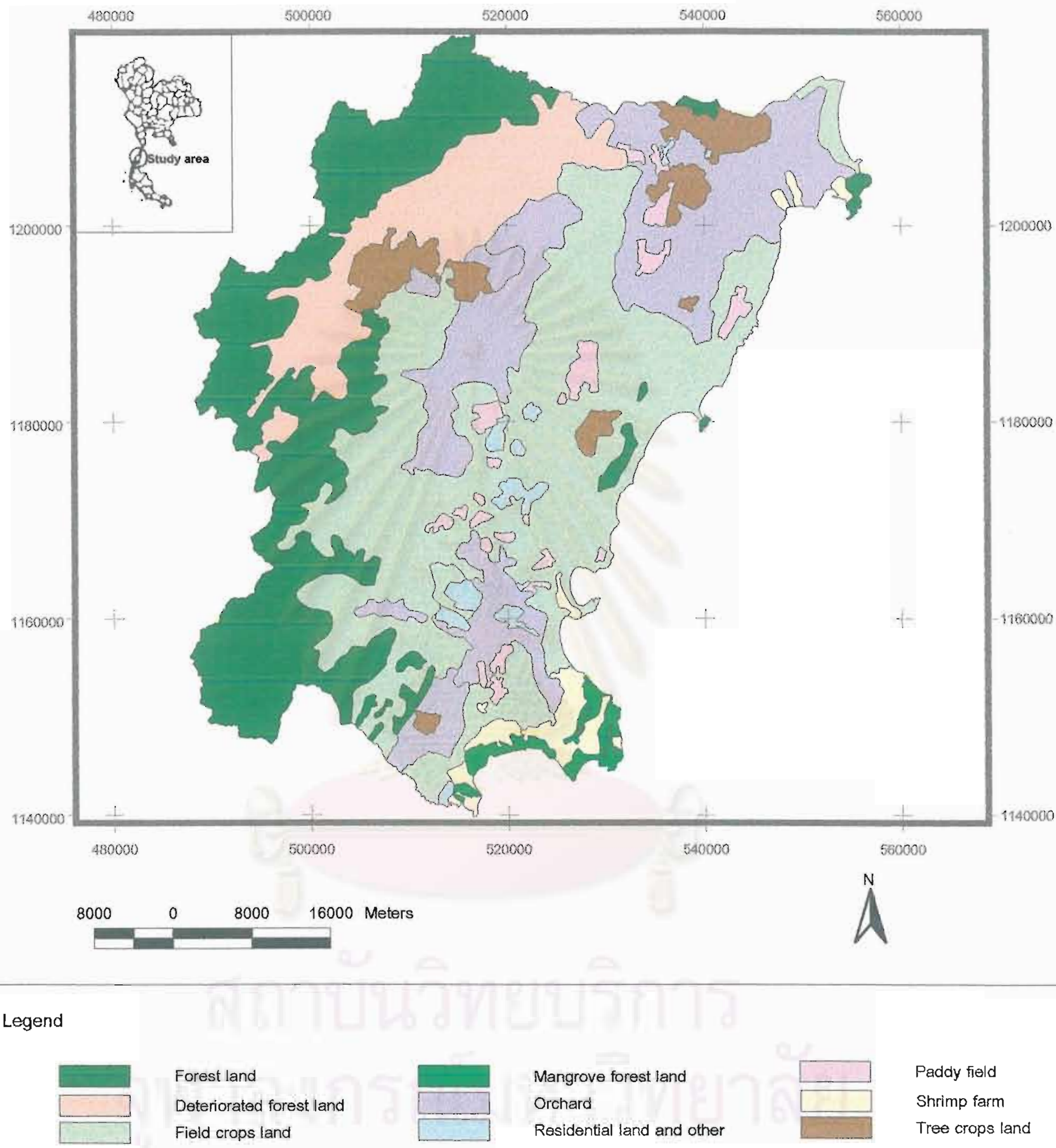


Figure 2.3 Land use and land cover in 3 Amphoes of the Chumphon basin, 1988

Map showing land use and land cover in 3 Amphoes, 1993



Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province

Miss Pranee Chareonying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 2.4 Land use and land cover in 3 Amphoes of the Chumphon basin, 1993.

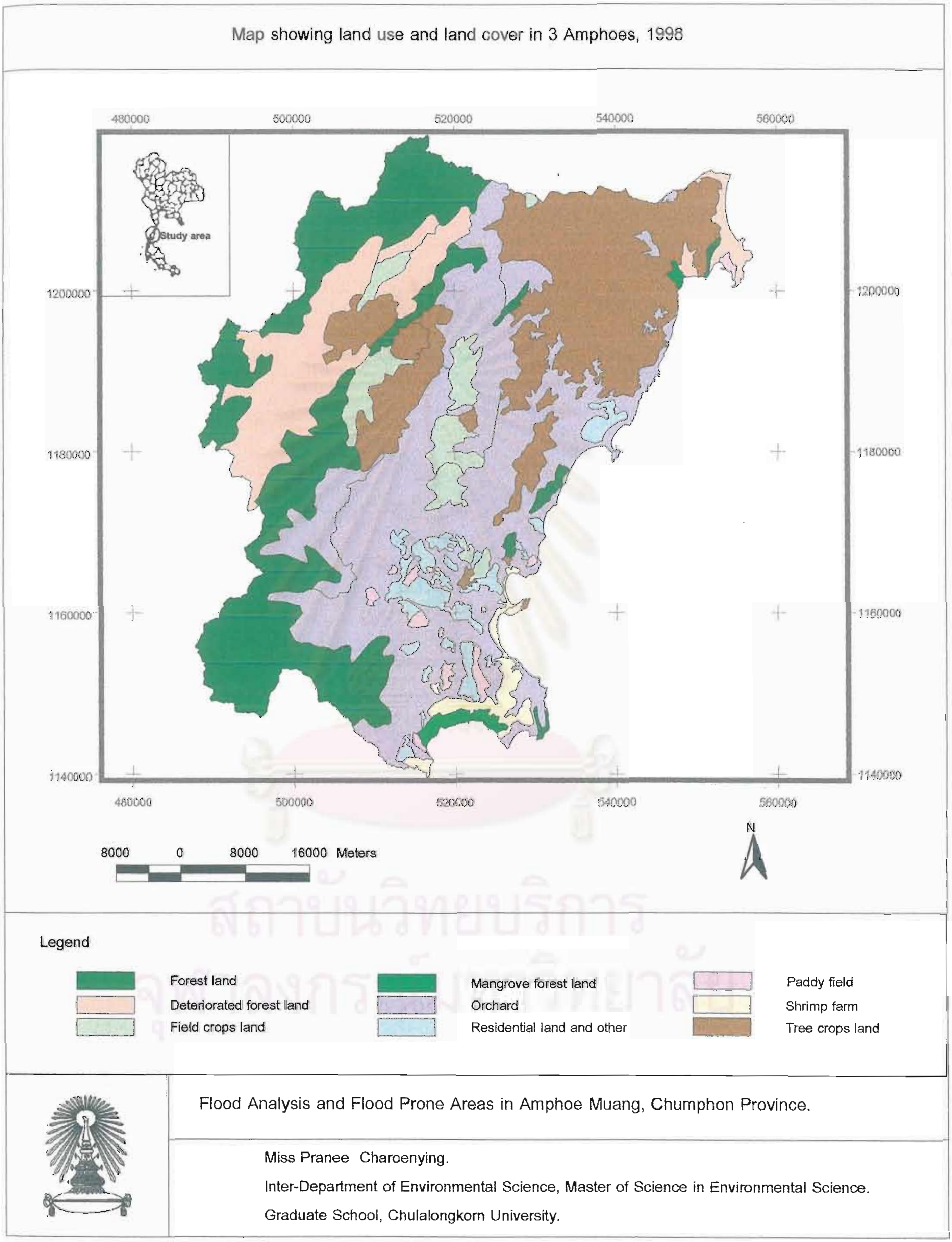


Figure 2.5 Land use and land cover in 3 Amphoes of the Chumphon basin, 1998.

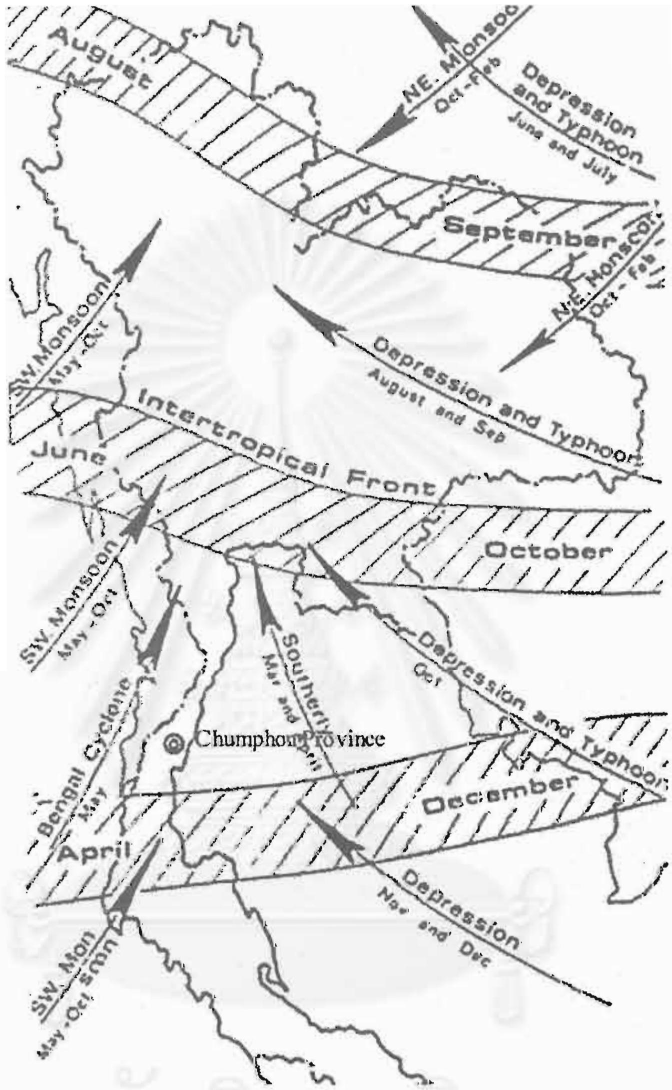


Figure 2.6 Type of storms pass through Chumphon province in each year.

Table 2.3 Average monthly climatic conditions of Chumphon province during 1968-1997.

Month	Av. rainfall (mm.)	Av. rain-day (day)	Av. temperature (^{o}C)	Relative humidity (%)	Evaporation (mm.)
Jan.	82.5	7.0	25.3	81	114.6
Feb.	55.5	5.2	26.4	79	115.7
Mar.	59.7	5.2	27.5	78	146.4
Apr.	84.1	7.5	28.5	77	148.6
May	173.0	16.8	28.0	81	129.6
Jun.	171.7	20.2	27.4	82	109.5
Jul.	178.3	21.0	27.0	82	111.0
Aug.	227.0	22.0	26.9	83	106.8
Sep.	159.9	19.5	26.8	84	108.0
Oct.	241.2	19.2	26.6	85	101.9
Nov.	354.3	14.5	25.9	85	93.3
Dec.	91.1	7.7	25.1	81	102.4

Source: Meteorological Department.

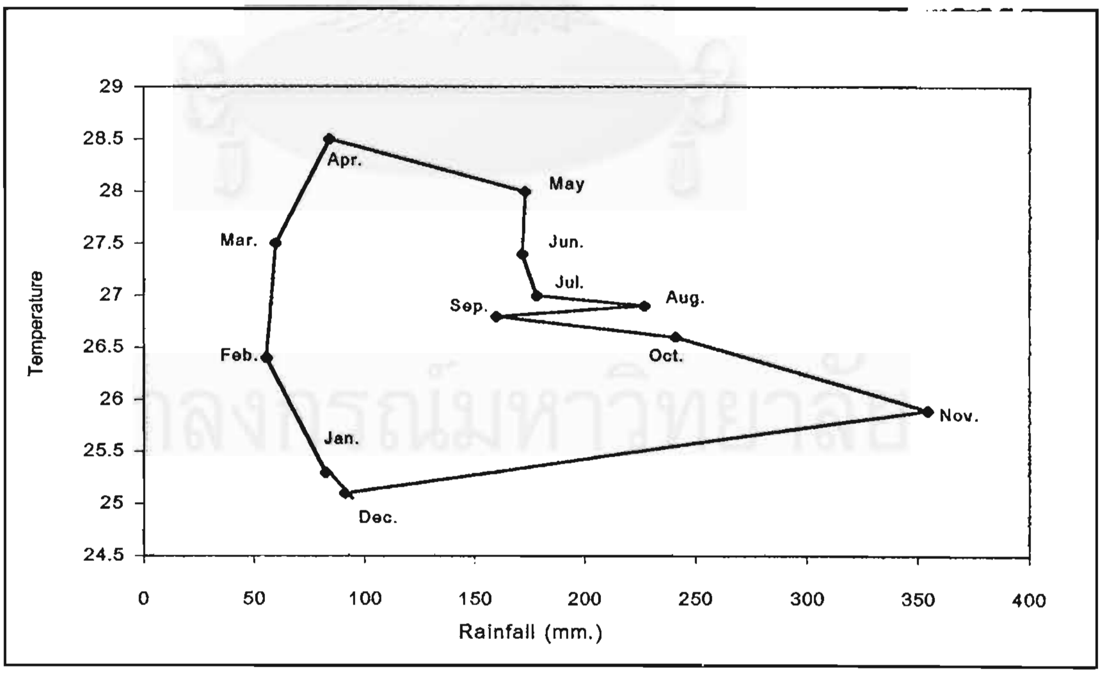


Figure 2.7 Hythergraph of Chumphon province over the 30 years period.

2.1.4 Hydrology.

There are totally 7 gauging stations available inside the Chumphon basin, namely, x.64, x.46, x46A, x.158, x.180, x.53 and x.53A. The source of data are operated by The Royal Irrigation Department.

The water discharge data collected at x.64 and x.158. in June,1993 revealed that the water discharge of khlong Tha Sae was about 6.935-23.475 m^3/sec. and the velocity was 0.453-1.009 m/sec. The water discharge and water stage collected in 1997 revealed that the maximum water stage and discharge in this area were highest in 24th August 1997 (Table 2.4). The water discharge and capacity of khlong Tha Taphao at A. Muang (x.158) were 2,000 m^3/sec. and 300 m^3/sec. The average runoff of khlong Tha Taphao at x.64 was about 256.5 - 510.5 million cubicmetres per annum, x.158 was 1280.31 million cubicmetres per annum, and the average runoff of khlong Chumphon at x.53 was 298.68 million cubicmetres per annum (Table 2.5).

Table 2.4 The maximum water discharge and water stage of Chumphon basin, 1997

Station name	Max. water stage (m. in MSL)	Max. water discharge (m^3/sec.)
x.64	9.83	485.65
x.46	9.67	2034.00
x.158	9.40	1242.20
x.53A	8.46	505.00
x.180	5.88	740.00

Source: Irrigation Project, Chumphon province, 1997

Table 2.5 The mean annual runoff, watershed area of the gauging stations in Chumphon basin.

Station name	Watershed area	Mean annual runoff (× 1,000,000 m^3)	Mean annual runoff (liters/sec./ km^2)	Period of measurement
x.46A	617	496.45	25.51	1977-present.
x.46	751	720.31	27.88	1971-present.
x.64	957	510.49	16.92	1973-present.
x.158	1,819	1280.31	22.32	1984-present.
x.53	223	298.68	42.47	1971-present.

Source: Team Consultant Engeneering Co.Ltd., 1995.

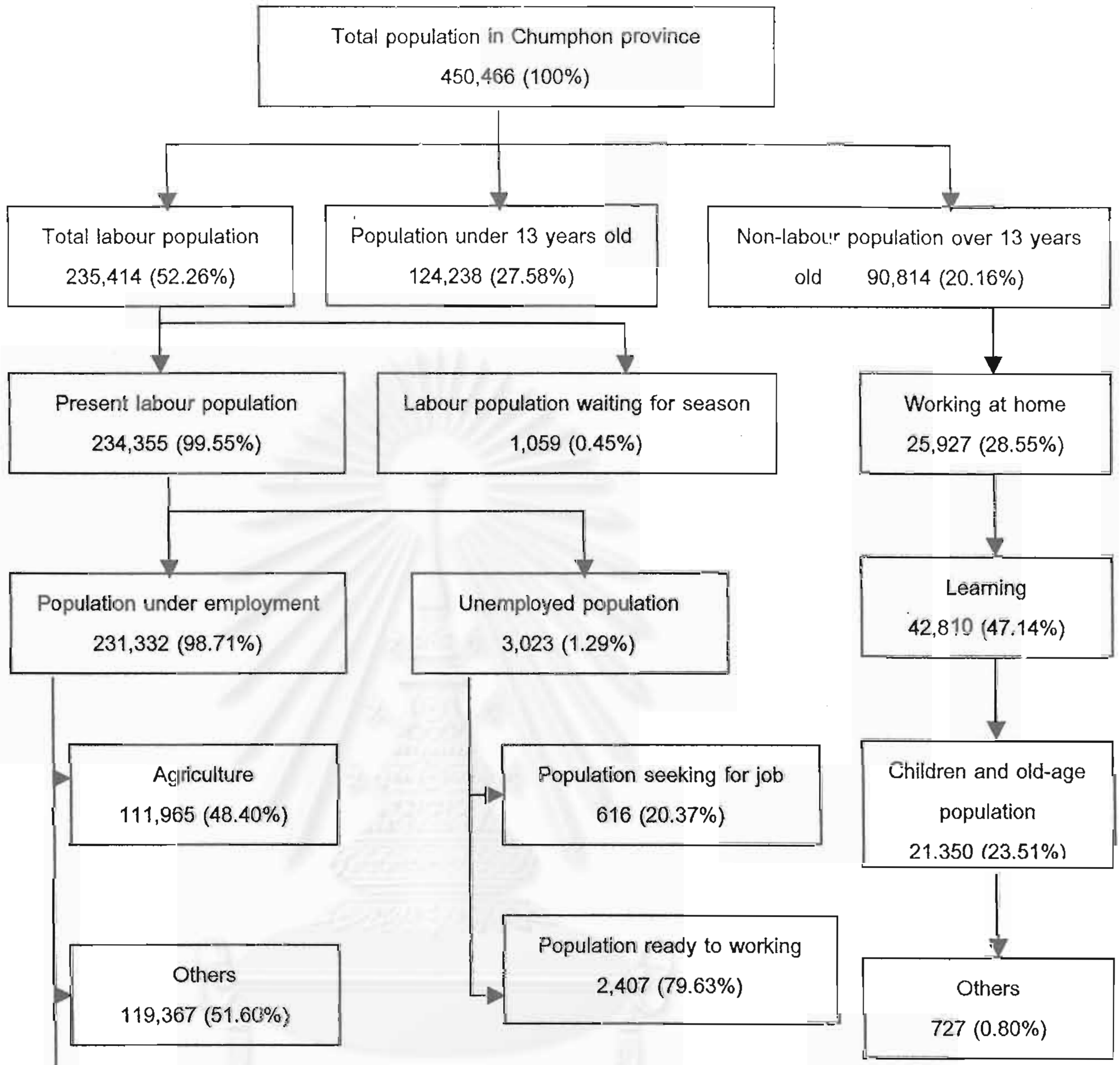
2.2 Social conditions.

Population structure of Chumphon province has higher birth rate about 15.8 %. Ratio of working population of Chumphon province and total population of the western of Thailand is 76.4%. Whilst, total working population of Chumphon province is 52.26%, which have less in agriculture than others (Figure 2.8). Furthermore, in this study the population in 3 Amphoes of Chumphon basin are presented in Figure 2.9. Table 2.6 shows population of 3 Amphoes, covered in this area.

Table 2.6 Number of population in 3 Amphoes of Chumphon basin and total population in Chumphon province.

Year	Chumphon province	A.Pathiu	A.Tha sae	A.Muang
1990	397,679	37,973	51,807	125,895
1991	402,625	38,704	52,894	126,667
1992	416,048	40,649	56,464	129,498
1993	420,644	40,684	56,599	124,091
1994	428,329	41,332	57,932	135,905
1995	432,867	41,297	58,866	138,119
1996	439,996	41,649	60,982	139,816
1997	448,087	42,118	64,132	141,001
1998	454,170	42,575	66,104	142,099

Source: The Registration Administration Bureau, Ministry of interior.



Agriculture	Type of job	Others
47,731 (42.63%)	Private business	26,058 (21.83%)
45,503 (40.64%)	Family business	13,118 (10.99%)
2,956 (2.64%)	Employer	3,307 (2.77%)
313 (0.28%)	Government employee	16,735 (14.02%)
15,462 (13.81%)	Businessl employee	60,149 (50.39%)

Source: Office of the Welfare and Labour Protection, Chumphon province

Figure 2.8 Population structure and labour population in Chumphon province of 1998

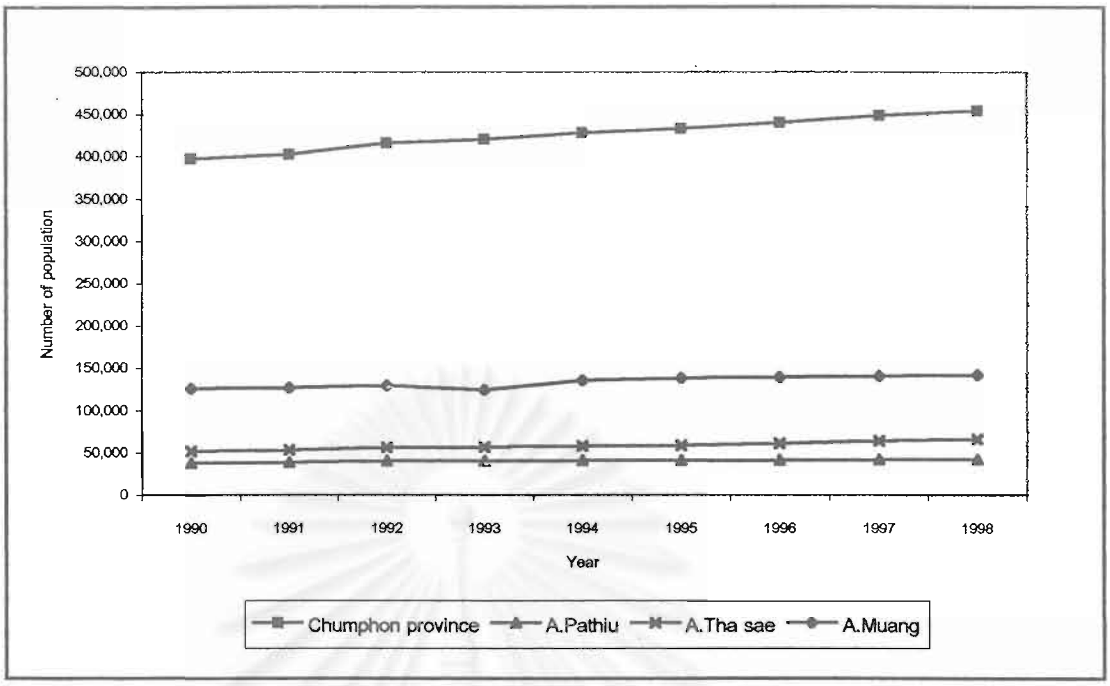
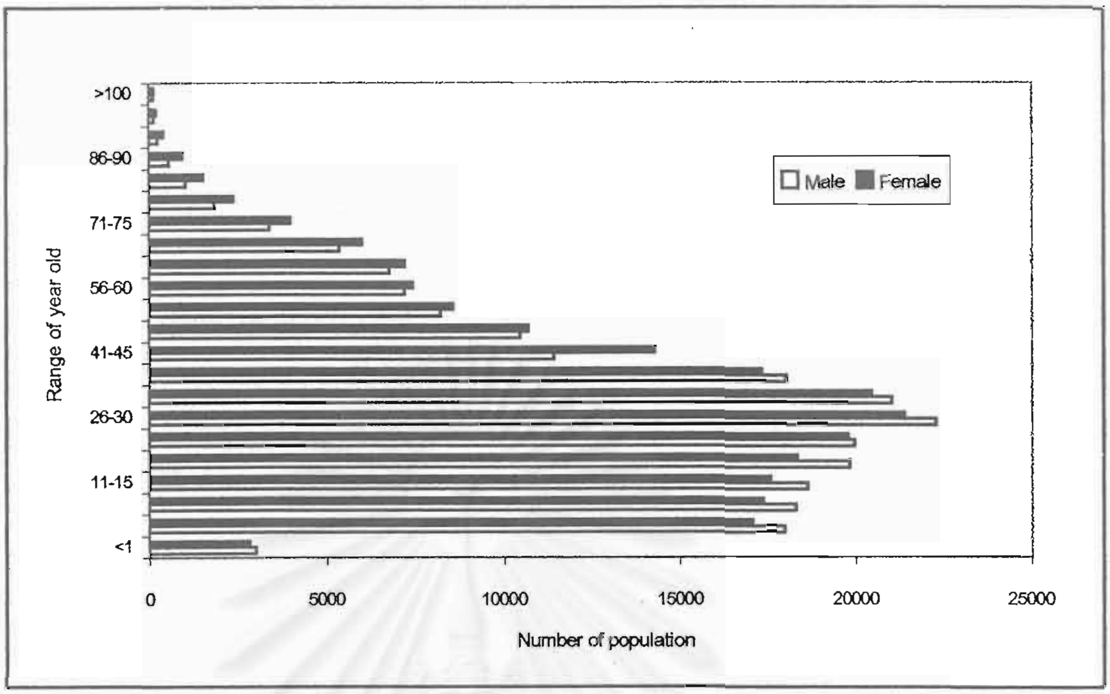


Figure 2.9 Number of population in A.Pathiu, A.Tha Sae, A.Muang and total population in Chumphon province during 1990 to 1998.



Source: The Registration Administration Bureau, Ministry of Interior.

Figure 2.10 Population structure by the range in age in Chumphon province ,1998.

The structure of working population with the age of 26-30 years old is the highest. The Figure 2.10 shows the population under 15 years old are very high in number. Furthermore, the base of pyramid has narrowed. In the future, the trend of working population will be decreasing.

2.3 Specific flood problem in the Tha Taphao and khlong Chumphon watersheds in Amphoe Muang, Chumphon province.

2.3.1 Causes of flood.

Causes of flood as summarized by Veerapun (1986) and Vongvisessomjai *et.al.* (1996) revealed that the flood is the result of one or more of the following natural causes

(1) A sequence of severe rainstorms in the upstream catchments producing high and prolonged discharges in the downstream catchments.

(2) Intense rainfall in specific subcacthments giving rises to local flash floods in the mountainous and hilly areas upstream, and in the flood plains of the lower basin; this is particularly critical in urban areas.

(3) Flood waves from different tributaries may coincide when they meet at the confluence. The resulting flooding will be more severe than flooding from an individual flood wave.

(4) High tides from the Gulf of Thailand propagating up the river.

Furthermore, combining with the deforestation, urban development factors, it increases the severity, duration and size of flood.

(5) Deforestation in the upstream catchments through systematic logging of forests and slash and burn cultivation. The consequence of deforestation is that storage of rainwater in the dense canopy of vegetation and in the root zone is lost. The runoff from the deforested areas to the rivers is more rapid and with higher peaks.

(6) Urban development has increased rapidly in the recent decades. A consequence of the urban growth is that a number of paddy fields, ponds and swamps in flood plains which formerly served as natural reservoirs for flood water are converted into impervious paved areas thus reducing flood retention capacity and increasing speed of flood wave and height of flood.

2.3.2 Flood descriptions.

Flooding is a temporary condition of inundation of land adjacent to river channels or along the shorelines of lakes and oceans. River and lake-shore flooding results from the occurrence of relatively unusual conditions such as dams, dikes, and levees. Flooding along oceanic coasts results from hurricanes, typhoons, and other storm activity and from tsunamis, or seismic sea waves, which are generated by earthquakes.

In Thailand, the flood can be generally categorised into 4 main types as follows :

(1) **Coastal flood.** Tropical storms can produce heavy rains or drive ocean water onto land. Beaches and coastal houses can be swept away by the water. Coastal flooding can also be produced by sea waves called tsunamis, tidal waves that are created by volcanoes or earthquakes in the ocean.

(2) **Flash flood.** After the heavy rain in the deforested mountainous part of the catchment area, the fast-moving water flow as sheet flood into tributaries and subsequently causes the sudden flood in the low-lying intermontane areas.

(3) **River flood.** Flooding along rivers is a natural event. Some floods occur seasonally during the heavy rainfalls of the monsoon period. Water fills river basins too quickly, and the river will overflow its banks. Often the land around a river will be covered by water for miles around.

(4) **Urban flood.** As undeveloped land is paved, different constructions are built, cut-and-fill are undertaken, and occasionally the ground surface is subsided due to many causes, it loses its ability to absorb and drain the rainwater. Rainwater in most cases is locked in urban area and caused flooding for extraordinary a long period of time.

2.3.3 Flood events in Amphoe Muang, Chumphon province.

In order to monitor the flood extent as one objective of this study, the background knowledge of flood phenomena in the past should be considered and fully understood.

The flood events in 1995, 1996 and 1997 were caused by heavy rainfall from a sequence of tropical storms. The heavy rainfall in the watershed area created high peak floods in the downstream of Chumphon basin, located in Amphoe Muang, Chumphon province.

In 1995, the flooding occurred during 13^{th} to 17^{th} November, the khlong Tha Taphao overflowed the bank. The low-lying villages and roads were submerged. The water level reached maximum in 15^{th} November with the flood stage of 5.29 metres (MSL). The total duratin of flood was 90 hours (3 days 18 hours).

In 1996, the magnitude of flood is larger than the flood in 1995 and had occurred during 31^{st} July to 4^{th} August. The maximum flood stage had reached 5.36 metres (MSL) and the duration of flood had lasted for 4 days.

Furthermore in 1997, flooding occurred two times during 7^{th} to 9^{th} August and 21^{st} to 31^{st} August. The maximum floods stage in the first time was about 50 – 80 centrimetres (MSL). Flood had inundated the municipal and surrounding area. The second flood during 21^{st} to 31^{st} August,1997 was the largest flood and caused damages more than the Gay typhoon in 4^{th} November 1989. The maximum flood stage was 6.62 metres (MSL) with the duration of flooding of 11 days (Figure 2.11-2.13).

2.3.4 Economic lost from flooding.

The cost of flood damages in Chumphon province in the past years were calculated by the Public Welfare Department and the Local Administration Department. The costs of damages during the years 1995 to 1997 are shown in Table 2.7

Table 2.7 Summary the costs of flood damage in Chumphon province.

A. Cost of damages of lives and properties :

Year	Casualty					People migration		House damage	
	No. of family	No. of people	No. of death	No. of loss	No. of injury	No. of family	No. of people	Total houses	Partiality of houses
1995	18,339	75,507	7	-	-	57	-	1	1
1996	14,529	61,939	1	-	-	-	-	-	-
1997	62,746	244,675	30	-	245	1,695	5,889	452	1,925

B. Cost of damages on agriculture :

Year	Paddy field (Rai)	Crop (Rai)	Orchard (Rai)	Total areas (Rai)	Total cost (Baht)
1995	32,301	6,498	42,150	80,949	47,000,000
1996	2,250	159	7,725	10,134	2,926,860
1997	24,259	6,117	24,099	54,475	38,000,000

C. Cost of damages of fishery and livestock :

Year	Fish / shrimp pond	Livestock (No.)	Total cost (Baht)
1995	145	44,688	2,564,400
1996	3	-	500,000
1997	6204	21,772	3,577,000

D. Cost of damages on public utilities :

Year	No. of Amphoe	Road.		Bridges.		Mines/dams.		School.	
		No. of roads	Total cost (Baht)	No. of bridges	Total cost (Baht)	No. of mines/dams	Total cost (Baht)	No. of schools	Total cost (Baht)
1995	8	338	47,666,813	33	4,220,534	6	449,600	-	-
1996	8	1,678	270,318,260	94	36,337,840	15	2,533,660	-	-
1997	9	1,402	175,120,263	223	128,522,527	58	7,014,859	115	39,150,601

(Continued)

Year	Temples.		Government building.		Others.		Summary of total cost (Baht)
	No. of temples	Total cost (Baht)	No. of government building	Total cost (Baht)	No. of others	Total cost (Baht)	
1995	-	-	-	-	2	381,000	52,717,947
1996	-	-	-	-	110	6,425,740	315,615,500
1997	96	12,293,900	22	12,780,194	25	24,917,200	399,799,544

Source: Office of the Civil Disaster Protection, Department of Local Administration, Ministry of Interior.

The statistics on the cost of flood damages in Chumphon province show that the trend is progressively increased. The cost of flood damages directly depending upon the flood stage and heavy rainfall. These costs of flood damages are the actual cost excluding the opportunity lost which is expected to be much higher than estimated. It is noted that the data and information on the cost of flood damages are far from perfection due to the lack of systematic evaluation and recording system.

2.4 Flood management activities.

Flood management includes all activities, which can be undertaken to reduce the severity of flooding and relieve its effects. The current flood management activities in Amphoe Muang for control of water movements to reduce or mitigate the severity of flooding, such as, flood by-pass channel or spillway, pumping stations to lift runoff out of the low lying areas and water-gate construction. They consist of 14 projects are as follows: (Figure 2.14 - 2.16).

1.1 Dredging of Khlong Hua Wung- Phanang Tak diversion in order to accelerate the flow of surface runoff from Khlong Tha Taphao to the Gulf of Thailand.

1.2 Dredging of Khlong Bang Long diversion in order to drain the surface runoff from Khlong Sam Kaeo to Ao Pak Had.

1.3 Water-gate construction on the east side of khlong Hua Wung- Phanang Tak for Kam Ling project (Nong Yai flood retention pond).

1.4 Constructing four pumping satations in Amphoe Muang area.

1.5 Improvement of municipal drainage system.

1.6 Improvement of Khlong Nong Muang Kom in the municipal Muang Chumphon of totally 2,150 metres long to be the retention pond and finally drain the surface runoff to khlong Tha Nang Sang.

1.7 Improvement of khlong Tha Nang Sang of totally 7,500 metres long to serve as the drainage of the surface runoff from Khlong Tha Taphao.

1.8 Improvement of khlong Noi, separated from khlong Tha Taphao, in order to drain the surface runoff directly to the Gulf of Thailand.

1.9 Improvement of khlong Sam Kaeo in the downstream area near Ao Phanang Tak Tumbon Na Cha-ang.

1.10 Construction of the Sam Kaeo water-gate.

1.11 Dredging of Khlong Ban Au Taphao-Ban Bang Tum diversion of totally 2,500 metres long at Tumbon Tha Yang in order to drain the surface runoff from khlong Tha Taphao to Ao Pak Had.

1.12 Improvement of Huai Ban Dan Sai Kaeo at Tumbon Na Thung in order to drain the surface runoff to Ao Pak Had.

1.13 Improvement of khlong Ta Duang at Tumbon Bang Mak and Tumbon Na Thung of totally 2,300 metres long.

1.14 Preparation of the Nong Yai-Kam Ling project (Nong Yai retention pond).

It is noted that the implementation and time-frame of these flood-control projects are not certain depending upon the project financing. Therefore, these activities have been excluded in the identification of flood-prone areas under the present study.

Figure 2.11 Flood stage in Amphoe Muang of the "Zita" typhoon in 24th August 1997.

Figure 2.12 Flood stage in Amphoe Muang of the "Zita" typhoon in 25th August 1997.

Figure 2.13 Flood stage in Amphoe Muang of the "Gay" typhoon in 5th November 1989.

Figure 2.14 Khlong Tha Nang Sang of totally 7,500 metres long to serve as the drainage of the surface runoff from Khlong Tha Taphao.

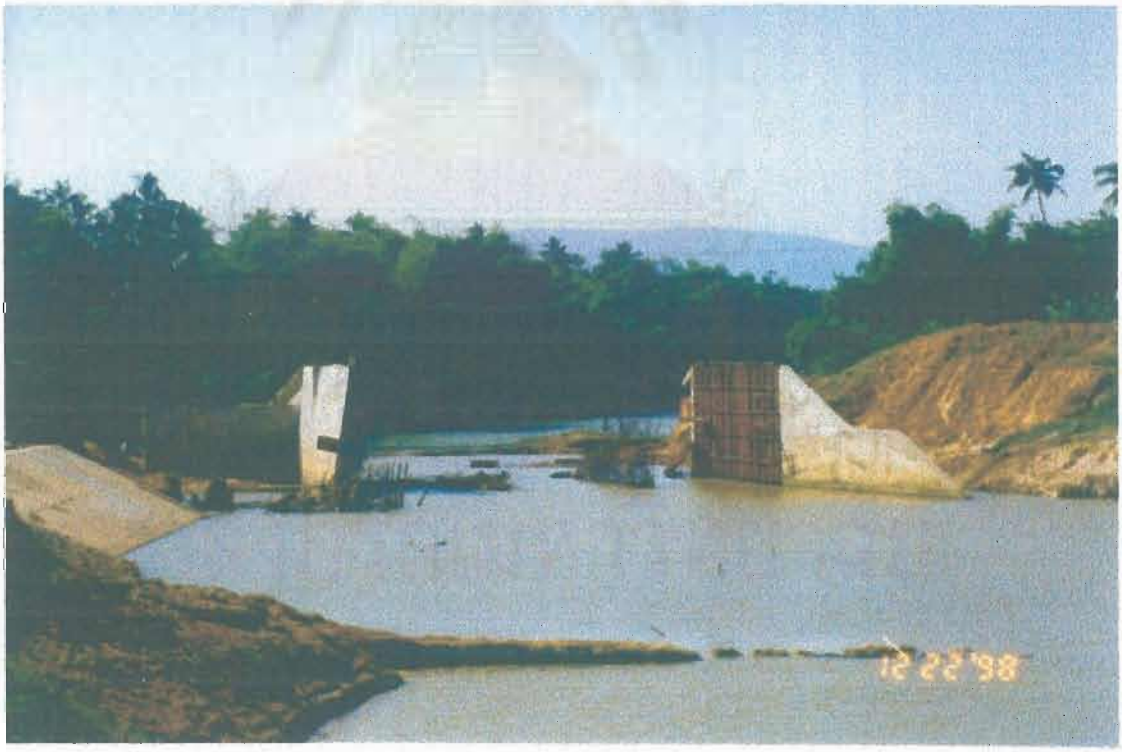


Figure 2.15 Construction of the Sam Kaeo water-gate.

Figure 2.16 The Nong Yai-Kam Ling project (Nong Yai retention pond).

CHAPTER III

THEORETICAL CONSIDERATIONS

3.1 General principles of flood risk analysis and mapping approaches.

Approaches to the flood risk analysis and mapping are classified into 3 types. The first is the geomorphological approach, the flood risk is evaluated on the basis of geomorphological units, such as, natural levees, and old river course which indicate flood susceptibility. The second is the past flood approach, the flood risk is evaluated on the basis of the inundation data of past floods. The third is the hydrological and hydraulic approach, the hydrological and hydraulic models are used for obtaining the inundation areas and depth. Each approach has advantages and disadvantages and thus the most suitable approach should be selected for consideration according to objectives, conditions of the study area, available data, etc.

In this study, the flood risk map is developed based on hydrological and hydraulic approach. The return period of water stage used in mapping are 2-yr, 5-yr, 15-yr, 25-yr, and 100-yr.

The hydrological and hydraulic approach can estimate the river stage corresponding to the given frequency and magnitude of flood. Generally, this method can be developed for the flood prone maps.

Rainfall analysis is to obtain the mean hyetograph over the basin that corresponds to the given return period. Flood analysis provides the water stage at designated points on rivers, using the extreme value obtained in the each year. Flooding conditions in the flood prone are can be estimated for the future land use with the planned flood mitigation measures corresponding to the arbitrary magnitude of flood.

3.2 Rainfall and flood frequency analysis.

The objective of frequency analysis of hydrological data is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distribution. This information on magnitude and frequency relationship is used in the design of flood control structures, dams, bridges, hydroelectric power plants etc. Commonly used empirical distributions for frequency analysis are Gumbel, Log Normal, Pearson type 3 and Extreme Value.

The Gumbel probability distribution is selected for flood frequency analysis in this study. The theoretical description of the Gumbel distribution, method of parameters estimation and plotting position formulae is given in the following paragraphs.

3.2.1 Gumbel distribution.

Gumbel method of frequency distribution considers the extreme values. Based on the argument that the distribution of flood is unlimited, i.e., there is no physical limit to the maximum flood, Gumbel proposed that the probability "P" of the occurrence of a value less than or equal to any value X (probability of non-exceedence) can be expressed as:

$$P(X \leq x) = \exp[-\exp(-\alpha (x-\mu))] \quad (3.1)$$

Where, $P(X \leq x)$ is the probability of non-exceedence and α and μ are the location and scale parameters respectively.

Taking $Y = \alpha (x-\mu)$ and substituting in to equation 3.1 we get:

$$P(X \leq x) = e^{-e^{-y}} \quad (3.2)$$

The expression, $Y = \alpha (x-\mu)$ represents a straight line on Gumbel paper. The return period, $T = 1/ \{1-[p (X\leq x)]\}$, indicates that once in T (years) the considered limit will be exceeded.

3.2.2 Parameters estimation.

The values of α and μ in equation 3.1 which are known as location and scale parameters respectively can be estimated by various methods. Probability weighted moment method, maximum likelihood and method of moments are commonly used. The approximate expression for the probability method of moment are given below:

$$\alpha = 1.2825/\sigma \quad (3.3)$$

$$\mu = X - 0.4500\sigma \quad (3.4)$$

where ;

σ = Variance of the observed

X = Mean of the observed

By estimating the values of α and μ from equations 3.3 and 3.4 the value of unknown event X_T can be estimated by the following expressions:

$$X_T = X + S^*K \quad (3.5)$$

or

$$X_T = \mu + \alpha Y_T \quad (3.6)$$

$$Y_T = -\ln(\ln(T/T-1)) \quad (3.7)$$

$T = (n+1)/m$ (3.8)

$K = (Y_T - Y_n)/S_n$ (3.9)

where ;

X_T = Computed rainfall/discharge

Y_T = Reduced variate

X = Mean of the observed

S = Standard deviation of the observed

K = Frequency factor

Y_n = Mean value of the reduced variate

S_n = Standard deviation of the reduced variate

T = Return period

n = Number of years of record

m = The rank of the event

3.2.3 Plotting Position.

Numerous method have been proposed for determination of plotting position, most of which are empirical in nature. To plot the flood (or other hydrologic) data, the data values must first be ranked from 1 to n (the number of years of record) in order of decreasing magnitude. The rank m and number of years of record n are then used to compute a plotting position, or empirical estimate of frequency or return period. The most commonly used are Weibull and Gringorten's formulae which are given below:

$P = m/(n+1)$ Weibull Formula (3.10)

$P = (m-0.44)/(n+0.12)$ Gringorton Formula (3.11)

where;

$P = 1/T$ = probability of exceedence

3.3 The Hydrologic Engineering Center model (HEC-1).

The HEC-1, Flood Hydrograph Package, computer program was originally developed in 1967 by Leo R.Beard and other members of the Hydrologic Engineering Center (HEC) staff. The latest version 4.0 (September 1990) was developed. It represents improvements and expansions to the hydrologic simulation capabilities together with interfaces to the HEC Data Storage System (DSS). New hydrologic capabilities include Green and Ampt infiltration, Muskingum-Cunge flood routing, reservoir releases input over time, and improved numerical solution of kinematic wave equations. The Muskingum-Cunge routing may also be used for the collector and main channels in a kinematic wave land surface runoff calculation. The HEC-1 model is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component models an aspect of the precipitation-runoff process within a portion of the basin, commonly referred to as a subbasin. A component may represent a surface runoff entity, a stream channel, or a reservoir. Representation of a component requires a set of parameters which specify the particular characteristics of the component and mathematical relations which describe the physical processes. The result of the modeling process is the computation of streamflow hydrographs at desired locations in the river basin.

The HEC-1 model components are used to simulate the rainfall-runoff process as it process as it occurs in an actual river basin. The model components function based on simple mathematical relationships which are intended to represent individual meteorologic, hydrologic and hydraulic processes which comprise the precipitation-runoff process. These processes are separated into precipitation, interception/infiltration, transformation of precipitation excess to subbasin outflow, addition of baseflow and flood hydrograph routing. The subsequent sections discuss the parameters and computation methodologies used by the model to simulate these processes.

3.3.1 Precipitation.

A precipitation hyetograph is used as the input for all runoff calculations. The specified precipitation is assumed to be basin average. Any of the options used to specify precipitation produce a hyetograph. The hyetograph represents average precipitation depths over a computation interval.

3.3.2 Interception/Infiltation.

Land surface interception, depression storage and infiltration are referred to in the HCE-1 model as precipitation losses. Interception and depression storage are intended to represent the surface storage of water by trees or grass, local depressions in the ground surface, in cracks and crevices in parking lots or roofs, or in an surface area where water is not free to move as overland flow. Infiltration represents the movement of water to areas beneath the land surface.

Two important factors should be noted about the precipitation loss computation in the model. First, precipitation which does not contribute to the runoff process is considered to be lost from the system. Second, the equations used to compute the losses do not provide for soil moisture or surface storage recovery. This fact dictates that the HEC-1 program is a single-event-oriented model.

The precipitation loss computations can be used with either the unit hydrograph or kinematic wave model components. In the case of the unit hydrograph component, the precipitation loss is considered to be a subbasin average. On the other hand, separate precipitation losses can be specified for each overland flow plane in the kinematic wave component. The losses are assumed to be uniformly distributed over each overland flow plane. In some instance, there are negligible precipitation losses for a portion of a subbasin. This would be true for an area containing a lake, reservoir or impervious area. In this case, precipitation losses will not be computed for a specified percentage of the area labeled as impervious. There are 3 methods that can be used to calculate the precipitation loss in this study as follow:

1. Initial and uniform loss rate.

An initial loss, STRTL (units of depth), and a constant loss rate, CNSTL (units of depth/hour), are specified for this method. All rainfall is lost until the volume of initial loss is satisfied. After the initial loss is satisfied, rainfall is lost at the constant rate, CNSTL.

2. Exponential loss rate.

This is an empirical method which relates loss rate to rainfall intensity and accumulated losses. Accumulated losses are representative of the soil moisture storage. The equations for computation of loss are given below

$$ALOSS = (AK + DLTK)\ PRCP^{ERAIN} \tag{3.12a}$$

$$DLTK = 0.2DLTKR(1-(CUML/DLTKR))^{2} \tag{3.12b}$$

For CUML $\leq$ DLTKR

$$AK = STRKR/(RTIOL^{0.1CUML}) \tag{3.12c}$$

Where ALOSS is the potential loss rate in inches (mm.) per hour during the time interval, AK is the loss rate coefficient at the beginning of the time interval, and DLTK is the incremental increase in the loss rate coefficient during the first DLTKR inches (mm.) of accumulated loss, CUML. The accumulated loss, CUML, is determined by summing the actual losses computed for each time interval.

DLTKR is the amount of initial accumulated rain loss during which the loss rate coefficient is increased. This parameter is considered to be a function primarily of antecedent soil moisture deficiency and is usually storm dependent. STRKR is the starting value of loss coefficient on exponential recession curve for rain losses. The starting value is considered a function of infiltration capacity and thus depends on such basin characteristics as soil type, land use and vegetal cover.

RTIOL is the ratio of rain loss coefficient on exponential loss curve to that corresponding to 10 inches (10mm.) more of accumulated loss. This variable may be considered a function of the ability of the surface of a basin to absorb precipitation and should be reasonably constant for large rather homogeneous areas.

ERAIN is the exponent of precipitation for rain loss function that reflects the influence of precipitation rate on basin-average loss characteristics. It reflects the manner in which storms occur within an area and may be considered a characteristic of a particular region. ERAIN varies from 0.0 to 1.0. Estimates of the parameters of the exponential loss function can be obtained by employing the HEC-1 parameter optimization option.

3. SCS curve number.

The Soil Conservation Service (SCS), U.S. Department of Agriculture, has instituted a soil classification system for use in soil survey maps across the country. Based on experience, the agency has been able to relate the drainage characteristics of soil groups to a curve number, CN. The SCS provides information on relating soil group type to a curve number as a function of soil cover, land use type and antecedent moisture conditions. Precipitation loss is calculated based on supplied values of CN and IA (where IA is an initial surface moisture storage capacity in units of depth). CN and IA are related to a total runoff depth for a storm by the following relationships:

$$ACEXS = (ACRAN - IA)^2/(ACRAN - IA + S) \qquad (3.13)$$

$$S = (1000 - 10 * CN)/CN \qquad \text{or}$$

$$S = (25400 - 254 * CN)/CN \ \text{(Metric units)} \qquad (3.14)$$

where ACEXS is the accumulated excess in inches (mm.). ACRAN is the accumulated rainfall depth in inches (mm.), and S is the currently available soil moisture storage deficit in inches (mm.).

In the case that user does not wish to specify IA, a default value is computed as

$$IA = 0.2 * S \qquad (3.15)$$

Since the SCS method gives total excess for a storm, the incremental excess (the difference between rainfall and precipitation loss) for a time period is computed as the difference between the accumulated excess at the end of the current period and the accumulated excess at the end of the previous period.

3.3.3 Unit hydrograph.

The unit hydrograph technique is used in the subbasin runoff component to transform rainfall excess to subbasin outflow. A 1-hour unit hydrograph is defined as the subbasin surface outflow due to a unit (1 inches or mm) rainfall excess applied uniformly over a subbasin in a period of one hour. Unit hydrograph durations other than an hour are common. HEC-1 automatically sets the duration of unit excess equal to the computation interval selected for watershed simulation.

The rainfall excess hyetograph is transformed to a subbasin outflow by utilizing the general equation:

$$Q(i) = \sum u(j) * X(i - j + 1) \qquad (3.16)$$

where Q(i) is the subbasin outflow at the end of computation interval i, U(j) is the jth ordinate of the unit hydrograph, X(i) is the average rainfall excess for computation interval i. The equation is based on two important assumptions. First, the unit hydrograph is characteristic for a subbasin and is not storm dependent. Second, the runoff due to excess from different periods of rainfall excess can be linearly superposed.

3.3.4 Synthetic unit hydrograph.

The parameters for the synthetic unit hydrograph can be determined from gage data by employing the parameter optimization option. Otherwise, these parameters can be determined from regional studies or from guidelines given in references for each synthetic technique. There are three synthetic unit hydrograph methods available in the model.

1. Clark unit hydrograph. The Clark method (1945) requires three parameters to calculate a unit hydrograph: TC, the time of concentration for the basin, R, a storage coefficient, and a time-area curve. A time-area curve defines the cumulative area of the watershed contributing runoff to the subbasin outlet as a function of time. In the case that a time area curve is not supplied, the program utilizes a dimensionless time area curve:

$$AI = 1.141\ T^{15} \qquad 0 \leq T < 0.5 \qquad (3.17)$$

$$1 - AI = 1.414(1\text{-}T)^{15} \qquad 0.5 \leq T < 1 \qquad (3.18)$$

where AI is the cumulative area as a fraction of total subbasin area and T is the fraction of time of concentration. The ordinates of the time-area curve are converted to volume of runoff per second for unit excess and interpolated to the given time interval. The resulting translation hydrograph is then routed through a linear reservoir to simulate the storage effects of the basin; and the resulting unit hydrograph for instantaneous excess is averaged to produce the hydrograph for unit excess occurring in the given time interval. The linear reservoir routing is accomplished using the general equation:

$$Q(2) = CA * I + CB * Q(1) \qquad (3.19)$$

The routing coefficients are calculated from:

$$CA = \Delta t/(R + 0.5\Delta t) \qquad (3.20)$$

$$CB = 1 - CA \qquad (3.21)$$

$$QUNGR = 0.5(Q(1) + Q(2)) \qquad (3.22)$$

where Q(2) is the instantaneous flow at end of period, Q(1) is the instantaneous flow at the beginning of period, I is the ordinate of the translation hydrograph, Δt is the computation time interval in hours (also duration of unit excess), R is the basin storage factor in hours, and QUNGR is the unit hydrograph ordinate at end of computation interval.

2. Synder unit hydrograph. The Synder method (1938) determined unit graph peak discharge, time to peak, and widths of the unit graph at 50% and 75% of the peak discharge. The method does not produce the complete unit graph required by HEC-1. Thus, HEC-1 uses the Clark method to affect a Snyder unit graph. The initial Clark parameters are estimated from the given Synder's parameters are computed from the resulting unit hydrograph by the following equations:

$$CPTMP = QMAX * (Tpeak-0.5*\Delta t)/(C*A) \qquad (3.23)$$

$$ALAG = 1.048* (Tpeak-0.75*\Delta t) \qquad (3.24)$$

where CPTMP is Synder's C_p for computed unit hydrograph, QMAX is the maximum ordinate of unit hydrograph, Tpeak is the time when QMAX occurs, in hours, Δt is the duration of excess, in hours, A is the subbasin area in square miles, C is a conversion factor, and ALAG is Synder's standard Lag, T_p for the computed unit hydrograph. Synder's standard Lag is for a unit hydrograph which has a duration of excess equal to $T_p/5.5$. The coefficient, 1.048, in equation results from converting the duration of excess to the given time interval.

3. SCS dimensionless unit hydrograph. Input data for the SCS dimensionless unit hydrograph method (1972) consists of a single parameter, TLAG, which is equal to the lag between the center of mass of rainfall excess and the peak of the unit hydrograph. Peak flow and time to peak are computed as:

$$TPEAK = 0.5*\Delta t + TLAG \qquad (3.25)$$

$$QPK = 484*AREA/TPEAK \qquad (3.26)$$

where TPEAK is the time to peak of unit hydrograph in hours, Δt is the duration of excess in hours or computation interval, QPK is the peak flow of unit hydrograph in cfs/inch, and AREA is the subbasin area in square miles.

3.3.5 Kinematic-wave rainfall-runoff modeling.

The kinematic-wave method is an alternative to the unit hydrograph approach to rainfall-runoff modeling. The parameters of this model are developed from physical characteristics of the basin, and equations of motion are used to simulate the movement of water through the system. This method is particularly useful in urban studies because the effects of urbanization can be accounted for by changing the measurable physical parameters of slope, catchment length, surface roughness, and etc. surface features of the basin are represented with two basic types of elements: overland flow and channel flow. One or two overland flow elements are combined with one or two channel flow elements to represent a subbasins together in a network. A typical urban drainage pattern is shown in Figure 3.1 Overland flow occurs on two general types of surfaces: pervious and impervious.

The kinematic-wave equqtions are the continuity equation for unsteady open channel flow with lateral inflow and a simplified Manning's equation are follows:

$$\partial A/\partial t + \partial Q/\partial x = q_0 \qquad (3.27)$$

where: Q = channel flow, ft^3/s

A = cross-sectional area of flow, ft^2

q_0= lateral inflow, $ft^3/(s)(ft)$

x = distance along the flow path

t = time, s

Manning's eqution is written in the form

$$Q = \alpha A^m \qquad (3.28)$$

The coefficient is found with the general equation:

$$\alpha = KS^{1/2} / n \qquad (3.29)$$

where: K = constant that depends on geometry

S = slope

n = Manning's roughness coefficient

These same basic equations are used in computations of flow both for overland flow elements and for channel flow elements.

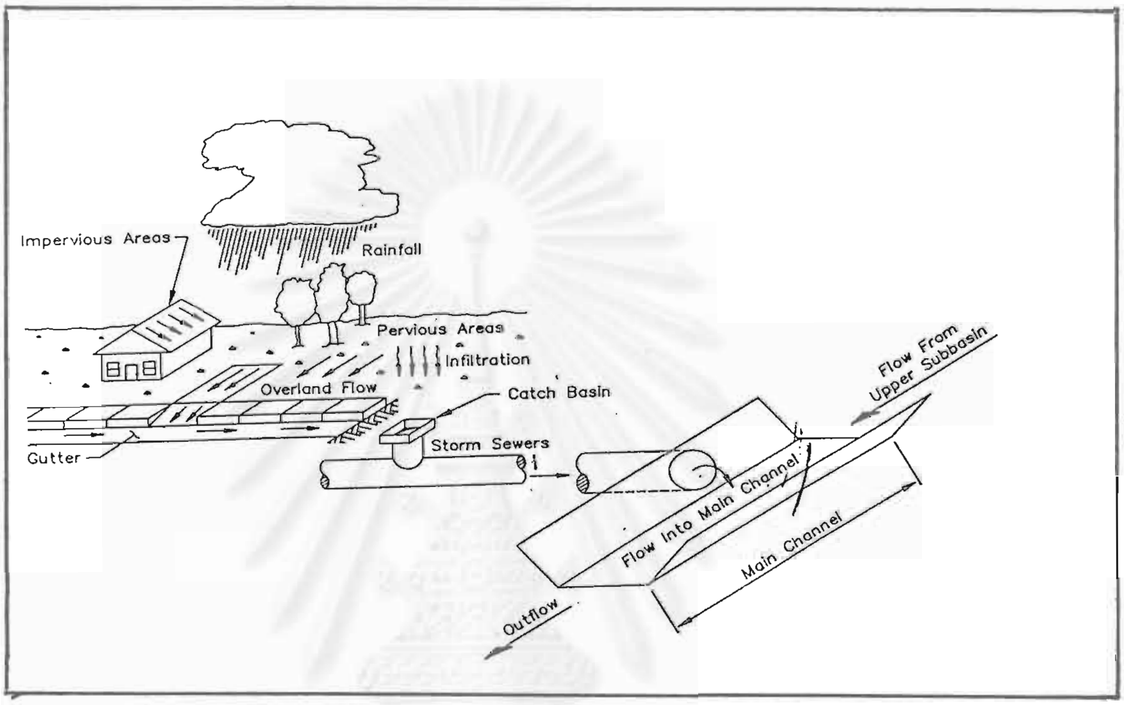


Figure 3.1 Typical urban drainage pattern.

The elements used in kinematic-wave computations in HEC-1 consist of three basic elements, shown in Figure 3.2, are used to model the runoff process with HEC-1: (1) one or two typical overland flow planes, (2) a typical collector channel, and (3) a typical main channel. The collector channel may also be modeled with an additional subcollettor channel. Each element represents average conditions in the basin. The relationships between flow elements are depicted in Figure 3.3

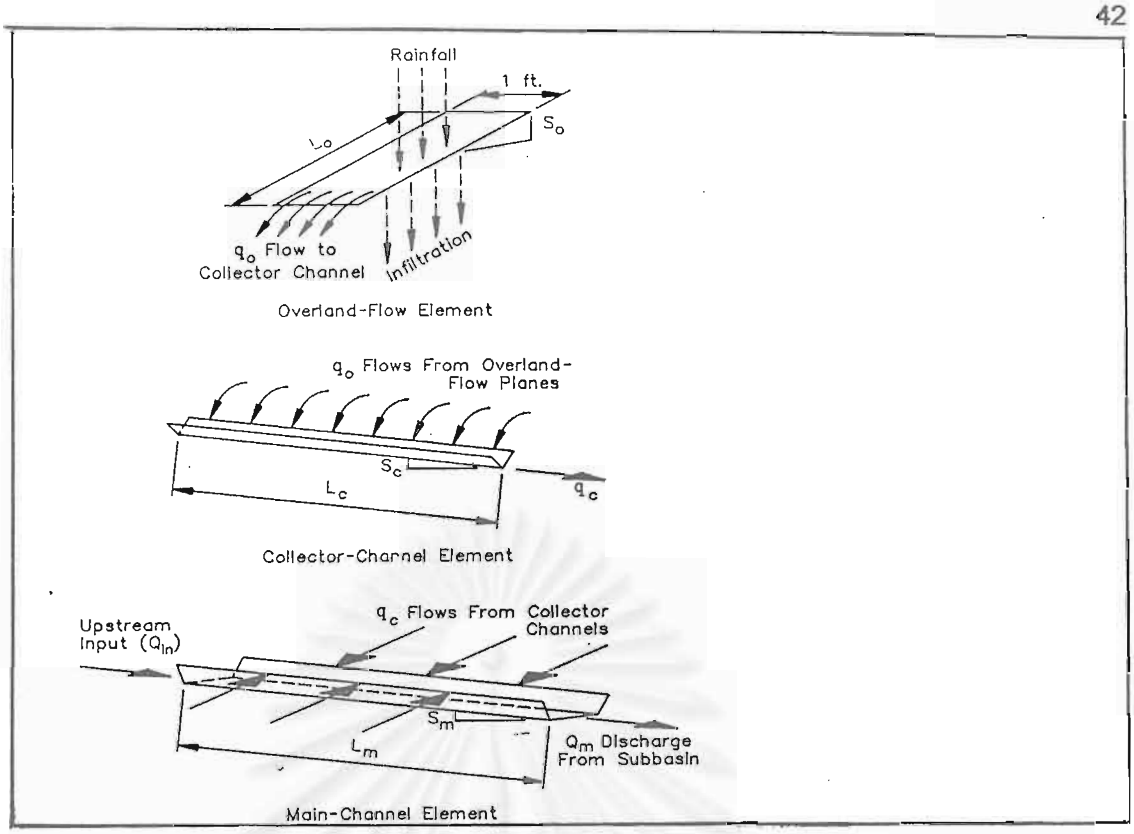


Figure 3.2 basic elements in kinematic-wave model.

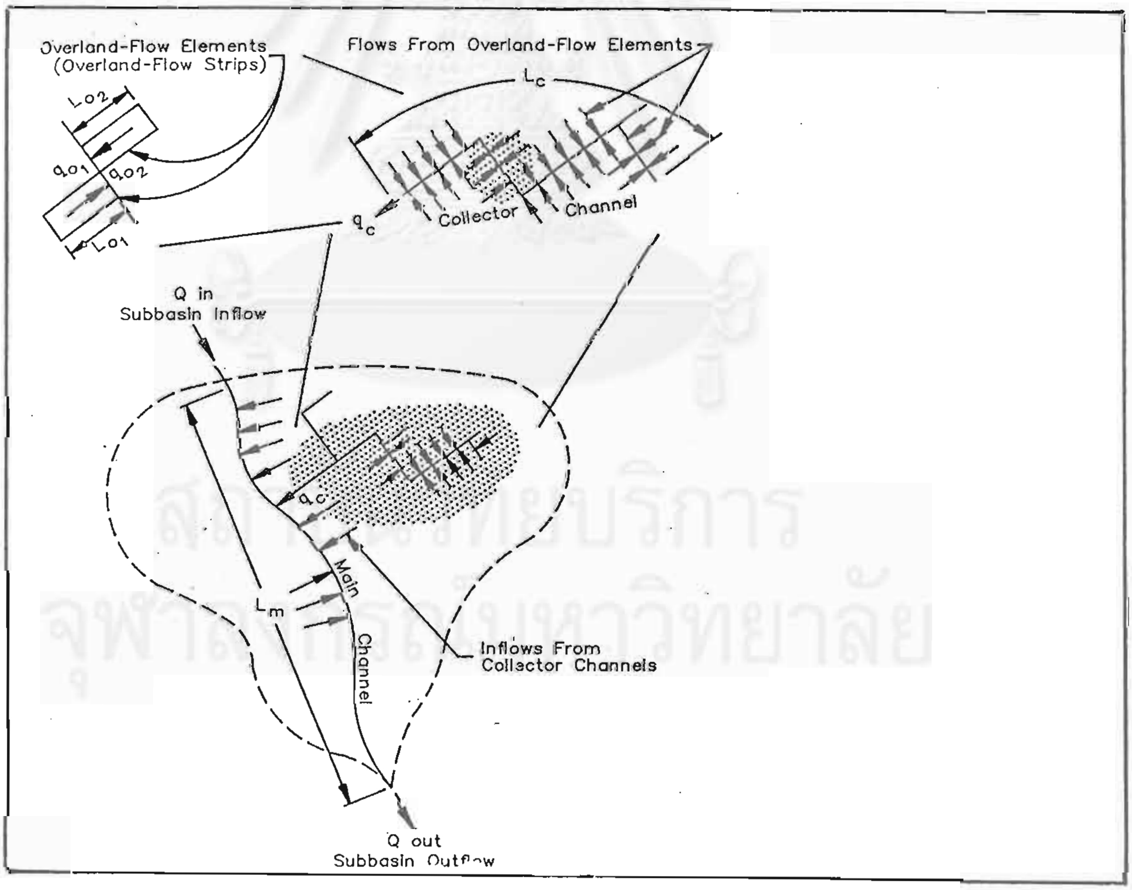


Figure 3.3 Schematic of flow elements in kinematic-wave model.

3.4 Definition of degree of flood hazard.

Hunt (1984) proposed the principles of the definition of flood hazard degree from several study areas in Geotechnical Engineering Investigation Manual in the detail as follows:

Flood hazard degree involves in the magnitude of flood occurrence and the probability of flood occurrence which relates with the return period of flood. Flood hazard degree is defined into the following 4 levels:

(1.) No Hazard Flooding: This level is defined the flood condition as the usual condition.

(2.) Low Hazard Flooding: This level is defined to be more than the usual condition. The flood condition is considered to be more than the usual condition approximately 1.25 to 1.5 times. The return period of the probability of the flood is between 2 to 5 year.

(3.) Moderate Hazard Flooding: This level is defined to be more than the usual condition about 1.5 to 2 times. The return period of the probability of the flood is between 5 to 25 year.

(4.) High Hazard Flooding: This level is defined to be more than the usual condition about 2 times. The return period of the probability of the flood is more than 25 year.

CHAPTER IV

METHODOLOGY

Under the present study, method of work can be divided into 5 steps as follows:

4.1 Acquisition of secondary data.

4.2 Preparation of database using the GIS.

4.3 Statistical analysis of secondary data, rainfall and flood frequency analysis.

4.4 HEC-1 model application.

4.5 Determination of flood prone area in Amphoe Muang, Chumphon province.

4.1 Acquisition of secondary data.

The existing data related to this study have been collected in the forms of maps, reports, books, and historical statistical records as follows:

4.1.1 Base maps.

- Topographic map of the scale 1:50,000 map sheet numbers 4729I, 4730I, 4730II, 4829IV, 4830I, 4830II, 4830III, 4830IV, and 4831III from the Royal Thai Survey Department, Bangkok, Thailand, 1993.

- Land use map of the scale 1:50,000 from the Pollution Control Department, Bangkok, Thailand,1994.

-Surface water resource map of the scale 1:50,000 from the Department of Land Development, Bangkok, Thailand,1994.

4.1.2 Remote sensing data.

Land use data classified from satellite images of LANDSAT-5 (TM) bands 2, 3 and 4 of the scale 1:50,000 in 1988, 1993 and 1998 from the Thailand Remote Sensing Center of the Office of the National Research Council of Thailand.

4.1.3 Reports and historical statistical records.

- Agricultural land use data were collected by the Chumphon Provincial Agricultural Extension Office and the census of agriculture, the National Statistical

Office. This basically consists of 3 components, namely, orchard land, paddy land, and crop land.

- Number of storms passing through Thailand in each year from the Meteorological Department.

- Population statistics from the Registration Administration Bureau, Ministry of Interior.

- Number of factories in each year from the Chumphon Provincial Industry Extension Office.

-Forest land statistics from the Royal Forest Department.

4.1.4 Rainfall data.

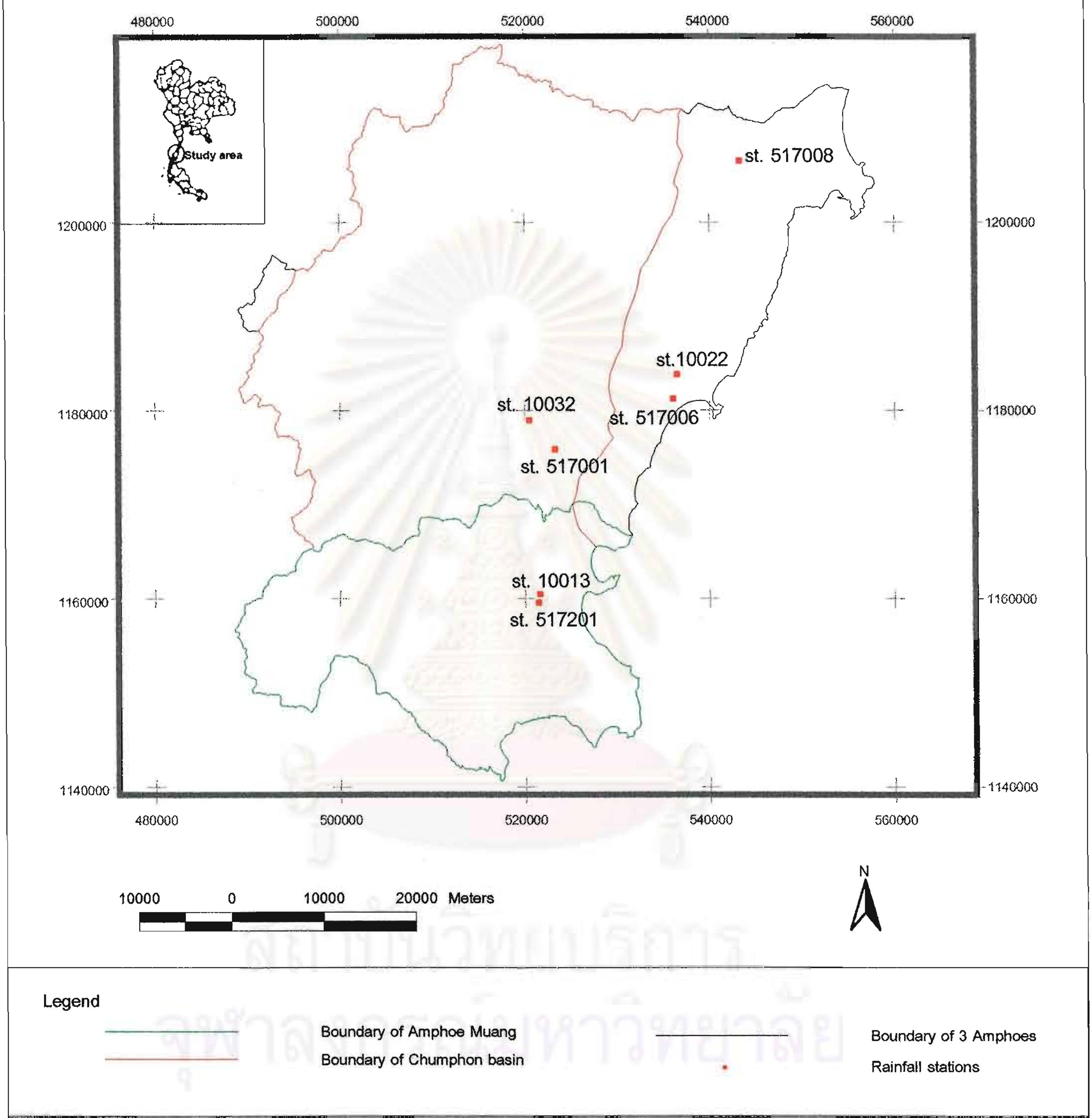
There are totally 7 rainfall stations available within the Chumphon basin. The sources of data are obtained from the Meteorological Department. Figure 4.1 shows the locations of these rainfall stations. Table 4.1 presents the list of rainfall stations and their locations, and the available rainfall data. All of stations have reasonable long period of record.

Table 4.1 Summary of the locations of rainfall stations and available rainfall data.

St. no.	St. name	St. code	Location		Available
			Latitude	Longitude	(year)
1	A. Muang	10013	10-29-30	99-11-04	1976-1995
2	A. Pathiu	10022	09-42-26	99-19-15	1951-1995
3	A. Thasae	10032	10-39-44	99-10-30	1953-1995
4	Thasae	517001	10-38-00	99-12-00	1975-1997
5	Pathiu	517006	10-41-00	99-19-00	1975-1997
6	Pathiu Agriculture co.Ltd	517008	10-55-00	99-23-00	1982-1997
7	Chumphon Muang	517201	10-29-00	99-11-00	1968-1997

Source: The Meteorological Department.

Map showing the location of rainfall stations in 3 Amphoes of the Chumphon basin



Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.

Inter-Department of Environmental Science, Master of Science in Environmental Science.

Graduate School, Chulalongkorn University.

Figure 4.1 The location of 7 rainfall stations in 3 Amphoes of the Chumphon basin.

4.1.5 Water level and discharge data.

There are totally 7 gauging stations available within the Chumphon basin. The sources of data are recorded by the Royal Irrigation Department. Figure 4.2 shows the locations of these gauging stations and Table 4.2 presents a list of gauging stations, their locations, and information concerned.

Table 4.2 Summary of locations of gauging stations, and information concerned.

St. no.	St. code	Khlong	Area	Location	Period of data (year)	No. of year	drainage area (sq.km.)	Gauge datum
1	x.46A	Rap Ro	A. Tha sae	Lat. 10 37' 19" N Long. 99 03' 39" E	1977-1984	8	617	AD
2	x.46	Rap Ro	A. Tha sae	Lat. 10 36' 47" N Long. 99 37' 07" E	1976,1985-1995	12	751	AD
3	x.64	Tha sae	A. Tha sae	Lat. 10 39' 49" N Long. 99 10' 17" E	1973-1995	22	957	AD
4	x. 180	Tha Taphao	A. Muang	Lat. 10 29' 42" N Long 99 10' 23" E	1993-1996	4	1550	MSL
5	x.158	Tha Taphao	A.Tha sae	Lat. 10 35' 34" N Long. 99 08' 42" E	1990-1995	6	1819	AD
6	x.53	Chumphon	A. Muang	Lat. 10 29' 57" N Long. 99 04' 15" E	1971-1990	19	223	AD
7	x.53A	Chumphon	A. Muang	Lat. 10 30' 20" N Long. 99 07' 12" E	1991-1995	4	305	AD

Source: The Royal Irrigation Department.

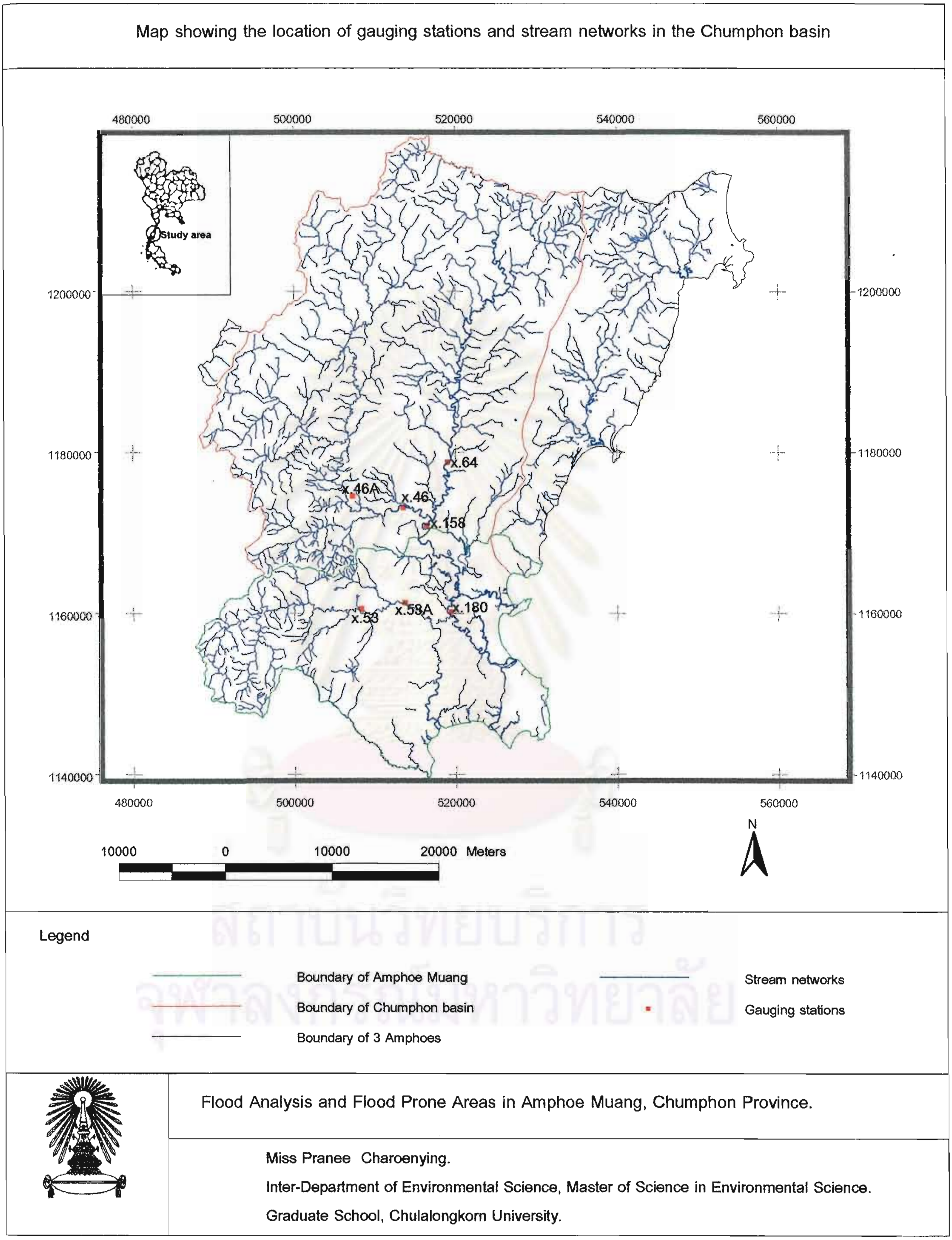


Figure 4.2 The location of 7 gauging stations and stream networks in the Chumphon basin.

4.2 Preparation of database using the GIS.

4.2.1 General of Geographic Information System (GIS).

GIS are computer-based tools to capture, manipulate, process, and display spatial or geo-referenced data. They contain both geometry data (coordinates and topological information) and attribute data, that is, information describing the properties of geometrical objects such as points, lines, and polygons.

Burrough (1986) defined GIS as "A powerful set of tools for collection, storing, retrieving at will transforming and displaying spatial data from the real world".

Arnoff (1989) defined GIS as "Any manual or computer based set of procedure used to store and manipulate geographically referenced data".

4.2.2 Geographic Information System Structure.

The two basic types of geographic data structures used in most GIS are *raster* and *vector*. The raster data structure is analogous to a grid placed over an image. The vector data structure is represented by uniform node, line and area of x,y coordinates. Geographic features such as rivers, roads and boundaries are represented as lines or vectors.

Components of GIS: A GIS has five major components

(a) Data Input: It collects and processes spatial data from a variety of sources, including digitized map information, coded aerial photographs, satellite and remote sensing images and geographically referenced data.

(b) Data management: It allows a database to be used through a combination of hardware and software facilities and to relation to each other.

(c) Data Manipulation and Analysis: It transforms the various data into a common form that permits subsequent spatial analysis. Tabular data, stored on computer systems for example, are converted first to a map scale common with other data, and then all data are analyzed together.

(d) Data Retrieval: In the creation procedure of a database, access procedure is established retrieval of both spatial and non-spatial data. Efficient data retrieval are largely dependent upon the volume of data stored, the method of data encoding and file structure design. In general there are well-developed procedure for efficient retrieval of non-spatial data in GIS.

(e) Data Display: The data reporting displays the database, the results of statistical computations, and produces hybrid maps. Outputs include tabular data, colour images, graphs and single or composite maps.

4.2.3 GIS Software (ARC/INFO).

ARC/INFO version 3.4D (ESRI, 1992) has been employed in this study. The software, that is a vector based GIS software, consists of two sub systems, ARC which is a set of tools for managing geographic features, such as, points, lines and polygons, and INFO which is a database management system for managing attributes associated with the geographic features by ARC.

Creation of database, the first step is to input the spatial data from maps and store in the computer. The computer is a tool for capture, manipulate process and display spatial data. The required database are topographic contour, land use and land cover, boundary of the study area, rainfall stations, and gauging stations. The elevation contour and boundary of the study area are obtained from the topographic map. The land use and land cover data are interpreted using LANDSAT-5TM image of the Thailand Remote Sensing Center of the Office of the National Research Council of Thailand. The rainfall stations and gauging stations data are obtained from the Meteorological Department and the Royal Irrigation Department. The steps of work are as follows:

(1) Digitization of maps.

For the digitization of maps, tic points are required. Tics are reference points that allow all coverage features to be registered to a common co-ordinate system. The tic points for maps are selected according to the location under studied.

The digitization of the tic points is very important before starting the digitization of a map. This is because when digitizing or editing a coverage, tics are used to automatically transform digitizer coordinates into coverage coordinates. The Root Mean Square (RMS) error is kept as low as 0.003. The ADS command of ARC/INFO is then used to digitize the maps.

(2) Digitization of coverages.

Before starting digitization of a coverage, tic points are entered each time with the same RMS error limit as accepted criteria during the digitization of tic points. By doing so, the map is registered and its spatial data are ready to be digitized. Different data layers having different RMS error results unwanted sliver polygons during the matching of the boundary of the same feature in overlay functions. The line digitized used in creation of the contour coverage. The polygon digitized used in creation of the boundary, land use and land cover coverages. The point digitized used in creation of rainfall stations and gauging stations.

(3) Identification & correction of digitization error.

After digitization of a coverage, the next step is to display the map and correction of the error that occurred during the digitization. Chiefly, dangle error (dangling nodes) is found. They indicate that a polygon does not close properly (undershoot)) or an arcs has exceeded its intersection with another arc (overshoot).

The undershoot errors are removed by using the CLEAN with an assignment of proper fuzzy tolerance and dangle length. The fuzzy tolerance was defined as the minimum distance that separates all arc coordinates in a coverage. During the use of CLEAN command, 2 or more arc coordinates within the fuzzy tolerance of each other are snapped together. Dangle length is the minimum length allowed for dangling arcs. Any dangling arc less than this length would be deleted during CLEAN. Remaining dangling arc is removed using the command REMOVE ARCS of ADS

(4) Adding user-ID to coverage features.

The feature in the coverage was categorized into different GIS classes, which were then assigned User-Ids. User-Ids could be assigning by keyboard entry.

(5) Building arc/polygon topology

The next step after correction of errors is the creation of texture coverage using BUILD command. In order to ensure that the arcs are stored as an order series of X, Y coordinate which defined a line, all arcs in coverage are sequentially numbered, the polygon is created by a number of arc which comprise its border.

Other maps, such as: surface water resources map, boundary of 3 Amphoes and boundary of administration of Tumbons in Amphoe Muang are obtained in the digitized map from. Finally, the coverages from digitization of map is completed for use in the next step of delineation flood prone areas.

4.3 Statistical analysis of secondary data and rainfall frequency analysis.

4.3.1 Statistical analysis of secondary data.

The correlation analysis of flooding, a dependent variable, and 8 independent variables, such as, maximum water level, rainfall and runoff, population, agriculture land use, forest land, number of storms and number of factories. Then, secondary data are collected, and analysed using the multiple linear regression equation.

4.3.2 Rainfall frequency analysis.

Annual maximum rainfalls of each station from the available data are used to calculate the frequencies of the annual rainfalls. The Gumbel probability distribution is applied for the rainfall frequency analysis. The moment of method has been employed for parameters estimation of each type. The design rainfall time series of 2, 5, 15, 25, and 100 years return period.

4.3.3 Flood frequency analysis.

The design water level time series of 2, 5, 15, 25, and 100 years return period are analysed by the Gumbel probability distribution. The results of different return period flood stage estimated the changes in the flood prone areas.

4.4 HEC-1 model application.

The input data required for HEC-1 are rainfall, rainfall loss factors,total area of main drainage basin and their composing subbasins, flow and channel elements, and synthetic unit hydrograph parameters.

4.4.1 Parameter estimation.

Calibration of a model with historical data is an essential part of model development. It is procedure of adjusting parameters until the model satisfactorily simulated the observed physical processes in the hydrologic system and procedure reliable results. The time of the parameter optimization are selected in 4th November, 1995 and 22nd August, 1997. The parameter optimization option in HEC-1 estimates unit hydrograph, rainfall loss function, and routing parameters using gauged precipitation and runoff data from the same event. The parameters are adjusted on the basis of the comparison, and the procedure is repeated until a suitable fit is obtained. A schematic diagram of the trial and error procedure used in parameter estimation is shown in Figure 4.3

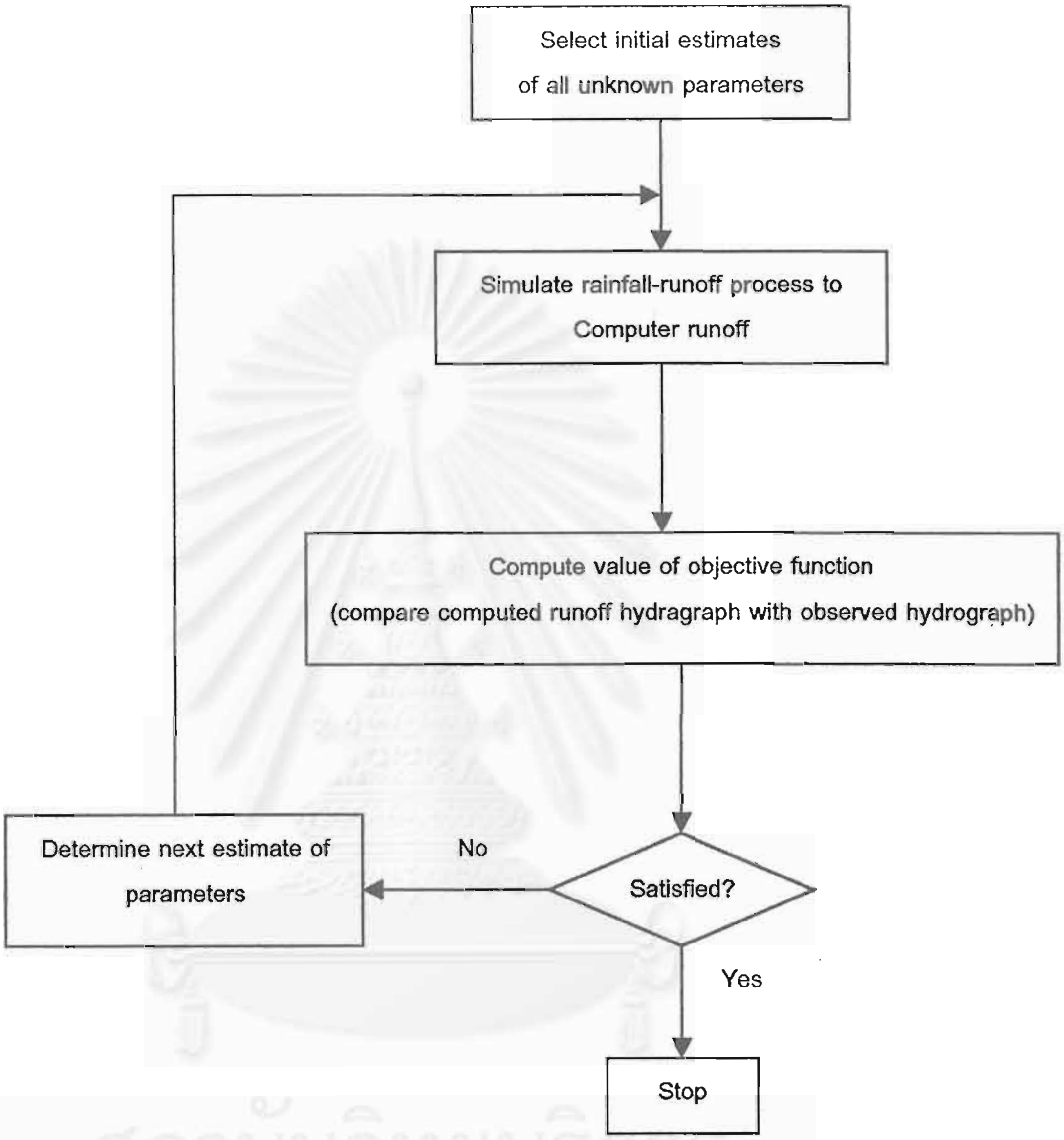


Figure 4.3 Schematic diagram of parameter estimation.

4.4.2 The kinematic wave method.

The areas of study are chosen 4 subbasins in the Chumphon basin, consist of, SUB1 covering the drainage area of x.64 in Amphoe Pathiu, SUB2 covering the drainage area of x.46 in Amphoe Tha Sae, and SUB3 covering the drainage area of x.158, and SUB4 covering the drainage area of x.180 in Amphoe Muang. (Figure 4.4) The time of its flood are selected in 1995 and 1997. These times represent a rang of urban development (Table 4.3 and 4.4). The typical parameters are determined using the topographic maps, land use maps, and the Royal Irrigation Department.

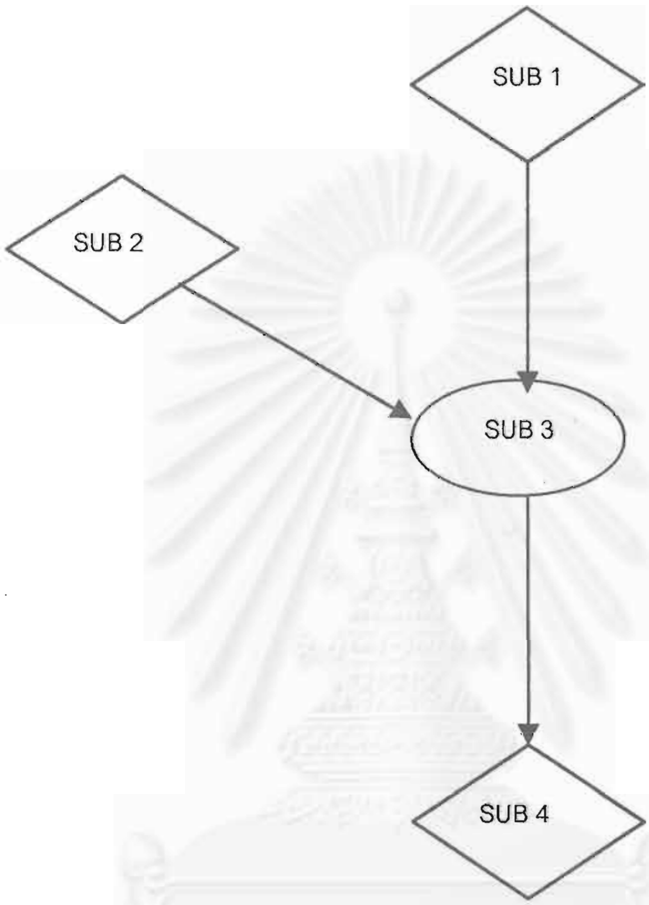


Figure 4.4 Kinematic Wave Model in the Chumphon basin Schematic.

Table 4.3 Mean overland flow elements over pervious and impervious subbasins by study area.

Study Area	Drain area (mi^2)	Flow element type	Area represented (%)		Over land Length (ft.)	Over land Slope (ft/ft)	Manning's n	Loss rate, SCS curve number
			1995	1997				
Sub1	369.5	Impervious	10	15	976	0.003	0.15	98
		Pervious	90	85	1291	0.002	0.13	82
Sub 2	289.96	Impervious	4	10	5789	0.002	0.15	98
		Pervious	96	90	780	0.003	0.12	83
Sub 3	702.32	Impervious	40	50	3448	0.003	0.15	98
		Pervious	60	50	1599	0.001	0.32	92
Sub 4	598.46	Impervious	40	50	1234	0.0001	0.15	98
		Pervious	60	50	991	0.0001	0.40	92

Table 4.4 The Channel data for input HEC-1 model.

Subbasin	Length (ft)	Slope (ft/ft)	Manning, N	Area (mi^2)	Shape	Width (ft)	Side slope (ft/ft)	Upstream Inflow
Sub1								
Collector channel	29527	0.0022	0.24	325.31	TRAP	0	0.015	....
Main channel	2099710	0.0008	0.24		TRAP	82.02	0.29	No
Sub 2								
Collector channel	22966	0.001	0.14	223.28	TRAP	0	0.09	....
Main channel	175523	0.0002	0.14		TRAP	114.8	0.19	No
Sub3								
Collector channel	21325	0.001	0.20	601.98	TRAP	0	0.09	....
Main channel	45931	0.001	0.20		TRAP	66	0.19	Yes
Sub4								
Collector channel	14749	0.001	0.20	547.80	TRAP	0	0.13	....
Main channel	72178	0.0003	0.20		TRAP	0	0.21	Yes

The collector-channel parameters can be determined by examining a drainage map of the basin and selecting a typical collector system for each subbasin. The selecting of the parameters is as follow:

1. The area associated with the collector system can be determined from the topographic map. This is area in square miles.
2. The channel shape and size will usually change along the length of the channel. The channel in the study area are represented a trapezoidal shape.
3. The channel slope can be estimated from a topographic map by taking the difference in elevation between the upstream and down stream ends and dividing by the length.

4. A Manning's N which best represents the roughness of the major part of the channel should be used. Tables of n for various types of channels are available in hydraulic handbooks and the Royal Irrigation Department (Table 4.5).

Table 4.5 Effective roughness parameters for overland flow.

Surface	Manning's N
Dense growth*	0.40-0.50
Pasture*	0.30-0.40
Short grass prairie**	0.10-0.20
Sparse vegetation**	0.05-0.13
Concrete/asphalt vary shallow depths*	0.10-0.15
Concrete/asphalt small depths*	0.05-0.10

* From Crawford and Linsley (1966)

** From Woolhiser (1975)

Source: Bedient and Huber, 1988

The purpose of this simulation is to develop a runoff hydrograph, due to the 10% chance strom, at the outlet of the watershed. The precipitation data are obtained from the Meteorology Department. Precipitation loss factors of rainfall to the soil follows Horton's infiltration capacity theory (Horton,1933). The program allows input of two loss rates: an initial or starting loss rate (STRTL) and a constant loss rate (CNSTL). STRTL dominates the process from the beginning of the storm until some value of basin recharge is reached. The events were mostly nocturnal, evaporation was assumed to be zero. A second loss factor is percent basin impervirousness. The impervious areas have an infiltration rate of zero.

4.5 Determination of flood prone area in Amphoe Muang, Chumphon province.

The results of different flood stage of different return period in Chumphon basin is being used to identify the flood prone area maps under the following procedures.

4.5.1 Delineation the sub-watershed areas.

There are 4 gauging stations in Amphoe Muang, namely, x.158, x.180, x.53, and x.53A. The data obtained from these stations are being used to generate the flood stage time series of return periods of 2-yrs., 5-yrs., 15-yrs., 25-yrs.and 100-yrs.. The watershed areas in the present study are sub divided into 3 sub-watersheds, such as, sub1-watershed of Tha Taphao watershed, sub2- watershed of Tha Taphao watershed, and khlong Chumphon watershed as shown in Figure 4.5. Finally, The flood prone areas are delineated by smoothly connecting the boundary line of sub-watershed areas

4.5.2 The flood storage model (flood cell).

The flood prone areas maps are delineated on the topographic map of the scale 1:50,000 (Figure 4.6) by drawing the boundary line of equal flood stage for different return periods as shown in Figure 4.7.

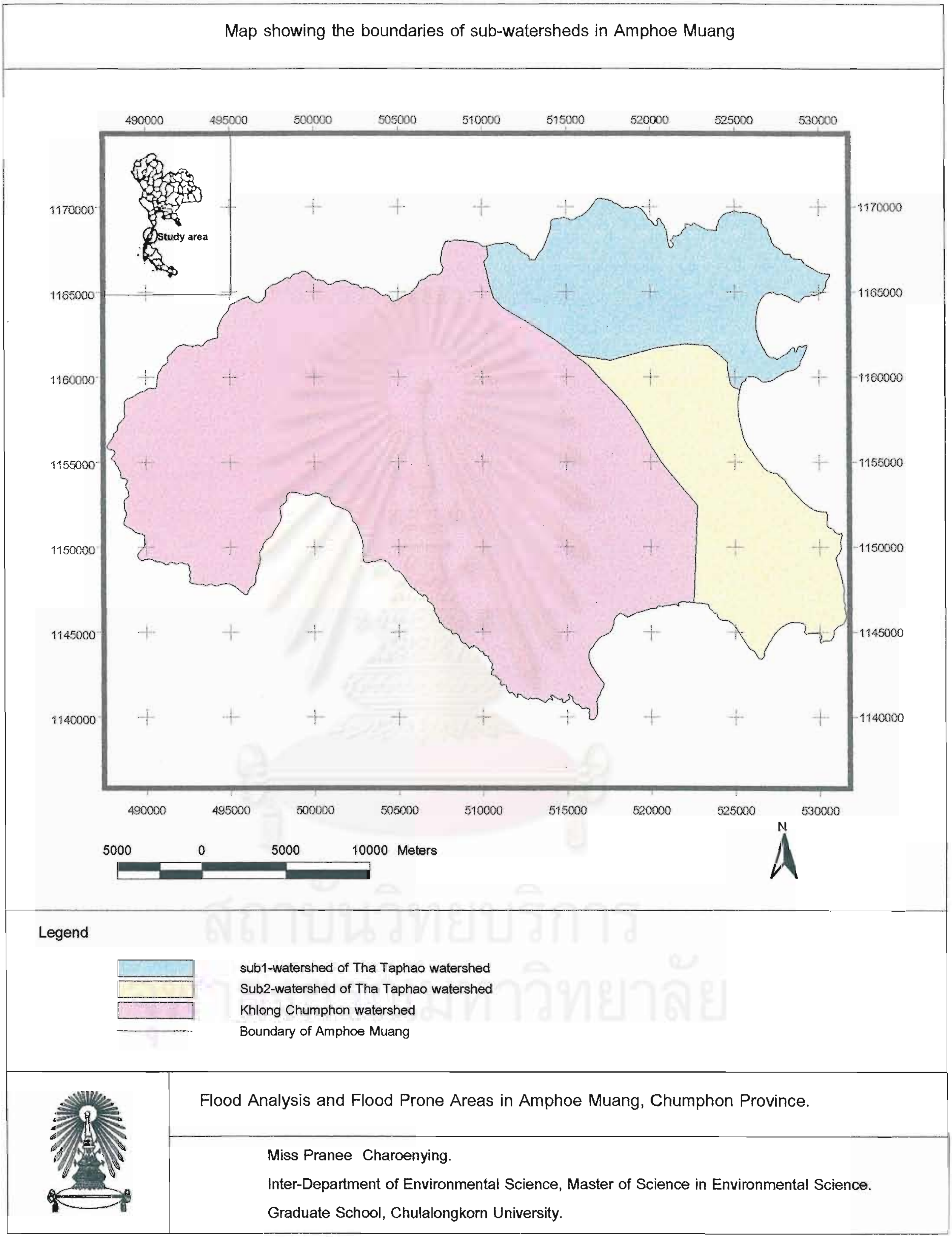
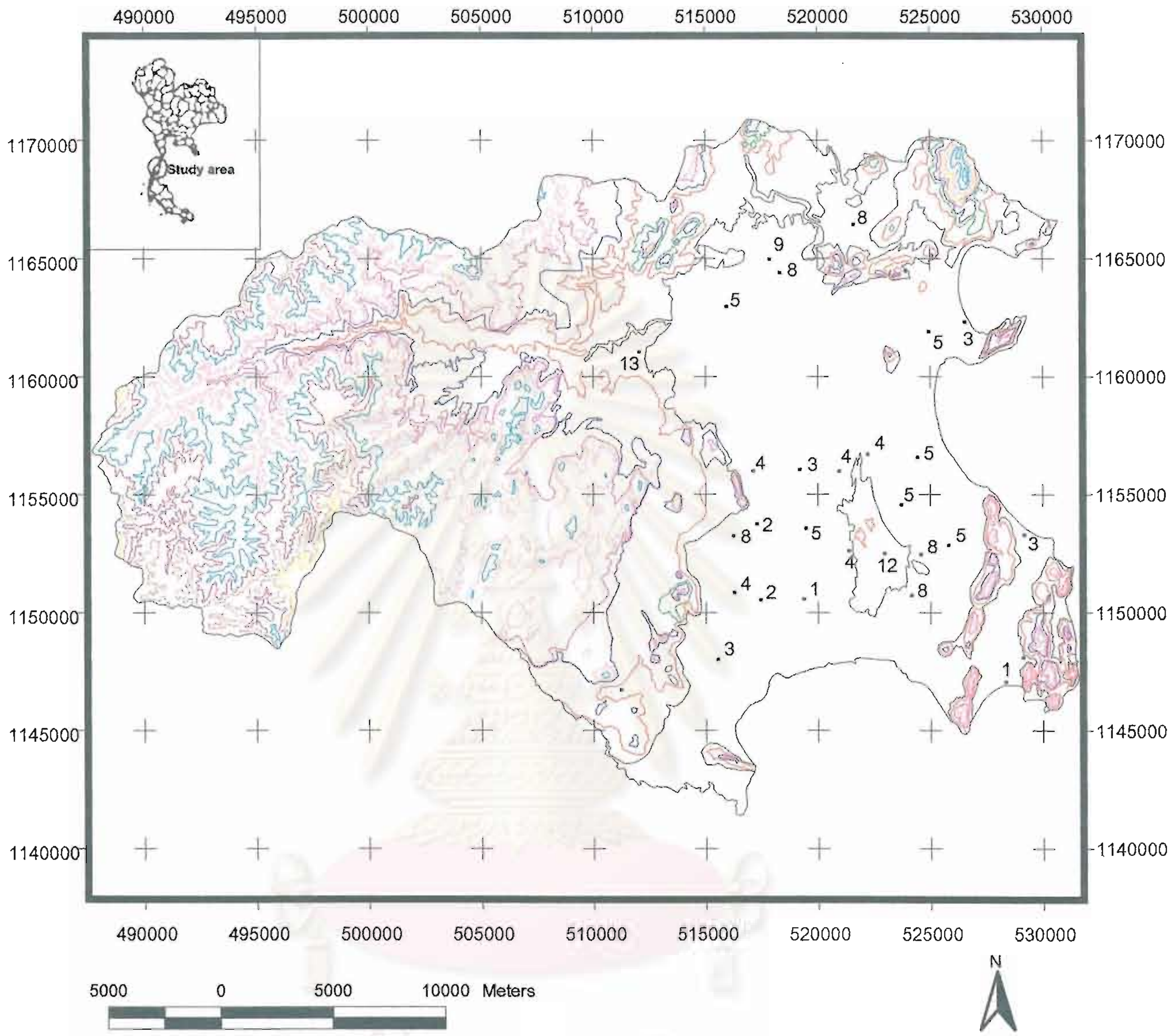


Figure 4.5 The boundaries of sub-watersheds in Amphoe Muang.

Map showing the topographic contour lines and elevation points in Amphoe Muang



Legend

Contour interval

10
20
30
40
50
60
80
100
120
160
200
300
400
500
Boundary of Amphoe Muang
Elevation points

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 4.6 The topographic contour lines and elevation points in Amphoe Muang.

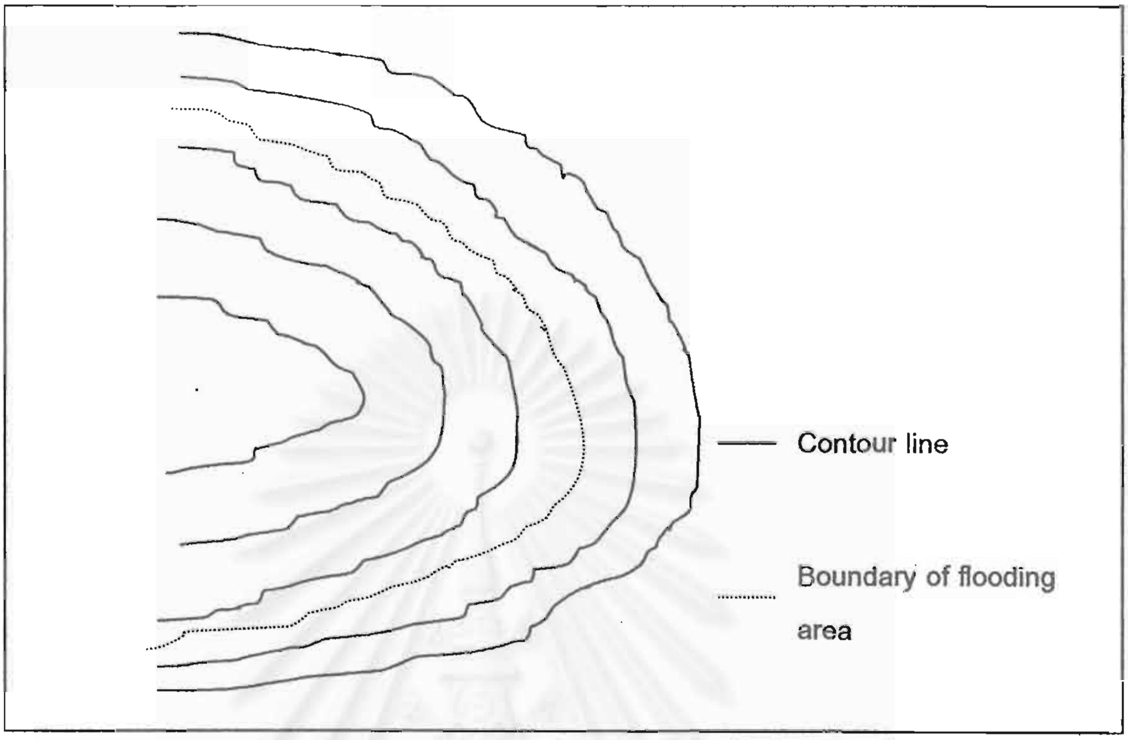


Figure 4.7 Delineation of flood prone area for flood storage model.

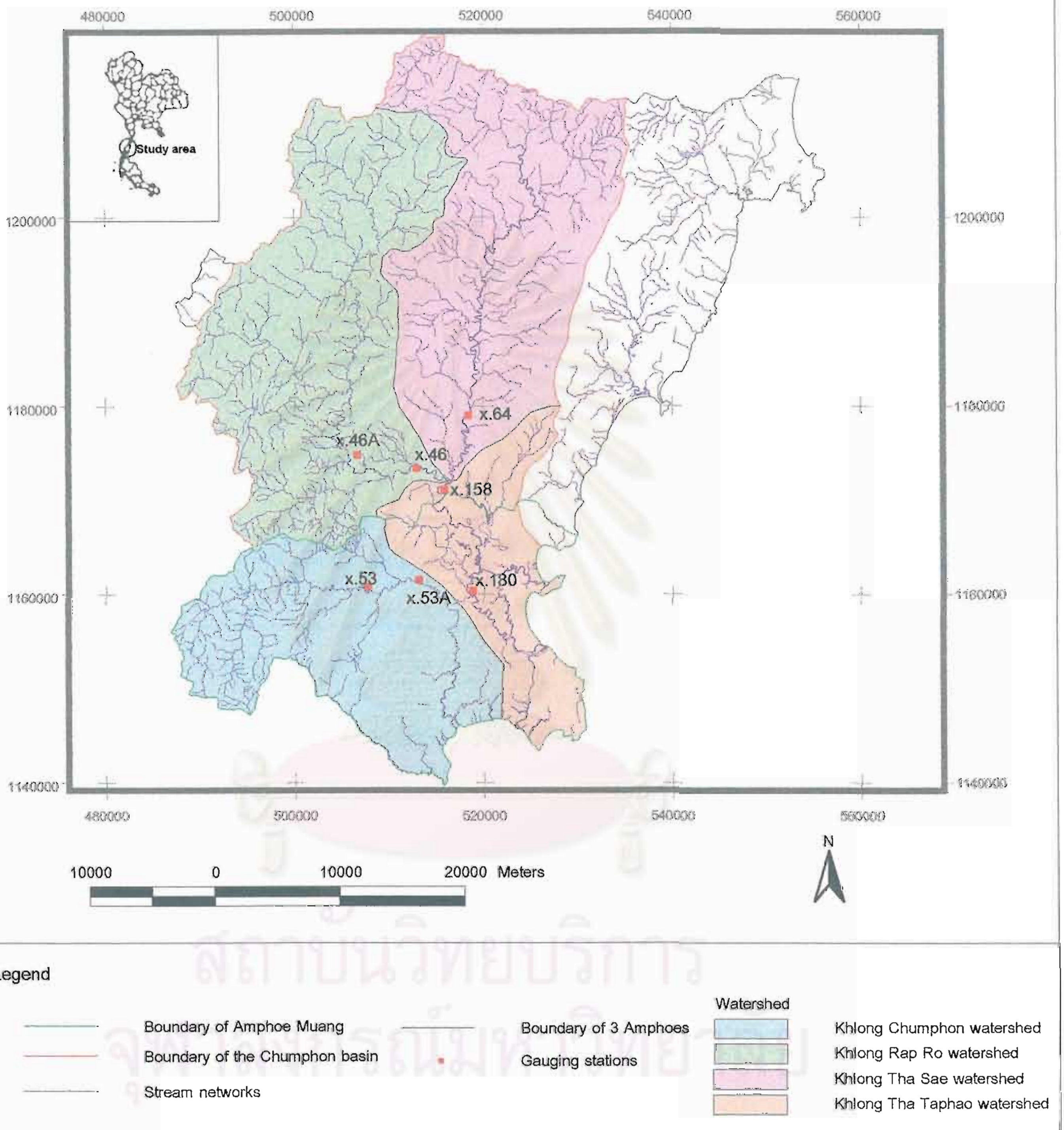
CHAPTER V

FLOOD ANALYSIS OF THE CHUMPHON BASIN

5.1 General characteristics.

The topographic maps of the scale 1:50,000 from The Royal Thai Survey Department map sheet numbers 4729I, 4730I, 4730II, 4829IV, 4830I, 4830II, 4830III, 4830IV, and 4831III are employed in the study. Besides, the stream profile of khlong Tha Taphao and khlong Chumphon in Amphoe Muang, Chumphon province and cross section data at all gauging stations in the Chumphon basin from The Royal Irrigation Department, are also used for delineation of the basin. The location of the Chumphon basin, the boundary of the drainage area of the basin, the surface drainage system, and the gauging stations are shown in Figure 5.1. Altogether 2 stream profiles along the main drainage system in Amphoe Muang are shown in Figure 5.2 and 5.3. The stream profiles of khlong Chumphon is begun at x.53 to x.53A and the stream profiles of khlong Tha Taphao is begun at x.158 to x.180. The 6 gauging stations along the main drainage system in the Chumphon basin, are x.46A, x.46, x.64, x.158, x.180, and x.53. There are recorded cross section profile, namely, 2 points at khlong Rap Ro (x.46A and x.46), 1 point at khlong Tha Sae (x.64), 2 points at khlong Tha Taphao (x.158 and x.180) and another 1 point at khlong Chumphon as illustrated in Figures 5.4 to 5.9.

Map showing the boundary of the Chumphon basin, the watersheds, stream networks, and gauging stations



Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.

Inter-Department of Environmental Science, Master of Science in Environmental Science.

Graduate School, Chulalongkorn University.

Figure 5.1 The boundary of the Chumphon basin, the watersheds, stream networks, and gauging stations.

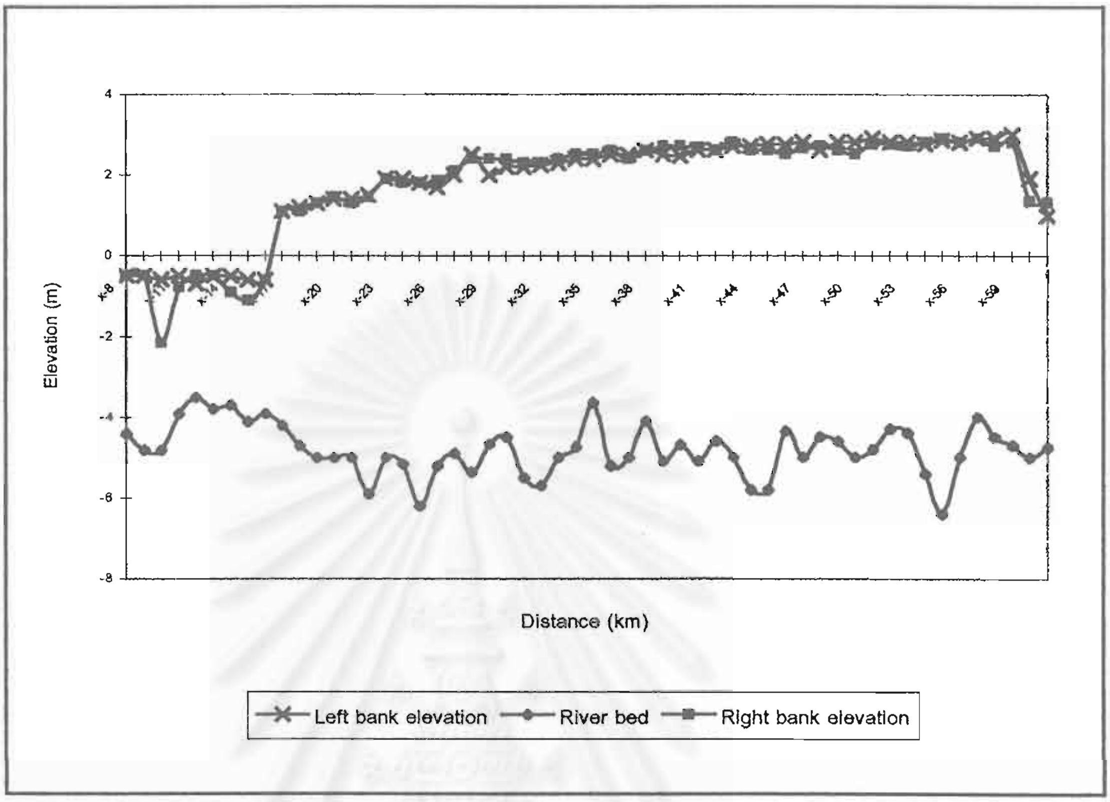


Figure 5.2 The stream profile of khlong Chumphon in 1991.

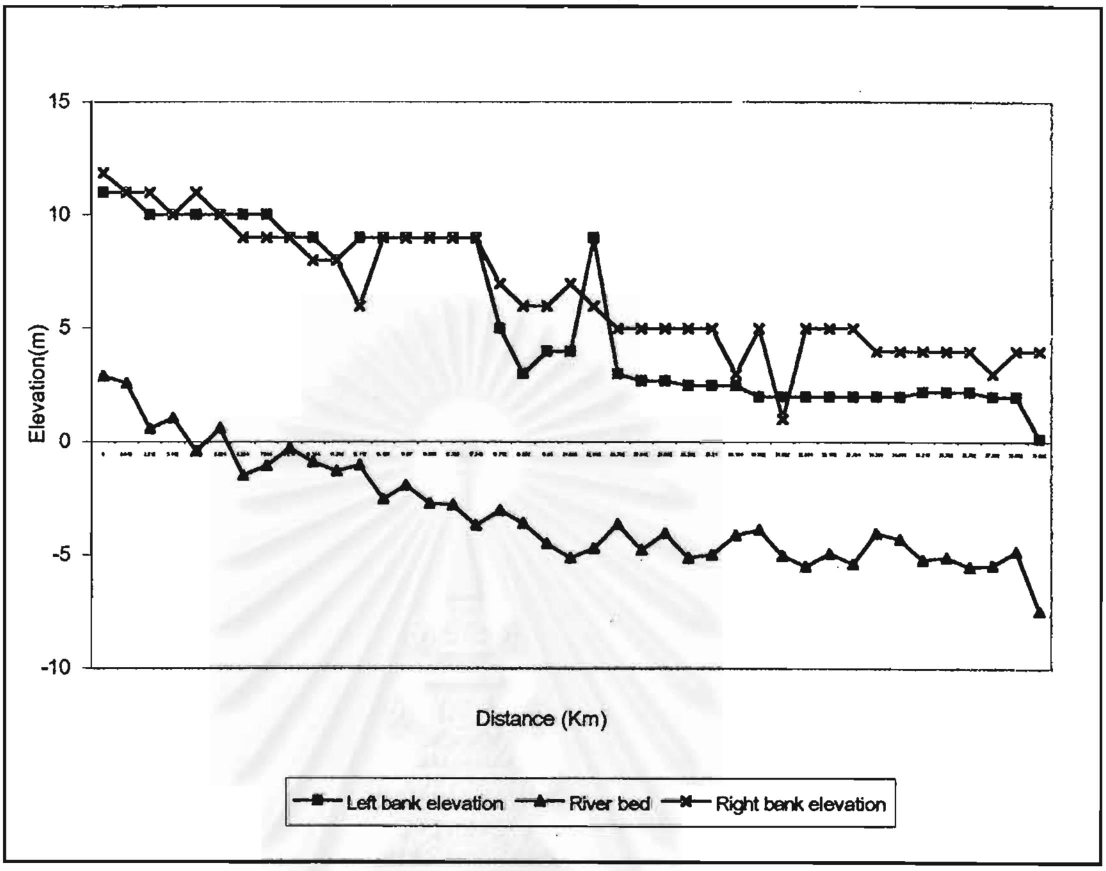


Figure 5.3 The stream profile of khlong Tha Taphao in 1991.

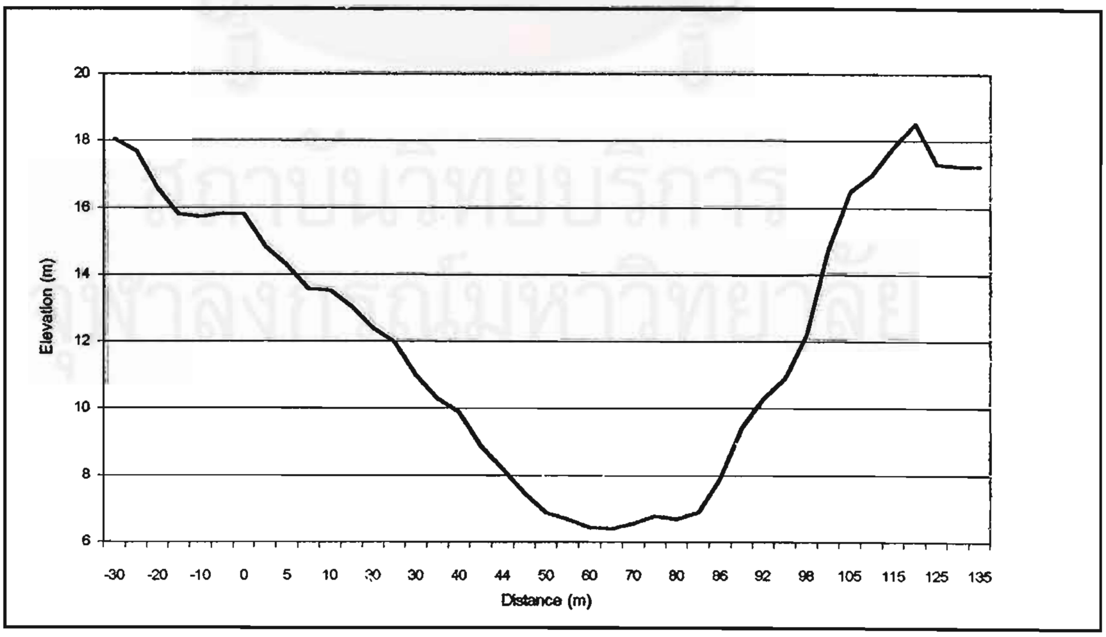


Figure 5.4 Cross section profile at x.46A of Khlong Rap Ro in 1997.

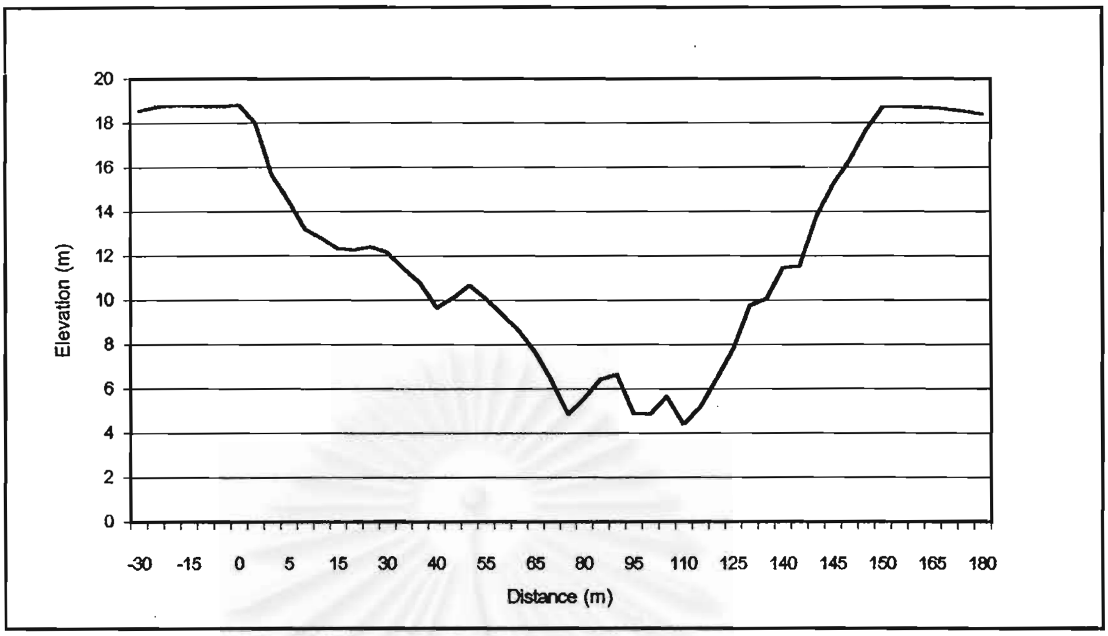


Figure 5.5 Cross section profile at x.46 of Khlong Rap Ro in 1997.

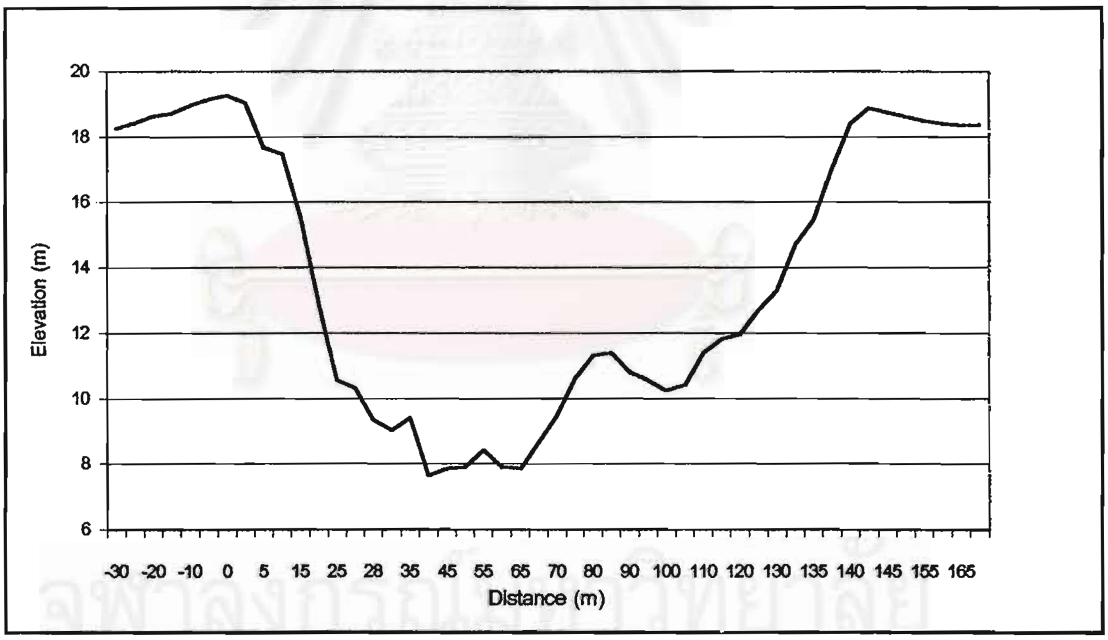


Figure 5.6 Cross section profile at x.64 of Khlong Tha Sae in 1997.

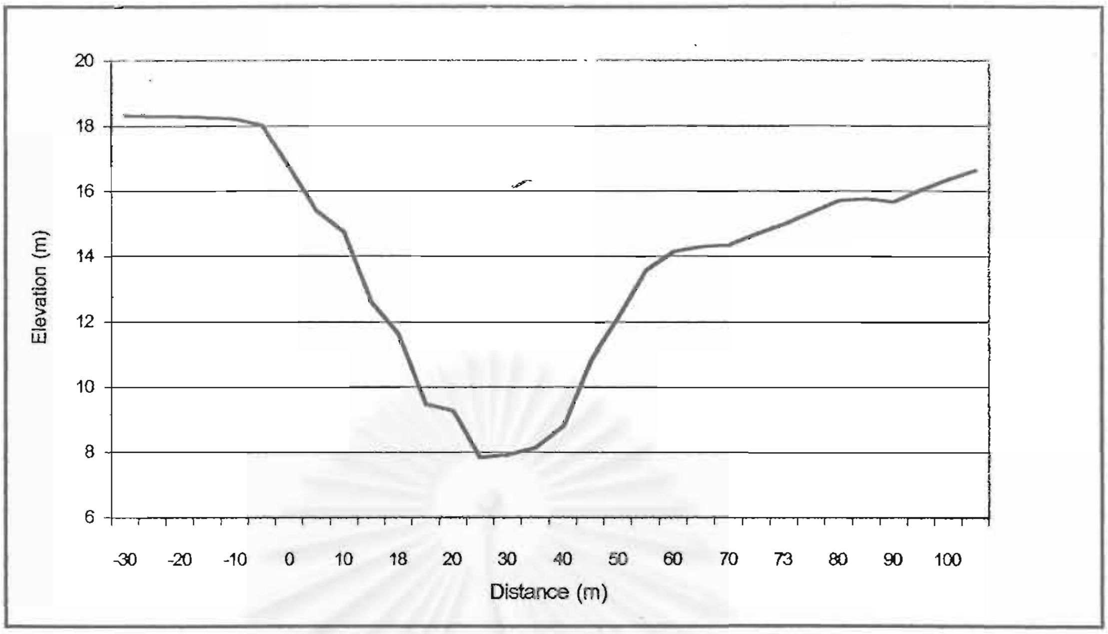


Figure 5.7 Cross section profile at x.53 of Khlong Chumphon in 1997.

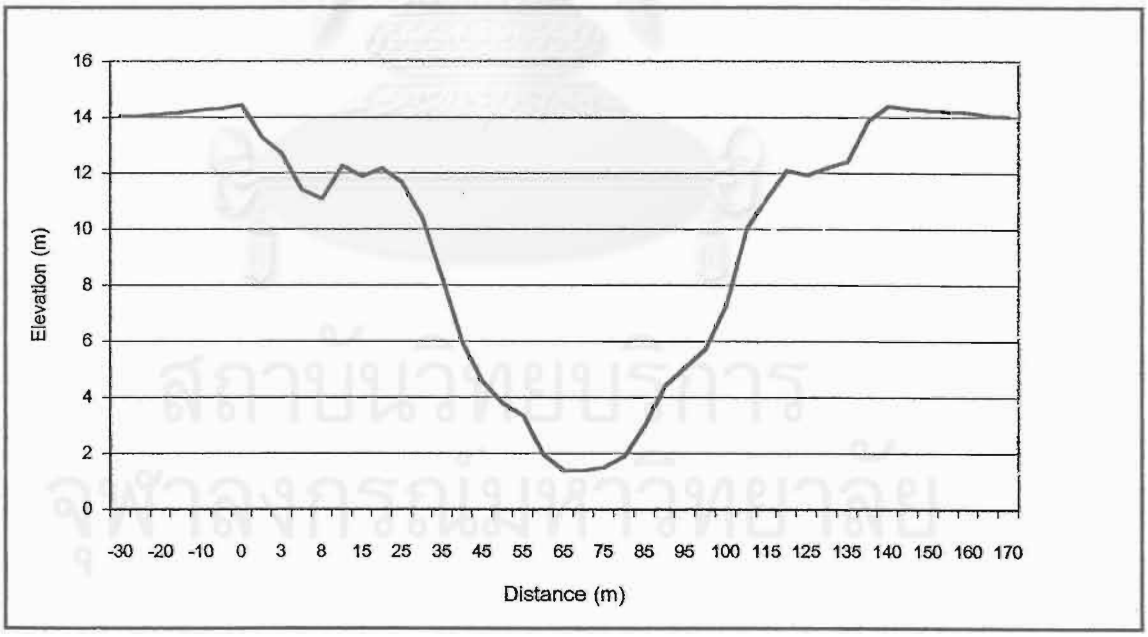


Figure 5.8 Cross section profile at x.158 of Khlong Tha Taphao in 1997.

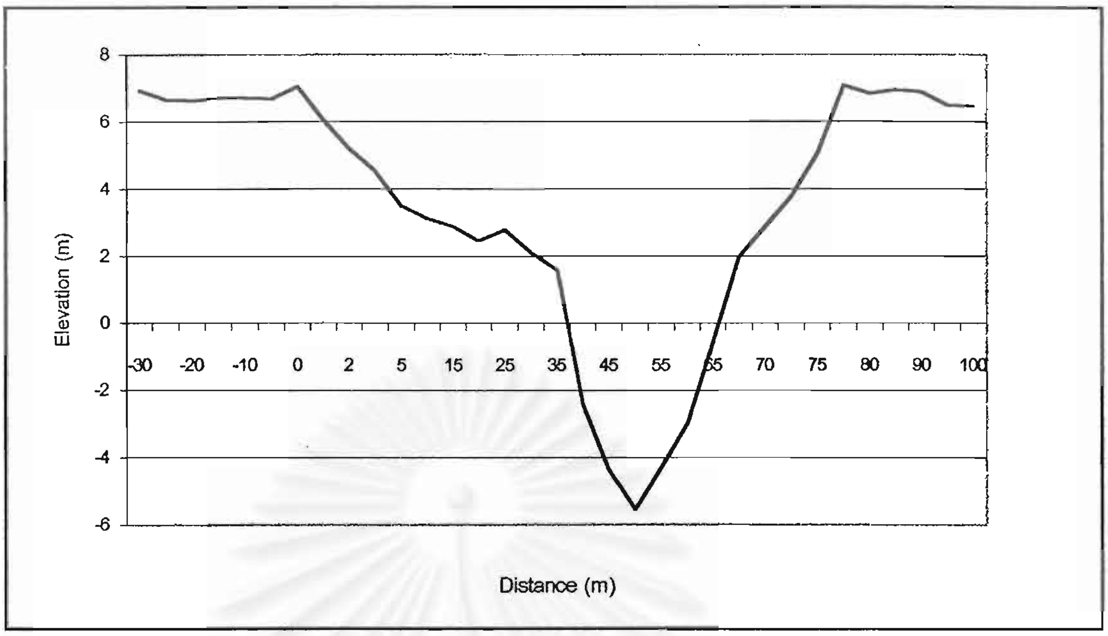


Figure 5.9 Cross section profile at x.180 of Khlong Tha Taphao in 1997.

5.2 The overview of flood in Chumphon basin.

The statistical records, namely, number of storms, number of industrial factories, forest area, number of population, runoff, rainfall, paddy field area, crop area, orchard area, water level or stage, and flooding during 1976-1995 are employed in the flood statistic analysis. They are used for determinaion of several flooding factors using the multiple regression and correlation's equations. The results are summarised in Table 5.1.

Table 5.1 Summary of coefficient of variable correlations.

	A	B	C	D	E	F	G	H	I	J	K
A	1.000										
B	.400	1.000									
C	.490*	.183	1.000								
D	-.036	.067	-.846**	1.000							
E	.181	-.221	.369	-.404	1.000						
F	.327	.115	.970**	-.918**	.370	1.000					
G	-.663**	-.305	-.881**	.571**	-.347	-.789**	1.000				
H	.327	-.013	-.106	.216	.159	-.170	-.063	1.000			
I	.114	.720**	.227	-.175	-.145	.220	-.299	-.076	1.000		
J	-.308	-.429	-.084	-.233	.397	-.016	.172	-.001	-.219	1.000	
K	.176	.744**	-.072	.301	-.304	-.127	-.081	.059	.361	-.395	1.000

Remarks:

* Coefficient of correlations at 0.05 significance

** Coefficient of correlations at 0.01 significance

A = Crop land. B = Flooding.

C = Orchard land. D = Forest land.

E = Number of industrial factories. F = Number of population.

G = Paddy land. H = Rainfall.

I = Runoff. J = Number of storms.

K = Water level or stage.

It is observed that the statistical records of floods in the Chumphon basin during 1971 to 1997 revealing the increasing in both frequency and magnitude. Mean annual rainfall and water level, and flooding in the basin are given in Table 5.2.

Table 5.2 Mean annual rainfall and runoff, and flooding in the Chumphon basin.

Year	Mean annual rainfall (mm.)			Mean annual water level (m, MSL)					Remarks
	517006	517001	517201	x.64	x.158	x.46	x.53A	x.180	
1971	n.a.	n.a.	4.69	n.a.	n.a.	n.a.	2.21	n.a.	Flood stage 0.7 m.
1972	n.a.	n.a.	5.71	n.a.	n.a.	n.a.	2.47	n.a.	-
1973	n.a.	n.a.	5.46	9.35	n.a.	n.a.	2.51	n.a.	-
1974	n.a.	n.a.	5.09	9.25	n.a.	n.a.	2.69	n.a.	-
1975	3.81	6.10	7.02	9.52	n.a	n.a.	2.64	n.a	-
1976	2.73	3.97	4.06	9.20	n.a.	8.24	2.76	n.a.	Flood stage 1.0 m.
1977	2.38	4.84	6.24	8.97	n.a.	9.87	2.51	n.a.	-
1978	4.07	5.66	6.16	9.28	n.a.	8.66	2.62	n.a.	-
1979	2.59	6.29	4.38	9.04	n.a.	8.53	2.49	n.a.	Flood
1980	3.01	5.45	4.91	8.89	n.a.	8.57	2.59	n.a.	Flood
1981	3.32	5.45	5.22	9.00	n.a.	8.55	2.56	n.a.	Flood
1982	3.95	4.90	7.15	9.04	n.a.	5.55	2.49	n.a.	
1983	1.81	3.51	3.78	8.74	n.a.	8.38	2.41	n.a.	
1984	2.73	2.31	4.63	8.80	n.a.	8.53	2.36	n.a.	
1985	3.94	4.62	5.17	8.86	n.a.	8.12	2.45	n.a.	Flood
1986	3.23	2.39	4.77	9.08	n.a.	8.31	2.58	n.a.	Flood
1987	3.41	2.73	3.67	8.75	n.a.	7.94	2.25	n.a.	
1988	3.64	3.44	3.58	8.95	n.a.	8.23	2.57	n.a.	Flood
1989	4.00	4.45	5.87	n.a.	n.a.	8.55	n.a.	n.a.	Flood
1990	2.62	2.79	4.02	8.71	4.81	8.35	2.52	n.a.	Flood
1991	3.96	4.17	4.67	8.86	4.80	8.27	2.88	n.a.	Flood
1992	2.13	3.79	3.83	8.71	4.47	8.06	2.48	n.a.	Flood
1993	2.75	3.92	4.32	8.64	4.48	8.17	n.a.	5.30	Flood
1994	3.44	4.92	5.41	8.85	4.71	8.38	4.44	1.91	Flood
1995	4.10	5.42	5.03	8.78	4.38	7.93	4.20	1.64	Flood stage 5.25 m.(MSL)
1996	6.15	6.54	5.60	9.3	4.76	8.13	3.03	3.42	Flood stage 5.36 m.(MSL)
1997	5.28	5.76	5.88	8.94	4.29	7.70	3.07	n.a.	Flood stage 6.62 m.(MSL)

Source: The Royal Irrigation Department and the Meteorological Department.

Naturally, the flood in this basin is primarily caused by heavy rainfall of tropical storm during the monsoon season during the months of August to November. However, the tropical storm tracks in the past have not regularly passed through the drainage area of the Chumphon basin. Therefore, the flood frequency is basically closely related to frequency of rainstorm within the drainage area.

With regard to the duration of rainfall in the drainage area and magnitude of the flood, which is directly related to the stream discharge or water level in the stream channel, it is indirectly depending upon numerous factors, namely, forest land, urbanization and population, industrialization, agricultural pattern, etc. Deforestation in the drainage area for logging and for expanding agricultural area not only promote the increase volume of stream discharge after heavy rainfall, but also shortening the lag time between peak rainfall and peak flood. Changing of forest land in 3 Amphoes of the basin is shown in Figure 5.10.

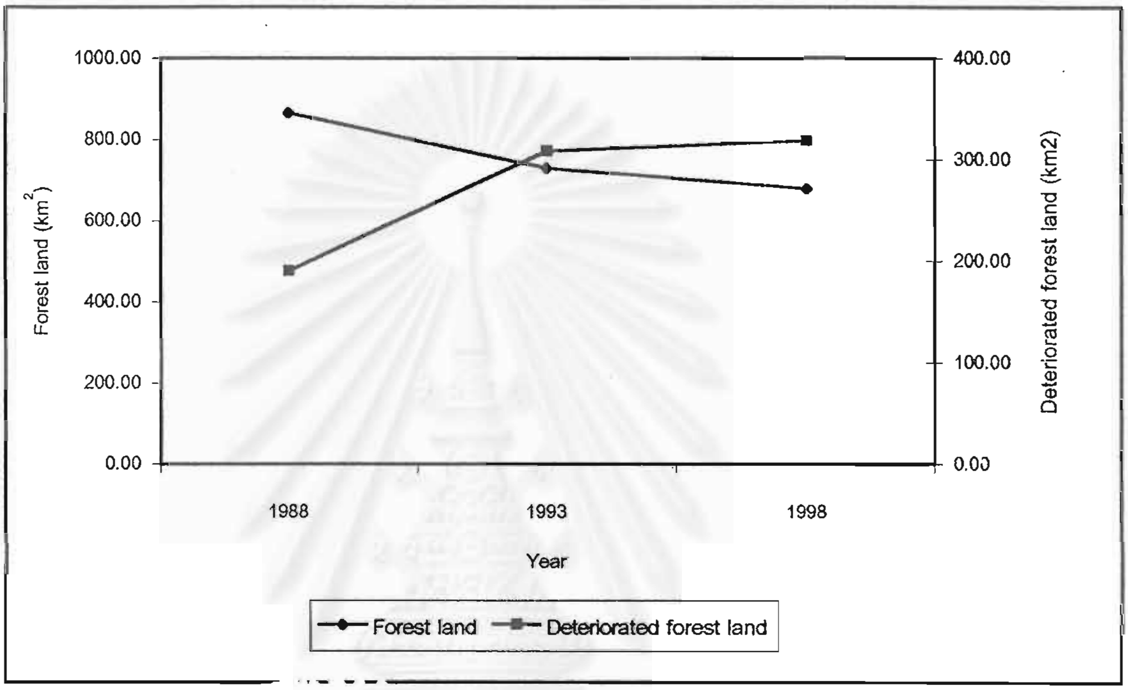


Figure 5.10 Forest area in 3 Amphoes of the Chumphon basin in 1988, 1993, and 1998.

The population increase and urbanization in 3 Amphoes, namely, Amphoe Pathui, Amphoe Tha Sae, and Amphoe Muang recently have decreased the infiltration of rainwater and consequently caused increasing flood magnitude in the downstream area of Amphoe Muang. The poppulation and population density in 3 Amphoes of the Chumphon basin are shown in Figure 5.11.

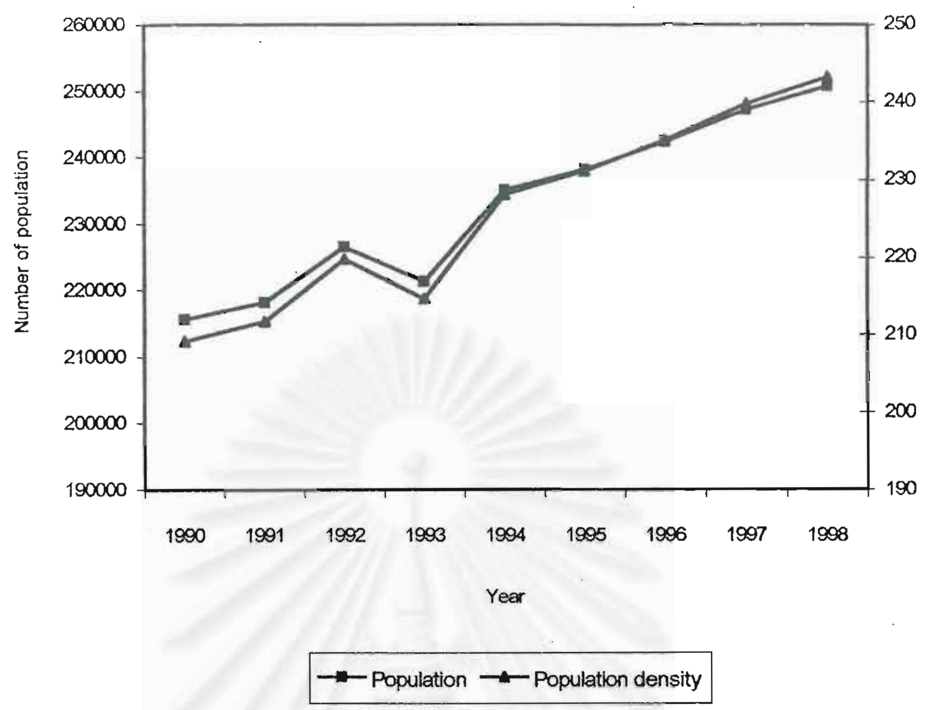


Figure 5.11 The population and population density in 3 Amphoes of the Chumphon basin during 1990 to 1998.

5.3 Rainfall and flood frequency analysis.

In the present study, the maximum annual rainfall records from 7 rainfall stations (Table 4.1) within the Chumphon basin have been employed in the rainfall frequency analysis. (Figure 5.12)

The rainfall frequency analysis has been carried out using the method of moment of parameter estimation for Gumbel Probability Distribution. Extreme values selected are maximum values of data set. The observed annual maximum daily rainfall values for each year make up a set of extreme values that can be analysed statistically. Rainfall return period of 2, 5, 15, 25, and 100 years estimated from Gumbel Probability Distribution of the local stations within the basin are shown in Table 5.3.

Table 5.3 Maximum annual rainfall for return period of 2, 5, 15, 25 and 100 years using Gumbel Probability Distribution.

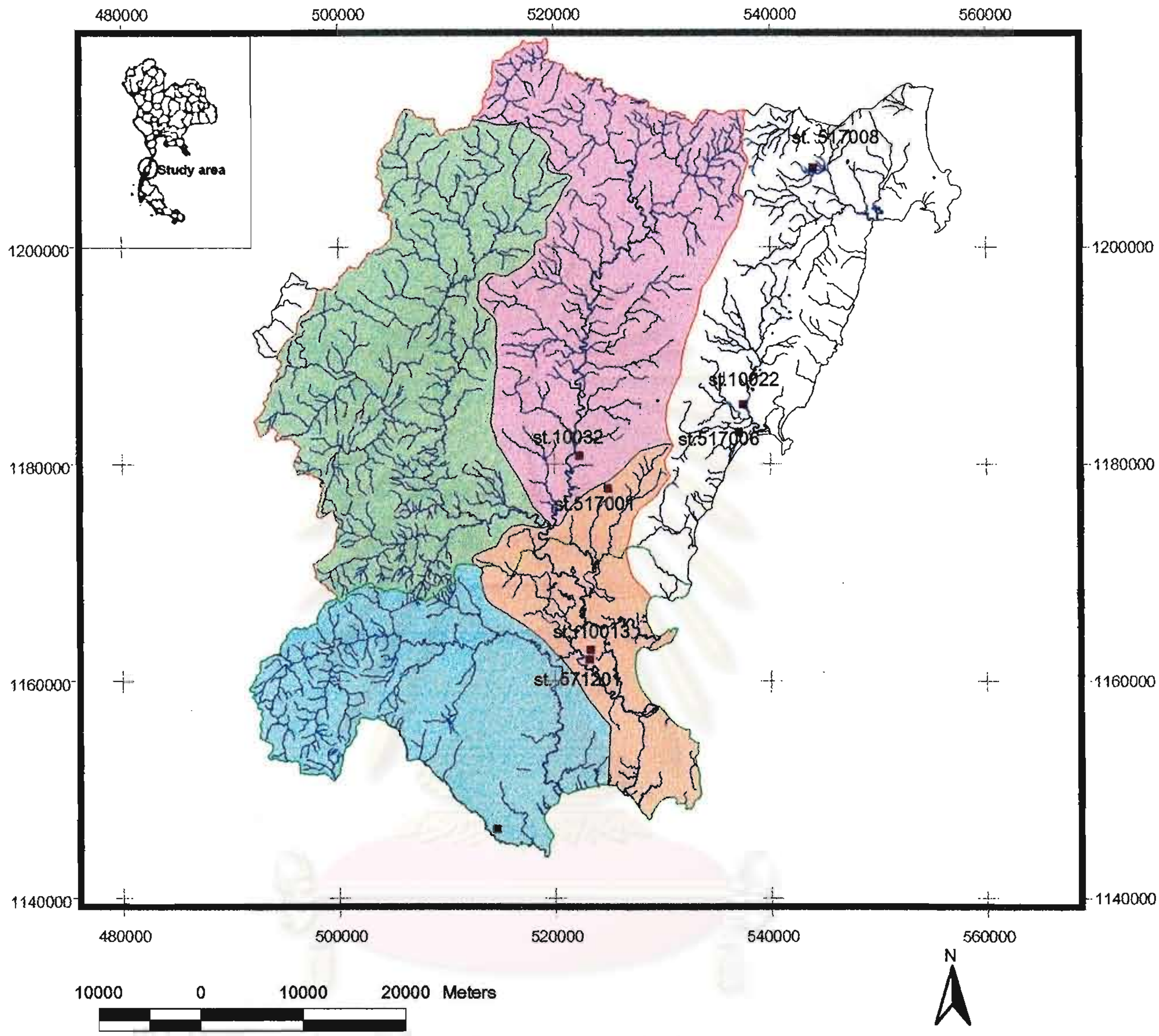
St. no.	St. code	Rainfall for return periods of (mm.)				
		2 yrs.	5 yrs.	15 yrs.	25 yrs.	100 yrs.
1	10013	108.95	144.54	181.40	197.88	241.89
2	10022	118.75	180.21	243.87	272.33	348.33
3	10032	105.45	154.10	204.48	227.01	287.17
4	517001	120.12	180.09	258.49	289.96	374.03
5	517006	141.92	192.37	244.62	267.97	330.36
6	517008	147.12	225.78	307.25	343.67	440.94
7	517201	118.72	196.02	276.07	311.86	407.45

The rainfall frequency analysis in terms of different rainfall return periods of 2, 5, 15, 25, and 100 years are further used in the evaluation of scale or magnitude of flooding of the Chumphon basin. It is apparent that the scale or magnitude of flooding depending upon the discharge or stage of the drainage system within the basin, where as the discharge or stage is mainly the consequence of rainfall within the cacthment area of that drainage system.

Under the present study. Altogether the stage records from 4 gauging stations (Table 4.2) are being used for the flood frequency analysis. (Figure 5.1) The records of maximum water level or maximum stage have been used in the flood frequency analysis of the Chumphon basin. The stage is simply the hydrological term for the height of the water surface of a stream or lake or other body of water above a reference surface or datum plane. In this study, the mean sea level is used as the datum plane.

The dimensionless time series water level or stage are used to derive the synthetic time series water level for the designed of 2, 5, 15, 25 and 100 years return periods using the probability weighted moment method of parameter estimation for Gumbel Probability Distribution of the 4 local gauging stations within the basin, namely, x.158, x.180, x.53, and x.53A. Extreme values selected are maximum values of data set. The water level or stage for the return periods of 2, 5, 15, 25 and 100 years estimated from Gumbel Probability Distribution of the 4 local stations in the Chumphon basin are shown in Table 5.4.

Map showing the boundaries of the Chumphon basin, the watersheds, stream networks, and rainfall stations.



Legend

Boundary of Amphoe Muang
Boundary of the Chumphon basin
Stream networks
Boundary of 3 Amphoes
Rainfall stations

Watershed
Khlong Chumphon watershed
Khlong Rap Ro watershed
Khlong Tha Sae watershed
Khlong Tha Taphao watershed

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 5.12 The boundary of the Chumphon basin, the watersheds, stream networks, rainfall stations.

Table 5.4 Maximum water level or maximum stage for the return period of 2, 5, 15, 25 and 100 years of the Chumphon basin.

St. no.	St. code	Water level for different return periods (m. , MSL)				
		2 yrs.	5 yrs.	15 yrs.	25 yrs.	100 yrs.
1	X. 158	10.486	12.204	13.983	14.779	16.904
2	X. 53*	5.718	7.554	9.456	10.306	12.576
3	X. 180**	3.999	4.882	5.797	6.206	7.298

Remarks: * Combination of water level or stage recorded from x.53 and x.53A.

** Calculation of water level or stage at x.180 using linear regression analysis between x.158 and x.180 existing data.

The water level or stage for the return periods of 2, 5, 15, 25 and 100 years estimated from Gumbel Probability Distribution of the 4 local stations in Amphoe Muang will be indicated the flood prone areas by drawing the boundaries which is equal to the flood stage for different return periods on the topographic contour map in each sub-watershed.

5.4 The results of HEC-1 model.

The calibration is accomplished by running HEC-1 with data from historical storm events and comparing the resulting synthetic hydrographs against hydrographs obtained from gauged sites. The parameters are adjusted and the computation repeated until a suitable fit between the two hydrographs is obtained.

HEC-1 successfully modeled the two features of most important to us, namely, peak flow and lag time. Model results are equally good of parameters.(Table 5.5)

Table 5.5 Comparison of computed and observed hydrographs.

	Sum of flow (ft^3)	Equiv. Depth(in.)	Mean flow (ft^3/sec.)	Time to center of max (h)	Lag cme to cmu (h)	Peak flow (ft^3/sec.)	Time to peak (h)
Precipitation excess		3.958		36.00			
Computed hydrograph	340573	2.646	7568	77.16	41.16	15749	36.0
Observed hydrograph	198794	2.646	7568	77.99	41.99	12217	36.0
Difference	0	0	0	-0.84	-0.84	3532	0
Percent difference	0				-1.99	28.91	

The calibration results of optimization parameters as follows:

Clark unit hydrograph parameters $T_c = 3.41$ R = 91.35

Synder standard unitgraph parameters $T_p = 5.50$ $C_p = 0.06$

Lag from center of mass of rainfall (cme)

Excess to center of mass of unitgraph (cmu) 90.60 h.

Unitgraph peak 3975 ft^3/sec.

Time of peak 6.00 h.

Exponential loss rate parameters: STRKR 2.21

DLTKR 5.71

RTIOL 1.00

ERAIN 0.50

Table 5.6 Summary of results of HEC-1 modeling of storm events in November, 1995 in the study areas.

Study area	Peak flow (ft^3/sec.)	Time of flow (h.)	Runoff depth (in.)
Sub1	3357.33	33	0.57
Sub2	2126.97	36	0.55
Sub3	34600.94	12	0.98
Sub4	13082.32	21	0.98

Table 5.7 Summary of results of HEC-1 modeling of storm events in August, 1997 in the study areas.

Study area	Peak flow (ft^3/sec.)	Time of flow (h.)	Runoff depth (in.)
Sub1	3673.09	32	0.61
Sub2	2311.05	37	0.59
Sub3	35430.23	12	1.01
Sub4	14813.51	19	1.01

The peak discharge of a flood event indicates its magnitude. The greater the peak the stronger the potential of the event to inflict damage. In August, 1997 produced the largest peak flow. The peak flow of SUB 3 is highest followed by the SUB 4. It follows that inundation should be deeper in SUB 3 than SUB 4, covering the Tha Taphao watershed, located in Amphoe Muang, Chumphon province. The lag time for the various flood events are shortest lag time belongs to SUB 3, this is followed by that of SUB 4. The premier storm event had the longest lag time. Thus, in terms of suddenness, residents of SUB 3 had the shortest period in which to react to their flood.

5.5 Flood prone area.

The flood problems particularly in the area of Amphoe Muang, Chumphon province is essentially caused by the overbank flow of the khlong Chumphon and khlong Tha Taphao during the high-flow period of the year. The discharge or stage of khlong Chumphon depends on the rainfall in the khlong Chumphon watershed area of approximately 540 square kilometres in the western and central parts of Amphoe Muang. Besides, the discharge or stage of khlong Tha Taphao depending upon the combination of discharges or stages of khlong Rap Ro and khlong Tha Sae under the influence of rainfall in the Tha Taphao watershed area of approximately 1700 square kilimetres. The Tha Taphao watershed covers the area of Amphoe Tha Sae, some parts of Amphoe Pathiu , and the eastern part of Amphoe Muang.

The critical stages of the khlong Tha Taphao and khlong Chumphon at 4 gauging stations are shown in Table 5.8. This means that any increase discharge over this critical stage will be seen as a rise in stage marked by spill over of the water onto the land adjacent to the channel (Figure 5.13).

The past 27 year records of floods in Amphoe Muang, Chumphon province between 1971-1997 have revealed that there are altogether 17 floods of different magnitudes and frequencies. However, there seems to be an increasing trend of scale or magnitude of floods. The year of floods and flood stages are summarized and presented in Table 5.2.

Table 5.8 Summarized the critical stages at 4 gauging stations and maximum capacity in Amphoe Muang, Chumphon province.

Name of stream	Gauging stations	Critical stages (m,MSL)	Maximum capacity (m^3/sec.)
Khlong Chumphon	x.53	14.00	n.a.
	x.53A	8.00	211
Khlong Tha Taphao	x.158	9.50	800
	x.180	3.40	254

Source: The Royal Irrigation Department.

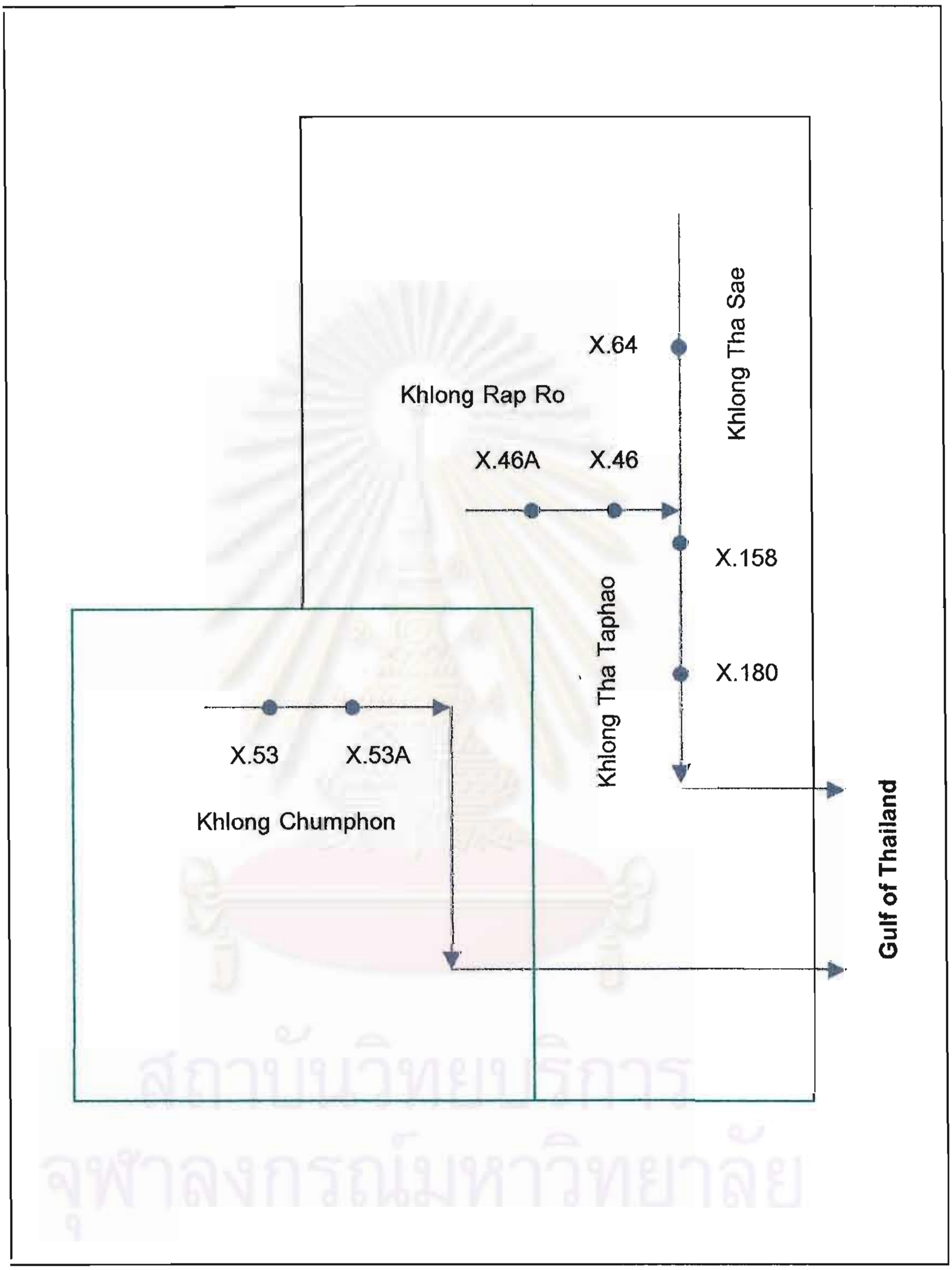


Figure 5.13 Schematic drawing of the flood analysis of Amphoe Muang, Chumphon province.

The maximum water levels at each gauging station are obtained from the Gumbel Probability Distribution for various designed flood events earlier outlined. The flooding boundary of each designed flood event is closed by comparison between the maximum water levels and the elevation contour lines on the topographic map. The boundary of the inundation areas of each sub-catchment area are finally connected. Figures 5.14 – 5.18 show the flood prone areas of various designed flood events, notables, 2, 5, 15, 25, and 100 years return periods. The flood prone areas for various designed flood events are given in Table 5.9.

The flood prone areas in the eastern part of khlong Tha Taphao of different return periods have occupied less area than the flood prone areas in the western part of khlong Tha Taphao. The location of flood prone areas of different of return periods cover numerous Tumbons of Hat Phan Ktar, Bang Luk, Na Cha-ang, Wang Mai, Wang Phai, Na Thung, Tha Taohao, Ban Na, Khun Krathing, Tak Daet, Bang Mak, Tha Yang, Pak Num, Thung Kha, Visai Nua and Hat Sai Ree in Amphoe Muang. Therefore, the results indicate that the large part of flood prone areas are in the western part of khlong Tha Taphao. The flood prone areas of various designed flood events, namely, 2, 5, 15, 25, and 100 years return periods cover 184, 212, 244, 253, and 269 km^2 or 23.19%, 26.66%, 30.74%, 31.89%, and 33.92% of the total area of Apmhoe Muang, respectively.

The flood hazard degree is delineated using the principles of the definition of flood hazard degree from several study areas in Geotechnical Engineering Investigation Manual (Hunt, 1984). The flood hazard degree is defined into the 4 following levels under the present study:

1. Very low hazard flooding: the return period of the probability of the flood is 2 years. The flood prone area is about 184 km^2.

2. Low hazard flooding: the return period of the probability of the flood is 5 years. The flood prone area is about 212 km^2.

3. Moderate hazard flooding: the return period of the probability of the flood are 15 and 25 years. The flood prone areas are about 244 km^2 and 253 km^2, respectively.

4. Very high hazard flooding: the return period of the probability of the flood is 100 years. The flood prone area is about 269 km^2.

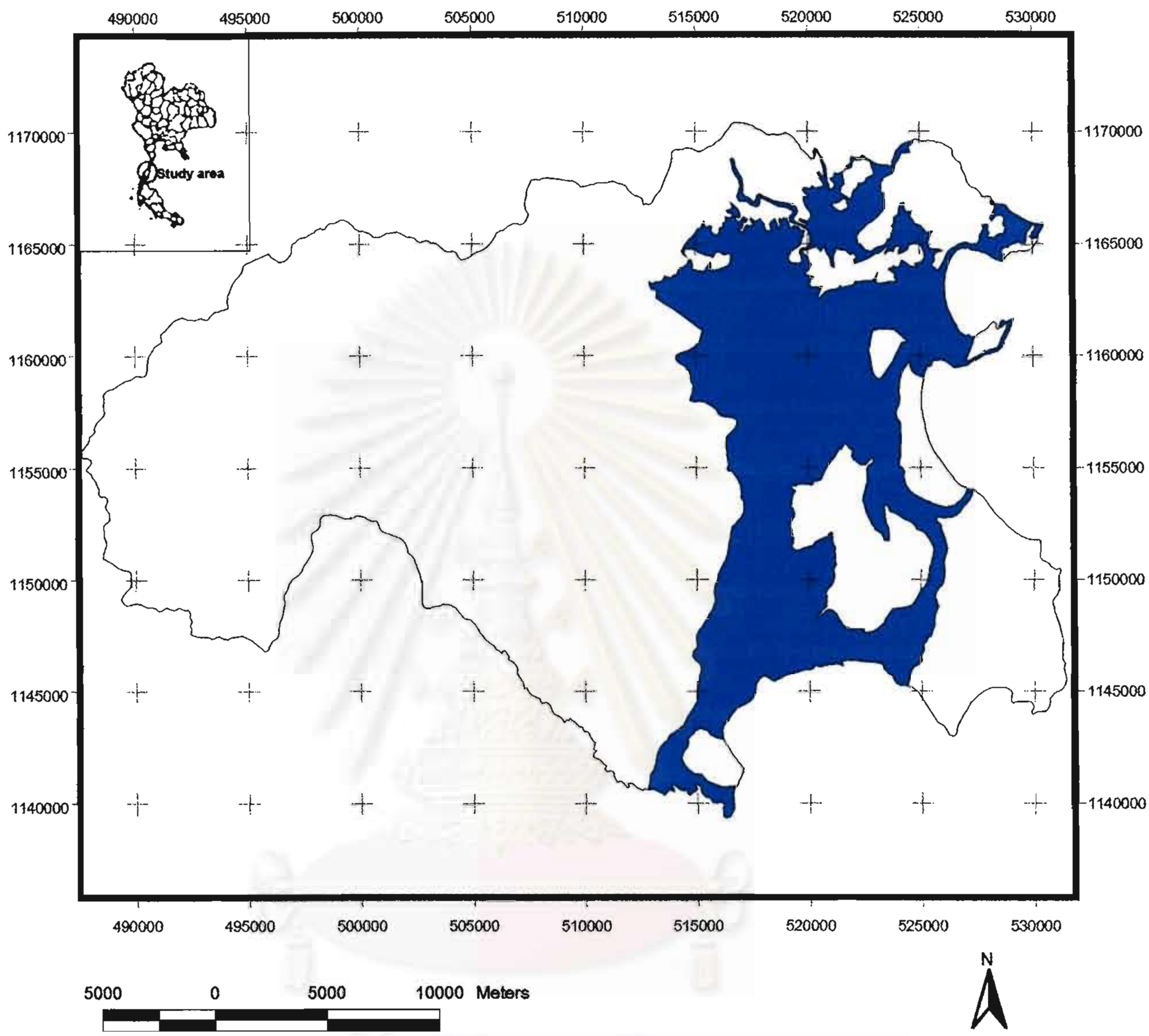
The areas adjacent to the khlong Tha Taphao and khlong Chumphon in the eastern part of Amphoe Muang, is generally low land of undulating terrain and flood plain. This eartern part of Amphoe Muang is also very important built-up area and agriculture land. Therefore, the flood damages in the area, both lives and properties are exceedingly high.

Table 5.9. Flood return periods, flood prone areas, and flood prone areas in the eastern and the western part as divided by the khlong Tha Taphao in Amphoe Muang, Chumphon province.

Flood return periods (years)	Flood prone areas (km^2)	Flood prone areas (%)	Flood prone areas as divided by the khlong Tha Taphao (km^2)	
			The eastern part	The western part
2	184.104	23.187	59.832	124.272
5	211.667	26.658	64.866	146.800
15	244.040	30.736	69.828	174.209
25	253.190	31.888	73.797	179.391
100	269.358	33.924	78.390	190.965

It is regarded that the flood analysis of khlong Chumphon and khlong Tha Taphao particularly in Amphoe Muang, Chumphon province including the preparation of the flood prone maps of different return periods are critically important. Against the background of the present study, numerous preventive and remedial measures as well as appropriate warning system can be accordingly formulated.

Map showing the flood prone area of 2 years return period



Legend

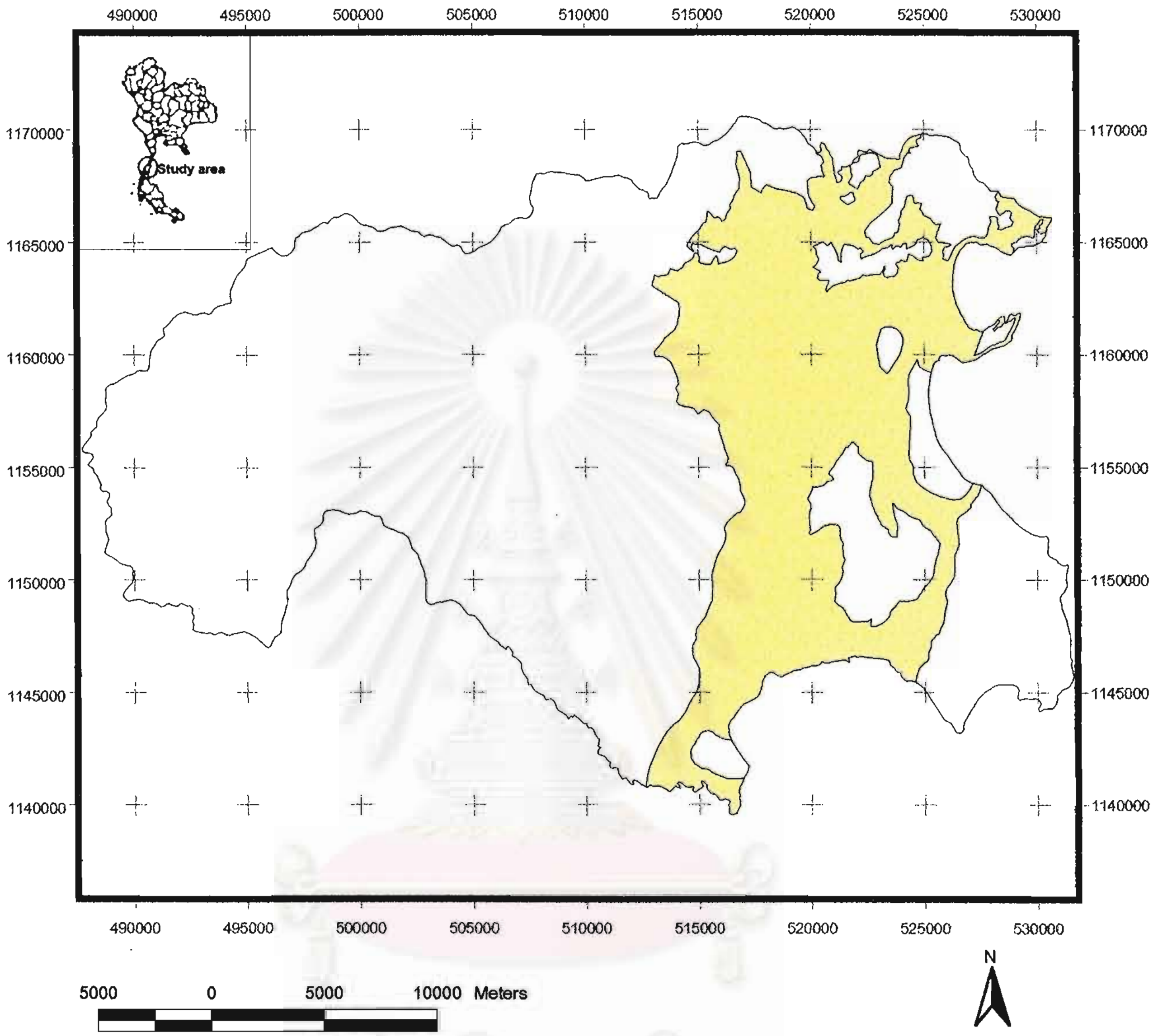
Flood prone area of 2 years return period

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 5.14 The flood prone map of the 2 years return period.

Map Showing the flood prone area of 5 years return period



Legend

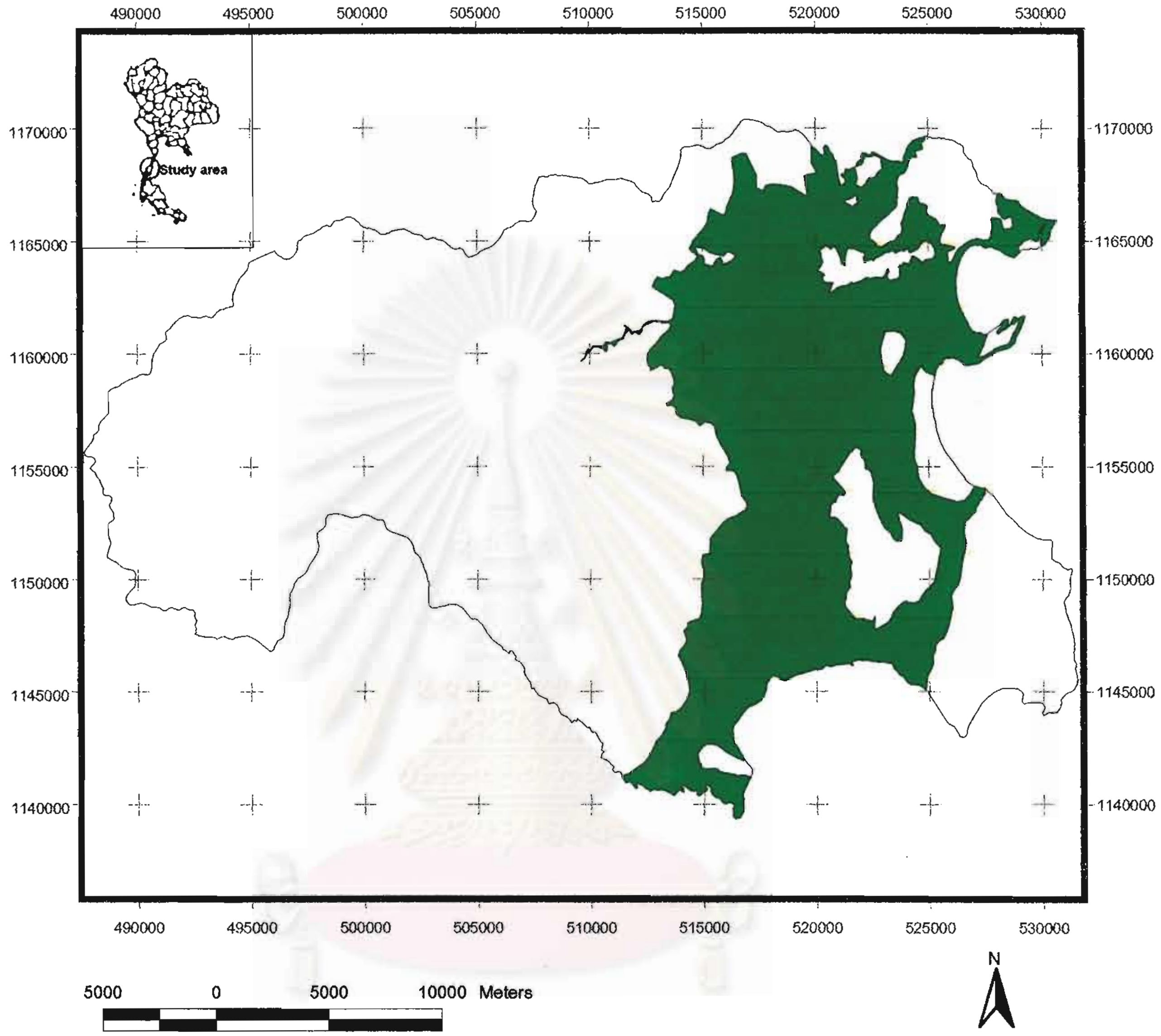
Flood prone area of 5 years return period

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 5.15 The flood prone map of the 5 years retund period.

Map showing the flood prone area of 15 years return period



Legend

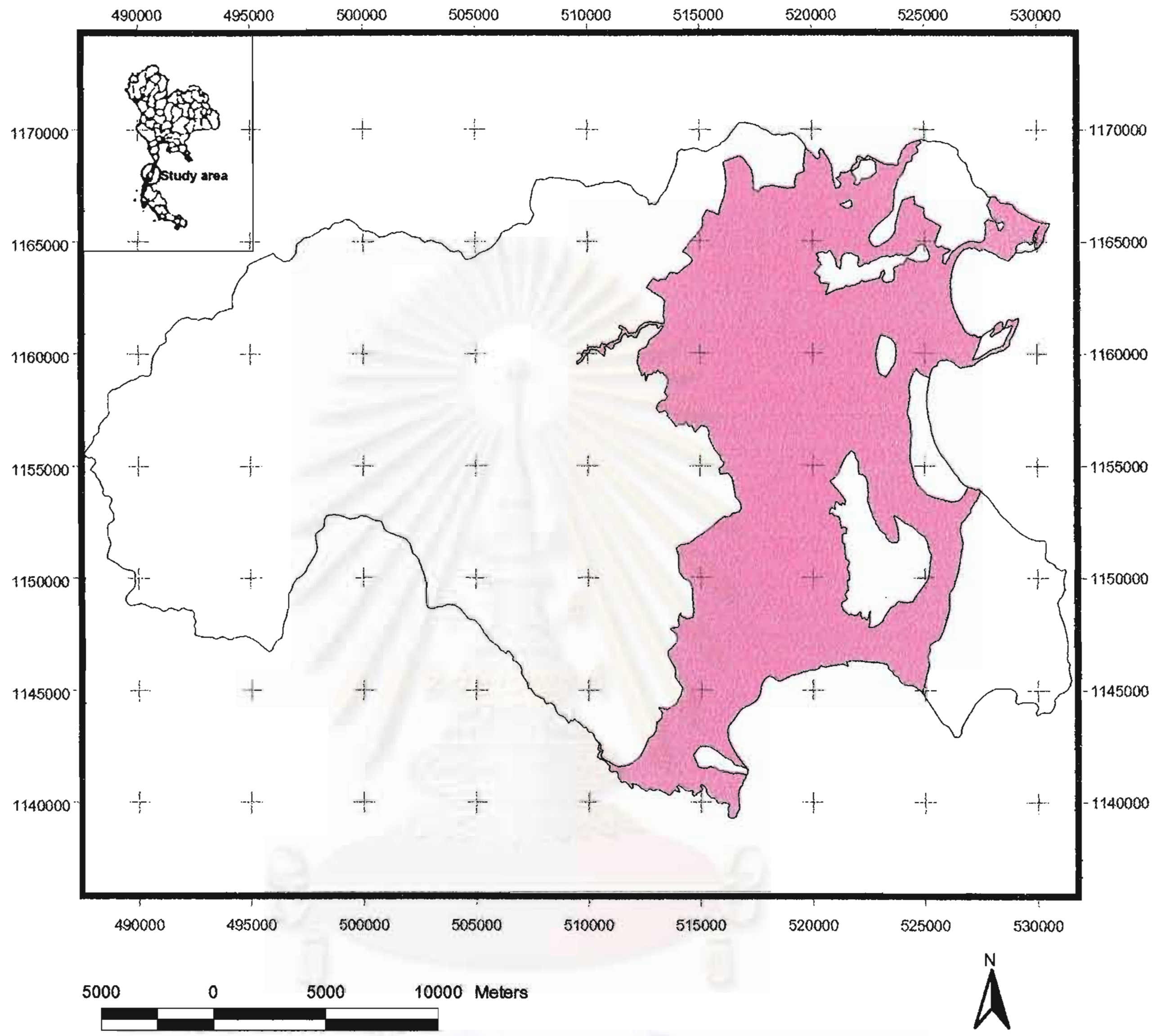
Flood prone area iof 15 years return period

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 5.16 The flood prone map of the 15 years return period.

Map showing the flood prone area of 25 years return period



Legend

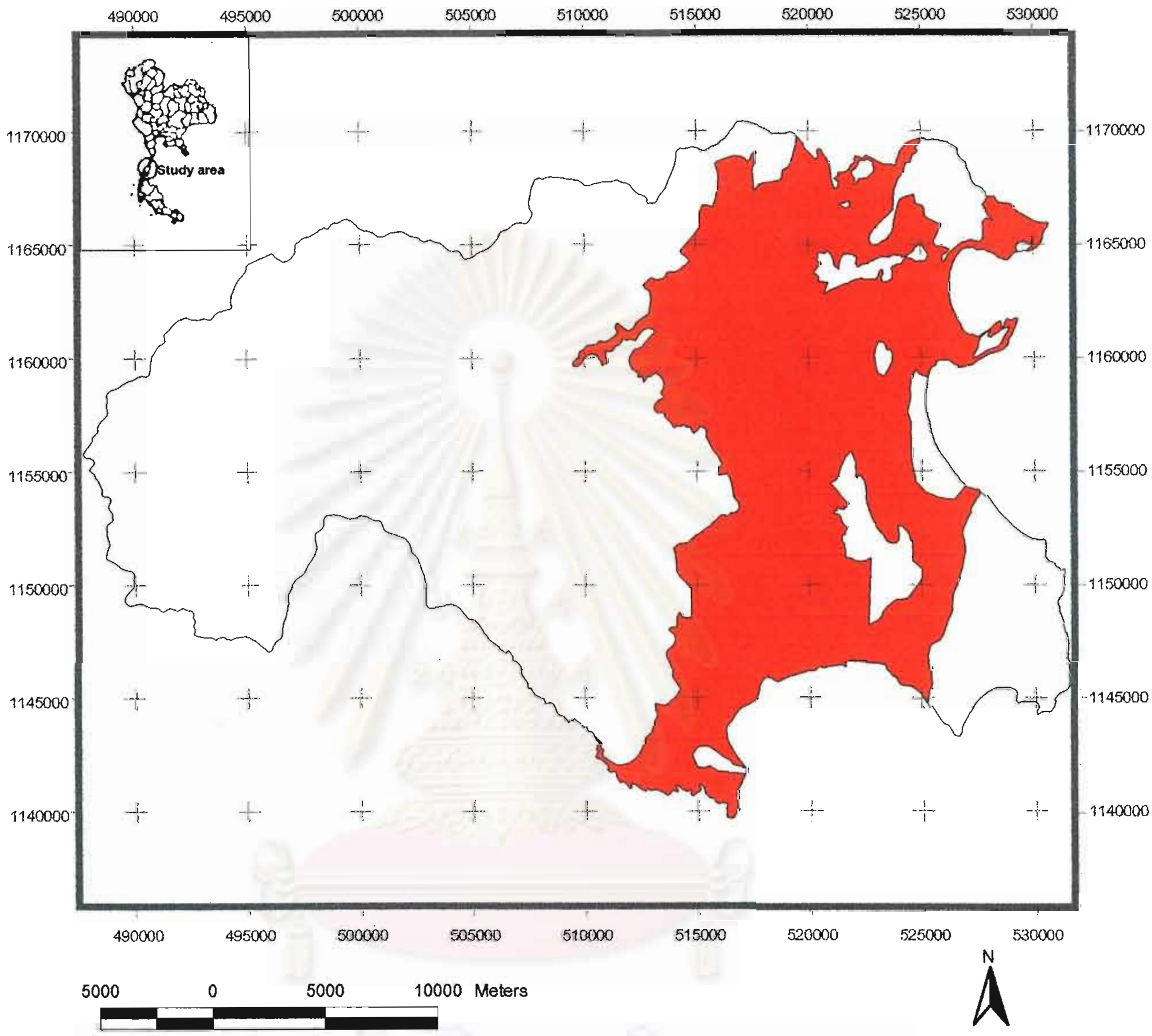
Flood prone area of 25 years return period

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.
Inter-Department of Environmental Science, Master of Science in Environmental Science.
Graduate School, Chulalongkorn University.

Figure 5.17 The flood prone map of the 25 years return period.

Map showing the flood prone area of 100 years return period



Legend

Flood prone area of 100 years return period

Flood Analysis and Flood Prone Areas in Amphoe Muang, Chumphon Province.

Miss Pranee Charoenying.

Inter-Department of Environmental Science, Master of Science in Environmental Science.

Graduate School, Chulalongkorn University.

Figure 5.18 The flood prone map of the 100 years return period.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion.

The Tha Taphao and khlong chumphon watersheds in the Chumphon basin at Amphoe Muang, Chumphon province have undergone several periods of serious flooding. Besides, the trend of scale or magnitude of flood has been increasing. The cause of flood resulted directly from heavy rainfall, promoted increasing runoff in the river of the basin during the monsoon season during degree of the months of August to November and indirectly depending upon the quantity of forest area, urbanization and population growth, as well as industrialization and agricultural pattern.

Rainfall and flood frequency analyses are carried out using extreme values of rainfall and water levels or stages recorded from 7 rainfall stations in the basin and 4 gauging stations in Amphoe Muang. In this study, regression techniques are often incorporated into other method, such as, the relationship between rainfall and runoff in the watershed, where data is not adequate enough for analysis, and relationship between runoff at stations x.158 and x.180 for analysis of peak or maximum stage. On the basis of the Gumble distribution, it is considered to be best fitted and appropriate for every basin in Thailand. Therefore, the Gumble distribution has been employed under the present study for the design of different flood return periods of 2, 5, 15, 25 and 100 years in order to delineate the flood prone areas.

The results of HEC-1 model, indicate the variation in lag time and flood peaks that would result from various levels of land use pattern and urban development. The changing of land use into the impervious areas in the watershed effect to the flood peak, rainfall excess, and runoff depth is increasing. In addition to, lag time and rainfall loss have decreased because of increasing of the pervious areas. Therefore, the areas are occurred flooding close to the Tha Taphao watershed in Amphoe Muang. HEC-1 did not model total runoff very well. However, it does not appear that increasing urbanization significantly affects runoff depth.

The flood prone areas in Amphoe Muang are mostly located in the western part of khlong Tha Taphao close to the khlong Tha Taphao and khlong Chumphon. Therefore, the location of flood prone areas of different of return periods cover numerous Tumbons of Hat Phan Ktar, Bang Luk, Na Cha-ang, Wang Mai, Wang Phai, Na Thung, Tha Taohao, Ban Na, Khun Krathing, Tak Daet, Bang Mak, Tha Yang, Pak Num, Thung Kha, Visai Nua and Hat Sai Ree in Amphoe Muang. The flood prone areas of 2 years return period is about 184 square killometres, 5 years return period is about 212 square killometres, 15 years return period is about 244 square killometres, 25 years return period is about 253 square killometres and 100 years return period is about 269 square killometres. The flood prone areas of 2, 5, 15, 25, and 100 years return periods cover 23.19%, 26.66%, 30.74%, 31.89%, and 33.92% of the total area of Apmhoe Muang, respectively. The flood of 2 years return period is very low hazard flooding. In contrast, the flood of 100 years return period is very high hazard flooding. These areas are very important residential and agriculture land areas. Thus, the flood cost damages are apparently very high. The analyses of flood prone areas are being used to generate the flood prone maps. The flood prone maps of different return periods are critically important in predicting the occurrence of floods and the damage they are likely to produce. Consequently, the formulation of flood controls planning, prevention and relief of flood.

The present flood management activities in Amphoe Muang not enough for reduce the effects from flood. Thus the flood management should be includes all activities, which can be undertaken to reduce the severity of flood and relieve its effects. The management activities are physical actions, which control the movement of water and relieve the conditions, which cause damage, danger and hardship. Flood management activities in this area should be includes structural flood mitigation and non-structural flood management measures as follows:

1. Structural flood mitigation options.
   1.1 Control of water movements to reduce or mitigate the severity of flooding such as floodway, diversion, reservoir, channel improvement works, and etc.
   1.2 Establishing and upholding standards of flood safety for strategic public facilities, such as, transportation infrastructure, public welfare supplies and energy supply.
2. Non-structural flood management measures.

2.1 Planning, regulation and enforcement of restrictions on land use in flood plains to reduce the public, private and commercial activities risk.

2.2 Forecasting, warning and emergency reponse to flood events.

6.2 Limitation of data to be used under the present study.

6.2.1 The lack of uniformity of data collected by different government agencies, the data collection based on administrative boundaries in stead of hydrological boundaries, and short periods of data collection are the main problems. Furthermore, the data collection system in different agencies is not under the similar system. Thus, the secondary data obtained from numerous agencies are not adequate enough for the analysis, and some data show error and inaccuracy

6.2.2 The remote sensing data in the past used for delineation of the flood prone areas and served as a basis for the indication and elevation of flood prone area maps of different return periods, are not available particularly during the critical time of flood periods.

6.2.3 The information of present flood management activities are not used for the analysis flood in this study.

6.2.4 The velocity runoff data are not available. So that, in the flood analysis under the present study does not include the identification of lag time and the evalution of discharge.

6.2.5 The data from limited gauging stations in Amphoe Muang are not adequate enough for the analysis definite of flood prone areas.

6.3 Recommendation for future studies.

This study is carried out as a preliminary work in identifying the flood prone areas of Amphoe Muang, Chumphon province. Additional improvements can be made as follows:

6.3.1 The detailed study on the effects of flood control structures, such as, reservoir, floodway, and dike on the changing condition of inundation area and flood stage should be undertaken made in order to develop the definite flood prone areas under the influence of the flood control activities.

6.3.2 The duration of flood should be estimated for each designed flood return period.

6.3.3 The historical records of flood and remote sensing data are important for the analyses and identification of flood. Therefore, all of the information and data, if available from any source, should be fully integrated in the study of flood in this area.

6.3.4 The rainfall frequency analysis in terms of different rainfall return periods can be further used in the evaluation of scale or magnitude of flooding of the Chumphon basin.

6.3.5 The extreme value analysis used for any flood of specific return period is not entirely based on rainfall or water stage. The return periods can be computed separately for synthetic flood peaks and lag time.

6.3.6 The results of other parameter optimization in HEC-1 are be used for synthetic unit hydrograph.

6.3.7 The future study should employ the GIS Software for generating the contour lines for delineation of the flood prone areas.

REFERENCES

Alamgir, S.1997. The application of remote sensing and GIS to the impact assessment and resource management of flood control, drainage and irrigation projects: Acase study of Meghna Dhonagoda irrigation project, Bangladesh. AIT thesis. Asian Institute of technology Bangkok. Thailand.

Aronoff, S. 1990. Geographic information systems: A Management Perspective. Canada: WDL publications.

Arora, K. and Singh, V.P.1986. An evaluation of seven methods for estimating parameters of Extreme Value Distribution. Hydrological Frequency Modeling. USA: D. Riedel.

Bedient, B.P. and Huber, C.W.1988. Hydrology and Floodplain Analysis. New York: Addison-wesley company.

Beven, K. and Carling, P.1989. Flood: Hydrological, Sedimentological and Geomorphological Implications. New York: John Wiley & Sons.

Boker,R.V., Kochel,R eraig and Patton, C.P.1988. Flood geomorphology. New York: John Wiley & Sons.

Brilly, M.1992. Flood protection on headwater streams. Journal of fluid mechanics and its applications. 5: 467-473.

Burrough, P.A. 1986. Principles of Geographic Information Systems for land resources assessment. New York: Oxford University Press.

Chatrcharoenmitr, V.1977. Flood flow computation in the Middle Chaophraya river. AIT thesis. Asian Institute of technology Bangkok. Thailand.

Chorley, R.J. (ed).1960. Water, Earth and man. London: Methuen & Co-London.

Christopherson, R.W.1995. Geosystem. New Jersey: Prentice Hall.

Chubpisan,C. and Srivittina,T.1986. Flood control and drainge system in Bangkok. Office of promotion and training of Kasatsart University.

Dunne, T. and Leopold, B.L.1978. Water in Environmental Planning. San Francisco: W.H. Freeman and company.

Economic and Social commission for Asia and the Pacific.1988. Proceedings of the expert group meeting on improvement of flood loss prevention systems based on risk analysis and mapping. United Nations, New York.

Environmental System Research Institute, Inc.1992. GIS by ESRI: PC ARC/INFO Quick Reference Guide. ESRI, U.S.A.

Environmental System Research Institute, Inc.1993. Understanding GIS: The ARC/INFO Method. ESRI, Redland C.A.

Hoggan, H.D.1989. Computer-Assisted Floodplain Hydrology and Hydraulics. New York: McGraw-Hill Book.

Hosking, J.R.M., Wallis, J.R. and Wood, E.F.1984. Estimation of General Extreme Value Distribution by the method of Probability Weighted Moments. Journal of Technometrics. 27:3 pp. 251-261.

Hunt, R.1984. The Geotechnical Engineering Investigation Manual. New York: McGraw-Hill Book.

Kanchanaham, S.1997. Application of flood plain mapping and risk assessment by the intergration of fused multisensor remote sensing derived information with in a GIS. AIT thesis. Asian Institute of technology Bangkok. Thailand.

Kanchanalak, B.1996. A note of construction of frequency curves. Journal of hydrology assembly. 5: 94-105.

Kawinpoonstan, W.1997. Flood risk mapping of the Yom river basin Phrae and Sukhothai areas, Thailand. AIT thesis. Asian Institute of technology Bangkok. Thailand.

Keller,E.A.1979. Environmental Geology (2nd ed). New York: Abell & Howell.

Linsley, K.R., Franzini, B.J., and Fregbery, L.D.1992. Water resources engineering. (4th ed.). New York: McGraw-Hill Book.

Lundgren, L.1986. Environmental Geology. New Jersey: Prentice-Hall.

Luveera and *et.al.*1987.The study of the environmental impact from improvement of drainage system in green area project. Environmental Institute. Chulalongkorn University.

Mc Cammon, B.R.1975. Concepts in Geostatistics. New York: Springer Verlarge.

McCall, J. and Marker, B. eds.1989. Earth Science Mapping. London: Graham & Trotman Book.

Murck, B.W., Skinner, B.J., and Porter, S.C.1996. Environmental Geology. New York: John Wiley & Sons.

Nkemdirim, C.L. and Kendrick, J.K.1996. Simulated interior floods and the flood experience in urban communities. Journal of Environmental Management. 20:1 pp. 99-111.

Office of the Environmental Policy and Planning and Forest Department.1996. the final report of project the flood prone area and natural disaster in Northeast basin of Northeastern part of Thailand.

Office of the Environmental Policy and Planning.1996. Seminar report of the flood prone area and natural disaster (eastern basin, western basin and central basin of Thailand) project. The report offer to Office of the Environmental Policy and Planning by Pre-development consultant. Ltd.

Rasid, H. and Mallik, A.1993. Poldering vs compartmentalization: the choice of flood control techniques in Bangladesh. Journal of Environmental Management. 17:1 pp. 59-71.

Sargent, M.D.1992. flood management in Rockhampton, Australia. Journal of fluid mechanics and its applications. 5: 3-15.

Savedpravitkun, I.1995. Flood routing in Phedburi downstream basin of Phedburi province. Thesis of master engineering, department of civil engineering, Chulalongkorn university.

Shrubsole, D., Hammond,J.V., and Green,M.1995. Floodplain management in London, Ontario, Canada. Assessing implementation of section 28 of the Conservation Authorities Act. Journal of Environmental Management. 19:5 pp. 703-717.

Smith, K.1992. Hydrologic hazards: Floods environmental hazards assessing risk and reducing disaster. London and New York: Biddles Ltd., Guildford and King's Lynn company.

Strahler, N.A. and Strahler, H.A.1973. Environmental geoscience: Interaction between natural systems and man. New York: John Wiley & Sons.

Tank, R.1973. Focus on Environmental Geology (A collection of case histories and reading from original source). New York: Oxford university Press London Toronto.

Tasombat, V.1987. Applied Hydrology. Department of water resources engineering, faculty of engineering. Kasatsart university.

Team Consulting Engineering Co. Ltd. and T A & E Consultant Co. Ltd. 1995. The study on the suitable and environmental impact assessment of Tha Sae-Rap Ro reservoirs project Chumphon province. Final report. Bangkok. Thailand.

The census of agriculture, the National Statistical Office.1997. Agriculture land use data in Chumphon province. Bangkok: Thailand. (Mimeographed)

The Chumphon Provincial Agricultural Extension Office.1997. Agriculture land use data in Chumphon province. Chumphon: Thailand. (Mimeographed)

The Irrigation Department.1997. Runoff data of 7 gauging stations available within the Chumphon basin in 30 years return period. Bangkok: Thailand. (Mimeographed)

The Meteorological Department.1997. Number of storms passing through Thailand in each year. Bangkok: Thailand. (Mimeographed)

The Meteorological Department.1997. Rainfall data of 7 rainfall stations available within the Chumphon province in 30 years return period. Bangkok: Thailand. (Mimeographed)

The Registration Administration Bureau, Ministry of Interior.1997. Population statistics in Chumphon province. Bangkok: Thailand. (Mimeographed)

The Thailand Remote Sensing Center of the Office of the National Research Council of Thailand.1998. Land use and land cover satellite image data in 1988, 1993, and 1998. Bangkok: Thailand. (Mimeographed)

Thongsuk,J.1997. Floods and flood prone areas in Changwat Phra Nakhon Si Ayutthaya. Thesis of master of science, Geography Department, Ramkhamhaeng University.

Townsend, NR. And Bartlett, JM.1992. Formulation of basin management plans for the Northern new territories, Journal of fluid mechanics and its applications.5: 39-49.

Tungtum,N. and Yuvananon,S.1996. The study of the impact of land use change, volume and characteristics of runoff flowing in Pasak basin. Journal of forest Department. 15:2 (July-December) pp.98-110.

Valdiya,K.S.1981. Environmental Geology. New Delhi: Tata McGrow-Will.

Veerapun,V.1986. Critical of rainfall for flash flood in Amphoe Muang Nakornsitummarat province. The Meteorological Office.

Veerapun,V.1988. Flash flood of 1987. Hydrological and Meteorological Department, The Meteorological Office.

Verodjanakun, P.1996. Hydrology of surface runoff. Department of the civil engineering, faculty of engineering. Khon Kaen university.

White, F.G.1974. Natural hazards local, national and global. London: Oxford university Press.

BIOGRAPHY

Miss Pranee Charoenying was born on 9 March, 1973 in Prachinburi province. She received the Bachelor Degree of Science from the Department of Marine Science, Faculty of Science, Chulalongkorn University in the academic year 1994. After graduation, she had worked with CP. Company Ltd. Then, she has further her study the leading to the Master Degree in Environmental Science, Inter-Department of Environmental Science, Graduate School, Chulalongkorn University in the academic year 1997.