THE KINGDOM OF THAILAND

AGRICULTURAL LAND REFORM OFFICE

FEASIBILITY STUDY ON SUKHOTHAI INTEGRATED AGRICULTURAL AND RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

APPENDICES




AUGUST, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND
AGRICULTURAL LAND REFORM OFFICE
FEASIBILITY STUDY ON SUKHOTHAI INTEGRATED AGRICULTURAL AND RURAL INFRASTRUCTURE DEVELOPMENT PROJECT
APPENDICES
AUGUST, 1990
JICA

THE KINGDOM OF THAILAND

AGRICULTURAL LAND REFORM OFFICE

FEASIBILITY STUDY
ON
SUKHOTHAI INTEGRATED AGRICULTURAL
AND
RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

A P P E N D I C E S

AUGUST, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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SCOPE OF WORK

FOR

THE FEASIBILITY STUDY

ON

SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

AGREED UPON

BETWEEN

AGRICULTURAL LAND REFORM OFFICE

AND

JAPAN INTERNATIONAL COOPERATION AGENCY

BANGKOK

DECEMBER 21,1988

Mr. Petipong Pungbun Na Ayudhya
Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE AND
COOPERATIVES

Mr. Toshiki SAITO
Leader
Preliminary Survey Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

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I. INTRODUCTION

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan has decided to implement the Feasibility Study on the Sukhothai Integrated Agricultural and Rural Infrastructure Development Project(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, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the 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 authorities of Thailand.

The Agricultural Land Reform Office (hereinafter referred to as "ALRO") shall act as a 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. OBJECTIVE OF THE STUDY

The objective of the Study is to conduct the Feasibility Study on the Integrated Agricultural and Rural Infrastructure Development Project in Sukhothai Province.

III. OUTLINE OF THE STUDY

In order to achieve the aforementioned objective, the Study shall cover the following items:

T.S.

1. Study Area

The Study Area shall cover the two (2) public lands of Thung Sai Yart (5,600ha) and Thung Nong Khon Khaen (1,300ha), located in Sukhothai province.

2. Scope of The Study

The Study will be divided into the following two Phases.

1) Phase I

Data collection, review of existing data and field survey are carried out in the study area.

1)-1. To collect and review existing data and information.

A. Natural condition
   a) Topography
   b) Meteorology and Hydrology
   c) Geology and Soil
   d) Hydrogeology

B. Agriculture
   a) Farm management
   b) Land use and land classification
   c) Agricultural production
   d) Agricultural inputs
   e) Farmer's organization
   f) Marketing system
   g) Farmer's income and productivity

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   h) Extension service
   i) Credit system

C. Agricultural infrastructure
   a) Irrigation and drainage system
   b) Farm road

D. Social condition
   a) Population
   b) Social economy
   c) Related development plan including land reform policy
   d) Living environment

E. Rural infrastructure
   a) Rural electrification
   b) Rural road networks
   c) Domestic water
   d) Social welfare

F. Others

1)-2. To conduct supplementary surveys in the study area on the items mentioned in 1)-1 that may be deemed to need further study for the Project.

1)-3. To draw up the basic development concept of the project.

1)-4. Based on the results of the above-mentioned survey, a preliminary study and analysis will be conducted.

2) Phase II.

Sukhothai Integrated Agricultural and Rural Infrastructure Development Project will be formulated based on the Phase I Study.

2)-1. To carry out additional field survey and collect additional data.

2)-2. To formulate the Integrated Agricultural and Rural Infrastructure Development Project concerning the following items:

A. Formulation of the following plans

a) Land use and classification

b) Small agro-industry and crop diversification

c) Cropping pattern and farming systems

d) Agricultural infrastructure

. Irrigation and drainage system

. Farm road

. Land consolidation

. Soil conservation

. Marketing facilities

e) Water management

f) Farmer's organization

g) Rural infrastructure

h) Land distribution

i) Others

B. Preliminary design of the major structure

C. Implementation schedule of the project

D. Estimation of the project cost and benefit

2)-3. Project evaluation

2)-4. Recommendation

IV. WORK SCHEDULE

The study will be executed in accordance with the attached tentative work schedule.

V. REPORTS

JICA shall 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 Study.

(2) Progress report (I)

Twenty (20) copies at the end of the field work in the Phase I Study.

(3) Interim report

Twenty (20) copies at the commencement of the Phase II Study

(4) Progress report (II)

Twenty (20) copies at the end of the field work in the Phase II Study.

(5) Draft final report

Twenty (20) copies at the end of the Phase II Study.

The Government of the Kingdom of Thailand shall provide its comments on the Draft Final Report to JICA within one (1) month after its receiving.

(6) Final report

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

VI. UNDERTAKING OF THE GOVERNMENT OF THE KINGDOM OF THAILAND

1. In accordance with the Agreement of Technical Cooperation between the Government of Japan and the Government of the Kingdom of Thailand dated November 5, 1981, 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 and sojourn in Thailand for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees,

(2) to exempt the members of the Team from taxes, duties and any other charges on equipment, machinery and other materials 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 emolument or allowance paid to the members of the Team for their services in connection with the implementation of the Study, and

(4) to bear claims, if any arises against the members ot the Team resulting from, occurring in the course of, or otherwise connected

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with the discharge or 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 conduct of the Study, ALRO shall take necessary measures in cooperation with other relevant organization;

(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. ALRO shall, at its own expense, provide the Team with the following:

(1) Available data and information related to the Study,

(2) Additional survey related to the Study,

(3) Counterpart personnel,

(4) Suitable office space with necessary equipment and furniture in Bangkok and Project sites, and

(5) Credentials or indentification cards to the members of the Team.

VII. UNDERTAKING OF JICA

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

1. To dispatch, at its own expenses, the Team to Thailand, and

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

VIII. OTHERS

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

APPENDIX

TENTATIVE WORK SCHEDULE

DESCRIPTION	MONTH													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
I. Phase I	■	■	■	■										
II. Phase II						■	■	■	■	■				
III. Explanation of Draft Final Report											■			
IV. Reports	△ IC/R		△ P/R(I)			△ IT/R		△ P/R(II)			△ DF/R			△ F/R

IC/R : Inception Report
P/R : Progress Report
IT/R : Interim Report
DF/R : Draft Final Report
F/R : Final Report

■ Work in Thailand
□ Work in Japan

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MINUTES OF MEETING
OF
PRELIMINARY SURVEY
FOR
THE FEASIBILITY STUDY

ON

SUKHOTHAI INTEGRATED AGRICULTURAL
AND
RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

AGREED UPON
BETWEEN
AGRICULTURAL LAND REFORM OFFICE
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

BANGKOK
DECEMBER 21, 1988

Mr. Petipong Pungbun Na Ayudhya
Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE AND
COOPERATIVES

Mr. Toshiki SAITO
Leader
Preliminary Survey Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan dispatched the Preliminary Survey Team for Sukhothai Integrated Agricultural and Rural Infrastructure Development Project from December 11 to 23,1988 through Japan International Cooperation Agency.

The Team headed by Mr. Toshiki SAITO, Director, Land Improvement Engineering Service Center, Kanto Regional Agricultural Administration Bureau, MAFF, and Thai officials concerned headed by Mr. Petipong Pungbun Na Ayudhya, Secretary General, Agricultural Land Reform Office, MOAC, had a series of discussions and exchanged their views on the Scope of Work for feasibility study on the Project.

As a result of the discussions, both sides have agreed on the Scope of Work and salient results of the discussions are as follows:

1. Both sides agreed that the priority area(s) for pilot project will be selected at the end of the phase-I study.

2. The ALRO agreed that completed cadastral and topographical maps will be submitted to JICA Headquarters through JICA Office in Thailand by the end of February, 1989.

3. The ALRO should provide the suitable office space in Bangkok and Sukhothai with necessary office equipment such as desks, chairs, cabinets and telephone(s).

4. The ALRO promissed that the counterpart personnel will be provided for the Study Team in Bangkok and Sukhothai offices.

5. The ALRO requested that the hydrogeological survey and the construction of observation well(s) should be carried out by the Study Team.

6. Topographical mapping which might be necessary for the preliminary design and estimations of major structures should also be carried

out by ALRO.

7. The Preliminary Study Team requested that data of existing wells such as location, depth, diameter, year of construction and the average commanded area per well, etc., should be provided by the ALRO before the arrival of the Study Team.

8. The ALRO agreed that the water level survey in both of certain points of natural streams and certain existing wells will be carried out by the ALRO under the technical guidance by the JICA Preliminary Study Team before the arrival of the Study Team.

9. The ALRO requested that the proposed vehicle(s) for the Study should be prepared by JICA, as the necessary vehicle(s) are not available in the ALRO.

The Preliminary Study Team give a promise to convey this request to the Government of Japan.

10. The ALRO requested that self-recording ground water level equipment, survey equipment such as digital flow meter and personal computer would be provided by JICA for the Study.

11. The ALRO requested that a seminar will be held at the time of submission of the draft final report.

12. Regarding to the technical transfer, ALRO requested the consideration of JICA for counterpart(s) training in Japan

13. The ALRO requested that JICA should carry out the Study as early as possible.

The attendance list is attached in annex.

ANNEX-1

LIST OF PARTICIPANTS

THAI SIDE

1. Mr. Petipong Pungbun Na Ayudhya	Secretary General
2. Mr. Sutin Mulphruk	Deputy Secretary General
3. Mr. Wijinn Cholithul	Director of Engineering Division
4. Mr. Theparit Anuphan	Chief of Sukhothai Land Reform Provincial Office
5. Mr. Noppadol Sresuparp	Chief of Engineering Program & Projects Branch
6. Mr. Jirachai Suthassanajinda	Chief of Engineering Plan Section
7. Mr. Prathan Rijana	Land Reform Officer 5
8. Mrs. Tritaporn Khomapat	Policy and Planning Analyst 5
9. Mr. Prayong Phosriprasert	Architect 3

ANNEX-2

LIST OF PARTICIPANTS

JAPANESE SIDE

1. Mr. Toshiki SAITO	Leader, Preliminary Survey Team
2. Mr. Hideo AGO	Irrigation & Drainage Engineer Preliminary Survey Team
3. Mr. Kenichi KAWAMOTO	Agronomist Preliminary Survey Team
4. Mr. Takashi SHINO	Coordinator Preliminary Survey Team
5. Mr. Harumi SAITO	JICA Expert Department of Land Development

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MINUTES OF MEETING

OF

THE INCEPTION REPORT FOR THE FEASIBILITY STUDY

ON

THE SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

BANGKOK, JULY 25, 1989

Mr. Petipong Pungbun Na Ayudhya
Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE
AND COOPERATIVES

Mr. Junichiro NAKAJIMA
Leader
Feasibility Study Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

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Mr. Sutin Mulphruk
Deputy Secretary General
Agricultural Land Reform Office
MOAC

Mr. Masasada ITO
Leader
Supervisory Committee for
the Feasibility Study
JICA

Joint meeting between the Agricultural Land Reform Office (hereinafter referred to as "ALRO") and the JICA Study Team (hereinafter referred to as "the Team") was held on 24th July, 1989 at Agricultural Land Reform Office, Ratchadamnoen Nok Road, to discuss the contents of the Inception Report. The Team submitted twenty (20) copies of the Inception Report to ALRO on 21th July, 1989.

After discussion, the contents of the Inception Report were agreed by and between both parties with confirmation of the following items:

1. ALRO has nominated the counterpart staff headed by Mr. Noppadol Sresuparp as Chief Thai Counterparts, and names and positions of the counterpart staff are listed in Attached Sheet No.2.

2. ALRO and the Team have confirmed that the proposed investigation wells to be dug in the Study Areas during the Study shall be considered as test wells.

3. Detailed strategy for conducting the Socio-Economic survey for beneficial farmers in the Study Areas shall be established after reviewing thoroughly all data and information available in ALRO. ALRO expressed its intention to provide every possible efforts to carry out the said survey.

4. Both sides agreed to open a seminar on the Integrated Agricultural and Rural Development at the end of Phase II field survey.

5. Both sides agreed to include a component of rural communities development in the rural infrastructure development plan.

6. ALRO has commented to put more emphasis on the following aspects;

   - Organization and management of the proposed project
   - Development of marketing infrastructures
   - Neccessary procedures or scenario of project implementation including recommendation on source of fund

(Attached Sheet No.1)

LIST OF ATTENDANCE

ALRO

1.	Mr. Petipong Pungbun Na Ayudhya	Secretary General
2.	Mr. Wijinn Cholitkul	Director, Engineering Division
3.	Mr. Teparit Anupun	Chief, Sukhothai Provincial L.R.O
4.	Mr. Noppadol Sresuparp	Chief, Project Planning Sect.
5.	Mr. Jirachai Suthassanajinda	Agricultural Engineer 5
6.	Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
7.	Ms. Atchara Vatanacharoen	Economist 5
8.	Mr. Apisit Phunsorn	Civil Engineer 4
9.	Mr. Wanchai Supabenjagoon	Civil Engineer 4
10.	Mr. Prayong Posriprasert	Architect 4

JICA

1.	Mr. Masasada Ito	Leader, Supervisory Committee
2.	Mr. Shigemitsu Tsukamoto	Coordinator
3.	Mr. Akira Hashimoto	JICA Expert, IEC, RID

Study Team

1.	Mr. Junichiro Nakajima	Team Leader
2.	Mr. Yoshitomo Miyanishi	Agr. Economy/Project Evaluation
3.	Mr. Takanori Takatsuka	Irrigation/Drainage
4.	Mr. Takuji Murakami	Groundwater/Geology
5.	Dr. Akwut Thasanasongchan	Land Use/Land Reform
6.	Mr. Kouzou Hoshi	Hydrology/Meteorology

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(Attatched Sheet No.2)

LIST OF COUNTERPART

	Name	Designation
1.	Mr. Noppadol Sresuparp	Chief Coordinator
2.	Mr. Jirachai Suthassanajinda	Agricultural Engineer 5
3.	Mr. Krisda Smithanont	Civil Engineer 5
4.	Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
5.	Ms. Atchara Vatanacharoen	Economist 5
6.	Mr. Suwan Boorapornnusorn	Land Reform Officer 5
7.	Mr. Assawin Ngosakul	Land Reform Officer 5
8.	Ms. Rewadee Chaisanit	Legal Officer 5
9.	Mr. Apisit Phunsorn	Civil Engineer 4
10.	Mr. Wanchai Supabenjagoon	Civil Engineer 4
11.	Mr. Prayong Posriprasert	Architect 4

MINUTES OF MEETING

OF

THE PROGRESS REPORT(1) FOR THE FEASIBILITY STUDY

ON

THE SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

BANGKOK, SEPTEMBER 26, 1989

Dr. Suthiporn Chirapanda
Deputy Secretary General
Acting Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE
AND COOPERATIVES

Mr. Junichiro NAKAJIMA
Leader
Feasibility Study Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

Joint meeting between the Agricultural Land Reform Office (hereinafter referred to as "ALRO") and the JICA Study Team (hereinafter referred to as "the Team") was held on 25th September, 1989 at Agricultural Land Reform Office, Ratchadamnoen Nok Road, to discuss the contents of the Progress Report(1). The Team submitted twenty (20) copies of the Progress Report(1) to ALRO on 21st September, 1989.

After discussion, the contents of the Progress Report(1) were agreed by and between both parties with confirmation of the following items:

1. ALRO has commented to put more emphasis on the following aspects;

   - Organization and management of the proposed project
   - Development of marketing infrastructures
   - Necessity of supporting services given by agencies concerned, during project implementation.

2. ALRO's understanding on the technical criteria is a criteria for engineering work which covers only the two study areas, and it should be included in the Phase II Study. However, ALRO requested that a development concept/model of the project should also be derived in order to apply for the other land reform areas in the lower northern region of Thailand.

3. ALRO has expressed its opinion to divide the seminar into two sessions, one is presentaion of the project concept and the results of the feasibility study, and another is that for a certain subject like "Japanese Agriculture after Land Reform (Current Issues)".

4. In connection with name of the study area, ALRO suggested that the name of "Thung Nong Khon Kaen" be changed to "Nong Khon Kaen".

5. Regarding a basic concept of the development to be formulated during the works in Japan, ALRO requested to include the following consideration into the study.

   - Possibility to introduce fruit tree in the proposed cropping pattern
   - Availability of bigger farm machinery in Thailand
   - Importance of farmers organization

(Attached Sheet No.1)

LIST OF ATTENDANCE

ALRO

1.	Dr. Suthiporn Chirapanda	Deputy Secretary General
2.	Mr. Worawate Tamrongtanyalak	Director, Land Reform Financing Div.
3.	Mr. Wijinn Cholitkul	Director, Engineering Division
4.	Mr. Teparit Anupun	Chief, Sukhothai Provincial L.R.O
5.	Mr. Noppadol Sresuparp	Chief, Project Planning Sect.
6.	Mr. Jirachai Suthassanajinda	Agricultural Engineer 5
7.	Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
8.	Ms. Watana Supaokij	Land Reform Officer 5
9.	Ms. Atchara Vatanacharoen	Economist 5
10.	Ms. Rewadee Chaisanit	Legal Officer 5
11.	Mr. Suwan Boorapornnusorn	Land Reform Officer 5
12.	Mr. Apisit Phunsorn	Civil Engineer 4
13.	Mr. Prayong Posriprasert	Architect 4

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JICA

1.	Mr. Akira Hashimoto	JICA Expert, IEC, RID

Study Team

1.	Mr. Junichiro Nakajima	Team Leader
2.	Mr. Yoshitomo Miyanishi	Agr. Economy/Project Evaluation
3.	Mr. Takanori Takatsuka	Irrigation/Drainage
4.	Mr. Hideo Hara	Agronomy/Farming Plan
5.	Mr. Akira Kadoya	Facility Plan/Infrastructure
6.	Mr. Takuji Murakami	Groundwater/Geology

Suthiporn Chirapanda

MINUTES OF MEETING

OF

THE INTERIM REPORT FOR THE FEASIBILITY STUDY

ON

THE SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

BANGKOK, DECEMBER 8, 1989

Mr. Bhachern Yimniam
Secretary
Acting Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE
AND COOPERATIVES

Mr. Junichiro NAKAJIMA
Leader
Feasibility Study Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

Joint meeting between the Agricultural Land Reform Office (hereinafter referred to as "ALRO") and the JICA Study Team (hereinafter referred to as "the Team") was held on 7th December, 1989 at Agricultural Land Reform Office, Ratchadamnoen Nok Road, to discuss the contents of the Interim Report. The Team submitted twenty (20) copies of the Interim Report to ALRO on 4th December, 1989.

After discussion, the contents of the Interim Report were agreed in principle by and between both parties with confirmation of the following items:

1. Both parties recognized that the interim report shows preliminarily the Team's views and opinion on the development concept as well as the plan formulation, based on which further review and examination shall be made to obtain best alternative on the integrated agricultural and rural development, during the Phase II study period.

2. ALRO proposed to have the seminar both in Sukhothai and in Bangkok. The former shall cover significant local persons including heads of villages (Muban), sub-district (Tambol), district (Amphoe) and so on. And the latter does middle-class and/or higher class ranking officers in those ministries concerned with the Study. The Study team expressed to convey ALRO's intention to JICA Head Quarter.

3. ALRO has commented to put more emphasis on the management plan and farmers' organization which is dealt in section 5.5 of the interim report.

LIST OF ATTENDANCE

ALRO

1.	Mr. Bhachern Yimniam	Secretary
2.	Mr. Wijinn Cholitkul	Director, Engineering Division
3.	Mr. Teparit Anupun	Chief, Sukhothai Provincial L.R.O
4.	Dr. Thiravira Subhanij	Chief, Statistical Analysis & Land Registration Sect., for Director, Research & Planning Div.
5.	Mrs Monthip Rujikanha	Chief, Farmers' Organ. Promotion Sect., for Director, Land Reform Operation Div.
6.	Mr. Noppadol Sresuparp	Chief, Project Planning Sect.
7.	Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
8.	Ms. Watana Supaokij	Land Reform Officer 5
9.	Ms. Atchara Vatanacharoen	Economist 5
10.	Mr. Decha Suwandej	Mechanical Engineer 5
11.	Mr. Krissada Smitananda	Civil Engineer 5
12.	Mr. Thamasak Veesarnsak	Land Reform Officer 5
13.	Mr. Narin Arepanichkul	Land Reform Officer 5
14.	Mr. Prayong Posriprasert	Architect 4
15.	Mr. Kisada Wongpaiboonwatana	Land Reform Officer 5
16.	Mr. Siang Sakpisit	Land Reform Officer 4

JICA

1.	Mr. Akira Hashimoto	JICA Expert, IEC, RID

Study Team

1.	Mr. Junichiro Nakajima	Team Leader
2.	Mr. Yoshitomo Miyanishi	Agr. Economy/Project Evaluation
3.	Mr. Takanori Takatsuka	Irrigation/Drainage
4.	Mr. Hideo Hara	Agronomy/Farming Plan
5.	Mr. Akira Kadoya	Facility Plan/Infrastructure
6.	Mr. Yuichi Matsumoto	Design/Cost Estimate
7.	Dr. Akwut Thasanasongchan	Land Use/Land Reform

MINUTES OF MEETING

OF

THE PROGRESS REPORT (2) FOR THE FEASIBILITY STUDY

ON

THE SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

BANGKOK, JANUARY 30, 1990

Mr. Petipong Pungbun Na Ayudhya
Secretary General
Agricultural Land Reform Office
MINISTRY OF AGRICULTURE
AND COOPERATIVES

Mr. Junichiro NAKAJIMA
Leader
Feasibility Study Team
JAPAN INTERNATIONAL
COOPERATION AGENCY

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Mr. Wijinn Cholitkul
Director
Engineering Division
Agricultural Land Reform Office
MOAC

Dr. Shoichiro NAKAGAWA
Chairman
Advisory Committee for
the Feasibility Study
JICA

Joint meeting between the Agricultural Land Reform Office (hereinafter referred to as "ALRO") and the JICA Study Team (hereinafter referred to as "the Team") was held on 30th January, 1990 at Agricultural Land Reform Office, Ratchadamnoen Nok Road, to discuss the contents of the Progress Report (2). The Team submitted twenty (20) copies of the Report to ALRO on 24th January, 1990.

After discussion, the contents of the Progress Report (2) were agreed by and between both parties with confirmation of the following items:

1. Both parties agreed in principle that the results of seminar in Sukhothai should be reviewed and analysed during the project plan formulation in the home office work in Japan.

2. ALRO has recommended that the following aspects should be investigated:-

   - Alternative cropping pattern and other agricultural activities
   - Procedures for the development of farmers' group toward the establishment of cooperatives
   - Technical guidance and recommendation for
     * shallow well interval
     * future operating system of the shallow wells not over pumping
     * appropriate (if any) recharge methodology and system to be done by farmers
   - Organization and management of the project for sustained development
   - Necessary procedures for project implementation including recommendation on source of funds for both pilot projects and sub projects

3. ALRO recommended that cost of detailed survey and engineering design, cost of agricultural development, credit and other supporting services and appropriate training programme cost should be also included in the project cost.

4. ALRO suggested that the project financial analysis, including cost recovery and economic farm size analysis should be done in parallel with the project economic analysis.

5. ALRO requested that detailed engineering design and cost estimation of the test wells be developed as the productive wells, should be done.

6. ALRO also requested to continuously use the following equipment brought by the Study Team for its survey purpose, and the Study Team promised to convey the ALRO's intention to JICA Head Quarter;
   - Vehicles
   - Microcomputer
   - Hydrological Equipment

LIST OF ATTENDANCE

ALRO

1. Mr. Petipong Pungbun Na Ayudhya	Secretary General
2. Mr. Danai Sooksri	Director, Research & Planning Div.
3. Mr. Wijinn Cholitkul	Director, Engineering Division
4. Mr. Teparit Anupun	Chief, Sukhothai Provincial L.R.O
5. Mrs. Monthip Rujikanha	Chief, Farmers Org. Prom. Sect. For Director, Land Reform Operation Div.
6. Mr. Noppadol Sresuparp	Chief, Project Planning Sect.
7. Mr. Opas Kapuknak	Land Reform Officer 6
8. Mr. Decha Suwandij	Mechanical Engineer 5
9. Mr. Jirachai Suthassanajinda	Agricultural Engineer 5
10. Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
11. Ms. Atchara Vatanacharoen	Economist 5
12. Ms. Watana Supakoj	Land Reform Officer 5
13. Mr. Narin Akpanichkul	Land Reform Officer 5
14. Mr. Wichan Somsri	Land Reform Officer 5
15. Mr. Suwan Boorapornunsorn	Lanf Reform Officer 5
16. Mr. Assawin Ngosakul	Land Reform Officer 5
17. Ms. Rewadee Chaisanit	Legal Officer 5
18. Mr. Wasun Juljior	Civil Engineer 5
19. Mr. Wanchai Supabenjagoon	Civil Engineer 4
20. Mr. Prayong Posriprasert	Architect 4

JICA

1. Mr. Shoichiro Nakagawa	Chairman, Advisory Committee
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3. Mr. Akira Hashimoto	JICA Expert, IEC, RID

Study Team

1. Mr. Junichiro Nakajima	Team Leader
2. Mr. Yoshitomo Miyanishi	Agr. Economy/Project Evaluation
3. Mr. Takanori Takatsuka	Irrigation/Drainage
4. Mr. Hideo Hara	Agronomy/Farming Plan
5. Mr. Yuichi Matsumoto	Design/Cost Estimate

MINUTES OF MEETING

OF

THE DRAFT FINAL REPORT FOR THE FEASIBILITY STUDY

ON

THE SUKHOTHAI INTEGRATED AGRICULTURAL

AND

RURAL INFRASTRUCTURE DEVELOPMENT PROJECT

IN

THE KINGDOM OF THAILAND

BANGKOK, JUNE 21, 1990

A-17

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MINISTRY OF AGRICULTURE
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Dr. Masasada ITO
Member
Advisory Committee for
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Joint meeting between the Agricultural Land Reform Office (hereinafter referred to as "ALRO") and the JICA Study Team (hereinafter referred to as "the Team") was held on 21st June, 1990 at Agricultural Land Reform Office, Ratchadamnoen Nok Road, to discuss the contents of the Draft Final Report. The Team submitted twenty (20) copies of the Report to ALRO through JICA Thailand Office on 10th May, 1990.

After the discussion, the contents of the Draft Final Report were agreed by and between both parties with confirmation of the following items:

1. ALRO has requested that the following aspects be incorporated into the final report.

   a) More detailed explanation on the proposed "Farmers Training and Strengthening Station (F.T.S.S.)" in terms of function, activities, costing and so on.

   b) Clarification of relation between project management and cost allocation among ministerial agencies/departments which are concerned with the project implementation.

   c) The project life for economic evaluation is appropriate at 30 years.

   d) Additional technical guidance on shallow wells interval, and recharge method as appropriate to farmers (if any).

   e) The production credit requirement for both areas shall be separately estimated from the project cost estimate.

   f) Function, operation and management system for the proposed marketing facilities shall be clarified.

   g) The proposed implementaion schedule shall be modified and annual cost disbursement be changed accordingly:

* Project administration starts with the commencement of the detailed design.

* Training package program starts with the commencement of construction of agricultural infrastructures.

* As for topo-survey for the pre-engineering works, topo-map and cadastral map with scale of 1:5,000 and 1:10,000 for Nong Khon Kaen and Thung Sai Yart area, respectively are available.

h) Project organization for both the project implementation and the operation an maintenance stages shall be reviewed, especially in terms of function and responsibility of the project committees.

2. The Study Team accepted ALRO's comments which shall be taken into consideration for the preparation of the final report.

3. Both parties agreed that the preparation of the final report shall be finalized in accordance with the comments raised in the joint meeting.

LIST OF ATTENDANCE

ALRO

1.	Mr. Petipong Pungbun Na Ayudhya	Secretary General
2.	Mr. Wijinn Cholitkul	Director, Engineering Division
3.	Mr. Chantalak Boozaya-Angool	Director, Research & Planning Division
4.	Mr. Somboon Kwaengsopha	Chief, Sukhothai Provincial L.R.O
5.	Mr. Seubsil Kovitangkul	Land Reform Officer 6, for Director, Land Reform Operation Division
6.	Mr. Noppadol Sresuparp	Chief, Project Planning Sect.
7.	Mr. Sumpun Pollapuk	Land Reform Officer 6
8.	Mr. Jirachai Suthassanajinda	Agricultural Engineer 5
9.	Mr. Teeravat Vidhayasilp	Agricultural Engineer 5
10.	Ms. Watana Supaokij	Land Reform Officer 5
11.	Ms. Atchara Vatanacharoen	Land Reform Officer 5
12.	Mr. Thamasak Veesarnsak	Land Reform Officer 5
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1.	Mr. Masasada Ito	Leader, Advisory Team
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Study Team

1.	Mr. Junichiro Nakajima	Team Leader
2.	Mr. Yoshitomo Miyanishi	Agr. Economy/Project Evaluation

Appendix B Engineering Aspect

B-1 Hydrology ..... B- 1

B-2 Groundwater B-17

B-3 Irrigation and Drainage B-51

B-4 Social Infrastructure B-81

B-5 Design and Cost Estimate B-93

Appendix B-1 HYDROLOGY

B-1-1 Present Condition of Meteorology and Hydrology

(1) Observation Station and Records

The location of hydro-meteorological observation stations are shown in Figure B-1-1. There is no stations in the areas.

(a) Meteorological observation station

There is the Phitsanulok station under the Meteorological Department in the vicinity of the study areas. Meteorological data and information for 1956 to 1985 have been collected.

(b) Rainfall and discharge observation station

Rainfall has been observed in terms of daily unit almost for more than 20 years. there are some discharge observation stations in the vicinity of the study area and they have observed for less than 20 years.

(2) Rainfall

As the representative rainfall station, Ban Dan Hoi (59062) in Thung Sai Yart and Kong Krai Lat (59042) in Nong Khon Kaen, are selected. As a result of analysis, Thung Sai Yart has less rainfall of around 1,000 mm, compared to the other area in Thailand as shown in Figure B-1-2. Annual rainfall in Nong Khon Kaen is approximately 1,200 mm, more than that in Thung Sai Yart. Annual fluctuation is represented by probability rainfall as follows.

	Probability Rainfall (mm)	
Probability Year	Nong Khon Kaen	Thung Sai yart
10	961	744
5	1,047	844
2	1,235	1,012

Note ; Observation period ; Nong Khon Kaen 1952 to 1987
Thung Sai Yart 1966 to 1987

Annual average number of rainfall days is shown as belows.

Rainfall Days (day)

Study Area	Rainy season	Dry season	In a Year	Cultivation Period May to July	Cultivation Period Aug. to Nov.
Nong Khon Kaen	58	8	66	26	32
Thung Sai Yart	74	11	85	36	38

In both areas, it is less than 100 days, and is considerably less than 122 days (1956 to 1985) in Phitsanulok.

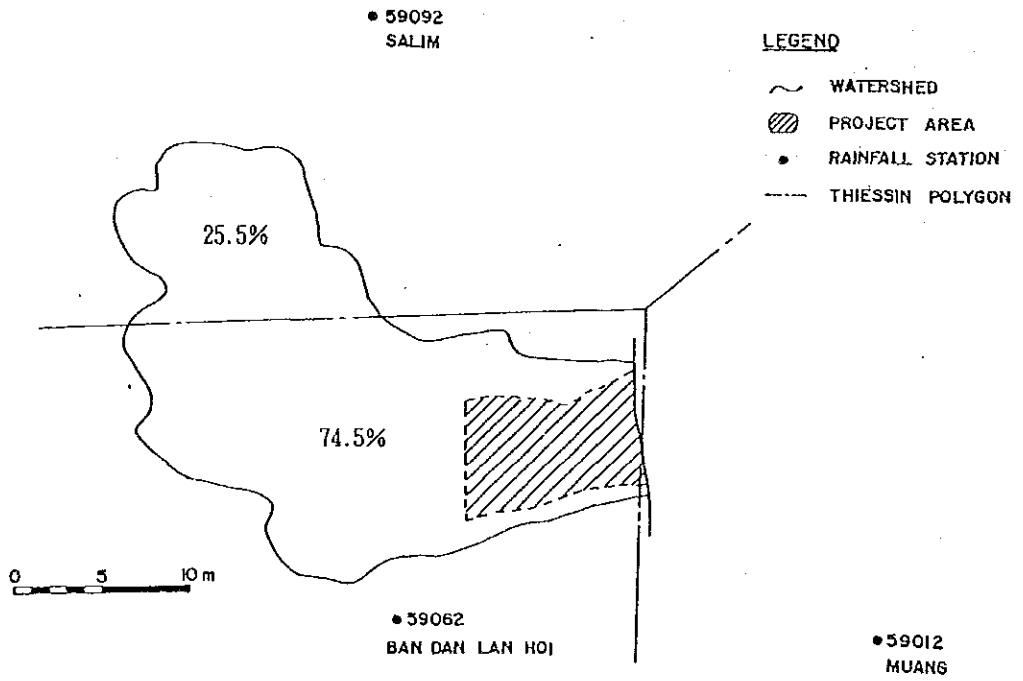
B-1-2 Study of Surface Water

(1) Runoff of Low Flow

(a) Rainfall analysis

a-1. Selection of representative observation station

Kong Krai Lat (59042) station in Nong Khon Kaen is used for analysis of river basin. As the representative station for analysis in Thung Sai Yart, there are Ban Dan Lan Hoi (59062), Thung Saliam (59092) and Muang (59012). Basin rainfall is estimated by using Tiesen method.



a-2. Probability rainfall

Probability rainfall are calculated as a basic information for irrigation planning purpose, with Thomas method, as follows.

Probability Annual Rainfall (mm)

Study Area	Probability Year			
	2-year	5-year	10-year	20-year
Nong Khon Kaen	1,235	889	800	733
Thung Sai Yart	1,030	855	776	716

(b) Analysis of runoff

b-1. Catchment area

Catchment area are estimated on the topographic maps of 1/50,000 and are shown in Figure B-1-3.

b-2. Preparation of runoff model

1) Analysis method of runoff

Tank model method is applied, considering the following conditions.

- Irrigation demand shall be calculated on 10-days basis.
- Daily flow shall be required for flood analysis.
- There are measurement records in the vicinity, at where correlation to the rainfall between them is recognized.

2) Runoff model

In the model, overall river basin including study area is regarded as one model and runoff amount is estimated with specific discharge.

3) Calibration of model constants

Constant values are verified with daily discharge data at Y.26 near Thung Sai Yart and daily rainfall at Thung Saliam(59092). In the model, loss of evaporation and infiltration at the beginning of

rainy season are considered. Three years from 1980 to 1982 is used for verification of model because correlation between rainfall and runoff is comparatively high and is hardly affected by quantity of water taken from river during these three years. Evaporation is regarded as 75% in Phitsanulok for verification because the basin of Y.26 is located in northeast and includes mountain area.

Diagram between measured and calculated values are compared for verification of runoff model.

b-3. Calculation of runoff by model

Using the model, runoff of both areas is calculated, of which period is from 1968 to 1987 in Nong Khon Kaen and from 1970 to 1987 in Thung Sai Yart. In the parameters to be defined, evaporation is set at 100% and 90% of Phitsanulok in Nong Khon Kaen and Thung Sai Yart, respectively. Calculation is conducted on a daily basis and result is summarized in Tables B-1-2 and B-1-3. An example of result is also shown in Figure B-1-4.

(2) Flood runoff

(a) Rainfall analysis

Rainfall probability is estimated by Thomas method to plan the design capacity of drainage facilities, as follows.

Continuous rainfall days	Rainfall by return-period(mm) 2-years	5-years	10-years	20-years
(Nong Khon Kaen)				
1-day	83	101	111	121
2-days	113	142	161	178
3-days	132	166	188	207
(Thung Sai Yart)				
1-day	77	98	112	124
2-days	102	131	149	166
3-days	119	152	172	191

(b) Runoff analysis by model

In Thung Sai Yart, flood is caused by excess runoff from upstream basin and insufficient drainage capacity of the present facilities, which takes place generally according to the intension of continuous three-days rainfall. Therefore, 114 mm of three-days rainfall in September in 1976, is selected to make flood runoff model, of which rainfall is almost equivalent to return period of 5-years. And, flood discharge is simulated based on the model, as follows.

Month/day	Rainfall(mm)	Simulated runoff(cu.m/s)
9/ 1	-	1.50
2	-	1.12
3	1.7	5.91
4	-	1.17
5	61.1	10.46
6	82.6	160.85
7	-	9.89
8	-	6.72
9	22.7	9.22
10	-	5.91

As a result of analysis, peak discharge is estimated at around 161 cu.m/s.

(c) Calculation of runoff by rational formula.

Besides the above model, rational formula is applied to estimate the peak flood discharge in both areas.

- Calculation formula

$$Q = 0.2778CIA$$

Q : Flood discharge (cu.m/s)

C : Coefficient of runoff

I : Rainfall intensity (mm/hr)

- Time of flood concentration

Time is calculated based on the following equation.

$$Tc = (0.87\ L^3\ /H)^{0.385}$$

Tc: Time (hr)

L : Length of catchment area (km)

H : Elevation difference between the remotest and terminal points (m)

"H" is obtained from topographical map of 1/50,000. And, watercourse is divided at some changing points of topographic features to estimate "Tc", and each "Tc" is calculated by each watercourse. Accumulated "Tc" is applied as shown in Figure B-1-5.

- Runoff coefficient

  Coefficient is applied at 0.3 and 0.1 in Thung Sai Yart and Nong Khon Kaen, respectively, based on the Table B-1-4.

- Rainfall intensity

  It is estimated by using rainfall intensity at A. Muang (Phitsanulok) nearest to the study areas. But, it should be modified with annual rainfall ratio, because amounts is different between them. Ratio, therefore, is calculated according to their amounts, at 0.7 in Thung Sai Yart and 0.9 in Nong Khon Kaen.

- Result

  The result is shown in Figure B-1-5, with specific yield. In 5 years return period, peak discharge is estimated at 162 cu.m/s and 10 cu.m/s in Thung Sai Yart and Nong Khon Kaen.

(d) Water level in Ban Mai canal

One of major cause of flooding is an influence of backwater from Yom river. Water level in Yom river, therefore, have been studied for plan formulation of drainage system.

There is no observation station at junction with Yom river and Ban Mai canal. Nearest point is Y.15 (Ban Kong) station, but, at that station, observation period is too short and its record is not by elevation, but by gate height. Therefore, its station is not useful for analysis. The Y.4 (Talat Thani) with long observation period is designate as a representative station.

Water level near the junction with Yom river is assumed by taking account of difference of ground elevation of 8.0 m between the Y.4 and its junction. And, judging from the difference of ground elevation between the junction and study area is small, water level in Ban Mai canal is regarded as equal to that at the junction. As a result of study, maximum water level is assumed at 40.0 to 42.0 m.

Table B-1-1 MONTHLY RAINFALL(1)

MONTHLY RAINFALL AT BAN DAN LAN HOI (59062)

UNIT:mm

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1965	****	****	****	****	155.5	****	150.3	1.7	0.0	21.3	19.6	0.0	****
1966	1.5	317.4	134.6	70.2	213.0	123.3	167.4	52.0	12.4	0.0	13.1	0.0	1105.0
1967	74.0	128.5	93.0	145.8	90.7	173.5	192.2	64.0	0.0	0.0	0.0	0.0	951.7
1968	172.0	231.1	133.0	158.1	36.8	152.0	164.6	0.0	0.0	93.0	0.0	32.0	1172.6
1969	49.3	163.2	42.0	104.4	150.6	460.6	0.0	0.0	0.0	31.2	0.0	0.0	1001.3
1970	62.0	222.7	85.7	149.7	211.6	234.0	127.1	30.0	8.9	0.0	0.0	0.0	1131.7
1971	6.3	166.9	115.2	105.2	111.4	198.8	44.2	0.0	0.0	0.0	0.0	0.0	748.0
1972	109.3	14.0	44.1	12.5	23.1	225.6	171.9	50.4	0.0	0.0	0.0	186.5	837.5
1973	0.0	206.4	66.7	86.6	112.3	393.9	23.2	0.0	0.0	0.0	0.0	122.6	1011.7
1974	92.8	243.8	47.0	116.7	174.6	208.3	272.1	66.5	0.0	0.0	0.0	0.0	1221.8
1975	30.2	167.8	137.2	142.6	146.6	170.8	167.5	27.2	0.0	0.0	0.0	0.0	979.9
1976	11.5	160.9	65.6	70.2	229.8	362.7	220.0	27.5	15.3	0.0	0.0	29.4	1193.0
1977	84.8	83.8	0.0	178.2	73.0	289.4	8.9	0.0	0.0	0.0	7.2	0.0	725.3
1978	16.6	102.9	84.0	194.5	95.0	241.7	151.4	0.0	0.0	0.0	0.0	0.0	886.1
1979	159.9	170.1	68.6	0.0	77.1	240.9	43.1	0.0	0.0	0.0	0.0	0.0	759.7
1980	16.8	397.7	261.6	206.0	90.7	350.9	168.2	30.9	0.0	0.0	10.5	0.0	1523.3
1981	67.0	123.3	127.7	159.4	145.2	88.3	144.0	128.5	0.0	0.0	0.0	0.0	983.4
1982	7.9	164.6	97.0	69.3	112.6	211.6	90.8	0.0	0.0	10.3	0.0	0.0	764.1
1983	4.0	233.4	165.1	109.1	237.1	234.9	276.5	71.1	17.6	0.0	12.0	0.0	1360.8
1984	43.5	104.2	153.6	126.0	36.5	284.0	161.0	12.2	0.0	5.0	6.2	0.0	931.2
1985	66.9	225.7	209.1	135.9	87.4	170.1	423.2	86.1	0.0	0.0	0.0	0.0	1404.4
1986	79.7	62.0	113.0	29.5	126.3	286.3	101.7	0.0	11.0	0.0	0.0	10.8	819.4
1987	40.4	114.0	192.1	0.0	190.5	381.5	109.5	110.5	110.5	0.0	17.0	0.0	1266.2
AVE.	54.39	172.47	110.27	107.69	127.28	249.19	146.90	32.56	7.64	6.99	3.72	16.58	1035.37

MONTHLY RAINFALL AT TUNG SALIAM (59092)

UNIT:mm

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1966	60.0	360.0	195.0	76.0	325.0	244.5	70.2	7.0	10.0	0.0	0.0	0.0	1326.7
1967	127.0	58.5	32.4	43.0	142.0	408.5	90.1	46.0	0.0	0.0	11.5	10.0	969.2
1968	****	****	****	****	****	****	135.4	0.0	0.0	38.1	0.0	48.0	****
1969	0.5	188.5	63.1	117.3	178.3	461.5	48.4	15.5	0.0	0.0	0.0	51.8	1125.1
1970	48.8	147.5	81.0	253.2	336.3	264.4	89.0	8.3	8.1	8.6	0.0	21.5	1255.7
1971	38.4	360.3	91.4	113.2	312.0	188.9	80.0	1.0	5.7	0.0	0.5	2.5	1193.9
1972	45.2	90.5	126.1	6.4	77.4	263.9	161.9	128.1	8.8	0.0	0.0	120.3	1018.6
1973	0.0	246.7	268.2	55.9	132.5	336.4	32.9	24.2	0.0	0.0	0.0	48.1	1145.0
1974	68.6	203.5	58.0	211.5	240.7	318.0	262.5	97.7	0.0	70.7	0.0	57.0	1578.3
1975	46.1	149.2	307.4	188.4	245.9	272.9	324.7	20.5	8.2	0.0	10.5	19.4	1694.3
1976	10.8	232.3	178.3	138.8	181.0	201.0	137.2	8.1	0.8	26.8	0.0	90.9	1206.0
1977	78.0	116.2	6.4	128.5	63.6	336.2	25.9	0.0	0.0	0.0	7.4	0.0	762.2
1978	0.0	113.5	76.7	331.1	64.7	170.2	3.7	0.0	0.0	0.0	0.0	0.0	759.9
1979	37.8	****	80.8	71.1	117.7	327.9	0.0	0.0	0.0	0.0	0.0	1.7	****
1980	61.4	266.5	348.3	200.3	203.9	421.3	93.1	0.0	0.0	0.0	0.0	0.0	1574.8
1981	77.2	217.7	164.4	169.1	118.6	49.9	129.4	120.8	0.0	0.0	0.0	0.0	1027.1
1982	41.0	150.6	89.8	45.6	78.9	234.5	103.1	0.0	2.0	0.0	0.0	0.0	745.4
1983	1.6	198.0	150.2	91.7	201.3	177.6	107.8	77.1	4.5	0.0	53.5	0.0	1063.2
1984	0.0	109.3	152.2	64.3	78.5	126.4	127.8	0.0	0.0	0.0	0.0	0.0	648.6
1985	110.0	119.8	82.3	103.6	43.0	311.0	219.6	73.5	0.0	0.0	0.0	0.0	1062.8
1986	66.1	84.2	117.0	128.5	204.2	238.4	44.2	0.0	3.1	0.0	0.0	23.8	909.5
1987	36.6	90.9	199.7	24.5	165.1	227.0	55.0	110.2	0.0	0.0	0.0	0.0	899.0
AVE.	44.53	174.19	136.13	121.00	166.70	265.26	106.64	33.55	2.33	6.55	3.80	22.50	1093.26

Table B-1-1 MONTHLY RAINFALL(2)

MONTHLY RAINFALL AT SUKHOTAI (59032)

UNIT:mm

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1952	30.8	10.5	293.8	119.0	170.1	291.7	146.1	8.4	0.0	62.3	44.3	2.9	1179.9
1953	122.2	68.1	204.4	161.9	128.3	263.8	190.6	0.0	0.0	0.0	3.0	38.7	1181.0
1954	37.8	97.6	11.0	235.9	175.5	129.3	162.6	2.9	1.7	0.0	0.0	24.3	878.6
1955	76.7	47.6	252.3	45.3	190.0	176.6	89.6	23.3	0.0	0.0	33.5	3.6	937.4
1956	35.4	166.5	71.9	153.0	46.2	235.9	110.5	0.0	0.0	0.0	0.0	0.0	819.4
1957	60.5	92.7	82.0	197.5	106.0	209.4	166.4	0.0	0.0	6.7	0.0	67.7	977.9
1958	39.9	12.6	214.0	32.8	218.1	149.6	179.9	0.0	0.0	0.0	6.1	7.4	860.5
1959	83.0	407.5	83.4	220.0	147.5	340.6	12.1	0.0	0.0	0.0	0.0	0.0	1294.1
1960	8.2	191.7	112.4	148.8	111.9	230.9	178.5	7.1	16.2	0.0	0.0	41.7	1046.4
1961	84.7	127.0	87.6	71.8	101.0	223.0	264.0	0.0	0.0	0.0	0.0	0.0	959.1
1962	33.5	132.2	66.6	203.7	169.5	282.2	236.7	0.0	3.6	0.0	0.0	7.4	1125.4
1963	0.0	92.3	77.9	158.5	224.3	182.3	406.8	100.8	0.0	0.0	6.1	3.4	1232.4
1964	63.8	258.1	98.6	86.9	81.4	256.0	438.1	13.2	0.0	0.0	7.1	22.8	1326.0
1965	28.5	96.1	80.6	6.6	80.1	179.7	245.8	23.4	0.3	13.9	28.4	3.1	786.5
1966	0.0	234.2	77.3	78.8	278.3	71.6	78.2	7.8	11.0	6.0	0.0	0.0	843.2
1967	75.6	102.1	161.9	82.5	96.6	309.0	48.9	39.8	0.0	0.0	7.2	4.9	918.4
1968	78.3	179.9	197.7	88.4	163.0	85.1	144.1	6.5	0.0	57.6	0.0	10.1	1009.7
1969	19.2	148.4	66.1	186.5	160.9	362.3	183.1	27.5	0.0	0.0	23.5	61.3	1238.8
1970	94.8	197.4	122.4	352.6	257.8	298.2	139.6	21.0	22.6	0.0	5.2	5.4	1517.0
1971	55.5	233.1	121.8	124.8	264.7	221.3	153.0	0.0	0.0	0.0	13.3	26.1	1213.6
1972	88.6	45.8	192.2	38.4	114.0	160.3	185.7	42.5	25.4	0.0	72.2	0.0	965.1
1973	0.0	204.3	186.8	89.9	465.3	887.5	50.5	0.0	0.0	0.0	0.0	240.3	2124.6
1974	100.7	568.2	442.0	465.3	239.0	64.7	58.4	5.0	0.0	18.4	0.0	3.8	1965.5
1975	25.8	165.1	213.4	213.0	245.3	298.7	240.1	20.6	2.6	0.0	16.4	7.0	1438.0
1976	1.7	61.4	34.3	37.4	109.8	164.7	44.0	17.3	8.2	7.8	0.0	4.3	480.9
1977	44.7	78.8	22.6	122.0	193.2	270.4	61.2	14.7	0.0	0.0	19.4	0.0	826.9
1978	23.0	163.5	88.6	478.6	80.8	384.0	142.0	0.0	0.0	0.0	7.6	0.0	1358.1
1979	57.6	158.9	110.6	45.9	132.0	98.6	0.0	0.0	0.0	0.0	0.0	0.0	603.6
1980	70.4	146.8	628.2	371.9	260.6	369.7	163.9	28.7	0.0	0.0	2.1	4.4	1946.7
1981	27.8	196.4	168.3	116.0	188.9	31.4	141.9	103.3	0.0	0.0	0.0	0.0	974.0
1982	26.0	48.9	100.7	61.7	151.1	261.8	58.8	0.0	0.0	0.0	0.0	0.0	719.0
1983	0.0	100.8	143.0	168.0	152.8	205.2	153.0	23.4	3.5	0.0	1.0	0.0	950.7
1984	19.6	97.7	196.9	101.0	139.8	252.5	100.4	0.0	0.0	0.0	0.0	4.2	912.1
1985	101.1	40.0	54.1	39.5	57.9	112.5	78.9	28.5	0.0	0.0	16.3	0.0	528.8
AVE.	47.19	145.66	145.74	149.53	167.40	236.78	148.89	16.61	2.77	6.08	9.20	17.49	1092.33

MONTHLY RAINFALL AT KONG KRAIT LAT(59042)

UNIT:mm

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1952	29.4	106.6	137.2	88.3	203.6	240.2	209.0	3.2	0.0	6.3	37.6	0.0	1067.4
1953	63.5	60.4	96.8	159.1	102.4	279.2	137.8	20.4	9.9	3.1	38.6	6.0	966.1
1954	0.0	57.7	113.6	111.4	251.2	167.6	161.2	0.0	0.5	0.0	20.3	51.6	935.0
1955	114.6	152.3	179.8	99.5	206.3	179.9	44.6	32.4	0.0	0.0	35.3	7.2	1051.8
1956	90.3	193.7	63.1	233.6	105.4	324.6	103.6	7.5	0.0	0.0	18.2	106.6	1245.6
1957	20.0	116.3	170.9	108.8	100.7	217.8	166.4	4.6	0.0	51.2	6.8	47.7	1009.2
1958	54.6	132.8	296.1	177.6	245.9	139.4	138.9	0.0	0.0	4.5	7.5	32.5	1229.8
1959	128.8	111.4	147.4	131.7	210.8	327.0	66.9	16.3	0.0	0.0	0.0	11.0	1151.3
1960	15.9	244.1	186.8	141.6	213.5	213.2	80.8	25.8	0.0	0.0	29.9	12.7	1164.5
1961	63.0	140.7	142.7	211.3	144.3	322.7	152.8	0.0	0.0	2.6	0.0	18.6	1198.7
1962	42.2	153.4	126.0	166.7	174.8	346.8	291.5	3.5	4.8	0.0	0.0	34.4	1344.1
1963	75.9	23.6	110.8	241.0	142.4	323.8	305.9	80.6	18.7	0.0	0.0	13.0	1335.6
1964	24.3	284.7	169.1	89.4	165.0	316.1	310.1	8.3	5.4	0.0	8.5	11.7	1391.6
1965	17.9	293.9	154.0	71.8	346.2	275.3	99.6	31.2	0.0	29.2	0.0	0.0	1319.1
1966	16.9	364.6	160.2	100.2	567.2	160.1	106.1	40.9	12.8	6.4	15.2	0.0	1540.6
1967	20.1	178.9	104.0	177.9	180.2	207.2	42.4	21.4	0.0	0.0	1.6	0.0	933.7
1968	24.8	206.0	79.2	176.4	108.6	143.3	85.1	0.0	0.0	69.8	0.0	75.8	958.9
1969	44.3	137.1	89.8	81.8	177.5	419.3	199.3	17.6	0.0	0.0	2.4	31.1	1200.2
1970	64.6	198.8	263.6	264.9	463.1	191.2	163.9	14.6	27.9	2.0	21.9	0.0	1676.5
1971	28.7	211.1	105.3	153.3	412.8	286.1	196.8	0.0	0.0	0.0	17.0	54.9	1465.0
1972	16.2	33.1	79.0	37.9	167.1	166.9	160.3	161.0	0.0	0.0	0.0	120.0	931.5
1973	49.4	165.4	126.6	93.5	180.1	327.0	117.0	0.0	0.0	0.0	0.0	66.7	1124.7
1974	85.6	95.9	67.6	226.2	236.2	169.1	196.4	38.8	0.0	55.3	29.0	9.5	1209.6
1975	37.3	70.3	263.7	129.2	396.6	546.1	321.1	58.0	0.0	0.0	26.4	0.0	1837.7
1976	21.7	366.4	28.4	236.7	226.4	261.8	168.2	24.2	0.0	10.8	0.0	41.2	1384.8
1977	64.6	100.6	38.1	200.6	146.7	313.7	80.1	0.0	0.0	0.0	81.9	2.6	1018.7
1978	19.0	92.4	92.6	372.0	93.9	293.9	61.2	0.0	0.0	0.0	86.3	0.0	1111.2
1979	138.3	107.6	263.3	196.3	172.6	193.2	27.0	0.0	0.0	0.0	4.2	0.0	1092.4
1980	56.6	348.6	331.0	327.8	244.9	443.0	190.8	2.0	0.0	0.0	1.8	1.0	1947.5
1981	51.1	244.6	315.3	259.3	165.2	127.0	138.3	119.8	0.0	0.0	1.3	0.0	1411.8
1982	83.5	162.2	204.9	91.6	268.8	266.2	108.7	17.7	2.1	9.2	21.3	6.5	1232.7
1983	0.0	77.4	331.6	121.2	174.1	216.7	211.4	95.1	9.0	0.0	45.4	0.0	1281.9
1984	46.9	168.0	253.8	94.3	198.5	238.0	277.4	0.0	0.0	14.6	53.0	0.0	1343.4
1985	84.6	163.9	188.4	159.3	224.6	366.4	369.9	77.2	0.0	0.0	0.0	0.0	1621.2
1986	70.4	359.2	161.7	92.1	319.8	163.7	164.3	30.0	0.0	0.0	0.0	19.1	1360.3
1987	70.6	162.2	146.1	59.0	276.9	376.6	83.7	41.8	0.0	0.0	31.6	0.0	1235.4
AVE.	50.40	168.46	159.84	157.85	222.03	264.76	159.09	27.61	2.63	7.08	17.86	21.65	1259.15

Table B-1-2 ESTIMATED MONTHLY RUNOFF DISCHARGE

ESTIMATED MONTHLY RUNOFF AT THUNG SAI YART

UNIT:MCM

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1970	0.4	5.1	3.3	7.5	11.8	11.3	6.6	2.9	1.0	0.1	0	0.2	50.2
1971	0.2	5.0	4.9	6.5	6.0	10.3	4.6	0.7	0.1	0	0	0.1	38.4
1972	1.4	0.3	1.1	0.6	0.9	5.0	8.7	3.4	0.5	0	0	1.9	23.8
1973	0.0	4.8	6.0	2.2	3.5	12.4	9.1	1.1	0	0	0	1.2	40.3
1974	1.1	7.2	4.0	3.1	8.5	10.5	14.0	8.2	1.7	0.6	0	0.2	59.1
1975	0.3	1.7	8.0	6.2	7.9	10.5	11.2	4.7	0.6	0.1	0.2	0.1	51.5
1976	0.2	3.6	2.0	1.0	7.4	19.8	11.1	5.0	0.7	0.3	0.0	0.3	51.4
1977	0.8	1.1	0.1	2.9	1.1	11.9	3.1	0.0	0	0	0.1	0	21.1
1978	0.1	1.0	0.7	8.6	3.4	7.1	6.0	0.5	0	0	0	0	27.4
1979	2.5	2.2	2.3	0.4	1.5	6.4	4.1	0.1	0	0	0	0.1	19.6
1980	0.4	16.4	14.4	9.5	6.9	23.5	12.2	3.8	0.5	0.3	0.3	0.0	88.2
1981	0.5	2.1	4.9	4.3	7.6	3.1	4.5	3.5	0.6	0.0	0	0.2	31.3
1982	0.2	2.7	3.3	0.6	1.7	8.8	4.4	0.5	0.1	0.1	0	0	22.4
1983	0.1	3.1	8.6	3.6	5.9	12.1	12.4	4.8	1.3	0.0	0.3	0	52.2
1984	0.2	0.6	5.6	1.1	1.4	5.3	7.8	1.4	0	0.1	0.1	0	23.6
1985	0.6	5.3	5.5	6.8	2.8	7.1	19.6	7.8	2.0	0.0	0	0	57.5
1986	0.3	10.4	5.8	1.8	2.5	9.6	5.4	0.8	0.1	0	0	0.1	36.8
1987	0.3	1.1	5.9	0.5	4.4	13.6	7.8	3.4	2.2	-	-	-	39.2
AVE.	0.5	4.1	4.8	3.7	4.7	10.5	8.5	2.9	0.6	0.1	0.1	0.2	40.8

ESTIMATED MONTHLY RUNOFF AT NONG KHON KAEN

UNIT:MCM

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1968	0.1	1.3	0.2	0.8	1.2	0.6	0.5	0	0	0.0	0	0.1	4.8
1969	0.1	0.2	0.7	0.2	1.0	4.3	2.7	1.0	0.0	0	0	0.0	10.2
1970	0.1	1.2	2.2	2.5	6.9	3.0	2.0	1.0	0.3	0.1	0.1	0.0	19.4
1971	0.1	1.0	0.7	1.1	3.7	3.8	3.7	1.0	0.1	0.1	0.1	0.1	15.5
1972	0.1	0.1	0.2	0.2	0.5	1.1	1.7	1.0	0.2	0	0	0.3	5.4
1973	0.0	0.7	1.0	0.4	1.2	2.2	2.9	0.4	0	0	0	0.1	8.9
1974	0.1	0.3	0.3	1.1	2.0	2.6	1.8	1.0	0.0	0.2	0.0	0.0	9.4
1975	0.0	0.2	1.6	1.0	7.6	12.7	7.4	2.0	0.5	0.1	0.1	0.0	33.2
1976	0.0	7.7	0.5	0.8	2.8	3.5	2.1	1.1	0.1	0.1	0.0	0.6	19.3
1977	0.1	0.2	0.1	1.2	1.0	3.2	1.8	0.3	0	0	0.6	0.0	8.5
1978	0.1	0.1	0.2	3.6	1.3	2.2	1.4	0.1	0	0	0.5	0.0	9.5
1979	0.3	0.3	1.5	2.3	1.6	1.9	0.6	0.0	0	0	0.0	0	8.5
1980	0.0	3.5	2.6	6.0	4.2	6.8	4.3	1.2	0.2	0.1	0.1	0.1	29.1
1981	0.1	1.4	3.3	2.6	3.4	1.4	1.5	1.1	0.3	0.2	0.1	0.1	15.5
1982	0.2	1.1	3.0	1.0	1.8	2.8	2.0	0.5	0.2	0.1	0.1	0.1	12.9
1983	0.0	0.2	3.1	0.9	1.3	3.2	2.0	1.1	0.3	0.1	0.0	0.0	12.2
1984	0.1	0.7	2.2	0.7	0.8	2.1	4.2	0.9	0.1	0.1	0.1	0.0	12.0
1985	0.2	0.8	1.3	1.2	2.7	3.3	7.4	1.4	0.4	0.1	0.1	0.0	18.9
1986	0.1	3.1	1.7	0.9	2.9	2.5	3.7	0.4	0.1	0.1	0.0	0.1	15.6
1987	0.2	0.3	0.4	0.3	1.8	4.1	1.9	0.6	0.1	-	-	-	9.7
AVE.	0.1	1.2	1.3	1.4	2.5	3.4	2.8	0.8	0.1	0.1	0.1	0.1	13.9

Table B-1-3 ANNUAL RUNOFF RATIO

Year	Thung Sai Yart Drainage area 423.6km²			Nong Khon Khaen Drainage area 100.1km²		
	Annual rainfall (mm)	Annual runoff (mcm)	Annual runoff ratio	Annual rainfall (mm)	Annual runoff (mcm)	Annual runoff ratio
1968	—	—	—	825	472	0.06
1969	—	—	—	1,291	995	0.08
1970	1,192	5,032	0.10	1,684	1,940	0.12
1971	869	3,869	0.11	1,415	1,512	0.11
1972	714	2,188	0.07	883	523	0.06
1973	1,112	4,118	0.09	1,179	828	0.07
1974	1,383	5,931	0.10	1,171	930	0.08
1975	1,154	5,202	0.11	1,984	3,318	0.17
1976	1,152	5,111	0.11	1,359	1,900	0.14
1977	779	2,160	0.08	986	802	0.08
1978	861	2,751	0.08	1,101	952	0.09
1979	769	1,940	0.05	1,175	900	0.08
1980	1,529	8,752	0.14	1,949	2,909	0.15
1981	1,003	3,166	0.07	1,403	1,533	0.11
1982	752	2,213	0.07	1,197	1,307	0.11
1983	1,268	5,178	0.10	1,274	1,231	0.10
1984	865	2,373	0.07	1,321	1,181	0.09
1985	1,319	5,759	0.10	1,589	1,878	0.12
1986	947	3,667	0.09	1,341	1,565	0.12
1987	1,174	3,932	0.08	1,222	984	0.08
Annual average	1,047	4,075	0.09	1,317	1,383	0.10

Table B-1-4 RUNOFF COEFFICIENTS

Topography and Vegetation	Value of C		
	Soil Texture		
	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat 0 - 5% slope	0.10	0.30	0.42
Rolling 5 -10%	0.25	0.35	0.50
Hilly 10 -30%	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82

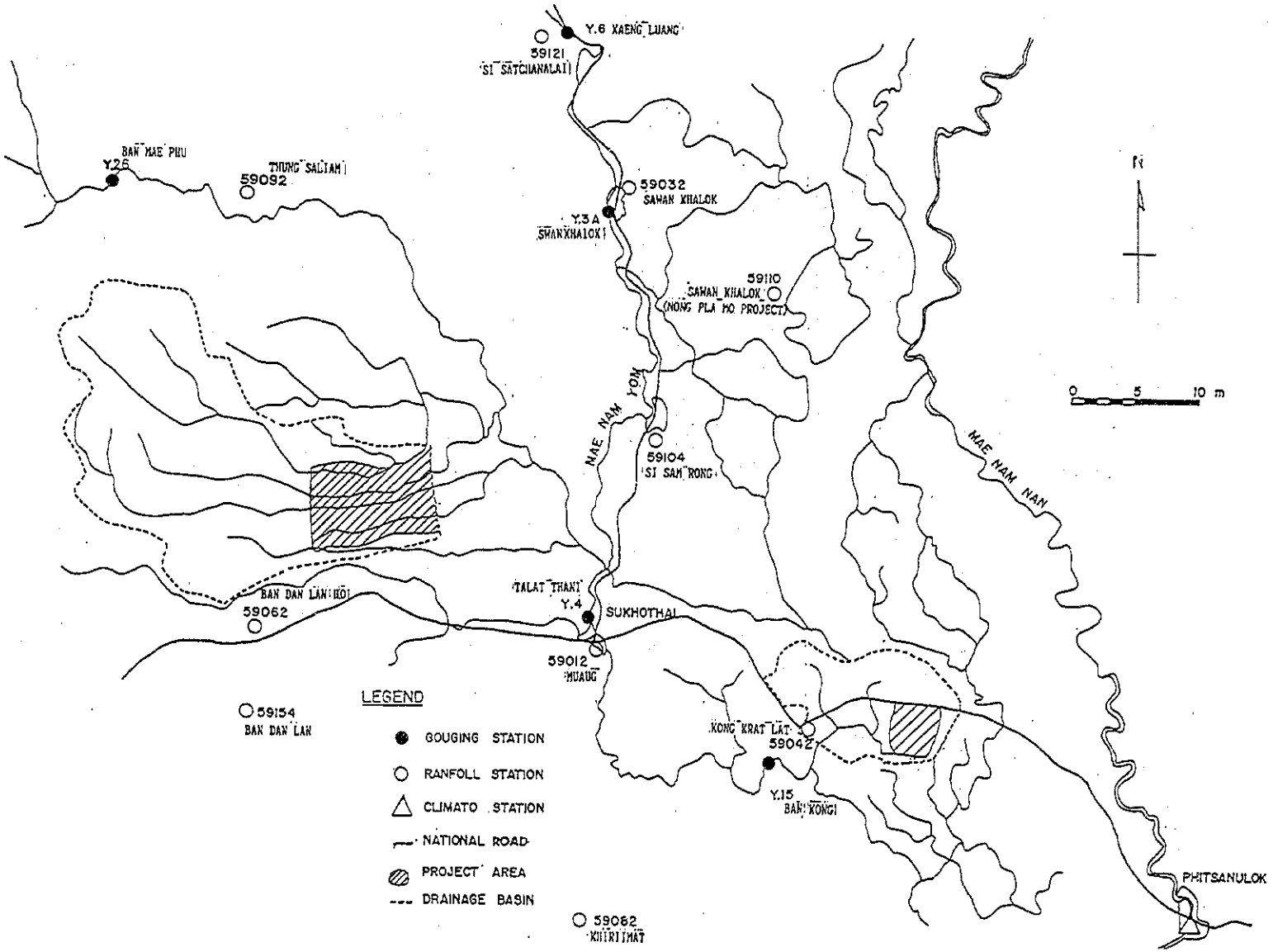


Figure B-1-1 LOCATION OF METEOROLOGICAL STATION AND GAUGING STATION

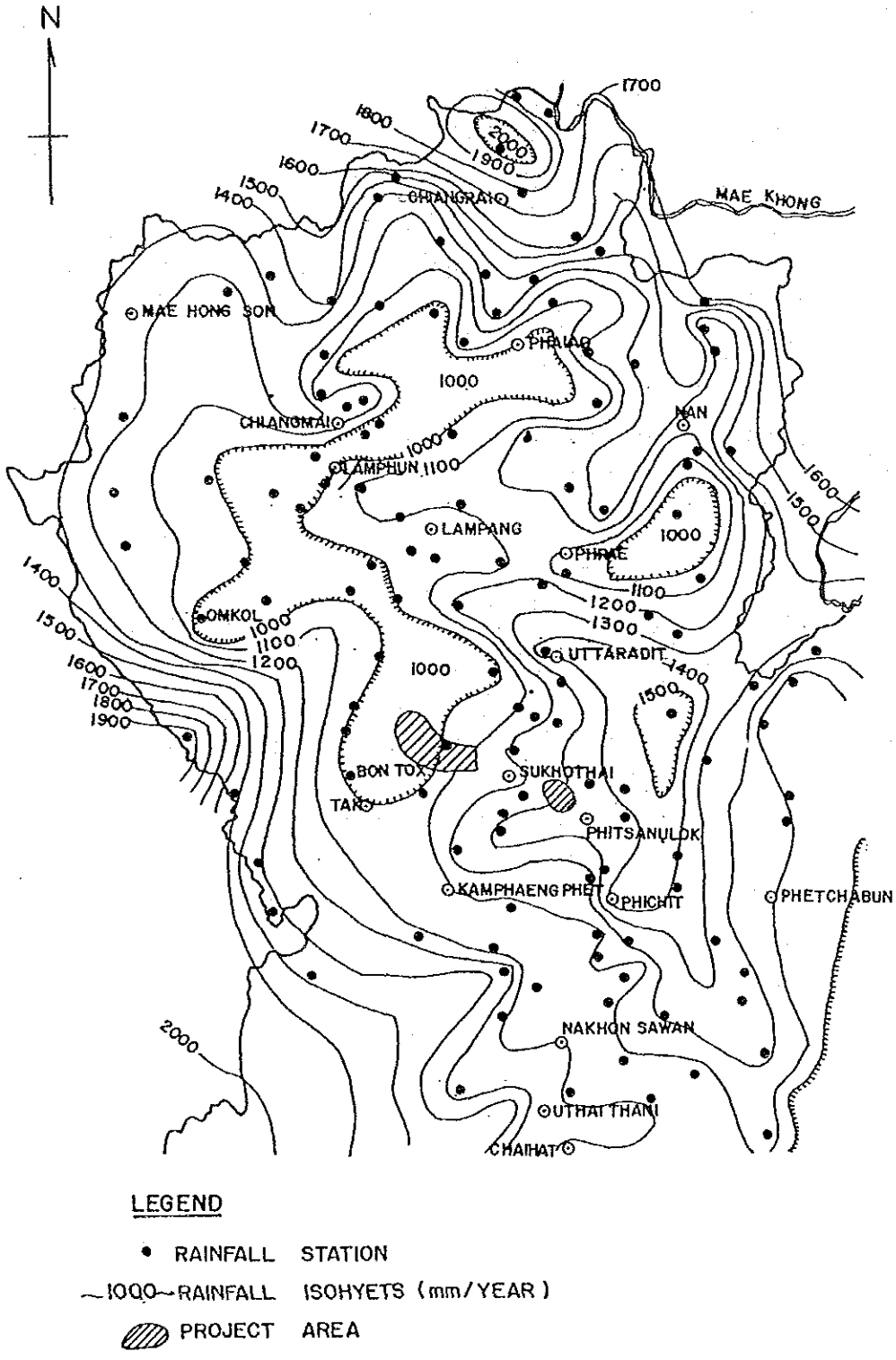


Figure B-1-2 MEAN ANNUAL RAINFALL MAP (1952-1980)

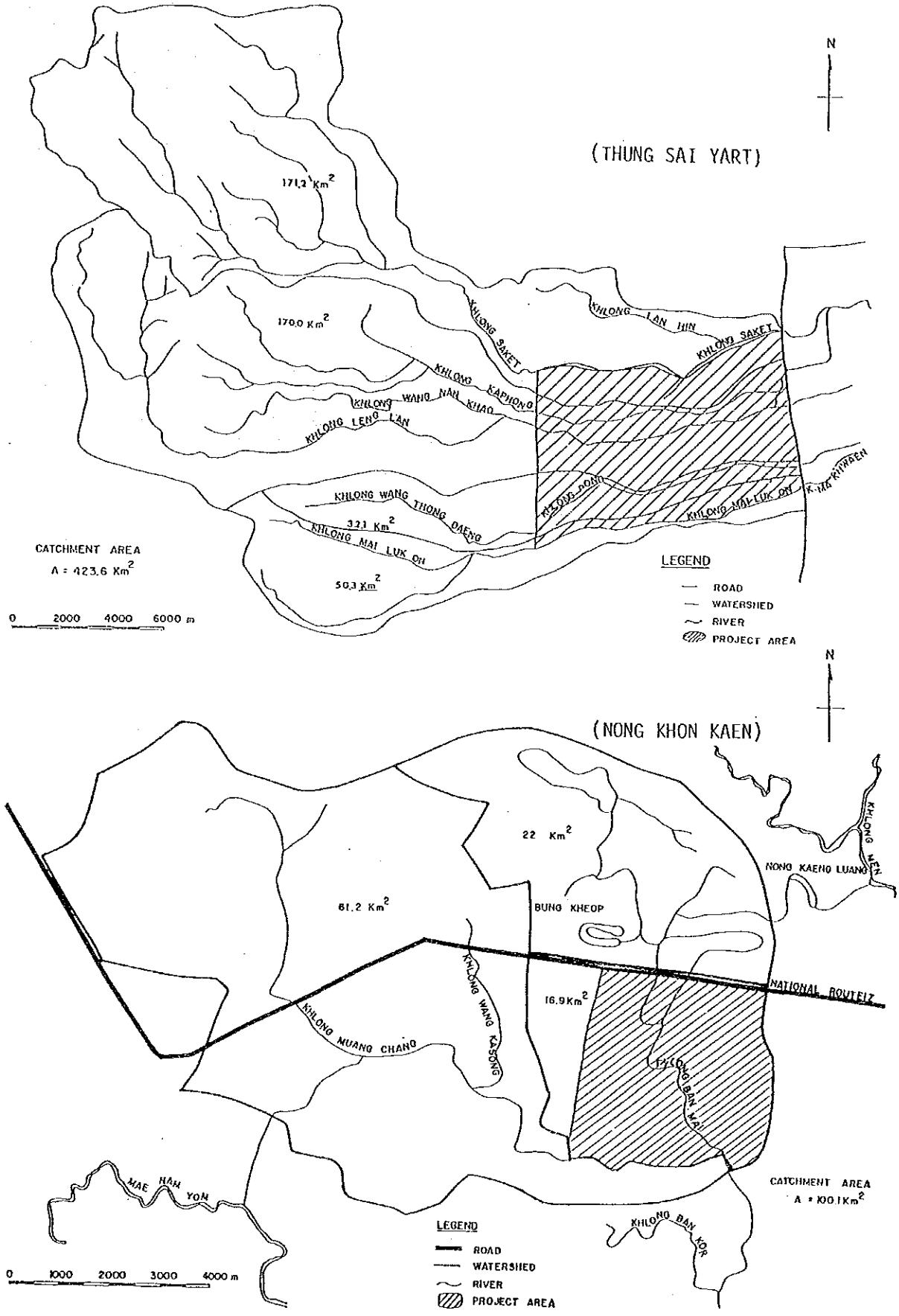


Figure B-1-3 DRAINAGE BASIN MAP

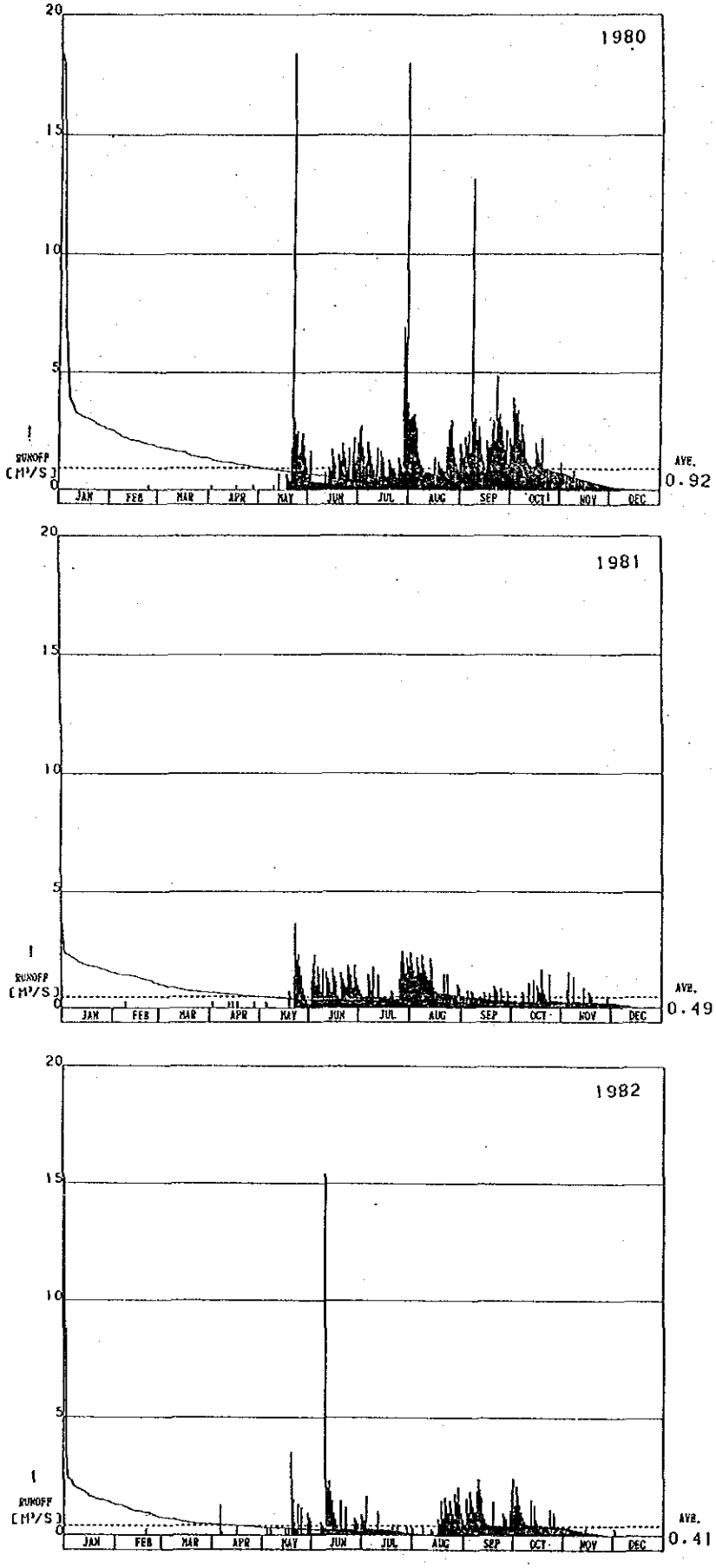


Figure B-1-4 ESTIMATED DAILY RUNOFF AT NONG KHON KAEN

DESIGN FLOOD DISCHARG

Study Area: Nong Khon Kaen

Calculating POint	A km^2)	Tc (hr)	I (mm/hr)				C	Q (m^3/s)			
			1/2	1/5	1/10	1/20		1/2	1/5	1/10	1/20
①Ban Mai	22.0	7.0	10.8	13.5	15.3	17.5	0.1	7	9	10	11
②Ban Mai	39.0	11.0	7.2	9.0	10.8	11.7	0.1	8	10	12	13
③Ban Mai	61.2	13.0	6.3	8.1	9.0	10.4	0.1	11	14	16	18
④Muang C.	100.1	13.0	6.3	8.1	9.0	10.4	0.1	18	23	26	29

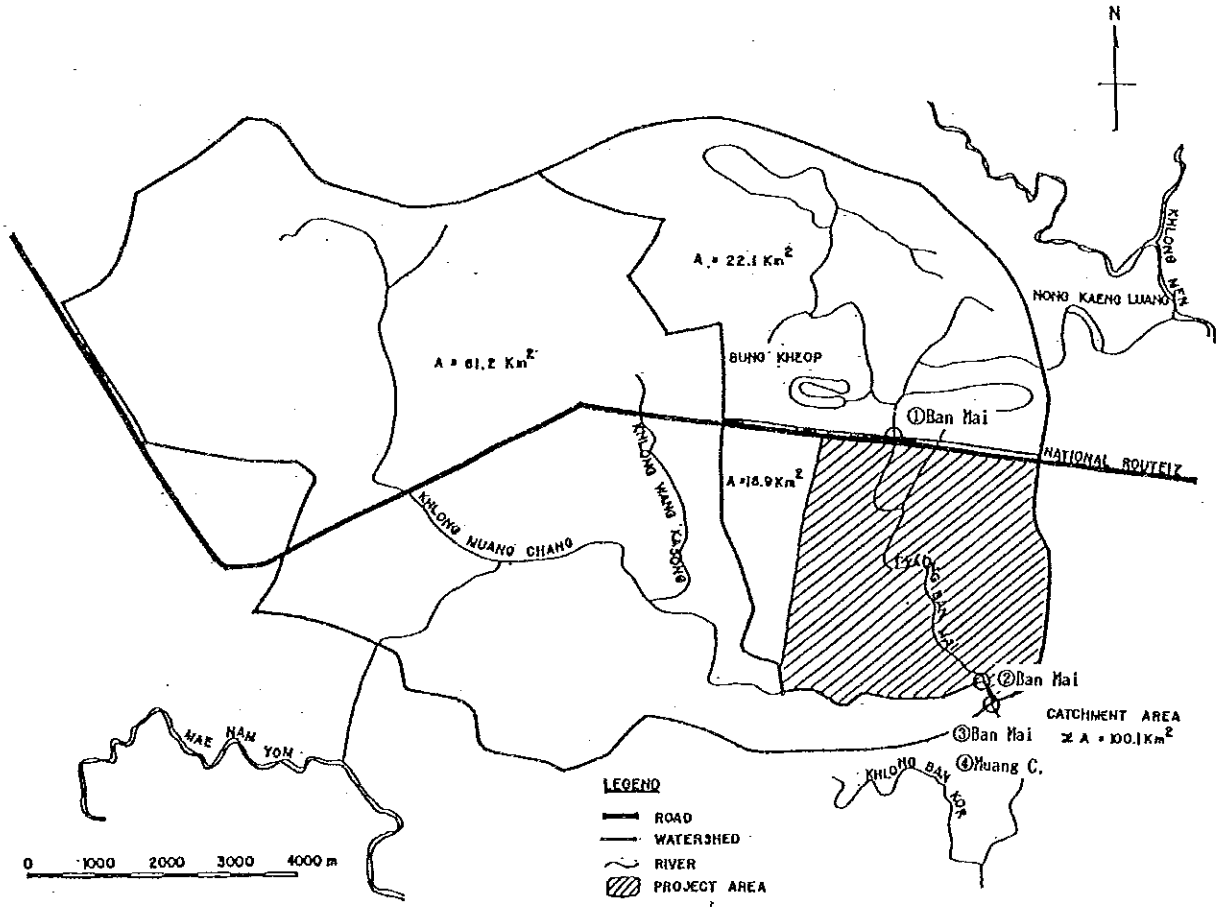
note:Rational Method Q=0.278CIA

Where Q;Flood Discharge (m^3/s)
C;Coefficient of Runoff
I;Raifall Intensity(mm/hr)
90% rainfallintensity at A.Mu ang,Phisanulok
A;Cathment Area(km^2)

Time of Concentration

$$T_c = (0.87L^3/H)^{0.385}$$

Where T_c ;Time of Concentration(mm/hr)
L ;Length of Catchment Area(km^2)
H ;Fall of Streamed From The Rmotest Part to The Outlet(m)



DRAINAGE BASIN MAP (NONG KHON KAEN)

Figure B-1-5 CATCHMENT AREA AND DESIGN FLOOD DISCHARGE(1)

DESIGN FLOOD DISCHARG

Study Area: Thung Sai Yart

Calculating POint	A km²)	Tc (hr)	I (mm/hr)				C	Q (m³/s)			
			1/2	1/5	1/10	1/20		1/2	1/5	1/10	1/20
①MaiLukon	50.3	15.0	4.4	5.5	6.2	6.9	0.3	19	24	26	29
②Pong	32.1	15.0	4.4	5.5	6.2	6.9	0.3	12	15	17	19
③Khao	170.0	20.0	3.4	4.3	4.9	5.4	0.3	49	61	70	77
④Saket	171.2	20.0	3.4	4.3	4.9	5.4	0.3	49	62	70	78

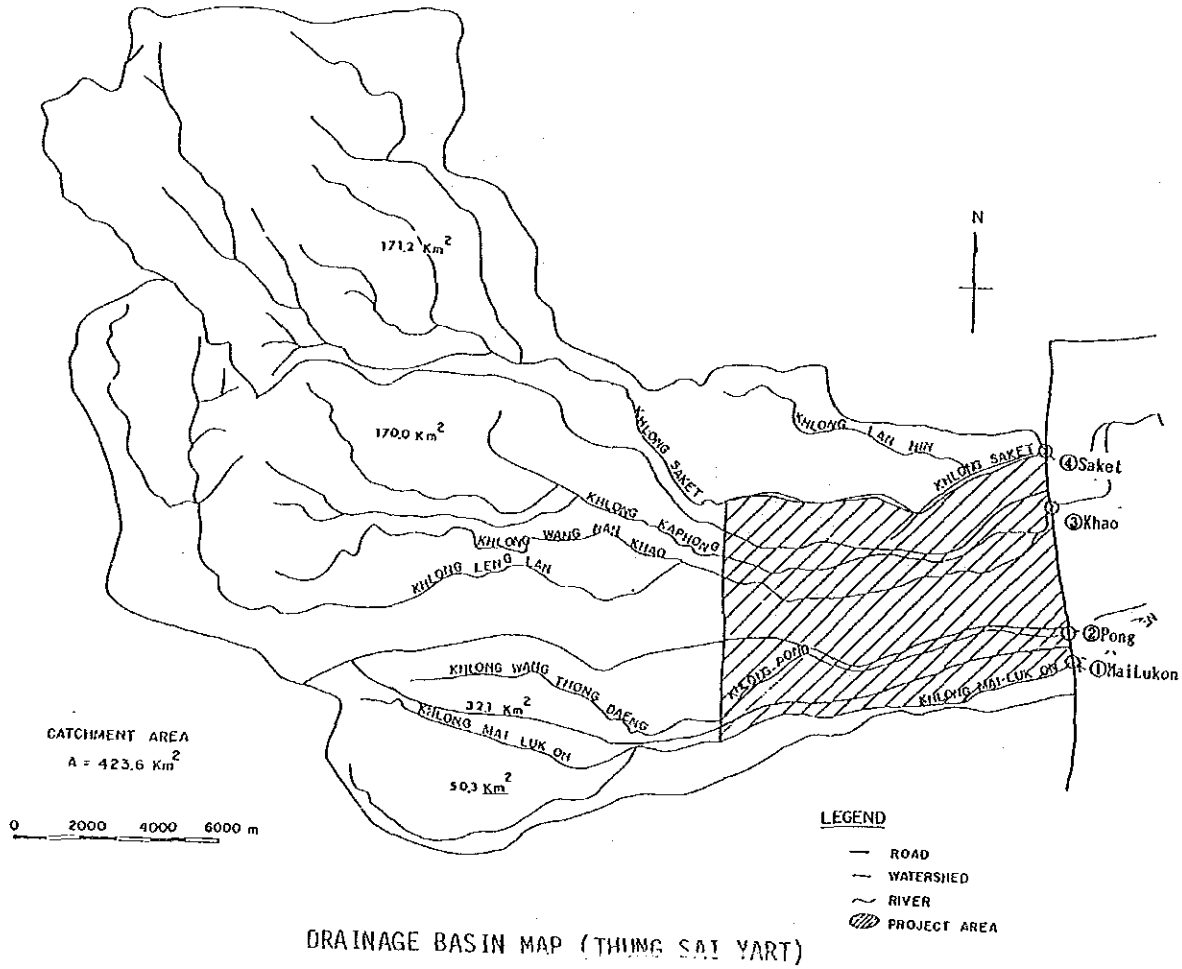
note:Rational Method Q=0.278CIA

Where Q;Flood Discharge (m³/s)
C;Coefficient of Runoff
I;Raifall Intensity(mm/hr)
70% rainfallintensity at A.Munang,Phisanulok
A;Cathment Area(km²)

Time of Concentration

$$T_c = (0.87L^3/H)^{0.385}$$

Where T_c ;Time of Concentration(mm/hr)
L ;Length of Catchment Area(km²)
H ;Fall of Streamed From The Rmotest Part to The Outlet(m)



DRAINAGE BASIN MAP (THUNG SAI YART)

Figure B-1-5 CATCHMENT AREA AND DESIGN FLOOD DISCHARGE(2)

Appendix B-2 GROUNDWATER

B-2-1 Outline of the Activities Performed

(1) Data collection on groundwater use and relevant projects

(2) Questionnair on existing wells and state of groundwater use

(3) Test well digging, logging and pumping test, as follows.

Items	Nong Khon Kaen	Thung Sai Yart
- Test well	1 site, 80 m	1 site, 80 m 1 site, 42 m
- Observation hole		
Boring with S.P.T.	1 site, 50 m	1 site, 50 m
Non-core boring		1 site, 35 m
- Geophysical logging	3 holes	3 holes
- Pumping test	1 test well 2 existing wells	2 test wells 1 existing well

(4) Groundwater level observation

In order to grasp the current fluctuation of groundwater level, they have been measured on a long-term basis from January in 1989 to January in 1990. A simultaneous observation has also been carried out in September.

(5) Water quality test

Sixteen samples were collected from deep and shallow wells in both areas.

(6) Hydrogeological study and analysis

B-2-2 Geology and Hydrogeology

(1) Outline of geology in the basin

Central Chao Phraya plain including the study areas is filled with unconsolidated and very low consolidated deposits which are formed by alluvium, pleistocene in Quaternary and upper Tertiary (Refer to Figure B-2-1). These deposits are composed of sand, gravel and clay and thickness of them is more than 500m.

(2) Geology of study areas

Two areas geologically consists of the sand, gravels and clay as

shown broadly in the existing columnar section (Refer to Figure B-2-2).

Nong khon Kaen

Judging from the data by test well JT-1 and observation hole JO-1 and existing data, it is consisted of horizontal deposits of alternating sand and clay layers of alluvial and diluvial formations in Quarternary period. Boundary between sand and clay layers to divide the alluvial and diluvial formations, is assumed at 34 m depth, taking account of geology and number of blows (N value) in the standard penetration test (S.P.T.). Geological sections are shown in Figures B-2-3 to B-2-6. Their details are as follows.

Surface layer of clay (Sc) is 5-14 m in thickness with clay, silt and containing organic substances near surface. Laterite gravels are also present, indicating the formation of laterite in some part of surface layer.

Alluvial sand layer (As) is present beneath the surface layer, which is measured at 14-29 m consisted mainly of sand with thin layer of clay. The sand is fine to coarse sand relatively well sorted. Some of fine gravels with less than 10 mm in diameter are contained.

Diluvial formations spread beneath the alluvial one and its boundary is almost horizontal. The sand and clay layers in the alluvial and diluvial formations lie almost horizontal, too.

Diluvial clay layer (Dc) lies beneath the alluvial sand layer (As) with thickness of 14-19 m and N values of 16 to 36 in depth of 34-38 m and 50 to 64 in depth of 38-48 m.

Diluvial sand layer (Ds) lies beneath the diluvial clay layer (Dc) with moderately sorted fine to coarse sand and fine gravels of calcareous mudstone, sandstone and quarts.

Thung Sai Yart

Results of drilling works are shown in Figure B-2-7 and B-2-8. Geological characteristics are shown in Figure B-2-9. More details are as

follows.

Surface layer of clay (Sc) is 3 to 5 m in thickness with clay, clay with sand and sandy clay. Some of clayey sand is present.

Alternating diluvial clay and sand layer I (D_{AL1}) lies beneath the surface layer of clay (Sc) with 38-48 m in thickness, which is consisted of sand, sand with clay, clayey sand, silt, sandy clay and clay. In some part of sand to clayey sand layer, fine gravels of quartz and rhyorite are included.

Diluvial clay layer I(D_{c1}) is present beneath the alternating diluvial and sand layer I(D_{AL1}) with thickness of 40-50 m.

Alternating clay and sand layer II (D_{AL2}) lies beneath the D_{c1} with 18-21 m in thickness. JT-2 and JT-3 dug in this study don't reach this layer, so that more details are unknown.

Beneath the above alternating layers, diluvial clay layer II (D_{c2}) and alternating clay and sand layer III (D_{AL3}), etc , are present.

B-2-3 Present Groundwater Condition

(1) Groundwater level

(a) Long-term observation

Twenty-five wells were selected to observe water level for 12 months from January in 1989. Results in Nong Khon Kaen are shown in Figure B-3-11. In Thung Sai Yart, yearly fluctuation is small to be less than 1.0 m.

(b) Simultaneous observation

It was carried out at 33 shallow wells, on September 22 - 23 in 1989 in Nong Khon Kaen and at 6 deep wells and 32 shallow wells on September 18 in 1989 in Thung Sai Yart. Results are shown in Table B-2-1.

(2) Water quality

In the water quality, as the turbidity and iron concentrations are

interrelated, it is possible to remove precipitates by aeration or chlorination.

Related to the value of SAR to examine irrigation water, higher value more than 10 was recorded at six wells in Thung Sai Yart. Some of them are in the very high zone. Therefore, it may be undesirable as irrigation water. Groundwater should be tested again to insure its applicability, in case of groundwater use for irrigation purpose.

(3) Groundwater use

(a) Current situation of the existing wells

Questionnair survey was carried out at 55 to 32% of the whole wells to grasp the current situation, in Nong Khon Kaen. In Thung Sai Yart, it was conducted at whole wells. An example of the results are shown in Tables B-2-3 to B-2-5.

(b) Groundwater use

Nong Khon Kaen

Result reveals that 47 of the 51 wells investigated are used for irrigation and utilization rate is 92.2% (47/51). Driving day of well is calculated based on the survey, as follows.

Dry season: Accumulated 3235.5 days → 3235.5/47 wells= 68.84 days
Wet season: Accumulated 1508.5 days → 1508.5/47 wells= 32.10 days
Total 100.94 days

Pumping discharge is about 18-20 m^3/hr, based on the measurement by using buckets and interview. Daily pumping discharge is calculated as follows.

(18 - 20 m^3/hr) × 18 hr/day ≒ 350 m^3/day

Annual pumping discharge is estimated as follows.

Dry season: 164 wells× 0.92 × 68 days× 350 m^3/day = 3.6 MCM
Wet season: 164 wells× 0.92 × 32 days× 350 m^3/day = 1.7 MCM
Total 5.3 MCM

Aside from the above, another examination has been also carried out from viewpoint of water requirement based on the current cropping pattern.

As a result of study from both aspects, annual pumping discharge is assumed at around 6.0 MCM (Details are described in Appendix B-3).

Thung Sai Yart

According to the qestionnair, average drinking water supply is estimated at 52ℓ /day/person.

(c) Fall of groundwater level

It was shown by survey that construction of jet wells were launched in 1967 and at that time, suction pumps were installed on the ground surface, but, in their history, pumping positions were getting lower and lower below the ground surface, because falling of groundwater level makes it difficult to continue pumping at the same position with time, as shown in Figure B-2-12.

At present, the position is located at around 8.5 m below surface. On the other hand, screen of well has not improved for that falling period. This situation shows that the position was transferred at lower point to keep static suction head to be about 8 to 10 m, as water level was falling.

Pumping position tends to be lower at the rate of 0.4 to 2.0 m per year since around 1979 when construction of well was prevailing. And, its rate is assumed at 1.0 m per year. The interrelation between depth of pumping position and falling of groundwater level is deemed to be on the same trend. Therefore, water level is falling at the rate of around 1.0 m in a year, if the pumping is continued under the same condition as the present.

B-2-4 Hydrogeology

(1) Hydrogeology in the study areas

Nong Khon Kaen

Based on the JT-1, aquifer condition is considered as follows.

- Alluvial formations
  - Depth 5 - 16 m : Fine to coarse sand including some gravels and clayey sand
  - 〃 21 - 28 m : Fine to coarse sand including some gravels
  - 〃 30 - 34 m : Fine to medium sand including some gravels

- Diluvial formations

Depth 48 - 56 m : Sand with gravels
〃 58 - 73 m : 〃
〃 more than 75 m : Sand with gravels

The 1st aquifer of alluvial formations presently supports groundwater table of 9-12 m with non-pressure. Water in the deeper aquifers is pressure water, if clay layers are continuous enough. Present shallow well takes water from 1st and 2nd aquifer with depth of 16 to 30 m.

Water in the diluvial formations is under pressure. Present deep wells for drinking water takes in water from diluvial aquifer at more than 50 m in depth.

Thung Sai Yart

Based on test wells, conditions are as follows.

- JT-2 weLl

Depth 6 - 7 m : Sand
〃 33 - 40 m : Sand with clay and gravels

- JT-3 well

DepTh 16 - 21 m : Sand and gravel with clay
〃 22 - 37 m : Sand with clay and gravels

These deposits are almost level. But, their continuity is poor. Clayey sand and sand with clay especially tend to undergo lateral changes like pinching out. Except for aquifer of 6 to 7 m in depth of JT-2, water is in pressure. Intake depth is unknown at present. But, some of them takes in water at 16-21m and 32-37 m below surface.

(2) Hydraulic constants

A series of pumping tests was done by using test and observation wells. Results of test wells are summarized in Table B-2-6.

(a) Pumping tests at existing wells

Nong Khon Kaen

Of the existing 169 wells, 24 were put to pumping test. Screen depth is 6 m in the alluvial sand aquifer with non-pressure water. The radius of influence area was 460 m.

Thung Sai Yart

Existing shallow wells are open well with hole diameter of around 1.0 m. Under the condition of no any adjacent well, pumping test was carried out to estimate the yield from bottom of well. As a result of test, yield was variable at 100 to 400 ℓ /hr with residual water level. As the test well was constructed 12 years ago, there are some deposits of fine clay on the bottom. In case of new well, therefore, much yield than the above test well may be expected.

Consideration

It is difficult to determine hydraulic constants, based on a few pumping test carried out. Tables B-2-7 and B-2-8 and Figure B-2-14 show the existing data on deep wells located around both areas and their discharge and capacity calculated based on the collected data. Compared with the both areas, Nong Khon Kaen is characterized by discharge and specific capacity and its aquifer condition are more favorable than Thung Sai Yart. Aquifer distribution is considered as follows.

(Nong Khon Kaen)
- alluvial and diluvial formations spread almost level, each containing aquifer thicker the impermeable layers.
- Aquifers in alluvial formations are more favorable than those in diluvial

(Thung Sai Yart)
- Favorable aquifer are scare. Its distribution fluctuates relatively widely

Hydraulic constants are summarized in Table B-2-9.

B-2-5 Groundwater Balance

Under a few study, it is difficult to grasp the condition of groundwater balance in the both areas. But the following items were studied on a trial basis for considering the recharge conditions.

The macro water balance expression to estimate the amount of recharge is as follows.

$$dh/dt = (Qd - Qr)/AZ$$

Where dh/dt : falling rate of groundwater
A : Related area
S : Useful porosity
Qd : Groundwater discharge
Qr : Groundwater recharge

Based on this equation, annual recharge is estimated at 20.8 to 28.8% of rainfall. But, these values are larger than the existing data. Therefore, the following examination were conducted.

- Vertical recharge by rainfall

According to the Water Balance and Economic Appraisal of Groundwater Development Project in Sukhothai Province, 1980, AIT, the conditions of vertical recharge are as follows.

Methods of Computation	Average annual recharge for basin	
	Yom(mm)	% of basin rainfall
Modified Penman	41.2	3.5
Pan Evaporation	119.3	10.2
Hargreaves	259.0	22.2

Note: % of basin rainfall=(Recharge in the basin/Basin rainfall) x 100

It is deemed reasonable to expect the vertical recharge amounting to around 10% of rainfall.

- Lateral inflow of groundwater

Lateral inflow is roughly calculated based on the cross-section in Figure B-2-6 and groundwater level in Figure B-2-11.

$$Q = K \times D \times (dh/dl) \times C = T \times (dh/dl) \times L$$

Where Q : Groundwater flow
K : Permeability
D : Thickness of aquifer
K x D =T ; Transmissivity
dh/dl : Hydraulic gradient

Q is estimated at 488,613 m^3/year.

- Recharge from river

Existing data indicates small recharge and flow rate from Yom and Nan river. Based on the analysis, it may be safe to estimate an yearly recharge of more than 2.2 MCM.

As a result of the above consideration, recharge in alluvial aquifer is assumed at 2.2 - 4.7 MCM (169-362 mm) in a year, amounting to 13.4 - 28.8% of rainfall. Around 3 MCM (231 mm) is deemed reasonable, which amounts to 18.4% of rainfall. It should be noted that the volume of recharge to diluvial aquifer in the both areas is difficult to estimate due to insufficient data. Recharge in Thung Sai Yart is calculated at 12 - 14% of rainfall.

B-2-6 Utilization of the existing shallow well

For the purpose of proper groundwater management in Nong Khon Kaen, annual pumping discharge should not exceed 3 MCM as the estimated annual recharge amount, observing the seasonal fluctuation of groundwater level. There are two ways to control pumping discharge, which are,

(a) To limit the number of wells to be driven in the area.
(b) To equally control annual pumping discharge of all the existing wells.

In the case of (a), while some wells are allowed to drive as they are presently operated, the rest shall be closed in order to prevent the falling of groundwater. In the case of (b), amount of pumping discharge of each wells shall be limited under severe monitoring activities.

(1) Interval of shallow well

In connection with the above (a), selected some wells are operated in the same way as the present. Therefore, the number of well to be driven is calculated based on the results of questionnaire survey as follows.

Driving day	Wet season	;	68.84 days
	Dry season	;	32.10 days
	Total	;	100.94 days
Pumping discharge by a well;			18 - 20 m^3/hr(about 5 - 6 l/sec)

Driving time ; Average 18 hours in a day

Daily pumping discharge per well is calculated as follows.

$(18 - 20\ m^3/hr) \times 18\ hrs = (324 - 360)\ m^3/day = 350\ m^3/day$

The number of well to be driven is calculated from annual recharge of 3.0 MCM, as follows.

3.0 MCM ÷ 100.94 days ÷ 350 m^3/day = 85 wells

Considering the scale of area of 1,050 ha, coverage area per well can be calculated;

1,050 ha ÷ 85 wells = 12.4 ha

Therefore, interval of well to be driven is estimated at around 350 m. This interval is a standard to avoid over-pumping. Actual well operation shall be applied practically under the existing distribution condition, considering the following well management.

(2) Well management

To control the pumping discharge, it is unable to force only some wells to decrease their pumping amount, due to private well. Under the present condition, management should be conducted through the following process.

① Making of well inventory

Well inventory, such as location, depth, owner and present operational condition is provided through survey.

② Observation of groundwater level

Fluctuation of groundwater table is observed at some representative wells in the area and observation records are compared to each other for understanding the current pumping condition.

③ Measurement of pumping discharge

Driving time of pump is recorded, since it will be difficult to measure the discharge by well. Amount of discharge will be assumed based on the driving records.

④ Management of rotational operation

Rotational driving is effective to avoid falling of groundwater table and interference by over-pumping. For carrying out of rotational operation, however, rules for driving wells in area and time under appropriate interval shall be defined through arrangement among farmers.

(3) Groundwater recharge

Artificial recharge method is as follows.

- Recharge by surface application
- Recharge by well

Recharge by well is the way that a well is newly constructed up to aquifer and surface water is injected into the well to supply water to aquifer. In this method, amount of injection into the new well will be limited. Therefore, some wells will have to be constructed to provide with sufficient recharge.

On the other hand, recharge by surface application is the way that surface water retained on the ground surface is infiltrated gradually into the aquifer. In this method, new facilities is not necessary. But, surface water is impounded widely on the ground surface.

Compared with the both methods, surface application is more economical and appropriate in farmer level. Farmer farming in and surrounding area have to intend to impound in their field as much as possible.

Table B-2-1 RESULTS OF WATER LEVEL MEASUREMENT IN NONG KHON KAEN AREA
[Wet Season, 22 and 23 Sep., 1989]

Well No.	Water level		Well elevation	Remarks
	Below G.L. (m)	in elevation (m)	(m)	
D1	8.89	33.71	42.6	
A-1	8.83	33.34	42.17	
A-2	10.91	30.99	41.9	
A-3	10.06	32.64	42.7	
A-7	9.23	33.17	42.4	
A-8	10.93	30.77	41.7	
A-9	9.67	32.53	42.2	
A-11	(11.80)	(30.10?)	41.9	?
A-12	10.67	31.13	41.8	
A-14	9.76	32.44	42.2	
A-22	10.81	30.59	41.4	
A-26	(14. 33)	(27.07?)	41.4	?
A-32	9.30	32.10	41.4	
A-33	8.92	32.48	41.4	
NO. 1	8.83	33.57	42.4	
NO. 2	10.82	31.44	42.26	
NO. 3	11.14	31.36	42.5	
NO. 4	9.91	32.45	42.36	
NO. 5	10.27	32.74	43.01	
NO. 6	9.86	33.29	43.15	
NO. 7	9.58	32.62	42.2	
NO. 8	10.00	32.37	42.37	
NO. 9	10.73	31.33	42.06	
NO. 10	10.14	32.01	42.15	
NO. 11	9.955	32.315	42.27	
NO. 13	10.5	31.37	41.87	
NO. 15	12.21	29.76	41.97	
NO. 16	9.31	31.93	41.24	
NO. 17	9.52	32.87	41.39	
NO. 18	10.52	30.77	41.29	
A-42	10.58	32.22	42.8	
A-43	9.86	31.94	41.8	
A-44	10.83	30.77	41.6	

Table B-2-1 RESULTS OF WATER LEVEL MEASUREMENT IN THUNG SAI YART AREA
[Wet Season, 18 Sep., 1989]

Well No.	Water level		Well elevation	Remarks
	Below G.L. (m)	in elevation (m)	(m)	
NO. 1	12.970	47.268	60.238	
NO. 2	15.780	39.627	55.407	
NO. 3	11.655	46.996	58.651	
NO. 5	7.505	44.112	56.617	
NO. 7	14.190	42.144	56.334	
NO. 9	12.730	41.359	54.089	
M-1	13.000	47.854	60.854	
M-3	11.740	48.153	59.893	
S-2	(0.200)	59.607	59.807	Flood
S-3	(1.150)	60.158	61.308	
S-4	(0.410)	57.318	57.728	Flood
S-5	3.910	53.543	57.453	
S-6	6.030	51.265	57.295	
S-7	4.980	52.092	57.072	
S-8	(0.920)	56.124	57.044	Flood
S-9	4.960	51.883	56.843	
S-10	4.320	52.234	56.554	
S-11	4.430	52.130	56.560	
S-12	(0.150)	56.882	57.032	Flood
S-13	(0.150)	56.589	56.739	Flood
S-14	4.570	52.474	57.044	
S-15	4.420	52.541	56.961	
S-16	4.310	52.544	56.854	
S-17	4.310	52.777	57.087	
S-18	3.890	52.538	56.428	
S-19	3.890	52.570	56.460	
S-20	5.945	50.053	55.998	
S-21	2.750	55.885	58.635	
S-22	2.700	55.213	57.913	
S-23	2.230	56.766	58.996	
S-24	(3.650)	59.131	62.781	Flood
S-25	6.930	54.663	61.593	
S-26	2.460	58.897	61.357	
S-27	2.260	57.003	59.263	
S-28	2.140	57.378	59.518	
S-29	2.760	55.452	58.212	
S-30	2.750	55.676	58.426	
S-31	2.800	55.674	58.474	

Table B-2-1 RESULTS OF WATER LEVEL MEASUREMENT IN NONG KHON KAEN and THUNG SAI YART AREAS [Dry Season, 1 May, 1989]

Well No.	Date M/D	Water level Below G.L. (m)	Water level in elevation (m)	Well elevation (m)	Remarks		
° Nong Khon Kaen							
1	5/1	9.969	32.435	42.404	4/24	8.959	32.445
2	4/27	10.323	31.934	42.257			
3	5/4	12.38	30.12	42.500	4/27	11.76	30.74
4	5/1	10.146	32.212	42.358	4/27	10.136	32.222
5	5/4	10.703	32.308	43.011	4/27	10.583	32.428
6	5/1	10.398	32.748	43.146	4/27	10.338	32.808
7	5/2	10.228	31.969	42.197	4/28	10.368	31.829
8	5/2	11.540	30.825	43.365	4/28	11.590	30.775
9	5/2	12.025	30.035	42.060	4/28	11.585	30.475
10	5/2	11.122	31.025	42.147	4/28	11.182	30.965
11	5/2	10.478	31.788	42.266	4/28	10.498	31.768
12	5/2	12.908	29.278	42.186	4/28	13.568	28.618
13	5/5	12.369	29.497	41.866	4/25	12.359	29.507
14	5/2	12.826	28.981	41.807	4/28	12.366	29.441
15	5/2	13.265	28.705	41.970	4/28	13.295	28.675
16	5/2	13.321	27.917	41.238	4/28	12.871	28.367
17	5/1	11.755	29.639	41.397	4/27	11.895	29.499
18	5/1	11.027	30.266	41.293	4/27	11.027	30.266
19	5/4	11.735	30.048	41.783	4/27	11.635	30.148
20	5/15	11.339	30.256	41.595	4/13	11.849	29.746
° Thung Sai Yart							
1	5/3	12.806	47.283	60.089	4/26	12.816	47.273
2	5/3	15.853	39.702	55.555	4/26	15.863	39.692
3	5/3	11.295	47.006	58.301	4/26	11.315	46.981
4	5/3	6.307	49.762	56.069	4/26	6.267	49.802
5	5/3	7.195	49.192	56.387	4/26	7.205	49.182

Figure B-2-2 RESULTS OF WATER QUALITY TEST

Study area	Sample of Well No.	Colour, Pt-Co unit	Turbidity, NTU	pH	Conductivity μmho/cm	mg/L (ppm) Total Dissolved solids	Total hardness as $CaCO_3$	Bicarbonate Alkalinity as $CaCO_3$	Carbonate Alkalinity as $CaCO_3$	Magnesium	Calcium	Chloride	Iron	Sulfate	Fluoride	Nitrate	Potassium	Sodium	SAR
Nong Khon Kaen	JT-1	2	** 23	6.79	276	175	100	128	nil	9.1	25	10	** 5.0	12	0.21	0.05	1.8	24.5	5.95
	JEP-1	4	** 29	7.04	239	133	94	103	0.1	8.6	23	4	** 8.3	nil	0.18	0.03	2.3	15	3.76
	A-37	5	** 140	6.59	456	292	170	128	nil	17	40	11	** 23	107	0.28	0.03	1.19	30.8	5.78
	A-13	5	** 120	6.59	406	244	110	114	nil	9.6	28	14	** 19	97	0.25	0.03	0.91	53	12.22
	A-36	5	** 100	6.44	238	147	93	98	nil	10	20	14	** 17	25	0.18	0.03	1.72	15	3.87
	D-2	5	* 5.1	7.74	269	163	106	141	0.7	11	25	6	0.25	nil	0.25	0.27	1.09	22.6	5.37
	D-1	4	** 100	7.41	272	144	102	145	0.4	10	24	4	** 9.0	nil	0.21	0.05	0.95	21.5	5.21
Thung Sai Yart	NO. 1	4	** 44	6.95	413	293	124	192	0.2	7.7	37	5	** 4.5	nil	0.21	0.12	0.8	49.5	10.49
	NO. 3	** 18	* 8.2	6.92	348	274	64	163	0.1	5.8	16	7	* 0.63	nil	0.28	0.07	0.69	60.6	18.36
	NO. 5	** 20	** 94	6.93	347	256	72	173	0.1	7.7	16	5	** 5.8	nil	0.28	0.04	0.67	52.3	15.19
	M-1	5	1.5	7.05	439	204	206	208	0.2	6.2	72	9	0.02	4.8	0.14	1.33	3.44	10.4	1.66
	M-3	5	1.2	7.27	871	580	212	342	0.6	16	58	47	0.02	52	0.31	1.96	2.06	125.9	20.69
	S-16	5	* 7.0	6.68	784	448	130	198	nil	12	32	118	0.28	27	0.21	0.19	1.06	128.8	27.44
	S-23	4	4.5	7.14	391	238	170	200	0.3	7.2	56	8	0.44	nil	0.21	0.08	0.93	19.4	3.45
	S-24	* 10	* 9.4	7.08	409	239	94	218	0.2	7.7	25	5	* 0.84	nil	0.25	0.09	1.09	72.2	17.91
	Rain jar	** 26	1.0	7.78	107	82	32	43	0.2	0.5	12	3	0.01	nil	0.14	1.14	9.6	3.9	1.56

* Over maximum acceptable concentration of water quality, criterion for drinking water in Thai

** Over maximum allowable concentration

Items	Thung Sai Yart S-16	Nong Khon Kaen A-37
Arsenic (As)	0.001	0.001
Chromium hexavalent (Cr)	0.001	0.002
Copper (Cu)	0.001	< 0.001
Cadmium (Cd)	0.0002	< 0.0001
Mercury (Hg)	0.0004	0.001
Lead (Pb)	< 0.001	< 0.001
Selenium (Se)	0.0003	0.0003
Zinc (Zn)	0.001	0.001

Table B-2-3 SUMMARY OF THE EXISTING WELL SURVEY(1)

STUDY AREA: Nong Khon Kaen TUMBON: Ban Mai Suk Kasem AMPHER: Kong Krailat PROVINCE: Sukhothai

No. 1

No.	Well No.	Type of Well	pH	Temp. (°C)	Measuring water level all at once	Ground Elevation (M)	Elev. of Water Level (M)	Depth of Water Level Below Ground Surface (M)	Sampling Water	Measuring Water Level for Long Term	Well of interview survey	Remark
1	D1	Deep Well	7.46	31.3	*	42.60	33.71	8.89	*		*	Health Center Hand pump
2	D2	" "	7.49	31.1	-						*	School - Submersible Motor Pump
3	A-1	Shallow Well	-		*	42.17	33.34	8.83			*	
4	A-2	" "	-		*	41.90	30.99	10.91			*	
5	A-3	" "	-		-						*	
6	A-4	" "	6.47	23.4	-						*	
7	A-5	" "	6.52	30.2	*	42.70	32.64	10.06			*	
8	A-6	" "	-		-						*	
9	A-7	" "	-		*	42.40	33.17	9.23			*	
10	A-8	" "	-		*	41.70	30.77	10.93			*	
11	A-9	" "			*	42.20	32.53	9.67			*	
12	A-10	" "			-						*	
13	A-11	" "			*	41.90	30.10	11.80			*	
14	A-12	" "			*	41.80	31.13	10.67			*	
15	A-13	" "	6.43	29.2	-				*		*	
16	A-14	" "			*	42.20	32.44	9.76			*	
17	A-15	" "			-						*	
18	A-16	" "			-						*	
19	A-17	" "			-						*	
20	A-18	" "			-						*	
21	A-19	" "			-						*	
22	A-20	" "			-						*	
23	A-21	" "			-						*	
24	A-22	" "			*	41.40	30.59	10.81			*	
25	A-23	" "			-						*	
26	A-24	" "			-						*	
27	A-25	" "			-						*	
28	A-26	" "	6.84	29.2	*	41.40	27.07?	14.33?			*	
29	A-27	" "			-						*	
30	A-28	" "			-						*	
31	A-29	" "			-						*	
32	A-30	" "	6.93	29.1	-						*	
33	A-31	" "			-						*	
34	A-32	" "			*	41.40	32.10	9.30			*	
35	A-33	" "			*	41.40	32.48	8.92			*	
36	A-34	" "			-						*	
37	A-35	" "			-						*	
38	A-36	" "	6.51	28.6	-				*		-	
39	A-37	" "	6.69	28.3	-				*		-	
40	A-38	" "	6.27	28.8	-						-	

Table B-2-4 RESULTS OF WELL INTERVIEW SURVEY(1)

Project Area: Nong Khon Kaen

No. 1

Well No.	Location						Population		Purpose		Type of Well			Dia.	Depth of Screen	Construction year	Intake Method					Service Method				Rain Tank	Remarks
	Public				Private		Nos. of household	Population benefited	Domestic	Irrigation	Shallow		Deep				Motor Pump		Hand Pump	Well Bucket	Others	Service Pipe to each house	Stand Pipe	Man Power	Direct to Paddy field		
	Temp.	School	Health Center	Village House	Paddy Field	Village House					Dug well Depth (m)	Tube well Depth (m)	Bore hole Depth (m)	(mm)	(m)		Suction Pump	Submersible Pump									Unit quantity lit/day-cap.
A-1					*		3	16	*	*		19		76	13-19	1981	*								*		39
A-2					*		1	2	*	*		28		76	22-28	1977	*								*		55
A-3					*		1	4	Δ	*		18		76	12-18	1979	*								*		30
A-4					*		1	6	Δ	*		18		76	12-18	1987	*								*		PH=6.47 28.4°C 20
A-5					*		1	2	*	*		21		76	15-21	1970	*								*		80
A-6					*		1	5	Δ	*		17		76	11-17	1979	*								*		84
A-7					*		1	2	Δ	*		18		76	12-18	1985	*								*	*	85
A-8					*		1	4	*	*		18		76	12-18	1972	*								*		54
A-9					*		1	7	Δ	*		21		76	15-21	1981	*								*		Drinking only 4
A-10					*		1	4		*		28		76	22-28	1989	*								*		Irrigation only -
A-11					*		1	6	*	*		18		76	12-18	1969	*								*		57
A-12					*		1	6	*	*		19		76	13-19	1975	*								*		37
A-13					*		2	6	Δ	*		19		76	13-19	1979	*								*		22
A-14					*		1	3	Δ	*		18		76	12-18	1980	*								*		43
A-15					*		1	2	*	*		-		76	-	1979	*								*		57
A-16					*		2	6	Δ	*		30		76	24-30	1979	*								*		25
A-17					*		1	3	Δ	*		18		76	12-18	1983	*								*		55
A-18					*		1	8	*	*		18		76	12-18	1982	*								*		105
A-19					*		1	4		*		18		76	12-18	1986	*								*		Irrigation only -
A-20					*		1	2	*	*		27		76	21-27	1969	*								*		55

Table B-2-5 RESULTS OF SHALLOW WELL INTERVIEW SURVEY(1)

Project Area: Nong Khon Kaen (Shallow Well for Irrigation) No. 1

Well No.	Dia. (mm)	Depth (m)	Depth of Screen (m) (Length of Screen (m))	Construction and Reconstruction Year Depth of Setting Motor Pump								Discharge for Irrigation									
				Year	Depth (m)	Year	Depth (m)	Year	Depth (m)	Year	Depth (m)	Area (Rai)	Discharge per day (m^3/day)	Dry Season			Wet Season			Per year
														Nos. of days for one irrigation (days/once) (1)	Nos. of pump-up irrigation for dry season (times) (2)	Total No. of discharge days for dry season (days) (1)x(2)	(1) (days/once)	(2) (times)	(3) (days) (1)x(3)	Total No. of discharge days per year (days)
A-1	76	19	13-19 (6)	1981	0	1983	2	1989	4	-	-	29		3	20	60	1	5.5	5.5	65.5
A-2	76	28	22-28 (6)	1977	0	1980	2	1986	4	-	-	13		2	24	48	1.5	5	7.5	55.5
A-3	76	18	12-18 (6)	1979	0	1984	6	-	-	-	-	7	432	2	17	34	1	12	12	46
A-4	76	18	12-18 (6)	1987	2	1989	5	-	-	-	-	27	432	3.5	16	56	3	5	15	71
A-5	76	21	15-21 (6)	1970	0	1986	3	1989	5.5	-	-	12		7	15	105	7	12	84	189
A-6	76	17	11-17 (6)	1979	4	-	-	-	-	-	-	10		3	20	60	2	16	32	92
A-7	76	18	12-18 (6)	1985	0	1985	2	1987	4	-	-	7		3.5	14.3	50	2.5	10	25	75
A-8	76	18	12-18 (6)	1972	0	1975	2	1984	4	1988	6.5	43-dry 48-wet		3.5	22	77	2	5	10	87
A-9	76	21	15-21 (6)	1981	0	1986	2	-	-	-	-	15		-	-	not done paddy field	3	4	12	12
A-10	76	28	22-28 (6)	1989	4	-	-	-	-	-	-	20		-	-	not done paddy field	7	10	70	70
A-11	76	18	12-19 (6)	1969	0	1972	1.5	1972	2	-	-	20		4	12	48	2	7	14	62
A-12	76	19	13-19 (6)	1975	0	1976	3	1989	6	-	-	16		2	40	80	-	-	use rain only	80
A-13	76	19	13-19 (6)	1979	0	1987	5	-	-	-	-	10	576	3	24	72	2	22	44	116
A-14	76	18	12-18 (6)	1980	0	1988	2	1989	6	-	-	8		3	16	48	3	7.5	22.5	70.5
A-15	76		(6)	1979	0	1989	2	1989	6	-	-	21		2	35	70	3	22.5	67.5	137.5
A-16	76	30	24-30 (6)	1979	4.5	1987	7	-	-	-	-	18		3	20	60	7	6	42	102
A-17	76	18	12-18 (6)	1983	0	1984	1	1985	4.5	-	-	30		5.5	10	55	5.5	6	33	88
A-18	76	18	12-18 (6)	1982	0	1987	2.5	1989	6.5	-	-	43		3	20	60	-	-	use rain only	60

Table B-2-6 RESULTS OF PUMPING TEST IN TEST WELL

Test well	Drilling depth (m)	Screen depth (m)	Test duration (hr)	Max. discharge (m^3/hr)	Discharge in constant rate test (m^3/hr)	Static water level (m)	Dynamic water level (m)	Draw down (m)	Specific capacity (m^3/hr/m)	Transmissivity (m^2/min)	Stratigvity (-)	Remarks
Nong Khon Kaen JT-1	80	12-18 22-34 50-68	2	86*	-	9.96	17.54	7.58	11.35	$3.0-8.0 \times 10^{-1}$	$1.2-4.4 \times 10^{-3}$	(1) Step draw down test
			6	-	42			2.63	15.97			(2) Continuous constant rate test
Thung Sai Yart JT-2	80	34-40	2	10.5	-	13.40	29.28	15.88	0.661	$3.3-7.5 \times 10^{-2}$	$2.9-6.6 \times 10^{-4}$	(1) Step draw down test
			6	-	9.2			15.54	0.592			(2) Continuous constant rate test
Thung Sai Yart JT-3	42	15-21 31-37	2	50	-	12.34	32.34	20.00	2.50	$8.5-10.1 \times 10^{-2}$	$1.0-1.4 \times 10^{-3}$	(1) Step draw down test
			6	-	25.5			10.97	2.32			(2) Continuous constant rate test

* Maximum Capacity of pump utilized in pumping test.

Table B-2-7 SUMMARY OF THE EXISTING DEEP WELLS [Nong Khon Kaen]

No.	Well No.	Area or Site Name	Grid reference Date Year.M	Diameter (mm)	Depth (m)	Screen Depth (m)	Yield (m^3/hr)	Water level Static (GL-m)	Water level Dinamic (GL-m)	Draw down (m)	Specific capacity (m^3/hr.m)	Total Iron (ppm)	Chloride	Total Hardness	Remarks
1	SKT 33	Health Center Kok. Kaet	67.10	(150) 100	65.0	54.67-60.77 (6.1)	18.0	5.5	15.8	10.30m	1.75	1.9	8.5	106.0	Sand
2	SKT 50	Ban Dong Yang	71.11	(150) 100	83.5	71.77-77.80 (6.03)	22.0	5.0	16.0	11.00	2.0	0.7	17.0	54.0	Sand
3	SKT 94	Ban Hai Pho Tong (2)	174/756 77.1	(100) 100	109.0	99.2-105.2 (6.0)	40.0	3.0	8.0	5.0	8.0	0.69	4.0	110.0	G/S.
4	SKT 95	Ban Don Samrong	093/692 77.1	(100) 100	88.0	78.10-84.10 (6.0)	20.0	5.0	20.0	15.0	1.33	0.05	15.0	88.0	Gravel
5	SKT 122	Ban Hai Pho Thong (1)	154/754 80.7	(150) 100	73.0	61.0-67.14 (6.14)	24.0	8.0	16.0	8.0	3.0	0.09	8.0	80.0	Gravel
6	SKT 149	Ban Haisuk Kasem School	133/756 83.1	(150) 100	71.0	60.77-66.87 (6.1)	22.0	5.1	9.7	4.6	4.78	0.27	3.0	120.0	Pebble
7	SKT 150	Wet Prak Rak School	086/794 83.2	(150) 100	64.0	54.64-60.74 (6.1)	65.0	6.6	7.7	1.10	59.09	0.80	4.0	108.0	Pebble
8	SKT 176	Ban Prak Thong	83.11	(150) 100	58.0	51.60-57.65 (6.05)	35.0	5.3	8.3	3.0	11.60	0.23	4.0	100.0	
9	SKT 200	Wat Hai Krai Klang	84.11	(150) 100	58.0	51.68-57.79 (6.11)	20.0	7.10	9.7	2.6	7.7	0.06	6.0	118.0	Hand pump
10	SKT 203	Ban Pa Rang	84.12	(150) 100	58.0	51.79-57.93 (6.14)	60.0	12.30	14.5	2.20	27.3	0.3	6.0	90.0	Hand pump
11	SKT 206	Wat Pa Rang	84.12	(150) 100	64.0	57.65-63.67 (6.02)	60.0	13.00	15.30	2.30	26.08	0.3	6.0	110.0	Hand pump
12	SKT 259	Ban Nong Ngoen	87.3	(150) 100	58.0	42.35-48.40 (6.05)	60.0	9.50	12.00	2.50	24.00	1.7	2.0	94.0	Hand pump
13	SKT 262	Ban Bung Khrob	87.4	(150) 100	58.5	51.43-57.48 (6.05)	60.0	8.00	10.00	2.00	30.00	2.3	10.0	104.0	
14															

Table B-2-8 SUMMARY OF THE EXISTING DEEP WELLS [Thung Sai Yart]

No.	Well No.	Area or Site Name	Grid reference Date Year.M	Diameter (mm)	Depth (m)	Screen Depth (m)	Yield (m^3/hr)	Water level Static (GL-m)	Water level Dinamic (GL-m)	Draw down (m)	Specific capacity (m^3/hr.m)	Total Iron (ppm)	Chloride	Total Hardness	Remarks
1	SKT 99	Wat Wang Thong Daeng	746/897 78.4	100	28.3	18.10-24.10 (6.0)	8.0	8.70	12.00	3.30	2.42	0.215	13.00	98.00	Hand pump Sand
2	SKT 237	Ban Wang Soa Poi	86.6	100	30.00	21.20-27.25 (6.05)	3.0	14.00	16.0	2.00	1.5				Hand pump
3	NQ 168	Wat Nong Ta Shot	?	100	131	?	2.5	12.5	17.5	5	0.5	1.4	19.0	?	
4	NQ 184	Wat Nong Yao	?	100	64	?	3.5	18	55	37	0.095	11	?	?	
5	NQ 183	Wat Ban Khlong Yo	?	100	52	?	2.5	11	14.5	3.5	0.71	4.3	6	?	
6	MB 488	Wang Thong Daeng School	?	100	47	?	9	7.5	20.0	12.5	0.72	?	?	?	
7	NQ 186	Wat Sai Yap		100	116	?	1	23	110	87	0.011	0.56	7	?	
8	NQ 187	Ban Lao Rang Ngan		100	33.5	?	2	14	18	4	0.5	3.80	8	?	
9	NQ 8	Ban Samnak		100	40	?	5.5	12.5	25.0	12.5	0.44	?	?	?	
10	MB 489	Ban Wang Won School		100	43		3	4	21.0	17	0.176	?	?	?	
11	P-13 ST24/29	Ban ?	86.1	100	38	30-37 (70)	2	?(18)	?	?		0.5	?	?	
12	" ST25/29	Ban Na Khun Krai	86.1	100	24	12-18 (6.0)	2	9	?	?		?	?	?	
13	" ST15/28	?													
14	25019	Ban Samnak School	86.3	100	36		1	12	24	12	0.083	?	?	?	
15	25012	?	85.2	100	29	24?	1.5	4.5	22.5	18	0.083	?	?	?	

Table B-2-10 SUMMARY OF HYDRAULIC PARAMETERS

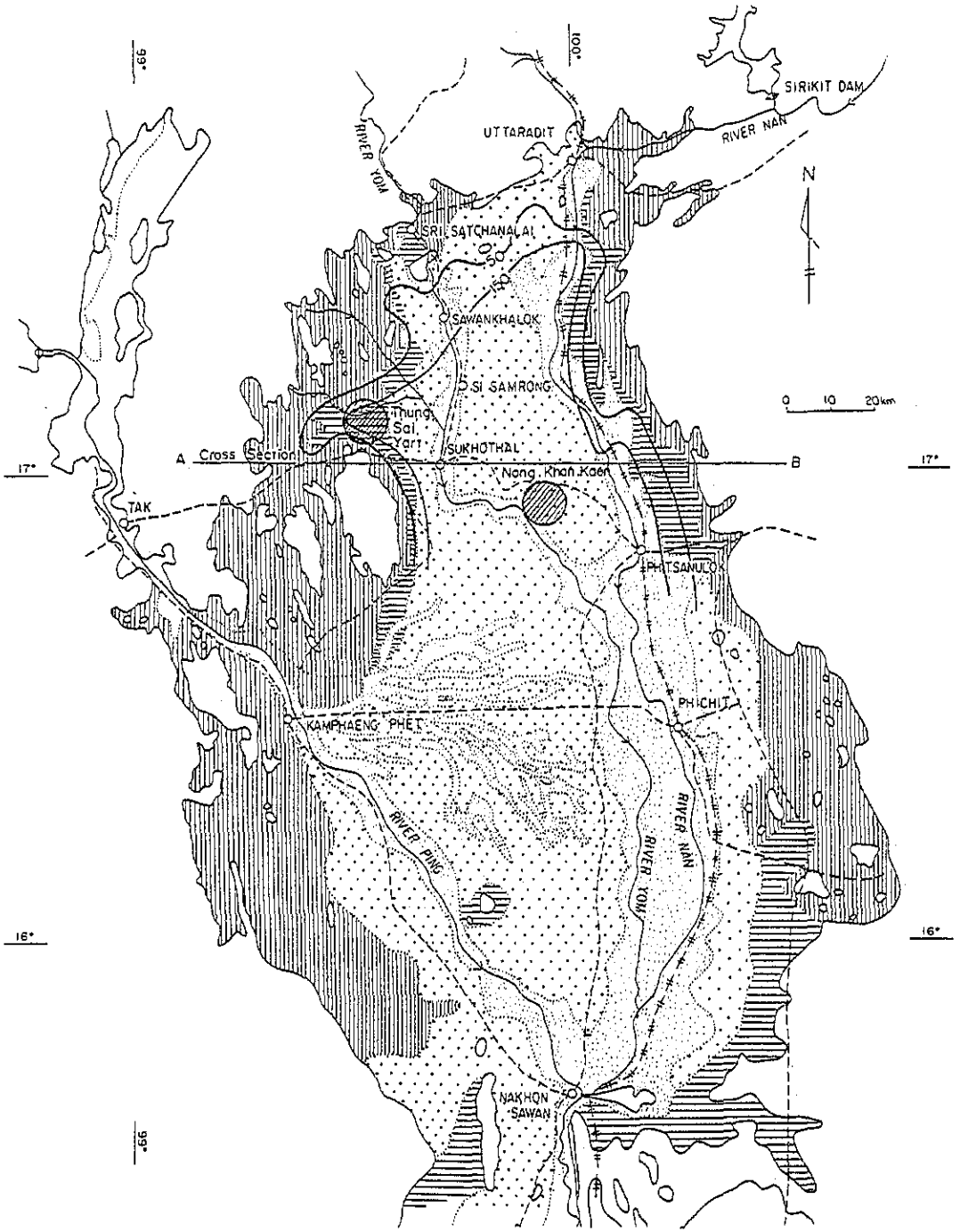
Items		Aquifer in Nong Khon Kaen area			Aquifer in Thung Sai Yar		
			Alluvium	Pleistocene	Pleistocene		
			<34m in depth	>34m in depth			
		JT-1	Existing well	Existing well	JT-2	JT-3	Existing data
Discharge (m^3/hr)	10 m draw down	105 m^3/hr	-	-	7.2	27	-
	20 m draw down	175 m^3/hr	-	-	13	50	-
	Pumping test	21-86	-	18-65	2.5-10.5	12-50	1-9
Specific capacity (m^3/hr/m)		11.3-17.2	-	1.3-59.1	0.59-1.05	2.28-3.76	0.08-2.42
Transmissivity (m^2/min)		$3.8-8.0\times10^{-1}$ [3.5×10^{-1}]	(<18m in depth) $2.5-4.5\times10^{-1}$ [3.0×10^{-1}]	-	$3.3-7.5\times10^{-2}$ [5.0×10^{-2}]	$8.5-10.1\times10^{-2}$ [9.0×10^{-2}]	-
Strativity (-)		$1.2-4.4\times10^{-3}$ [2.5×10^{-3}]	$6.6-8.2\times10^{-3}$ [7.5×10^{-3}]		$2.9-6.6\times10^{-4}$ [4.0×10^{-4}]	$1.0-1.4\times10^{-3}$ [1.2×10^{-3}]	-
Remarks		Thickness of aquifer is more than that of aquiclude.			Aquifer is poorly found and has lateral change of its lithology.		

[ ] : reasonable value inferred

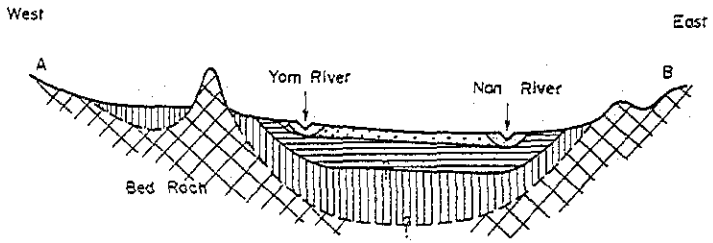
Table B-2-9 AVERAGE ANNUAL GROUNDWATER RECHARGE

	Average Annual Groundwater Recharge									
	From Infiltration Rate Using				Corey's Investigation (Zone II)	Howard Humphrey & Sons (Zone II)	Through-Flow Method	Specific Yield Method	Acceptable Value	This Study
	Penman Method	Pan Evaporation Method	Hargreaves Method	140 Days Flooding						
Recharge (mm)	129.1	174.4	173.3	132.7	300-400	109.0	150.0	80.0	100.0	169-362
% of Rainfall	11	14	14	11	25-33	9	13	7	8	13.4-28.8
	Annual rainfall - Swankhalok - 1,200 mm Source: AIT (1980)									Nong Khon Kaen 1,259 mm

Annual rainfall: Nong Khon Kaen - 1,259 mm



Cross Section A – B



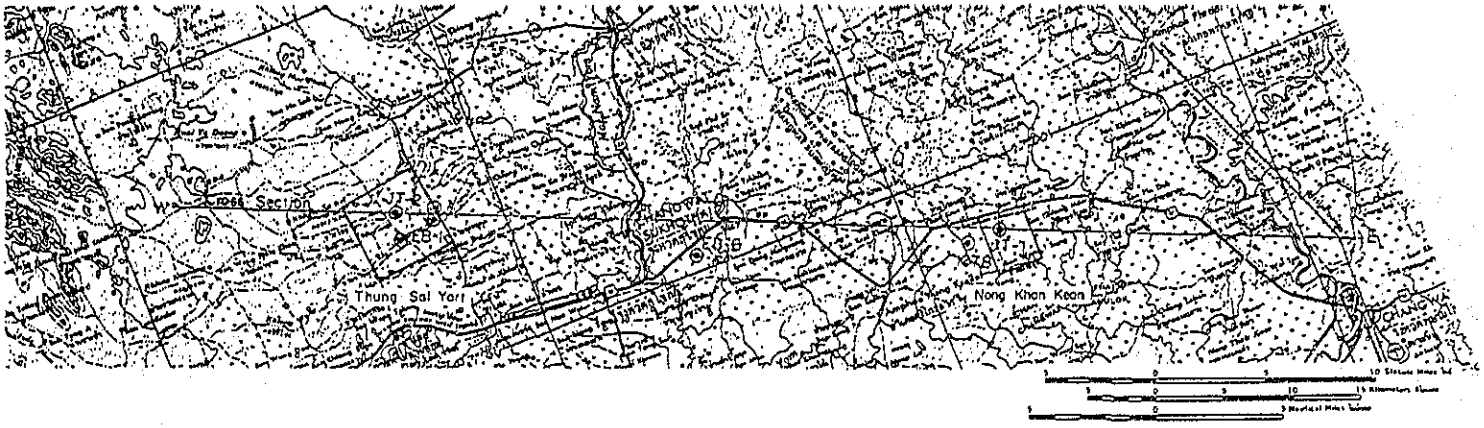
Study Area

Legend

Alluvium		Alluvium 1 Along the Recent River
		Alluvium 2
Pleistocene		Chiang Rai Series
Pleistocene Upper Tertiary		Chiang Mai Series
Mesozoic Older		Bed Rock

—150— Depth to the Bed Rock(m)

Figure B-2-1 HYDRO-GEOLOGICAL MAP



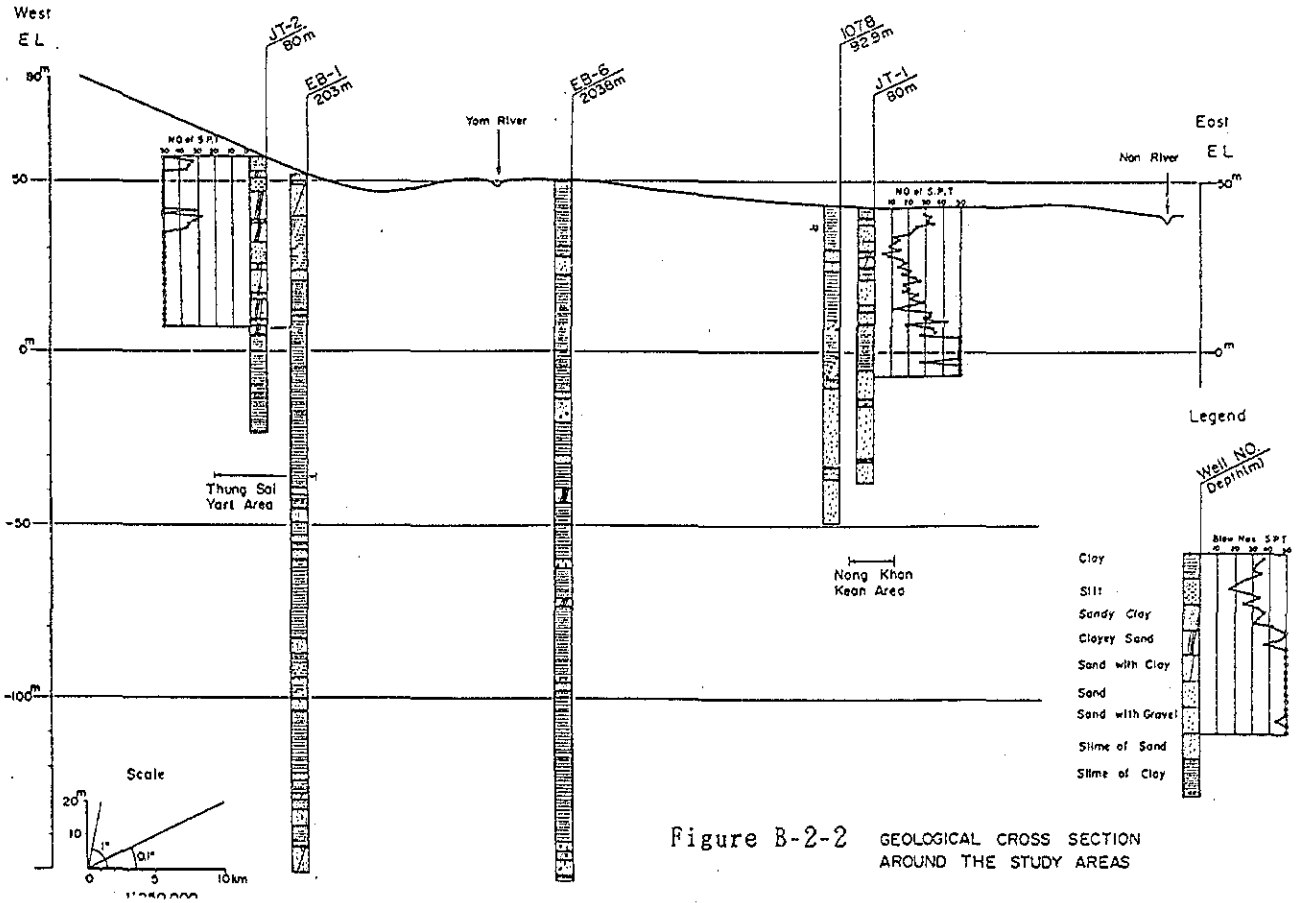


Figure B-2-2 GEOLOGICAL CROSS SECTION AROUND THE STUDY AREAS

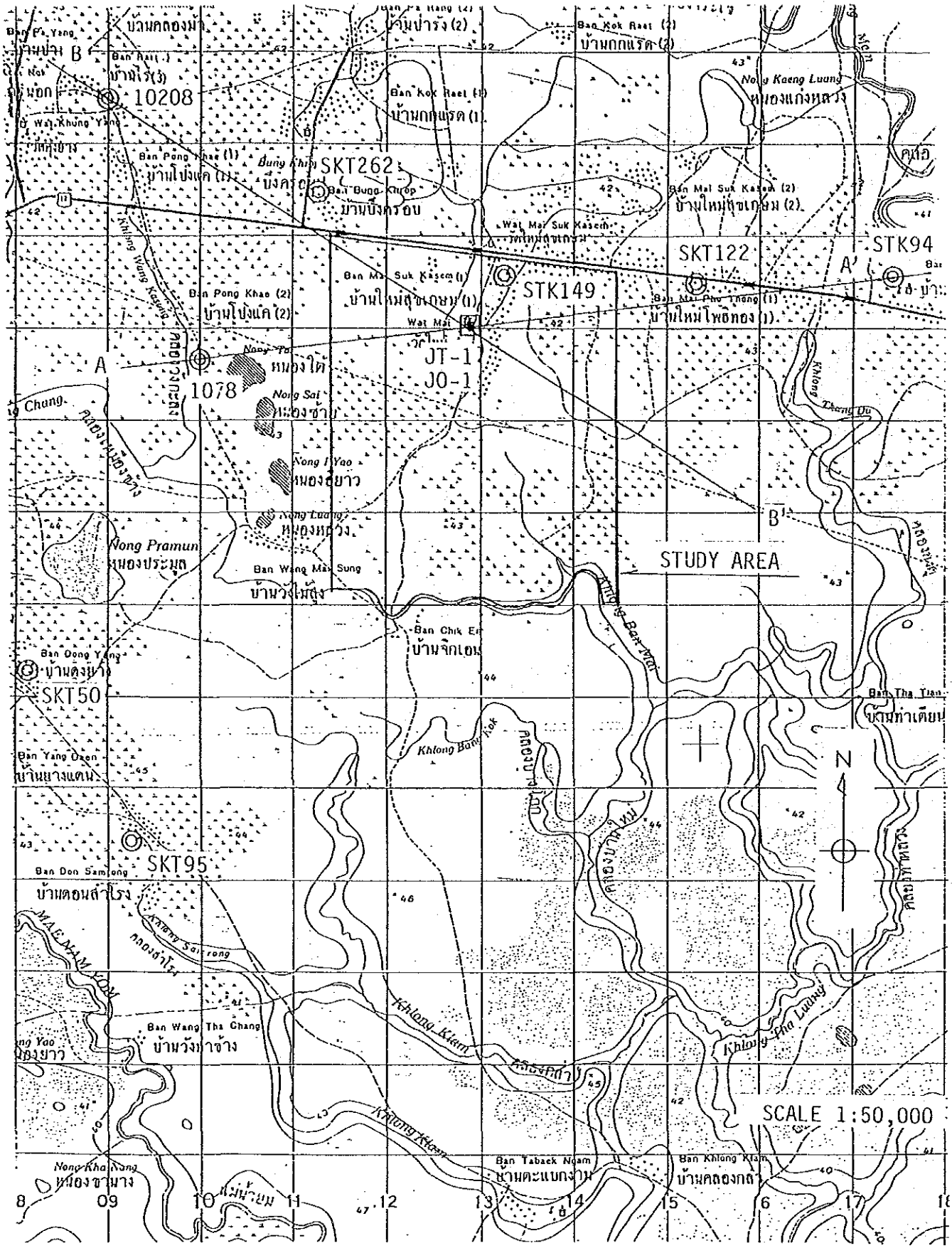


Figure B-2-3 LOCATION OF WELLS AND CROSS SECTION IN NONG KHON KAEN

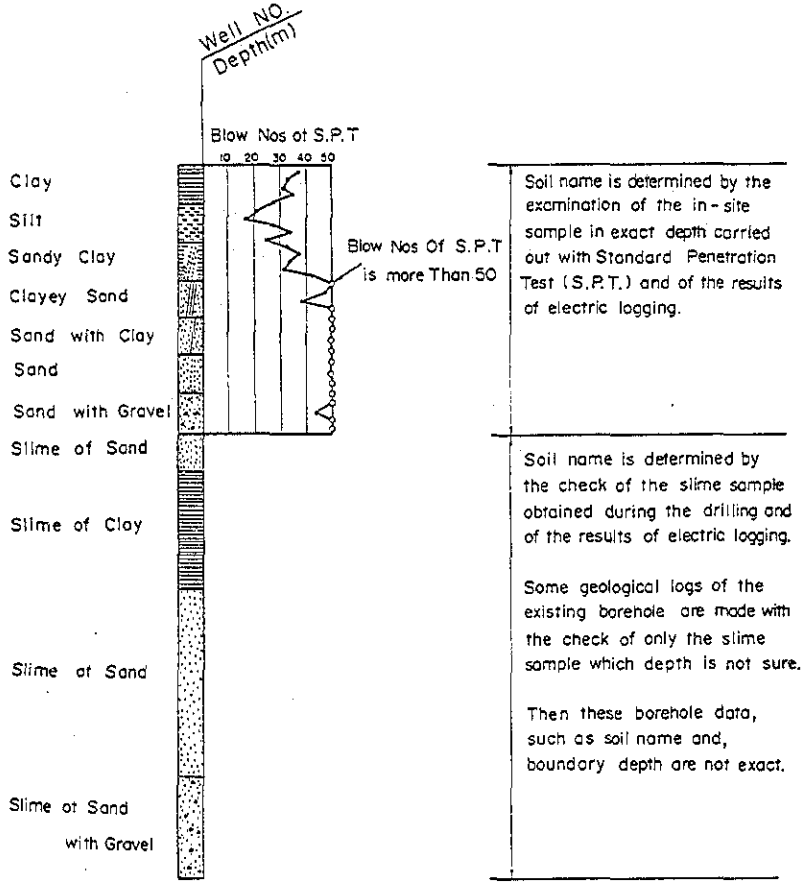


Figure B-2-4 LEGEND OF BORING LOG

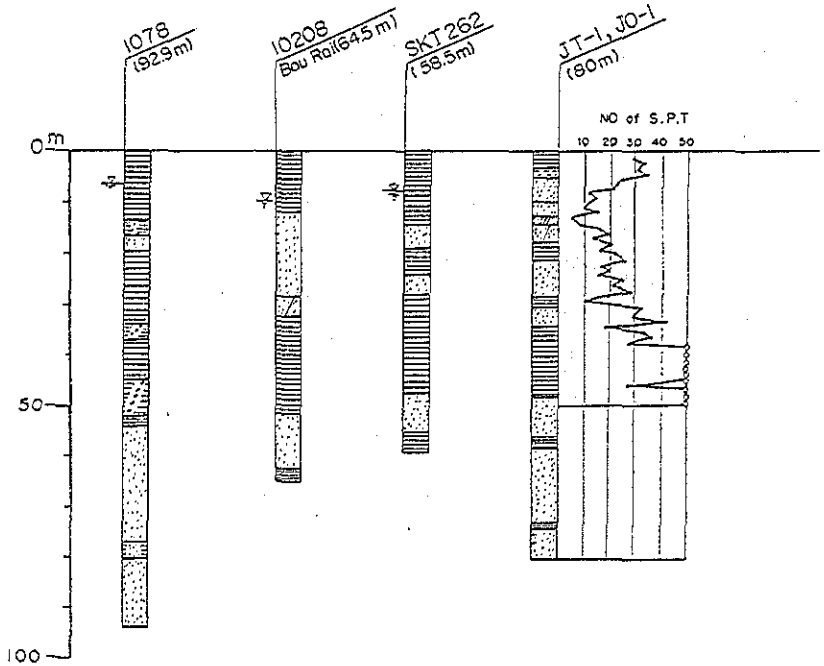


Figure B-2-5 SUMMARY OF BORING LOGS IN NONG KHON KAEN
Scale 1:1,000

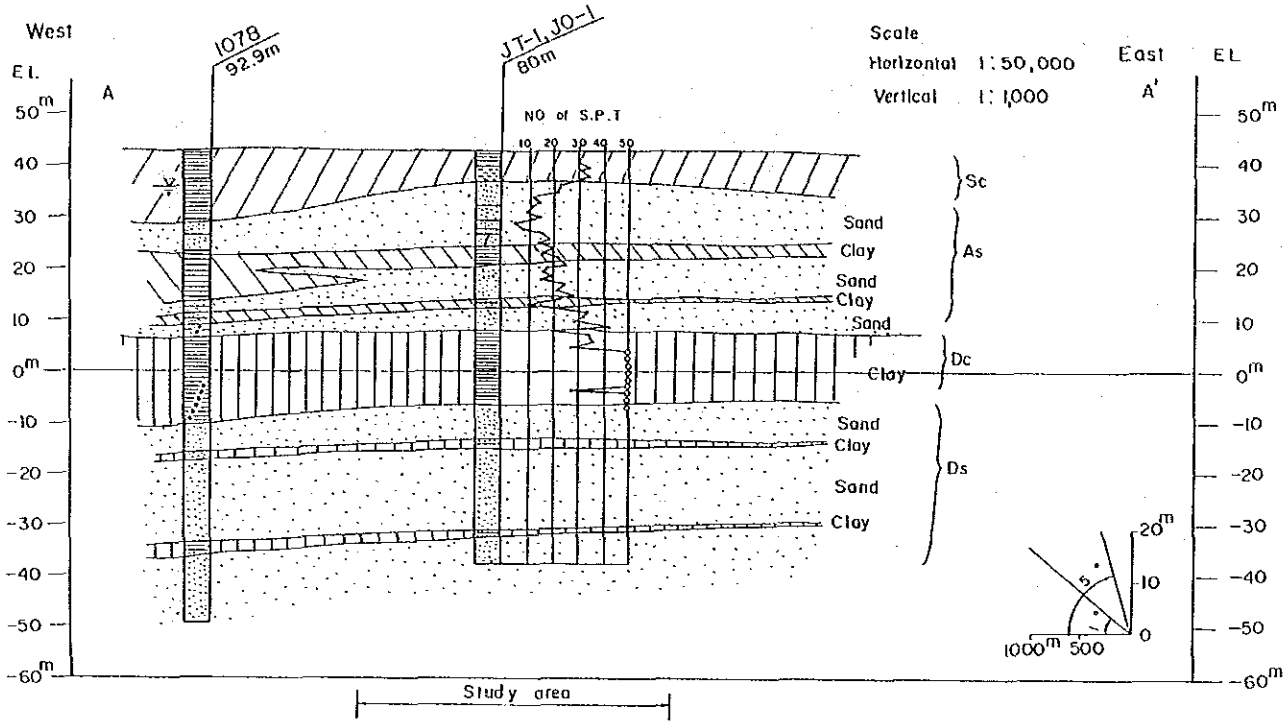


Figure B-2-6 GEOLOGICAL CROSS SECTION A-A' IN MONG KHON KAEN AREA

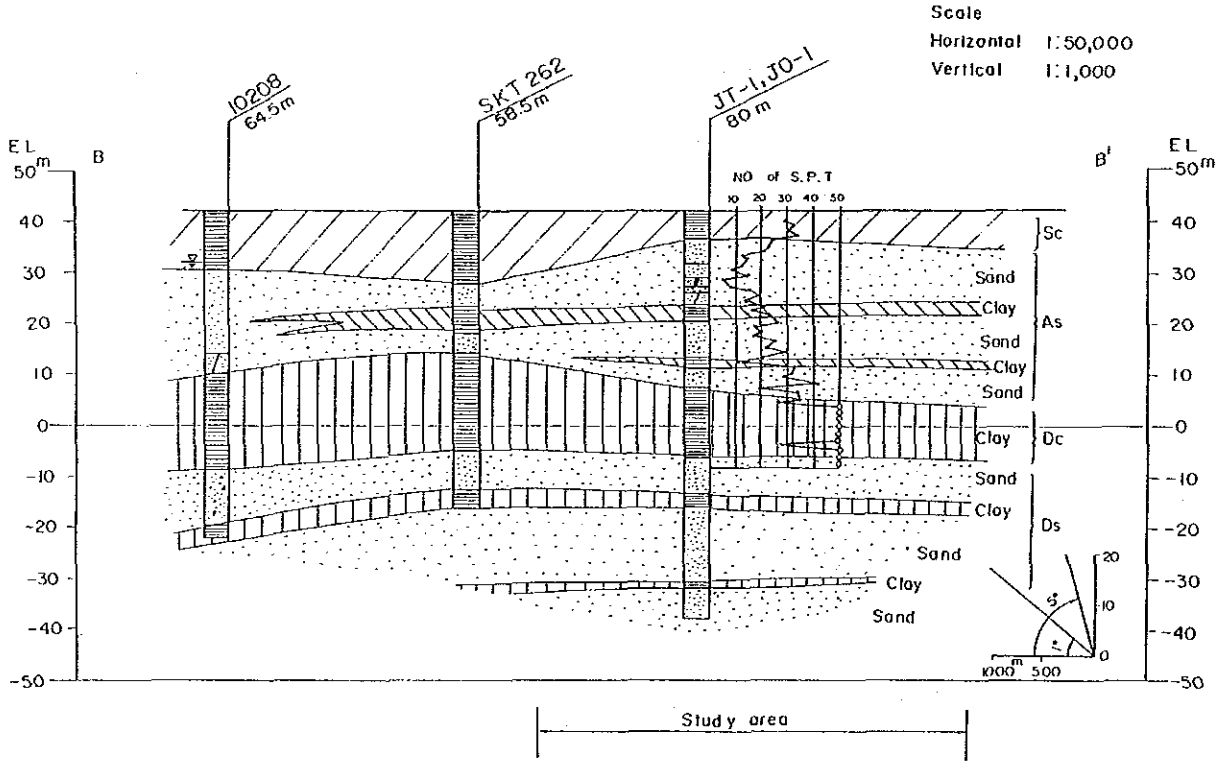


Figure B-2-6 GEOLOGICAL CROSS SECTION B-B' IN NONG KHON KAEN AREA

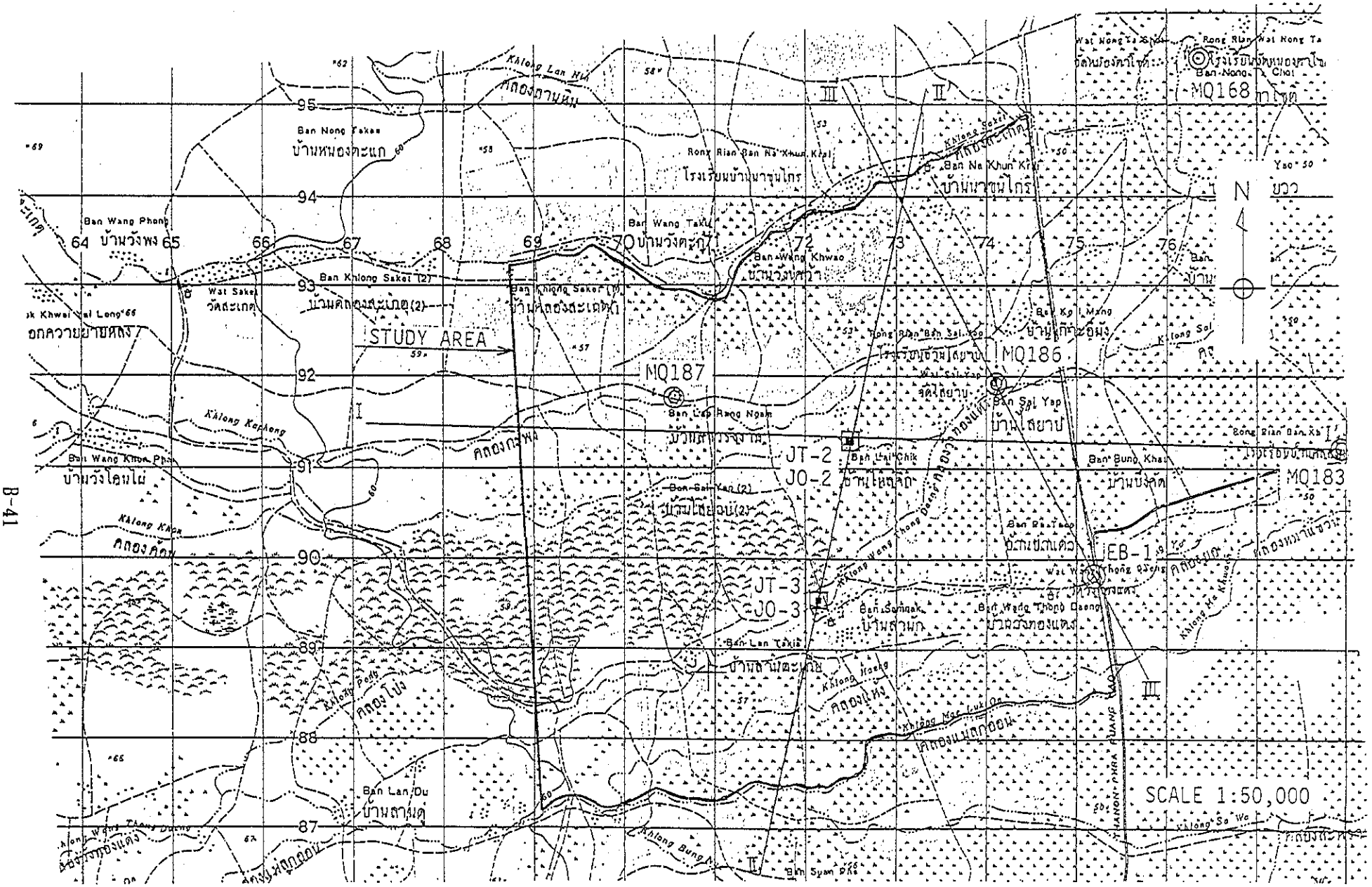


Figure B-2-7 LOCATION OF WELLS AND CROSS SECTION IN THUNG SAI YART

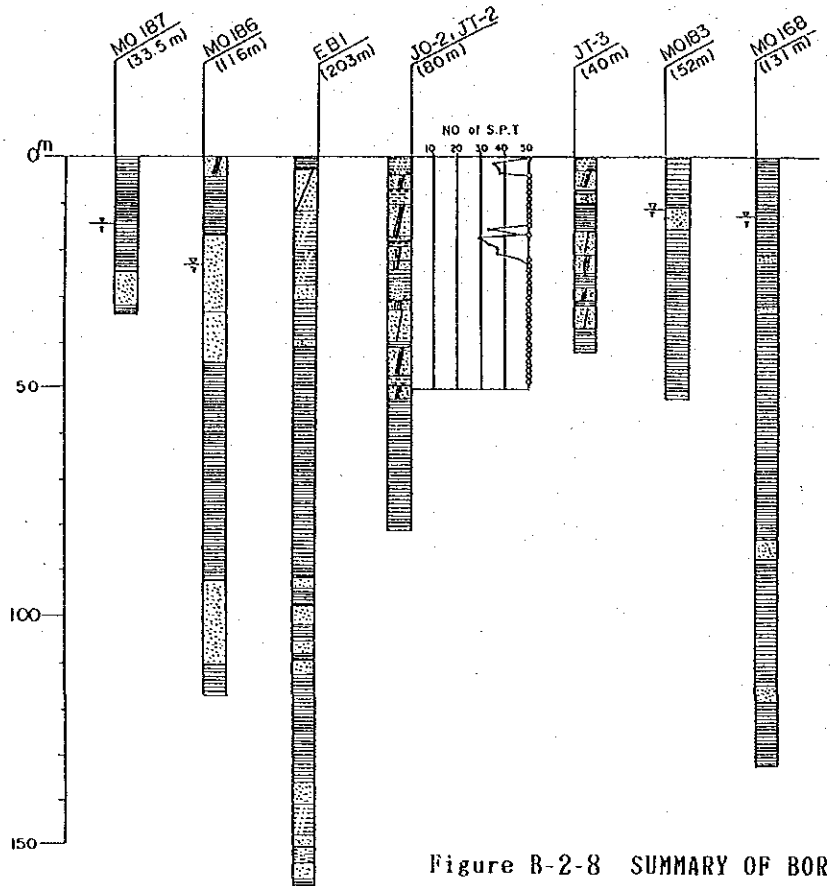


Figure B-2-8 SUMMARY OF BORING LOGS IN THUNG SAI YART

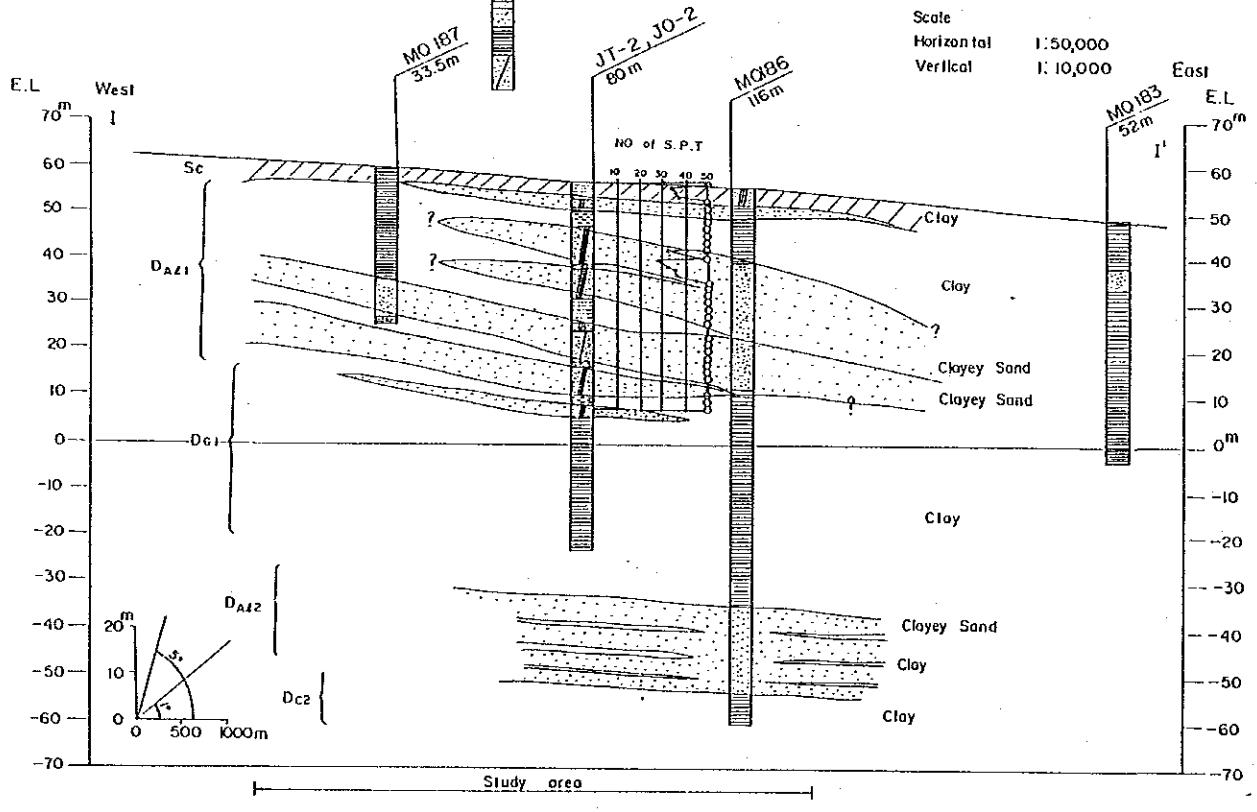


Figure B-2-9 GEOLOGICAL CROSS SECTION I-I' IN THUNG SAI YART

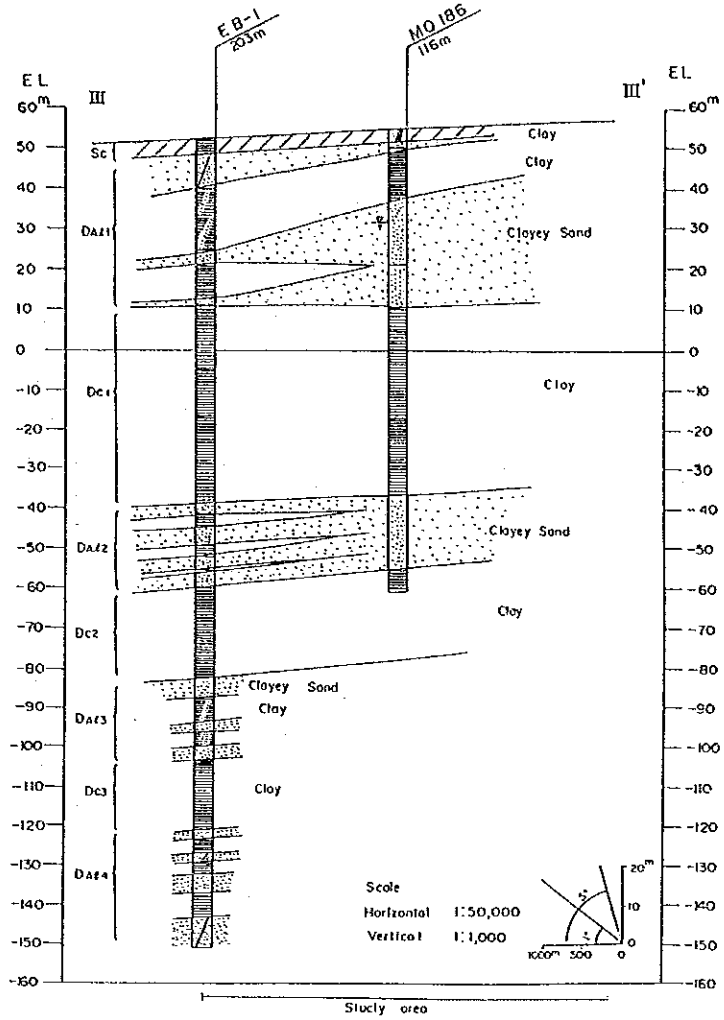


Figure B-2-9 GEOLOGICAL CROSS SECTION II-II' IN THUNG SAI YART

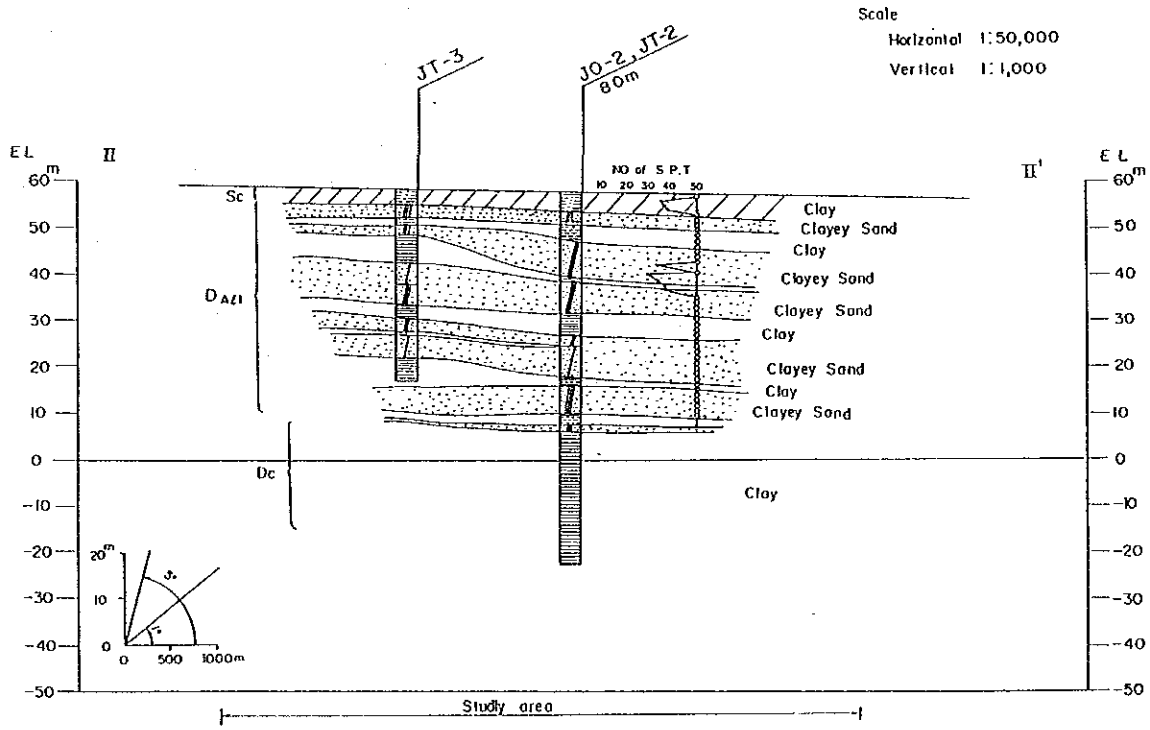
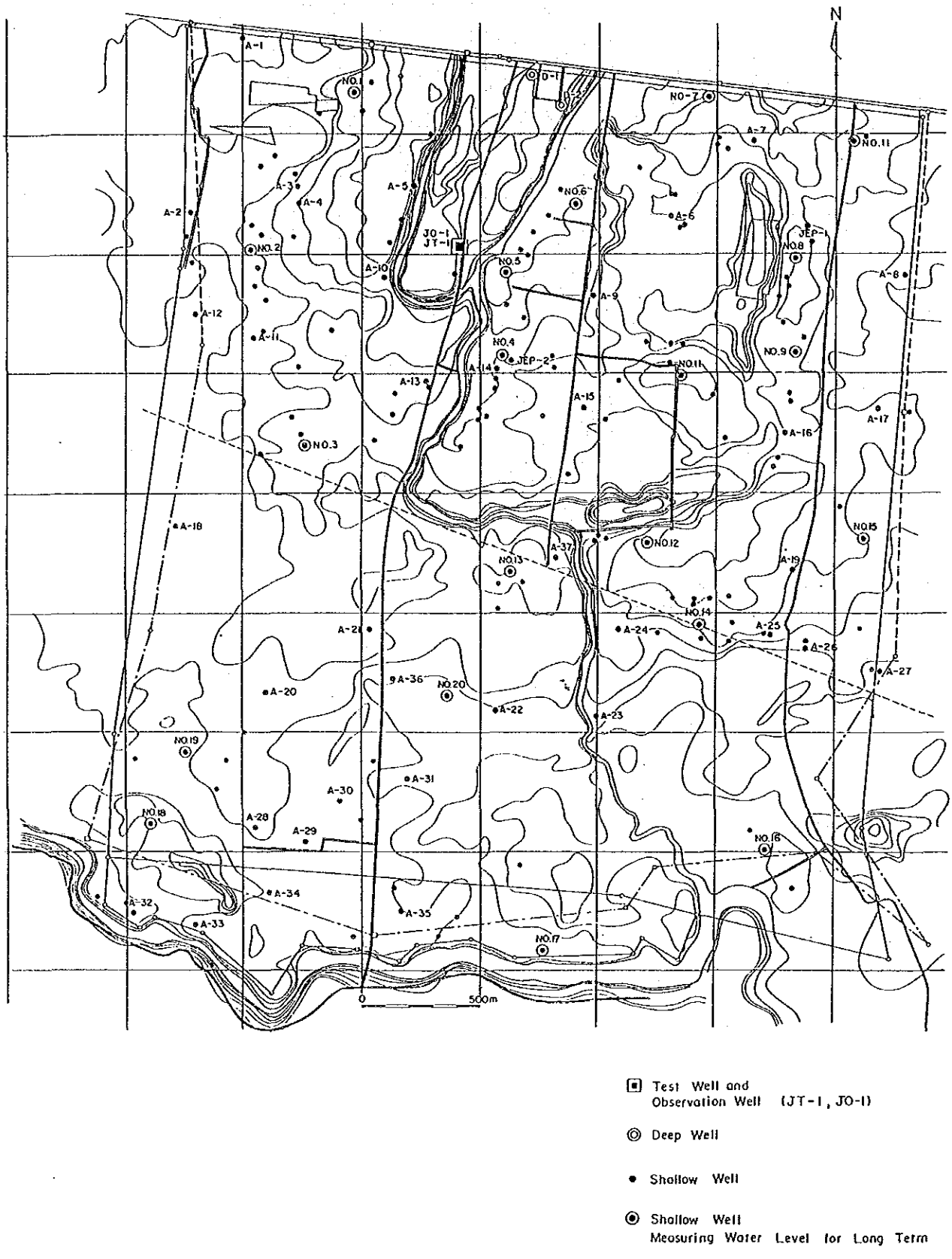


Figure B-2-9 GEOLOGICAL CROSS SECTION II-II' IN THUNG SAI YART



Test Well and Observation Well (JT-1, JO-1)

Deep Well

Shallow Well

Shallow Well Measuring Water Level for Long Term

Figure B-2-10 LOCATION MAP OF WELLS IN NONG KHON KAEN AREA

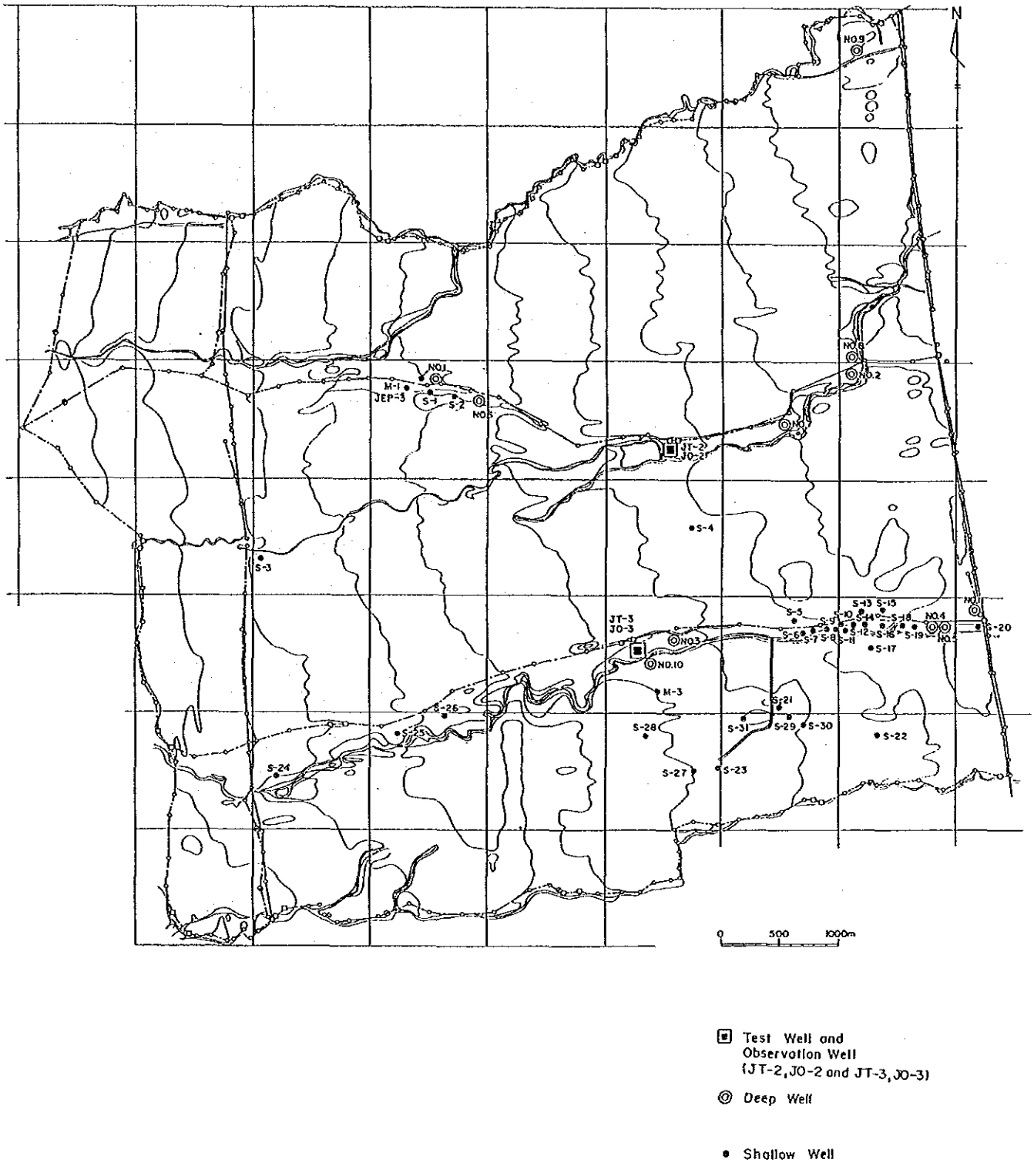


Figure B-2-10 LOCATION MAP OF WELLS IN THUNG SAI YART AREA

Figure B-2-11 COUNTER MAP OF WATER LEVEL MEASURED IN SHALLOW WELL

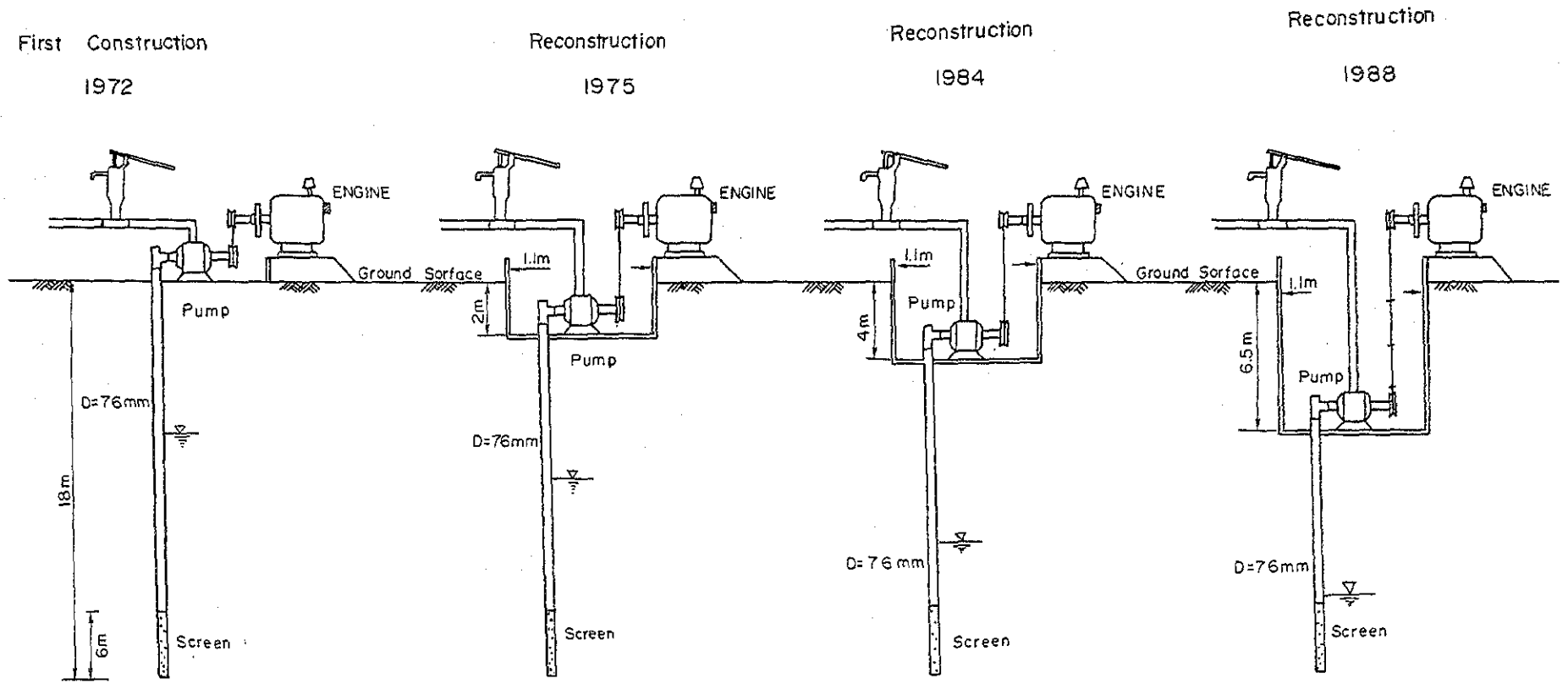
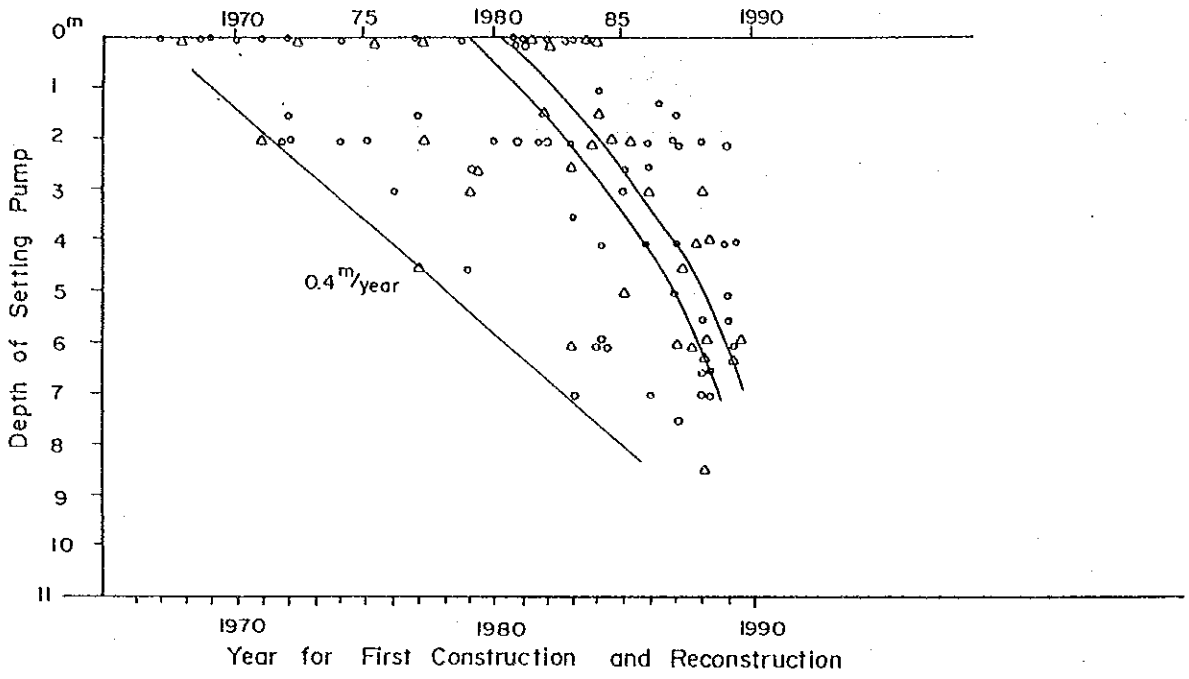


Figure B-2-12 SAMPLE OF RECONSTRUCTION DETAILS OF SHALLOW JET WELL A – 8



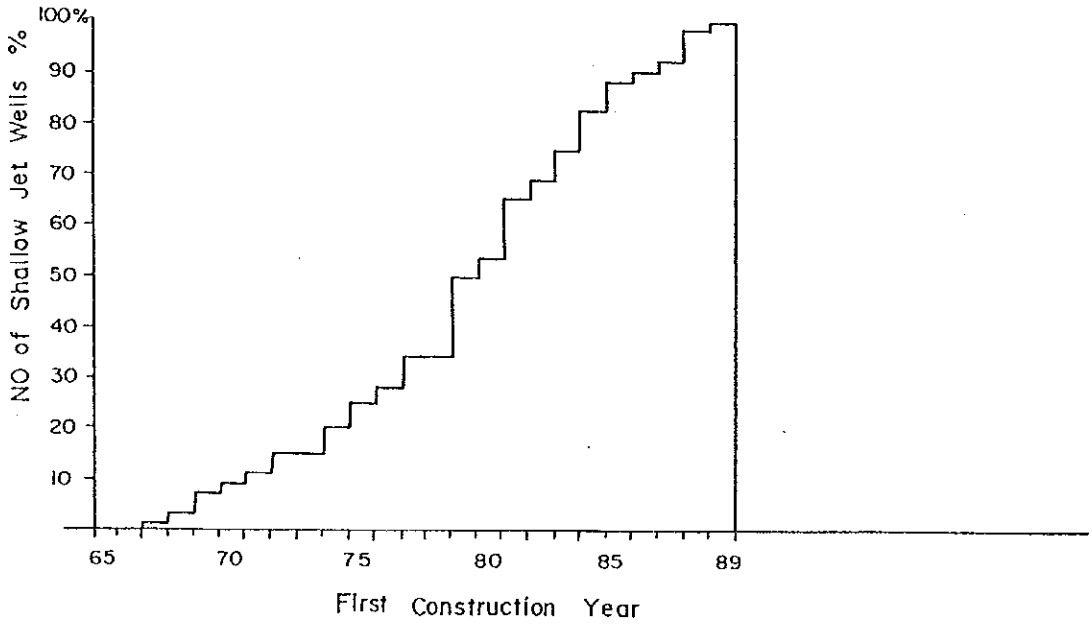


Figure B-2-13 CHANGE OF SETTING DEPTH OF PUMP AND CONSTRUCTION NO OF SHALLOW JET WELLS (NONG KHON KAEN)

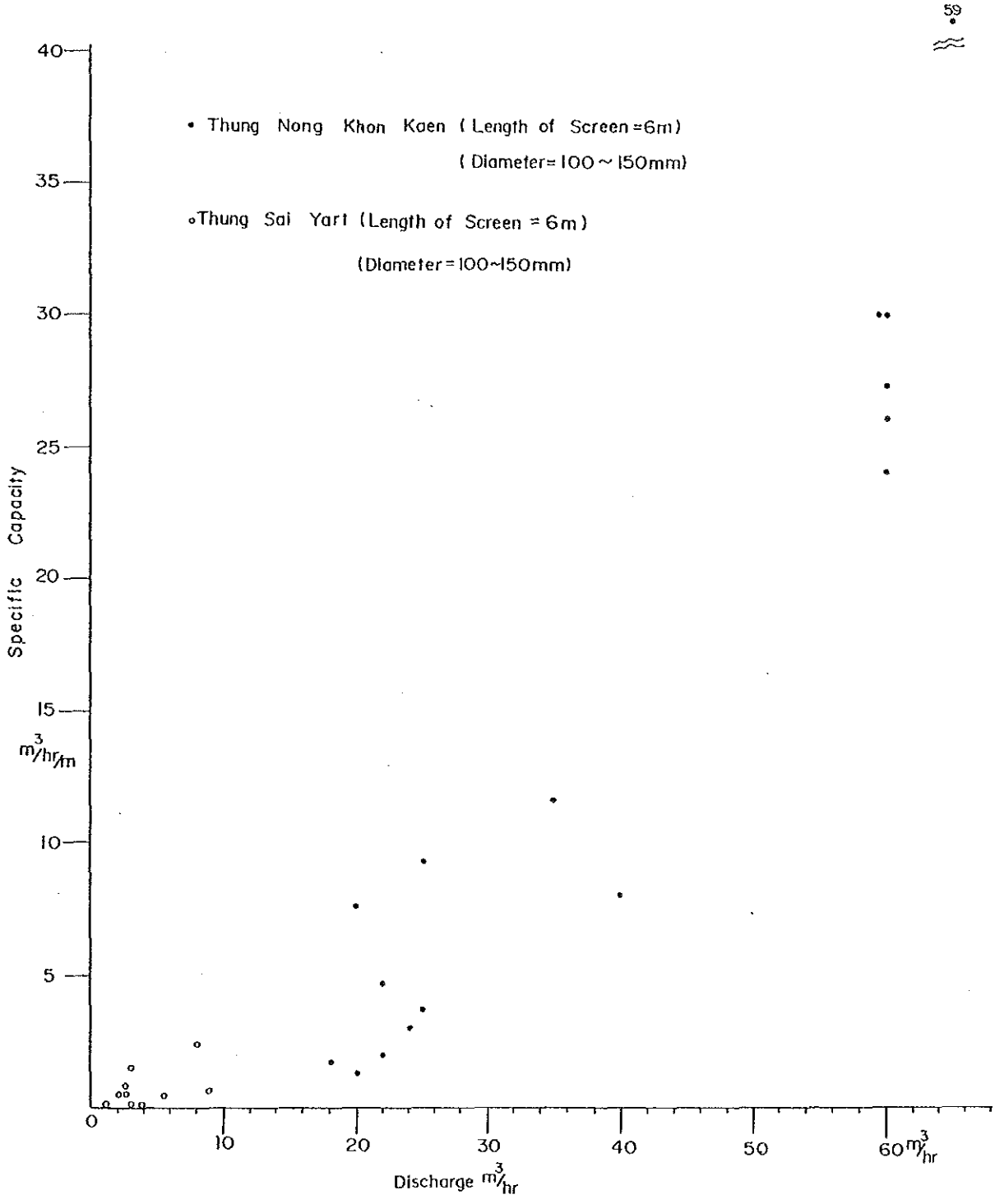


Figure B-2-14 EXISTING DATA BETWEEN SPECIFIC CAPACITY AND DISCHARGE

Appendix B-3 IRRIGATION AND DRAINAGE

B-3-1 Present Condition

(1) Water Resources Facilities

Nong Khon Kaen

In the existing canal, many small temporary dikes with 0.5 to 1.0 m in height were constructed across the canal to store excess water, so that the discharge area of canal is smaller as streams run down.

Run-off condition of these canals has been changed due to small scale irrigation projects and swamp inland fishery projects constructed in the upstream basin. Namely, timing of run-off is delayed and amount of discharge available for irrigation is likely to be limited except from September to November in wet season, as a result of water use in their projects. Developed projects are shown in Figure B-3-1 and Table B-3-1.

There are two swamps with 0.5 to 1.0 m of depth and one pond constructed by DLD. Pond is not useful at present due to lack of collecting canals. Present condition is shown in Table B-3-2.

Thung Sai Yart

Collected data and information shows that moderate run-off pattern takes place in from September to October and no water flows in February to March in dry season. In the canal, many small dikes constructed by farmer with height of 0.5 to 1.0 m exist across the canal to retain irrigation water as much as possible.

There is a weir crossing the Wang Tong canal, which has been constructed by Small Scale Irrigation Project of RID in 1988 to irrigate service area of 500 rai. And, earthfill dike constructed by farmer is also in downstream of the weir which has capacity of about 490,000 cu.m with dike height of about 3.0 m and is capable of retaining water even in dry season.

(2) Irrigation and Drainage Condition

Nong Khon kaen

Low-lying cultivated land of 35% of whole area is subject to flooding/inundation. The extent and severity of flooding is dependent on many factors. In west low-lying paddy area, inflow of excess water from upstream paddy field and insufficient capacity of canals sometimes cause inundation. And, in east low-lying area, insufficient drainage capacity of Ban Mai canal and backwater from Yom river obstructs appropriate drainage flow.

Severity is assumed that the average depth of inundation is from 0.4 to 0.6m for a duration of one month, depending on downstream drainage capacity of Ban Mai canal and Yom river, as a result of interviews to farmer. Extent and inundation depth is shown in Figure B-3-2. Remainder is not subject to any significant flooding.

Ban Mai canal joins to Yom river at 10 km downstream of the study area, at where field elevation is from 37 m to 40 m. In 3 km of Ban Mai canal, RID has dredging plan with completion year of 1990.

Canal, pond, swamp, culverts under the road exist in the study area, as a facilities with both functions of irrigation and drainage. Those facilities are shown in Table B-3-3 and Figure B-3-3.

Thung Sai Yart

Agricultural land adjacent to the secondary road route 1113 is liable to severe flooding. It is difficult to estimate the average situation of damaged area and its severity in a normal year. But, for planning purpose, it is assumed from interviews to farmer that 23% of agricultural land is subject to flooding and its average depth of inundation is from 1.0 to 1.5 m for a duration of 7 days, as shown in Figure B-3-4. In the interviews to farmer, it was reported that most of farm land had not experienced severe flooding excepting partial inundation, before construction of neighboring secondary road.

There are 33 of pipe culvert from 600 to 1,200 mm and 3 of bridge under the road as shown in Figure B-3-5. Natural drainage is possible judging from ground slope of 1/700 to 1/1000 in the drainage basin. Insufficient drainage capacity, therefore, is considered to be one of factors caused inundation in the area.

Four streams joins to Yom river at 12 km down of secondary road, at where field elevation is average 48.0 m. Since lowest field elevation in the study area is 55.0 m, it is considered to be no influence of backwater from Yom river.

There are canals, pond, weir and pipe culverts with both functions of irrigation and drainage, as shown in Figure B-3-6. Many of ponds are located along the canal to take water easily, but, are not equipped with inflow and outflow facilities. Borrow pits are also utilized as a irrigation facility. Location and capacity of those facilities have been investigated as shown in Table B-3-2.

(3) On-farm facilities

Nong Khon Kaen

Cadastral map shows that the number of farm plot is 532 and a width of allocated plot is mostly in a range of 30 to 200 m and 200 to 600 m in short and long sides, respectively, and its average size is 12 rai. Farm plots along the canals are allocated as its short side is close to that canal, in order that all plots possible are accessible to storage water.

A farm plot is actually divided into some farming fields by border, depending on farming practices of each farmer. But, most of farm plots hardly equipped with access road and irrigation/drainage canals. Those physical constrains has prevented each farmer to improve daily farming practices.

Thung Sai Yart

Cadastral map shows that the number of farm plot is 2,106 and a width of allocated plot is mostly in a range of 30 to 100 m and 200 to

1,000 m in short and long sides and its average size is 15 rai. Farm plots more than 25 rai exists in the area. Most of farm plots are allocated along the existing canal, and on-farm condition is almost same as the Nong Khon kaen.

B-3-2 Water Resources Development Plan

(1) Annual Pumping Discharge by the Existing Wells in Nong Khon Kaen

(a) Estimation by current utilization condition

In this area, there are two deep wells for drinking water and 169 shallow wells for wet and dry paddies irrigation. In the 169 wells, 164 wells are used at present. In the 51 of the 164 wells, current utilization conditions were studied by questionnaire. Results are summarized as follows.

- 47 of the 51 wells investigated are used at present for irrigation. Utilization ratio is (47/51 x 100 = 92%).

- Driving days is as follows.
  Dry season: Total is 3235.5 days in the 47 wells
  3235.5 days / 47 wells = 68.84 days per one well.
  Wet season: Total is 1508.5 days in the 47 wells
  1508.5 days / 47 wells = 32.10 days per one well.

- Pumping capacity is from 18 - 20 m^3/hr (about 5 - 6 l/sec). Driving time is assumed at 18 hours in a day.

- Pumping discharge is calculated as follows :
  (18 - 20 m^3/hr) x 18 hr = (324 - 360)m^3/day = 350m^3/day.

- Annual pumping discharge is estimated as follows :
  Dry season: 164 wells x 0.92 x 68 days x 350m^3/day = 3.6 MCM
  Wet season: 164 wells x 0.92 x 32 days x 350m^3/day = 1.7 MCM
  Total = 5.3 MCM

(b) Estimation based on water requirement

Water requirement for rice crop varies due to method of cultivation. However, average water requirement from land preparation to harvest is ;

from 9,000 to 10,000 m^3 per ha (1,400 - 1,600m^3/rai) in wet paddy
from 10,000 to 13,000 m^3 per ha (1,600 - 2,000m^3/rai) in dry paddy

In dry season, most of irrigation water is supplied by wells. But, in wet season the existing wells are used as a supplementary supply facility. Pumping discharge in each season is assumed as follows.

Dry season : Irrigation area - 490 ha
Water requirement: 11,500m^3/ha x 490 ha = 5.6 MCM
Pumping discharge: In general, water requirement more than 80% is from groundwater due to limited storage water in the canal and swamp. Therefore, pumping discharge is assumed as follows : 5.6 MCM x 0.9 = 5.0 MCM

Wet season : Irrigation area - 1,050 ha
Pumping discharge: Pumping is dependent on uncertain rainfall and run-off. But, it is estimated to be 1.5 to 1.8 MCM based on water balance study, assuming that rainfall and run-off are used effectively.

Annual pumping discharge is estimated at (5.0 + 1.7 = 6.7 MCM).

Based on the above (a) and (b), annual pumping discharge is assumed at average 6.0 MCM.

(2) Storage Capacity

It will be impossible to construct large-scale storage facility with full operation throughout the year. Storage facilities, therefore, is consisted of improved swamps, canals and newly constructed ponds. Scale of storage ponds is planned based on excess run-off available and future way of farming practices. Related to the future irrigation system, utilization method of storage water in the pond has to be considered as

follows.

Plan-(a): Irrigation water is lifted by farmer's portable pump from dual purpose canal leading to the pond into each farm without any control. In this case, effective depth of pond is limited at around 2.0 m due to limited available depth of canal.

Plan-(b): Irrigation water is supplied by cooperative pump installed at pond and irrigation purpose canal. Supply is controlled by the pump operation. In this case, effective depth of pond is capable of pumping at around 4.0 m.

In the plan-(b), appropriate water management has to be carried out by beneficial farmer for fair water distribution by common use pump. In this study, therefore, this plan is applied in development model-3 because it is attended with higher improvement level of physical condition and intensive farming practices. Plan-(a) is applied in model-1 and 2.

Storage capacity by model is planned as shown in Table B-3-4. Detailed capacity of model-2 is planned as shown in Table B-3-5 and Figure B-3-7.

(3) Irrigable area in Thung Sai Yart

In wet season, agricultural land will be divided into two of rain-fed and irrigation areas, even if irrigation facilities are provided fully, because run-off available is limited at the initial stage of paddy planting from June to August.

Irrigation area is dependent on amount of rainfall, run-off and available volume of storage pond and canal at that period. Scale of area, therefore, has been examined based on the relation among them, as shown in Figure B-3-8.

- Maximum irrigable area is around 3,000 ha in a normal year, with around 5.2 MCM of available storage volume. Even if any storage facilities with more than 5.2 MCM are constructed, irrigable area is unable to extend due to limited run-off and rainfall at the beginning of wet season.
- And, the less is available storage volume, the less is irrigable area.

- In case of no storage pond, irrigable area is assumed at around 1,000 to 1,500 ha, on the assumption that feeder canal is provided fully in the field.

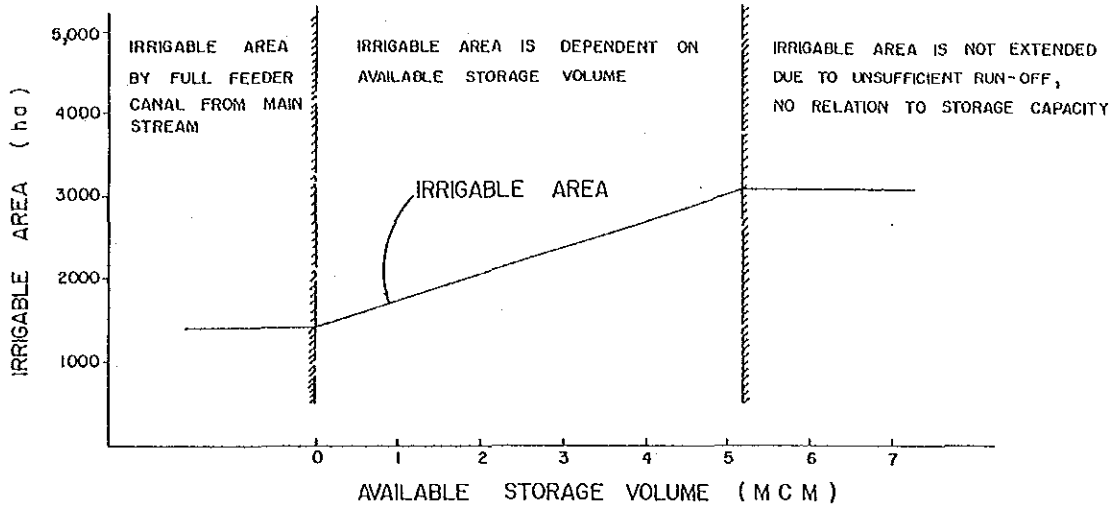


Figure B-3-8 RELATION BETWEEN STORAGE CAPACITY AND IRRIGABLE AREA

B-3-3 Agricultural Infrastructure Development Plan

(1) Alternative Development Models

Alternative models have been studied based on development components and land classification as shown in Figures B-3-9. As a result of study, layouts of each models are shown in Figures B-3-10 to B-3-12. and quantity of construction facilities are shown in Table B-3-6. Based on the layouts, construction cost, impact to the surrounding agriculture and capability of farming technique have been examined.

In each models, construction cost and O/M cost are estimated as shown in Table B-3-7. In the model-1 and 2, private shallow well and portable pump is operated to supply water. In the model-3, cooperative well and pump is operated instead of private ones, which is driven by electric. Electric charge and operator recruited, therefore, will be required.

(2) Calculation of Water Requirement

(a) Potential evapotranspiration

There are some methods for estimation of potential e vapotranspiration. In this study, Penman method used generally in Thailand is applied. As a necessary climatic information, data at Phitsanulok observation station is used, due to no station in the study areas. Estimated potential evapotranspiration is as follows.

Potential Evapotranspiration (mm/day)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
3.63	4.91	5.31	5.83	5.13	4.77	4.38	4.05	4.27	4.16	4.02	3.48

(b) Consumptive use of crop

Consumptive use of crops could be estimated by multiplying potential evapotranspiration by crop coefficient of crop growing stages. Crop coefficient used in this study is summarized in Table B-3-8.

Table B-3-8 SUMMARY OF CROP COEFFICIENTS

Stage	Crop Coefficient						
(10-days)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0.90	0.83	0.50	0.50	0.50	0.80	0.70
2	0.95	0.87	0.99	0.50	0.50	0.80	0.70
3	1.06	0.93	0.99	0.70	0.70	0.80	0.70
4	1.16	1.06	0.99	0.90	0.80	0.80	0.70
5	1.20	1.06	1.08	1.10	0.90	0.80	0.70
6	1.27	1.06	1.16	1.10	0.90	0.80	0.70
7	1.30	1.06	1.20	0.90	1.10	0.80	0.70
8	1.30	1.06	1.27	0.50	1.10	0.80	0.70
9	1.20	0.96	1.30	0.50	1.10	0.80	0.70
10	-	0.83	1.32	-	0.90	0.80	0.70
11	-	0.72	1.32	-	0.50	0.80	0.70
12	-	-	1.24	-	-	0.80	0.70
13	-	-	-	-	-	0.80	-
14	-	-	-	-	-	0.80	-

Note: (1) Wet season transplant, high yield
(2) Wet season transplant, local
(3) Wet season broadcast, high yield
(4) Soybean, (5) Soybean, (6) Orchard, (7) Vegetables.

(c) Field water requirement

Field water requirement is estimated based on percolation loss, water requirement for land preparation and nursery bed and soil sampling test for availability of residual moisture.

(d) Irrigation water requirement

Irrigation water requirement is calculated based on the field water requirement, effective rainfall and irrigation efficiency.

The effective rainfall for paddy fields is assumed at the rate of 60 to 90% of monthly rainfall, as follows.

	Rate of effective rainfall(k)										
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
(k)	0.90	0.90	0.90	0.75	0.75	0.75	0.75	0.75	0.65	0.80	0.90	0.90

The effective rainfall for upland crop is assumed at the rate of 65 to 85% of monthly rainfall, based on crop evapotranspiration and available water retention capacity of 75 mm in soil.

Irrigation water requirement is calculated based on the above conditions and field efficiency of 60% applied in this study. The results are shown in Table B-3-9 and Figure B-3-13.

(3) Estimation of unit drainage discharge

(a) Drainage in paddy field

In general, excess water flows in the paddy field as follows.

- Paddy field is capable of retaining water with boundary border.
- Excess water retained is drained through notch outlet or overflow from border.
- Paddy does not suffer from inundation damage in case that ponding depth and its duration are allowable which are considered to be 250 mm and three days.
- Unit duration of severe continuous rainfall is from three to five days,

judging from daily records of rainfall in the area.

Design drainage discharge, therefore, is defined that three-days continuous rainfall is drained in a duration of three-days, assuming that initial ponding depth is 50 mm and after three days, it is 100 mm, and consumptive use and percolation are negligible. Return period of 10-years is applied in this study.

Nong Khon Kaen

3-days continuous rainfall of 10-year return period = 188 mm

Design discharge (q) is ;

q = (188 - (100 - 50))/3 days = 46 mm/day (5.32 l/sec/ha)

Thung Sai Yart

3-days continuous rainfall of 10-year return period = 172 mm

q = (172 - (100 - 50))/3 days = 41 mm/day (4.75 l/sec/ha)

(b) Drainage in upland field

In upland crop area, excess water should be drained without severe inundation damage. Design discharge is projected as one-day rainfall is drained in a duration of one-day. In this case, peak run-off coefficient is assumed at 60% in case of cultivated flat area.

Nong Khon Kaen

One-day rainfall of 10-year return period = 111 mm

q = (111 × 0.6) / 1 day = 67 mm (7.75 l/sec/ha)

Thung Sai Yart

One-day rainfall of 10-year return period = 112 mm

q = (112 × 0.6) / 1 day = 67 mm (7.75 l/sec/ha)

(3) Inland fishery

Inland fishery is capable of practicing fish culture by using improved storage ponds, as a side job of agriculture. Data and information, such as type of fish expected in this region, rearing period and stocking rate, were collected as shown in Table B-3-10.

Table B-3-1 SMALL SCALE IRRIGATION PROJECTS BY RID RELATED TO STUDY AREA(1)

Name of of Project	No.	Irrigation Area (rai)	Construction Plan Facility	Scale	Const. Cost (mil.Baht)	Comple--tion Year
Completion						
Huai Khrai	(1)	3,000	Weir	L=25m, H=2.5m	2,328	1982
Huai Khao Makok	(2)	1,500	Weir	L=13m, H=1.5m	0.734	1985
Khao Khwang	(3)	3,000	Weir	L=15m, H=1.5m H=1.5m	1.483	1984
Wang Hin	(4)	2,000	Dredging	W=30m, L=6km D=1.5m	1.134	1988
Lan Ta Kia	(5)	500	Reservoir	W=4m, H=2m L=300m	0.684	1988
Khlong Ta Pai	(6)	500	Dredging	W=40m, L=2km D=1.5m	0.279	1981
Under-Construction						
Na Kaw Bao-Nong Ngoen	(7)	500	Dredging	W=2m, L=300m D=1.0m	0.510	1989
Under-Planning						
Khlong Wang AI Mod	(8)	700	Dredging	W=12m, L=3km D=3.0m	0.817	1990
Khlong Lai Him Dat	(9)	-	Dredging	W=5m, L=1500m D=3.0m	n.a.	1991
San Pa Him	(10)	3,000	Weir	L=25m, H=2.0m	n.a.	1991
Wang Sai Yoi	(11)	1,800	Weir	L=25m, H=2.0m	n.a.	1991

Note ; No. showes the location of projects on the Figure B-3-1.
Khlong Lai Him Dat Project is for domestic use.

Table B-3-1 WATER RESOURCES DEVELOPMENT PROJECTS RELATED TO THE STUDY

Inland Fishery Project related to Study Area

Related Study Area	Upstream Canal	Num--ber	Swamp Area(rai)	Water Depth(m)	Connected Culvert	Const. Cost(Baht)
Nong Khon Kaen						
Nong Bang Khrop	Yai	(1)	25.0	3 ~4	φ600 ×1 φ800 ×1	577,000
- do -	Yai	(2)	135.6	3.0	n.a.	1,911,650
Sai Yart						
Klong Khan Sua	Sai Yat	(3)	19.5	2 ~3	φ600 ×2	591,700
Nong Nam Khon	Sai Yat	(4)	12.0	n.a.	n.a.	330,000

Note : Small swamp inland fishery projects are planned and constructed year by year. There are no plans in the basins of both areas, as of 1989.

Small Scale Irrigation Project under planning in Yom River

Name of Project	No.	Purpose
Wang Hin Weir	(12)	Domestic Use
Ban Bang Ba Weir	(13)	- do -
Ban Kong Weir	(14)	- do -
Ban Tha-Chai Weir	(15)	- do -
Ban Pai Lom Weir	(16)	- do -
Ban Ta Kway Weir	(17)	- do -
Nong Mae Ra Wing	(18)	- do -
Bong Yai	(19)	- do -

Note ; 1. Nong Mae Ra Wing is the excavation of swamp and construction of dike with structures.
2. Bong Yai is the construction of canal from Bong Yai to Yom River.

Medium Scale Irrigation Projects relevant to Study Area

Name of Project	Construc--tion year	Irrigation Area(rai)	Improvement Facility
Tha Cha Nuan	1975-1977	20,000	3 Head Regulators 3 Natural Channels (L=13 km)
Ban Lom	1969-1971	n.a.	1 Head Pipe Regulator 1 Natural Channel
Klong Ka Chong	1976-1976	4,000	2 Head Pipe Regulators 1 Natural Channel (L=6.3 km)

Table B-3-2 CAPACITY OF EXISTING STORAGE FACILITY

Facility	Quantity	Area(sq.m)	Total Capacity(cu.m)	
Nong Khon Kean				
Swamp(1)	1	24,000	16,800	
Swanp(2)	1	66,000	26,400	
Pond by DLD	1	52,000	145,000	
Canal	6.1 km		240,300	
Total			428,500	
Thung Sai Yart				
Pond	19	46,000	165,000	
Borrow pit(1)	7.4 km	70,000	43,900	(Wang Thong Daeng)
Borrow pit(2)	4.6 Km	23,000	22,900	(Sai Yart)
Canal	58.8 km		1,016,000	
Pond by RID	1		625,400	
Pond by farmer	1		489,900	
Total			2,363,100	

Note ; Swanp(1) is located in northwest and swamp(2) is near to Noi canal
Related to capacity of pond, that by DLD is estimated by drawing map and the others is assumed by topography maps.

Table B-3-3 SCALE OF THE EXISTING CANAL

Name of Canal	Length (km)	Average width(m)	Average depth(m)	Estimated Capacity(cu.m)
Nong Khon Kaen				
Yai	1.40	30-70	1.5-2.2	102,700
Noi	4.68	20-50	0.5-2.0	137,600
Total	6.08			240,300
Sai Yart				
Sra Ket	9.80	10-20	1.8-2.0	223,400
Ta Look	5.60	10-15	1.2-1.6	61,600
Sai Yat	14.00	10-20	1.5-2.0	210,000
Wang Tong Daeng	14.80	10-20	2.0-2.5	268,800
Mae Luk Onn	14.60	10-20	1.0-2.5	252,200
Total	58.80			1,016,000

Note ; Capacity is estimated based on average width and depth assumed by topography maps and cross-section measured for water level observation. Capacity of Wang Tong Deang canal is estimated except for dike and weir.

Table B-3-4 STORAGE CAPACITY BY MODEL IN THUNG SAI YART

Unit ; MCM

Facilities	Current		Model-1		Model-2		Model-3	
	Full	Eff.	Full	Eff.	Full	Eff.	Full	Eff.
RID's weir	0.63	0.37	0.72	0.63	0.72	0.63	1.34	1.25
Farmer's pond	0.49	0.29	0.63	0.33	0.63	0.33	0.76	0.65
Canal	1.02	0.60	1.00	0.80	1.00	0.80	1.00	0.80
Others	0.23	0.16	0.23	0.18	0.23	0.18	0.23	0.18
New pond	-	-	-	-	2.45	1.98	6.61	6.00
Total	2.37	1.42	2.58	1.94	5.03	3.92	9.94	8.88

Note ; Full is total capacity and Eff. is effective capacity for irrigation.
Farmer's pond has both functions of irrigation and fishery in the model.

Table B-3-4 STORAGE CAPACITY BY MODEL IN NONG KHON KAEN

Unit ; 1000 cu.m

Facilities	Current		Model-1		Model-2		Model-3	
	Full	Eff.	Full	Eff.	Full	Eff.	Full	Eff.
Swamp-(1)	17	17	55	48	63	48	72	60
Swamp-(2)	26	26	174	132	174	132	220	165
DLD's pond	145	-	145	104	145	104	145	130
Canals	240	144	276	221	276	221	276	221
New pond	-	-	-	-	318	208	450	405
Total	428	187	650	505	942	713	1163	981

Note ; Full is total capacity and Eff. is effective capacity for irrigation.
Swamp-(2) has both functions of irrigation and fishery in the model.
Swamp-(1) is located near road 12 and swamp-(2) is close to Noi canal.

Table B-3-5 STORAGE CAPACITY BY PONDS IN NONG KHON KAEN

No.	Designed pond area (1000㎡)	Effective capacity (1000 ㎥)	Fish pond for dry season Pond area (1000 ㎡)	Fish pond for dry season Capacity (1000 ㎥)	Full capacity (1000 ㎥)
1	10	16	-	-	23
2	10	16	-	-	23
3	10	16	-	-	23
4	10	16	-	-	23
5	10	16	-	-	23
6	40	64	14	14	100
7	20	32	-	-	35
8	20	32	-	-	34
Sub-total	130	208	14	14	284
Swamp-(1)	24	48	-	-	63
Swamp-(2)	66	132	22	22	174
DLD's pond	52	104	-	-	145
Canal	-	221	-	-	276
Sub-total	-	505	30	30	658
Total	-	713	44	44	942

Table B-3-5 STORAGE CAPACITY BY PONDS IN THUNG SAI YART

No.	Designed pond area (1000㎡)	Effective capacity (1000 ㎥)	Fish pond for dry season Pond area (1000 ㎡)	Fish pond for dry season Capacity (1000 ㎥)	Full capacity (1000 ㎥)
1	40	80	-	-	92
2	100	200	40	40	290
3	40	80	-	-	92
4	240	480	-	-	552
5	40	80	-	-	92
6	100	200	-	-	230
7	40	80	-	-	92
8	100	200	40	40	290
9	40	80	-	-	92
10	40	80	-	-	92
11	40	80	-	-	92
12	90	180	36	36	261
13	40	80	-	-	92
14	40	80	-	-	92
Sub-total	990	1,980	116	116	2,451
RID weir	313	630	-	-	720
Farmer dike	163	330	65	65	630
Canals	-	800	-	-	1,000
Others	-	180	-	-	230
Sub-total	-	1,940	65	65	2,580
Total	-	3,920	181	181	5,031

Table B-3-6 QUANTITIES OF FACILITIES BY MODEL

Description	Unit	Nong Khon Kaen M-1	Nong Khon Kaen M-2	Nong Khon Kaen M-3	Thubg Sai Yart M-1	Thubg Sai Yart M-2	Thubg Sai Yart M-3
1. Water Resources Facility							
- Construction of pond	place	2	8	1	-	14	7
- Improvement of swamp	〃	1	2	3	2	2	2
- Weir of overflow-type	〃	1	1	1	8	1	1
- Weir with gate	〃	-	1	1	-	-	-
- Deep well with pump	〃	-	-	17	-	-	-
2. Agricultural Land Infra.							
2-1. Irrigation/drainage							
- Irrigation canal	km	-	-	41.7	-	-	42.9
- Drainage canal	〃	-	-	33.0	-	-	48.2
- Dual purpose canal	〃	9.8	31.7	-	20.2	60.3	-
- Road crossing	place	23	50	88	14	35	29
- Related structure	L.S	-	-	1	-	-	1
- Dredging of the canal	km	9.3	9.3	9.3	40.4	40.4	40.4
- Culvert with gate	place	3	3	3	-	-	-
- Bridge	〃	-	-	-	2	2	2
2-2. Farm Road							
- Main road (W=6.0 m)	km	-	3.8	3.8	9.3	9.3	9.3
- Lateral road (W=4.0 m)	〃	9.8	6.8	6.9	3.1	3.1	3.1
- Branch road (W=3.0 m)	〃	-	14.3	26.8	7.8	39.2	39.2
2-4. Land leveling	ha	-	230	1,049	-	-	-

Note ; M-1, M-2, M-3 are Model-1, 2 and 3.
The above is approximate quantities for alternative study.

Table B-3-7 APPROXIMATE ESTIMATE COST BY MODEL

Description	Model-(1)	Model-(2)	Model-(3)
Nong Khon Kaen			
Construction cost			
- Water resources facilities	6,200	16,900	129,100
- Agricultural infrastructure	12,200	26,900	75,700
Total	18,400	43,800	204,800
Operation/Maintenance cost			
- Private well	1,104	1,104	-
- Private portable pump	923	982	-
- Public well	-	-	2,249
- Public pump of pond	-	-	455
Total	2,027	2,086	2,704
Thung Sai Yart			
Construction cost			
- Water resources facilities	16,500	104,100	288,000
- Agricultural infrastructure	35,500	49,500	45,500
Total	52,000	153,600	333,500
Operation/Maintenance cost			
- Private portable pump	2,252	3,047	1,105
- Public pump of pond	-	-	1,520
Total	2,252	3,047	2,725

Note ; The above is based on approximate quantities for alternative study.
In the Model-3, constructed pond and swamp have electric irrigation pump.

Table B-3-9 WATER REQUIREMENT IN NONG KHON KAEN(1)

Month		Noi canal Run-off (MCM)	Rain-fall (mm)	Wet season Paddy North H.Y.V. 420 ha (MCM)	North Vegetable 30 ha (MCM)	South H.Y.V. 230 ha (MCM)	South H.Y.V. 250 ha (MCM)	South Orchard 40 ha (MCM)
Apr.	I	0.009	12.4					0.025
	II	0.009	13.7					0.024
	III	0.019	24.3					0.019
May	I	0.175	52.7					0.004
	II	0.083	53.3					0.003
	III	0.216	62.5					0.002
Jun.	I	0.173	64.8	0.427				-
	II	0.180	49.4	0.232				0.003
	III	0.170	45.6	0.291				0.005
Jul.	I	0.162	42.0	0.466				0.004
	II	0.132	36.0	0.227	-	0.104	0.113	0.007
	III	0.255	79.9	0.049	-	0.043	0.046	-
Aug.	I	0.265	64.7	-	-	0.127	0.137	-
	II	0.267	70.6	0.068	-	0.162	0.176	-
	III	0.429	86.7	0.042	-	-	-	-
Sep.	I	0.528	93.0	0.095	-	0.030	0.032	-
	II	0.356	84.8	0.138	-	0.050	0.055	-
	III	0.456	87.0	0.127	-	0.050	0.055	-
Oct.	I	0.411	74.8	-	-	0.025	0.027	-
	II	0.431	56.3	-	-	0.088	0.095	-
	III	0.226	28.0	-	0.007	0.204	0.222	0.012
Nov.	I	0.148	11.7	-	0.009	0.217	0.236	0.015
	II	0.101	10.7	-	0.008	0.156	0.176	0.016
	III	0.065	5.2		0.005	0.109	0.119	0.019
Dec.	I	0.027	2.5		0.002	0.048	0.052	0.019
	II	0.022	-					0.019
	III	0.007	-					0.019
Jan.	I	0.010	3.1					0.019
	II	0.010	4.0					0.019
	III	0.007	-					0.021
Feb.	I	0.013	6.1					0.026
	II	0.013	1.8					0.026
	III	0.019	10.0					0.021
Mar.	I	0.003	2.3					0.028
	II	0.007	8.1					0.028
	III	0.011	11.2					0.031
Total		5.409	1259.2	5,147 (m³/ha)	1,033 (m³/ha)	6,143 (m³/ha)	6,164 (m³/ha)	10,850 (m³/ha)

Table B-3-9 WATER REQUIREMENT IN NONG KHON KAEN(2)

Month		Ban Mai canal Run-off (MCM)	Rain-fall (mm)	Paddy South H.Y.V. 250 ha (MCM)	Upland Crop - North Vegetable 60 ha (MCM)	North Soy-b. 240 ha (MCM)	South Soy-b. 70 ha (MCM)	Total of Water Requirement (MCM)
Apr.	I	0.014	12.4		0.029		0.012	0.066
	II	0.014	13.7		0.020			0.044
	III	0.029	24.3		0.011			0.030
May	I	0.276	52.7					0.004
	II	0.130	53.3					0.003
	III	0.338	62.5					0.002
Jun.	I	0.273	64.8					0.427
	II	0.282	49.4					0.235
	III	0.266	45.6					0.296
Jul.	I	0.254	42.0					0.470
	II	0.207	36.0	(0.113)				0.451
	III	0.401	79.9	(0.046)				0.138
Aug.	I	0.415	64.7	(0.137)				0.264
	II	0.420	70.6	(0.176)				0.406
	III	0.673	86.7	-				0.042
Sep.	I	0.829	93.0	(0.032)				0.157
	II	0.559	84.8	(0.055)				0.243
	III	0.706	87.0	(0.055)				0.232
Oct.	I	0.646	74.8	(0.027)				0.052
	II	0.678	56.3	(0.095)				0.183
	III	0.354	28.0	(0.222)		0.240		0.685
Nov.	I	0.233	11.7	(0.236)		0.001		0.478
	II	0.158	10.7	(0.176)		0.002		0.352
	III	0.102	5.2	(0.119)		0.008		0.260
Dec.	I	0.042	2.5	(0.052)	0.002	0.092		0.215
	II	0.034	-		0.006	0.111	0.105	0.241
	III	0.012	-		0.011	0.133	0.011	0.174
Jan.	I	0.016	3.1		0.015	0.141	0.021	0.196
	II	0.016	4.0		0.019	0.150	0.030	0.218
	III	0.012	-		0.026	0.176	0.037	0.260
Feb.	I	0.021	6.1		0.034	0.202	0.052	0.314
	II	0.021	1.8		0.034	0.139	0.052	0.251
	III	0.029	10.0		0.028	0.055	0.050	0.154
Mar.	I	0.005	2.3		0.036	0.016	0.068	0.148
	II	0.010	8.1		0.036		0.068	0.132
	III	0.018	11.2		0.032		0.050	0.113
Total		8.493	1259.2	(5,147) (m³/ha)	5,650 (m³/ha)	6,108 (m³/ha)	7,943 (m³/ha)	5,922 (m³/ha)

Table B-3-9 WATER REQUIREMENT IN THUNG SAI YART(3)

Month		Run-off (MCM)	Rain-fall (mm)	Wet season Paddy: West H.Y.V. 440 ha (MCM)	Middle H.Y.V. 1400 ha (MCM)	East H.Y.V. 340 ha (MCM)	East L.V. 380 ha (MCM)	Total of wet paddy (MCM)
Apr.	I	0.104	5.6					
	II	0.207	21.4					
	III	0.199	27.4					
May	I	0.420	28.2					
	II	0.649	57.2					
	III	3.010	87.1					
Jun.	I	1.897	43.1	0.025				0.025
	II	1.639	39.6	0.026	0.082			0.108
	III	1.255	27.6	0.029	0.093			0.122
Jul.	I	1.074	28.6	0.715	0.092	0.022		0.829
	II	1.020	35.6	0.872	1.199	0.021	0.023	2.115
	III	1.625	43.5	0.233	1.769	0.019	0.021	2.042
Aug.	I	1.450	33.3	0.257	2.084	0.515	0.024	2.880
	II	1.380	43.0	0.224	0.595	0.624	0.519	1.962
	III	1.924	51.0	0.241	0.665	0.128	0.669	1.703
Sep.	I	3.154	89.9	0.018	-	-	-	0.018
	II	3.220	79.0	0.082	0.217	0.035	-	0.334
	III	4.120	80.3	0.060	0.231	0.042	-	0.333
Oct.	I	3.046	43.5	0.030	0.917	0.228	0.195	1.370
	II	3.066	64.8		0.061	0.153	0.113	0.327
	III	2.368	38.6			0.273	0.256	0.529
Nov.	I	1.268	13.4			0.118	0.284	0.402
	II	1.070	17.5				0.234	0.234
	III	0.575	1.7				0.284	0.284
Dec.	I	0.373	2.8				0.111	0.111
	II	0.152	-					
	III	0.104	4.8					
Jan.	I	0.052	-					
	II	0.035	4.6					
	III	0.019	2.4					
Feb.	I	0.026	1.0					
	II	0.017	0.8					
	III	0.014	1.9					
Mar.	I	0.026	2.6					
	II	0.035	2.8					
	III	0.181	11.2					
Total		40.774	1035.4	6,362 (m³/ha)	5,719 (m³/ha)	6,411 (m³/ha)	7,192 (m³/ha)	6,128 (m³/ha)

Table B-3-9 WATER REQUIREMENT IN THUNG SAI YART(4)

Month		Dry Season Soy-bean: West 120 ha (MCM)	Middle 380 ha (MCM)	East 100 ha (MCM)	East 60 ha (MCM)	Total of Dry Soy-bean (MCM)	Orchard East 40 ha (MCM)	Total of W.R. (MCM)
Apr.	I						0.028	0.028
	II						0.020	0.020
	III						0.017	0.017
May	I						0.015	0.015
	II						0.014	0.014
	III						-	-
Jun.	I						0.005	0.030
	II						0.006	0.114
	III						0.012	0.134
Jul.	I						0.009	0.838
	II						0.006	2.121
	III						-	2.042
Aug.	I						0.006	2.886
	II						0.002	1.964
	III						-	1.703
Sep.	I						-	0.018
	II						-	0.334
	III						-	0.333
Oct.	I						0.002	1.372
	II						-	0.327
	III	0.120				0.120	0.006	0.655
Nov.	I	0.009	0.380			0.389	0.014	0.805
	II	0.012	0.038			0.050	0.012	0.296
	III	0.056	0.089		0.060	0.205	0.021	0.510
Dec.	I	0.063	0.132		0.017	0.212	0.017	0.340
	II	0.077	0.176	0.150	0.017	0.420	0.019	0.439
	III	0.084	0.243	0.032	0.027	0.386	0.018	0.404
Jan.	I	0.065	0.253	0.030	0.033	0.381	0.019	0.400
	II	0.036	0.230	0.042	0.040	0.348	0.019	0.367
	III	0.020	0.177	0.060	0.044	0.301	0.021	0.322
Feb.	I		0.109	0.090	0.044	0.243	0.026	0.269
	II		0.047	0.090	0.025	0.162	0.026	0.188
	III			0.054	0.010	0.064	0.021	0.085
Mar.	I			0.044		0.044	0.028	0.072
	II			0.022		0.022	0.028	0.050
	III						0.031	0.031
Total		4,517 (m³/ha)	4,932 (m³/ha)	6,140 (m³/ha)	5,283 (m³/ha)	5,071 (m³/ha)	11,700 (m³/ha)	5,994 (m³/ha)

Table B-3-10 DATA AND INFORMATION RELATED TO INLAND FISHERY

Size and Stocking rate for nursing to be Fingerling

Name	Size (cm)	Expected Size (cm)	Stocking rate (tail/m²)	Stocking rate (tail/rai)
Nile Tilapia	0.8-1	3-4	200	320,000
Common Carp	0.8-1	3-4	200	320,000
Thai Carp	1	3-4	400-500	640,000-800,000
Rohu	1	3-5	200	320,000
Chinese Carp	1	3-5	100-150	160,000-240,000

Size and Stocking rate for Grow out Stage

Name	Size (cm)	Stocking rate (tail/m²)	Stocking rate (tail/rai)
Nile Tilapia	1-3	2	3,200
Common Carp	2-5	1	1,600
Thai Carp	3-5	2	3,200
Rohu	5-10	1	1,600
Chinese Carp	5-7	0.125	200

Type of feed and Expected Production

Name	Type of feed	Rearing period (month)	Expected production (kg/rai)
Nile Tilapia	- Manure	9	300 - 400
	- Supplementary feed	6-8	600 - 800
	- Manure and table garbage	5-6	400 - 600
Common Carp	- Supplementary feed	12	600 - 800
Thai Carp	- Manure	8	300 - 400
	- Supplementary feed	8	600 - 800
Rohu	- Manure	8-12	400 - 450
Chainese Carp	- Manure	6	150

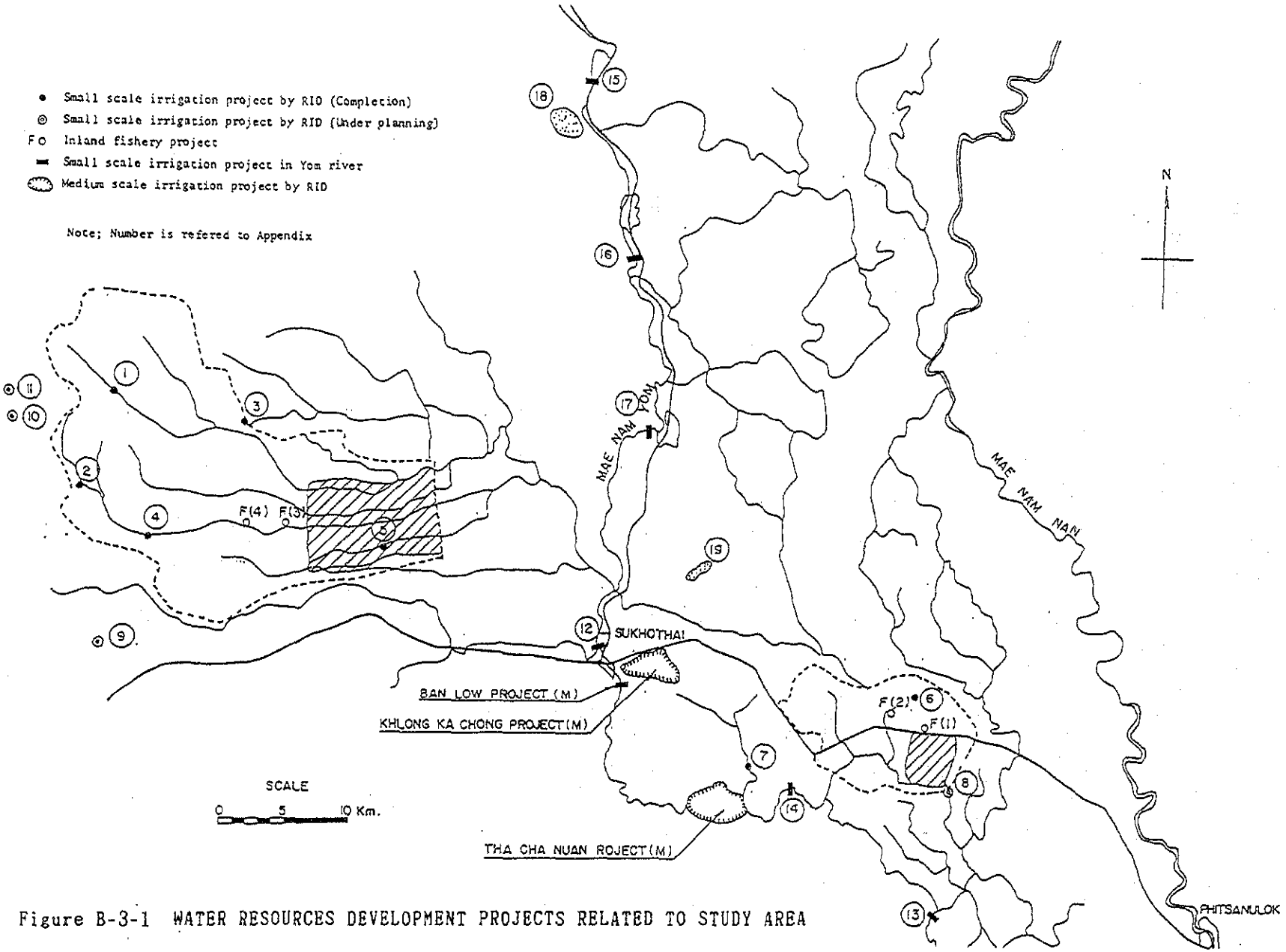


Figure B-3-1 WATER RESOURCES DEVELOPMENT PROJECTS RELATED TO STUDY AREA

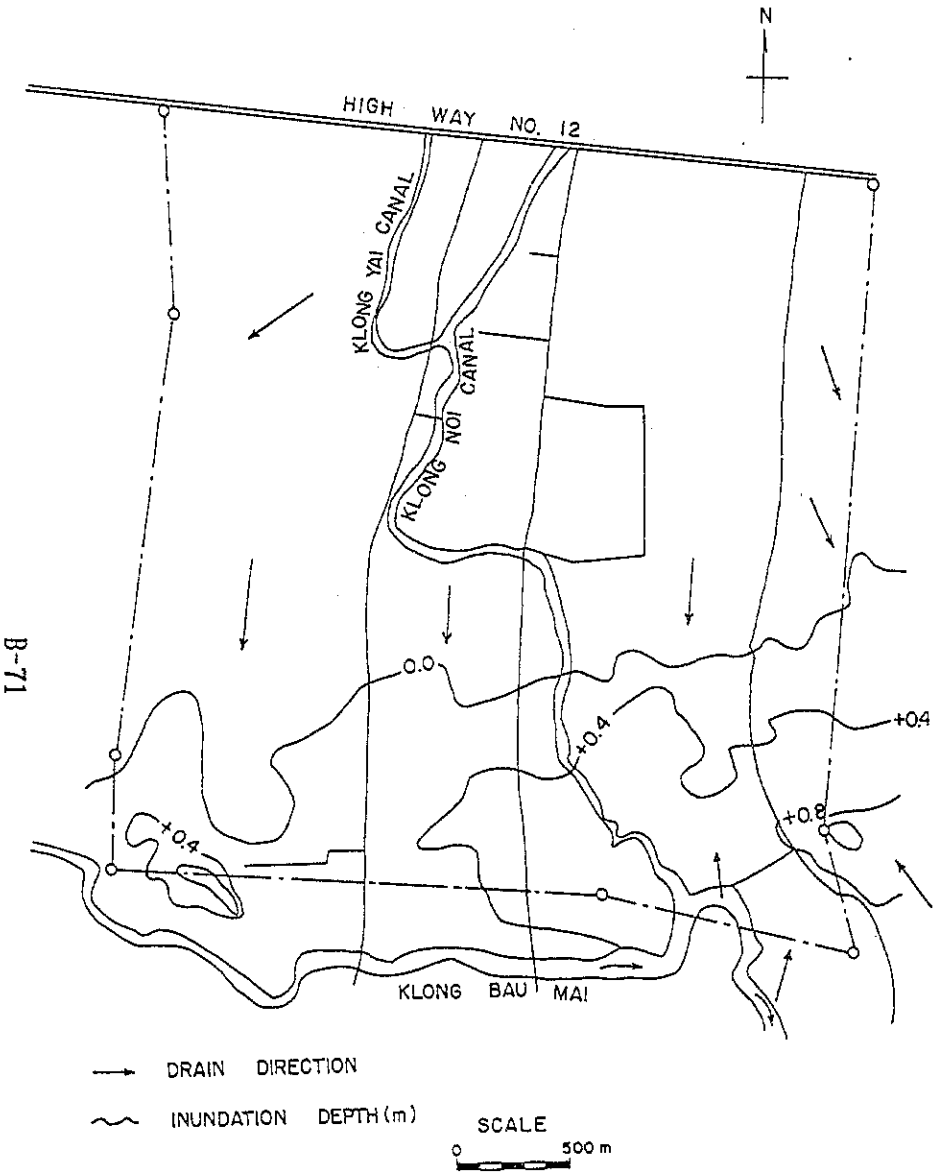


Figure B-3-2 INUNDATION DEPTH IN NONG KHON KAEN

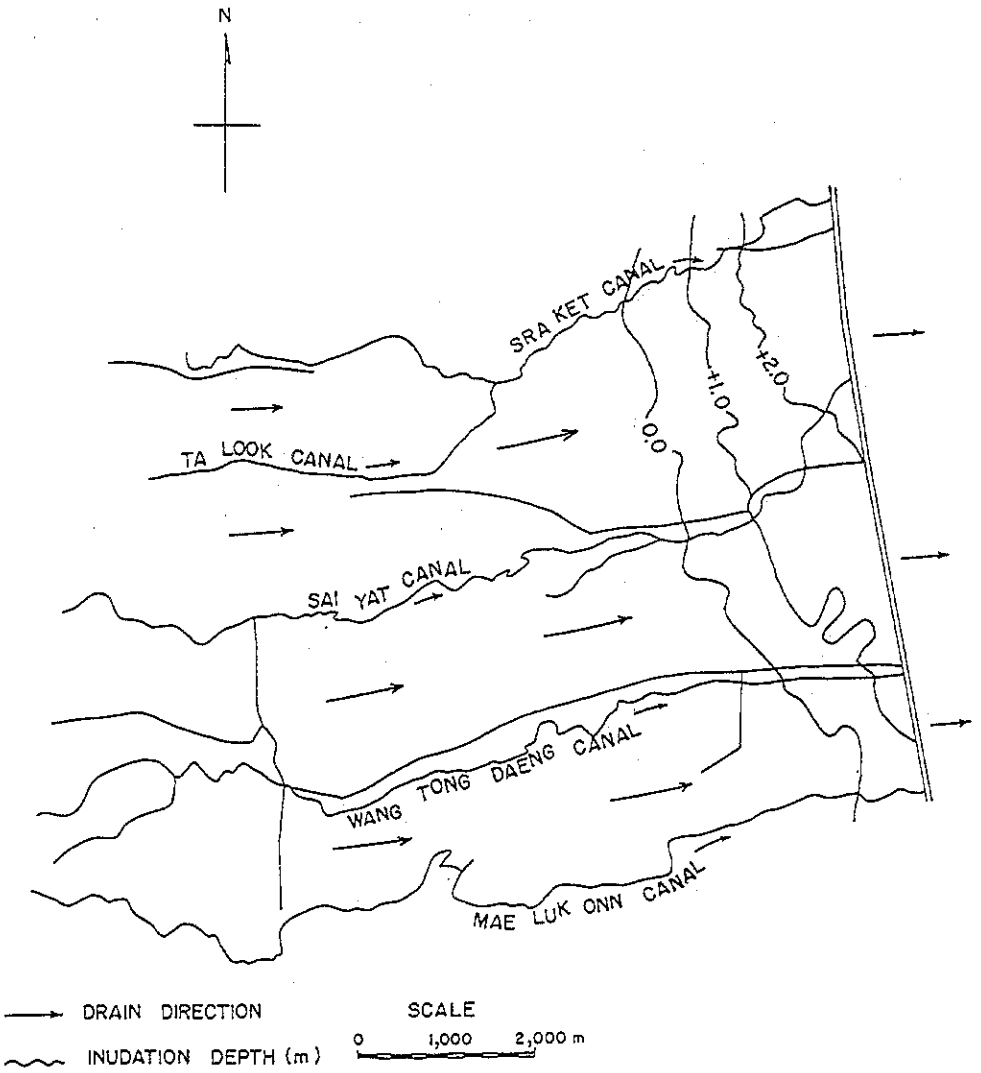
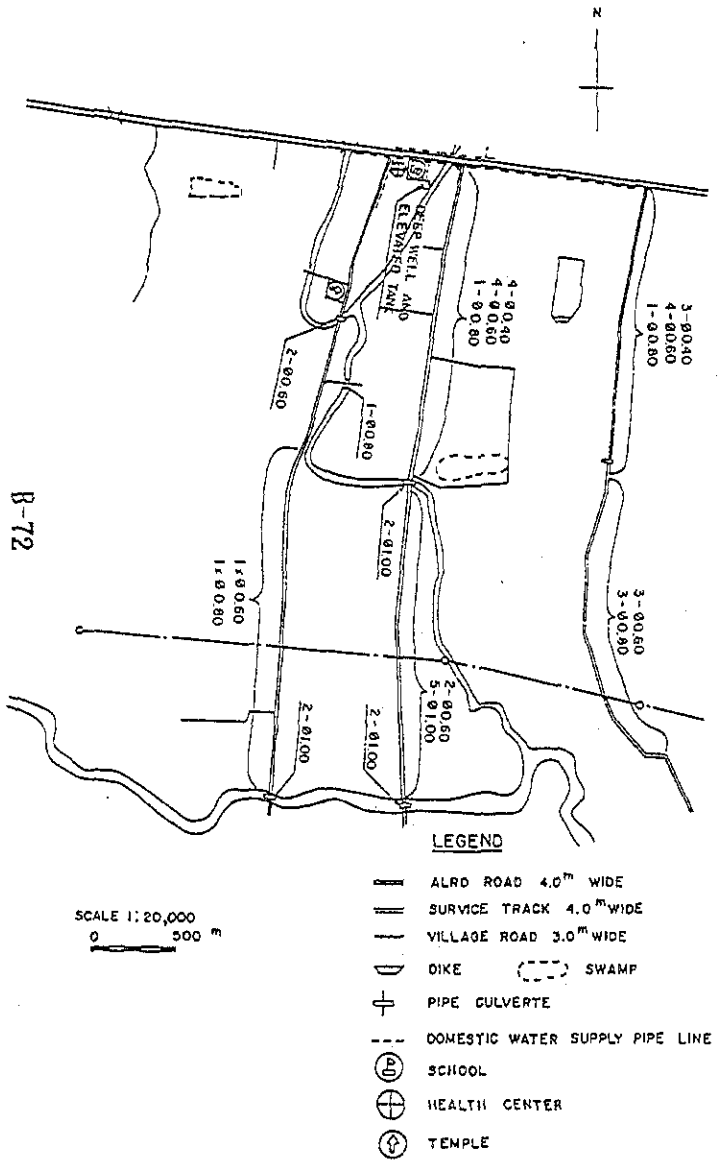


Figure B-3-4 INUNDATION DEPTH IN THUNG SAI YART

Figure B-3-3 EXISTING INFRASTRUCTURE IN NONG KHON KAEN



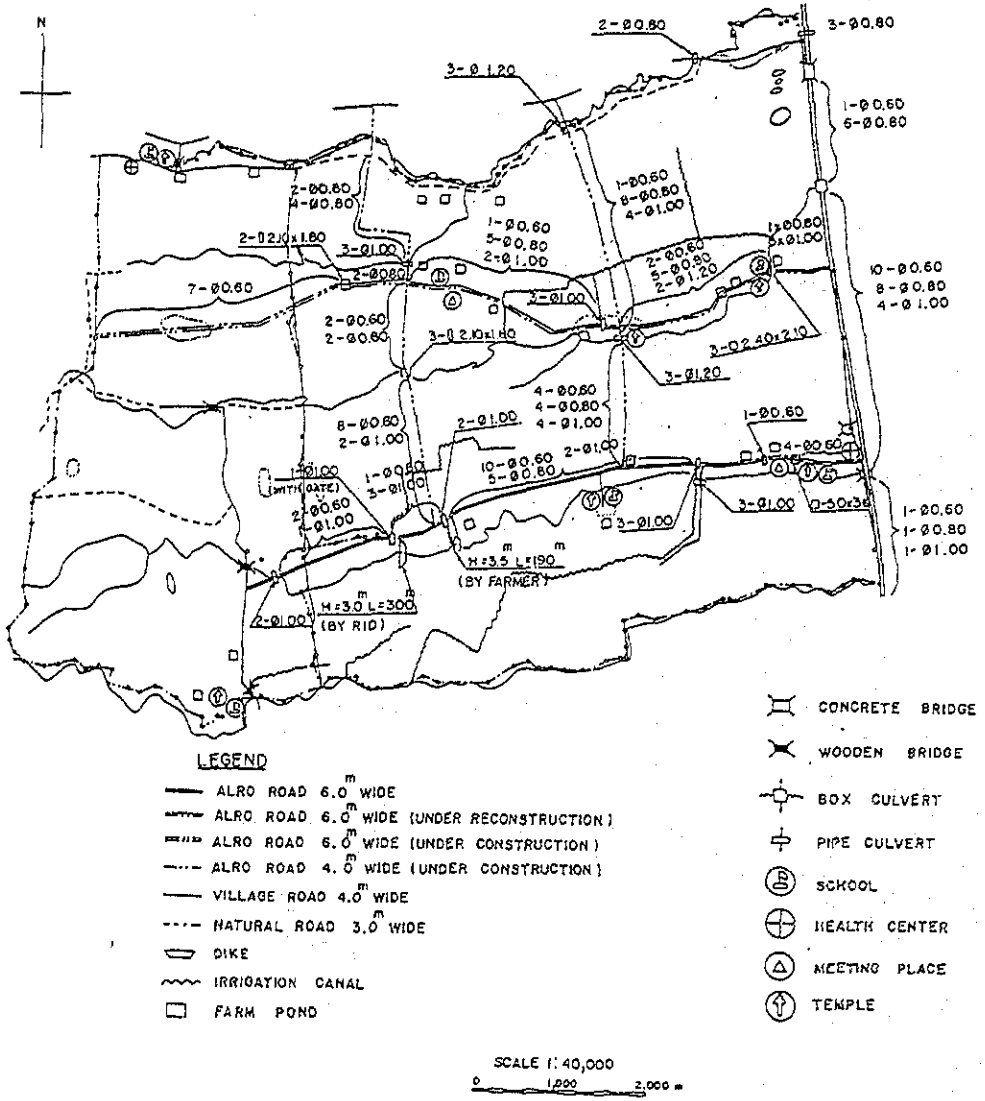
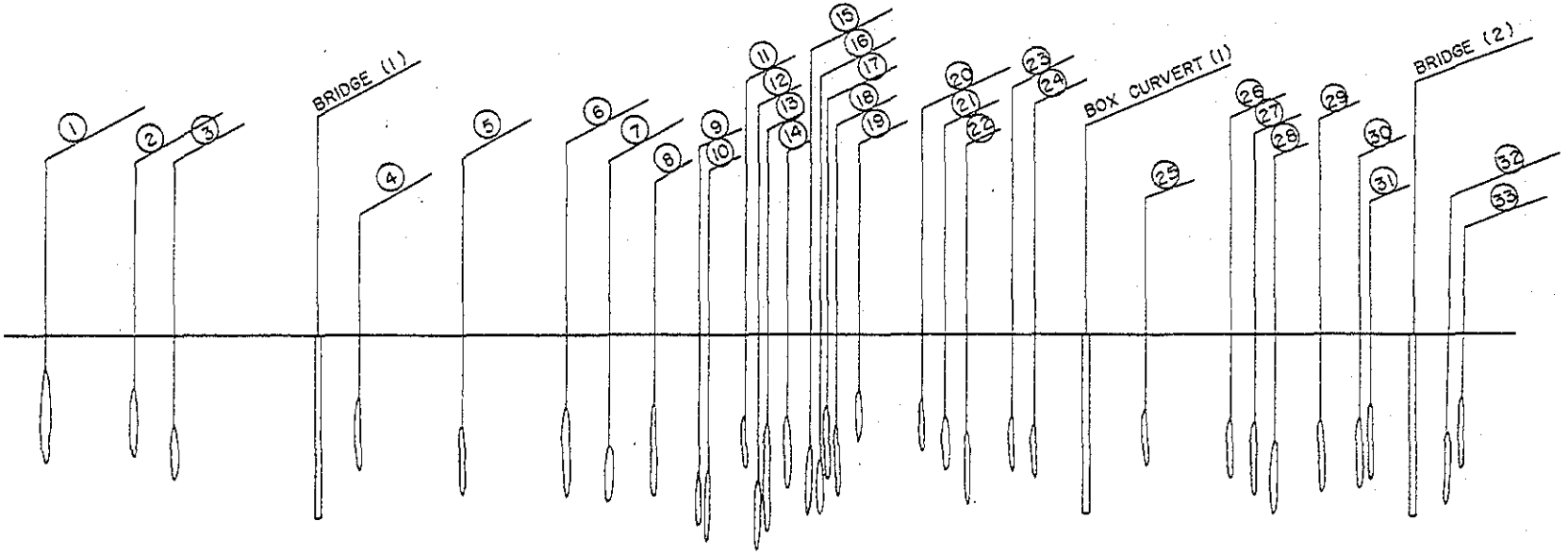


Figure B-3-6 EXISTING INFRASTRUCTURE IN THUNG SAI YART



Pipe Culvert

No	Row	φ (mm)	No	Row	φ (mm)	No	Row	φ (mm)	No	Row	φ (mm)
1	1	1,000	11	2	600	21	1	600	31	1	800
2	1	800	12	1	800	22	1	800	32	2	800
3	1	600	13	2	1,200	23	1	600	33	1	800
4	2	800	14	1	800	24	1	600			
5	1	800	15	1	800	25	1	600			
6	2	1,000	16	2	600	26	1	800			
7	1	600	17	1	800	27	1	800			
8	2	1,000	18	1	800	28	1	800			
9	2	600	19	1	600	29	1	800			
10	1	800	20	1	600	30	1	800			

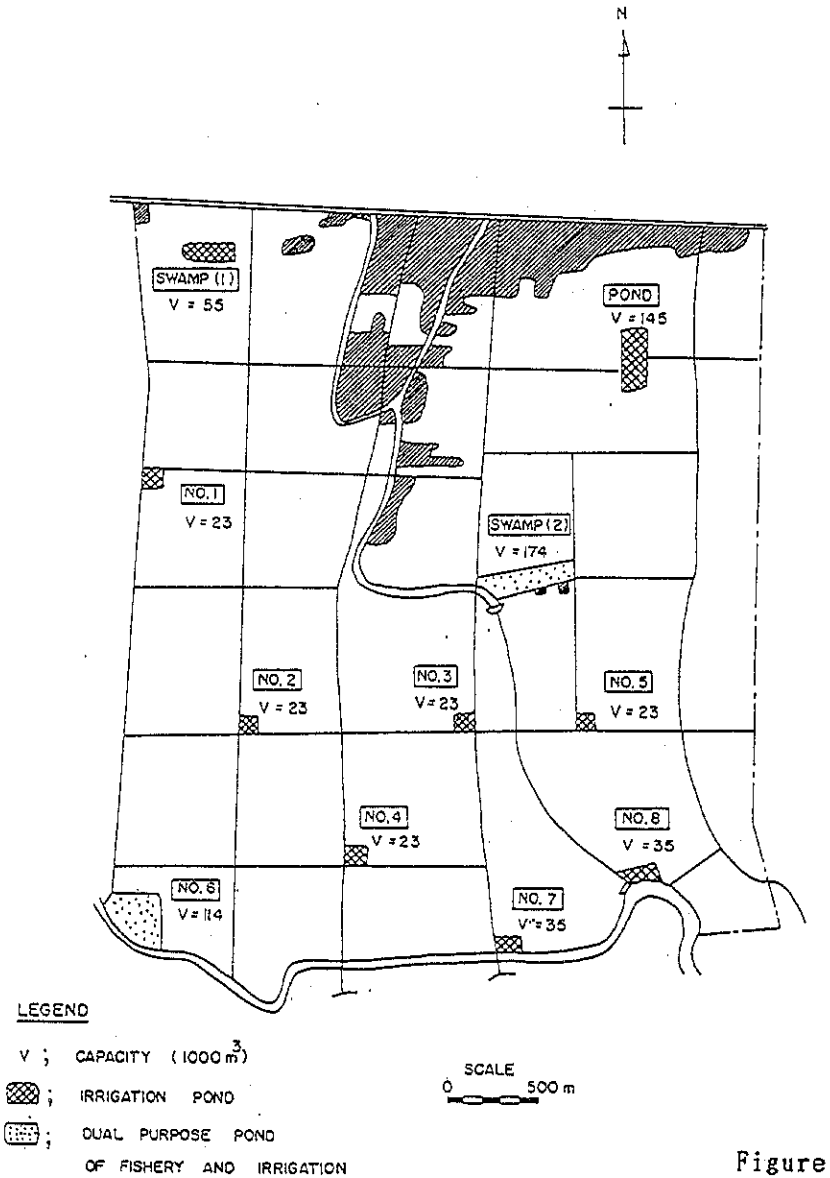
Cross Section under the Bridge

No.	Width(m)	Hight(m)
1	15.0	2.0
2	15.0	2.0

Cross Section of Box Culvert

No	Width(m)	Hight(m)	Row
1	3.0	2.0	3

Figure B-3-5 DRAINAGE FACILITIES UNDER THE ROAD 1113



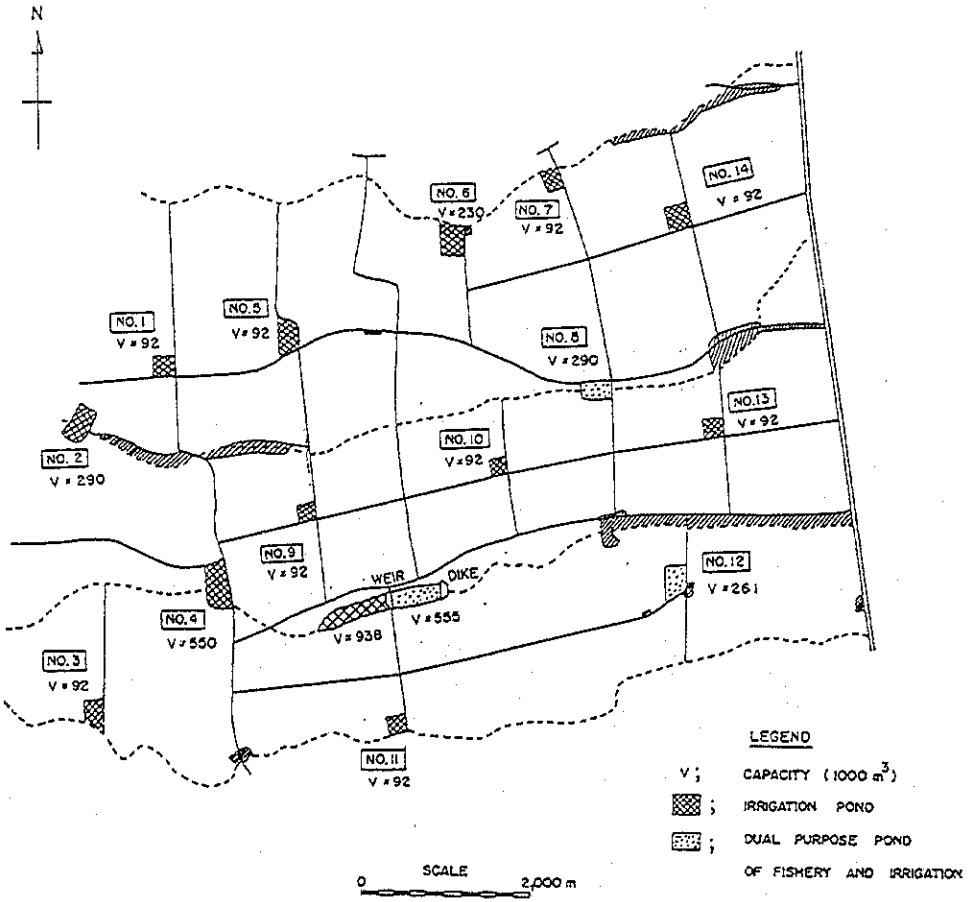
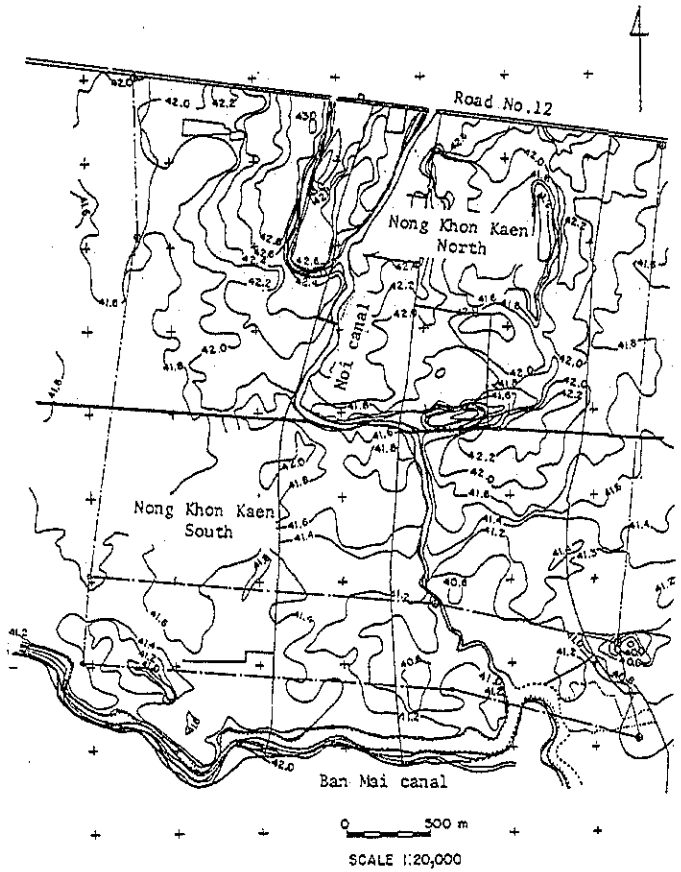
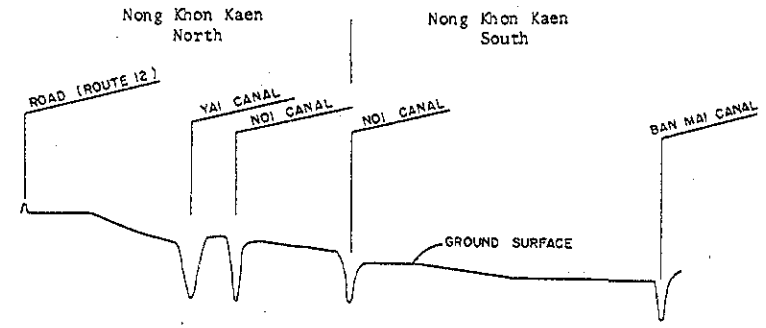
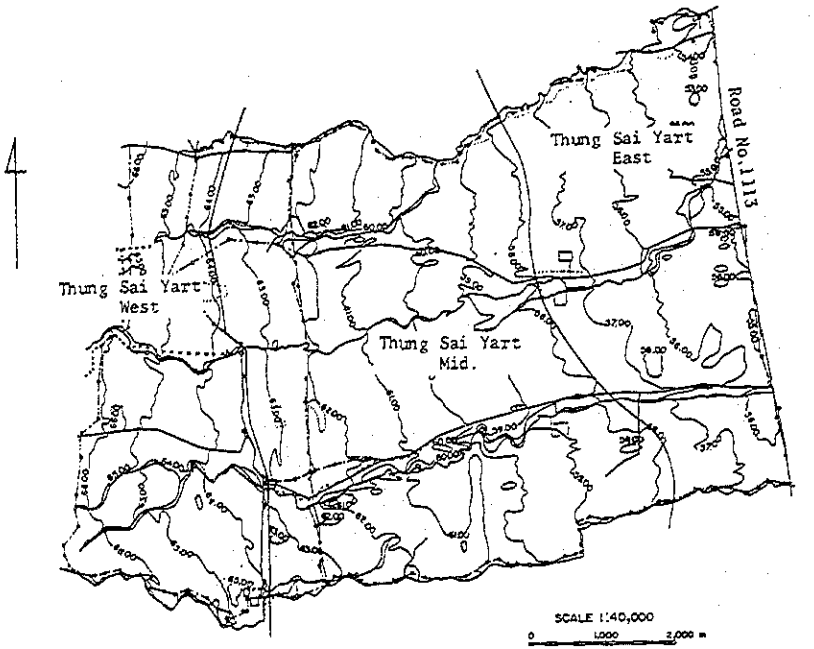


Figure B-3-7 LOCATION AND CAPACITY OF STORAGE PONDS







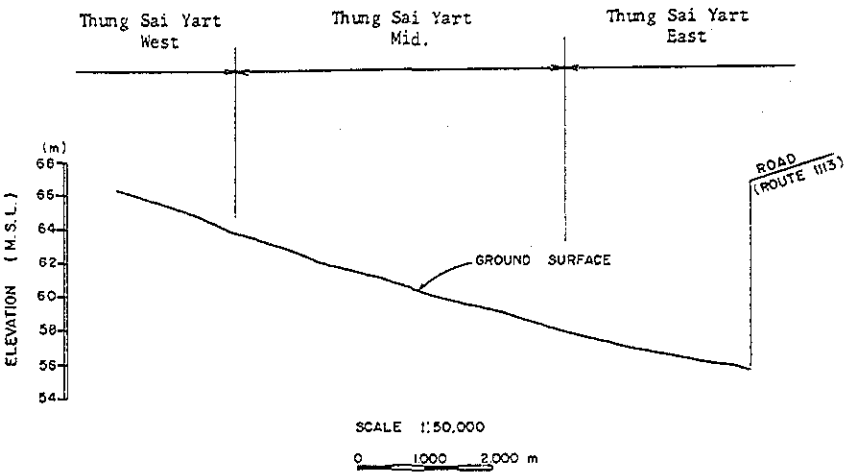


Figure B-3-9 LAND DEVELOPMENT CLASSIFICATION

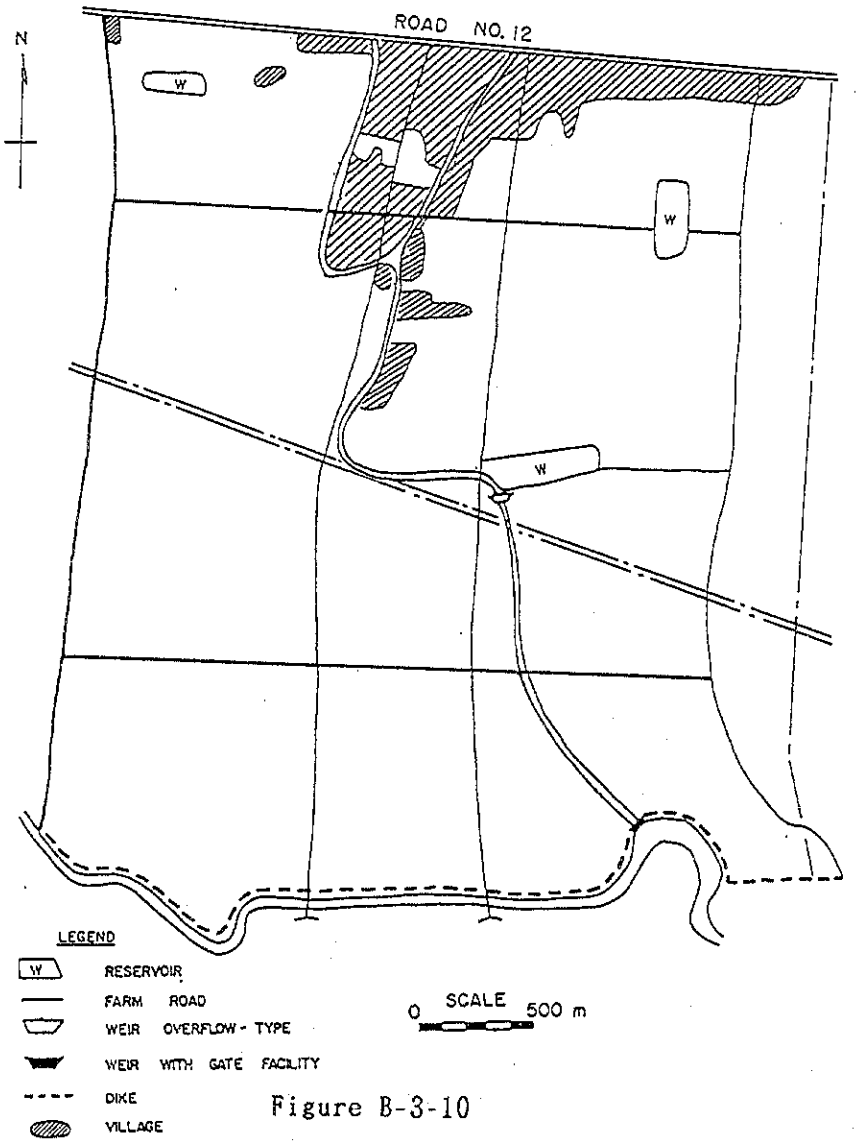


Figure B-3-10

IMPROVEMENT PLAN-(1) (MODEL-1) IN NONG KHON KAEN

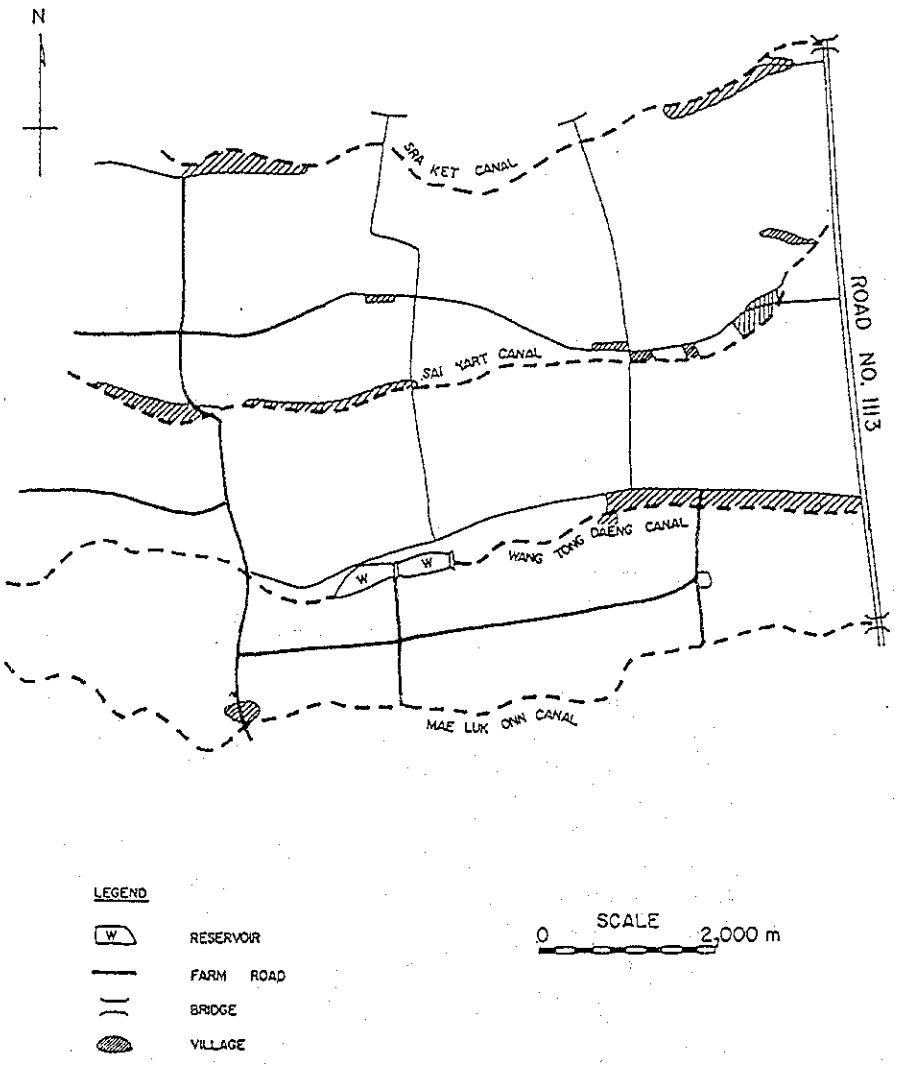


Figure B-3-10 IMPROVEMENT PLAN-(1) (MODEL-1) IN THUNG SAI YART

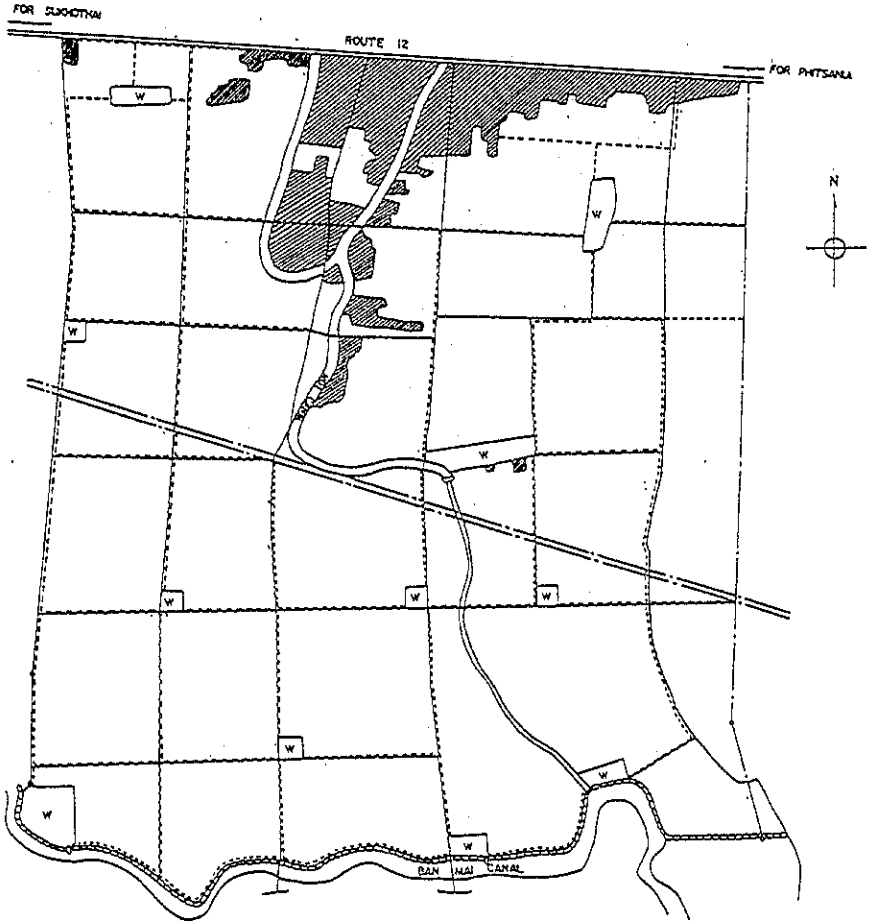


Figure B-3-11

IMPROVEMENT PLAN-(2) (MODEL-2) IN NONG KHON KAEN

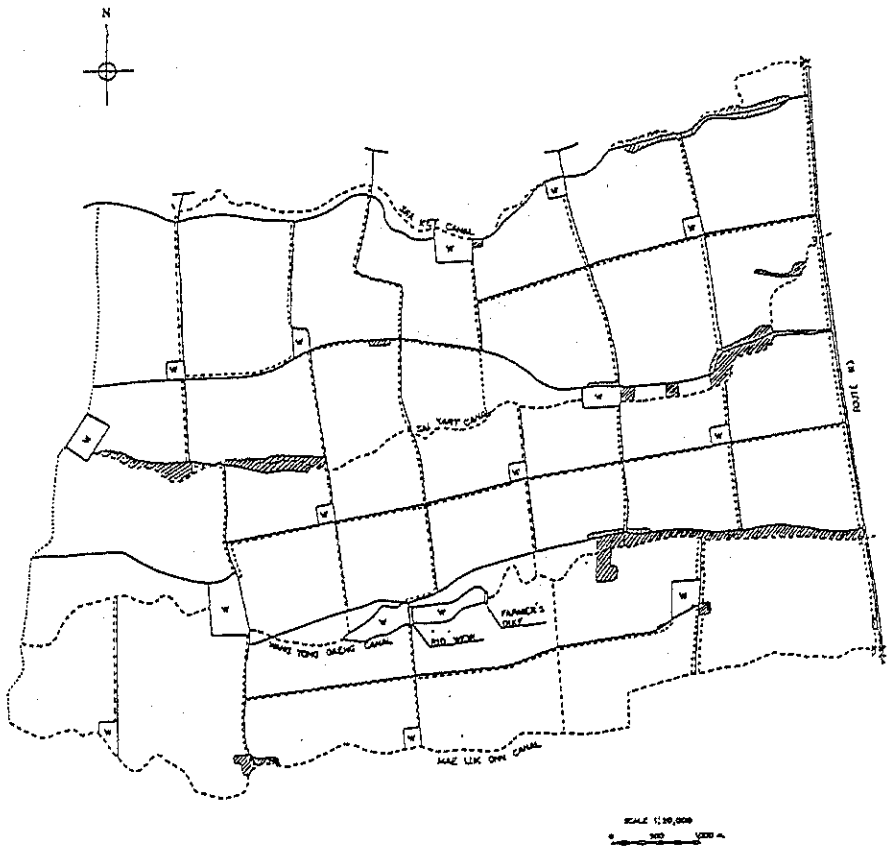


Figure B-3-11

IMPROVEMENT PLAN-(2) (MODEL-2) IN THUNG SAI YART

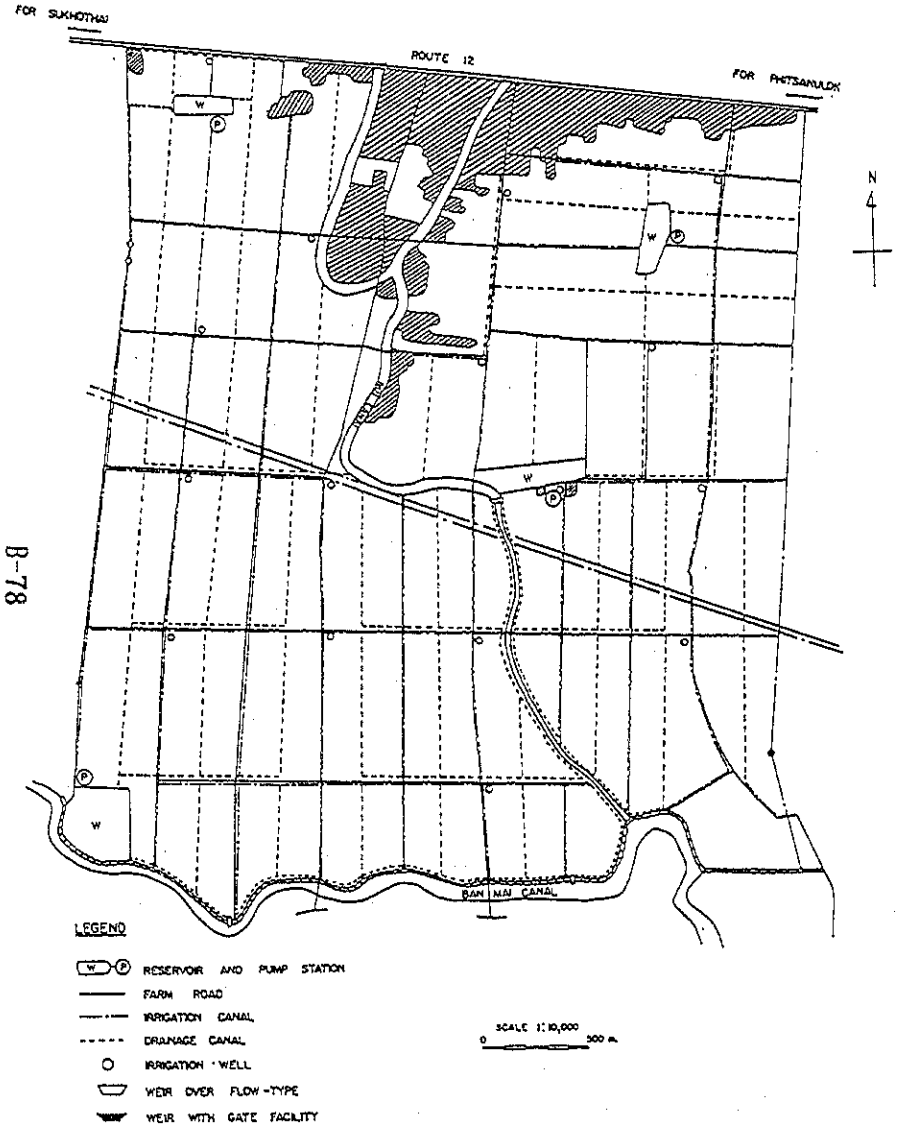


Figure B-3-12

IMPROVEMENT PLAN-(3) (MODEL-3) IN NONG KHON KAEN

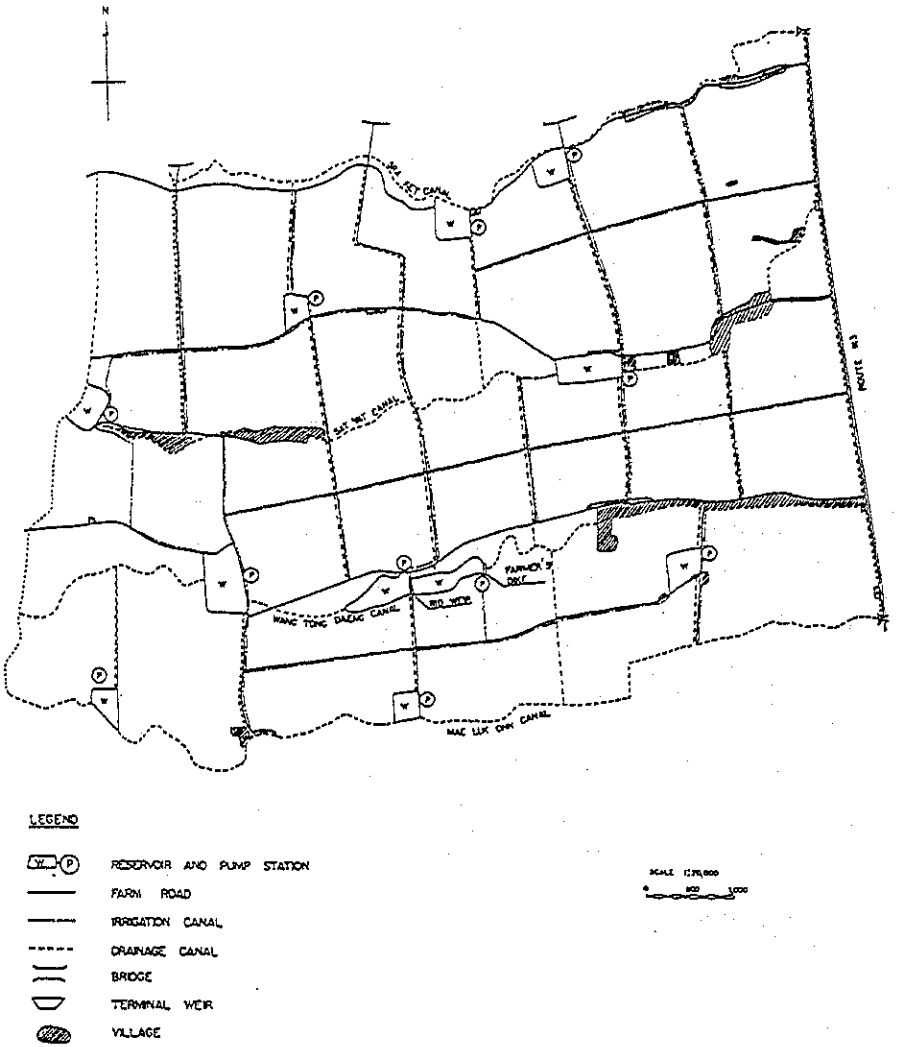


Figure B-3-12

IMPROVEMENT PLAN-(3) (MODEL-3) IN THUNG SAI YART

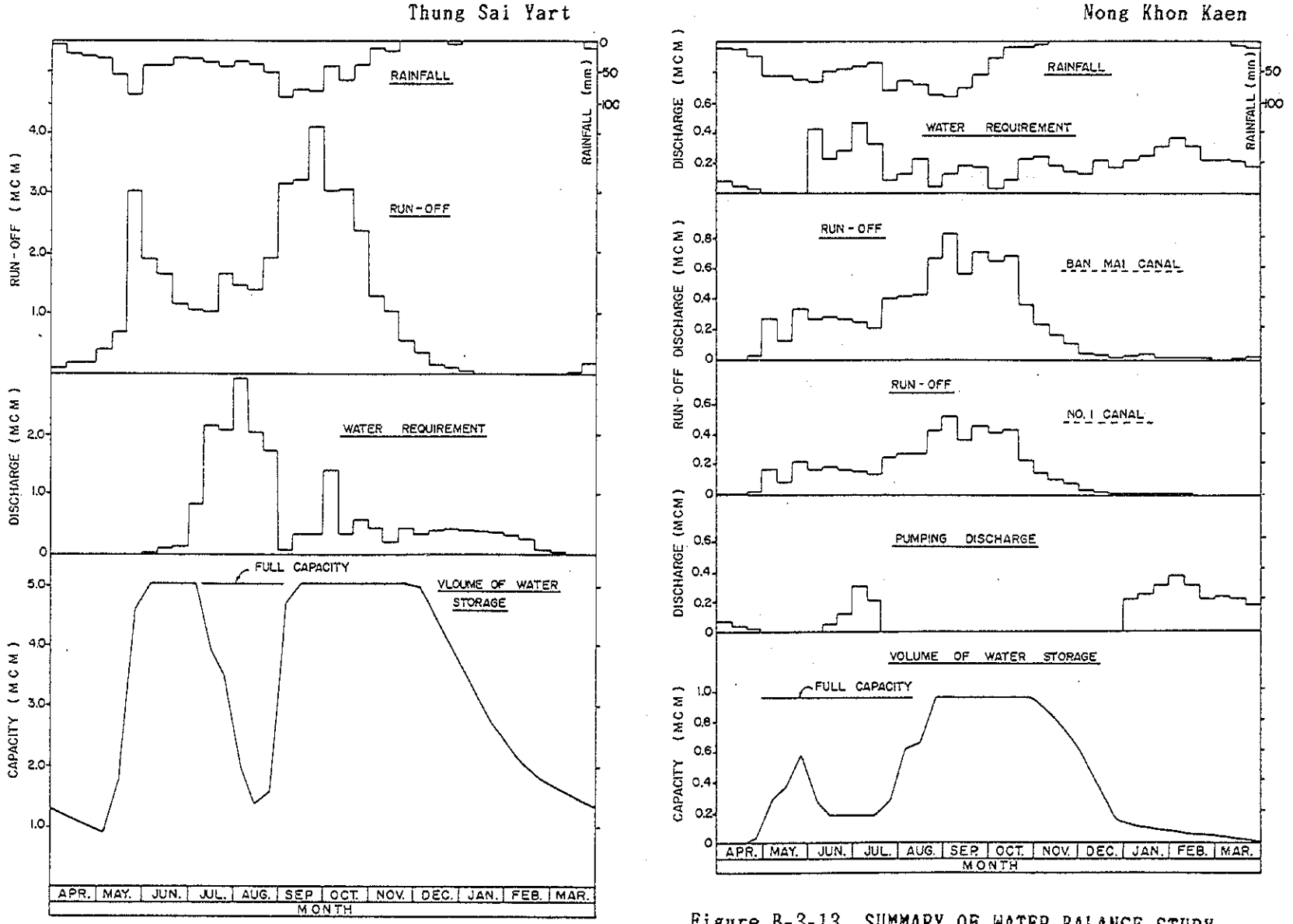


Figure B-3-13 SUMMARY OF WATER BALANCE STUDY

Appendix B-4 SOCIAL INFRASTRUCTURE

B-4-1 Present Condition

(1) Number of farm household and population

The number of household and population to be studied is based on the statistical data of NESDB. But, in the planning, they are limited to the villages situated within the study areas. As a result of site survey and study, they are defined as shown in Table B-4-1.

(2) Present condition

Present condition has been studied through the site survey. locations of facilities are shown in Figures B-3-3 and B-3-6 in Appendix B-3.

B-4-2 Rural Infrastructure Development Planning

(1) The number of household to be projected in the study

1) Rural water supply

Village and population to be covered by piped water supply system is shown in Table B-4-2. Deep well with handpump is provided in the isolated and relatively remote villages in Thung Sai Yart, as shown in Table B-4-3.

2) Rural electrification

The number of household to be supplied electricity is based on the target in Sukhothai Province and present condition in the study areas. As a result of study, it is projected in each village as shown in Table B-4-4.

3) Public sanitation

In order to prevent leak of human waste and to clean living environment, toilets with tanks are supplied in all households without them, the number of which is estimated by each villages as shown in Table B-4-5.

(2) Facility Planning

1) Piped water supply system

(a) Design criteria

Criteria and standard of PWA are applied basically in this study.

Target year

Target is 2,000 year.

Increasing ratio of population

In the criteria, ratio is defined at 1.5% up to 1990 and 1.0% from 1990 to 1995. In this study, the value of 1.0% is applied.

Daily water consumption per capita

According to the criteria, it may be planned at 50 lcd in rural area under adequate operation by villager, though it is basically 90 lcd. Therefore, daily average is 50 lcd and maximum is 50 x 1.5 = 75 lcd.

Pumping hours

Average 10 hours and maximum is 15 hours.

Storage capacity of tank

Clear water tank : 70% of daily average supply

Elevated tank : 20% of daily average supply

(b) Amount of water supply

Items	Nong Khon Kaen	Thung Sai Yart(1)	Thung Sai Yart(2)
Village	-	Wang Thong Daeng Sam Nak	Sai Yart Rao Rang Ngam
Present population	818	1,277	1,098
Population served	910	1,410	1,220
Water consumption (m^3/day)			
(1) Domestic	61	106	92
(2) Public facility	6	11	10
(3) Daily maximum	67	117	102
(4) Water leakage	7	12	11
(5) Daily max. amount	74	129	113

Note ; Population served ≒ Present population× $(1 + 0.01)^{10}$

(1) = Population served x 0.075, (2) = assumed at 10% of (1),

(3) = (1) + (2), (4) = assumed at 10% of (3),

(5) = (3) + (4), Each distribution system is shown in Figure B-4-1.

(c) Water source facility

Design pumping discharge

In Thung Sai Yart, amount of pumping discharge from a deep well is safely assumed at around 10 cu.m/h. Daily driving time of pump is average 10 hours. Piped supply facility is standardized by DOH on the 5.0 cu.m basis. Design discharge, therefore, is planned at 10 cu.m/h. Driving time is estimated in each piped systems, as follows.

Nong Khon Kaen ; 74 cu.m/day ÷ 10 cu.m/hr = 7.4 hr
Thung Sai Yart(1); 129 cu.m/day ÷ 10 cu.m/hr = 12.9 hr
Thung Sai Yart(2); 113 cu.m/day ÷ 10 cu.m/hr = 11.3 hr

Deep well

Three piped systems is planned in this study. Depth of well is designed based on the hydro-geological cross sections assumed by core boring. Diameter of casing pipe is 200 mm, considering that opening space between inner diameter of casing pipe and outer diameter of turbine pump is needed at more than 40 mm. Drilling diameter(R) is estimated by the following equation.

$R \geq$ 140 mm + (Diameter of casing pipe) = 140 + 200 = 340 → 400mm

400 mm is applied because inflow velocity through casing is possibly controlled at low rate, if R is large possible.

Pump for well

Turbine pump is selected as follows.

Specification	Nong Khon Kaen	Thung Sai Yart
Number of unit	1	2
Design discharge (m^3/min)	0.17	0.17
Pumping head (m)	35	50
Bore(mm)	ϕ 50	ϕ 50
Output of motor(kw)	2.2	3.7

(d) Treatment facilities

Sand filter

Lifted groundwater is treated with aeration and filtration. Aerator with slope like cascade is located on the top of sand filter. As a filtration method there is two types of rapid and slow sand filtrations. Compared with the two, slow sand filtration requires wide area for facility and much labor requirement for treatment of filter beds.

Therefore, it is not applied recently in Thailand as a simple treatment facility. On the other hand, rapid sand filtration, of which treatment is done with faster velocity than that in slow type, and scale of facility is more compact and economical. Standard designs is also prepared by DOH on a 5.0 m^3/hr basis. In this study, therefore, rapid type is adapted and its capacity is planned at 10.0 m^3/hr.

Clear water tank

Capacity is designed at around 70% of daily average water demand.

Capacity = 113 m^3 × 0.7 ≒ 80 m^3

(e) Elevated tank

High service pump

Type	: Single suction centrifugal pump
Design discharge	: 10.0 m^3/hr → 0.17 m^3/min
Pumping head	: Elevated tank H.W.L - Clear tank L.W.L + Pipe loss = 17.0 - (-3.0) + 2.0 = 22.0 m
Bore	: φ 50
Output of motor	: 2.2 kw

Elevated tank

Height of tank	: H.W.L = G.L + 17.0 m , L.W.L = G.L + 15.0 M
Capacity	: 113 m^3/day × 0.2 × 1/ 1.5 = 15 m^3
Structure	: Concrete type standardized by DOH

2) Public well

(a) Daily maximum water supply

Population served 125 x daily average 20 lcd x 1.5 = 3.75 m^3/day

(b) Diameter of drilling well(R)

R ≧ 140 + Diameter of casing pipe 150 = 290 mm

R is designed at 350 mm, considering in keeping stable aquifer.

3) Rural community facility

(a) Scale of meeting hall

It is estimated based on the following items

- Population served : Same as the number of farm household
- Area to be served : Around 1.0㎡ per one farm household
- The number of farm household : Average of four village (153 + 142 + 94 + 107) / 4 = 124

- Area required : 124 × 1.0㎡ = 124㎡
- Structure : Wooden building, concrete floor 21 m× 6 m

(b) Scale of multi-purpose hall

Nong Khon Kaen

- Lecture room : 96 ㎡ (8 × 12)
- Library,etc : 128 ㎡ Total = 224 ㎡

Thung Sai Yart

- Lecture room : 48 ㎡ (6 × 8)
- Library,etc : 128 ㎡ Total = 176 ㎡

(3) Reconstruction of test well

In the study, three test wells with 300 mm of casing pipe have been constructed to grasp the present conditions of groundwater and to observe water level. After completion of the study, these wells will be available as a production well for irrigation or domestic use. In any case, lifting pump has to be installed at the top of well, at where groundwater level observation equipment is set at present. As a results of the following consideration, it is advisable to use them as a domestic use well.

- Three wells have been constructed in the village area.
- Therefore, in case of irrigation use, many feeder canals from well to field have to be provided for water distribution.
- Villages adjacent to the wells have no domestic water supply system.
- Domestic use is appropriate for urgent need.

As a water supply facility, handpump and rapid sand filtration are planned as shown in Figure B-4-2. And, approximate reconstruction cost of one well is estimated at 46,000 baht, as shown in Table B-4-6.

Table B-4-1 HOUSEHOLD AND POPULATION IN THE STUDY AREA

Area	No.	Name of Village	Household	Population
①	1	Bang Crob	30	135
	2	Mai Suk Kasem	83	470
	3	Mai Suk Kasem	51	321
	4	Na Taew	78	397
	5	Mai Phothong	42	205
		Total	284	1,528
②	1	Wang Thong Daeng	153	738
	2	Sai Yart	142	617
	4	Rao Rang Ngam	94	481
	7	Sam Nak	107	539
	3	Lan Doo	22	106
		Sub total	518	2,481
		I	25	125
		II	15	75
		III	10	50
		IV	32	160
		V	9	45
		Sub total	91	455
		Total	609	2,936

Note ; Area ① – Nong Khon Kaen

Area ② – Thung Sai Yart

I to V – Isolated Village

Table B-4-2 HOUSEHOLD AND POPULATION SERVED BY PIPED WATER SUPPLY SYSTEM

Area	Name of Village	Household	Population
①	Bang Crob	30	130
	Mai Suk Kasem 1	25	146
	Mai Suk Kasem 2	20	106
	Na Taew	78	402
	Mai Photong	7	34
	Total	160	818
②-1	Wang Thong Daeng	153	738
	Sam Nak	107	539
	Total	260	1,277
②-2	Sai Yart	142	617
	Rao Rang Ngam	94	481
	Total	236	1,098

Note; Area ① — Nong Khon Kaen

Area ② — Thung Sai Yart

Table B-4-3 HOUSEHOLD AND POPULATION SERVED BY DEEP WELL WITH HANDPUMP

Symbol or Name of Village	Household	Population	Number of Deep Well
I	25	125	1
II	15	75	1
III	10	50	1
IV	32	160	2
V	9	45	1
Lan Doo	22	106	1

Table B-4-5 NUMBER OF HOUSEHOLD TO BE PROVIDED WITH LAVATORY

Area	Name of Village	Whole Household	Household whih / has Lavatory	Household to be Provided with Lavatory
①	Bang Crob	30	14	16
	Mai Suk Kasem	83	72	11
	Mai Suk Kasem	51	46	5
	Na Taew	78	50	28
	Mai Phothong	42	42	0
	Total	284	224	60
②	Wang Thong Daeng	153	34	119
	Sai Yart	142	35	107
	Rao Rang Ngam	94	7	87
	Sam Nak	107	7	100
	Lan Doo	22	8	14
	Isolated Village	91	0	91
	Total	609	91	518

Note ; Area ① — Nong Khon Kaen
Area ② — Thung Sai Yart

Table B-4-4 NUMBER OF HOUSEHOLD TO BE ELECTRIFIED

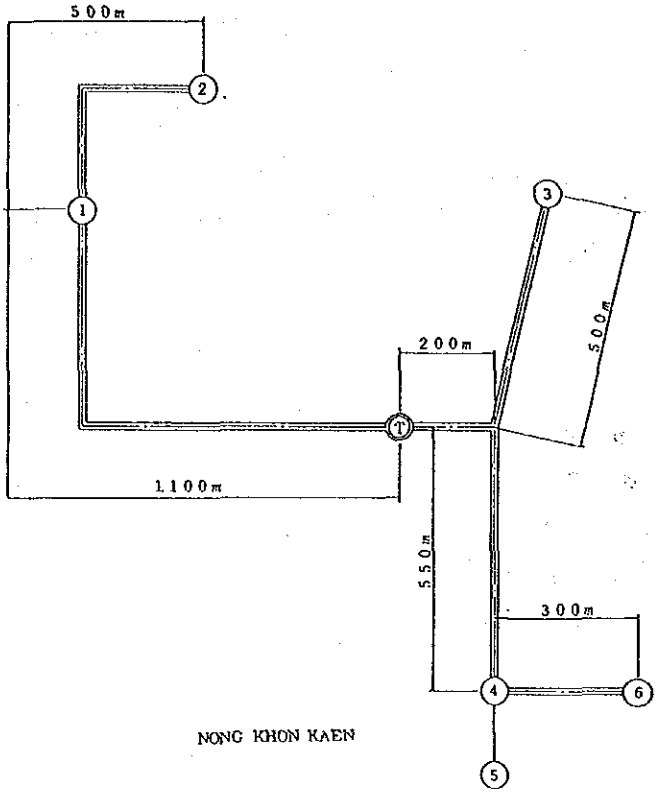
Area	Name of Village	Whole Household	Electrified Household	Household to be Electrified
①	Bang Crob	30	14	13
	Mai Suk Kasem	83	75	0
	Mai Suk Kasem	51	47	0
	Na Taew	78	37	34
	Mai Phothong	42	35	3
	Total	284	208	50
②	Wang Thong Daeng	153	53	85
	Sai Yart	142	71	57
	Rao Rang Ngam	94	0	85
	Sam Nak	107	27	70
	Lan Doo	22	0	20
	Isolated Village	91	0	82
	Total	609	151	399

Note ; Area ① — Nong Khon Kaen
Area ② — Thung Sai Yart

Table B-4-6 RECONSTRUCTION COST OF EXISTING TEST WELL

Description	Quantity	Unit	Unit cost(baht)	Amount (baht)
1. Materials				
- Hand pump	1	set	8,000	8,000
- PVC pipe ϕ 1.25	0.20	m	41	8
- PVC pipe ϕ 1.0	3.00	〃	32	96
- Joint pipe ϕ 1.25- ϕ 1.0	1	piece	10	10
- PVC bend pipe ϕ 1.0	3	〃	10	30
- PVC pipe screen ϕ 1.0	1.40	m	38	53
- Wood 2 × 6 × 0.6 m	2	piece	60	120
- Bolt ϕ 0.5 × 0.10 m	4	〃	50	200
- Concrete pipe ϕ 1.0 m × 0.40 m	3	〃	420	1,260
- Outlet ϕ 0.75	1	set	50	50
- Sand	0.40	m^3	230	92
- Charcoal	0.16	〃	250	40
- Gravel	0.24	〃	230	55
- Reinforced concrete	0.43	〃	3,665	1,576
- Brick 6 ×3 ×2	150	nos	1	150
- Cylinder ϕ 70mm	1	set	10,000	10,000
- Galvanized steel pipe ϕ 2.0	20	m	84	1,680
Sub-total				23,420
2. Labours				
- Foreman	30	man-day	160	4,800
- Skilled worker	45	〃	150	6,750
- Common labour	90	〃	75	6,750
Sub-total				18,300
3. Miscellaneous (1 + 2)× 0.1				4,280
Grand total				46,000

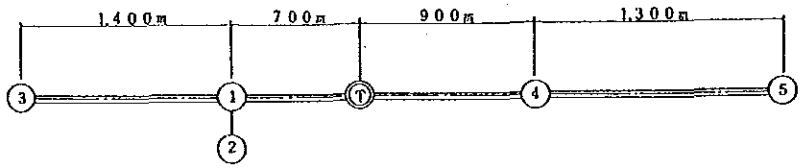
Note: Cost for removal of the existing gauge is included in labour cost.
Transportation cost is included in Material.



NONG KHON KAEN

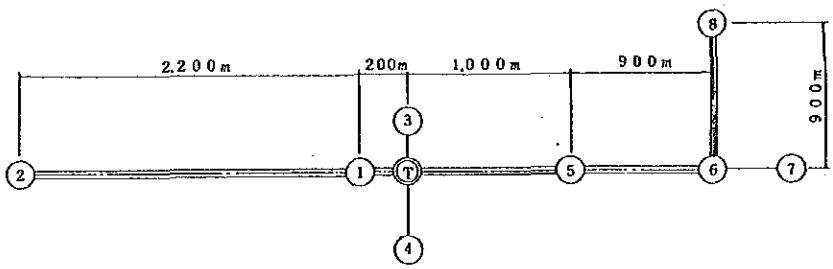
NO	Q
1	13.9 m³/day
2	11.6
3	12.5
4	13.9
5	6.0
6	16.1
Total	74.0

Q : Supply quantity
(Maximam per day)



THUNG SAI YART (1)

NO	Q
1	34.7 m³/day
2	9.9
3	29.8
4	34.7
5	19.9
Total	129.0

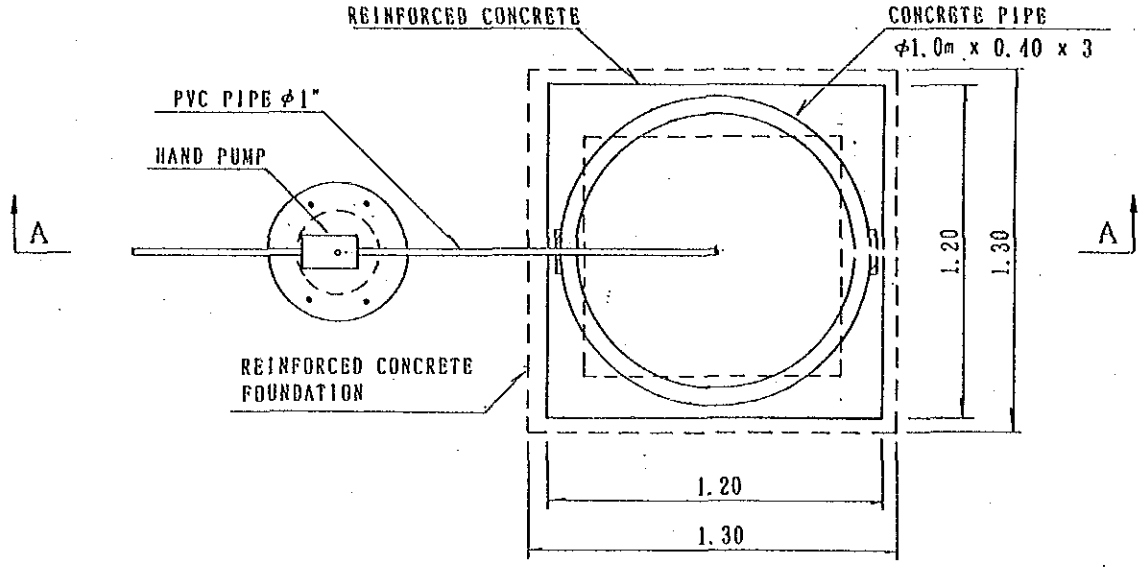


THUNG SAI YART (2)

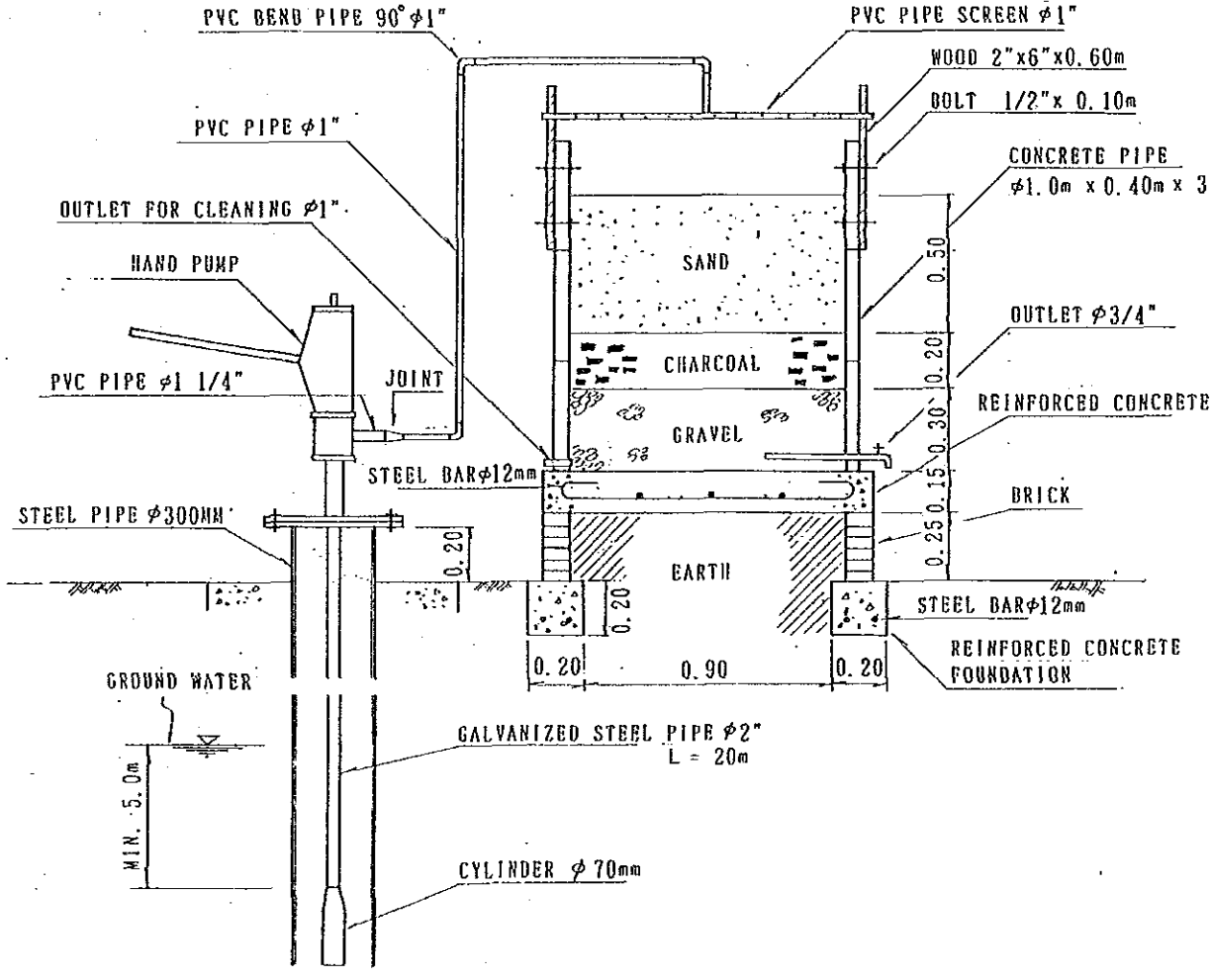
NO	Q
1	42.4 m³/day
2	42.8
3	2.8
4	6.3
5	16.8
6	21.0
7	4.8
8	16.3
Total	113.0

Q : Supply quantity
(Maximam per day)

Figure B-4-1 SUPPLY QUANTITY AND ITS DISTRIBUTION



PLAN



SECTION A－A

Figure B-4-2 RECONSTRUCTION OF EXISTING TEST WELL AS PRODUCTIVE WELL

Appendix B-5 DESIGN AND COST ESTIMATE

B-5-1 Flow Capacity of Dual-purpose Canal

Flow capacity of dual-purpose canal is calculated on the basis of Manning formula.

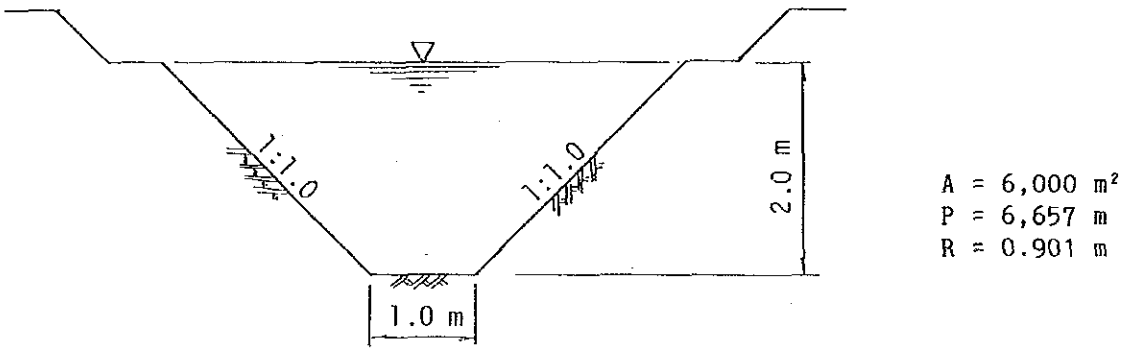
- Manning formula

$$Q = A \cdot V \qquad V = \frac{1}{n} R^{2/3} \times I^{1/2}$$

where Q : Discharge (m^3/s)
A : Flow area (m^2)
V : Velocity (m/s)
n : Coefficient of roughness n = 0.030
R : Hydraulic radius (m) R = A/P
P : Wetted perimeter (m)
I : Hydraulic gradient I = 1/3,000

$V = 1/0.030 \times 0.901^{2/3} \times (1/3,000)^{1/2} = 0.57$ m/s

$Q = 6,000\ m^2 \times 0.57$ m/s $= 3.42\ m^3/s$



B-5-2 Design of Overflow Weir

(1) Design overflow discharge

Design overflow discharge is equal to the canal flow discharge after canal improvement construction.

Weir Type	Overflow Discharge	Applied Canal
I	42.8 m^3/s	Sra Ket, Sai Yart
II	18.3	W.T. Daeng, Mae Luk Onn
III	17.1	Noi

(2) Qualification

Height (H) and top length (B) of weir are determined, following the below qualification.

- Storage rate is obtained more than 50%.

$$\text{Storage rate} = \frac{\text{Storage volume at height of weir (H)}}{\text{Storage volume at full depth (d = 2.0 m)}}$$

- Water depth (H1) behind the weir, which is calculated critical depth on top of weir plus height of weir, is to be less than the full depth (d = 2.0 m) of canal.

(3) Critical depth on top of weir

The critical depth of trapezoid section canal is calculated with the below formula.

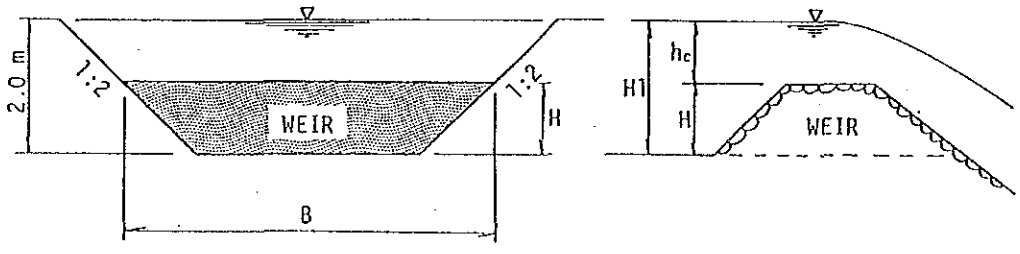
$$hc = \frac{\sqrt[3]{1 + 2\,m\,hc/B}}{1 + m\,hc/B}\sqrt{\frac{Q^2}{g \cdot B^2}}$$

where
hc:	Critical depth	(m)	
Q :	Discharge	(m^3/s)	
B :	Length on top of weir	(m)	
m :	Side slope	m = 2	
g :	Gravity velocity	g = 9.8 m/s^2	

(4) Height and top length of weir

Height (H) and top length (B) of weir, which is satisfied with the above qualification, is determined as follows;

Type	Q	hc	B	H	Remarks
	m^3/s	m	m	m	Storage rate
I	42.8	0.75	20	1.25	56%
II	18.3	0.55	14	1.45	61%
III	17.1	0.48	16	1.50	70%



CALCULATION OF CANAL FLOW CAPACITY

Flow capacity of canal section after construction is calculated with Manning formula.

$$Q = A \cdot V \qquad V = \frac{1}{n} R^{2/3} I^{1/2}$$

Note: Hydraulic gradient is equal to the gradient of canal.

Description	Symbol	Unit	Canal Grouping		
			Type I	Type II	Type III
Bottom width of canal	B	m	10.0	3.0	10.0
Water depth	d	m	2.0	2.0	2.0
Coefficient of roughness	n	-	0.030	0.030	0.030
Flow area	A	m^2	28.0	14.0	28.0
Hydraulic radius	R	m	1.478	1.172	1.478
Hydraulic gradient	I	-	1/800	1/800	1/800
Velocity	V	m/s	1.53	1.31	0.61
Discharge	Q	m^3/s	42.8	18.3	17.1

B-5-3 Division of Construction Area and Cost

(1) Division of construction area

Nong Khon Kaen area is divided into three construction area, and the construction term of each area is as follows, according to the implementation schedule.

Construction Area	Construction Period
N-1	from 3rd year to 4th year
N-2	4th -do- 5th
N-3	5th -do- 6th

Thung Sai Yart area is divided into four construction area, and the construction term of each area is as follows, according to the implementation schedule.

Construction Area	Construction Period
T-1	from 3rd year to 4th year
T-2	4th -do- 5th
T-3	5th -do- 6th
T-4	6th -do- 7th

(2) Construction cost of each area

The construction cost of each construction area was estimated as shown at the latter table.

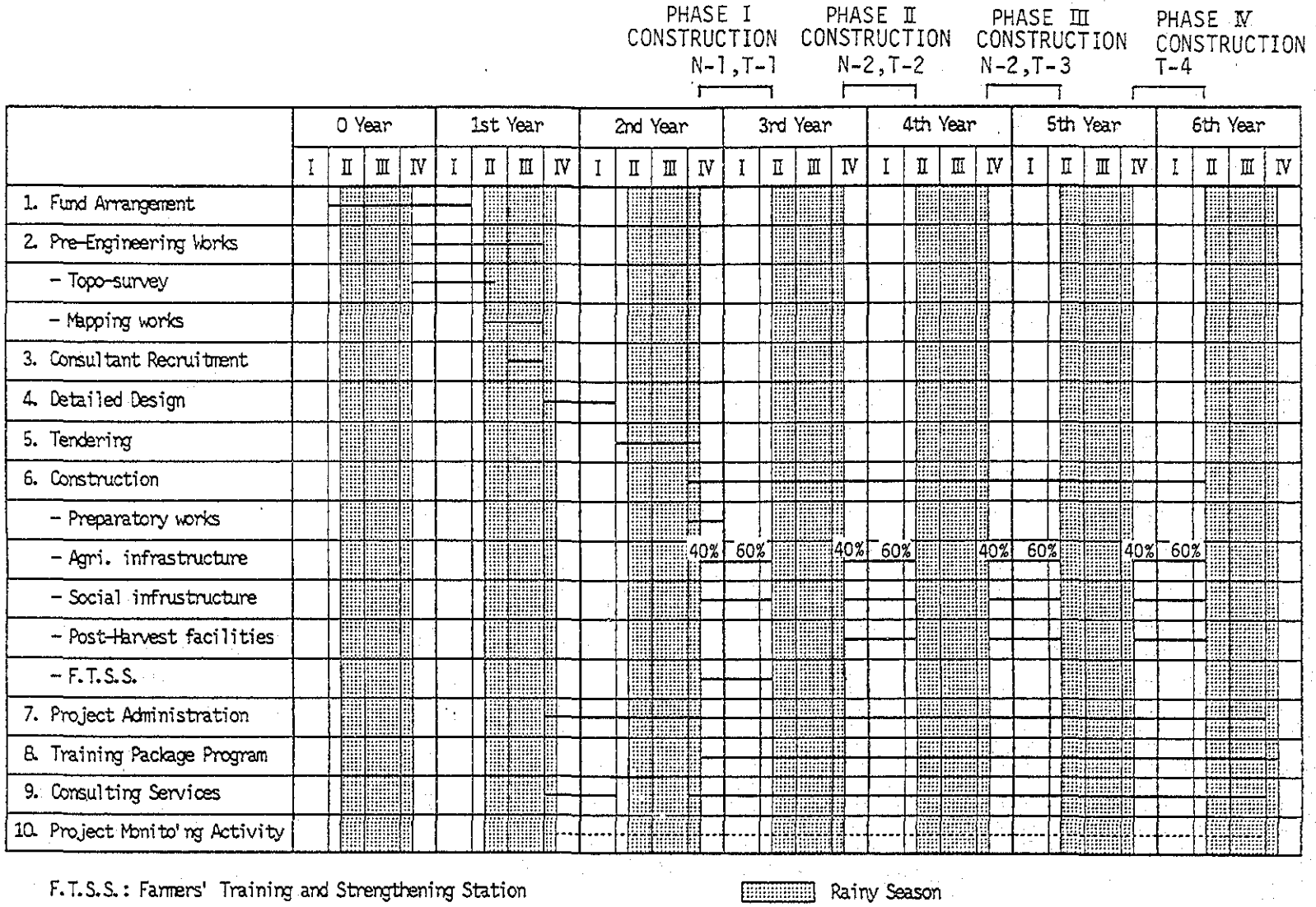


Figure B-5-1 IMPLEMENTATION SCHEDULE OF EACH CONSTRUCTION AREA