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 III-B

APPENDICES
FOR

UBON RATCHATHANI
AND
WARIN CHAMRAP

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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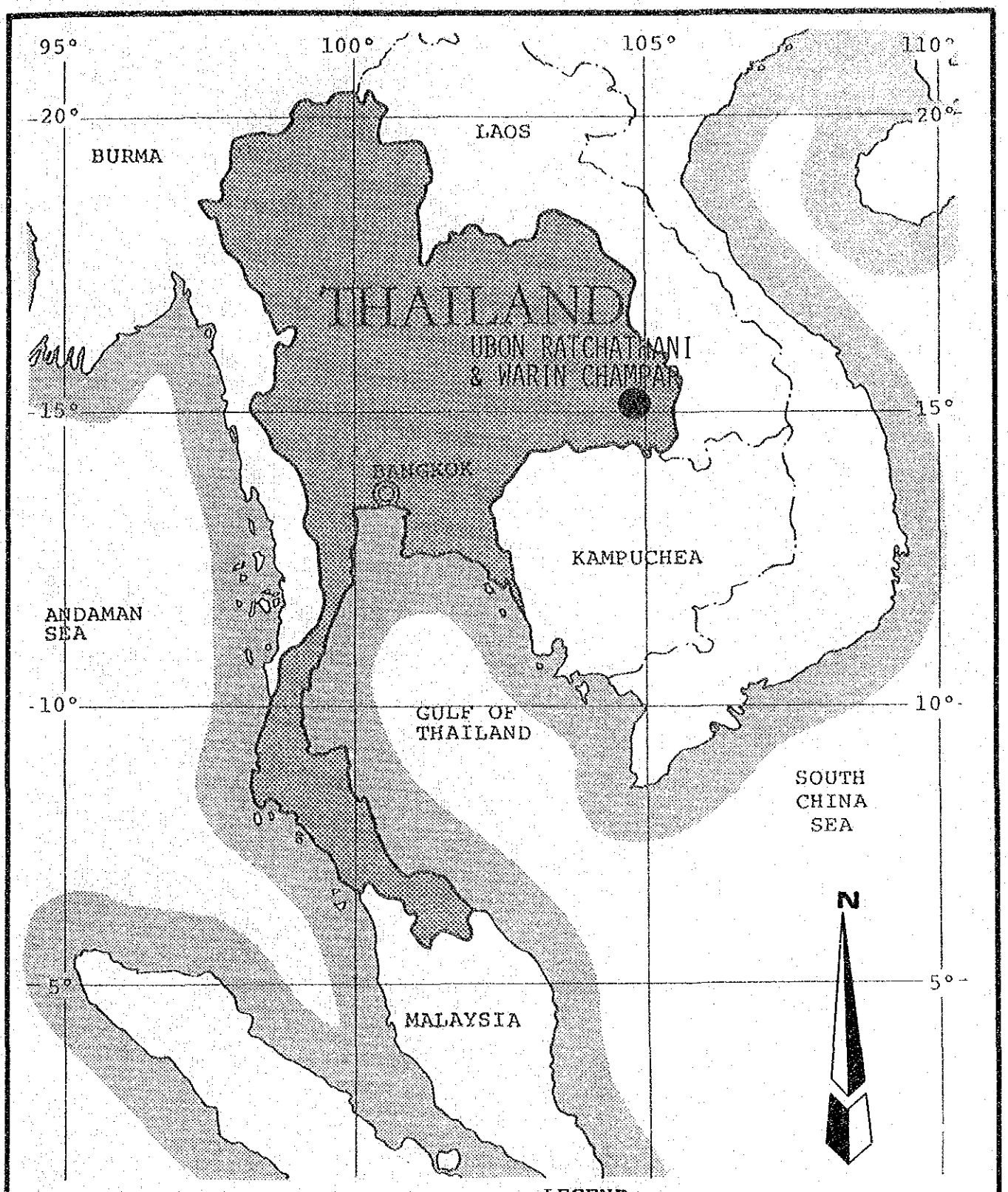

LEGEND

● : UBON & WARIN MUNICIPALITIES

◎ : 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 eight districts, Ubon Ratchathani Municipality, Warin Chamrap Municipality, Ubon Sanitary District, Ban Pak Huai Wang Nong, Ban Don Klang, Ban Tha Bong Mang, Ban Hat Suan Ya, and Ban Mai Klang. 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 Ubon and Warin Municipalities are shown in Table-1.1 and plotted in Fig-1.1.

As for the records of the past population of Ubon Sanitary District and five villages, only the data in 1984 were available and they are shown in Table-1.2.

Regarding the population in Ubon Municipality, as shown in Fig-1.1, it is found that two big fluctuations occurred in the past. The sharp increase in 1972 - 1973 and gradual decrease in 1976 - 1977 probably indicates the Vietnam War's influence which ended in 1975. The sudden jump in 1981 - 1982 resulted from merging with neighboring villages.

Warin's population increased linearly at a slow and steady rate, seemingly unaffected much by the War.

In 1984, the total population, including Ubon, Warin, sanitary district, and five villages, was 142,640. The populations in each area and their proportions are shown in Table-1.3.

Table-1.1 DATA OF PAST POPULATION

YEAR	AREA	
	UBON	WARIN
1965	31,189	8,968
1966	32,052	21,427
1967	34,619	22,500
1968	35,224	22,652
1969	37,005	23,609
1970	38,744	24,854
1971	40,710	24,815
1972	41,755	25,290
1973	52,690	25,950
1974	52,713	26,507
1975	52,281	27,393
1976	52,159	27,845
1977	49,883	27,720
1978	48,227	28,180
1979	48,208	29,183
1980	48,466	29,183
1981	48,596	29,643
1982	99,469	30,201
1983	100,219	30,143
1984	98,319	30,535

DATA SOURCE : PWA

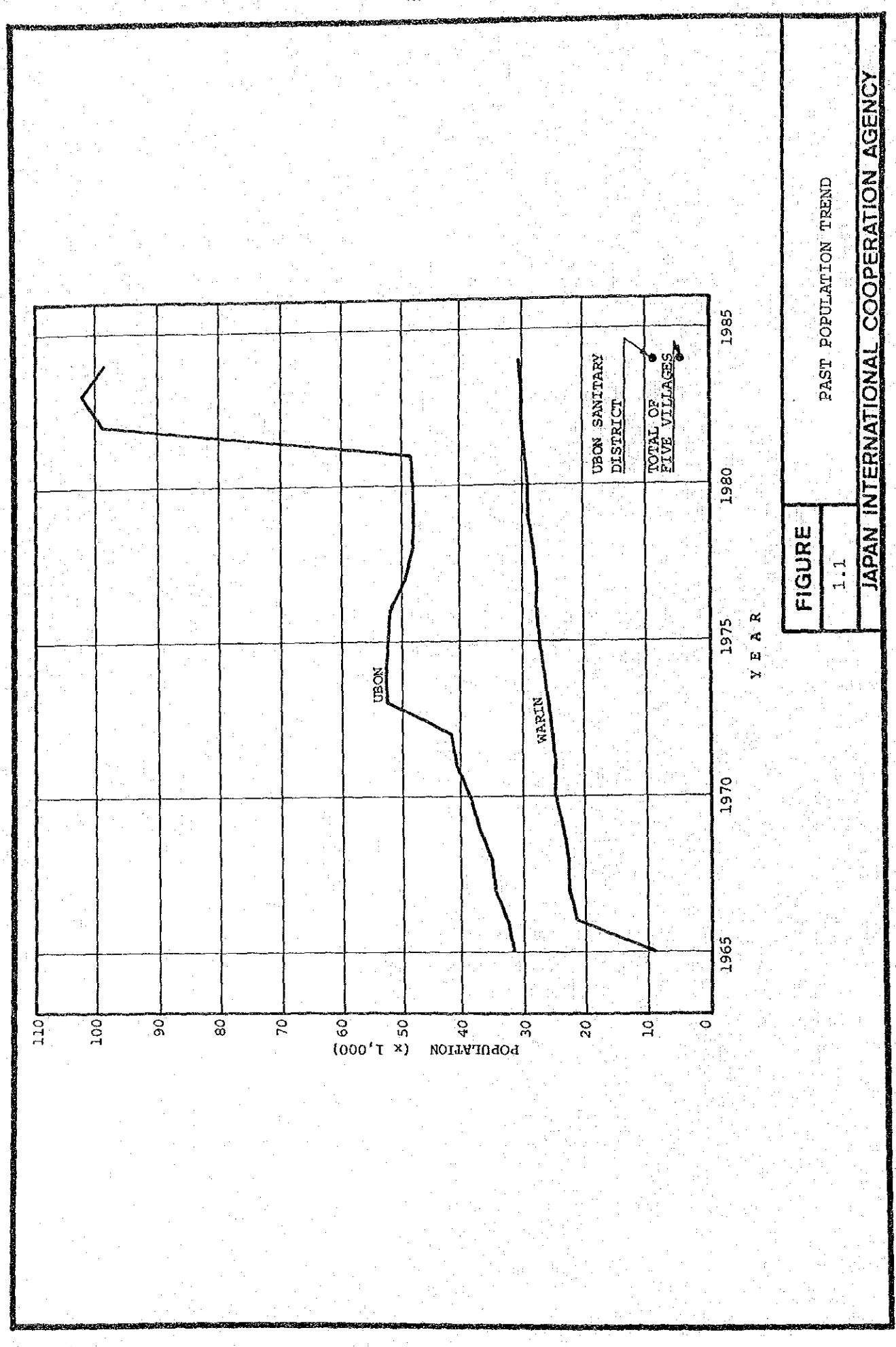

FIGURE 1.1 PAST POPULATION TREND

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Table-1.2 POPULATION OF UBON SANITARY DISTRICT AND FIVE VILLAGES IN 1984

AREA	POPULATION
UBON SANITARY DISTRICT	8,929
FIVE VILLAGES TOTAL	4,844
1. BAN PAK HUAI WANG NONG	779
2. BAN DON KLANG	1,958
3. BAN THA BONG MANG	1,143
4. BAN HAT SUAN YA	
5. BAN MAI KLANG	964

DATA SOURCE : PWA

Table-1.3 POPULATIONS IN EACH AREA AND THEIR PROPORTION IN 1984

AREA	POPULATION	PROPORTION (%)
UBON MUNICIPALITY	98,319	68.9
WARIN MUNICIPALITY	30,535	21.4
UBON SANITARY DISTRICT	8,929	6.3
FIVE VILLAGES	4,844	3.4
TOTAL	142,627	100

1.3 Population Forecast

The results of population forecast for Ubon Municipality and Warin Municipality are shown on Figs-1.2 and 1.3 respectively.

1.3.1 Ubon and Warin Municipalities

Figs-1.2 and 1.3 shows five lines calculated by the before mentioned formulae for Ubon and Warin Municipalities respectively.

In the case of population forecast for Ubon Municipality, the transitory rise and fall, affected probably by the Vietnam War from 1972 to 1977 as mentioned before and shown in Fig-1.1, is disregarded. That it was a temporary phenomenon is observed in the slow but steady increase after 1977, similar to that before 1972.

After the sudden jump in 1981 - 1982 resulted from the merger with neighboring villages, the available data's number is too few to be relied on. Therefore, the mentioned slow and steadily increasing trends before 1972 and in 1977 - 1981 were made the basis of the population forecast.

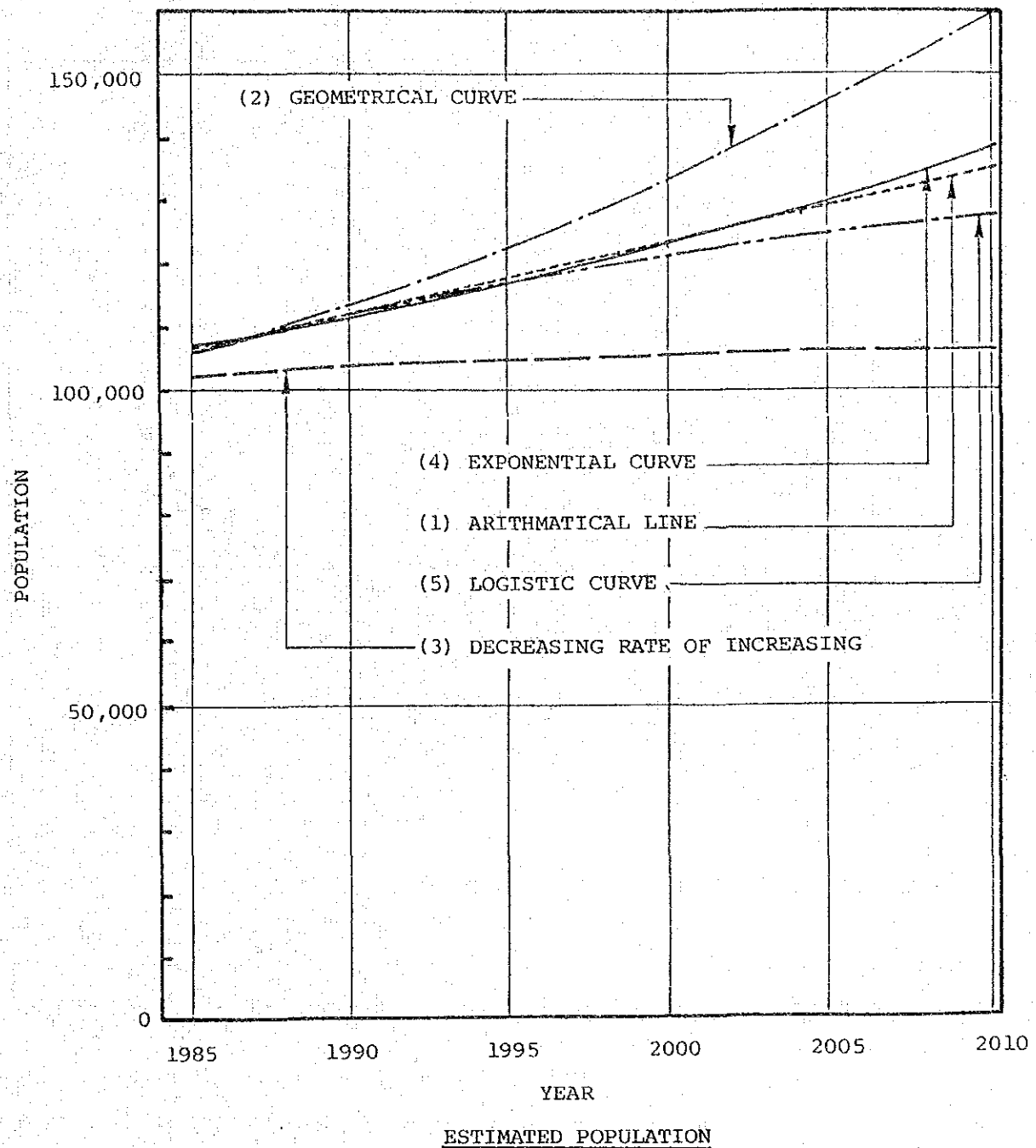
For the both municipalities, the result from the geometrical progression shows a rather high increase ratio, the decreasing rate of increase shows a lower increase ratio in comparison with the past data. These two results are to be discarded, therefore.

Among the other three curves and line, the arithmetical line was selected, because of the 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 military, educational, administrative and commercial activities dealing in farm products of surrounding agricultural areas, as mentioned in Chapter 4, the population increase will not lose the present momentum.

3) This line fits best to the past trend.



ESTIMATED POPULATION

CASE	1985	1990	1995	2000	2005	2010
(1)	106,475	112,232	117,989	123,746	129,503	135,260
(2)	105,167	113,238	122,508	133,156	145,388	159,437
(3)	102,113	103,647	104,619	105,235	105,626	105,874
(4)	106,969	112,524	117,970	123,327	128,610	133,829
(5)	106,452	111,796	116,671	120,996	124,738	127,905

FIGURE 1.2 POPULATION FORECAST OF UBON

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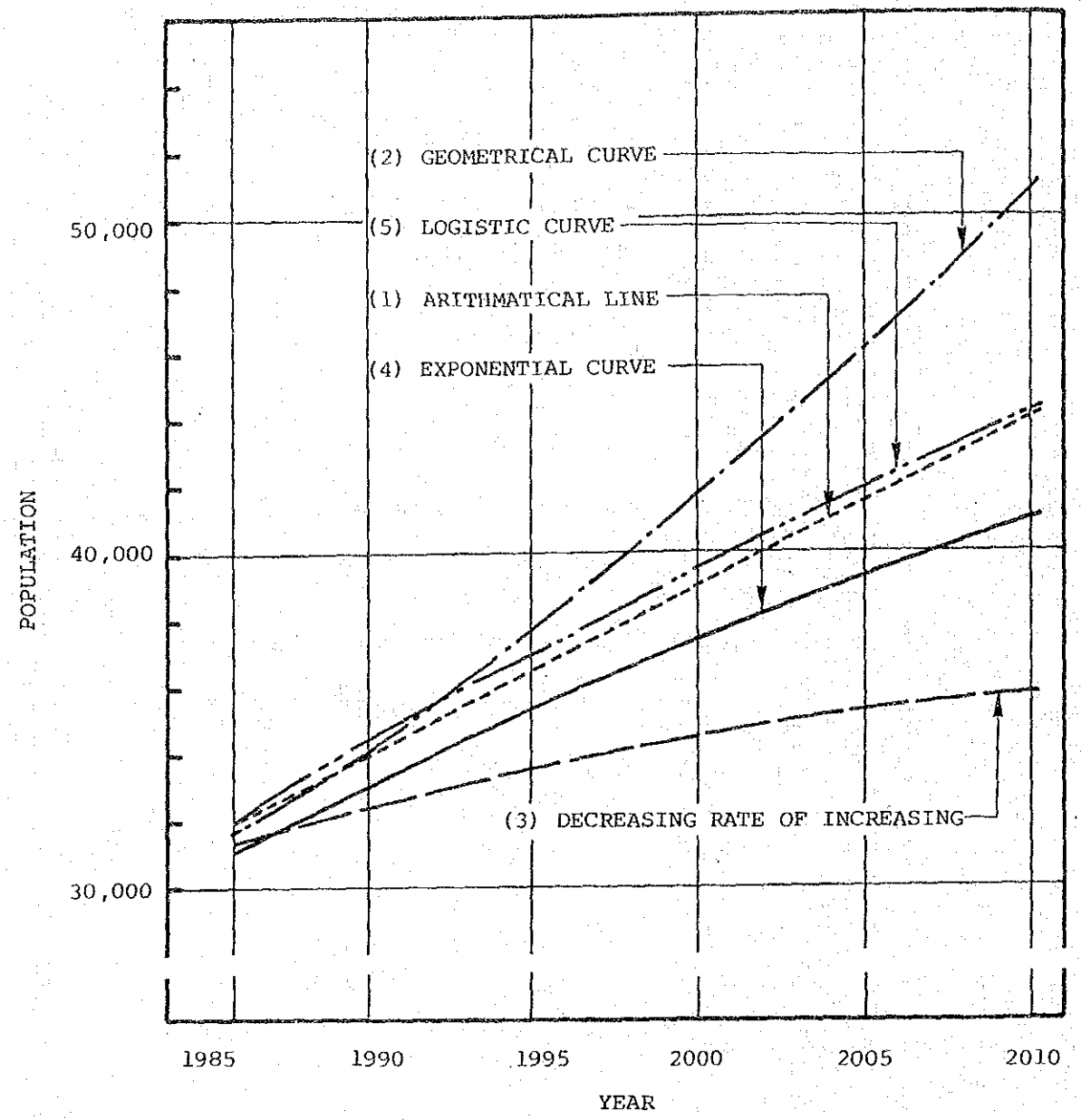

ESTIMATED POPULATION

CASE	1985	1990	1995	2000	2005	2010
(1)	31,714	34,213	36,711	39,210	41,708	44,207
(2)	31,142	34,362	37,915	41,835	46,161	50,934
(3)	31,042	32,473	33,623	34,548	35,293	35,891
(4)	31,446	33,515	35,501	37,421	39,285	41,103
(5)	31,814	34,415	36,992	39,513	41,948	44,272

FIGURE 1.3	POPULATION FORECAST OF WARIN
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The town/city plan prepared by DTCP, projecting the land use plan and population density corresponding the designated land uses in the target year, forecasts 259,400 persons as the 2002 population. The growth rate in 1985 - 2002 of the plan is calculated to be 3.39 % per year as the geometric rate. It was an obvious over-estimation and disregarded.

1.3.2 Ubon Sanitary District

Only one data (as of 1984) of the past population was available, therefore, it could not be used in the forecast.

The future population of Ubon Sanitary District is estimated, applying the same ratio as that of Ubon Municipality. The sanitary district shares the boundary with the municipality, thus, the future trend of population increase will be similar to the trend of Ubon Municipality.

The estimated population is shown in Table-1.4.

1.3.3 Five Villages

Similarly to Ubon Sanitary District, the future population of five villages can not be estimated from the past trend of population increase because of insufficiency of data.

Thus, the future population is estimated introducing the same increasing ratio as that of Phophraya Sanitary District of Suphanburi area which seems to have similar characters of a rural area.

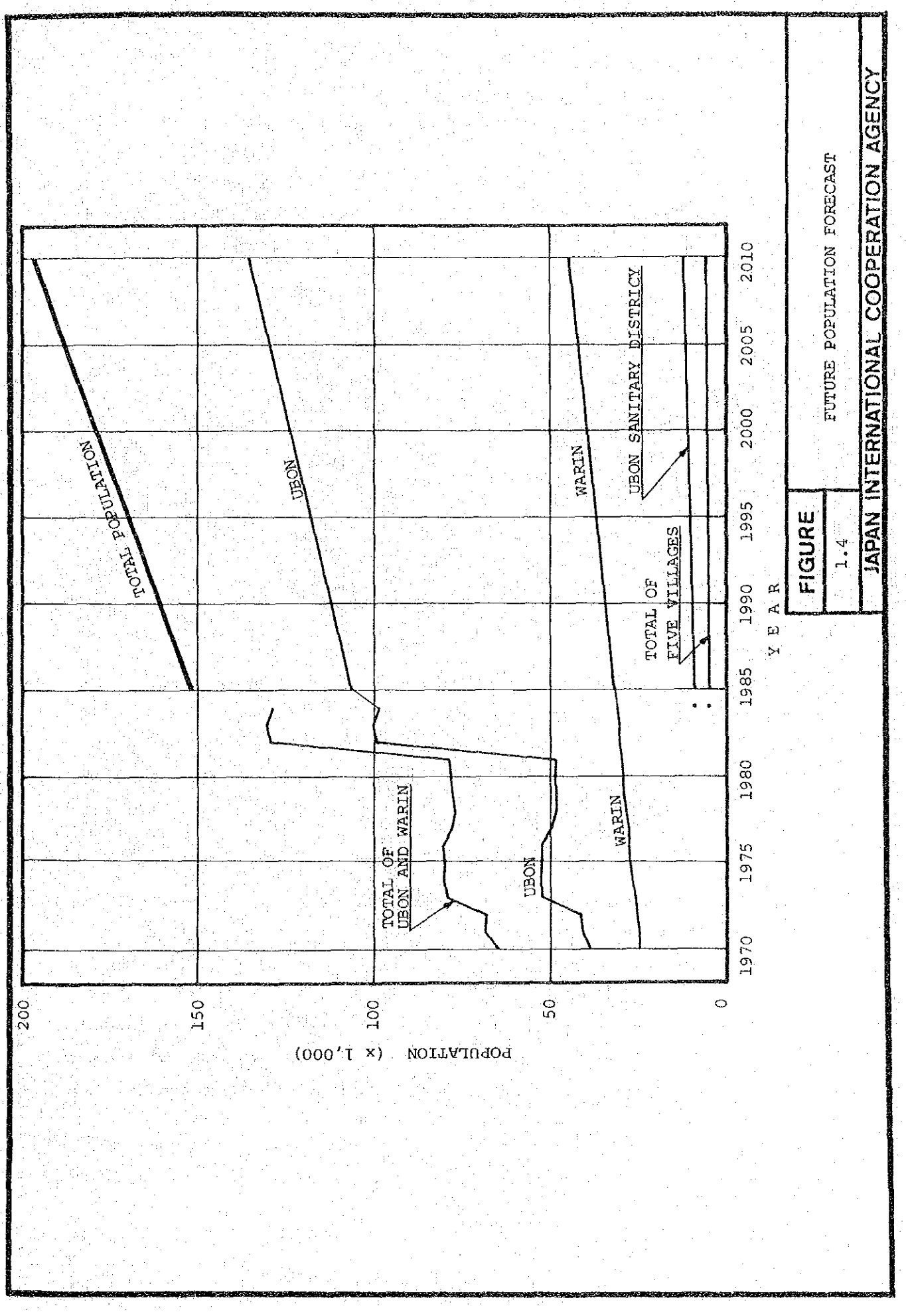
The estimated population is shown in Table-1.4.

1.3.4 Total Population of Project Area

Summarizing 1.3.1 to 1.3.3, the total population of Ubon and Warin Municipalities, Ubon Sanitary District and five villages is shown in Table-1.4 and in Fig-1.4.

Table-1.4 TOTAL POPULATION OF PROJECT AREA

	A R E A				
YEAR	UBON MUNICIPALITY	WARIN MUNICIPALITY	UBON SANITARY DISTRICT	FIVE VILLAGES	TOTAL
1985	106,480	31,710	8,930	4,850	151,970
1990	112,230	34,220	9,470	4,950	160,860
1995	117,990	36,710	10,000	5,050	169,750
2000	123,750	39,210	10,540	5,150	178,650
2005	129,500	41,710	11,070	5,250	187,530
2010	135,260	44,210	11,600	5,360	196,430


POPULATION (x 1,000)
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
YEAR
TOTAL POPULATION
UBON
WARIN
UBON SANITARY DISTRICY
TOTAL OF FIVE VILLAGES
TOTAL OF UBON AND WARIN
UBON
WARIN
FIGURE
1.4
FUTURE POPULATION FORECAST
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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 is shown in Table-1.4.

Table-1.5 SERVICE AREA

YEAR	SERVICE AREA (ha)
1985	1,970
2000	3,900
2010	4,600

Fig-1.5 shows the present service area of Ubon-Warin Waterworks and the future service area, planned for expansion, in 2000 and 2010.

As shown in Fig-1.5, the future service area of Ubon Municipality will expand north-, northwest- and east-ward from the present service area.

The north- and northwest-ward service area expansion will cover Ban Don Klang, Ubon Sanitary District and the educational and institutional facilities which are planned in the northwest of the sanitary district. The east-ward expansion of service area will cover Ban Pak Huai Wang Nong.

The service area of Warin Municipality will expand east-, south- and west-ward. In the east-and west-ward expansion, residential area will be developed. The service area's south-ward expansion will cover Ban Mai Klang.

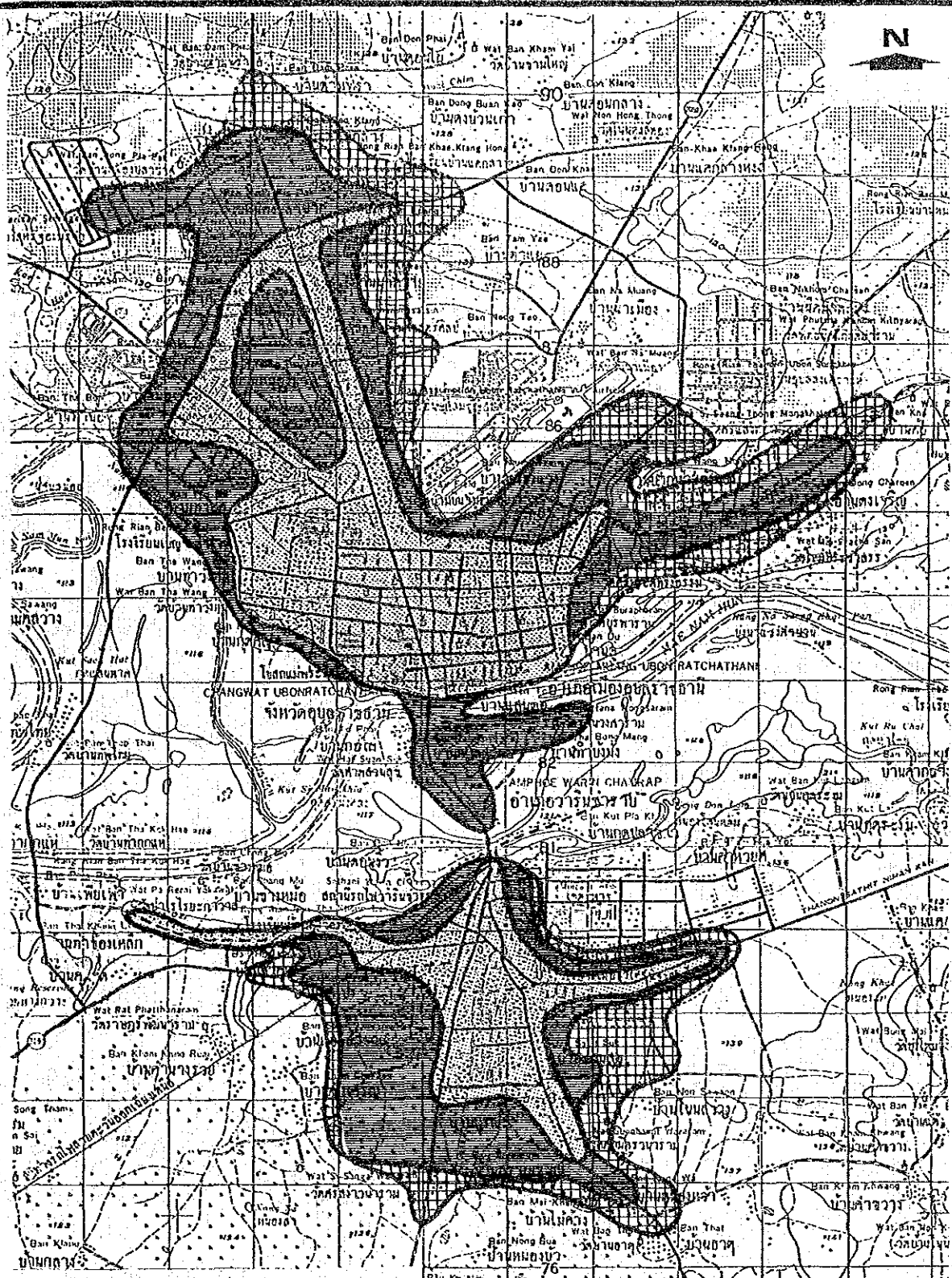

FIGURE 1.5

EXISTING AND FUTURE SERVICE AREA

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1.5 Service Ratio

Regarding the past trend of service ratio of Ubon and Warin, until 1981 the ratio increased continuously, though it fluctuated occasionally. The sudden fall of the ratio in 1981 - 1982, resulted from the administrative merger mentioned before, changed the character of Ubon regarding water supply conditions.

In the Ubon Municipality, two different types of service area exist now. One is the urbanized, high service ratio area and other the rural, low service ratio area, merged in 1981 - 1982.

The service ratio, approximating 40 % in 1984, is the average of Ubon and Warin including the low service ratio area of Ubon.

As shown in Fig-1.6, the following four service ratios were forecasted for Ubon and Warin Municipality.

Ubon Sanitary District and five villages are currently outside of the service area. Forecast of the service ratio for these area will be discussed afterward.

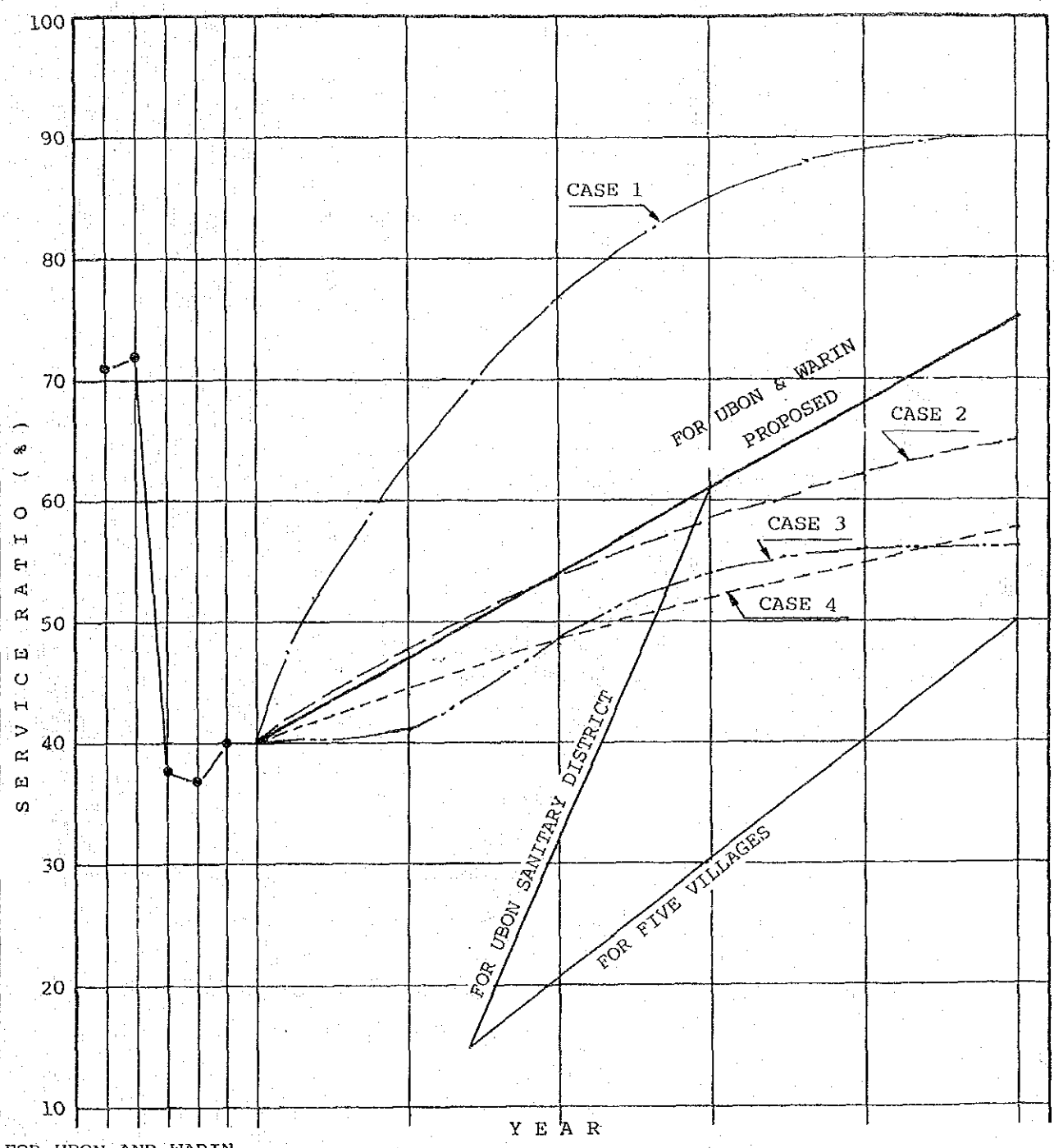
Case 1

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 income level growth rate of 8 % per year, highest in the past.



FOR UBON AND WARIN MUNICIPALITIES	1985	1990	1995	2000	2005	2010
PROPOSED	40	47	54	61	68	75
CASE 1	40	63	77	85	89	90
CASE 2	40	48	54	58	62	65
CASE 3	40	41	49	54	56	56
CASE 4	40	45	49	52	55	58
FOR UBON S.D.	0	0	32	61	68	75
FOR VILLAGES	0	0	21	31	41	50

FIGURE 1.6 ESTIMATION OF FUTURE SERVICE RATIO

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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 52 %. All of the willing people will be supplied before 2010, at a presumed pace.

2) Of the incremental population in future, 52 % will be supplied by the service immediately responding to the increase.

CASE 4

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

The above four cases are characterized as bellow:

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 it is explained in Appendix IV study on Water Quality, groundwater as an alternative supply source in the area is problematical regarding pH, alkalinity and nitrate. As the people begin to pay more attention to water quality matters, the willingness will increase.

After considering the above conditions of the four curves, a new line is proposed, as shown in Fig-1.6. It has been made on the expectations that

the willingness would grow stronger and the regional economy would raise the income level rather rapidly.

The service ratio for Ubon Sanitary District and five villages are forecasted, as also shown in the foregoing Fig-1.6.

These currently unserved area will be supplied from 1992 as it will be discussed in Chapter 7.

The service ratio for Ubon Sanitary District will start from 15 % in 1992 and will catch up with the service ratio of Ubon and Warin Municipalities by the linear increase.

The reasons of justifying such high increase rate of the Ubon Sanitary District's service ratio are as follows:

1) Development of the Ubon Municipality is expected northward.

2) Due to the closeness of the sanitary district and the Ubon - Municipality, the living standard will be raised to a similar level as the Ubon Municipality's in the nearest future.

3) There is already installed distribution main pipe (dia. 400mm) along the sharing boundary with Ubon Municipality and it is expected that the existing implicit demands will become explicit quite easily as branch distribution pipes can readily be - introduced into the sanitary district.

On the otherhand, the service ratios of the five villages, which range from 15 % in 1992 to 50 % in 2010 are expected to grow at a slower pace, as they are located at longer distance from the existing service areas compared with Ubon Sanitary District.

1.6 Served Population

In Table-1.5 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-1.5 FUTURE SERVED POPULATION

ITEM YEAR	1985	1990	1992	1995	2000	2005	2010
UBON AND WARIN							
TOTAL POPULATION	138,190	146,450		154,700	162,950	171,210	179,470
SERVICE RATIO	40	47		54	61	68	75
SERVED POPULATION	55,280	68,540		83,540	99,400	116,420	134,600
UBON SANITARY DISTRICT							
TOTAL POPULATION	8,930	9,470	9,682	10,000	10,540	11,070	11,600
SERVICE RATIO	0	0	15	32	61	68	75
SERVED POPULATION	0	0	1,450	3,200	6,430	7,530	8,700
FIVE VILLAGES							
TOTAL POPULATION	4,850	4,950	4,990	5,050	5,150	5,250	5,360
SERVICE RATIO	0	0	15	21	31	41	50
SERVED POPULATION	0	0	750	1,060	1,600	2,150	2,680
T O T A L							
TOTAL POPULATION	151,970	160,870		169,750	178,640	187,530	196,430
SERVED POPULATION	55,280	68,540		87,800	107,430	126,100	145,980

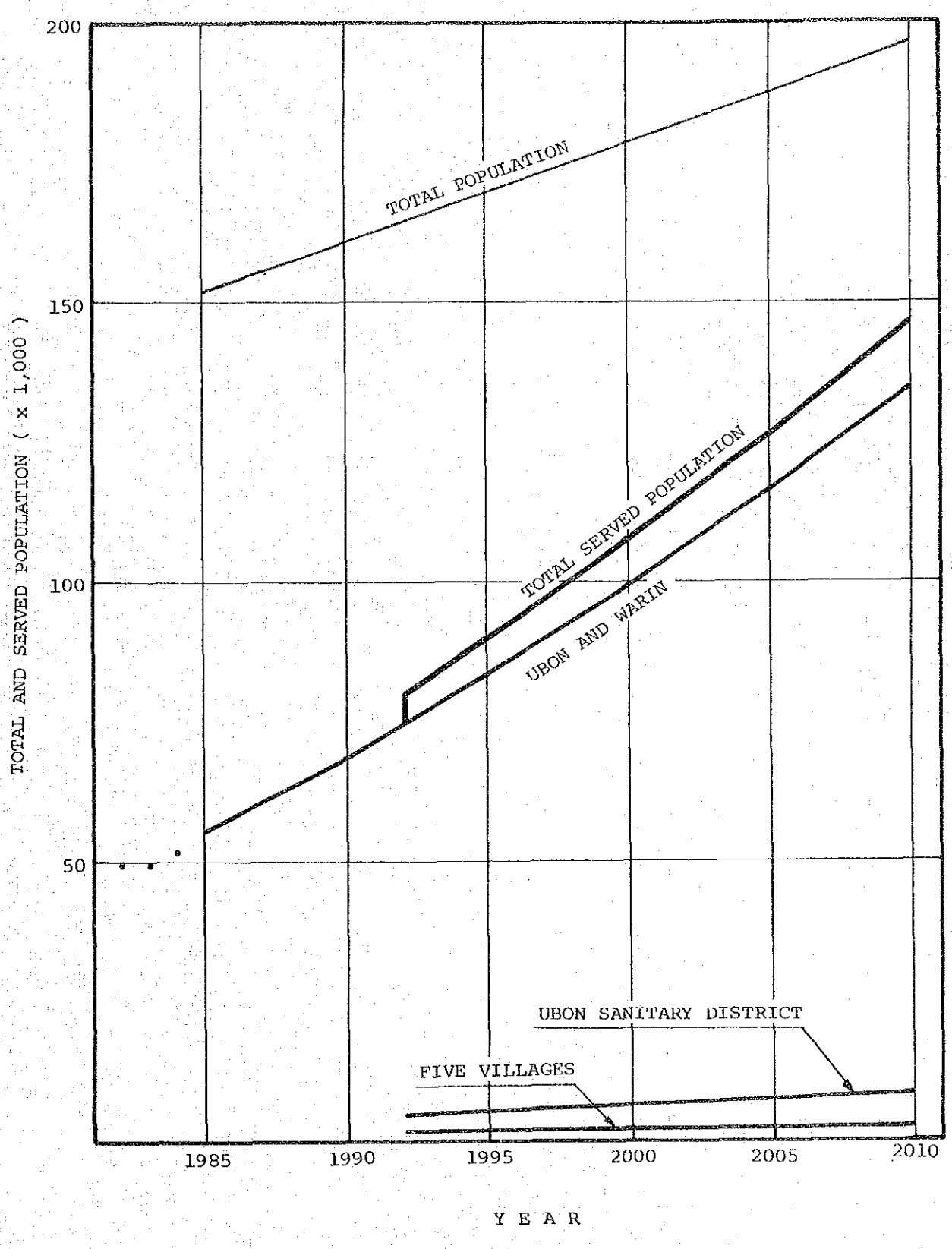

FIGURE	FUTURE SERVED POPULATION
1.7	
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APPENDIX 2

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.

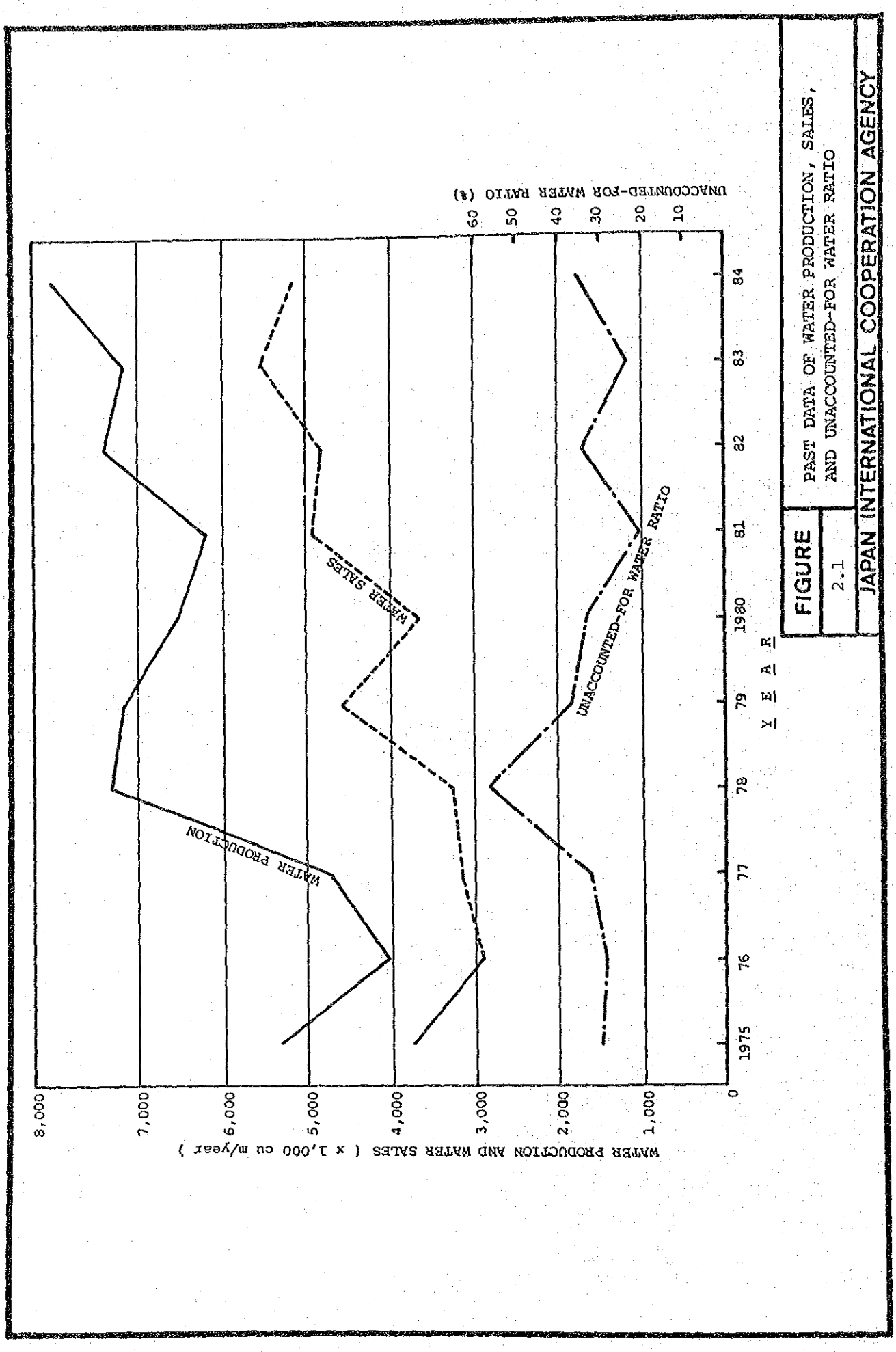

FIGURE 2.1

PAST DATA OF WATER PRODUCTION, SALES, AND UNACCOUNTED-FOR WATER RATIO

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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	5,317,308	3,722,116	6,428	48
1976	4,055,682	2,905,198	6,786	36
1977	4,723,337	3,186,709	7,191	37
1978	7,343,766	3,266,800	7,487	36
1979	7,188,892	4,587,058	8,087	47
1980	6,536,757	3,685,100	8,785	35
1981	6,215,186	4,943,187	9,034	46
1982	7,412,564	4,856,392	9,335	43
1983	7,186,391	5,511,141	9,808	47
1984	8,028,823	5,131,667	10,299	42

DATA SOURCE : PWA

As shown in Fig-2.1, the water production jumped up from 4.7 MCM in 1977 to 7.3 MCM in 1978 because the Warin Treatment Plant started its operation from 1978. The water sales also increased gradually following the production increase. In 1978 to 1982, the unaccounted-for water ratio gradually decreased, however, it increased afterward.

In Table-2.1, the consumption per connection was calculated by dividing the water sales by the number of connection. It fluctuated noticeably as seen in the table.

The number of served population was calculated approximately by multiplying the connections' number and six persons per family, an assumed average.

The per capita consumption in 1980 - 1984, thus calculated from Table-2.1, fluctuated from 194 to 261 lpcd, averaging 220 lpcd.

In the said 220 lpcd included are the domestic, public, private business and other consumptions. For future projection, however, it is divided into two presumably, one the domestic consumption and another the large consumer's consumption.

The domestic per capita consumption increased from 86 lpcd in 1980 to 140 lpcd in 1983 and then dropped to 120 lpcd in 1984, as shown in Fig-2.2 later, according to the available data. Presently, the consumption is assumed to be 140 lpcd of the before mentioned 220 lpcd.

PWA surveyed the large consumers' consumption in 1982 and classified it as shown in Table-2.2. The large residential building's consumption in the table is, in nature, for domestic use and to be included in the 140 lpcd mentioned above. Excluding it, the public uses consumption and large businesses' consumption are 70 % to 30 % in the ratio.

Table-2.2 LARGE CONSUMERS' CONSUMPTION IN UBON AND WARIN MUNICIPALITIES

Classification	Item	Consumption (cu m/month)	Sub-Total (cu m/month)	Percentage (%)
Public	Government	2,953	4,483	70
	School	634		
	Hospital	1,241		
	Temple	15		
Large Business	Commercial	692	2,021	30
	Factory	245		
	Hotel	1,084		
Sub-Total			6,504	100
Large Residencial Building	Residence	1,345	1,345	
Total		7,849	7,849	

DATA SOURCE : PWA, 1982

2.3 Future Water Consumption

In this section, the future water consumption of Ubon and Warin Municipalities is estimated for each of the three categories, domestic, public and large business. The water consumption of Ubon Sanitary District and five villages is broken down into the domestic and others for separate estimation.

2.3.1 Ubon and Warin Municipalities

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.

Water demanding plans like industrial and urban development have not been prepared for the Ubon and Warin area. It is expected to grow as an administrative, military and trade center supported by agricultural activities, preserving the present characteristics.

The domestic per capita consumption will increase as the income level and the living standard rise. A linear growth of 142 lpcd in 1985 (approximate to 140 lpcd, previously mentioned), 177 lpcd in 2000 and 200 lpcd in 2010 is forecasted. The consumption will be similar, in size, to that of Khon Kaen.

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.

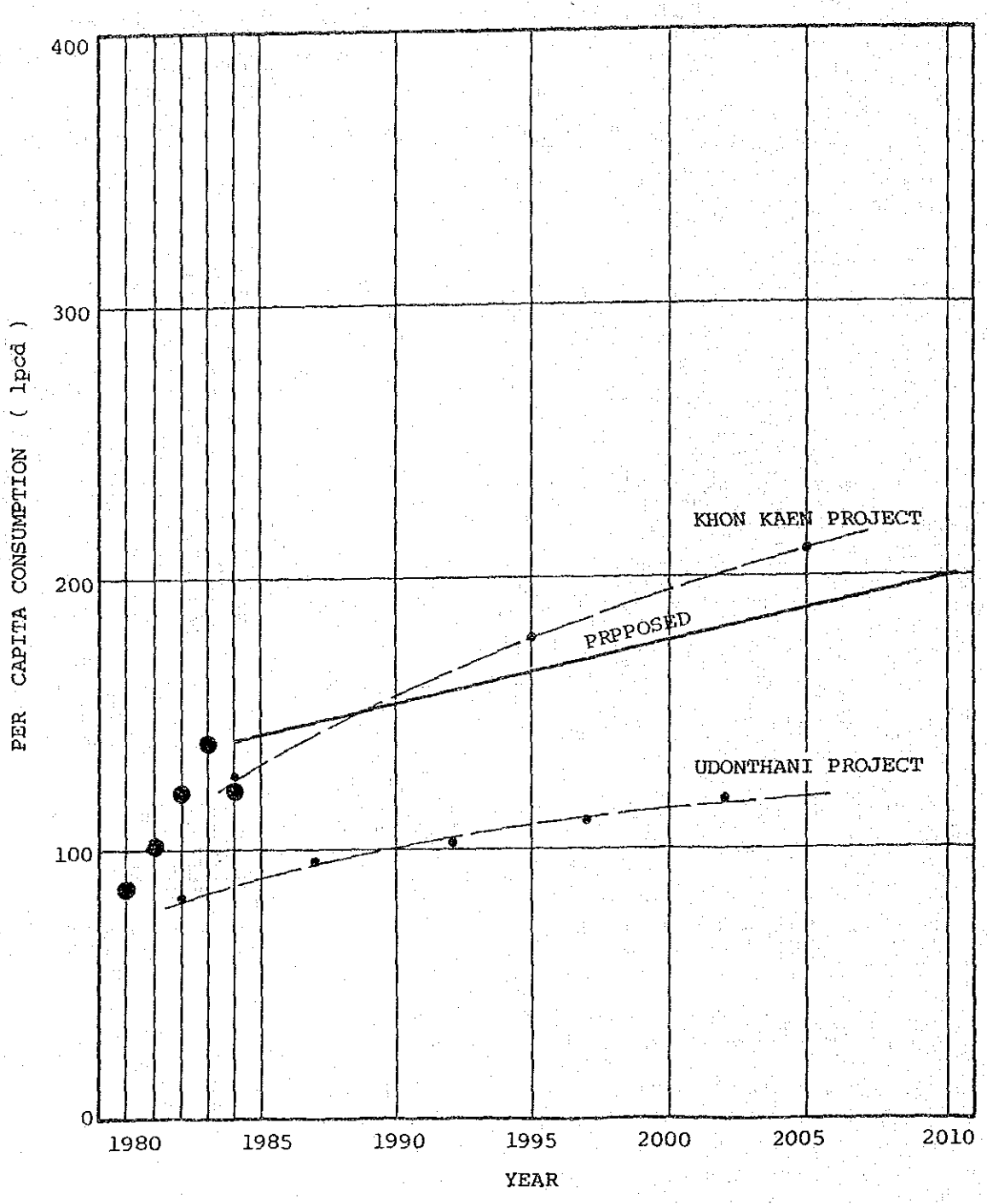

FIGURE	ESTIMATION OF PER CAPITA CONSUMPTION OF DOMESTIC USE (UBON & WARIN)
2.2	

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Table-2.3 DOMESTIC WATER CONSUMPTION FOR UBON AND WARIN MUNICIPALITIES

YEAR	SERVED POPULATION	DOMESTIC PER CAPITA CONSUMPTION (lpcd)	DOMESTIC WATER CONSUMPTION (cu m/day)
1985	55,280	142	7,850
1990	68,540	154	10,560
1995	83,540	165	13,780
2000	99,400	177	17,590
2005	116,420	188	21,890
2010	134,600	200	26,920

2) Public Water Consumption

In Section 2.2, the large consumer's consumption was estimated at 80 lpcd in terms of the per capita, and 70 and 30 % of it were assumed to be used by the public institutions and large businesses (Table-2.2). The public water consumption in 1985 was assumed as 56 lpcd.

A linear growth from 56 lpcd in 1985 to 77 lpcd in 2000 and 90 lpcd in 2010 is projected.

The rate of growth is slightly higher than that of the domestic consumption, because the water demand for public uses tends to increase as a municipality grows in size and as urbanization proceeds.

Table-2.4 PUBLIC WATER CONSUMPTION FOR UBON AND WARIN MUNICIPALITIES

YEAR	SERVED POPULATION	PUBLIC PER CAPITA CONSUMPTION (lpcd)	PUBLIC WATER CONSUMPTION (cu m/day)
1985	55,280	56	3,100
1990	68,540	63	4,340
1995	83,540	70	5,850
2000	99,400	77	7,650
2005	116,420	83	9,660
2010	134,600	90	12,110

3) Large Business Water Consumption

30 % of the before mentioned 80 lpcd, or 24 lpcd, was assumed as the large business water consumption presently.

The consumption was assumed to grow at the same rate as the public consumption. It will grow linearly from 26 lpcd in 1985, to 40 lpcd in 2000 and 50 lpcd in 2010 as shown in Table-2.5.

Table-2.5 LARGE BUSINESS WATER CONSUMPTION FOR UBON AND WARIN MUNICIPALITIES

YEAR	SERVED POPULATION	LARGE BUSINESS PER CAPITA CONSUMPTION (lpcd)	LARGE BUSINESS WATER CONSUMPTION (cu m/day)
1985	55,280	26	1,440
1990	68,540	31	2,120
1995	83,540	35	2,920
2000	99,400	40	3,980
2005	116,420	45	5,240
2010	134,600	50	6,730

2.3.2 Ubon Sanitary District

Ubon Sanitary District, not served by PWA currently, will start to receive the service from 1992 as described in Chapter 7. The water consumption is estimated from 1992, therefore.

In the case of Ubon 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 Ubon and Warin Municipalities' is assumed. Because of the district's character, consumption of the large consumers such as public institution and large business is not probable. The small size consumptions other than the domestic will be collectively defined as the other consumption.

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

Table-2.6 WATER CONSUMPTION FOR UBON 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)
1992	1,452	158	230	66	96
1995	3,230	165	530	70	230
2000	6,430	177	1,140	77	500
2005	7,530	188	1,420	83	620
2010	8,700	200	1,740	90	780

2.3.3 Five Villages

Similarly to Ubon Sanitary District, the water consumption is estimated from 1992 when the water supply will start.

The water consumption was categorized into two, like in the case of Ubon Sanitary District, namely domestic and other water consumption. In estimating future water consumption of the five villages, the data and types of water consumption in the rural parts of other project areas such as Phophraya Sanitary District in Suphanburi and the surrounding sanitary districts of Chiangmai were assimilated because of the difficulty in collecting solid data on the water consumption of the villages as they are not receiving PWA services.

For the domestic water consumption, the per capita consumption is estimated at 84 lpcd in 1992. It is comparatively low to the Ubon and Warin Municipalities'. Assuming continuous development of this area, a linear growth to reach 94 lpcd in 2000 and 112 lpcd in 2010 is forecasted.

Regarding the other consumption, a linear growth from 13 lpcd in 1992 to 42 lpcd in 2010 is forecasted.

The domestic and other water consumptions are shown in Table-2.7.

Table-2.7 WATER CONSUMPTION FOR FIVE VILLAGES

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)
1992	749	84	63	13	10
1995	1,060	88	93	18	19
2000	1,600	94	150	26	42
2005	2,150	104	224	34	73
2010	2,680	112	300	42	113

2.3.4 Total Water Consumption

The total of the categorized consumptions, of Ubon and Warin Municipalities, Ubon Sanitary District and five villages, is shown in Table-2.8.

Table-2.8 TOTAL WATER CONSUMPTION

UNIT : cu m/day

	1985	1990	1995	2000	2005	2010
UBON AND WARIN MUNICIPALITIES						
DOMESTIC	7,850	10,560	13,780	17,590	21,890	26,920
PUBLIC	3,100	4,320	5,850	7,650	9,660	12,110
LARGE BUSINESS	1,440	2,120	2,920	3,980	5,240	6,730
SUB-TOTAL	12,390	17,000	22,550	29,220	36,790	45,760
UBON SANITARY DISTRICT						
DOMESTIC	0	0	530	1,140	1,420	1,740
OTHERS	0	0	230	500	620	780
SUB-TOTAL	0	0	760	1,640	2,040	2,520
FIVE VILLAGES						
DOMESTIC	0	0	93	150	224	300
OTHERS	0	0	19	42	73	113
SUB-TOTAL	0	0	112	192	297	413
T O T A L	12,390	17,000	23,422	31,052	39,127	48,693

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. PWA set a target of reducing it 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-2.8 and the unaccounted-for water ratio projected as above, the average day water demand is calculated, as shown in Table-2.9.

Table-2.9 AVERAGE DAY WATER DEMAND

YEAR	TOTAL WATER CONSUMPTION (cu m/day)	UNACCOUNTED-FOR WATER RATIO (%)	AVERAGE DAY DEMAND (cu m/day)
1985	12,390	35	19,060
1990	17,000	30	24,290
1995	23,422	25	31,230
2000	31,052	23	40,330
2005	39,127	22	50,170
2010	48,693	20	60,870

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.

A record of the Ubon Treatment Plant's output from Jan 1st to Sep 30th in

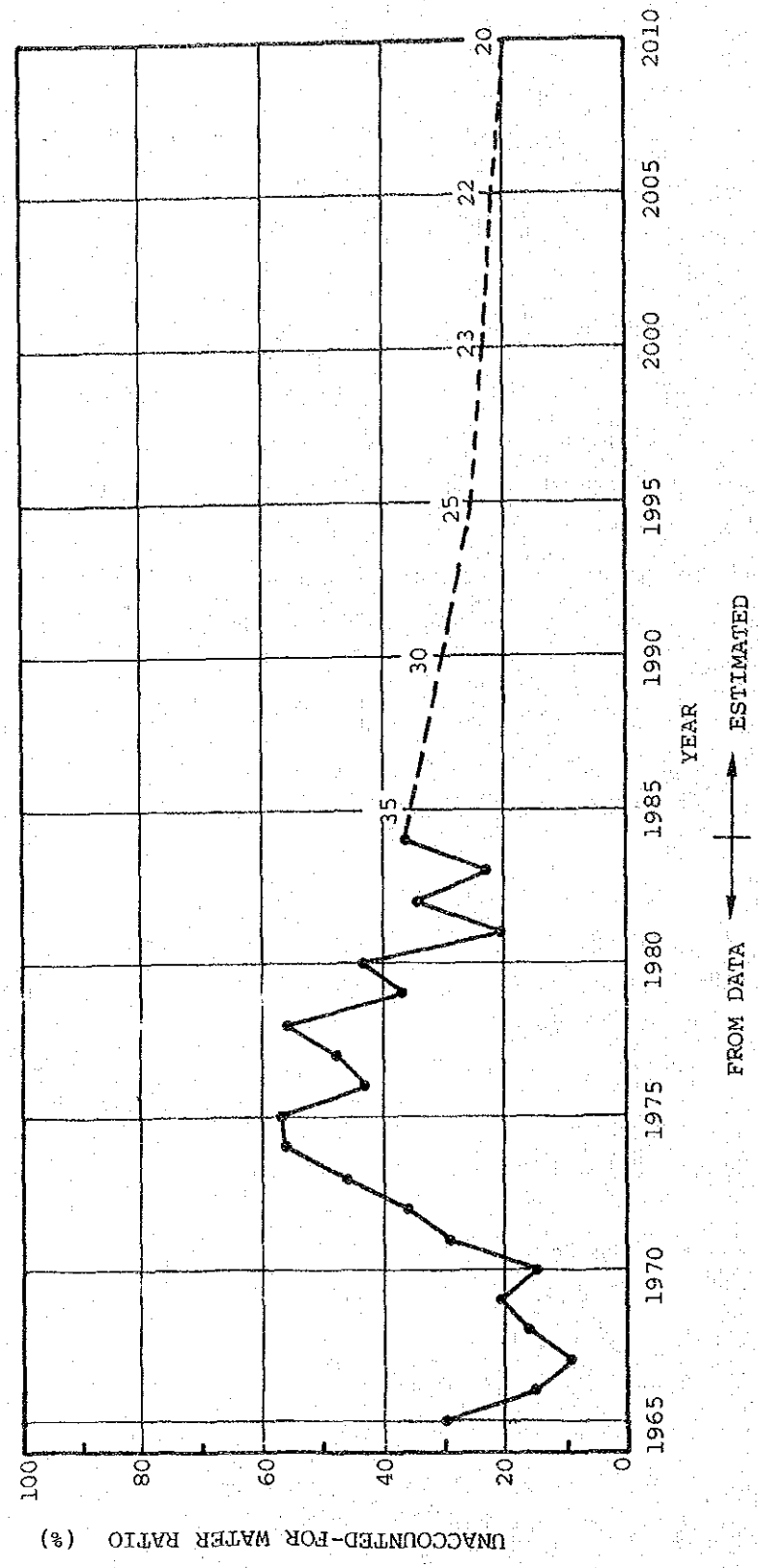

FIGURE	UNACCOUNTED-FORWATER RATIO OF UBON & WARIN
2.3	
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1985, was processed to formulate Table-2.10 and used for estimating the peak factor of this area.

Table-2.10 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

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

1.30 was adopted and applied to the Ubon and Warin Municipalities, Ubon Sanitary District and five villages.

Table-2.11 showing the maximum day demand is calculated by the peak factor and the average day demand in Table-2.9. The maximum and average day demands are plotted in Fig-2.4.

Table-2.11 MAXIMUM DAY WATER DEMAND

Item	1985	1990	1995	2000	2005	2010
AVERAGE DAY DEMAND	19,060	24,290	31,230	40,330	50,170	60,870
PEAK FACTOR	1.30	1.30	1.30	1.30	1.30	1.30
MAXIMUM DAY DEMAND	24,780	31,580	40,600	52,430	65,220	79,130

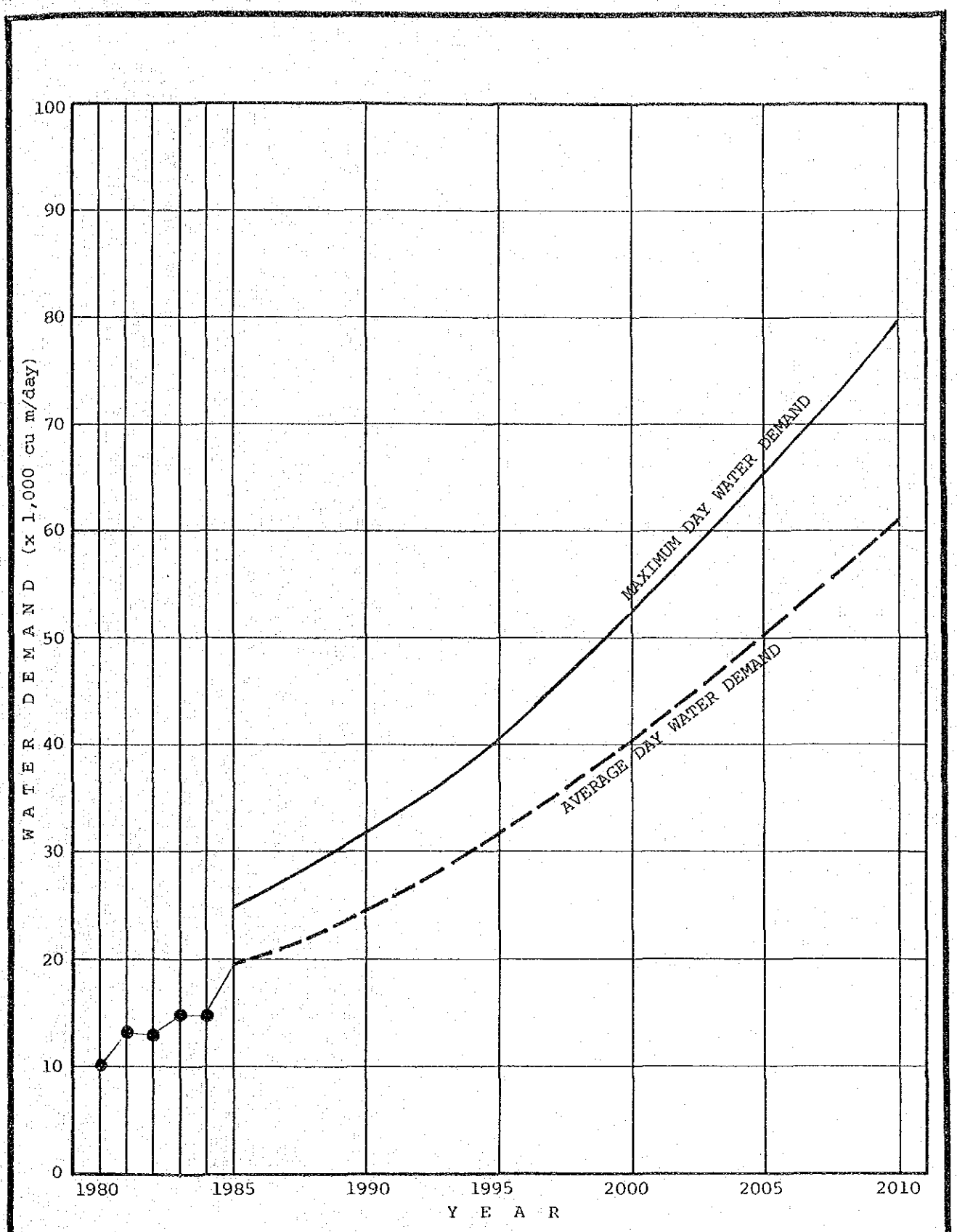

FIGURE 2.4

FUTURE TOTAL WATER DEMAND

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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 the water resources conditions for the future water supply development program of Ubon and Warin.

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 Project.

From the view points of the climatic, geographical, topographical, hydrological, and hydrogeological conditions, the availability of water resources and possibility of developing them to meet the planned future water demand, has been studied in detail as seen in the following sections.

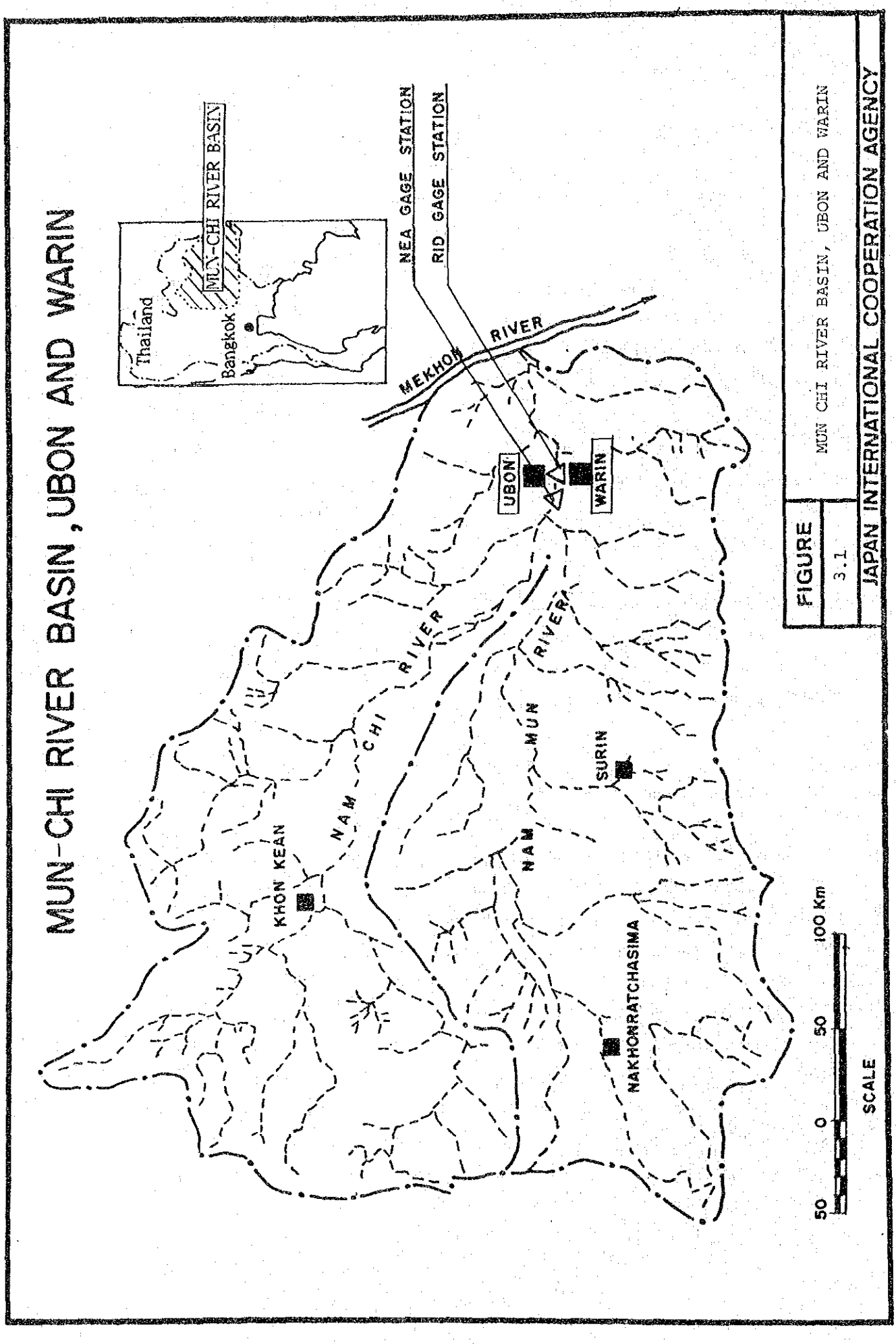
As qualitative assessment of water resources is as important as quantitative one, an appendix, Appendix 4, studying exclusively water quality in the area has been prepared by the team. In this report, the relevant matters are referred to and quoted from it.

3.2 Location and Topography

The project areas of Ubon Ratchathani, Warin Chamrap and surrounding villages namely Ban Mai Khang, Ban Hat Suan Ya, Ban Tha Bong Mang, Ban Pak Huai Wang Nong, and Ban Don Klang are located in the eastern edge of the Khorat Plateau and/or the Mun-Chi River basin in the northeast region of Thailand. (Fig-3.1)

The Mun-Chi River basin, having over 117,000 sq km of drainage area, is formed mainly by the Khorat Plateau which largely covers the northeast region. The mean altitude of Khorat Plateau is about 150 m MSL. The Mun and Chi Rivers join together at about 10 km upstream and west of Ubon. From Ubon, where the river is at the elevation of approximate 114 m MSL down to the Mekong confluence at elevation 90 m MSL.

Reportedly, the Pak Mun Reservoir is under planning in the area, as a part


MUN-CHI RIVER BASIN, UBON AND WARIN
Thailand
Bangkok
MUN-CHI RIVER BASIN
NEA GAGE STATION
RID GAGE STATION
MEKHON RIVER
UBON
WARIN
KHON KEAN
NAM CHI RIVER
NAM MUN RIVER
SURIN
NAKHONRATCHASIMA
SCALE
50 0 50 100 Km
FIGURE
3.1
MUN CHI RIVER BASIN, UBON AND WARIN
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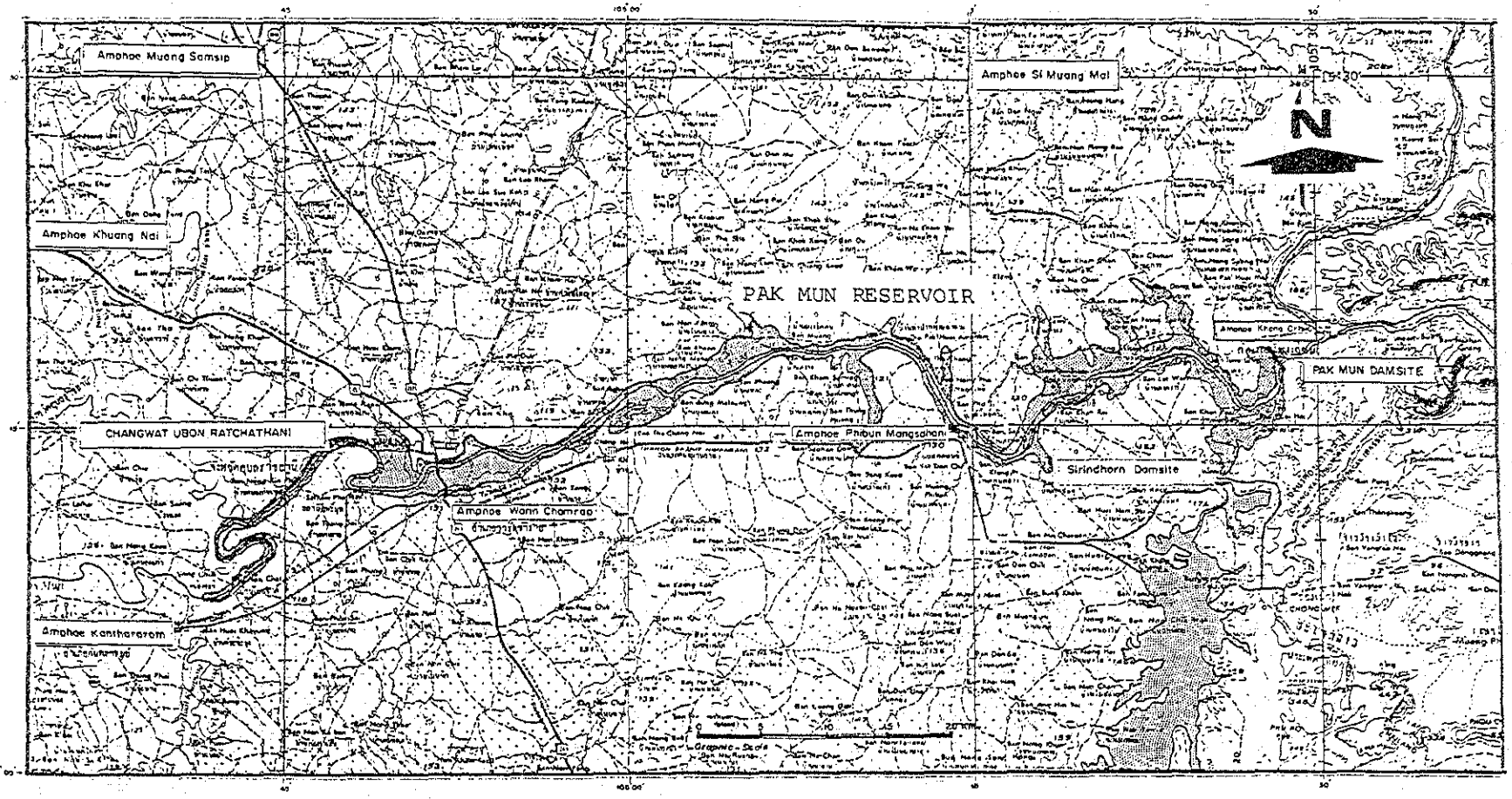
of the Mekhong River Basin Development Project. The Pak Mun Dam site is located at about 70 km downstream of Ubon city and the normal high water level of the reservoir is planned to be at 112 m MSL. (Fig-3.2)

Ban Hat Suan Ya and Ban Tha Bong Mang, a part of the planned service area under the study, are two communities located at around 115 m MSL on the bank of the river. They have been flooded in the past sometimes.

The communities may be submerged by the backwater of the dam project occasionally or permanently.

Regarding the Pak Mun Project, environmental and ecological studies are said to have been completed in 1982. However, implementation as part of the mid-term program before 2000 or of a long-term program after 2000 has not been planned yet, reportedly.

This water supply plan for 2010 will not be affected by the dam project, therefore.



DATA, EGAT 1982

LEGEND

: WATER IMPOUNDED IN RESERVOIR

FIGURE 3.2	PAK MUN RESERVOIR OF UNDER PLANNING
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3.3 Climate

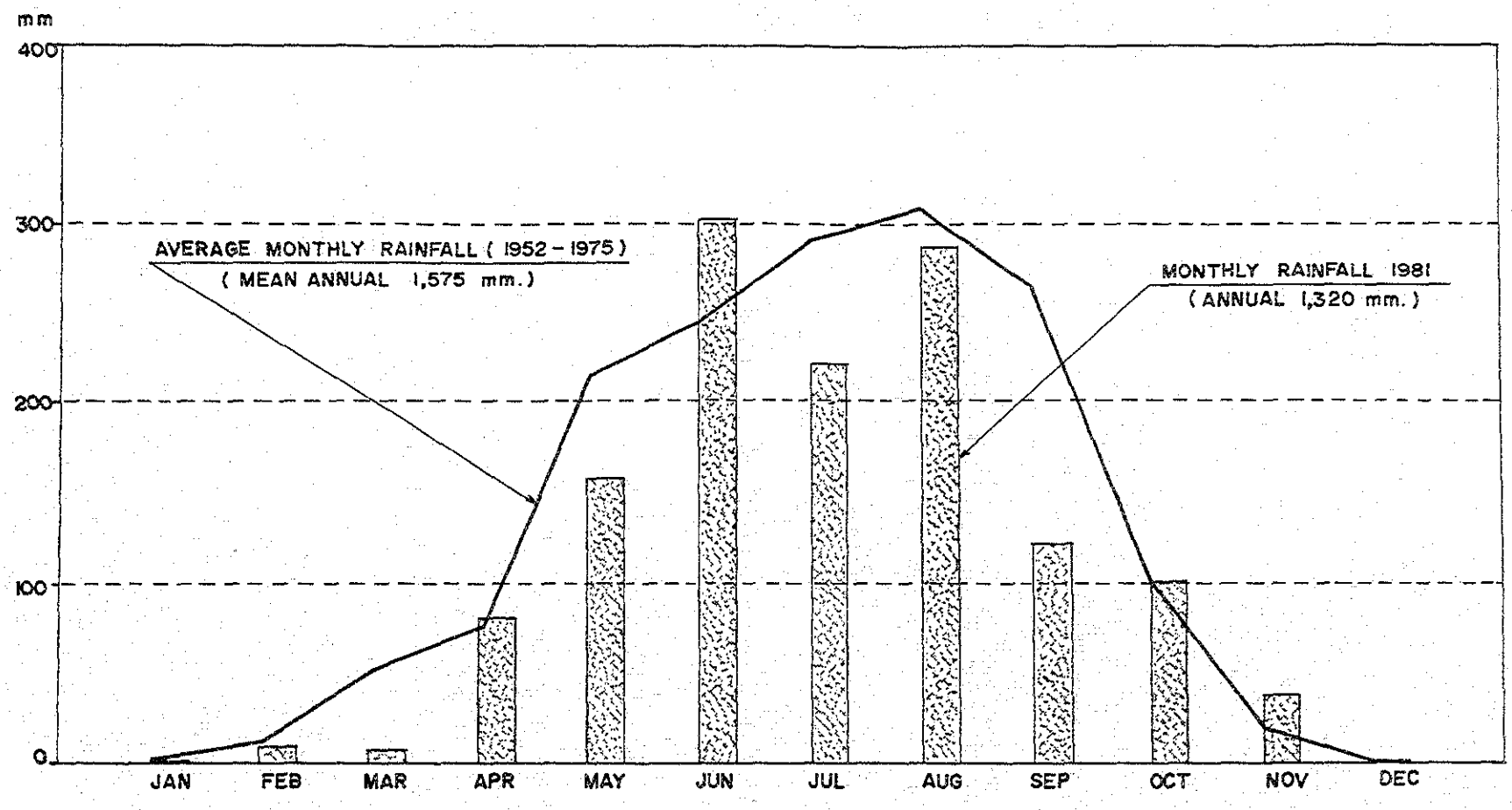
The climate of Ubon area is governed by the tropical monsoons which are characterized by the southwest monsoon, northeast monsoon and tropical storms. The southwest monsoon usually extends from mid-May to September, rainy season in Thailand. October is the transition period of the southwest monsoon to the northeast monsoon, the northeast monsoon, influenced by the Northern Hemisphere winter, extends from November to February, the dry season.

Fig-3.3 illustrates the monthly precipitation in 1981 at Ubon, in comparison with the average monthly precipitation during the period of 24 years in the area. Rainfall usually starts at about mid-April, reaches its peak in August and then ends gradually at about mid-October. From August to September in the rainy season, frequent heavy rainfall occurs, caused by the depression originating in the South China Sea.

The climatological data of Ubon in 1981 are summarized in Table-3.1. Regarding the maximum temperature in a month, the highest was 40 degree C in April, the beginning of the rainy season and the lowest 33 degree C in December and January in the dry season. Regarding the minimum temperature, the highest was 23 degree C in June - August and the lowest 12 degree C in January.

The average annual pan evaporation was 2,060.8 mm in 1981, at Ubon. Evaporation normally changes by the season. During the rainy season, the evaporation rate is usually lower than in the dry season and the maximum evaporation occurred in March. The evaporation varied from the lowest 152.5 mm in September to the highest 226.5 mm in March.

MONTHLY RAINFALL AT UBON



DATA: EGAT, 1980

FIGURE	MONTHLY PRECIPITATION AT UBON
3.3	

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Table - 3.1 CLIMATOLOGICAL DATA

Ubon, 1981

DATA : NEA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nev	Dec	Total
Precipitation (mm)	0.0	9.8	7.9	80.2	157.1	302.3	220.1	287.0	122.0	97.9	36.4	0.0	1320.7
Daily Evaporation (mm)	168.2	170.4	226.5	197.4	195.1	160.3	147.8	169.2	152.5	155.9	154.2	163.3	2060.8
Water Temperature (°c) (max/min)	29.1 21.7	33.0 27.3	33.3 30.2	37.2 24.1	35.5 29.4	34.6 27.9	33.8 28.0	33.8 26.1	34.9 29.3	33.0 26.5	33.1 24.6	28.2 21.7	37.2 21.7
Temperature (°c) (max/min)	33.0 12.0	38.0 16.5	39.5 21.0	40.0 22.0	38.0 21.0	36.0 23.0	34.0 23.0	34.0 23.0	35.0 22.0	34.0 19.5	34.0 16.0	33.0 12.5	40.0 12.0
Daily Wind movement Mean (Km)	50.1	42.8	42.5	45.7	42.5	47.9	41.4	51.5	32.0	47.7	58.7	77.2	-
Daily Relative Humidity (max/min) (cm)	95 78	95 82	96 76	100 60	100 85	96 88	100 84	96 84	100 88	100 86	100 80	100 73	-
Daily Sunshine (Mean Hours)	8.80	9.20	8.50	6.58	7.56	4.72	4.17	5.38	6.54	6.07	7.73	7.45	-

3.4 Hydrology

As the Mun-Chi river, joined by two rivers, is the important water source for Ubon and also the northeast Thailand region, more than one hundred streamflow gauging stations have been installed in the Mun and the Chi river and their tributaries since 1950. They are under operation mostly by RID and NEA, as shown in Fig-3.4.

Ubon Ratchathani is located at 10 km downstream of the Mun-Chi confluence and the drainage area of the Mun-Chi river measured at the gauging of station Muang Ubon Ratchathani (M7) is 106,673 sq km. Based on the RID records of 1983, as summarized in Table-3.2, the mean annual runoff is 19,532 MCM from 1950 to 1980 and an average annual yield of runoff is 5.81 lit/sec/sq km, or 0.183 MCM/sq km as of the drainage area.

From the past data, the runoff at the station M7 seems to change cycle on a 30 years period. For instance, the runoff in 1955 - 1980 fluctuated from the minimum of 8,000 MCM/yr to the maximum of 41,000 MCM/yr.

The NEA gauging station at Ubon, where the drainage area is slightly less (104,000 sq km) than the above quoted, registered the average discharge of 625.0 cu m/s (19,710 MCM/yr) from 1951 to 1981. The largest was 7,260 cu m/s on October 17, 1978.

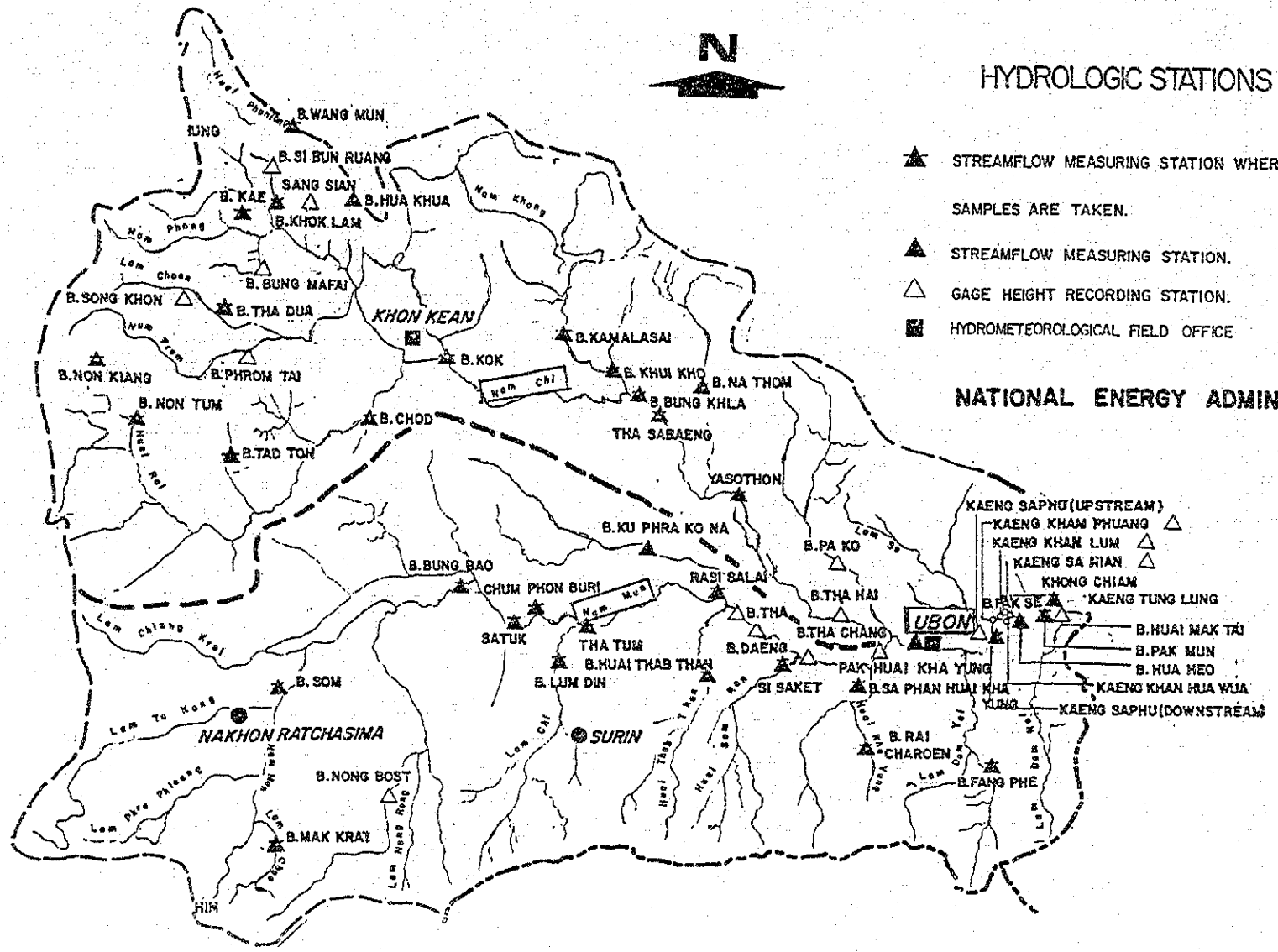

FIGURE	MUN-CHI RIVER BASIN AND GAGING STATIONS
3.4	

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Table - 3.2 HYDROLOGIC DATA OF MUN RIVER AT UBON RATCHATHANI

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 & Specific Yield		
						Discharge (m3 / sec)	Runoff (MCM)	Lit./sec./km2	(m3/ sec)	Date	(m3/sec/km2)
1.	Lam Nam Mun	RID (M7) Muang Ubon-Ratchathani	106,673	29	1950 - 1980	619.4	19,532	5.81	7,458	Oct. 17 1978	0.070
2.	Lam Man Mun	NEA Muang Ubon-Ratchathani	104,000	31	1951 - 1981	625.0	19,710	6.01	7,296	Oct. 17 1978	0.070

3.5 Available Water Resources

3.5.1 Surface Water

To evaluate the hydrologic conditions of the Mun River, two drought years, 1968 and 1981, were selected in the hydrologic yearbooks of RID and NEA in 1952 - 1984. In Table-3.3, the monthly precipitation and runoff of the two years are shown.

Of the two, 1968 was studied further as it was worse than 1981.

The NEA data recording everyday's maximum, average and minimum flow were analyzed and used in two ways, as illustrated in Fig-3.5 and 3.6.

In Fig-3.5, the daily average was plotted from January to December in a curve and from the curve, the second curve of accumulated probability was made. On the second curve, the flood flow, nominal flow and droughty flow, according to the hydrological definition, were designated. The droughty flow is defined as a flow rate, the probability of occurrence of lower than which is 30 days in a year.

Fig-3.5 shows that the monthly runoff of August, September and October were 15, 41 and 23 % of the annual runoff respectively, totaling 79 % in the three months. It suggests that flood and drought occur cyclically.

Fig-3.6 shows the maximum, mean and minimum of both flow and water level. The water level data were needed in judging the problem of flow intake.

Conclusively from the two figures, the droughty flow in Fig-3.5, 44.8 cu m/s and the minimum runoff in fig-3.6, 41.8 cu m/s, are approximate and the both are far larger than the present water supply intake, 0.32 cu m/s. Regarding the water level of the river, falling down to 1.56 m under the low flow, no inconvenience is felt in the operation of water intake.

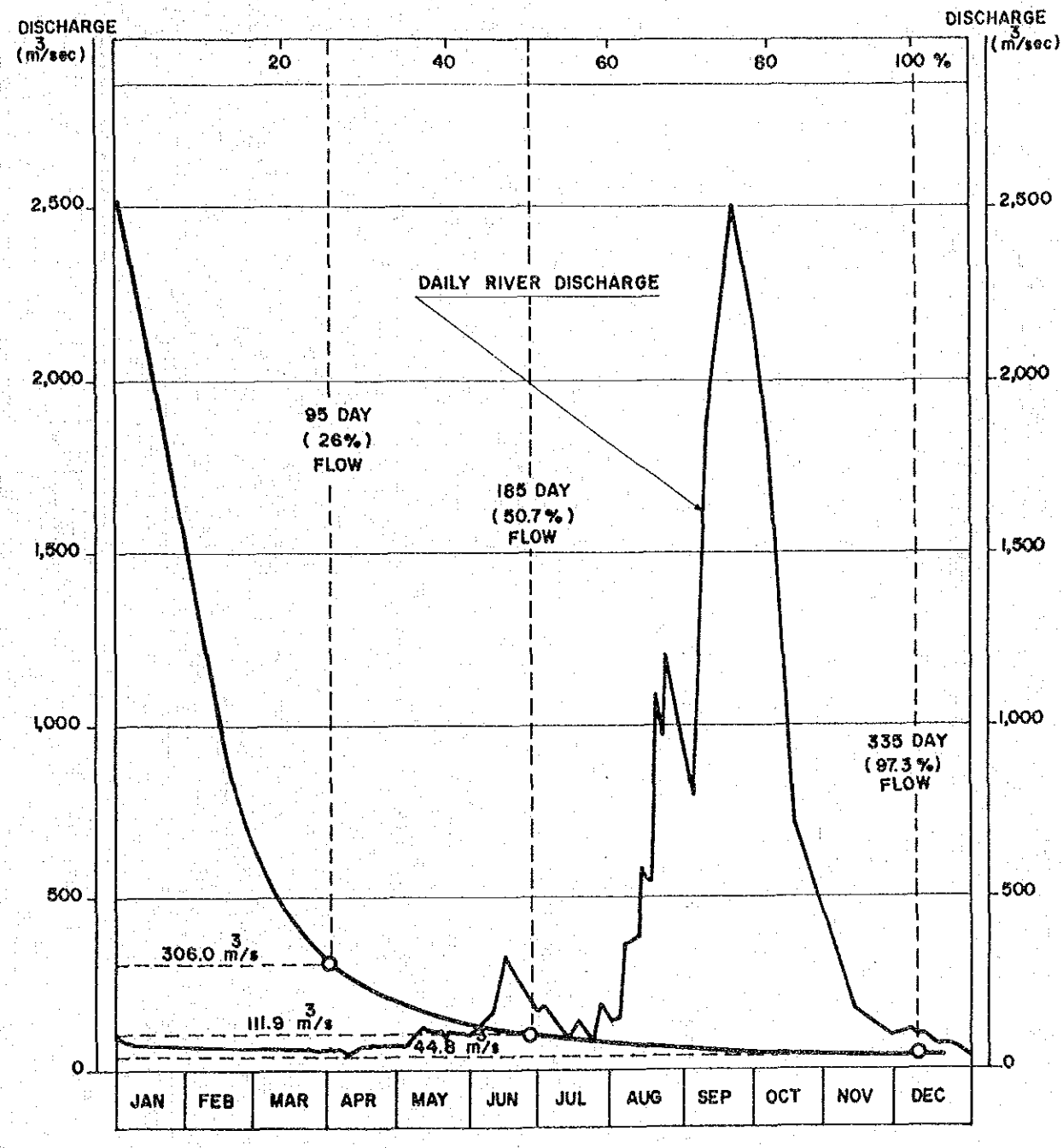
Flow in the Mun river largely fluctuates with maximum level variation being about 8.0 m. In 1968, a drought year, the maximum and minimum flows records 2,400 and 44.8 cu m/sec, respectively. Still the minimum flow is far higher than the present intake flow of 0.32 cu m/sec (27,840 cu m/day).

Table - 3.3 NAM MUN RIVER RUNOFF AT UBON

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Minimum Precipitation (1952-75)	Precipitation (mm) 1968	0	0	2.0	32.0	110.3	207.5	117.2	256.9	408.9	7.0	0	0	1,140
	River Runoff (MCM) 1968	185	153	143	142	267	550	357	1830	4950	2830	511	219	12,100
Recent Drought Year	Precipitation (mm) 1981	0	9.8	7.9	80.2	157.1	302.3	220.1	287.0	122.0	97.9	36.4	0	1,320.7
	River Runoff (MCM) 1981	400	319	423	531	589	1220	2460	5580	2720	1570	896	406	17,100

DATA: RID, NEA Hydrologic Yearbooks

NAM MUN RIVER FLOWS AT UBON , 1968



HYDROLOGIC DATA , NEA , 1970

FIGURE	NAM MUN RIVER FLOWS AT UBON, 1968
3.5	
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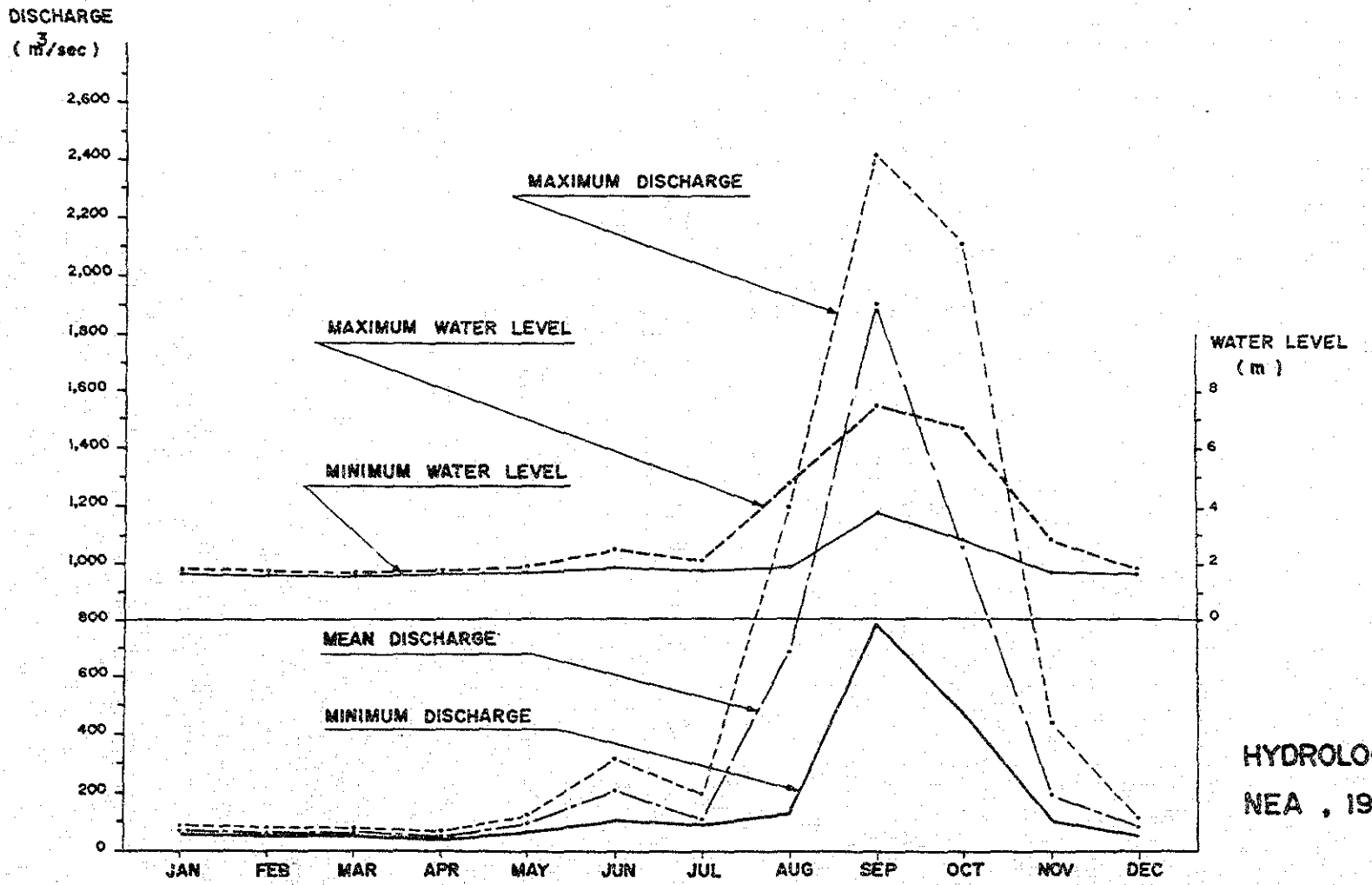
NAM MUN RIVER MONTHLY DISCHARGE AND WATER LEVEL AT UBON , 1968



HYDROLOGIC DATA ,
NEA , 1970

FIGURE	NAM MUN RIVER MONTHLY DISCHARGE
3.6	AND WATER LEVEL AT UBON, 1968
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Turbidity of the Mun river and Mun Noi river water is generally high in the beginning and during the rainy season, while very low during the middle of the dry season. The turbidity ranges from 2.4 to 54 SiO2 units, and pH ranges from 6.6 to 8.0, staying is on lower side in the rainy season. Alkaliity ranges from 10 to 84 mg/lit as CaCO3 and it tends to remarkably decrease in the rainy season. (Appendix 4 Water Quality)

Water quality of the rivers is mostly acceptable, except for the alkalinity. Even though the low alkalinity has not affected treatment seemingly, feeding alkaline chemicals will be desirable for treatment and for protection of asbestos cement pipes against corrosion.

The Mun River flow is abundant and the quality acceptable, throughout the year. the projected water demand in 2010 is 81,140 m^3/day and the estimated drought flow in the driest year of 33 years period is 44.8 m^3/s, that is, 3,870,000 cu m/day. The water demand is only 2.1 % of the drought flow. Therefore, the Mun River is a suitable water source for the public water supply of Ubon and Warin Waterworks.