JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF AGRICULTURE AND COOPERATIVES
THE KINGDOM OF THAILAND

THE STUDY
ON
THE AGRICULTURAL LAND REHABILITATION AND CONSERVATION
PROJECT
IN
SURAT THANI AND NAKHON SI THAMMARAT PROVINCES

FINAL REPORT
(APPENDICES)

OCTOBER, 1995

SANYU CONSULTANTS INC.

THE STUDY ON THE AGRICULTURAL LAND REHABILITATION AND CONSERVATION
FINAL REPORT (APPENDICES) OCTOBER, 1995 SANYU CONSULTANTS

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF AGRICULTURE AND COOPERATIVES
THE KINGDOM OF THAILAND

THE STUDY
ON
THE AGRICULTURAL LAND REHABILITATION AND CONSERVATION
PROJECT
IN
SURAT THANI AND NAKHON SI THAMMARAT PROVINCES

FINAL REPORT
(APPENDICES)

OCTOBER, 1995

SANYU CONSULTANTS INC.

LIST OF APPENDICES

A. GENERAL

B. HYDROMETEOROLOGY

C. GEOLOGY AND GROUNDWATER

D. REMOTE SENSING

E. AGRICULTURAL AND RURAL INFRASTRUCTURE / REHABILITATION PROJECT

F. SOIL AND LAND USE

G. FLOOD DAMAGE AND GENERAL RESTORATION PROGRAM

H. AGRICULTURE

I. AGRO-ECONOMY / PROJECT EVALUATION

J. FARMER'S ORGANIZATION / AGRICULTURAL SUPPORTING SERVICE

K. ENVIRONMENT

L. FIELD TEST

M. COST ESTIMATION

APPENDIX A

GENERAL

Contents

A-1 General . . . . . A- 1

A-2 Socio-Economic Condition of the Study Area . . A-17

A-3 Subdivided Area for Selection of F/S Area . . . A-24

A-4 Land Use Plan of Ban Na San A-26

A-5 Land Use Plan of Lan Saka A-29

SCOPE OF WORK FOR THE STUDY

ON

THE AGRICULTURAL LAND REHABILITATION AND CONSERVATION PROJECT

IN

SURAT THANI AND NAKHON SI THAMMARAT PROVINCES

AGREED UPON BETWEEN

THE DEPARTMENT OF LAND DEVELOPMENT
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

BANGKOK, APRIL 9, 1993

M. Narong

DR. NARONG MINANANDANA
DIRECTOR GENERAL,
THE DEPARTMENT OF LAND DEVELOPMENT
MINISTRY OF AGRICULTURE AND
COOPERATIVES

Takuji Nakano

TAKUJI NAKANO
LEADER,
PREPARATORY STUDY TEAM,
JAPAN INTERNATIONAL
COOPERATION AGENCY

I. Introduction

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan has decided to conduct the Study on the Agricultural Land Rehabilitation and Conservation Project in Surat Thani and Nakhon Si Thammarat Provinces (hereinafter referred to as "the Study"), within the general framework of technical cooperation between Japan and Thailand, which is set forth in the Agreement on Technical Cooperation between the Government of Japan and the Government of the Kingdom of Thailand signed on November 5, 1981.

Accordingly, Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, will undertake the Study, in accordance with the relevant laws and regulations in force in Japan and in close cooperation with the concerned authorities of Thailand.

The Department of Land Development, Ministry of Agriculture and Cooperatives (hereinafter referred to as "DLD") shall act as counterpart agency to the Japanese Study Team (hereinafter referred to as "the Team") and also as coordinating body in relation with other relevant organizations for the smooth implementation of the Study.

The present document sets forth the scope of work for the Study.

II. Objectives of the Study

The objectives of the Study are:

1. to prepare a master plan in order to formulate the concept of rehabilitation and conservation works of agricultural land for the Study area;

2. to conduct a feasibility study in order to formulate implementation plans for the selected project areas through the master plan study; and

3. to carry out technology transfer to the Thai counterpart personnel in the course of the Study.

III. Study Area

The Study Area covers approximately 300 sq.km. at both Surat Thani and Nakhon Si Thammarat provinces.

IV. Scope of the Study

In order to achieve the above objectives, the Study consists of the following two(2) phases.

1. Master Plan Study

1.1. Implementation of general study in order to obtain the outline of Khao Luang mountainous area and agricultural land of approximately 5,170 sq.km. in Surat Thani and Nakhon Si Thammarat Provinces.

(1) natural conditions such as location of land slide areas, distribution of sediment deposit, and etc.

(2) agro-economic conditions

(3) environmental conditions

1.2. Collection of existing information and/or field survey on the following items, and preliminary analysis:

(1) natural conditions (topography, meteorology, hydrology, geology, soil, vegetation, etc.)

(2) social and economic conditions (population, social organization, employment, socio-economy, land tenure, finance, etc.)

(3) agricultural conditions (farming practice, land use, cropping pattern, productivity, extension, marketing, agricultural input, farmers' organizations, water management, etc.)

(4) agricultural infrastructures (irrigation and drainage, farm roads, marketing facilities, etc.)

(5) existing inventory of disaster damage and on-going restoration program of flood affected area

(6) environmental aspects (living environment, sanctuary area, etc.)

1.3. Formulation of the following master plan for agricultural land rehabilitation and conservation for the Study Area:

(1) examination and proposal of methodology of agricultural land rehabilitation and conservation.

(2) drawing of topographic map and preparation of land slide occurrence map.

(3) formulation of the master plan for agricultural land rehabilitation and conservation.

1.4. Preparation of feasibility study

(1) selection of the feasibility study areas taking into consideration the financial resource limitation, DLD's project implementing capacity and so on.

(2) implementation of preliminary topographical survey and investigations required for the feasibility study.

2. Feasibility Study

2.1. Collection and analysis of supplementary information through field surveys.

(1) topographical survey

(2) meteorology survey

(3) hydrological survey

(4) soil survey

(5) irrigation and drainage facility survey

(6) agro-socio-economic survey

(7) land use and tenure survey

2.2. Formulation of the agricultural land rehabilitation and conservation plans consisting of;

(1) land use plan

(2) soil improvement plan

(3) agricultural land rehabilitation and conservation plan

(4) irrigation and drainage plan

(5) design methodology of main facilities

(6) project implementation schedule

(7) drawing of maps required for plan formulation

(8) estimation of the project costs and benefits.

(9) operation and maintenance plan

2.3. Proposal of technical guidance for appropriate agricultural land rehabilitation and conservation works.

2.4. Evaluation of the project.

2.5. Recommendation.

V. Study Schedule

The Study will be carried out in accordance with the tentative schedule attached in Annex.

VI. Report

JICA will prepare and submit the following reports in English to the government of the Kingdom of Thailand.

1. Inception Report
Twenty (20) copies at the commencement of the Phase I field work.

2. Progress Report (1)
Twenty (20) copies at the end of the Phase I field work.

3. Interim Report
Twenty (20) copies at the commencement of the Phase II field work.

4. Progress Report (2)
Twenty (20) copies at the end of the Phase II field work.

5. Draft Final Report
Twenty (20) copies at the end of the Phase II home office work. The Government of the Kingdom of Thailand will provide its comments on the Draft Final Report to JICA within one (1) month after receiving the Draft Final Report.

6. Final Report
Fifty (50) copies within two (2) months after the receipt of comments of the Government of the Kingdom of Thailand on the Draft Final Report.

VII. Undertakings of the Government of the Kingdom of Thailand

1. In accordance with the Agreement on Technical Cooperation between the Government of Japan and the Government of the Kingdom of Thailand, the Government of the Kingdom of Thailand shall accord benefits to the Team as follows:

   (1) to permit the members of the Team to enter, leave and sojourn in Thailand for the duration of their assignment therein, and exempt them from foreign regulation requirements and consular fees;

   (2) to exempt the members of the Team from taxes, duties, fees and any other charges on equipment, machinery and other materials to be brought into Thailand for the conduct of the Study;

   (3) to exempt the members of the Team from income taxes and charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the Team for their services in connection with the implementation of the Study; and

   (4) to bear claim, if any arises against the members of the Team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the members of the Team.

2. To facilitate smooth execution of the Study, DLD shall take necessary measures in cooperation with other relevant organizations:

   (1) to secure permission for entry into private properties or restricted areas for the conduct of the Study;

   (2) to secure permission for the Team to take all data and documents related to the Study out of Thailand to Japan;

   (3) to provide the medical services as needed. Its expenses will be chargeable on the members of the Team; and

   (4) to ensure the safety of the members of the Team when and as it is required in the course of the Study.

3. DLD shall, at its own expense, provide the Team with the followings in cooperation with other organizations concerned:
   (1) available data and information related to the Study;

   (2) counterpart personnel;

T.N.

(3) suitable office space with necessary equipment and furniture; and

(4) credentials or identification cards.

VIII. Undertakings of JICA

For the implementation of the Study, JICA shall take the following measures:

(1) to dispatch, at its own expense, the Team to Thailand, and

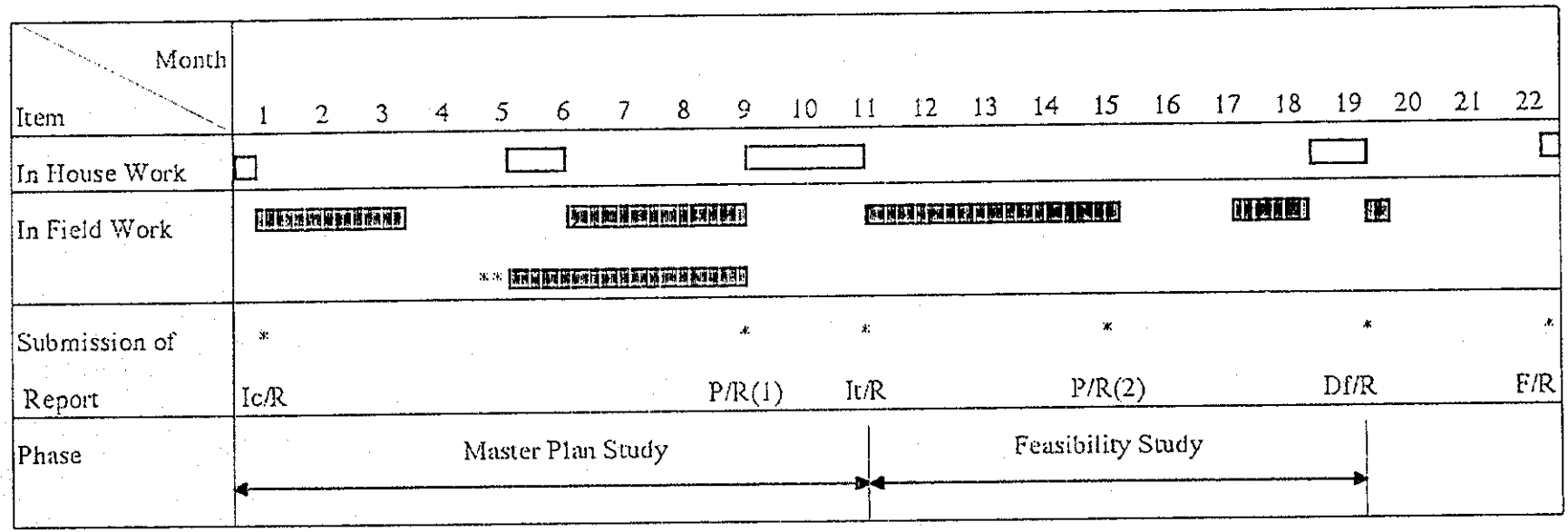
(2) to pursue technology transfer to the Thai counterpart personnel in the course of the Study.

IX. Others

JICA and DLD shall consult with each other in respect of any matter that may arise from or in connection with the Study.

ANNEX

TENTATIVE SCHEDULE



Ic/R : Inception Report

P/R(1) : Progress Report(1)

It/R : Interim Report

P/R(2) : Progress Report(2)

Df/R : Draft Final Report

F/R : Final Report

** : Topo Mapping

MINUTES OF MEETING

FOR

THE SCOPE OF WORK FOR THE STUDY

ON

THE AGRICULTURAL LAND REHABILITATION AND CONSERVATION PROJECT

IN

SURAT THANI AND NAKHON SI THAMMARAT PROVINCES

AGREED UPON BETWEEN

THE DEPARTMENT OF LAND DEVELOPMENT
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

BANGKOK, APRIL 9, 1993

DR. NARONG MINANANDANA
DIRECTOR GENERAL,
THE DEPARTMENT OF LAND DEVELOPMENT
MINISTRY OF AGRICULTURE AND
COOPERATIVES

TAKUJI NAKANO
LEADER,
PREPARATORY STUDY TEAM,
JAPAN INTERNATIONAL
COOPERATION AGENCY

The Preparatory Study Team headed by Mr. Takuji Nakano was dispatched by the Government of Japan to the Kingdom of Thailand from 30 March to 10 April, 1993 for concluding the Scope of Work for the Study on Agricultural Land Rehabilitation and Conservation Project in Surat Thani and Nakhon Si Thammarat Provinces with concerned officials of Thailand.

The Preparatory Study Team and the Thai side had a series of meetings and discussions during this period, the results of meeting and discussion mentioned above are as follows;

1. Regarding implementation of the general study

In the case which aerial photo or satellite image cannot be applied for the general study, the general study shall not be included in the Study.

2. Regarding drawing of topographic map and preparation of land slide occurrence map

In the case which aerial photo or satellite image cannot be applied for the master plan study, following study items shall not be included in the master plan study.

(1) drawing of topographic map
(2) preparation of land slide occurrence map

3. Regarding examination tests

In order to conduct the Study DLD requested the Preparatory Study Team to carry out the examination tests of proposed rehabilitation and conservation methods for agricultural land in the Study .

The Preparatory Study Team promised to convey this request to the Government of Japan.

4. Regarding undertakings

Office space for the Japanese Study Team will be provided by DLD in DLD's Headquarters in Bangkok and in the Study areas. Japanese side requested DLD to furnish such office space with necessary equipment and furniture including telephone, and DLD agreed to do so.

T. N.

5. Regarding equipment

DLD requested the Preparatory Study Team to bring into Thailand the following equipment for carrying out the project-study. Japanese side took note of such request.

(1) vehicles
(2) soil survey equipment
(3) hydrological survey equipment
(4) topographical survey equipment
(5) other necessary equipment

6. Regarding the environmental impacts of the Study

In order to carry out the project smoothly, the Preparatory Study team and DLD have discussed the environmental impact of the study through the joint screening on the scope of work. Both sides agree that heavy negative impacts created by the project cannot be found on the view point of environmental aspects.

7. Regarding technical transfer to counterpart personnel

DLD requested that technical training in Japan be given to counterpart personnel of the Study. Japanese side took note of such request.

8. Regarding letter of invitation

Japanese side requested DLD to issue letters of invitation to members of the Japanese Study Team in order for them to obtain entry visa to Thailand, and also to give assistance to the Japanese Study Team, when necessary, to facilitate the customs clearance of their study equipment on tax exemption basis. DLD agreed to do so.

T. H.

LIST OF ATTENDANTS

The Study on Agricultural Land Rehabilitation and Conservation Project in Surat Thani and Nakhon Si Thammarat Provinces

April 9 ,1993

at DLD/Bangkok

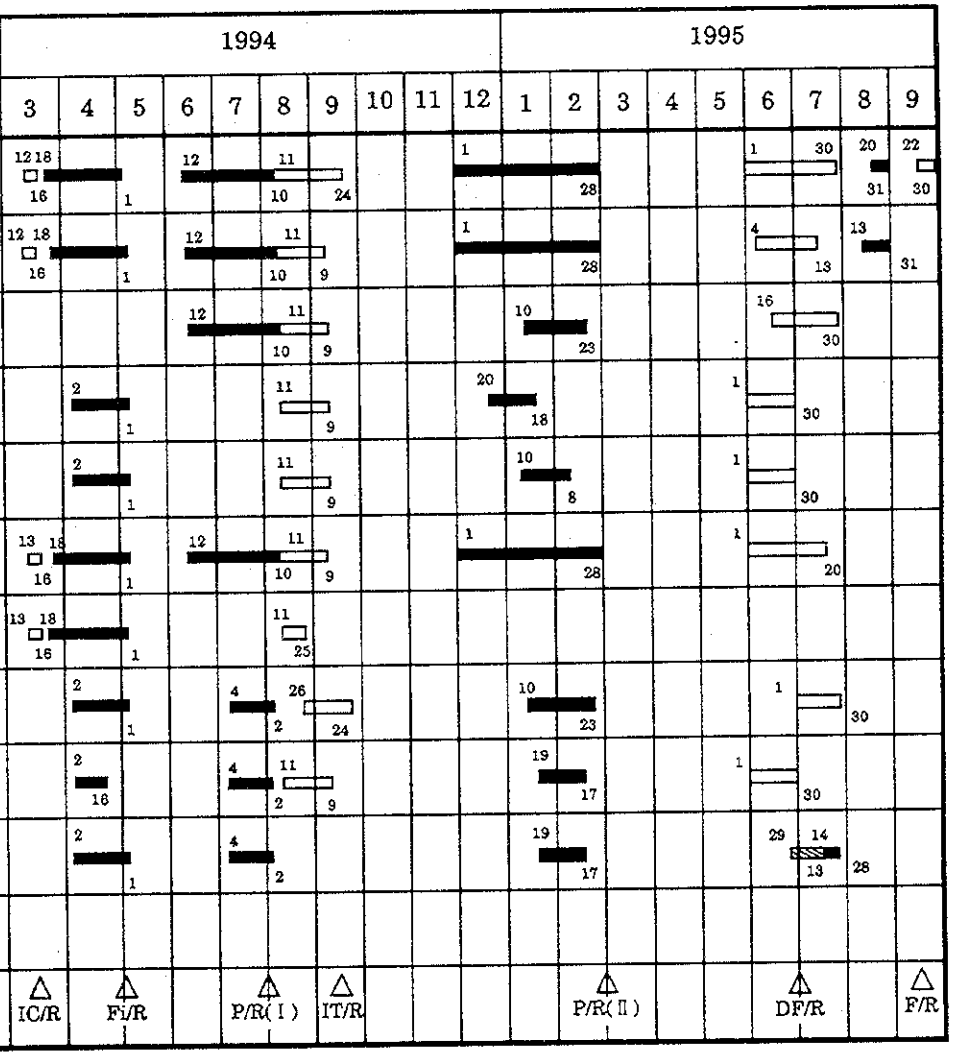
NAME	OFFICE	SIGNATURE
JICA		
1. Mr. Takuji NAKANO	Assistant Director, MAFF	Takuji Nakano
2. Mr. Satoshi OHHASHI	Senior Engineer Hokkaido Development Bureau	Satoshi Ohashi
3. Mr. Takashi ADANIYA	Senior Agronomist Okinawa Development Agency	Takasi Adaniya
4. Mr. Hiromi MOTOMURA	JICA	Hiromi Motomura
5. Mr. Yoshihisa ONISHI	Chief Engineer System Science Consultants Inc.	.....
JICA Expert attached to DLD		
1. Mr. Hiroyasu KOBAYASHI	JICA Expert/DLD	H. Kobayashi

NAME	OFFICE	SIGNATURE
DLD		
1. Dr. Narong Minanandana	Director General	M. Narong
2. Mr.Boonyaruk Suebsiri	Deputy Director-General	B. Suebsiri
3. Mr.Upatham Potisuwan	Director,Soil & Water Conservation Division	U. Potisuwan
4. Mr.Sophon Chomchan	Director, Land Use Planning Division	
5. Mr. Ard Somrang	Director,Planning Division	Ard Somrang
6. Mr. Poonsak Paichayon	Director,Land Development Regional Office 11	P. Paichayon
7. Mr.Surapol Charoenpong	Soil Survey & Classification Division	Surapol Charoenpong
8. Mr.Sutham Paladsongkram	Soil & Water Conservation Division	S. Paladsongkram
9.Mr.Sompong Santhanakanit	Land Development Regional Office 11	
10.Miss Bhatra Chindanon	Planning Division	Bhatra
11.Miss Phachongchit Boonyarach	Planning Division	P. Boonyarach
12. Mr.Rangsrit Sampaopol	Land Development Regional Office 11	
MR. TANIT THONG-JUTHA	DIRECTOR, SOIL SURVEY & CLASSIFICATION DIV.	Tanit Thongjutha
MR. JARAN SANGVANPONG	SECRETARY, DLD.	
MR. PRATHOM ATTANARD	LDRO 10	P. Attanard

NAME	OFFICE	SIGNATURE
DLD		
13..Mr.Rangsrit Boonyasin	Planning Division	.....
14.Mrs.Waraporn Boonsorn	Planning Division	.....
15.Miss Kittima Trowattana	Planning Division	.....
16.Miss Kreeyaporn Devahastin	Planning Division	.....
17.Miss Prathueang Wanaeloh	Planning Division	.....

MANNING SCHEDULE

Designation	Name
Leader / Farm Land Conservation / Structure Planning / Surveyor	Takanori TAKATSUKA
Sub-leader / Agriculture / Farming	Paitoon PALAYASOOT
Irrigation / Drainage / Structure Design / Cost Estimate	NG AH LEK
Hydrology / Meteorology	Mototaka NISHI
Topography / Geology / Groundwater	Satoshi KAWASAKI
Soil / Land Use	Yukio SATO
Remote Sensing / Land Classification	Takehiko HIRANO
Agro-Economy / Project Evaluation	Shou INADA
Farmers' Organization / Agricultural Supporting System	Yasushi GOTO
Environment	Praphant KOESOMBOON
Report	



Study in Thailand
Study in Japan
Study in Thailand

IC/R : Inception Report
IT/R : Interim Report
Fi/R : Field Report
DF/R : Draft Final Report
P/R(Ⅰ) : Progress Report(Ⅰ)
F/R : Final Report
P/R(Ⅱ) : Progress Report(Ⅱ)

Counterpart Personnel

DLD assigned the following counterpart personnel for the Team.

Field	Name and Position	
Farm Land Conservation/ Structure Planning	Mr. Upatham Potisuwan	Deputy Director General
Agriculture/Farming	Mr. Kasem Taksinakul	Chief of LD Station Surat Thani
	Mr. Songkram Sukkhee	Chief of LD Station Nakon Si Thammarat
	Mr. Sutham Paladsongkram	Soil & Water Conservation Division
Irrigation and Drainage/ Structure Design/Cost - Estimate	Mr. Songsak Wong	Engineering Division
Hydrology/Meteorology	Mr. Sompong Santhanakanit	Chief of Technical Section
	Mr. Rangsarit Samphaophol	LDRO 11
Topography/Geology/ Groundwater	Mr. Sawad Phanthipphaet	Chief of Soil Survey & Classification Division
	Mrs. Wannarat Thothong	Chief of Photogrammetry Section
Soil/Land Use	Mr. Sawad Phanthipphaet	Chief of Soil Survey & Classification Division
Remote Sensing/ Land Classification	Mr. Chumphol Wattanasarn	Chief of Land Use Analysis Section
Agro-Economy/ Project Evaluation	Miss Chetanee Prapruttrong	LDRO 11
Farmers' Organization/ Agricultural Supporting - System	Miss Chetanee Prapruttrong	LDRO 11
Environment	Mr. Manu Srikhajon	Soil & Water Conservation Division
Co-ordinators	Mr. Chumpol Lilittham	Chief of Planning Section
	Miss Bhatra Chindanon	Planning Division

Improvement of Agricultural Production Structure and System

1. Operation : Period 1994-1996
   Cabinet approved the project on December 28,1993
2. Objective : To decrease the acreage of market problem crops, rice, cassava, coffee and pepper to another high potential crops and better agricultural activities.
3. Budget of the Project :

Unit : million baht

	1994	1995	1996	1997-2010	Total
Second rice and inproper paddy land	6,900	7,497	11,433	7,926	33,756
Cassava	2,700	2,940	3,572	-	9,212
Coffee	180	270	330	-	780
Pepper	540	1,013	1,605	18,968	22,126
Total	10,320	11,720	16,940	26,894	65,874

4. Government Subsidy and Service :

Rice and cassava reduction

1. Interest rate 5% per year, payment period 15 years
2. Providing some farm input and farm pond for cultivation & livestock.
3. Providing technical advice.

Coffee and pepper reduction

1. Government will pay 6,800 baht per rai for substitution.
2. Providing technical advice.

Providing credit for water resources to grow fruit trees and trees.

Marketing

Fast growing tree : with the cooperation with Forest Industry Organization will set up the pulp and paper factory in Ubon Ratchathani or Burirum.

Dairy Cow : The Dairy Farming Promotion Organization of Thailand will buy the milk production and cooperate with the private sector.

Principle Agencies	Supporting Agencies
1. DOAE	1. Office of the Permanent Secretary
2. DOLD	2. Department of Fisheries
3. RFD	3. DLD
4. RID	4. Cooperative Promotion Department
5. Office of the Rubbber Replanting Aid Fund	5. DOA
6. OAE	6. ALRO
7. BAAC	

Target of Improvement of Agricultural Production Structure and System Project

Activities	1994	1995	1996	Total
Decrease of Growing Area (rai)				
Second rice and improper paddy land	1,000,000	1,000,000	1,500,000	3,500,000
Cassava	400,000	400,000	400,000	1,200,000
Coffee	70,000	70,000	70,000	210,000
Pepper	2,000	-	-	2,000
Total	1,472,000	1,470,000	1,970,000	4,912,000
Substitution Activities (rai)				
Upland Crops	400,000	400,000	400,000	1,200,000
Beef Cattle (3 Rai/Head)	150,000	180,000	120,000	450,000
Beef Cattle (2 Rai/Head)	12,000	13,000	12,000	37,000
Dairy Cows (5 Rai/Head)	50,000	50,000	50,000	150,000
Fruit trees	269,400	227,000	258,000	754,400
Mixed Farming	315,000	345,000	625,000	1,285,000
Sweet Bamboo	150,000	130,000	250,000	530,000
Fast Growing Trees	100,000	100,000	230,000	430,000
Vegetables, Cut Flowers and Ornamental Plants	25,600	25,000	25,000	75,600
Total	1,472,000	1,470,000	1,970,000	4,912,000

Source : Office of Agricultural Economics

Note : 1) Upland Crops (Maize, Soybean, Mungbean etc.)
2) Fruit Trees (Mango, Durian, Pomelo, Mangosteen, Lychee etc.)
3) Mixed Farming (Broiler, Fish, Swine, Vegetable, Field Crop, Fruit Tree)

Irrigable Area by Various Water Resources
(as of 1993)

Area : million rai

Items	North Reg.	N-E Reg.	Central Reg.	South Reg.	Whole Country
RID Projects 1972	1.48	1.28	10.97	0.63	13.73
Large and Medium Scale	1.48	1.28	10.97	0.63	13.73
Small Scale	-	-	-	-	-
RID Projects 1977	2.57	1.43	11.73	0.86	16.59
Large and Medium Scale	2.34	1.40	11.70	0.85	16.29
Small Scale	0.23	0.03	0.03	0.01	0.30
RID Projects 1982	4.82	2.81	12.15	1.92	21.70
Large and Medium Scale	3.36	2.00	11.50	1.42	18.28
Small Scale	1.46	0.81	0.65	0.50	3.42
RID Projects 1987	6.15	3.95	13.00	2.54	25.64
Large and Medium Scale	3.60	2.48	11.88	1.68	19.64
Small Scale	2.55	1.47	1.12	0.86	6.00
RID Projects 1990	6.52	4.31	13.56	2.82	27.21
Large and Medium Scale	3.61	2.55	12.15	1.86	20.17
Small Scale	2.91	1.76	1.41	0.96	7.04
RID Projects 1993	7.48	4.95	14.56	3.17	30.16
Large and Medium Scale	3.64	2.72	12.47	1.90	20.73
Small Scale	3.84	2.23	2.09	1.27	9.43
Pumping Projects 1993	1.19	1.91	0.48	0.31	3.89
By DEDP	1.14	1.80	0.42	0.27	3.63
By DOCP	0.05	0.11	0.06	0.04	0.26
Small Storage Tank 1993	0.03	0.07	0.02	0.02	0.14
By RID	0.02	0.03	0.01	0.01	0.07
By CPD	0.01	0.03	0.01	0.01	0.06
By DLD	0.00	0.01	0.00	0.00	0.01
Total Irrigable Area in 1993	8.70	6.93	15.06	3.50	34.19

Estimated Available Water Resources in Thailand (1993)

Items	North Reg.	N-E Reg.	Central Reg.*	South Reg.	Whole Country
Land Area (1,000km2)	169.64	168.85	103.90	70.72	513.11
Annual Rainfall (BCM)	220.50	236.40	167.70	169.70	794.30
Annual Runoff (BCM)	65.20	36.70	47.90	49.40	199.20
Stored Water (BCM)**					
as of 1972	11.74	4.58	0.64	0.00	16.96
as of 1977	11.74	4.58	0.69	0.00	17.01
as of 1982	12.16	5.19	5.75	1.43	24.53
as of 1987	12.97	7.44	11.44	4.14	35.99
as of 1992	13.88	7.77	11.61	4.18	37.44
as of 1993	13.96	7.78	11.81	4.19	37.74

* : Including Central, West and East Regions.

** : For large scale projects, stored water is based on annual average inflow, while for medium and small scale projects, there are estimated by total storage capacity.

Source : RID

Farm Household Income and Expenses by Region

Unit : Baht/Household/Year

Description	Plan 2 1970	Plan 3 1973	Plan 4 1978	Plan 5 1982	Plan 6 1988
N-E Region					
Farm & Off-farm Income	3,203	8,718	14,690	24,023	26,015
Farm Expenses	1,194	2,502	3,550	5,748	6,167
Net Income (NI)	2,012	6,216	10,540	18,275	19,848
Farm Household Cash Expenses	n.a.	n.a.	8,281	16,040	15,233
Cash Saving	n.a.	n.a.	2,259	2,235	4,615
% of NI. in C. Region	34.0	50.0	43.6	55.3	37.3
N Region					
Farm & Off-farm Income	5,768	13,376	22,892	31,954	41,990
Farm Expenses	2,055	3,784	6,658	9,895	14,523
Net Income (NI)	3,713	9,593	16,234	22,059	27,467
Farm Household Cash Expenses	n.a.	n.a.	10,451	19,477	19,261
Cash Saving	n.a.	n.a.	5,783	2,582	8,206
% of NI. in C. Region	62.8	77.0	67.2	66.8	51.6
C Region					
Farm & Off-farm Income	12,200	23,009	42,827	54,358	88,281
Farm Expenses	6,291	10,552	18,655	21,335	35,050
Net Income (NI)	5,900	12,457	24,172	33,023	53,231
Farm Household Cash Expenses	n.a.	n.a.	20,831	31,422	38,050
Cash Saving	n.a.	n.a.	3,341	1,601	15,181
% of NI. in C. Region	100.0	100.0	100.0	100.0	100.0
S Region					
Farm & Off-farm Income	5,458	13,560	24,725	38,004	55,313
Farm Expenses	1,504	2,463	4,549	5,612	9,930
Net Income (NI)	3,954	11,097	20,176	32,392	45,383
Farm Household Cash Expenses	n.a.	n.a.	15,478	24,074	30,050
Cash Saving	n.a.	n.a.	4,698	8,318	15,333
% of NI. in C. Region	66.9	89.1	83.5	98.1	85.3

Source : Office of Agricultural Economics, MOAC

Utilization of Farm Holding Land by Region in 1992

Unit : Thousand Rai

Farm Holding Land	Northeastern	Northern	Central	Southern	Whole Kingdom	
					Area	%
Paddy	41,366	14,742	11,585	3,344	71,037	54.37
Upland Crop	13,342	8,483	8,015	125	29,965	22.94
Fruit Tree Crop, Tree Crop	1,744	1,528	3,033	10,740	17,045	13.05
Vegetables and Flowers	212	270	338	77	897	0.69
Livestock Farm Area	484	103	125	36	748	0.57
Others	4,513	1,669	2,415	2,355	10,952	8.38
Total	61,661	26,795	25,511	16,677	130,644	100
	(47.20)	(20.51)	(19.53)	(12.77)	(100)	

Source : Agricultural Statistics Center, Office of Agricultural Economics, MOAC

Size of Farm Holding in 1992

Description	Region				Whole Kingdom
	Northeastern	Northern	Central	Southern	
No.of Farm (household)	2,361,194	1,244,550	801,108	703,339	5,110,191
No.of farm classified by size of farm holding (%)					
< 2 rai	1.25	2.47	2.56	1.58	1.80
2 - 10 rai	15.66	32.61	17.38	23.00	21.07
10 - 20 rai	29.53	26.91	22.54	31.97	28.13
20 - 30 rai	22.00	14.56	18.58	18.62	19.19
30 - 40 rai	13.39	8.52	12.94	10.56	11.74
40 - 50 rai	7.55	5.61	8.20	5.25	6.86
50 - 60 rai	4.20	3.67	6.27	3.27	4.27
60 - 70 rai	2.53	1.86	3.61	1.35	2.37
> 70 rai	3.89	3.79	7.92	4.40	4.57
Total	100	100	100	100	100
Average Farm Holding per Farm (rai/household)	26.12	21.53	31.84	23.71	25.57

Source : Office of Agricultural Economics, MOAC

Investment Costs for Irrigation Development Works
During the National Plan I-VI

Unit : million Baht

Period		Investment Costs		
		Budget	Loan	Total
Before National Plan	(1952 - 1960)	3,089.94		
National Plan I	(1961 - 1966)	3,370.76	3,007.75*	27,208.38*
National Plan II	(1967 - 1971)	7,849.15		
National Plan III	(1972 - 1976)	9,890.78		
National Plan IV	(1977 - 1981)	24,939.26	5,413.50	30,352.76
National Plan V	(1982 - 1986)	43,178.79	14,715.75	57,894.54
National Plan VI	(1987 - 1991)	59,855.64	1,571.65	61,427.29
National Plan VII	(upto - 1992)	17,753.35	-	17,753.35
Total		169,927.67	24,708.65	194,636.32

Source : Office of Agricultural Economics, MOAC
* During 1952-1976

Number of Farm Families by Region (1975 - 1991)

Unit : Household

Year	Northeast	North	Central	South	Whole Kingdom
1977	1,740,386	1,117,175	867,978	587,752	4,313,291
1982	1,945,713	1,236,449	878,827	624,466	4,685,455
1987	2,101,938	1,289,772	930,600	667,198	4,989,508
1988	2,116,097	1,304,394	927,133	692,508	5,040,132
1989	2,117,488	1,295,829	925,123	718,466	5,056,906
1990	2,131,448	1,298,423	909,088	734,572	5,073,471
1991	2,183,557	1,281,697	898,444	766,833	5,130,531

Source : Office of Agricultural Economics

Status and Occupations of the Farm Household Members by Region
Crops Years 1986 - 1988

Description	Northeast		North		Central		South		Whole Kingdom	
	1986	1988	1986	1988	1986	1988	1986	1988	1986	1988
Family Size (people/household)	5.67	5.47	4.55	4.53	4.99	4.89	5.37	5.12	5.23	5.05
Status of the Farm Families (%)										
Sex (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Male	49.74	49.93	49.89	50.35	50.50	48.68	49.72	50.37	49.71	49.70
Femal	50.26	50.07	50.11	49.65	49.50	51.32	50.28	49.63	50.29	50.25
Age (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
〈 15 years	36.24	30.59	28.54	24.70	30.70	25.10	37.51	31.81	33.78	28.07
15 - 40 years	42.22	44.79	43.95	46.14	41.49	41.59	37.80	40.10	41.92	43.41
41 - 65 years	18.62	21.00	23.50	24.21	22.84	26.30	20.47	22.64	20.65	23.32
〉 65 years	2.92	3.63	4.00	4.95	4.90	7.02	4.23	5.44	3.65	5.14
Education Level (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
〈 Primary School	32.77	29.81	40.52	33.99	36.81	28.96	43.29	40.87	32.01	32.60
Primary School	58.19	63.42	51.19	58.22	52.68	59.34	42.76	48.52	59.88	58.68
Secondary School	6.21	4.41	5.88	5.19	7.38	8.03	10.56	7.62	6.27	5.92
Vocational School	0.49	0.49	0.57	0.59	1.04	1.43	1.26	0.97	1.68	0.79
University and above	2.33	1.87	1.84	2.01	2.12	2.23	2.12	2.02	0.37	2.00
Occupations (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Operating Own Farms	19.64	44.70	22.32	34.15	17.06	35.08	21.83	38.55	20.34	39.22
Farming Elsewhere	3.48	1.54	3.64	0.94	3.98	1.57	3.74	1.27	3.63	1.36
Farming Own Farms and Elsewhere	12.04	5.93	15.93	14.90	16.13	14.50	18.09	7.31	14.34	9.97
Farming and Being Employed off-farm	57.36	11.03	50.75	15.03	52.56	7.41	42.66	9.23	53.14	10.86
Off-farm work	3.19	4.47	3.88	4.47	4.73	6.91	6.97	3.36	4.08	4.77
Schooling	2.93	14.54	1.95	14.16	2.64	17.48	3.57	23.24	2.75	16.65
Unemployed within the Age Range of 15 - 65 years	0.48	2.63	0.56	4.01	1.04	3.29	1.26	2.72	0.64	3.10
Unemployed 〈 15 and 〉 65 years	0.88	15.15	0.97	12.34	1.86	13.76	1.88	14.31	1.18	14.08

Source : Rural Socio-economic Survey 1988, Office of Agricultural Economics

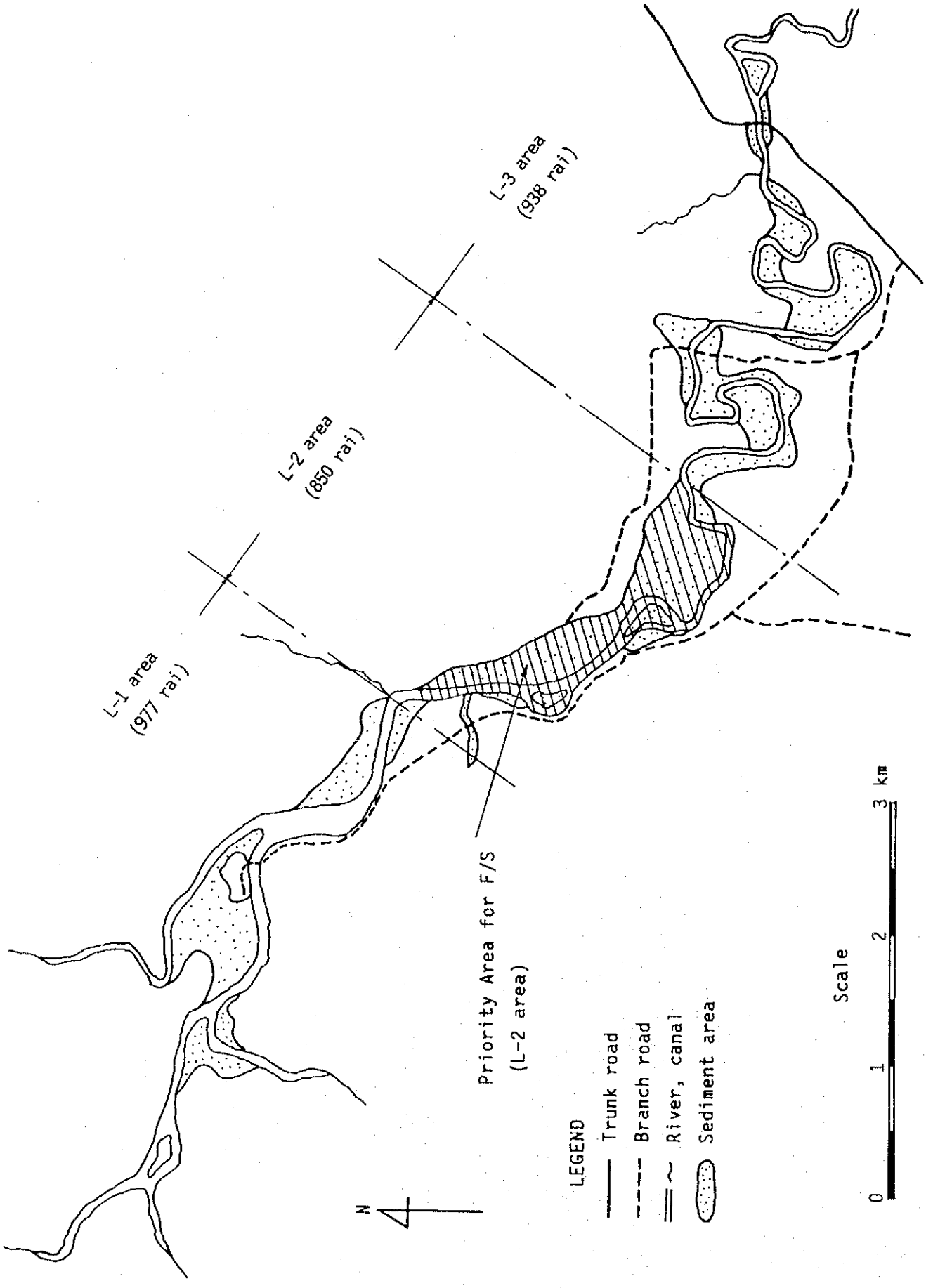
Summary of BAAC-AMC Operation Result
As of May, 1992

Business Amount : Million Baht

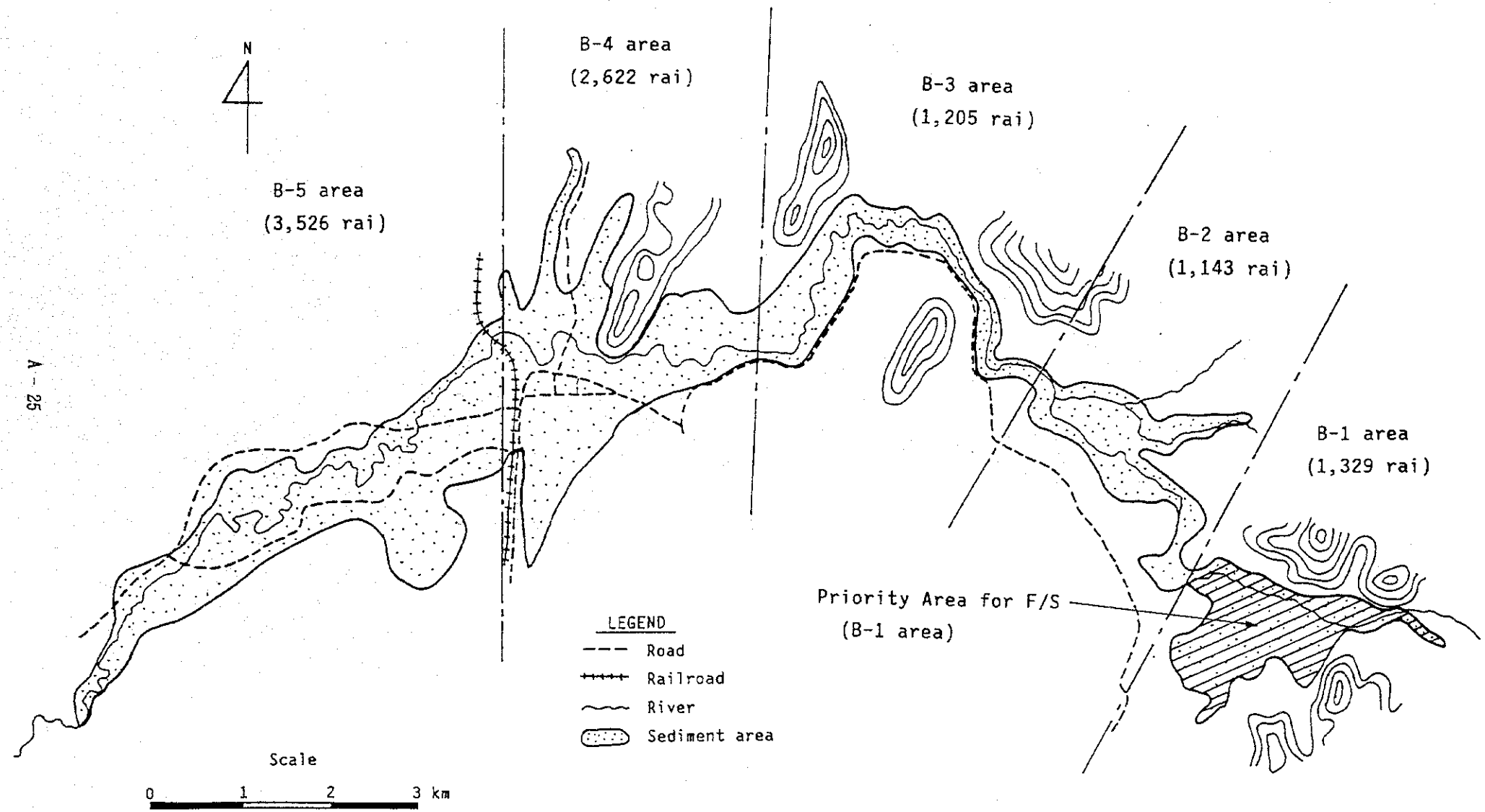
Items	Northern Region	N-E Region	Central-East Region	South-West Region	Whole Country
(1) Total No. of Farm Families	922,820	1,474,253	425,536	713,985	3,536,594
(2) Total No. of Individual Client	629,214	990,541	278,559	435,366	2,333,680
(3) No. of AMC Members	361,910	471,962	140,159	162,516	1,136,547
(4) % of (3)/(2)	58%	48%	50%	37%	49%
(5) Paid Capital (Million Baht)	55.13	64.68	24.51	24.86	169.18
(6) Input Supply Business					
Apr.1991 - Mar. 1992	231.57	433.09	105.92	150.85	921.43
Apr.1992 - May 1992	216.94	189.13	53.54	35.55	495.16
Total Input	448.51	622.22	159.46	186.40	1,416.59
Per AMC Member	1,239	1,318	1,138	1,147	1,246
(7) Output Marketing Business					
Apr. 1991 - Mar. 1992	8.46	0.89	10.50	0.11	19.96
Apr. 1992 - May 1992	2.02	2.52	-	0.03	4.57
Total Output	10.48	3.41	10.50	0.14	24.53
Per AMC Member	29	7	75	1	22
(8) Total Business Amount					
Apr. 1991 - Mar. 1992	240.03	433.98	116.42	150.96	941.39
Apr. 1992 - May 1992	218.96	191.65	53.54	35.58	499.73
Total Amount	458.99	625.63	169.96	186.54	1,441.12

Source : Surveyed data from the BAAC Branch Office. July, 1992
* : This accomplishment is achieved only in 7 AMCs

A-3 Subdivided Area for Selection of F/S Area

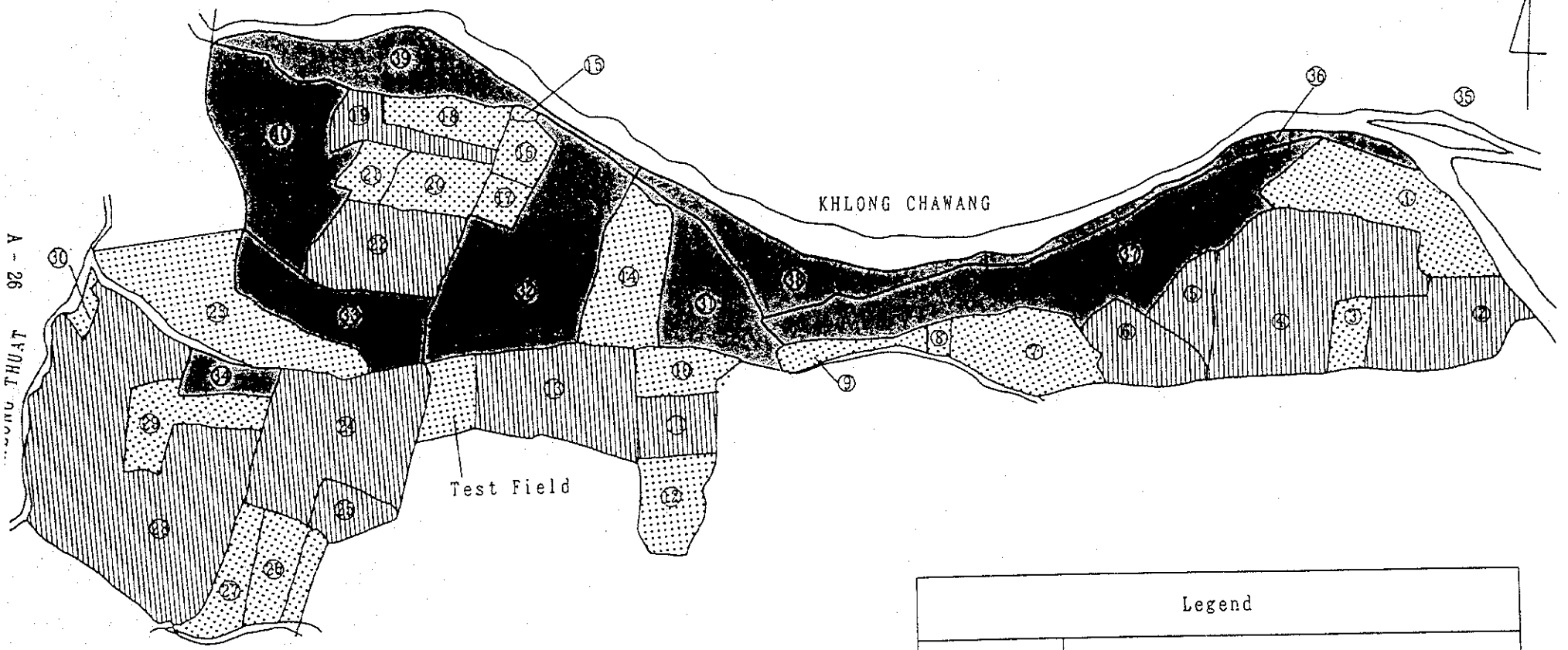


Subdivided Area for Selection of F/S Area in Lan Saka

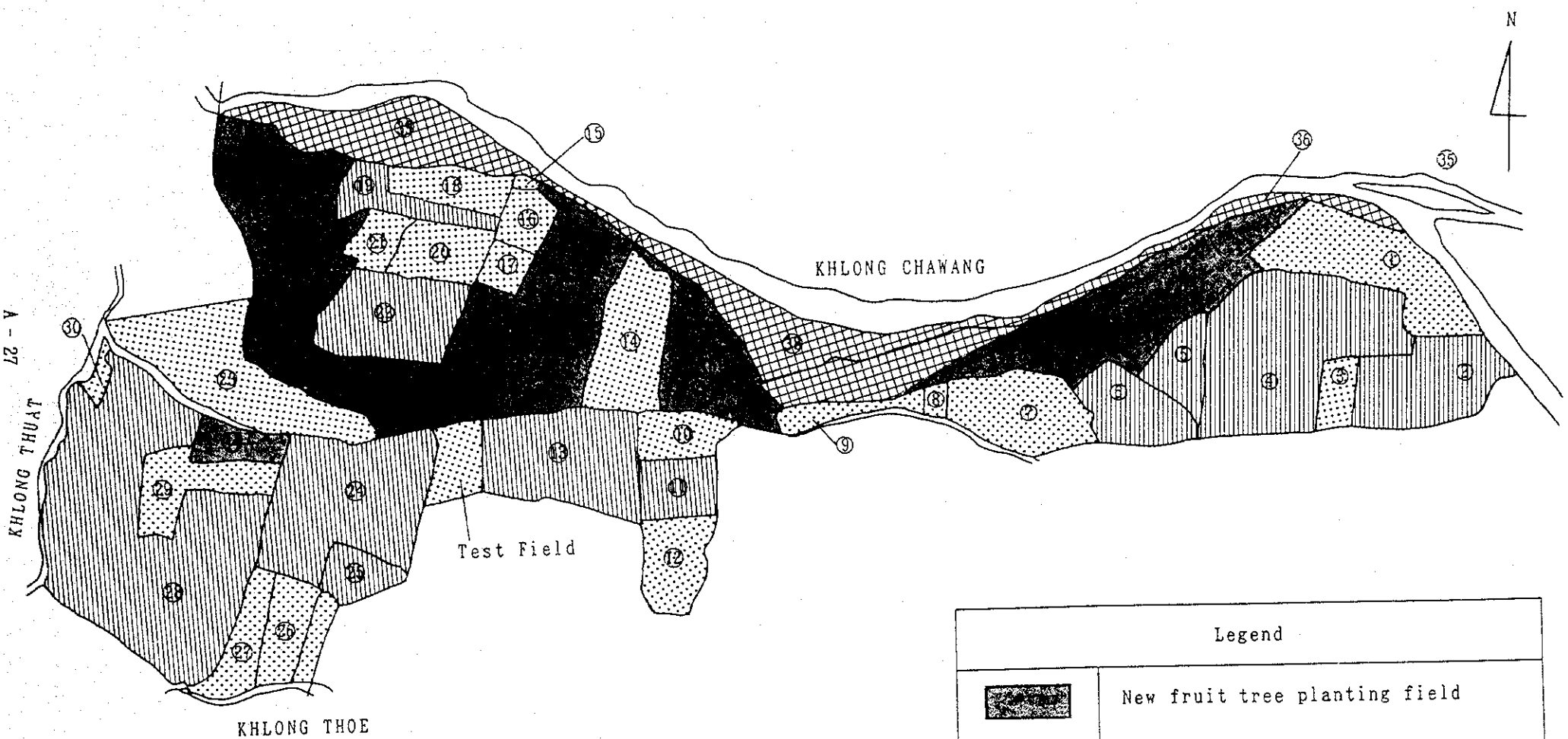


Subdivided Area for Selection of F/S Area in Ban Na San

Land Use Plan (Ban Na San) (Case-1)



Land Use Plan (Ban Na San) (Case-2)



Legend	
	New fruit tree planting field
	Soil/soil layer improvement field
	No improvement field
	No land use field

SCALE

0 100 200 300 400 500 m

Agricultural Land Use Plan in Ban Na San (Case-1)

Unit : rai

Land	Present Area	Land loss	Agricultural Land Use Plan						Waste land
			Y.R.	O.R.	Y.D.	O.D.	C.N.	N.R.	
Fruit tree Plantation									
Y.R.	261.16	1.76	259.40	-	-	-	-	-	-
O.R.	85.69	0.53	-	85.16	-	-	-	-	-
Y.D.	55.07	0.22	-	-	54.85	-	-	-	-
O.D.	1.05	-	-	-	-	1.05	-	-	-
C.N.	8.50	-	-	-	-	-	8.50	-	-
Others									
Sand	110.09	17.25	-	-	-	-	-	89.36	3.48
Grass	94.96	1.28	-	-	-	-	-	93.68	-
Marsh	35.93	1.56	-	-	-	-	-	34.37	-
Total	652.45	22.60	259.40	85.16	54.85	1.05	8.50	217.41	3.48

Note : Y.R. = Rambutan tree before fruitage, planting after 1988 flood.
O.R. = Rambutan tree, still growing nevertheless the tree was damaged by 1988 flood.
Y.D. = Durian tree, same as the Y.R.
O.D. = Durian tree, same as the O.R.
C.N. = Cashew nut
N.R. = New planting of rambutan trees with the project.
Land loss = Area for dike, road and other common use facilities.

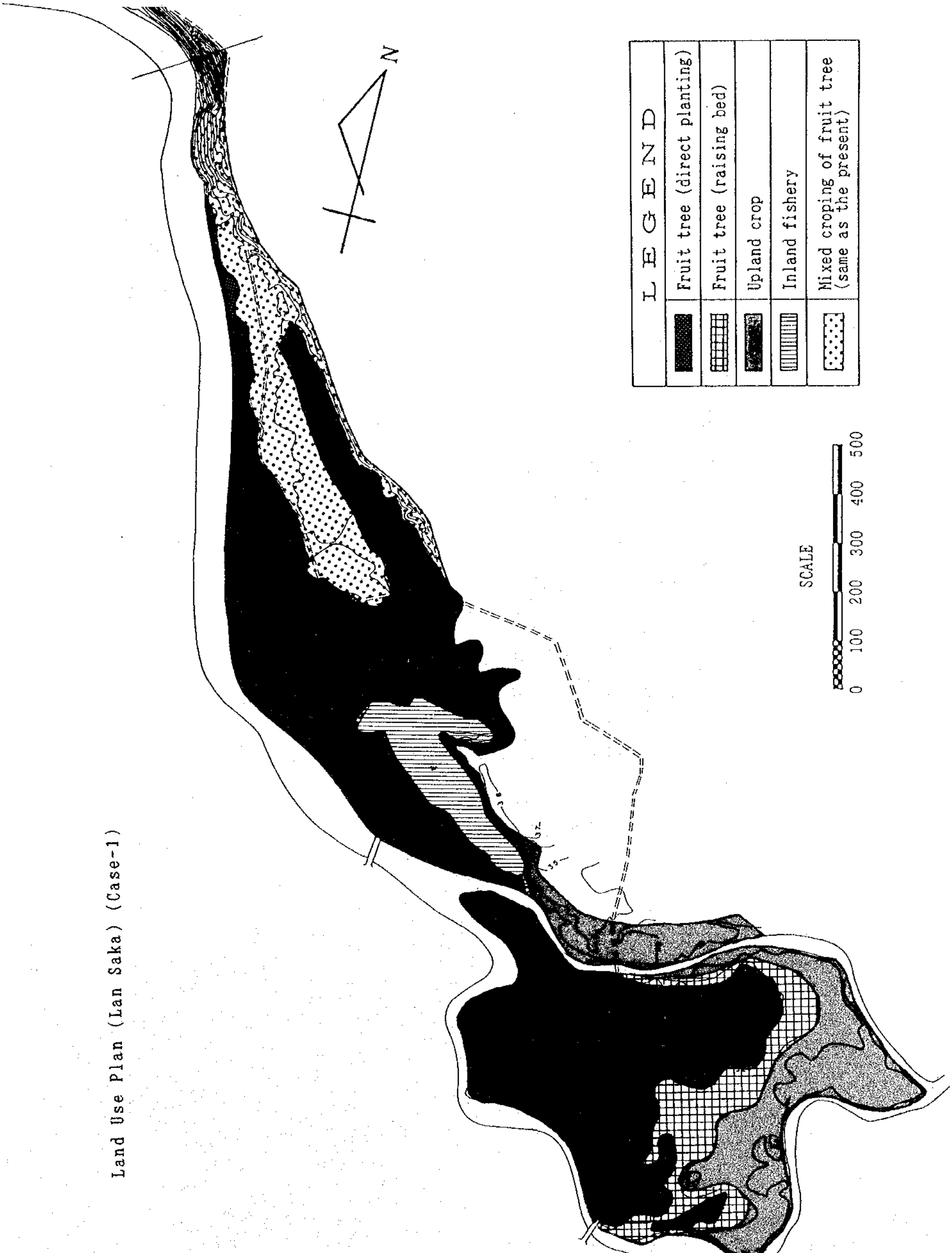
Agricultural Land Use Plan in Ban Na San (Case-2)

Unit : rai

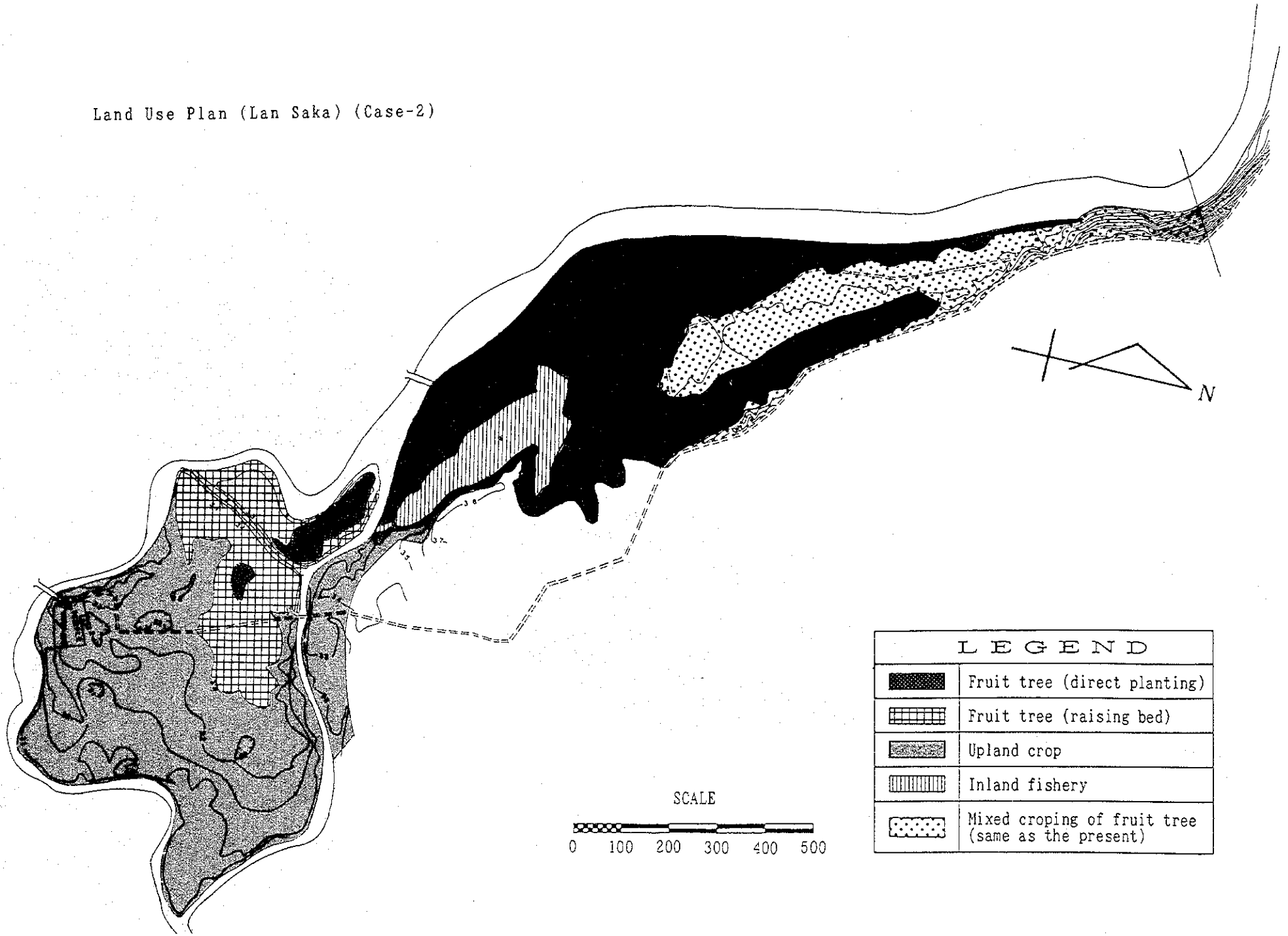
Land	Present Area	Land loss	Agricultural Land Use Plan						Waste land
			Y.R.	O.R.	Y.D.	O.D.	C.N.	N.R.	
Fruit tree Plantation									
Y.R.	261.16	1.76	259.40	-	-	-	-	-	-
O.R.	85.69	0.53	-	85.16	-	-	-	-	-
Y.D.	55.07	0.22	-	-	54.85	-	-	-	-
O.D.	1.05	-	-	-	-	1.05	-	-	-
C.N.	8.50	-	-	-	-	-	8.50	-	-
Others									
Sand	110.09	1.56	-	-	-	-	-	41.46	67.07
Grass	94.96	1.28	-	-	-	-	-	93.68	-
Marsh	35.93	1.56	-	-	-	-	-	34.37	-
Total	652.45	6.91	259.40	85.16	54.85	1.05	8.50	169.51	67.07

Note : Y.R. = Rambutan tree before fruitage, planting after 1988 flood.
O.R. = Rambutan tree, still growing nevertheless the tree was damaged by 1988 flood.
Y.D. = Durian tree, same as the Y.R.
O.D. = Durian tree, same as the O.R.
C.N. = Cashew nut
N.R. = New planting of rambutan trees with the project.
Land loss = Area for dike, road and other common use facilities.

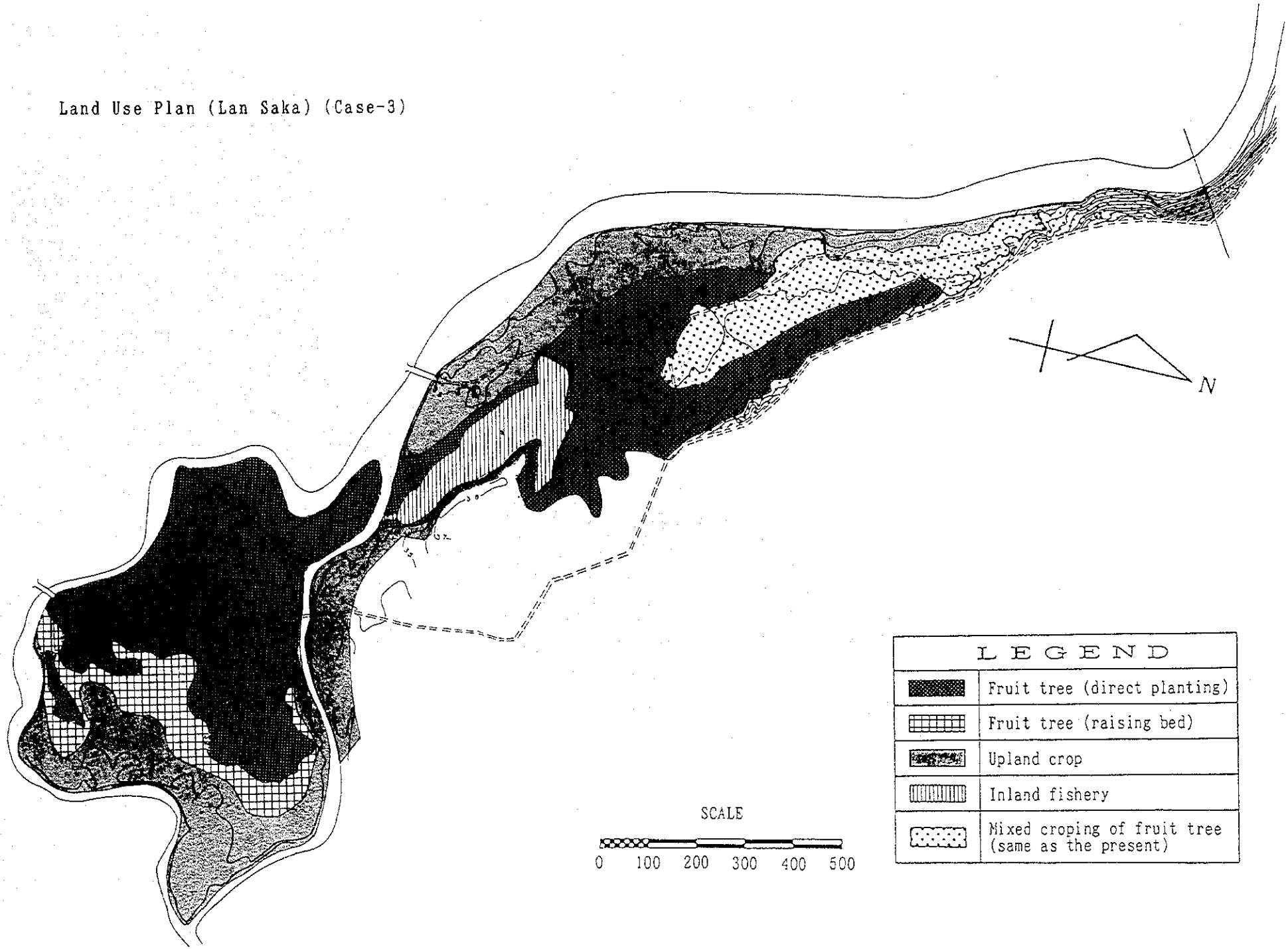
A-5 Land Use Plan of Lan Saka



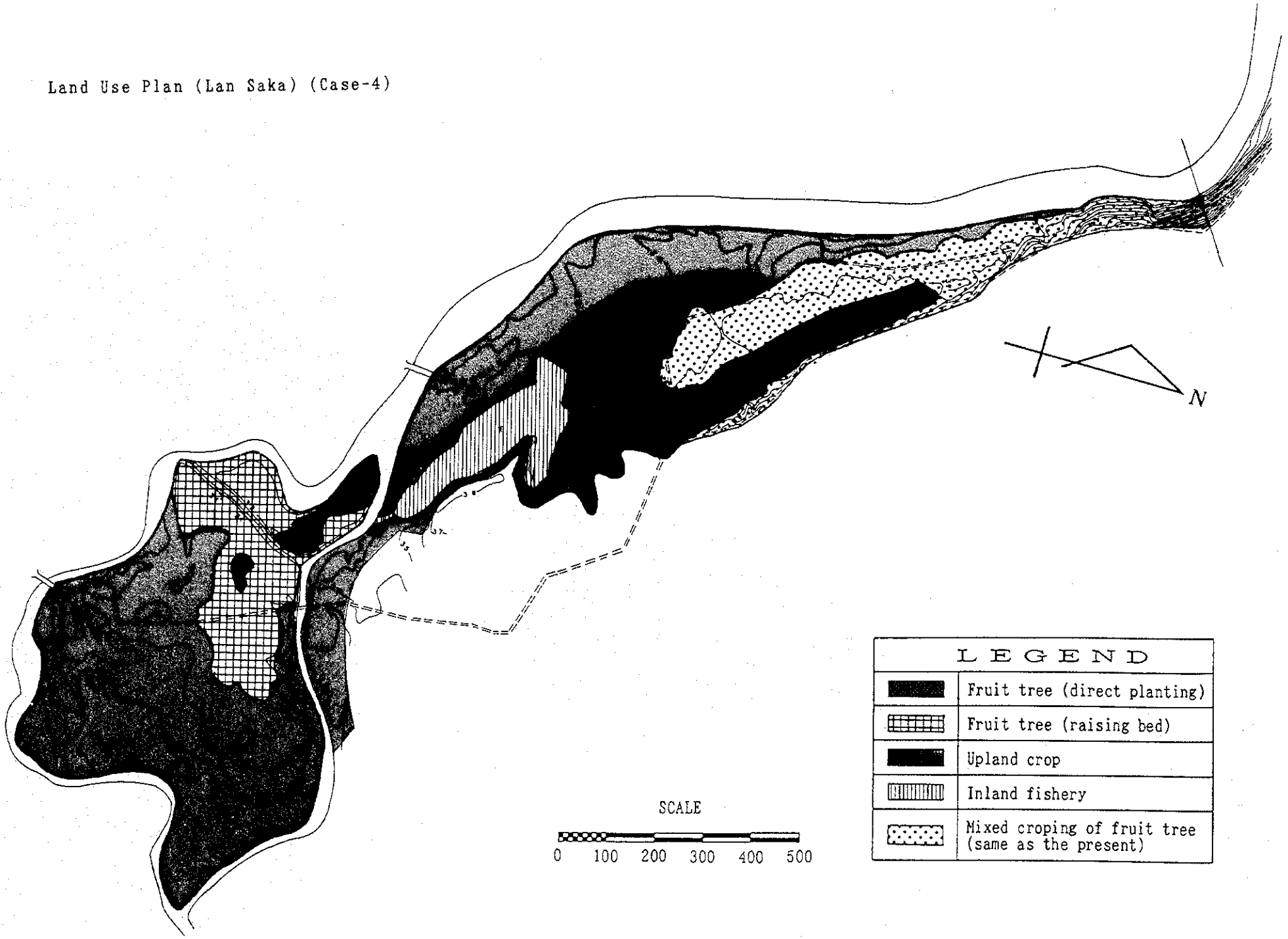
Land Use Plan (Lan Saka) (Case-2)



Land Use Plan (Lan Saka) (Case-3)



Land Use Plan (Lan Saka) (Case-4)



Land Use Plan (Case-1)

Unit : rai

Area	Land Classification	Present Land Use		Land Use Plan						Total
		Area (rai)	Land Use	Same as the Present	Fruit Tree		Upland Crop	Inland Fishery	Land for Public Facilities	
					Direct Planting	Raising Bed				
Upstream	I	74.50	Partly Upland Crops	-	49.36	-	-	-	25.14	74.50
	II	47.08	Mixed Fruit Trees	46.95	-	-	-	-	0.13	47.08
	III	27.03	Marsh	-	-	-	-	24.27	2.76	27.03
	IV	87.03	Grass & Fruit Trees	-	77.22	-	-	-	9.81	87.03
	V	92.28	Mixed Fruit Trees	92.22	-	-	-	-	0.06	92.28
	Sub total	327.92		139.17	126.58	-	-	24.27	37.90	327.92
Downstream	I	248.12	Partly Upland Crops	-	98.32	28.42	76.90	-	47.13	250.77
	II	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-	-	-
	Sub total	248.12		-	98.32	28.42	76.90	-	47.13	250.77
Grand Total		576.04	-	139.17	224.90	28.42	76.90	24.27	85.03	578.69

Note : Area of land use plan (578.69)
= Present land use (576.04) - Temple and test field (3.6) + Canal in downstream (6.25)

Land Use Plan (Case-2)

Unit : rai

Area	Land Classification	Present Land Use		Land Use Plan						Total
		Area (rai)	Land Use	Same as the Present	Fruit Tree		Upland Crop	Inland Fishery	Land for Public Facilities	
					Direct Planting	Raising Bed				
Upstream	I	74.50	Partly Upland Crops	-	49.36	-	-	-	25.14	74.50
	II	47.08	Mixed Fruit Trees	46.95	-	-	-	-	0.13	47.08
	III	27.03	Marsh	-	-	-	-	24.27	2.76	27.03
	IV	87.03	Grass & Fruit Trees	-	77.22	-	-	-	9.81	87.03
	V	92.28	Mixed Fruit Trees	92.22	-	-	-	-	0.06	92.28
	Sub total	327.92		139.17	126.58	-	-	24.27	37.90	327.92
Downstream	I	248.12	Partly Upland Crops	-	8.02	45.64	172.33	-	24.78	250.77
	II	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-	-	-
	Sub total	248.12		-	8.02	45.64	172.33	-	24.78	250.77
Grand Total		576.04	-	139.17	134.60	45.64	172.33	24.27	62.68	578.69

Note : Area of land use plan (578.69)
= Present land use (576.04) - Temple and test field (3.6) + Canal in downstream (6.25)

Land Use Plan (Case-3)

Unit : rai

Area	Land Classification	Present Land Use		Land Use Plan						Total
		Area (rai)	Land Use	Same as the Present	Fruit Tree		Upland Crop	Inland Fishery	Land for Public Facilities	
					Direct Planting	Raising Bed				
Upstream	I	74.50	Partly Upland Crops	-	-	-	74.36	-	0.14	74.50
	II	47.08	Mixed Fruit Trees	46.95	-	-	-	-	0.13	47.08
	III	27.03	Marsh	-	-	-	-	24.27	2.76	27.03
	IV	87.03	Grass & Fruit Trees	-	80.35	-	-	-	6.68	87.03
	V	92.28	Mixed Fruit Trees	92.22	-	-	-	-	0.06	92.28
	Sub total	327.92		139.17	80.35	-	74.36	24.27	9.77	327.92
Downstream	I	248.12	Partly Upland Crops	-	98.32	28.42	76.90	-	47.13	250.77
	II	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-	-	-
	Sub total	248.12		-	98.32	28.42	76.90	-	47.13	250.77
Grand Total		576.04	-	139.17	178.67	28.42	151.26	24.27	56.90	578.69

Note : Area of land use plan (578.69)
= Present land use (576.04) - Temple and test field (3.6) + Canal in downstream (6.25)

Land Use Plan (Case-4)

Unit : rai

Area	Land Classification	Present Land Use		Land Use Plan						Total
		Area (rai)	Land Use	Same as the Present	Fruit Tree		Upland Crop	Inland Fishery	Land for Public Facilities	
					Direct Planting	Raising Bed				
Upstream	I	74.50	Partly Upland Crops	-	-	-	74.36	-	0.14	74.50
	II	47.08	Mixed Fruit Trees	46.95	-	-	-	-	0.13	47.08
	III	27.03	Marsh	-	-	-	-	24.27	2.76	27.03
	IV	87.03	Grass & Fruit Trees	-	80.35	-	-	-	6.68	87.03
	V	92.28	Mixed Fruit Trees	92.22	-	-	-	-	0.06	92.28
	Sub total	327.92		139.17	80.35	-	74.36	24.27	9.77	327.92
Downstream	I	248.12	Partly Upland Crops	-	8.02	45.64	172.33	-	24.78	250.77
	II	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-	-	-
	Sub total	248.12		-	8.02	45.64	172.33	-	24.78	250.77
Grand Total		576.04	-	139.17	88.37	45.64	246.69	24.27	34.55	578.69

Note : Area of land use plan (578.69)
= Present land use (576.04) - Temple and test field (3.6) + Canal in downstream (6.25)

APPENDIX B

HYDROMETEOROLOGY

Appendix B Hydrometeorlogy

B.1	**Meteorology**	B-1
B.2	**Hydrology (General and Master Plan Study Area)**	B-6
B.3	**Hydrology (Ban Na San F/S Area)**	B-19
B.4	**Hydrology (Lan Saka F/S Area)**	B-32

List of Tables

Table B.1.1	Climatological Data for the Period 1961 - 1990 in Surat Thani	B-1
Table B.1.2	Climatological Data for the Period 1961 - 1990 in Nakhon Si Thammarat	B-1
Table B.1.3	Monthly Rainfall Data in General Study Area	B-2
Table B.1.4	Monthly Rainfall Data for the Period 1954 - 1992 in Ban Na San	B-3
Table B.1.5	Monthly Rainfall Data for the Period 1961 - 1992 in Khlong Sao Thong	B-4
Table B.2.1	Relationship Rainfall and Runoff Percentage	B-7
Table B.2.2	Calculation of Design Rainfall of 100 mm. per Day	B-10
Table B.2.3	Effective Rainfall in Ban Na San (to=0.5hr)	B-11
Table B.2.4	Effective Rainfall in Lan Saka (to=0.5hr)	B-11
Table B.2.5	Calculation of Flood Concentration Time	B-12
Table B.3.1	Specific Flood Discharge of Khlong Chawang	B-19
Table B.3.2	Design Drainage Discharge in the Ban Na San F/S Area	B-20
Table B.3.3	Droughty Discharge, Low Discharge of Khlong Chawang	B-20
Table B.3.4	Ordinary Discharge in Each Month of Khlong Chawang	B-21
Table B.3.5	Effective Rainfall in Ban Na San	B-22
Table B.3.6	Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui (Return Period 2 years)	B-29
Table B.3.7	Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui (Return Period 5 years)	B-29
Table B.3.8	Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui (Return Period 10 years)	B-30
Table B.3.9	Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 2 years)	B-30

Table B.3.10	Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 5 years)	B-31
Table B.3.11	Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 10 years)	B-31
Table B.4.1	Specific Flood Discharge of Khlong Tha Di	B-32
Table B.4.2	Design Drainage Discharge in the Lan Saka F/S Area	B-33
Table B.4.3	Droughty Discharge, Low Discharge of Khlong Tha Di	B-33
Table B.4.4	Ordinary Discharge in Each Month of Khlong Tha Di	B-34
Table B.4.5	Effective Rainfall in Lan Saka	B-35
Table B.4.6	Calculation of Irrigable Area in the Lan Saka F/S Area (Return Period 2 years)	B-39
Table B.4.7	Calculation of Irrigable Area in the Lan Saka F/S Area (Return Period 5 years)	B-39
Table B.4.8	Calculation of Irrigable Area in the Lan Saka F/S Area (Return Period 10 years)	B-40
Table B.4.9	Flood Discharge at the point of the Sandbank Island in the Lan Saka F/S Area	B-40

List of Figures

Figure B.1.1	Location of Rainfall Station and Zone of Rainfall Pattern	B-5
Figure B.2.1	Relationship of Catchment Area and Flood Specific Discharge in the General Study Area	B-9
Figure B.2.2	Relationship Rainfall and Runoff Ratio	B-9
Figure B.2.3	Unit Graph (Ban Na San)	B-13
Figure B.2.4	Unit Graph (Lan Saka)	B-13
Figure B.2.5	Calculation of Flood Discharge by Unit Graph (Ban Na San, 2 years)	B-14
Figure B.2.6	Calculation of Flood Discharge by Unit Graph (Ban Na San, 5 years)	B-14
Figure B.2.7	Calculation of Flood Discharge by Unit Graph (Ban Na San, 10 years)	B-15
Figure B.2.8	Calculation of Flood Discharge by Unit Graph (Ban Na San, 25 years)	B-15
Figure B.2.9	Calculation of Flood Discharge by Unit Graph (Ban Na San, 50 years)	B-16
Figure B.2.10	Calculation of Flood Discharge by Unit Graph (Lan Saka, 2 years)	B-16
Figure B.2.11	Calculation of Flood Discharge by Unit Graph (Lan Saka, 5 years)	B-17
Figure B.2.12	Calculation of Flood Discharge by Unit Graph (Lan Saka, 10 years)	B-17
Figure B.2.13	Calculation of Flood Discharge by Unit Graph (Lan Saka, 25 years)	B-18
Figure B.2.14	Calculation of Flood Discharge by Unit Graph (Lan Saka, 50 years)	B-18

Figure B.3.1	Unit Graph (Khlong Thuat)	B-2 3
Figure B.3.2	Calculation of Flood Discharge by Unit Graph (Khlong Thuat, 2 years)	B-2 3
Figure B.3.3	Calculation of Flood Discharge by Unit Graph (Khlong Thuat, 5 years)	B-2 4
Figure B.3.4	Calculation of Flood Discharge by Unit Graph (Khlong Thuat, 10 years)	B-2 4
Figure B.3.5	Calculation of Flood Discharge by Unit Graph (Khlong Thuat, 25 years)	B-2 5
Figure B.3.6	Calculation of Flood Discharge by Unit Graph (Khlong Thuat, 50 years)	B-2 5
Figure B.3.7	Flood and Drainage Discharge Corresponding to each Return Period (F/S Area in Ban Na San)	B-2 6
Figure B.3.8	Droughty Discharge of Corresponding to each Return Period (F/S Area in Ban Na San)	B-2 7
Figure B.3.9	Low Discharge of Corresponding to each Return Period (F/S Area in Ban Na San)	B-2 8
Figure B.4.1	Flood and Drainage Discharge Corresponding to each Return Period (F/S Area in Lan Saka)	B-3 6
Figure B.4.2	Droughty Discharge of Corresponding to each Return Period (F/S Area in Lan Saka)	B-3 7
Figure B.4.3	Low Discharge of Corresponding to each Return Period (F/S Area in Lan Saka)	B-3 8

B.1 Meteorology

Table B.1.1 Climatological Data For the Period 1961 - 1990 in Surat Thani

Item	Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Oct.	Sep.	Oct.	Nov.	Dec.	Year
Temperature	Mean	25.0	25.8	27.0	27.9	27.4	27.1	26.8	26.7	26.4	26.1	25.5	25.2	26.4
(Celsius)	Max.	30.3	32.2	33.7	34.6	33.7	32.9	32.6	32.3	32.1	31.1	29.6	29.2	32.0
	Min.	20.3	20.0	20.9	22.6	23.5	23.5	23.2	23.2	23.0	22.8	22.5	21.7	22.3
Relative	Mean	81	77	75	76	81	81	81	82	84	86	87	84	81
Humidity (%)	Max.	96	96	95	95	95	94	94	94	95	97	97	96	95
	Min.	62	54	51	52	58	60	60	61	62	67	72	69	61
Evaporation (mm)	Mean-pan	120.7	141.8	179.0	165.1	144.1	141.2	146.8	137.2	129.5	117.3	102.9	102.6	1628.2
Sunshine Duration (hr)	Mean	249.1	262.8	267.6	242.2	203.9	178.8	194.8	186.2	166.3	161.5	149.6	186.4	2449.2
Wind (Knots)	Mean Speed	2.2	2.3	2.2	1.8	1.5	1.9	1.9	2.1	1.6	1.2	1.6	2.5	1.9
	Prevailing	NE	E	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	
	Max. Speed	28	29	34	41	42	38	43	46	35	40	36	28	46
Rainfall (mm)	Mean	50.2	10.0	19.6	55.6	174.7	135.0	145.2	141.3	193.0	249.0	331.2	130.7	1635.5
	Rainy Day	6.4	2.1	2.9	6.6	17.5	16.6	17.3	17.7	19.1	19.6	19.3	13.1	158.2
	Daily Max.	216.6	44.8	67.2	119.2	106.8	92.1	75.3	147.1	95.3	177.3	457.1	104.1	457.1

Station	Surat Thani
Latitude	09-07 N
Longitude	99-21 E
Elevation of Station above MSL	10 Meters

Table B.1.2 Climatological Data For the Period 1961 - 1990 in Nakhon Si Thammarat

Item	Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Oct.	Sep.	Oct.	Nov.	Dec.	Year
Temperature	Mean	25.8	26.6	27.7	28.5	28.3	28.3	28.0	27.9	27.5	26.9	26.1	25.8	27.3
(Celsius)	Max.	29.7	31.1	32.7	33.8	33.5	33.5	33.3	33.3	32.7	31.4	29.6	29.2	32.0
	Min.	21.8	21.8	22.3	23.4	23.9	23.8	23.3	23.3	23.1	23.0	22.9	22.5	22.9
Relative	Mean	82	79	76	77	79	76	75	75	79	83	86	84	79
Humidity (%)	Max.	96	96	95	95	94	93	93	92	95	96	96	96	95
	Min.	66	61	57	58	60	57	56	56	59	66	73	71	62
Evaporation (mm)	Mean-pan	96.6	111.2	143.7	135.4	123.7	130.1	129.9	135.7	113.7	108.1	84.4	84.7	1397.2
Sunshine Duration (hr)	Mean													
Wind (Knots)	Mean Speed	2.4	2.6	2.7	2.3	2.7	3.6	3.3	3.7	2.4	1.7	1.9	2.3	2.6
	Prevailing	E	E	E	E	SW	SW	SW	SW	SW	SW	N	N,E	
	Max. Speed	32	30	32	50	44	40	35	40	40	50	32	30	50
Rainfall (mm)	Mean	173.5	42.5	44.6	94.4	169.6	95.1	108.1	97.3	160.8	338.3	643.1	414.0	2381.3
	Rainy Day	12.7	5.5	4.4	8.3	16.9	13.1	13.8	13.9	17.4	20.8	22.2	20.2	169.2
	Daily Max.	433.3	102.3	70.1	161.0	76.6	76.6	70.3	84.2	83.5	271.7	447.8	237.7	447.8

Station	Nakon Si Thammarat
Latitude	08-28 N
Longitude	99-58 E
Elevation of Station above MSL	7 Meters

Table B.1.3 Monthly Rainfall Data in General study Area

Zone	Observation Number	Apr.	May	Jun.	Jul..	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Mean of Max. Rainfall 1 Day	2 Days	3 Days
(a)	2705	42.6	109.2	89.4	94.9	93.8	127.7	249.9	440.3	223.0	130.7	20.8	25.4	1648.9	122.3	189.8	234.7
	2704	69.9	101.9	64.2	77.2	75.5	105.0	293.5	576.6	361.0	157.1	34.1	32.0	1943.5	165.7	250.6	304.6
	2701	91.9	175.2	89.4	106.5	104.7	151.1	332.3	593.0	426.4	171.3	44.0	42.1	2327.9	183.3	269.8	323.6
	2721	67.0	157.7	103.7	130.4	124.1	155.0	288.5	516.4	296.5	156.6	34.1	33.3	2049.4	147.7	220.9	270.0
	2708	97.2	140.1	75.5	83.0	84.4	114.0	230.4	438.2	320.1	133.3	33.8	66.1	1816.0	151.4	220.0	265.9
	2715	135.2	198.4	93.1	96.4	92.3	141.7	315.7	546.4	421.1	200.2	55.6	74.3	2370.3	181.0	257.6	308.2
	2703	94.3	142.0	66.1	69.7	84.0	110.3	233.0	413.2	263.2	121.6	20.7	35.3	1731.5	138.6	199.4	234.6
	Average	85.4	146.4	83.1	94.0	94.1	129.3	277.6	503.4	330.2	153.0	34.7	44.1	1983.9	155.7	229.7	277.4
(b)	2707	82.4	218.0	193.8	212.9	221.6	256.6	272.4	212.7	107.9	30.1	13.1	33.1	1863.7	92.9	123.1	141.9
	2711	71.6	195.3	175.9	199.7	200.9	215.7	224.1	212.5	107.8	30.7	8.4	22.1	1664.8	87.8	132.2	156.4
	2706	99.7	208.5	155.2	200.0	187.8	220.6	269.8	265.9	154.7	48.4	20.8	44.3	1919.4	117.9	150.7	176.2
	2709	88.5	179.2	127.3	160.1	182.8	199.5	242.2	186.4	66.3	51.6	17.8	43.6	1491.3	84.3	115.2	137.8
	6107	81.9	187.7	177.4	201.7	202.1	237.0	226.4	190.4	62.3	23.4	11.2	37.4	1664.6	91.8	119.1	143.0
	6108	83.8	178.6	156.0	167.4	170.7	231.1	246.3	191.0	87.5	36.0	20.5	50.3	1664.1	90.6	120.4	147.8
	Average	84.6	194.5	164.3	190.3	194.3	226.7	246.9	209.8	97.7	36.7	15.3	38.5	1711.3	94.2	126.8	150.5
(c)	6102	58.3	146.4	125.8	131.7	124.9	161.4	268.0	337.3	141.9	56.3	4.2	13.9	1558.6	116.1	167.9	192.0
	6103	55.6	178.4	138.5	147.3	140.0	186.5	259.8	314.4	135.7	52.1	10.2	19.6	1638.1	118.8	162.3	188.3
	6105	61.1	179.9	123.2	151.2	120.2	182.0	227.1	290.1	117.2	49.8	8.5	23.0	1533.4	121.1	156.4	172.2
	Average	58.3	168.3	129.2	143.4	128.4	176.6	251.6	313.9	131.6	52.7	7.6	18.8	1576.7	118.6	162.2	184.2

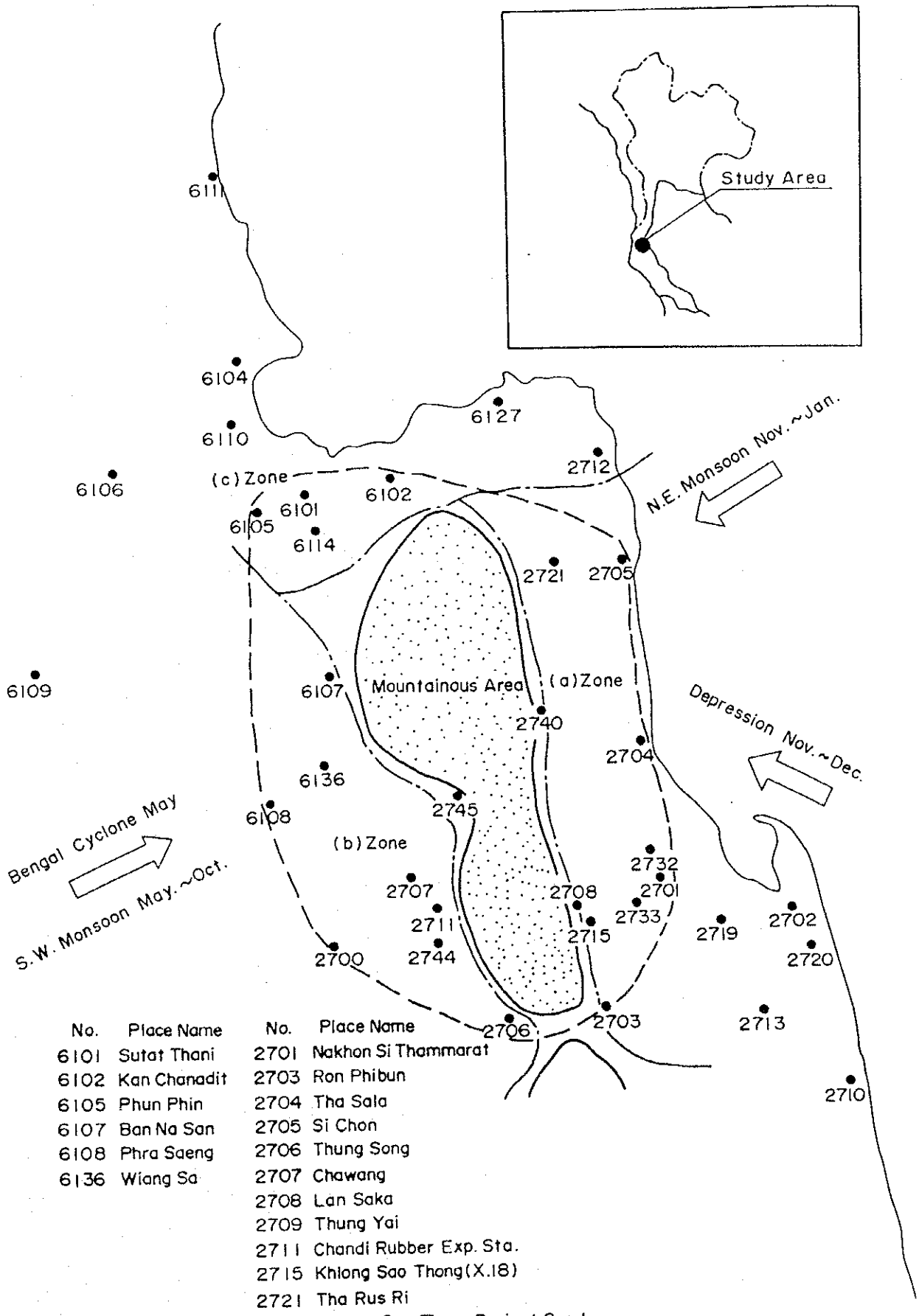
Note : Observation Number and Zone are referred to Fig. 3.1 of Main Report

Table B.1.4 Monthly Rainfall Data for the Period 1954-1992 in Ban Na San

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total	1 Day Max.	2 Days Max.	3 Days Max.
1952																
1953																
1954	194.3	172.2	133.5	153.6	119.2	133.7	55.8	18.7	38.2	17.6	0.0	0.0	1036.8	42.0	68.2	84.1
1955	96.9	74.7	164.2	140.6	90.9	164.9	189.7	495.8	0.0	0.0	0.0	16.0	1433.7	100.2	150.7	240.7
1956	123.0	280.0	178.0	227.7	255.0	360.0	270.8	236.5	303.0	0.0	10.0	54.0	2298.0	100.0	150.0	225.5
1957	61.9	76.7	173.5	342.9	320.4	213.0	226.8	102.8	58.7	0.0	12.4	0.0	1589.1	75.0	79.5	85.9
1958	42.0	186.4	182.1	158.2	281.5	353.0	333.4	231.5	0.0	15.3	0.0	37.0	1820.4	47.0	91.5	112.9
1959	186.6	1.3	171.4	288.4	161.4	259.6	397.2	352.1	94.9	37.1	26.9	182.5	2159.4	73.1	115.6	127.7
1960	98.2	340.9	147.5	324.2	224.5	380.7	215.7	247.5	56.7	58.9	0.0	62.1	2156.9	94.3	117.8	132.6
1961	17.0	275.8	223.1	74.5	157.7	293.6	331.1	181.3	69.6	0.0	0.0	56.3	1680.0	102.2	116.8	138.7
1962	113.6	104.3	143.6	235.7	121.5	198.0	238.3	39.7	47.2	18.8	0.0	60.2	1320.9	76.8	105.9	121.5
1963	71.9	194.7	197.4	98.3	162.4	334.0	460.8	149.7	57.6	39.1	17.6	0.0	1783.5	162.3	162.3	172.6
1964	8.9	318.9	74.7	119.2	233.1	259.0	171.0	149.6	121.1	0.0	18.5	0.0	1474.0	93.5	102.1	102.1
1965	114.4	111.3	132.6	157.8	155.0	309.0	145.0	133.0	196.7	11.5	0.0	177.0	1643.3	130.7	130.7	130.7
1966	17.4	142.0	302.3	153.3	205.3	320.8	461.4	264.5	168.7	126.7	0.0	0.0	2162.4	304.3	304.3	305.0
1967	121.2	222.8	147.6	292.9	162.4	133.1	0.0	3.2	81.4	17.5	0.0	0.0	1182.1	92.3	130.0	173.1
1968	0.0	125.9	229.2	340.4	200.7	189.6	260.3	0.0	52.0	54.6	68.9	56.8	1578.4	77.1	107.5	114.5
1969	61.8	200.7	138.8	172.7	208.8	292.9	136.4	117.7	29.7	51.0	0.0	15.8	1426.3	60.0	68.7	68.7
1970	37.3	131.3	45.8	136.8	129.0	148.2	137.3	112.4	60.9	0.0	0.0	0.0	939.0	55.7	64.9	85.2
1971	0.0	84.2	141.0	101.5	224.3	157.3	431.8	166.6	127.4	5.6	9.4	27.1	1476.2	104.8	110.0	134.3
1972	84.7	188.3	120.8	127.9	93.1	327.4	222.6	184.7	21.4	0.0	0.0	0.0	1370.9	80.8	112.8	179.2
1973																
1974	132.4	206.3	75.2	202.6	157.4	309.5	164.2	329.2	124.0	150.7	69.6	0.0	1921.1	115.2	154.0	187.8
1975	0.0	36.0	209.9	115.4	100.0	0.0	73.0	153.0	0.0	0.0	0.0	0.0	687.3	97.0	97.0	97.0
1976	0.0	130.8	145.6	189.4	91.1	207.6	84.1	341.6	80.8	0.0	0.0	0.0	1271.0	86.7	130.0	150.4
1977	0.0	289.6	247.9	93.7	259.3	183.9	154.2	489.4	54.2	1.3	0.0	90.1	1863.6	100.5	200.5	296.0
1978	87.0	234.0	151.0	376.0	208.0	296.1	253.2	132.5	49.8	3.6	2.3	51.0	1844.5	73.6	96.5	114.1
1979	159.7	280.3	295.0	337.4	103.4	399.3	76.9	195.4	7.4	0.0	50.8	107.7	2013.3	92.3	107.6	110.1
1980	101.2	133.4	337.3	354.6	220.7	261.3	298.6	322.5	28.4	5.2	28.6	6.3	2098.1	94.7	107.0	113.8
1981	248.2	362.1	333.0	197.2	77.9	137.3	151.8	257.4	55.7	0.0	0.0	111.5	1932.1	98.5	115.0	128.2
1982	149.6	119.4	237.9	615.2	622.6	561.7	646.0	765.9	102.6	172.7	0.0	75.1	4068.7	90.8	181.4	213.7
1983	70.0	583.8	652.2	552.3	397.9	155.2	220.2	132.4	28.7	39.1	11.6	27.7	2871.1	90.8	161.4	191.8
1984	99.9	137.0	165.8	68.3	315.1	238.1	121.2	0.0	0.0	0.0	34.9	31.8	1212.1	70.2	70.2	110.7
1985	69.1	105.2	109.2	36.7	91.0	130.6	207.9	88.5	40.3	0.0	24.6	26.5	929.6	34.5	56.9	57.5
1986	89.4	358.4	108.4	140.2	241.4	192.7	266.6	209.9	25.4	19.0	0.0	12.4	1663.8	57.5	97.2	136.4
1987	78.2	178.3	129.7	16.2	361.3	148.6	308.9	145.7	94.2	13.0	0.0	9.0	1483.1	93.6	93.6	116.2
1988	0.0	70.3	42.3	258.0	172.2	147.4	48.1	119.9	0.0	0.0	0.0	0.0	858.2	69.7	69.7	93.1
1989	116.0	233.0	182.4	215.8	190.5	319.9	262.3	94.8	0.0	0.0	25.5	13.8	1654.0	99.8	99.8	100.0
1990	87.3	122.6	51.8	169.8	95.6	248.8	315.0	183.5	40.4	0.0	5.4	31.1	1351.3	56.5	89.0	121.2
1991	69.1	365.7	195.1	122.8	224.7	249.8	125.5	80.4	46.2	39.7	0.0	0.0	1519.0	122.6	171.8	187.0
1992	113.7	63.6	65.4	95.6	293.2	174.5	345.5	140.4	7.7	12.8	21.5	126.0	1459.9	72.9	137.7	173.0
Average	82.2	190.6	178.5	205.4	203.4	241.8	231.8	193.9	62.4	24.0	11.5	38.5	1664.0	91.8	119.1	143.0

Table B.1.5 Monthly Rainfall Data for the Period 1961-1992 in Khlong Sao Thong

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total	1 Day Max.	2 Days Max.	3 Days Max.
1952																
1953																
1954																
1955																
1956																
1957																
1958																
1959																
1960																
1961	164.0	170.5	65.5	37.6	57.6	66.8	232.5	850.9	581.0	274.5	36.5	0.0	2537.4	127.1	172.6	236.6
1962														146.2	197.5	209.9
1963	0.0	8.3	83.1	125.3	55.5	149.3	711.1	669.0	217.6	396.3	136.0	51.9	2603.4	293.8	355.1	433.1
1964	19.4	270.3	47.2	76.9	109.8	71.5	187.5	223.6	580.0	28.5	85.5	97.9	1798.1	158.4	252.6	362.4
1965	153.2	408.8	130.0	149.5	135.3	72.9	326.8	386.0	587.5	197.2	29.1	296.9	2873.2	140.1	176.2	188.5
1966	118.7	73.5	139.8	51.1	89.1	247.8	473.2	727.7	728.0	550.6	130.0	54.3	3383.8	202.4	299.8	353.0
1967	189.6	109.4	136.8	88.9	124.3	105.2	470.6	642.5	240.5	26.3	17.4	42.0	2193.5	86.8	150.5	172.2
1968	115.4	253.4	90.1	116.2	106.6	47.1	478.1	349.3	231.7	282.3	40.3	32.0	2142.5	141.0	187.5	203.2
1969	89.8	169.2	80.5	51.3	118.4	132.7	247.5	682.4	356.5	325.5	30.5	137.1	2421.4	126.8	187.8	202.3
1970	182.7	233.8	82.0	117.4	121.6	117.3	221.7	627.9	492.0	28.8	126.6	184.2	2536.0	120.5	157.7	185.4
1971	26.3	119.1	71.5	44.5	12.5	82.3	462.1	338.8	632.2	92.3	42.7	57.4	1981.7	161.7	251.4	306.6
1972	212.9	83.6	191.4	46.5	36.9	204.2	353.0	504.1	251.6	72.2	16.5	57.4	2030.3	101.0	146.4	183.4
1973	60.5	370.3	68.7	140.4	130.4	55.9	613.7	868.0	579.7	24.8	93.4	30.9	3036.7	215.5	323.5	377.5
1974	176.3	232.1	102.8	84.1	53.6	188.1	127.4	529.7	890.4	1639.7	162.0	44.4	4230.6	604.0	875.0	936.7
1975	60.4	121.7	89.9	82.8	68.0	171.4	312.6	481.8	329.7	20.9	1.2	20.7	1761.1	161.0	203.5	213.0
1976	121.5	147.3	59.9	70.2	102.0	89.0	369.4	888.5	136.8	245.8	64.9	97.8	2393.1	230.5	267.5	297.6
1977														305.0	428.0	512.0
1978	124.6	145.8	24.1	121.7	66.2	97.3	266.7	282.2	501.8	169.9	25.2	8.4	1833.9	120.0	195.0	266.3
1979	127.5	128.2	195.2	174.5	124.5	137.2	290.8	712.4	179.5	62.8	5.6	142.0	2280.2	195.0	262.0	302.0
1980	68.5	160.2	64.5	106.0	70.6	112.3	149.8	528.7	255.3	39.2	43.0	0.3	1598.4	81.2	130.5	186.2
1981	279.1	327.5	101.1	19.8	49.2	284.2	311.8	384.7	533.5	21.8	2.4	64.6	2379.7	145.3	219.4	303.0
1982	261.3	292.1	44.3	52.8	63.5	110.6	289.0	429.5	181.5	195.1	24.6	66.1	2010.4	147.5	163.2	186.2
1983	89.2	178.6	107.7	78.8	62.6	93.0	147.6	298.9	506.9	381.5	172.2	90.7	2207.7	114.9	154.5	198.3
1984	171.9	206.4	85.3	228.1	60.7	209.1	211.8	688.8	626.4	55.9	117.6	123.3	2785.3	278.5	407.2	526.5
1985	196.2	219.9	129.5	68.9	65.6	180.9	220.5	513.1	319.4	49.7	14.7	22.2	2000.6	100.9	126.7	133.9
1986	175.0	283.0	74.9	103.0	69.2	314.5	268.9	577.5	333.8	127.5	5.4	33.9	2366.6	104.3	164.1	217.6
1987	59.9	174.5	128.9	41.0	256.4	71.9	277.4	273.6	888.0	192.7	88.3	35.8	2488.4	204.7	285.7	412.7
1988	200.9	355.4	71.8	199.3	181.7	149.0	67.4	1522.1	184.8	168.7	9.6	102.4	3213.1	472.3	788.5	944.0
1989	117.5	188.3	57.2	134.9	57.3	300.0	373.4	274.0	61.2	86.9	16.8	26.9	1694.4	90.3	143.3	174.6
1990	132.9	170.4	36.4	81.9	118.9	152.9	465.8	405.7	380.3	39.3	44.7	76.2	2105.4	168.2	192.1	231.7
1991	239.3	186.0	119.9	90.9	65.5	168.2	204.7	461.1	512.3	118.5	72.0	41.9	2280.3	121.6	192.7	208.2
1992	122.1	164.5	113.1	106.3	134.7	67.8	339.1	269.8	333.4	91.8	12.0	188.5	1943.1	125.6	185.0	197.0
Average	135.2	198.4	93.1	96.4	92.3	141.7	315.7	546.4	421.1	200.2	55.6	74.3	2370.3	181.0	257.6	308.2



No.	Place Name
6101	Sutat Thani
6102	Kan Chanadit
6105	Phun Phin
6107	Ban Na San
6108	Phra Saeng
6136	Wiang Sa

No.	Place Name
2701	Nakhon Si Thammarat
2703	Ron Phibun
2704	Tha Sala
2705	Si Chon
2706	Thung Song
2707	Chawang
2708	Lan Saka
2709	Thung Yai
2711	Chandi Rubber Exp. Sta.
2715	Khlong Sao Thong(X.18)
2721	Tha Rus Ri
2732	Khlong Sao Thong Project Sec.1
2733	Khlong Sao Thong Project Sec.2
2740	Khlong Klai (X.149)
2745	Phi Pun

Figure B.1.1 Location of Rainfall Station and Zone of Rainfall Pattern

B.2 Hydrology (General and Master Plan Study Area)

1. Flood Specific Discharge in the General Study Area

Based on the observation data of X.55(A=105km^2), X.70(A=39km^2), X.80(A=114km^2), X.81(A=219km^2), X101(A=95km^2), and X.163(A=97km^2), the flood discharge corresponding to each return period in the General Study Area is calculated. (See Figure B.2.1)

2. Estimation of Flood Discharge of Khlong Chawang and Khlong Tha Di in the Master Plan Study Area

Flood discharge is estimated by using unit graph method and design rainfall. Unit hydrograph method is suitable to estimate characteristics of flood discharge in such a scanty observed flood information. Unit hydrograph method is possible to estimate characteristics of flood discharge by using the information of characteristics of catchment area such as topography, river length, and river bed slope. And this method is adapted to a short term direct runoff well.

Number of estimation plot are 4 (A,B,C,D) in Khlong Chawang, and 2 (A,B) in Khlong Tha Di from the viewpoint of river shape. In case of Khlong Chawang, the catchment area is wide relatively, therefore the catchment area is divided into 4 area. And the flood discharge is determined by adding up each flood discharge of each divided area taking into consideration a delay of the flood concentration time. (Location of each plot is referred to Figure 4.1 and Figure 5.1 of the Main Report.)

a) Runoff Percentage

Based on the observation data of Khlong Chawang (X.81) and Khlong Tha Di (X.55), the relationship of runoff percentage and rainfall is calculated. (See Figure B.2.2)

$$Y = 2.19\ X^{0.5915}$$

Where Y : Runoff Percentage (%)
X : Rainfall (mm)

Based on the formula above, the design runoff percentage is as follows.

Table B.2.1 Relationship Rainfall and Runoff Percentage

Rainfall (mm)	Runoff Percentage (%)
Less than 50	22
50 to 100	33
100 to 200	50
200 to 300	64
300 to 400	76
More than 400	86

b) Design Rainfall

Design Rainfall is determined from rainfall intensity curve (hyetograph) owing to no observation data of hourly rainfall. Design rainfall for daily rainfall of 100 mm. is shown in Table B.2.2.

c) Effective Rainfall

Effective rainfall is calculated by multiplying design rainfall and runoff percentage. Runoff percentage is adopted the value corresponding 3 days rainfall. Table B.2.3 and B.2.4 show effective rainfall for every 0.5 hour.

d) Flood concentration time

Flood concentration time is calculated by using the Kraven formula. Flood velocity based on the Kraven Formula is as follows.

River Bed Slope	Flood velocity (m/s)
More than 1/100	3.5
1/100 to 1/200	3.0
Less than 1/200	2.1

According to flood velocity above, flood concentration time traveling to each plot is shown in Table B.2.5.

e) Unit Graph method

Characteristics of flood discharge by unit graph method is as follows.

Peak Discharge $Qp=(AR_0/3.6) / (0.3Tp+Tk)$

Climbing Curve $(Q/Qp)=(T/Tp)^{2.4}$

Recession Curve	$1 > (Q/Qp) > 0.3$	$(Q/Qp)=0.3^{((T-Tp)/Tk)}$
	$0.3 > (Q/Qp) > 0.3^2$	$(Q/Qp)=0.3 \times 0.3^{(T-Tp-Tk)/1.5Tk)}$
	$0.3^2 > (Q/Qp)$	$(Q/Qp)=0.3^2 \times 0.3^{(T-Tp-Tk-1.5Tk)/2.0Tk)}$

Where

Qp : Peak Runoff Discharge (m^3/s)

Q : Runoff Discharge on optional time

R_0 : Unit Rainfall (mm)

T : Optional Time (hour)

Tp : flood concentration time (hour)

Tk : Time required shifting from Qp to 0.3Qp

$Tk=0.47(AL)^{0.25}$

A : Catchment Area (km^2)

L : Length of River (km)

Based on the formula above, the characteristics of runoff discharge for effective rainfall of 10 mm. are shown in Figure B.2.3 and Figure B.2.4.

f) Flood Discharge

Flood discharge corresponding each return period is estimated by using the characteristics of runoff discharge for effective rainfall of 10 mm and design rainfall. As Figure B.2.3 and Figure B.2.4 show, most of direct runoff concludes within 24 hours, therefore length of design rainfall is adopted 1 day. Figure B.2.5 to Figure B.2.14 show the result of flood discharge corresponding to each return period.

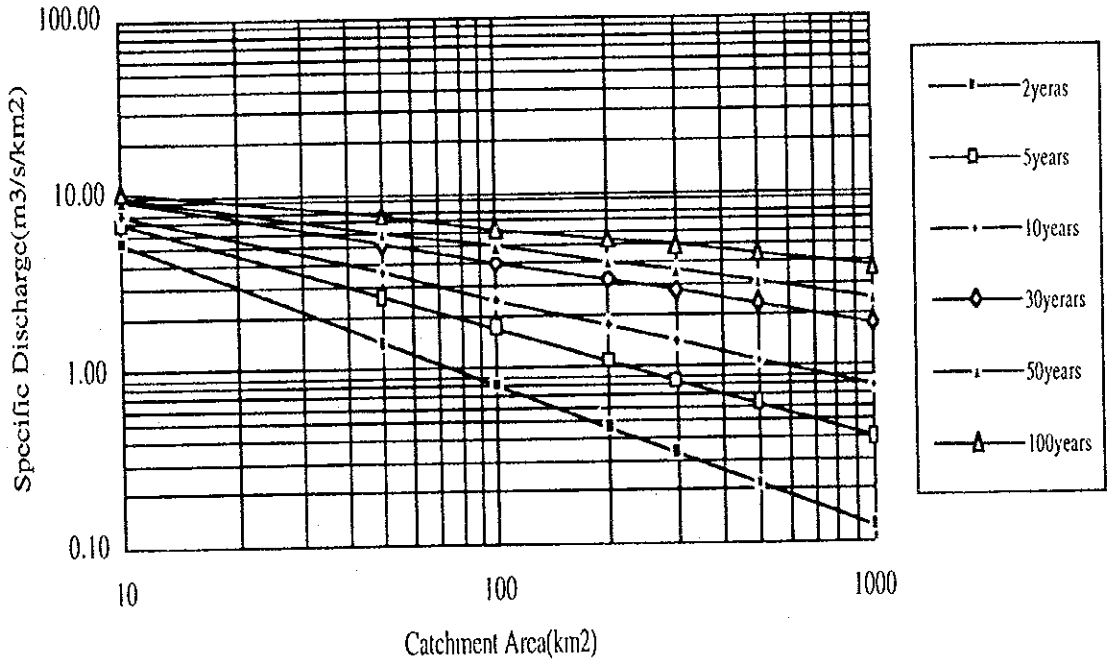


Figure B.2.1 Relationship of Catchment Area and Flood Specific Dischage in the General Study Area

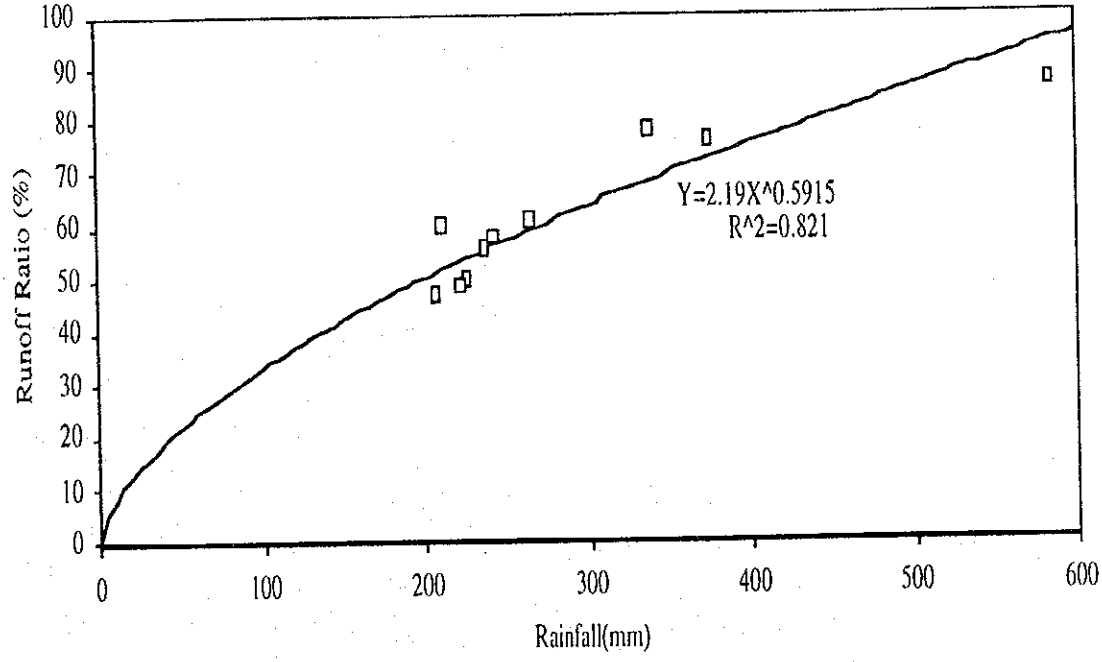


Figure B.2.2 Relationship Rainfall and Runoff Ratio

R24= 100.0 mm b= 3 a'= 27 a= 2700 r= 0.8

Time	tb2	tb1	ta1	ta2	(1) abr^2	(1)' ab(1-r)^2	(2) 1/(tb1+br)	(3) 1/(tb2+br)	(4) (2)-(3)	(5) 1/(ta1+b(1-r))	(6) 1/(ta2+b(1-r))	(7) (5)-(6)	(8) (1)x(4)	(9) (1)'x(7)	(10) (8)+(9)	(11) (mm) (10)/24
0.5	18.8	18.3			5184		0.0483	0.0472	0.0011				5.9		5.9	0.2461
1.0	18.3	17.8			5184		0.0495	0.0483	0.0012				6.2		6.2	0.2583
1.5	17.8	17.3			5184		0.0508	0.0495	0.0013				6.5		6.5	0.2714
2.0	17.3	16.8			5184		0.0521	0.0508	0.0013				6.9		6.9	0.2855
2.5	16.8	16.3			5184		0.0535	0.0521	0.0014				7.2		7.2	0.3008
3.0	16.3	15.8			5184		0.0549	0.0535	0.0015				7.6		7.6	0.3173
3.5	15.8	15.3			5184		0.0565	0.0549	0.0016				8.0		8.0	0.3353
4.0	15.3	14.8			5184		0.0581	0.0565	0.0016				8.5		8.5	0.3547
4.5	14.8	14.3			5184		0.0599	0.0581	0.0017				9.0		9.0	0.3760
5.0	14.3	13.8			5184		0.0617	0.0599	0.0018				9.6		9.6	0.3992
5.5	13.8	13.3			5184		0.0637	0.0617	0.0020				10.2		10.2	0.4246
6.0	13.3	12.8			5184		0.0658	0.0637	0.0021				10.9		10.9	0.4526
6.5	12.8	12.3			5184		0.0680	0.0658	0.0022				11.6		11.6	0.4834
7.0	12.3	11.8			5184		0.0704	0.0680	0.0024				12.4		12.4	0.5174
7.5	11.8	11.3			5184		0.0730	0.0704	0.0026				13.3		13.3	0.5552
8.0	11.3	10.8			5184		0.0758	0.0730	0.0028				14.3		14.3	0.5972
8.5	10.8	10.3			5184		0.0787	0.0758	0.0030				15.5		15.5	0.6442
9.0	10.3	9.8			5184		0.0820	0.0787	0.0032				16.7		16.7	0.6970
9.5	9.8	9.3			5184		0.0855	0.0820	0.0035				18.2		18.2	0.7566
10.0	9.3	8.8			5184		0.0893	0.0855	0.0038				19.8		19.8	0.8242
10.5	8.8	8.3			5184		0.0935	0.0893	0.0042				21.6		21.6	0.9012
11.0	8.3	7.8			5184		0.0980	0.0935	0.0046				23.7		23.7	0.9896
11.5	7.8	7.3			5184		0.1031	0.0980	0.0051				26.2		26.2	1.0916
12.0	7.3	6.8			5184		0.1087	0.1031	0.0056				29.0		29.0	1.2102
12.5	6.8	6.3			5184		0.1149	0.1087	0.0062				32.4		32.4	1.3493
13.0	6.3	5.8			5184		0.1220	0.1149	0.0070				36.3		36.3	1.5139
13.5	5.8	5.3			5184		0.1299	0.1220	0.0079				41.1		41.1	1.7105
14.0	5.3	4.8			5184		0.1389	0.1299	0.0090				46.8		46.8	1.9481
14.5	4.8	4.3			5184		0.1493	0.1389	0.0104				53.7		53.7	2.2388
15.0	4.3	3.8			5184		0.1613	0.1493	0.0120				62.4		62.4	2.5999
15.5	3.8	3.3			5184		0.1754	0.1613	0.0141				73.3		73.3	3.0560
16.0	3.3	2.8			5184		0.1923	0.1754	0.0169				87.4		87.4	3.6437
16.5	2.8	2.3			5184		0.2128	0.1923	0.0205				106.1		106.1	4.4190
17.0	2.3	1.8			5184		0.2381	0.2128	0.0253				131.3		131.3	5.4711
17.5	1.8	1.3			5184		0.2703	0.2381	0.0322				166.8		166.8	6.9498
18.0	1.3	0.8			5184		0.3125	0.2703	0.0422				218.9		218.9	9.1216
18.5	0.8	0.3			5184		0.3704	0.3125	0.0579				300.0		300.0	12.5000
19.0	0.3	0	0	0.2	5184	324	0.4167	0.3704	0.0463	1.6667	1.2500	0.4167	240.0	135.0	375.0	15.6250
19.5			0.2	0.7		324				1.2500	0.7692	0.4808		155.8	155.8	6.4904
20.0			0.7	1.2		324				0.7692	0.5556	0.2137		69.2	69.2	2.8846
20.5			1.2	1.7		324				0.5556	0.4348	0.1208		39.1	39.1	1.6304
21.0			1.7	2.2		324				0.4348	0.3571	0.0776		25.2	25.2	1.0481
21.5			2.2	2.7		324				0.3571	0.3030	0.0541		17.5	17.5	0.7305
22.0			2.7	3.2		324				0.3030	0.2632	0.0399		12.9	12.9	0.5383
22.5			3.2	3.7		324				0.2632	0.2326	0.0306		9.9	9.9	0.4131
23.0			3.7	4.2		324				0.2326	0.2083	0.0242		7.8	7.8	0.3270
23.5			4.2	4.7		324				0.2083	0.1887	0.0197		6.4	6.4	0.2653
24.0			4.7	5.2		324				0.1887	0.1724	0.0163		5.3	5.3	0.2196
															Total=	100.00

Table.B.2.2 Calculation of Design Rainfall of 100mm per Day

Time	Ret.Period	2years	5yeras	10years	25years	50years
	R24(mm)	85.9	118.8	138.3	161.1	177.0
	R72(mm)	129.4	183.2	218.3	262.0	294.3
	Runoff Ratio	0.5	0.5	0.64	0.64	0.64
	Coefficient	Effective Rainfall(mm)				
0.5	0.002461	0.1	0.1	0.2	0.3	0.3
1.0	0.002583	0.1	0.2	0.2	0.3	0.3
1.5	0.002714	0.1	0.2	0.2	0.3	0.3
2.0	0.002856	0.1	0.2	0.3	0.3	0.3
2.5	0.003009	0.1	0.2	0.3	0.3	0.3
3.0	0.003174	0.1	0.2	0.3	0.3	0.4
3.5	0.003353	0.1	0.2	0.3	0.3	0.4
4.0	0.003548	0.2	0.2	0.3	0.4	0.4
4.5	0.003761	0.2	0.2	0.3	0.4	0.4
5.0	0.003993	0.2	0.2	0.4	0.4	0.5
5.5	0.004247	0.2	0.3	0.4	0.4	0.5
6.0	0.004526	0.2	0.3	0.4	0.5	0.5
6.5	0.004834	0.2	0.3	0.4	0.5	0.5
7.0	0.005175	0.2	0.3	0.5	0.5	0.6
7.5	0.005552	0.2	0.3	0.5	0.6	0.6
8.0	0.005973	0.3	0.4	0.5	0.6	0.7
8.5	0.006443	0.3	0.4	0.6	0.7	0.7
9.0	0.006972	0.3	0.4	0.6	0.7	0.8
9.5	0.007567	0.3	0.4	0.7	0.8	0.9
10.0	0.008243	0.4	0.5	0.7	0.8	0.9
10.5	0.009013	0.4	0.5	0.8	0.9	1.0
11.0	0.009897	0.4	0.6	0.9	1.0	1.1
11.5	0.010917	0.5	0.6	1.0	1.1	1.2
12.0	0.012104	0.5	0.7	1.1	1.2	1.4
12.5	0.013495	0.6	0.8	1.2	1.4	1.5
13.0	0.015141	0.7	0.9	1.3	1.6	1.7
13.5	0.017108	0.7	1.0	1.5	1.8	1.9
14.0	0.019484	0.8	1.2	1.7	2.0	2.2
14.5	0.022392	1.0	1.3	2.0	2.3	2.5
15.0	0.026003	1.1	1.5	2.3	2.7	2.9
15.5	0.030565	1.3	1.8	2.7	3.2	3.5
16.0	0.036443	1.6	2.2	3.2	3.8	4.1
16.5	0.044197	1.9	2.6	3.9	4.6	5.0
17.0	0.054720	2.4	3.3	4.8	5.6	6.2
17.5	0.069509	3.0	4.1	6.2	7.2	7.9
18.0	0.091231	3.9	5.4	8.1	9.4	10.3
18.5	0.125020	5.4	7.4	11.1	12.9	14.2
19.0	0.156275	6.7	9.3	13.8	16.1	17.7
19.5	0.064914	2.8	3.9	5.7	6.7	7.4
20.0	0.028851	1.2	1.7	2.6	3.0	3.3
20.5	0.016307	0.7	1.0	1.4	1.7	1.8
21.0	0.010483	0.5	0.6	0.9	1.1	1.2
21.5	0.007306	0.3	0.4	0.6	0.8	0.8
22.0	0.005384	0.2	0.3	0.5	0.6	0.6
22.5	0.004132	0.2	0.2	0.4	0.4	0.5
23.0	0.003271	0.1	0.2	0.3	0.3	0.4
23.5	0.002654	0.1	0.2	0.2	0.3	0.3
24.0	0.002196	0.1	0.1	0.2	0.2	0.2
Total	1.000000	43.0	59.4	88.5	103.1	113.3

Table B.2.3 Effective Rainfall in Ban Na San (to=0.5hr)

Time	Ret.Period	2years	5yeras	10years	25years	50years
	R24(mm)	152.7	230.4	292.3	382.2	457.3
	R72(mm)	254.4	387.0	498.8	667.5	813.3
	Runoff Ratio	0.64	0.76	0.86	0.86	0.86
	Coefficient	Effective Rainfall(mm)				
0.5	0.002461	0.2	0.4	0.6	0.8	1.0
1.0	0.002583	0.3	0.5	0.6	0.8	1.0
1.5	0.002714	0.3	0.5	0.7	0.9	1.1
2.0	0.002856	0.3	0.5	0.7	0.9	1.1
2.5	0.003009	0.3	0.5	0.8	1.0	1.2
3.0	0.003174	0.3	0.6	0.8	1.0	1.2
3.5	0.003353	0.3	0.6	0.8	1.1	1.3
4.0	0.003548	0.3	0.6	0.9	1.2	1.4
4.5	0.003761	0.4	0.7	0.9	1.2	1.5
5.0	0.003993	0.4	0.7	1.0	1.3	1.6
5.5	0.004247	0.4	0.7	1.1	1.4	1.7
6.0	0.004526	0.4	0.8	1.1	1.5	1.8
6.5	0.004834	0.5	0.8	1.2	1.6	1.9
7.0	0.005175	0.5	0.9	1.3	1.7	2.0
7.5	0.005552	0.5	1.0	1.4	1.8	2.2
8.0	0.005973	0.6	1.0	1.5	2.0	2.3
8.5	0.006443	0.6	1.1	1.6	2.1	2.5
9.0	0.006972	0.7	1.2	1.8	2.3	2.7
9.5	0.007567	0.7	1.3	1.9	2.5	3.0
10.0	0.008243	0.8	1.4	2.1	2.7	3.2
10.5	0.009013	0.9	1.6	2.3	3.0	3.5
11.0	0.009897	1.0	1.7	2.5	3.3	3.9
11.5	0.010917	1.1	1.9	2.7	3.6	4.3
12.0	0.012104	1.2	2.1	3.0	4.0	4.8
12.5	0.013495	1.3	2.4	3.4	4.4	5.3
13.0	0.015141	1.5	2.7	3.8	5.0	6.0
13.5	0.017108	1.7	3.0	4.3	5.6	6.7
14.0	0.019484	1.9	3.4	4.9	6.4	7.7
14.5	0.022392	2.2	3.9	5.6	7.4	8.8
15.0	0.026003	2.5	4.6	6.5	8.5	10.2
15.5	0.030565	3.0	5.4	7.7	10.0	12.0
16.0	0.036443	3.6	6.4	9.2	12.0	14.3
16.5	0.044197	4.3	7.7	11.1	14.5	17.4
17.0	0.054720	5.3	9.6	13.8	18.0	21.5
17.5	0.069509	6.8	12.2	17.5	22.8	27.3
18.0	0.091231	8.9	16.0	22.9	30.0	35.9
18.5	0.125020	12.2	21.9	31.4	41.1	49.2
19.0	0.156275	15.3	27.4	39.3	51.4	61.5
19.5	0.064914	6.3	11.4	16.3	21.3	25.5
20.0	0.028851	2.8	5.1	7.3	9.5	11.3
20.5	0.016307	1.6	2.9	4.1	5.4	6.4
21.0	0.010483	1.0	1.8	2.6	3.4	4.1
21.5	0.007306	0.7	1.3	1.8	2.4	2.9
22.0	0.005384	0.5	0.9	1.4	1.8	2.1
22.5	0.004132	0.4	0.7	1.0	1.4	1.6
23.0	0.003271	0.3	0.6	0.8	1.1	1.3
23.5	0.002654	0.3	0.5	0.7	0.9	1.0
24.0	0.002196	0.2	0.4	0.6	0.7	0.9
Total	1.000000	97.7	175.1	251.4	328.7	393.3

Table B.2.4 Effective Rainfall in Lan Saka (to=0.5hr)

River Name	Plot	Catchment Area(km2)	Length (km)	River Slope	Velocity (m/s)	Time (mm)	Time (hr)
Khlong Chawang	A	104	13.0	~ 1/100	3.5	61.9	
			1.1	1/100 ~ 1/200	3.0	6.1	
		Total	14.1			68.0	1.0
	B	133	13.0	~ 1/100	3.5	61.9	
			3.5	1/100 ~ 1/200	3.0	19.4	
		Total	16.5			81.3	1.5
		29	4.5	~ 1/100	3.5	21.4	
			4.0	1/100 ~ 1/200	3.0	22.2	
		Total	8.5			43.7	1.0
	C	173	13.0	~ 1/100	3.5	61.9	
			8.0	1/100 ~ 1/200	3.0	44.4	
		Total	21.0			106.3	2.0
		40	6.1	~ 1/100	3.5	29.0	
			4.0	1/100 ~ 1/200	3.0	22.2	
		Total	10.1			51.3	1.0
	D	210	13.0	~ 1/100	3.5	61.9	
			8.8	1/100 ~ 1/200	3.0	48.9	
			6.9	1/200 ~	2.1	54.8	
		Total	28.7			165.6	3.0
		37	2.0	~ 1/100	3.5	9.5	
			3.4	1/100 ~ 1/200	3.0	18.9	
			7.2	1/200 ~	2.1	57.1	
		Total	12.6			85.6	1.5
Klong Tha Di	A	71	10.4	~ 1/100	3.5	49.5	
			1.8	1/200 ~	2.1	14.3	
		Total	12.2			63.8	1.0
	B	105	10.4	~ 1/100	3.5	49.5	
			14.7	1/200 ~	2.1	116.7	
		Total	25.1			166.2	3.0

Table.B.2.5 Calculation of Flood Concentration Time

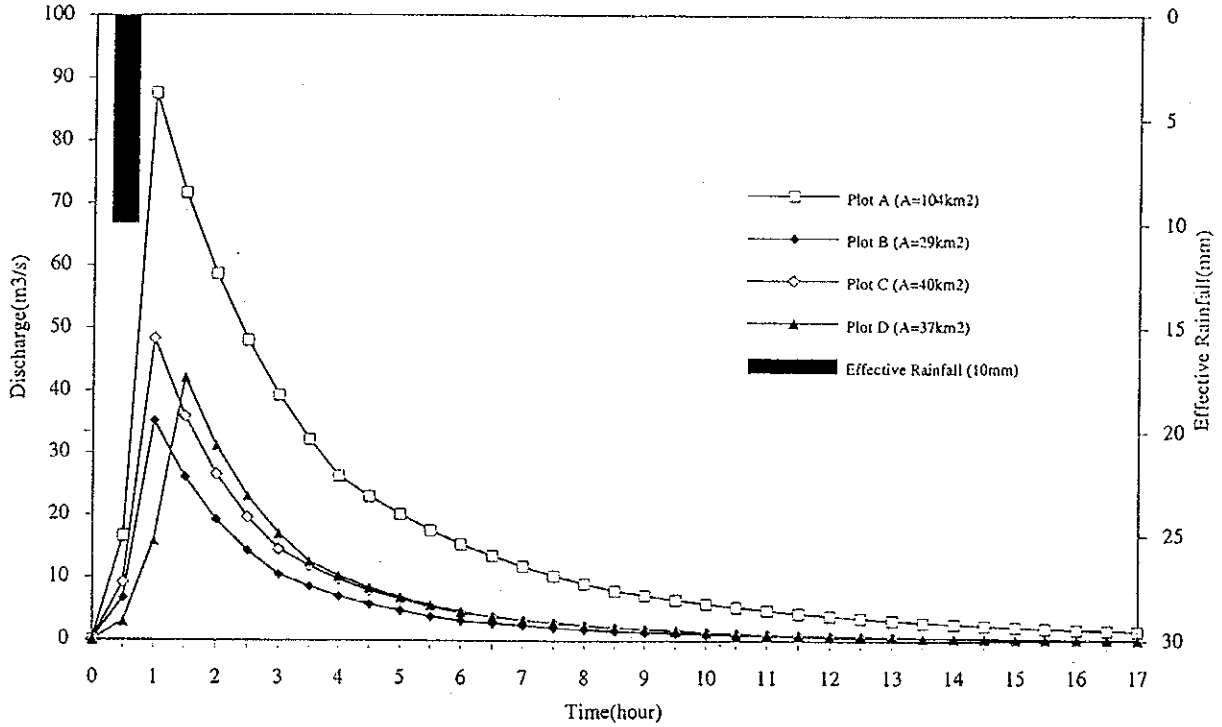


Figure B.2.3 Unit Graph (Ban Na San)

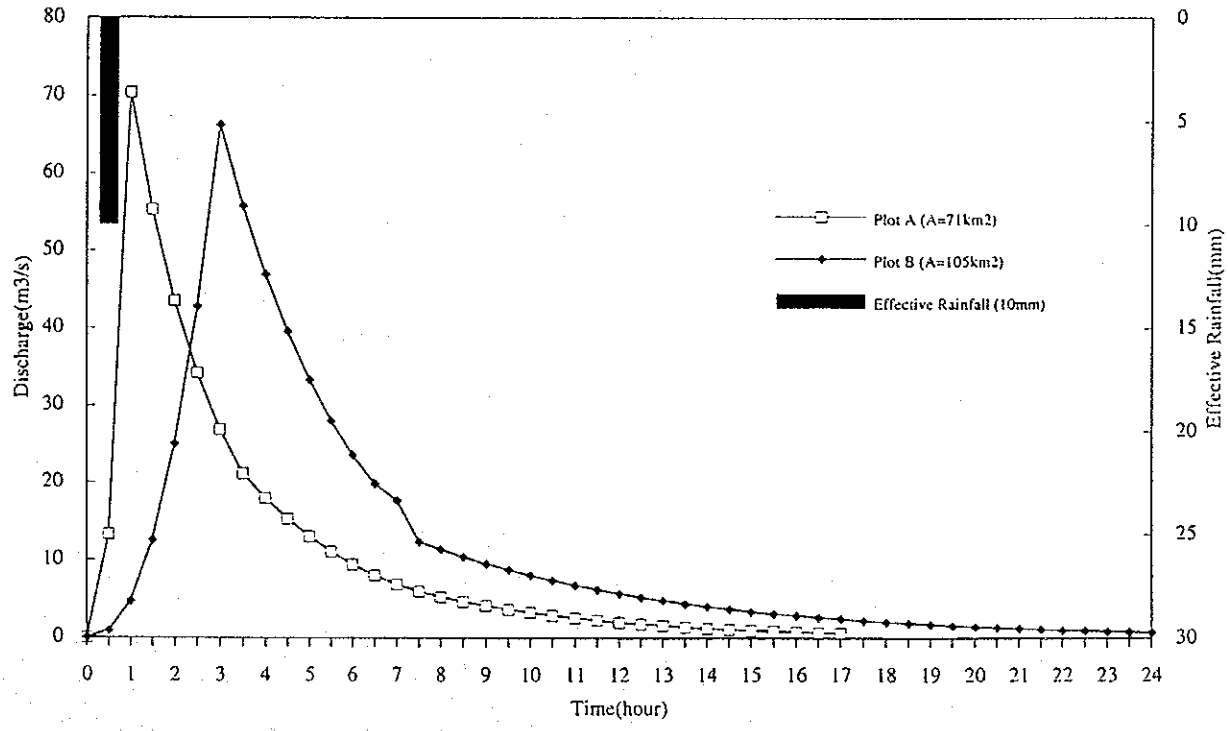


Figure B.2.4 Unit Graph (Lan Saka)

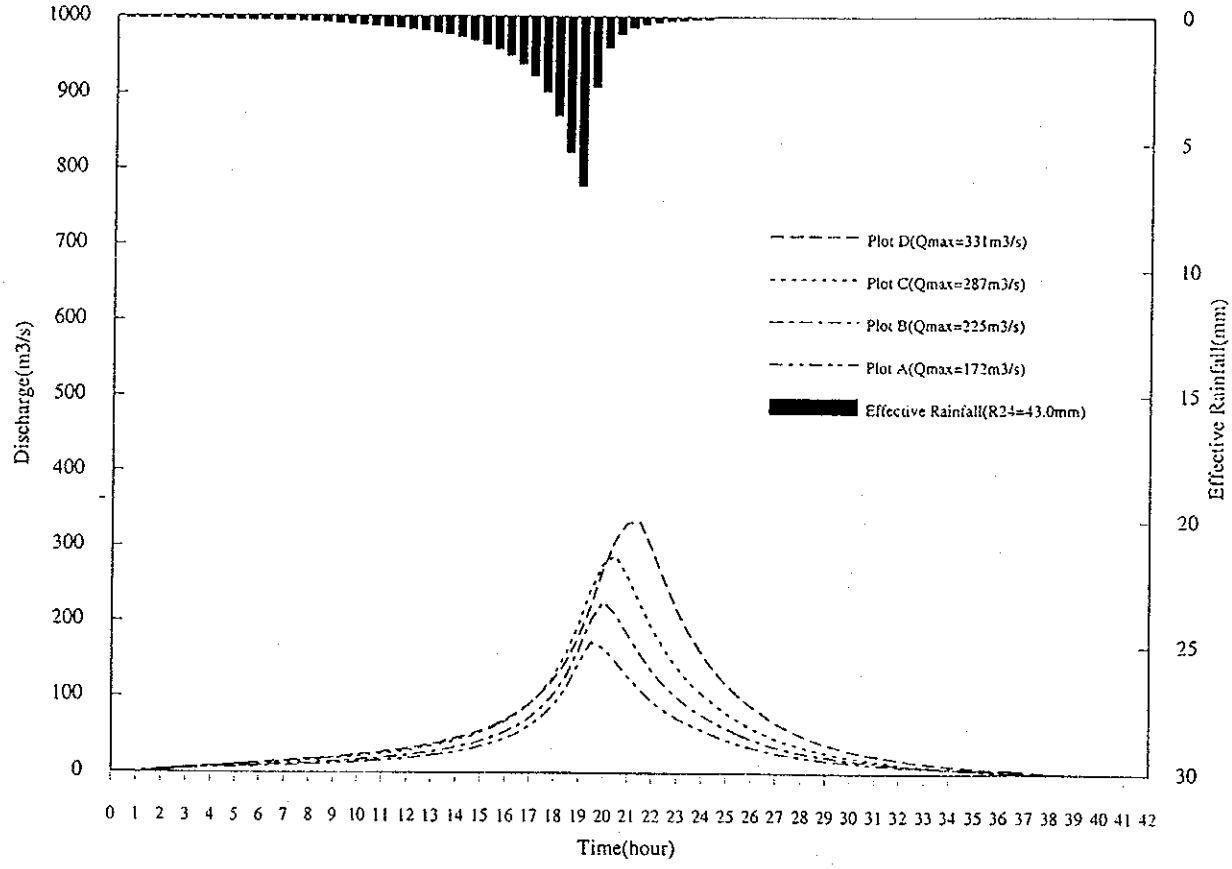


Figure B.2.5 Calculation of Flood Discharge by Unit Graph (Ban Na San, 2 years)

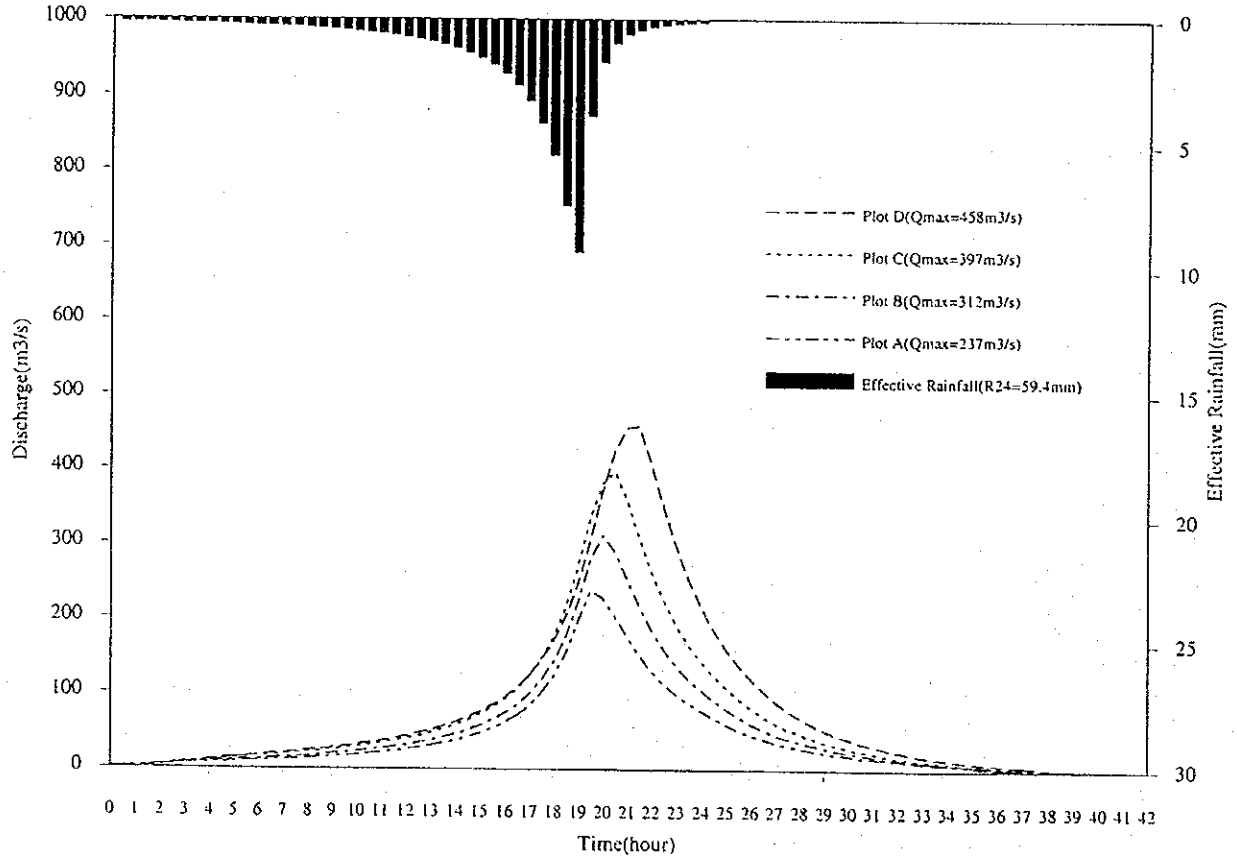


Figure B.2.6 Calculation of Flood Discharge by Unit Graph (Ban Na San, 5 years)

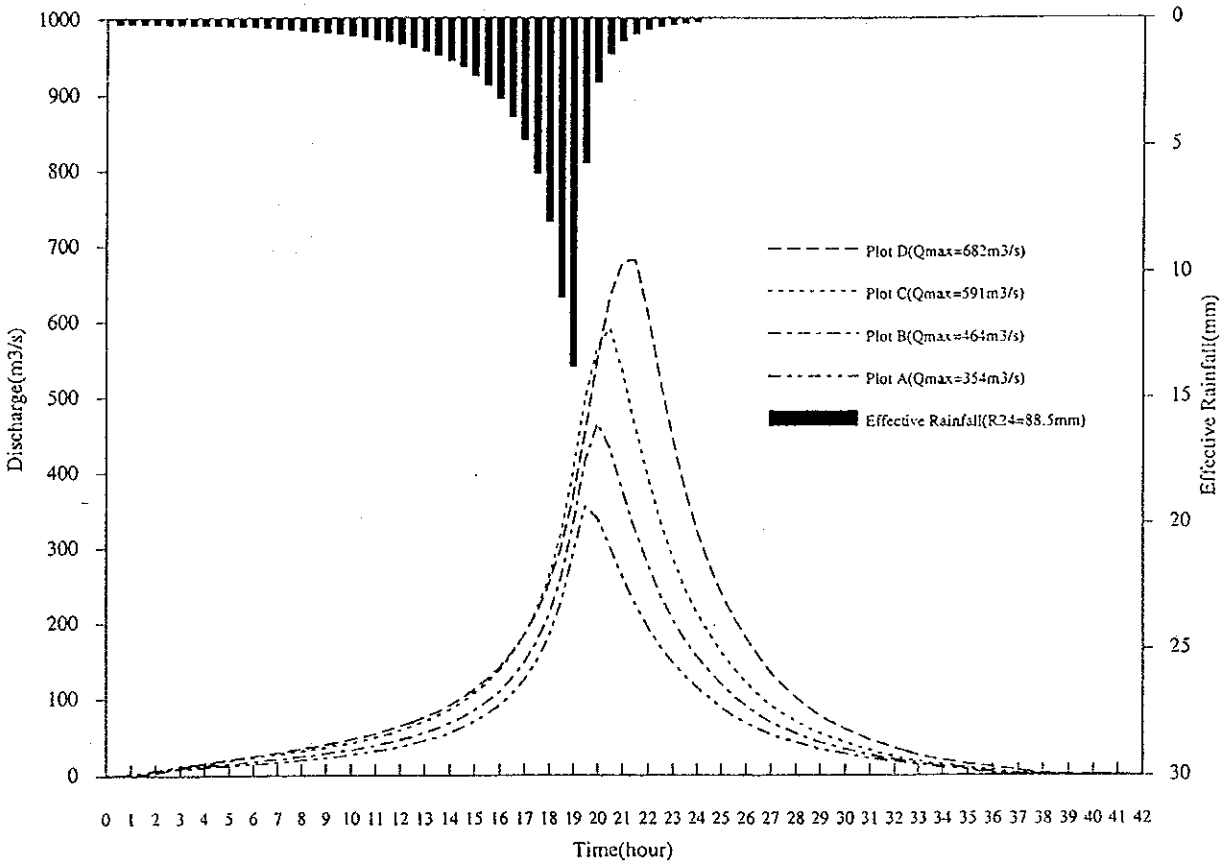


Figure B.2.7 Calculation of Flood Discharge by Unit Graph (Ban Na San,10years)

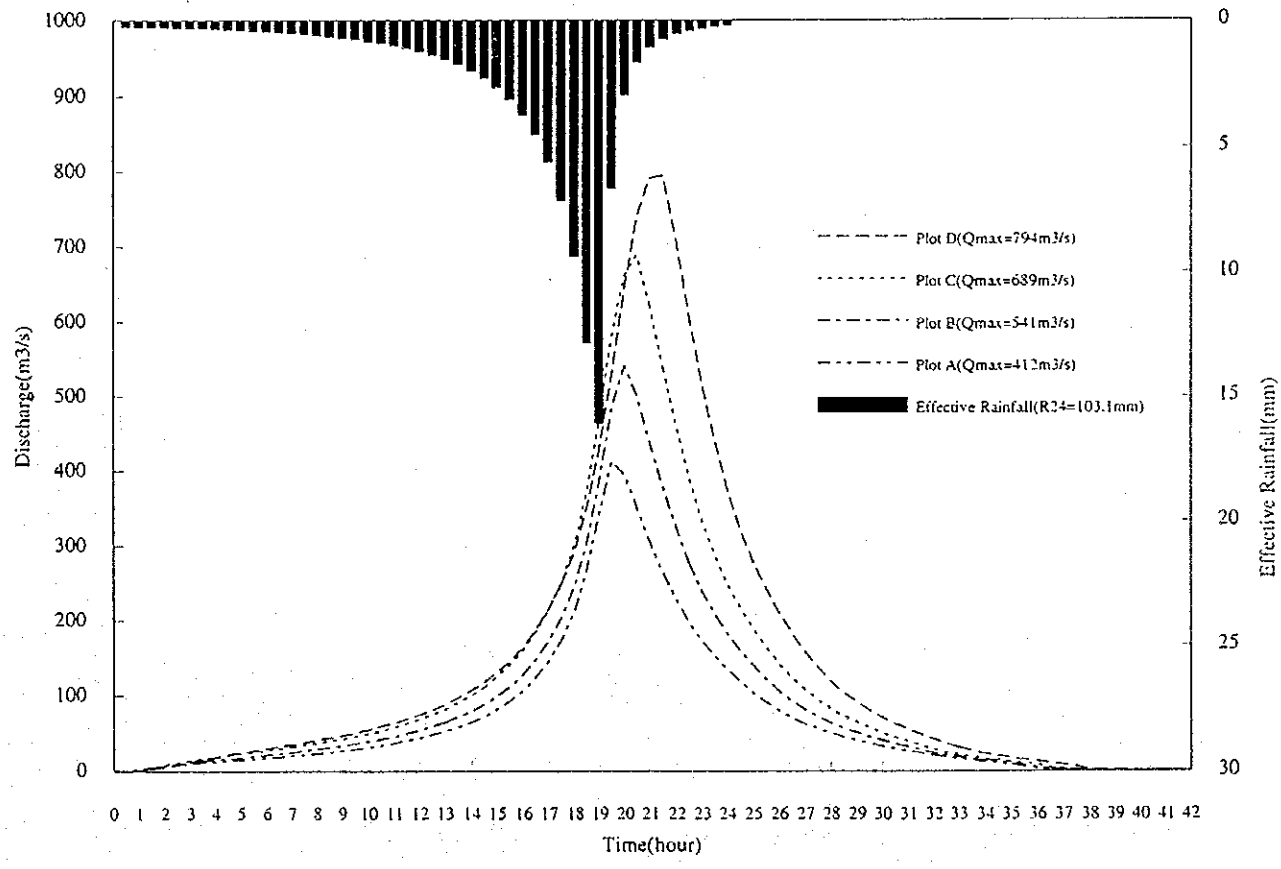


Figure B.2.8 Calculation of Flood Discharge by unit graph (Ban Na San,25years)

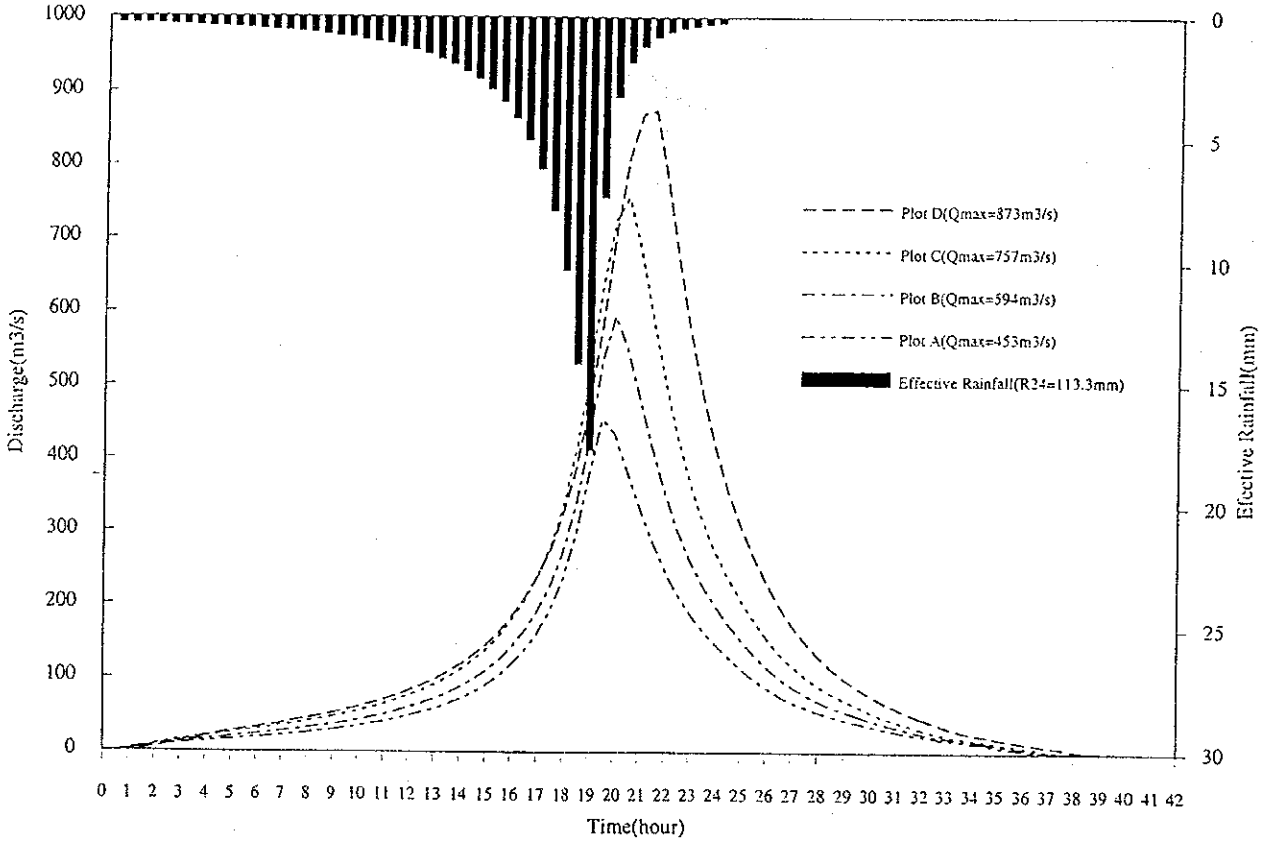


Figure B.2.9 Calculation of Flood Discharge by unit graph (Ban Na San,50years)

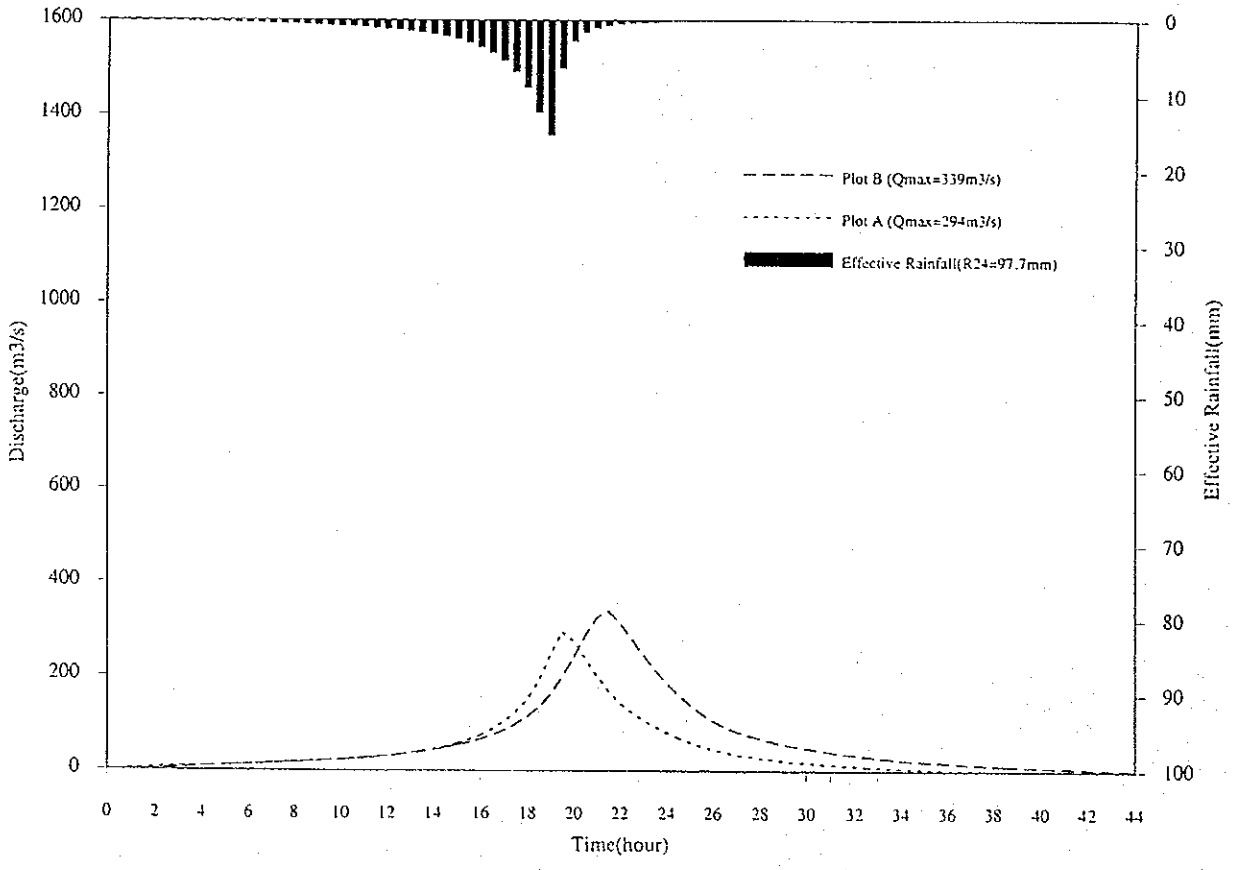


Figure B.2.10 Calculation of Flood Discharge by Unit Graph (Lan Saka, 2 years)

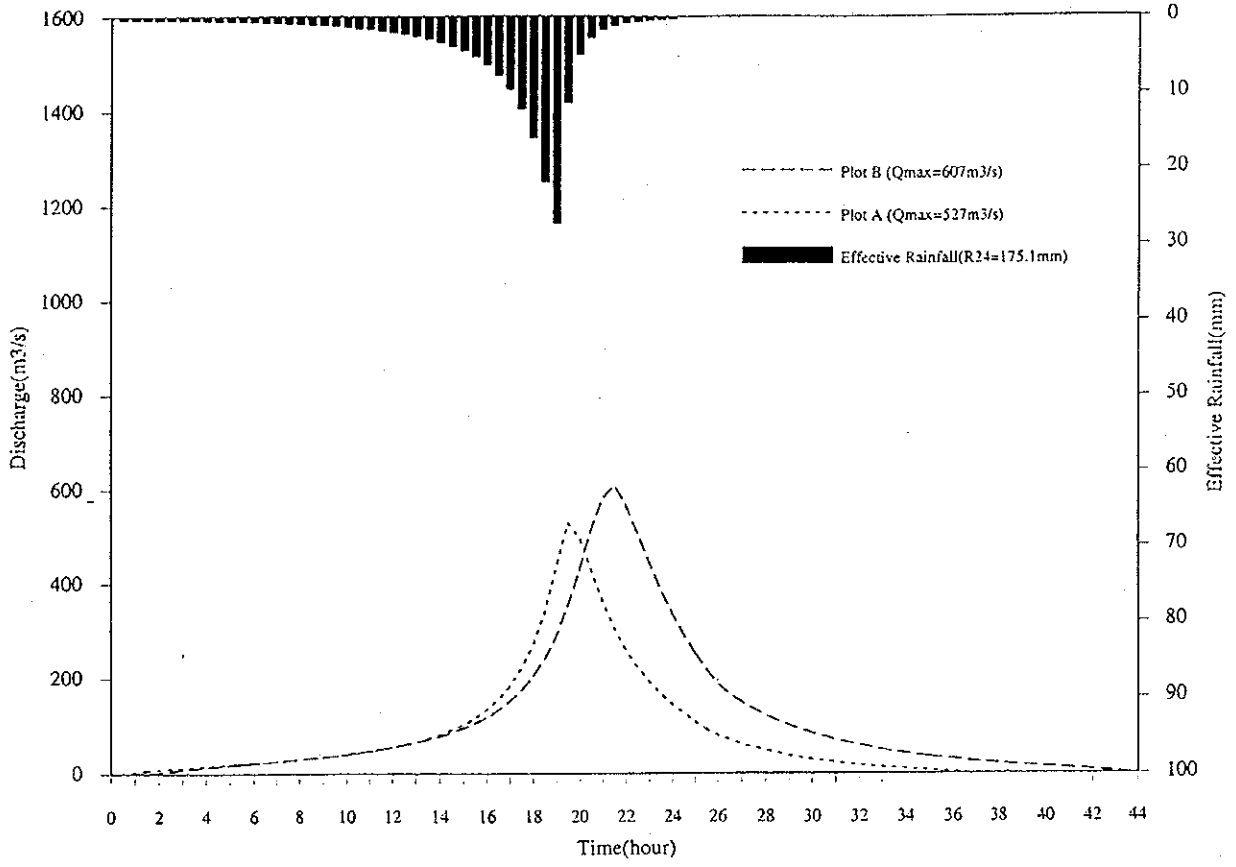


Figure B.2.11 Calculation of Flood Discharge by Unit Graph (Lan Saka, 5 years)

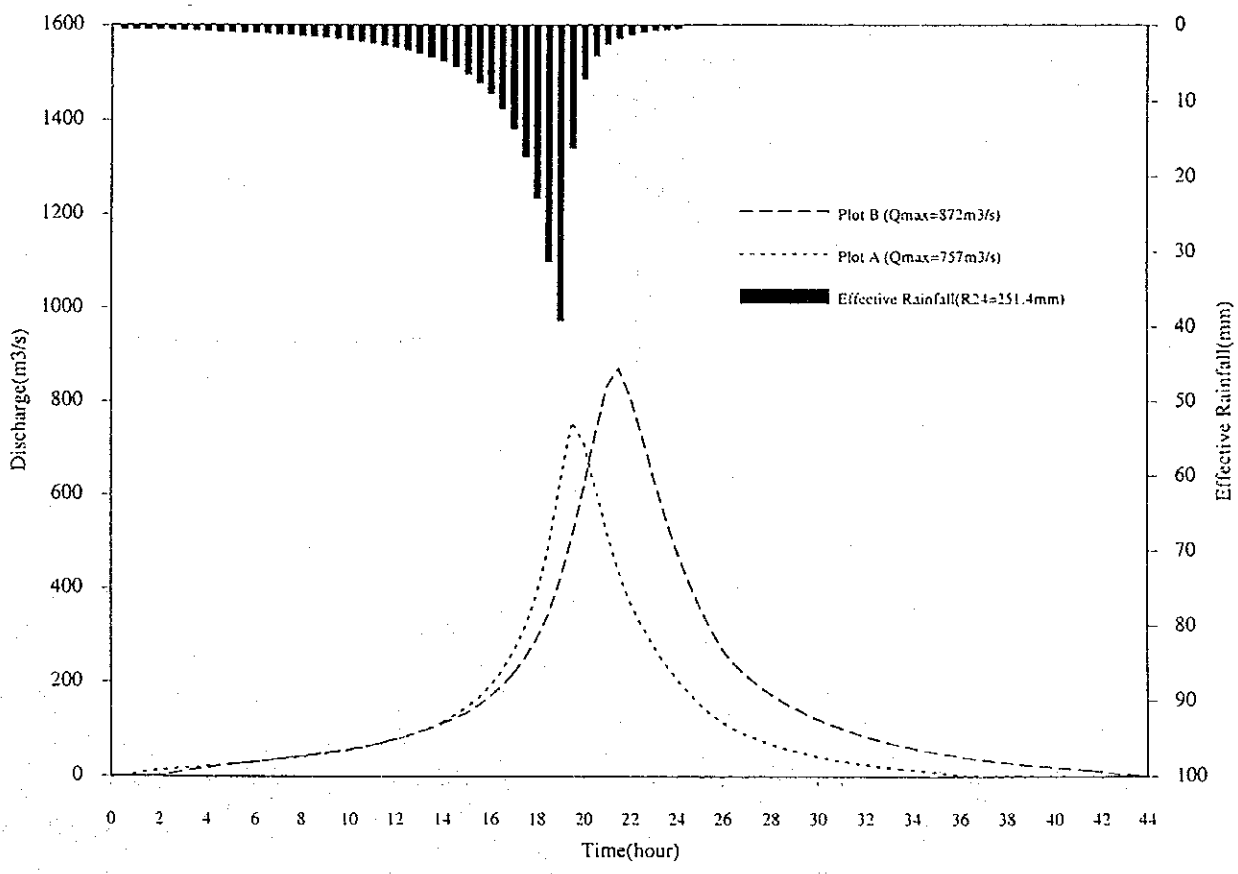


Figure B.2.12 Calculation of Flood Dischage by Unit Graph (Lan Saka, 10 years)

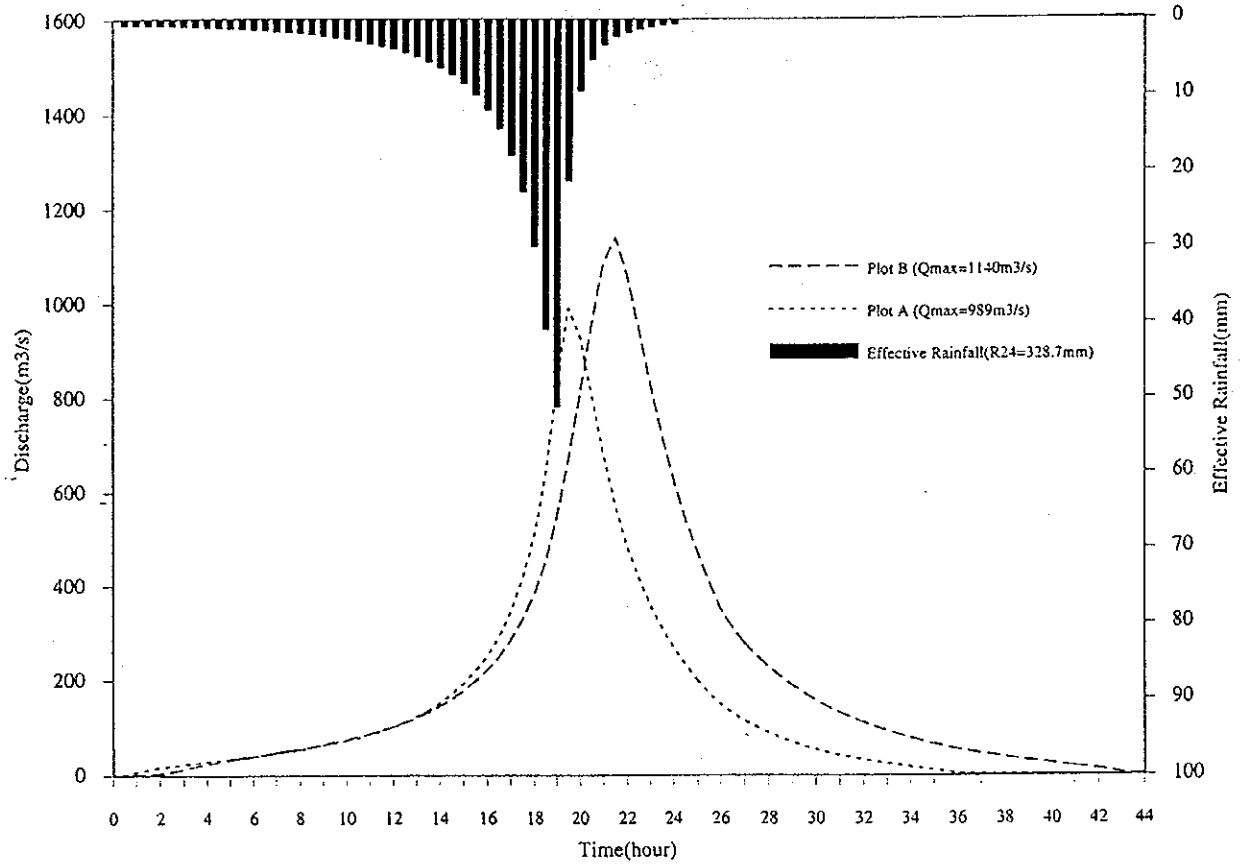


Figure B.2.13 Calculation of Flood Discharge by Unit Graph (Lan Saka, 25 years)

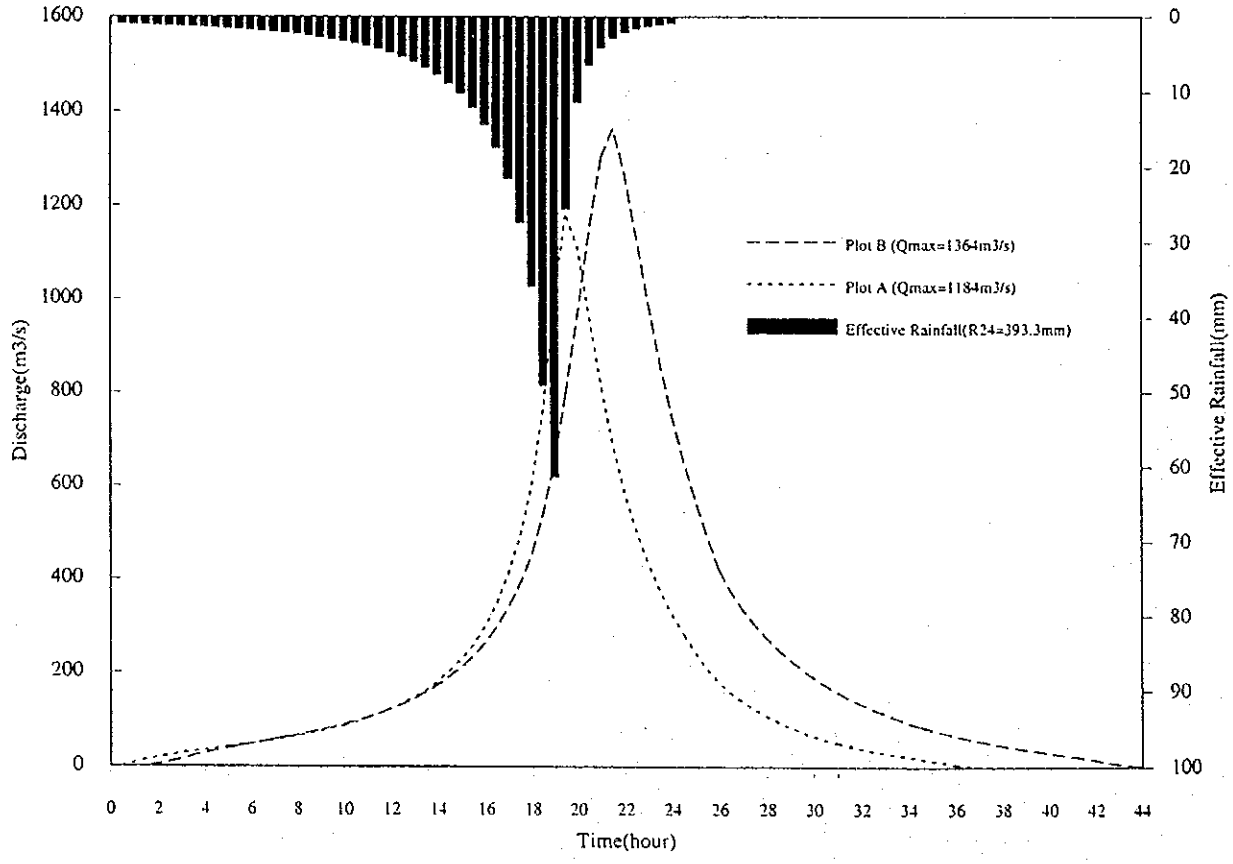


Figure B.2.14 Calculation of Flood Discharge by Unit Graph (Lan Saka, 50 years)

B.3 Hydrology (Ban Na San Feasibility Study Area)

1 Flood and, Drainage Discharges

a) Flood Discharge of Khlong Chawang and Khlong Mui

As mentioned in the Main Report, the flood discharge corresponding to each return period at the most upstream point in the F/S Area (Plot A) and most downstream point (Plot B) are shown in the table below.

unit : m^3/s

Location	Catchment Area (sq. km)	Return Period				
		2 years	5 years	10 years	25 years	50 years
A	104	172	237	354	412	453
B	133	225	312	464	541	594

On the basis of the table above, the specific flood discharge is as follows;

Table B.3.1 Specific Flood Discharge of Khlong Chawang

unit : m^3/s

Return Period	Catchment Area (sq. km)	
	A<104	104<A<133
2 years	1.654A	1.828(A-104)+172
5 years	2.279A	2.586(A-104)+237
10 years	3.404A	3.793(A-104)+354
25 years	3.962A	4.448(A-104)+412
50 years	4.356A	4.862(A-104)+453

Note A : Catchment Area (sq. km)

b) Flood discharge of Khlong Thuat

For the design flood discharge of Khlong Thuat, the unit hydrograph method is adopted similarly to the case of Khlong Chawang. The flood concentration time at the point of the junction with Khlong Chawang is estimated to be one hour. The unit graph of effective rainfall (10 mm) is shown in Figure B.3.1. Runoff percentage, design rainfall, and so on were already mentioned in the Appendix B.2.

On the basis of the unit graph of effective rainfall (10 mm) and design rainfall, flood discharge of Khlong Thuat was estimated, which are shown in Figure B.3.2~6.

c) Design Drainage Discharge in the F/S Area

For the design drainage discharge, a 1/10 exceedance probable daily rainfall from the viewpoint of drainage requirement for young tree is used. Design drainage discharge is determined by using the Rational Formula mentioned below.

$$Q = 1/3.6\ f\ r\ A$$

Where, f : Runoff percentage, this value is determined by 3 days rainfall (see Table B.2.1)

r : Average rainfall intensity (mm/hour)

A : Catchment Area (sq. km)

Table B.3.2 Design Drainage Discharge in the Ban Na San F/S Area

Return Period	3 days rainfall (mm)	f	1 day rainfall (mm)	r (mm/hour)	Q (m^3/s)
2 years	129.4	0.50	85.9	3.579	0.497A
5 years	183.2	0.50	118.8	4.950	0.688A
10 years	218.3	0.64	138.3	5.763	1.024A
25 years	262.0	0.64	161.1	6.713	1.193A
50 years	294.3	0.64	177.0	7.375	1.311A

2. Droughty Discharge, Low Discharge

Droughty discharge and low discharge are defined as 355th and 275th discharge respectively in a year in order of large amount of discharge. The discharges corresponding to each return period are estimated on the basis of the observed data by RID at the point of X.81. (Refer to Figure B.3.7~8)

Table B.3.3 Droughty Discharge, Low Discharge of Khlong Chawang

Items	Return Period		
	2 years	5 years	10 years
Droughty discharge of X.81 (m^3/s)	0.98	0.68	0.56
Specific droughty discharge ($m^3/s/100km^2$)	0.445	0.309	0.255
Low discharge of X.81 (m^3/s)	2.17	1.71	1.50
Specific low discharge ($m^3/s/km^2$)	0.986	0.777	0.682

3. Ordinary Discharge of Each Month

Ordinary discharge of each month is defined as a middle discharge in a month. The discharge corresponding to each return period is estimated on the basis of the observed data similarly to droughty discharge.

Table B.3.4 Ordinary Discharge in Each Month of Khlong Chawang

Month	Items	Return Period		
		2 years	5 years	10 years
April	Ordinary discharge (m^3/s)	1.27	0.88	0.72
	Specific ordinary discharge ($m^3/s/100km^2$)	0.577	0.400	0.327
May	Ordinary discharge (m^3/s)	2.68	1.88	1.50
	Specific ordinary discharge ($m^3/s/100km^2$)	1.218	0.855	0.682
Jun.	Ordinary discharge (m^3/s)	2.79	2.04	1.70
	Specific ordinary discharge ($m^3/s/100km^2$)	1.268	0.927	0.773
Jul.	Ordinary discharge (m^3/s)	2.98	1.84	1.42
	Specific ordinary discharge ($m^3/s/100km^2$)	1.355	0.836	0.645
Aug.	Ordinary discharge (m^3/s)	3.78	2.82	2.54
	Specific ordinary discharge ($m^3/s/100km^2$)	1.718	1.282	1.155
Sep.	Ordinary discharge (m^3/s)	6.09	4.02	3.39
	Specific ordinary discharge ($m^3/s/100km^2$)	2.768	1.827	1.541
Oct.	Ordinary discharge (m^3/s)	8.30	7.10	6.72
	Specific ordinary discharge ($m^3/s/100km^2$)	3.773	3.227	3.055
Nov.	Ordinary discharge (m3/s)	8.75	6.19	4.97
	Specific ordinary discharge ($m^3/s/100km^2$)	3.977	2.814	2.259
Dec.	Ordinary discharge (m^3/s)	5.63	3.94	3.34
	Specific ordinary discharge ($m^3/s/100km^2$)	2.559	1.791	1.518
Jan.	Ordinary discharge (m^3/s)	3.42	2.42	2.05
	Specific ordinary discharge ($m^3/s/100km^2$)	1.555	1.100	0.932
Feb.	Ordinary discharge (m^3/s)	2.19	1.53	1.31
	Specific ordinary discharge ($m^3/s/100km^2$)	0.995	0.695	0.595
Mar.	Ordinary discharge (m^3/s)	1.43	0.92	0.78
	Specific ordinary discharge ($m^3/s/100km^2$)	0.650	0.418	0.355

4. Effective Rainfall

Effective rainfall for irrigation planning is estimated by the following method.

In case of,	0 < R < 5	E.R. = 0 (mm)
in case of,	5 < R < (TRAM/0.8)	E.R. = 0.8R (mm)
in case of,	R > (TRAM/0.8)	E.R. = TRAM (mm)

Where, R : Rainfall (mm)
E.R. : Effective rainfall (mm)
TRAM : Total readily available moisture, TRAM is assumed as 40 (mm)

It was calculated on the basis of the observed daily rainfall data by RID at the point of Ban Na San (6107). Annual and monthly effective rainfall corresponding to each return period are as follows.

Table B.3.5 Effective Rainfall in Ban Na San

unit mm

Items	Return Period		
	2 years	5 years	10 years
Apr.	61.8	45.7	39.1
May	139.6	103.3	88.4
Jun.	131.5	97.3	83.3
Jul.	140.6	104.0	89.0
Aug.	146.6	108.4	92.8
Sep.	160.0	118.3	101.3
Oct.	160.1	118.4	101.4
Nov.	136.6	101.0	86.5
Dec.	30.3	22.4	19.2
Jan.	13.8	10.2	8.7
Feb.	9.5	7.0	6.0
Mar.	24.8	18.3	15.7
Year (Total)	1155.2	854.4	731.2

5. Estimation of Irrigable Area

Table B.3.6~11 shows the calculation results of the irrigable area, which is estimated for periods of peak demands associated with low amount of available river water occurring specially in March or April for tree crops .

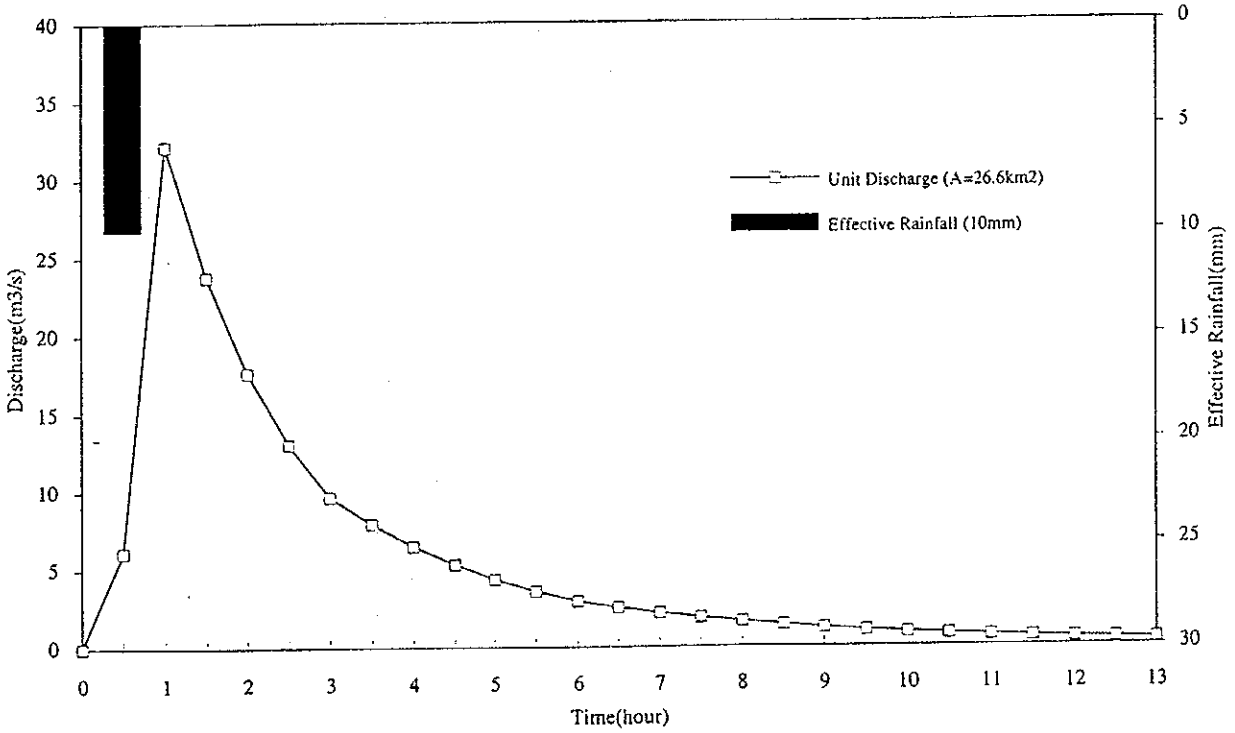


Figure B.3.1 Unit Graph (Khlong Thuat)

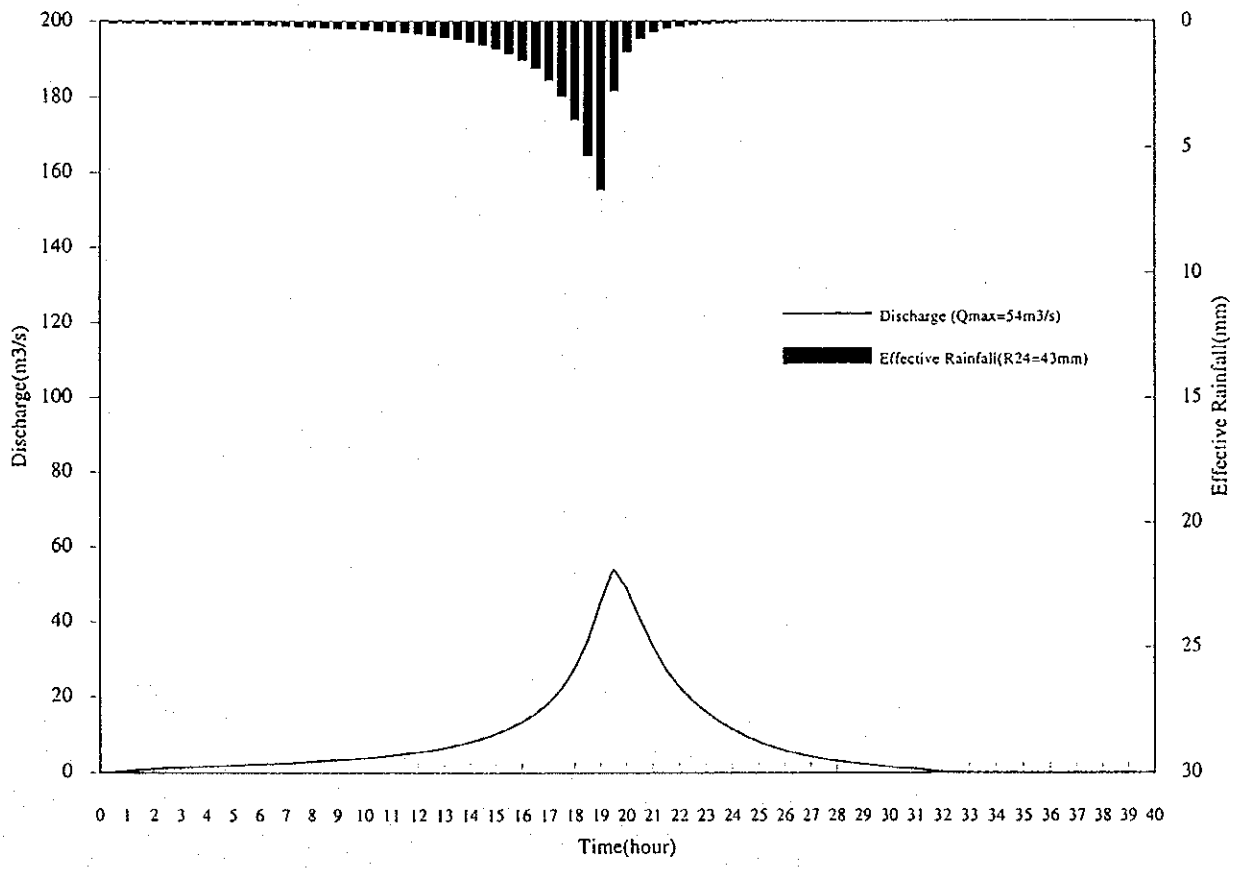


Figure B.3.2 Calculation of Flood Discharge by Unit Graph (Khlong Thuat,2 years)

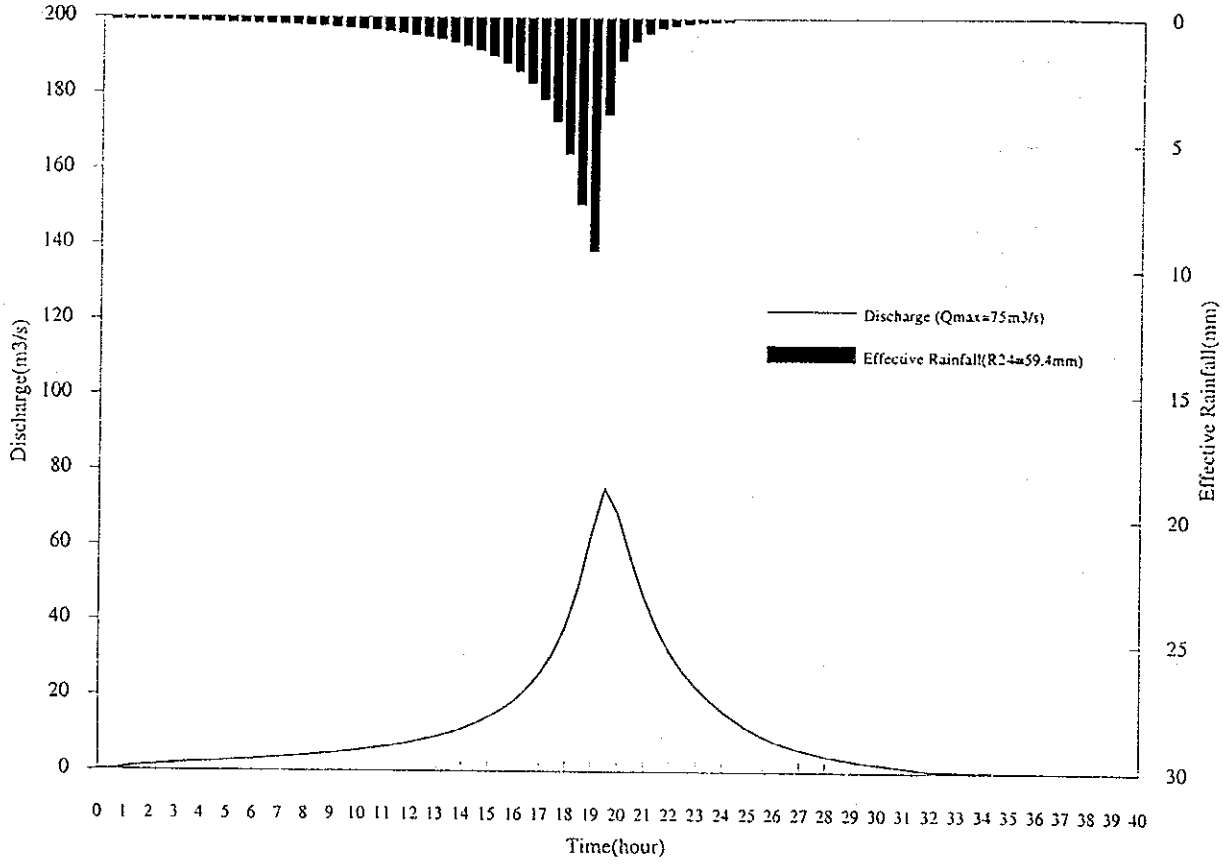


Fig.B.3.3 Calculation of Flood Discharge by Unit Graph (Khlong Thuat,5years)

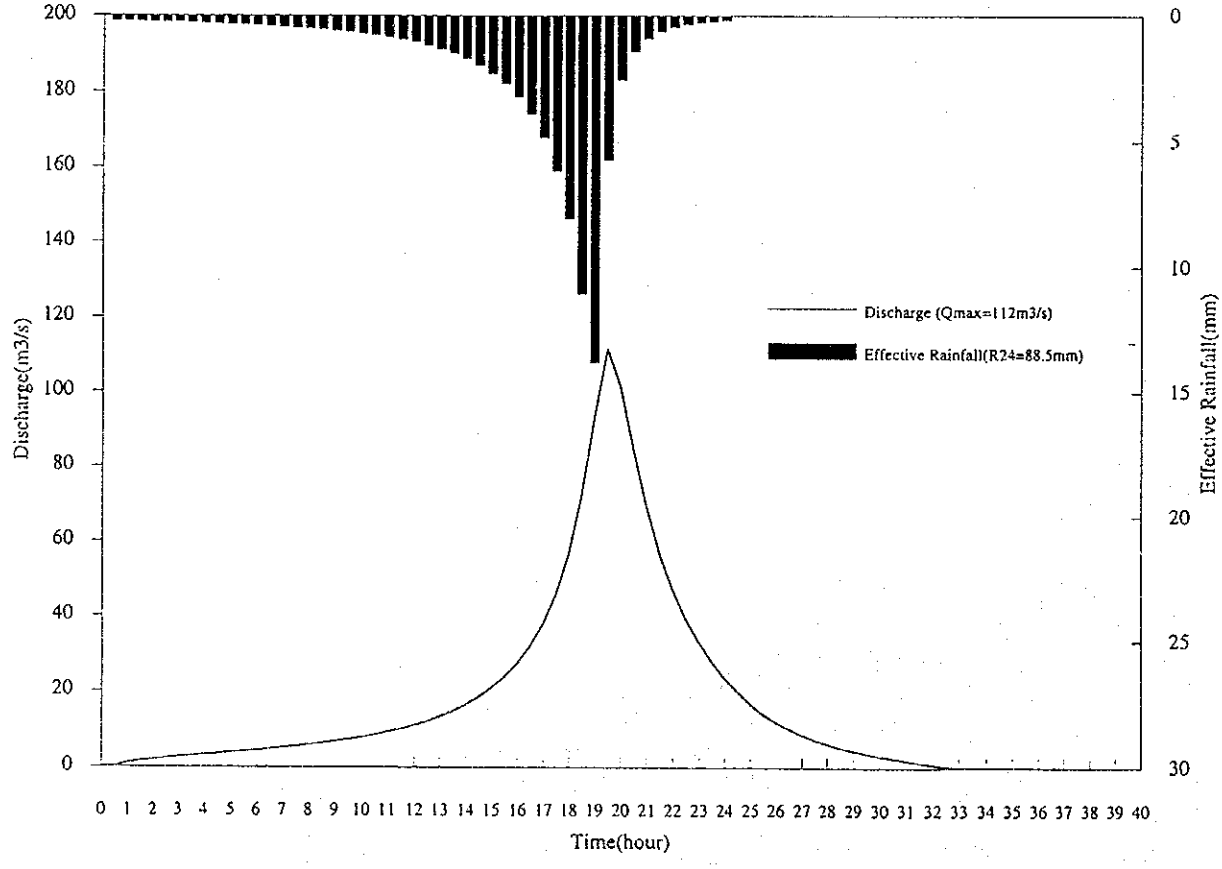


Figure B.3.4 Calculation of Flood Discharge by Unit Graph (Khlong Thuat,10years)

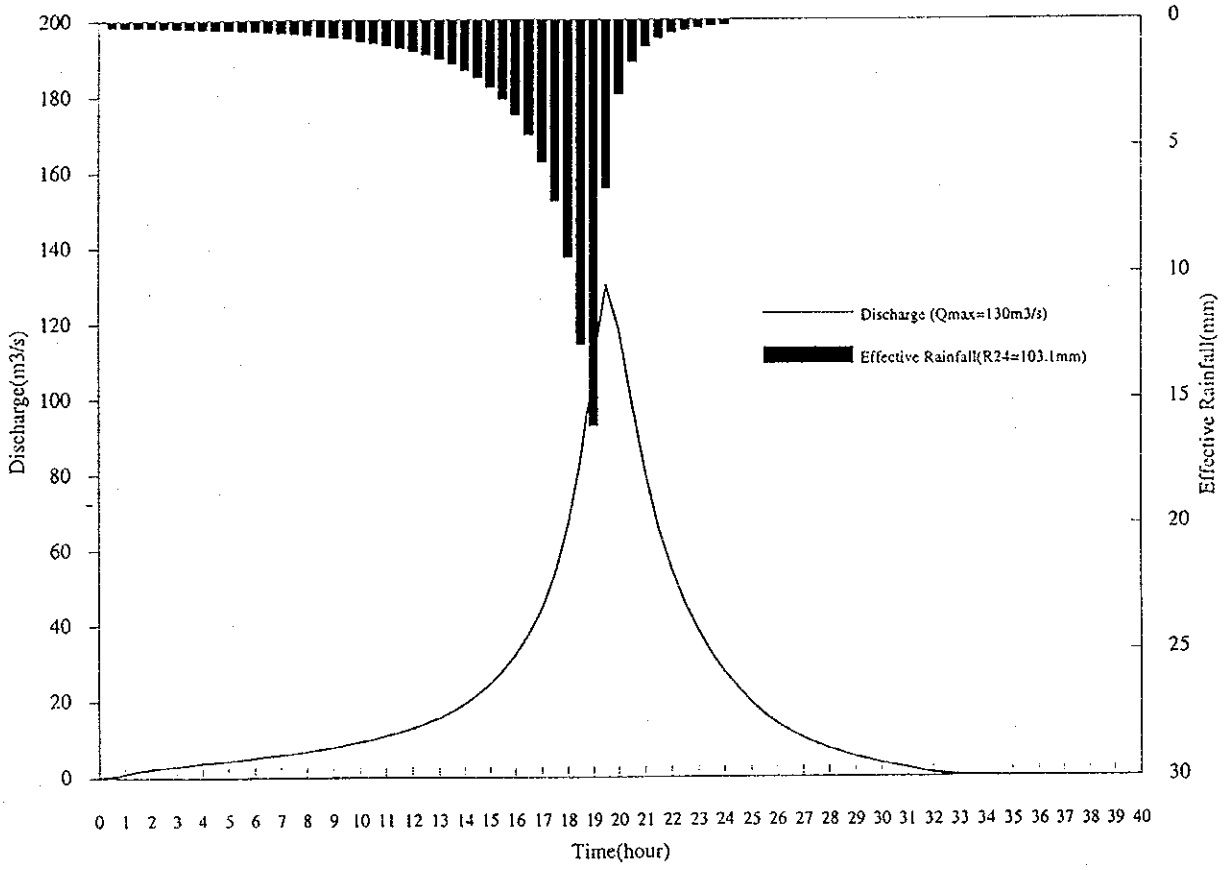


Fig.B.3.5 Calculation of Flood Discharge by Unit Graph (Khlong Thuat,25years)

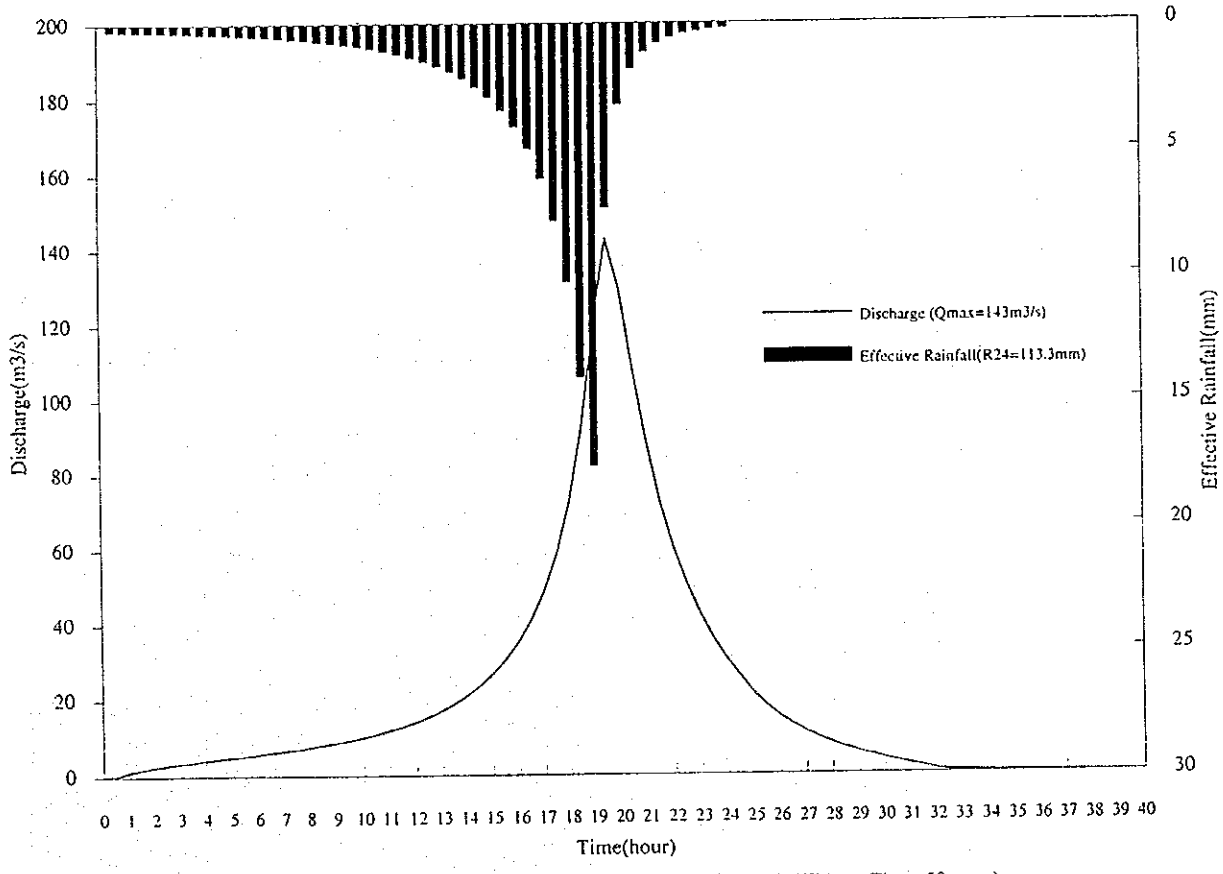


Figure B.3.6 Calculation of Flood Discharge by Unit Graph (Khlong Thuat,50years)

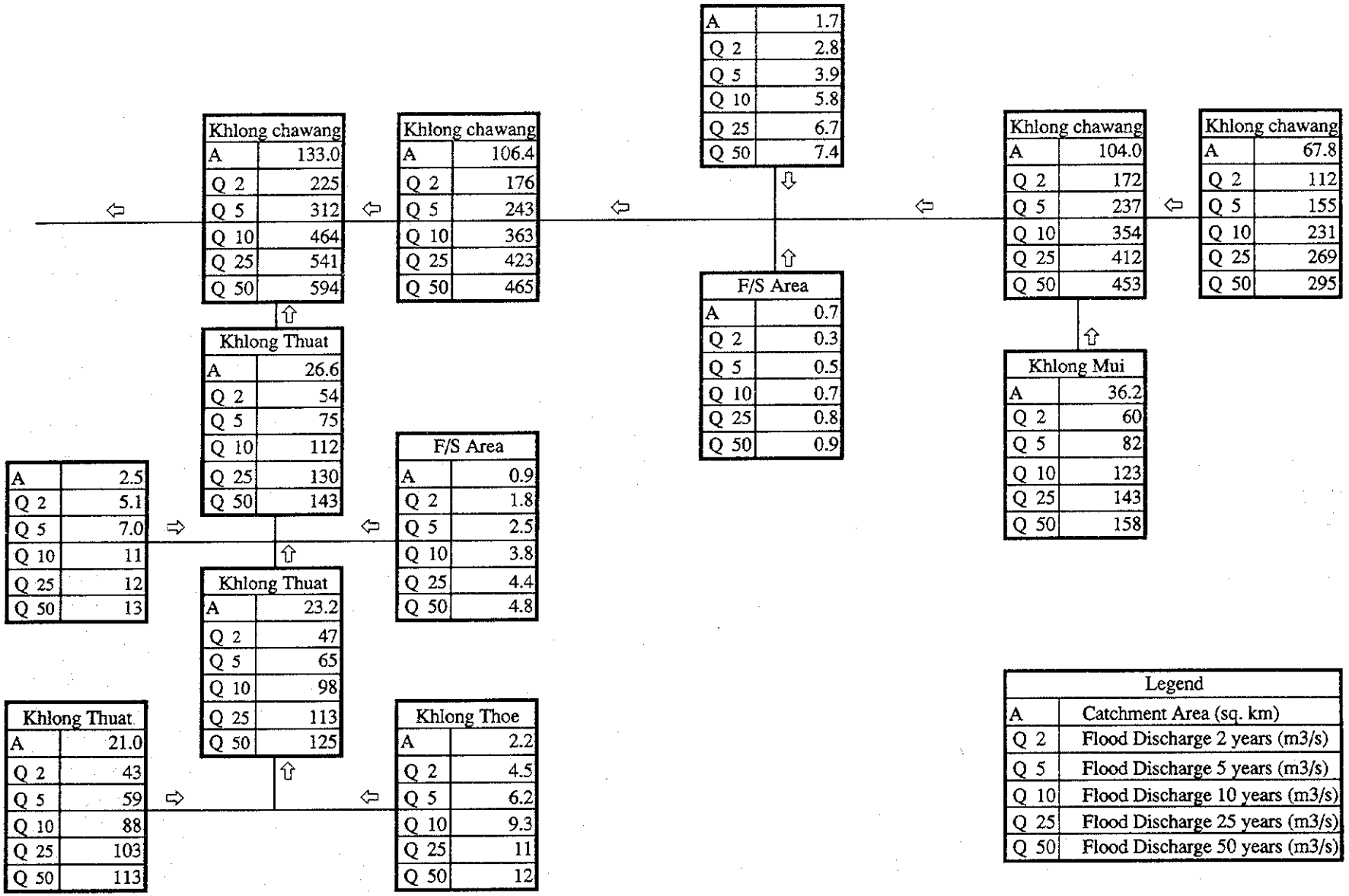


Figure B.3.7 Flood and Drainage Discharge Corresponding to each Return Period (F/S Area in Ban Na San)

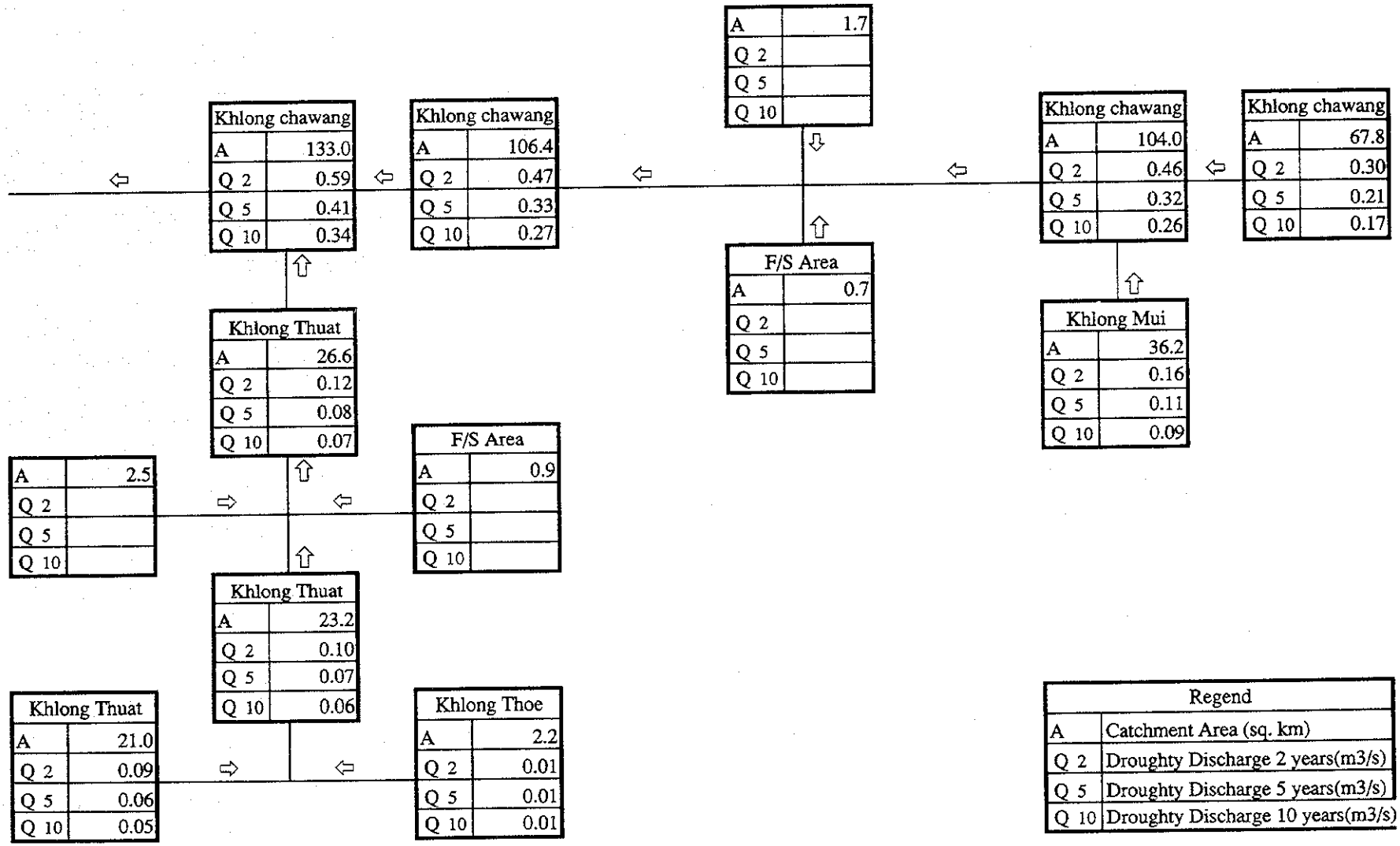


Figure B.3.8 Droughty Discharge of Coressponding to Return Period (F/S area in Ban Na San)

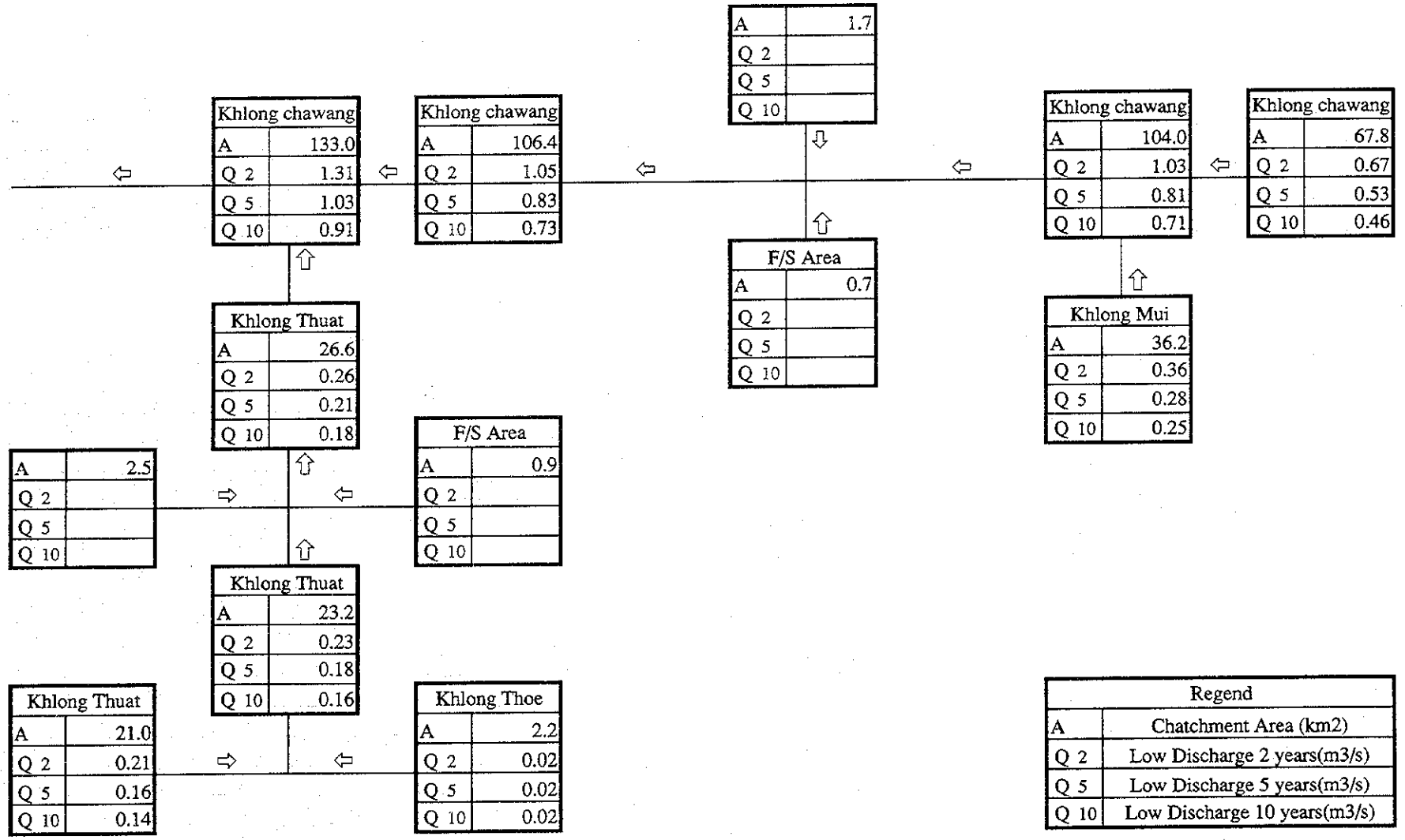


Fig. B.3.9 Low Discharge of Coressponding to Return Period (F/S area in Ban Na San)

Table B.3.6 Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui

Place : Ban Na San, Junction of Khlong Chawang and Khlong Mui (A=104 km2)

Return Period : 2 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm) (3)=(1)-(2)	(4) Discharge (Chawang) (m3/s) A=104km2	(5) Droughty Discharge (m3/s) A=104km2	(6) Utillzable Discharge (m3/s) (6)=(4)-(5)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month) (10)=(6)x3600 x(7)x(8)x(9)	(11) Estimated Irrigable Area (ha) (11)=(10)/(3)x100
Apr.	61.8	181.3	-119.5	0.60	0.26	0.34	8 ~ 24	30	0.70 ~ 0.85	206 ~ 749	170 ~ 630
May	139.6	169.7	-30.1	1.27	0.26	1.01	8 ~ 24	31	0.70 ~ 0.85	631 ~ 2299	2100 ~ 7640
June	131.5	159.9	-28.4	1.32	0.26	1.06	8 ~ 24	30	0.70 ~ 0.85	641 ~ 2335	2260 ~ 8220
July	140.6	166.6	-26.0	1.41	0.26	1.15	8 ~ 24	31	0.70 ~ 0.85	719 ~ 2618	2770 ~ 10070
Aug.	146.6	167.0	-20.4	1.79	0.26	1.53	8 ~ 24	31	0.70 ~ 0.85	956 ~ 3483	4690 ~ 17070
Sep.	160.0	154.2	0.0	2.88	0.26	2.62	8 ~ 24	30	0.70 ~ 0.85	1585 ~ 5772	~
Oct.	160.1	151.1	0.0	3.92	0.26	3.66	8 ~ 24	31	0.70 ~ 0.85	2287 ~ 8333	~
Nov.	136.6	138.5	-1.9	4.14	0.26	3.88	8 ~ 24	30	0.70 ~ 0.85	2347 ~ 8548	~
Dec.	30.3	148.2	-117.9	2.66	0.26	2.40	8 ~ 24	31	0.70 ~ 0.85	1500 ~ 5464	1270 ~ 4630
Jan.	13.8	159.1	-145.3	1.62	0.26	1.36	8 ~ 24	31	0.70 ~ 0.85	850 ~ 3096	580 ~ 2130
Feb.	9.5	161.4	-151.9	1.04	0.26	0.78	8 ~ 24	28	0.70 ~ 0.85	440 ~ 1604	290 ~ 1060
Mar.	24.8	187.8	-163.0	0.68	0.26	0.42	8 ~ 24	31	0.70 ~ 0.85	262 ~ 956	160 ~ 590
Total	1155.2	1944.8	-804.4	23.33	3.12	20.21		365		12424 45257	

Table B.3.7 Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui

Place : Ban Na San, Junction of Khlong Chawang and Khlong Mui (A=104 km2)

Return Period : 5 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm) (3)=(1)-(2)	(4) Discharge (Chawang) (m3/s) A=104km2	(5) Droughty Discharge (m3/s) A=104km2	(6) Utillzable Discharge (m3/s) (6)=(4)-(5)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month) (10)=(6)x3600 x(7)x(8)x(9)	(11) Estimated Irrigable Area (ha) (11)=(10)/(3)x100
Apr.	45.7	181.3	-135.6	0.42	0.26	0.16	8 ~ 24	30	0.70 ~ 0.85	97 ~ 353	70 ~ 260
May	103.3	169.7	-66.4	0.89	0.26	0.63	8 ~ 24	31	0.70 ~ 0.85	394 ~ 1434	590 ~ 2160
June	97.3	159.9	-62.6	0.96	0.26	0.70	8 ~ 24	30	0.70 ~ 0.85	423 ~ 1542	680 ~ 2460
July	104.0	166.6	-62.6	0.87	0.26	0.61	8 ~ 24	31	0.70 ~ 0.85	381 ~ 1389	610 ~ 2220
Aug.	108.4	167.0	-58.6	1.33	0.26	1.07	8 ~ 24	31	0.70 ~ 0.85	669 ~ 2436	1140 ~ 4160
Sep.	118.3	154.2	-35.9	1.90	0.26	1.64	8 ~ 24	30	0.70 ~ 0.85	992 ~ 3613	2760 ~ 10060
Oct.	118.4	151.1	-32.7	3.36	0.26	3.10	8 ~ 24	31	0.70 ~ 0.85	1937 ~ 7058	5920 ~ 21580
Nov.	101.0	138.5	-37.5	2.93	0.26	2.67	8 ~ 24	30	0.70 ~ 0.85	1615 ~ 5883	4310 ~ 15690
Dec.	22.4	148.2	-125.8	1.86	0.26	1.60	8 ~ 24	31	0.70 ~ 0.85	1000 ~ 3643	790 ~ 2900
Jan.	10.2	159.1	-148.9	1.14	0.26	0.88	8 ~ 24	31	0.70 ~ 0.85	550 ~ 2003	370 ~ 1350
Feb.	7.0	161.4	-154.4	0.72	0.26	0.46	8 ~ 24	28	0.70 ~ 0.85	260 ~ 946	170 ~ 610
Mar.	18.3	187.8	-169.5	0.43	0.26	0.17	8 ~ 24	31	0.70 ~ 0.85	106 ~ 387	60 ~ 230
Total	854.4	1944.8	-1090.5	16.81	3.12	13.69		365		8424 30687	

Table B.3.8 Calculation of Irrigable Area at the point of the junction of Khlong Chawang and Khlong Mui

Place : Ban Na San, Junction of Khlong Chawang and Khlong Mui (A=104 km2)

Return Period : 10 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm)	(4) Discharge (Chawang) (m3/s)	(5) Droughty Discharge (m3/s)	(6) Utillzable Discharge (m3/s)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month)	(11) Estimated Irrigable Area (ha)
			(3)=(1)-(2)	A=104km2	A=104km2	(6)=(4)-(5)				(10)=(6)x3600 x(7)x(8)x(9)	(11)=(10)/(3)x100
Apr.	39.1	181.3	-142.2	0.34	0.26	0.08	8 ~ 24	30	0.70 ~ 0.85	48 ~ 176	30 ~ 120
May	88.4	169.7	-81.3	0.71	0.26	0.45	8 ~ 24	31	0.70 ~ 0.85	281 ~ 1024	350 ~ 1260
June	83.3	159.9	-76.6	0.80	0.26	0.54	8 ~ 24	30	0.70 ~ 0.85	327 ~ 1190	430 ~ 1550
July	89.0	166.6	-77.6	0.67	0.26	0.41	8 ~ 24	31	0.70 ~ 0.85	256 ~ 933	330 ~ 1200
Aug.	92.8	167.0	-74.2	1.20	0.26	0.94	8 ~ 24	31	0.70 ~ 0.85	587 ~ 2140	790 ~ 2880
Sep.	101.3	154.2	-52.9	1.60	0.26	1.34	8 ~ 24	30	0.70 ~ 0.85	810 ~ 2952	1530 ~ 5580
Oct.	101.4	151.1	-49.7	3.18	0.26	2.92	8 ~ 24	31	0.70 ~ 0.85	1825 ~ 6648	3670 ~ 13380
Nov.	86.5	138.5	-52.0	2.35	0.26	2.09	8 ~ 24	30	0.70 ~ 0.85	1264 ~ 4605	2430 ~ 8860
Dec.	19.2	148.2	-129.0	1.58	0.26	1.32	8 ~ 24	31	0.70 ~ 0.85	825 ~ 3005	640 ~ 2330
Jan.	8.7	159.1	-150.4	0.97	0.26	0.71	8 ~ 24	31	0.70 ~ 0.85	444 ~ 1616	300 ~ 1070
Feb.	6.0	161.4	-155.4	0.62	0.26	0.36	8 ~ 24	28	0.70 ~ 0.85	203 ~ 740	130 ~ 480
Mar.	15.7	187.8	-172.1	0.37	0.26	0.11	8 ~ 24	31	0.70 ~ 0.85	69 ~ 250	40 ~ 150
Total	731.2	1944.8	-1213.4	14.39	3.12	11.27		365		6939 25279	

Table B.3.9 Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 2 years)

Place : Ban Na San, existing weir of Khlong Mui (A=36.2 km2)

Return Period : 2 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm)	(4) Discharge (Mui) (m3/s)	(5) Droughty Discharge (m3/s)	(6) Utillzable Discharge (m3/s)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month)	(11) Estimated Irrigable Area (ha)
			(3)=(1)-(2)	A=36.2km2	A=36.2km2	(6)=(4)-(5)				(10)=(6)x3600 x(7)x(8)x(9)	(11)=(10)/(3)x100
Apr.	61.8	181.3	-119.5	0.21	0.09	0.12	8 ~ 24	30	0.70 ~ 0.85	73 ~ 264	60 ~ 220
May	139.6	169.7	-30.1	0.44	0.09	0.35	8 ~ 24	31	0.70 ~ 0.85	219 ~ 797	730 ~ 2650
June	131.5	159.9	-28.4	0.46	0.09	0.37	8 ~ 24	30	0.70 ~ 0.85	224 ~ 815	790 ~ 2870
July	140.6	166.6	-26.0	0.49	0.09	0.40	8 ~ 24	31	0.70 ~ 0.85	250 ~ 911	960 ~ 3500
Aug.	146.6	167.0	-20.4	0.62	0.09	0.53	8 ~ 24	31	0.70 ~ 0.85	331 ~ 1207	1620 ~ 5920
Sep.	160.0	154.2	0.0	1.00	0.09	0.91	8 ~ 24	30	0.70 ~ 0.85	550 ~ 2005	~
Oct.	160.1	151.1	0.0	1.37	0.09	1.28	8 ~ 24	31	0.70 ~ 0.85	800 ~ 2914	~
Nov.	136.6	138.5	-1.9	1.44	0.09	1.35	8 ~ 24	30	0.70 ~ 0.85	816 ~ 2974	~
Dec.	30.3	148.2	-117.9	0.93	0.09	0.84	8 ~ 24	31	0.70 ~ 0.85	525 ~ 1912	450 ~ 1620
Jan.	13.8	159.1	-145.3	0.56	0.09	0.47	8 ~ 24	31	0.70 ~ 0.85	294 ~ 1070	200 ~ 740
Feb.	9.5	161.4	-151.9	0.36	0.09	0.27	8 ~ 24	28	0.70 ~ 0.85	152 ~ 555	100 ~ 370
Mar.	24.8	187.8	-163.0	0.24	0.09	0.15	8 ~ 24	31	0.70 ~ 0.85	94 ~ 341	60 ~ 210
Total	1155.2	1944.8	-804.4	8.12	1.08	7.04		365		4328 15765	

Table B.3.10 Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 5 years)

Place : Ban Na San, existing weir of Khlong Mui (A=36.2 km2)

Return Period : 5 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm)	(4) Discharge (Mui) (m3/s)	(5) Droughty Discharge (m3/s)	(6) Utillzable Discharge (m3/s)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month)	(11) Estimated Irrigable Area (ha)
			(3)=(1)-(2)	A=36.2km2	A=36.2km2	(6)=(4)-(5)				(10)=(6)x3600 x(7)x(8)x(9)	(11)=(10)/(3)x100
Apr.	45.7	181.3	-135.6	0.14	0.09	0.05	8 ~ 24	30	0.70 ~ 0.85	30 ~ 110	20 ~ 80
May	103.3	169.7	-66.4	0.31	0.09	0.22	8 ~ 24	31	0.70 ~ 0.85	137 ~ 501	210 ~ 750
June	97.3	159.9	-62.6	0.34	0.09	0.25	8 ~ 24	30	0.70 ~ 0.85	151 ~ 551	240 ~ 880
July	104.0	166.6	-62.6	0.30	0.09	0.21	8 ~ 24	31	0.70 ~ 0.85	131 ~ 478	210 ~ 760
Aug.	108.4	167.0	-58.6	0.46	0.09	0.37	8 ~ 24	31	0.70 ~ 0.85	231 ~ 842	390 ~ 1440
Sep.	118.3	154.2	-35.9	0.66	0.09	0.57	8 ~ 24	30	0.70 ~ 0.85	345 ~ 1256	960 ~ 3500
Oct.	118.4	151.1	-32.7	1.17	0.09	1.08	8 ~ 24	31	0.70 ~ 0.85	675 ~ 2459	2060 ~ 7520
Nov.	101.0	138.5	-37.5	1.02	0.09	0.93	8 ~ 24	30	0.70 ~ 0.85	562 ~ 2049	1500 ~ 5460
Dec.	22.4	148.2	-125.8	0.65	0.09	0.56	8 ~ 24	31	0.70 ~ 0.85	350 ~ 1275	280 ~ 1010
Jan.	10.2	159.1	-148.9	0.40	0.09	0.31	8 ~ 24	31	0.70 ~ 0.85	194 ~ 706	130 ~ 470
Feb.	7.0	161.4	-154.4	0.25	0.09	0.16	8 ~ 24	28	0.70 ~ 0.85	90 ~ 329	60 ~ 210
Mar.	18.3	187.8	-169.5	0.15	0.09	0.06	8 ~ 24	31	0.70 ~ 0.85	37 ~ 137	20 ~ 80
Total	854.4	1944.8	-1090.5	5.85	1.08	4.77		365		2933 ~ 10693	

Table B.3.11 Calculation of Irrigable Area at the point of existing weir of Khlong Mui (Return Period 10 years)

Place : Ban Na San, existing weir of Khlong Mui (A=36.2 km2)

Return Period : 10 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm)	(4) Discharge (Mui) (m3/s)	(5) Droughty Discharge (m3/s)	(6) Utillzable Discharge (m3/s)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month)	(11) Estimated Irrigable Area (ha)
			(3)=(1)-(2)	A=36.2km2	A=36.2km2	(6)=(4)-(5)				(10)=(6)x3600 x(7)x(8)x(9)	(11)=(10)/(3)x100
Apr.	39.1	181.3	-142.2	0.12	0.09	0.03	8 ~ 24	30	0.70 ~ 0.85	18 ~ 66	10 ~ 50
May	88.4	169.7	-81.3	0.25	0.09	0.16	8 ~ 24	31	0.70 ~ 0.85	100 ~ 364	120 ~ 450
June	83.3	159.9	-76.6	0.28	0.09	0.19	8 ~ 24	30	0.70 ~ 0.85	115 ~ 419	150 ~ 550
July	89.0	166.6	-77.6	0.23	0.09	0.14	8 ~ 24	31	0.70 ~ 0.85	87 ~ 319	110 ~ 410
Aug.	92.8	167.0	-74.2	0.42	0.09	0.33	8 ~ 24	31	0.70 ~ 0.85	206 ~ 751	280 ~ 1010
Sep.	101.3	154.2	-52.9	0.56	0.09	0.47	8 ~ 24	30	0.70 ~ 0.85	284 ~ 1036	540 ~ 1960
Oct.	101.4	151.1	-49.7	1.11	0.09	1.02	8 ~ 24	31	0.70 ~ 0.85	637 ~ 2322	1280 ~ 4670
Nov.	86.5	138.5	-52.0	0.82	0.09	0.73	8 ~ 24	30	0.70 ~ 0.85	442 ~ 1608	850 ~ 3090
Dec.	19.2	148.2	-129.0	0.55	0.09	0.46	8 ~ 24	31	0.70 ~ 0.85	287 ~ 1047	220 ~ 810
Jan.	8.7	159.1	-150.4	0.34	0.09	0.25	8 ~ 24	31	0.70 ~ 0.85	156 ~ 569	100 ~ 380
Feb.	6.0	161.4	-155.4	0.22	0.09	0.13	8 ~ 24	28	0.70 ~ 0.85	73 ~ 267	50 ~ 170
Mar.	15.7	187.8	-172.1	0.13	0.09	0.04	8 ~ 24	31	0.70 ~ 0.85	25 ~ 91	10 ~ 50
Total	731.2	1944.8	-1213.4	5.03	1.08	3.95		365		2430 ~ 8859	

B.4 Hydrology (Lan Saka Feasibility Study Area)

1 Flood and, Drainage Discharges

a) Flood Discharge of Khlong Tha Di

As mentioned in the Main Report, the flood discharge corresponding to each return period at the upstream point of the F/S Area (Plot A), and downstream point (Plot B) are shown in the below table .

unit : m^3/s

Location	Catchment Area (sq. km)	Return Period				
		2 years	5 years	10 years	25 years	50 years
A	71	294	527	757	989	1,184
B	105	339	607	872	1,140	1,364

On the basis of the table above, the specific flood discharge is as follows;

Table B.4.1 Specific Flood Discharge of Khlong Tha Di

unit : m^3/s

Return Period	Catchment Area (sq. km)	
	A<71	71<A<105
2 years	4.183A	1.324(A-71)+294
5 years	7.423A	2.353(A-71)+527
10 years	10.662A	3.382(A-71)+757
25 years	13.930A	4.441(A-71)+989
50 years	16.676A	5.294(A-71)+1,184

Note A : Catchment Area (sq. km)

b) Design Drainage Discharge in the F/S Area

For the design drainage discharge in the F/S Area, a 1/10 exceedance probable daily rainfall from the viewpoint of drainage requirement for young tree and upland crops is used. Design drainage discharge is calculated by using the Rational Formula mentioned below.

$$Q = 1/3.6\ f\ r\ A$$

Where, f : Runoff percentage, this value is determined by 3 days rainfall (see Table B.2.1)

r : Average rainfall intensity (mm/hour)

A : Catchment Area (sq. km)

Table B.4.2 Design Drainage Discharge in the Lan Saka F/S Area

R. Period	3 days rainfall (mm)	f	1 day rainfall (mm)	r (mm/hour)	Q (m^3/s)
2 years	254.4	0.64	152.7	6.363	1.131A
5 years	387.0	0.76	230.4	9.600	2.027A
10 years	498.8	0.86	292.3	12.179	2.909A
25 years	667.5	0.86	382.2	15.925	3.804A
50 years	813.3	0.86	457.3	19.054	4.552A

2. Droughty Discharge, Low Discharge

Droughty discharge and low discharge are defined as 355th and 275th discharge respectively in a year in order of large amount of discharge. The discharges corresponding to each return period are estimated on the basis of the observed data by RID at the point of X.55. (Refer to Figure B.4.1~2)

Table B.4.3 Droughty Discharge, Low Discharge of Khlong Tha Di

Items	Return Period		
	2 years	5 years	10 years
Droughty discharge of X.55 (m^3/s)	1.20	0.54	0.32
Specific droughty discharge ($m^3/s/100km^2$)	1.143	0.514	0.305
Low discharge of X.55 (m^3/s)	2.15	1.05	0.63
Specific low discharge ($m^3/s/km^2$)	2.048	1.000	0.600

3. Ordinary Discharge of Each Month

Ordinary discharge of each month is defined as a middle discharge in a month, which corresponding to each return period is estimated on the basis of the observed data similarly to droughty discharge.

Table B.4.4 Ordinary Discharge in Each Month of Khlong Tha Di

Month	Items	Return Period		
		2 years	5 years	10 years
April	Ordinary discharge (m^3/s)	2.15	0.95	0.53
	Specific ordinary discharge ($m^3/s/100km^2$)	2.048	0.905	0.505
May	Ordinary discharge (m^3/s)	2.28	0.99	0.61
	Specific ordinary discharge ($m^3/s/100km^2$)	2.171	0.943	0.581
Jun.	Ordinary discharge (m^3/s)	2.10	0.87	0.52
	Specific ordinary discharge ($m^3/s/100km^2$)	2.000	0.829	0.495
Jul.	Ordinary discharge (m^3/s)	2.21	1.01	0.63
	Specific ordinary discharge ($m^3/s/100km^2$)	2.105	0.962	0.600
Aug.	Ordinary discharge (m^3/s)	2.50	1.24	0.75
	Specific ordinary discharge ($m^3/s/100km^2$)	2.381	1.181	0.714
Sep.	Ordinary discharge (m^3/s)	2.27	1.34	1.09
	Specific ordinary discharge ($m^3/s/100km^2$)	2.162	1.276	1.038
Oct.	Ordinary discharge (m^3/s)	3.20	2.15	1.84
	Specific ordinary discharge ($m^3/s/100km^2$)	3.048	2.048	1.752
Nov.	Ordinary discharge (m^3/s)	10.22	6.05	4.59
	Specific ordinary discharge ($m^3/s/100km^2$)	9.733	5.762	4.371
Dec.	Ordinary discharge (m^3/s)	9.96	5.76	4.37
	Specific ordinary discharge ($m^3/s/100km^2$)	9.486	5.486	4.162
Jan.	Ordinary discharge (m^3/s)	5.32	2.84	2.11
	Specific ordinary discharge ($m^3/s/100km^2$)	5.067	2.705	2.001
Feb.	Ordinary discharge (m^3/s)	3.28	1.76	1.28
	Specific ordinary discharge ($m^3/s/100km^2$)	3.124	1.676	1.219
Mar.	Ordinary discharge (m^3/s)	2.31	1.14	0.81
	Specific ordinary discharge ($m^3/s/100km^2$)	2.200	1.086	0.771

4. Effective Rainfall

Effective rainfall for irrigation planning is calculated by the following method.

In case of,	$0 < R < 5$	E.R. = 0 (mm)
in case of,	$5 < R < (TRAM/0.8)$	E.R. = 0.8R (mm)
in case of,	$R > (TRAM/0.8)$	E.R. = TRAM (mm)

Where, R : Rainfall (mm)
E.R. : Effective rainfall (mm)
TRAM : Total readily available moisture, TRAM is assumed as 40 (mm)

It was calculated on the basis of the daily rainfall at the point of Khlong Sao Thong (2715). Annual and monthly effective rainfall corresponding to each return period are as follows.

Table B.4.5 Effective Rainfall in Lan Saka

unit : mm

Items	Return Period		
	2 years	5 years	10 years
Apr.	98.5	85.8	79.6
May	132.0	114.9	106.7
Jun.	62.2	54.1	50.3
Jul.	62.8	54.6	50.7
Aug.	55.3	48.2	44.7
Sep.	102.3	89.0	82.6
Oct.	188.7	164.3	152.5
Nov.	288.8	251.4	233.4
Dec.	244.8	213.0	197.8
Jan.	108.3	94.2	87.5
Feb.	33.9	29.5	27.4
Mar.	42.4	36.9	34.3
Year (Total)	1420.1	1236.0	1147.7

5. Presumption of Irrigable Area

Table B.4.6~8 shows the calculation results of the irrigable area, which is estimated for periods of peak demands associated with low amount of available river water occurring specially in April or May for tree crops.

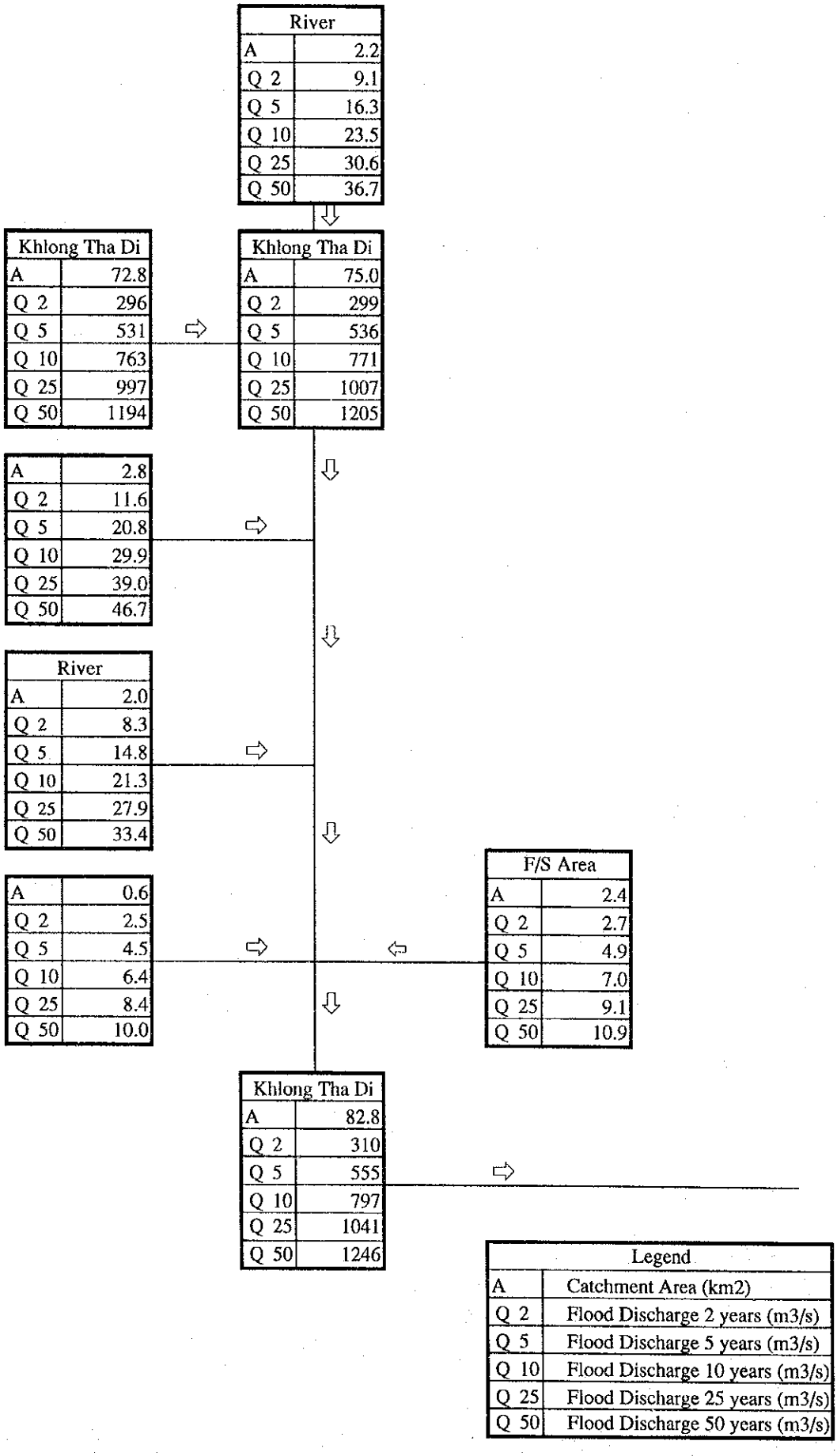


Figure B.4.1 Flood Discharge Corresponding to each Return Period (F/S area in Lan Saka)

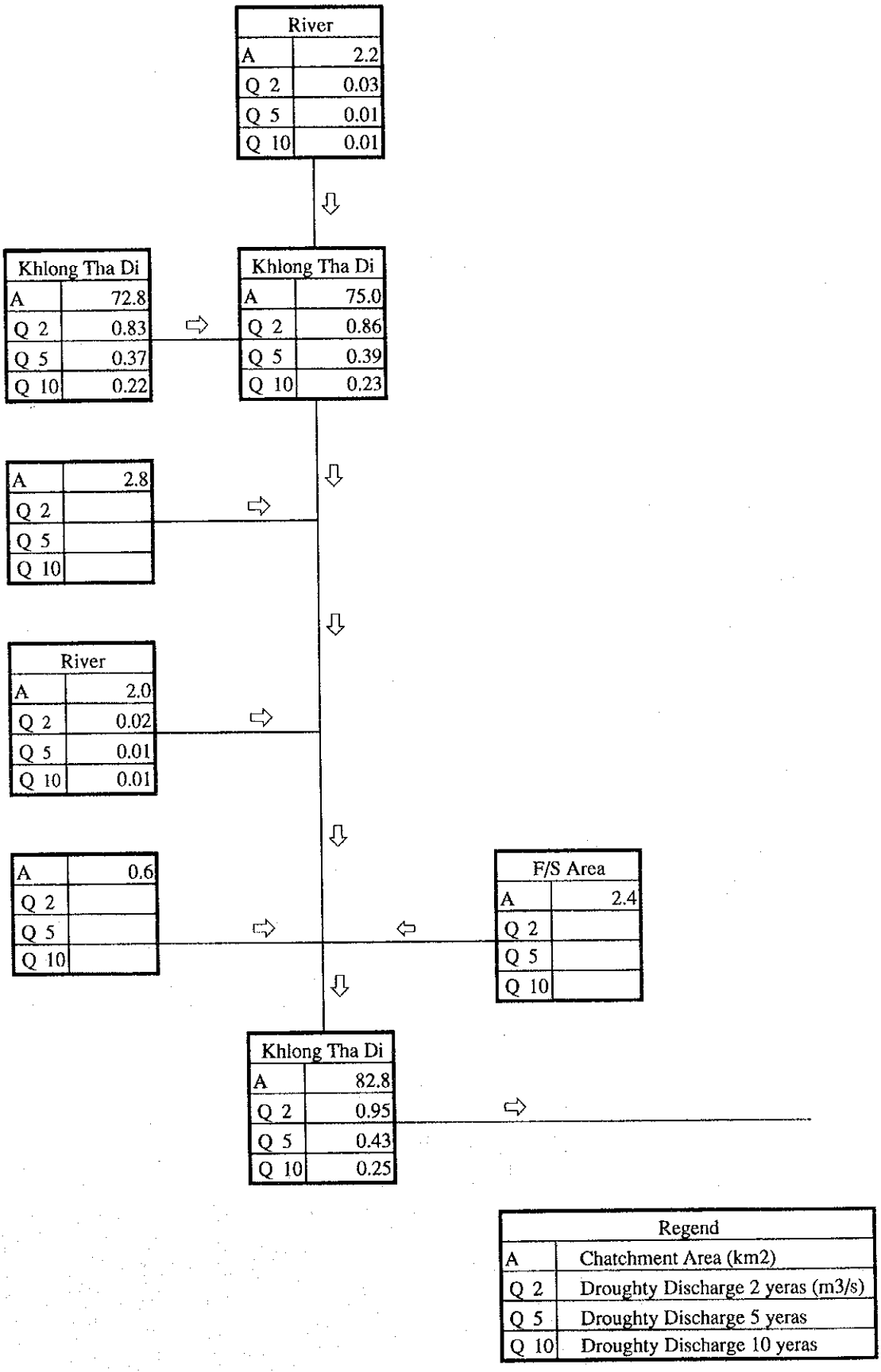


Figure B.4.2 Droughty Discharge Corresponding to each Return Period (F/S area in Lan Saka)

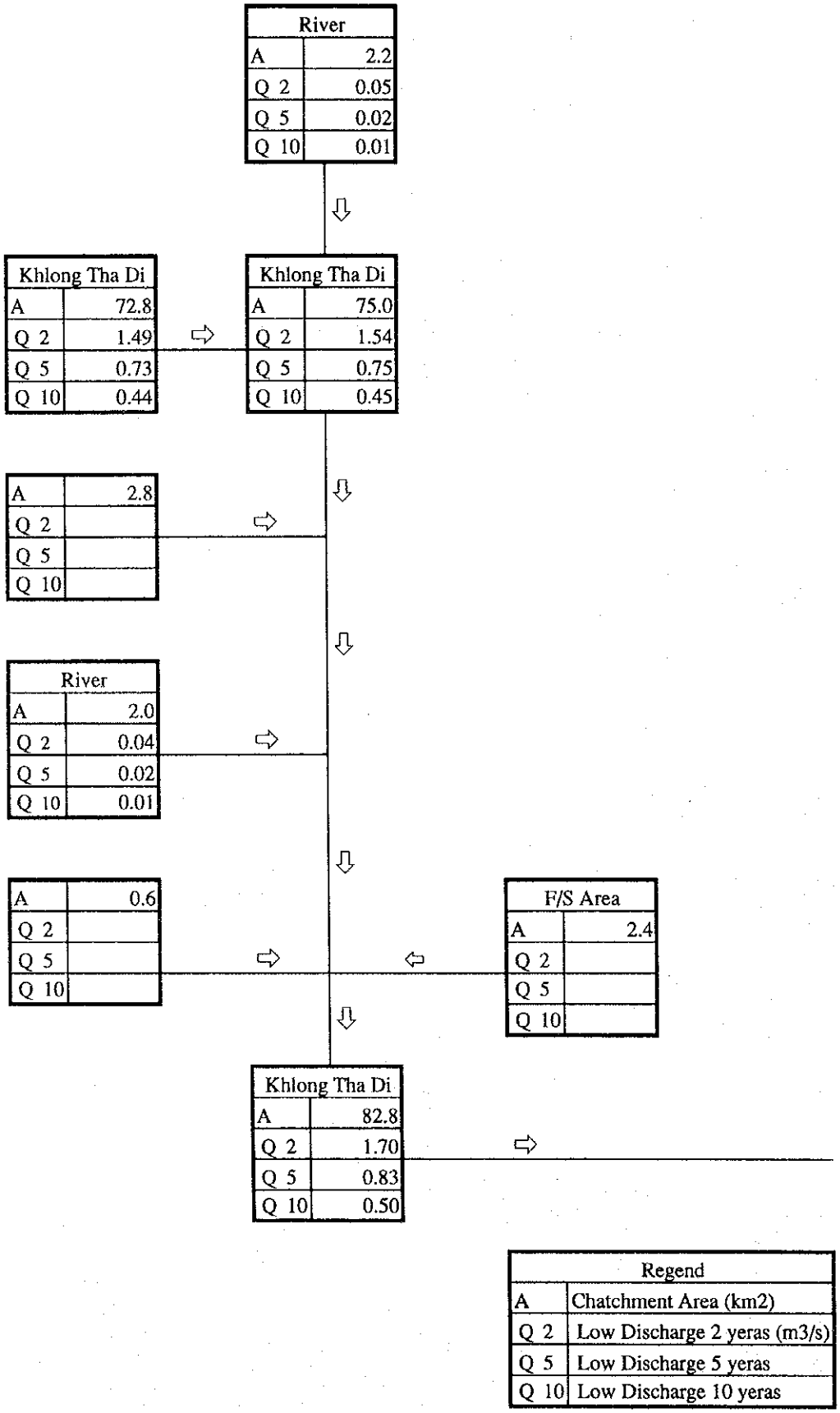


Fig. B.4.3 Low Discharge Corresponding to each Return Period (F/S area in Lan Saka)

Table B.4.6 Calculation of Irrigable Area in the Lan Saka F/S Area

Place : Lan Saka, Khlong Tha Di (A=75 km2)

Return Period : 2 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm) (3)=(1)-(2)	(4) Discharge (Tha Di) (m3/s) A=75km2	(5) Droughty Discharge (m3/s) A=75km2	(6) Utilizable Discharge (m3/s) (6)=(4)-(5)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month) (10)=(6)x3600 x(7)x(8)x(9)	(11) Estimated Irrigable Area (ha) (11)=(10)/(3)x100
Apr.	98.5	186.1	-87.6	1.54	0.23	1.31	8 ~ 24	30	0.70 ~ 0.85	792 ~ 2886	900 ~ 3290
May	132.0	180.1	-48.1	1.63	0.23	1.40	8 ~ 24	31	0.70 ~ 0.85	875 ~ 3187	1820 ~ 6630
June	62.2	176.6	-114.4	1.50	0.23	1.27	8 ~ 24	30	0.70 ~ 0.85	768 ~ 2798	670 ~ 2450
July	62.8	182.8	-120.0	1.58	0.23	1.35	8 ~ 24	31	0.70 ~ 0.85	844 ~ 3073	700 ~ 2560
Aug.	55.3	185.7	-130.4	1.79	0.23	1.56	8 ~ 24	31	0.70 ~ 0.85	975 ~ 3552	750 ~ 2720
Sep.	102.3	164.6	-62.3	1.62	0.23	1.39	8 ~ 24	30	0.70 ~ 0.85	841 ~ 3062	1350 ~ 4910
Oct.	188.7	157.3	0.0	2.29	0.23	2.06	8 ~ 24	31	0.70 ~ 0.85	1287 ~ 4690	~
Nov.	288.8	142.1	0.0	7.30	0.23	7.07	8 ~ 24	30	0.70 ~ 0.85	4276 ~ 15577	~
Dec.	244.8	149.9	0.0	7.11	0.23	6.88	8 ~ 24	31	0.70 ~ 0.85	4300 ~ 15663	~
Jan.	108.3	163.1	-54.8	3.80	0.23	3.57	8 ~ 24	31	0.70 ~ 0.85	2231 ~ 8128	4070 ~ 14830
Feb.	33.9	165.8	-131.9	2.34	0.23	2.11	8 ~ 24	28	0.70 ~ 0.85	1191 ~ 4339	900 ~ 3290
Mar.	42.4	193.2	-150.8	1.65	0.23	1.42	8 ~ 24	31	0.70 ~ 0.85	887 ~ 3233	590 ~ 2140
Total	1420.1	2047.3	-900.3	34.15	2.76	31.39		365		19267 70188	

Table B.4.7 Calculation of Irrigable Area in the Lan Saka F/S Area

Place : Lan Saka, Khlong Tha Di (A=75 km2)

Return Period : 5 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm) (3)=(1)-(2)	(4) Discharge (Tha Di) (m3/s) A=75km2	(5) Droughty Discharge (m3/s) A=75km2	(6) Utilizable Discharge (m3/s) (6)=(4)-(5)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month) (10)=(6)x3600 x(7)x(8)x(9)	(11) Estimated Irrigable Area (ha) (11)=(10)/(3)x100
Apr.	85.8	186.1	-100.3	0.68	0.23	0.45	8 ~ 24	30	0.70 ~ 0.85	272 ~ 991	270 ~ 990
May	114.9	180.1	-65.2	0.71	0.23	0.48	8 ~ 24	31	0.70 ~ 0.85	300 ~ 1093	460 ~ 1680
June	54.1	176.6	-122.5	0.62	0.23	0.39	8 ~ 24	30	0.70 ~ 0.85	236 ~ 859	190 ~ 700
July	54.6	182.8	-128.2	0.72	0.23	0.49	8 ~ 24	31	0.70 ~ 0.85	306 ~ 1116	240 ~ 870
Aug.	48.2	185.7	-137.5	0.89	0.23	0.66	8 ~ 24	31	0.70 ~ 0.85	412 ~ 1503	300 ~ 1090
Sep.	89.0	164.6	-75.6	0.96	0.23	0.73	8 ~ 24	30	0.70 ~ 0.85	442 ~ 1608	580 ~ 2130
Oct.	164.3	157.3	0.0	1.54	0.23	1.31	8 ~ 24	31	0.70 ~ 0.85	819 ~ 2982	~
Nov.	251.4	142.1	0.0	4.32	0.23	4.09	8 ~ 24	30	0.70 ~ 0.85	2474 ~ 9011	~
Dec.	213.0	149.9	0.0	4.11	0.23	3.88	8 ~ 24	31	0.70 ~ 0.85	2425 ~ 8833	~
Jan.	94.2	163.1	-68.9	2.03	0.23	1.80	8 ~ 24	31	0.70 ~ 0.85	1125 ~ 4098	1630 ~ 5950
Feb.	29.5	165.8	-136.3	1.26	0.23	1.03	8 ~ 24	28	0.70 ~ 0.85	581 ~ 2118	430 ~ 1550
Mar.	36.9	193.2	-156.3	0.81	0.23	0.58	8 ~ 24	31	0.70 ~ 0.85	362 ~ 1320	230 ~ 840
Total	1236.0	2047.3	-990.8	18.65	2.76	15.89		365		9754 35532	

Table B.4.8 Calculation of Irrigable Area in the Lan Saka F/S Area

Place : Lan Saka, Khlong Tha Di (A=75 km2)

Return Period : 10 years

Mon.	(1) Effective Rainfall (mm)	(2) Water Requirement (mm)	(3) Shortage (mm) (3)=(1)-(2)	(4) Discharge (Tha Di) (m3/s) A=75km2	(5) Droughty Discharge (m3/s) A=75km2	(6) Utilizable Discharge (m3/s) (6)=(4)-(5)	(7) Time for Irrigation (hour/day)	(8) Days	(9) Irrigation Efficiency	(10) Amount of Utilizable Water (1000m3/Month) (10)=(6)x3600 x(7)x(8)x(9)	(11) Estimated Irrigable Area (ha) (11)=(10)/(3)x100
Apr.	79.6	186.1	-106.5	0.38	0.23	0.15	8 ~ 24	30	0.70 ~ 0.85	91 ~ 330	90 ~ 310
May	106.7	180.1	-73.4	0.44	0.23	0.21	8 ~ 24	31	0.70 ~ 0.85	131 ~ 478	180 ~ 650
June	50.3	176.6	-126.3	0.37	0.23	0.14	8 ~ 24	30	0.70 ~ 0.85	85 ~ 308	70 ~ 240
July	50.7	182.8	-132.1	0.45	0.23	0.22	8 ~ 24	31	0.70 ~ 0.85	137 ~ 501	100 ~ 380
Aug.	44.7	185.7	-141.0	0.54	0.23	0.31	8 ~ 24	31	0.70 ~ 0.85	194 ~ 706	140 ~ 500
Sep.	82.6	164.6	-82.0	0.78	0.23	0.55	8 ~ 24	30	0.70 ~ 0.85	333 ~ 1212	410 ~ 1480
Oct.	152.5	157.3	-4.8	1.31	0.23	1.08	8 ~ 24	31	0.70 ~ 0.85	675 ~ 2459	~
Nov.	233.4	142.1	0.0	3.28	0.23	3.05	8 ~ 24	30	0.70 ~ 0.85	1845 ~ 6720	~
Dec.	197.8	149.9	0.0	3.12	0.23	2.89	8 ~ 24	31	0.70 ~ 0.85	1806 ~ 6579	~
Jan.	87.5	163.1	-75.6	1.51	0.23	1.28	8 ~ 24	31	0.70 ~ 0.85	800 ~ 2914	1060 ~ 3850
Feb.	27.4	165.8	-138.4	0.91	0.23	0.68	8 ~ 24	28	0.70 ~ 0.85	384 ~ 1398	280 ~ 1010
Mar.	34.3	193.2	-158.9	0.58	0.23	0.35	8 ~ 24	31	0.70 ~ 0.85	219 ~ 797	140 ~ 500
Total	1147.7	2047.3	-1039.0	13.67	2.76	10.91		365		6700 24402	

Table B.4.9 Flood Discharge at the point of the Sandbank Island in the Lan Saka F/S Area

Time (h)	Discharge from the sandbank island Catchment Area A=0.364 sq. km Return Period 2 years	10 years	Discharge at the point of junction between two river branches, point located downstream of the sandbank Catchment Area A=82.8 sq. km Return Period 2 years	10 years
0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.1	0.3	0.9
2.0	0.0	0.1	2.7	7.0
3.0	0.1	0.1	5.4	13.8
4.0	0.1	0.2	7.5	19.3
5.0	0.1	0.2	9.4	24.2
6.0	0.1	0.2	11.3	29.0
7.0	0.1	0.2	13.3	34.1
8.0	0.1	0.3	15.4	39.7
9.0	0.1	0.3	17.9	46.1
10.0	0.1	0.4	20.8	53.6
11.0	0.2	0.4	24.4	62.7
12.0	0.2	0.5	28.8	74.0
13.0	0.2	0.6	34.4	88.4
14.0	0.3	0.8	41.7	107.4
15.0	0.4	1.0	51.8	133.1
16.0	0.5	1.3	66.0	169.6
17.0	0.7	1.9	87.2	224.3
18.0	1.1	3.0	121.5	312.6
19.0	1.9	4.9	183.1	470.8
20.0	1.6	4.2	275.4	708.4
20.5	1.4	3.5	301.7	776.0
21.0	1.1	2.8	280.6	721.7
22.0	0.5	1.4	213.5	549.3
23.0	0.2	0.5	158.1	406.7
24.0	0.1	0.2	120.3	309.4
25.0	0.0	0.1	93.5	240.5
26.0	0.0	0.0	71.7	184.6
27.0	0.0	0.0	55.2	142.0
28.0	0.0	0.0	43.3	111.3
29.0	0.0	0.0	34.8	89.6
30.0	0.0	0.0	28.3	72.7
31.0	0.0	0.0	23.0	59.2
32.0	0.0	0.0	18.7	48.2
33.0	0.0	0.0	15.3	39.3
34.0	0.0	0.0	12.5	32.1
35.0	0.0	0.0	10.2	26.1
36.0	0.0	0.0	8.2	21.2
37.0	0.0	0.0	6.7	17.2
38.0	0.0	0.0	5.4	13.8
39.0	0.0	0.0	4.3	11.0
40.0	0.0	0.0	3.3	8.5
41.0	0.0	0.0	2.4	6.3
42.0	0.0	0.0	1.6	4.0

APPENDIX C

GEOLOGY AND GROUNDWATER

List of Figures

Figure C-1 Geological Map of General Study Area..... C-1

Figure C-2 Distribution of Landslides in Ban Na San... C-2

Figure C-3 Distribution of Landslides in Lan Saka..... C-3

Figure C-4.1 W-3 s-t Curve (Ban Na San)..... C-5

Figure C-4.2 BW-3 s-logt (Ban Na San)..... C-5

Figure C-4.3 BW-3 s-logt' (Ban Na San)..... C-5

Figure C-4.4 LW-8 s-t 1995.1.20..... C-6
LW-8 s-logt' (Recoverly) 1995.1.20 (logt'>.2)

Figure C-4.5 W24 s-t, W24 s-logt (>10)..... C-7

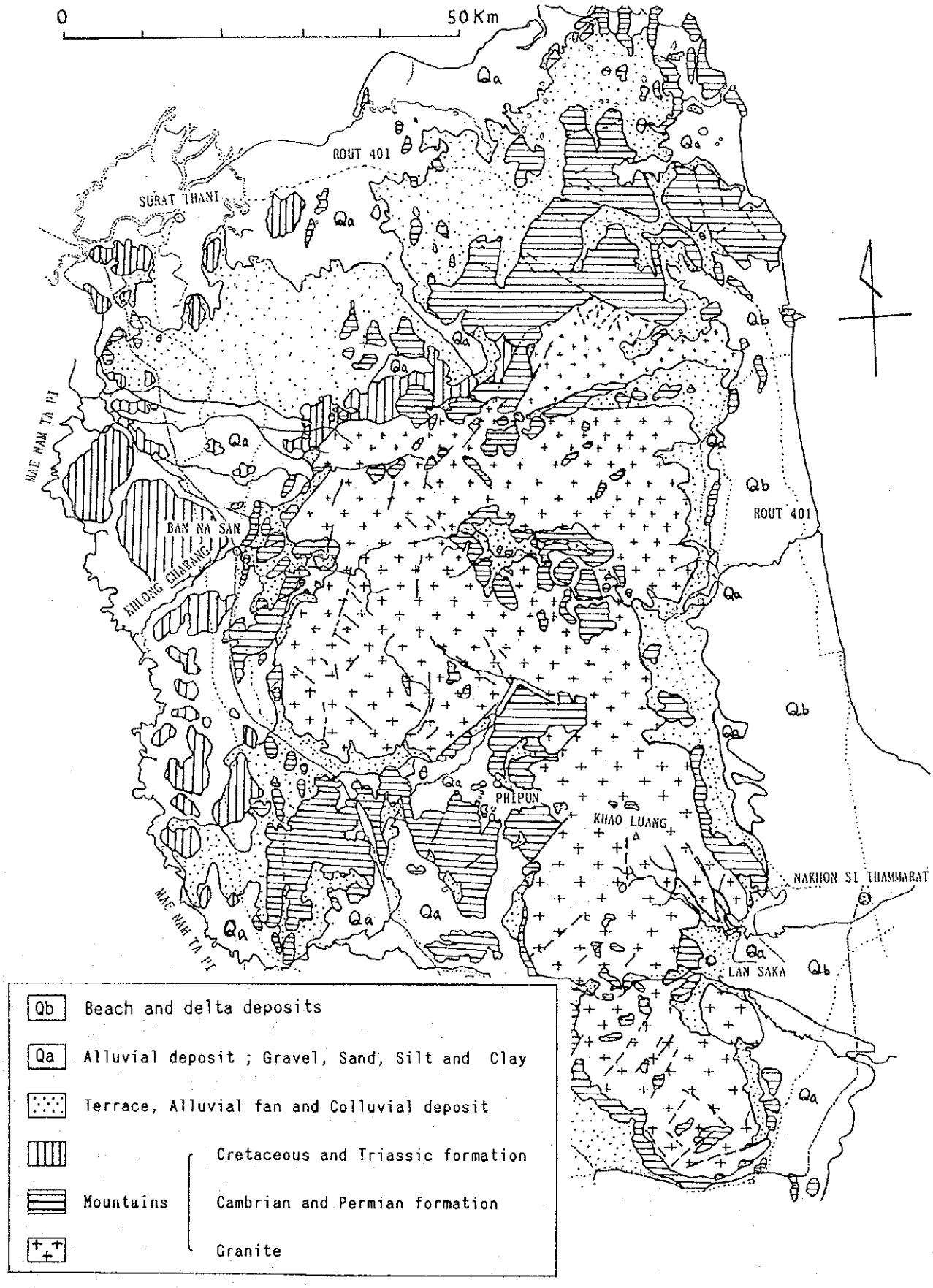
Figure C-5 Contour Map of Surface of Buried Old Soil of Lan Saka F/S Area..... C-8

Figure C-6 Contour Map of Surface of Buried Old Soil of Lan Saka F/S Area..... C-9

List of Tables

Table C-1 Inventory of Farmer's Domestic and Irrigation Use Well..... C-4

figure c - 1 GEOLOGICAL MAP OF GENERAL STUDY AREA



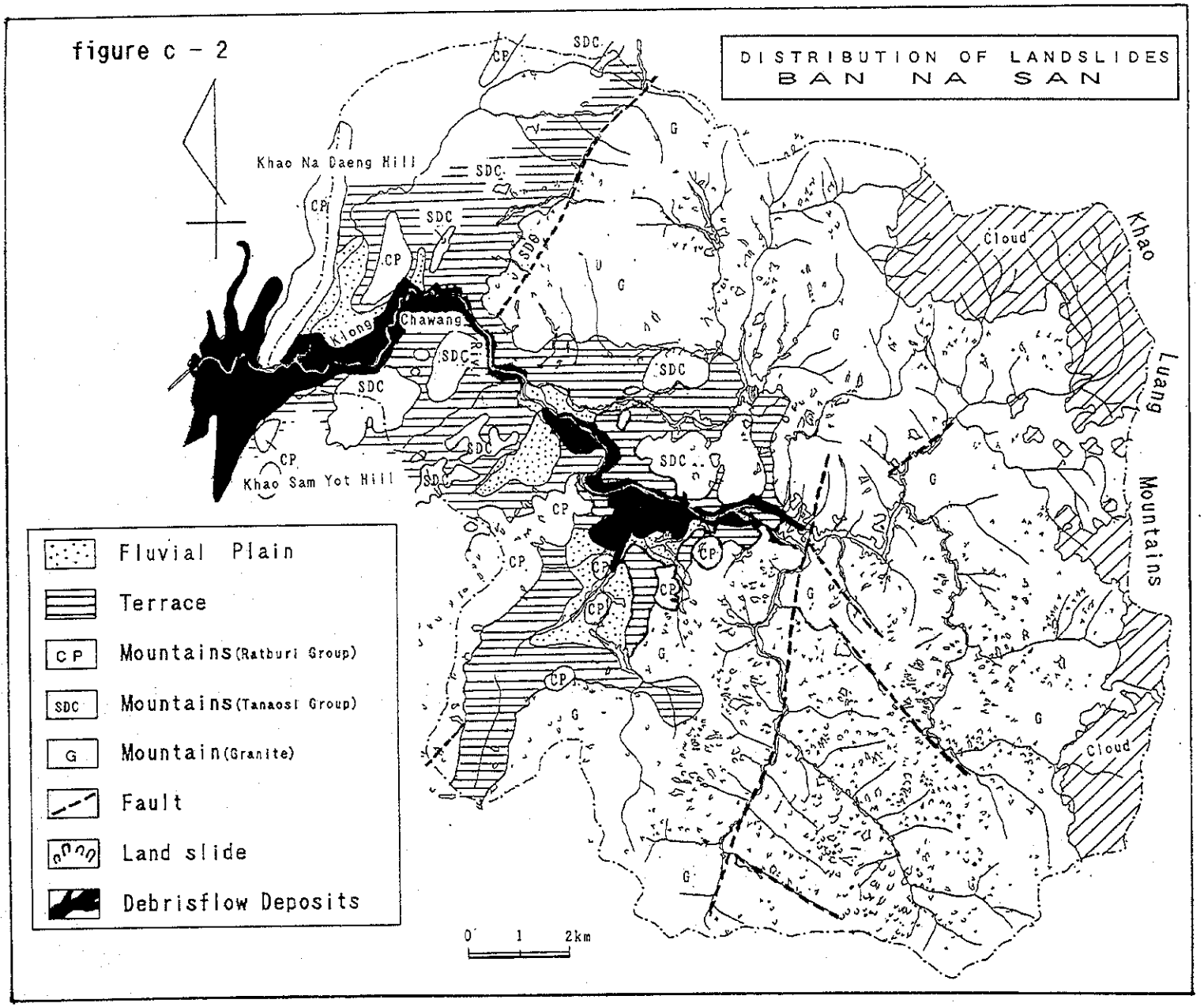


figure c - 2
DISTRIBUTION OF LANDSLIDES
BAN NA SAN
Khao Na Daeng Hill
Khao Sam Yot Hill
Klong Chawang
Khao Luang Mountains
Cloud
CP
SDC
G
Fluvial Plain
Terrace
Mountains(Ratburi Group)
Mountains(Tanaosi Group)
Mountain(Granite)
Fault
Land slide
Debrisflow Deposits
0 1 2km

figure c - 3

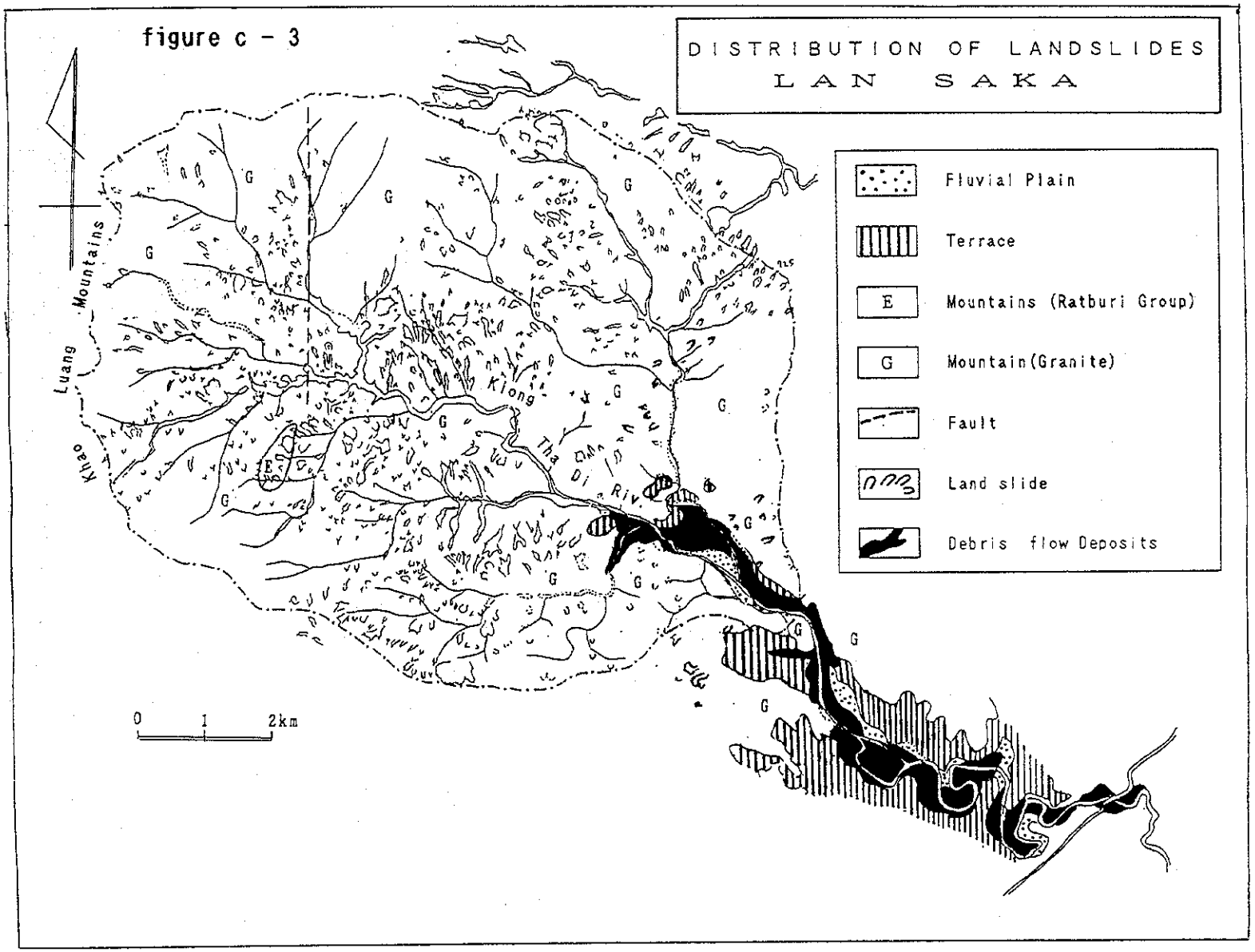

DISTRIBUTION OF LANDSLIDES
LAN SAKA
Fluvial Plain
Terrace
E Mountains (Ratburi Group)
G Mountain(Granite)
Fault
Land slide
Debris flow Deposits
Khao Luang Mountains
Khong
Tha Di Riv.
0 1 2km

TABLE C-1 INVENTORY OF FARMER'S DOMESTIC AND IRRIGATION USE WELL

STUDY AREA	WELL NO.	ELEVATION m	DEPTH GL-(m)	WATER TABLE GL-(m)	ELEVATION OF WATER TABLE (m)	DIAMETER (m)	WATER QUALITY	REMARKS
LAN SAKA	LW- 1	37.10	-	2.23	34.87	0.80	GOOD	IN LAN SAKA AREA DOMESTIC ONLY
	LW- 2	37.00	-	2.40	34.60	0.90	IMPURE	
	LW- 3	37.10	-	1.86	35.24		IMPURE	
	LW- 4	37.00	-	1.52	35.48		BAD	
	LW- 5	37.10	-	2.05	35.05	0.90	BAD IN DRY SEASON	WITH PUMP
	LW- 6	38.10	-	2.21	35.89	0.90	BAD IN DRY SEASON	
	LW- 7	37.50	-	1.27	36.23	0.80	GOOD	
	LW- 8	36.50	4.66	2.01	34.49	0.80	GOOD	PUMPING TEST
	LW- 9	36.00	5.13	1.83	34.17	0.90	GOOD	
	LW-10	35.90	4.01	0.96	34.94	1.00	SMELL IN DRY SEASON	
	LW-11	36.50	3.41	2.51	33.99	0.90		
	LW-12	36.00	4.55	2.00	34.00	0.90		WITH PUMP
	LW-13	35.00	3.75	1.00	34.00	0.90	IMPURE UNDER FLOOD	
	LW-14	34.90	3.29	0.91	33.99	1.10	SMELL	GREY SOIL 66cm DEPTH
	LW-15	35.10	3.54	0.98	34.12	0.90	BAD IN DRY SEASON	
	LW-16	40.00	5.34+	1.34	38.66	1.00		SITUATED ON THE TERRACE
	LW-17	39.00	5.25+	4.93	34.07	1.00	GOOD	SITUATED ON THE TERRACE
	LW-18	38.30	5.34+	3.91	34.39	0.90	GOOD	SITUATED ON THE TERRACE
	LW-19	38.20	5.35+	4.91	33.29	0.90		SITUATED ON THE TERRACE
	LW-20	34.00	0.87	0.00	34.00	1.00	GOOD	SPRING
	LW-21	36.00	5.26+	2.26	33.74	0.90		
	LW-22	34.20	5.12+	2.84	31.36	0.90	BAD	
	LW-23	34.00	5.15+	2.15	31.85	0.90		
	LW-24	34.50	4.99	2.15	32.35	0.90	BAD	PUMPING TEST
	LW-25	34.50	3.87	0.55	33.95	0.80	IMPURE	
	LW-26	34.20	3.53	1.84	32.36	1.00	IMPURE	
	LW-27	32.50	5.29	2.27	30.23	0.80	BAD	
	LW-28	32.70	4.57	2.32	30.38	0.90		
BAN NA SAN	BW- 1	85.00	4.20	4.2+	85.00-	1.00		IN BAN NA SAN AREA IRRIGATION USE ONLY
	BW- 2	102.00	4.48	4.16	97.84	0.90		PUMPING TEST
	BW- 3	94.60	-	3.46	91.14	1.00		
	BW- 4	92.30	4.65	3.78	88.52	1.00		
	BW- 5	83.50	5.08+	4.25	79.25	1.00		

TABLE C-2
ESTIMATED 'T' & 'k' BY PUMPING TEST

WELL NO.	FIGURE	⊿ s (cm)	TRANSMISSIBILITY T(cm2/sec.)	THICKNESS OF AQUIFER m(m)	PERMEABILITY k(cm/sec.)
BW-3	C-2.2	15.20000	7.68382	10.00000	0.00768
	C-2.3	19.40000	6.02031	10.00000	0.00602
LW-8	C-2.4	0.70000	166.84859	10.00000	0.16685
LW-24	C-2.5	1.60000	72.99626	10.00000	0.07300

FIGURE C - 4.1 W-3 s-t CURVE(BAN NA SAN)

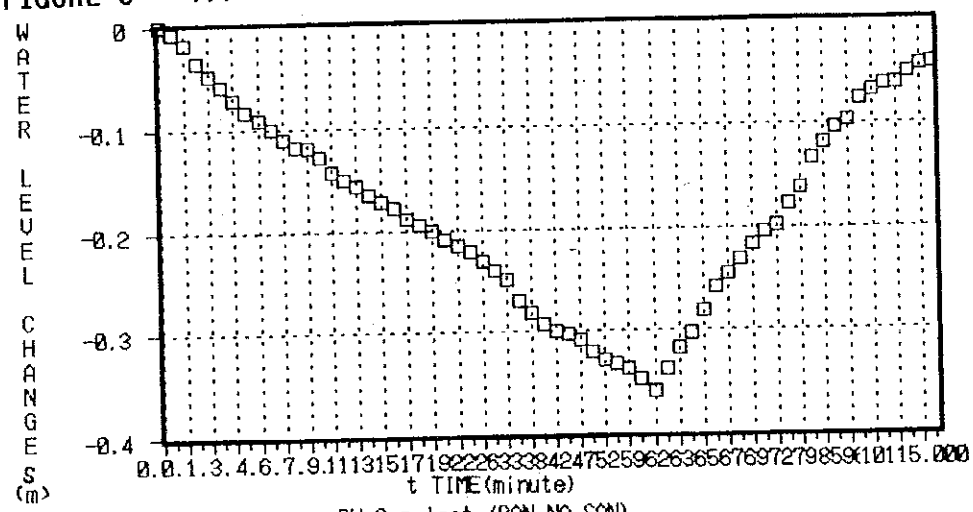


FIGURE C - 4.2 BW-3 s-logt (BAN NA SAN)

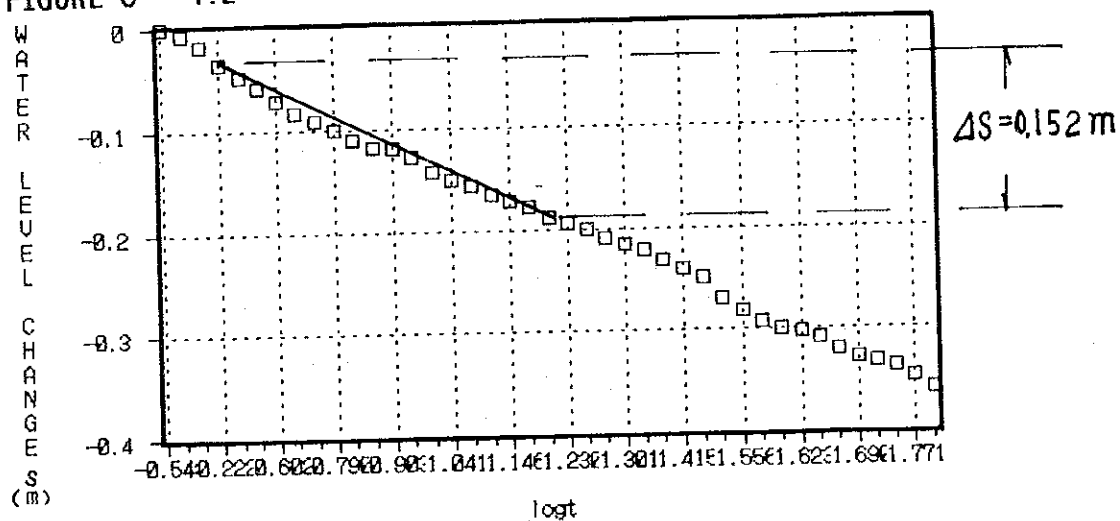


FIGURE C - 4.3 BW-3 s-logt' (BAN NA SAN)

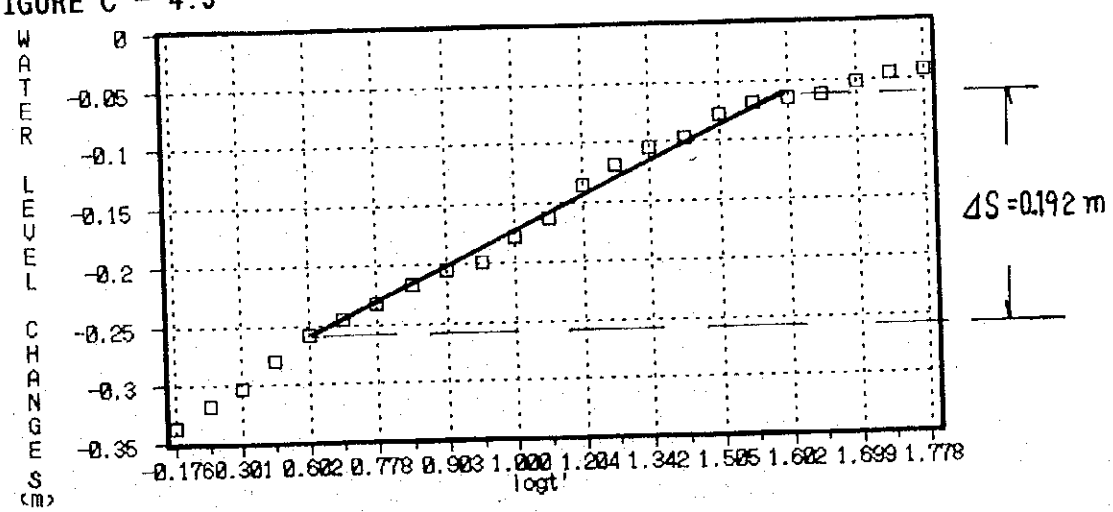
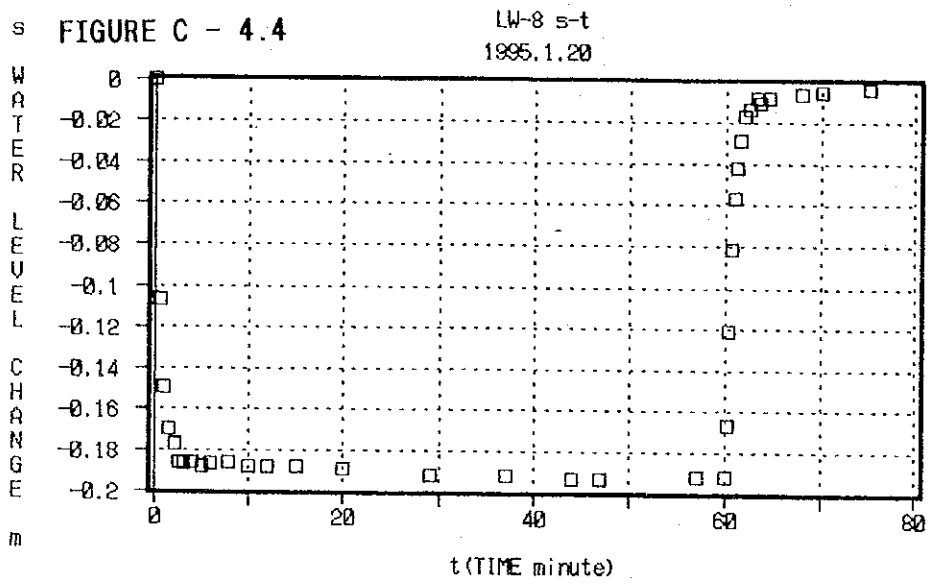


FIGURE C - 4.4


LW-8 s-t
1995.1.20
s
WATER LEVEL CHANGE m
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
-0.18
-0.2
0
20
40
60
80
t(TIME minute)

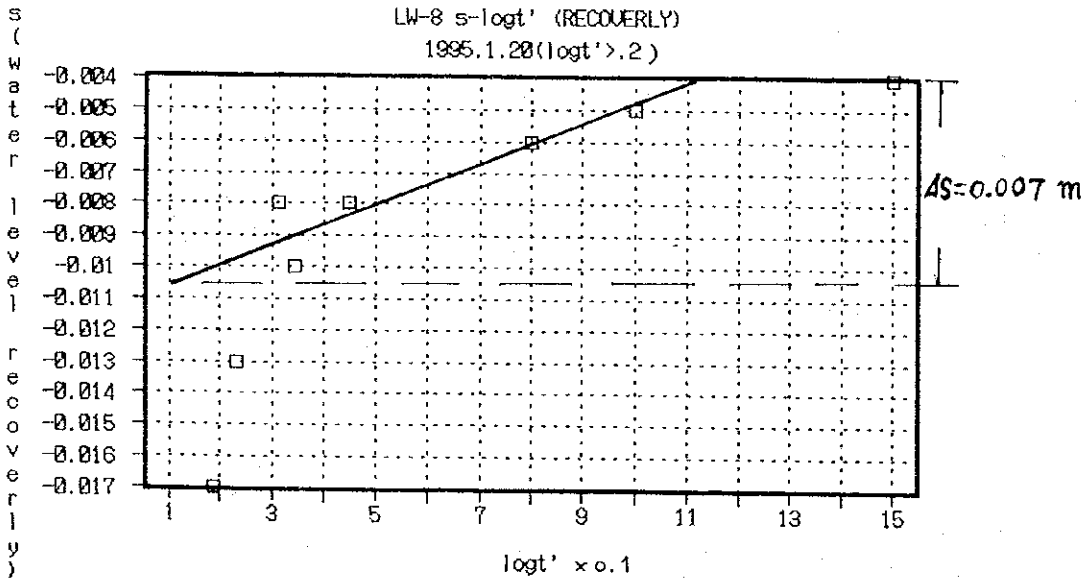
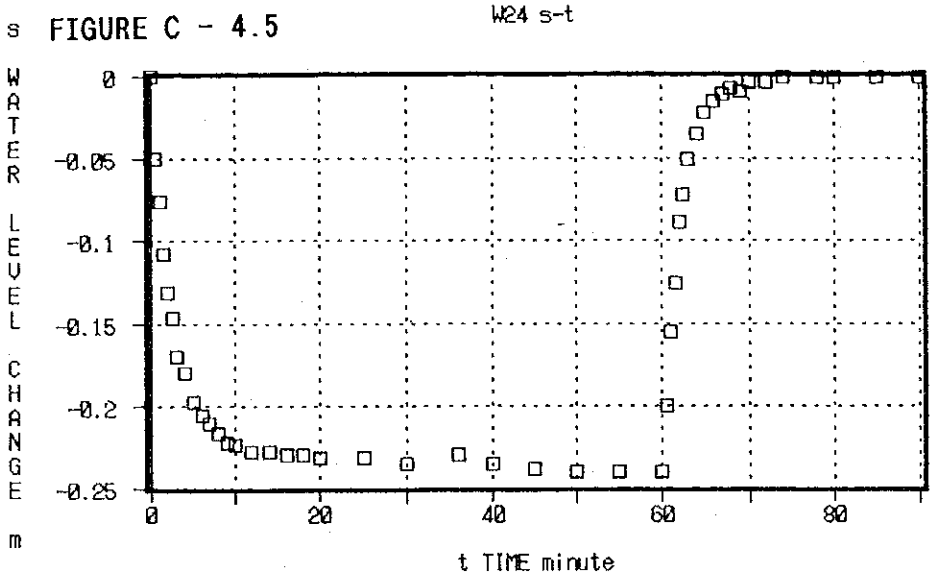

LW-8 s-logt' (RECOVERLY)
1995.1.20(logt'>.2)
s(water level recoverly)
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
-0.011
-0.012
-0.013
-0.014
-0.015
-0.016
-0.017
1
3
5
7
9
11
13
15
logt' x o.1
ΔS=0.007 m

FIGURE C - 4.5


W24 s-t
s
WATER LEVEL CHANGE
m
0
-0.05
-0.1
-0.15
-0.2
-0.25
0
20
40
60
80
t TIME minute

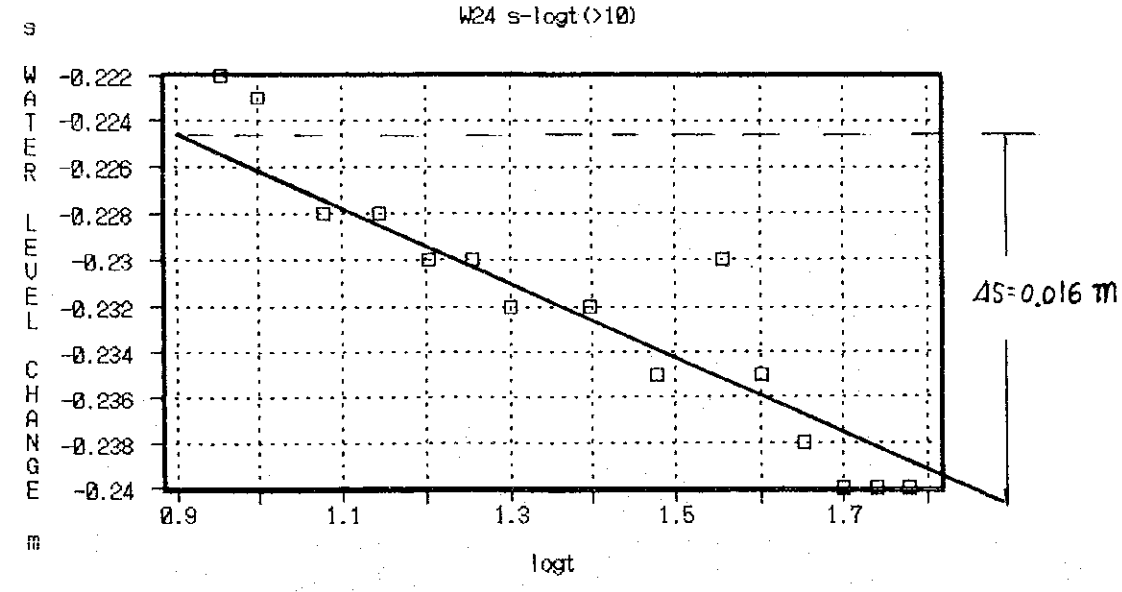

W24 s-logt(>10)
s
WATER LEVEL CHANGE
m
-0.222
-0.224
-0.226
-0.228
-0.23
-0.232
-0.234
-0.236
-0.238
-0.24
0.9
1.1
1.3
1.5
1.7
logt
ΔS=0.016 m

figure c - 5

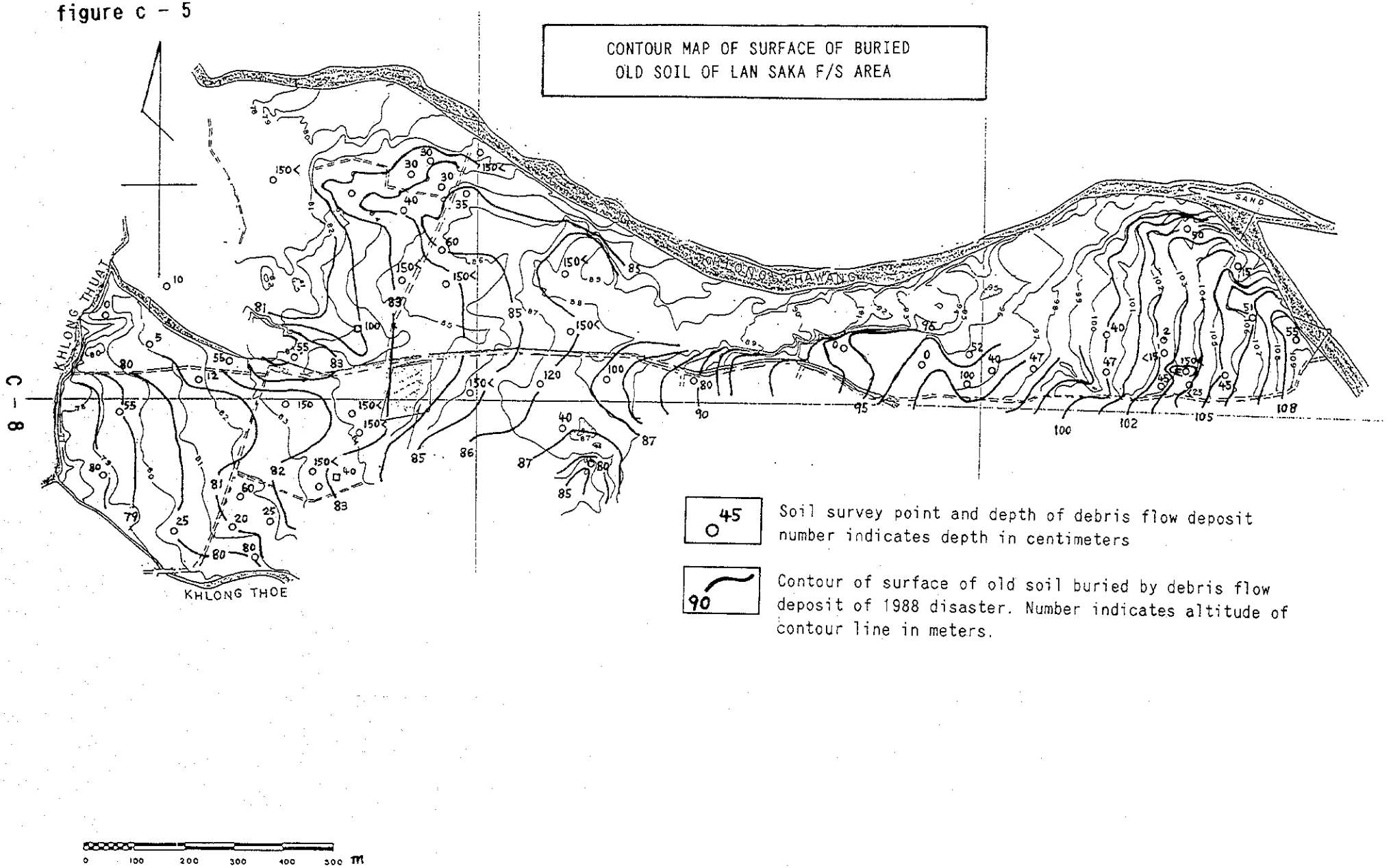
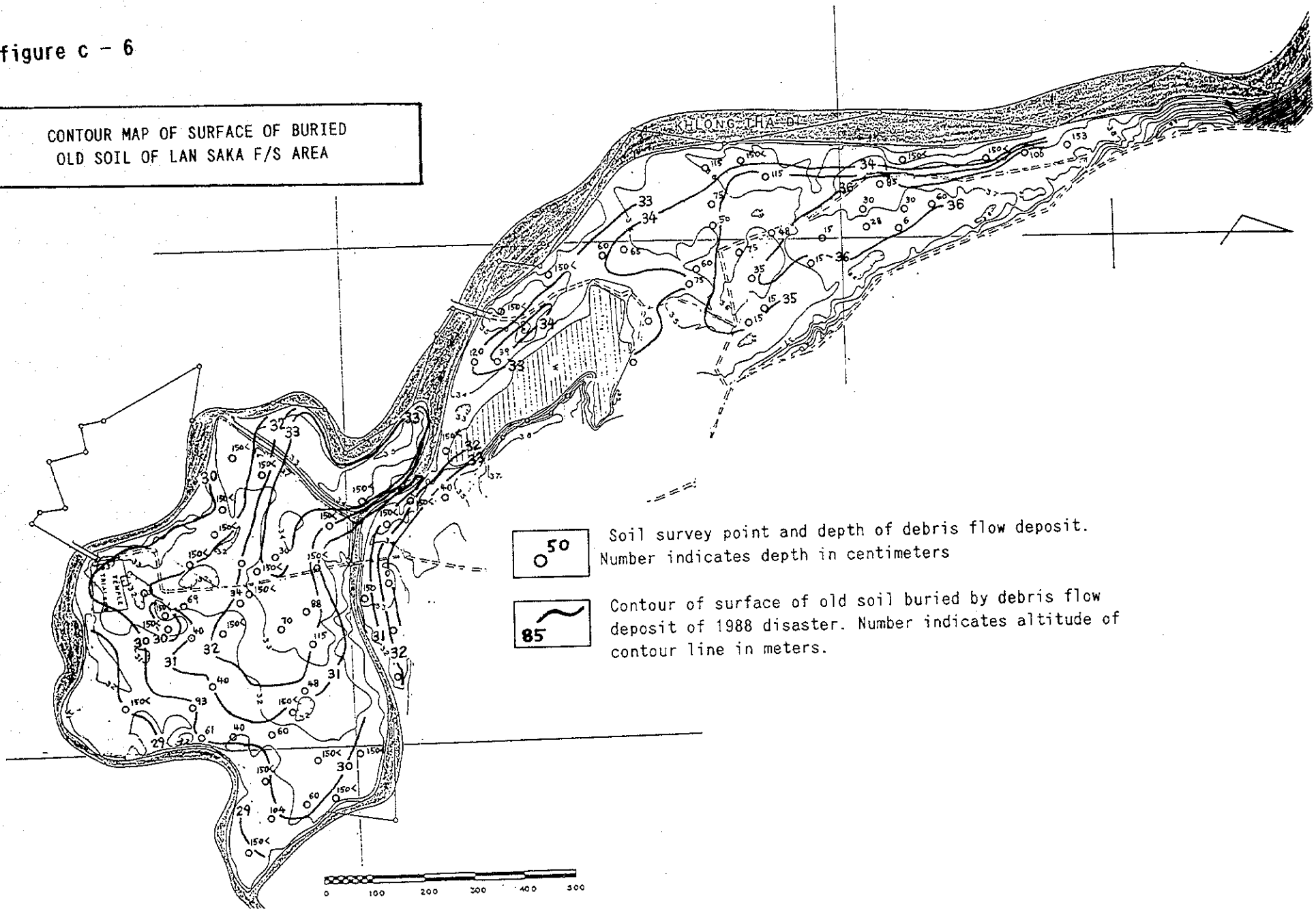

CONTOUR MAP OF SURFACE OF BURIED
OLD SOIL OF LAN SAKA F/S AREA
KHLONG THUAT
KHLONG HAWANG
KHLONG THOE
SAND
Soil survey point and depth of debris flow deposit number indicates depth in centimeters
Contour of surface of old soil buried by debris flow deposit of 1988 disaster. Number indicates altitude of contour line in meters.
0 100 200 300 400 500 m

figure c - 6

CONTOUR MAP OF SURFACE OF BURIED
OLD SOIL OF LAN SAKA F/S AREA



APPENDIX D

REMOTE SENSING

Contents

1. Outline of the Study . . . . . D- 1

1.1 Purpose of the Study . . . . . D- 1

1.2 The Study Area . . . . . D- 1

1.3 Details of the Study . . . . . D- 2

2. The First Half Study . . . . . D- 6

2.1 Retrieval and Acquisition of Artificial Satellite Data . . . . . D- 6

2.2 Preliminary Processing . . . . . D- 7

2.3 False Color Image . . . . . D- 7

2.4 Vegetation/Land Use Map . . . . . D- 8

2.5 Collapse Distribution Map D-11

3. Last Half Study D-14

3.1 Land Use Secular Change Map D-15

3.2 Compilation of Thematic Maps by Topographic Analysis D-17

3.3 Analysis of Factors causing Land Collapses D-18

3.4 Land Safety Classification Map D-27

4. Summary D-28

Postscript D-29

List of Tables and Figures

Tables

Table D-1 List of Artificial Satellite Data Used for the Study . . . . . D- 6

Table D-2 Relation Between Objects and Color on False Color Images . . . . . D- 7

Table D-3 Classification Categories of Vegetation/Land Use . . . . . D- 8

Table D-4 List Showing the Area by Vegetation/Land Use in Area A . . . . . D- 9

Table D-6 Change is the Area of Natural Forest from 1988-1993 . . . . . D-16

Table D-7 List of Inclination Classification of Ban Na San District D-19

Table D-8 List of Slope Direction Classification of Ban Na San District D-19

Table D-9 List of Vegetation/Land use Classification of Ban Na San District D-20

Table D-10 List of Altitude Classification of Ban Na San Distirct D-20

Table D-11 List of Geology Classification of Ban Na San District D-21

Table D-12 List of Distance from Fault in Ban Na San District D-21

Table D-13 List of Inclination Classification of Lan Saka District H-23

Table D-14 List of Slope Direction Classification of Lan Saka District D-23

Table D-15 List of Vegetation/Land Use Classification of Lans Saka District D-24

Table D-16 List of Altitude Classification of Lan Saka District D-25

Table D-17 List of Geology Classification of Lan Saka District D-26

Table D-18 List of Distance from Faults in Lan Saka District D-26

Figures

Figure D-1 Study Location Map . . . . . D- 1

Figure D-2 Flow Chart of the Study . . . . . D- 2

Figure D-3 Collapse Distribution Map (Ban Na San) D-12

Figure D-4 Collapse Distribution Map (Lan Saka) D-13

1. Outline of the Study

1.1 Purpose of the Study

Our study was implemented for the purpose of providing the basic materials for the full scaled study of the land classification map made by the factor analysis, based on the thematic maps such as vegetation and land use maps of total disaster area and those of restoration and conservation planned area.

The study was carried out in two stages, a first half study and a last half study. The first half study was made for the total study area and the last half study for the detailed study area.

1.2 The Study Area

We designated the disaster area (approx. 5,179 square Km) attacked by the great 1988 flood in Surat Thani Province and Nakhon Si Thammarat Province as the total study area (called Area A), and the two basins (approx. 300 square Km) of Ban Na San district in Surat Than Province and Lan Saka district in Nakhon Si Thammarat Province as the detailed study area (called Area B) which are subject to the arable land restoration basic plan.

(1) Total study area (Area A): Disaster area in Nakhon Si Thammarat (approx. 5,170 square Km)

(2) Detailed study area (Area B): two basins (approx. 300 square Km) of Ban Na San district in Surat Thani Province and Lan Saka district in Nakhon Si Thammarat Province

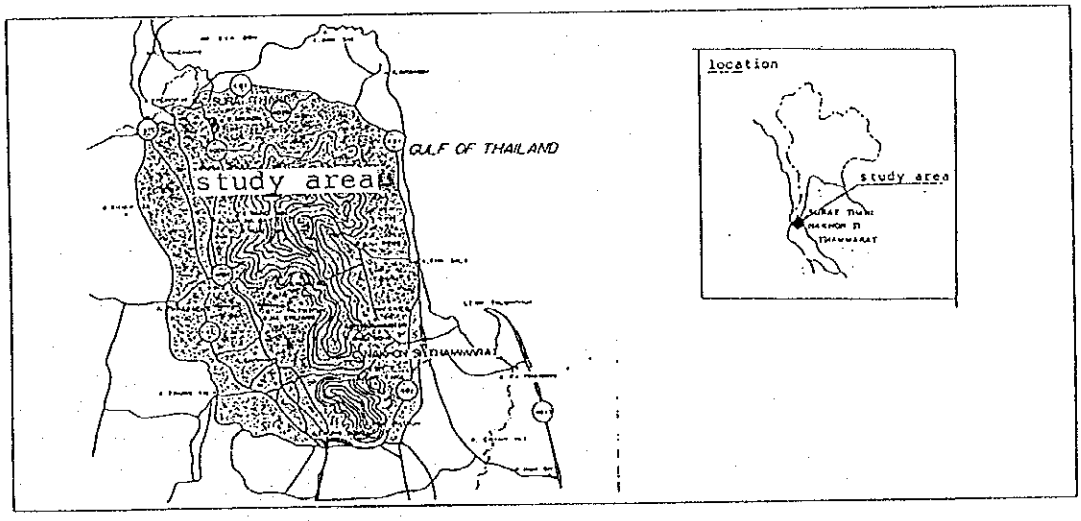


Fig. D-1 Study location map

1.3 Details of the study

The study was implemented in two stages, a first half study and a last half study. Fig. D-2 shows the flow chart of the study.

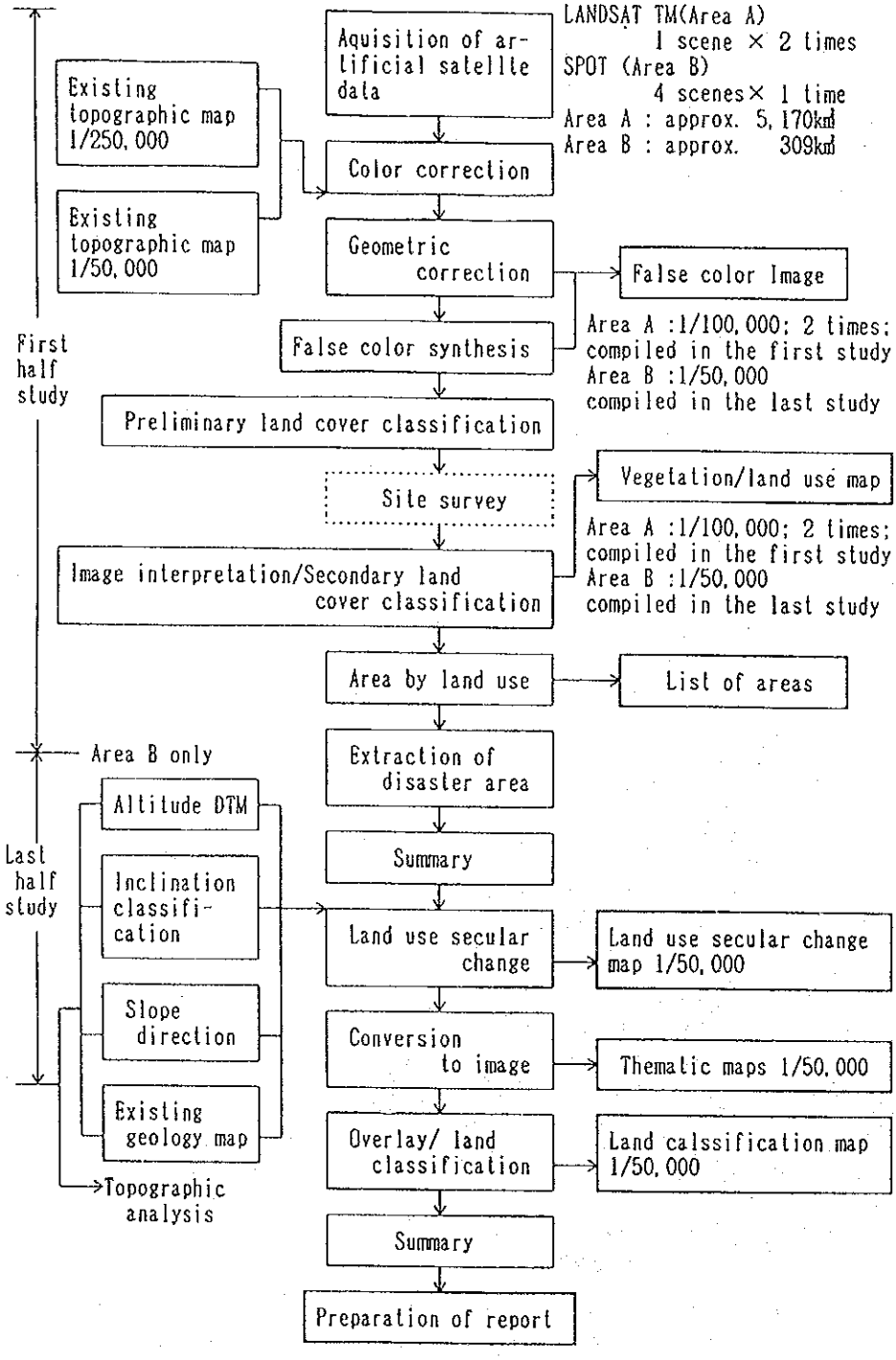


Fig. D-2 Flow chart of the Study

(i) Preliminary study

1) Retrieval and acquisition of artificial satellite data

We retrieved the artificial satellite data necessary for the study of their cloud volume and picture quality, and acquired them in the form of magnetic tape through the Remote Sensing Center (Foundation) and others.

i) We used LANDSAT TM data of 30m land resolution (1 scene x 2 temporarily different times) for the total study area (Area A). The LANDSAT TM data used for the study was a scene of Path 129-ROW 52.

ii) We used SPOT data of 20m land resolution (4 scenes x 1 time). The SPOT data used for the study are 4 scenes of K262-J332, K262-J332 and K263-J333.

2) Color correction

Color correction was made to the original data of artificial satellite by means of image emphasis, etc. so that the color of the total image could be seen more easily. Specifically, it was brought to our attention the change in density and features of forests could be expressed in the change of color tone.

3) Geometric correction

Since the original data of artificial satellite has geographic deformation, we made a geometric correction using the ground control points on the map so that the data coincide with the coordinates of the map.

4) Synthesis of false color

We made color synthesis using the data of necessary wavelengths (blue, red, infrared) among the satellite data, and compiled the false color image which was to be used as the basic map of the study. On the false color image, forests are mainly expressed in a reddish pink color, farmland and grassland in light pink and collapsed land in white.

5) Primary land cover classification

We made primary land cover classification making cluster classification by a computer taking advantage of color differences on the false color image, and compile the primary classification image to be used for preliminary survey. The land was roughly classified into the categories of forest, farmland, collapsed land, water area and street.

6) Compilation of vegetation/land use maps of temporarily different times.

Based on the result of the site survey, we made secondary land cover classification using the maximum likelihood method, and then compiled the vegetation/land use maps (at 1/100,000 for Area A and at 1/50,000 Area B) before and after the disaster applying image interpretation for the portion where the classification was difficult. The map of Area A was compiled in the first half study and that of Area B in the last half study.

The points where afforestation and farmland were clearly confirmed by the site survey were incorporated in the vegetation/land use map. The vegetation/land use map (at 1/100,00 for Area A and 1/50,000 for Area B) was produced as a colored map. The map of Area A was made in the first half study, and that of Area B in the last half study.

Area A was made in the first half study, and that of Area B in the last half study.

7) List of area by the kinds of lands use

We summed up the area by the categories of land use using the vegetation/land use maps of temporarily different times, and summarized it in the form of a list.

8) Extraction of disaster areas

We extracted the disaster areas such as collapsed land, the land where an avalanche of earth and rocks occurred and the flooded area using the vegetation/land use map after the disaster.

9) Summary of the first half study

We summarized the regional characteristics and situation of disaster basing on the results of the above studies.

(2) Last half study (only for Area B)

1) Secular change of land use

We constructed land use change map (at 1/50,000) using the vegetation land use maps before and after the disaster.

2) Topographic analysis

In order to seek for the factors causing the land to collapse, we made DTM mainly from 1/50,000 topographic map using a digitizer, and then made the inclination classification and slope direction classification using a calculator. In addition, we edited existing geology maps and made images from them by means of digitizer input.

3) Compilation of thematic maps

Basing on the result of analysis of 1) and 2), we produced the thematic maps in color (1/50,000).

4) Overlay and land classification

We made factor analysis from area ratio, etc. by overlaying the collapsed land, land of earth and rock avalanche and flooded area with the vegetation/land use map before the disaster. Basing on the result of this analysis, we discussed the standard for classification, made classification as to the safety of land and possibility of land use, and compiled the result as the land classification map (at 1/50,000)

1.4 Results of the study

(1) First half study

1) False color image (attached separately)
Area A: at the scale 1/100,000; two temporarily different data of LANDSAT TM

2) Vegetation/land use map (attached separately)
Area A+ at the scale 1/100,000; two temporarily different data of LANDSAT TM

3) List of area

4) Collapse distribution map (Area B: two areas of Ban Na San district and Lan Saka district

5) Summary

(2) Last half study (Area B: two areas of Ban Na San district and Lan Kasa district)

1) False color image
Scale at 1/50,000; SPOT; one temporal time

2) Vegetation/land use map
Scale at 1/50,000; SPOT; one temporal time

3) Land use secular change map: Scale at 1/50,000

4) Thematic maps

i) Altitude classification map: Scale at /50,000
ii) Inclination classification map: Scale at 1/50,000
iii) Slope direction classification map: Scale at 1/50,000
iv) Geology classification map: Scale at 1/50,000

5) Land classification map
i) Land safety classification map: Scale at 1/50,000
ii) Land use possibility classification map: Scale at 1/50,000

6) Summary

7) Preparation of report

2. The First Half Study

2.1 Retrieval and Acquisition of Artificial Satellite Data

The artificial data used for the study are those observed before and after the heavy rain disaster which took place in northern Thailand in November 1988. Table 1 shows the list of artificial satellite data used for the study.

The data of LANDSAT satellite of the U.S. and SPOT satellite of France are generally used for this kind of study. Since the observation was started in 1872, the huge volume of LANDSAT data have been accumulated. Two kinds of sensors are mounted on the LANDSAT satellite, and are selectively used according to the purpose. These two sensors are called MSS and TM. MSS is an abbreviation of multi spectral Scanner and its land resolution is 80m. TM denotes the thematic mapper and its land resolution is 30m. The observation with TM has started since 1984. In general, MSS is used for the study of wider area, and TM is used for the study of limited area where high resolution is required.

On the other hand, SPOT satellite was launched in 198, and many data have been accumulated since then just like LANDSAT data. SPOT has the sensor called HRV (high resolution instrument) which provides two kinds of data, the panchromatic and multi-spectrum. The land resolution of panchromatic mode (monochrome) is 10m, and that of multi-spectrum mode (color) is 20m. In case of the panchromatic mode, it is possible to visually see the data.

As shown in figure 3 and 4 of reference report "The Study on the Agricultural Land Rehabilitation and Conservation Project in Surat Thani and Nakhon Si Tammarat Province <Remote Sensing>, Nov. 1994, JICA=ICOKUSAI ICOGYO co., LTD.", hereafter will be shown Fig. -- in this paper. The artificial satellite data which covers total study area is one scene of PATH 129 - ROW 54 in case LANDSAT> In case of SPOT, the total study area is covered by two scenes of K262-J332 and K262-J333.

We decided to use the artificial satellite data observed before and after the disaster, and retrieved the availability of good data in terms of picture quality and volume of clouds contained in the scene. And we acquired the data in the form of magnetic tape mainly through Remote Sensing Technical Center.

Table D-1 List of Artificial Satellite Data used for the Study

LANDSAT TM data				
PATH	ROW	Observation date	Cloud volume	Remarks
129	54	1988. 3.30	5 %	Before disaster
		1993. 3.28	0 %	After disaster
SPOT data				
PATH	ROW	Observation date	Cloud volume	Remarks
262	332	1988.12.30	20 %	After disaster
263	333	1989. 2. 9	40 %	After disaster

2.2 Preliminary processing (color correction and geometric correction)

Color correction and geometric correction were made as the preliminary processing.

The color correction was made by image emphasis, etc. so that the artificial satellite data of temporarily different times may show the similar color.

On the other hand, the original data of artificial satellite intrinsically have geometric deformation. The geometric correction is made to remove these geographic deformation. In concrete, we selected ground control points which were clearly identified both on existing topographic map and satellite data, and the made the geometric correction by coordinates conversion. Affine linear equation was used for the coordinates conversion.

2.3 False Color Image

The false color image is most effective for identifying the situation of land surface, and can be used as a substitution of topographic map. As the color synthesis method of artificial satellite data, there are natural color synthesis and true color synthesis in addition to the false color synthesis, but false color synthesis is generally used in case of the analysis of vegetation, land use and topography. The false color image is easy to interpret as the vegetation is expressed in red, and the color changes to pink and blue according to the condition of surface land such as from forest to grassland and bare land. The false color synthesis of LANDSAT TM data was made by placing a blue filter on Band 2, green filter on Band 3 and red filter on Band 4. Table D-2 shows the relation between the objects on land and color on a false color image. FIg. 5 and Fig. 6 show the reduced picture of LANDSAT TM false color image.

Table D-2 Relation between objects and color on false color image

Object	Color	Object	Color
Forest	Red	Water area(Turbid)	Light blue
Farmland, grassland	Pink(Yellow brown)	Water area(nomal)	Dark blue
Bare land	White	Cloud	Pure White
Swamps	Light Blue	Thick cloud	Pure White
street	light blue	Thin cloud	White

Also, we compiled the false color image of total study area (at the sale of 1/100,000) from LANDSAT TM data and that of detailed study area (at the scale of 1/50,000) from SPOT data (described later) as a separate annex material.

2.4 Vegetation/land use map

Identification of land use at the total study area and planned area provides most basic materials for drafting each kind of plan. Since the study area is so spacious, we compiled the vegetation/land use map using the artificial satellite data and basing on the results of land cover classification and site survey. The land cover classification was made by defining the classification categories of land use in advance on the false color image and applying the maximum likelihood method.

The maximum likelihood classification is a method to specify some number of areas where the land use has been already known (these areas are called the training fields) for each classification category, and statistically summarize the areas which have similar spectrum properties in the total image. It is possible to obtain almost correct results by this method, but it would be possible to make the classification map with higher accuracy if the verification is made by the site survey. In this study, we implemented the preliminary land cover classification before the site survey, verified the classification results by the site survey, and compiled the vegetation/land use map by adding corrections basing on the verification results.

The classification categories of vegetation/land use are as shown in Table D-3.

Table D-3 Classification categories of vegetation/land use

Classification categories	Description
River/water area	Open water area such as sea, river and lake
Paddy field	Farmland of paddy rice
Farmland/grassland	Farmland/grassland (grassland means the land covered by harbaceous plant; no classification is made as whether artificial or natural)
Palm/orchard	Palm plantation such as of coco palm and oil palm; and other orchard such as of lambutan and mangosteen
Rubber plantation	Plantation of rubber
Bare land	Flat land and hill areas with no vegetation (including artificial bare land around the farmland and natural bare land such as riverbed and sedimentation of earth/rock avalanche)
Swamp	Swamp
Mountain waste land A	Disaster area where land collapse and avalanche occurred at the time of heavy rain in Nov. 1988 and which has become bare land because the restoration of vegetation is deterred
Mountain waste land B	Collapsed land and sedimentation of avalanche where the restoration of vegetation was more rapid comparing with mountain waste land A and which is covered by vegetation
Community	Densely population street, etc. in Nakhon si Thammarat and Surat Thani provinces
Other artificially modified land	Quarries, etc.

Fig. 7 shows the reduced vegetation/land use map of total study area (Area A) of 1988, and Fig. 8 shows that of 1993. As a separate annex material, we also compiled the vegetation/land use map at the scale of 1/100,000/. Basing on this map, we calculated the area of each classification category in two temporarily different times, which is shown in Table D-4.

Table D-4 List showing the area by vegetation/land use in Area A

	1988		1993		Change
	ha	%	ha	%	
River/water area	2,374.1	0.4	2,936.1	0.4	± 0.0
Paddy field	108,854.1	16.0	100,076.9	14.7	− 1.3
Glassland/farmland	94,909.6	13.9	69,107.0	10.2	− 3.7
Palm/orchard	186,777.9	27.4	209,924.2	30.8	+ 3.4
Rubber plantation	92,736.1	13.6	114,436.6	16.8	+ 3.2
Bare land	1,582.4	0.2	1,702.5	0.3	+ 0.1
Swamps	8,053.2	1.2	8,653.8	1.3	+ 0.1
Natural forest	184,824.4	27.1	167,059.3	24.5	− 2.6
Mountain waste land A	15.8	0.0	5,899.1	0.9	+ 0.9
Mountain waste land B	6.6	0.0	162.2	0.0	± 0.0
Community	831.5	0.1	1,057.7	0.1	± 0.0
Other artificially modified land	149.1	0.1	99.4	0.0	− 0.1
Total area	681,114.8	100.0	681,114.8	100.0	——

The above table shows the calculated area by the categories of land cover classification in Area A (total study area). However, the areas occupied by clouds and shadows of clouds are not included in both '88 and '93.

The trend in total study area (Area A) will be summarized as follows from vegetation/land use maps of two different times (before and after the collapse) as shown in Fig. 7 and 8 and the list of area by vegetation/land use as shown in Table D-4.

(1) The space of study area (Area A) has become a little larger that the original space (5,170 square Km) to about 6,811 square Km (681,114.8 square Km).

(2) The study area is characterized by the natural forest located at mountain area with relatively high altitudes (1,000m or higher), rubber trees at the mountain foot, and the palm trees and orchards spreading from mountain foot to flat land. With the mountain area as a border line, palm trees and orchards are dominant at the east side, and rubber trees in the west side.

(3) As the general trend of vegetation/land use in the study area, palm trees and orchards were most dominant occupying 27.4% of the total area in 1988, followed by natural forest which shared 27.1% of the total. These two categories occupied more than half of the total study area in 1988. In 1993, however, this trend showed a change, and palm trees and orchards increased to 30.8% of the total.

(4) When the change in occupying share from 1988 to 1993 is analyzed, the palm tree/orchard showed conspicuous increase of 3.4% and 3.2% respectively. On the contrary, farmland/grassland consciously decreased by 3.7%, and the natural forest by 2.6%.

(5) Mountain waste land A amounts to approximately 1% of the total in 1993 because of the collapse land and accumulation of earth/rock avalanche.

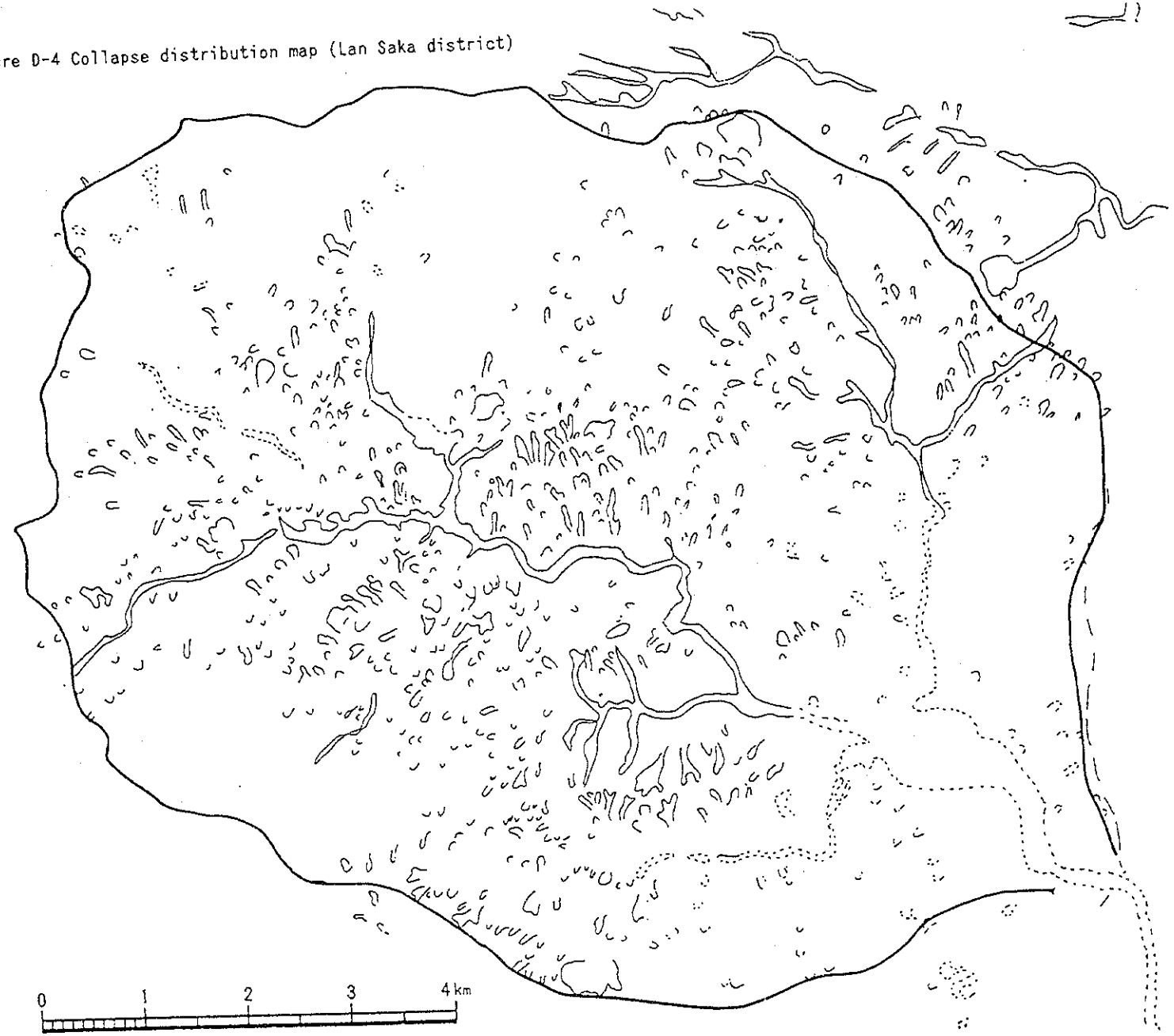
2.5 Collapse Distribution Map

Many sand/soil disasters occurred in the detailed study (Area B) area in November 1988 due to earth and rock at torrents caused by heavy rainfall. In this study, we compiled the sand/soil disaster distribution map by interpreting the image made by false color synthesis from the SPOT satellite data observed just after the disaster occurrence.

Fig D-3 and D-4 show the distribution of the collapsed area of Ban Na San district and Lan Saka district.

Figure D-3 Collapse distribution map (Ban Na San district)

Figure D-4 Collapse distribution map (Lan Saka district)



3. Last half study

The last half study was carried out to two districts (Ban Na San and Lan Saka districts) in Area B which is the detailed study area. In this study, we made the detailed land use map (scale: 1/50,000) and analyzed the factors causing land collapse and earth/rock avalanche.

Fig. 13 and 14 show the scope of the respective study areas.

3.1 Land use Secular change map

In this stage, we compiled the vegetation/land use maps of two temporarily different times for the detailed study area and then made land use secular change map basing on these maps (see Fig.). The scale of this map was 1/50,000, and the place where there was a change in land use was indicated by the minimum unit of 20 square meters. Conspicuous increase is seen to the rubber plantation during these 5 years in Ban Na San district. Table D-6. Also, the collapsed lands where restoration is deterred after the disaster area seen at mountain areas. Also in Lan Saka district, there are many collapsed lands caused by the heavy rainfall in 1988 where the vegetation was not restored yet in 1993.

Table D-6 Change in the area of natural forest from 1988 to 1993

	Ban Na San district		Lan Saka district	
	ha	%	ha	%
River/water area	50.5	0.3	36.8	0.7
Paddy field	530.9	3.1	1.2	0.0
Farmland/grassland	854.1	4.9	35.2	0.6
Palm/orchard	2,495.7	14.3	99.7	1.7
Rubber plantation	2,481.9	14.2	9.8	0.2
Bare land	13.3	0.1	——	——
Swamp	55.1	0.3	2.9	0.1
Natural forest	10,693.5	61.3	5,397.8	95.4
Mountain waste land A	238.0	1.4	71.3	1.3
Mountain waste land B	17.0	0.1	2.5	0.0
Community	——	——	——	——
Other artificially modified land	——	——	——	——
Total area	17,430.0	——	5,657.2	——

* The above table shows the change in the area of natural forest as a result of comparison of calculation results of areas by land cover classification categories for 1988 and 1993.
* The area occupied by clouds and shadows of clouds are not included in the area calculation.

3.2 Compilation of thematic maps by topographic analysis

In this stage, we compiled the thematic maps for Area B (two districts) using existing topographic maps and geology maps to analyze the factors causing the land collapse, and converted them into image data so that they could be used for land classification of a later stage.

We made the following thematic maps by converting the counter lines of topographic maps and geology map of the detailed study area into digital data and thereto adding several kinds of calculations.

(1) Inclination Classification Map

We calculated the inclination angle of maximum inclination direction for each grid of 20m square, demarcated the sections by the unit of 5 degrees, and arranged so that each section could be identified by computer.

(2) Slope Direction Classification Map

We worked out the direction angle of slope for each 20m square pixel. The obtained angles were then classified into 8 direction sections, and were arranged so that each direction section could be identified by computer. However, the pixel which has inclination angle less that 3 degrees was treated as the flat land, and excluded from the slope direction classification.

(3) Altitude Classification Map

We demarcated the altitude of the study area by the height of 100m, and arranged so that each demarcated section could be identified by computer.

(4) Surface geology classification Map

We used a digitizer to input the geology classification map of study area edited comprehensively from existing geology maps and results of site surveys, and created the geology classification data with the minimum unit of 20m square pixel.

(5) Distance from Fault

Geometric position correction was made to the above thematic maps so that they could be overlaid on land cover classification map and false color images by the computer. Fig. 7 and 8 show the thematic maps in the above processes.