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 Ⅳ-B
APPENDICES
FOR
SUPHANBURI

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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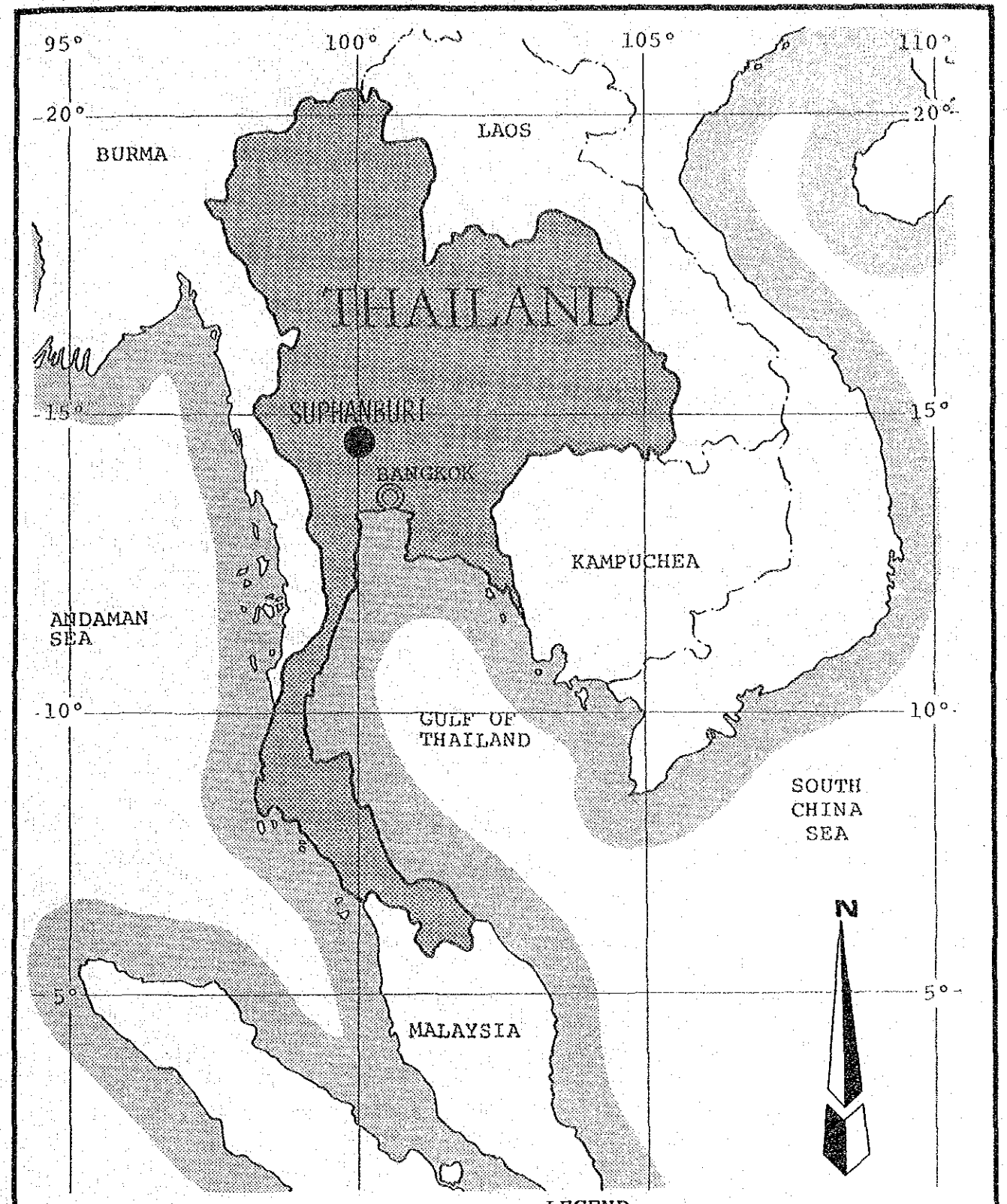

LEGEND

● : SUPHANBURI MUNICIPALITY

◎ : CAPITAL CITY

SCALE 1 : 10,000,000

FIGURE	LOCATION MAP

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APPENDICES

APPENDICES

APPENDIX 1

POPULATION FORECAST

APPENDIX 1

APPENDIX 1 POPULATION FORECAST

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APPENDIX 1 POPULATION FORECAST

1.1 General

This appendix forecasts the future total and served population in the study area for the Development Plan. The area, as defined in the scope of work, consists of two districts, Suphanburi Municipality and Phophraya Sanitary District. The estimated served population will be used for projecting the water demand which is to be detailed in Appendix 2.

Widely used five types of mathematical formulae were used in forecasting the total population. To determine the most appropriate coefficients in the formulae, population data in the past were fed and the least square method was employed. The population in future was calculated by the formulae, then.

1)	Arithmetical Progression	$Y = aX + b$
2)	Geometrical Progression	$Y = Y_o \times (1 + b)^X$
3)	Decreasing Rate of Increase	$Y = K - ab^X$
4)	Exponential	$Y = Y_o + aX^b$
5)	Logistic	$Y = K / (1 + e^{(a - bX)})$

Where, Y : Population Forecasted
Y_o : Population in Base Year
X : Year from Base Year
a, b, K : Coefficient

Demographic and socio-economic features, such as recent tendency of migration and habitation in the area, future possibilities of industrial and commercial development etc. were discussed with the local officials. Materials related to them were provided and studied for evaluating the mathematical results.

In planning the future service area, the waterworks development program and the municipality's land use plan were studied and in forecasting the served population, the results of questionnaire survey were reflected.

1.2 Population Statistics

Available records of the population of Suphanburi Municipality and Phophraya Sanitary District are shown in Table-1.1 and plotted on Fig-1.1.

As shown in Fig-1.1, the population of Suphanburi has increased almost linearly at a rate of 310 persons per year to reach about 24,000 in 1984. And the population of Phophraya, from 1981 to 1984, showed noticeable fluctuation which was unexplainable.

Table-1.1 DATA OF PAST POPULATION

YEAR	AREA	
	SUPHANBURI	PHOPHRAYA
1965	17,099	
1966	16,316	3,515
1967	18,434	3,555
1968	18,734	3,528
1969	19,148	3,571
1970	19,515	3,644
1971	19,774	3,815
1972	20,128	3,747
1973	20,505	3,859
1974	20,882	3,595
1975	21,232	3,726
1976	21,522	3,929
1977	21,961	3,936
1978	22,024	3,983
1979	22,544	4,008
1980	22,903	4,058
1981	22,989	4,141
1982	23,294	3,562
1983	23,445	4,214
1984	23,738	3,149

DATA SOURCE : PWA

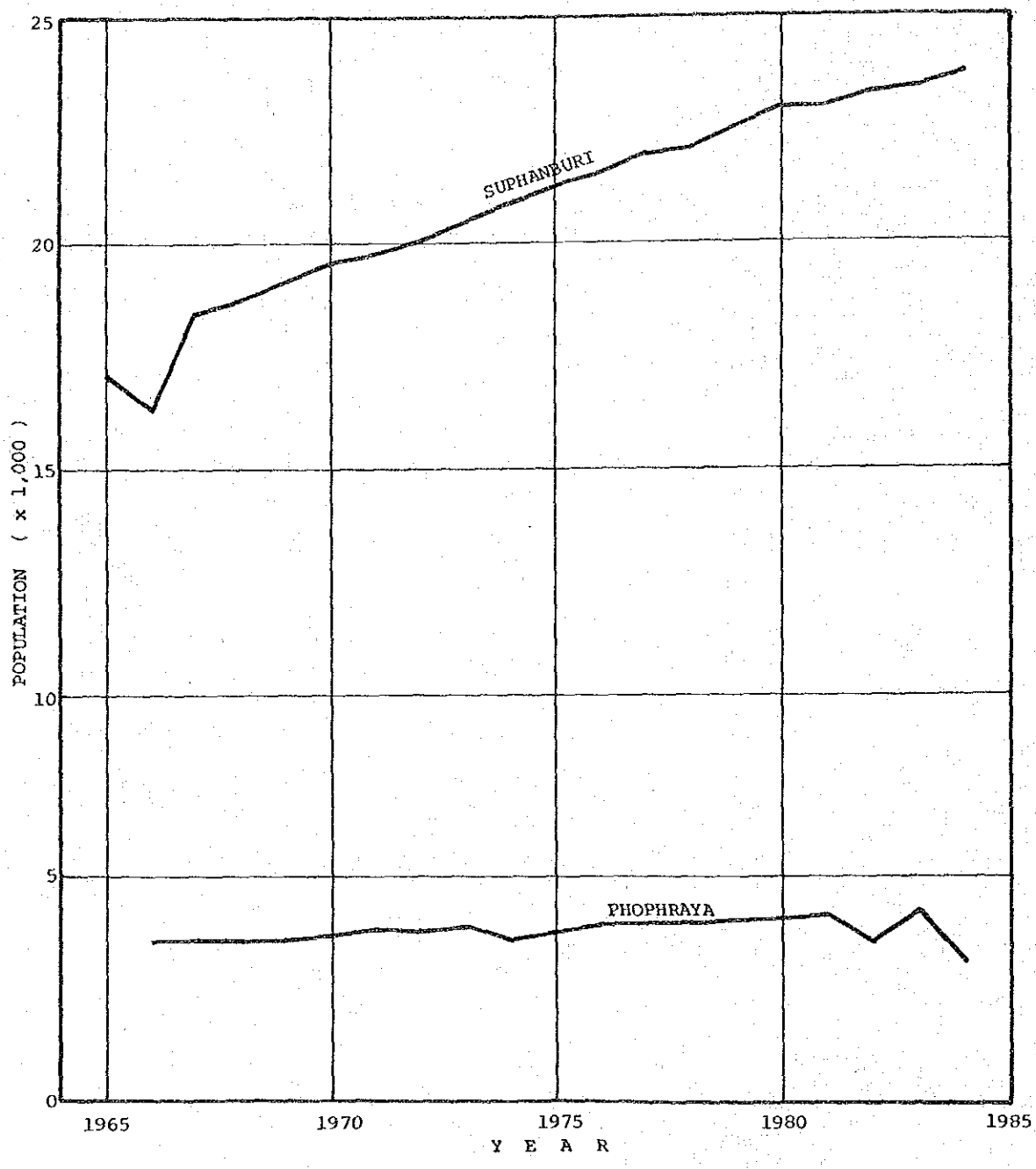

FIGURE	PAST POPULATION TREND
1.1	

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1.3 Population Forecast

The results of population forecast for Suphanburi Municipality and Phophraya Sanitary District are shown on Figs-1.2 and 1.3 respectively.

1.3.1 Suphanburi Municipality

Fig-1.2 shows four lines calculated by the before mentioned formulae.

The results from the geometrical and logistic progression show rather high increase ratios, the decreasing rate of increase shows a lower increase ratio comparison with the past data.

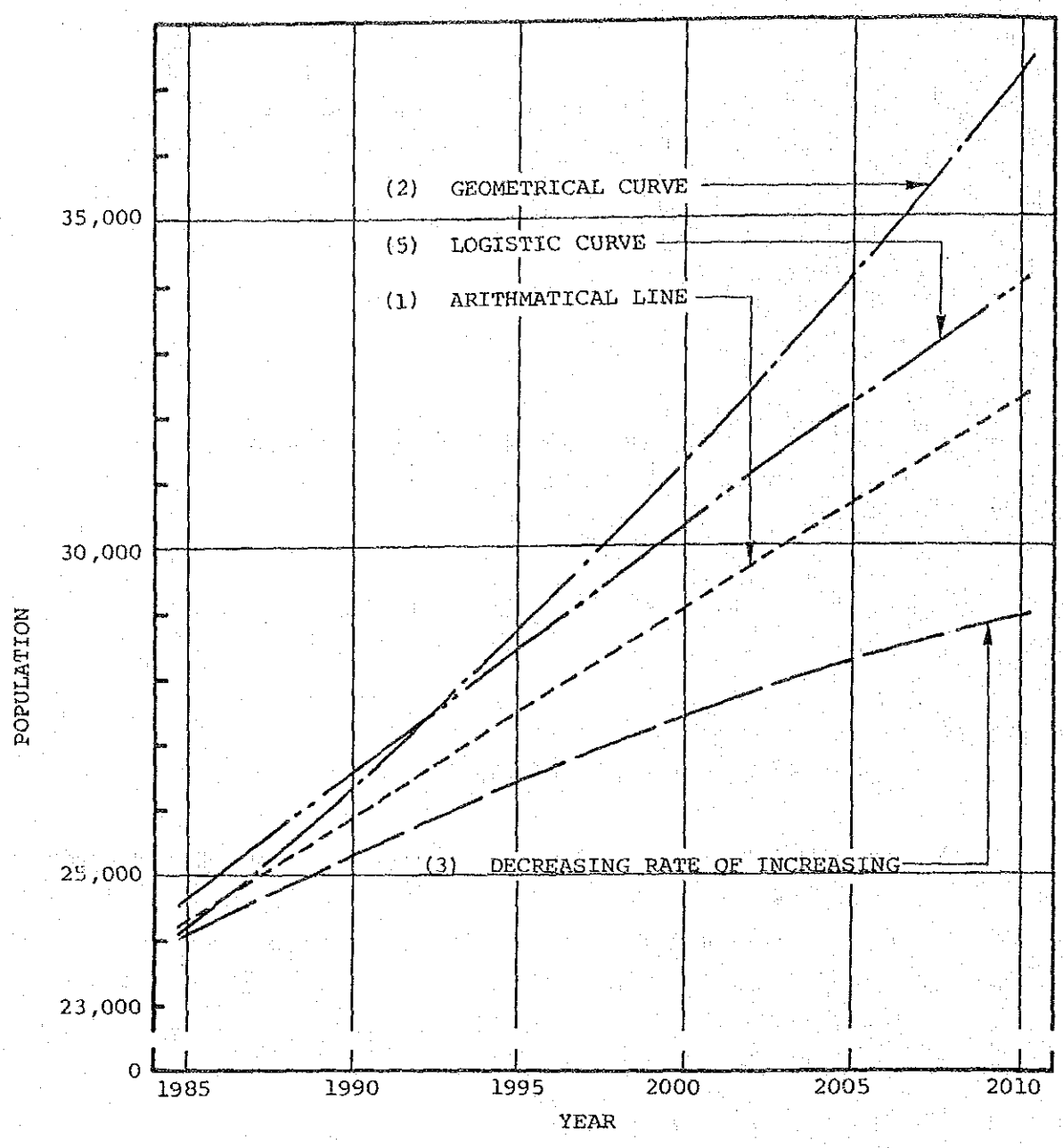
Of the four curves, the arithmetical line was selected, because of following reasons:

1) There is no development plan in and near this area which will induce high rate growth of population.

2) As a center of administrative and commercial activities, dealing in farm products of surrounding agricultural areas, Suphanburi's population increase will not lose the present momentum. A lower growth rate than the present 310 persons per year will result in under estimation.

3) This line fits best to the past trend.

As the study area of the DTCP's Town Planning included the surrounding area of Suphanburi and Phophraya and the growth rate of population was estimated at 2.75 - 2.88 % per year in 1985 - 2004, the forecasted population showed a very high figures. The result was not used.



ESTIMATED POPULATION

CASE	1985	1990	1995	2000	2005	2010
(1)	24,295	25,891	27,486	29,081	30,676	32,271
(2)	24,151	26,891	28,703	31,291	34,112	37,188
(3)	24,099	25,315	26,397	27,362	28,221	28,986
(4)	EXPONENTIAL CURVE can not be applied due to mathematical reason.					
(5)	24,643	26,542	28,450	30,348	32,220	34,048

FIGURE	POPULATION FORECAST OF SUPHANBURI
1.2	
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1.3.2 Phophraya Sanitary District

The 1982 and 1984 populations, shown in Table-1.1 and Fig-1.1, fell remarkably from the year before. Because of their irregularity, the two were disregarded in preparing the five curves in Fig-1.3 which resulted form calculation by the same formulae used previously.

The calculated curves, except that of the decreasing rate of increase, show similar tendency. The decreasing rate of increase is to be discarded.

Among the other four lines and curves, the arithmetical line, (1) of Fig-1.3, is proposed here because of the following reasons:

1) This line fitted best to the past trend.

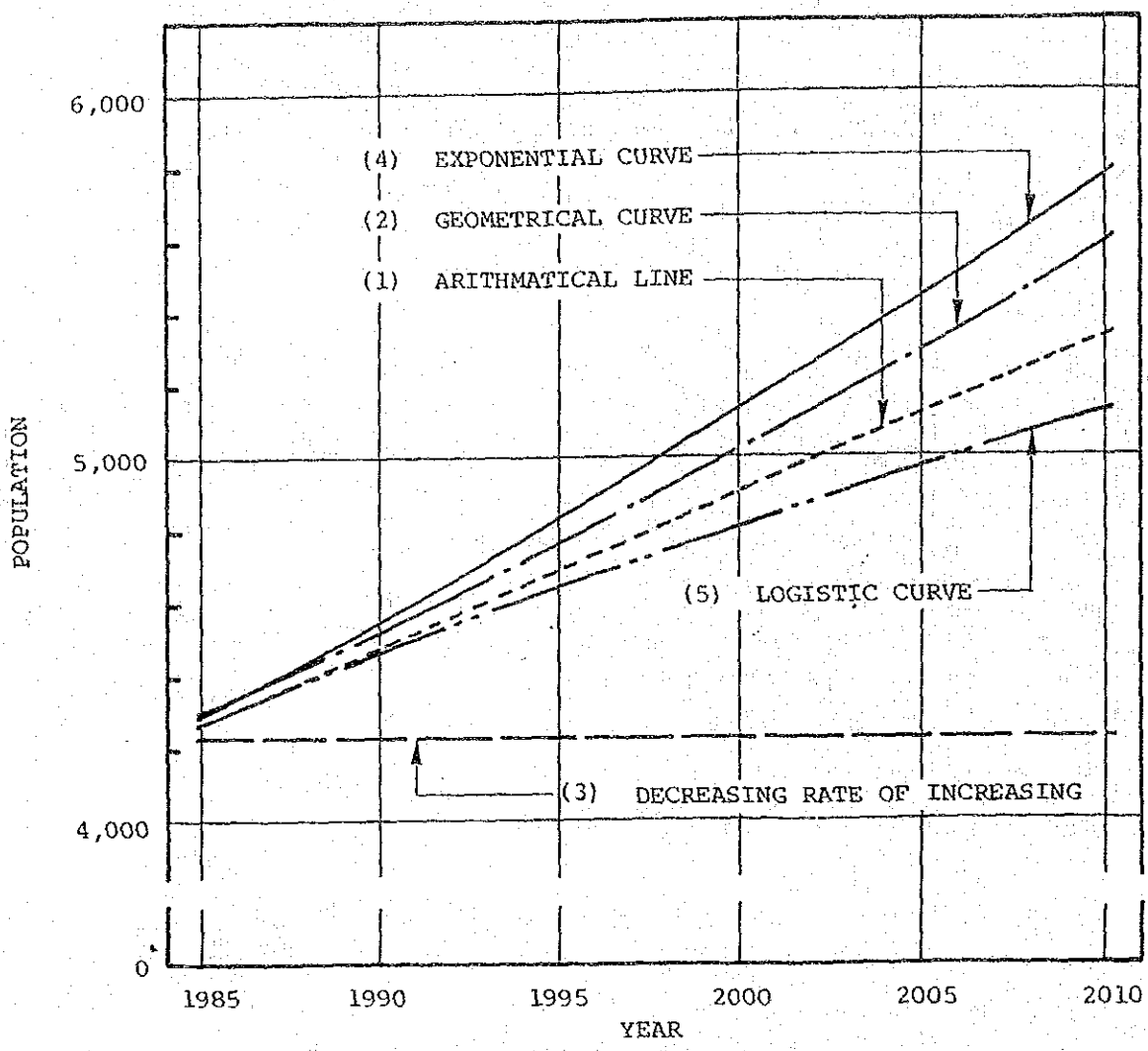
2) Phophraya will follow the pattern of Suphanburi which is arithmetical increasing.

1.3.3 Total Population of Project Area

Summarizing 1.3.1 to 1.3.2, the total population of Suphanburi Municipality and Phophraya Sanitary District is shown in Table-1.2 and in Fig-1.4.

Table-1.2 TOTAL POPULATION OF PROJECT AREA

	A R E A		
YEAR	SUPHANBURI	PHOPHRAYA	TOTAL
1985	24,300	4,300	28,600
1990	25,900	4,500	30,400
1995	27,500	4,700	32,200
2000	29,100	4,900	34,000
2005	30,700	5,100	35,800
2010	32,300	5,300	37,600



ESTIMATED POPULATION

CASE	1985	1990	1995	2000	2005	2010
(1)	4,275	4,484	4,694	4,904	5,113	5,323
(2)	4,295	4,528	4,773	5,031	5,304	5,592
(3)	4,233	4,233	4,233	4,233	4,233	4,233
(4)	4,289	4,556	4,838	5,134	5,442	5,761
(5)	4,268	4,460	4,644	4,817	4,979	5,130

FIGURE	POPULATION FORECAST OF PHOPHRAYA
1.3	

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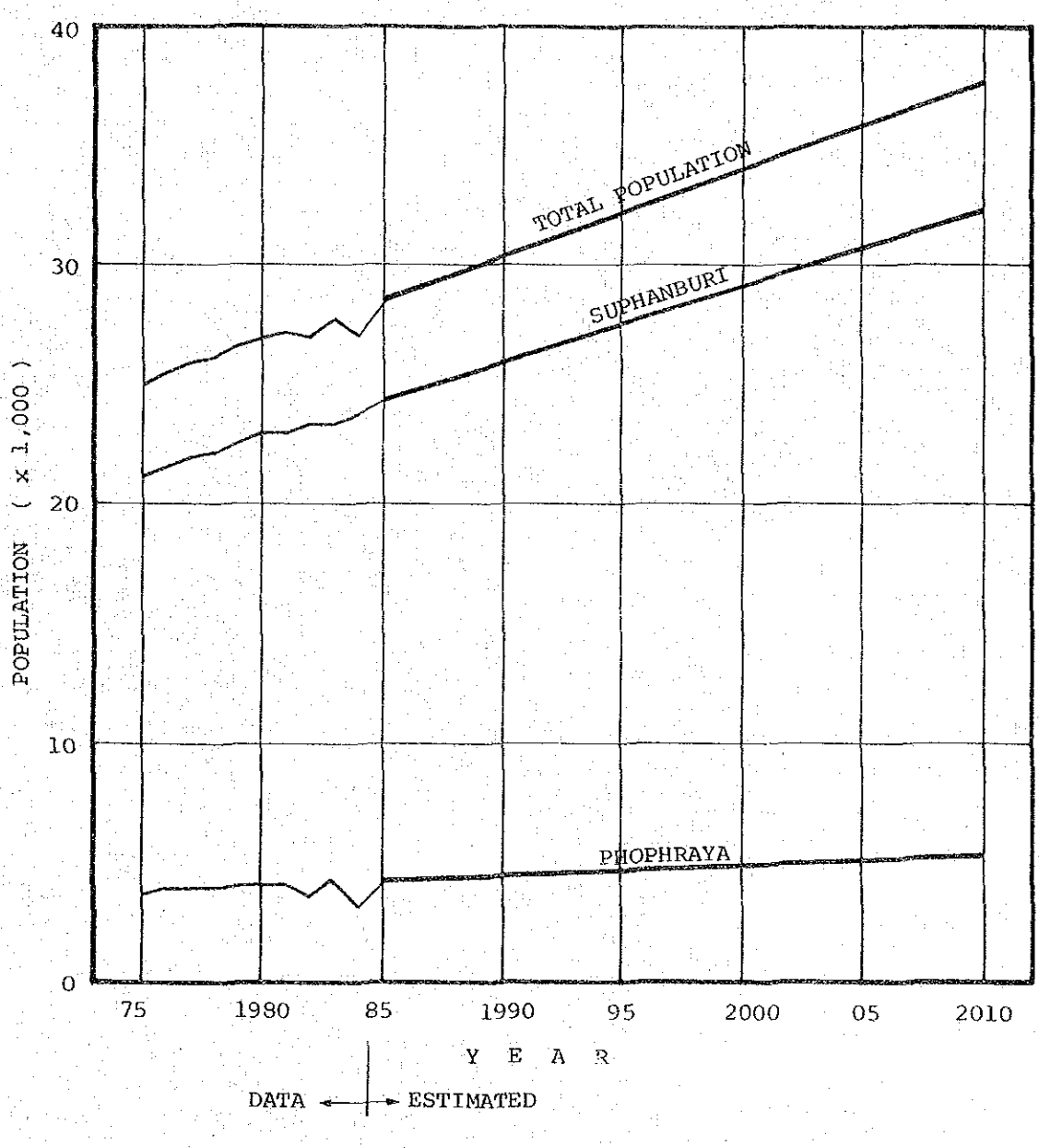

FIGURE 1.4	FUTURE POPULATION FORECASTED

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1.4 Present and Future Service Area

The future service area was delineated based on the development program of the waterworks and the future land use plan prepared by DTCP, and also taking into account of the Municipality officials' comments and considering natural conditions. Size of the service area in 1985, 2000 and 2010 are shown in Table-1.3.

Table-1.3 SERVICE AREA

YEAR	SERVICE AREA (ha)
1985	1,200
2000	2,300
2010	3,100

Fig-1.5 shows the present service area of Suphanburi Waterworks and the future expanded service area in 2000 and 2010.

As shown in Fig-1.5, the future service area will expand both east- and west-ward from the present service area which has been developed along the Tha Chin River, forming the central part.

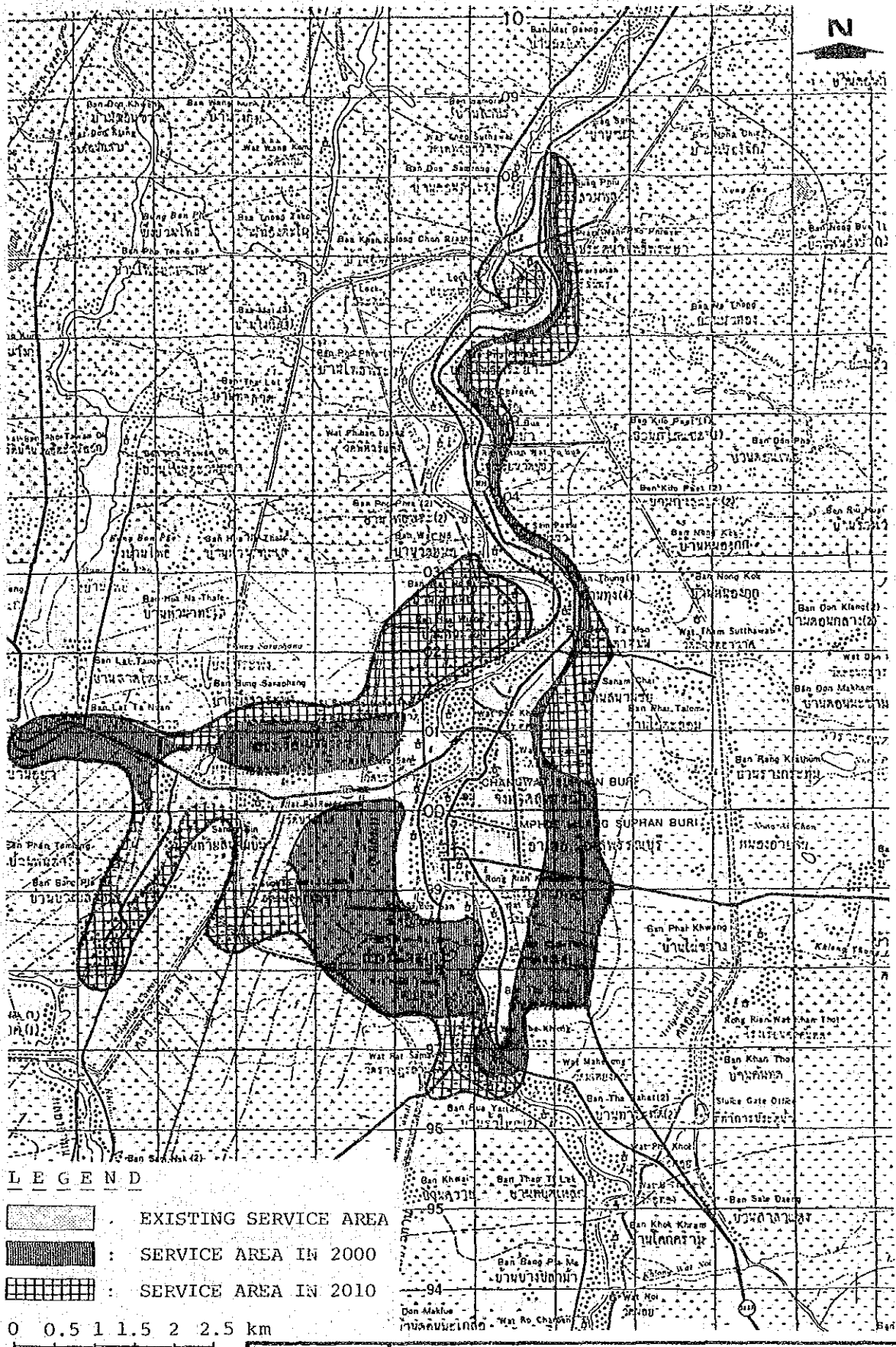

FIGURE 1.5 SERVICE AREA OF SUPHANBURI

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1.5 Service Ratio

The service ratio has been increasing in the Project Area. Other than the public service, there is no available alternative water source, except deep well and rain water. Deep well is costly for private domestic use and rain water is unreliable. Therefore, about 80 % of the dwellers have their own connection from the waterworks already.

As shown in Fig-1.6, the following four service ratios were forecasted.

Case 1

The curve of Case 1 followed the past trend.

Case 2

Case 2 was plotted, reflecting the results of the questionnaire survey.

An apparent correlation existed between the service ratio and the income level of the people surveyed. In future, as the income level grows the service ratio will increase. The curve was made on an assumed growth rate of 8 % per year, highest in the past.

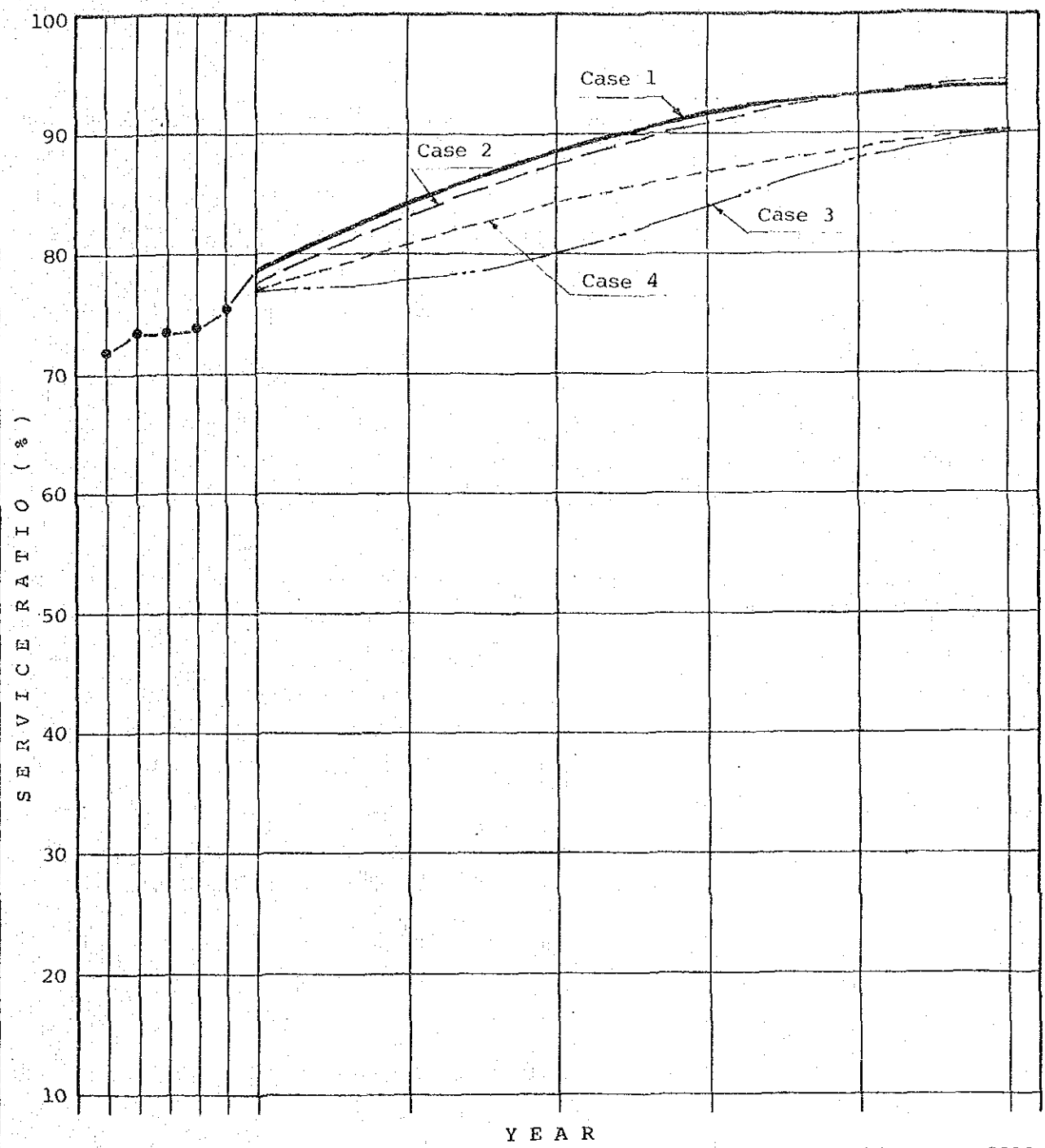
CASE 3

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

The curve was made based on the following assumptions:

1) Of the presently unserved people, the willingness for the public service was 86 %. All of the willing people will be supplied before 2010, at a presumed pace.

2) Of the incremental population in future, 86 % will be supplied by the service immediately responding to the increase.



	1985	1990	1995	2000	2005	2010
Case 1	79	85	89	92	93	94
Case 2	77	83	86	91	93	94
Case 3	77	78	80	84	88	90
Case 4	77	81	84	87	89	90

FIGURE 1.6 ESTIMATION OF SERVICE RATIO FOR SUPHANBURI AND PHOPRAYA

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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 cases are characterized as follows:

Case 1 prepared on the basis of the past trend shows a high rate of increase.

Case 2 and 4, made on the basis of the income level solely, are limited in usefulness, because other factors also affect the service ratio. They cannot be used without modification.

Case 3, made on the basis of the present willingness, is also limited in usefulness, as the willingness may change in future. As the availability of other supply sources is low while the water demands are pushed by development, the dependence on the public supply will grow stronger as the years go.

After considering the above conditions of the four curves, the line of Case 1 which show the highest ratio is proposed, as shown in Fig-1.6.

The service ratio for Phophraya will follow the Suphanburi's pattern.

1.6 Served Population

In Table-1.4 the future total population, service ratio and served population are listed and in Fig-1.7, the population, total and served, are plotted. Calculation was made based on the total population in Table-1.2 and the service ratio in Fig-1.6.

Table-1.4 FUTURE SERVICE RATIO AND SERVED POPULATION

	POPULATION			SERVICE	SERVED POPULATION		
YEAR	SUPHANBURI	PHOPHRAYA	TOTAL	RATIO	SUPHANBURI	PHOPHRAYA	TOTAL
1985	24,300	4,300	28,600	79	19,200	3,400	22,600
1990	25,900	4,500	30,400	85	22,000	3,800	25,800
1995	27,500	4,700	32,200	89	24,500	4,200	28,700
2000	29,100	4,900	34,000	92	26,800	4,500	31,300
2005	30,700	5,100	35,800	93	28,600	4,700	33,300
2010	32,300	5,300	37,600	94	30,300	5,000	35,300

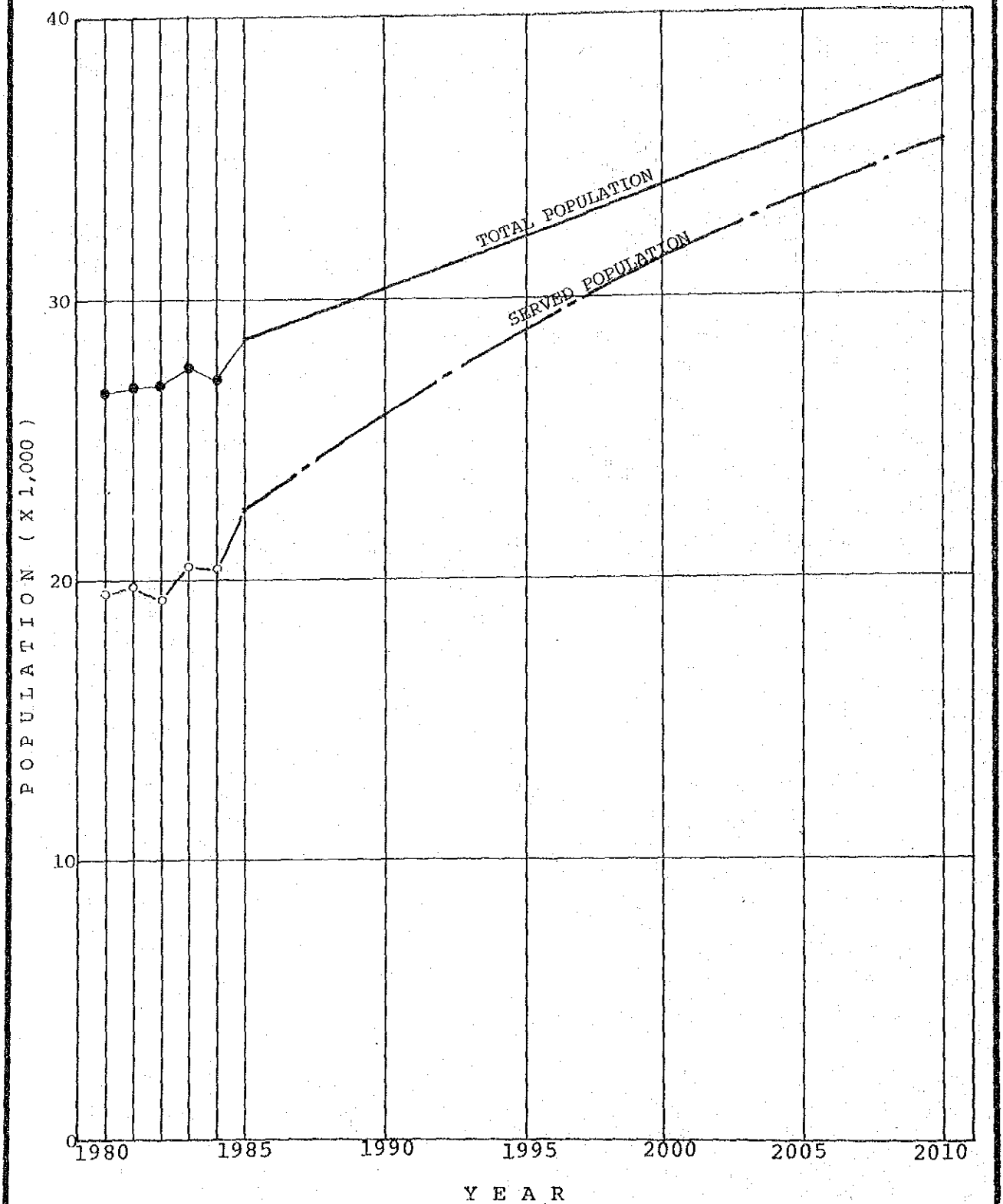

FIGURE	TOTAL POPULATION AND SERVED POPULATION FORECAST FOR SUPHANBURI
1.7	
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APPENDIX 2

FUTURE WATER DEMAND

APPENDIX 2

APPENDIX 2 FUTURE WATER DEMAND

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APPENDIX 2 FUTURE WATER DEMAND

2.1 Introduction

In this Appendix, the water demands in the planned service area are forecasted for the Development Plan, based on the analysis of records provided by PWA and the served population in future estimated in Appendix 1 to this report.

In section 2.2, available data regarding water consumption are described to clarify the present situation in the area. Section 2.3 describes the process and methodology applied in forecasting the water consumption together with the results of projection. After adding up the categorized water consumptions, the total water demand including the unaccounted- for water is summarized. Estimated in section 2.4 are the maximum-day and average-day water demands that are basic information for working out the Development Plan.

2.2 Records of Water Consumption

As the data collected during the site survey, the yearly water production and water sales from 1975 to 1984, are given in Fig-2.1 and Table-2.1.

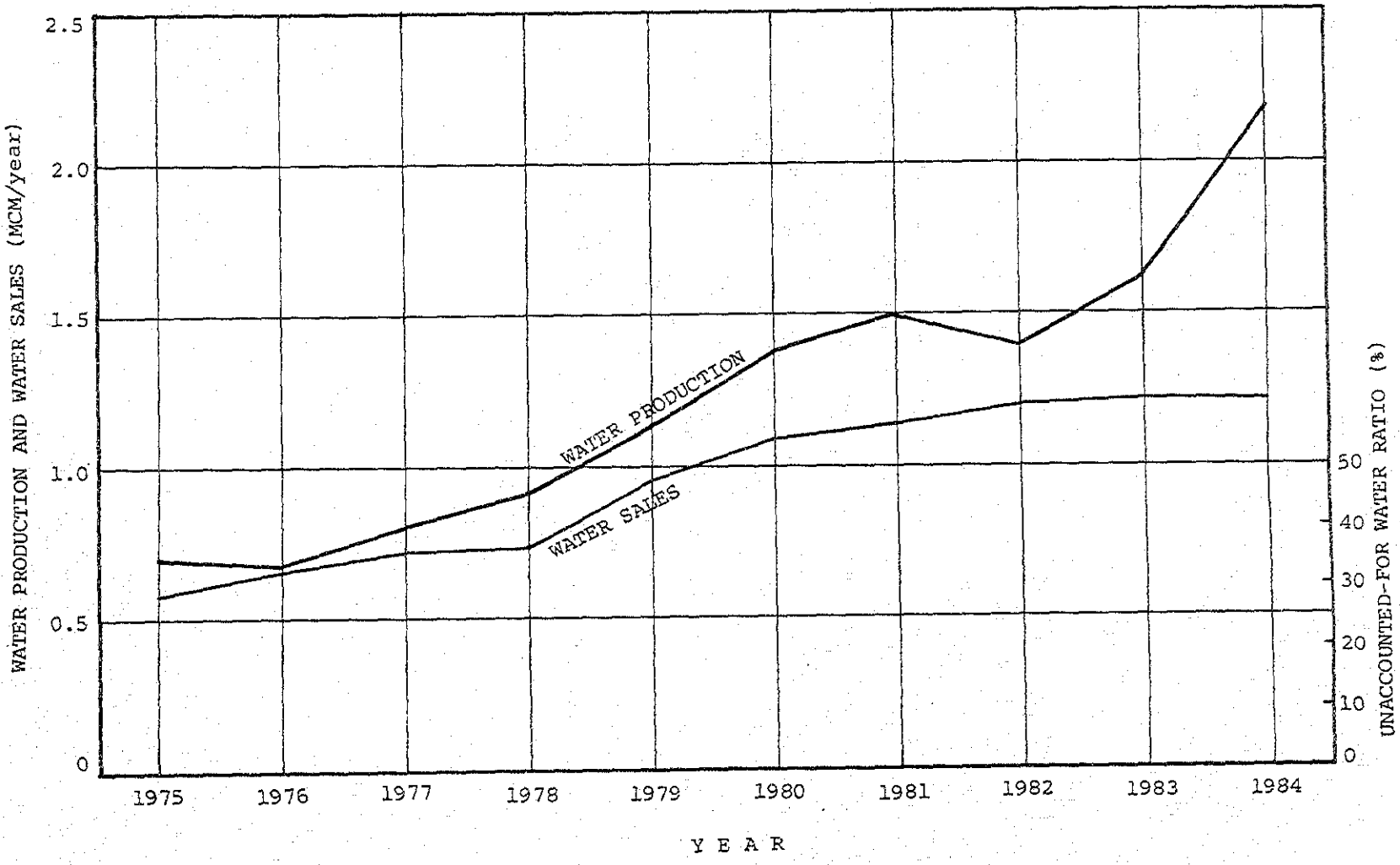

FIGURE	PAST DATA OF WATER PRODUCTION AND WATER SALES
2.1	

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Table-2.1 WATER PRODUCTION AND WATER SALES

YEAR	WATER PRODUCTION (cu m/year)	WATER SALES (cu m/year)	NUMBER OF CONNECTION	CONSUMPTION PER CONNECTION (cu m/month)
1975	691,550	579,606	2,518	19
1976	684,359	657,993	2,716	20
1977	805,565	724,645	2,923	21
1978	920,964	729,470	3,219	19
1979	1,189,187	942,270	3,551	22
1980	1,372,200	1,080,100	3,889	23
1981	1,487,800	1,138,046	3,937	24
1982	1,391,915	1,187,212	4,041	24
1983	1,622,970	1,211,156	4,199	24
1984	2,168,555	1,211,786	4,320	23

DATA SOURCE : PWA

As shown in Fig-2.1, both water production and water sales are increasing gradually year by year. In recent few years, however, the water production has risen rapidly in contrast with the almost constant water sales. This widening gap shows that the unaccounted-for water ratio has increased remarkably in the recent years.

The water sales in 1984, as seen in Table-2.1, was 3,320 cu m/day (1,211,786 cu m/year). When the figure was divided by the served population estimated from connection number and average person per family (6 persons), the per capita consumption was 128 lpcd.

The per capita consumption is classified into two. The first, the domestic per capita was, as seen in Fig-2.2, about 70 - 80 lpcd in 1980 - 1984. The second, the balance of total and domestic, was large consumers' consumption, approximately 50 lpcd in 1984.

The large consumers' consumption is further classified into three, as seen in Table-2.2 which was made on the basis of PWA surveys conducted in 1985, namely government/public institution, large business and large residential building. The table also shows that the ratio of government/public institution to large business is 63 % to 37 %.

Hereafter, the large residential buildings' use will be included in the domestic consumption and the total consumption will be categorized into 1) domestic, 2) public (government/public institution), 3) large business.

Table-2.2 LARGE CONSUMERS' CONSUMPTION IN SUPHANBURI

Classification	Item	Consumption (cu m/month)	Sub-Total (cu m/month)	Percentage (%)
Government/ Public Institution	Government	4,187	11,436	63
	School	5,746		
	Hospital	105		
	Temple	1,398		
Large Business	Commercial	5,420	6,795	37
	Factory	670		
	Hotel	610		
	Others	95		
Sub-Total			18,231	100
Large Residential Building	Residence	6,134	6,134	
Total		24,365	24,365	

DATA SOURCE : PWA, 1985

2.3 Future Water Consumption

In this section, the Suphanburi's future water consumption, with breakdown of three categories, domestic, public and large business, is presented. Regarding the Phophraya's, two categories of domestic and others are estimated.

2.3.1 Suphanburi Municipality

1) Domestic Water Consumption

The domestic per capita consumption in future is projected in Fig-2.2. For comparison, the forecasted for Khon Kaen and Udonthani are also plotted in the figure.

As Suphanburi's town planning does not involve water-demanding plans like industrial development and sewerage system and the growth as the administrative, commercial and light industries center will be slow, the domestic per capita consumption is expected to increase, corresponding to the growth of the average income level and living standards.

The domestic water consumption, calculated on the forecast of served population in Appendix 1 and per capita consumption shown in Fig-2.2, is shown in Table-2.3.

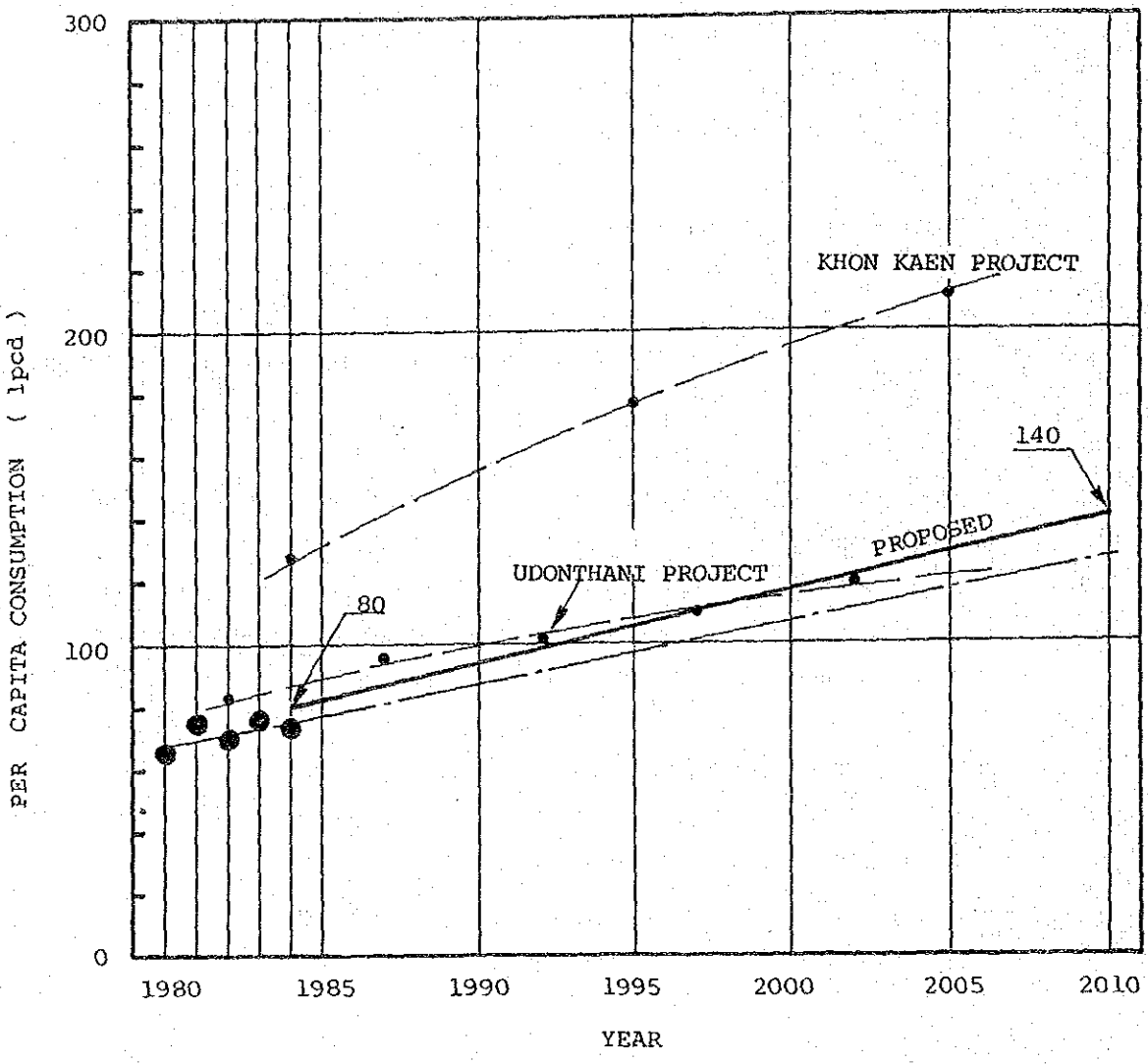

FIGURE	ESTIMATION OF PER CAPITA CONSUMPTION OF DOMESTIC USE (SUPHANBURI)
2.2	

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Table-2.3 DOMESTIC WATER CONSUMPTION FOR SUPHANBURI MUNICIPALITY

YEAR	SERVED POPULATION	DOMESTIC PER CAPITA CONSUMPTION (lpcd)	DOMESTIC WATER CONSUMPTION (cu m/day)
1985	19,200	82	1,570
1990	22,000	94	2,070
1995	24,500	105	2,570
2000	26,800	117	3,130
2005	28,600	128	3,660
2010	30,300	140	4,250

2) Public Water Consumption

As mentioned in Section 2.2, the large consumer's consumption was estimated at 50 lpcd in terms of the per capita and 63 and 37 % of it were used, assumingly, by the public institutions and large businesses (Table-2.2). The public water consumption in 1984 was assumed as 32 lpcd.

The consumption is assumed to increase at a slightly higher rate than the domestic water consumption, in terms of the per capita, and the linear growth will make it 32 lpcd in 1984, 55 lpcd in 2000 and 60 lpcd in 2010, as shown in Table-2.4.

Table-2.4 PUBLIC WATER CONSUMPTION FOR SUPHANBURI

YEAR	SERVED POPULATION	PUBLIC PER CAPITA CONSUMPTION (lpcd)	PUBLIC WATER CONSUMPTION (cu m/day)
1985	19,200	33	630
1990	22,000	40	890
1995	24,500	47	1,160
2000	26,800	55	1,470
2005	28,600	62	1,760
2010	30,300	69	2,100

3) Large Business Water Consumption

37 % of the before mentioned 50 lpcd, namely 18 lpcd (50 lpcd x 37 %) was allocated for the large business water consumption, as of 1984.

The consumption was assumed to grow at the same rate as the public consumption. It will grow linearly from 18 lpcd in 1984, to 32 lpcd in 2000 and 41 lpcd in 2010 as shown in Table-2.5.

Table-2.5 LARGE BUSINESS WATER CONSUMPTION

YEAR	SERVED POPULATION	LARGE BUSINESS PER CAPITA CONSUMPTION (lpcd)	LARGE BUSINESS WATER CONSUMPTION (cu m/day)
1985	19,200	19	370
1990	22,000	24	520
1995	24,500	28	680
2000	26,800	32	860
2005	28,600	36	1,040
2010	30,300	41	1,240

2.3.2 Phophraya Sanitary District

In the case of Phophraya Sanitary District, the water consumption was categorized into two, domestic water consumption and others. For the domestic water consumption, the same per capita consumption as Suphanburi's was assumed. Because of the district's character, large consumers' consumption by such as public institution and large business is not distinct. The small size consumptions other than the domestic will be defined as the other consumption.

The domestic and other water consumptions are shown in Table-2.6.

Table-2.6 WATER CONSUMPTION FOR PHOPHRAYA SANITARY DISTRICT

YEAR	SERVED POPULATION	DOMESTIC PER CAPITA CONSUMPTION (lpcd)	DOMESTIC WATER CONSUMPTION (cu m/day)	OTHER PER CAPITA CONSUMPTION (lpcd)	OTHER WATER CONSUMPTION (cu m/day)
1985	3,400	82	270	12	40
1990	3,800	94	360	24	90
1995	4,200	105	440	35	150
2000	4,500	117	530	47	210
2005	4,700	128	610	58	280
2010	5,000	140	700	70	350

2.3.3 Total Water Consumption

The total of the categorized consumptions, of Suphanburi Municipality and Phophraya Sanitary District, is shown in Table-2.7.

Table-2.7 TOTAL WATER CONSUMPTION FOR SUPHANBURI AND PHOPHRAYA SANITARY DISTRICT

Unit: cu m/day

	SUPHANBURI			PHOPHRAYA		
	DOMESTIC	PUBLIC	LARGE BUSINESS	DOMESTIC	OTHERS	TOTAL
1985	1,570	630	370	270	40	2,880
1990	2,070	890	520	360	90	3,930
1995	2,570	1,160	680	440	150	5,000
2000	3,130	1,470	860	530	210	6,200
2005	3,660	1,760	1,040	610	280	7,350
2010	4,250	2,100	1,240	700	350	8,640

2.4 Average Day and Maximum Day Water Demand

2.4.1 Unaccounted-for Water and Average Day Water Demand

To the total water consumption, the unaccounted-for water shall be added to determine the average day demand.

The unaccounted-for water ratio from 1965 to 1984 is shown in Fig-2.3. It stayed below or close to 20 % before 1980, except in a few occasional years. After 1980 however, it started to rise and in 1984 it reached 42 %.

The recent high ratio is most possibly attributable to the aged and weakened pipes. The pipelines installed in 1950s are said to be of Class 15 Asbestos Cement Pipe and after more than 30 years' service, they must have become less resistant to pressure and may be leaking substantially.

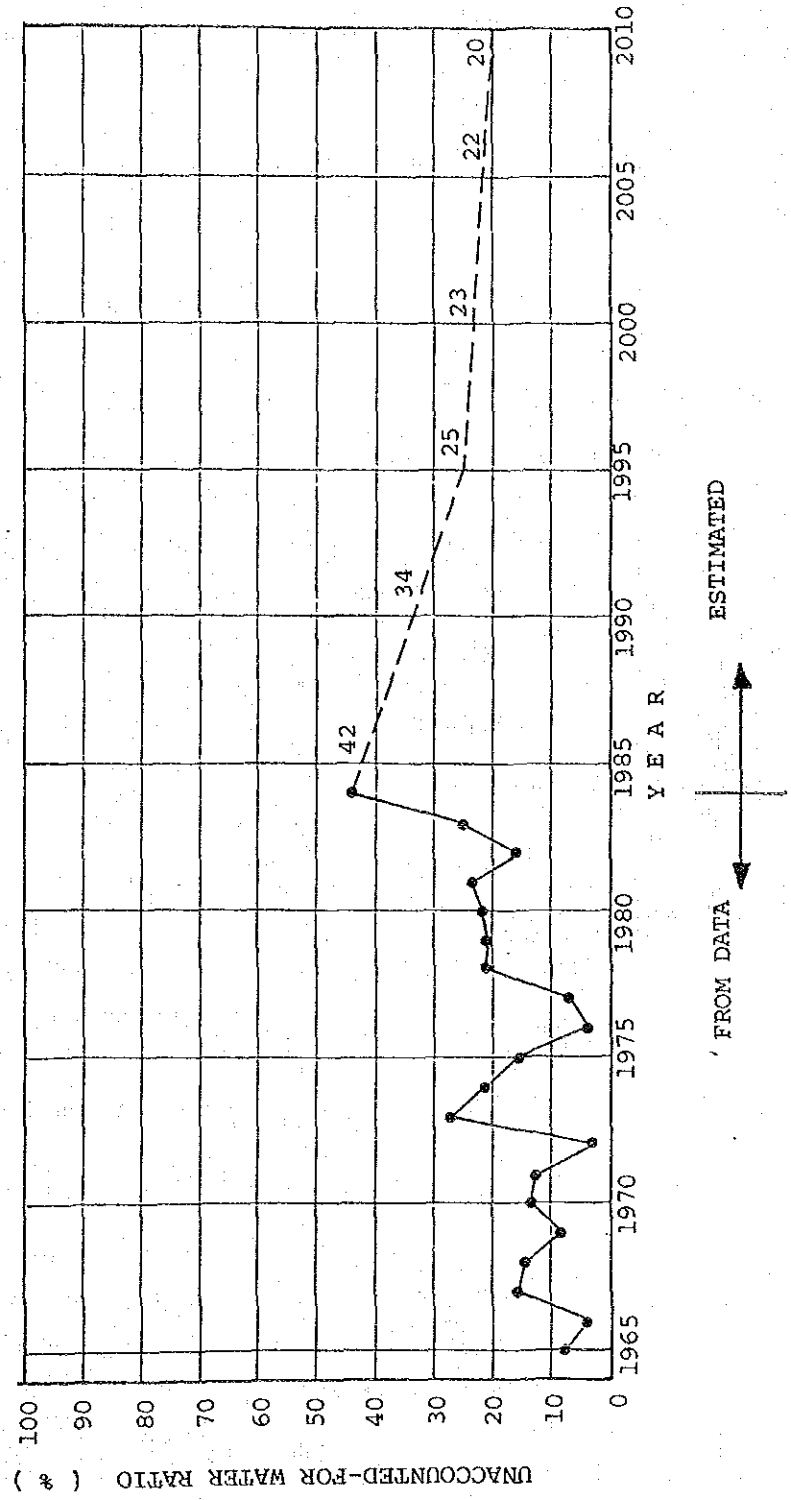

FIGURE	UNACCOUNTED-FOR WATER RATIO OF SUPHANBURI
2.3	

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PWA set a target of reducing the unaccounted-for water ratio to 25 % in 1995 and 20 % in 2010. The planned rehabilitation and modification works will enable to attain it and the projection is made in accordance with the target.

From the total water consumption in Table-2.7 and the unaccounted-for water ratio projected as above, the average day water demand is calculated, as shown in Table-2.8.

Table-2.8 AVERAGE DAY WATER DEMAND

YEAR	TOTAL WATER CONSUMPTION (cu m/day)	UNACCOUNTED-FOR WATER RATIO (%)	AVERAGE DAY DEMAND (cu m/day)
1985	2,880	42	4,970
1990	3,930	34	5,950
1995	5,000	25	6,670
2000	6,200	23	8,050
2005	7,350	22	9,420
2010	8,640	20	10,800

2.4.2 Peak Factor and Maximum Day Water Demand

The maximum day demand is calculated by multiplying the average day demand by the peak factor, the ratio of maximum to average day water demand. Regarding this water supply system, no information related to the factor, applicable directly, was not available.

A record of the Umong Treatment Plant's output in Chiangmai, from Jan 1st to Sep 30th in 1985, was processed to formulate Table-2.9 and used for estimating the peak factor of Suphanburi.

Table-2.9 NUMBER OF DAYS ON PEAK FACTOR OF MAX. DAY DEMAND TO AVE. DAY DEMAND
(Jan 1, 1985 - Sep 30, 1985, Umong Treatment Plant, Chiangmai)

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

The table shows, for example, that 6 days fell in 1.25 - 1.29 peak factor range in 31 days of March, and 42 days of the total 121 days of the period belonged to 1.00 - 1.04 range.

The table says that the maximum of 1.30 - 1.34 size occurs in February or March most probably.

The peak factors employed in other cities' plan are referred and cited bellow:

Name of City	Peak Factor
Bangkok	1.20
Khon Kaen	1.37
Udonthani	1.30
PWA Criteria	1.50

1.35 was adopted and applied to the Suphanburi Municipality and Phophraya Sanitary District.

Table-2.10 showing the maximum day demand is calculated by the peak factor and the average day demand in Table-2.8. The maximum and average day demands are plotted in Fig-2.4.

Table-2.10 MAXIMUM DAY WATER DEMAND

Item	1985	1990	1995	2000	2005	2010
AVERAGE DAY DEMAND	4,970	5,950	6,670	8,050	9,420	10,800
PEAK FACTOR	1.35	1.35	1.35	1.35	1.35	1.35
MAXIMUM DAY DEMAND	6,710	8,030	9,000	10,870	12,700	14,580

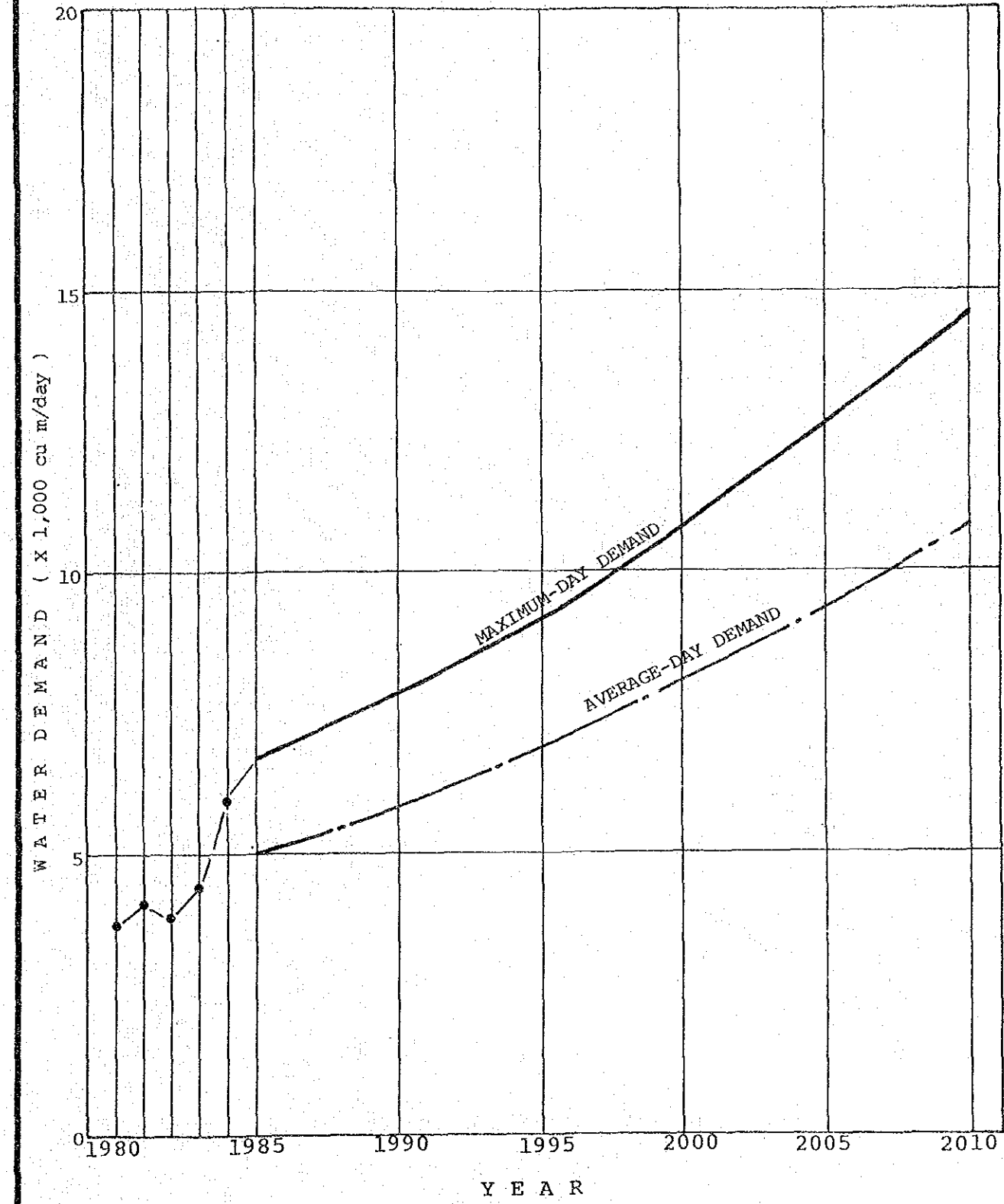

FIGURE 2.4

FUTURE WATER DEMAND FOR SUPHANBURI

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APPENDIX 3

STUDY ON WATER SOURCE

APPENDIX 3

APPENDIX 3 STUDY ON WATER SOURCES

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APPENDIX 3 STUDY ON WATER SOURCES

3.1 Introduction

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

This water sources study was undertaken in two period, one from December 16 to February 13, 1986 and another from June 1 to August 31, 1986 to prepare the master plan and feasibility study of the Provincial Water Supply - Project. In this report, plans to meet the water demand conditions in 2010 are discussed.

Availability of water resources and possibility of developing them have been looked into, from the climatic, geographical, topographical, hydrological and hydrogeological conditions, and attention has been paid on the groundwater as well as the surface water.

To assess the quality problems of the prospective water sources, Appendix 4, a study of water quality, has been prepared also and relevant matters are quoted in this report from the appendix.

3.2 Climate

The climate of Suphanburi is influenced by tropical monsoon. The southwest monsoon usually extends from May to October in the area, causing long rainy season of 6 months duration. The average number of rainy day is around 108 and the average rainfall around 1,270 millimeters a year. (Table-3.1)

From 1956 to 1974, AIT and DMR, under the request of the National Environment Board, made hydrologic evaluation of the area and the result was reported in February 1980. The report, evaluating the hydrologic conditions of the Lower Central Chao Praya Plain including Suphanburi, showed the water balance as seen in Table-3.2 and Fig-3.1.

The mean annual rainfall over the Plain is 1,190.9 mm, and the measured streamflow (runoff) corresponds to 184.9 mm, 15.5 % of the annual rainfall. Assuming the area of Lower Central Chao Phraya Plain of 53,400 sq km, an

Table - 3.1 MONTHLY RAINFALL : 1969 - 1978

ปี Year	มกราคม January		กุมภาพันธ์ February		มีนาคม March		เมษายน April		พฤษภาคม May		มิถุนายน June		กรกฎาคม July		สิงหาคม August		กันยายน September		ตุลาคม October		พฤศจิกายน November		ธันวาคม December		ทั้งปี Annual	
	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 (Mean)...	1	15.2	1	9.6	3	28.4	5	93.5	13	155.8	13	115.0	16	113.8	16	152.7	20	337.5	14	200.6	4	30.6	2	24.1	108	1,273.7
เบี่ยงเบน (S.D.)	1.8	28.7	1.5	15.1	1.3	41.0	2.5	82.2	5.6	88.4	2.6	57.5	3.3	51.8	3.0	55.7	2.2	119.7	4.0	79.9	2.7	22.9	1.7	30.3	16.2	219.7
2512 (1969) ...	0	T	1	39.4	3	37.8	7	126.2	7	74.2	12	100.6	18	197.8	12	186.5	21	478.7	10	51.6	4	26.4	0	0.0	95	1,319.2
2513 (1970) ...	1	0.4	2	2.0	2	7.6	7	38.8	18	239.9	19	199.0	18	123.5	22	220.3	21	240.4	16	188.6	2	14.8	5	60.4	133	1,335.7
2514 (1971) ...	1	3.0	2	1.4	1	10.4	8	138.9	14	93.8	12	91.8	15	54.4	17	185.4	17	259.2	13	222.2	2	0.6	3	10.0	105	1,071.1
2515 (1972) ...	0	0.0	1	0.2	4	16.1	8	109.6	3	78.8	14	111.6	15	71.0	14	96.8	19	488.4	15	235.4	10	68.9	4	71.9	107	1,348.7
2516 (1973) ...	0	T	0	0.0	3	55.2	2	5.8	13	196.3	16	180.6	15	127.8	16	160.2	22	409.8	7	154.7	5	8.4	1	1.4	100	1,308.2
2517 (1974) ...	1	0.2	0	0.0	5	141.1	8	227.2	13	80.9	15	196.9	21	102.7	18	175.4	22	228.0	21	380.9	6	43.3	0	0.0	130	1,576.6
2518 (1975) ...	6	86.1	0	0.0	3	9.1	2	10.6	15	258.3	12	123.4	10	80.7	16	237.4	17	198.3	18	193.1	7	62.4	3	76.2	109	1,335.6
2519 (1976) ...	0	0.0	2	37.8	1	1.3	4	14.1	22	306.6	13	44.5	12	57.4	18	110.6	18	431.8	15	245.5	4	47.1	1	7.1	110	1,303.8
2520 (1977) ...	0	0.0	0	0.0	3	5.6	2	32.7	6	41.4	9	29.1	12	110.7	12	87.0	20	180.6	9	187.4	1	28.8	1	14.4	75	317.7
2521 (1978) ...	2	31.9	5	14.7	1	0.1	6	230.7	17	187.4	12	72.6	19	212.3	19	67.6	24	459.4	15	146.5	1	4.8	0	0.0	121	1,428.0

T Not measurable.

Source : Meteorological Department, Ministry of Communications.

DATA: NSO, 1983

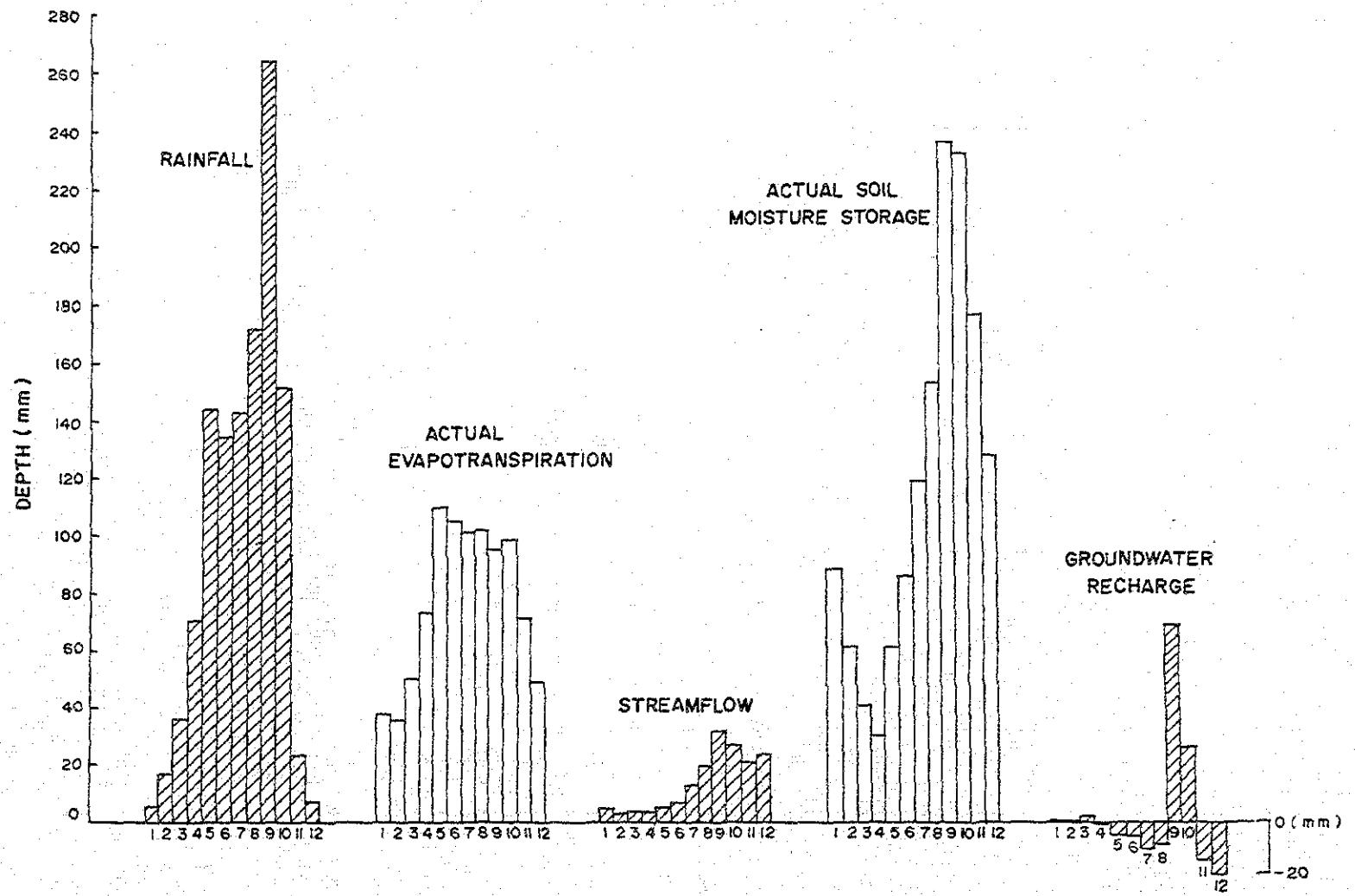
Table - 3.2 WATER BALANCE COMPONENTS LOWER CHAO PHRAYA PLAIN PERIOD 1956 TO 1974

(mm)

	RAINFALL	ACTUAL EVAPO-TRANSPIRATION	STREAMFLOW	ACTUAL SOIL MOISTURE	CHANGE IN SOIL MOISTURE	GROUNDWATER RECHARGE
JAN	6.5	39.8	6.9	92.2	-41.0	+ 0.8
FEB	17.2	39.1	4.3	63.8	-28.4	+ 2.2
MAR	36.5	52.4	4.8	43.1	-20.7	+ 0.0
APR	71.7	76.6	5.2	33.4	- 9.7	- 0.4
MAY	145.7	112.7	7.7	63.6	+30.2	- 4.9
JUN	136.1	108.7	8.2	89.4	+25.8	- 6.6
JUL	144.9	105.7	14.3	123.5	+34.1	- 9.2
AUG	173.6	105.9	21.4	179.0	+55.0	- 8.7
SEP	269.1	98.0	33.9	245.1	+66.1	+71.1
OCT	154.6	102.1	26.8	242.4	- 2.7	+26.4
NOV	25.8	75.5	23.2	183.7	-58.7	-14.2
DEC	9.2	52.1	26.2	133.2	-50.5	-18.6
ANNUAL	1190.9	968.6	184.9			+37.9

DATA: NEB + AIT, Feb. 1980

WATER BALANCE COMPONENTS OF LOWER CHAO PHRAYA BASIN



DATA : AIT , DMR / NEB , 1980

FIGURE	WATER BALANCE COMPONENTS
3.1	OF LOWER CHAO PHRAYA BASIN

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effective outflow is counted as 9,874 million cu m/year.

The average annual evapo-transpiration is 968.6 mm, which equals to 81.3 % of the annual rainfall, while the annual groundwater recharge is 37.9 mm equivalent, only 3.2 % of the annual rainfall of the area.

3.3 Geographical and Geological Setting

Suphanburi is located in the Lower Central Chao Phraya Plain along the Tha Chin river (Suphanburi river), at 115 km upstream from the coast. The area forms flat deltic plain, and is from 4 to 9 m above the mean sea level. The lower Central Chao Phraya Plain comprises approximately 53,400 sq km, an area extending from north to south, roughly 250 km long and about 200 km wide.

The Plain is covered by thick Alluvial and Tertiary sediments. The topmost thick clay called "Bangkok Clay" is about 20 to 30 m thick covering the whole Bangkok Metropolis, extended from the Suphanburi area.

The mountains surrounding the Chao Phraya Plain were formed during the Paleozoic to Teriary Orgeny. The present Chao Phraya River Basin was probably formed as the result of the north-south trending fault tectonic, occurred during the Cretaceous to Tertiary time and followed by heavy Quaternary depositions. The basin structures were evidently formed by block faulting into graben and forst southward to the Gulf of Thailand. Aeromagnetic data indicate that the depth to basement in the area ranges from 400 m to 3,000 m. The sediments were described as fluvial and deltaics from the Oligocene to Recent age (Achalabhuti C., 1974).

3.4 Hydrogeology

In the Lower Central Chao Phraya Plain, there exist large artesian groundwater basins in the graben structures which were formed by the north-south trending block fault. Groundwater is found in a series of vast confined aquifers consisting of sand and gravel which extends to the depth of 400 m to 500 m of the Pleistocene underlying the Bangkok Clay. The top confining unit called the Bangkok Clay (20 m to 30 m thick) is continuously lying through the Lower Central Chao Phraya Plain, and the clay unit, due to its poor permeability, makes recharge from the ground surface difficult.

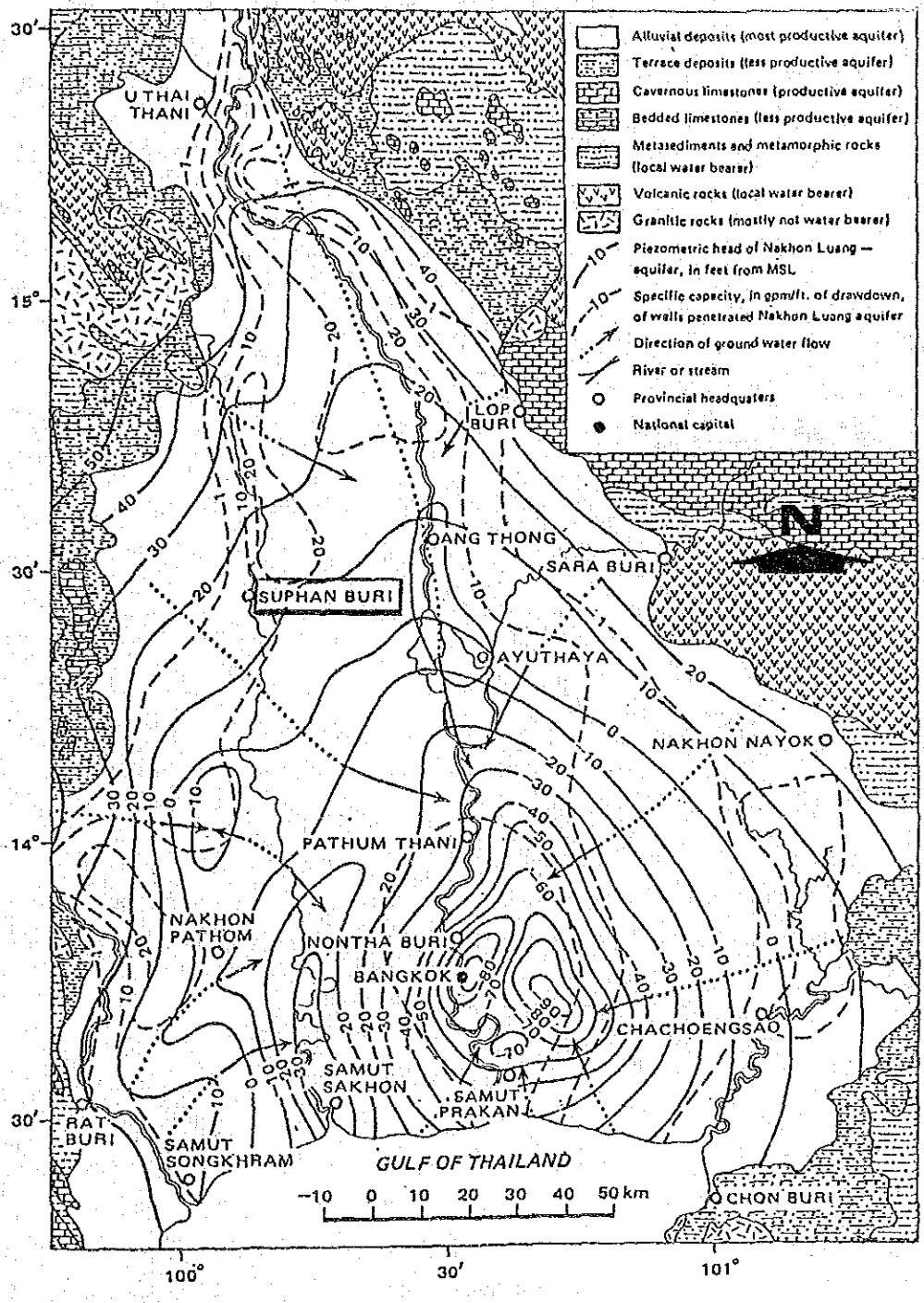
The mountains are surrounding the artesian basin in which the hydrogeological basement and/or old rocks consisting of limestone, sandstone, shale, granite and metamorphics crop out, and groundwater recharge is thought to be coming from outside of the basin. The topmost aquifer of the Bangkok Upper 30 m zone is exposed above the ground near Ayuttaya 90 km north of Bangkok, and groundwater is directly recharged there by the river and from the surface. In Saraburi and Kanchanaburi provinces, it is believed that there is a source which recharges into the deeper part of confined aquifers from the cropping-out limeston on the hills.

Groundwater flows from the periphery of the artisan basin towards the central core of basin, as shown in Fig-3.2. A slope of piezometric surface indicates transmissibility of the aquifers. Steep slopes along the periphery of the basin show relatively low permeability and/or thin aquifers. Therefore, the groundwater potential in the steeply sloped contours is low, and the gently sloped area shows high transmissibility and permeability, and/or thick aquifer. Consequently, the groundwater potential in the Lower Central Chao Phraya Plain is relatively high at the center core of the artesian basin. (Rf. SEATEC, 1978)

3.5 Aquifer System

Regarding the Lower Central Chao Phraya Basin, DMR, CDM-GMI, M & E (1969 - 1981) and NSC (1982 - 1984) presented reports, studying the aquifer system and the properties related to groundwater such as the depth and thickness of aquifer, lithology, groundwater quality and present situation of groundwater uses.

Hydrogeologic map of the Lower Central Plain



(Rf. Ch. Pincharoen, 1978)

FIGURE	ARTESIAN GROUNDWATER BASIN
3.2	IN THE LOWER CENTRAL CHO PHRAYA PLAIN

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In the area of Suphanburi and Bangkok, a series of nine (9) confined aquifers with depth of 30 m to 550 m level have been already found, as listed below. Hydrogeological cross section of the above aquifers system is illustrated in Fig-3.3.

1. Bangkok Upper Aquifer (30 m zone)
2. Bangkok Lower Aquifer (50 m zone)
3. Phra Pradaeng Aquifer (100 m zone)
4. Nakhon Luang Aquifer (150 m zone)
5. Nonthaburi Aquifer (200 m zone)
6. Sam Khok Aquifer (250 m zone)
7. Phya Thai Aquifer (350 m zone)
8. Thonburi Aquifer (450 m zone)
9. Pak Nam Aquifer (550 m zone)

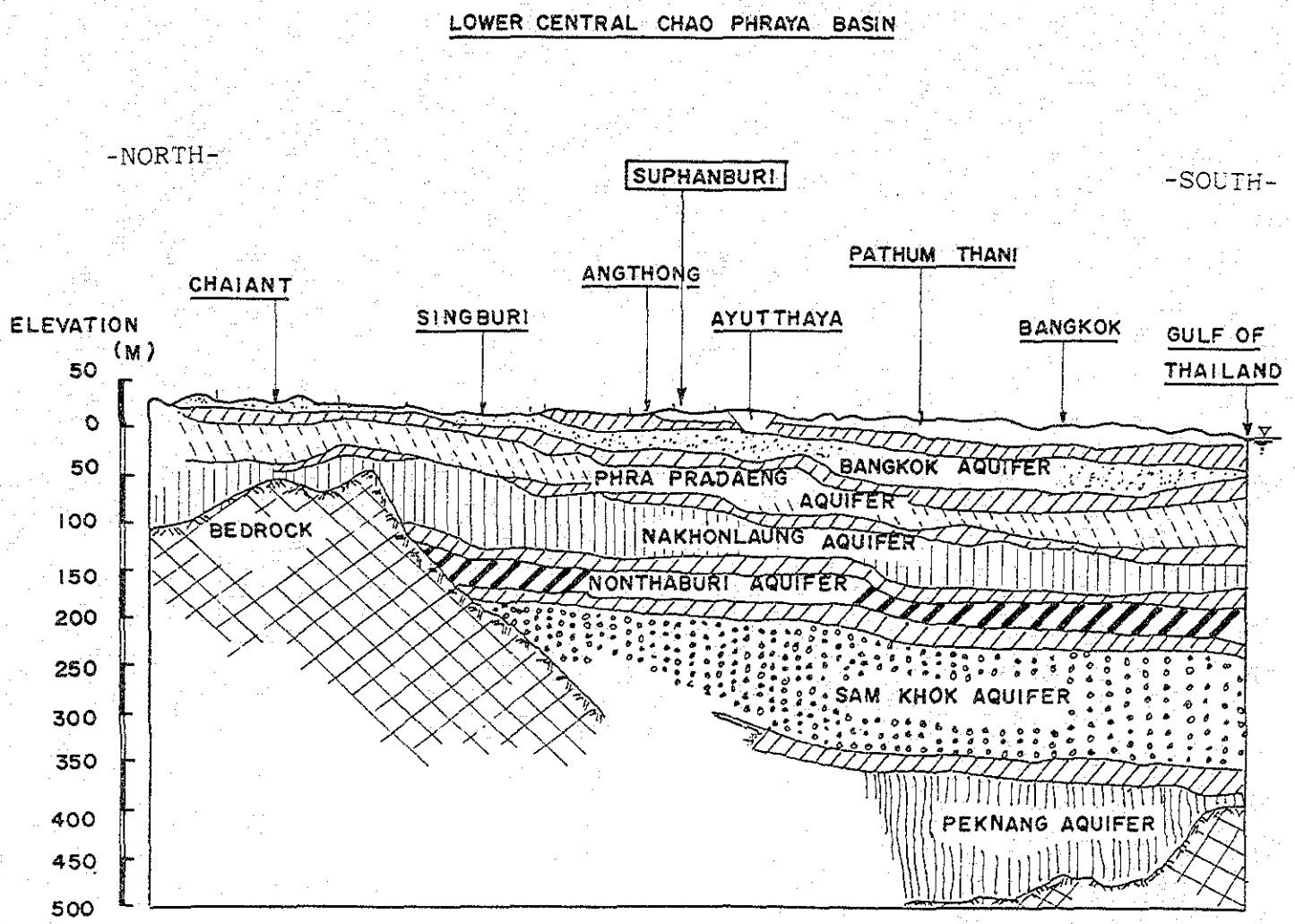
The top five (5) aquifers have been widely used in the existing wells, due to their superior productivity.

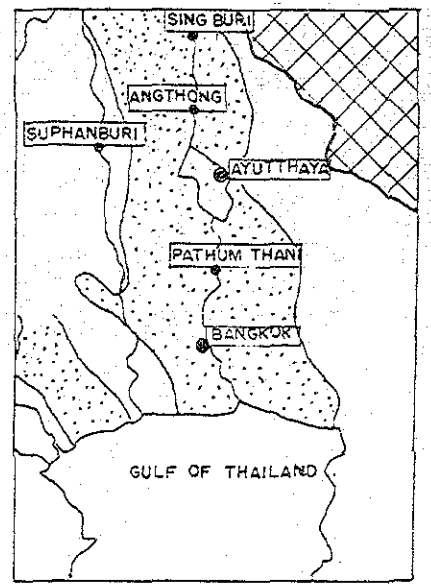
The top aquifer is called "Bangkok Aquifer", and it is divided into two parts by the depth: namely, Bangkok Upper 30m Aquifer and Bangkok Lower 50 m Aquifer. The Bangkok Upper 30 m Aquifer is overlied by thick impermeable Bangkok Clay (20m to 30m), and it is a confined aquifer consisting of sand and gravel, interbedded with clay of the Pleistocene age.

The third aquifer is the Phra Pradaeng 100 m Aquifer, which consists of white sand and gravel and is separated from the Bangkok Lower 50 m Aquifer by hard brown to brownish grey clay.

The Nakhon Luang 150 m Aquifer which is producing the largest part of groundwater has superior productivity and good quality as fresh water, and it is the principal aquifer of both the public and private wells in Bangkok Metropolis presently.

The Nonthaburi 200 m Aquifer is becoming an important groundwater source of the public deep wells, because of good water quality, high productivity due to the thick beds and the properly distributed particles, from fine sand to coarse gravel, with void-filling sandy clay.





After Lutfor Rahma, AIT 1976

FIGURE	HYDROGEOLOGICAL CROSS SECTION
3.3	OF LOWER CENTRAL CHAO PHRAYA BASIN

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The Samkok 250 m Aquifer is one of the deep aquifers which underlie the northern part of Nonthaburi and Patahumthani. It is a moderately productive aquifer and yields fresh water with good quality.

The Samkok 250 m Aquifer, Phya Thai 350 m Aquifer and Thonburi 450 m Aquifer provide fresh water but occasionally contain high chloride, iron and fluoride. These Aquifers are presently producing small amount of water in Bangkok Metropolis.

According to the reports (Rf. Ch. Piancharoen et al, 1978 and others), the Phya Thai 350 m Aquifer was found during the test hole drilling in the compound of the Ministry of Industry, Phya Thai district. The Aquifer consists of quartz and chert sands of dirty brown, poorly sorted angular sand and gravel interbedded with brown clay. The Thonburi 450 m Aquifer is separated from the Phya Thai 350 m Aquifer by dense clay, consisting of grayish brown sands and gravels interbedded with clay.

The deepest aquifer is the Pak Nam 550 m Aquifer, separated from the Thonburi Aquifer by thick clay. The aquifer is composed of well sorted sand and gravel interbedded with greenish-to-dark gray clay..

3.6 Available Water Sources

3.6.1 Surface Water Evaluation

The Tha Chin River (Suphanburi River), the important water resource in the lower Central Chao Phraya Plain, contributes to the large part of water uses, inclusive of irrigation, flood control, navigation and drinking water supply (Fig-3.4). The Suphanburi waterworks depend on the Tha Chin River (Suphanburi River) of its water source.

The first plant at Prapuwasa was built in 1956 and the second plant at Dab Fafhun in 1965, and the both took water from the Tha Chin river at points not far from the central part of Suphanburi. However, as pollution of the river proceeded in the following years, these two plants experienced difficulty in producing good quality water and, eventually in 1966 the Phophraya Plant of 200 cu m/h (4,800 cu m/day) capacity replaced the production of the two plants which produced 40 cu m/h (960 cu m/day) each. The newly

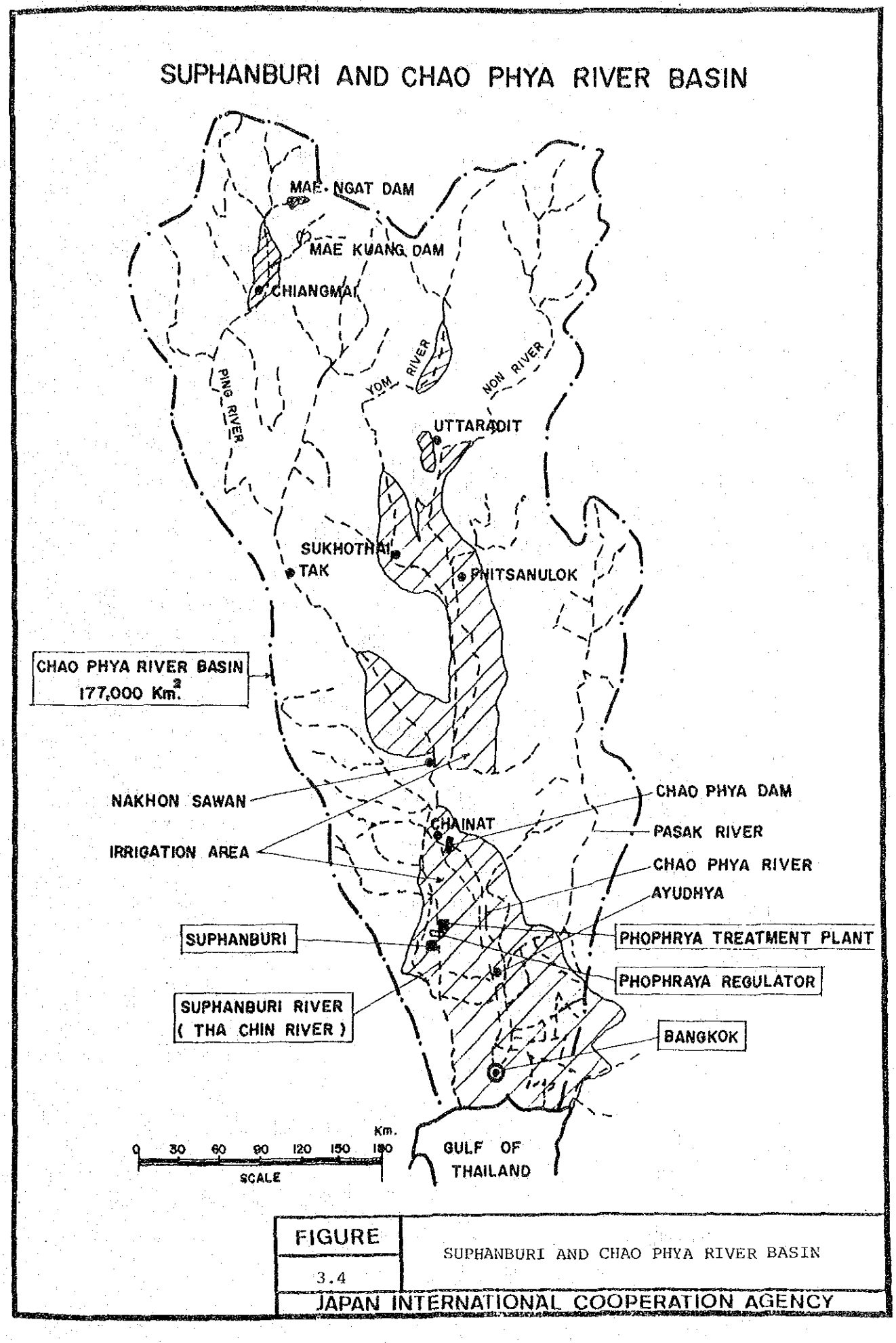

FIGURE	SUPHANBURI AND CHAO PHYA RIVER BASIN
3.4	
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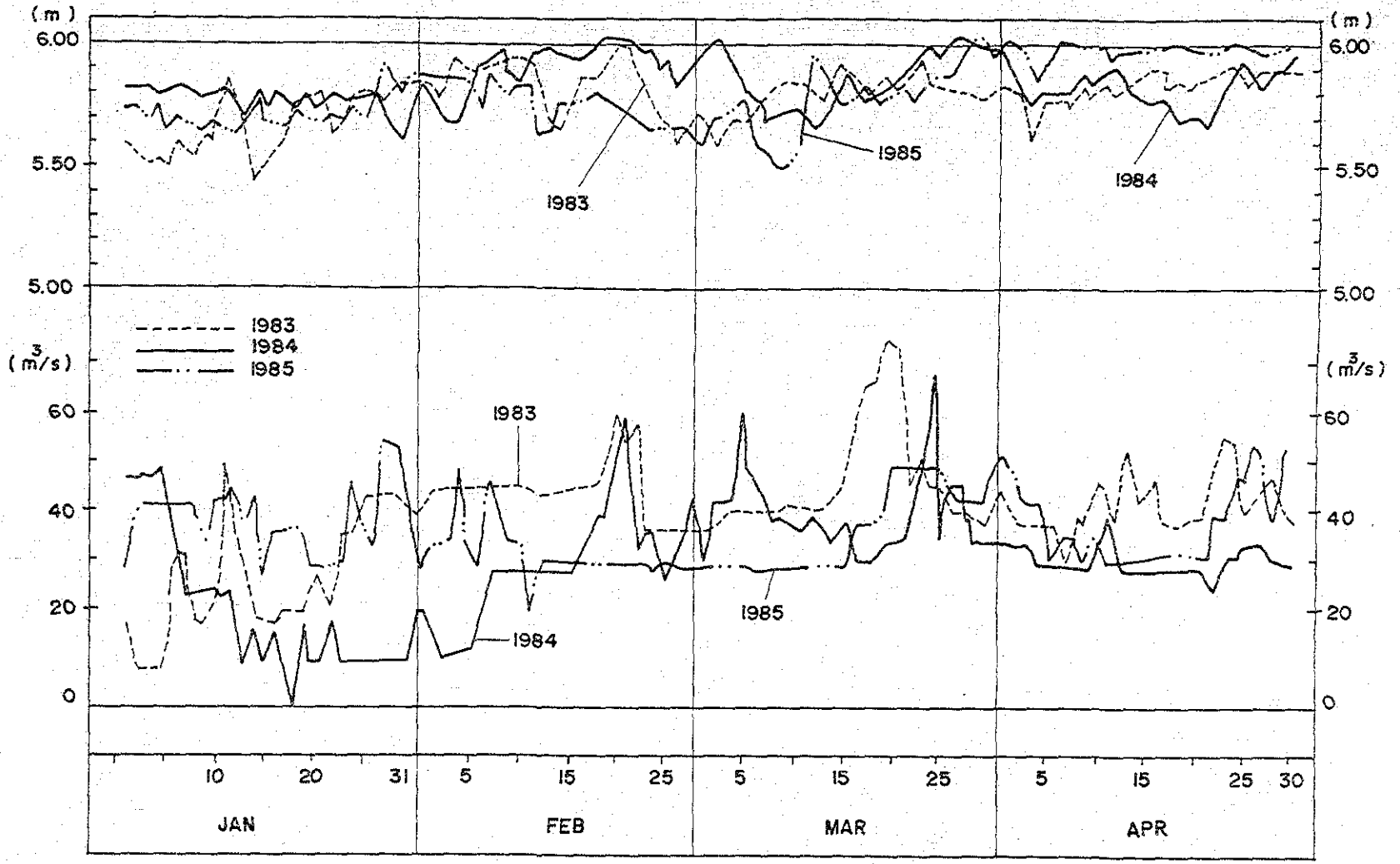
constructed Phophraya Plant was located at about 10 km upstreams of the old plants along the same river.

Figs-3.5, 3.6 and 3.7 indicate the river flow and stored water level at the Pho Phaya Regulator on the Tha Chin River from 1982 to 1985. The river's water level is controlled by this Regulator. The river discharge increases in February and March, owing to the irrigation demand for the dry period, ranging from 30 to 40 cu m/s. And during the southeast monsoon in September through November, the discharge is maintained at a higher level, reaching 200 cu m/s occasionally. Afterwards it falls rapidly, staying low till February.

The water source used currently by the Suphanburi Waterworks is the Tha Chin River from which 1.75 MCM/year (0.056 cu m/sec) is being taken. As 10 to 20 cu m/s (315 to 630 MCM/yr) flows steadily even in the dry season at the Regulator, the present intake of 1.75 MCM/yr (4,800 cu m/day) is a minute portion of the river flow. Aside from the flow, as the intake is located upstreams of the Phophraya Regulator, a water gate, which is controlled to maintain water level by RID, the waterworks intake is assured of the stability of intake operation.

The water quality at the intake is concerned about, as pollution by the wastewater of households and livestock breeders is taking place. However, the water quality at Phophraya is almost acceptable, except for iron which tends to run high in the rainy season and is detected in the treated water.

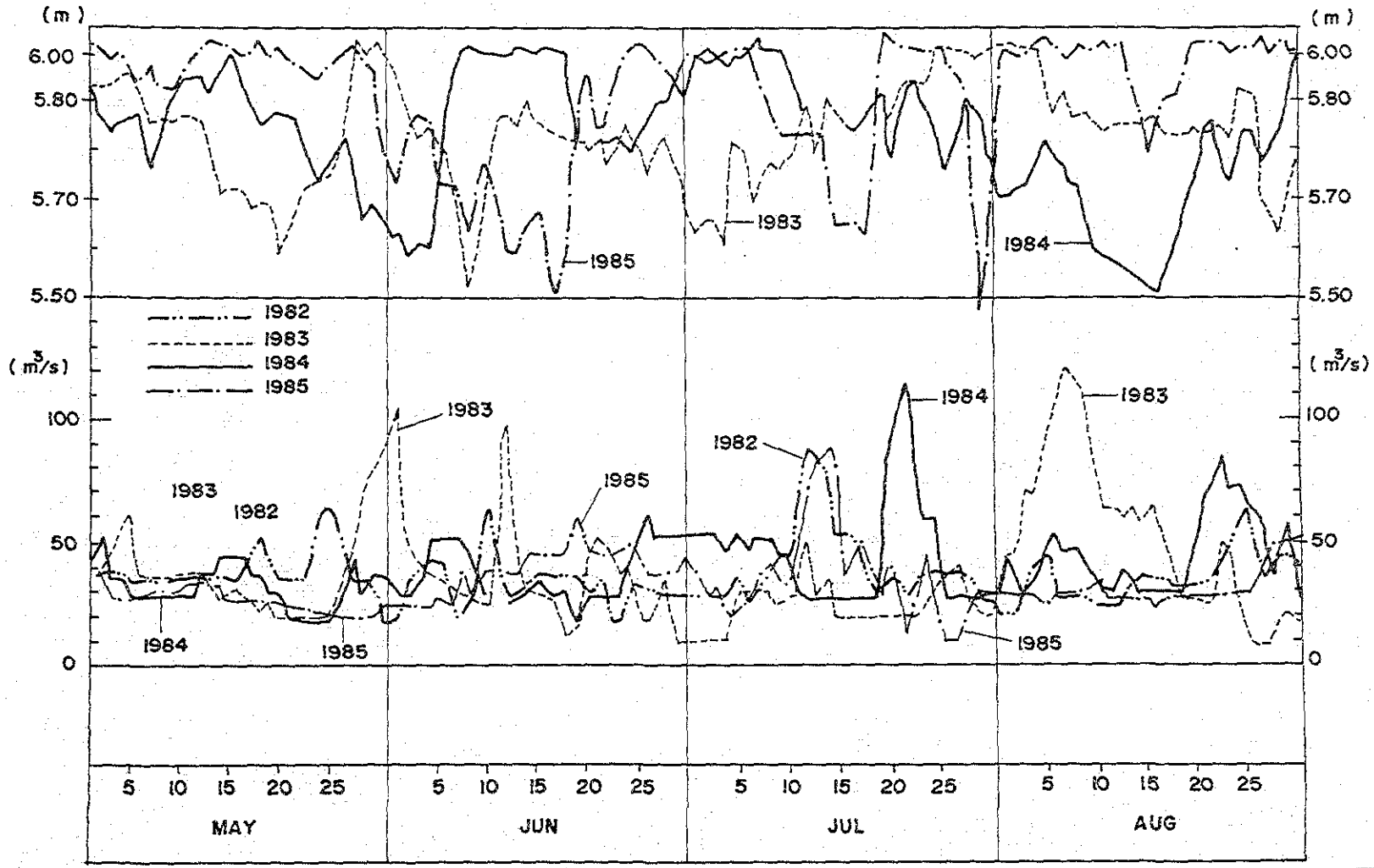
DISCHARGE AND WATER LEVEL AT PHO PHAYA REGULATOR , SUPHANBURI (I)



DATA: RID, 1986

FIGURE	DISCHARGE AND WATER LEVEL
3.5	AT PHO PHAYA REGULATOR, SUPHANBURI (1)
JAPAN INTERNATIONAL COOPERATION AGENCY	

DISCHARGE AND WATER LEVEL AT PHO PHAYA REGULATOR , SUPHANBURI (2)

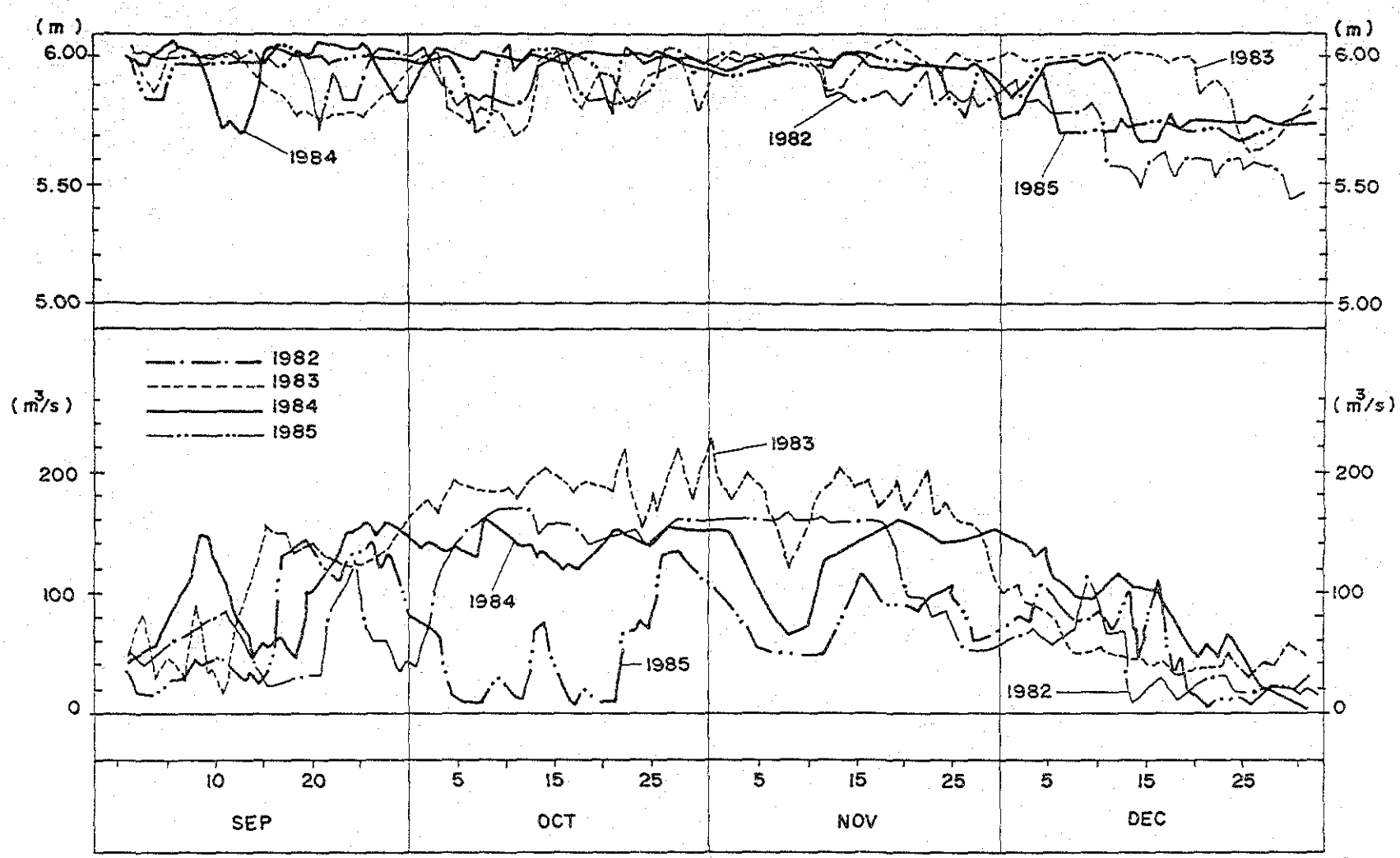


DATA: RID, 1986

FIGURE	DISCHARGE AND WATER LEVEL AT PHO PHAYA REGULATOR, SUPHANBURI (2)
3.6	

JAPAN INTERNATIONAL COOPERATION AGENCY

DISCHARGE AND WATER LEVEL AT PHO PHAYA REGULATOR , SUPHANBURI (3)



DATA: RID, 1986

FIGURE	DISCHARGE AND WATER LEVEL
3.7	AT PHO PHAYA REGULATOR, SUPHANBURI (3)

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