MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

FINAL REPORT
FOR
DEVELOPMENT PLAN AND FEASIBILITY STUDY
ON
PROVINCIAL WATER SUPPLY PROJECTS
IN
THE KINGDOM OF THAILAND

VOLUME II-B
APPENDICES
FOR
CHIANGMAI

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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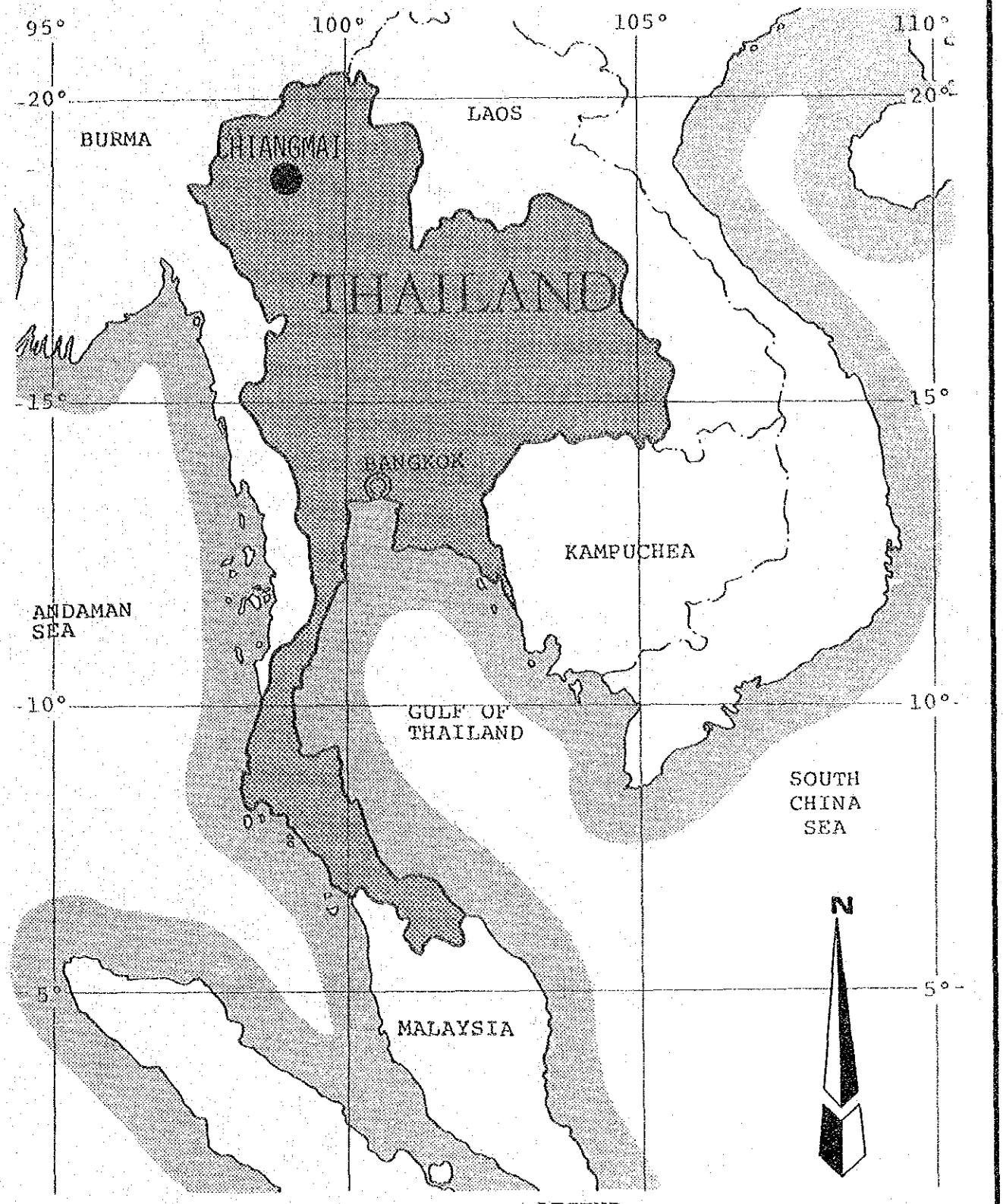

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● : CHIANGMAI MUNICIPALITY

◎ : CAPITAL CITY

SCALE 1 : 10,000,000

FIGURE	LOCATION MAP
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POPULATION FORECAST

APPENDIX 1

APPENDIX 1 POPULATION FORECAST

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APPENDIX 1 POPULATION FORECAST

1.1 General

This appendix forecasts the future population and served population in the study area. The area, as defined in the scope of work, consists of Chiangmai Municipality, and five sanitary districts: Mae Rim, San Sai, Saraphi, Hang Dong, and San Kamphaeng. The estimated served population will be used in projecting the water demand, of which Appendix 2 to this report gives full explanation.

Chiangmai Municipality is the second largest city in Thailand and noted for its tourism. As the tourists visiting there are increasing every year, the water demand by the tourism industry has to be duly considered in the future water supply development plan.

Demographic and socio-economic features, such as recent tendency of migration and habitation in the area, as well as future possibilities of industrial and commercial development were discussed with the local officials.

Population forecast was made employing the following five mathematical models with approximation by the least square method:

1)	Arithmetical progression	$y = aX + b$
2)	Geometrical Progression	$y = y0 \times (1 + b) \exp X$
3)	Decreasing rate of increase	$y = K - ab \exp X$
4)	Exponential	$y = y0 + aX \exp b$
5)	Logistic	$y = K / (1 + e \exp(a - bX))$

Where, y : Population Forecasted
y0 : Population in Base Year
X : Year from Base year
a, b, K : Coefficient

Appropriateness of forecasts by the above models was examined for consistency with the demographic and socio-economic features, such as recent tendency of migration and habitation in the area and regional development plans established by the other organizations. These existing plans refer-

red to in the study are listed at the end of the Appendix.

The forecast of the served population and service area made herein is found consistent with the waterworks development program and the Municipality's Land Use Plan and it further reflects the inhabitants' willingness for house connections, expressed in the questionnaire survey.

One of the main industry of Chiangmai is tourism, hence the number of tourists are also forecasted in this study with the same mathematical methods as described before.

1.2 Population Statistic

The population statistics of Chiangmai and five sanitary districts are shown in Table-1.1 and Fig-1.1. The data for the past 20 years were provided by the Local Administration Department (LAD), the Ministry of Interior (MOI).

The population in Chiangmai Municipality rapidly increased up to 1970 with the yearly rates ranging from 3% to 5%. The growth rate thereafter slightly decreased and the rate indicated 1.8% per annum on the average after 1970.

Due to the Municipality's incorporation of the surrounding areas enacted in 1983, the population of Chiangmai was increased by about 50,000 within the year. Although the detailed demographic data was unavailable for each of the incorporated areas, populations of the incorporated areas were somewhat analyzed. The incorporation enlarged the Municipality area to 40 sq km from 17.5 sq km.

Regarding the five sanitary districts' population shown in Table-1.1, the data before 1980 recorded extraordinary changes for some years. Therefore the demographic data older than 1980 is excluded from the forecasting to minimize the error.

Table-1.1 PAST POPULATION AND GROWTH

YEAR	CHIANG MAI POP.	ratio	MAI RIM POP.	ratio	SAN SAI POP.	ratio	SAM KAMPHENG POP.	ratio	SARAPHEE POP.	ratio	HAN DONG POP.	ratio	T O T A L POP.	ratio
1965	77,858				2137								79,995	
		-0.015				0.022								0.367
1966	76,694		7,243		2,183		13,630		7,010		2,587		109,347	
		0.041		0.001		0.023		0.019		0.009		0.020		0.033
1967	79,823		7,252		2,234		13,890		7,074		2,640		112,913	
		0.054		0.052		0.031		-0.010		0.007		0.020		0.042
1968	84,105		7,626		2,303		13,747		7,126		2,694		117,601	
		0.030		0.029		0.050		0.237		0.005		0.027		0.053
1969	86,638		7,850		2,417		17,003		7,160		2,766		123,834	
		0.030		0.006		0.026		-0.280		0.009		0.032		-0.015
1970	89,272		7,897		2,481		12,239		7,224		2,854		121,967	
		0.022		0.000		0.025		0.117		0.000		-0.079		0.027
1971	91,264		7,897		2,543		13,669		7,227		2,628		125,228	
		0.026		0.541		0.025		-0.043		0.056		0.066		0.053
1972	93,616		12,173		2,606		13,086		7,630		2,801		131,912	
		0.025		-0.219		0.033		0.003		0.000		0.043		-0.001
1973	95,967		9,508		2,693		13,129		7,627		2,921		131,845	
		0.025		0.000		0.004		-0.108		0.009		0.031		0.008
1974	98,319		9,511		2,704		11,714		7,698		3,012		132,958	
		0.026		-0.001		-0.008		0.223		0.000		-0.002		0.038
1975	100,837		9,502		2,683		14,321		7,698		3,007		138,048	
		0.037		0.120		4.262		0.165		0.000		0.500		0.146
1976	104,519		10,640		14,118		16,689		7,697		4,512		158,175	
		0.007		-0.014		0.004		0.003		0.009		0.045		0.006
1977	105,230		10,486		14,179		16,746		7,770		4,715		159,126	
		0.016		0.002		0.004		0.004		0.021		0.022		0.013
1978	106,886		10,511		14,231		16,814		7,931		4,821		161,194	
		-0.085		0.003		0.565		-0.113		-0.618		0.010		-0.048
1979	97,839		10,545		22,273		14,920		3,026		4,867		153,470	
		0.024		-0.001		0.004		0.007		1.653		0.009		0.049
1980	100,146		10,538		22,363		15,018		8,029		4,913		161,007	
		0.012		0.002		-0.028		-0.004		0.037		0.009		0.006
1981	101,394		10,559		21,744		14,962		8,325		4,959		161,943	
		0.028		0.041		0.006		-0.023		-0.001		0.001		0.019
1982	104,190		10,993		21,884		14,622		8,314		4,962		164,965	
		0.444		-0.005		0.004		0.105		0.027		0.014		0.292
1983	150,499		10,939		21,964		16,156		8,540		5,031		213,129	
		0.020		-0.010		0.004		0.035		0.020		-0.030		0.017
1984	153,537		10,831		22,050		16,720		8,707		4,881		216,726	
		0.013		0.090		0.004		0.014		0.030		0.003		0.016
1985	155,471		11,804		22,148		16,953		8,965		4,896		220,237	

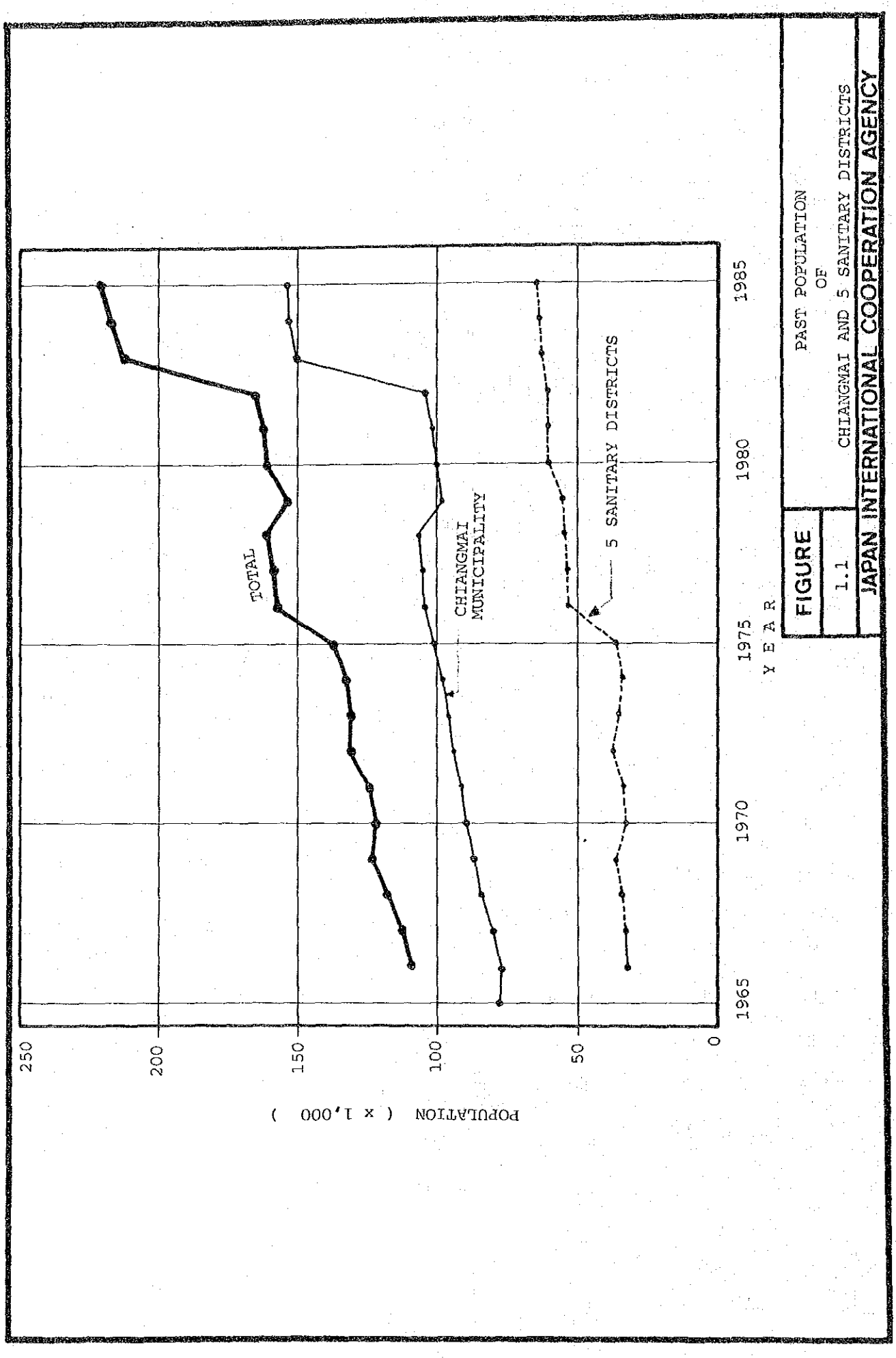

FIGURE 1.1

PAST POPULATION OF CHIANGMAI AND 5 SANITARY DISTRICTS

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1.3 Population Forecast

The results of population forecast for Chiangmai Municipality and five sanitary districts are shown on Fig-1.2 to Fig-1.7.

1.3.1 Chiangmai Municipality

The arithmetical progression model shows best correlation with the past trend and is found consistent with the Regional Cities Development Plan prepared by UNDP in 1983.

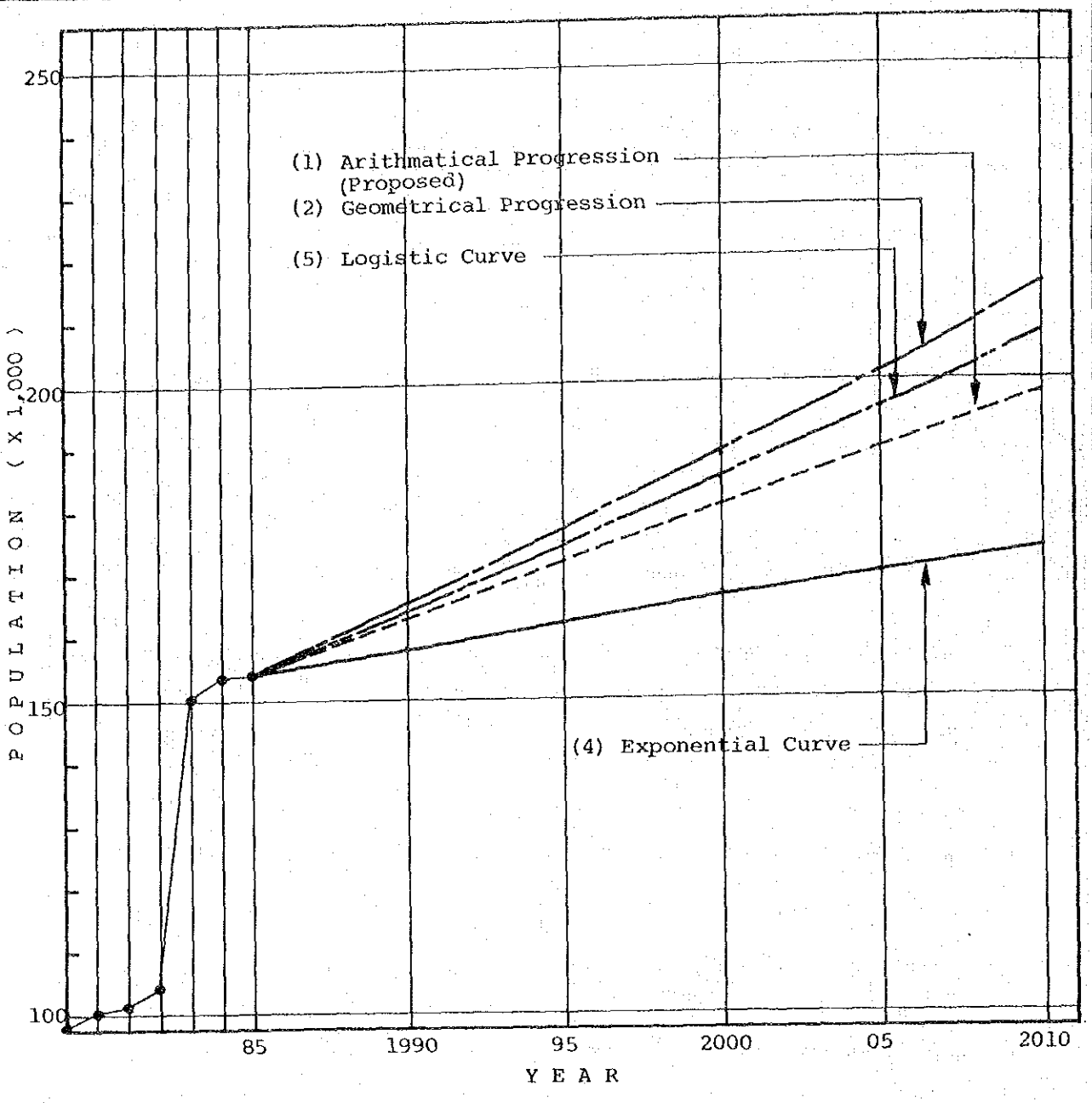
1.3.2 Five Sanitary Districts

The arithmetical progression model was found appropriate for San Kamphaeng, San Sai and Hang Dong and the geometric progression model for Mae Rim and Saraphi. The future populations are calculated based on the adopted model.

San Kamphaeng is the only town which has its own town planning for future and the computed population projection is found consistent with the plan.

1.3.3 Total Population

The concluded population of Chiangmai and five sanitary districts is listed in Table-1.2 and plotted in Fig-1.8.



CASE	1985	1990	1995	2000	2005	2010
(1)	155,271	163,936	172,602	181,267	189,933	198,598
(2)	155,456	165,577	176,640	188,731	201,946	216,391
(3)	Decreasing Rate of Increase was not applied					
(4)	154,647	159,652	164,102	168,215	172,088	175,780
(5)	155,361	164,817	174,827	185,376	196,446	208,004

FIGURE	POPULATION FORECAST OF CHIANGMAI
1.2	

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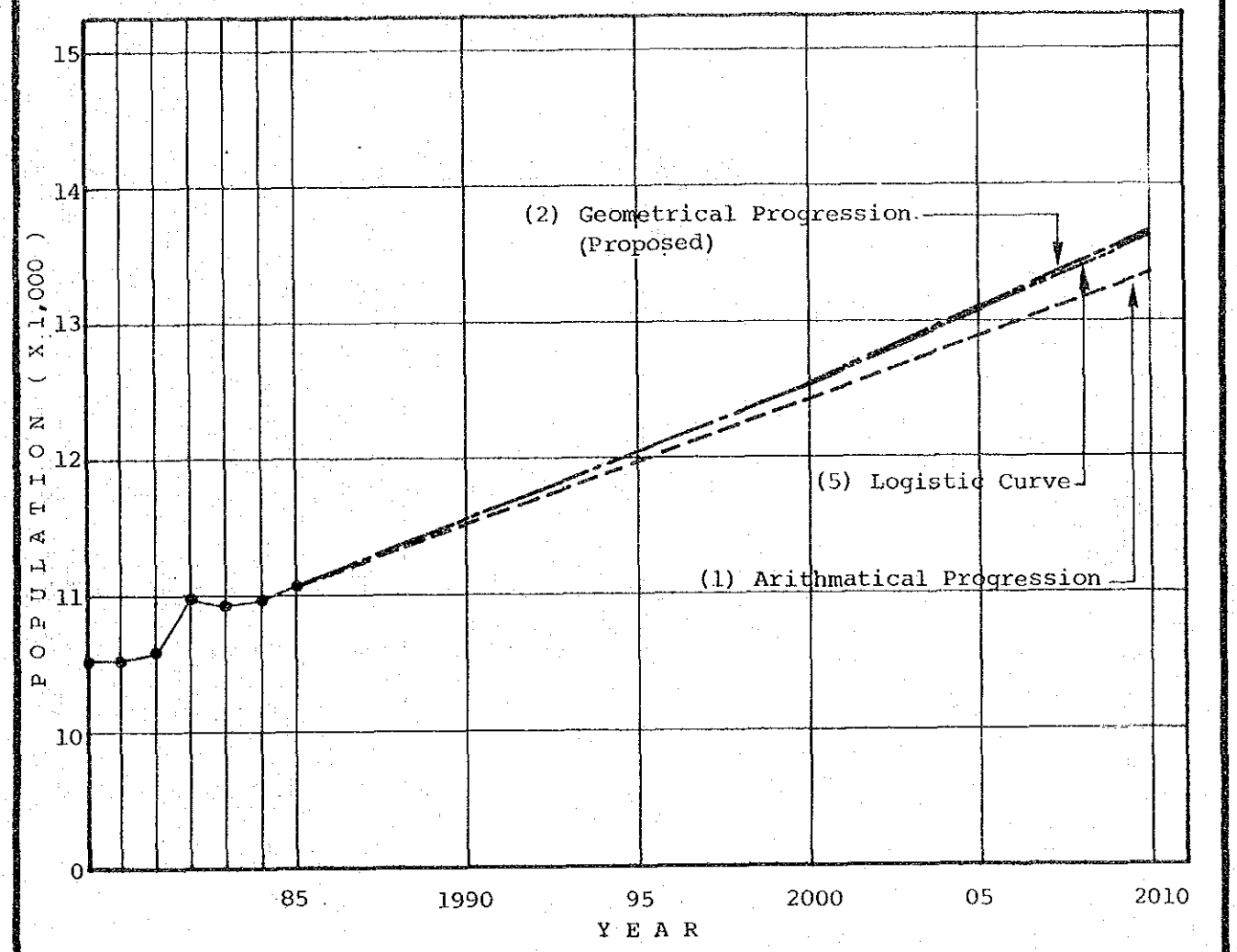
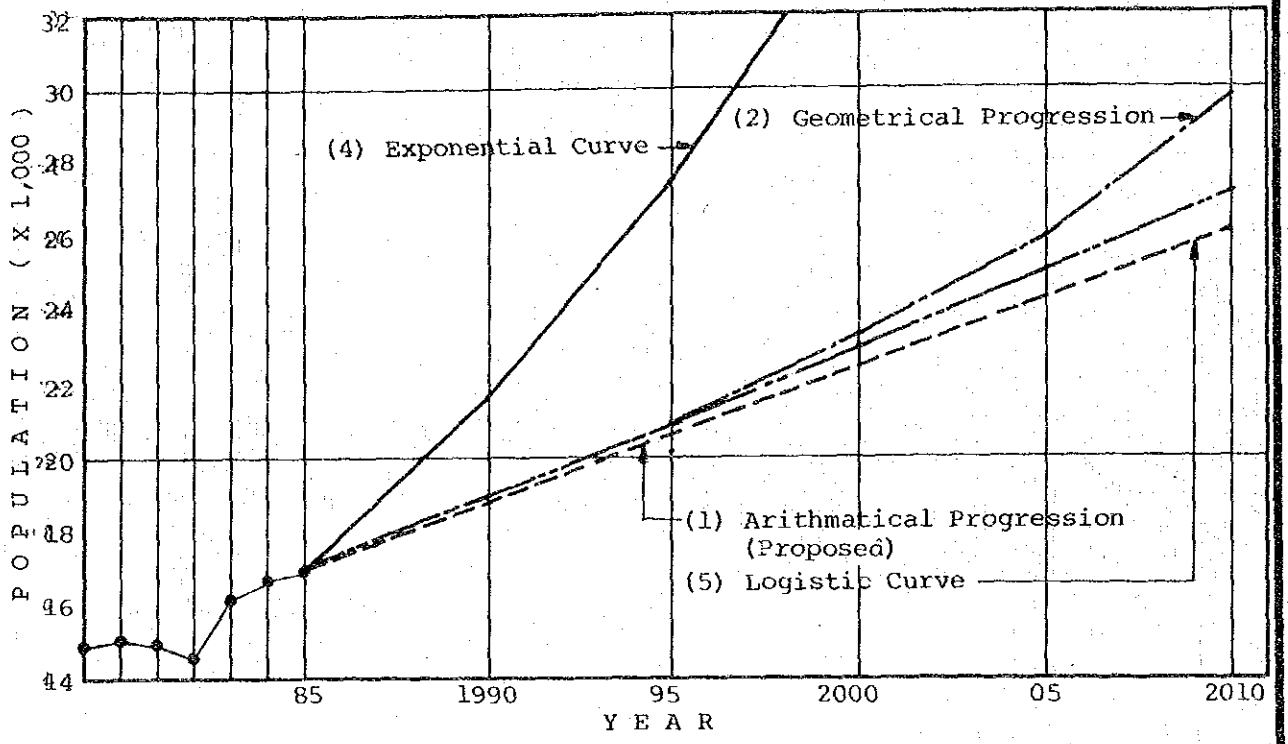


CASE	1985	1990	1995	2000	2005	2010
(1)	11,084	11,522	11,983	12,445	12,906	13,367
(2)	11,084	11,554	12,044	12,555	13,088	13,643
(3)	Decrasing Rate of Increase was not applied					
(4)	Exponential Curve was not applied					
(5)	11,084	11,540	12,033	12,541	13,064	13,602

FIGURE	POPULATION FORECAST OF MAE RIM SANITARY DISTRICT
1.3	

JAPAN INTERNATIONAL COOPERATION AGENCY



CASE	1985	1990	1995	2000	2005	2010
(1)	16,957	18,778	20,599	22,420	24,241	26,061
(2)	16,953	18,857	20,975	23,331	25,952	28,867
(3)	Decreasing Rate of Increase was not applied					
(4)	17,382	21,664	27,493	34,680	43,104	52,677
(5)	16,967	18,898	20,914	22,977	25,073	27,168

FIGURE	POPULATION FORECAST OF SAN KAMPHAENG SANITARY DISTRICT
1.4	

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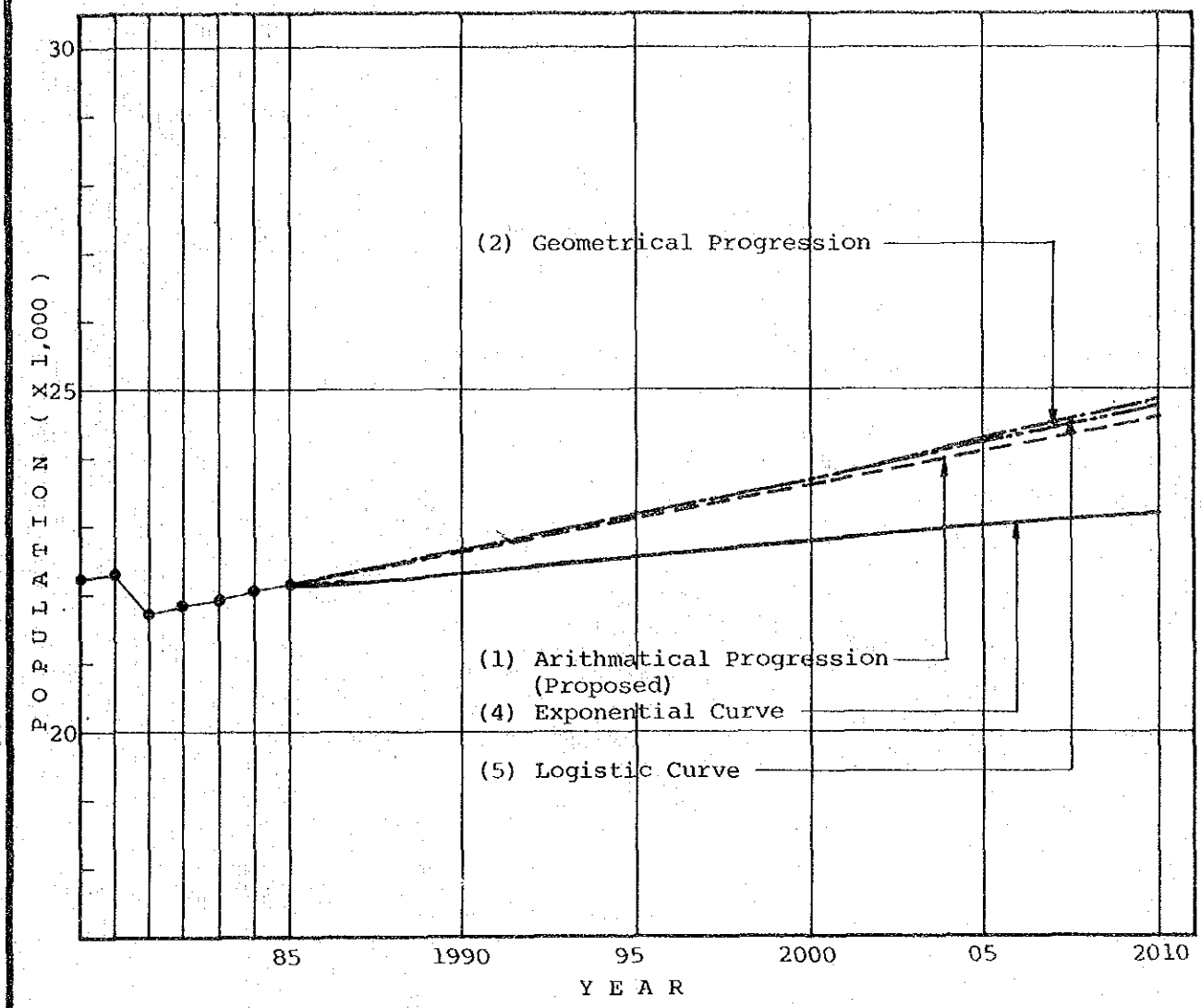

CASE	1985	1990	1995	2000	2005	2010
(1)	22,160	22,659	23,150	23,657	24,156	24,655
(2)	22,153	22,675	23,209	23,756	24,316	24,889
(3)	Decreasing Rate of Increase was not applied					
(4)	22,113	22,397	22,636	22850	23,048	23,234
(5)	22,160	22,668	23,184	23,707	24,239	24,779

FIGURE	POPULATION FORECAST OF SAN SAI SANITARY DISTRICT
1.5	

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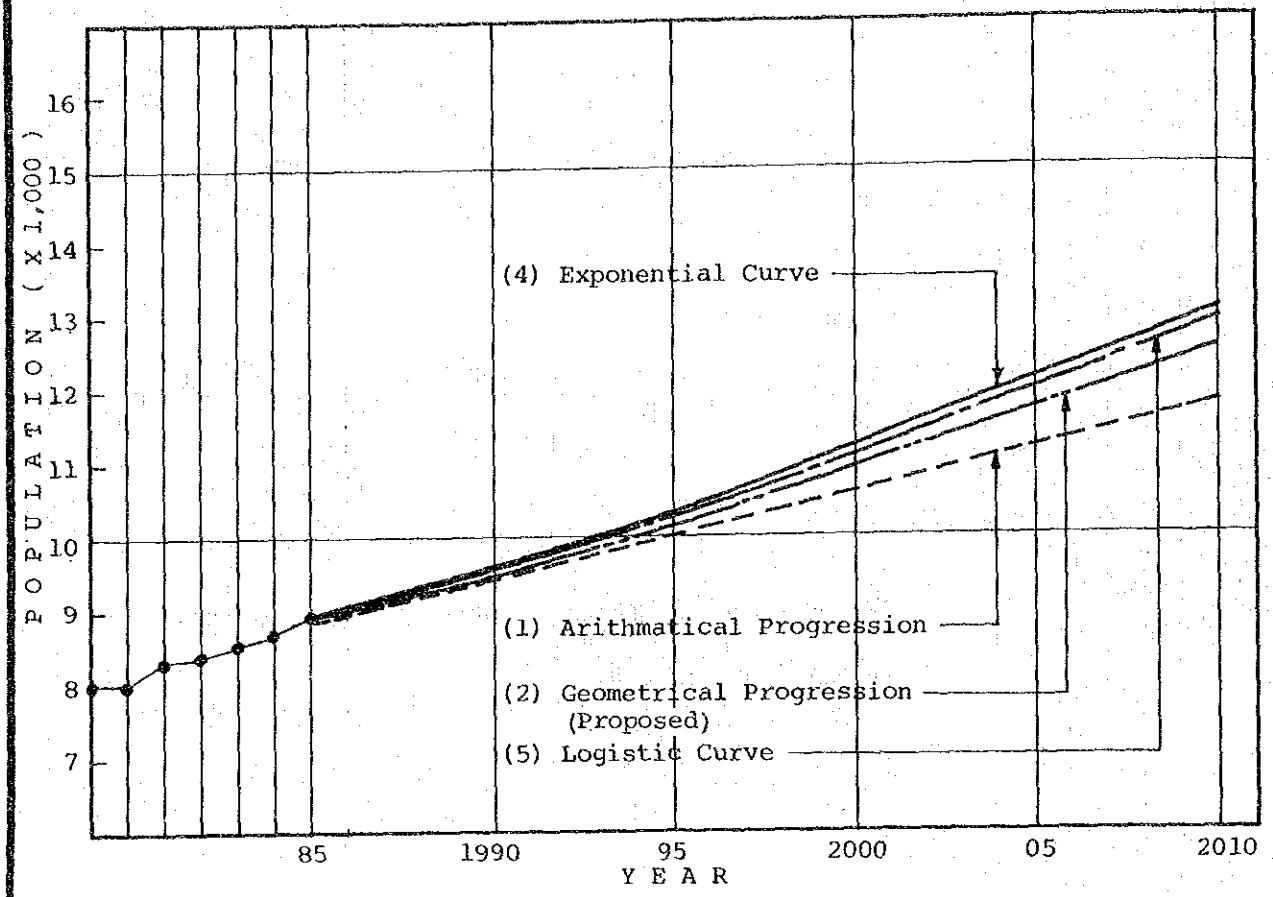

CASE	1985	1990	1995	2000	2005	2010
(1)	8,765	9,387	10,009	10,631	11,252	11,874
(2)	8,842	9,551	10,316	11,142	12,035	12,999
(3)	Decreasing Rate of Increase was not applied					
(4)	8,804	9,578	10,409	11,286	12,200	13,146
(5)	8,777	9,455	10,173	10,930	11,727	12,563

FIGURE	POPULATION FORECAST OF SARAPHI SANITARY DISTRICT
1.6	

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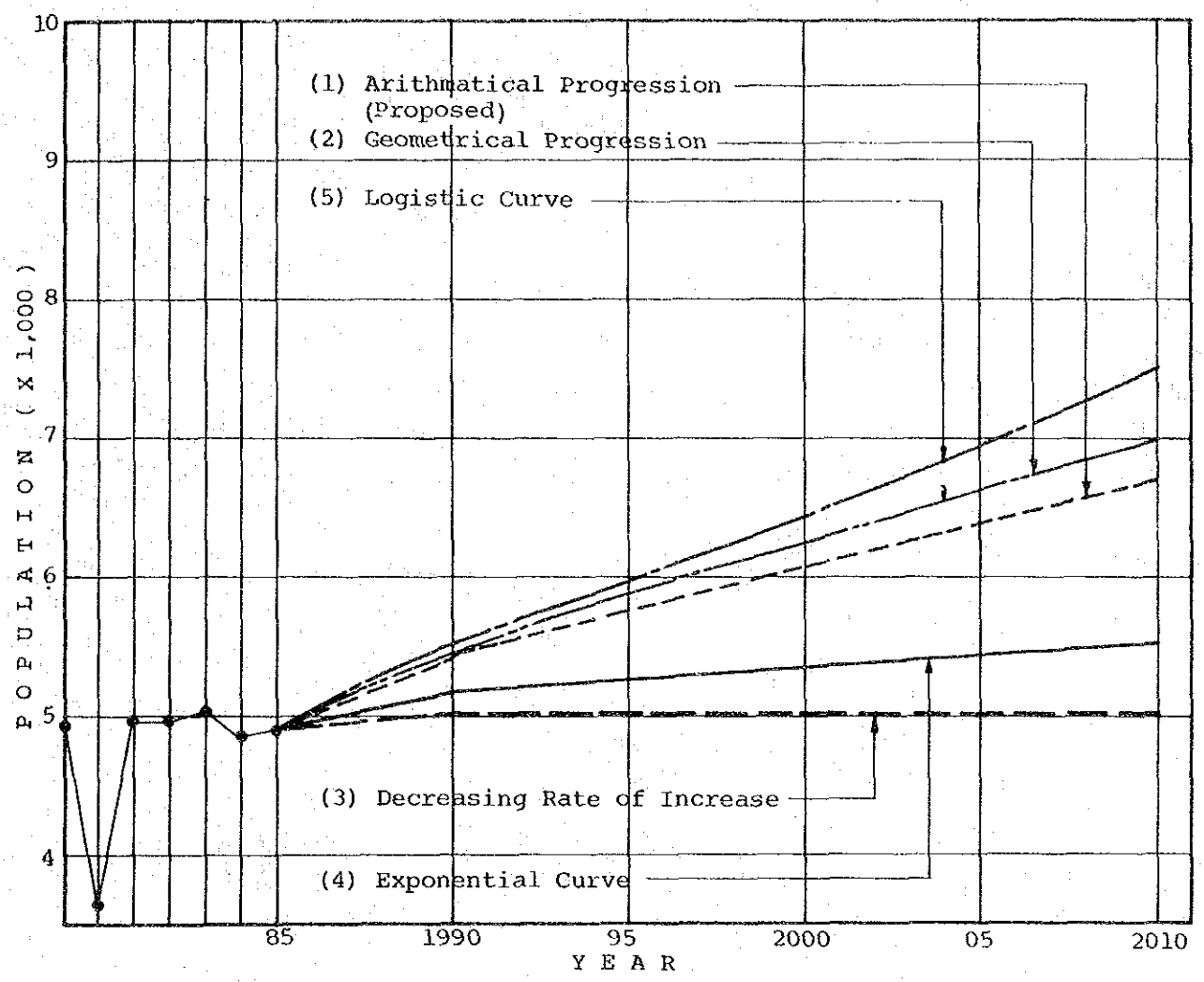

CASE	1985	1990	1995	2000	2005	2010
(1)	5,186	5,496	5,805	6,115	6,424	6,734
(2)	5,166	5,570	6,005	6,474	6,979	7,575
(3)	5,021	5,046	5,051	5,053	5,053	5,053
(4)	5,080	5,203	5,303	5,390	5,467	5,537
(5)	5,196	5,533	5,886	6,257	6,636	7,033

FIGURE	POPULATION FORECAST OF HANG DONG SANITARY DISTRICT
1.7	
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Table-1.2 POPULATION OF THE PROJECT AREA

AREA	1985	1990	1995	2000	2050	2010
CHIANGMAI	155,000	164,000	173,000	181,000	190,000	199,000
MAE RIM	11,100	11,600	12,000	12,600	13,100	13,600
SAN KAMPHAENG	17,000	18,800	20,600	22,400	24,200	26,100
SAN SAI	22,200	22,700	23,200	23,700	24,200	24,700
SARAPHI	8,800	9,600	10,300	11,100	12,000	13,000
HANG DONG	5,200	5,500	5,800	6,100	6,400	6,700
TOTAL	219,300	232,200	244,900	256,900	269,900	283,100

1.4 Present and Future Service Area

The present service area consists of Chiangmai Municipality, Mae Rim Sanitary District connected to the Municipality area, and two detached areas of San Kamphaeng and Hang Dong Sanitary Districts. The present service area of three waterworks totals to 51 sq km. Hang Dong Sanitary District is currently served by its own undertaking and excluded from the PWA management.

With due consideration to the urban development plans of the Municipality and the PWA's strategies, the future service area is worked out as follows:

By the year 2000, the total service area of Chiangmai, Mae Rim and San Kamphaeng will be enlarged to 73 sq km.

By the year 2010, the service area will expand, including Hang Dong Sanitary District, to 150 sq km, though Hang Dong will remain isolated from the other united areas.

Fig-1.9 presents the present and future service area.

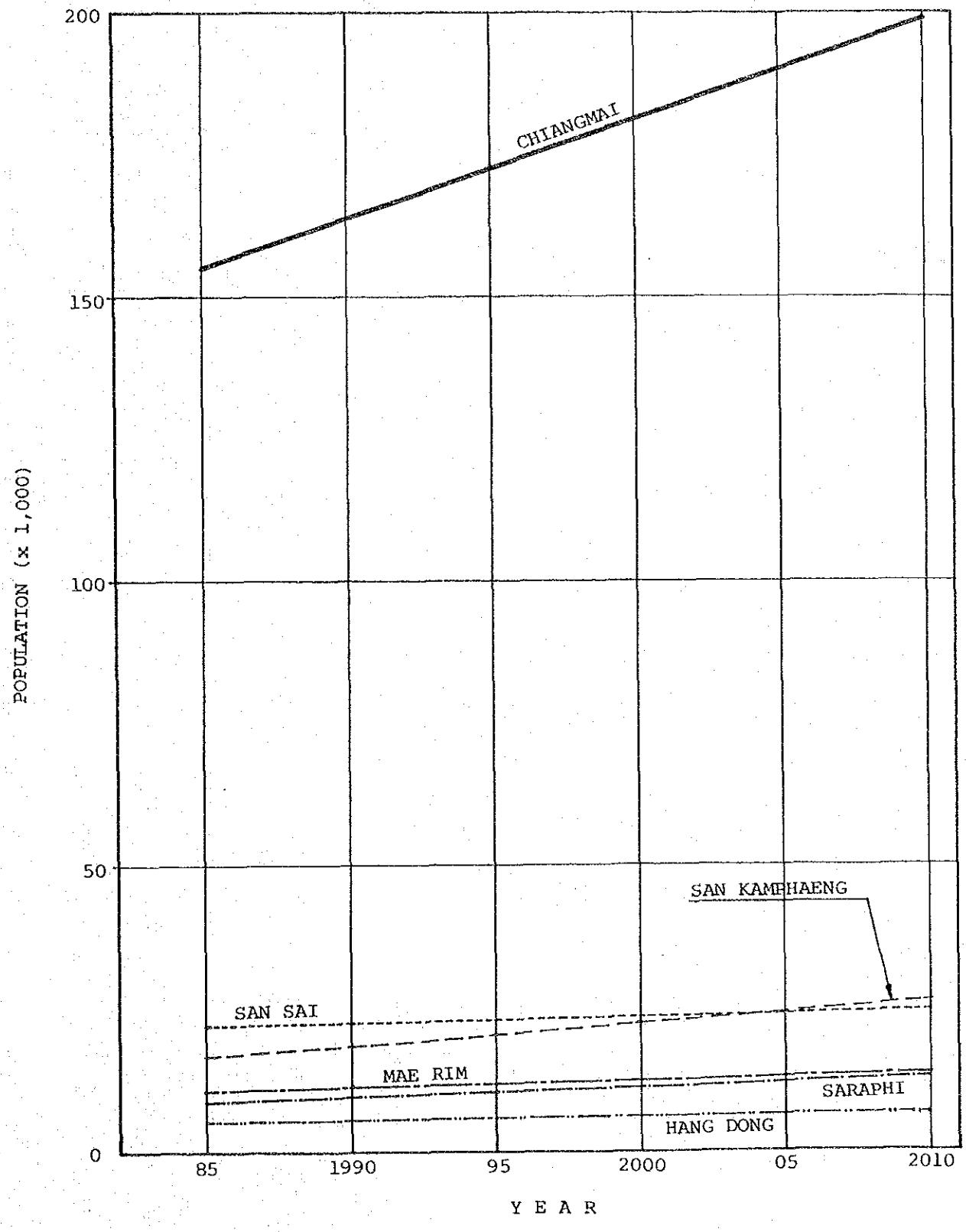

FIGURE	POPULATION FORECAST OF PROJECT AREA
1.8	(CHIANGMAI AND FIVE SANITARY DISTRICTS)

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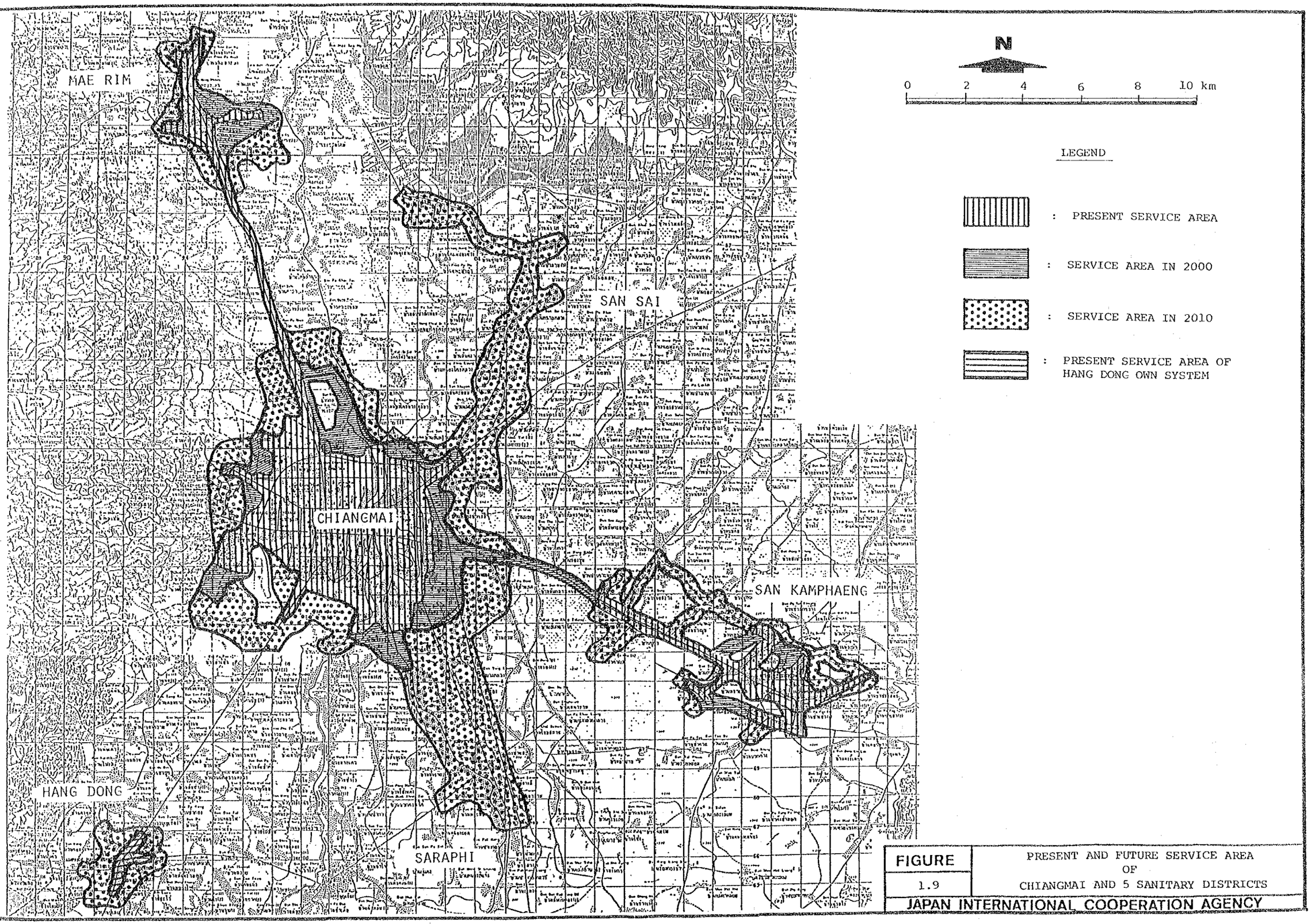

FIGURE	PRESENT AND FUTURE SERVICE AREA OF CHIANGMAI AND 5 SANITARY DISTRICTS
1.9	

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1.5 Service Ratio

1.5.1 Chiangmai

The service ratio in Chiangmai which had come up to 67 % in 1982 dropped sharply down to 45 % in 1983, caused by the sudden increase of population, resulting from the administrative incorporation described before.

As shown in Fig-1.10, the following four models of the service ratio increase were computed.

Case 1

The model of Case 1 is an application of the past trend.

Case 2

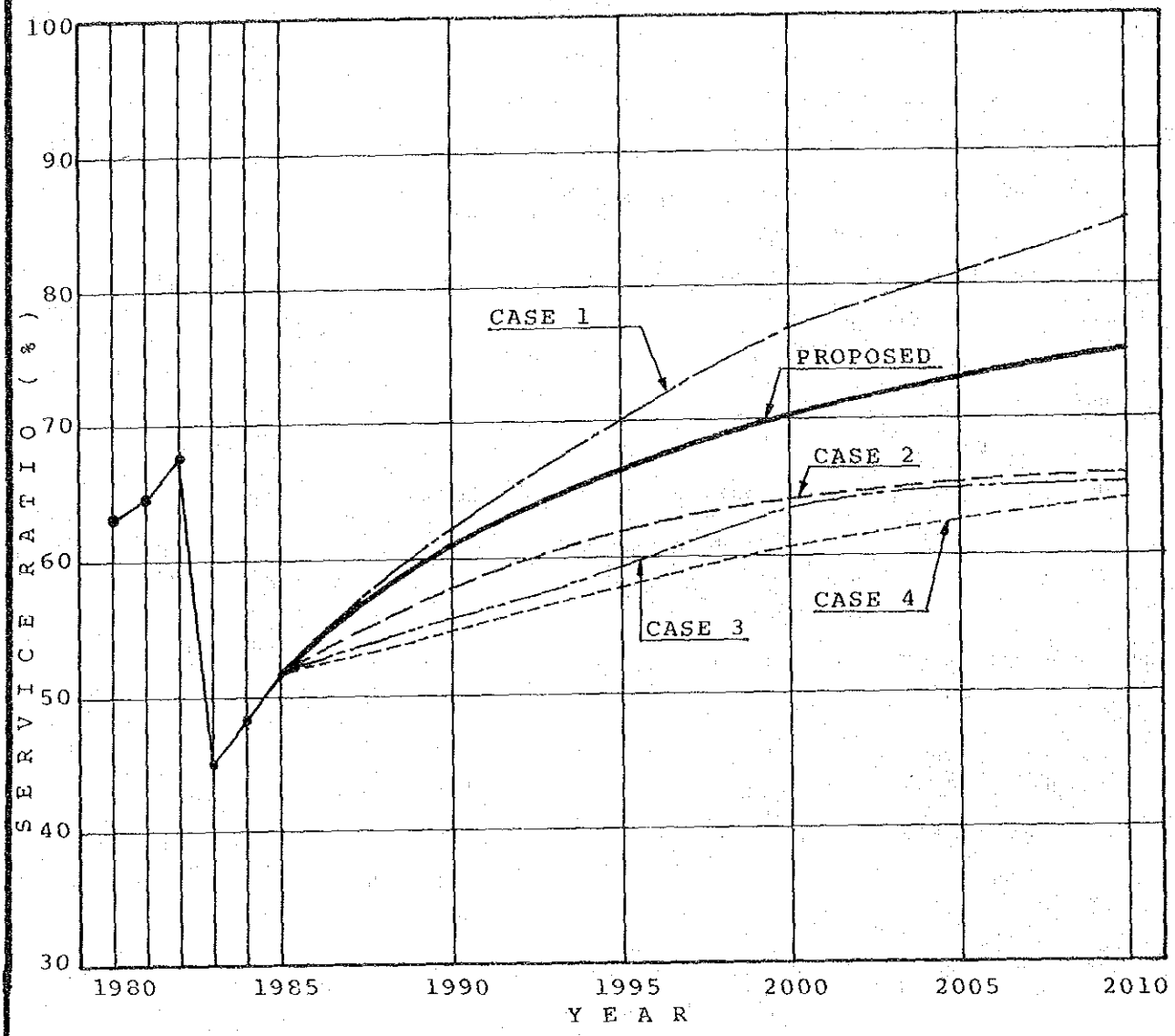
Case 2 was plotted, reflecting the results of the questionnaire survey. Apparently the house-connection service ratio positively correlated with the household income bracket. The model was drawn on an assumption that future upgrading of the average income level will increase the service ratio by house-connection. An annual increase of income is assumed at 8 % herein. Case 4 is an another model applying a lower rate of 4.5%.

CASE 3

Case 3 was plotted, reflecting the results of the questionnaire survey.

The model was made based on the following assumptions:

1) Of the presently unserved people, 42 % showed willingness to have house-connection. All of the willing people will be supplied by the year of 2010.
2) 42 % of the incremental population will be supplied by the service, immediately responding to it.



	1985	1990	1995	2000	2005	2010
CASE 1	52	62	70	77	81	85
CASE 2	52	58	62	64	65	66
CASE 3	52	56	59	64	65	65
CASE 4	52	54	58	61	63	64
PROPOSED	52	61	67	70	73	75

FIGURE	ESTIMATION OF SERVICE RATIO FOR CHIANGMAI
1.10	

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CASE 4

Case 4 was plotted in the same way as in Case 2, at an assumed growth rate of 4.5 %, lowest in the past.

The above four case are characterized as bellow:

Case 1 shows a ratio similar to the past average increase ratio in all over Japan. This trend may be applicable to such areas as showing rapid development of industries and commerce, but is to be considered too high in view of the characteristics of Chiangmai Municipality.

In Case 2 and Case 4, only one correlation factor such as the people's income level is employed, although there are some other factors which have lower corelationship to service ratio. Therefore, Case 2 and Case 4 can not be directly applied for the estimation of the future service ratio.

While the people's willingness may normally increase as the years go, Case 3 is made on an assumption that the present willingness be unchanged in the future, resulting in the apparently too low service ratio.

Considering the four cases, a service ratio forecast was projected, as seen in Fig-1.10.

1.5.2 Five Sanitary Districts

Fig-1.11 shows the future service ratio of the five sanitary districts under this plan.

In Mae Rim and San Kamphaeng where water supply is undertaken by their own existing systems, the ratio will increase following the past trend.

Three other sanitary districts are assumed at an initial service ratio of 15 % in 1992. The ratio is expected to rapidly increase, reaching the 1990-1995 level of Mae Rim and San Kamphaeng in 2010.

	1985	1990	1995	2000	2005	2010
MAE RIM	42	53	61	65	68	70
SAN KAMPHAENG	34	43	50	57	62	65
OTHER THREE S.O.		15	27	36	44	50

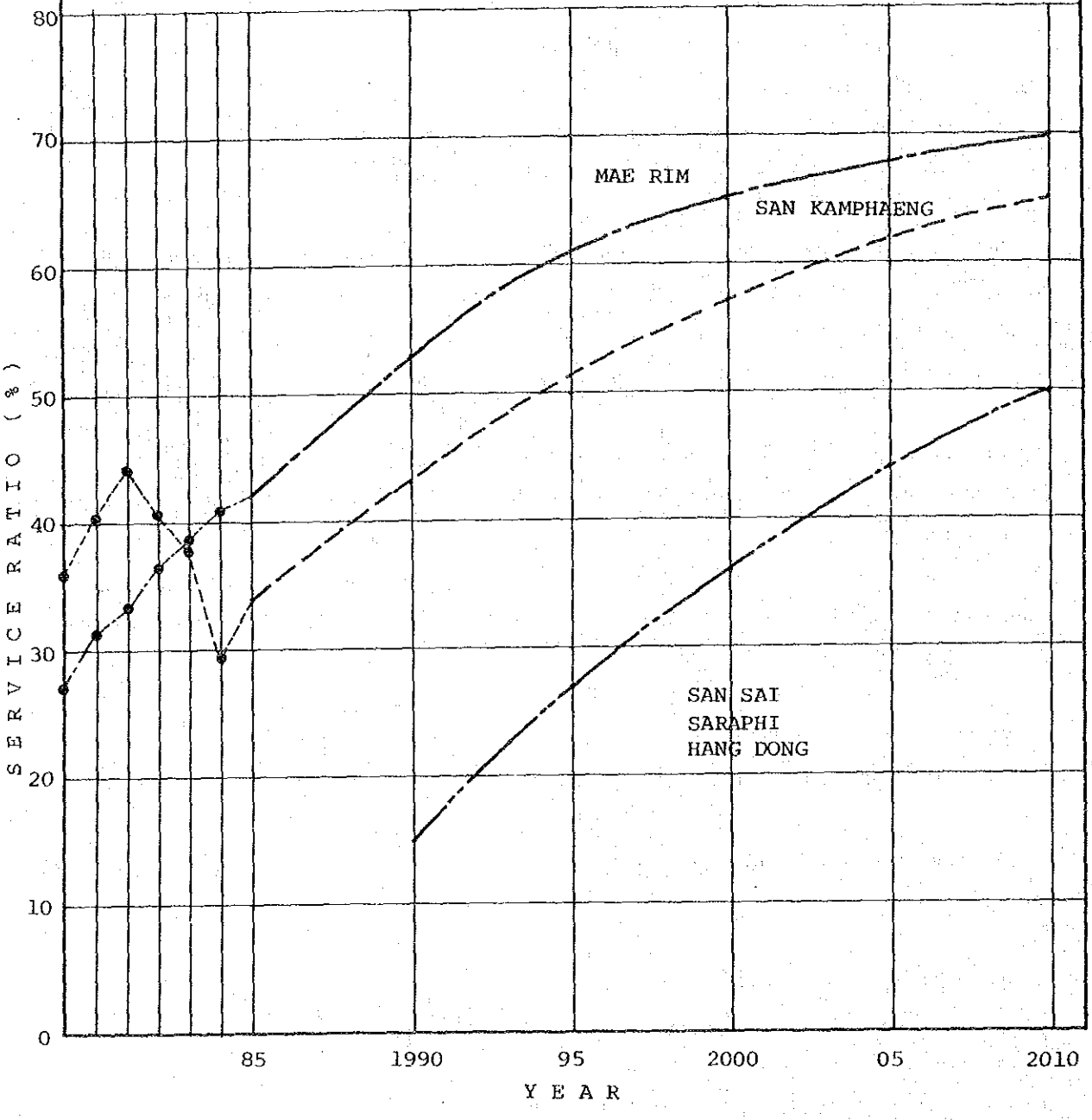

FIGURE	ESTIMATION OF SERVICE RATIO FOR 5 SANITARY DISTRICTS
1.11	

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1.6 Served Population

With the future service ratio calculated as above and the total population as listed in Table-1.2 previously, the future served population was estimated, as shown in Table-1.3.

1.7 Tourist Forecast

In forecasting the number of tourists, the same mathematical approach as applied to the population projection was employed. The results of such forecast employing the four mathematical models are shown in Fig-1.12 together with the past record.

Through the discussions with the Tourism Authority of Thailand (TAT) in Bangkok, regarding the number of tourists as well as the average length of stay, the exponential curve was concluded most realistic. It is shown in Fig-1.12.

Table-1.4 shows the average number of tourists a day, in every fifth year up to 2010.

Although the tourist population, certainly influential upon the water demand, was forecasted as above, the forecast was excluded from the served population and reflected in the hotel demand of the categories composing the water demand.

Concerning the tourist population forecast, the study team held discussions with DTCP and the Municipal Office in addition to TAT as mentioned above. The available reports on tourism development were also studied.

Table-1.3 FUTURE SERVICE RATIO AND SERVED POPULATION

Description	1985	1990	1995	2000	2005	2010
Chiangmai						
- Population	155,000	164,000	173,000	181,000	190,000	199,000
- Service Ration (%)	52	61	67	70	73	75
- Served Population	80,600	100,040	115,910	126,700	138,700	149,250
Mae Rim						
- Population	11,084	11,600	12,000	12,600	13,100	13,600
- Service Ration (%)	42	53	61	65	68	70
- Served Population	4,655	6,150	7,320	8,190	8,910	9,520
San Kamphaeng						
- Population	17,000	18,800	20,600	22,400	24,200	26,100
- Service Ration (%)	34	43	50	57	62	65
- Served Population	5,780	8,080	10,300	12,770	15,000	16,970
San Sai						
- Population	22,200	22,700	23,200	23,700	24,200	24,700
- Service Ration (%)	0	15	27	36	44	50
- Served Population	0	3,410	6,260	8,530	10,650	12,350
Saraphi						
- Population	8,800	9,600	10,300	11,100	12,000	13,000
- Service Ration (%)	0	15	27	36	44	50
- Served Population	0	1,440	2,780	4,000	5,280	6,500
Hang Dong						
- Population	5,200	5,500	5,800	6,100	6,400	6,700
- Service Ration (%)	0	15	27	36	44	50
- Served Population	0	830	1,570	2,200	2,820	3,350
Total						
- Population	219,280	232,200	244,900	256,900	269,900	283,100
- Served Population	91,040	119,950	144,140	162,390	181,360	197,940

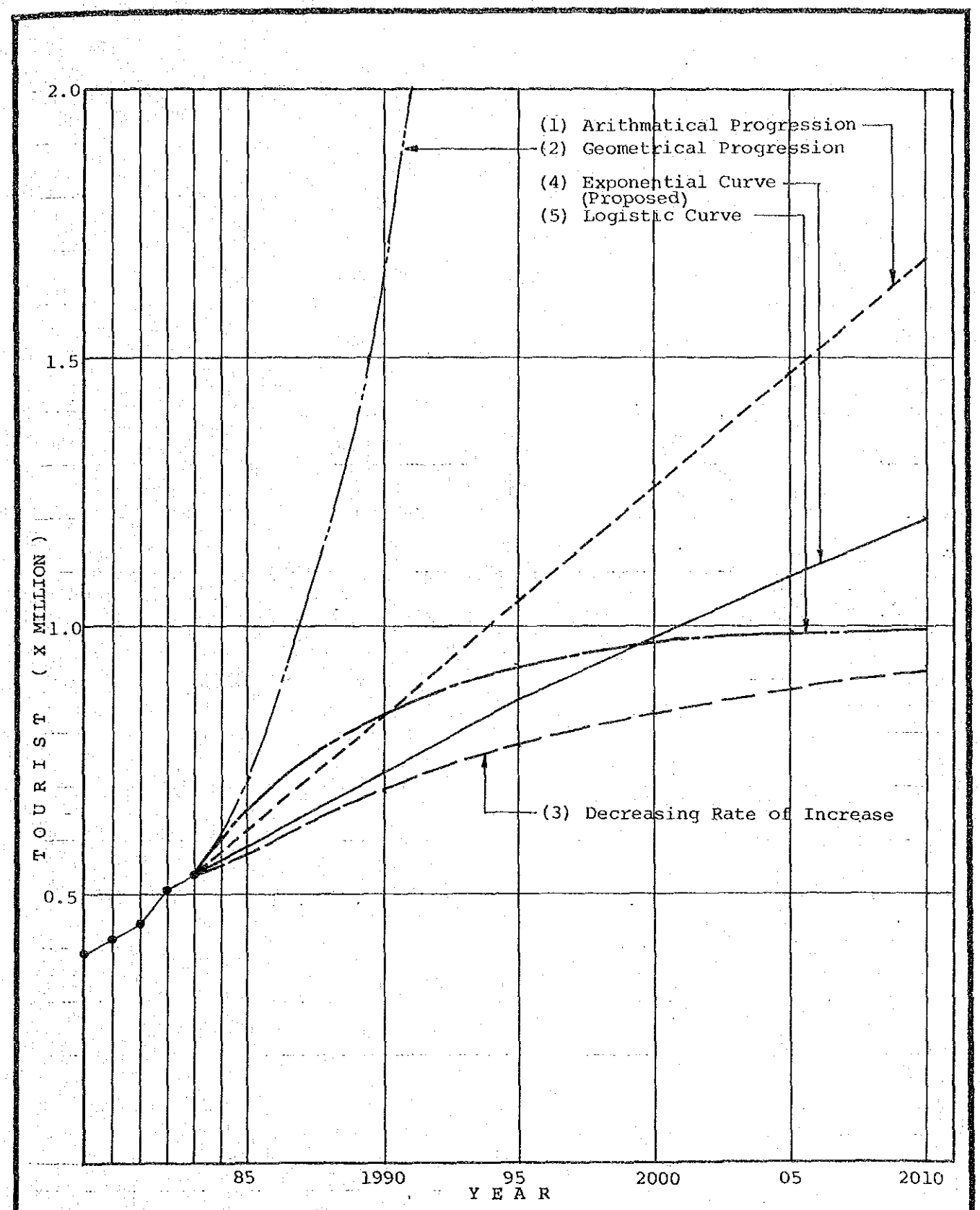

FIGURE	TOURIST FORECAST OF CHIANGMAI
1.12	

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Table-1.4 FORECAST OF TOURISTS IN CHIANGMAI

YEAR	ANNUAL TOURISTS (persons)	AVERAGE LENGTH OF STAY (days)	ANNUAL TOTAL STAY (man-days)	AVERAGE DAILY TOURISTS (persons/day)
1985	592,000	3	1,776,000	4,870
1990	733,000	3	2,199,000	6,020
1995	883,000	3	2,649,000	7,260
2000	983,000	3	2,949,000	8,080
2005	1,100,000	3	3,300,000	9,040
2010	1,205,000	3	3,615,000	9,900

NOTE : (ANNUAL TOTAL STAY) = (ANNUAL TOURISTS) X (AVERAGE LENGTH OF STAY)

(AVERAGE DAILY TOURISTS) = (ANNUAL TOTAL STAY)/365

Reference

In addition to the demographic data provided by PWA, the following information was referred to as the necessity errands:

- "Feasibility Study for Regional Cities Development," UNDP, 1983;
- "City Development Plan with 2005," Chiangmai Municipality Office; and
- "Master Plan Tourism Development of Chiangmai," Tourism Authority Thailand, 1979

APPENDIX 2

FUTURE WATER DEMAND

APPENDIX 2

APPENDIX 2 FUTURE WATER DEMAND

APPENDIX 2 FUTURE WATER DEMAND

2.1 Introduction

In this Appendix, the water demands in the planned service area are forecasted based on the analysis of records provided by PWA and the served population in future studied in Appendix to this report.

Fig-2.1 shows the steps taken in calculating the future water demand. The past record of water consumption was used in estimating the present per capita domestic water consumption and the classified consumption of government/public/Institution, tourism, commercial and others use. For each of the five classified consumptions, the future demand was forecasted.

Data of other areas like Pattaya, Phuket, Bangkok, Khon Kaen and Udonthani were referred to see the validity of estimation of the classified consumptions, proportion, toursist's per capita consumption, unaccounted for ratio and peak factors.

2.2 Present State of Water Use in Chiangmai

2.2.1 Production and Sale

The water consumption records collected during the site survey relate to the total water production, water sale and unaccounted-for ratio of the three waterworks in 1980 up to 1985 on the yearly basis, as given in Table-2.1.

As for Chiangmai and San Kamphaeng, the supply capacity is sufficient to meet the present demand, but Mae Rim, feeling shortage, has completed new plant recently.

Presently, the unaccounted-for ratio of the three is about 30 %.

2.2.2 Classification of Consumption

Available data resulted from the PWA survey in September 1985 show the

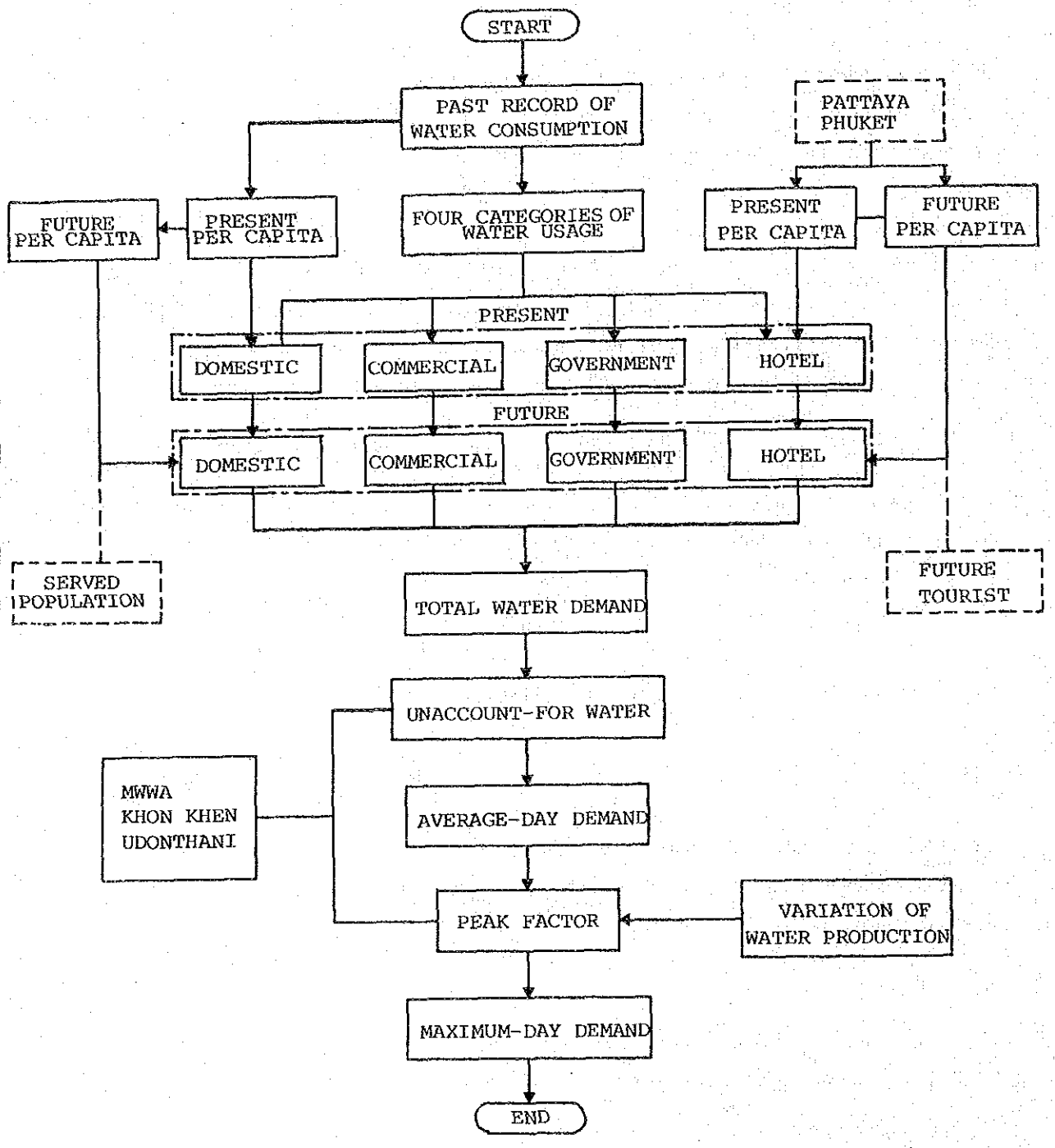

FIGURE	FLOW CHART OF PROJECTION OF WATER DEMAND
2.1	

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Table-2.1 PRODUCTION, SALES, UNACCOUNTED-FOR RATIO

CHIANGMAI WATERWORKS

YEAR	Production (cu m/year)	Water Sales (cu m/year)	(%)	Unaccounted-for (cu m/year)	(%)
1980	10,862,640	10,330,880	95	531,760	5
1981	12,631,880	6,410,714	51	6,221,166	49
1982	13,209,000	7,333,917	56	5,875,083	44
1983	13,706,790	7,530,044	55	6,176,746	45
1984	12,503,450	8,254,115	66	4,249,335	34
1985*	6,387,908	4,338,275	68	2,049,633	32

MAE RIM WATERWORKS

YEAR	Production (cu m/year)	Water Sales (cu m/year)	(%)	Unaccounted-for (cu m/year)	(%)
1980	399,995	333,480	83	66,515	17
1981	462,500	451,019	98	11,481	2
1982	553,140	534,583	97	18,557	3
1983	780,088	705,592	90	74,496	10
1984	818,940	652,872	80	166,068	20
1985*	402,540	283,776	70	118,764	30

SAN KAMPHAENG WATERWORKS

YEAR	Production (cu m/year)	Water Sales (cu m/year)	(%)	Unaccounted-for (cu m/year)	(%)
1980	320,745	211,248	66	109,497	34
1981	283,295	233,051	82	50,244	18
1982	301,410	288,416	96	12,994	4
1983	435,070	333,153	77	101,917	23
1984	498,416	339,570	68	158,846	32
1985*	251,290	173,369	69	77,921	31

Note :* From October 1984 to March 1985

consumption by categorized consumer, as listed in Table-2.2. It explains the character of Chiangmai as the center of northern region. Consumption by the domestic and government/public institution accounts for almost 90 % of the total water consumption.

Table-2.2 TYPE OF CONNECTIONS AND CONSUMPTION
(Chiangmai Waterworks, Sept. 1985)

Classification	No. of Connections	Consumption (cu m/month)	Percentage of Total (%)
Domestic	15,031	355,775	48.65
Government/Public Institution			
Government	94	182,057	24.90
School, University	44	13,209	1.81
Temple	13	1,438	0.20
Hospital	11	99,522	13.61
Sub-total	162	297,226	40.52
Tourism			
Hotel	35	14,766	2.02
Bungalow	1	340	0.05
Massage	3	353	0.05
Sub-total	39	15,459	2.12
Commercial			
Commercial	151	15,787	2.16
Restaurant	50	5,928	0.81
Sub-total	201	21,715	2.97
Others			
Resident/Rent House	62	6,669	0.91
Industry	23	6,960	0.95
Others	151	28,479	3.89
Sub-total	236	42,108	5.75
Total	15,669	731,283	100.00

In September 1985 when the data of Table-2.2 were collected, the per capita production was 445 lpcd and, as 34 % of it did not bear revenue, the revenue-bearing consumption was 294 lpcd.

The thirteen classified uses listed in Table-2.2 are re-grouped into five for the convenience of estimating water demands in future. Table-2.3 shows the five groups' percentage to the total and consumption expressed in terms of per capita. The percentage was calculated by re-grouping and the per capita consumption was calculated by dividing the consumption in Table-2.2 by the 1985 served population.

Table-2.3 PER CAPITA CONSUMPTION OF FOUR GROUPS
(Chiangmai Waterworks, Sept. 1985)

Group	Percentage of Total (%)	Per Capita Consumption (lpcd)
Domestic	48.65	143
Government/Public Institution	40.52	119
Tourism	2.12	6
Commercial	2.97	9
Others	5.75	17
Sub-total	100.00	294 (66 % of Total)
Non-revenue Water		151 (34 % of Total)

2.3 Future Water consumption in Chiangmai

The five consumption listed in Table-2.3 will be forecasted separately for future, as they are different in the nature.

The tourism consumption will be paid attention especially, as the area expects to receive increasing number of tourists.

2.3.1 Domestic Water Consumption

Other cities' planned consumption was referred in projecting the future change, as shown in Fig-2.2. Of the three cities, Khon Kaen is most close to Chiangmai in the aspects like size, level of urbanization and other apparent socio-economic conditions.

Chiangmai's domestic per capita consumption was assumed to be assimilated to Khon Kaen's. It will increase to 155 lpcd in 1990, 170 lpcd in 1995, 185 lpcd in 2000, 200 lpcd in 2005 and 210 lpcd in 2010.

2.3.2 Government/Public Institution Water Consumption

It includes the consumption of government/public institution, hospital, school and university, and temple.

The government offices are using 24.90 % of the total and in terms of per capita of the presently served population, their use amounts to 73 lpcd. Hospitals' use, 13.61 % of the total, equals 40 lpcd. As these two consumptions are already high, increase in the future was not counted.

The educational institutions and temples' consumption, put together, is 2.01 % or 6 lpcd at present and it was projected to grow at a slow rate to reach 8 lpcd in 2010.

Overall consumption of the above will be 119 lpcd in 1985 and 1990, 120 lpcd in 1995 and 2000, and 121 lpcd in 2000 and 2010.

2.3.3 Tourism Water Consumption

Consumption of hotels, bungalows and massage parlors included in the category is only 2.12 % of the total consumption. As Chiangmai is tourism-oriented, the unexpected lowness of consumption was looked into.

According to an estimate of tourists' number per day, studied by the Tourism Authority of Thailand (TAT), the tourists staying in Chiangmai numbered 4,862 on the average in 1985. Assuming the per capita consumption

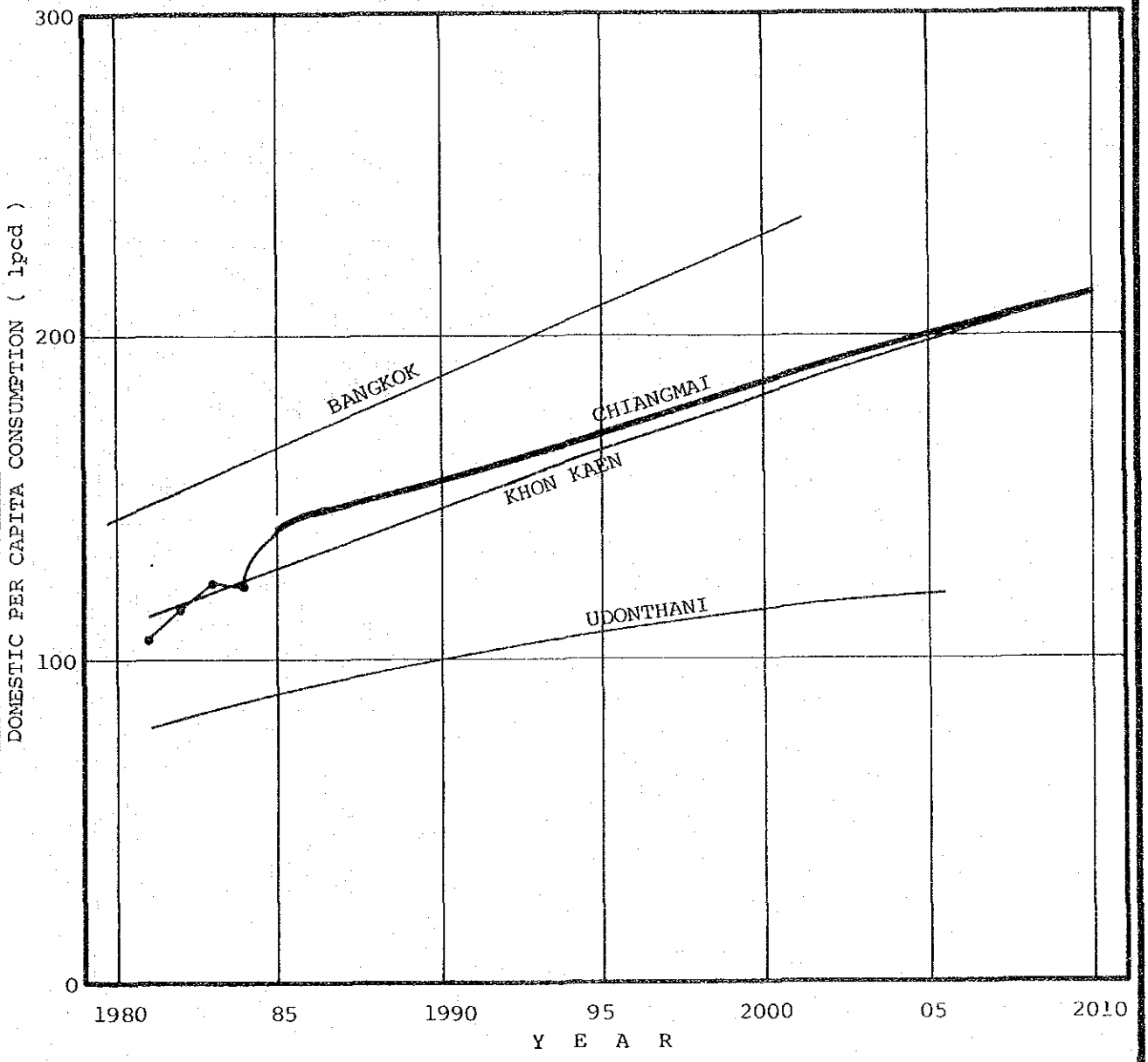

FIGURE	DOMESTIC PER CAPITA CONSUMPTION
2.2	

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as 700 lpcd which is quoted from the data of Pattaya and Phuket, the tourists' consumption should have amounted to 3,400 cu m/d.

The actual consumption was 515 cu m/d (15,459 cu m/month in Table-2.2) and 15.2 % of the calculated 3,400 cu m/d. The interpretation will be that those businesses are using water from other sources than the public supply.

The ratio, when increased from the said 15.2 % at present to 90 % in 2010.

In forecasting the future consumption, reliance on the public supply was presumed to increase at a rather high rate. The ratio, when increased from the said 15.2 % at present to 90 % in 2010, as listed later in Table-2.4, will force to change the situation.

The tourists' number, per capita consumption, reliance factor and consumption of the public supply are listed in Table-2.4.

Table-2.4 TOURISM WATER CONSUMPTION

Description	1985	1990	1995	2000	2005	2010
Tourists No.	4,862	6,028	8,079	8,079	9,015	9,907
Per Capita Consumption (lpcd)	700	700	750	750	750	750
Consumption (cu m/d)	3,404	4,219	5,317	6,060	6,761	7,431
Reliance Factor (%)	15	25	45	65	80	90
Consumption of Public Supply (cu m/d)	515	1,055	2,392	3,939	5,409	6,688

2.3.4 Commercial Water Consumption

It includes the consumption of commercial shops and restaurants. The consumption may be partially related to tourism, but here it is dealt with as an independent consumption.

For a tourism resort area, the consumption by commercial shops and restaurants is low seemingly, equal to 6.4 and 2.4 lpcd respectively, when calculated from Table-2.2. The commercial will grow linearly to 9 lpcd and the restaurants' 5 lpcd in 2010, it is estimated.

2.3.5 Other Water Consumptions

Included in this category are the resident/rent house, industry and other consumptions which do not belong to the defined classification.

Presently the consumptions, altogether, equal to 17 lpcd and it is assumed to grow linearly 29 lpcd in 2010.

2.3.6 Summary of Future Water consumption

Except for the tourism water consumption, the mentioned consumptions were expressed in terms of per capita of the served population.

For the convenience of calculation, the tourism will also be converted to the per capita and the result will be tabulated, as shown in Table-2.5.

Table-2.5 FUTURE WATER CONSUMPTION OF CHIANGMAI (lpcd)

Classification	1985	1990	1995	2000	2005	2010
Domestic	143	155	170	185	200	210
Government/ Public Institution	119	119	120	120	121	121
Tourism	6	11	20	31	39	45
Commercial	9	10	11	12	13	14
Others	17	19	22	24	27	29
Total	294	314	343	372	400	419

2.4 Future Water Consumption in Sanitary Districts

Mae Rim and San Kamphaeng have been served by the waterworks under the control of PWA and Hang Dong has a small water supply system controlled by the sanitary district. San Sai and Saraphi, though designated as sanitary districts, water supply system at present.

As Mae Rim and San Kamphaeng have some data to be relied on, the forecast will be made individually, upon consideration of foreseeable future change. Regarding San Sai, Saraphi and Hang Dong, no reliable information is found available. The forecast will have to be made on reasonable assumptions.

2.4.1 Mae Rim

The present total consumption can be divided into three parts. The first and largest is the government/public institutions and industries' use. As it is estimated at 290 lpcd, equaling to 69 % of the total, future increase is presumed to be low. The forecast is 290 lpcd in 1985, 296 lpcd in 2000 and 300 lpcd in 2010, a linear growth.

The second is the domestic consumption which is 80 lpcd presently, occupying 19 % of the total. It is comparatively low to the Chiangmai's current 143 lpcd. Assuming fast urbanization of the area, a linear growth to reach 103 lpcd in 2000 and 120 lpcd in 2010 is forecasted.

The third, other consumptions including commercial and domestic-size factories' use, is presently 50 lpcd. It also will be affected by urbanization and is assumed to grow to 65 lpcd in 2000 and 75 lpcd in 2010.

2.4.2 San Kamphaeng

San Kamphaeng's present consumption is divided into two parts. As the first part, the domestic consumption is also 80 lpcd presently and the possibility of fast urbanization will make the growth in future similar to Mae Rim.

The second, the other consumptions are 50 lpcd here. The same increase as that of Mae rim is forecasted.

2.4.3 San Sai, Saraphi, Hang Dong

Under this project, the supply to the three districts is planned to start in 2000. At the initial stage, the domestic per capita consumption will be 80 lpcd, same as the present Mae Rim and San Kamphaeng's consumption. It is expected to grow linearly to 120 lpcd in 2010, catching up on the two sanitary districts.

Regarding the other consumptions, a linear growth from 50 lpcd in 1990 to 70 lpcd in 2010 is assumed.

2.4.4 Summary of Future Water Consumption

Table-2.6 summarizes the above mentioned figures.

Table-2.6 FUTURE WATER CONSUMPTION FOR SANITARY DISTRICTS

Unit : lpcd

Location/ Classification	1985	1990	1995	2000	2005	2010
Mae Rim						
-Government/ Public Institution, Industries	290	292	294	296	298	300
-Domestic	80	87	95	103	112	120
-Others	50	55	60	65	70	75
Total	420	434	449	464	480	495
San Kamphaeng						
-Domestic	80	87	95	103	112	120
-Others	50	55	60	65	70	75
Total	130	142	155	168	182	195
San Sai, Saraphi, Hang Dong						
-Domestic		80	90	100	110	120
-Others		50	55	60	65	70
Total		130	145	160	175	190

2.5 Unaccounted-for Water Ratio

2.5.1 Chiangmai

The unaccounted-for water ratio of Chiangmai, 34 % in 1984 and 32 % in 1985, was not unreasonably high. These ratios are due to that some distribution pipelines laid more than 15 years ago have been aged and weakened.

Observing the PWA target of reducing the ratio to 25 % and 20 % respective-

ly in 1995 and 2010, the future ratio is forecasted as 27 % in 1990, 25 % in 1995, 23 % in 2000, 21 % 2005 and 20 % in 2010.

2.5.2 Mae Rim and San Kamphaeng

For the two sanitary districts, the present ratio is estimated at 33 %. The forecasted ratio for the future is 23 % in 2000 and 20 % in 2010, the same of Chiangmai's.

2.5.3 San Sai, Saraphi, Hang Dong

Even though the leakage ratio may be low at the initial stage of supply, the unaccounted-for water ratio will be affected by other factors. The forecasted ratio made for the Mae Rim and San Kamphaeng's is applied from 2000 to 2010.

2.6 Peak Factors

It is defined as the ratio of Maximum Day Demand to Average Day Demand.

A record taken at the Ubon Treatment Plant's output in Ubon was analyzed and the results were tabulated as shown in Table-2.7.

The average was calculated by dividing the total output by 274 days, from Jan 1st to Spt 30th of the year.

Considering the data 1.25 was selected for Chiangmai. The probability of occurrence exceeding the value is 13/121, on 11 % in the period. Most probably the maximum day appears in February and March.

Table-2.7 NUMBER OF DAYS ON PEAK FACTOR OF MAXIMUM DAY DEMAND TO AVERAGE DAY DEMAND
(Jan 1, 1985 - Sep 30, 1985, Ubon Treatment Plant)

NUMBER OF DAYS

Peak Factor	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total
1.35 -	-	-	-	-	-	-	-	-	-	0
1.30 - 1.34	-	2	2	-	-	-	-	-	-	4
1.25 - 1.29	-	3	6	-	-	-	-	-	-	9
1.20 - 1.24	-	2	4	-	-	-	-	-	-	6
1.15 - 1.19	-	4	9	-	-	-	-	-	-	13
1.10 - 1.14	-	9	3	6	4	2	-	-	-	24
1.05 - 1.09	3	2	1	9	7	1	-	-	-	23
1.00 - 1.04	10	4	2	7	6	9	1	2	1	42
Total	13	26	27	22	17	12	1	2	1	121

Regarding the five sanitary districts, 1.35 was adopted upon consideration that the factor tends to be higher for smaller size communities.

2.7 Future Water Demand

In Appendix 1 the served population of every fifth year from 1985 to 2010 is listed Table-1.3 and in Table-2.6 of this paper, the total consumption expressed in terms of per capita are tabulated. In Section 5 of this paper, the unaccounted-for water ratio in the planned period is described.

From the above, the average day demand has been calculated and the demand, multiplied by the peak factor in Section 6, has led to the maximum day demand. Table-2.8 shows the average day and maximum day water demand for the studied areas and in Fig-2.3 (1) and (2) are plotted the curves of Chiangmai and the five sanitary districts, respectively.

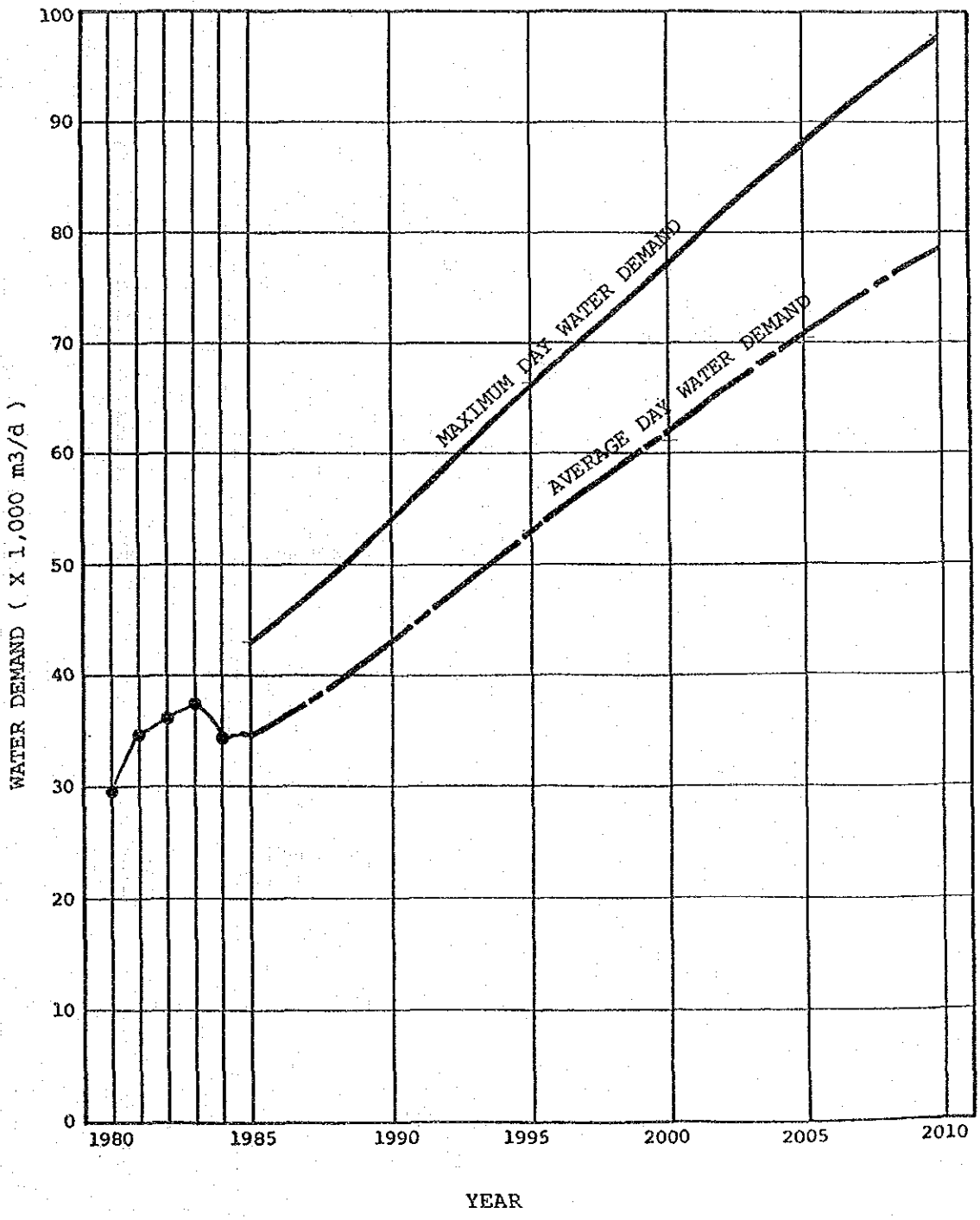

FIGURE	FUTURE AVERAGE DAY AND MAXIMUM DAY DEMAND OF CHIANGMAI
2.3(1)	

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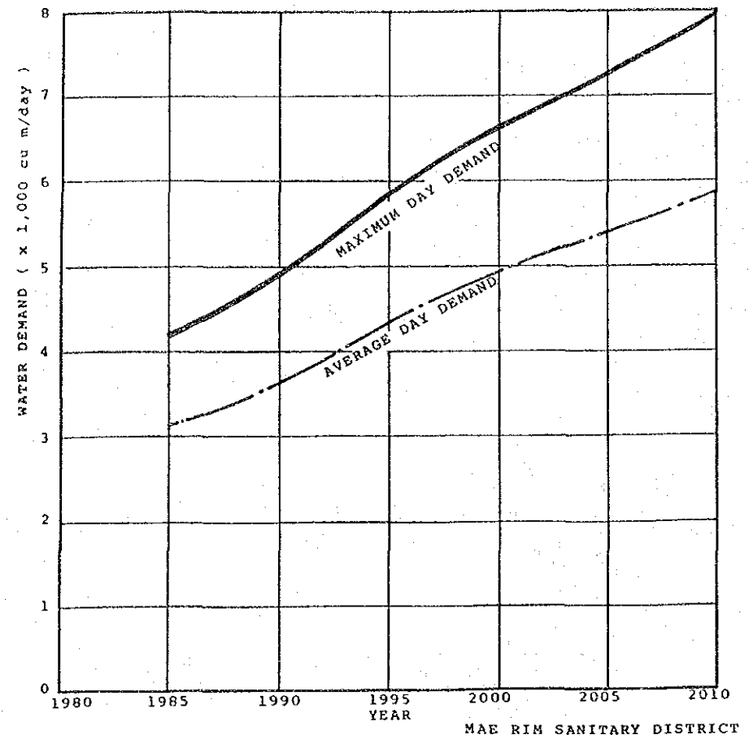
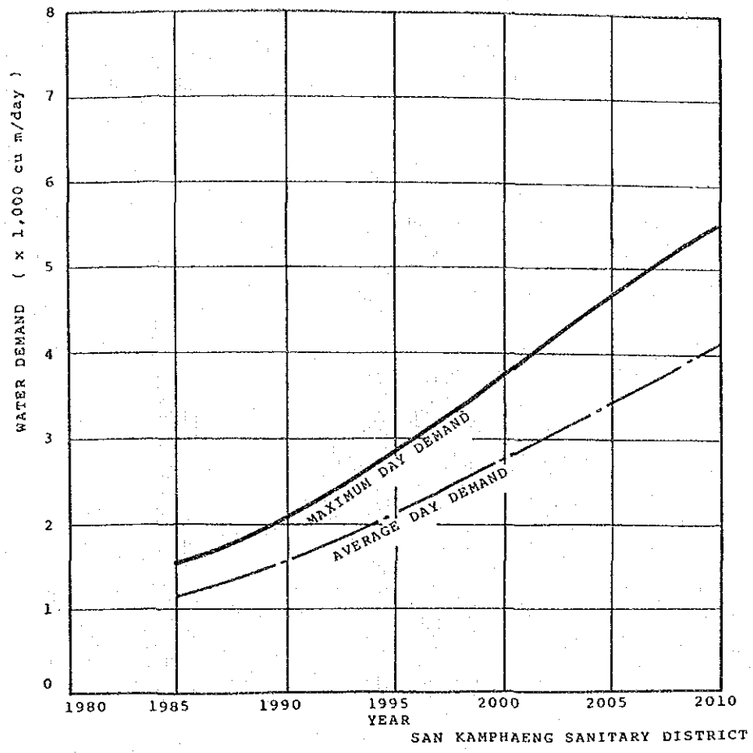
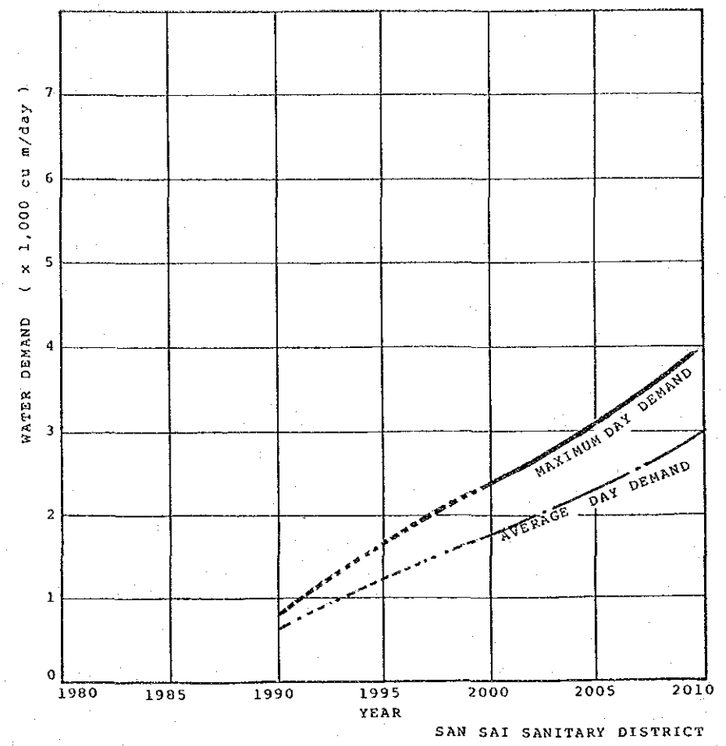
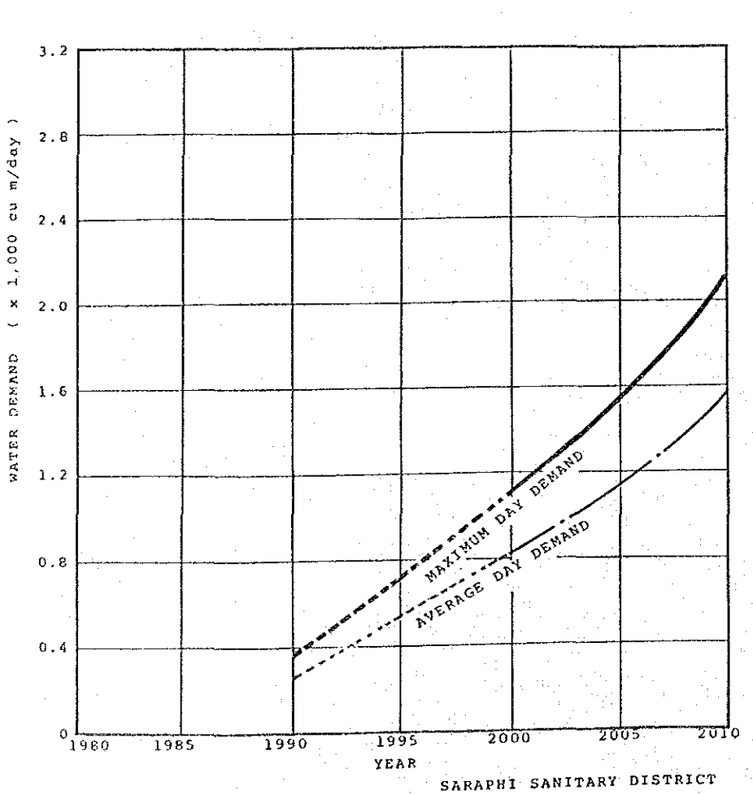
Table-2.8 AVERAGE DAY AND MAXIMUM DAY WATER DEMAND
(CHIANGMAI AND FIVE SANITARY DISTRICTS)

City/S.D.	1985		1990		1995		2000		2005		2010	
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Chiangmai	34,400	43,000	43,000	53,800	53,100	66,400	61,200	76,500	70,300	87,900	78,300	97,900
Mae Rim	2,920	3,940	3,650	4,920	4,370	5,900	4,940	6,660	5,410	7,310	5,880	7,940
San Kamphaeng	1,120	1,510	1,561	2,110	2,120	2,860	2,790	3,760	3,460	4,670	4,110	5,550
San Sai	0	0	0	0	0	0	1,750	2,360	2,290	3,090	2,960	4,000
Saraphi	0	0	0	0	0	0	820	1,110	1,140	1,530	1,560	2,110
HangfDong	0	0	0	0	0	0	450	610	610	820	800	1,090
S.D. Total	4,040	5,450	5,211	7,030	6,490	8,760	10,750	14,500	12,910	17,420	15,310	20,690
TOTAL	38,440	48,450	48,211	60,830	59,590	75,160	71,950	91,000	83,210	105,320	93,610	118,590









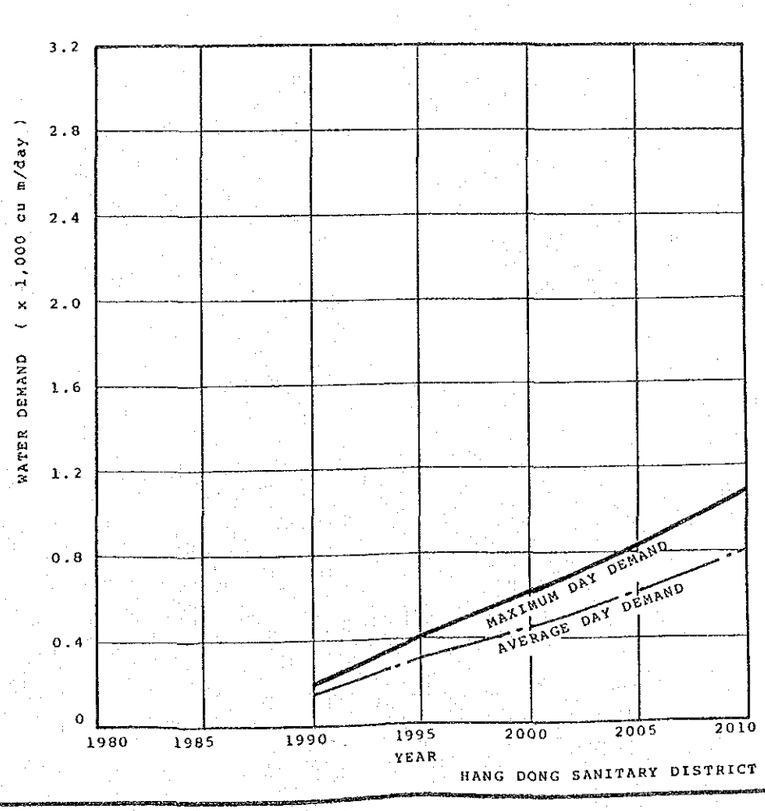


FIGURE	FUTURE AVERAGE DAY AND MAXIMUM DAY WATER DEMAND OF 5 SANITARY DISTRICTS
2.3(2)	

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APPENDIX 3

STUDY ON WATER SOURCE

APPENDIX 3

APPENDIX 3 STUDY ON WATER SOURCES

TABLE OF CONTENTS

3.1 Introduction

This Appendix aims to review and summarize the water resources conditions for the future development program of Chiangmai.

The study was carried out on both surface water and groundwater conditions, from December 16, 1985 to February 13, 1986 and from June 1 to August 31, 1986, to prepare the Development Plan and Feasibility Study on the Provincial Water Supply Projects.

From the viewpoints of climatic, geographical, topographical, hydrological and hydrogeological conditions, the availability of water resources and possibility of developing them to meet the planned future demand have been studied in detail, as seen in the following chapters and sections. Attention has been paid on the groundwater development as well as on the surface water development, in the study.

As qualitative assessment of water resources is as important as quantitative one, an appendix, Appendix 4, studying exclusively water quality in the area has been prepared by the team. In this report, the relevant matters are referred to and quoted from it.

3.2 Climate

The climate of Chiangmai is greatly influenced by the presence of the nearby mountains. There are two seasons, rainy and dry. The southwest monsoon usually affects the area, from May to October, and the long rainy season continues for 6 months. The annual average number of rainy days is about 115, while the total average rainfall is around 1,200 millimeters. (Table-3.1)

Climatological data of Chiangmai in 1981 are summarized in Table-3.2. The annual precipitation in 1981 was 1,173.4 mm. Rainfall begins the in mid-April, reaches its peak in July and then decreases gradually till about November.

The mean monthly maximum temperature ranges from 25.2 deg. C during dry season to 32.4 deg. C in September, 1981. The mean monthly minimum temperatures are in the range of 11.6 deg. C in December to 27.0 deg. C in June.

The annual pan evaporation is 1,754.2 mm which is comparatively higher than the annual precipitation of 1,173.4 mm at Chiangmai in 1981. The actual evapo-transpiration approximates 70 % of the Pan evaporation normally.

Based on the 1956 - 1974 data of the National Environmental Board, prepared by AIT and DMR (Feb. 1980), the water balance of the Upper Chao Phraya Plain including Chiangmai has been studied to evaluate hydrologic conditions in the area. The result is shown in Table-3.3 and Fig-3.1.

The mean annual rainfall over the area is 1,202.2 mm, and mean stream flow (runoff) as measured at 217.4 mm is 18.1 % of the annual rainfall.

The average annual evapo-transpiration is 887.0 mm, which equals 73.8 % of the annual rainfall, while the annual groundwater recharge is 95.9 mm, only 8.0 % of the annual rainfall in the area.

3.3 Location and Topography

Chiangmai city is located in the flat plain of the northern part of the

Table-3.1 MONTHLY RAINFALL : 1972 - 1981

ปี Year	ทั้งปี Annual		มกราคม January		กุมภาพันธ์ February		มีนาคม March		เมษายน April		พฤษภาคม May		มิถุนายน June		กรกฎาคม July		สิงหาคม August		กันยายน September		ตุลาคม October		พฤศจิกายน November		ธันวาคม December	
	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.	วัน Days	มม. mm.
เฉลี่ย Average	115	1,217.7	2	21.6	1	3.6	3	21.5	6	49.7	15	156.3	15	122.0	18	185.4	21	237.7	17	230.2	11	115.3	5	53.4	2	29.5
เบี่ยงเบน S.D.	11.1	169.5	2.5	31.8	1.2	5.4	1.9	28.5	2.8	46.7	3.4	51.3	4.2	39.1	3.5	113.1	3.9	75.7	3.2	46.8	2.5	68.9	3.6	57.1	2.0	33.1
2515 (1972) ...	111	1,079.8	–	T	1	6.3	1	5.2	8	156.1	12	65.0	16	91.2	16	70.0	21	264.3	12	193.2	8	46.4	11	164.7	5	17.4
2516 (1973) ...	132	1,296.8	0	0.0	0	0.0	5	86.5	2	4.4	22	163.0	17	128.7	23	233.5	27	330.1	21	295.4	11	30.2	4	25.0	0	0.0
2517 (1974) ...	114	1,173.0	0	0.0	0	0.0	5	13.8	10	51.6	13	88.4	11	106.6	16	159.9	19	203.2	20	278.6	11	175.1	8	90.8	1	5.0
2518 (1975) ...	127	1,560.4	6	74.9	1	4.5	1	3.5	3	7.8	11	171.6	19	185.8	20	190.9	25	378.4	18	243.2	13	168.9	6	77.7	4	53.2
2519 (1976) ...	105	1,043.0	0	0.0	1	5.4	5	6.5	5	20.8	13	173.7	13	96.5	14	97.3	21	209.7	16	198.1	12	223.8	3	3.1	2	8.1
2520 (1977) ...	120	1,272.5	3	63.2	1	2.2	3	35.0	9	90.2	17	121.0	11	98.3	19	120.1	17	222.5	17	303.6	16	164.2	1	3.0	6	49.2
2521 (1978) ...	111	1,350.8	5	34.6	4	17.2	–	T	5	13.9	16	198.2	10	61.9	22	455.7	20	279.4	17	211.5	8	70.0	2	2.1	2	6.3
2522 (1979) ...	96	967.8	0	0.0	1	0.7	1	1.7	4	63.1	17	194.3	12	178.1	13	89.9	20	145.0	17	200.0	11	95.0	0	0.0	0	0.0
2523 (1980) ...	109	1,224.0	0	0.0	0	0.0	4	20.0	7	29.0	12	232.2	19	142.9	16	182.9	15	146.0	19	172.9	9	146.1	6	54.4	2	97.6
2524 (1981) ...	126	1,209.1	–	T	0	0.0	–	T	9	60.5	17	156.0	22	130.2	21	253.7	26	198.6	11	205.1	9	33.7	9	113.2	2	58.1

– Not available.

T Not measurable.

Source : Meteorological Department, Ministry of Communications.

Table-3.2 CLIMATOLOGICAL DATA

Chiangmai, 1981

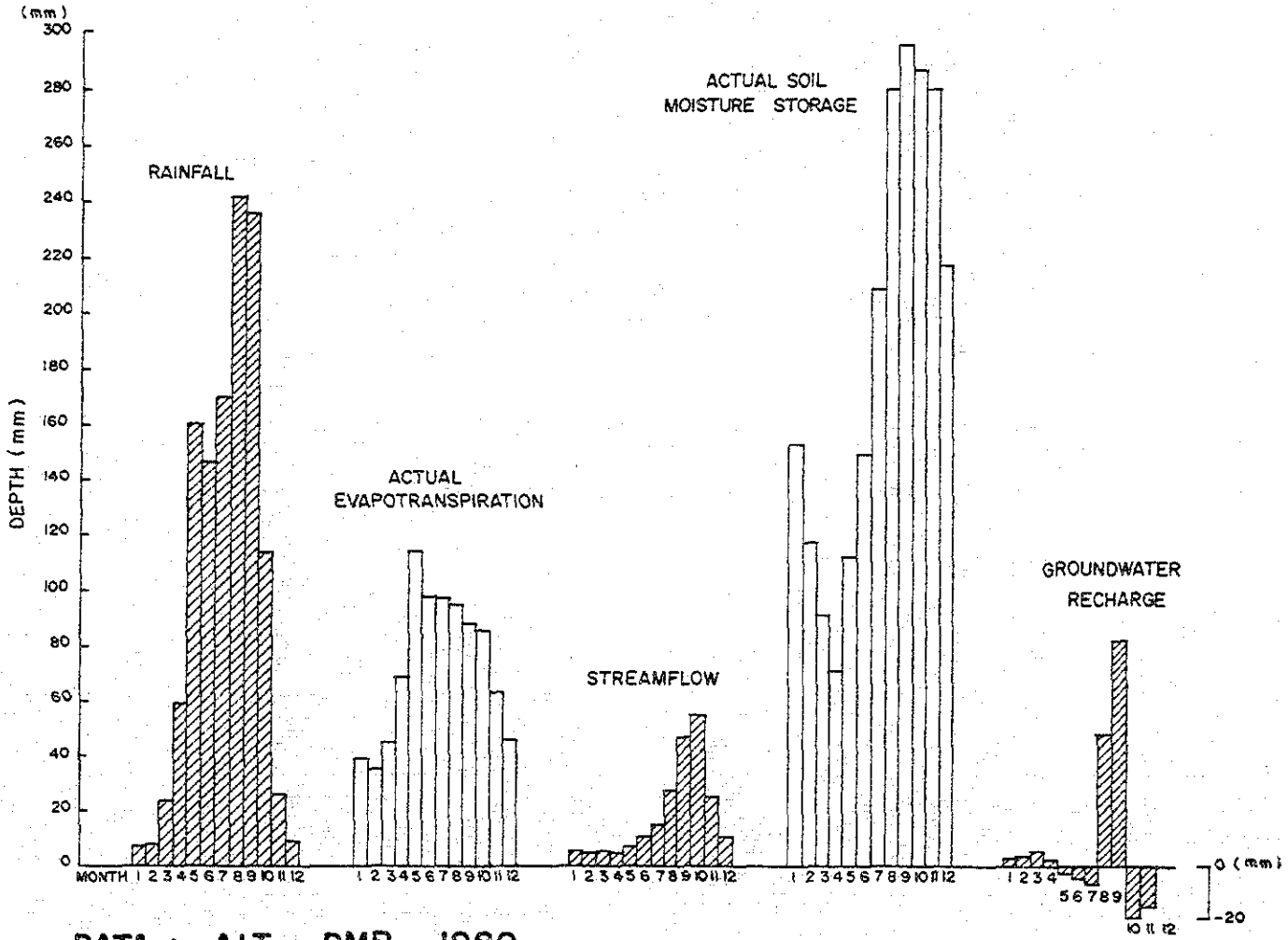
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nev	Dec	Total
Precipitation (mm)	0.6	0.0	0.0	52.8	261.8	98.2	276.4	134.2	155.7	33.8	114.5	45.4	1173.4
Daily Evaporation (mm)	113.6	156.0	200.4	210.9	168.0	131.5	135.6	130.9	151.2	154.9	108.0	93.2	1754.2
Water Temperature (°c) (max/min)	25.2 19.3	26.6 21.1	29.8 24.4	31.5 22.9	32.4 25.5	31.6 27.0	31.4 23.8	32.1 25.1	32.4 24.4	32.2 26.2	31.0 19.5	27.1 11.6	32.4 11.6
Temperature (°c) (max/min)	30.1 11.0	35.5 10.0	38.0 15.0	38.5 17.4	38.0 20.2	33.5 23.0	33.8 25.5	33.5 23.0	36.0 22.0	34.0 21.0	34.0 16.2	32.0 11.1	38.5 10.0
Daily Wind movement Mean (Km)	44.3	46.0	54.7	54.3	53.6	43.2	40.6	44.4	40.8	42.5	36.0	34.6	-
Daily Relative Humidity (max/min) (cm)	92 81	92 75	90 66	90 62	89 78	88 78	89 80	90 77	99 82	89 82	90 78	92 70	-
Daily Sunshine (Mean Hours)	8.06	8.86	8.79	7.54	6.27	3.33	3.21	4.26	5.62	6.38	5.14	6.16	-

Table-3.3 WATER BALANCE COMPONENTS UPPER CHAO PHRAYA BASIN PERIOD 1956 TO 1974

	RAINFALL	ACTUAL EVAPO-TRANSPIRATION	STREAMFLOW	ACTUAL SOIL MOISTURE	CHANGE IN SOIL MOISTURE	GROUNDWATER RECHARGE
JAN	6.9	40.3	5.9	153.9	-45.5	+ 2.5
FEB	7.8	36.1	4.4	118.1	-35.8	+ 3.8
MAR	24.0	46.5	4.8	86.3	-31.8	+ 5.4
APR	59.5	70.1	4.6	72.1	-14.2	+ 2.5
MAY	160.5	114.8	6.7	113.0	+40.9	- 2.3
JUN	147.2	98.7	10.5	150.8	+37.8	- 4.5
JUL	170.6	98.1	14.6	211.4	+60.6	- 7.0
AUG	240.9	93.5	27.9	283.9	+72.5	+48.0
SEP	236.1	89.3	47.1	299.7	+15.8	+82.7
OCT	113.3	89.1	55.3	291.3	- 8.4	-19.6
NOV	26.4	64.2	25.5	244.4	-46.9	-14.7
DEC	9.0	46.8	10.1	199.4	-45.0	- 0.9
ANNUAL	1202.2	887.0	217.4			+95.9

(ALL VALUES ARE IN MILLIMETERS) DATA : AIT, DMR, 1980

WATER BALANCE COMPONENTS OF UPPER CHAO PHRAYA BASIN



DATA : AIT , DMR , 1980

(1956 – 1974)

FIGURE	WATER BALANCE COMPONENTS OF
3.1	UPPER CHAO PHRAYA BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY	

Ping river basin, about 650 km north of Bangkok, at the elevation of 300 to 320 m above the Mean Sea Level (MSL), developed along the Ping River and surrounded by mountains. In the city area, the north to south slope is gentle while the east to west moderately steep.

The major river in the basin is the Ping River, which has its origins in the Chiang Dao northern districts mountains. The river flows south through Chiangmai city dividing it into two.

3.4 Hydrology

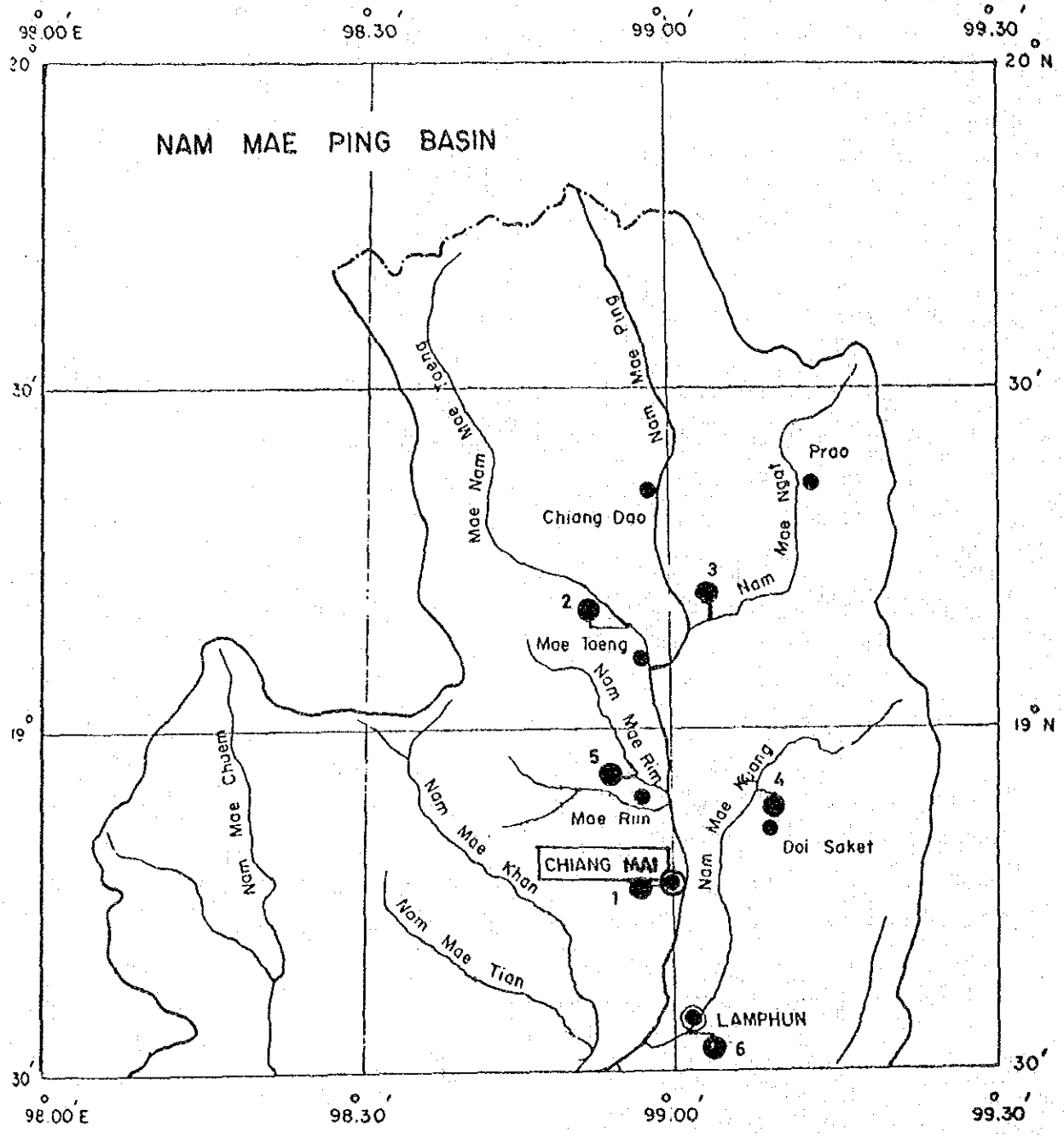
The Ping River and its tributaries are the main water source for Chiangmai city and the Northern region. Fig-3.2 illustrates the main tributaries of the Ping River consisting of Mae Taeng, Mae Ngat, Mae Rim and Mae Kuang, and the location of gauging stations by the mainstream which are under control of RID mostly. Table-3.4 summarizes the hydrologic records in the Ping River Basin in the vicinity of Chiangmai, made on the basis of RID data in 1983.

1) Ping River

The drainage area of the Ping River, measured at the gauging station Nawarath Bridge Muang Chiangmai, is 6,355 sq km and the mean annual runoff based on 1921 to 1980 data, 2,026.5 MCM (64.26 cu m/s) corresponds with 0.319 MCM/sq km or 10.11 l/s/sq km average yield of runoff. On the other hand, the instantaneous peak discharge was 729 cu m/s recorded August 25, 1973, and the specific yield of peak discharge was 0.115 cu m/s/sq km.

Fig-3.3 shows the recent flow duration curve of Mae Ping River based on the daily runoff data of 1981 at RID gauge station in Chiangmai, before the operation of Mae Ngat Dam. The droughty flow, the 335 days probability in a year or 97.3 % of probability, was 0.3 cu m/s or 25,900 cu m/d against the intake capacity of Paton and Wang Shig Kam Treatment Plans of 23,800 cu m/d, about 92 % of droughty flow.

In the year of 1986, the situation has changed for the better, increasing the river flow. The Mae Ngat Dam was newly constructed in 1985 the upper stream of Mae Ping River, about 45 km northeast of Chiangmai city, and



DATA : EGAT, Dec. 1980

Surface Runoff and Specific Yield of River Basins in Thailand

FIGURE 3.2	THE PING RIVER AND TRIBUTARIES, LOCATION OF GAUGING STATIONS

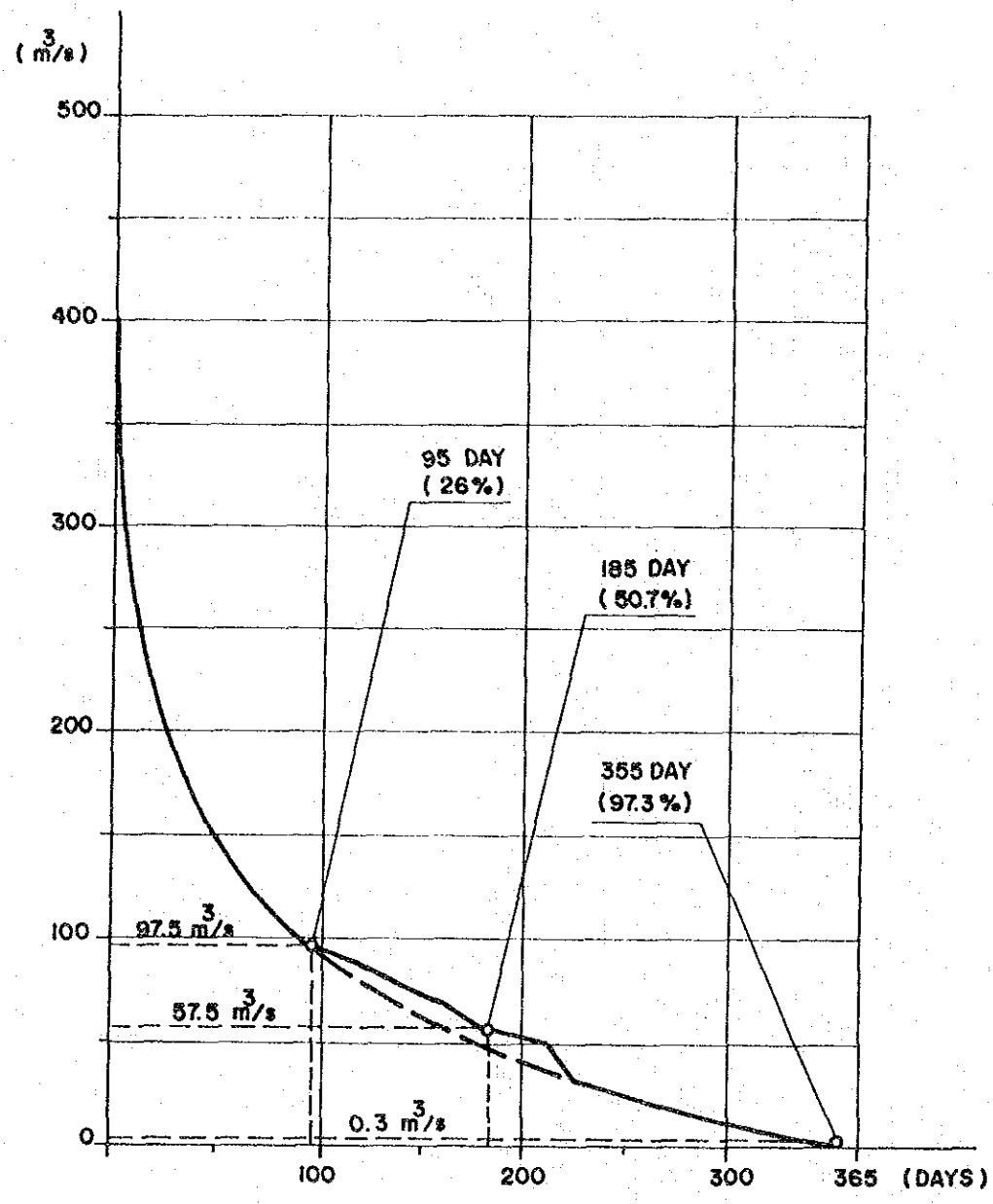
JAPAN INTERNATIONAL COOPERATION AGENCY

Table-3.4 HYDROLOGIC DATA OF PING RIVER AT CHIANGMAI

DATA: RID, Apr., 1983
NEA, 1981, 1983

No.	River Stream	Station	Drainage Area (km2)	No. of Years	Period	Mean Annual		Average Yield of Runoff	Instantaneous Peak Discharge and Specific Yield		
						Discharge (m3/s)	Runoff (MCM)	Lit./sec./km2	(m3/s)	Date	(m3/s/km2)
1.	Ping	Nawarath Bridge Muang (P.1) Chiangmai	6,355	58	1921 - 1980	64.26	2,026.5	10.11	729	Aug. 25 1973	0.115
2.	Mae Taeng	Mae Taeng Bridge (P.4A)	1,902	25	1955 - 1980	20.18	636.4	10.61	739	Aug. 24 1973	0.388
3.	Mae Ngat*	Ban Mai (P. 34)	1,261	14	1966 - 1979* (Ending)	12.02	379	9.53	503	Aug. 24 1973	0.399
4.	Mae Kuang	Ban Pha Taek (P. 34)	566	7	1974 - 1980	7.28	229.4	12.85	347	Aug. 25 1973	0.613
5.	Mae Rim	Mae Rim Bridge (P. 21)	515	26	1954 - 1980	5.07	159.8	9.84	96	Sep. 22 1975	0.186
6.	Mae Kuang	Tha Singh Phitak Br. Muang Lamphun (P. 5)	1,569	29	1951 - 1980	25.79	831.2	16.43	376	Aug. 26 1973	0.240

FLOW CURVE OF PING RIVER AT CHIANGMAI , 1981



DATA , RID , 1983

FIGURE	FLOW CURVE OF PING RIVER AT CHIANGMAI, 1981
3.3	

JAPAN INTERNATIONAL COOPERATION AGENCY

starting reservoir operation for main purpose of irrigation including water power plant and domestic uses for Chiangmai city.

2) Mae Taeng River

The Mae Taeng River originates in the Dan Lao mountain range in the north of Chiangmai and flows through Mae Taeng District before joining the Ping River. This tributary is 125 km long and carries water throughout the year. The drainage area at Mae Taeng bridge is 1,902 sq km with the mean annual runoff of 636.4 MCM or 20.18 cu m/s through 25 years from 1955 to 1980, corresponds with 0.335 MCM/sq km or 10.61 l/s/sq km average yield of runoff. On the other hand, the instantaneous peak discharge was 739 cu m/s recorded August 24, 1973, and the specific yield of peak discharge was 0.388 cu m/s/sq km.

The Mae Taeng Irrigation Canal originates from this river at an upstream point of the Mae Taeng - Ping confluence. The Mae Taeng Irrigation Canal starts from Mae Taeng Diversion, about 30 km north of Chiangmai city, runs in the north-south direction through the western side of Chiangmai having the total length of 75 km. Mae Taeng Irrigation Canal constructed and maintained by RID is the important water source for the Umong Treatment Plant supplying the rate of 30,000 cu m/d (10.95 MCM/y).

Fig-3.4 illustrates the comparison of discharge pattern of Mae Taeng River and Mae Taeng Irrigation Canal from 1971 to 1986. The average annual canal flow ranges from 6.91 to 13.42 cu m/s(597,000 to 1,159,000 cu m/d) which is quite large capacity for the raw water supply 30,000 cu m/d of the Umong Treatment Plant.

3) Mae Ngat River

The Mae Ngat River origins in the northeastern mountains of Chiangmai province. The tributary is 100 km long and supplies water throughout the year and, now 1986 the Mae Ngat Dam is constructed on this river. The drainage area at Ban Mai is 1,261 sq km and the mean annual runoff is 379 MCM from 1966 to 1979, corresponds with 0.301 MCM/sq km or 9.53 l/s/sq km average yield of runoff. On the other hand, the instantaneous peak discharge was 503 cu m/s recorded August 24, 1973, and the specific yield of peak discharge was 0.399 cu m/s/sq km.

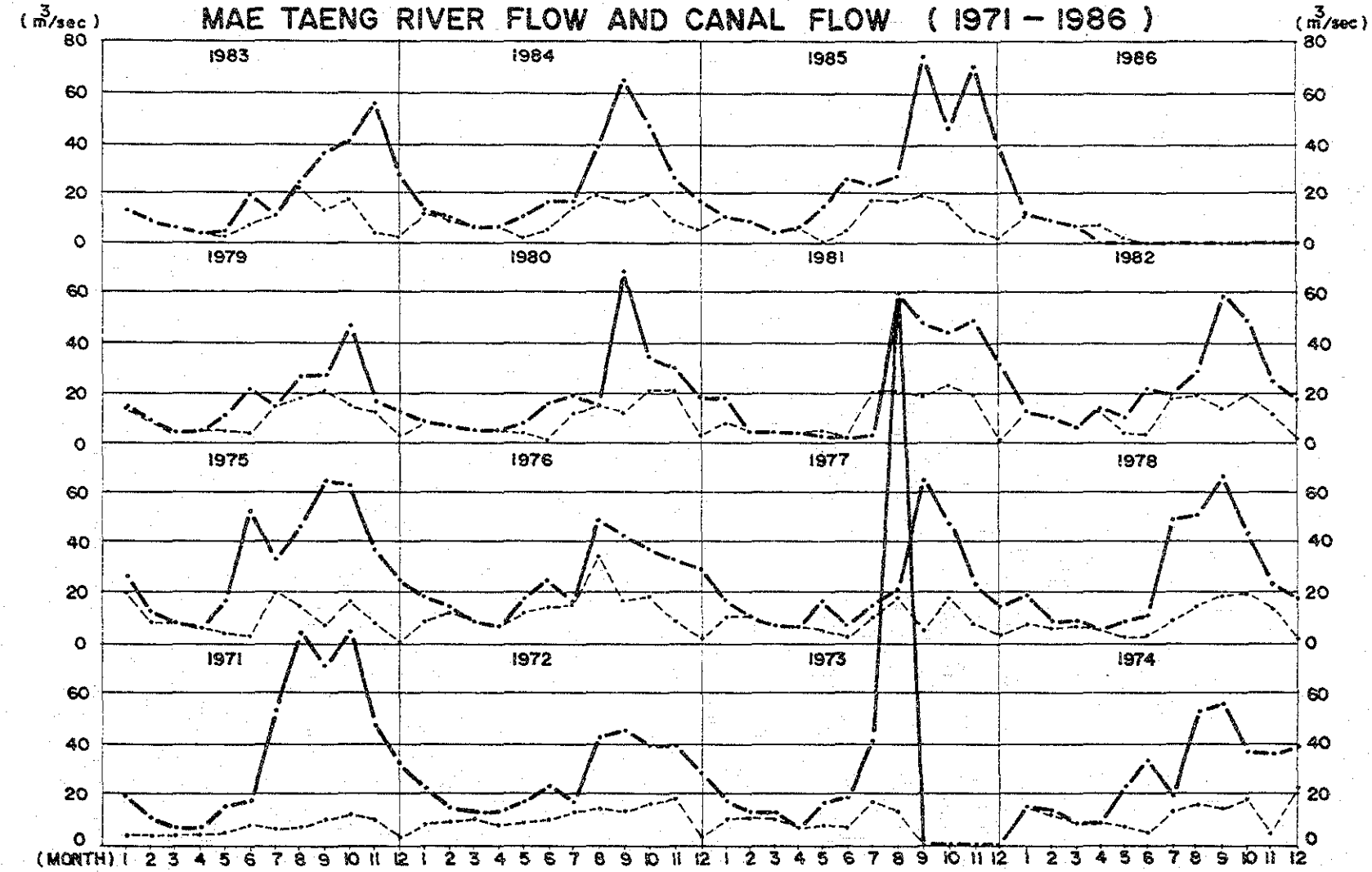


FIGURE	MAE TAENG RIVER FLOW AND CANAL FLOW (1971-1986)
3.4	

JAPAN INTERNATIONAL COOPERATION AGENCY

4) Mae Kuang River

The Mae Kuang River origins in the northeastern mountains in Doi Saket district, the east of Chiangmai. It runs totally 42 km and joins the Ping River at the north of Lamphun city. The drainage area at Ban Pha Taek where the Mae Kuang dam is under construction, is 566 sq km and the mean annual runoff is 229.4 MCM during 7 years from 1974 to 1980. Therefore, the average yield of runoff is 0.405 MCM/sq km or 12.85 l/s/sq km. On the other hand, the instantaneous peak discharge was 347 cu m/s recorded August 25, 1973, and the specific yield of peak discharge was 0.613 cu m/s/sq km.

5) Mae Rim River

The Mae Rim River origins in the Doi Suthep mountains, the northwest of Chiangmai and flows through Mae Rim district before joining the Ping River. The drainage area of Mae Rim River at Mae Rim bridge is 515 sq km with the mean annual runoff of 159.8 MCM (5.07 cu m/s) during 26 years from 1954 to 1980, corresponds with 0.310 MCM/sq km or 9.84 l/s/sq km average yield of runoff. On the other hand, the instantaneous peak discharge was 96 cu m/s recorded September 22, 1975, and the specific yield of peak discharge was 0.186 cu m/s/sq km.

6) Ping River Basin Discharge

Table-3.5 summarizes the representative annual rainfall and river discharge of Ping River Basin including Chiangmai city.

During 30 years period from 1952 to 1981, the maximum annual rainfall which occurred in 1980 was 1,368.1 mm, and its river discharge was 4,253.9 MCM/y. On the other hand, the minimum annual rainfall which occurred in 1979 was 906.9 mm and the river discharge was 1,079.2 MCM/y. Also, the average annual rainfall from 1952 to 1975 was 1,138.7 mm and its river discharge was 2,114 MCM/y.

The driest year of Chiangmai area was 1979 and also the hardest drought year in the recent 30 years. Of the year, the mean monthly river runoff and the minimum monthly river runoff has been reviewed for evaluation of available water source of Ping River and its tributaries. Fig-3.5 illus-

Table-3.5 RAINFALL AND RIVER FLOW AT CHIANGMAI (1952 - 1981)

Item	Maximum Annual Rainffall (1980)	Minimum Annual Rainfall (1979)	Average Annual Rainfall (1952 - 1975)
Rainfall (mm)	1,368.1	906.9	1,138.7
River Flow Ping River (P_1) (MCM)	4,253.9	1,079.2	2,114.0

DATA : RID, 1980 and 1983

THE MONTHLY RUNOFF OF PING RIVER BASIN , 1979

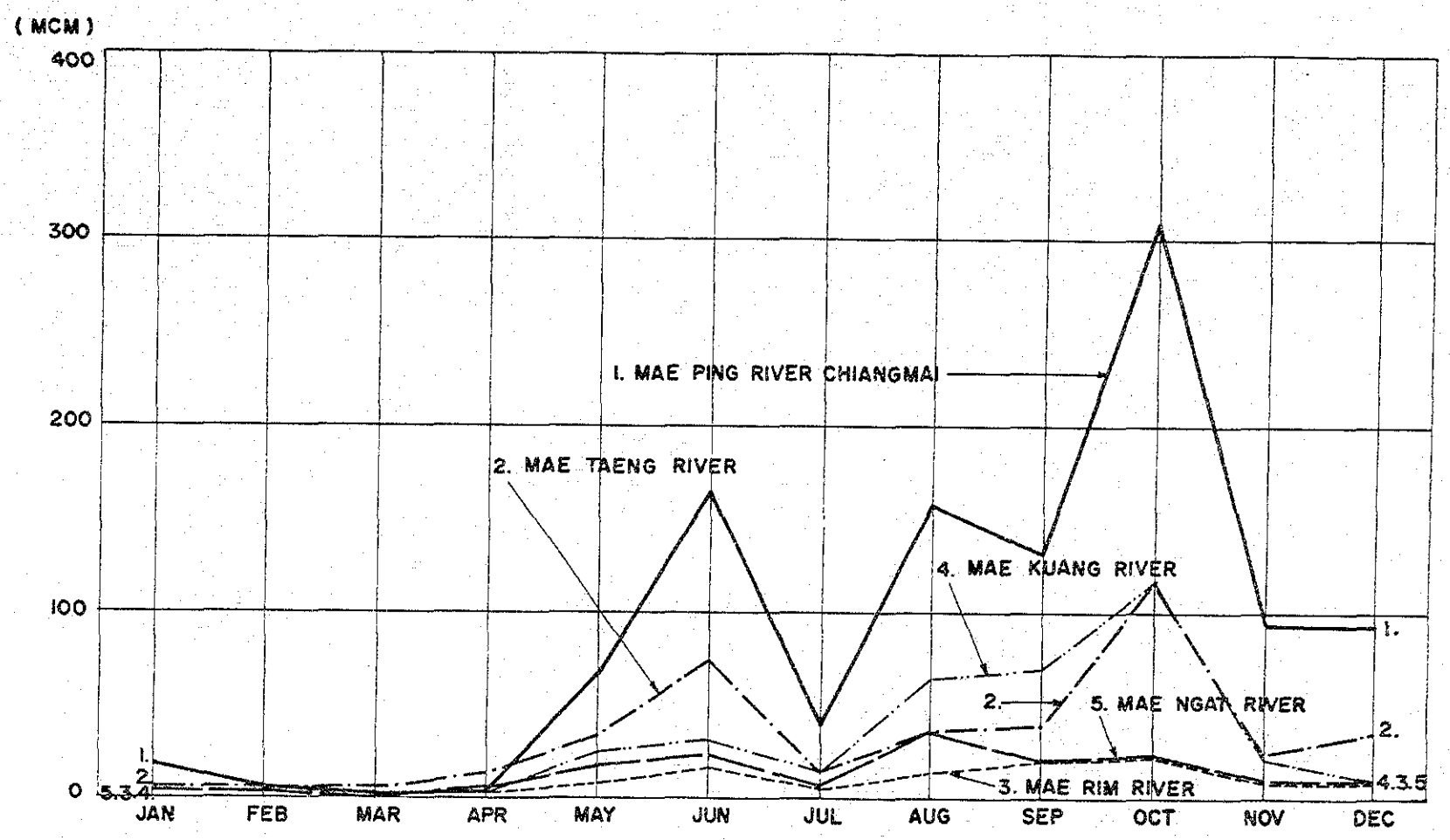


FIGURE	THE MONTHLY RUNOFF OF PING RIVER BASIN, 1979
3.5	
JAPAN INTERNATIONAL COOPERATION AGENCY	

trates the mean monthly runoff of the Ping River, Mae Taeng River, Mae Rim River, and Mae Ngat River in 1979. And also, Fig-3.6 shows the density of the runoff in 1979.

The Ping River has the dominative flow when compared with other 4 rivers and during 9 months, May to January, occupies 50 % to 60 % of the total river flow in the area. However, during the dry season especially February to April, the river flow decreases due to decreasing natural flow and increasing irrigation demand. The Mae Taeng River, another important tributary of Ping River, maintains steady flow in the dry season due to the control of Mae Taeng diversion and occupies 20 % to 50 % of the total river flow. The Mae Kuang, Mae Ngat and Mae Rim rivers occupy the remaining 20 % to 30 % of the total river flow in the area.

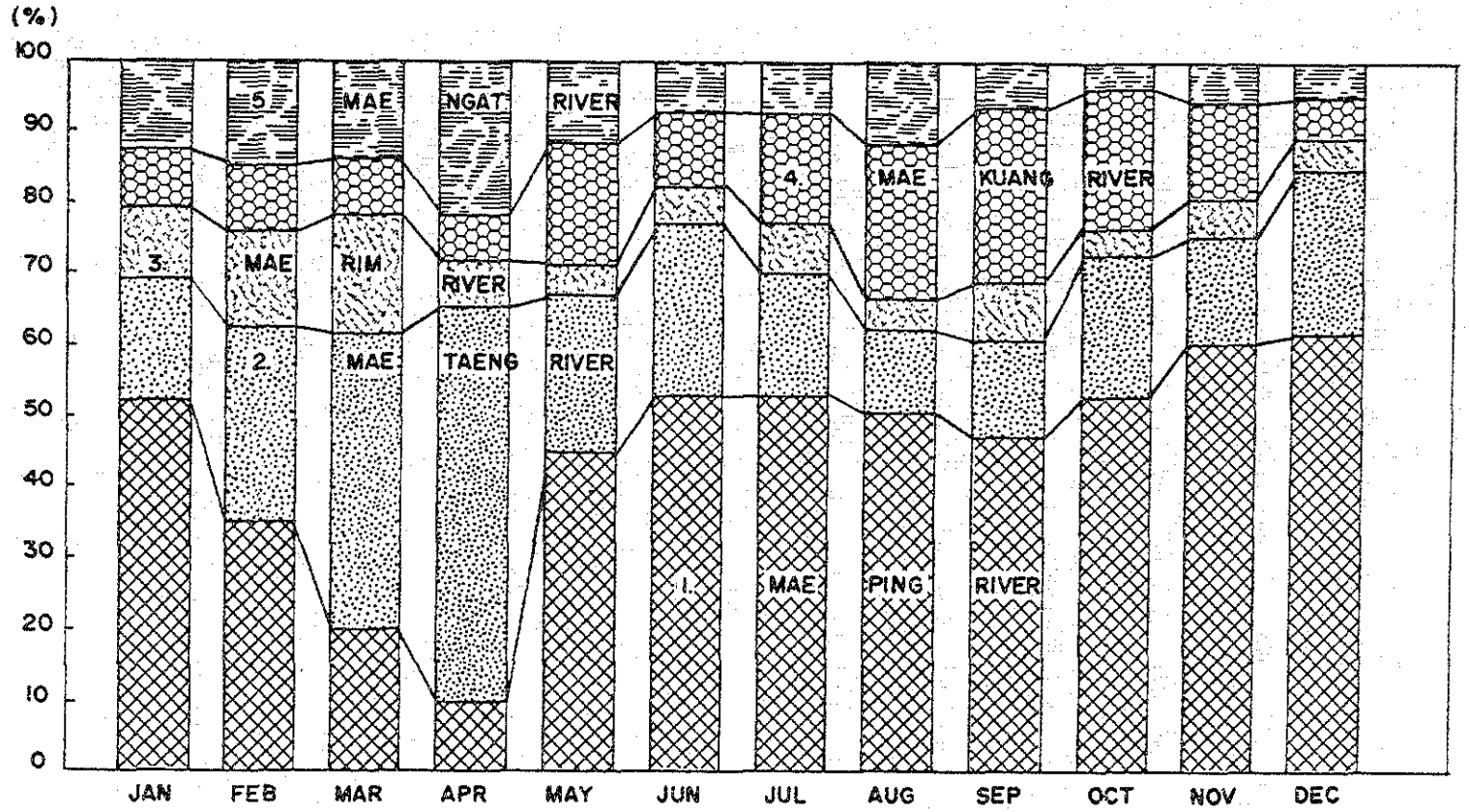
Fig-3.7 illustrates the minimum monthly river flow of the Ping River and its tributaries. The Ping River has the largest flow in the area, followed by the Mae Taeng River, Mae Kuang River, Mae Ngat River and Mae Rim River.

The Ping River keeps its minimum flow ranging from 8 cu m/s to 30 cu m/s, during the rainy season of June to December. On the other hand, during the dry season of January to May, its minimum flow decreases extremely ranging from 0.5 cu m/s to 3.5 cu m/s. The Mae Taeng River's minimum flow in 1979 ranged from 2.5 cu m/s to 6.0 cu m/s in the rainy season, and about 1.5 cu m/s in the dry season. For Chiangmai the present raw water supply from the Ping River is 24,720 cu m/d or 0.29 cu m/s, and that from Mae Taeng Irrigation Canal is 30,000 cu m/d or 0.35 cu m/s. Therefore, the natural flow in the driest period can manage the present water demand of Chiangmai city.

For the future, the Royal Irrigation Department (RID) is continuing to built multipurpose storage dams on the Mae Ngat and Mae Kuang Rivers. The Mae Ngat project has been already completed in 1986 and the Mae Kuang project has started its construction work in 1986 and is due for completion after 1990. These are outlined in Table-3.6.

Considering the present and future water sources for the city of Chiangmai, recommendable and suitable ware the well-controlled, stable flows from the above two dams.

THE DENSITY MONTHLY RUNOFF OF PING RIVER BASIN , 1979

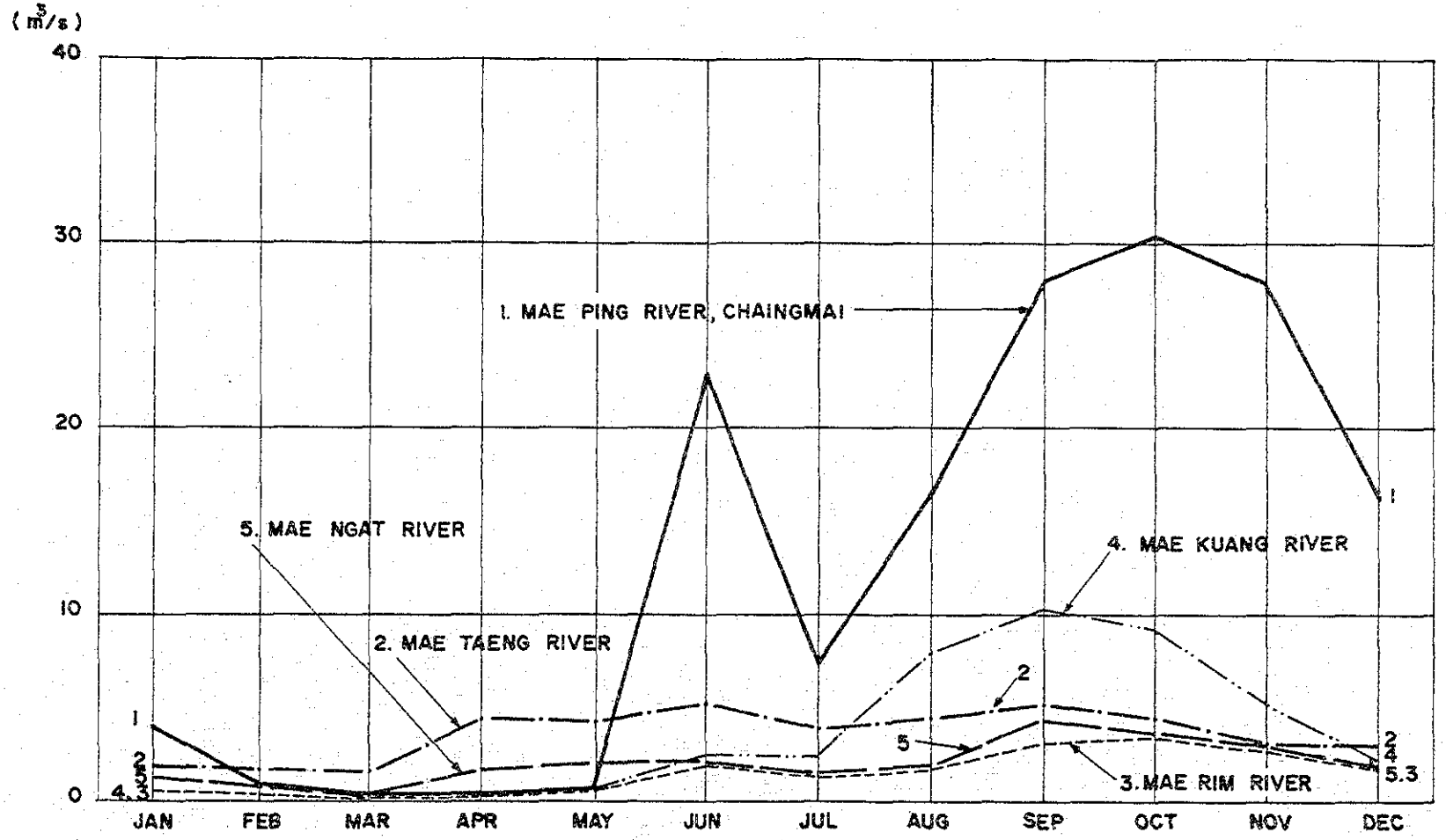


DATA , RID , NEA

FIGURE	THE DENSITY MONTHLY RUNOFF OF PING RIVER BASIN, 1979
3.6	

JAPAN INTERNATIONAL COOPERATION AGENCY

THE MINIMUM MONTHLY RUNOFF OF PING RIVER BASIN , 1979



DATA , RID , NEA

FIGURE	THE MINIMUM MONTHLY RUNOFF OF PING RIVER BASIN, 1979
3.7	
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table-3.6 Salient Feature of Mae Ngat, and Mae Kuang Dams

	Description		Mae Ngat Dam	Mae Kuang Dam
1.	Construction Period		1977-1985	1986-1990
2.	Hydrology			
	a) Name of River		Mae Ngat	Mae Kuang
	b) Catchment Area	(sq km)	1,281	569
	c) Average Annual Inflow	(MCM)	406	229
3.	Reservoir			
	a) Gross Storage Capacity	(MCM)	265	263
	b) Active Storage Capacity	(MCM)	255	249
	c) Dead Storage Capacity	(MCM)	10	14
	d) High Water Level	(m)	396.0	385.0
	e) Low Water Level	(m)	360.5	350.0
	f) Reservoir Surface Area at H. W. L.	(sq km)	16	11.8
4.	Dam			
	a) Type		Earth Fill	Zone Fill
	b) Crest Elevation	(m)	404.0	390.0
5.	Irrigation Area	(ha)	30,400	28,000

DATA, RID, EGAT