3.5 Available Water Resources

3.5.1 Surface Water

Fig-3.8 conclude the available water sources for Chiangmai city at present and in future. The evaluation of water sources for each treatment plant for Chiangmai waterworks at present and in future has been discussed as follows:

1) Water Source for Umong Treatment Plant

Production capacity of the Umong Treatment Plant is 20,000 cu m/d and it depends its source on the nearby Mae Taeng Irrigation Canal. There are three intakes which pump the raw water directly to the treatment plant or the reservoir with a capacity of 200,000 cu m.

There was a problem that the irrigation canal flow was suspended for about 50 days periodically every year, by reason of regular inspection and repair works, while the reservoir's storage could manage only 7 to 10 days supply.

Conceivable solutions, from the technical, economical and political points, are as follows:

a) Raw Water Supply from Ping River by Pipeline

Several alternative routes from the Ping river to the Umong Treatment Plant have been considered technically and economically. The pipeline can supply steady flow and is attractive, but the cost is obviously higher than the other alternatives.

b) Supply from Mae Tha Ching Diversion by Pipeline

The Mae Tha Ching Diversion has been surveyed by the study team. The pipeline route from the diversion to the Umong Treatment Plant is about 19 km long. However, detailed technical study is needed to evaluate it as a new water source.

AVAILABLE WATER SOURCES FOR CHIANGMAI

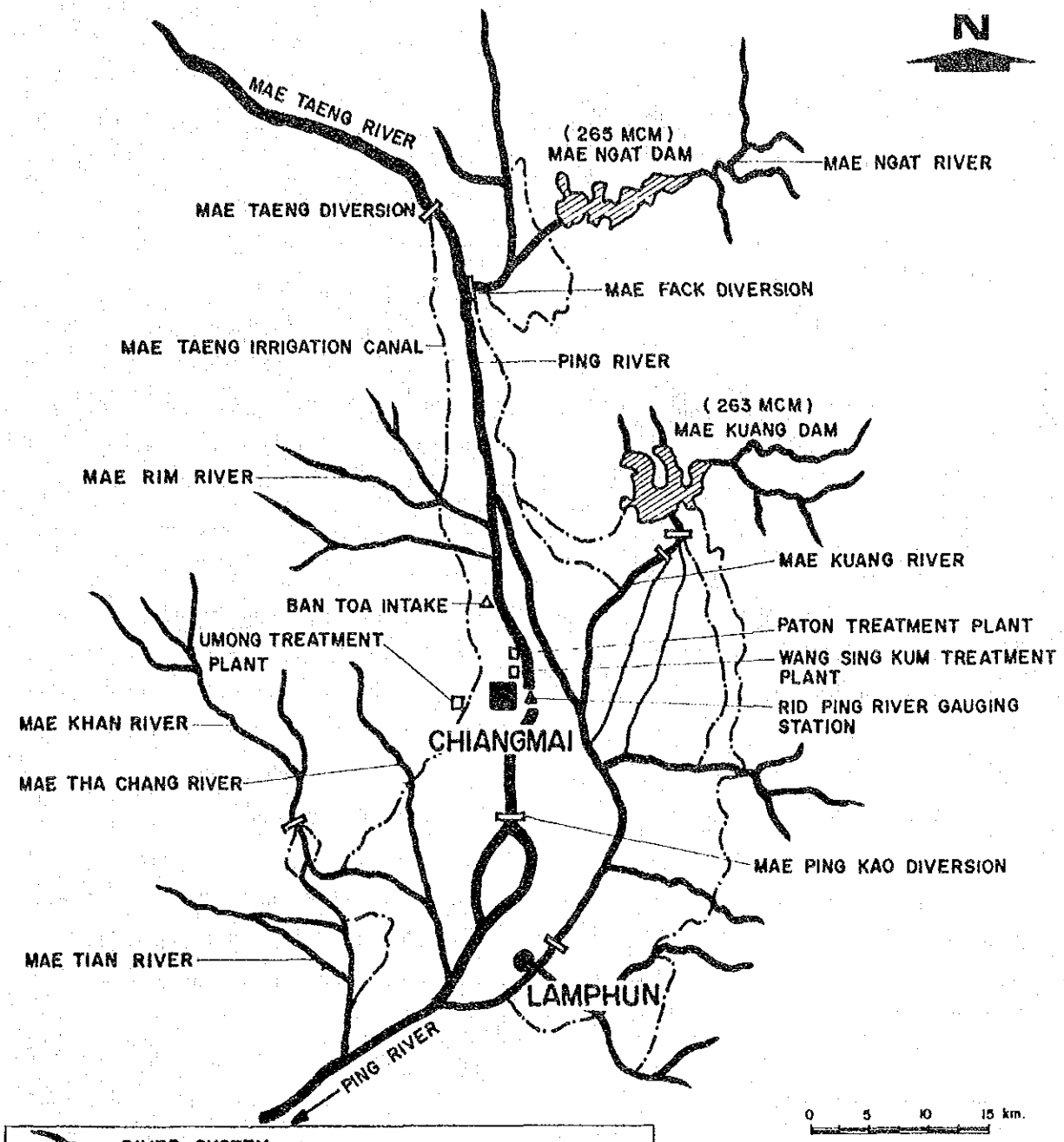


FIGURE	AVAILABLE WATER SOURCES FOR CHIANGMAI
3.8	

JAPAN INTERNATIONAL COOPERATION AGENCY

c) Temporary Bypass of the Irrigation Canal

This alternative is the most economical solution, even though the temporary bypass works will have to be done every year. The Chiangmai waterworks purchased the necessary provisions, and under the cooperation of RID, made the bypass works successfully.

d) Expansion and/or Construction of Existing Reservoir

An existing reservoir of 200,000 cu m capacity may be expanded possibly, by making a sizable construction works after buying available land around it. Although technically feasible, economically the cost of land and construction is obviously higher than the other alternatives.

e) Groundwater Development

Groundwater potentiality in this area is moderate as the yield ranges from 500 to 1,000 cu m/d/well. To replace the surface water supply of 20,000 cu m/d by ground water, more than 20 deepwells are needed. Therefore, the other alternatives are economically cheaper.

Conclusively, the most economical solution of the temporary bypass of the irrigation canal has been selected and the Mae Taeng Irrigation Canal, supplying raw water of 30,000 cu m/d, is made the sole source of the Umong Treatment Plant at present and in future.

2) Water Source for Paton Treatment Plant

The Paton Treatment Plant with supply capacity of 15,840 cu m/d depends its water source on the Ping River at the Ban Tao Intake, constructed in 1981, about 3.5 km upstream of the plant. There was occasional shortage of raw water supply to the plant in dry season, due to decreased natural flow of the Mae Ping River.

An improved way of raw water intake and an alternative source have been considered, as follows:

a) Infiltration Galleries

Infiltration galleries have been considered, to be constructed in the riverbed of the Ping river, to receive raw water especially in dry season. The geological well logs in the riverbed have been collected from PWA and RID to evaluate the subsurface conditions. Although hydraulically feasible, infiltration galleries will become useless within a few months, as the high turbidity and other suspended materials settle, cover the riverbed and clog the galleries.

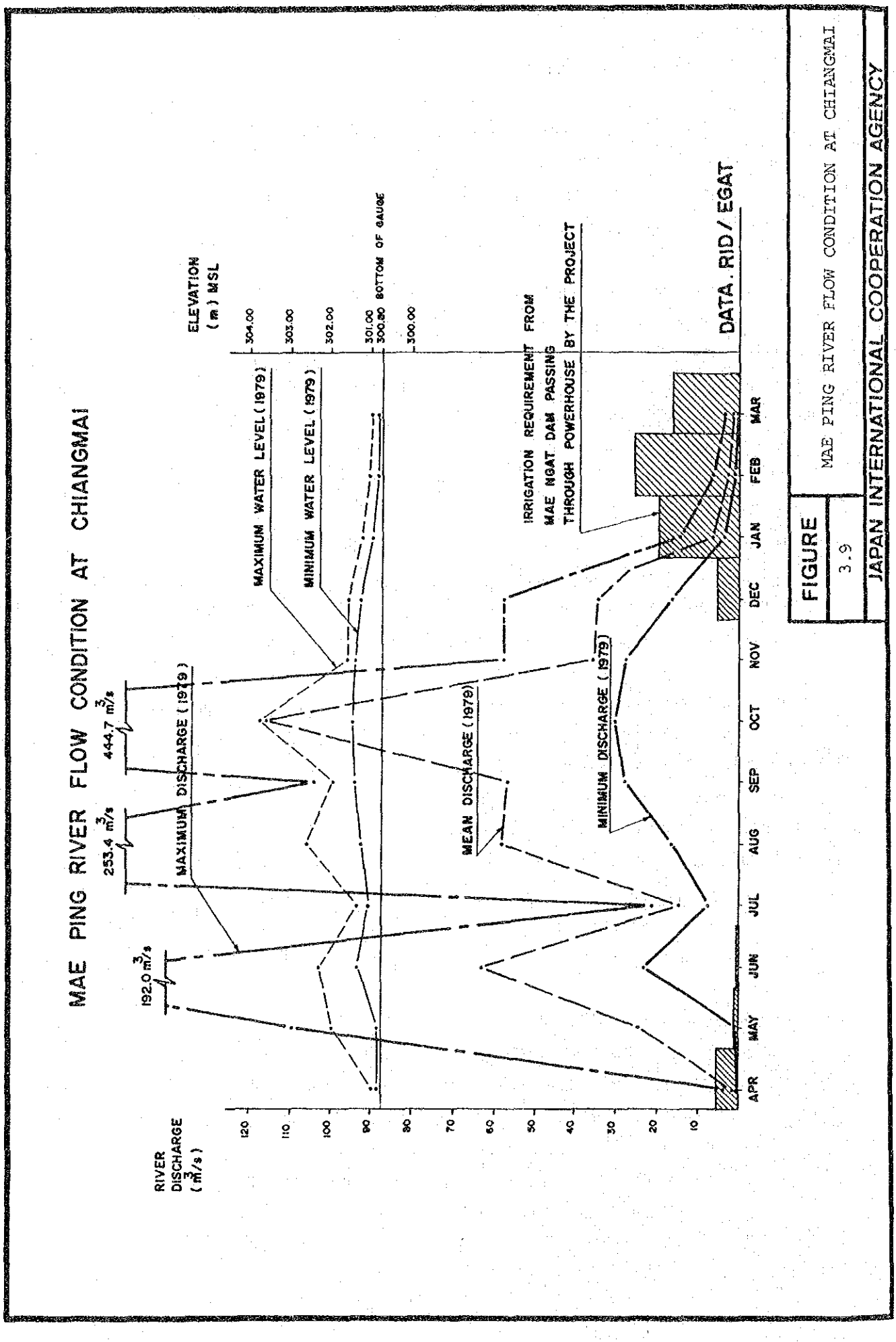
Therefore, infiltration galleries are not recommended in this project.

b) Groundwater

Groundwater is not recommended for the water source of the Chiangmai waterworks because the potentiality is no so high. Groundwater productivity is moderate with an estimated capacity ranging from 500 to 1,000 cu/m/d/well in Chiangmai city area. To replaces the present supply capacity or the future water source by groundwater many deepwells are needed. Although not recommendable for chiangmai, groundwater is useful for the public water supplies in the surrounding sanitary districts.

Both of the conceived alternatives are found to be impractical. However, the water source problem of the Paton Treatment Plant has been improved remarkably, owing to the completion of the Mae Ngat Dam.

Completed in 1985, the dam was constructed by RID to store 265 MCM and use the water for power generation, irrigation, river maintenance and water supply. As the designated irrigation area, Mae Ping Kao, is located downstream of Chiangmai, a minimum flow of 5 to 6 cu m/s for irrigation is promised to flow through Chiangmai, even in dry season. The water management of the project has illustrated in Fig-3.9.


MAE PING RIVER FLOW CONDITION AT CHIANGMAI
ELEVATION (m) MSL
304.00
303.00
302.00
301.00
300.80 BOTTOM OF GAUGE
300.00
MAXIMUM WATER LEVEL (1979)
MINIMUM WATER LEVEL (1979)
IRRIGATION REQUIREMENT FROM MAE NGAT DAM PASSING THROUGH POWERHOUSE BY THE PROJECT
DATA. RID / EGAT
444.7 m³/s
253.4 m³/s
192.0 m³/s
MAXIMUM DISCHARGE (1979)
MEAN DISCHARGE (1979)
MINIMUM DISCHARGE (1979)
RIVER DISCHARGE (m³/s)
120
110
100
90
80
70
60
50
40
30
20
10
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
FIGURE
3.9
MAE PING RIVER FLOW CONDITION AT CHIANGMAI
JAPAN INTERNATIONAL COOPERATION AGENCY

Compared to the flow, the required intake of the Paton Treatment Plant is far low, 0.55 cu m/s for 2000 demand and 0.78 cu m/s for 2010 demand. Under the said favorable condition, the Paton Plant will be assured of taking the water steadily in the future.

3) Water Source for Wang Sing Kam Treatment Plant

The Wang Sing Kam Treatment Plant with supply capacity of 7,920 cu m/d which is the oldest treatment plant in Chiangmai depends its water source on the Ping River. The old intake, right in front of the plant, was moved upstream because of pollution and the Ban Tho Intake mentioned before is now serving raw water to both of the Paton and Wang Sing Kam Plants.

At present and in future, the Ping River is the source for this plant.

4) Future Water Sources

The Mae Kuang Dam is under construction as of 1986 and is scheduled for completion in 1990. As RID plans to use the stored water not only for irrigation but also for power generation and cities' water supply. The Dam, however, is designed to be located 23 km from Paton Treatment Plant. There are considered the following two methods to transmit raw water from the Dam to the treatment plant: (1) to transmit through a pipeline, utilizing the difference in the water levels of the Dam and the treatment plant, and (2) to transmit through the Mae Kuang River. Either of methods (1) and (2) will require a vast capital investment, approximately four times as large as that for the present method of taking in water from Ban Tho.

The Mae Kuang Dam will, however, be a prospective source of Chiangmai in future, promising steady, substantial supply. PWA is therefore recommended to collect necessary data relevant to the possible use of the Dam in future.

On the other hand, as the flow condition of the Ping River has remarkably improved, as described before, and the availability of land space for expansion in the Paton Plant site was weighed than the Mae Kuang alternative, technically and economically. Therefore, the new project will be supplied raw water from the Ping River.

3.5.2 Groundwater

The city of Chiangmai and surrounding Sanitary Districts are located in the northern parts of the Ping River Artesian Groundwater Basin, extending from north to south, roughly 35 km long and 20 km wide. It starts from Mae Taeng area and extends south to Chiangmai, Lamphun and slightly further beyond as shown in Fig-3.10.

Productive aquifers of the Ping River Groundwater Basin are usually the Alluvial and terrace deposits of Pleistocene to Recent consisting of clay, sands and gravels with interbedded laterites. Thickness of the recent Alluvial deposits found in the flood plains may reach 100 m in the upper part and more than 200 m in the lower part. Groundwater is abundant in the flood plains of the Ping River and terraces along the tributary rivers.

Groundwater has not been used in a large quantity, except by some large hotels, factories, hospitals, restaurants in Chiangmai city. However, as many as 40 to 50 % of the households used shallow well water for cooking and laundering, as a survey in 1981 revealed.

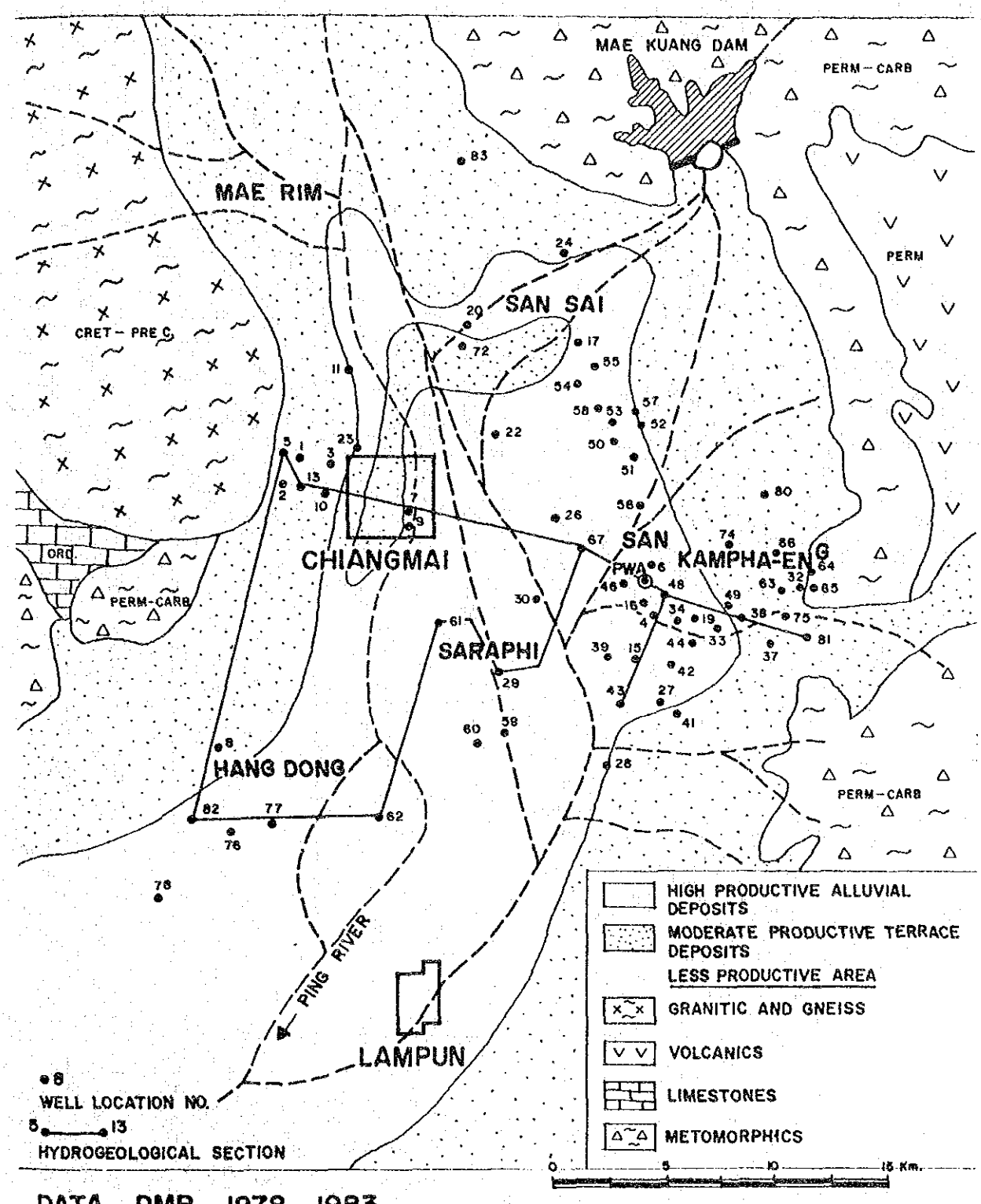
Table-3.7 concludes the hydrogeological evaluation of existing deepwells in Chiangmai Area.

Considering the size and source, groundwater resources in the Chiangmai area can be divided roughly into the following three groups:

a) The highly potential source of groundwater in the basin is the recent Alluvium on the flood plains of Mae Ping and Mae Kuang Rivers which include San Kamphaeng, Saraphi, Hang Dong and Lamphun area. Wells drilled in the flood plains ranging in depth from 100 to 165 m, can yield 1,000 to 3,000 cu m/d/well and/or more than 3,000 cu m/d/well by pumping.

b) The low terrace deposits along the edge of the basin are moderately good aquifers. In the area of Mae Taeng, Mae Rim, San Sai and Chiangmai city on the northern and western terrace, a well may yield 100 to 1,000 cu m/d at some sites.

HYDROGEOLOGICAL MAP IN CHIANGMAI



DATA , DMR , 1978 , 1983

FIGURE	HYDROGEOLOGICAL MAP IN CHIANGMAI
3.10	

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Table -3.7 Prospective Aquifer System in Chiangmai

Aquifer System		Mean Piezometric Level (m)	Mean Specific Capacity ($m^3/d/m$)	Maximum Drawdown (m)	Potential Production (m^3/d)	Water Quality: pH	Iron (ppm)	Chloride (ppm)	T-Solid (ppm)	T-Hardness (ppm)	DATA BASE
Chiangmai	(9 - 17 m)	2.5	498.1			6.9	60	8	202	100	1
	(15 - 36 m)	5.7	176.5	10	155~4,981	6.5 - 7.9	0.9 - 8.5	5 - 6	70 - 100	32 - 38	6
	(42 - 63 m)	4.8	60.6			5.8	54	8	140	24	5
	(60 - 90 m)	5.6	15.5			5.8 - 8.4	7.2 - 54	4 - 8	140 - 305	24 - 30	3
Saraphi	(9 - 17 m)	1.5	164.0			6.9	60	8	202	100	3
	(15 - 36 m)	4.1	449.0		1,640	6.5 - 8.4	1.2	1.2	220	112	4
	(42 - 63 m)	3.9	594.1	10	~9,378	6.5 - 7.7	5.4 - 34	3 - 4	80 - 116	36 - 47	6
	(60 - 90 m)	3.6	937.8			7.7	8.4	8	152	116	5
	(105 - 117 m)	2.2	524.5			-	-	-	-	-	1
San Kamphaeng	(9 - 17 m)	3.4	63.7			7.8 - 8.2	1.9 - 3.6	14 - 32	117 - 122	64 - 72	4
	(15 - 36 m)	4.4	151.2			6.3 - 8.5	0.4 - 11	0.4 - 7.8	80 - 552	60 - 266	20
	(42 - 63 m)	5.0	176.3	10	637~1,800	7.3 - 8.6	1.9 - 33	0.4 - 16	183 - 383	121 - 238	13
	(60 - 90 m)	5.5	104.4			7.3 - 8.6	1.3 - 8.6	0.8 - 16	293 - 334	148 - 184	7
	(105 - 117 m)	4.5	180.0			8.6	8.6	16	293	184	2
	(126 - 144 m)	5.4	123.2			8.6	8.6	16	293	184	1
	(150 - 156 m)	4.5	180.0			8.6	8.6	16	293	184	1
San Sai	(9 - 14 m)	3.4	63.7			7.8 - 8.2	1.9 - 3.6	3.2 - 14	117 - 122	64 - 72	1
	(15 - 36 m)	4.4	151.2	10	571~1,763	6.3 - 8.5	0.4 - 11	0.4 - 7.8	80 - 552	60 - 266	12
	(42 - 63 m)	5.0	176.3			7.3 - 8.6	1.3 - 8.6	0.8 - 16	293 - 334	148 - 184	7
	(60 - 90 m)	4.7	57.1			-	-	-	-	-	3
Hang Dong	(15 - 36 m)	4.9	21.6			6.4 - 6.6	7.4 - 10	8.5 - 27	-	126 - 134	5
	(42 - 63 m)	5.4	369.9	10	216~3,699	6.8 - 8.2	4.1 - 9.6	4.8 - 12	92 - 406	48 - 80	3
	(60 - 90 m)	7.6	40.2			6.4	10	27	-	126	1
Mae Rim	(9 - 14 m)	3.4	832.8	10	1,766	-	-	-	-	-	1
	(15 - 36 m)	4.4	177.6		~8,328	7.9	0.86	5	70	32	1

c) Consolidated rocks crop out in the hills and mountains surrounding the Ping River Basin. Ingeous rocks, granite, diorite, basalt, gneiss and schist are not groundwater-bearing formations usually, while consolidated rocks comprise some productive aquifers of sedimentary and metamorphic rocks along with the river valley associated with cracks and faults. Small yield in the order of up to 100 cu m/d/well may be possible.

Fig-3.11 illustrates the hydrogeological cross section of Ping River Groundwater Basin, the east-west direction, and also Fig-3.12 illustrates the PWA well design and well logs at San Kamphaeng and Lamphun. Groundwater is abundant in the area of Chiangmai in the artesian condition. Therefore, Sanitary Districts will be recommended for the use of groundwater, as it is suitable water source for public water supply. However, the water quality of groundwater should be studied carefully, because high iron contents are detected in wide area.

3.6 Water Resources Development Plan

There is no problem of water source for Chiangmai under the suitable water resources management of Ping River basin by RID. Fig-3.13 concludes the existing water source and recommendable future water sources for Chiangmai up to the year of 2010.

1) Present Water Source (1986)

a)	Ping River :	23,760 cu m/d
	a) Paton Treatment Plant :	15,840 cu m/d
	b) Wang Sing Kam Treatment Plant :	7,920 cu m/d
b)	Mae Taeng Irrigation Canal :	30,000 cu m/d
	a) Umong Treatment Plant :	30,000 cu m/d

The problem of Mae Taeng Irrigation Canal which stop the raw water supply several times in a year for periods about 50 days. The solution has been decided the most economical method of the bypass of irrigation canal.

HYDROGEOLOGICAL FENCE DIAGRAM OF PING RIVER BASIN

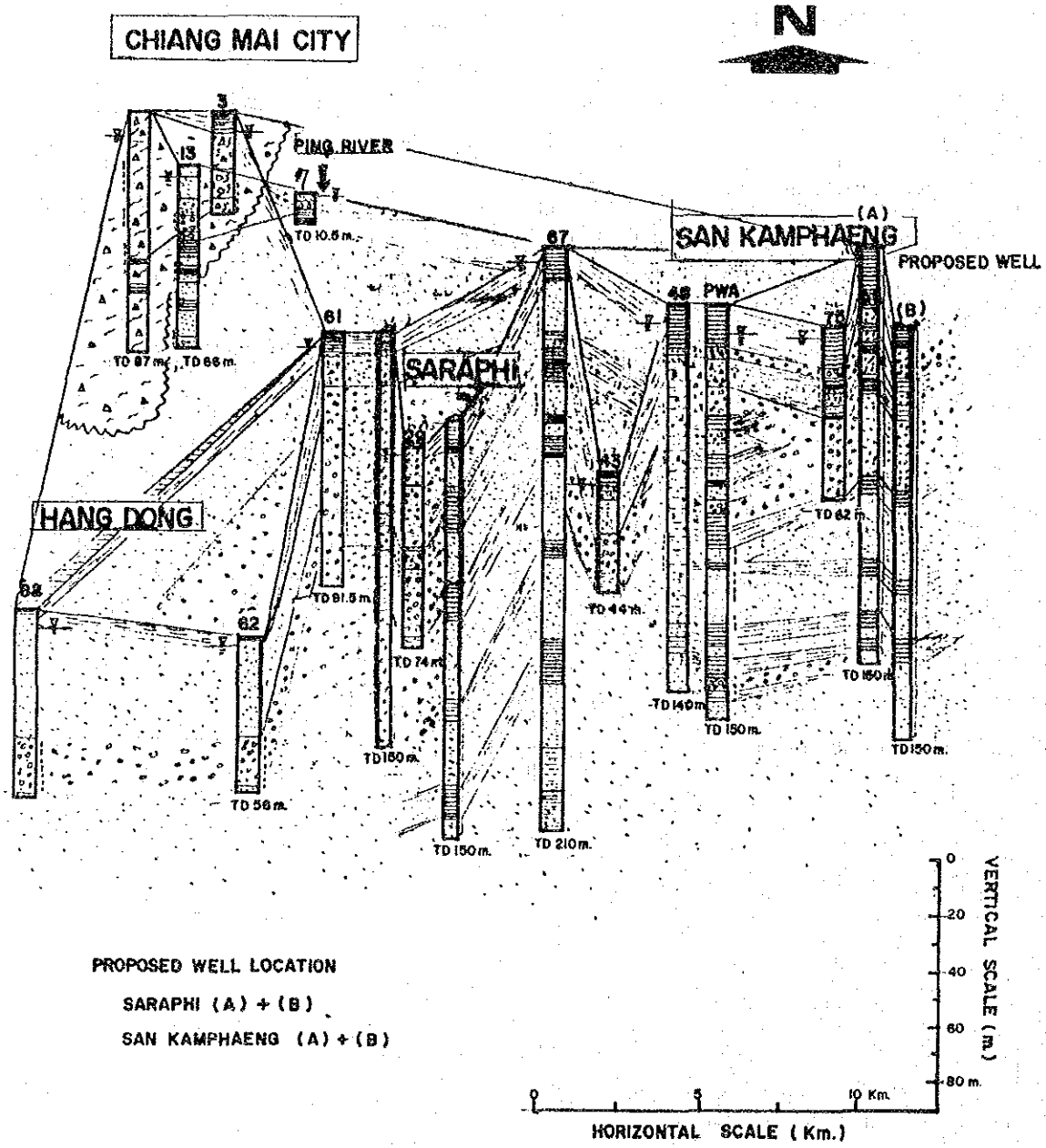
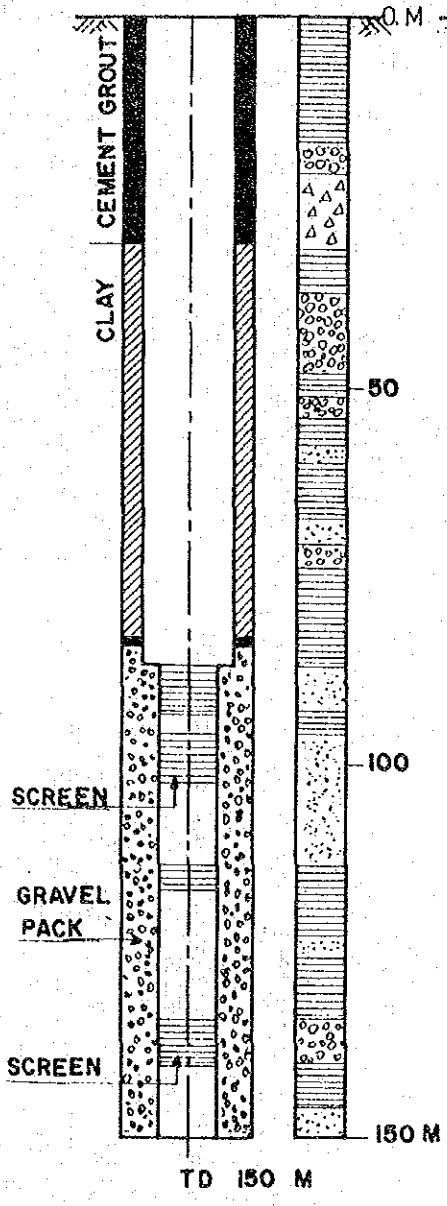


FIGURE	HYDROGEOLOGICAL FENCE
3.11	DIAGRAM OF PING RIVER
JAPAN INTERNATIONAL COOPERATION AGENCY	

WELL LOGS AND WELL DESIGN , PWA

SAN KAMPHAENG

WELL NO. 4

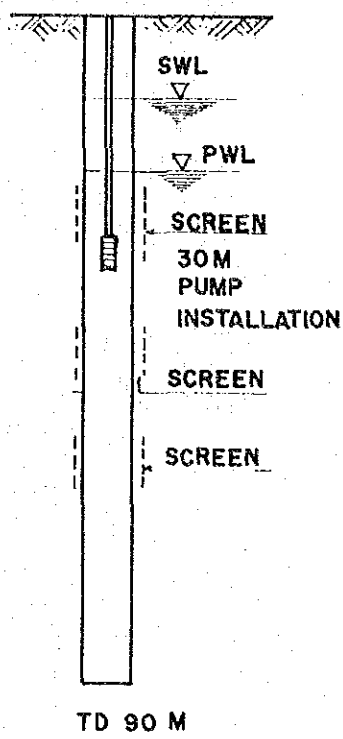


WATER QUALITY

EC 350 μS/CM

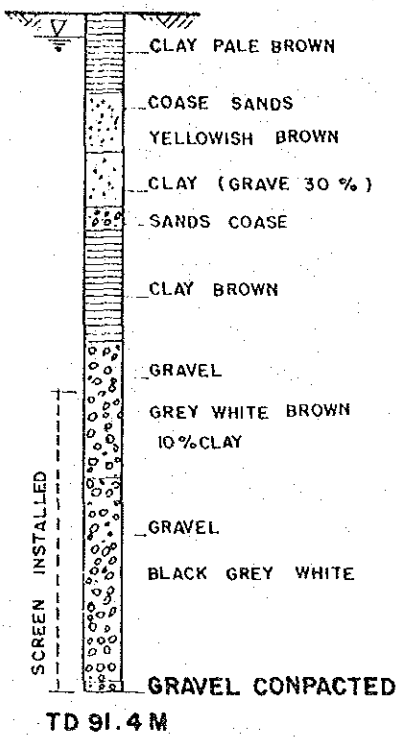
Q = 80 M^3/HR

WELL NO. 1 AND NO. 2



LUMPHUN

ELV 289 M. MSL



WATER QUALITY OF LAMPHUN. PWA, 1969

F	0.91	PPM
CL	9	PPM
EC	370	μS/CM
FE	0.44	PPM
MG	7.7	PPM
PH	7.7	

FIGURE	WELL LOGS AND WELL DESIGN, PWA
3.12	

JAPAN INTERNATIONAL COOPERATION AGENCY

WATER RESOURCES DEVELOPMENT PLAN FOR CHIANGMAI (1985 - 2010)

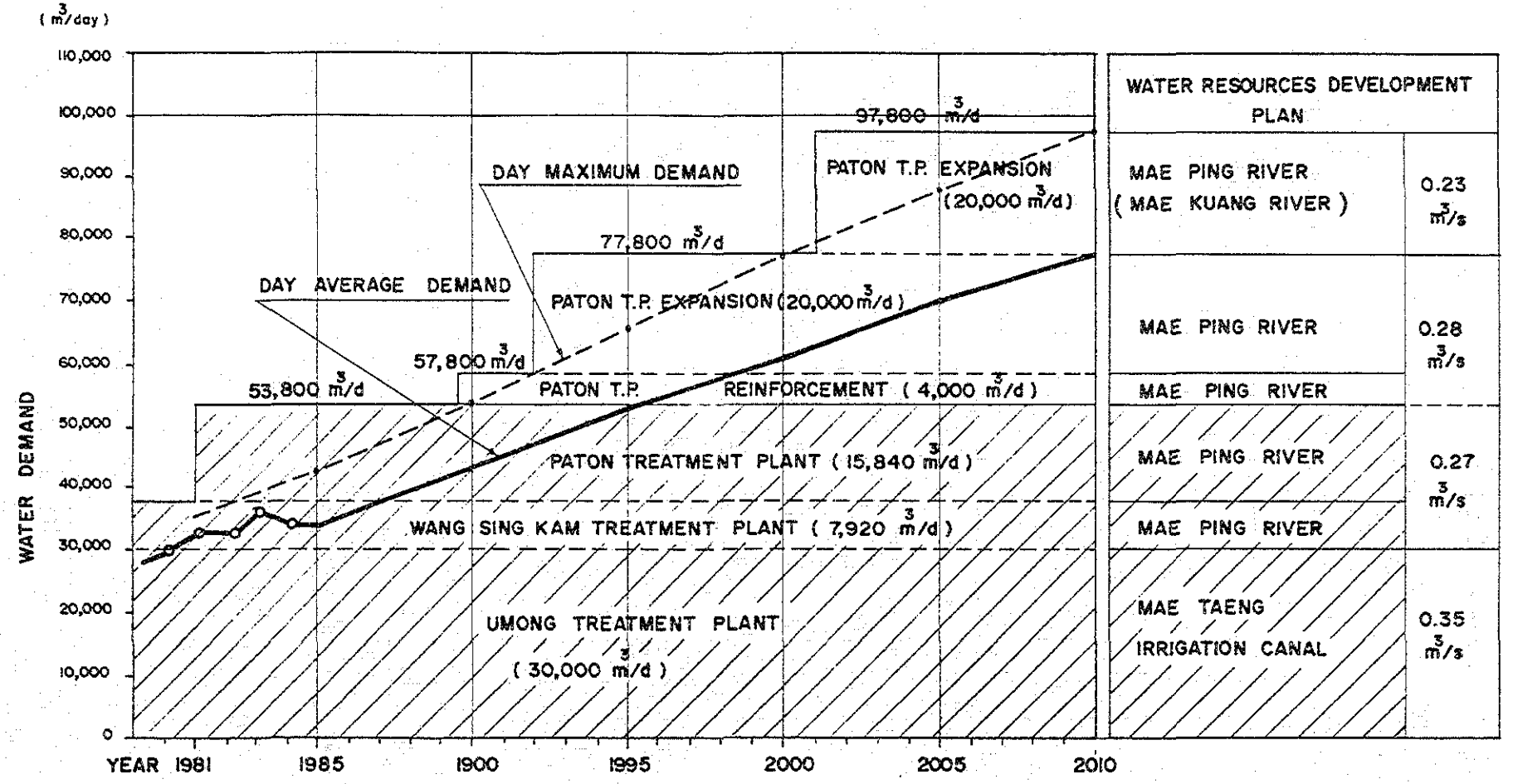


FIGURE	WATER RESOURCES DEVELOPMENT PLAN FOR CHIANGMAI (1985-2010)
3.13	

JAPAN INTERNATIONAL COOPERATION AGENCY

2) Recommendable Water Sources up to the Year 2010

The future recommendable water sources have been also concluded in Fig-3-13. The main source of water for Chiangmai city is surface water from the Ping River, Mae Taeng Irrigation Canal, and Mae Kuang River originating from Mae Kuang Dam to be completed after 1990 is the most promising alternative water source for Chiangmai. Therefore, at the economical and technical points of view, the Ping River is the most recommendable water source for future as follows:

a) The Year of 1989
   Mae Ping River : 4,000 cu m/d
b) The Year of 1992
   Mae Ping River : 20,000 cu m/d
c) The Year of 2001
   Mae Ping River : 20,000 cu m/d

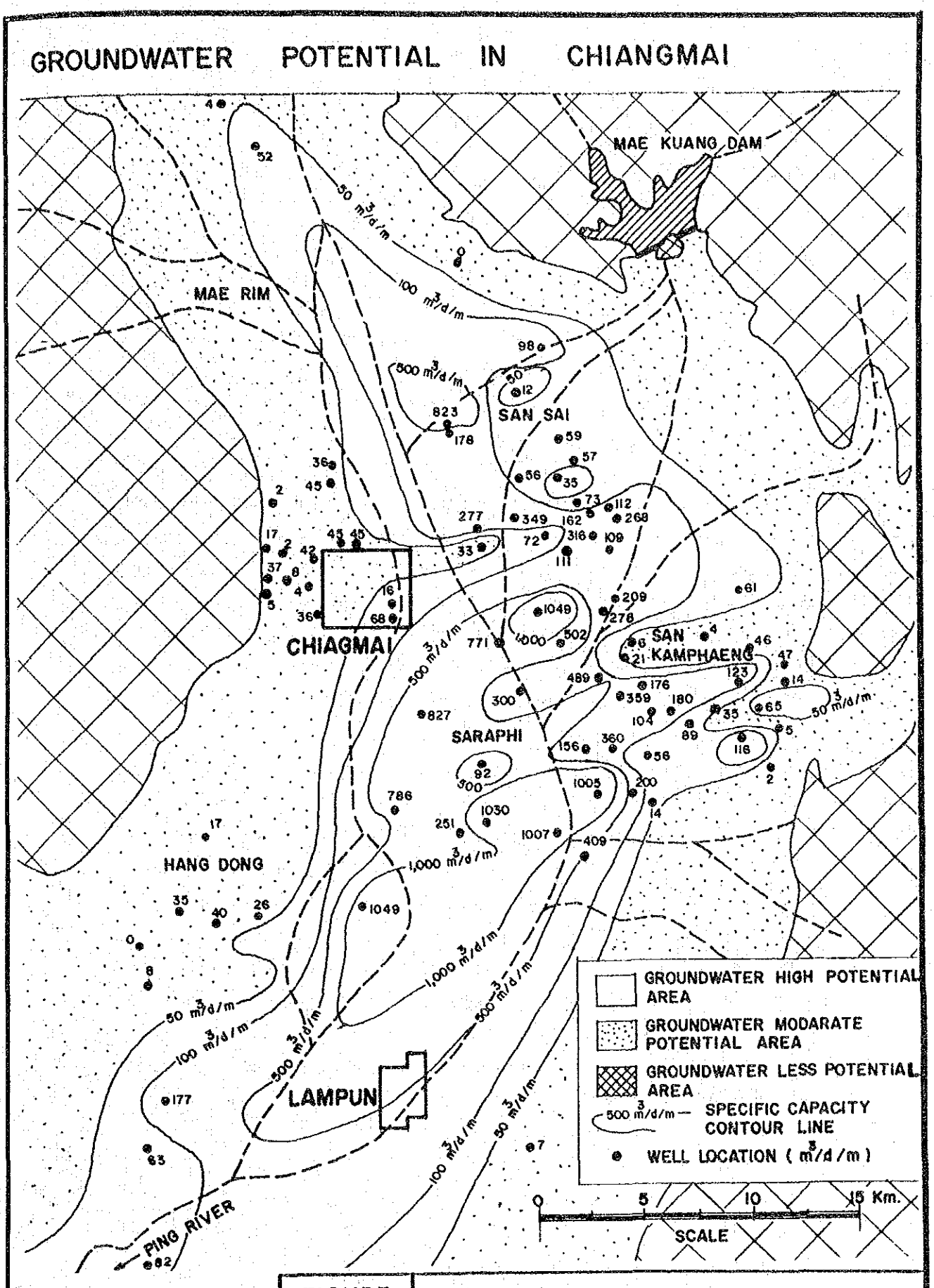
3.7 Sanitary Districts around Chiangmai City

There are five separate Sanitary Districts, namely Mae Rim, San Sai, San Kamphaeng, Saraphi, and Hang Dong. Groundwater is abundant in the area, and therefore, it is the most recommendable water source for the Sanitary Districts at the present and for the future. The problems of water quality indicates high iron concentration ranging from 0.4 to 60 ppm in wide area. Therefore it is necessary to treat water by aeration, filtration and others, depending on the conditions.

Fig-3.14 illustrates the groundwater potential in Chiangmai and especially Sanitary Districts. The hydrogeologic potentiality of groundwater divided into three areas, namely, a high potential area, a moderate potential area and a less potential area.

Each Sanitary Districts have been evaluated groundwater potentiality as follows.

Description	(I) High Potential Area	(II) Moderate Potential Area	(III) Less Potential Area
Yield Expected (cu m/d)	1,000-3,000 (+)	100-1,000 (+)	100 (-)
Aquifer Depth (m)	10-160 (+)	10-90 (+)	5-20 (+)
Topography and Areas Distribution	Recent alluvium on the flood-plains of Ping river and Mae Kuang river including San Kamphaeng, Saraphi, and San Sai Area	The low terrace deposit along the edge of the basin including Mae Rim, Hang Dong, and Chiangmai City	Sedimentary and metamorphic rocks along with the river valley associated with cracks and faults
Project Area	Saraphi San Sai San Kamphaeng	Chiangmai city Mae Rim Hang Dong	-



DMR , 1964 - 1981
PWA , 1986

FIGURE	GROUNDWATER POTENTIAL IN CHIANGMAI
3.14	

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APPENDIX 4

STUDY ON WATER QUALITY

APPENDIX 4

APPENDIX 4 STUDY ON WATER QUALITY

TABLE OF CONTENTS

APPENDIX 4 STUDY ON WATER QUALITY

4.1 Water Sources

4.1.1 Water Sources for Chiangmai Waterworks

The results of water quality analysis made by PWA and the study team are shown in Table-4.1(1)-(3).

1) Characteristics of water

a) Turbidity

The value ranges from 15 to 180 NTU for the Ping River and from 12 to 200 NTU for the Mae Tang Irrigation Canal. It tends to rise in the end of the rainy season and fall in the dry season.

b) pH

The value ranges from 7.23 to 7.84 for the river and from 7.29 to 8.21 for the canal. The value stays within DWS tolerance.

c) Alkalinity

The value ranges from 64 to 115 mg/l as CaCO3 for the river and from 61 to 114 mg/l as CaCO3 for the canal. It tends to decrease as the river flow increases at the end of the rainy season.

d) Hardness

The value, ranging from 60 to 137 mg/l as CaCO3 for the river and from 62 to 131 mg/l as CaCO3 for the canal, is moderate.

e) Iron and Manganese

Iron ranges from 1.28 to 2,07 mg/l for the river and from 0.3 to 2.02 mg/l for the canal, exceeding DWS sometimes. However, through the ordinary treatment process of coagulation, sedimentation, filtration and disinfection, iron has been controlled to fall within DWS. Manganese ranges from nil to 0.25 mg/l for the river and from nil to 0.40 for the canal. It satisfied DWS except in December 1984.

Table-4.1 (1) WATER QUALITY OF MAE TANG IRRIGATION CANAL AND PING RIVER

MAE TANG IRRIGATION CANAL

Item	Year 1984/85 Month / Unit	12	1	2	3	4	5	6	7	8	9	10	11	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	10	5	5
Turbidity	NTU	110	12	15	20	27	33	28	120	120	200	26	14	5
pH		7.46	8.02	7.94	7.7	7.84	8.21	7.29	7.58	7.37	7.49	7.39	7.93	6.5-8.5
Conductivity	micromhos/cm	175	158	204	241	217	217	210	160	130	130	150	130	-
Alkalinity	mg/l as CaCO3	72	89	99	114	102	113	81	83	61	62	63	62	-
Hardness	mg/l as CaCO3	62	89	85	96	95	131	74	96	68	90	68	66	-
Magnesium	mg/l	0.4	5.3	0.9	2.6	0.9	5	5.5	10.6	2.6	8.9	14.6	5.5	50
Iron	mg/l	2.02	0.66	0.73	0.68	1.35	0.94	0.45	1.01	1.72	1.31	0.68	0.3	0.5
Manganese	mg/l	0.4	nil	nil	nil	nil	0.05	nil	0.05	nil	nil	nil	nil	0.3
Sulfate	mg/l	17	6	6.2	6.6	7.9	9.7	6.8	7.7	5	2.8	13	3.4	200
Chloride	mg/l	9	4.5	16	4.5	5.5	3	5.5	4	3.5	3.5	4	4	250
Nitrite-N	mg/l	0.02	nil	nil	nil	<0.01	nil	0.05	nil	nil	nil	0.01	<0.01	-
KMnO4 consumed	mg/l	19.8	2.8	8.7	6.6	17.4	9.87	12.1	27.5	50.4	43.3	11.4	27.8	-

DATA SOURCE : PWA

Table-4.1 (2) WATER QUALITY OF MAE TANG IRRIGATION CANAL AND PING RIVER

PING RIVER

Item	Year 1984/85 Month / Unit	12	1	2	3	4	5	6	7	8	9	10	11	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	60	50	5
Turbidity	NTU	-	38	16	15	68	77	105	63	170	180	140	120	5
pH		-	7.53	7.6	7.5	7.71	7.84	7.56	7.52	7.23	7.34	7.52	7.36	6.5-8.5
Conductivity	micromhos/cm	-	204	251	210	231	235	210	190	185	135	140	140	-
Alkalinity	mg/l as CaCO3	-	105	104	99	96	115	97	97	85	61	66	64	-
Hardness	mg/l as CaCO3	-	106	102	87	95	137	129	116	84	88	94	60	-
Magnesium	mg/l	-	0.5	5.8	3.8	2.6	4.1	13.7	11	2.6	7.2	9.8	3.1	50
Iron	mg/l	-	1.3	1.24	1.28	1.34	0.53	1.85	1.69	1.83	2.07	2.05	2	0.5
Manganese	mg/l	-	0.25	0.2	0.1	nil	0.15	0.25	0.05	nil	nil	nil	nil	0.3
Sulfate	mg/l	-	7.5	7.6	7.2	7.7	6.4	4.8	6.6	8.5	4.6	11	15	200
Chloride	mg/l	-	8.3	7.5	5	5.5	3.5	4	4.5	3.5	5	3	3	250
Nitrite-N	mg/l	-	nil	nil	nil	<0.01	nil	nil	nil	nil	nil	0.01	<0.01	-
KMnO4 consumed	mg/l	-	25	5.74	5	6.2	13.9	22.9	6.3	50.4	37.3	41.8	61.6	-

DATA SOURCE : PWA

Table-4.1 (3) WATER QUALITY OF MAE TANG IRRIGATION CANAL AND PING RIVER

Item	Unit	MAE TANG IRRIGATION	PING RIVER
Date		28/1/'86	28/1/'86
Temperature	°C	21.8	23.2
Color	Pt•Co units	20	30
Turbidity	NTU	15	10
pH		8.14	7.7
Conductivity	micromhos/cm	160	192
Alkalinity	mg/l as CaCO3	112	82
Hardness	mg/l as CaCO3	73	89
Calcium	mg/l	24	33
Magnesium	mg/l	3.3	1.5
Iron	mg/l	0.73	1.04
Manganese	mg/l	0.03	0.05
Sulfate	mg/l	4	5
Chloride	mg/l	4	3
Ammonia-N	mg/l	<0.1	<0.1
Nitrite-N	mg/l	<0.01	<0.01
Nitrate-N	mg/l	0.1	0.2
Coliform group	N/100ml	1900	6000
Total colonies	N/ml	190	>300

DATA SOURCE : STUDY TEAM

Table-4.2 WATER QUALITY OF MAE NGAT DAM

Item	Unit	
Date		20/12/'85
Temperature	°C	21.0
Color	Pt•Co units	8
Turbidity	N T U	2
pH		7.3
Conductivity	micromhos/cm	112
Total solids	mg/l	64
Alkalinity	mg/l as $CaCO_3$	52
Hardness	mg/l as $CaCO_3$	52
Calcium	mg/l	14
Iron	mg/l	0.1
Manganese	mg/l	<0.03
Chloride	mg/l	3
sulfate	mg/l	1.5
Ammonia-N	mg/l	<0.2
Coliform group	N/100ml	400
Total colonies	N/ml	85

DATA SOURCE : STUDY TEAM

f) Organic pollution

Ammonia, nitrite and nitrate, the pollution indices are not noticeably high. The Coliform number was 6,000 N/100 ml for the river and 1,900 N/100 ml for the canal, but when those values are viewed together with the chloride and nitrogen concentration, it can be seen that pollution has not reached an advanced stage yet.

2) Evaluation

a) Both the river and canal water present no qualitative problem for drinking after having been treated appropriately by the conventional treatment system.

b) A whisky distillery located 25 km upstream of the Ban Tho intake on the Ping River, discharges waste water. The distillery has been suspected of causing water pollution. According to the results of PWA's periodic survey on the problem, however, no meaningful difference was detected between the upstream and down-stream samples. Periodic inspection and analysis,however,should be continued.

c) The Mae Ngat dam (a dam for multipurpose use) was completed 40 km upstream of Chiangmai on the Ping River. The flow into the Ping River will be used to meet the increasing demand of water supply in future. The water quality at the dam is good for the use of water supply presently (Table-4.2), but the dam's eutrophication may be problematical in future and the river water's qualitative changes, caused by stagnation in the dam, will have to be studied.

4.1.2 Other Sources

In and out of the public water service area of Chiangmai city, groundwater is used by household and commercial consumers. Some of the large consumers, like gas stations and large hotels, use both groundwater and the public supply. In some hotels, groundwater is treated by their own aeration and filtration equipment to be used for miscellaneous purposes. Hotels and hospitals which use groundwater for drinking sterilize it further, after treating by the previously mentioned process.

The sampling points of groundwater which were surveyed by the study team are shown in Fig-4.1 with the result of analysis in Table-4.3.

All samples, except ST.9, iron concentration, range from 0.62 to 12.27 mg/l, exceeded DWS and at all these points, aeration and filtration equipment was found to be installed, to remove iron. At ST.7, 8 and 9, pH also exceeded DWS. In the surveyed area, groundwater contains a noticeable amount of iron , irrelevant to the depth of the sampled wells, which ranged from 7 to 120 m. It makes iron removal treatment necessary. For shallow wells, the users are to be cautioned against pollution by the domestic wastewater.

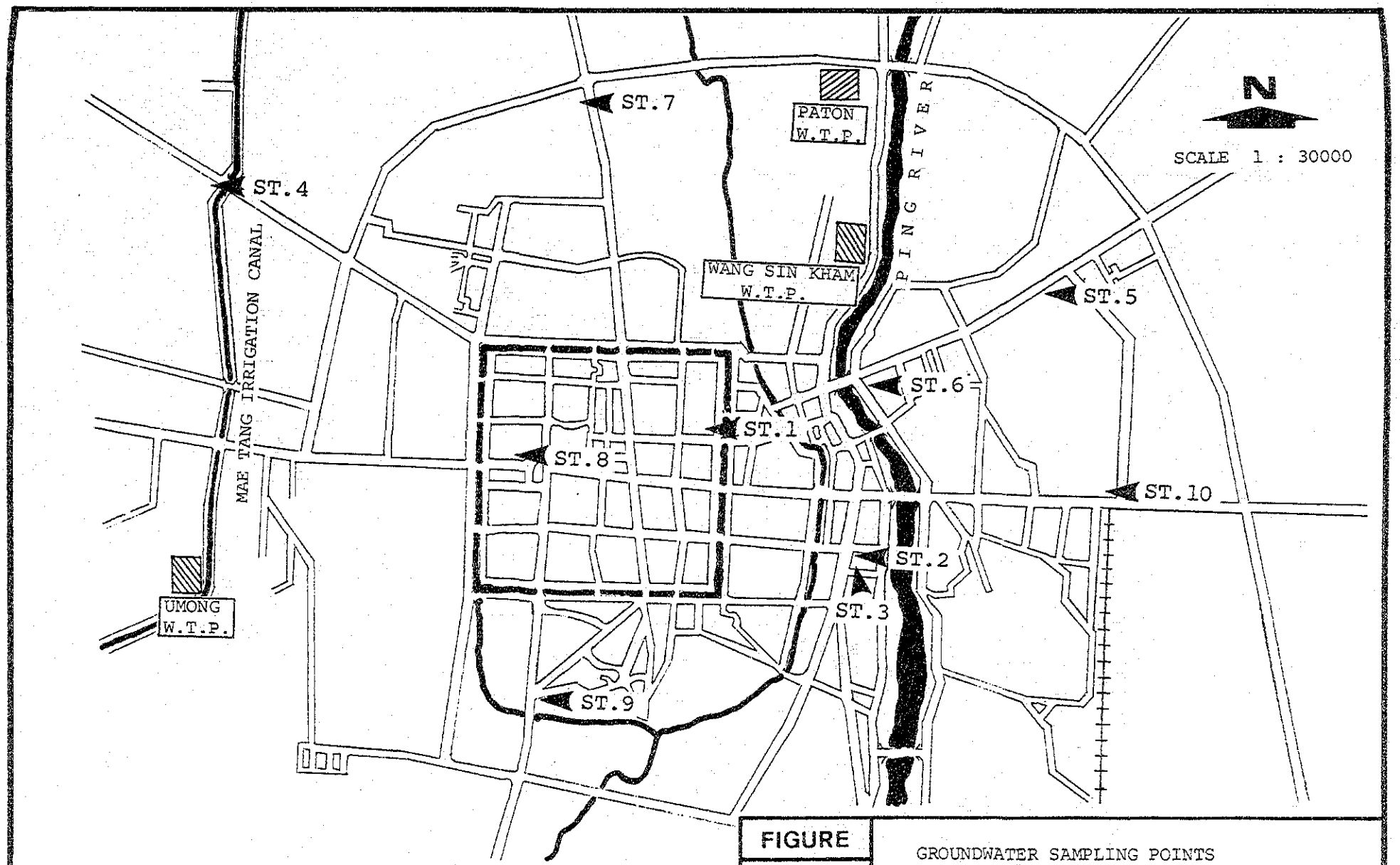
4.1.3 Water Sources for Sanitary Districts

The study area is five sanitary districts, namely 1) Mae Rim, 2) San Kamphaeng, 3) San Sai, 4) Saraphi and 5) Hang Dong. Of the five, Mae Rim and San Kamphaeng are served by the PWA system presently.

Mae Rim

The treatment plant takes water from a small stream, Lam Nam Mae Sa. The result of water quality analysis is shown in Table-4.4 and it indicates the following features:

a) Turbidity, ranging from 4.8 to 66 NTU, changes by the season. It tends to decrease in the dry season.



ST.No : SAMPLING POINT

FIGURE	GROUNDWATER SAMPLING POINTS
4.1	IN THE CHIANGMAI AREA

JAPAN INTERNATIONAL COOPERATION AGENCY

Table-4.3 WATER QUALITY OF GROUNDWATER IN THE CHIANGMAI AREA

Sampling Point (No.)	Well depth (m)	Temperature (°C)	pH	Conductivity (micromhos/cm)	Hardness (mg/l)	Iron (mg/l)	Chloride (mg/l)
ST.1	24	27.8	6.77	860	161	1.42	67
ST.2	18	27.8	7.24	430	130	10.27	18
ST.3	36	27.5	7.17	350	123	6.52	5
ST.4	120	26.5	6.34	140	31	8.66	2
ST.5	70	26.0	6.80	450	160	10.56	15
ST.6	7	23.2	6.98	550	186	12.27	13
ST.7	18	27.5	6.27	43	6	1.80	1
ST.8	40	28.0	6.38	188	31	0.62	11
ST.9	25	29.0	5.98	440	94	0.04	40
ST.10	18	27.8	7.19	540	175	8.05	44

NOTE :

SAMPLING DATE 30-31 JANUARY,1986

DATA SOURCE : STUDY TEAM

Table-4.4 WATER QUALITY OF LAM NAM MAE SA

Item	Year 1984/85 Month / Unit	12	1	2	3	4	5	6	7	8	9	10	11	PWA STANDARD
Color	Pt•Co units	-	-	-	-	-	-	-	-	-	-	40	10	5
Turbidity	NTU	6	7.5	7.2	4.8	6.7	19	6.5	37	41	48	34	66	5
pH		7.56	7.82	7.81	7.4	7.59	7.77	7.46	7.13	7.18	7.43	7.35	7.66	6.5-8.5
Conductivity	micromhos/cm	280	303	355	350	335	320	360	320	220	205	180	190	-
Alkalinity	mg/l as CaCO3	148	156	156	170	162	160	150	140	106	102	93	91	-
Hardness	mg/l as CaCO3	141	142	139	145	154	183	182	151	101	98	94	89	-
Magnesium	mg/l	nil	5	8.4	4.3	2.6	4.8	13	11	5.5	2.4	20.2	3.8	50
Iron	mg/l	0.23	0.36	0.52	0.37	0.37	0.57	0.42	0.89	1.32	0.39	1.29	1.11	0.5
Manganese	mg/l	0.15	0.15	0.25	0.25	nil	0.15	0.25	0.1	nil	nil	nil	nil	0.3
Sulfate	mg/l	9	5.8	6.6	5.8	6.6	4.6	2.9	2.9	9.1	11	12	6.1	200
Chloride	mg/l	3	4.5	4.5	4.5	4.5	1.5	3	5	3.5	5	3	4	250
Nitrite-N	mg/l	<0.01	<0.01	<0.01	nil	<0.01	<0.01	<0.01	nil	<0.01	<0.01	<0.01	<0.01	-
KMnO4 consumed	mg/l	7.9	2.8	9.2	4.4	7.5	5.73	9.5	6.3	11.2	31.3	16.2	49.8	-

DATA SOURCE : PWA

Item	Unit		Item	Unit	
Date		20/12/85	Magnesium	mg/l	6.2
Temperature	°C	21.5	Iron	mg/l	0.25
Turbidity	N T U	25	Manganese	mg/l	<0.03
pH		7.8	Chloride	mg/l	3
Conductivity	micromhos/cm	303	Sulfate	mg/l	1.5
Total solids	mg/l	164	Ammonia-N	mg/l	<0.2
Alkalinity	mg/l as $CaCO_3$	124	Coliform group	N/100ml	300
Hardness	mg/l as $CaCO_3$	122	Total colonies	N/ml	>300
Calcium	mg/l	38	Dissolved oxygen	mg/l	6.7

DATA SOURCE : STUDY TEAM

b) pH of 7.13 to 7.82 satisfies DWS.

c) Alkalinity ranges from 91 to 170 as CaCO3 and hardness ranges from 89 to 182 as CaCO3. Both alkalinity and hardness tend to decrease, at the end of the rainy season, corresponding to a turbidity increase.

d) Iron, ranging from 0.23 to 1.32 mg/l, tends to change correlated with turbidity. Manganese, ranging nil to 0.25 mg/l, satisfies DWS.

e) The total colonies above 300 N/ml and coliform group of 300 N/100 ml were detected. They can be treated and no problem will be presented in processing the raw water for drinking.

San Kamphaeng

Deep well water is treated by the treatment plant. The result of water quality analysis made by PWA is shown in Table-4.5 and it indicates the following features:

a) Turbidity, ranging from 0.8 to 6.0, is low.

b) pH, ranging from 6.61 to 7.51, is within DWS.

c) Conductivity, ranging from 340 to 620 micromhos/cm, is high and indicates high concentration of the dissolved solids.

d) Alkalinity of 175 to 340 mg/l as CaCO3 and hardness of 105 to 232 mg/l as CaCO3 are both high. High Alkalinity and low pH indicate high concentration of free carbon dioxide. Coliform was not detected and ammonia nitrogen was under the detection limit of 0.2 mg/l when the survey was carried out by study team. From the results of analysis, it can be derived that groundwater pollution does not exist and the water, when removed of iron and manganese, can be used for the public water supply.

Table-4.5 WATER QUALITY OF GROUNDWATER

Item	Year 1984/85 Month Unit	12	1	2	3	4	5	6	7	8	9	10	11	PWA STANDARD
Color	Pt Co units	-	-	-	-	-	-	-	-	-	-	5	2	5
Turbidity	NTU	1.5	1.7	2.9	0.8	2.5	1.6	1.7	6	4.4	1.4	2.1	1	5
pH		7.46	7.51	6.87	6.85	6.61	6.9	6.75	6.75	6.68	6.62	6.68	6.87	6.5-8.5
Conductivity	micromhos/cm	500	459	401	415	405	420	440	620	580	340	350	360	-
Alkalinity	mg/l as CaCO3	267	303	192	197	189	210	201	340	320	177	175	182	-
Hardness	mg/l as CaCO3	166	176	105	105	115	160	158	232	212	109	114	111	-
Magnesium	mg/l	22.1	14.9	12	12	14	14.4	13.9	27.6	25.7	10.8	27.1	15.4	50
Iron	mg/l	0.24	0.18	0.29	0.4	0.39	0.19	0.25	0.23	0.46	0.28	0.3	0.38	0.5
Manganese	mg/l	0.35	0.35	0.35	0.5	0.35	0.35	0.35	1	0.1	nil	nil	nil	0.3
Sulfate	mg/l	13	12	7.6	7.4	9.7	6.6	5.2	26	16	5.8	8	6.3	200
Chloride	mg/l	1	6	7	7	6	9.5	6	7	6	5.5	5.5	6	250
Nitrite-N	mg/l	<0.01	nil	nil	nil	nil	nil	nil	nil	nil	nil	<0.01	<0.01	-
KMnO4 consumed	mg/l	4.4	2.2	4.8	6	1.2	0.01	0.9	1.4	0.3	2.1	1.6	1.6	-

DATA SOURCE : PWA

San Sai, Saraphi, Hang Dong

Among San Sai, Saraphi, Hang Dong sanitary districts, Hang Dong has a small public water supply but not San Sai and Saraphi. People depend mostly on well water and stored rain water. The study team tested groundwater and the result is shown in Table-4.6.

In San Sai, both public institutions and households use groundwater from wells, more or less 10 m in depth. No well of more than a 30 m depth has been found. As iron concentration is high, filters are used in many cases. In Saraphi, conductivity, hardness and ammonia showed rather high values and pH was 6.5, rather low. Coliform group was not detected.

In Hang Dong, the groundwater quality satisfies DWS, though hardness is slightly higher than normal.

Summing up the situation in San Sai, Saraphi and Hang Dong, the water demand in future will not rise that high, so that the groundwater can continue to be a reliable source. However for potable water equipment will be needed for removing iron (San Sai) and controling pH (Saraphi), aeration (San Sai) and other treatment as well as sterilization (San Sai, Saraphi, Hang Dong).

4.2 Treated Water

4.2.1 Existing Conditions

Chiangmai Waterworks

Table-4.7(1) and (2) shows the result of water quality analysis in the Umong and Paton Treatment Plant. Fig-4.2 shows the monthly average dosage of alum, chlorine and lime.

Present condition of the treated water quality is dscribed below.

a) Turbidity of the treated water exceeds DWS in some months in both of the Umong and Paton Plant. The cause is considered to be inadequate floc formation due to poor management of chemical dosage. As a result

Table-4.6 WATER QUALITY OF THE SANITARY DISTRICTS (GROUNDWATER)

Item	Unit	SAN SAI	SARAPHI	HANG DONG
Date		30/1/'86	21/12/'85	21/12/'85
Well depth	m	11	10	50
Temperature	°C	26.8	25.1	28.8
Color	Pt·Co units	1	2	2
Turbidity	NTU	2	0.8	1.2
pH		7.11	6.5	7
Conductivity	micromhos/cm	305	629	304
Total solids	mg/l	-	372	222
Alkalinity	mg/l as CaCO3	148	202	230
Hardness	mg/l as CaCO3	132	222	152
Calcium	mg/l	42	55	34
Magnesium	mg/l	7	20	16
Iron	mg/l	6.05	0.15	0.1
Manganese	mg/l	-	-	<0.03
Sulfate	mg/l	-	22	1.5
Chloride	mg/l	1	50	12
Ammonia-N	mg/l	0.8	1	<0.2
Coliform group	N/100ml	0	0	0
Total colonies	N/ml	54	1	1

DATA SOURCE : STUDY TEAM

Table-4.7(1) WATER QUALITY OF THE UMONG TREATMENT PLANT

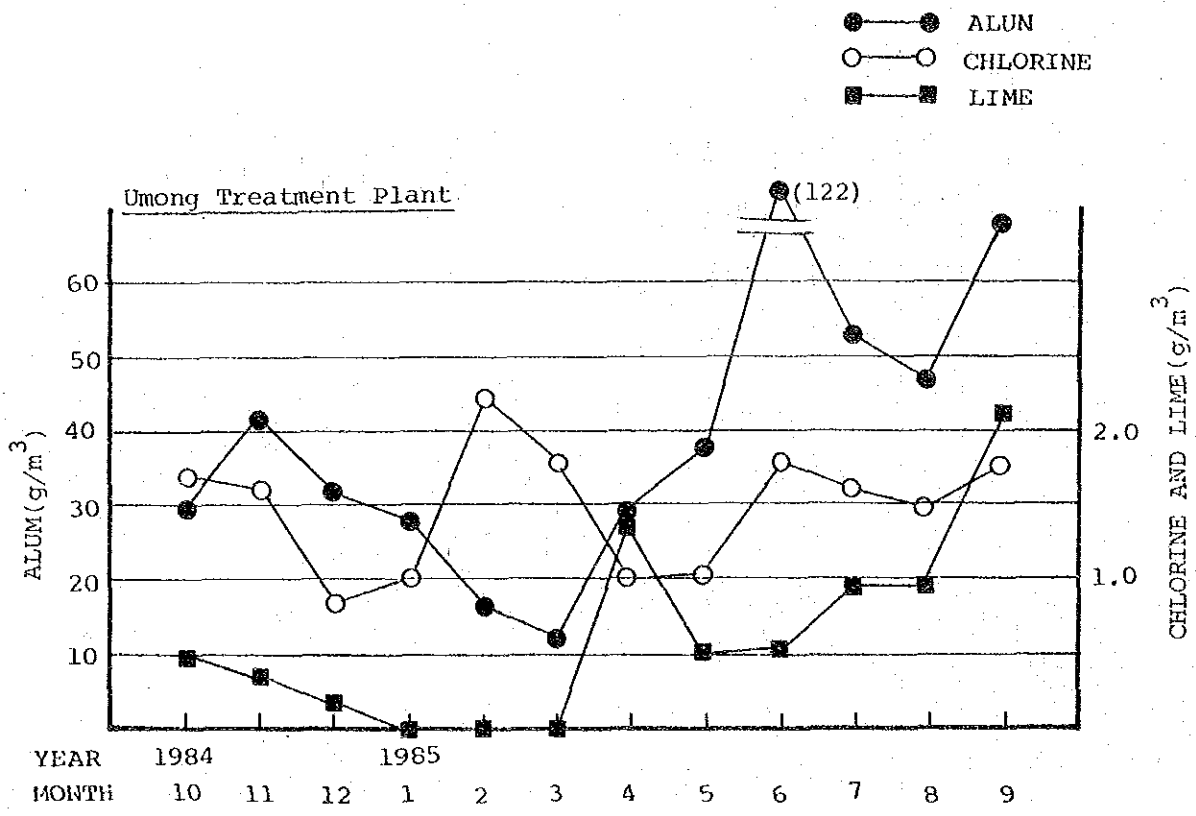
Item	Year 1984/85 Month / Unit	12 RAW	12 TRE.	1 RAW	1 TRE.	2 RAW	2 TRE.	3 RAW	3 TRE.	4 RAW	4 TRE.	5 RAW	5 TRE.	6 RAW	6 TRE.	7 RAW	7 TRE.	8 RAW	8 TRE.	9 RAW	9 TRE.	10 RAW	10 TRE.	11 RAW	11 TRE.	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	5	5	2	5
Turbidity	NTU	110.0	2.9	12.0	1.0	15.0	1.3	20.0	4.8	27.0	4.5	33.0	4.3	28.0	2.2	120.0	5.6	120.0	9.8	200.0	7.1	26.0	1.5	14.0	4.6	5
pH		7.46	7.27	8.02	7.63	7.95	7.71	7.70	7.50	7.84	7.54	8.21	7.81	7.29	7.31	7.58	6.93	7.37	7.03	7.49	6.61	7.39	7.51	7.93	7.39	6.5-8.5
Conductivity	micromhos/cm	175	220	158	159	204	205	241	247	217	230	217	230	210	170	160	175	130	155	130	155	150	165	130	150	-
Residual Chlorine	mg/l	-	0.3	-	0.8	-	0.2	-	0.2	-	0.3	-	0.2	-	0.1	-	0.1	-	0.6	-	0.1	-	nil	-	0.2	-
Alkalinity	mg/l as CaCO3	72	52	89	78	99	91	114	109	102	77	113	97	81	74	83	55	61	43	62	30	63	58	62	56	-
Hardness	mg/l as CaCO3	62	69	89	82	85	85	96	95	95	93	131	134	74	96	96	99	68	73	90	99	68	63	66	57	-
Magnesium	mg/l	0.4	0.2	5.3	2	0.9	2.9	2.6	1.4	0.9	1.9	5	6.9	5.5	11	10.6	10.8	2.6	4.3	8.9	10.6	14.6	14.2	5.5	3.1	50
Iron	mg/l	2.02	0.06	0.66	<0.05	0.73	0.05	0.68	0.19	1.35	0.26	0.94	<0.05	0.45	<0.05	1.01	0.06	1.72	<0.05	1.31	0.28	0.68	<0.05	0.30	0.08	0.5
Manganese	mg/l	0.40	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.05	nil	nil	nil	0.05	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.3
Sulfate	mg/l	17.0	22.0	6.0	13.0	6.2	8.3	6.6	8.5	7.9	26.0	9.7	11.0	6.8	12.0	7.7	17.0	5.0	20.0	2.8	33.0	13.0	17.0	3.4	6.5	200
Chloride	mg/l	9.0	11.5	4.5	7.5	16.0	4.5	4.5	4.5	5.5	6.5	3.0	5.0	5.5	6.5	4.0	8.0	3.5	7.0	3.5	9.0	4.0	4.0	4.0	6.0	250
Nitrite-N	mg/l	0.02	<0.01	nil	nil	nil	nil	nil	nil	<0.01	nil	nil	nil	0.05	nil	nil	nil	nil	nil	nil	nil	0.01	nil	<0.01	nil	-
KMnO4 consumed	mg/l	19.8	-	2.8	-	8.7	-	6.6	-	17.4	-	9.87	-	12.1	-	27.5	-	50.4	-	43.3	-	11.4	-	27.8	-	-

DATA SOURCE : PWA

Table-4.7(2) WATER QUALITY OF THE PATON TREATMENT PLANT

Item	Year 1984-85 Month / Unit	12 RAW	12 TRE.	1 RAW	1 TRE.	2 RAW	2 TRE.	3 RAW	3 TRE.	4 RAW	4 TRE.	5 RAW	5 TRE.	6 RAW	6 TRE.	7 RAW	7 TRE.	8 RAW	8 TRE.	9 RAW	9 TRE.	10 RAW	10 TRE.	11 RAW	11 TRE.	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	2	50	5	5
Turbidity	NTU	-	-	38.0	12.0	77.0	2.1	15.0	2.0	68.0	2.1	77.0	2.1	105.0	8.0	63.0	6.8	170.0	3.8	180.0	2.4	140.0	1.0	120.0	3.4	5
pH		-	-	7.53	7.57	7.84	7.42	7.50	7.35	7.71	7.54	7.84	7.42	7.56	7.21	7.52	7.06	7.23	6.93	7.34	6.78	7.52	6.77	7.36	7.11	6.5-8.5
Conductivity	micromhos/cm	-	-	204	204	235	245	210	208	231	225	235	245	210	240	190	210	185	200	135	165	140	155	140	150	-
Residual Chlorine	mg/l	-	-	-	0.6	-	0.4	-	0.2	-	0.5	-	0.4	-	0.40	-	0.06	-	0.3	-	0.4	-	0.60	-	0.3	-
Alkalinity	mg/l as CaCO3	-	-	105	97	115	87	99	87	96	85	115	87	97	96	97	67	85	69	61	35	66	32	64	40	-
Hardness	mg/l as CaCO3	-	-	106	96	137	143	87	82	95	99	137	143	129	134	116	108	84	86	88	90	94	64	60	58	-
Magnesium	mg/l	-	-	0.5	0.5	4.1	6.7	3.8	1.9	2.6	5.3	4.1	6.7	13.7	15.8	11	11.2	2.6	2.9	7.2	9.1	9.8	13.2	3.1	3.8	50
Iron	mg/l	-	-	1.30	0.86	0.53	<0.05	1.28	<0.05	1.34	0.13	0.53	<0.05	1.85	0.28	1.69	0.17	1.83	0.27	2.07	0.08	2.05	0.10	2.00	0.14	0.5
Manganese	mg/l	-	-	0.25	nil	0.15	nil	0.10	nil	nil	nil	0.15	nil	0.25	nil	0.05	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.3
Sulfate	mg/l	-	-	7.5	9.0	6.4	20.0	7.2	11.0	7.7	14.0	6.4	20.0	4.8	9.3	6.6	19.0	8.5	19.0	4.6	28.0	11.0	38.0	15.0	22.0	200
Chloride	mg/l	-	-	8.3	11.0	3.5	6.5	5.0	6.5	5.5	6.0	3.5	6.5	4.0	8.5	4.5	8.0	3.5	7.5	5.0	9.0	3.0	6.0	3.0	7.5	250
Nitrite-N	mg/l	-	-	nil	nil	nil	nil	nil	nil	<0.01	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.01	nil	<0.01	nil	-
KMnO4 consumed	mg/l	-	-	25	-	13.9	-	5	-	6.2	-	13.9	-	22.9	-	6.3	-	50.4	-	37.3	-	41.8	-	61.6	-	-

DATA SOURCE : PWA



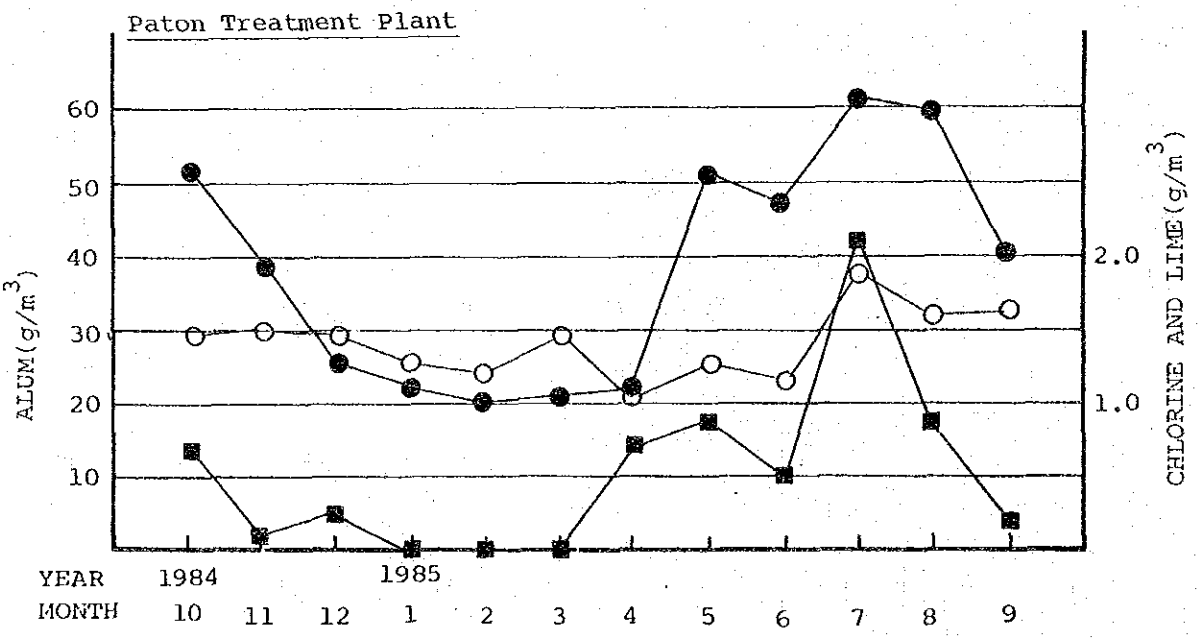


FIGURE 4.2	CHEMICAL DOSAGE MONTHLY AVERAGES

JAPAN INTERNATIONAL COOPERATION AGENCY

the sedimented water which still contains lots of turbid matters or unsettled flocs flows into the filter and affects its function seriously, resulting in high turbidity of the finished water. Another cause may be unclean filter sand, resulting from inadequate back washing.

b) Removal of iron in the raw water is effectively made in both plants.

c) In the Umong Plant, the monthly chlorine consumption and residual chlorine in the treated water fluctuate. A chlorine measuring system is to be installed so that accurate dosage will be made possible. The Paton Plant's dosage of chlorine is kept steady and residual chlorine in the treated water is less fluctuant than that of Umong Plant.

d) The average annual dosage rate of chlorine gas in the Chiangmai waterworks is 1.31 mg/l and except for only one point, the residual chlorine was detected under the survey of residual chlorine concentration (Fig-4.3, Table-4.8), at water taps in the whole water supply area. Even at the dead end of service pipes, residual chlorine up to 0.8 mg/l was found. The above indicates that a bactericidal effect is maintained in most of the water supply area.

However, depletion or low concentration of the residual chlorine was found in some parts of area. The periodical examination should be strengthened in the whole water supply area in order to prevent depletion of the residual chlorine in service taps, caused naturally or by intrusion of sewage, and safeguard the quality of the drinking water.

e) The Umong Treatment plant has a raw water storage reservoir of about 200,000 cu m. Natural sedimentation of particulate matters in the reservoir is effective in decreasing turbidity and chemicals consumption.

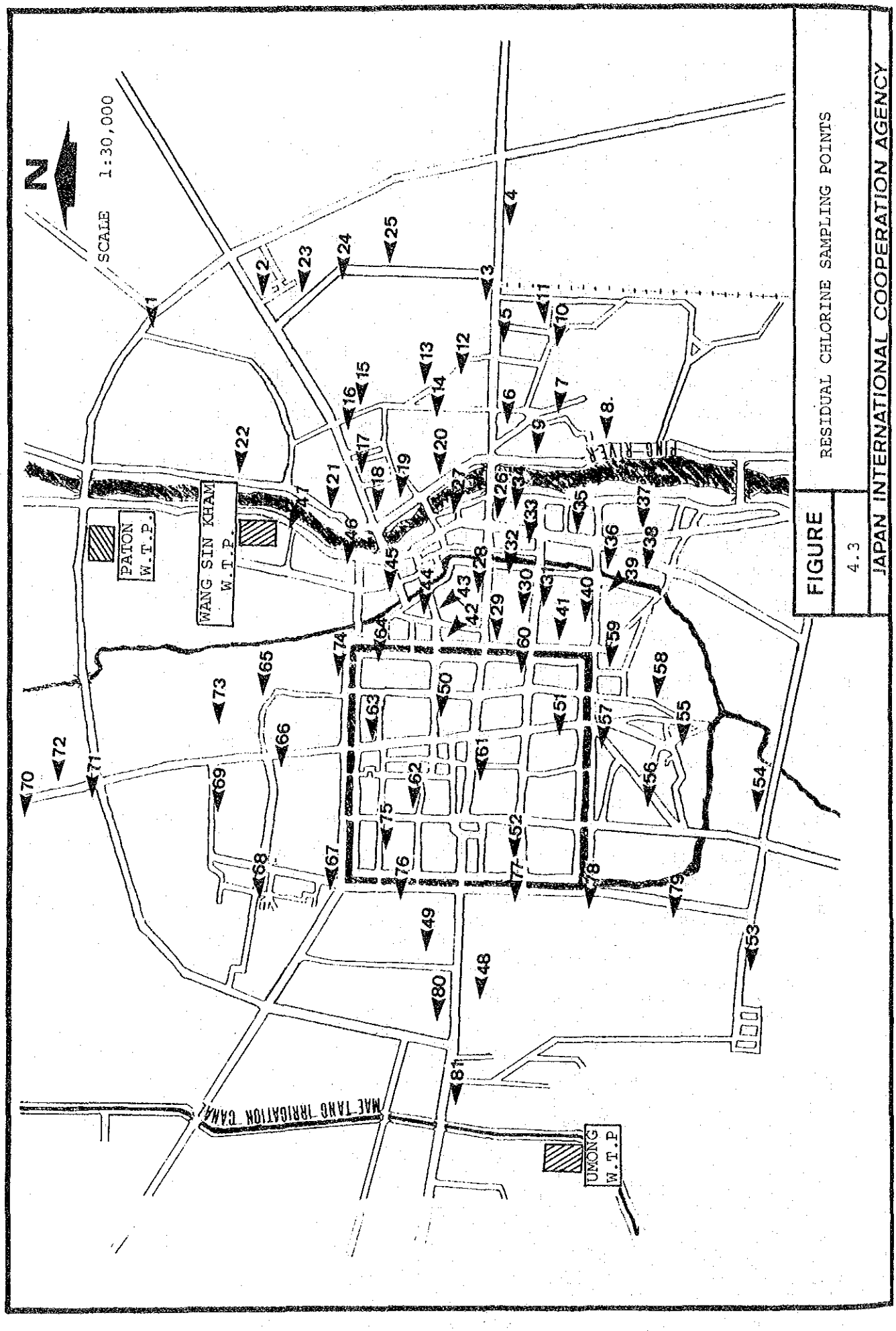

N
SCALE 1:30,000
PATON W.T.P.
WANG SIN KHAM W.T.P.
PING RIVER
MAE TANG IRRIGATION CANAL
UMONG W.T.P.
FIGURE
4.3
RESIDUAL CHLORINE SAMPLING POINTS
JAPAN INTERNATIONAL COOPERATION AGENCY

Table-4.8 RESIDUAL CHLORINE AT SERVICE TAP (CHIANG MAI)

Sampling Point(ST.) No.	Residual Chlorine (mg/l)	Sampling Point(ST.) No.	Residual Chlorine (mg/l)	Sampling Point(ST.) No.	Residual Chlorine (mg/l)	Sampling Point(ST.) No.	Residual Chlorine (mg/l)
1	0.6	22	0.6	43	0.4	64	0.4
2	0.8	23	0.4	44	0.6	65	0.8
3	0.4	24	0.4	45	0.4	66	0.6
4	0.6	25	0.6	46	0.4	67	0.4
5	0.6	26	0.6	47	0.6	68	0.4
6	0.4	27	0.8	48	0.2	69	0.4
7	0.1	28	0.8	49	0.2	70	0.4
8	0.6	29	0.8	50	0.6	71	0.4
9	0.4	30	0.6	51	0.4	72	0.6
10	0.8	31	0.4	52	0.2	73	0.4
11	0.6	32	0.2	53	0.2	74	0.2
12	0	33	0.2	54	0.4	75	0.4
13	0.4	34	0.4	55	0.6	76	0.4
14	0.8	35	0.6	56	0.2	77	0.4
15	0.3	36	0.6	57	0.2	78	0.6
16	0.4	37	0.6	58	0.4	79	0.4
17	0.6	38	0.4	59	0.2	80	0.4
18	0.4	39	0.6	60	0.2	81	0.2
19	0.6	40	0.4	61	0.4	Paton Plant	0.9
20	0.6	41	0.6	62	0.4	Umong Plant	0.4
21	0.4	42	0.4	63	0.6		

Sampling Date: 31 January,1986

DATA SOURCE : STUDY TEAM

Mae Rim

Table-4.9 shows the result of water quality analysis of the plant made by PWA and Fig-4.4 pictures the monthly average dosage of chemicals. Present conditions of the treated water quality are described below.

a) The treated water turbidity exceeds DWS in some months possibly due to over-dosing of aluminum sulfate for purpose of coagulation. For these occasions noticeable concentrations of sulfate are detected in the treated water. The dosage tends to decrease in dry season and it correlates with decreasing turbidity of the raw water. The dosage of alum depends mainly on the turbidity of raw water. Appropriate alum dosage shall be determined by the result of jar testing which is done daily to experiment on coagulation and flocculation.

b) Bleaching powder (27 to 35 % effective chlorine) was used until April 1984, when it switched to chlorine gas. The dosage seemed to be too low to maintain adequate residual chlorine throughout the entire system, when bleaching powder was in use. Since the change-over to chlorine gas, the monthly consumption of chlorine has recorded a steadiness, except in the first month. Residual chlorine in the treated water varied from zero to 2.0 mg/1. The facts suggest that the daily chlorine dosage may be fluctuating, even though the recorded monthly consumption was steady.

Chlorine dosage should be controlled to maintain a certain level of residue, by surveying the consumers taps.

Periodical investigation of residual chlorine concentration has not been conducted in the distribution system. It is necessary to measure the residual chlorine in tap water at the pipe end and to maintain adequate residual chlorine throughout the entire system, to safeguard the hygienic quality of potable supply.

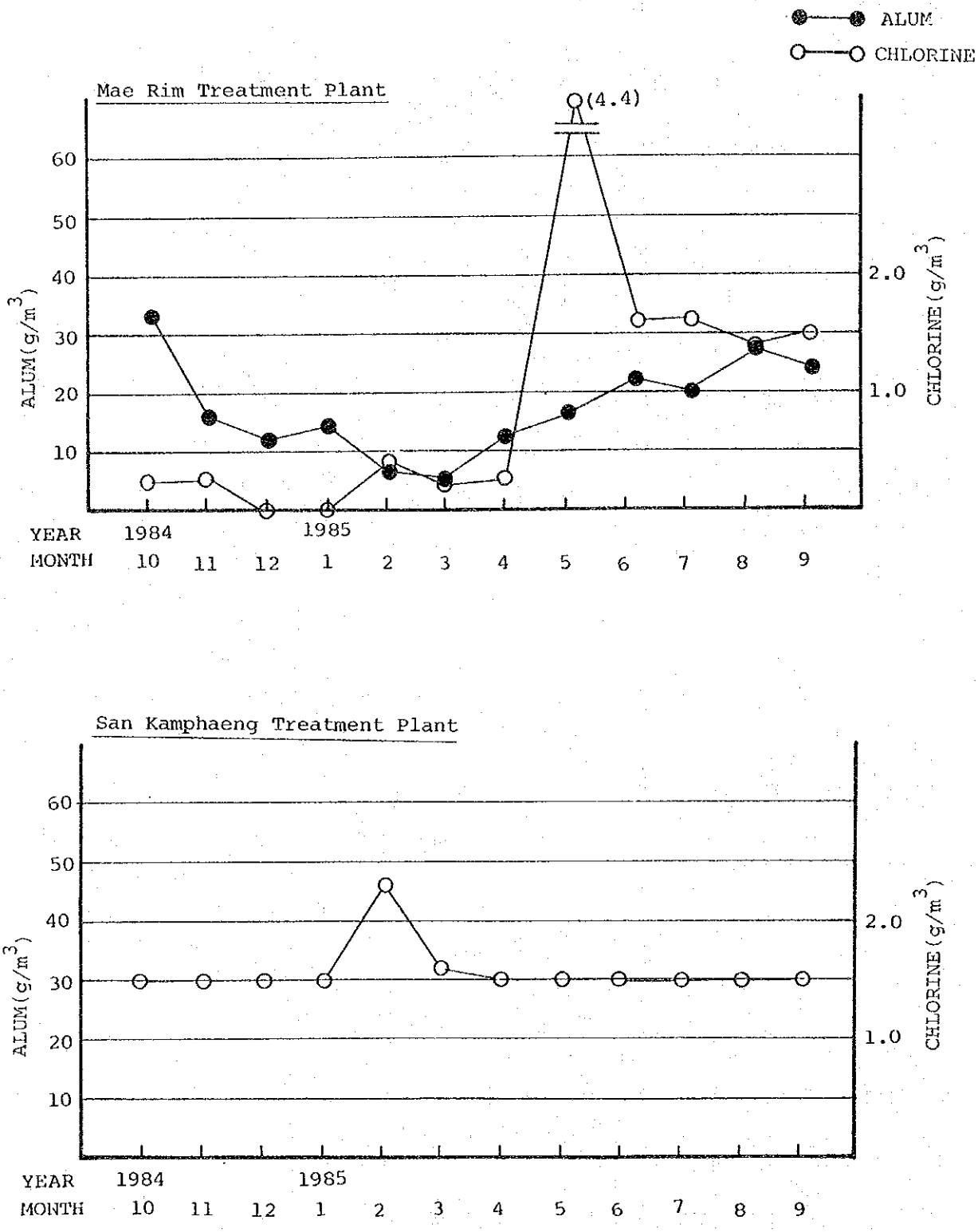
San Kamphaeng Waterworks

Table-4.10 shows the results of water quality analysis and Fig-4.4 shows the monthly average consumption of chemical dosage.

Table-4.9 WATER QUALITY OF THE MAE RIM TREATMENT PLANT

Item	Year 1984/85 Month / Unit	12 RAW	12 TRE.	1 RAW	1 TRE.	2 RAW	2 TRE.	3 RAW	3 TRE.	4 RAW	4 TRE.	5 RAW	5 TRE.	6 RAW	6 TRE.	7 RAW	7 TRE.	8 RAW	8 TRE.	9 RAW	9 TRE.	10 RAW	10 TRE.	11 RAW	11 TRE.	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	2	10	2	5
Turbidity	NTU	6.0	0.5	7.5	1.2	7.2	2.4	4.8	2.6	6.7	2.1	12.0	0.8	6.5	0.7	37.0	0.9	41.0	6.6	48.0	5.6	34.0	1.0	66.0	2.1	5
pH		7.56	7.71	7.82	7.50	7.81	7.91	7.40	7.75	7.59	7.61	7.77	7.50	7.46	7.34	7.13	7.14	7.18	6.75	7.43	7.06	7.35	7.18	7.66	7.33	6.5-8.5
Conductivity	micromhos/cm	280	340	303	304	355	356	350	357	335	350	320	325	360	355	320	335	220	245	205	215	180	205	190	180	-
Residual Chlorine	mg/l	-	1.5	-	0.7	-	0.3	-	0.4	-	0.3	-	0.5	-	nil	-	0.1	-	2.0	-	1.5	-	0.10	-	1.8	-
Alkalinity	mg/l as CaCO3	148	140	156	144	156	154	170	175	162	154	160	146	150	137	140	132	106	66	102	74	93	68	91	81	-
Hardness	mg/l as CaCO3	141	157	142	146	139	142	145	154	154	154	183	184	182	189	151	159	101	110	98	100	94	96	89	85	-
Magnesium	mg/l	nil	5.5	5	6	8.4	4.8	4.3	5.8	2.6	5.2	4.8	5.5	13	13.2	11	14.4	5.5	7.4	2.4	2.6	20.2	21.8	3.8	4.6	50
Iron	mg/l	0.23	<0.05	0.36	<0.05	0.52	0.16	0.37	0.11	0.37	<0.05	0.57	<0.05	0.42	0.05	0.89	<0.05	1.32	0.09	0.39	0.10	1.29	<0.05	1.11	0.07	0.5
Manganese	mg/l	0.15	nil	0.15	nil	0.25	nil	0.25	nil	nil	nil	0.15	nil	0.25	nil	0.10	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.3
Sulfate	mg/l	9.0	11.0	5.8	10.0	6.6	7.2	5.8	5.8	6.6	14.0	4.6	6.6	2.9	12.0	2.9	5.8	9.1	56.0	11.0	24.0	12.0	22.0	6.1	8.7	200
Chloride	mg/l	3.0	6.0	4.5	8.0	4.5	5.5	4.5	6.0	4.5	7.0	1.5	7.5	3.0	10.5	5.0	5.5	3.5	8.0	5.0	8.5	3.0	8.5	4.0	6.0	250
Nitrite-N	mg/l	<0.01	<0.01	<0.01	nil	<0.01	nil	nil	nil	<0.01	nil	<0.01	nil	<0.01	nil	nil	nil	<0.01	nil	<0.01	nil	0.007	nil	0.004	nil	-
KMnO4 consumed	mg/l	7.9	-	2.8	-	9.2	-	4.4	-	7.5	-	5.73	-	9.5	-	6.3	-	11.2	-	31.3	-	16.2	-	49.8	-	-

DATA SOURCE : PWA



Note: Bleaching powder has been calculated 30% available chlorine.

FIGURE 4.4	CHEMICAL DOSAGE MONTHLY AVERAGES
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table-4.10 WATER QUALITY OF THE SAN KAMPHAENG TREATMENT PLANT

Item	Year 1984/85 Month / Unit	12 RAW	12 TRE.	1 RAW	1 TRE.	2 RAW	2 TRE.	3 RAW	3 TRE.	4 RAW	4 TRE.	5 RAW	5 TRE.	6 RAW	6 TRE.	7 RAW	7 TRE.	8 RAW	8 TRE.	9 RAW	9 TRE.	10 RAW	10 TRE.	11 RAW	11 TRE.	PWA STANDARD
Color	Pt-Co units	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	2	2	5
Turbidity	NTU	1.5	1.5	1.7	1.1	2.9	0.6	0.8	0.4	2.5	0.5	1.6	0.3	1.7	0.5	6.0	1.3	4.4	1.0	1.4	1.3	2.1	0.6	1.0	0.9	5
pH		7.46	6.92	7.51	7.74	6.87	7.26	6.85	7.18	6.61	7.10	6.90	7.23	6.75	7.20	6.75	7.21	6.68	6.98	6.62	7.36	6.68	7.04	6.87	7.24	6.5-8.5
Conductivity	micromhos/cm	500	540	459	458	401	402	415	425	405	411	420	490	440	490	620	650	580	600	340	390	350	410	360	560	-
Resdual Chlorine	mg/l	-	0.6	-	1.1	-	0.9	-	0.9	-	1.0	-	0.9	-	0.9	-	1.0	-	0.4	-	0.7	-	0.8	-	0.6	-
Alkalinity	mg/l as CaCO3	267	292	303	298	192	184	197	199	189	195	210	253	201	231	340	245	320	223	177	179	175	180	182	273	-
Hardness	mg/l as CaCO3	166	192	176	177	105	104	105	116	115	121	160	206	158	186	232	160	212	142	109	115	114	120	111	186	-
Magnesium	mg/l	22.1	15.6	14.9	21.1	12	12	12	15	14	13	14.4	13.4	13.9	15.8	27.6	17.5	25.7	15.6	10.8	12.5	27.1	28.6	15.4	25.9	50
Iron	mg/l	0.24	<0.05	0.18	0.08	0.29	0.12	0.40	<0.05	0.39	0.06	0.19	<0.05	0.25	0.05	0.23	<0.05	0.46	0.11	0.28	0.08	0.30	0.09	0.38	0.11	0.5
Manganese	mg/l	0.35	nil	0.35	nil	0.35	nil	0.50	nil	0.35	0.10	0.35	0.10	0.35	nil	1.00	nil	0.10	nil	nil	nil	nil	nil	nil	nil	0.3
Sulfate	mg/l	13.0	15.0	12.0	14.0	7.6	7.9	7.4	8.0	9.7	9.7	6.6	10.0	5.2	6.6	26.0	8.5	16.0	8.6	5.8	5.0	8.0	7.0	6.3	16.0	200
Chloride	mg/l	1.0	6.0	6.0	9.0	7.0	12.0	7.0	11.0	6.0	9.5	9.5	13.5	6.0	12.0	7.0	10.0	6.0	10.5	5.5	11.0	5.5	10.0	6.0	12.0	250
Nitrite-N	mg/l	<0.01	<0.01	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	<0.01	nil	<0.01	nil	-
KMnO4 consumed	mg/l	4.4	-	2.2	-	4.8	-	6	-	1.2	-	0.01	-	0.9	-	1.4	-	0.3	-	2.1	-	1.6	-	1.6	-	-

DATA SOURCE : PWA

Present conditions of the treated water quality are described below.

a) In the initial stage of operation, the groundwater was treated by aeration followed by alum-using coagulation, sedimentation and a filtration process. Comparing it to the present chlorine-using oxidation, sedimentation and filtration, the process alteration may have resulted from a substantial decrease of iron concentration. In future, a change in water quality may occur, requiring further alteration of the process.

b) Manganese concentration is larger than iron concentration in some months. Present treatment process, pre-chlorination, is effectively used in removing both iron and manganese, though iron concentration by itself is allowably low.

c) The average dosage of chlorine, 1.5 mg/l has been kept steady, except for 2.3 mg/l in February 1985. Chlorination has been effective owing to the stable raw water quality. However, periodical investigation of the residual chlorine concentration has not been conducted in the service area. It is necessary, to secure the safety of drinking water, to measure the residual chlorine of tap water at the pipe end, lest the residual chlorine be found lacking.

d) No problem is foreseen as long as the treated water quality does not change remarkably.

4.2.2 Improvement of Treatment Method

Chiangmai Waterworks

Judging from the data of the treated water quality, the dosage control is not done properly. In order to adjust to the appropriate dosage, it is indispensable to determine the dosage by the result of jar test. Furthermore, in order to remove the turbidity of treated water sufficiently, the backwashing of filter should be carried out by reading head loss of each filter and/or checking turbidity of filtered water. Head loss is an index of the filter conditions, which should be checked constantly. A sudden rise

or fall of it indicates trouble in the filter bed. Continuous checking is needed.

Filter sand should be checked of cleaness occasionally, by sampling sand of different depth and scrubbing it by hand in clear water.

During the rainy season, when turbidity of the raw water rises to high levels, alkali should be fed to control pH for effective coagulation. Alkali dosage also is subject to jar test, for optimum.

Mae Rim Waterworks

In general, the present treatment system, consisting of alum-using coagulation, sedimentation, filtration and disinfection, is suitable for treating the raw water. The filtered water satisfied DWS except for turbidity. The cause of excessive turbidity above DWS seems to be inadequate alum dosage and/or filter operation. In order to adjust to the adequate dosage, it is indispensable to determine the dosage by the result of jar test. Furthermore, in order to remove the turbidity sufficiently, backwashing of the filter should be carried out by reading head loss of each filter and/or checking residual turbidity of filtered water. Head loss is an index of the filter conditions, which should be checked constantly. The sudden rise or fall of it indicates trouble in the filter bed. Continuous checking is needed.

Filter sand should be checked of cleaness occasionally, by sampling sand of different depth and scrubbing it by hand in clear water.

San Kamphaeng Waterworks

The present condition of the treatment method is satisfactory and should be maintained in future.

APPENDIX 5

QUESTIONNAIRE SURVEY

APPENDIX 5

APPENDIX 5 QUESTIONNAIRE SURVEY

APPENDIX 5 QUESTIONNAIRE SURVEY

5.1 Objective

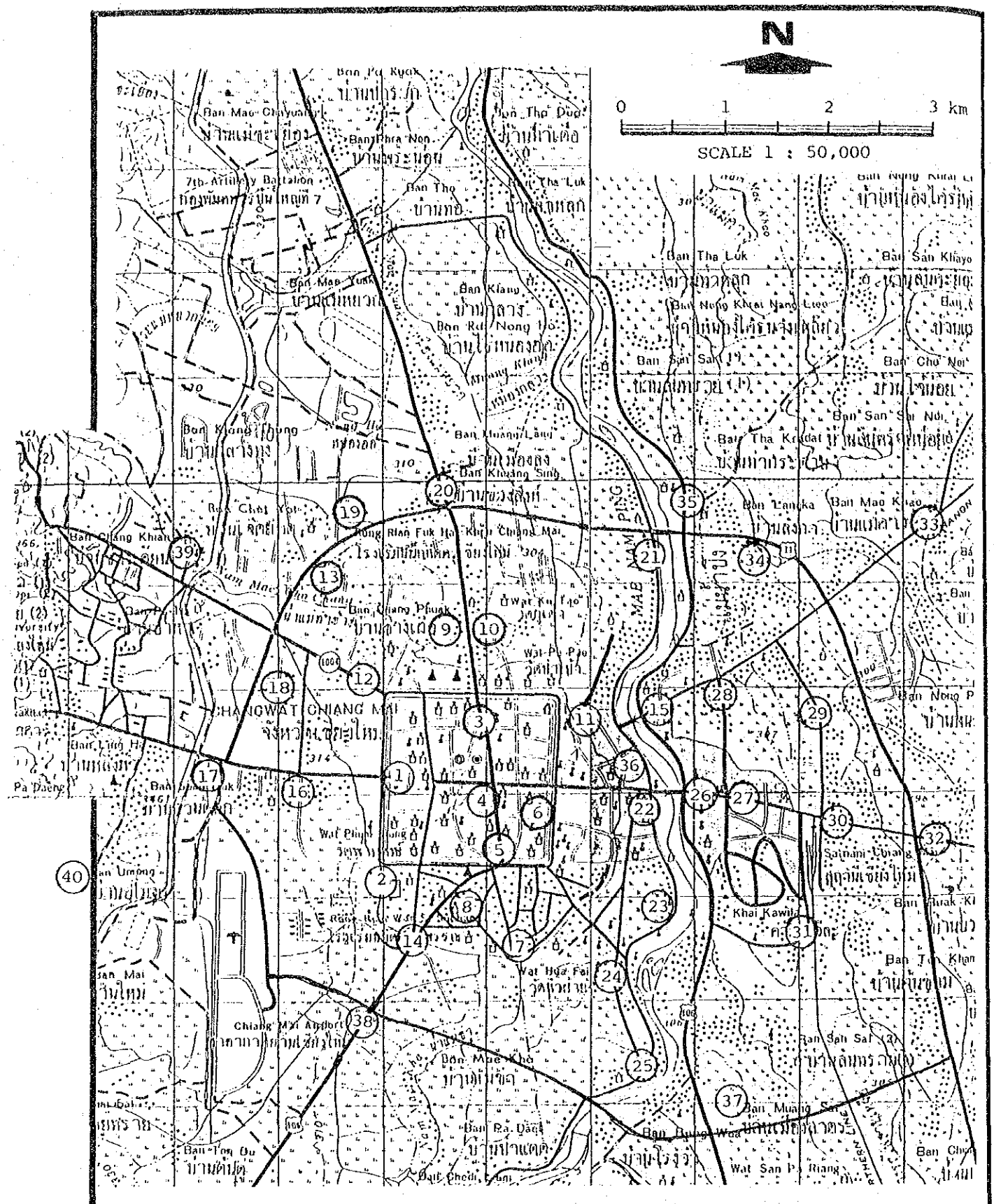
The JICA Study Team conducted a door-to-door questionnaire survey as a part of the Development Plan and Feasibility Study on the Provincial Water Supply Projects in the Kingdom of Thailand, in cooperation with the counterparts of the Provincial Waterworks Authority.

This survey was intended to obtain the basic and direct information on the present water use pattern of the inhabitants in Chiangmai Municipality and other five sanitary districts including their willingness for house-connection supply. These results of survey will be used for preparing Development Plan and Feasibility Study.

5.2 Survey Areas and Interviewees

The survey area covered to all districts in the project areas, inclusive of both the served and unserved area. The points where the questionnaire survey was conducted are shown in Fig-5.1(1)-(6).

The interviewees included not only the present consumers of the PWA service but also the people using other water sources.



(No.) Surveyed points

FIGURE	MAP OF SURVEYED ZONE
5.1(1)	CHIANGMAI MUNICIPALITY

JAPAN INTERNATIONAL COOPERATION AGENCY

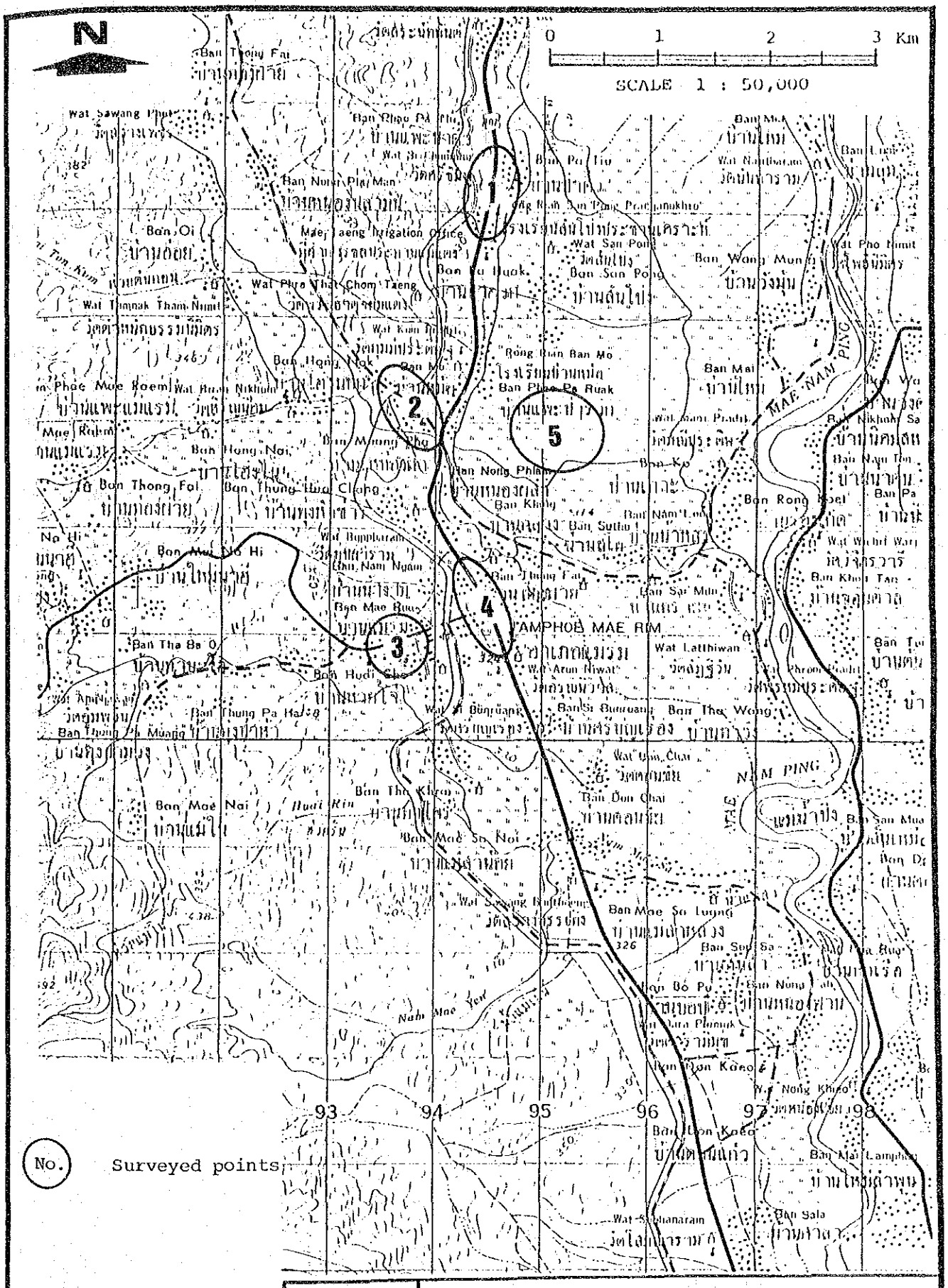


FIGURE	MAP OF SURVEYED ZONE
5.1(2)	MAE RIM SANITARY DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

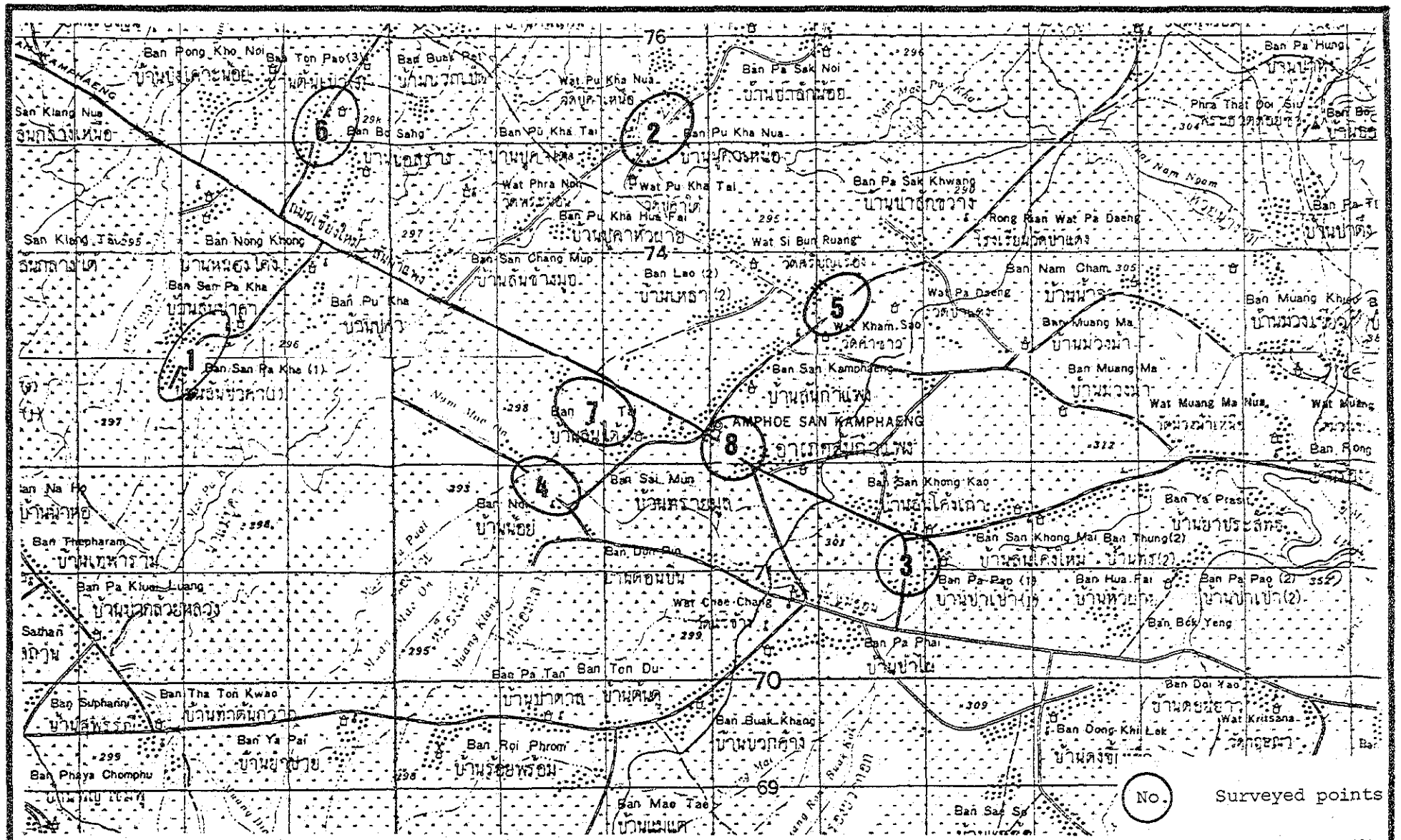
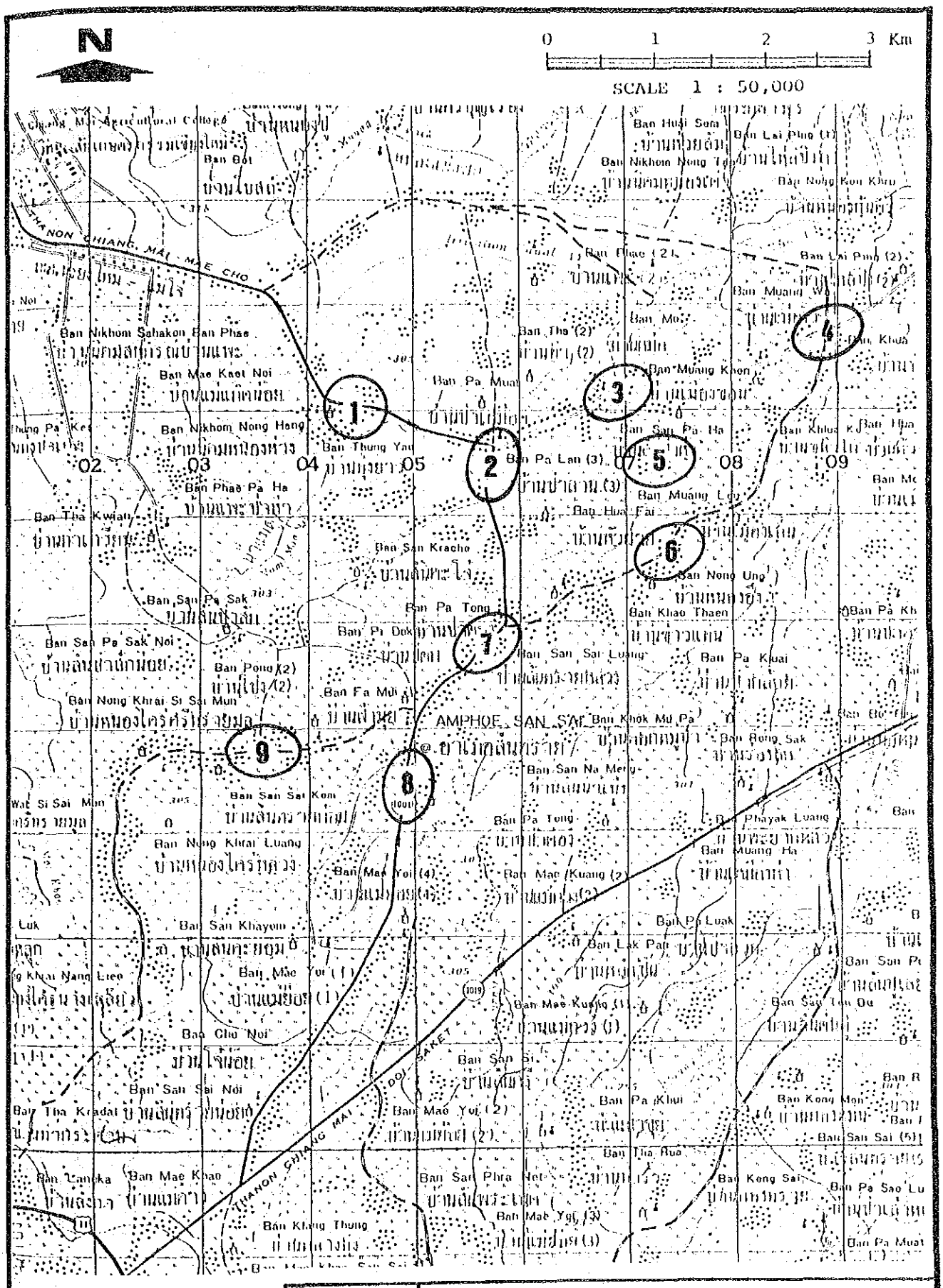


FIGURE	MAP OF SURVEYED ZONE
5.1(3)	SAN KAMPHAENG SANITARY DISTRICT

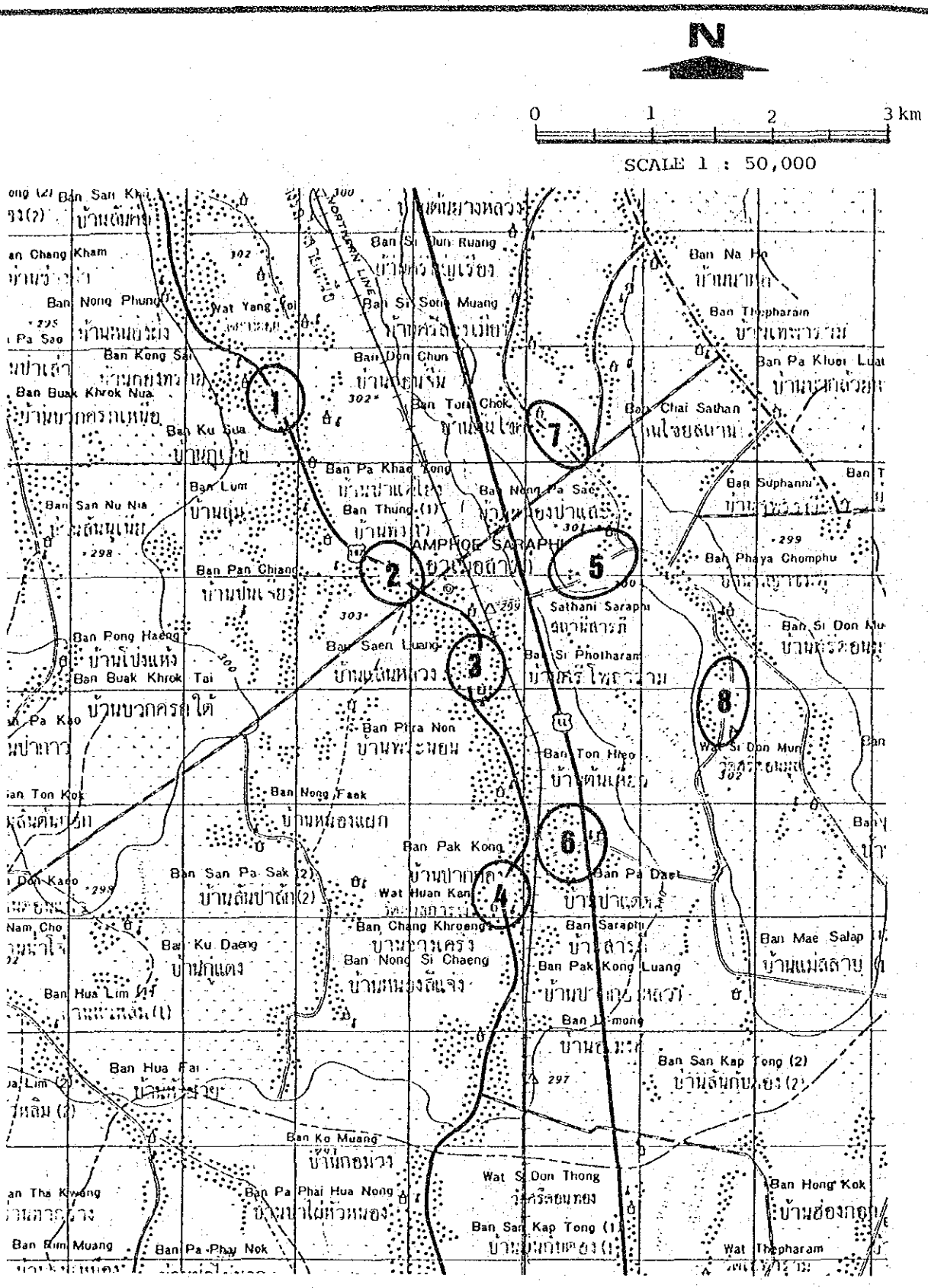
JAPAN INTERNATIONAL COOPERATION AGENCY



No.	Surveyed points

FIGURE	MAP OF SURVEYED ZONE
5.1(4)	SAN SAI SANITARY DISTRICT

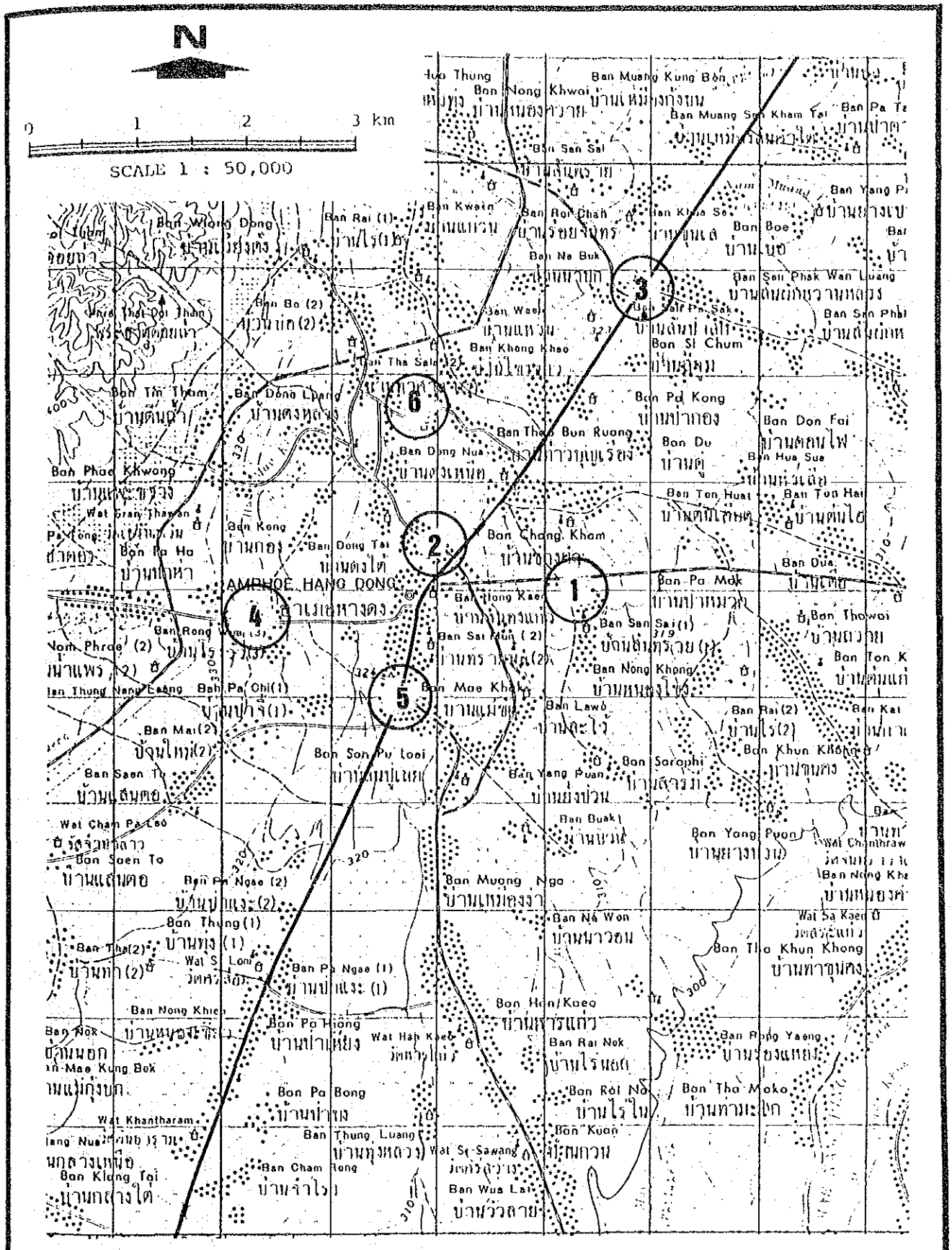
JAPAN INTERNATIONAL COOPERATION AGENCY



(No.) Surveyed points

FIGURE	MAP OF SURVEYED ZONE
5.1(5)	SARAPHI SANITARY DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY



No. Surveyed points

FIGURE 5.1(6)

MAP OF SURVEYED ZONE
HANG DONG SANITARY DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

5.3 Survey Items

As seen in Table-5.1, the questionnaire form used for the survey consists of the following ten items:

- Q-1 Type of Building Surveyed
- Q-2 Type of Water Supply Source
- Q-3 Number of Persons per Connection
- Q-4 Number of Persons per Household
- Q-5 Current Status of Water Supply
- Q-6 Monthly Average Water Consumption
- Q-7 Average Cost of Water per Month
- Q-8 Willingness to be Connected to Municipal System
- Q-9 Willingness to Pay for Water per Month
- Q-10 Average Monthly Income per Household

5.4 Survey Method

The survey team consisted of staff members of the JICA team, three officials from the PWA Head Office, the personnel of the PWA Regional Office and the Chiangmai Waterworks.

The total of 45 local people, employed as interviewers, were engaged in the survey and the interviewees, numbering 1897 in total(997 in Chiangmai and 900 in five Sanitary Districts), were selected randomly.

Questioning was made by the interviewer, assisted by the local PWA personnel, under the guidance of the PWA Head Office Staff.

The survey was conducted on 28th through 31st of February, 1986.

Table-5.1 QUESTIONNAIRE FORM

QESTIONNAIRE

FOR

PROVINCIAL WATER SUPPLY PROJECT

Ward No. :

Interviewer :

Date : / / 19

Registration No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Sample Reference No.																										
Name of Street																										
House/Building No.																										
Q-1. Type of Building Surveyed (Check appropriate one)	Pure Residential																									
	Residential & Commercial																									
	Pure Commercial																									
	Institutional																									
	Industrial																									
Q-2. Type of Water Supply Source (Check appropriate one/ones)	Municipal System																									
	Sources Other Than Municipal System: Rain/River Water																									
	Spring																									
	Water Vendor																									
	Ground-water: Shallow Well																									
	Deep Well																									
	Well depth: 1 - 10 m																									
	10 - 20 m																									
	20 - 50 m																									
	50 - 100 m																									
	100 - 200 m																									
	over 200 m																									
	Water level: 1 - 5 m																									
	5 - 10 m																									
	10 - 20 m																									
	20 - 50 m																									
	over 50 m																									
	Fluctuation (Dry and Rainy): 1 - 3 m																									
	3 - 5 m																									
	over 5 m																									
	drinking																									
	not drinking																									
	colored																									
	smell																									
Q-3. Number of Persons Per Household (Should not Include neighbors)																										
Q-4. Number of Persons Per House Connection (Applicable only to those being supplied by Municipal System. Should include neighbors using same house connection)																										
Q-5. Current Status of Water Supply (Check appropriate one. If unsatisfactory, check appropriate reason/reasons)	Satisfactory																									
	Unsatisfactory: Poor Quality																									
	Low Pressure																									
	Unusable																									
	Expensive																									
Q-6. Average Monthly Water Consumption (Check appropriate one)	Less than 15 m³																									
	15 - 30																									
	30 - 50																									
	50 - 75																									
	75 - 100																									
	100 - 150																									
	150 - 200																									
	200 - 300																									
	over 300																									
Q-7. Average Cost of Water Per Month (Check appropriate one)	Less than 50 Baht																									
	50 - 100																									
	100 - 150																									
	150 - 200																									
	200 - 300																									
	300 - 500																									
	500 - 1,000																									
	1,000 - 3,000																									
	3,000 - 10,000																									
	over 10,000																									
Q-8. Willingness to be connected to Municipal System (Applicable only to those not being supplied by Municipal System. Check 'Yes' or 'No')	Yes																									
	No																									
Q-9. Willingness to pay for Water Per Month (Applicable to only those who answered 'Yes' to Q-6. Check appropriate one)	Upto 50 Baht																									
	100																									
	150																									
	500																									
	1,000																									
	2,000																									
	5,000																									
	10,000																									
Q-10. Average Monthly Income Per Household (Check appropriate one)	Less than 2,000 Baht																									
	2,000 - 3,000																									
	3,000 - 4,500																									
	4,500 - 6,000																									
	6,000 - 7,500																									
	7,500 - 10,000																									
	10,000 - 15,000																									
	15,000 - 50,000																									
	over 50,000																									

5.5 Survey Results

5.5.1 Chiangmai

The survey results are summarized in Table-5.2 and shown in Fig-5.2 (1) to (6) graphically.

1) Type of Building Surveyed (see Table-5.2 and Fig-5.2 (1))

Of the 974 households answering the captioned question, 44.5 % lived in residential-only (purely residential) buildings while 51.1 % in residential -commercial buildings. Altogether 95.6 %, most of the 974, lived in the residential-purported buildings and consumed water for domestic uses.

2) Type of Water Supply Sources (see Table-5.2 and Fig-5.2 (1), (2))

Of the 992 households answering the captioned question, 50.9 % used the municipal system only, 10.6 % the municipal system and other sources and 38.5 % other sources only. (Fig-5.2 (1)). Fig-5.2 (2) shows how the other sources were used. When the two graphs are combined, the groundwater's share is the largest, 407 of the total 487, or 83.6 %, followed by the combined sources' 8.0 % and the water buyer's 7.2 %.

3) Current Status of Water Supply (Table-5.2, Fig-5.2 (3))

Of the 586 households using the PWA system wholly or partly, 59.9 % was found to be dissatisfied with the service. Of the reasons, 43.9 % of the 351, pointed out costliness, 31.6 % combined reasons, 10.6 % poor quality and 8.8 % chronic low pressure.

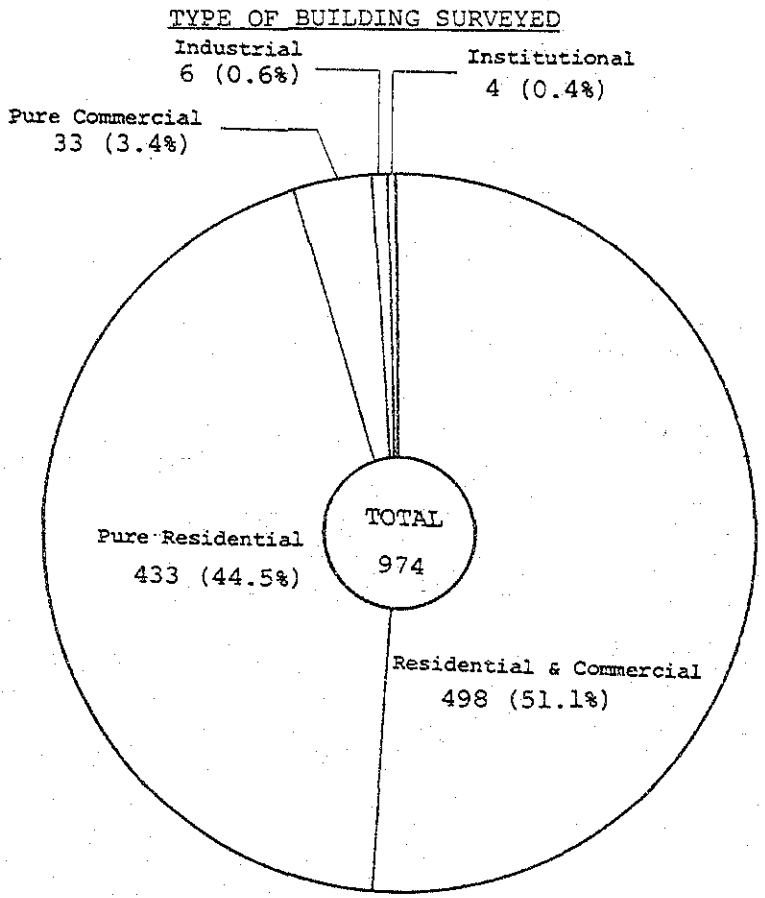
4) Monthly Average Consumption and Payment (Table-5.2, Fig-5.2 (4))

Consumption and payment are closely related. Of the 598 households surveyed, the less-than-15 cu m/month consumer, numbering 123 and comprising 20.6 %, corresponds to the less-than 50 Baht payer, numbering 96 and

Table-5.2 SURVEY RESULTS

CHIANGMAI

QUESTIONNAIRE	TOTAL
Q-1 :Type of Building Surveyed	
Pure Residential	433
Residential & Commercial	498
Pure Commercial	33
Institutional	4
Industrial	6
No Anser	23
TOTAL Q-1	997
Q-2 :Type of Water Supply Sources	
A :Municipal System Only	505
B :Municipal System Plus Other Sources	
B-1 : Rain/River Water	5
B-2 : Pond / Reservoir Water	0
B-3 : Water Vender	33
B-4 : Groundwater	60
B-5 : Combined Sources	7
C :Sources Other Than Municipal System	
C-1 : Rain/River Water	0
C-2 : Pond / Reservoir Water	1
C-3 : Water Vender	2
C-4 : Groundwater	347
C-5 : Combined Sources	32
D :No Answer	5
Sub total (A + B)	610
Sub total (C)	387
TOTAL Q-2	997
Q-5 :Current Status of Water Supply (Municipal System)	
A :Satisfactory	235
B :Unsatisfactory	
B-1 : Poor Quality	37
B-2 : Low Pressure	31
B-3 : Unstable	18
B-4 : Expensive	154
B-5 : Combined Reasons	111
C :No Answer	24
TOAL Q-5	610
Q-6 :Average Monthly Water Consumption	
1 :Less than 15 m3	123
2 :15 - 30	231
3 :30 - 50	140
4 :50 - 75	52
5 :75 - 100	22
6 :100 - 150	16
7 :150 - 200	8
8 :200 - 300	3
9 :Over 300	3
10 :No Answer	12
TOTAL Q-6	610
Q-7 :Average Cost of Water Per Month	
1 :Less than 50 Baht	96
2 :50 - 100	150
3 :100 - 150	105
4 :150 - 200	68
5 :200 - 300	78
6 :300 - 500	53
7 :500 -1,000	36
8 :1,000 - 5,000	12
9 :5,000 - 10,000	0
10 :Over 10,000	0
11 :No Answer	12
TOTAL Q-7	610
Q-8 :Willingness to be Connected	
1 :Yes	161
2 :No	215
3 :No Answer	11
TOTAL Q-8	387
Q-9 :Willingness to Pay for Water per Month	
1 :Upto 50 Baht	72
2 : 100	57
3 : 200	19
4 : 500	8
5 : 1,000	2
6 : 2,000	0
7 : 5,000	0
8 : 10,000	0
9 :No Answer	3
TOTAL Q-9	161
Q-10:Average Monthly Income per Household	
A :Sources Other Than Municipl System	
1 :Less than 2,000 Baht	55
2 : 2,000 - 3,000	88
3 : 3,000 - 4,500	83
4 : 4,500 - 6,000	62
5 : 6,000 - 7,500	42
6 : 7,500 -10,000	17
7 : 10,000 -15,000	13
8 : 15,000 -50,000	5
9 :Over 50,000	2
10 :No Answer	20
Sub total Q-10-A	387
B :Municipal System Plus Sources	
1 :Less than 2,000 Baht	22
2 : 2,000 - 3,000	70
3 : 3,000 - 4,500	106
4 : 4,500 - 6,000	115
5 : 6,000 - 7,500	96
6 : 7,500 -10,000	74
7 : 10,000 -15,000	45
8 : 15,000 -50,000	28
9 :Over 50,000	5
10 :No Answer	49
Sub total Q-10-B	610
TOTAL Q-10	997



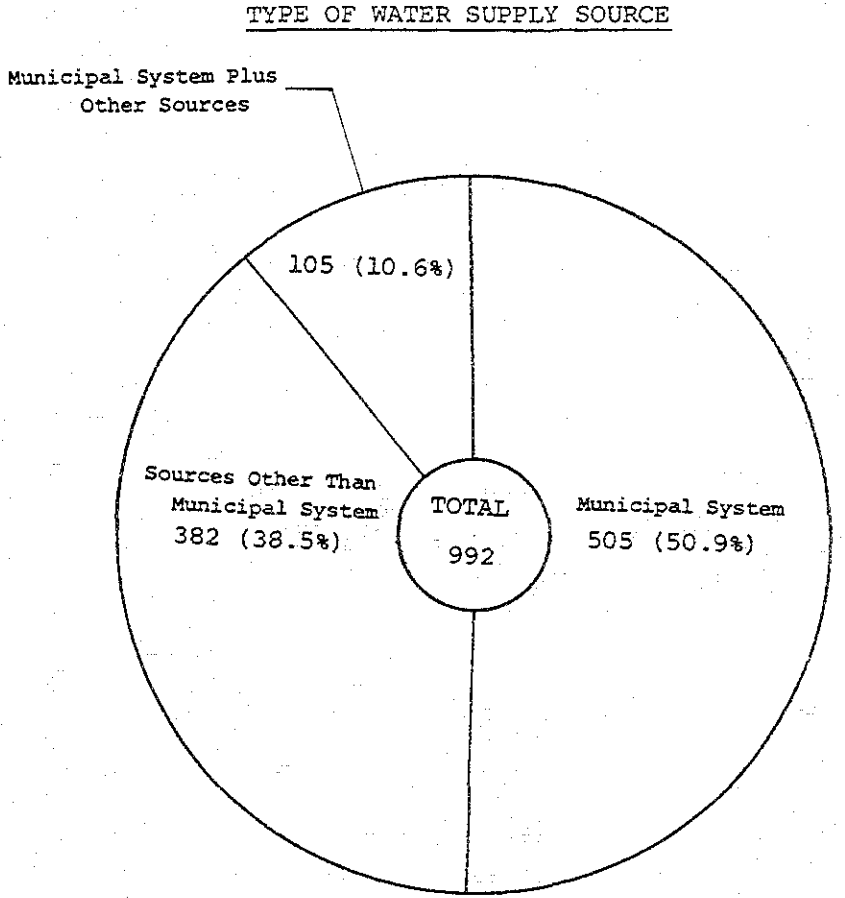
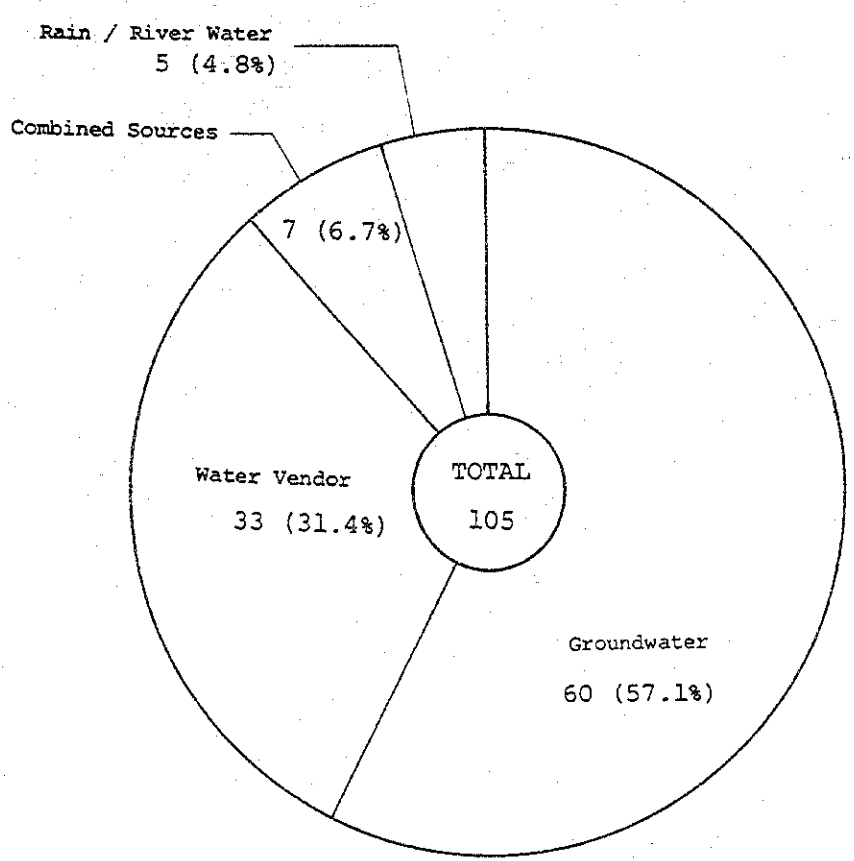


FIGURE	QUESTIONNAIRE SURVEY RESULTS (1)
5.2(1)	(CHIANGMAI)
JAPAN INTERNATIONAL COOPERATION AGENCY	



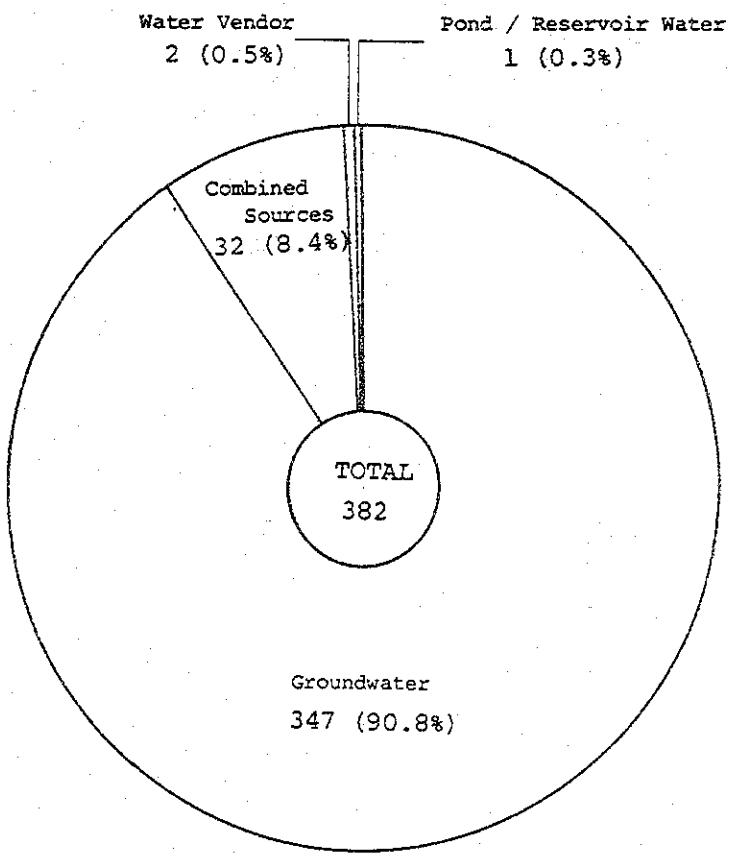


FIGURE	QUESTIONNAIRE SURVEY RESULTS (2)
5.2(2)	(CHINGMAI)

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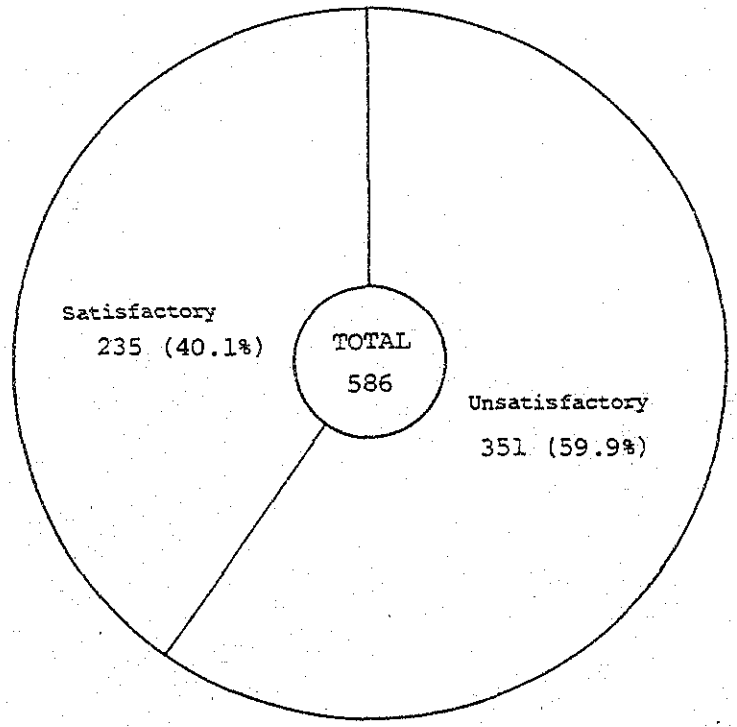
CURRENT STATUS OF WATER SUPPLY
MUNICIPAL SYSTEM



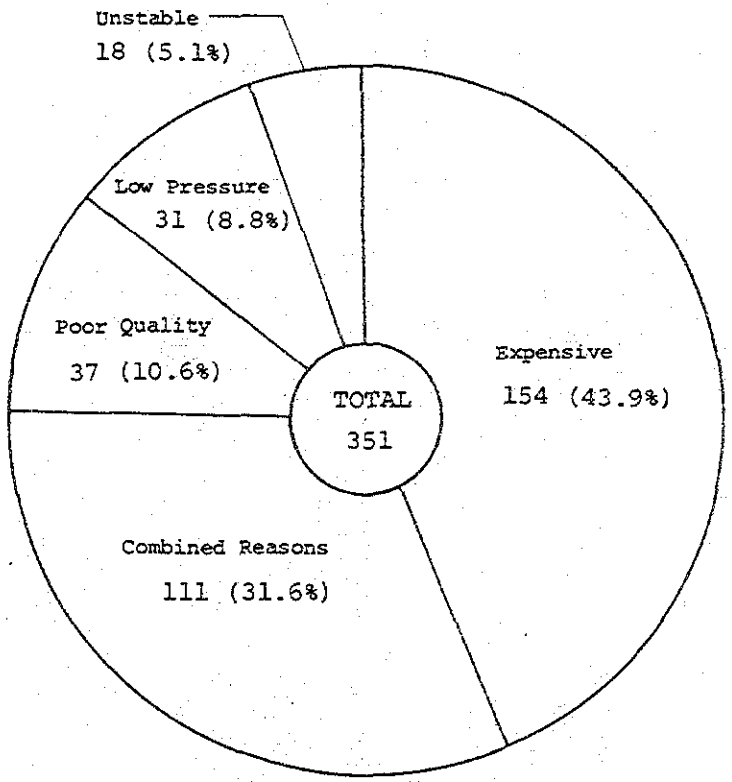
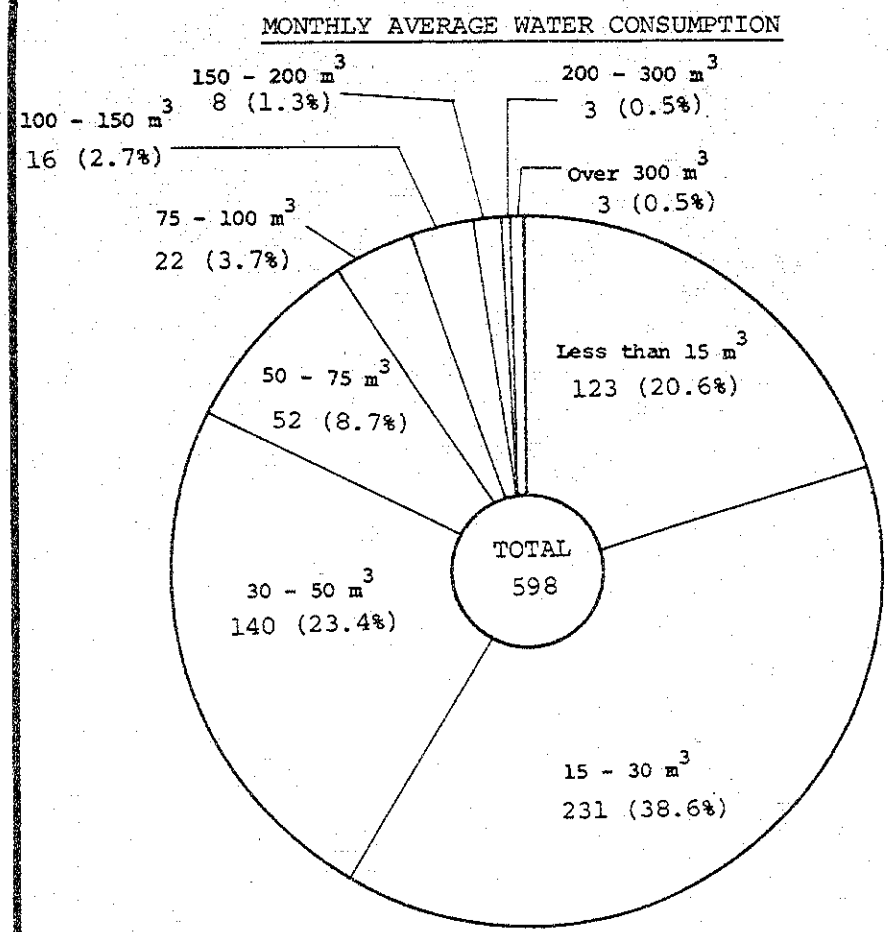


FIGURE	QUESTIONNAIRE SURVEY RESULTS (3)
5.2(3)	(CHIANGMAI)

JAPAN INTERNATIONAL COOPERATION AGENCY



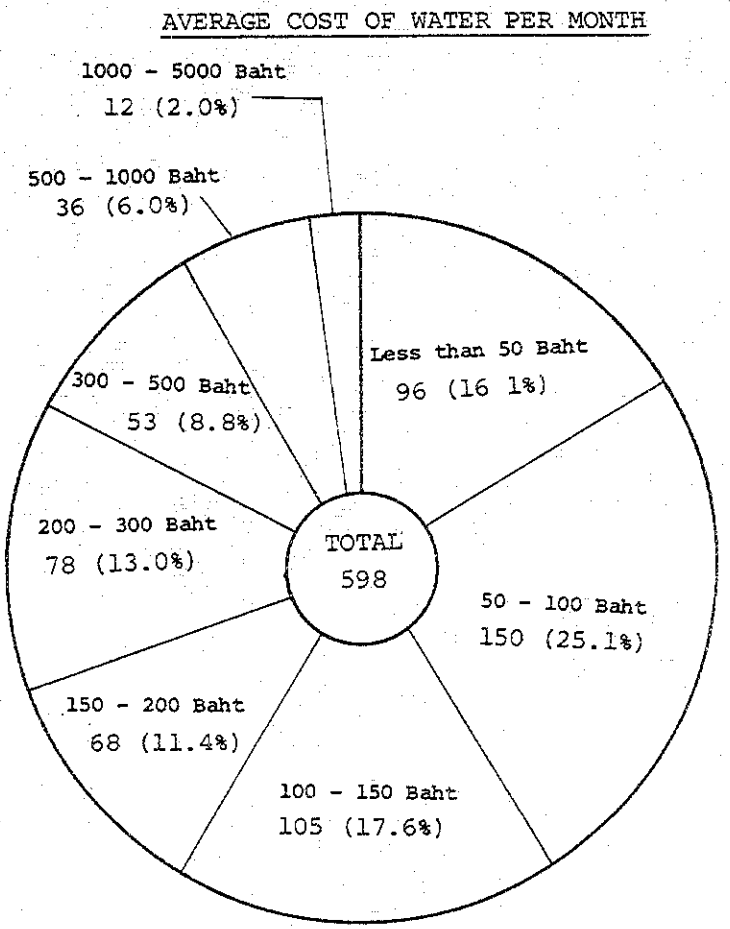


FIGURE	QUESTIONNAIRE SURVEY RESULTS (4)
5.2(4)	(CHIANGMAI)

JAPAN INTERNATIONAL COOPERATION AGENCY

comprising 16.1 %. Likewise, 15-30 cu m/month consumer correspond to the payer of 50-150 baht.

It also indicates that a limit in economizing consumption and payment exists at rather low level.

5) Willingness to be connected to Municipal System (Table-5.2, Fig-5.2 (5))

By the people using sources other than the Municipal system, the captioned question was answered.

Nearly 43 %, or 161 of 376 of the answer, was positive.

The others, more than half, were not willing to be connected, which might be due to use of groundwater and/or high water tariff.

6) Willingness to Pay for Water per Month (Table-5.2, Fig-5.2 (5))

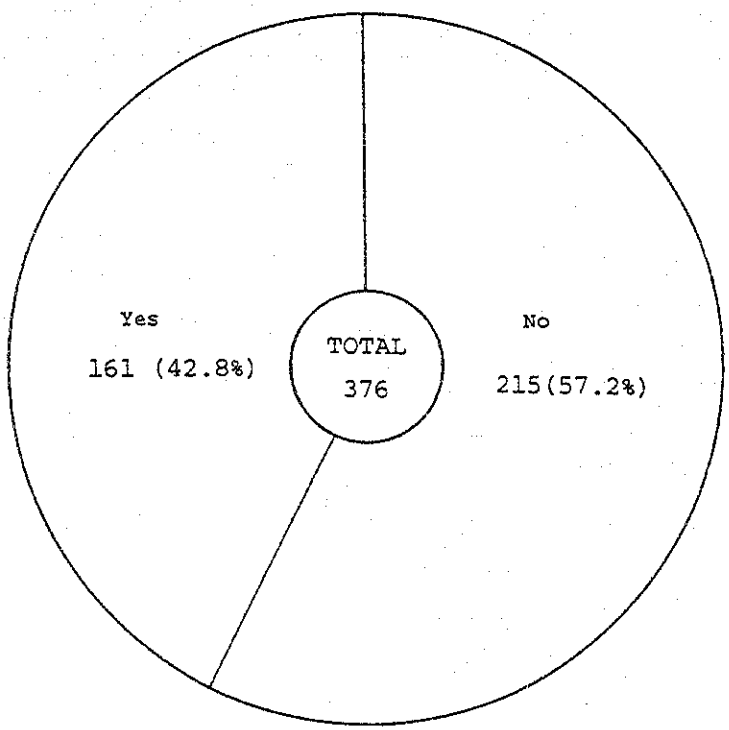
Of those repliers willing-to-be-connected people, nearly a half i.e., 72 out of 158, answered 50 Baht or less as a willing-to-pay amount. This percentage contrasts with the finding that presently the less-than-50 Baht paying group comprises only 16.1 % of the total. The portion willing 100 Baht or less payment is 81.7 %, contrasting with the present percentage of users which is 41.2 %.

7) Average Monthly Household Income (Table-5.2, Fig-5.2 (6))

367 other sources-than-Municipal-System users and 561 wholly-or-partly-Municipal-System users were questioned and the result is shown for each separately.

Obviously, the income levels differ between the two. The less-than-4,500 baht income group comprises 66.1 % of the non-users and 34.4 % of the wholly-or-partial-users. This shows those households with higher income were receiving PWA services.

WILLINGNESS TO BE CONNECTED



WILLINGNESS TO PAY FOR WATER PER MONTH

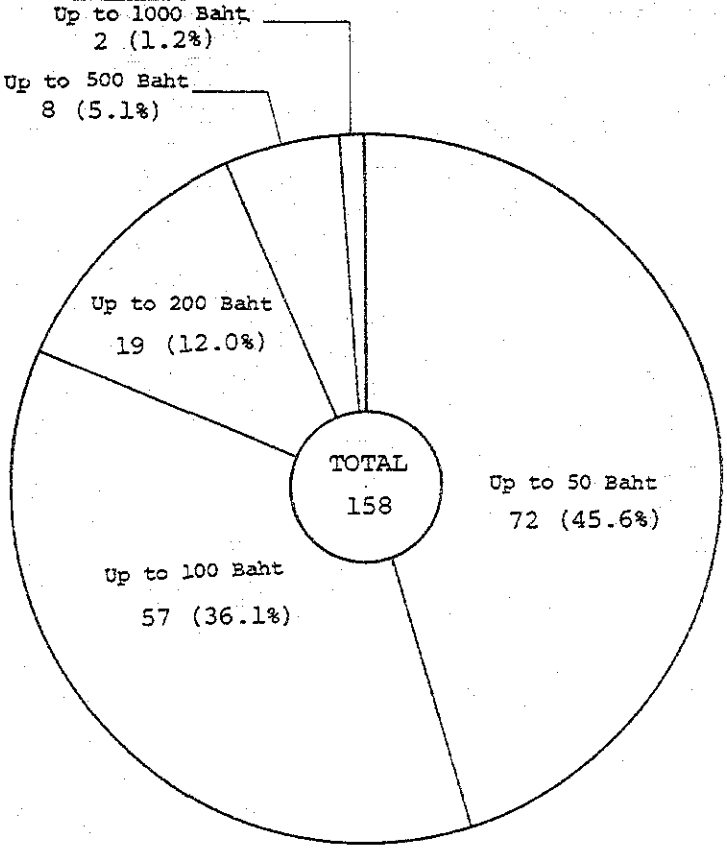


FIGURE	QUESTIONNAIRE SURVEY RESULTS (5)
5.2(5)	(CHIANGMAI)

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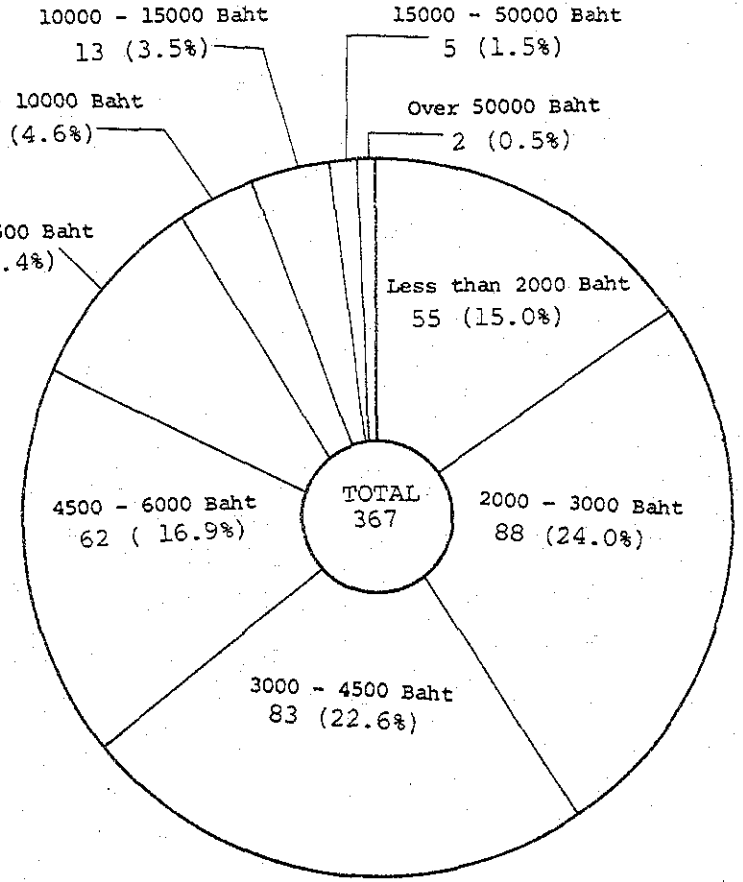
AVERAGE MONTHLY HOUSEHOLD INCOME
(SOURCE OTHER THAN MUNICIPAL SYSTEM)



AVERAGE MONTHLY HOUSEHOLD INCOME
(MUNICIPAL SYSTEM PLUS OTHER SOURCES)

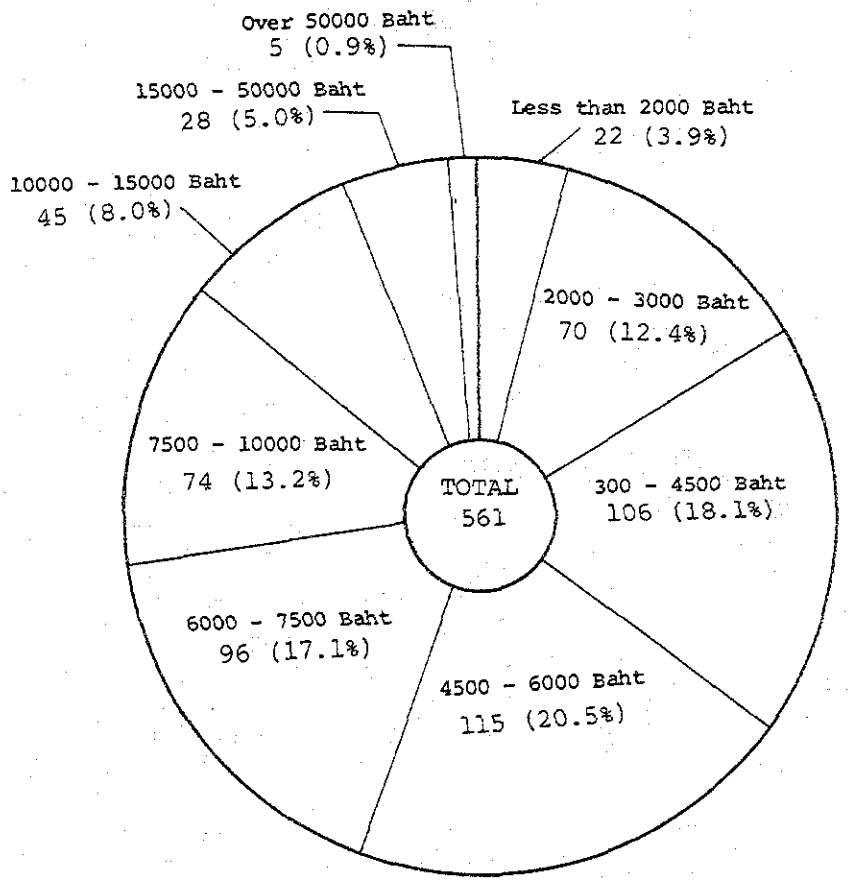


FIGURE	QUESTIONNAIRE SURVEY RESULTS (6)
5.2(6)	(CHIANGMAI)

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