NO. 41

THE KINGDOM OF THAILAND

REPORT

ON
WATER SUPPLY FACILITIES
FOR
THE PROMOTION OF PROVINCIAL
HEALTH SERVICES PROJECT

March, 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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F O R E W A R D

The Japan International Cooperation Agency (JICA), intrusted with its work by the Government of Japan, has been extending medical cooperation to the Government of Thailand since 1976 on the project "Promotion of Provincial Health Services".

The purpose of the Project is to improve the public health conditions and at the same time to accelerate the public health development in the rural areas.

As part of the above project, the Government of Thailand planned to establish model water supply facilities in the Province of Chanthaburi and requested JICA to study its feasibility.

In compliance with this request, JICA has decided to conduct a feasibility study on the planned model water supply facilities and sent to Thailand a survey team headed by Dr. Konosuke FUKAI, Professor of the Research Institute for Microbial Diseases, Osaka University, in November 1980.

With extensive cooperation from the central and local government agency personnel, the Japanese survey team could successfully completed the whole series of field surveys and related activities in Thailand and has prepared the present feasibility study report.

I hope that this feasibility study report will go a long way toward early implementation of the model water supply facilities and help to promote the public health and well-being of people in Chanthaburi Province.

I express my deep appreciation to all people related to this feasibility study for their cooperation and support extended to the Team.

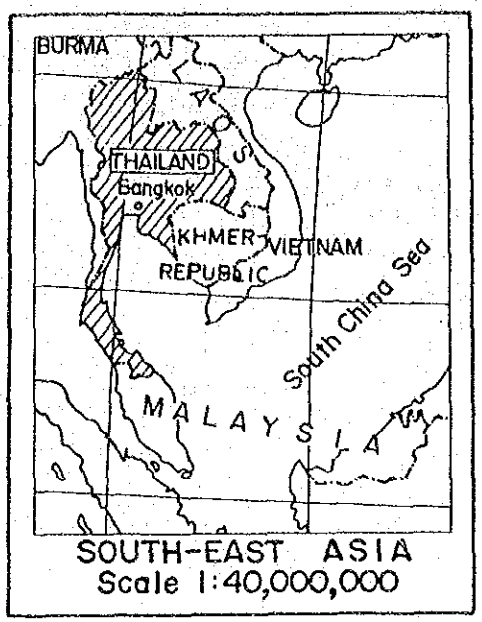
Keisuke Arita

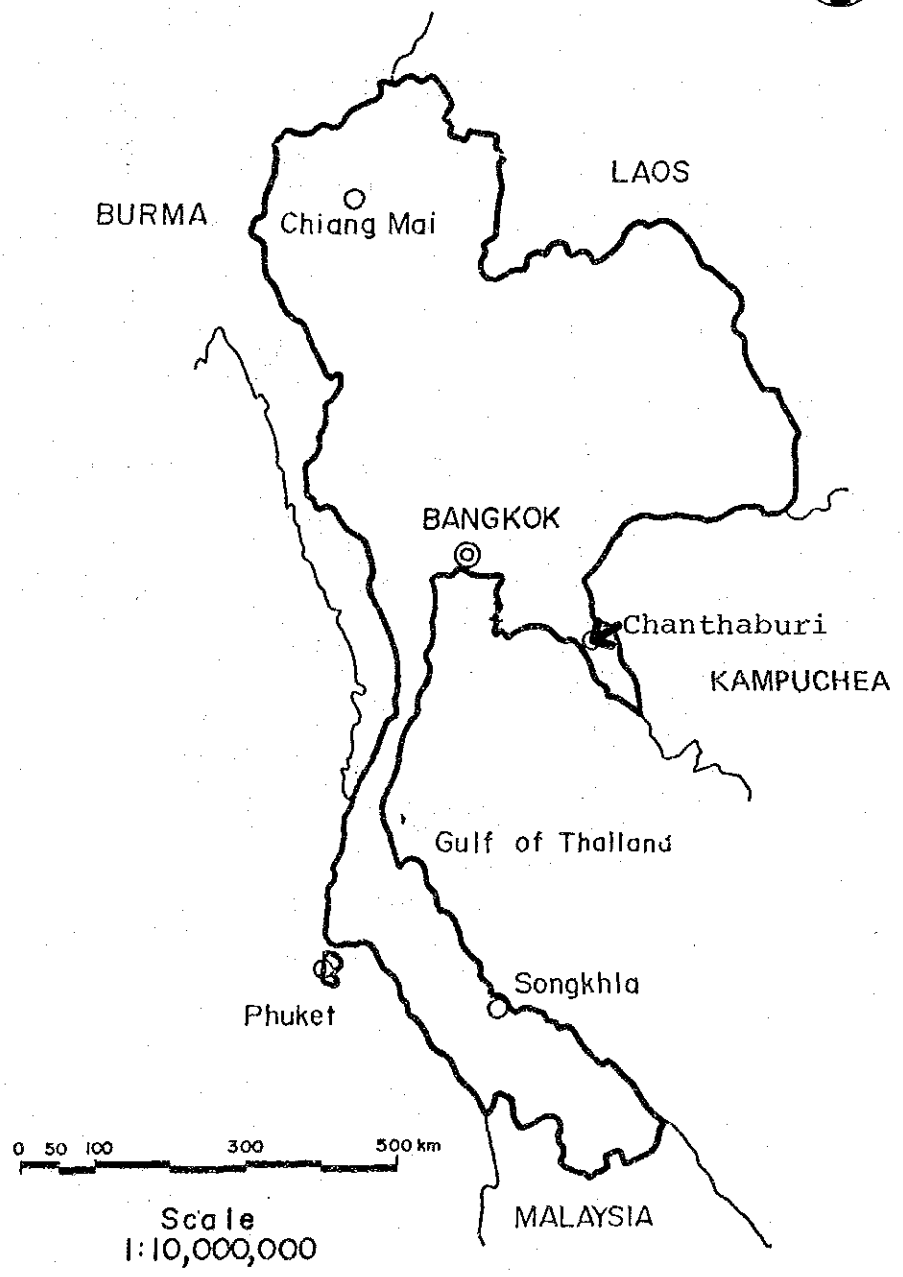
President

Japan International Cooperation Agency

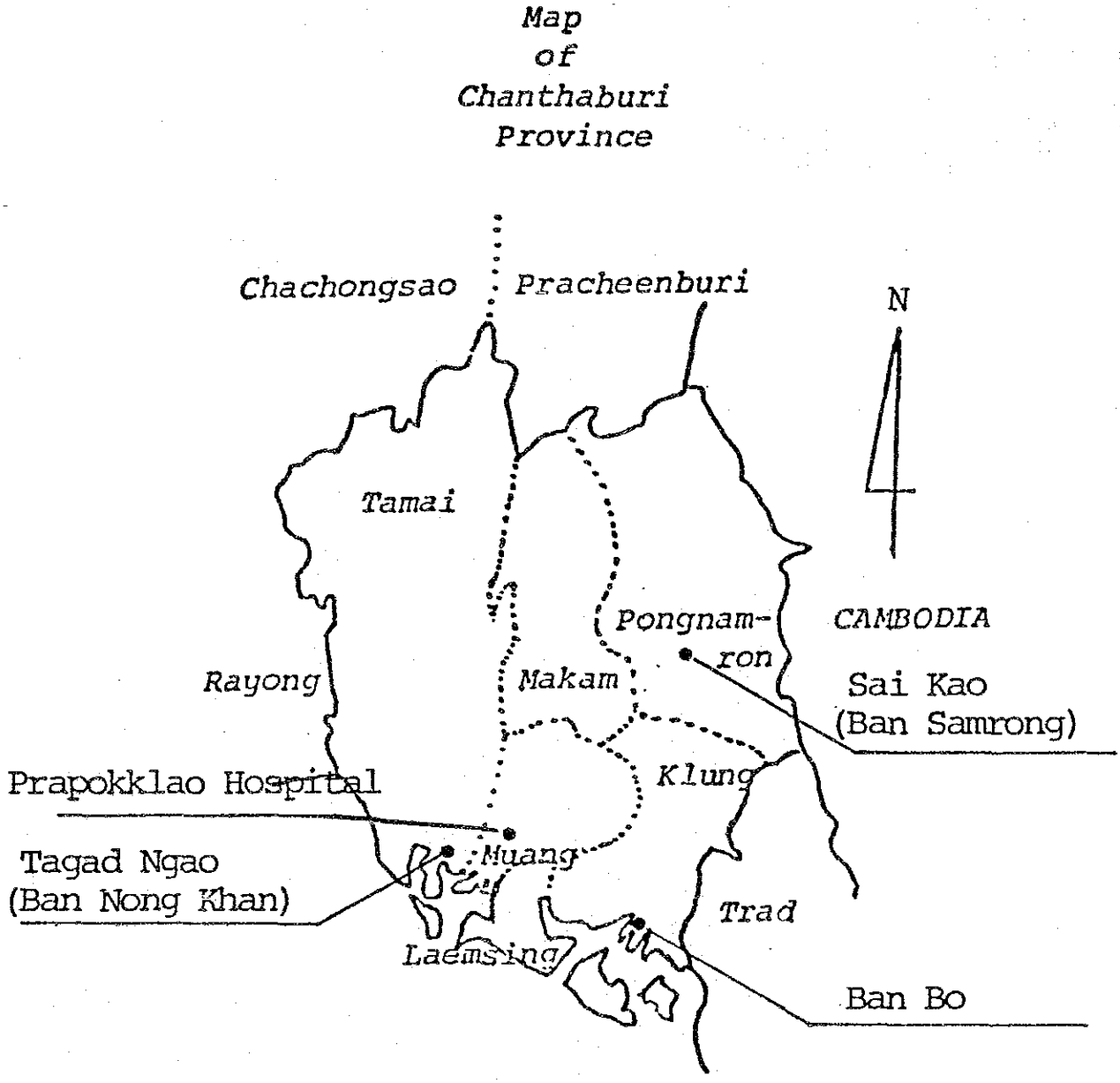
March, 1981

LOCATION MAP





Map of Chanthaburi Province



SUMMARY AND RECOMMENDATIONS

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Summary

The present preliminary water works survey was undertaken by the Japan International Cooperation Agency as part of the Promotion of the Provincial Health Services Project.

The survey covers four areas selected in the province of Chanthaburi in southeastern Thailand. Field surveys were carried out to collect on-site information during a period of about one month from November 30 to Decmeber 27, 1980.

The present survey report is divided into the following sections and subsections.

1. General Information on the Model Areas

(1) Model Areas

Four model areas were selected in the province of Chanthaburi in southeastern Thailand.

(2) Regional Character

Agricultural region

(3) Climatic Character

Tropical climate characterized by typical rainy and dry seasons

(4) Main Industry

Agriculture (and small-scale fishery)

(5) Incidence of Contageous Diseases

The incidence of communicable water-borne diseases is high.

(6) Water Supply Facilities

No water supply system exists except in the Prapokklao Hospital. All communities have access to private wells for their supply of water.

(7) Electricity

No commercial electric power is available in the model districts except in the Prapokklao Hospital area.

2. Population Served

The populations to be served in the four districts are listed in the Table below.

Population and Area Served

Plan	Model Area	Village	Tambol	Amphur	Population or Area
A	Ban Samroong	No. 2	Sai Kao	Pangnamroon	665 persons
		No. 8			423 Persons
B	Ban Nong Khan	No. 4	Tagad Ngao	Thamai	564 persons
C	Ban Bo	No. 3	Bo	Khlung	545 persons
D	Prapokklao Hospital Area	-	-	Muang	700 m^2

3. Basic Design Policy and Design Criteria

(1) Objective

The present preliminary survey has been conducted in order to plan a model water supply system which will not run dry during the dry season and which will secure a reliable source of supply which is appropriate and adequate from the standpoint of public health.

(2) Source of Water

Water will be distributed from deep wells (70 ∿ 80 m deep) and semi-deep wells (30 ∿ 40 m deep) to be driven in the model areas and also from rainwater storage facilities to be constructed in the model areas.

(3) Water Quality

The water to be obtained from the sources mentioned above will be of acceptable quality and meet WHO drinking water standards.

(4) Facility Planning

Preliminary to planning a model water supply system for the model areas the following should be taken into consideration as called for by the regional characteristics of the model areas.

- Since the water supply system will be operated, maintained and managed mainly by the community persons, the running and maintenance costs of the water supply system should be reduced to a minimum and the water supply system should be designed to permit easy operation.
- The hydrogeologic condition of the model areas do not permit tapping a large aquifer. For ther present, the water works project should have as a primary objective to secure a minimum supply of drinking water for the communities. If the system could supply more water than the community population needs for the drinking, the system would be modified to meet other household purposes as well.
- The water supply system will in principle be designed so that no water treatment plant will be required. However, if the use of shallow wells and rainwater is to be considered, a minimum water treatment facility will be planned.
- The daily water demand per person is assumed to be 20 liters.

The design specifications of wells and filtration equipment are outlined in the table below.

Water Production Facilities

Items \ Model Plan	Model Plan A	Model Plan B	Model Plan D
Water Demand (m^3/day)	30	15	20
Type of Well	Deep well	Semi-deep well	Deep well
Depth (m)	80	20 ∿ 30	70
Pump Type	Hand pump	Hand pump	Submersible pump
Estimated Production (m^3/day)	100	50	50
Bore Hole Diameter (mm)	200	300	250
Casing Pipe Diameter (mm)	100	200	150
Screen Diameter (mm)	100	200	150
Screen Length (m)	30	10	30

Water Treatment Facilities

Items \ Model Plan	Model Plan A	Model Plan B	Model Plan C	Model Plan D
Water Demand (m^3/day)	30	15	11	20
Water Reservoir (m^3)	-	1.5	420 x 3	8
Filter Diameter (mm)	-	2,000	1,500	-
Calcium Hypochlorite Dosage (kg/day)	0.2	0.1	0.08	0.14
Number of Water Taps	1	1	1/set	-

4. Construction Costs

- The water supply system construction costs have been estimated, using the market material and labor costs surveyed in Chanthaburi Province as of December 1980.
- The civil engineering work and foundation work required in the construction of the proposed water supply system of the scale considered are well within the capabilities of local contractors

operating in the province of Chanthaburi; however, drilling the well appears to be beyond the those local contractors. Accordingly, the well drilling costs have been estimated with reference to the prices quoted by contractors operating in the city of Bangkok.

- The construction cost estimate contained in the present report exclude contingencies and price increases expected to occur after December 1980.
- On-site engineering supervision will be planned such that the project is supervised during two periods: at the time of ordering and on completion of construction work for inspection and turn-over.

Construction Cost Estimate

Item / Model Plan	Construction Cost in Baht (%)	Construction Period (Days)	Population Served (Persons)	Water Demand (m^3)	Construction Cost (Baht)		
					Per Person	Per household *	Per m^3
Model Plan A	1,090,000 (27)	120	1,088	30	1,002	4,008	36,334
Model Plan B	800,000 (19)	90	564	15	1,419	5,676	53,334
Model Plan C	700,000 (17)	90	545	11	1,285	5,140	63,637
Model Plan D	1,479,000 (37)	120	--	20	-	-	73,950
Total	4,069,000 (100)	390	2,197	76	3,706	14,824	227,255
Average	1,017,250	97.5	733	19	1,236	4,942	56,874

* A household (= 4 persons)

5. Maintenance and Management Planning

- The water supply system will in principle be maintained and managed by the beneficiary, that is, the community people at their own expense.
- A water supply system maintenance and management committee will be set up in each model area.
- The water supply system maintenance and management committee will appoint community members in charge of daily maintenance and management of the water supply system.

- The volunteer communicators and health volunteers of each model area will assist the water supply system maintenance and management committee and its members.

Estimate of Maintenance and Management Costs (in Baht)

Model Area	Item / Model Plan	Energy Costs	Consumables	Administrative Costs	Total	Water Supply Costs		
						Per person	Per household	Per m^3
Sai Kao (Ban Sam Rong)	A	–	5,000	9,000	14,000	14	56	467
Tagad Ngao (Ban Nong Khan)	B	--	5,000	9,000	14,000	25	100	934
Bo (Ban Bo)	C	–	2,500	9,000	11,500	22	88	1,046
Prapokklao Hospital	D	12,500	10,000	10,000	32,500	–	–	1,625
Total		12,500	22,500	37,000	72,000	61	244	4,072
Average		12,500	5,625	9,250	18,000	21	82	1,018

Recommendations

The Japanese survey team proposes the following recommendations for early implementation of the proposed water works project in due consideration of the results of field surveys and planning work, and meetings with the Thai central and local government agency personnel.

1. It is recommended that an executive committee be set up prior to puting this project into action in order to facilitate early and efficient implementation and that the executive committee be developed into an organization which will maintain and manage the water supply system.

2. It is desirable to have the community people participate in the proposed water works project in many ways from the early stage of the project. For instance, their participation in such phases of the project as facility siting, land acquisition and construction work will promote early and efficient materialization of the project. It is desirable that the community people who offer land or labor to help realize the project be compensated reasonably.

3. It will be necessary to keep on hand spare parts and repair tools in readiness in each model district to remedy problems which may arise after completion and it is also desirable that service personnel be organized for the maintenance of the water supply system at the changwad level or at the Amphur level to meet the growing needs of the community in each model area.

4. In the proposed water works project no treatment facility will in principle be provided. However, it is anticipated that the water supply system will tap the rainwater reservoirs depending the location, and hence, suscepitibility to contagious diseases is a possibility in the model areas. It is therefore desirable that proper disinfectants be kept close at hand and under the guidance of the water supply system maintenance and management organization. In the foregoing table of water treatment facilities, guidelines on the daily dosage of calcium hypochlorite is mentioned for the four model plans.

5. The proposed water treatment is, in a word, an emergency measure which will be taken to cope with the prevalence of communicable water-borne diseases. It is hoped that systematic water treatment will be planned in the near future in order to bring a water supply system, in its proper sense of the term, into the reach of all the members of the community.

ABBREVIATIONS AND ACRONYMS

Unless the text states otherwise, the following terms and abbreviations have the following definitions:

WHO	:	Wold Health Organization
UNICEF	:	United Nations International Children Emergency Fund
UNDP	:	United Nations Development Program
IBRD/IDA	:	International Bank for Reconstruction and Development/International Development Association
ADB	:	Asian Development Bank
MWWA	:	Metropolitan Water Works Authority
PWWA	:	Provincial Water Works Authority
cm	:	Centimeters
cm/sec	:	Centimeters per second
m^3	:	cubic meters
m^3/h	:	cubic meters per hour
EL	:	Elevation, meters
Fig.	:	Figure
kg/sq cm	:	Kilograms per square centimeter
kwh	:	kilowatt-hour
kva	:	kilovolt-ampere
lpd	:	liters per day
l/sec	:	liters per second
Max	:	maximum
Max day	:	maximum day
Min day	:	minimum day
mg/l	:	miligrams per liter

Min	:	minimum
mm	:	millimeters
mm/year	:	millimeters per year
m	:	meters
m/day	:	meters per day
MVA	:	mega volt-ampere
pH	:	potential of Hydrogen
ppm	:	parts per million
PVC	:	polyvinylchloride
rpm	:	revolutions per minute
cm^2	:	square centimeters
m^2	:	square meters
V	:	volts
m^3/sec	:	cubic meters per second
m^3/min	:	cubic meters per minute
m^3/day	:	cubic meters per day

CURRENCY EQUIVALENTS:

Currency Unit	= Thailand Bhats (฿)
US$1	= ฿ 20.25
US$1 million	= ฿ 20.25 million
฿ 1	= US$0.049
฿ 1 million	= US$49,000

FISCAL YEAR PERIOD, from APRIL 1 to MARCH 31

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CHAPTER 1 GENERAL

CHAPTER 1 GENERAL

1–1 Objective of the Survey

The present survey was undertaken by the Japanese International Co-operation Agency (JICA) as part of its Promotion of the Provincial Health Services in order to plan the water supply system in the selected model areas in a way which reflects the wishes of the Thai central and local government agencies. Study was also carried out to determine the technical, economic and social appropriateness of the water works proposed to combat communicable water-borne diseases in the model areas of the Chanthaburi Province.

1–2 Background of the Survey Request

Potable water is available in limited quantities across Thailand; consequently, the incidence of communicable water-borne diseases, such as cholera, dysentery and dengue, is very high. Under such circumstances it has long been strongly desired to promote the construction of a water supply system which would provide safe drinking water in a reliable manner. Against this background, the Government of Thailand requested the Japanese Government for technical and economic cooperation in its national project of public health promotion.

This project is based on the minutes of meeting between the Thai and Japanese officials signed on April 1, 1976. Its purpose is to accomplish the technical transfer necessary to combat contagious diseases, and to promote public health and hygiene service, public health examinations, public health education and other public health services in the province of Chanthaburi, thereby improving the public health standards of the community. In compliance with the request of the Thai side, the Japanese side sent a preliminary survey team to Thailand for the purpose of collecting on-site information required to improve the water supply in the model areas in July 1980, and a project planning survey team in November 1980.

1–3 Members of the Survey Team

The survey team, headed by Dr. Konosuke Fukai, Professor from Osaka University, consisted of the following members:

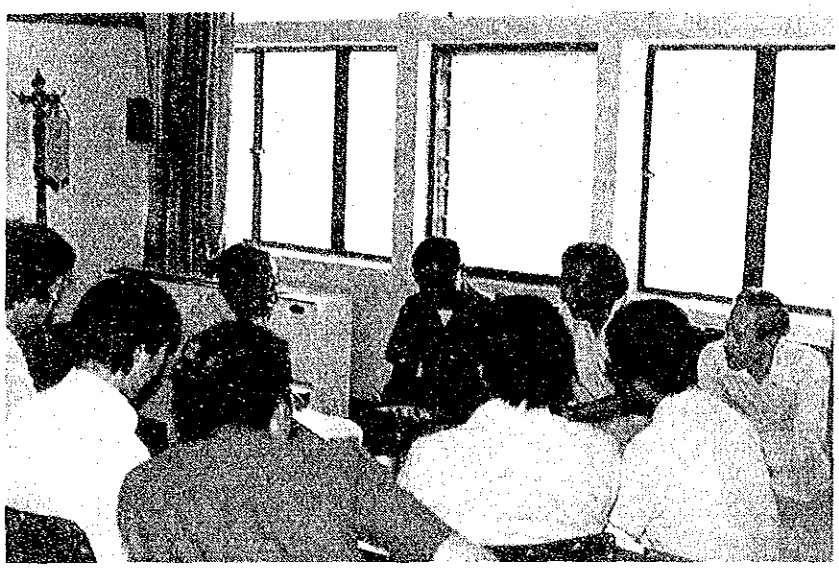
Team Leader	Kohnosuke Fukai	General	Institute for Microbial Diseases, Osaka University
Member	Johji Yanagawa	Water Supply Planning	Environment Sanitation Bureau, the Ministry of Health and Welfare
Member	Yoshikazu Itoh	Water Engineer	Pacific Consultants International
Member	Noboru Sugiura	Water Supply Enginner	Naka Nihon Consultant
Member	Yoshimi Kishikawa	Water Resource Engineer	Pacific Consultants International
Member	Eiji Terasawa	Coordinater	Medical Cooperation Division, JICA

1-4 Survey Trip Itinerary

Date		Purpose of Trip	Destination
1980	Nov. 30 (Sun)	Trip	Left Tokyo for Bangkok
	Dec. 1 (Mon)	Courtesy Call	Paid courtesy call to the Japanese Embassy (First Secretary Muraoka) and JICA Bangkok office (Res. Rep. Mr. Kitano).
	Dec. 2 (Tue)	Conference	JICA Bangkok office (Regional Coordinator, Mr. Jibiki and Mr. Watanabe
	Dec. 3 (Wed)	Courtesy Call	PWWA, Department of Medical Sciences, Ministry of Public Health and Department of Mineral Resources, Ministry of Industry
		Trip	Left Bangkok for Chathanburi
	Dec. 4 (Thu)	Courtesy Call	Provincial Medical Office (Dr. Thongyoi Swasdichai) and Governor
		Conference	Provinical Medical Office and Provincial and District Hospital
		Trip/Sampling	Visited Tagad Ngao area (where four wells are now in use)
	Dec. 5 (Fri)	Trip/Sampling	Visit to Ban Bo area
		Conference	Met with the Japanese medical experts (medical cooperation team)
	Dec. 6 (Sat)	Trip/Sampling	Visited Ban Sam Rong area (where three wells are now in use).
	Dec. 7 (Sun)		Prepared for electric prospecting and classified materials and data.

Date		Purpose of Trip	Destination
1980	Dec. 8 (Mon)	Survey	Visited the Chathanburi Provincial Hospital and performed geoelectric prospecting
	Dec. 9 (Tue)	Survey/Sampling	Surveyed deep wells in Laem Sing area and the Khlong river.
	Dec. 10 (Wed)	Survey and Sampling	Collected water samples from existing wells in Chathanburi city.
		Conference	Team conference (presided over by Team Leader Fukai)
	Dec. 11 (Thu)	Survey	Performed electric logging at 2 sites in Tagad Ngao area.
	Dec. 12 (Fir)	Survey	Performed geoelectric prospecting at 2 sites in Ban Sam Rong district.
	Dec. 13 (Sat)	Survey	Surveyed water sources in Ban Sam Rong area.
	Dec. 14 (Sun)		Classified materials and data.
	Dec. 15 (Mon)	Conference	Met with provincial public health technical office officials and Japanese experts (medical cooperation team).
	Dec. 16 (Tue)	Marketing survey	Performed marketing survey in Chathanburi city to collect information on material and labor costs.
	Dec. 17 (Wed)	Conference	Met with provincial public health technical office officials.
	Dec. 18 (Thu)		Classified materials and data.
	Dec. 19 (Fri)		Left Chathanburi for Bangkok.
	Dec. 20 (Sat)		Classified materials and data.
	Dec. 21 (Sun)		Classified materials and dtta.
	Dec. 22 (Mon)	Marketing survey	Performed marketing survey in Bangkok city.
	Dec. 23 (Tue)	Marketing survey	Continued marketing survey in Bangkok city.
	Dec. 24 (Wed)		Classified materials and data
	Dec. 25 (Thu)	Conference	Met with Department of Medical Sciences officials to discuss the water works project from an overall viewpoint and briefed them on the progress report.
		Courtesy call	Visited the Japanese Embassy and JICA Bangkok office.
	Dec. 26 (Fri)	Conference	Classified materials and data and met with Japanese expoerts (medical cooperation team).
	Dec. 27 (Sat)	Trip	Left Bangkok for Tokyo.

1–5 Minutes of Discussions



Discussion Meeting at Chanthaburi
with Chanthaburi Governor and team

Minutes of Discussion

for

Improvement of Water Supply Facilities in the Model Areas

of

"Promotion of Provincial Health Services Project"

On the occasion of the Japanese Team visited to Bangkok for observation and discussion in at site a series of discussions on the above "Project" were held between the Thai side and Japanese side on 3rd of December 1980.

The followings were the major point discussed and concluded in the meeting.

1) This study shall be performed as a part of Health Promotion Project "Promotion Of Provincial Health Services" in accordance with Model Infrastructure in Chanthaburi Province.

2) The following four model areas has been selected in the past activities of the "Project".

   -1 Ban Sam Rong, Tambol Sai Kao, Amphur Pongnamron.

   -2 Ban Nong Khan, Tambol Tagard Ngao, Amphur Thamai.

   -3 Ban Bo, Tambol Bo, Amphur Khlung.

   -4 The vicinity of Prapokklao Hospital, Amphur Muang.

3) The above model areas have basically following characteristics mentioned in Inception Report respectively.

   This field survey is to be carried out in these model areas.

   a. An area where no other water source is expected other than deep wells because water level is too low.

   b. An area near a coast or a swamp where deep wells are expected to contain much salt.

   c. An area where water sources can be found in mountain torrents which do not dry up even in dry season.

   d. The vicinity of Prapokklao Hospital where the project bases is located.

4) The purpose of this survey is to study the engineering design and cost estimates for the rural water supply facilities of said areas in accordance with analysis of the present conditions.

December 3, 1980

Sutas Guptarak, M.D.
The Project Director
Promotion of Provincial Health
Services Project

Konosuke Fukai, M.D.
Team Leader
Japanese Detailed Design Team
for Water Supply Facilities

CHAPTER 2

GENERAL INFORMATION ON THE MODEL AREAS

CHAPTER 2 GENERAL INFORMATION ON THE MODEL AREAS

2—1 Model Areas Selection

The provincial health services promotion project in eastern Thailand has been planned with emphasis placed on the three model areas selected in the province of Chanthaburi. The southwestern border of this province borders the Gulf of Thailand, with hilly landforms on its northern and eastern borders. The three model areas represent a rather peculiar part of Thailand, as will be described later, from the standpoint of social structure as well as topology. Accordingly, the approach to health promotion will of course differ from one area to the other and efforts made to improve the public health services in each area will be extended to the hilly area, the old estuary coastal area and the littoral marshy land area.

Generally speaking, the effort to improve water supply facility is liable to be regarded only as a combat with infectuous diseases, especially gastrointestinal infections, and in point of fact, the reward for such efforts is the containment of infectuous diseases in many instances. However, when public health promotion is considered from the standpoint of the whole community, the water supply facility has still greater implications. In the villages choses as model areas, health communicators who are elected to cover a certain proportion to the population of each village, engage in provincial public health services based at the health centers; however, such health promotional activities are not systematic yet. One of the chief objectives of this project consists in motivating the people of the community to shoulder the task of public health promotion in the whole community. In this light, the water supply facility will play a role of pivotal importance in stimulating the provincial public health consciousness of all community people. A systematic approach to teach community people how water, which is an element of cardinal importance to human life, can be secured and safely and reliably distributed to every community member, will prove to be an understable, easy-to-tackle task to realize and promote the cooperation of the community in the public health promotion project for the whole community. This task will provide an excellent opportunity to utilize to the full extent the wisdom of the community in close touch with local conditions and develop their capabilities. The community if so motivated and stimulated will reap the rewards for their efforts and learn that health is an asset which they can acquire for themselves. The recognition of this axiom

will lead the community to the next stage of public health services: health promotion. Their services in this advanced stage will pave the way for systematic participation of the community in the Provincial Public Health Services Promotion Project.

The actual condition of the three model areas has been studied in detail as the result of activities related to the Provincial Public Health Services Promotion Project over the past 4 years, and the demand for health improvement in each of the three model area is clearly known. If the water supply project, which will form the basis of future health promotion servicies, could be implemented in these areas, the water supply facilities would develop in a way well suited to the characteristics of each area and also form the basis of extension programs to other areas.

1) The area of Ban Sam Kong consists of two villages situated in the hilly land in northern part of the province of Chanthaburi; Sai Kao and Ban Samroong. These are typical agricultural villages which are developed on a hilly strip of land. In this area malaria rages with high frequency and the villages worse off. As the villages are situated on the hilly land, ground water occurs at quite deep levels. Furthermore, it is extremely difficult to tap ground water for domestic use, since the ground water resources which are located near the border with Kampuchea are very far away. Unlike in the villages in the littoral area, real poverty prevails in this model area. Perhaps because of the poverty, the health communicators in this area are much more active than those in other model areas.

2) The village of Tagad Ngao which was built by clearing littoral marshy land has always been afflicted by bacterial and parasitic enteric infections, notably ankylostomiasis, and ulcers in the lower extremities (of unknown cause) which occur with high frequency during the dry season. Furthermore, the long distance which the villagers must walk to reach the water source consumes much time and is a great burden on their lives. The scarce water resources are also apt to be ruined by uncontrolled use. Water drawn from the wells dug by villagers is not good to drink due

to the lack of apprppriate technical guidance. During the dry season the villagers only have access to stored rainwater and expensive commercial drinking water.

The picture of water paucity described above can be considered to be typical of the situation of all villages situated in the southwestern littoral area in the Province of Chanthaburi.

3) The village of Ban Bo, is typical of ones situated in the southeastern coastal area in the Province of Chanthaburi and is situated on the old estuary sand bar. This village is also plagued by the prevalence of enteric infections which occur due to lack of safe water. As the soil is sandy over the greater part of the land, the villagers virtually only have stored rainwater to drink. The Wel river which flows on the outskirt of the Ban Bo village provides only brackish water which is not good to drink.

For all the reasons mentioned above, it was considered to be worth while to undertake a survey and a feasibility study for the water supply facilities for the selected model area in the province of Chanthaburi.

In the Provincial Public Health Promotional Services in Thailand, it is important to obtain cooperation from the village headman, the temple abbot, and school master and prominent figures of the village who have the support of village seniors and juniors, alike. It is such key persons that will form the nucleus of activities directed forwards the improvement of Provincial Public Health Services. The fact that these key persons of the three model areas are deeply concerned with the health and water supply facility of their communities, suggests that they will generate great community support for the future activities in this project.

The present survey was conducted not only in these three model areas, but also in the Prapokklao Hospital compound located in the city of Chanthaburi. The addition of this model area was considered necessary, because it appears to be the sole possible place to perform the scientific work required in the proposed project. To illustrate the importance of a reliable year-round water supply, at the Prapokklao Hospital an episode is related below.

A reliable supply of good water is indispensable to efficient and safe examination of patients for causative organisms of enteric infections, an important measure of provincial public health. In the other three model areas however, the water sources run dry during the dry season so that in the past, screening test could not be performed. (It should be noted that it is in the dry season rather than in the wet season that such tests are required). Unless this problem is solved, the survey and research activities may not be effective.

For the reasons stated above, the present study was designed to cover the three model area directly related to the Project "Promotion of Provincial Health Services" using the Prapokklao Hospital compound as a base for project infrastructure improvement.

2-2 Social and Economic Conditions

Tha main export items of Thailand consist of primary products such as rice, corn, rubber, tapioca starch, sugar, and tin. Rice is grown mainly in nothern Thailand and in the fertile central land irrigated by the Chao Phraya river. The model areas in the province of Chanthaburi are for the most part suitable for paddy rice growing, which is a major crop of the area. In the hilly land plantations spread far and wide, and the areas on either side of the national highways rubber is planted.

In recent years, however, a shift from rubber to cayenne has been taking place in pursuit of greater profits.

In the Ban Bo area near the sea, there are villages where people engage in both agriculture and fishery, making use of natural creeks for protection. In this province there are many orchards where fruits such as durian and rambutan are grown. This province also produces precious stones. In the business district of Chanthaburi city there are many gem polishing shops and jewellery stores. For a local city located in an agricultural district, Chanthaburi city does brisk business. In conducting the present survey, model villages of a population of 500 to 1,000 were selected. Most working villagers are engaged in agriculture. The village is centered around the wat and primary school, and the educational system has been changed from the 4-3-3-2 to the 6-3-3 system. The period of compulsory education is 6 years. According to the 1975 census, the people who have completed the primary 6-year course of education, account for about 40 percent of the population, and those who have completed the next 3-year course, account for 27 percent.

It appears that villagers of the selected model areas have about the same educational levels as mentioned above. The social infrastructure of the model areas is yet to be established. The water supply system which is closely related to the everyday lives of the community is not adequate, and during the dry season community people suffer badly from a water supply shortage. In the province of Chanthaburi only a few areas are served with water. In the model areas the community depends for its supply of water on rainwater and shallow wells which produce water of poor quality. During the dry season the community people buy water for drinking. Individuals pay about 200 baht for 1 m^3 of drinking water (and big users like hospitals pay only about 50 baht for the same quantity of water). Judging from the

living standard of villagers in the model area, this water cost seems rather high. In Chanthaburi city, bottled drinking water is sold: Each 950-ml bottle sells for 12 baht and a 20-liter bottle sells for as much as 70 baht. These expenses are far beyond the reach of villagers to afford.

Electric power supply is also in a very poor situation. The 220-volt line voltage is unstable and power failures are frequent. In the hilly Ban Samroong area and the coastal Ban Nong Khan area, no electric power is available. Communications including telephone service are not developed, but the local health centers are provided with radio communication equipment.

The medical system of Thailand is like a pyramid: midwifery centers at the bottom, then second-class health centers and first-class medical & health centers (with 10 to 30 beds), national hospitals and provincial health technical offices at the top. According to the 1979 report, just over 30 doctors are registered in the province of Chanthaburi, but 27 of them attend the national hospitals and 7 are administrative officers. Thus, about 200,000 lives of the community people of Chanthaburi Province excluding the city of Chanthaburi are placed in the hands of only 4 doctors. The Thai Ministry of Public Health has a plan to send volunteer communicators and health volunteers.

One communicator per 10 families is selected in consideration of his academic career, personality, personal assets, reputation, and other characteristics. He is trained in public health care and is assigned to the job of attending villagers' gatherings to collect information on the health of villagers, report his findings to the local health center, and furnish villagers with public health-related information, such as preventive inoculations, family planning campaign, and public health education programs.

Health volunteers are selected in still smaller numbers. They engage in simple first aid and other similar jobs.

Table 2-1 Organization of the Ministry of Public Health

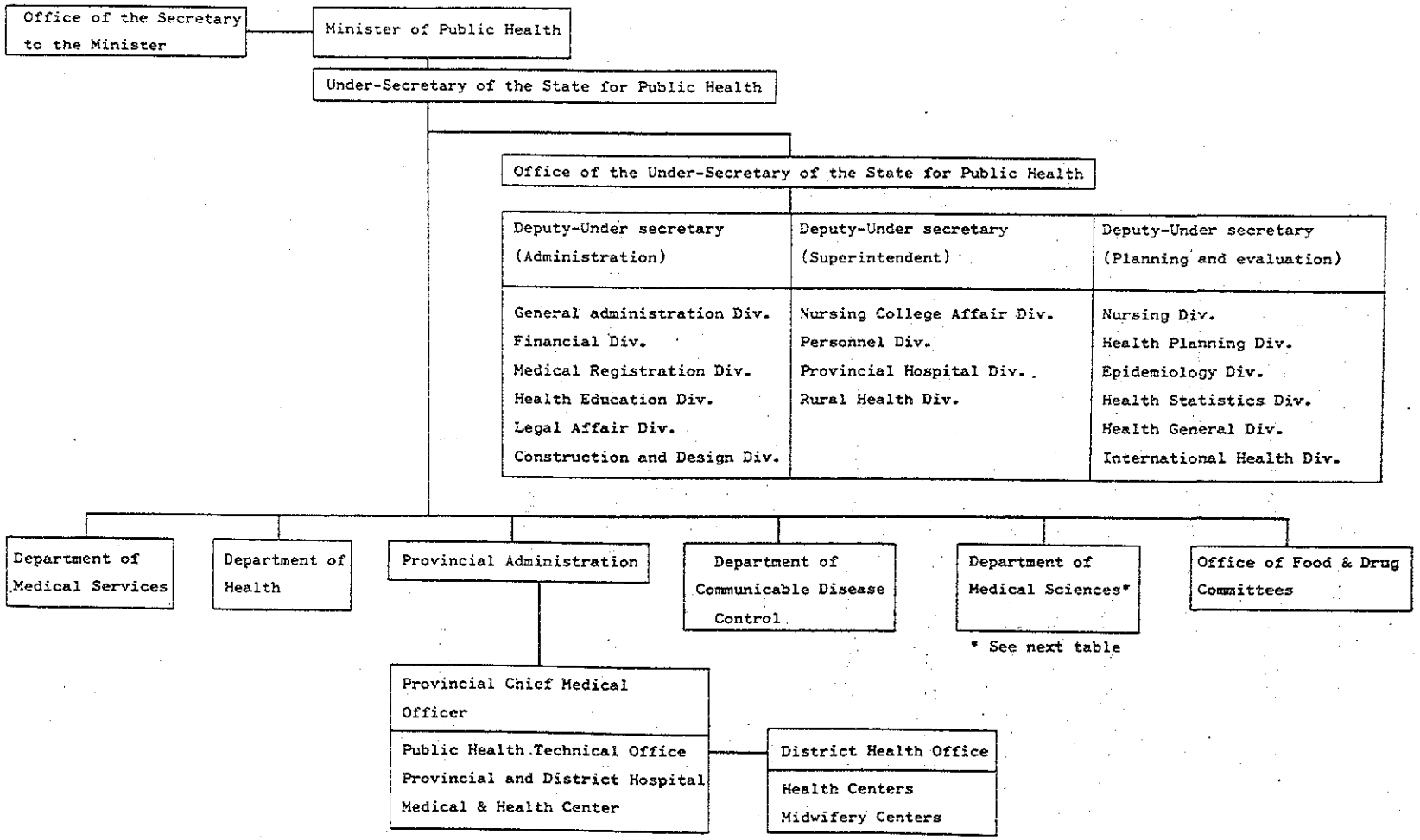


Table 2-2 Department of Medical Science

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i) Office of the Secretary

ii) Division of Medical Entomology

iii) Division of Provincial Health Laboratory Services

Medical Laboratory Assistant (MLA), Medical Laboratory Technologist

iv) Division of Radiation Protection Service

v) Division of Clinical Pathology

vi) Division of Toxicology

vii) Division of Drug Analysis

viii) Division of Food and Bevarage Analysis

ix) Division of Medical Research

x) Virus Research Institute

Fig.2-1 Map of Chanthaburi Province

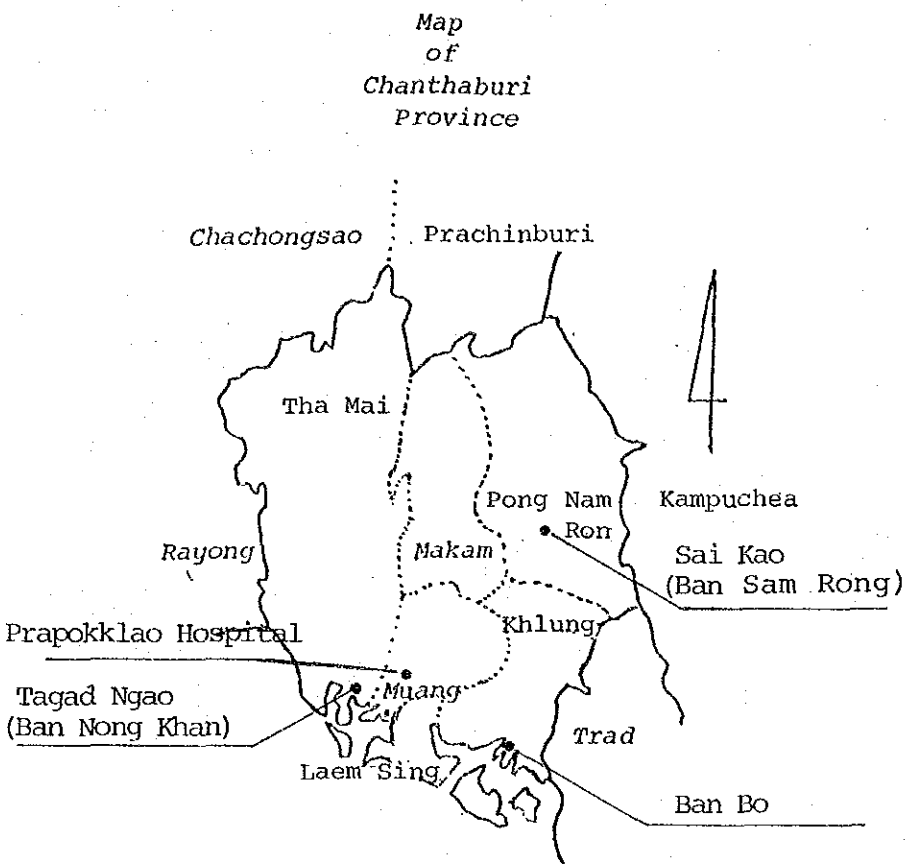


Table 2-3 Description of the Model Villages

AMPORE	MODEL VILLAGE	VOLUNTEER COMMUNICATOR	POPULATION
Tha Mai	Tagad Ngao Village 4	7	564
Khlung	Bo Village 3	10	545
Pongnamron	Sai Kao Village 2,8	20	1,088
Muang	Prapokklao Hospital	-	-

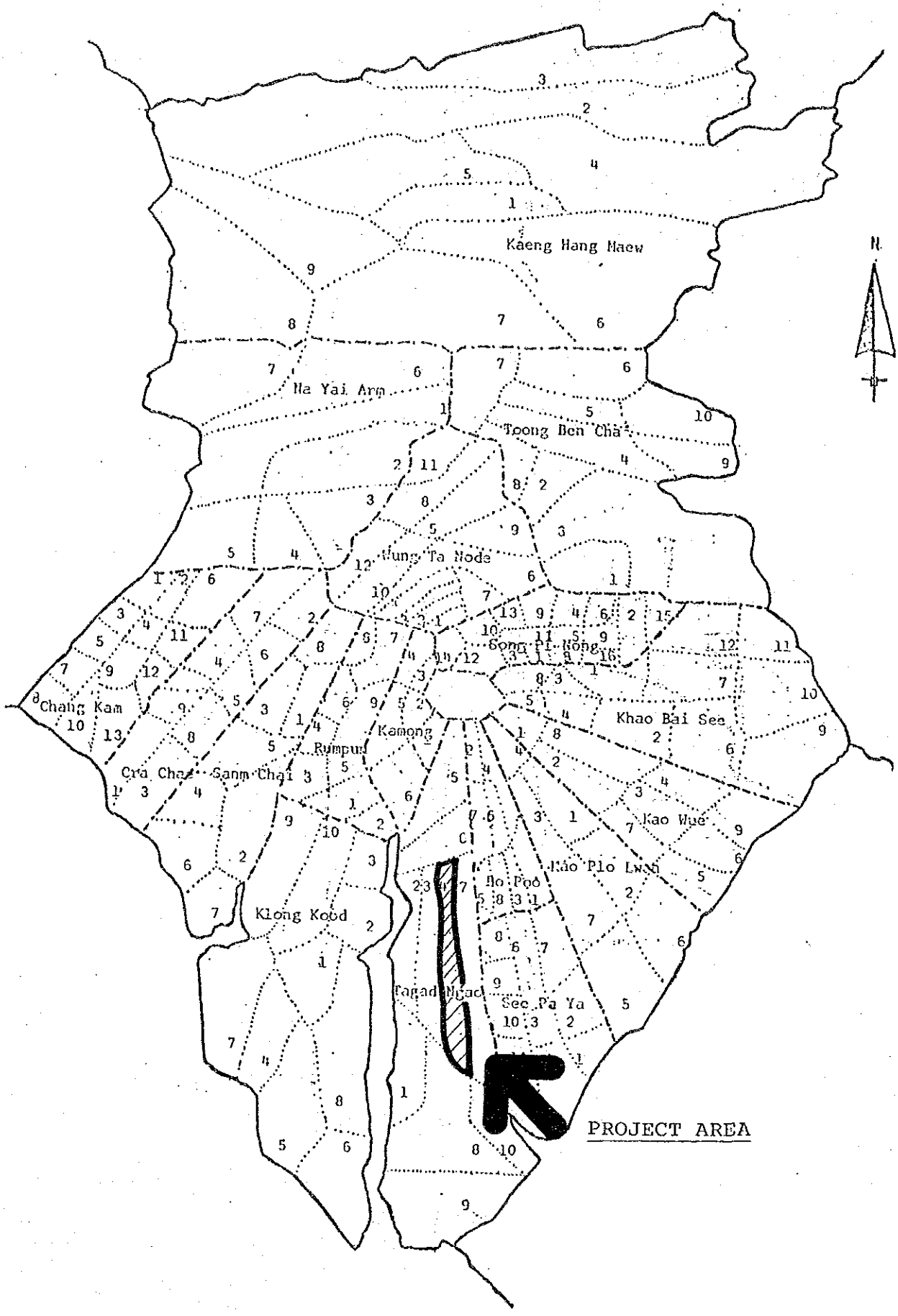


Fig.2-2 Map of Amphur Tamai

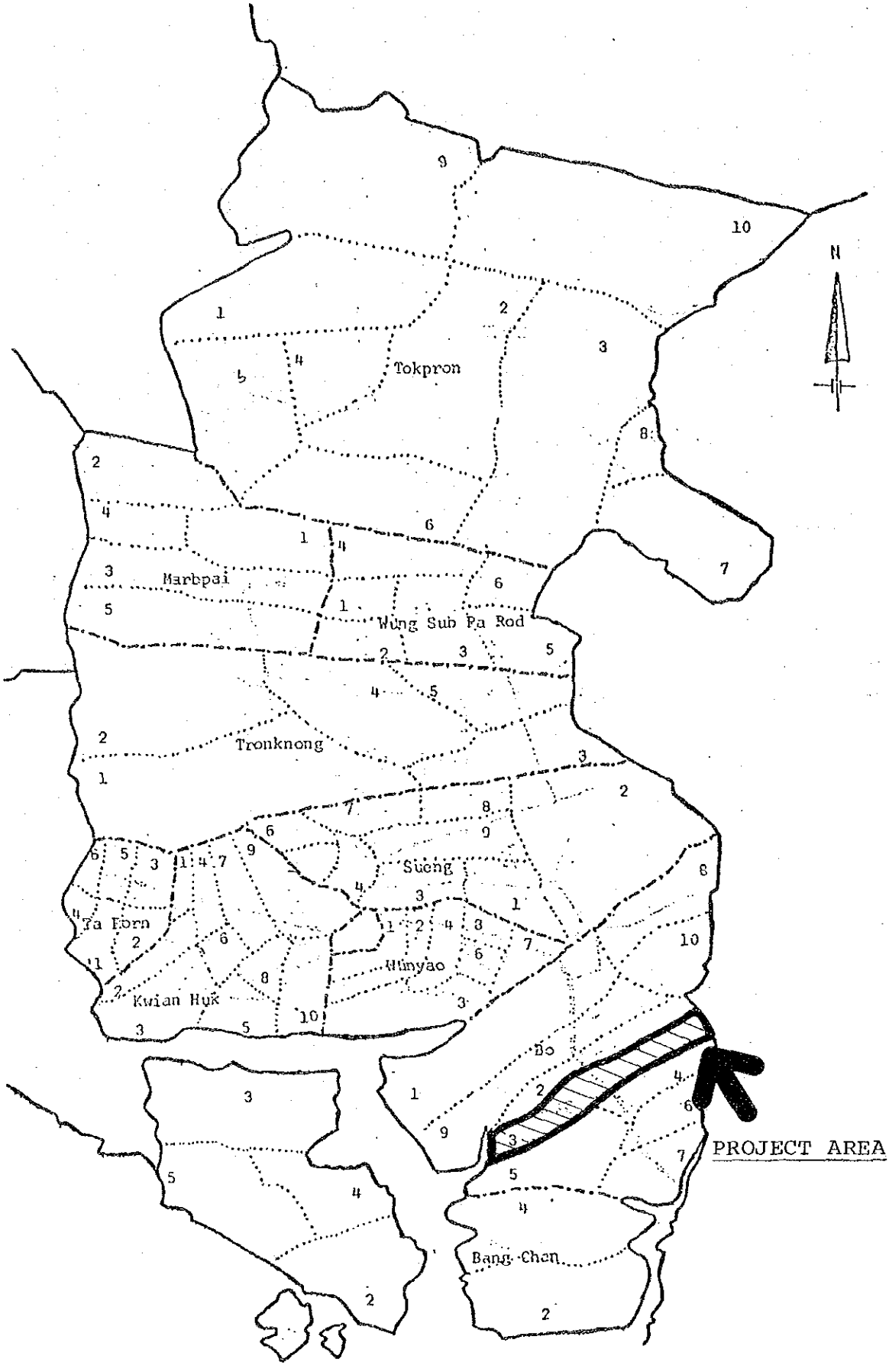


Fig.2-3 Map of Amphur Khlung

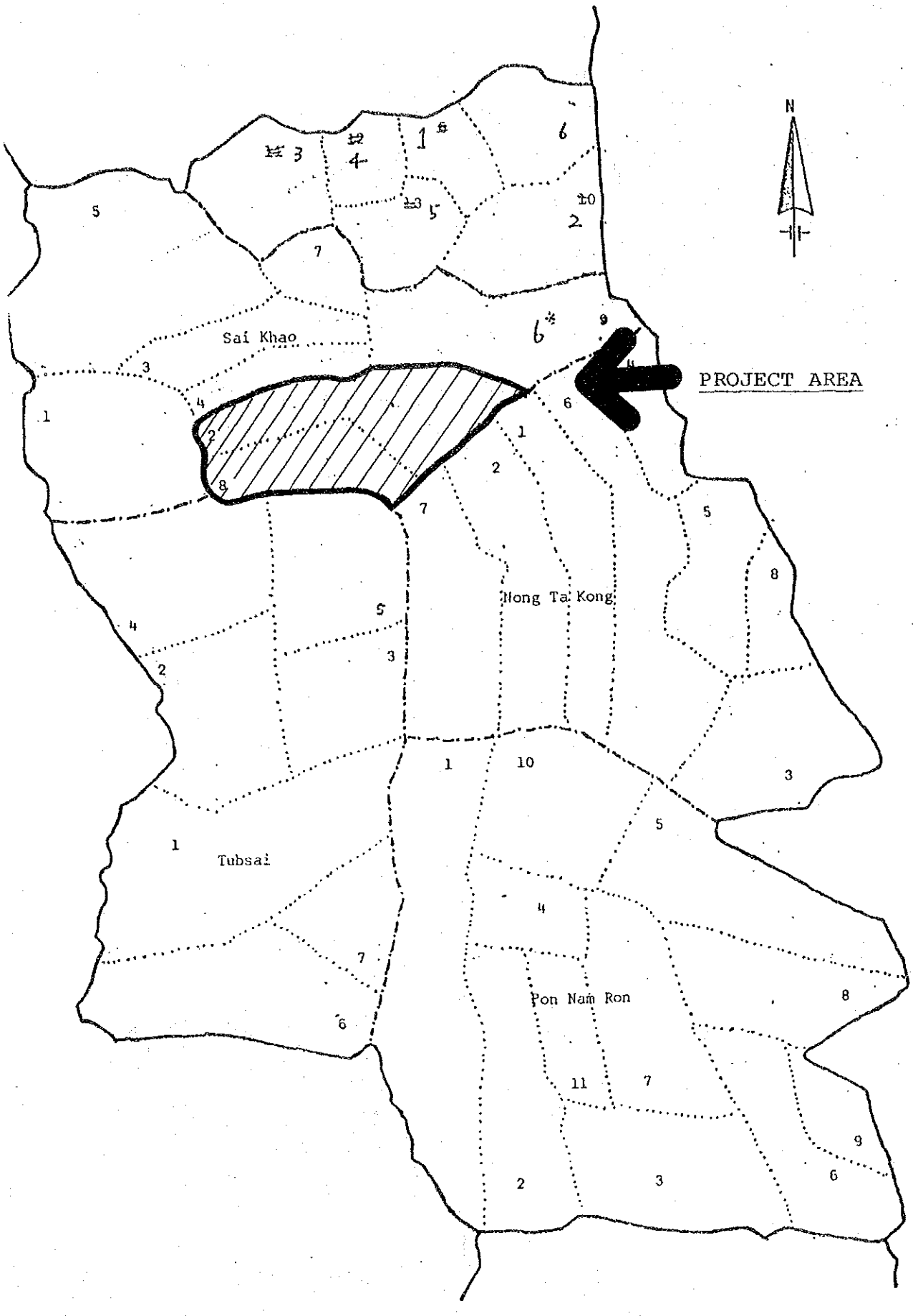


Fig.2-4 Map of Amphur Pong Nam Ron

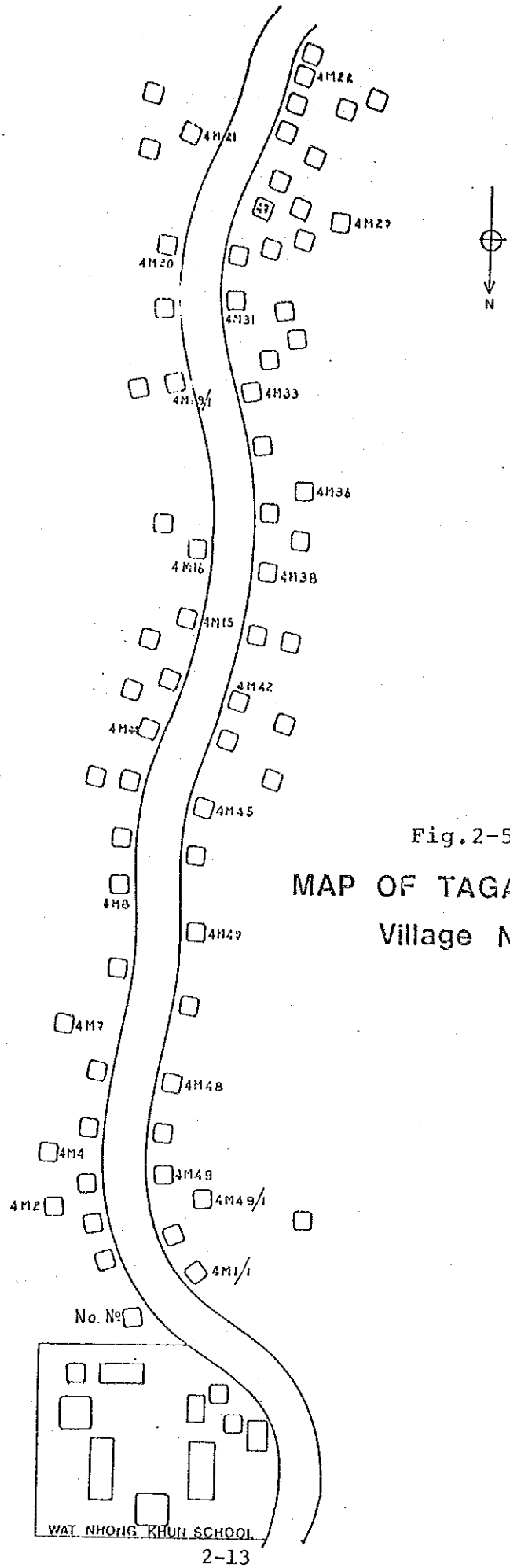


Fig.2-5

MAP OF TAGAD-NGAO

Village No.4

Fig.2-6

MAP OF BAN BO

Village No.5,6

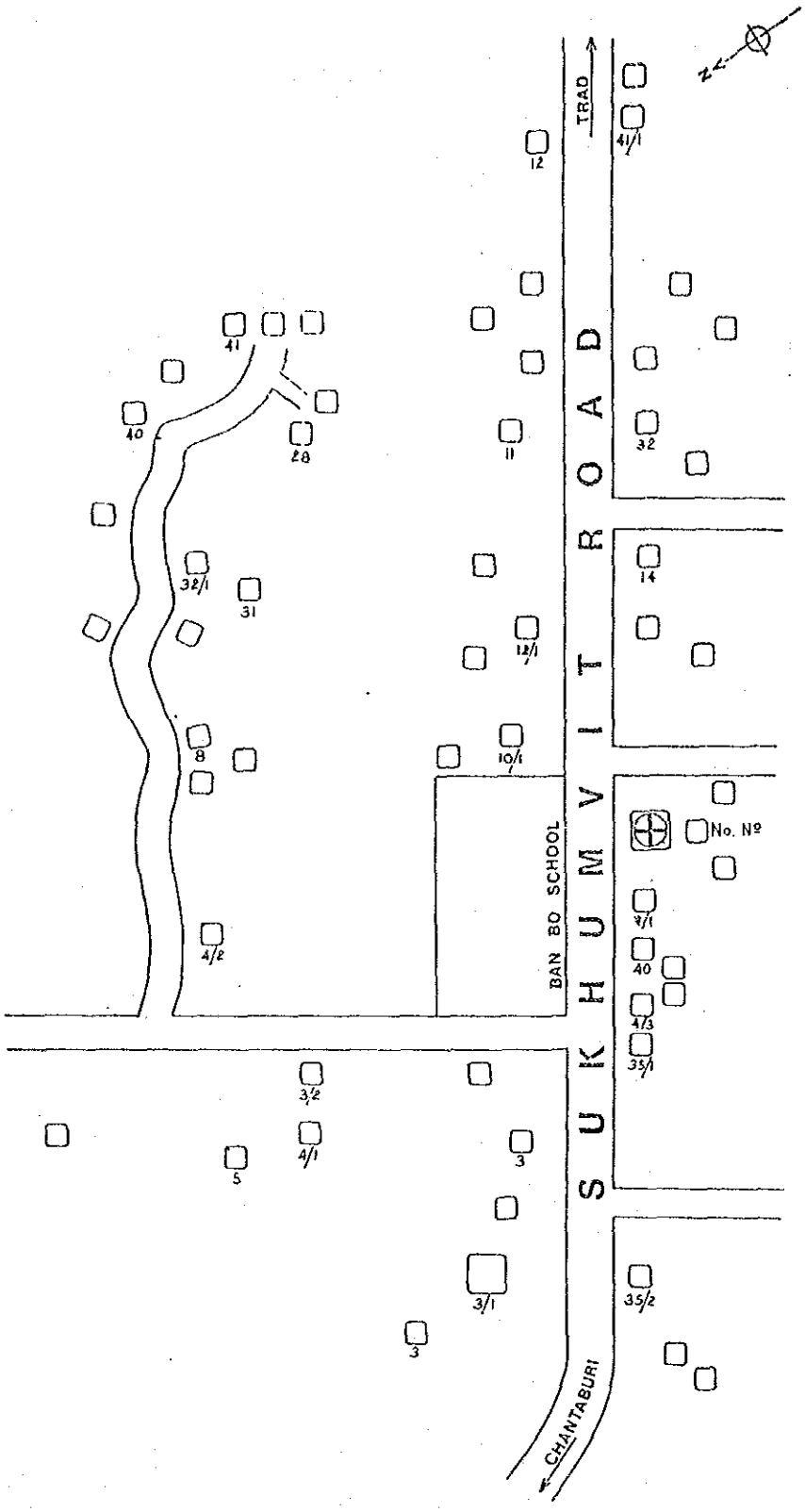


Fig.2-7

MAP OF BAN SAM-RONG

Village No.2

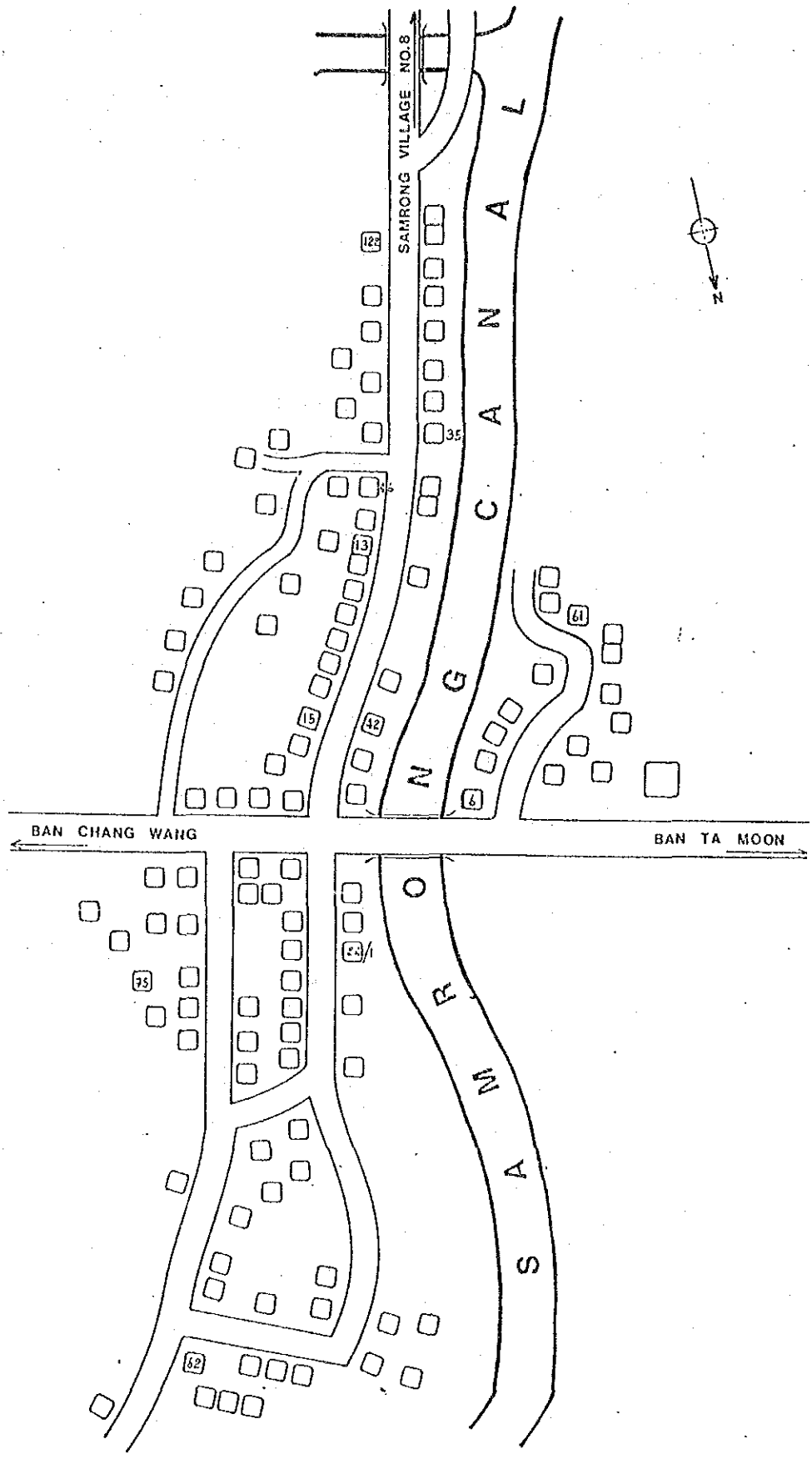


Fig.2-8

MAP OF BAN SAM-RONG

Village No.8

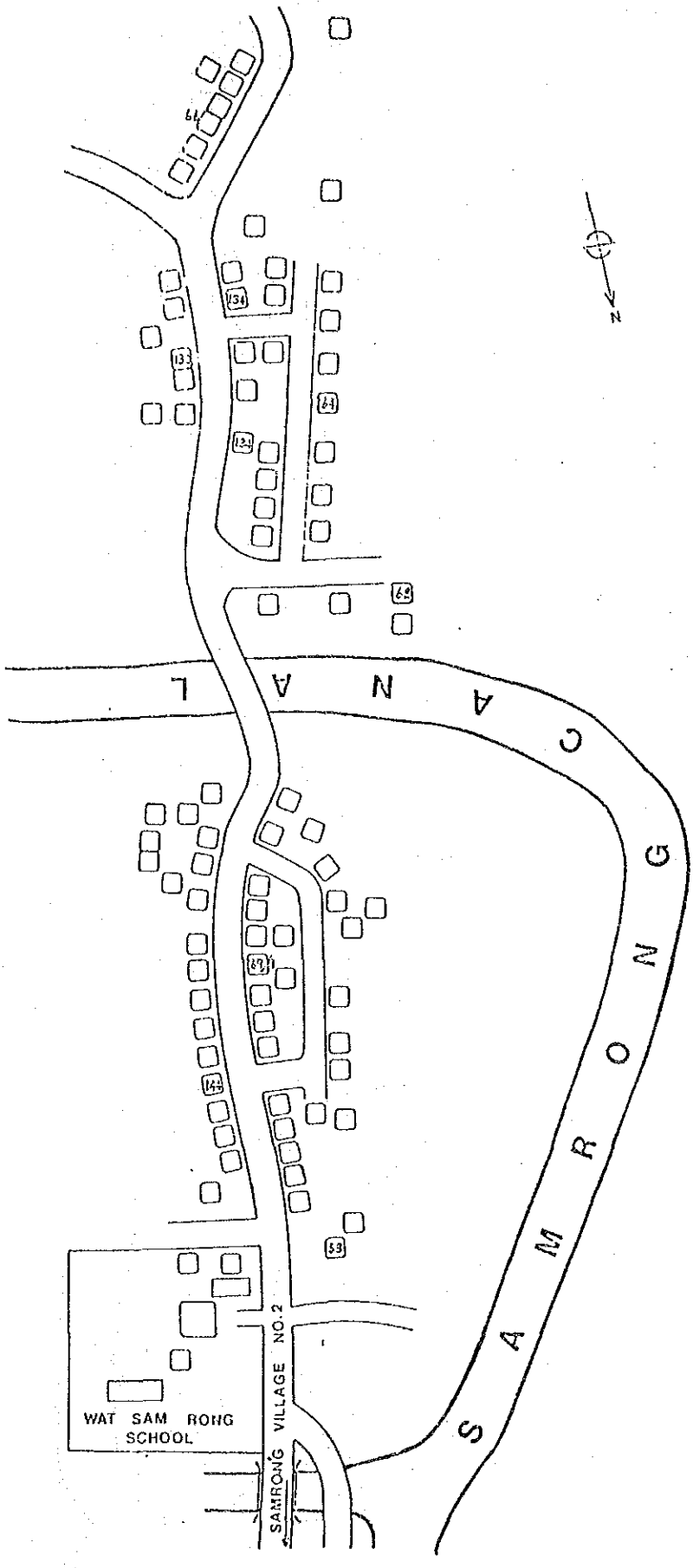


Table. 2 - 4 (a) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Tamai"	February (August)						
Tamai	7400 (7519)	405	54.7	42	5.7	+48.28	964.3
Yaira	1413 (1427)	1	0.7	11	7.8	-7.01	9.1
See-Pa-Ya	1726 (1740)	0	0	7	4.1	-4.02	0
Kao-Pla-Lwan	1637 (1643)	4	2.4	15	9.2	-6.70	26.7
Kao-Bai-Sri	5896 (5906)	22	3.7	35	5.9	-2.20	62.9
Song-Pi-Nong	6594 (6695)	21	3.2	16	2.4	+0.75	131.3
Chang-Kam	4693 (4702)	51	10.9	40	8.5	+2.34	127.5
Bo-Poo	1477 (1490)	1	0.7	4	2.7	-2.01	25.0
Sanm-Chai	3642 (3679)	57	15.7	27	7.4	-8.15	211.1
Tagad-Ngao	5874 (5881)	35	6.0	32	5.4	+0.51	109.4
Toong-Ben-Cha	10866 (10963)	140	12.9	62	5.7	+7.11	225.8
Na-Yai-Arm	8200 (8277)	153	18.7	27	3.3	+15.22	566.7
Kamong	2161 (2168)	22	10.2	12	5.6	+4.61	183.3
Kra-Chac	4193 (4216)	52	12.4	18	4.3	+8.06	288.9
Wung-Ta-Node	6465 (6567)	64	9.9	39	6.0	+3.81	164.1
Kao-Wue	2892 (2880)	65	22.5	11	3.8	+18.75	590.9

Table. 2 - 4 (b) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Thamai"2	February (August)						
Rumpun	2954 (2984)	58	19.6	35	11.8	+7.71	165.7
Klong-Kood	3542 (3577)	46	13.0	20	5.6	+7.27	230.0
Kaeng-Hang-Maew	3283 (3358)	139	42.3	31	9.4	+31.23	448.4
Sam-Pee-Nong	2827* (2981)	108	38.2	11	3.9	+32.54	981.8
	* April						
Whole Tamai	87735 (88753)	1444	16.4	495	5.6	+10.69	291.7
Whole Chanthaburi	313340 (318395)	8774	28.0	1925	6.1	+21.51	455.8

Table. 2 - 4 (c) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Khlung"	February (August)						
Municipal	7954 (8101)	338	42.5	50	6.3	+35.55	676.0
Bo	5384 (5578)	112	20.8	30	5.6	+14.70	373.3
Kwian-Huk	3901 (3942)	20	5.1	29	7.4	-2.28	69.0
Ta-Porn	3183 (3185)	9	2.8	21	6.6.	-3.77	42.9
Bang-Chan	3563 (3552)	75	21.0	9	2.5	+18.58	833.3
Wunyao	4200 (4221)	56	13.3	19	4.5	+8.77	294.7
Sueng	4234 (4246)	50	11.8	16	3.8	+8.01	312.5
Marbpai	1811 (1832)	24	13.3	18	9.9	+3.28	133.3
Wung-Sub-Pa-Rod	1929 (1957)	48	24.9	23	11.9	+12.77	208.7
Tronknong	1932 (1951)	8	4.1	5	2.6	+1.54	160.0
Tokpron	3979 (4027)	69	17.4	13	3.3	+13.91	530.8
Whole Klung	42060 (42592)	809	19.2	233	5.5	+13.52	347.2

Table. 2 - 4 (d) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Pong Nam Ron"	February (August)						
Pong Nam Ron	5695 (5883)	148	25.6	37	6.5	+18.87	400.0
Tubsai	5430 (5637)	123	22.6	44	8.1	+14.01	279.5
Nong-Ta-Kong	5818 (6055)	154	26.5	56	9.6	+16.18	275.0
Sai-Kao	26576 (27728)	758	28.5	130	4.9	+22.65	583.1
Whole Pong Nam ron	43516 (45303)	1183	27.2	267	6.1	+20.22	443.1

Table. 2 - 4 (e) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Muang"	February (August)						
	44 (50)						
Market	3967 (3989)	47	11.8	18	4.5	+7.27	261.2
Wudmai	24248 (24891)	4441	184.1	204	8.4	+170.22	2177.0
Chan-Tanimid	7380 (7582)	29	3.9	54	7.3	-3.30	53.7
Konbang	4226 (4302)	33	7.8	19	4.5	+3.25	173.7
Klong-Na-Rai	5123 (5240)	13	2.5	48	9.4	-6.68	27.1
Nongbua	4712 (4742)	17	3.6	20	4.2	-0.63	85.0
Plub-Pla	4946 (4982)	7	1.4	35	7.1	-5.62	20.0
Ta-Hang	6439 (6531)	67	10.4	24	3.7	+6.58	279.2
Bang-Gacha	9328 (9502)	7	0.8	38	4.1	-3.26	18.4
Salang	3756 (3732)	14	3.7	11	2.9	+0.80	127.3
Kao-Kwang	3873 (3924)	14	3.6	20	5.1	-1.53	70.0
Whole Muang	77998 (79412)	4689	60.1	491	6.4	+52.86	955.0

Table. 2 - 4 (f) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Laem Sing"	February (August)						
Park-Nam	8128 (8216)	78	9.6	52	6.4	+3.16	150.0
Plew	4678 (4660)	20	4.3	28	6.0	-1.72	71.4
Nong-Shim	4547 (4544)	30	6.6	24	5.3	+1.32	125.0
Klong-Nam-Kem	1703 (1709)	11	6.5	14	8.2	-1.76	78.6
Bangsa-Kao	2098 (2097)	15	7.1	7	3.3	+3.81	214.3
Kaoprird	3200 (3229)	33	10.3	12	3.8	+6.50	275.0
Banggka-Chai	3185 (3196)	24	7.5	17	5.3	+2.19	141.2
Whole Laemsing	27539 (27651)	211	7.7	154	5.6	+2.06	137.0

Table. 2 - 4 (g) Vital Statistics

	Population	Number of Birth	Birth Rate	Number of Death	Death Rate	Rate of Natural increase of population	Birth Death Ratio
Amphoe "Ma Kham"	February (August)						
Ma Kham	9823 (9888)	81	8.2	76	7.7	+0.51	106.6
Taluang	2303 (2320)	14	6.1	27	11.7	-5.60	51.9
Pudtawee	3261 (3305)	45	13.8	39	12.0	+1.82	115.4
Cha-Mun	2600 (2630)	35	13.5	20	7.7	+5.70	175.0
Wan-Sam	3444 (3443)	52	15.1	27	7.8	+7.26	192.6
Pluang	7178 (7282)	65	9.1	49	6.8	+2.20	132.7
Takian-Tong	5883 (6011)	146	24.8	47	8.0	+16.47	310.6
Whole Ma-Kham	34492 (34627)	438	12.7	285	8.3	+4.41	153.7

2-3 Present Water Supply Situation in Model Areas

General information was collected from the Provincial Water Works Authority and other central and local government agencies in order to determine the present condition of the water supply system in the entire province of Chanthaburi and the characteristics in the selected model areas.

In the field survy of the existing water supply system, the important community members were interviewed to collect information on the seasonal characteristics, use and other conditions of the water supply system in each area.

The field survey was designed to produce the following information on the present utilization of water in the model areas:

1. Present condition and local characteristics of water resources and water supply system
2. Present water demand and seasonal fluctuations
3. Quality and quantity of available water

2-3-1 Water Supply in Chanthaburi Province

There are five water supply systems of varying size (Chanthaburi city, Tha Mai, Laem Sing, Klung and Ban Ta Mun) which obtain surface water from rivers and mountain streams. Water is distributed by pipeline to individual households.

The Laem Sing and Klung water supply systems which tap the mountain stream in the Khao Sa Bap mountain located in the southeast of Chanthaburi city supply water all the year round, but all other water supply systems run short of water during the dry season. They even go completely dry from time to time during the dry season.

Except in the city of Chanthaburi, the water supply system is quite simple: a simple intake is built on the bank of a mountain stream and a steel pipe is laid from the intake to a storage reservoir. After chlorination the water is distributed by pumping to households. The area served is only 5 km or less from the supply source.

The water supply system of the city of Chanthaburi was constructed by the local water works division of the Public Works Department of the Ministry of the Interior in 1967 and is presently managed by the Provincial Water Works Authority.

This water supply system intakes its water from the Chanthaburi River upstream at a point about 20 km northeast of the city. The water enters the system by means of a suction pipe erected upright in the reiver and is moved by a lifting pump. Other than this, no intake structure of weir is provided. During the rainy season the river is deep enough to permit easy pumping of water. Water is transported in the system in a asbestos-cement pipe of 400 mm diameter for a distance of 9 km to a water treatment plant. During the dry season, however, the river become so shallow that the water is insufficient to meet the minimal requirements of the city. During the dry season the Chanthaburi River, flows through the center of the city, does not run completely dry, but becomes so shallow and narrow so that it cannot be continuously tapped. In the greater part of the city the water supply ceases when the Chanthaburi River water reaches its lowest level during the dry season.

The water intake is located at a point of about 40 km from the estuary and has an elevation of about 15 m. It is not affected by the ebb and flow of sea water so that not tide enbankment is necessary; however, the construction of a dam, weir or other facilities to improve the water intake function is an important task to secure a stable supply source and cope with the future increases in water demand. Furthermore, the existing water supply system presents the danger that the water may contaminated with organic matter.

In the whole Province of Chanthaburi, there is no household which is a sewage treatment tank. Most households discharge domestic sewage without treatment. The local health centers are the sole establishments which are equipped with a simple septic tank system where the sewage is pooled in the settling tank to separate solids and the sewage is treated by putrefaction by anaerobic bacteria. The sewage so treated is discharged into the ground by permeation or allowed to overflow the settling tank. On the other hand, the domestic sewage is treated by the self-cleansing action of the river. However, as the population living the upstream areas increases and their lifestyle changes, the amounts of sewage will some day exceed the capacity of the river to discharge. Contamination of water with organic matter should also be prevented.

The water treatment plant of the city of Chanthaburi is located at a point of 10 km northwest of the city.

The water treatment process of this plant consists of three steps;

1. Double loop coagulation-sedimentation using aluminum sulfate as a coagulant
2. Six gravity-type tank sand filters
3. Sterilization by chlorination

In the coagulation and sedimentation tank, the coagulation process is not stable; hence flocculation is inadequate. Considerable amounts of floating material overflow the baffles. This inadequate flocculation presumably occurs because the rate of adding the coagulant is not properly controlled in accordance with the change in quality and quantity of water, but it is added at a flat rate (100 kg/day). Inadequate agitation may also be a problem.

The sand filter basin is equipped backflush pumps and seems to be regularly cleaned by backwashing.

In the chlorination unit, chlorine is added at a rate of 7 ppm presumably because of the lack of defined treatment process and high content of organic matter in water. Due to lack of an agitation basin and an injection basin, the chemical is added drop by drop at one corner of the storage tank; hence, uniform sterilization is not obtained. When the survey team visited this water treatment plant, chlorine was added drop by drop by means of a vinyl hose which appeared to be in temporary use. It is recommended that the equipment of this water treatment plant be improved as soon as possible.

The pumping room was built near the reservoir and was equipped with four pumps (from Siemens of West Germany) rated at 1,500 l/min, 55 kW, 380 V, and 50 Hz. One of them is used to clean the sand filter basin by backwashing.

The population to be served consists of 20,000 people living in part of the city of Chanthaburi and 7,000 inhabitants of part of Tha Mai city; 27,000 people in all. The pumping station has a capacity of 250 m^3/hour or about 6,000 m^3/day. If the fire demand for water is ignored, the pumping station can supply 220 to 230 L/day/person of water. This water treatment plant has adopted the WHO drinking water standards.

The transmission main is an asbestos-cement pipe, 200 mm in diameter.

The pipe is connected to the service reservoirs of the cities of Chanthaburi and Tha Mai.

The model water storage tank of the Sanitation Division of the Ministry of Public Health is shown in Fig. 2-9.

2-3-2 Non-served Area

This subsection deals briefly with the present condition of the area which is not served by the water supply system of the Provincial Water Works Authority.

Most people in the non-served area store ground water taken from uncurved dug wells 5 to 6 m deep and rainwater from the roof in unglazed jars or concerte tanks. They use rainwater for drinking purposes and obtain water for other domestic use from shallow wells, bogs, irrigation ditches, mountain streams, rivers and other sources of poor quality water.

Algae and mosquito larvae grow in the rainwater stored. If rainwater is stored in this way, there is danger that dead organisms are putrefied in it. Water near the bottom of jars is of very poor quality. During the dry season people use water near the bottom of jars and even drink underground water or surface water without treatment. This is one of the main reasons why contageous diseases occur with high frequency toward the end of dry season, April to May, each year. People in the model areas also buy drinking water of high quality, but this is a heavy economic burden. In the interest of sanitation and hygiene, provision should be made so that people can avoid using rainwater stored for extended periods and can avoid using water taken from shallow wells without treatment. At present information communicators and health volunteers are appointed to furnish the community people with advice regarding the use of water. The community people are advised to boil water before drinking, but this advice is not always followed on account of various problems such as the traditional lifestyle, lack of water boiling equipment, fuel cost, and so forth.

2-3-3 Ban Sam Rong

The Ban Sam Rong model area is divided by the Sam Rong River which originates in the Khao Saba hills. The people of this model area use surface water taken from the river all the year round, except when it runs dry. During the dry season, however, the water in this river decreases

sharply until part of the riverbed is exposed to view.

During the dry season the dry riverbed has deep holes in places, made by nearby inhabitants to tap ground water.

In the upstream area, houses and small colonies are scattered. There is danger that the water of Sam Rong River may be contaminated with organic matter from the domestic sewage of these households.

The results of analysis of water samples taken from this river are shown in Table 2-5. On account of various constraints in sampling, the BOD of this water could not be determined. However, ammonia has been detected in water samples taken in the downstream area. Therefore, use of this surface water for drinking purposes without treatment should be avoid. Survey data of the Sam Rong River is displayed in Table 2-6 for well.

Shallow wells as seen in the Chanthaburi River basin are not present in the model district of the Ban Sam Rong province. One municipal shallow well (existing well No. S-3 given in Table 2-6) is located at the entrance to the village. The water level of this well falls as the stream of the Sam Rong River shrinks during the dry season. One concrete rainwater storage tank is provided in the wat and one in the primary school; however, the tank in the primary school has cracks in the bottom, allowing water to leak into the ground. As a matter of fact, it is serving no useful purpose at present.

The rainwater storage concrete tank provided in the wat is 10.3 m long, 5 m wide and 3.2 high and contains 150 m of water. A hand pump is installed on the concrete slab to take water from the tank, but this pump does not serve its purpose either because its handle is broken. Villagers take water directly out of the tank with buckets and anything else serviceable at hand. The population of this model area is estimated to be 1,098; 665 in village No. 2 and 423 in village No. 8.

2-3-4 Ban Nong Khan

Village No. 4, the Ban Nong Khan model area, is also so near the coast that the aquifer may be intruded by salt water as in the province of Ban Bo. Fortunately, there is a small rise in the landform about 70 m above sea level near the model area. The aquifer under this rise may be expected to have a considerably higher yield of fresh water.

The population of this model area has been reported to be 564 (as of 1980). This community utilizes shallow wells and collects rainwater for drinking and other household purposes as in the Ban Bo model area. People of this model area also have to buy water commercially during the dry season because well water turns brackish and the rainwater storage is not large enough to satisfy the demand throughout the dry season.

The model area has several shallow wells 3 to 4 m deep, but all of them are badly contaminated. People only draw water from these wells for doemstic purposes. There is a municipal shallow well (existing well data given in Table 2-6) at a point of about 1 km from village No. 4, the Ban Nong Khan model area. During the dry season, the great majority of people in the community rely on this municipal well for their supply of water so that a great amount of water is drawn, causing the ground water level to sink to a considerable extent. About 500 m away from this well, there is another municipal shallow well (existing well data given in Table 2-6). As this municipal well is located at a considerable distance from the model area, people appear to use it only when the ground water level of the other well has declined excessively.

2-3-5 Ban Bo

The people in the Ban Nong Khan and Ban Bo model areas which border the sea, use rainwater and poor quality shallow well water for both drinking and other domestic purposes.

Village No. 3, the Ban Bo model area, located about 35 km southeast of the city of Chanthaburi is situated on a sand bar in the estuary with a population of about 545. Thick mangrove forests grow in the marsh land of the area. The ground water of this model area is greatly affected by salt water. Wells built in this area are 3 to 4 m deep; hence the water drawn from them may be contaiminated with domestic sewage. During the rainy season heavy rainfalls and highly permeable soil (sand and fine sand) cause the level of ground water to rise and people tap it with shallow wells. During the dry season, however, ground water of this model area turns blackish on account of its geographical proximity to the sea.

Villagers store rainwater in jars and concrete storage tanks to use for drinking purposes, but during the dry season it appears that they have to purchase expensive water sold commercially to fulfill their needs.

From the standpoint of supply source, village No. 3 in the Ban Bo province seems to be in the poorest situation of all the model districts selected in the present survey.

From the geographical and geological standpoint it seems impossible to use shallow ground water in this model area. In the long run it may be necessary to study the feasibility of serving this community from the Klung water supply system which has its supply source in the Khao Sa Bap Mountains 15 km northwest of this model area. There is also the possibility of utilizing ground water at depths 200 m or deeper at a point a little further on shore from Ban Bo. For the present, however, a more practical solution should be sought such as planning a municipal rainwater storage and management system.

2-3-6 Prapokklao Hospital

The Prapokklao Hospital is the only establishment in the four selected model areas that is served by the municipal water supply system of the city of Chanthaburi. Even in this establishment, the supply ceases quite often during the dry season. A few shallow wells 4 to 5 m deep are dug in the premises of the hospital, but are not in use on account of heavy contamination. When the water supply is shut off, the hospital draws water from one relatively deep well (about 10 m deep) which is also located in the hospital premises. A pumping hut is located near the well and water is pumped to an elevated tank at a height of 4 to 5 m. From the elevated tank, water distributed by gravity throughout the hospital premises. During the dry season this facility alone is insufficient to supply the demand.

To meet the demand, the hospital buys about 400 m^3 of water a year. This amount of water is presumed to cost about 20,000 baht.

2-3-7 Existing Wells and Water Quality

There are shallow dug wells located randomly in the province of Chanthaburi and people draw water from most of these wells for drinking and other household purposes. The existing well data is summarized in Table 2-6. Typical shallow wells are 3 $\sim$ 5 m deep and 1 $\sim$ 1.5 m in diameter. They are excavated manually with laborers or mechanical power, protective covers are not usually used. Water is drawn with a bucket on a rope. On the way to the cities of Bangkok and Chanthaburi windmills draw water from

shallow wells, but there were no similar wells in the province of Chanthaburi.

In the Ban Sam Rong province jars suspended by rope are used with the aid of a pulley to draw water from public shallow wells presumably because of low ground water levels. In the premises of the Propokklao Hospital which has electric power service, there is a shallow well and a pumping house where water is lifted by a Japanese-made pump to and delivered an elevated tank situated at a height of 4 m.

The Ban Bo Health Center has a power generator, and water can be lifted by a piston-type pump from the public well located in its premises.

In the province of Chanthaburi few deep wells are present. There may be hydrogeological and geological constraints, but it appears that neither survey nor prospecting has ever been done in this province.

The Ministry of Industry keeps data on prospecting wells (see Table 2-8) excavated to a depth of 100 to 400 ft (30 to 120 m) in the Laem Sing and Klung districts which border the sea. The data show that all water samples taken from these prospecting wells are quite brackish, indicating that ground water in these districts is contaminated by salt water.

In the premises of the Laem Sing Health Center there is a deep well of this type equipped with a hand pump.

The existing wells are classified from the standpoint of water utilization as public and private wells. Each public well seems to serve 200 to 400 people on the average, and each privately owned well serves no more than 1 to 3 households (or 5 to 15 people). In addition, public and private wells co-exist together. It appears that the people in the community use both of them according to their needs and circumstances.

Basically, both the private and public wells which exist in the model area are shallow wells; however public wells generally produce better water, for they are at a relatively greater distance from households and a little deeper than private ones. Furthermore, public wells appear to be far less contaminated with human and livestock sewage than the private wells.

The results of analysis of water samples taken from the existing wells are given in Table 2-5. Contamination with ammonia and chloride was much less than expected. However, this may be due to the fact that the water

samples were collected in December, and although December is a month that belongs to the Thai dry season, it is still an early dry month so that the water shortage is not very severe.

In addition to the chloride concentration, the content of other ions and suspended matter was to be determined by the EC (Electrical Conductivity) test and COD (Chemical Oxygen Demand) test; however, the circumstances at the sites did not permit these tests to be performed.

Table 2-5 Water Analysis of Existing Well

ที่ PH.0504/5459

กรมวิทยาศาสตร์การแพทย์
กระทรวงสาธารณสุข

23 December 1980

เรื่อง **Analysis of Well Water from Chantaburi province**

เรียน Design Team , the Promotion of the Provincial Health Services Project.

ขอแจ้งผลการตรวจวิเคราะห์ **Well water** ซึ่งได้
รับเมื่อวันที่ 12 December 1980 พร้อมกับหนังสือที่ - ลงวันที่
ตามรายงานการตรวจวิเคราะห์ท้ายหนังสือนี้

ขอแสดงความนับถือ

(SUTAS GUPTARAK M.D.)
Signed for Deputy Director General
Department of Medical Sciences.

รายงานการตรวจวิเคราะห์

หมายเลขวิเคราะห์ที่ F.4135/23 (W.105)

รายละเอียดวัตถุที่ทำการตรวจวิเคราะห์ **Eleven Samples of Well water :**

S - 2 , S - 3 , S - 4 , S - 5 , B - 1 , K - 1 , T - 1 , T - 2 ,
T - 3 , L - 1 , P - 1 .

Results.

Water Analysis of Existing Well Sampled in Model Ares

Sample	pH.	E.C.	Turbidity	Total Fe	Cl^-	NH_4	O_2 Consumed	Tatal Bact.	Coliform
S - 2	6.81	-	3	0.05	144	0.01	nil	1.5×10^4	< 2.2
S - 3	7.31	-	3	0.15	14	0.01	1.0	1.0×10^4	15.0 (with E.coli)
S - 4	7.75	-	3	0.25	5	0.01	1.55	5.2×10^4	240
S - 5	6.69	-	3	0.1	26	0.01	nil	1.2×10^4	< 2.2
B - 1	6.35	-	4	0.75	47	0.01	nil	7.1×10^3	240
K - 1	4.41	-	3	0.05	28	0.01	nil	2.9×10^5	> 240
T - 1	4.55	-	4	0.3	12	0.01	nil	580	7.5
T - 2	5.05	-	3	0.65	15	0.01	nil	5.6×10^4	38.0
T - 3	5.15	-	3	0.12	12	0.01	nil	9.0×10^3	240 (with E.coli)
L - 1	6.01	-	15	8.0	16	0.4	nil	480	< 2.2
P - 1	6.55	-	25	2.0	34	0.01	2.59	5.5×10^3	> 240
Standard.	6.5 - 8.5		5	0.5	250	0.1	1.0	500	< 2.2

Name Garnchana Mongchavanich Analyst.
(Mrs. Garnchana Mongchavanich)

Food Analysis Division
Tel. 2231444 ext 7,8

Standard of Drinking Water

The Notification of the Ministry of Public Health No. 20 (1979)

1. Physical Properties

- Colour	not more than 20
- Odor	no other oder (not include chlorine)
- Turbidity	not more than 5
- pH value	between 6.5 - 8.5

2. Chemical Properties

- Total solids	not more than 1,000 mg/kg.
- Total hardness	not more than 300 mg/kg.
- Chloride (expressed as chlorine)	not more than 250 mg/kg.
- Fluoride (expressed as fluorine)	not more than 1.5 mg/kg.
- Albuminoid ammonia (expressed as ammonia)	not more than 0.1 mg/kg.
- Free ammonia (expressed as ammonia)	not more than 0.1 mg/kg.
- Nitrates (expressed as nitrogen)	not more than 4.0 mg/kg.
- Nitrite (expressed as nitrogen)	not more than 0.1 mg/kg.
- Iron	not more than 0.5 mg/kg.
- Lead	not more than 0.1 mg/kg.
- Arsenic	not more than 0.05 mg/kg.

3. Bacterial properties

- Standard plate Count at 35° - 37° C , 24 hours, not exceeding 500 colories per 1 ml.
- Most Probable Number of Coliform Organism per 100 ml (M.P.N.) less than 2.2
- Free from E. coli type I (Escherichia coli)

Table 2-6

DATA SHEET OF EXISTING WELL

Survey NO. B-1

Date: Dec. 9 Time: 15:00 Weather: Fine Temp. 30°C

--Deatails of Well-- Shallow Well

Depth of Well:	3.15 (m)
Well Diameter:	1.50 (m)
Water Level:	GL-1.45 (m)
Method of Yeild:	Suction Pump

--Well location--

District

Ban Bo Tambol Bo

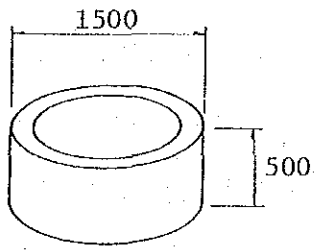
Village

Village No. 3

Proprietor

Public

-- Sketch of Well--



--Water Analysis--

pH:	6.35
Turbidity:	4 mg/kg
Total Fe:	0.75
Cl^-:	47
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	7.1×10^3
Coliform Group:	240 colo/ml

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. B-2

Date: Dec. 5 Time: 14:30 Weather: Fine Temp. -

--Deatails of Well-- Shallow Well

Depth of Well: 2.40 (m)

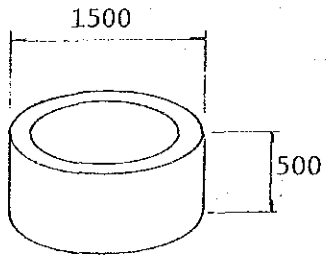
Well Diameter: -

Water Level: GL - 1.10 (m)

Method of Yeild: Manual

--Well location--

-- Sketch of Well--



--Water Analysis--

pH:	5.80 - 6.0
Turbidity:	
Total Fe:	
Cl^-:	
NH_4:	
O_2 Consumed:	
Total Bact.:	
Coliform Group:	

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. S - 1

Date: Dec. 6 Time: 11:00 Weather: Fine Temp. 31.0°C

--Deatails of Well-- Shallow Well

Depth of Well: 4.00 (m)

Well Diameter: 1.50 (m)

Water Level: Dry up

Method of Yeild: -

--Well location--

District

Bon Sam Rong Tombol Sai Kao

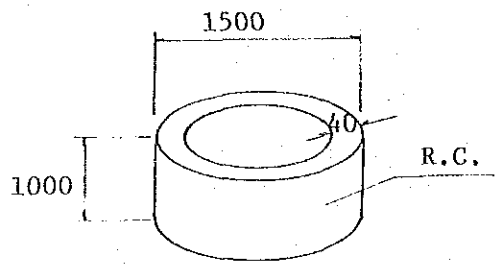
Village

No. 2

Proprietor

Public

-- Sketch of Well--



--Water Analysis-- No

pH:

Turbidity:

Total Fe:

Cl^-:

NH_4:

O_2 Consumed:

Total Bact.:

Coliform Group:

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. S - 2

Date: Dec. 6 Time: 11:05 Weather: Fine Temp. 31°C

--Deatails of Well-- Shallow Well

Depth of Well: 7.80 (m)

Well Diameter: 1.50 (m)

Water Level: GL-0.30 (m)

Method of Yeild: Manual

--Well location--

District

Ban Sam Rong Tambol Sai Kao

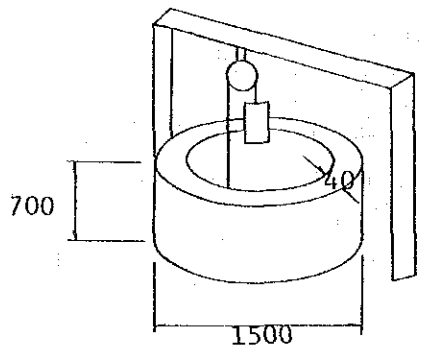
Village

No. 2

Proprietor

Public

-- Sketch of Well--



--Water Analysis--

pH:	7.1
Turbidity:	3
Total Fe:	0.05
Cl^-:	144
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	1.5×10^4
Coliform Group:	< 2.2

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. S - 3

Date: Dec. 6 Time: 11:45 Weather: Fine Temp. 31°C

--Deatails of Well-- River

Depth of Well:

Well Diameter:

Water Level:

Method of Yeild:

--Well location--

District

Ban Sam Rong Tambol Sai Kao

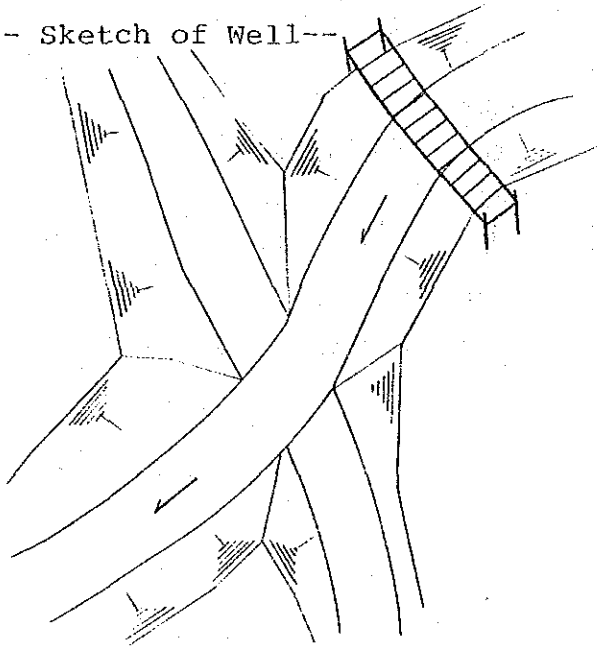
Village

No. 8

Proprietor

River

-- Sketch of Well--



--Water Analysis--

pH:	7.31
Turbidity:	3
Total Fe:	0.15
Cl^-:	14
NH_4:	0.01
O_2 Consumed:	1.0
Total Bact.:	1.0×10^4
Coliform Group:	15.0 (with E. Coli)

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. S - 4

Date: Dec. 6 Time: 14:00 Weather: Fine Temp. 32°C

--Deatails of Well-- Shallow Well

Depth of Well:

Well Diameter:

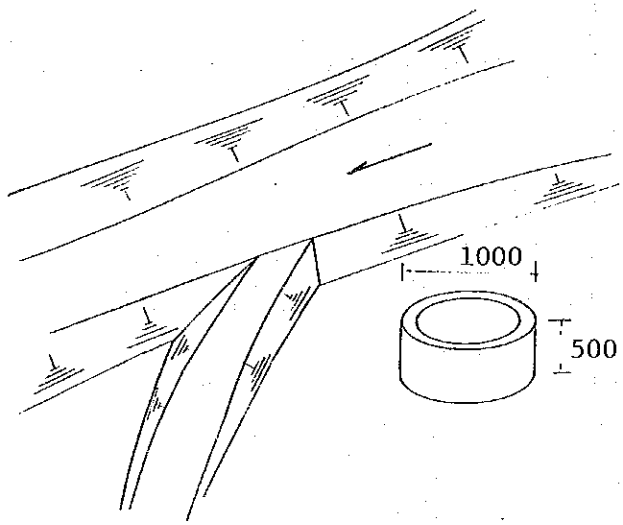
Water Level:

Method of Yeild:

--Well location--

Well of Rural Water System

-- Sketch of Well--



--Water Analysis--

pH:	7.75
Turbidity:	3
Total Fe:	0.025
Cl^-:	5
NH_4:	0.01
O_2 Consumed:	1.55
Total Bact.:	5.2×10^4
Coliform Group:	240

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/1
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. S - 5

Date: Dec. 6 Time: 15:00 Weather: Fine Temp. 32°C

--Deatails of Well-- Deep Well

Depth of Well: About 100 (m)

Well Diameter: About 200-300 (mm)

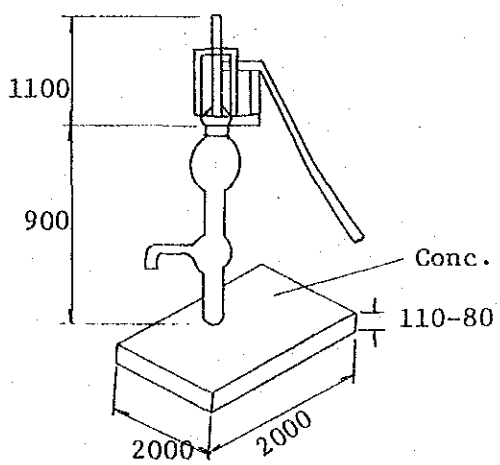
Water Level: -

Method of Yeild: Hand Pump

--Well location--

Kamphuchea Camp Amphoe Pong Namnong

-- Sketch of Well--



AERMOTOR CHICAGO P1330

--Water Analysis--

pH:	7.4
Turbidity:	3
Total Fe:	0.1
Cl^-:	26
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	1.2×10^4
Coliform Group:	< 2.2

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. L - 1

Date: Dec. 9 Time: 10:15 Weather: Fine Temp. 32°C

--Deatails of Well-- Shallow Well

Depth of Well: About 30 (m)

Well Diameter: 200 - 300 (mm)

Water Level: -

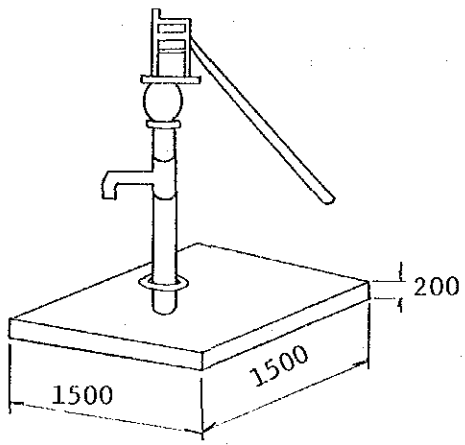
Method of Yeild: Hand Pump

--Well location--

Ban-Loom-Chim Amphoe Khlung

Well in Health Center

-- Sketch of Well--



--Water Analysis--

pH:	6.8
Turbidity:	15
Total Fe:	8.0
Cl^-:	16
NH_4:	0.4
O_2 Consumed:	nil
Total Bact.:	480
Coliform Group:	< 2.2

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. L - 2

Date: Dec. 9 Time: 12:00 Weather: Fine Temp. 32°C

--Deatails of Well--

Depth of Well: -

Well Diameter: ϕ200 (mm)

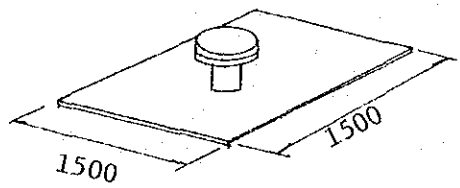
Water Level: GL-1.30 (m)

Method of Yeild: -

--Well location--

Well in Health Center

-- Sketch of Well--



--Water Analysis--

pH:

Turbidity:

Total Fe:

Cl^-:

NH_4:

O_2 Consumed:

Total Bact.:

Coliform Group:

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/1
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. T - 1

Date: Dec. 10 Time: 9:00 Weather: Fine Temp. 29°C

--Deatails of Well-- Shallow Well

Depth of Well: 6.50 (m)

Well Diameter: 2.285 (m)

Water Level: GL-2.68 (m)

Method of Yeild: Manual

--Well location--

District

Ban Nong Khan, Tambol
Tagad Ngao, Amphoe Thamai

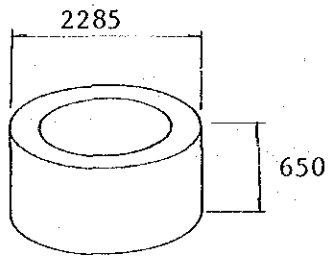
Village

No. 4

Proprietor

Public

-- Sketch of Well--



--Water Analysis--

pH:	5.6
Turbidity:	4
Total Fe:	0.3
Cl^-:	12
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	580
Coliform Group:	7.5

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. T - 2

Date: Dec. 10 Time: 10:00 Weather: Fine Temp. 30°C

--Deatails of Well-- Shallow Well

Depth of Well: 4.28 (m)

Well Diameter: 1.46 (m)

Water Level: GL-1.16 (m)

Method of Yeild: Manual

--Well location--

District

Ban Nong Khan, Tambol
Tagad Ngao, Amphoe Thamai

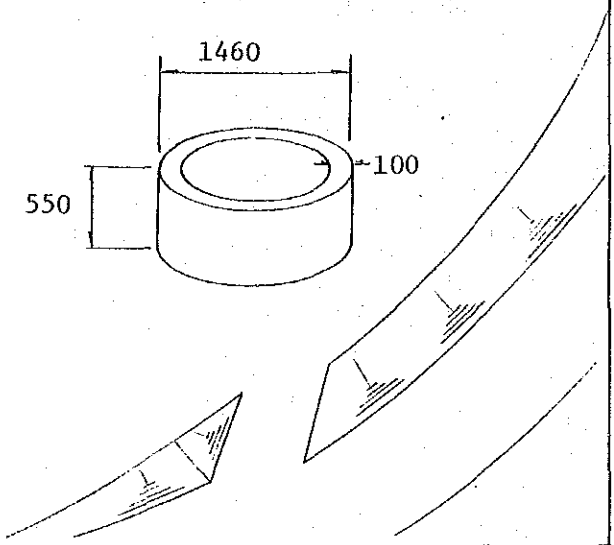
Village

No. 4

Proprietor

Public

-- Sketch of Well--



--Water Analysis--

pH:	5.6 - 5.8
Turbidity:	3
Total Fe:	0.65
Cl^-:	15
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	5.6×10^4
Coliform Group:	38.0

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/1
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. T - 3

Date: Dec. 10 Time: 10:00 Weather: Fine Temp. 30°C

--Deatails of Well-- Shallow Well

Depth of Well: 2.96 (m)

Well Diameter: 1.16 (m)

Water Level: GL-1.60 (m)

Method of Yeild: Manual

--Well location--

District

Ban Nong Khan, Tambol
Tagad Ngao, Amphoe Thamai

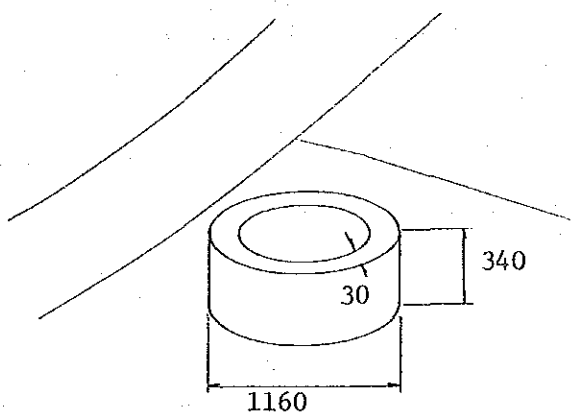
Village

No. 4

Proprietor

Private

-- Sketch of Well--



--Water Analysis--

pH:	5.7
Turbidity:	3
Total Fe:	0.12
Cl^-:	12
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	9.0×10^3
Coliform Group:	240 (with E. Coli)

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. T - 4

Date: Dec. 10 Time: 10:15 Weather: Fine Temp. 30°C

--Deatails of Well-- Shallow Well

Depth of Well: 5.10 (m)

Well Diameter: 5.34 x 3.12 (m)

Water Level: GL-1.64 (m)

Method of Yeild: Manual

--Well location--

District

Ban Nong Khan, Tambol
Tagad Ngao, Amphoe Thamai

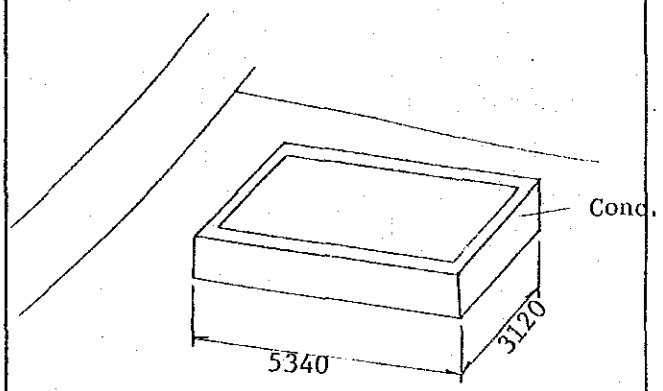
Village

No. 4

Proprietor

Private

-- Sketch of Well--



--Water Analysis-- No sampling

pH:

Turbidity:

Total Fe:

Cl^-:

NH_4:

O_2 Consumed:

Total Bact.:

Coliform Group:

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. K - 1

Date: Dec. 10 Time: 11:30 Weather: Fine Temp. 30°C

--Deatails of Well-- Shallow Well

Depth of Well: -

Well Diameter: 4.50 (m)

Water Level: GL-3.88 (m)

Method of Yeild: Suction Pump

--Well location--

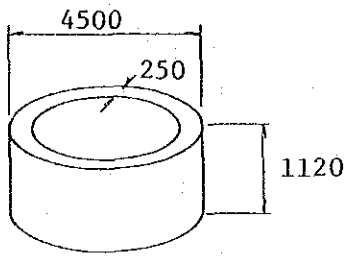
The Propokklao Hospital, Amphoe Muang

Well in Hospital

Proprietor

Public

-- Sketch of Well--



--Water Analysis--

pH:	5.8
Turbidity:	3
Total Fe:	0.05
Cl^-:	28
NH_4:	0.01
O_2 Consumed:	nil
Total Bact.:	2.9×10^5
Coliform Group:	>240

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. K - 2

Date: Dec. 10 Time: 12:00 Weather: Fine Temp. 31°C

--Deatails of Well-- Shallow Well

Depth of Well: 3.90 (m)

Well Diameter: 1.40 (m)

Water Level: GL-1.48 (m)

Method of Yeild: Pump

--Well location--

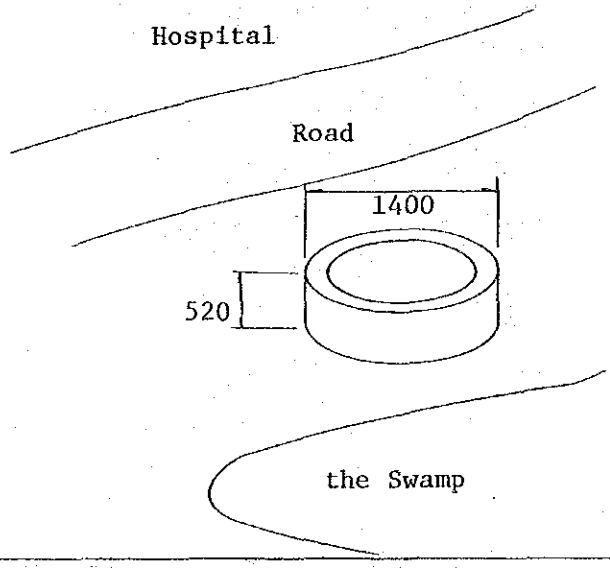
Near the Prapokklao Hospital, Amphoe Muang

Well by the Swamp

Proprietor

Public

-- Sketch of Well--



--Water Analysis-- No sampling

pH:	5.8
Turbidity:	
Total Fe:	
Cl^-:	
NH_4:	
O_2 Consumed:	
Total Bact.:	
Coliform Group:	

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. P - 1

Date: Dec. 10 Time: 12:00 Weather: Fine Temp. 31°C

--Deatails of Well--

Depth of Well:

Well Diameter:

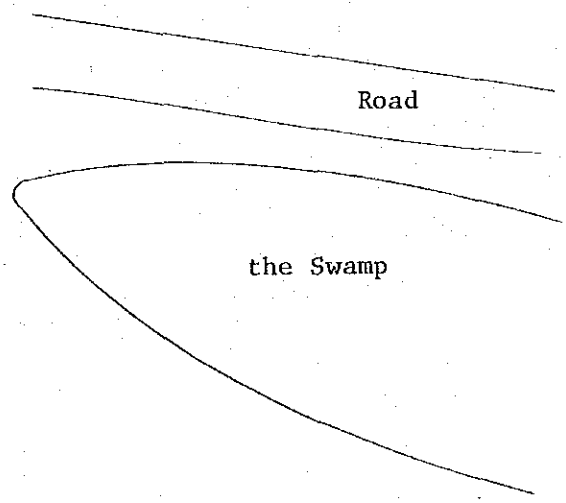
Water Level:

Method of Yeild:

--Well location--

The Swamp in front of Hospital

-- Sketch of Well--



--Water Analysis--

pH:	7.4
Turbidity:	25
Total Fe:	2.0
Cl^-:	34
NH_4:	0.01
O_2 Consumed:	2.59
Total Bact.:	5.5×10^3
Coliform Group:	>240

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

DATA SHEET OF EXISTING WELL

Survey NO. P - 2

Date: Dec. 10 Time: 12:00 Weather: Fine Temp. 31°C

--Deatails of Well-- Shallow Well

Depth of Well: 3.76 (m)

Well Diameter: 2.76 x 2.24 (m)

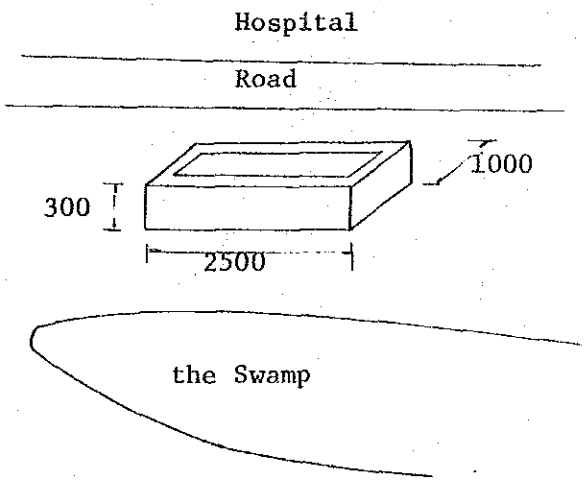
Water Level: GL-1.61 (m)

Method of Yeild: -

--Well location--

Well between the Hospital and the Swamp

-- Sketch of Well--



--Water Analysis--

pH:	5.8
Turbidity:	
Total Fe:	
Cl^-:	
NH_4:	
O_2 Consumed:	
Total Bact.:	
Coliform Group:	

--Standard of Water Quality--

pH:	between 6.5 - 8.5
Turbidity:	Not more than 5 mg/l
Total Fe:	" " 0.5 "
Cl^-:	" " 250 "
NH_4:	" " 0.1 "
O_2 Consumed:	1.0
Total Bact.:	Not exceeding 500 colo/ml
Coliform Group:	MPN less than 2.2

Fig.2-9 (a) Model Plan of Water Storage Tank by Sanitation Division

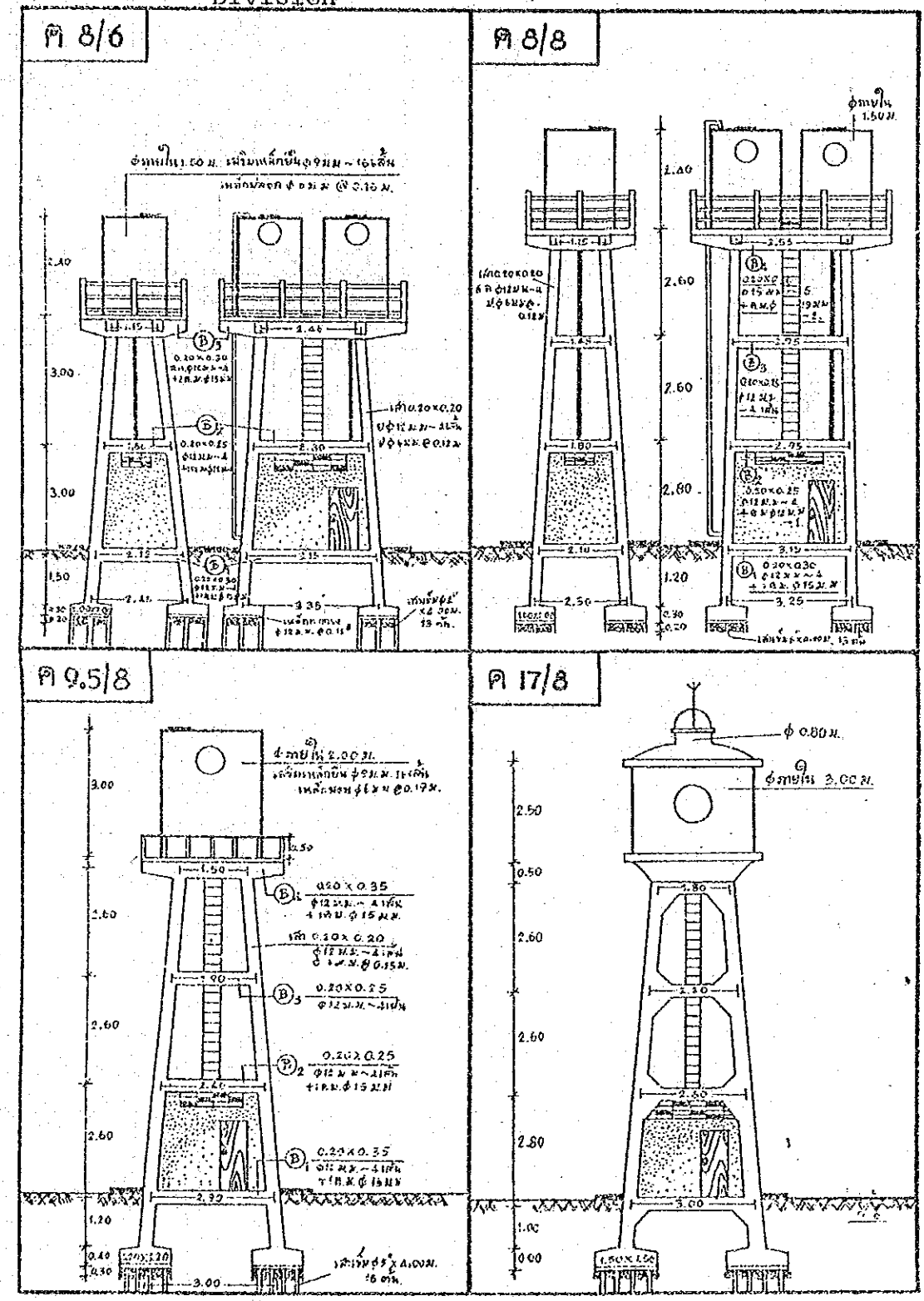
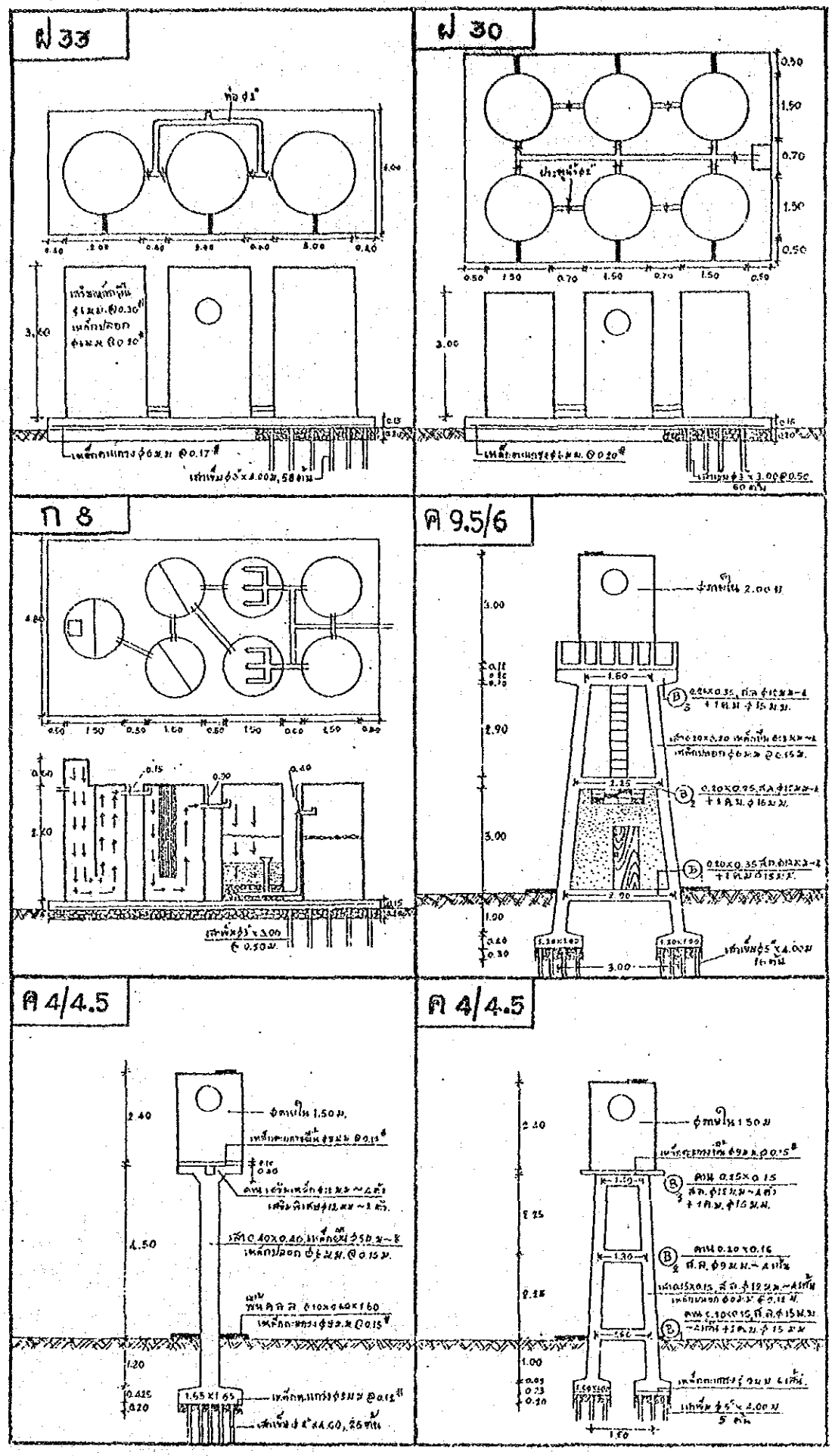


Fig.2-9 (b) Model Plan of Water Storage Tank by Sanitation Division



2-4 Topography and Hydrogeology of Model Areas

2-4-1 Results of the Hydrogeological Survey

The province of Chanthaburi, where the model areas are distributed, is located about 300 km southeast of Bangkok, the capital of Thailand and has a common border with Kampuchea. The province of Chanthaburi is topographically divisible into three areas: marshy coastal lowland which is affected by the sea water, plains drained by the Chanthaburi River and its tributaries, and highland bordering Kampuchea on the east side.

All the four model areas are located within the Province of Chanthaburi. Ban Sam Rong area is located in hills 80 km north of Chanthaburi city at an elevation of about 150 m. Ban Bo and Tagad Ngao areas are located in the coastal lowland, and the Propokklao Hospital is located on reclaimed land of the marshy area a short distance from the city of Chanthaburi. These model areas belong to the coastal lowland.

The coastal lowland has many creeks which intrude deeply into the marshy land and many mangrove forests which are unaffected by salt water grow there luxuriantly. The greater part of the marshy land is utilized as paddy and grass fields; the rest is a strip of marshy land with low shrubs.

A lifting test was performed by the recharge method in a municipal well in the Ban Bo model area. The coefficient of permeability of this public well was calculated to be $Kb = 1.00 \times 10^{-3} cm^2/sec$. The soil of this area was presumed to be fine sand or silty fine sand, but coarse to medium grain sand mixed with gravel are exposed on the ground surface.

In the Tagad Ngao model area which is also located in the coastal lowland, hills rise 70 m above sea level from the lowland surrounded by creeks. These hills extend north-south for a distance of about 3.5 km with a breadth of about 1 km. Luxuriant shrubs are the main vegetation. On one slope of the hills, there are layers of compact deposits of sandstone and slate, but the soil of these hills is generally cimprised of coarse to medium grain sand mixed with gravel. Based on the Ghyben-Herzberg's law, it can be expected that there is a lens-like aquifer of fresh water under these hills.

The Prapokklao Hospital is located a little west of the city of Chanthaburi. It is situated on an area reclaimed from marshy land with

luxuriant shrubs and has an elevation of about 5-6 m. The back of the hospital faces a bog and marshy land with many shrubs growing. There is a large artificial lake beside the road. This artificial lake which is about 200 m wide and 500 m long appears to maintain a constant water level even during the dry season.

On either side of the small river flowing through this bogland and marsh, thick mangrove forests grow; hence, the ground water in this area must be affected by salt water. In the dry season, measures should be taken to counter the influence of salt water on ground water.

The Chanthaburi River has its origin in the Khao Soi Dao Tai mountains with an elevation of 1,670 m which are situated about 60 km north-northeast of the city of Chanthaburi. Khao Soi Dao Nua mountain with an elevation of 1,556 m is followed by Khao Soi Dao Tai mountain with a height of 1,670 m and a series of hills with an elevation of 150 m or so. This series of low mountain ranges extends to Khao Sam Ngam mountain with a height of 727 m and further to Phnum Chrang mountain with an elevation of 1,167 m located on the Kampuchean side of the border. These mountain ranges form the watershed of the Thai border area; the Thai river system including the Chanthaburi River empties itself into the Gulf of Thailand, and the other river systems find their way into Sam Rong model area belongs to the latter river system.

The meteorological data, such as temperatures, precipitation, wind direction, and wind velocity, recorded at the Meteorological Station (Lat. 12°37'N, Long. 102°06'E) in Chanthaburi city are presented in Table 2-9 and Fig. 2-9.

The data over the past two years show that the coolest monthly temperature of 17°C occurs in December or January, and that temperatures rise to about 36°C from March through May. Mean temperatures are 27 to 29° throughout the year.

Annual precipitation ranges from 2,400 - 2,500 mm; the greater part of the rain falls from late April until early October. Average annual precipitation in Thailand from 1978 through 1980 is shown with monthly fluctuations in Fig. 2-11. The dry season generally begins in late October or in early November and ends in late March. Based on past data, monthly precipitation is never zero even in the dry season. As shown in Table 2-9, in Chanthaburi Province, the districts of Chanthaburi and

Laem Sing which are located near the sea receive more rain than Pon Nam Ron and Ban Sam Rong which are located inland in the hilly area.

There is a time lag between rainfall and rise of the ground water table. This time lag is related to the thickness and permeability of the soil layer between the ground surface and the water table.

Whereas the time lag is a few hours for a well excavated in the alluvial plain, the time lag may be 1 month or longer for a deep well in an upland area. The fluctuations in well water level after rainfalls differ from one well to the other, reflecting the differences in soil profile. Such fluctuations in well water levels can be classified into 8 types (A to G), as shown in Table 2-7. (The case cited is unconfined ground water).

In the majority of existing wells, unconfined ground water is drawn from depths of several meters. For example, the existing shallow wells in the Ban Bo model district have Type-A well water level fluctuations.

The meteorological data on wind direction and velocity obtained from the Chanthaburi Meteorological Stations were collected with a view to studying the possibility of using windmills to lift well water. However, it appears that wind directions and velocities differ considerably from one district to the other. The annual mean wind velocity seems to be rather constant ranging from 9.5 m/sec in the month of the lowest force to 20 m/sec in the month of the highest force.

Table 2-7 Precipitation and Well Water Level Fluctuations

	Type	Topographic and Geologic Features
A	Well water level rises immediately after rainfall and sinks during dry periods.	Most wells dug in the high permeabile sand layer belong to this type.
A'	This is a variation of type-A. Well water level shows a fast response to rainfalls.	Wells of this type are seen in the areas where the soil is highly permeable, like loose sand and alluvial soil which allow relatively free passage of ground water.
B	Well water level does not rise after small rainfalls, but does not easily sink a long time after heavy rainfalls.	Many of wells dug in the plateau are of this type.
C	Well water level does not rise immediately after rainfalls, and begins to rise a few days after a rainfall. Drop in water level also lags several days behind dry periods. The water level fluctuation cycle is long.	The area where wells of this type are distributed has the following low permeabile soils. 1. Silt layer of low permeability 2. Compact sand layer 3. Sand layer interspersed with clay (impermeable to water)
D	Well water level suddenly sinks after expended periods of fine weather and the well runs dry when fine weather continues. Rise in water level lags a few days behind rainfalls.	The topography and geology is such that neighboring ground water is not abanduntly recharged. Once the drawdown has exceeded a certain limit, it takes a long time for rainwater to permeate the soil and appear as well water.
E	Well water level hardly fluctuates, no matter whether rain falls or not.	Many of wells dug in the plateau near paddy fields are of this type from a topographical viewpoint. Geologically, ground water is at a shallow depth under an alluvial plain (paddy field surface). Well water level is about the same as the water table under the alluvial plain. The water table remains stable at all times since rainwater drains into the nearby rivers and irrigation ditches.
F	Well water level shows little fluctuation throughout the year.	Deep wells dug in the plateau are for the most part of this type. As the well is at a deep depth from the ground surface, water can be drawn from the deep aquifer even after long spells of dry weather. Conversely, well water level does not rise markedly after extended dry periods.
G	Well water level fluctuates, no matter whether rain falls or not.	Heavy drafts seem to be responsible for water level fluctuations and the acquifer takes time to be recharged.

Table 2-8 Description of Existing Wells in Chanthaburi Province

WELL NUMBER	LOCATION CHANGWAT / AMPHOE	DATE DRILLING STARTED (ABOVE) COMPLETED (BELOW)	DEPTH DRILLED (Feet)	CASING USED	SLOTTED PERFORATION (Feet)	STATIC WATER LEVEL (Feet)	YIELD US. (gpm)	DRAW-DOWN (Feet)	TYPE OF PUMP INSTALLED	DATE & METHOD OF REDEVELOPMENT	WATER QUALITY PH (ppm)	IRON (Total) (ppm)	CHLORIDE (ppm)	TOTAL DISSOLVED SOLIDS (ppm)	TOTAL HARDNESS AS $CaCO_3$ (ppm)
MA10CTB1	Chanthaburi Laem Sing	1.28.72 1.31.72	375	None	None	..... Salty water, hole abandoned									
MA11CTB2	Chanthaburi Laem Sing	2.13.72 2.17.72	185	6"-165'	120-163	6.01	28.96	25.76	Hand	Pump 6.23.72	6.8	3.6	944	2208	795
MA12CTB3	Chanthaburi Laem Sing	2.24.72 3. 6.72	430	None	None	..... Salty water, hole abandoned									
MA13CTB4	Chanthaburi Laem Sing	3. 8.72 3. 8.72	40	8"-22'	Screen 35 8-18	5	20	15	Hand	Air Lift 3.12.72					
MA14CTB5	Chanthaburi Laem Sing	3.17.72 3.27.72	281	4"-260'	140-260	47	10	127	Hand		7.3	2.4	421	1017	300
MA15CTB6	Chanthaburi Laem Sing	3.31.72 4.15.72	470	None	None	..... Abandoned, dry hole									
MA16CTB7	Chanthaburi Laem Sing	4.20.72 4.23.72	250	None	None	..... Salty water, hole abandoned									
MA17TRT1	Trat Muang	4.27.72 4.29.72	100	6"-100'	70-90	8.05	25.29	33.30	Hand	Pump 6.30.72					
MA18TRT2	Trat Muang	5. 2.72 5. 5.72	130	6"-60'	40-60	3.32	25.29	65.42	Hand	Pump 6.27.72					
MA19TRT3	Trat Khlong Yai	5. 8.72 5.12.72	100	6"-80' 4"-100'	60-80 80-100	5	30	40	Hand						

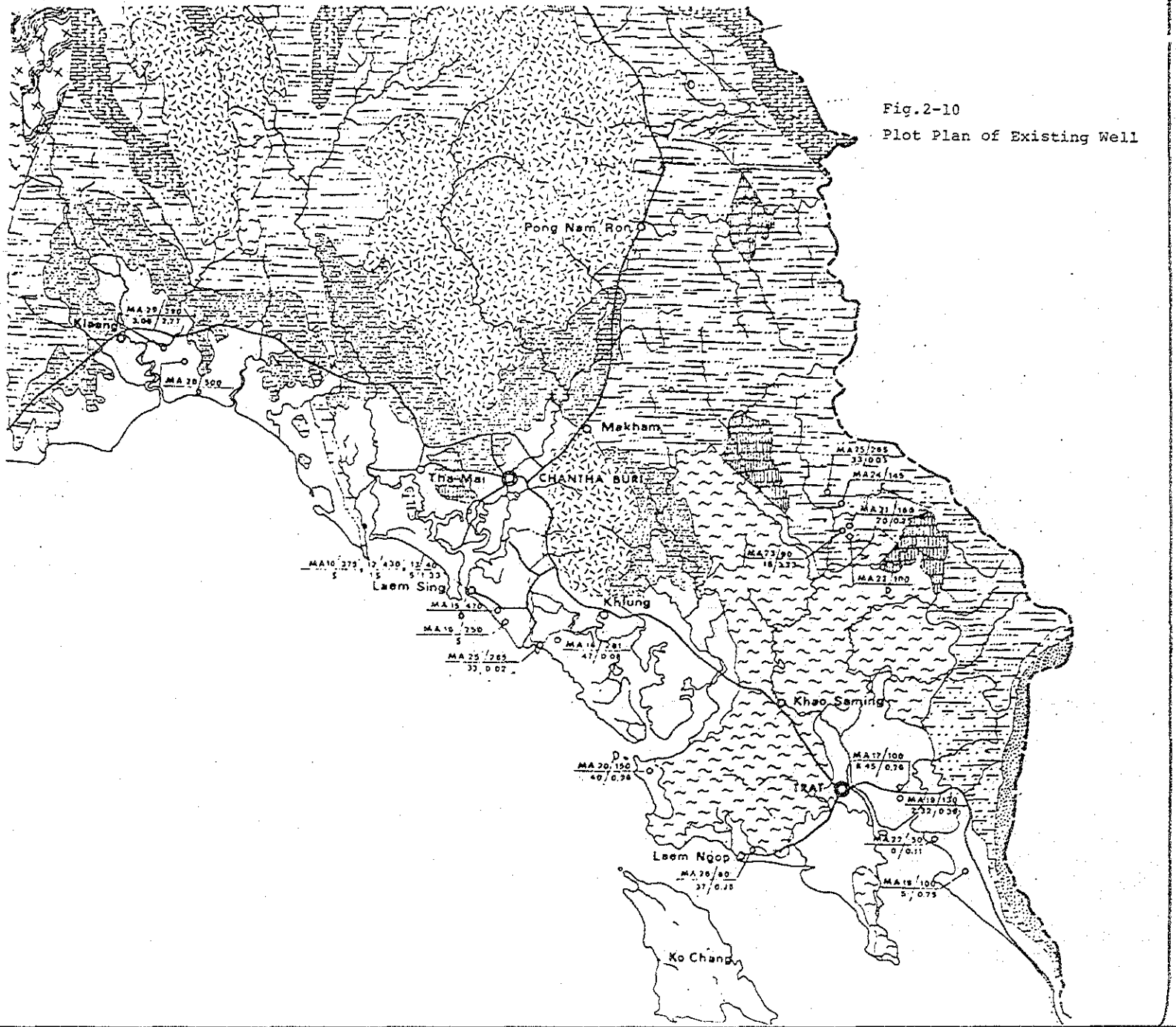


Fig.2-10
Plot Plan of Existing Well

Table 2-9(a) Meteological Data

Meteorological Records in Chanthaburi Municipality

1978 Temperature (°C)

	Highest	Lowest	Average	Rain-fall(m/m)
Jan.	34.3	18.0	27.00	78.8
Feb.	34.6	20.5	27.01	27.5
Mar.	35.3	22.5	28.56	22.7
Apr.	34.8	22.3	28.73	77.8
May	34.7	22.5	28.30	376.9
Jun.	33.0	22.6	27.93	513.4
Jul.	32.0	22.7	27.39	454.7
Aug.	31.5	22.8	27.36	621.4
Sep.	33.5	21.2	26.83	675.9
Oct.	33.5	20.0	26.85	280.3
Nov.	33.5	18.0	26.85	8.0
Dec.	34.8	18.0	26.64	-

Total : 3,137.4 mm

Table 2-9(b) Meteological Data

Meteorological Records in Chanthaburi Municipality

1979 Temperature (°C)

	Highest	Lowest	Average	Rain-fall (m/m)
Jan.	35.2	19.7	27.18	10.8
Feb.	34.7	20.7	27.64	2.9
Mar.	35.8	21.0	28.80	1.8
Apr.	35.6	21.5	29.06	177.5
May	35.2	22.3	28.97	297.5
Jun.	33.1	23.0	27.81	409.1
Jul.	33.2	22.8	27.56	675.5
Aug.	34.6	22.7	28.05	288.7
Sep.	34.0	22.6	27.50	620.5
Oct.	35.3	21.0	28.00	75.5
Nov.	35.0	18.8	22.20	23.5
Dec.	34.7	17.7	26.58	2.0

Total : 2,585.3mm

Table 2-9(c) Meteological Data

Meteorological Records in Chanthaburi Municipality

1980 Temperature (°C)

	Highest	Lowest	Average	Rain-fall (m/m)
Jan.	35.0	17.0	26.47	-
Feb.	36.0	18.3	27.59	23.2
Mar.	34.8	20.9	28.36	39.8
Apr.	34.8	23.2	29.38	50.7
May	35.5	23.5	29.55	217.2
Jun.	34.7	23.3	27.62	844.7
Jul.	34.0	22.6	27.78	514.7

Table 2-9(d) Meteological Data

Total Rainfall for each Month (1979 - 1980) (mm)

1979	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chanthaburi	10.8	2.9	1.8	177.5	297.5	409.1	675.5	288.7	620.5	75.5	23.5	2.0
	(2)	(2)	(2)	(14)	(21)	(21)	(25)	(21)	(23)	(5)	(1)	(1)
Lam Sing	19.1	118.6	19.0	-	53.3	225.7	375.6	34.3	82.8	-	-	-
	(12)	(29)	(4)		(7)	(20)	(18)	(7)	( )			
Phon Namron	-	3.6	8.0	70.4	149.9	305.2	277.7	238.2	217.8	63.6	1.8	-
		( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	
Klung	-	-	-	73.1	98.3	137.4	195.2	15.3	100.5	171.9	50.7	-
				(4)	(7)	(10)	(5)	(1)	(2)	(4)	(1)	
Makam	-	-	-	134.0	133.5	674.6	539.8	100.6	236.0	46.6	-	-
				(3)	(3)	(11)	(9)	(3)	(9)	(1)		
Tamai	-	14.8	-	115.1	341.0	376.8	462.3	201.3	639.2	110.0	-	-
		(1)		(5)	(9)	(11)	(8)	(9)	(12)	(4)		

Remarks :

( ) shows number of rainy day.

Table 2-9(e) Meteological Data

Total Rainfall for each month (1979 - 1980) (mm)

1980	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chanthaburi	-	23.2	39.8	50.7	217.2	844.7	514.7	733.5	367.8	266.9	25.3	-
		(4)	(5)	(7)	(13)	(27)	(25)	(30)	(21)	(21)	(5)	
Lam Sing	-	-	123.2	9.0	112.0	162.9* ..... (* up to 24th)						
			(2)	(2)	(8)	(19)						
Phon Namron	-	0.9	47.4	31.0	233.2	374.1						
		( )	( )	( )	( )	( )						
Klung	-	-	143.7	90.1	145.3	739.3**..... (** up to 26th)						
			(2)	(6)	(14)	(18)						
Makam	-	-	35.2	104.0	245.6	96.0						
			(2)	(3)	(7)	(2)						
Tamai	-	36.0	117.2	59.7	194.7	620.5						
		(4)	(2)	(4)	(8)	(13)						

Remarks :

( ) shows number of rainy day.

Table 2-9(f) Meteological Data

Yearly Record of Wind for each Month

Chanthaburi Meteorological Station
(Lat. 12°37'N. Long 102°06'48"E)

Year 1976 (Month)	Average Wind Velocity (km/h)	Direction (Degrees)
January	52	040
February	29	220
March	47	040
April	60	130
May	46	180
June	47	220
July	46	230
August	52	220
September	24	210
October	52	060
November	70	040
December	52	040

Table 2-9(g) Meteological Data

Yearly Record of Wind for each Month

Chanthaburi Meteorological Station
(Lat. 12°37'N. Long 102°06'48"E)

Year 1977 (Month)	Average Wind Velocity (km/h)	Direction (Degrees)
January	60	050
February	54	040
March	62	040
April	44	180
May	38	220
June	46	220
July	63	230
August	56	290
September	44	270
October	34	320
November	52	040
December	60	040

Table 2-9(h) Meteological Data

Yearly Record of Wind for each Month

Chanthaburi Meteorological Station
(Lat. 12°37'N. Long 102°06'48"E)

Year 1978 (Month)	Average Wind Velocity (km/h)	Direction (Degrees)
January	52	040
February	63	020
March	34	180
April	42	140
May	52	140
June	45	230
July	43	200
August	53	230
September	54	270
October	71	020
November	55	040
December	62	040

Table 2-9(i) Meteological Data

Yearly Record of Wind for each Month

Chanthaburi Meteorological Station
(Lat. 12°37'N. Long 102°06'48"E)

Year 1979 (Month)	Average Wind Velocity (km/h)	Direction (Degrees)
January	35	040
February	32	360
March	30	180
April	42	140
May	54	300
June	45	270
July	41	230
August	48	220
September	54	270
October	51	360
November	56	360
December	45	040

Table 2-9(j) Meteological Data

Yearly Record of Wind for each Month

Chanthaburi Meteorological Station
(Lat. 12°37'N. Long 102°06'48"E)

Year 1980 (Month)	Average Wind Velocity (km/h)	Direction (Degrees)
January	44	040
February	51	360
March	33	030
April	66	230
May	74	180
June	54	230
July	40	210
August	58	220
September	37	290
October	42	050
November	57	040
December		

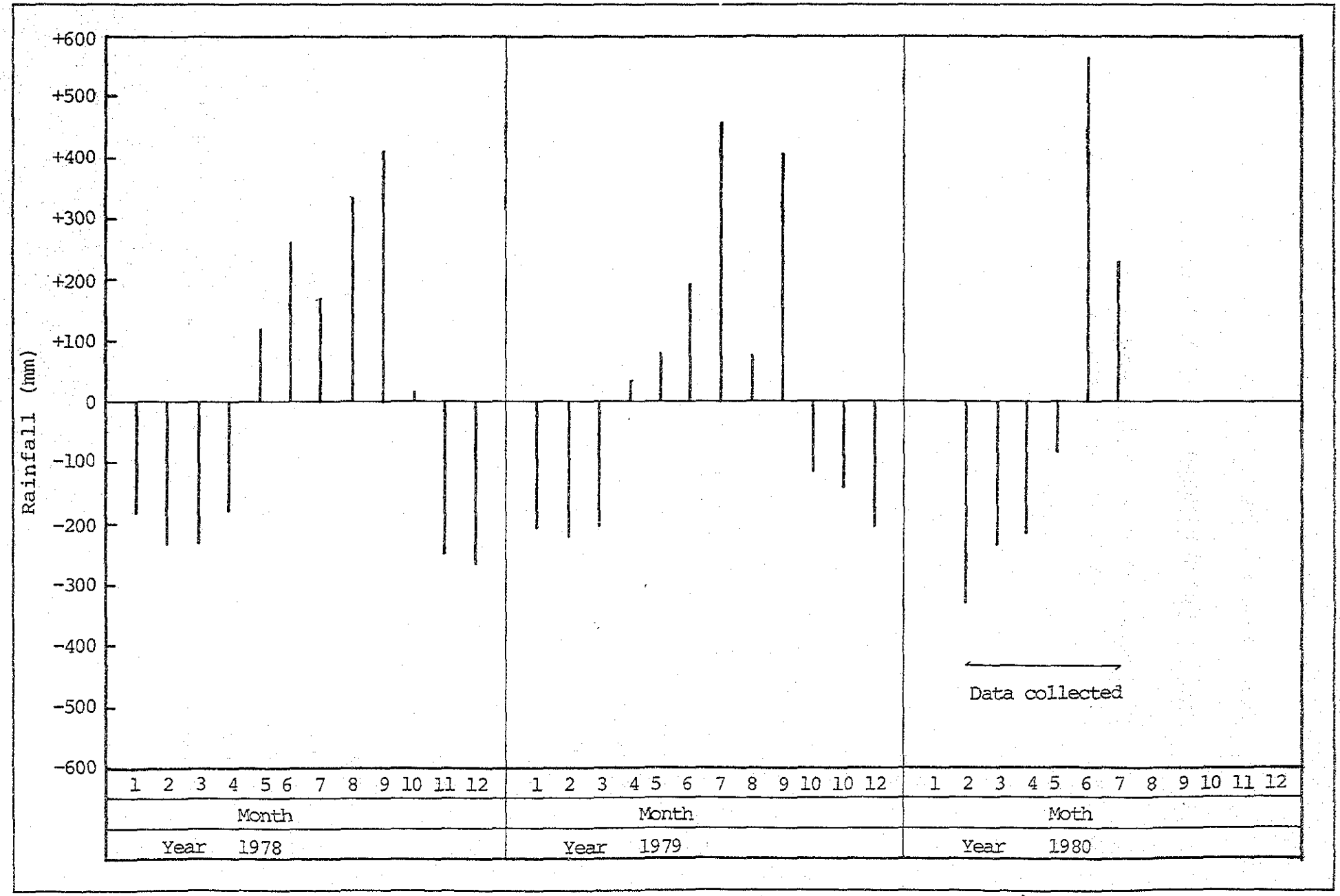


Fig. 2-11 Monthly Difference from Average Rainfall

Fig.2-12 Max.Temperature (1951 - 1970)

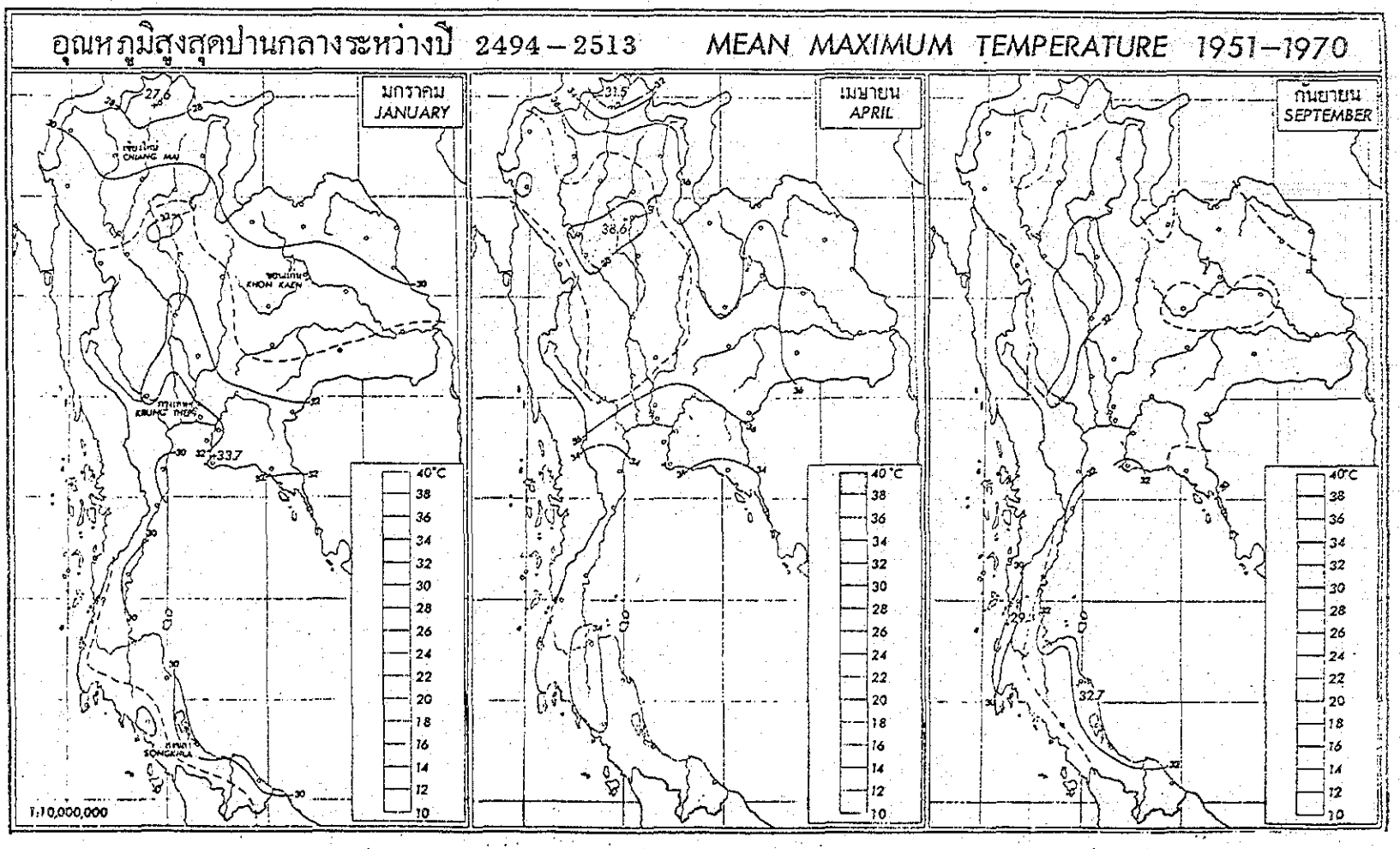


Fig.2-13 Min. Temperature (1951 - 1970)

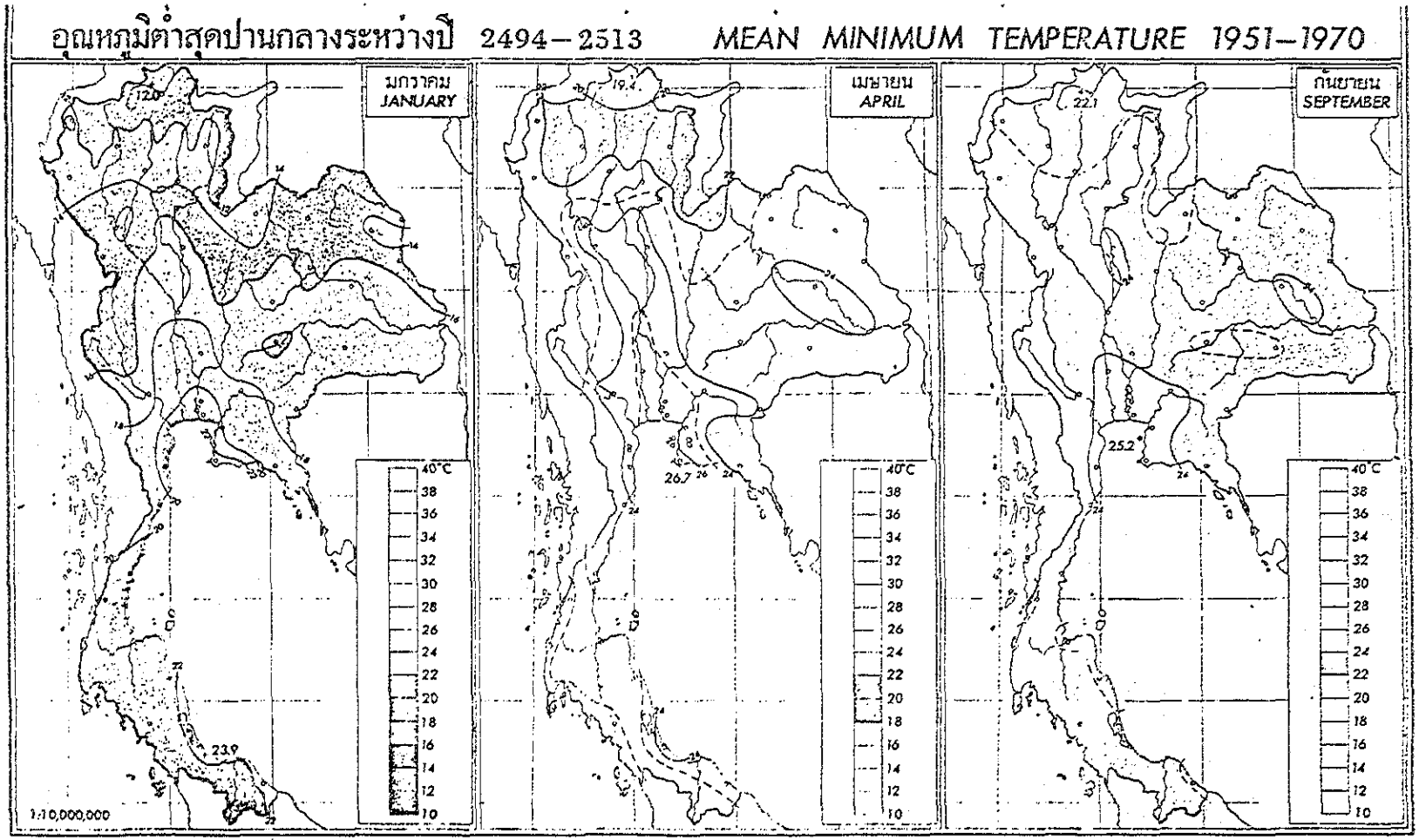


Fig.2-14 Monthly Rainfall (1951 - 1970)

Fig.2-15 Humidity (1951 - 1970)

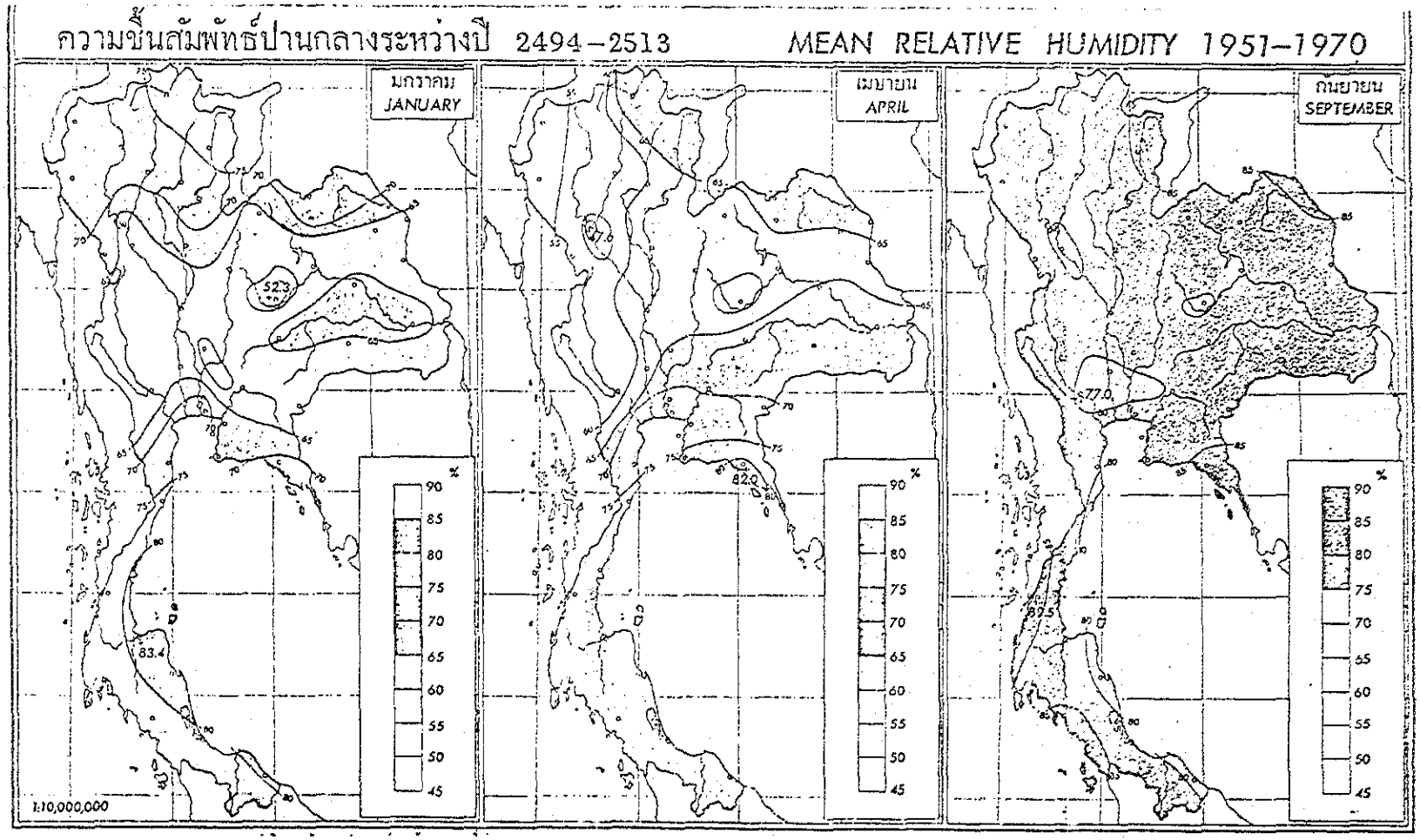
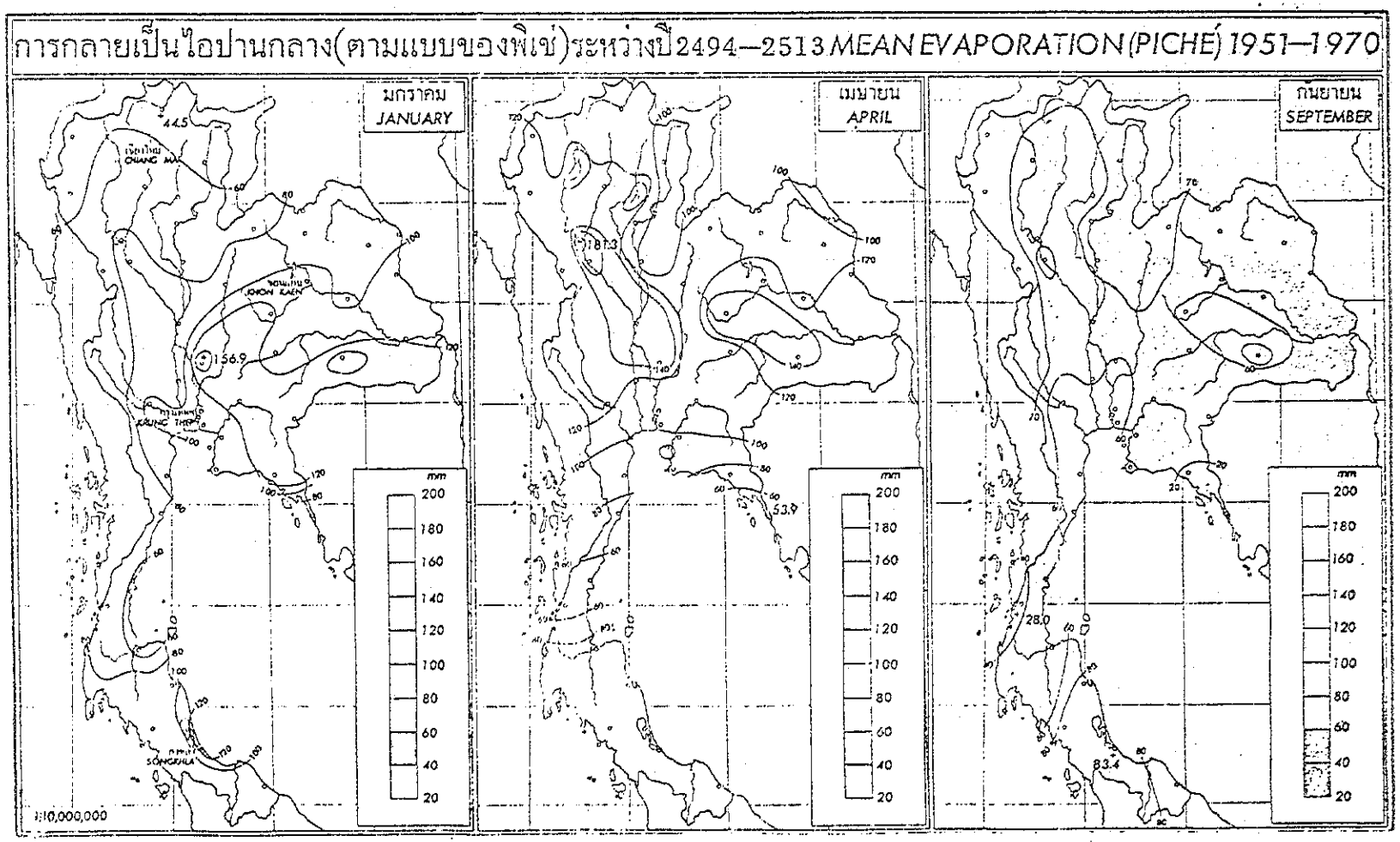


Fig.2-16 Evaporation (1951 - 1970)



2-4-2 General Geological Information on the Province of Chanthaburi

An outline of the geological features of the province of Chanthaburi were obtained from the Hydrogeological Map of the Eastern Part of Thailand given in Fig. 2-18. As can be seen in this map, granite is distributed from south to north in this province. Around it, fossils are widely deposited and in places effusive rock, such as quartz dolerite and basalt, is exposed. A small-scale quaternary layer is deposited on such older rock in the coastal lowland and river basin.

This older rock is composed of sandstone, slate and limestone. The older rock as well as granite and effusive rock such as quartz dolerite and basalt appears to be of early formation and forms quite a compact rock layer.

The quaternary layer which overlies the older rock is composed of clay and sand. Being perhaps of late formation, this layer appears to be an unconcreted formation.

Judging from the geologic features of this province, it appears that rock of early formation predominates with formations of compact rock well distributed so that large aquiters of ground water will be difficult to locate.

Furthermore, as discussed in sec. 2-4-1, annual precipitation is considerable in this province, but is concentrated in the rainy season. Precipitation differs to greatly from the wet season to the dry, and as hot temperatures occur most of the year, much ground water is lost by evaporation. In view of these geologic and climatic conditions of the province, low levels of natural recharge are likely.

If ground water is to be tapped in this province, there is no alternative but to draw water flowing through the crevices and pores in the quanternary sand layer or older rock in the lowland. If the quaternary layer were thick, much ground water could be secured; however, this is not the case since the quaternary formation is limited in scale here. In a word, the hydrogeologic condition of this province does not favor large aquifers of ground water.

Ban Samroong

The quaternary alluvial deposits are distributed in this area and fossil organisms and metamorphic rock are developed in the surrounding

mountains. In the left Kho Sa Dao Tai mountain ranges granite is distributed. Accordingly, it is assumed that older rock occurs in the lower part of the quaternary layer and that ground water is present in the crevices in the sand and older rock of the quaternary diluvium.

Prapokklao Hospital Compound

The quaternary alluvial layer is developed in the estuary of the Chanthaburi river, but the fossil layer and basalt are distributed in the mountains behind the Prapokklao Hospital compound and granite is exposed a short distance from it. Also in this area slate and sandstone of the fossil layer are believed to occur immediately below the quaternary alluvial layer, and ground water appears to occur in the alluvial sand layer and sandstone of the fossil layer.

Tagad Ngao

The quaternary alluvial layer is distributed in this area. In the small mountainous area near village No. 4, sandstone and slate of the fossil layer are exposed. It appears that the fossil layer is immediately below the quaternary layer and that ground water occurs in the pores in the quaternary sand layer and in the crevices in the sandstone underlying it.

The topographic features of this area and the results of electric prospecting suggest that Ghyben-Herzberg's law applies to it.

Generally speaking, a lens-like body of fresh water floats over the sea water in islands in the pacific ocean and coastal sandhills. This fact can be easily accounted for by the theory of static equilibrium based on the difference in specific gravity between fresh water and sand water. In short, the weight of a body of fresh water having a thickness of (H + h) is equal to thickness H of salt water. Accordingly, if the specific gravity of salt water is ρ' and that of fre h water is ρ, we obtain the equation as follows.

$$(H + h)\rho = H\rho'$$

$$\frac{H}{h} = \frac{\rho}{\rho' - \rho} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

where: ρ is assumed to be 1.000 and ρ', 1.024.

Substituting these assumed values for ρ and ρ', we obtain:

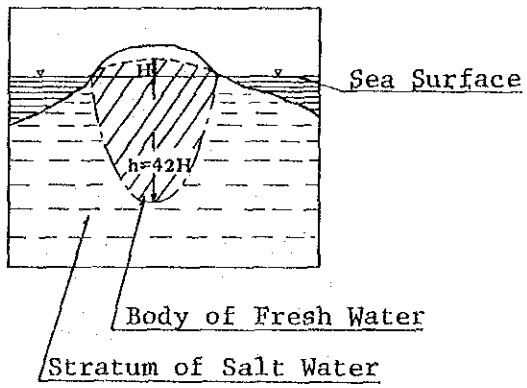
$$\frac{H}{H} = \frac{1.000}{1.024 - 1.000} = \frac{1.000}{0.024}$$

$$H = 42h$$

This series of calculations indicates that if the thickness of fresh water above the sea surface is given, the thickness of fresh water under sea surface can be known (i.e., 42 h in the case cited above).

In actuality, however, this phenomenon is by far more complicated and there is no distinct boundary between fresh water and salt water. Equilibrium is securely maintained when fresh water is always replenished from the surface and is flowing. Furthermore, this equilibrium is affected by various factors, especially the amount and distribution of precipitation, soil profile, (notably the thickness of the sand layer), tidal level, ground level and discharge.

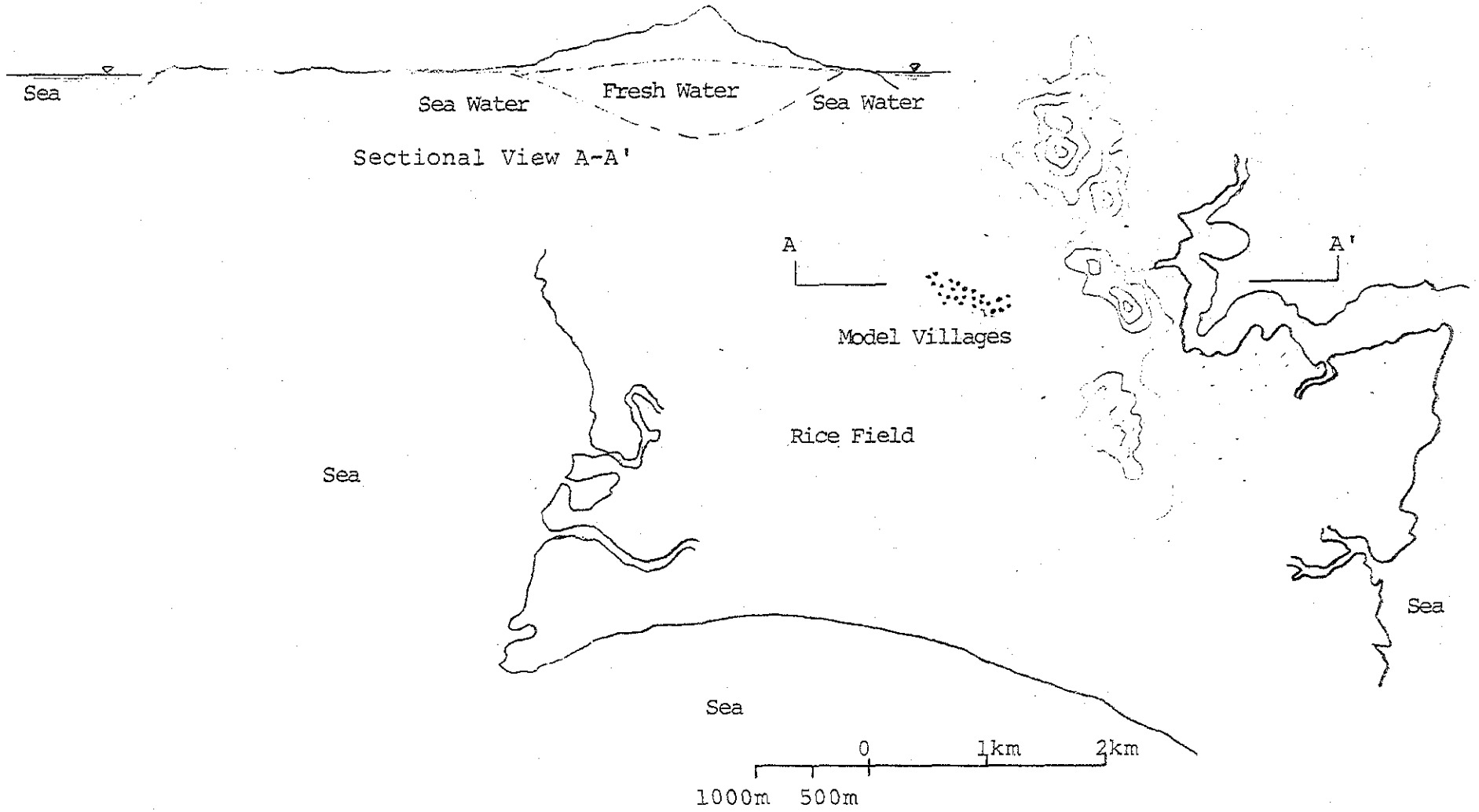
Judging from the distribution of precipitation, loss of rainwater by evaporation and geologic conditions in the Tagad Ngao area, it is safer to expect that fresh water only occurs in a very thin layer near the ground surface.



Map of Ghyben-Herzberg

---- Tagad Ngao ---

Fig.2-17 Layout Plan of Tagad Ngao



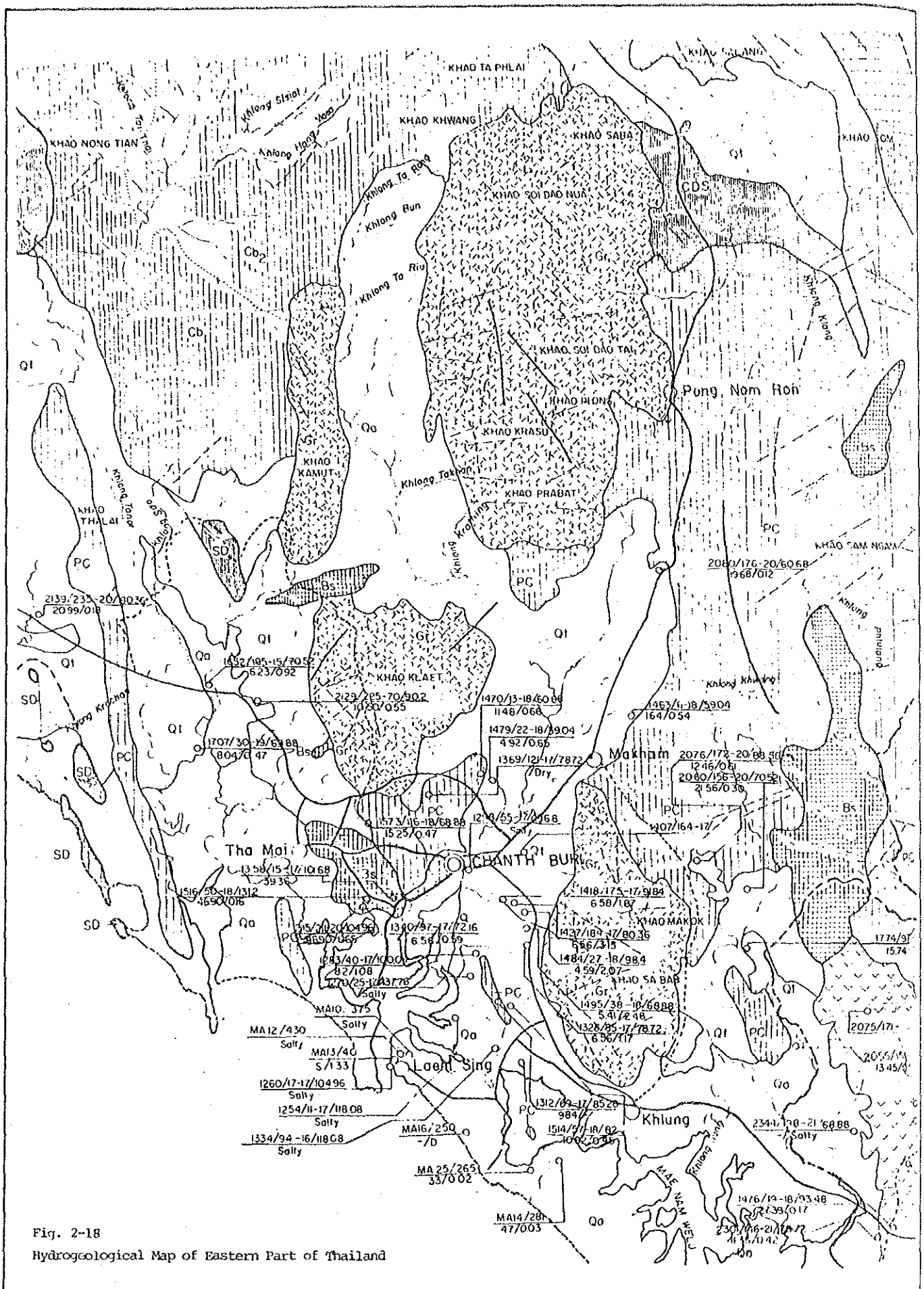


Fig. 2-18
Hydrogeological Map of Eastern Part of Thailand

LEGEND AND HYDROGEOLOGICAL NOTES OF HYDROGEOLOGICAL MAP

1. AQUIFERS IN WHIC FLOW IS DOMINANTLY INTERGRANULAR

a - EXTENSIVE AND PRODUCTIVE AQUIFER

Qa

RIVER, DELTIC AND LITTORAL DEPOSITS (QUARTERNARY) : Consisted of clay sand and gravel, marine and farmer tidal flat clay found in coastal plain of Cha Choeng Sao, Chon Buri and Trat provinces. The formations are characteristically moderate to well sorted, loosely to slightly cemented, range in thickness from 15 meters in western to southern coastal plain to 250 meters in the Bang Pakong River Basin, yield from 10 to over 100m^3/hr of water of variable mineral contents. Potable water can be locally obtained to a limited extent but brackish to salty water is generally yielded by most wells in the coastal area.

b - EXTENSIVE BUT LESS PRODUCTIVE AQUIFER

Qt

TERRACE DEPOSITS (QUARTERNARY) : Consisted of weathered granite and other hard rock as well as tallus are also included, composed of sand clay, gravel, and pebble up to boulder sizes, angular, poorly to moderately sorted, locally slightly cemented Thickness usually not exceed 50 meters. Yield range 2 - 10 m^3/hr of water of fair to good quality except in area close to sea shore. Drilling in areas adjacent to hill side may result in dry hole.