3.1.3 Distribution System

(1) Description of Existing Distribution System

(a) Patum Thani

The center of the town as shown in Figure 3-1-3 is covered with a distribution system of the Patum Thani Waterworks.

The schematic plan of the network is shown in Figure 3-1-4.

Breakdown of the pipeline is tabulated in Table 3-1-3.

Table 3-1-3 Distribution Pipe

Dia. (mm)	Approximate Length (m)	Material
300	540	AC
250	410	AC
200	1,170	AC
150	5,380	AC
100	6,620	AC
200	90	GS
150	210	GS
100	560	GS
Total	14,980	

One of two elevated tanks is presently not in use because of the lack of a hydraulic head to deliver treated water. Another elevated tank is connected to the outflow pipe of the high lift pump and acts like a surge tank or stand pipe for the distribution system. Pumps are turned on and off manually while the operators observe the pressure at the delivery side of pumps.

The number of connections of the waterworks are counted as shown in Table 3-1-4.

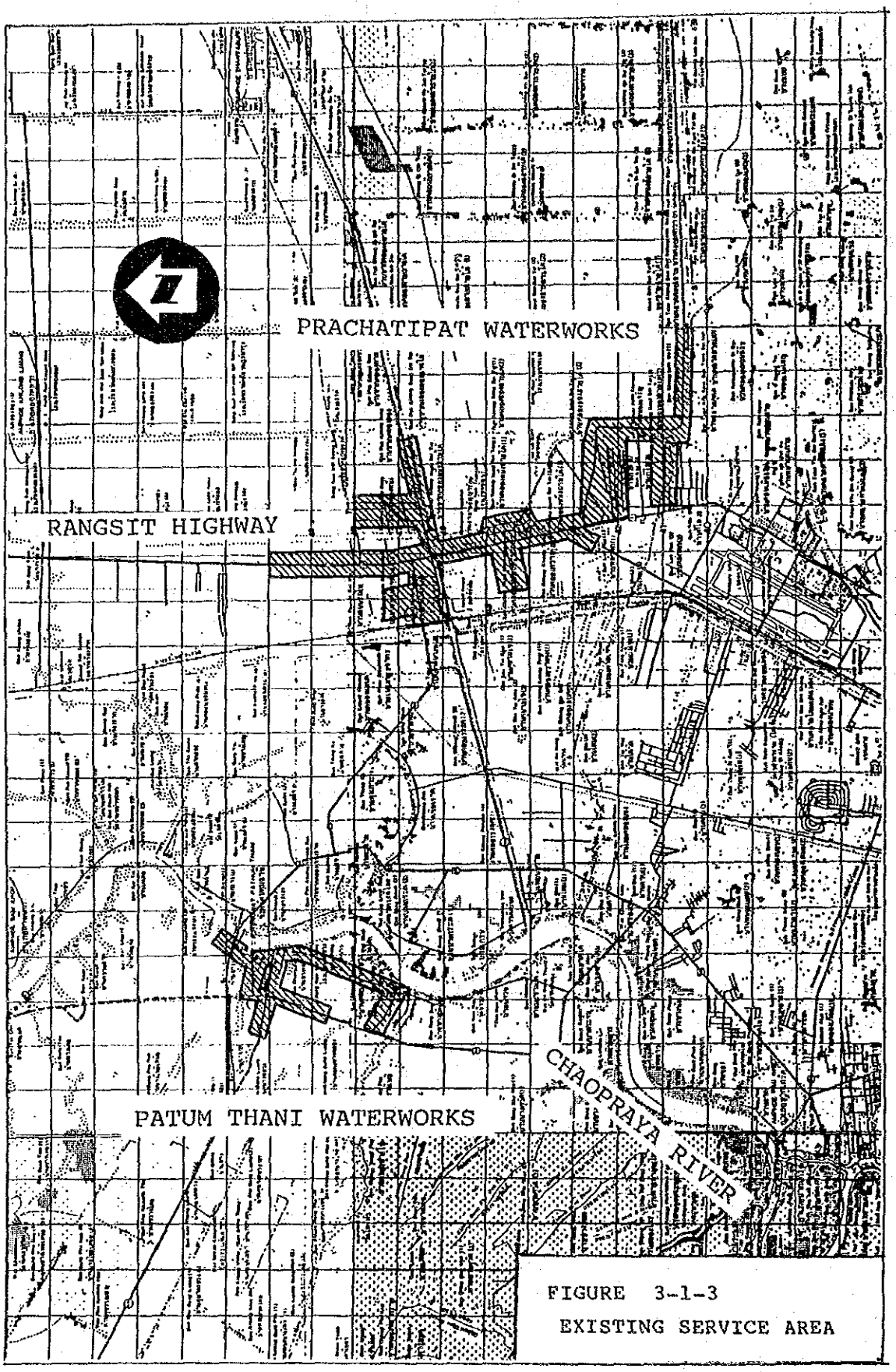


FIGURE 3-1-3
EXISTING SERVICE AREA

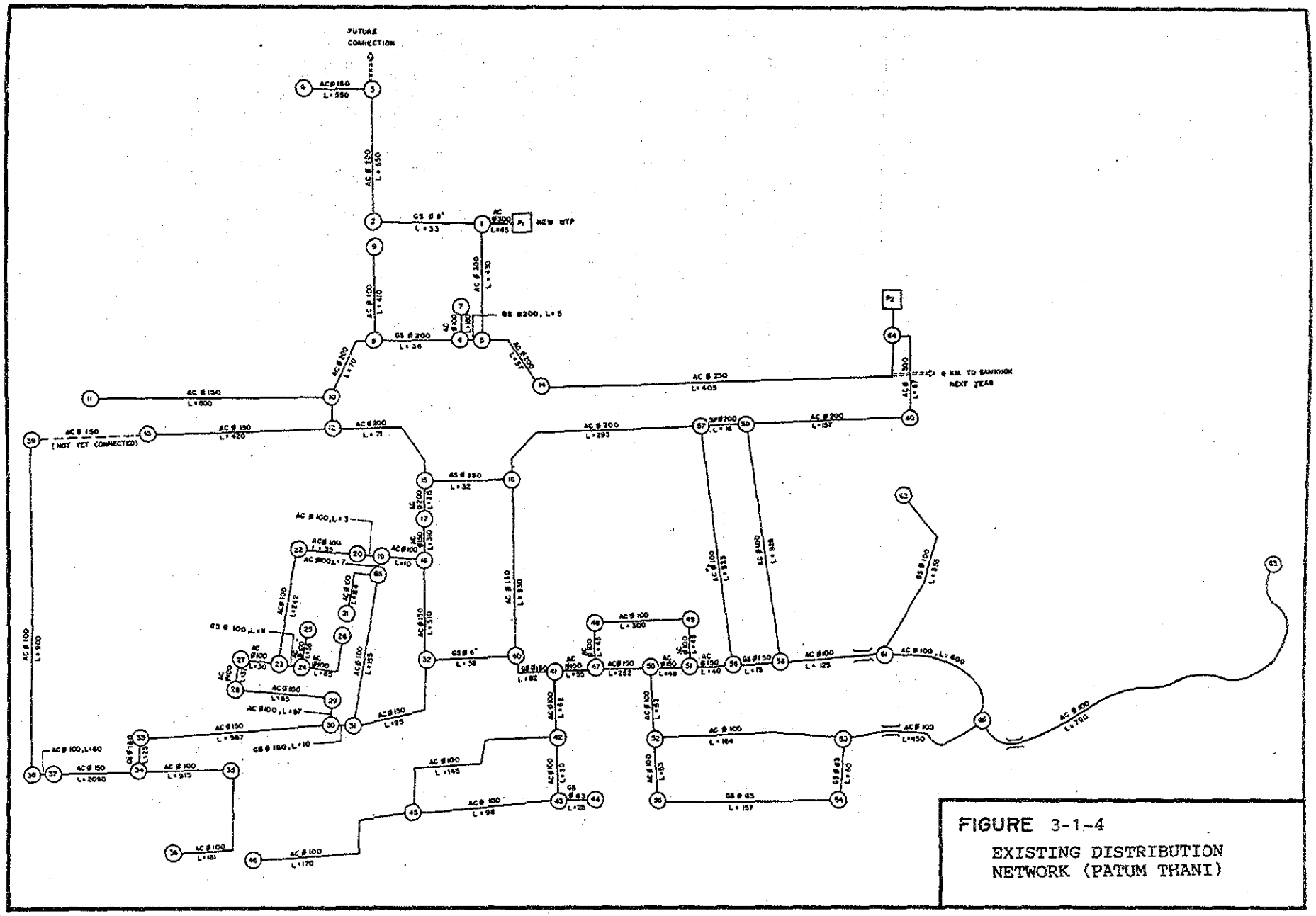


FIGURE 3-1-4
EXISTING DISTRIBUTION NETWORK (PATUM THANI)

Table 3-1-4 No. of Connections

Year	No. of Connections
1980	822
1981	842
1982	954
1983	999
1984	1,060
1985	1,180
1986	1,255
1987	1,445

(b) Prachatipat

The distribution system of the Prachatipat Waterworks covers the area along the Rangsit Highway and the adjacent areas thereof as shown in Figure 3-1-3. The schematic plan of the network is shown in Figure 3-1-5.

The distribution pipeline has been expanded year by year to cope with the boom of the development of industry and housing estates. This results in some operational inconsistency in the system. The most remarkable is the existence of many elevated tanks and deep wells in the various housing estates, which makes the pressure and flow control difficult when all the pipelines are connected and in use.

At present, main pipelines running along the Rangsit Highways are cut off by closing valves at the ESSO gas station located at the southern side of the entrance road to the Muang Ake housing estate. The northern side of the closed valve is supplied water from the Prachatipat Waterworks while the southern side area is supplied from the MWA's distribution main with a connection at the Phaholyothin Road.

The housing estate just beside the Prachatipat Waterworks has also five elevated tanks, each of which is equipped with a deep well. The operation of these deep well and elevated tank creates a higher pressure in the estate than in the waterworks. This is because the waterworks system uses as distribution pumps the pumps for deep wells. These have less lift head than they normally should have, if used as distribution pumps. The pressure at the delivery side of these pumps were observed to be less than 1.0 kg/sq.cm. This means that most of water being supplied to these areas does not come from the waterworks' deep wells but from the deep wells in the housing estate which has been turned over to the PWA.

The number of connections of the waterworks are counted as shown in Table 3-1-5.

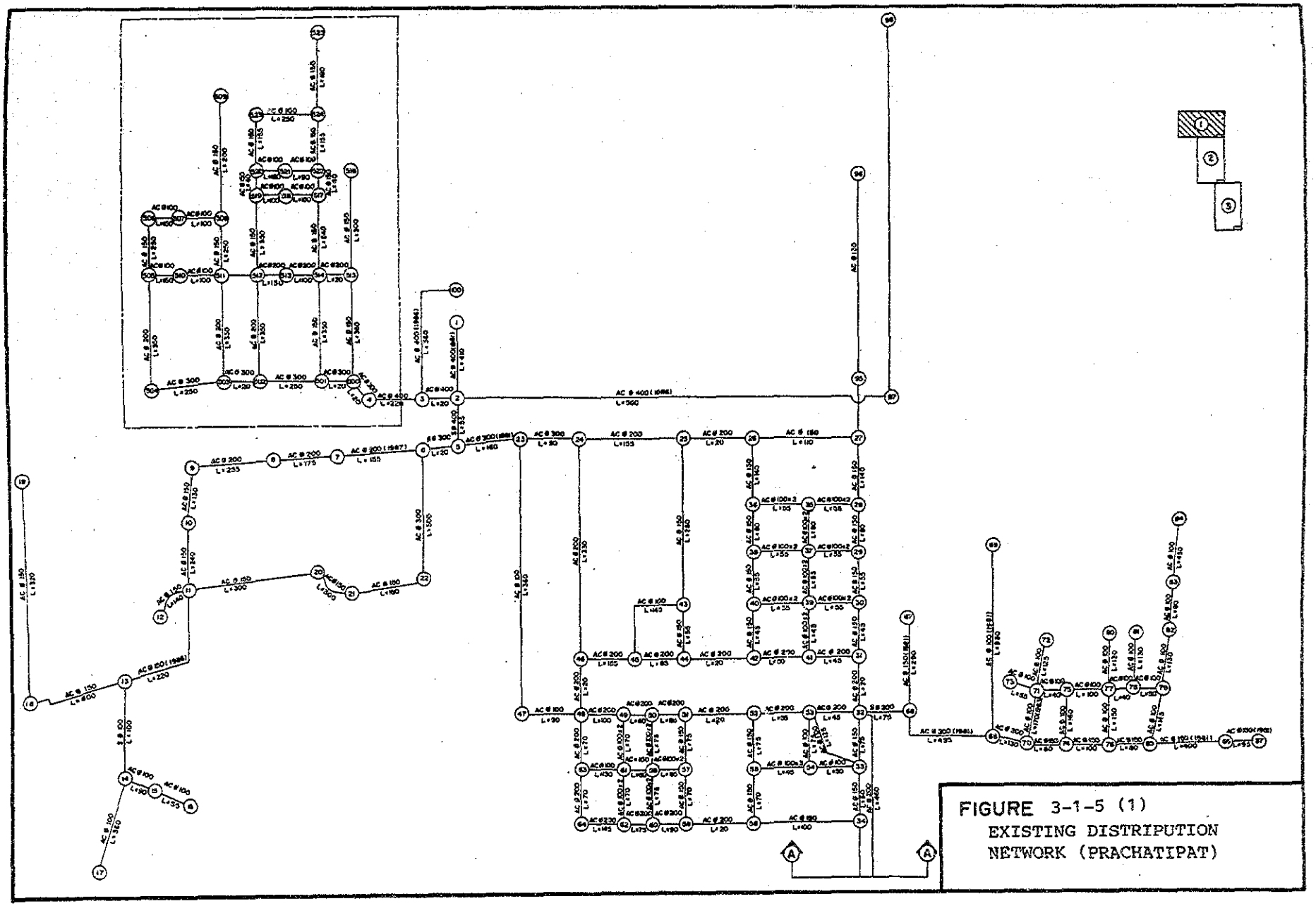


FIGURE 3-1-5 (1)
EXISTING DISTRIPUTION
NETWORK (PRACHATIPAT)

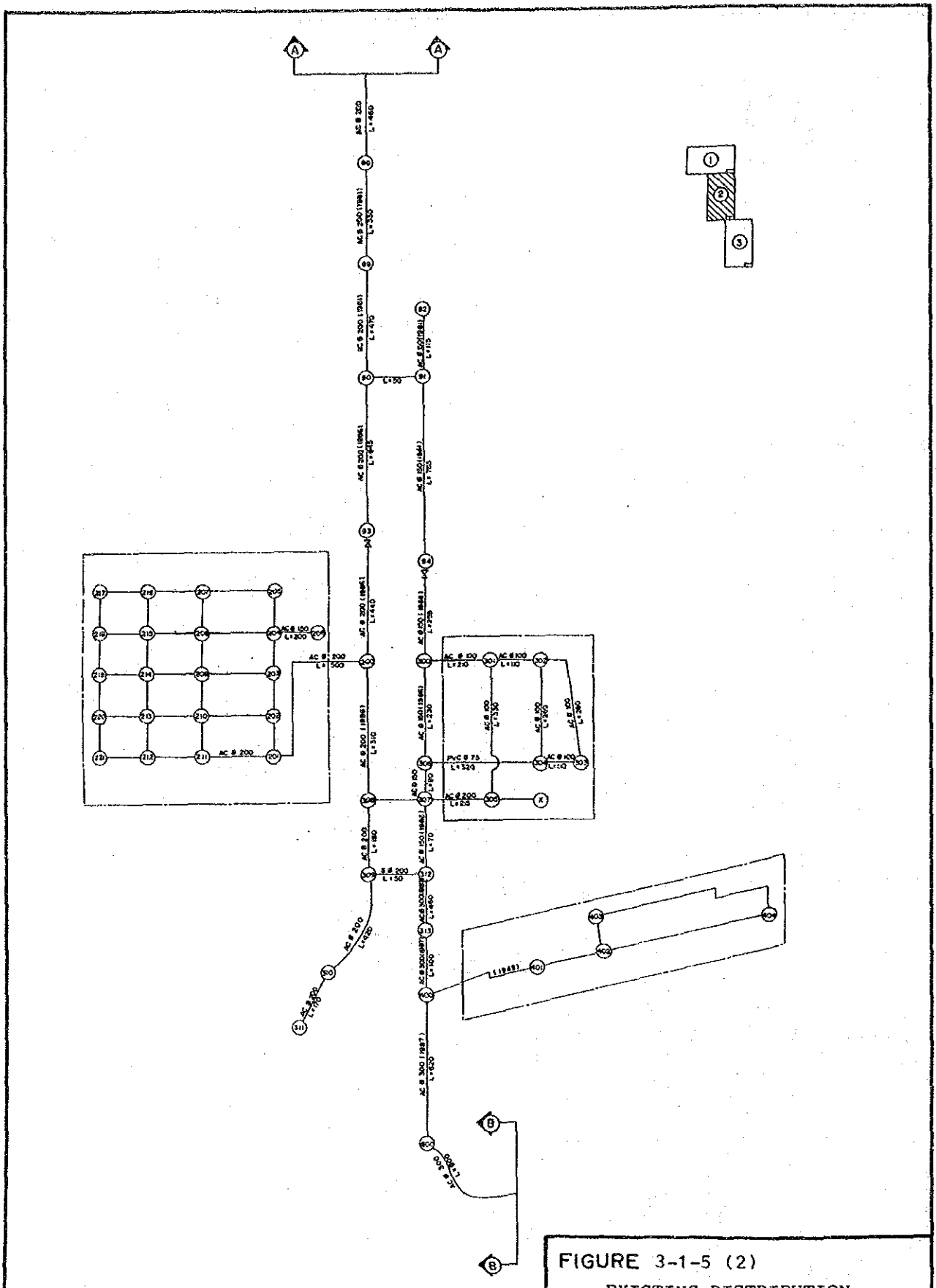


FIGURE 3-1-5 (2)
EXISTING DISTRIBUTION NETWORK (PRACHATIPAT)

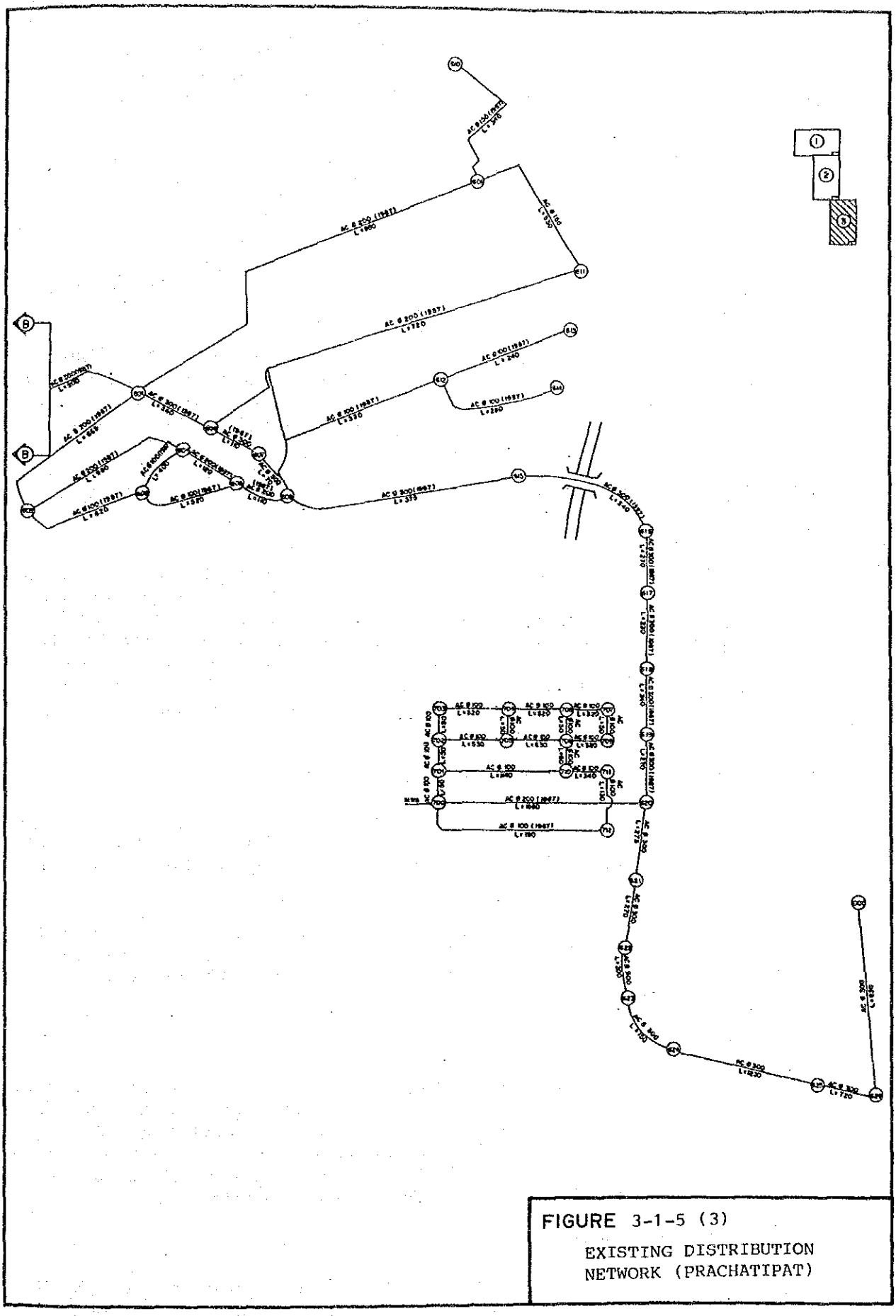


FIGURE 3-1-5 (3)

EXISTING DISTRIBUTION NETWORK (PRACHATIPAT)

Table 3-1-5 No. of Connections

Year	No. of Connections
1983	230
1984	1,121
1985	1,295
1986	1,516
1987	1,735

Although all the house connections are metered, some meters seem to be defective or have measuring errors.

Another defect is that most of meters cannot detect small flows of less than 5 l/hr. Therefore, some consumers collect water in pots or jars just by choking their faucets in the stated level. The defects of the meters as described above will be reflected when considering the unaccounted-for water.

(2) Distribution Network Analysis

(a) Method of Analysis

A computer model was used to analyze the distribution system and to determine the improvements necessary to meet the projected water demand. The model uses a standard Hardy-Cross network analysis technique where head losses are calculated using the Hazen-Williams equation. An interactive process is used in the model to balance the hydraulic grade line at each pipe junction in the network, with adjustments made in the hydraulic grade to satisfy the continuity equation at each junction.

(b) Hazen-Williams Discharge Coefficients ("C" Value)

Estimates of the Hazen-Williams discharge coefficients for existing pipeline are made based on the age of the pipes which was obtained from both the Patum Thani and Prachatipat Waterworks during the field survey.

Although the C value for asbestos cement pipe usually remains at 110 or close to its original level, newly installed pipes in the past 2 to 3 years use a C value of 110, and a C value of 100 was adopted for other remaining pipes.

(c) Demand Distribution

Based on the water sales recorded, a demand distribution at each node was prepared. It was assumed for the purpose of initial analysis that the existing treatment plants can supply enough treated water to meet the daily maximum demand, and amounts of 3,283 cu.m/d in Patum Thani and 3,963 cu.m/d in Prachatipat (or 1.35 times the maximum daily demand) under hourly maximum demand conditions.

(d) Evaluation of the Existing Distribution System

Using the data described above, a simulation was made to the existing systems by the computer model described earlier. This simulation shows that a pressure of about 25m in water column is required at the existing treatment plants in both Patum Thani and Prachatipat.

The results for Patum Thani and Prachatipat are shown with the pressure contour lines in Figures 3-1-6 and 3-1-7 and the computer output of distribution network analysis are presented in the separate volume.

The system has a proper pressure range which shows similar pressure conditions to the actual field measurements described in Appendix A-3-1.

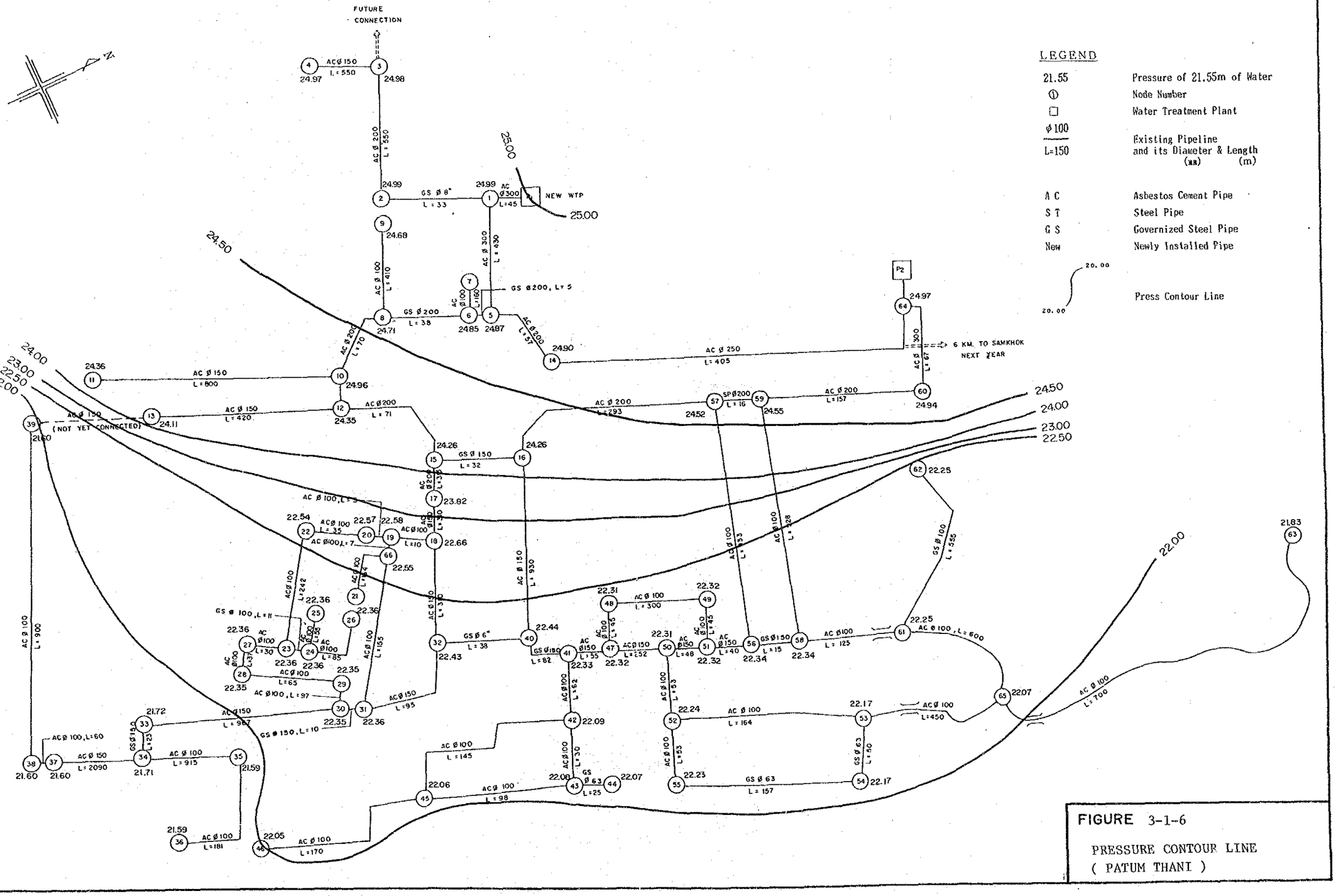


FIGURE 3-1-6

PRESSURE CONTOUR LINE
(PATUM THANI)

N

LEGEND

21.55	Pressure of 21.55m of Water
①	Node Number
□	Water Treatment Plant
φ100 / L=150	Existing Pipeline and its Diameter & Length (mm) (m)
A C	Asbestos Cement Pipe
S T	Steel Pipe
G S	Governized Steel Pipe
New	Newly Installed Pipe
20.00 / 20.00	Press Contour Line

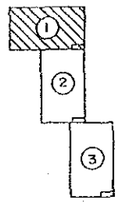


FIGURE 3-1-7 (1)

PRESSURE CONTOUR LINE

(PRACHATIPAT)

LEGEND

21.55	Pressure of 21.55m of Water
①	Node Number
□	Water Treatment Plant
φ100 / L=150	Existing Pipeline and its Diameter & Length (mm) (m)
A C	Asbestos Cement Pipe
S T	Steel Pipe
G S	Governized Steel Pipe
New	Newly Installed Pipe
20.00 / 20.00	Press Contour Line

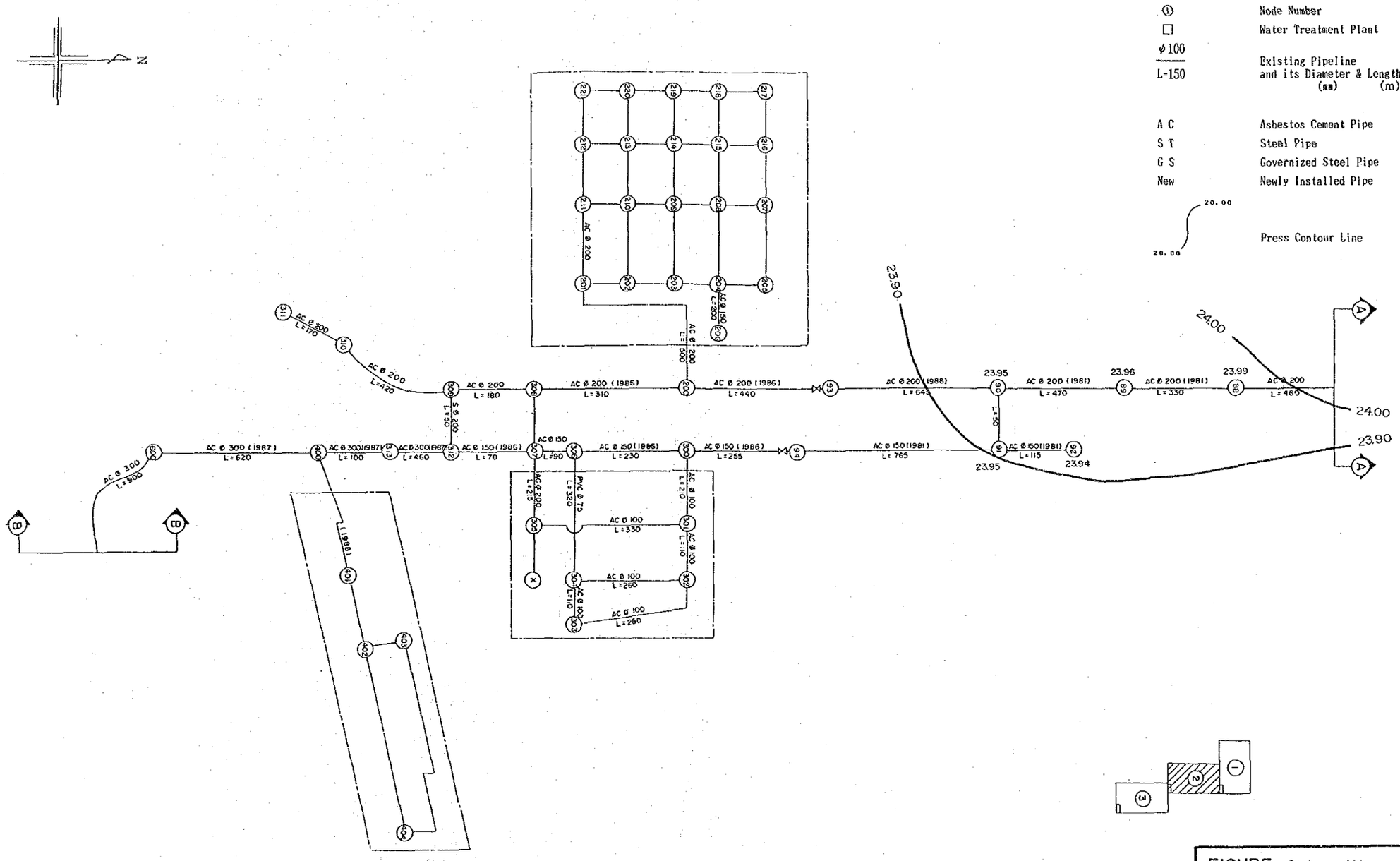


FIGURE 3-1-7 (2)

PRESSURE CONTOUR LINE
(PRACHATIPAT)

3.2 Operation and Maintenance

(1) Patum Thani

The operational status during the past one year from August 1987 to July 1988 is shown in Table 3-2-1.

The water intake averages 131.8 cu.m/h, 112.9 cu.m/h at the minimum and 150.0 cu.m/h at the maximum. This exceeds the intake capacity of 100 cu.m/h by 50%.

The chemical used for chlorination was changed from bleaching powder to chlorine gas since April 1988. About 100 kg of chlorine gas was used every month with the chlorine dosage rates in the low range of 0.93 mg/l and 1.05 mg/l. Though the number of connections was 1,713 at the end of July 1933 or 26.0% up from the previous year, the increase in water sales was not so clear. The average rate of unaccounted-for water to water production shows a high value of 45.1%.

A big crack was found at the pump foundation horizontally and could be due to the ground subsidence which caused the pump delivery pipe to be vended.

(2) Prachatipat

The operational status during the past one year from August 1987 to July 1988 is shown in Table 3-2-2.

There was a big change in the data of July 1988, since the private water supply systems of two housing estates were put under the control of the PWA Prachatipat Waterworks. Therefore, the following considerations were based on the data for eleven months with the exception of July 1988.

The water intake has increased from October 1987 with an average of 196.4 cu.m/h, the minimum of which is 145.9 cu.m/h and the maximum of 196.4 cu.m/h. These exceeded the intake capacity of 160 cu.m/h (one 120 cu.m/h intake pump was out of order) by 22.8%.

The chlorine gas was used for chlorination but dosage rates were in the very low range of 0.15 mg/l and 0.23 mg/l.

The number of connections have increased from 1,615 in July 1987 to 2,281 in June 1988 or by 41.2% reflective of development in the area. The water sales have also been steadily increasing. The average rate of unaccounted-for water to production is 42.1% and could be due to some cracks found around the pump foundation, like in Patum Thani.

Table 3-2-1 Operational Record (Oct. 1986 - Sep. 1987)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Avc
A) Raw Water	80789	87177	94958	85101	86253	78887	88644	85400	90862	79911	89999	94472	1042453	86871
Ground Water	80789	87177	94958	85101	86253	78887	88644	85400	90862	79911	89999	94472	1042453	86871
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.930	1.004	1.093	0.980	0.993	0.908	1.020	0.983	1.046	0.920	1.036	1.087	-	-
B) Raw Water Used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-
C) Treated Water	80756	87134	84532	85101	86199	78846	88575	85341	90817	79879	89907	94395	1031482	85957
*Variation	0.939	1.014	0.983	0.990	1.003	0.917	1.030	0.993	1.057	0.929	1.046	1.098	-	-
D) Treated Water Used	390	445	390	440	440	440	480	495	490	440	495	490	3835	453
Filter Washing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical Mixing	40	45	40	0	40	40	30	45	40	40	45	40	445	37
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	350	400	350	440	400	100	350	300	150	300	100	150	3390	283
Used in Houses	0	0	0	0	0	300	100	150	300	100	350	300	0	133
*(D)/(C)	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.006	0.005	0.006	0.006	0.005	0.004	-
E) Distributed Water	80756	87134	84490	85040	86199	78846	88575	85341	90817	79879	89907	94395	1031379	85948
*Variation	0.940	1.014	0.983	0.989	1.003	0.917	1.031	0.993	1.057	0.929	1.046	1.098	-	-
F) Sold Water	44084	45104	44505	46640	42987	42420	54233	55974	44888	53078	50829	45577	570319	47527
Connection Meters	43939	44937	44352	46640	42492	42175	53944	55682	44712	52739	50508	45367	567487	47291
Public Meters	145	167	153	0	495	245	289	292	176	339	321	210	2832	236
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.928	0.949	0.936	0.981	0.904	0.893	1.141	1.178	0.944	1.117	1.069	0.959	-	-
G) Unaccounted-for Water	36672	42030	39985	38400	43212	36426	34342	29367	45929	26801	39078	48818	461060	38422
*(G)/(E)	0.454	0.482	0.473	0.452	0.501	0.462	0.388	0.344	0.506	0.336	0.435	0.517	0.447	-
H) No. of Connections	1278	1280	1289	1286	NA	1305	1311	1338	1351	1359	1396	1445	-	-
I) Per Conn. Consumption	NA	68.07	65.58	66.17		60.42	67.56	63.78	67.22	58.78	64.40	65.33		
*Variation	NA												-	-
J) Chemical														
Alum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleaching Powder	360	360	360	520	320	400	480	400	360	360	360	300	4580	382
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K) Chemical Dosage Rate														
Alum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Bleaching Powder	4.46	4.13	4.26	6.11	3.71	5.07	5.42	4.69	3.96	4.51	4.00	3.18	-	4.44
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00

Note: The unit, if not specified, is a cu m and the marked items (*) are dimmensionless.

Table 3-2-1 Operational Record (Oct. 1987 - Jul. 1988)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	89845	94170	83944	88345	106431	90607	108135	102250	107971	95280	0	0	966978	96698
Ground Water	89845	94170	83944	88345	106431	90607	108135	102250	107971	95280	0	0	966978	96698
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.929	0.974	0.868	0.914	1.101	0.937	1.118	1.057	1.117	0.985	0.000	0.000	-	-
B) Raw Water Used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			0.000	-
C) Treated Water	89785	94119	83876	88259	106359	90520	108046	102158	107865	95205	0	0	966192	96619
*Variation	0.929	0.974	0.868	0.913	1.101	0.937	1.118	1.057	1.116	0.985	0.000	0.000	-	-
D) Treated Water Used	515	490	490	540	650	745	800	950	900	620	0	0	2670	970
Filter Washing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical Mixing	45	40	40	40	50	45	0	0	0	0	0	0	260	26
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	160	150	150	150	200	300	300	350	300	350	0	0	2410	241
Used in Houses	310	300	300	350	400	400	500	600	600	270	0	0	0	493
*(D)/(C)	0.006	0.005	0.006	0.006	0.006	0.008	0.007	0.009	0.008	0.007			0.003	-
E) Distributed Water	89785	94119	83876	88259	106359	90520	108046	102158	107865	95205	0	0	966192	96619
*Variation	0.929	0.974	0.868	0.913	1.101	0.937	1.118	1.057	1.116	0.985	0.000	0.000	-	-
F) Sold Water	50428	48828	50162	52811	48982	51896	62278	62834	57776	55023	0	0	541018	54102
Connection Meters	50150	48616	49857	52288	48136	51135	61773	62048	57270	54591	0	0	535864	53586
Public Meters	278	212	305	523	846	761	505	786	506	432	0	0	5154	515
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.932	0.903	0.927	0.976	0.905	0.959	1.151	1.161	1.068	1.017	0.000	0.000	-	-
G) Unaccounted-for Water	39357	45291	33714	35448	57377	38624	45768	39324	50089	40182	0	0	425174	42517
*(G)/(E)	0.438	0.481	0.402	0.402	0.539	0.427	0.424	0.385	0.464	0.422			0.440	-
H) No. of Conn. (nos.)	1481	1521	1566	1608	1633	1654	1663	1683	1698	1718	0	0	-	-
I) Per Conn. Consumption	60.62	61.88	53.56	54.89	65.13	54.73	64.97	60.70	63.52	55.58	0.00	0.00	595.58	.60
*Variation	1.018	1.039	0.899	0.922	1.094	0.919	1.067	1.019	1.067	0.933	0.000	0.000	-	-
J) Chemical (kg)														
Alum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleaching Powder	360	360	400	360	360	0	0	0	0	0	0	0	1840	184
Chlorine Gas	0	0	0	0	0	0	100	100	100	100	0	0	400	40
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K) Dosage Rate (mg/l)														
Alum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00
Bleaching Powder	4.01	3.82	4.77	4.08	3.38	0.00	0.00	0.00	0.00	0.00			-	1.90
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.98	0.93	1.05			-	0.41
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00

Note: The unit, if not specified, is a cu m and the marked items (*) are dimmensionless.
The total and average are for ten months.

Table 3-2-2 Operational Record (Oct. 1986 - Sep. 1987)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	96116	92408	94958	95204	85352	97533	112536	117339	103185	94839	108536	106966	1204972	100414
Ground Water	96116	92408	94958	95204	85352	97533	112536	117339	103185	94839	108536	106966	1204972	100414
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.957	0.920	0.946	0.948	0.850	0.971	1.121	1.169	1.028	0.944	1.081	1.065	-	-
B) Raw Water Used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-
C) Treated Water	96116	92408	94958	95204	85352	97533	112536	117339	103185	94839	108536	106966	1204972	100414
*Variation	0.957	0.920	0.946	0.948	0.850	0.971	1.121	1.169	1.028	0.944	1.081	1.065	-	-
D) Treated Water Used	600	600	600	650	650	650	650	650	650	650	650	650	5224	638
Filter Washing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical Mixing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	600	600	600	418	418	418	380	380	380	380	380	270	5224	435
Used in Houses	0	0	0	232	232	232	270	270	270	270	270	380	0	202
*(D)/(C)	0.006	0.006	0.006	0.007	0.008	0.007	0.006	0.006	0.006	0.007	0.006	0.006	0.004	-
E) Distributed Water	97495	91243	97011	93720	87613	96883	111886	116089	101573	82749	107111	105402	1180375	99115
*Variation	0.984	0.921	0.979	0.946	0.884	0.977	1.129	1.177	1.025	0.835	1.081	1.063	-	-
F) Sold Water	53981	53905	55964	57207	56075	51944	63142	63191	66385	66190	64857	54808	707649	58971
Connection Meters	53563	53340	55172	56373	55483	50541	61495	62287	65350	65066	63796	53894	696360	58030
Public Meters	418	565	792	834	592	1403	1647	904	1035	1124	1061	914	11289	941
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.915	0.914	0.949	0.970	0.951	0.881	1.071	1.072	1.126	1.122	1.100	0.929	-	-
G) Unaccounted-for Water	43514	37338	41047	36513	31538	44939	48744	53498	35188	16559	42254	50594	481726	40144
*(G)/(E)	0.446	0.409	0.423	0.390	0.360	0.464	0.436	0.458	0.346	0.200	0.394	0.480	0.405	-
H) No. of Connections	NA	1532	1537	1545	1550	1557	1580	1584	1592	1615	1628	1735	-	-
I) Per Conn. Consumption	NA	60.32	61.78	61.62	55.07	62.64	71.23	74.08	64.81	58.72	66.67	61.65	698.59	63.51
*Variation	NA	0.950	0.973	0.970	0.867	0.986	1.021	1.166	1.021	0.925	1.050	0.971	-	-
J) Chemical														
Alum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleaching Powder	0	0	0	0	0	10	10	0	0	0	0	0	20	2
Chlorine Gas	28	27.09	28	28	28	16.74	33.4	50	31	15	16	0	301.23	25
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K) Chemical Dosage Rate														
Alum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Bleaching Powder	0.00	0.00	0.00	0.00	0.00	0.10	0.09	0.00	0.00	0.00	0.00	0.00	-	0.02
Chlorine Gas	0.29	0.29	0.29	0.29	0.33	0.17	0.30	0.43	0.30	0.16	0.15	0.00	-	0.25
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00

Note: The unit, if not specified, is a cu m and the marked items (*) are dimmensionless.

Table 3-2-2 Operational Record (Oct. 1987 - Jul. 1988)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	121105	137245	151373	166561	153232	160355	160417	170140	133889	311427	0	0	1665744	166574
Ground Water	121105	137245	151373	166561	153232	160355	160417	170140	133889	311427	0	0	1665744	166574
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.727	0.824	0.909	1.000	0.920	0.963	0.963	1.021	0.804	1.870	0.000	0.000	-	-
B) Raw Water Used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			0.000	-
C) Treated Water	121105	137245	151373	166561	153232	160355	160417	170140	133889	311427	0	0	1665744	166574
*Variation	0.727	0.824	0.909	1.000	0.920	0.963	0.963	1.021	0.804	1.870	0.000	0.000	-	-
D) Treated Water Used	650	650	650	650	650	650	650	650	650	650	0	0	3800	650
Filter Washing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical Mixing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	380	380	380	380	380	380	380	380	380	380	0	0	3800	380
Used in Houses	270	270	270	270	270	270	270	270	270	270	0	0	0	270
*(D)/(C)	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.002			0.002	-
E) Distributed Water	119707	136595	150723	165911	152582	159705	159767	169490	133239	310727	0	0	1658446	165845
*Variation	0.722	0.824	0.909	1.000	0.920	0.963	0.963	1.022	0.803	1.874	0.000	0.000	-	-
F) Sold Water	71656	72081	83754	83434	78765	96756	95217	104399	102695	173332	0	0	962089	96209
Connection Meters	70656	71310	83195	82765	77878	95609	94334	103750	102223	172937	0	0	954657	95466
Public Meters	1000	771	559	669	887	1147	883	649	472	395	0	0	7432	743
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.745	0.749	0.871	0.867	0.819	1.006	0.990	1.085	1.067	1.802	0.000	0.000	-	-
G) Unaccounted-for Water	48051	64514	66969	82477	73817	62949	64550	65091	30544	137395	0	0	696357	69636
*(G)/(E)	0.401	0.472	0.444	0.497	0.484	0.394	0.404	0.384	0.229	0.442			0.420	-
H) No. of Conn. (nos.)	1796	1957	2013	2084	2196	2225	2225	2263	2281	4981	0	0	-	-
I) Per Conn. Consumption	67.43	70.13	75.20	79.92	69.78	72.07	72.10	75.18	58.70	62.52	0.00	0.00	703.03	70
*Variation	0.959	0.998	1.070	1.137	0.993	1.025	0.835	1.069	0.835	0.889	0.000	0.000	-	-
J) Chemical (kg)														
Alum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleaching Powder	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorine Gas	28.1	30.1	30.5	30.5	30.5	30.5	28	30	30.5	30	0	0	298.7	30
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K) Dosage Rate (mg/l)														
Alum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00
Bleaching Powder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00
Chlorine Gas	0.23	0.22	0.20	0.18	0.20	0.19	0.17	0.18	0.23	0.10			-	0.18
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00

Note: The unit, if not specified, is a cu m and the marked items (*) are dimmensionless.
The total and average are for ten months.

3.3 Existing Improvement/Expansion Plan

3.3.1 Patum Thani

The distribution pipeline is being expanded year by year. The most recent one was the expansion of pipes towards the southwest of the municipality along two main roads. Likewise, the waterworks has planned to extend the pipeline to the north. The water production facility is, however, not being planned to be improved or be expanded.

3.3.2 Prachatipat

The waterworks is now implementing the construction of four deep wells: one at the old plant, another one for the new plant and the rest for still another new plant. These plants will start operation early in 1989 because their completion is needed to cope with the rapid development in this area. The planned water production capacity of these additional wells is:

1)	Plant A (one well)	120 cu.m/h
2)	Plant B (two wells)	240
3)	Old plant (one well)	70
	Total	430 cu.m/h

For the distribution pipeline, the expansion is mainly follows the housing development project. Aside from the PWA's own construction works, the facilities constructed by private developers have been turned over to PWA. Since the housing and industrial development is too fast in this area for PWA to follow, the construction of additional deep wells and water distribution systems are being implemented by the developers themselves.

3.4 Existing Constraints

During an intensive field survey, the following constraints on the existing water supply system are reported:

(1) Water Source

- Land subsidence. sea water intrusion and water level decline.
- Well water contains iron and/or chloride.

(2) Intake and Conduction Pipe

- Motor axis is often seen uneven by differential settlement.

(3) Distribution

- Elevated tank is not being used effectively due to operational defects.
- Unaccounted-for water is fairly large.

(4) Operation and Maintenance

- Chlorine dozing amount is fairly small in Prachatipat.

3.5 Organization

3.5.1 Organization of Regional Office

The regional offices of PWA directly supervise the urban waterworks and assist the rural waterworks in technical aspects.

The Patum Thani and Prachatipat Waterworks are supervised by the Regional Office III in Bangkok which covers 15 waterworks in this region. Figure 3-5-1 shows the organization chart of the Regional Office III. The functions of each section are described as follows:

(1) Personnel & Clerical Section

This section is responsible for personnel administration of the waterworks, including the training of waterworks personnel.

(2) Finance & Accounting Section

A charge of finance and accounts of the waterworks including borrowing and depositing at their bank accounts.

(3) Procurement and Stores Section

This section takes charge of procuring and storing materials and supplies necessary for operating water supply facilities of the waterworks.

(4) Maintenance Section

This section gives guidance and instruction on the operation and maintenance of the waterworks facilities.

(5) Technical Service Section

A preliminary survey of projected waterworks schemes for both urban and rural waterworks is provided by this section.

(6) Water Quality Control Section

This section is responsible for conducting the water quality analyses of both raw and treated water.

(7) Survey Section

This section is responsible for providing the Head Office with information concerning rural waterworks and planning new water supply projects.

(8) Price Estimation Section

This is responsible for estimating the expansion/ rehabilitation cost of water supply systems for both urban and rural waterworks and for preparing documents, drawings and others for bidding.

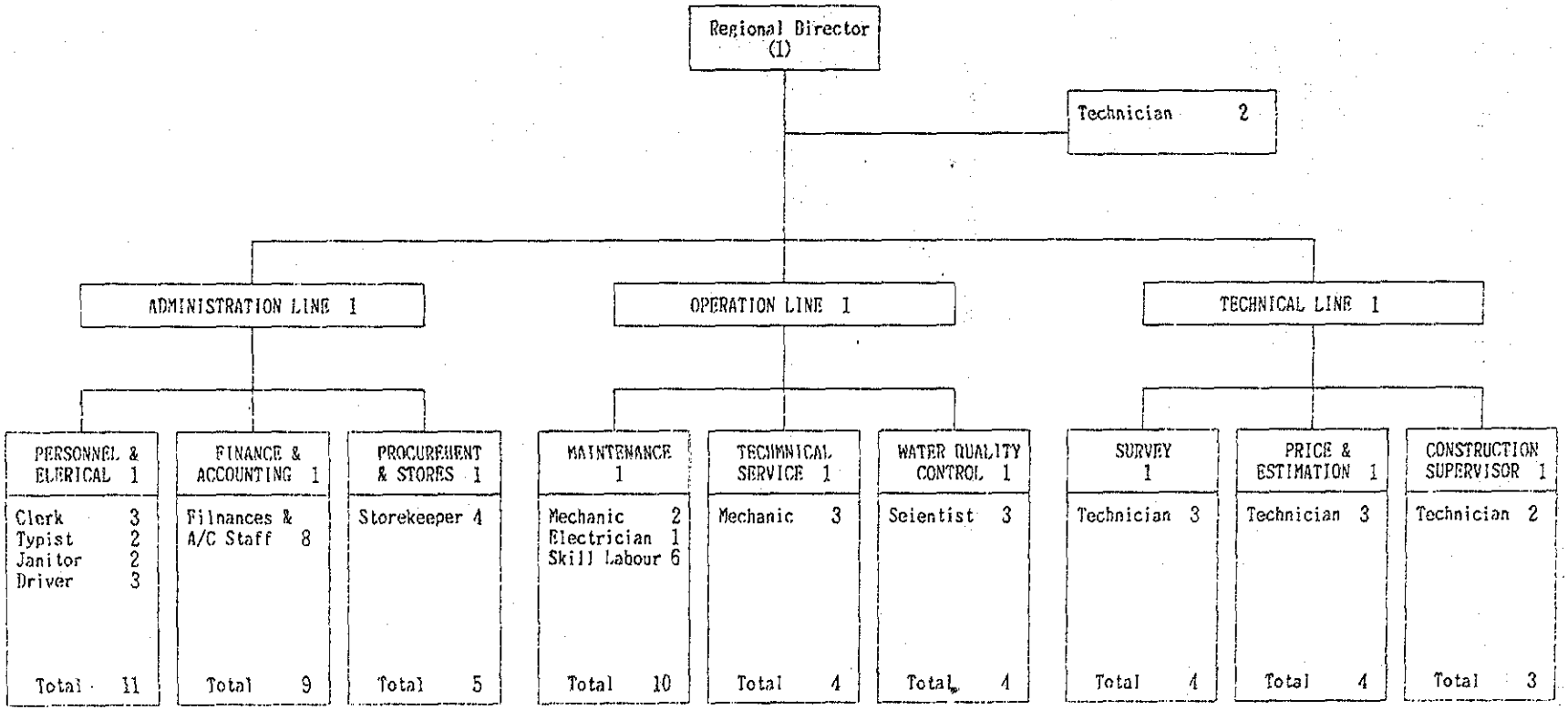


FIGURE 3-5-1

ORGANIZATION CHART OF REGIONAL OFFICE 3

(9) Construction Supervision Section

This is responsible for supervising the construction and expansion/rehabilitation works of water supply facilities.

3.5.2 Organization of Waterworks

The organizations of the Patum Thani and Prachatipat Waterworks consist of three sections, respectively; namely, production, services, and administration sections. The organization chart with the number of employees is shown in Figures 3-5-2 and 3-5-3, and the functions of each section are described as follows:

(1) Water Production Section

This section is responsible for operation and maintenance of water production facilities.

(2) Service Section

Services of setting and repairing house-connections are provided by this section.

(3) Administration Section

This section takes charge of meter reading and bill- collection, book-keeping of customers accounts, financing, record-keeping of waterworks income and expenditure, and other administrative works and meters.

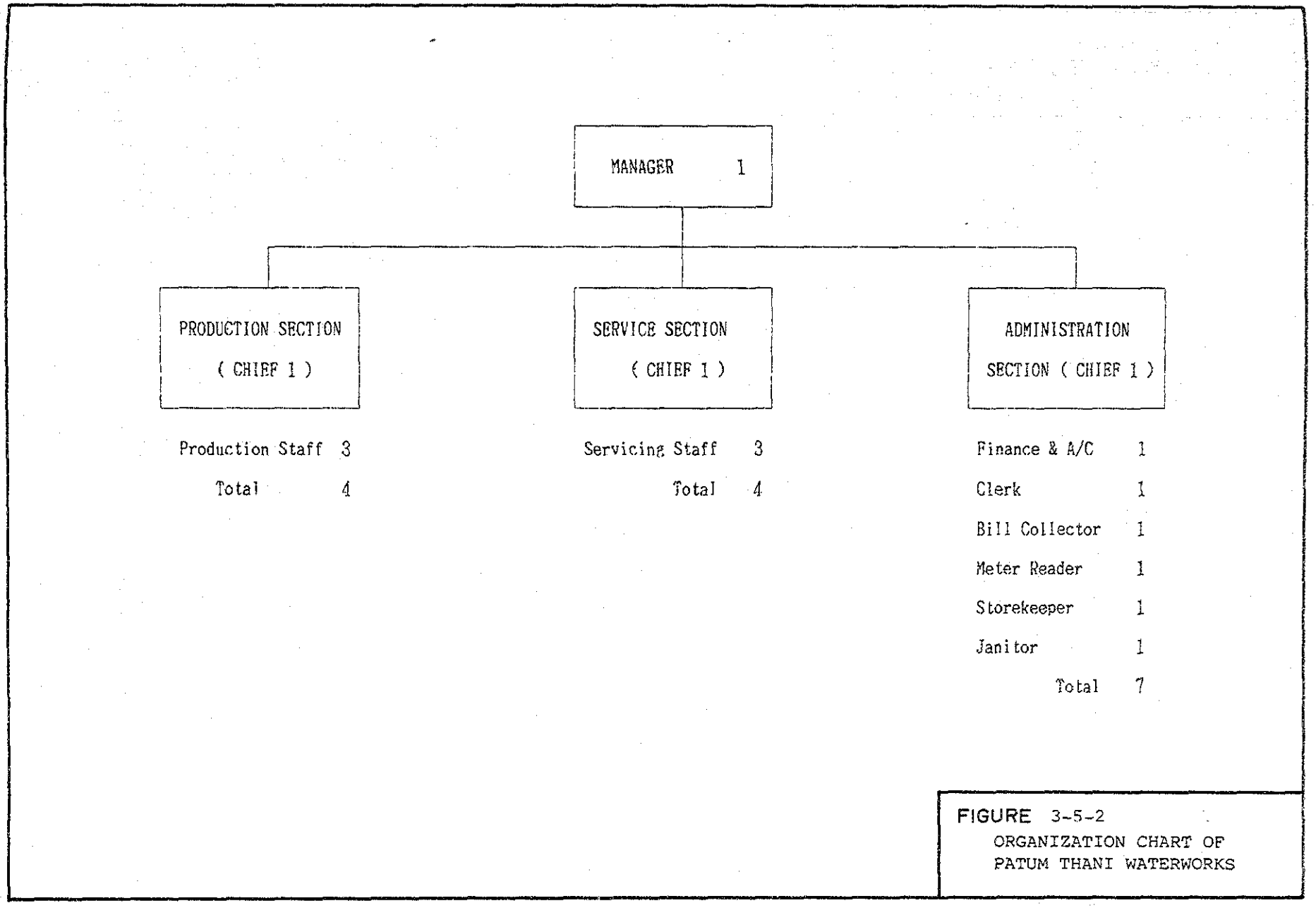


FIGURE 3-5-2
ORGANIZATION CHART OF
PATUM THANI WATERWORKS

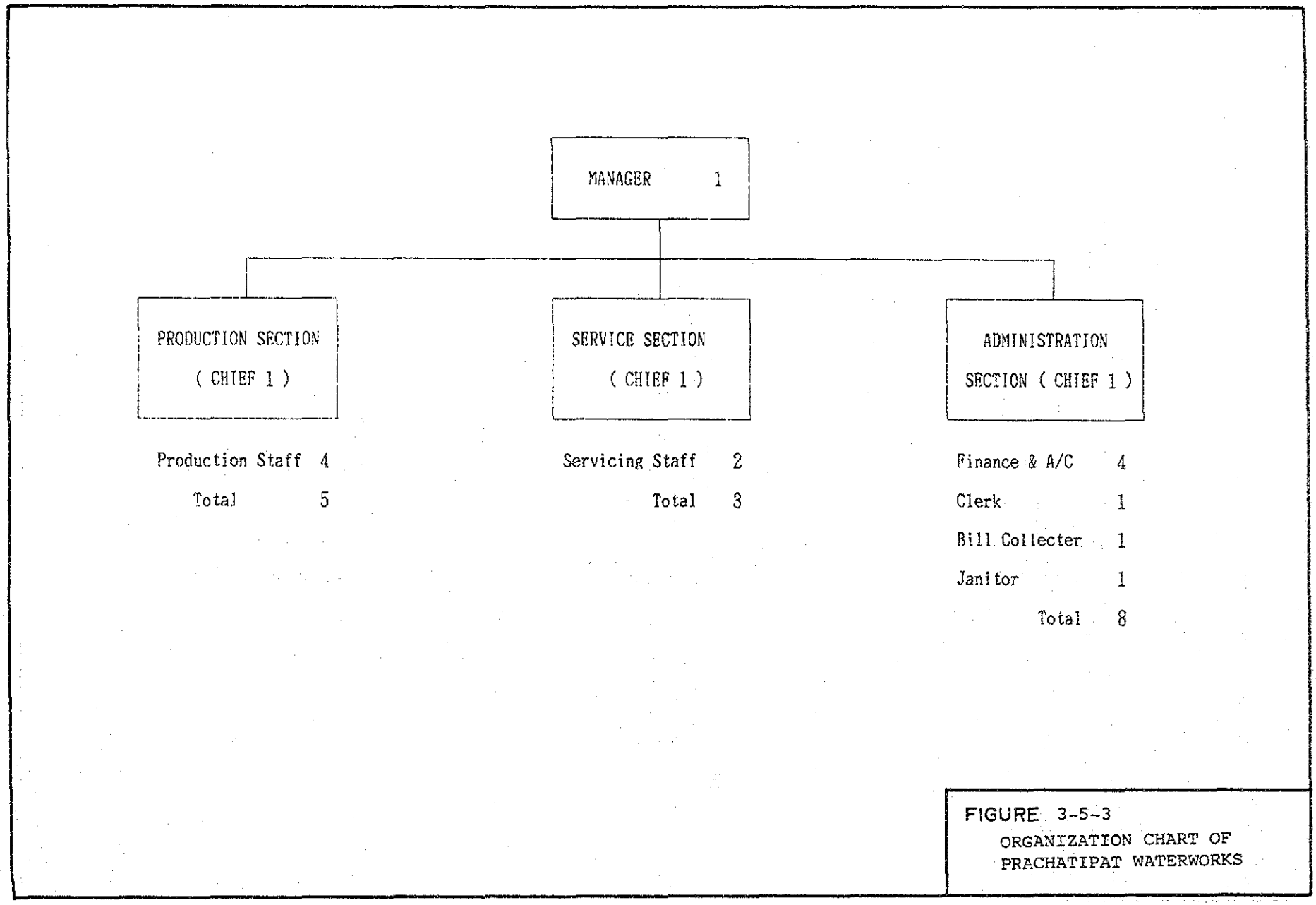


FIGURE 3-5-3
ORGANIZATION CHART OF
PRACHATIPAT WATERWORKS

3.6 Financial Status

3.6.1 Present System

As of 1987, Patum Thani Waterworks has 1,445 connections. For the same year, water production stood at 1,031,440 cu.m while water sale was 570,319 cu.m.

The Prachatipat Waterworks has 1,735 connections as of 1987. The water produced and water sale in 1987 were 1,204,972 cu.m and 707,649 cu.m, respectively.

PWA has three major sources of tariff revenue: namely water sales, service charges and connection fees, the details of which is described in Section 17.1.

3.6.2 Revenue and Expenditure

The annual revenues and expenditures of the waterworks in the last three years are shown in Table 3-6-1.

Table 3-6-1 (a) Patum Thani Waterworks

(Unit : 1,000 ฿)

Year	Revenue	Expenditure	Profit(loss)
1985	3,490	2,406	1,084
1986	4,085	2,486	1,599
1987	4,613	2,594	2,019

Table 3-6-1 (b) Prachatipat Waterworks

(Unit : 1,000 ฿)

Year	Revenue	Expenditure	Profit(loss)
1985	3,901	2,055	1,846
1986	4,828	2,103	2,725
1987	5,700	2,842	2,858

In the accounting system of PWA, all the revenues of waterworks are transferred to the PWA Head Office. All the expenses are also allocated by the PWA Head Office. However, as shown in Table 3-6-3, such accounts as capital investment, debt service and depreciation and amortization are not within the waterworks' own financial system.

To identify and quantify the financial status of the waterworks, one of the financial ratios (Revenue/Expenditure) is computed as shown below:

Table 3-6-2 Ratio of Revenue to Expenditure

	1985	1986	1987
PWA Head Office	1.45	1.72	1.76
Patum Thani Waterworks	1.45	1.64	1.78
Prachatipat Waterworks	1.90	2.30	2.01

When this ratio is equal to or greater than 1.0, the financial status of the waterworks is in good condition.

As shown above, the waterworks earned a net profit on its annual operations. Also the ratio is greater than both 1.0 and the average rate of all PWA waterworks.

A breakdown of the revenue and expenditure is shown in Table 3-6-3.

Table 3-6-3 (a) Revenue and Expenditure of Patum Thani Waterworks

(Unit : Baht)

Description	1985	1986	1987
Water Production cu.m	899,398	1,071,769	1,031,440
Water Sales cu.m	519,785	530,103	570,319
No. of Connections	1,180	1,255	1,445
Revenue			
Water Sales	2,775,751.75	3,596,639.80	3,857,042.75
Service Charge	154,025.00	167,125.00	181,275.00
Connection Fee	506,335.00	286,979.00	550,798.00
Other Revenue	53,741.97	34,524.65	24,331.89
Total Revenue (A)	3,489,853.72	4,085,268.45	4,613,447.64
Expenditure			
Salaries	1,012,400.00	1,035,630.97	1,102,915.00
Remuneration	152,425.60	184,822.55	173,743.43
Chemical	58,420.00	51,520.00	56,120.00
Material & Maintenance	213,681.57	65,411.48	97,608.67
Oil & Fuel	70,003.39	20,102.00	18,114.00
Office Supplies	13,068.12	19,656.58	19,215.34
Hired Service	16,931.00	43,417.06	120,968.00
Other Operating Expense	4,202.50	631.00	650.00
Public Utilities	18,946.25	30,115.00	14,213.00
Electricity	656,211.89	937,465.18	830,928.15
Connection Cost	184,452.15	94,317.29	156,393.14
Material Sold	5,425.08	2,920.00	3,282.00
Total Expenditure (B)	2,406,167.55	2,486,009.11	2,594,150.73
Profit (Loss)	1,083,686.17	1,599,259.34	2,019.296.91

Table 3-6-3 (b) Revenue and Expenditure of Prachatipat Waterworks

(Unit : Baht)

Description	1985	1986	1987
Water Production cu.m	1,255,873	1,166,847	1,204,972
Water Sales cu.m	587,454	621,016	707,649
No. of Connections	1,395	1,516	1,735
Revenue			
Water Sales	3,081,087.50	4,129,272.00	4,747,888.50
Service Charge	187,475.00	259,535.00	238,245.00
Connection Fee	585,237.75	402,759.00	641,932.00
Other Revenue	47,663.19	36,306.31	72,496.74
Total Revenue (A)	3,901,463.44	4,827,872.31	5,700,562.24
Expenditure			
Salaries	773,038.60	838,140.00	918,431.44
Remuneration	121,323.24	155,780.69	163,848.92
Chemical	—	1,090.00	890.00
Material & Maintenance	153,833.68	151,710.29	89,089.30
Oil & Fuel	29,390.29	26,667.94	28,984.11
Office Supplies	23,272.17	28,469.05	59,177.25
Hired Service	5,590.00	111,420.00	62,306.00
Other Operating Expense	1,200.00	2,025.00	23,783.00
Public Utilities	368.75	100.00	25,893.45
Electricity	709,808.02	655,209.82	1,275,879.80
Connection Cost	236,973.32	126,217.98	193,535.48
Material Sold	--	6,373.52	509.20
Total Expenditure (B)	2,054,798.07	2,103,204.29	2,842,327.95
Profit (Loss)	1,846,665.37	2,724,668.02	2,858.234.29

4. POPULATION AND WATER DEMAND

4.1 Project Horizon

The study area is Patum Thani Province except Amphoe Nong Sua.

This area is thought to be large enough to meet future urban expansion, currently growing from the town planning areas of Patum Thani and Prachatipat by 2011.

Amphoe Nong Sua will also have housing and industrial development. The development can however be considered separately from a viewpoint of water supply, due to the remoteness of the Amphoe from the existing water supply facilities and the main target areas.

The study area is shown in Figure 4-1-1.

The total area of the province is approximately 1,500 sq.km.

Table 4-1-1 Administrative Hierarchy of Patum Thani Province

Amphoe/Municipality	No. of Tambons
Patum Thani Municipality	1
Amphoe Muang Patum Thani	13 besides Patum Thani Municipality
Amphoe Sam Khok	11
Amphoe Lad Lum Kaeo	7
Amphoe Thanyaburi	6
Amphoe Lam Luka	7
Amphoe Khlong Luang	7
Amphoe Nong Sua	-

4.2 Population

4.2.1 Historical Population

The population in the study area is 376,800 in 1987. The population has increased rapidly at 3.8% per annum on average since 1980 and 4.2% in the last five years. The growth rates are considerably higher than the national average of 2.0% from 1980 to 1985.

In the study area, Amphoe Lam Luka, Tanyaburi and the Municipality have higher growth rates than the average of the area.

The rapid growth is thought to result from industrial and housing development taking advantage of good access to Bangkok and Don Muang Airport.

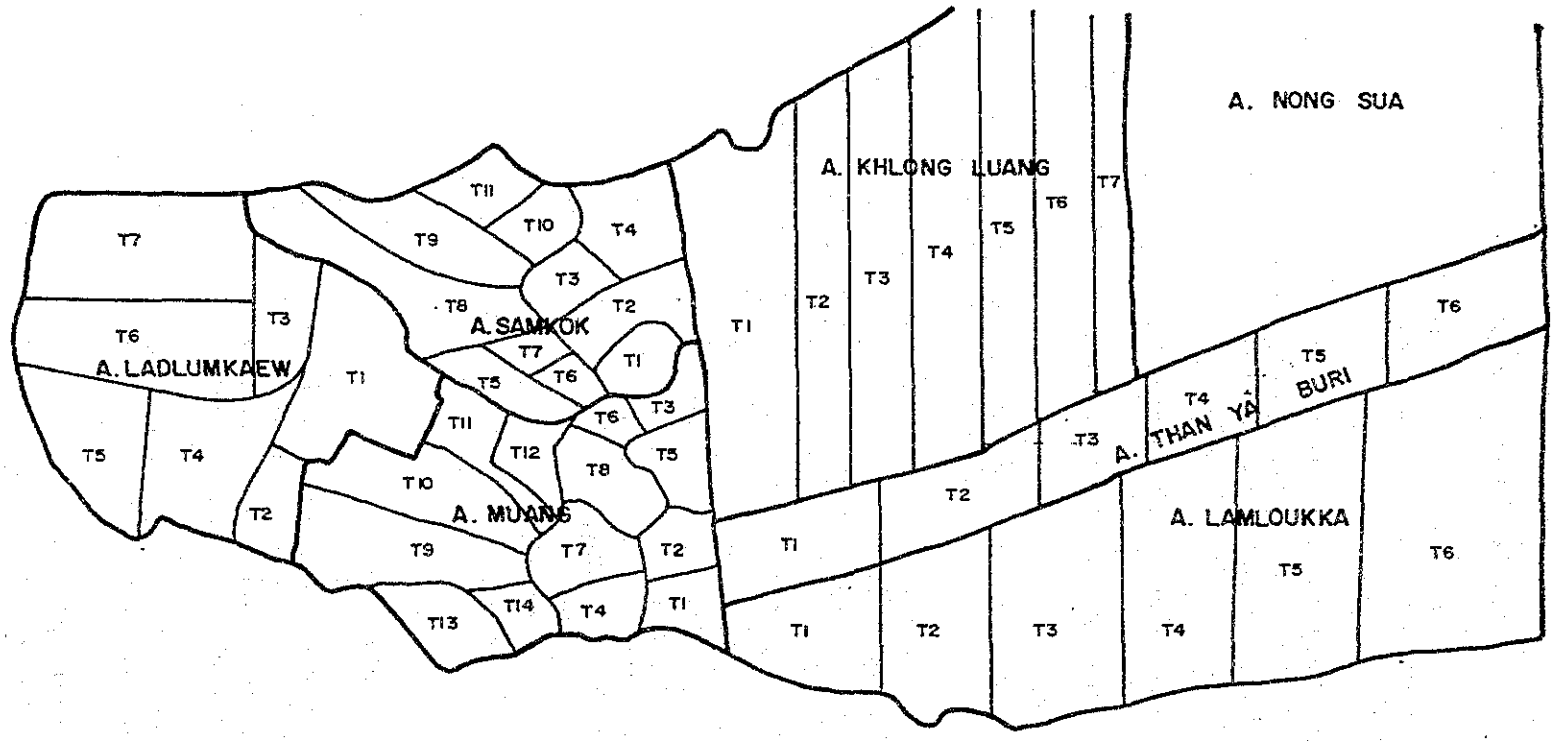


FIGURE 4-1-1
STUDY AREA

4.2.2 Future Population

Future population was firstly calculated with the following five mathematical formulae:

A)	Arithmetical progression	$y = aX + b$
B)	Geometrical progression	$y = y0 \times (1 + b)^{X}$
C)	Decreasing rate of increase	$y = K - ab^{X}$
D)	Exponential	$y = y0 + aX^{b}$
E)	Logistic	$y = k / (1 + \exp(a - bX))$

Where,

y	: Population forecasted
y0	: Population in the base year
X	: Years from the base year
a, b, K	: Coefficient

Aside from these mathematical models, annual growth rates were also considered from the socioeconomic conditions of each tambon. Therefore, mathematical models are used only for comparison.

Future population of the study area is estimated based on the following assumptions.

(1) Firstly population of each amphoe by 2001 is estimated assuming its growth rates equal to those in the last seven years.

(2) Population of the study area by 2001 is calculated by adding the amphoe population.

The sum falls between two estimated figures, one obtained from the trend since 1980 of the population of the study area, and the other from the trend in the last five years.

(3) Population of each tambon is calculated in two ways. For tambon having sanitary districts, past trend data of which is available, growth rates since 1980 are assumed. For tambon without a sanitary district, present shares among those tambons in the amphoe are assumed.

(4) Then minor modification of shares of tambon is made in an ad hoc way considering the following aspects.

Industrial location trend
Housing location trend
Expansion of universities/colleges
MWA conservation area
Outward urbanization trend of the municipality beyond the present municipality boundary
Road network

(5) The population after 2001 is assumed to grow linearly. The annual increment is assumed to be the average annual increment between 1987 and 2001 considering that high growth in recent years will change to stable growth in a long run.

(6) In case of Tambon Klong Nung of Amphoe Khlong Luang, contribution by universities/colleges and Nava Nakorn Industrial Estate is added separately.

Population of the study area in 2011 is estimated at 938,900 as presented in Table 4-2-1. The average growth rate of the area between 1987 and 2001 is 4.9% and that between 2001 and 2011 is 2.5%.

Figures 4-2-1 to 4-2-10 show the population projection by amphoe for reference. In these figures, legends "A" to "E" correspond to the formulae as mentioned above, respectively and legend "T" shows the values adopted.

Presently the average family and house sizes are estimated at approximately 5.61 and 5.55, respectively. According to the HOMES Research Report prepared in 1987 for the Seminar on Demographic and Economic Forecast for Thailand, the average household size of the nation in 2011 will be approximately 71% of the 1987 level. Following the general trend, the family and house sizes of the study area in 2011 are estimated at approximately 4.01 and 3.97, respectively as shown in Table 4-2-2.

Accordingly the number of families in the study area in 2011 is estimated at 234,200 and the number of houses at 236,700. Both figures are 3.5% times the present level.

Table 4-2-1 Population Projection of Patum Thani Province

	1980	1981	1982	1983	1984	1985	1986	1987	1991	1996	2001	2006	2011
Patum Thani Province	324468	332111	341336	357809	366767	384713	402080	415193	497450	625488	781808	889992	998149
Patum Thani Municipality	7755	10583	10898	10919	13238	12618	12856	14297	18091	18654	21625	24242	26859
Amphoe Muang except Munici	57340	56505	58192	59670	61042	63458	66697	68579	79084	99370	125060	146168	167269
T1 Lak Hok								6469	7870	10056	12848	15126	17404
T2 Bang Paon								3958	4814	6148	7852	9243	10633
T3 Bang Poud								4928	5610	6597	7757	8767	9777
T4 Ban Mai								7088	8532	10757	13562	15874	18186
T5 Suan Prick Thai								2361	2688	3160	3716	4200	4683
T6 Ban Kra Cheng								3336	3798	4466	5251	5935	6618
T7 Bang Kra Dee								5193	6385	8269	10707	12676	14645
T8 Ban Klang								5761	6558	7712	9068	10249	11430
T9 Bang Ouar								6132	7452	9510	12135	14279	16422
T10 Bang Luong								3769	4773	6413	8616	10347	12078
T11 Bang Chang								2802	3552	4777	6424	7718	9011
T12 Bang Prok(Munici.)								0	0	0	0	0	0
T13 Bang Ju Nak								7207	8634	10821	13562	15832	18101
T14 Bang Ka Yaeng								6955	8417	10684	13562	15922	18281
Amphoe Sam Kok	35761	35956	36149	36141	36363	37555	38237	38567	40152	42435	44850	47148	49441
T1 Cheing Rak Yhai								5079	5316	5628	5958	6272	6585
T2 Ban Pathum								3291	3444	3646	3860	4063	4266
T3 Banngew								3182	3330	3525	3732	3928	4124
T4 Chieng Rak Noi								1184	1239	1311	1388	1461	1533
T5 Bang Phor Nuor								1463	1531	1621	1716	1806	1896
T6 Kra Cheng								2217	2320	2456	2600	2737	2873
T7 Sam Kok								3251	3403	3602	3813	4014	4214
T8 Bangtoey								8498	8841	9290	9761	10212	10663
T9 Bang Kra Bue								1459	1527	1616	1711	1801	1891
T10 Klong Kawai								5574	5834	6176	6538	6882	7226
T11 TaiKaow								3217	3367	3564	3773	3972	4170
Amphoe Lad Lum Kaeo	29467	29636	30052	31365	31596	32874	33909	34341	36534	41244	46637	51437	56233
T1 Ku Bang Luong						5769		5904	6620	7638	8813	9852	10890
T2 Khlong Pra Audom						2665		2749	3082	3556	4103	4587	5070
T3 Ku Kwang						2925		2935	3291	3797	4381	4897	5413
T4 Lad Lum Kaeo						3579		3612	4050	4673	5391	6026	6661
T5 Nha Mai						6066		6326	7093	8184	9443	10556	11669
T6 Ra Maeng						7963		8125	8422	8809	9213	9602	9990
T7 Bor Nguon						3578		3546	3976	4587	5293	5917	6540
Amphoe Thanyaburi	52326	54506	56703	59194	62676	68795	72915	75679	93068	121065	159300	187808	217313
T1 Prachatipat S.D.	21675	22600	23741	25618	28044	29797	31912	36732	46321	61900	82718	99142	115565
T2 Bung Yi Thor	6232	5803	5742	5791	6172	9134	9870	5684	7918	12189	18623	23244	27865
T3+T4 Thanyaburi S.D.	15768	16530	17468	17913	18296	19343	20573	20919	24003	28505	33852	38471	43089
T5+T6 Samanrak S.D.	8651	9573	9752	9872	10164	10521	10560	12344	14766	18471	23107	26951	30794
Amphoe Lam Luka	50099	50923	52970	62261	64025	67118	70193	73158	92096	119475	155999	184874	213746
T1 KuKot								24771	31943	43895	60319	73015	85710
T2 Lad Sawai								5621	7306	10138	14069	17086	20103
T3 Bung Khum Proy								11024	12287	14072	16116	17935	19753
T4 Lam Luka								10706	11933	13666	15651	17417	19183
T5 Bung Thong Lang								7661	9957	13818	19175	23287	27399
T6 Lua Sai								10573	12438	15238	18668	21559	24450
T7 Bung Kor Hai								4795	6232	8648	12001	14575	17148
Amphoe Klong Luang	58260	59838	61557	63079	62952	66153	69782	72180	98894	137427	178790	193426	208058
T1 Klong Nung								30326	55181	87701	122108	130602	139095
T2 Klong Song								8837	10427	12822	15767	18242	20717
T3 Klong Sam								6654	7227	8012	8883	9679	10475
T4 Klong Si								7282	7909	8768	9721	10592	11463
T5 Klong Ha								6419	6971	7729	8569	9337	10104
T6 Klong Hok								6804	7389	8193	9083	9897	10710
T7 Klong Jaed								3490	3790	4202	4659	5077	5494
Amphoe Nung Sua	33460	34154	34815			36142	37491	38392	41531	45818	50547	54889	59230
Study Area	291008	297957	306521	322429	331892	348571	364589	376801	455919	579670	731261	835103	938919

Note : Past population data of Amphoe and Tambon have some inconsistency due to difference of data sources.

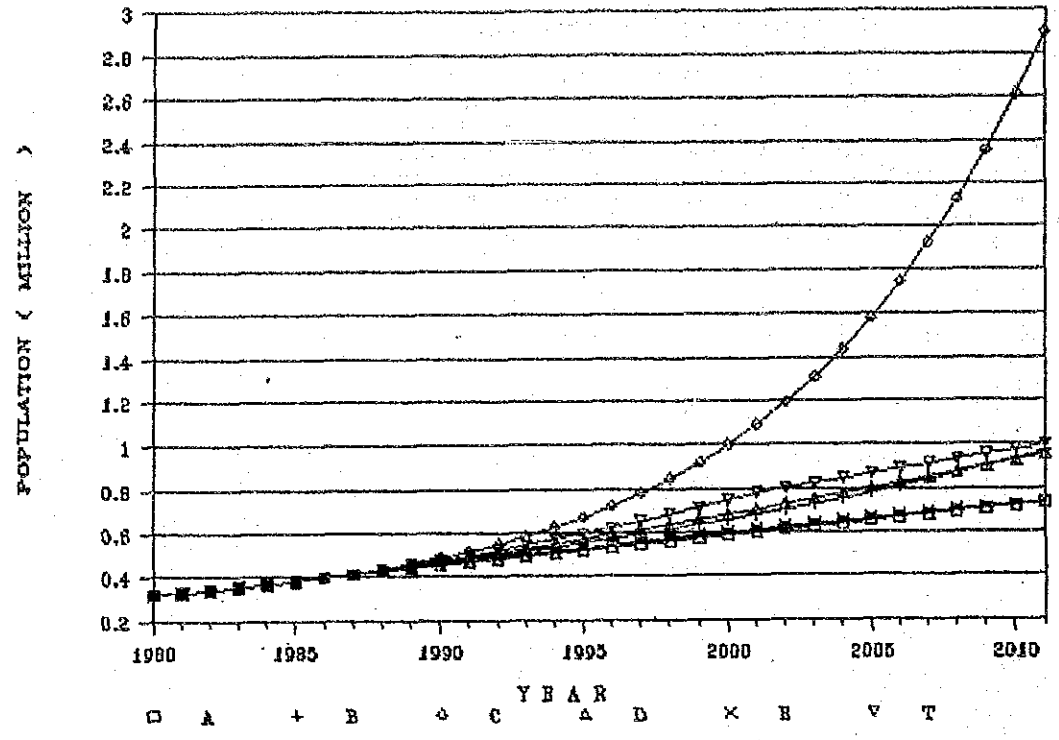


FIGURE 4-2-1

POPULATION PROJECTION OF PATUM THANI PROVINCE

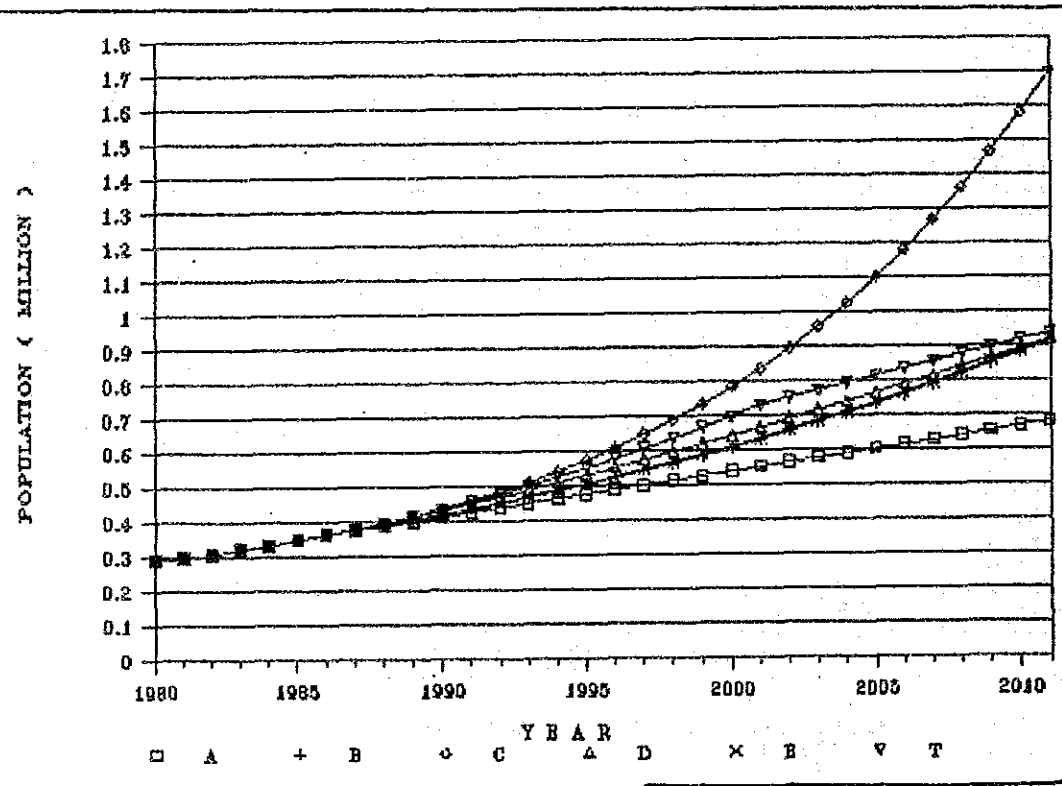


FIGURE 4-2-2

POPULATION PROJECTION OF STUDY AREA

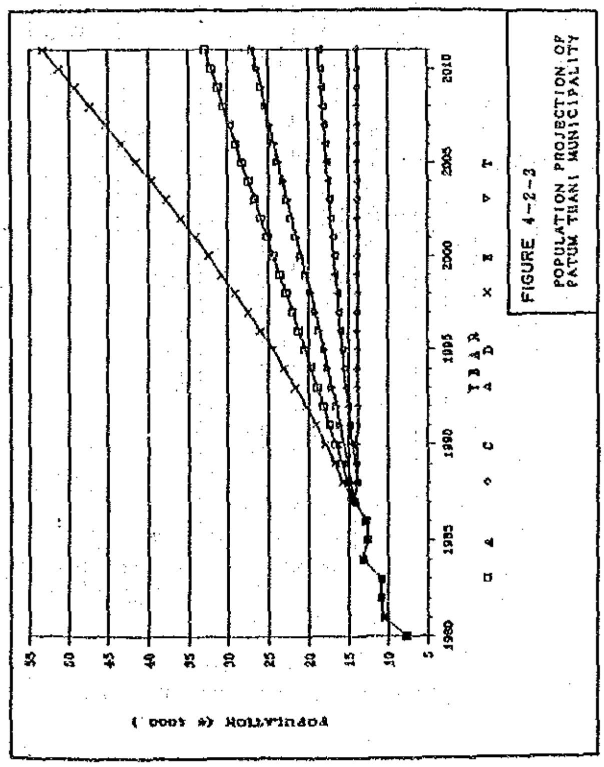


FIGURE 4-2-3
POPULATION PROJECTION OF PATUM THANI MUNICIPALITY

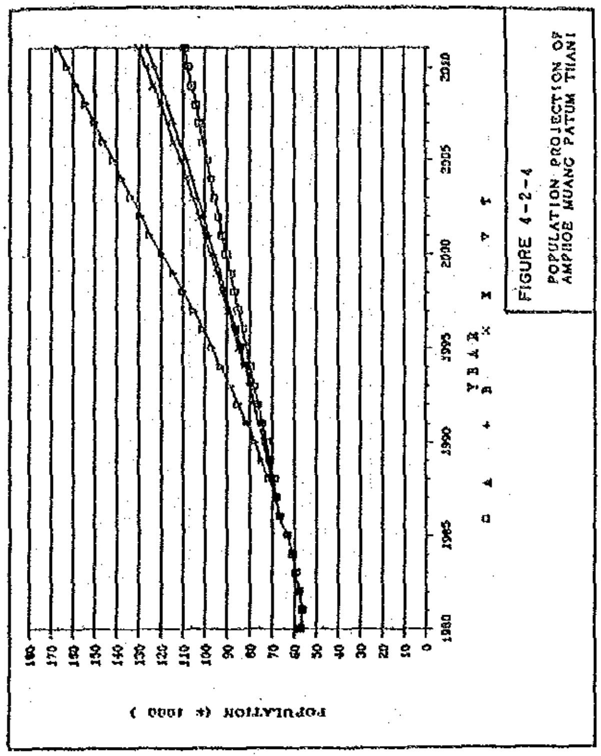


FIGURE 4-2-4
POPULATION PROJECTION OF AMPHOE MUANG PATUM THANI

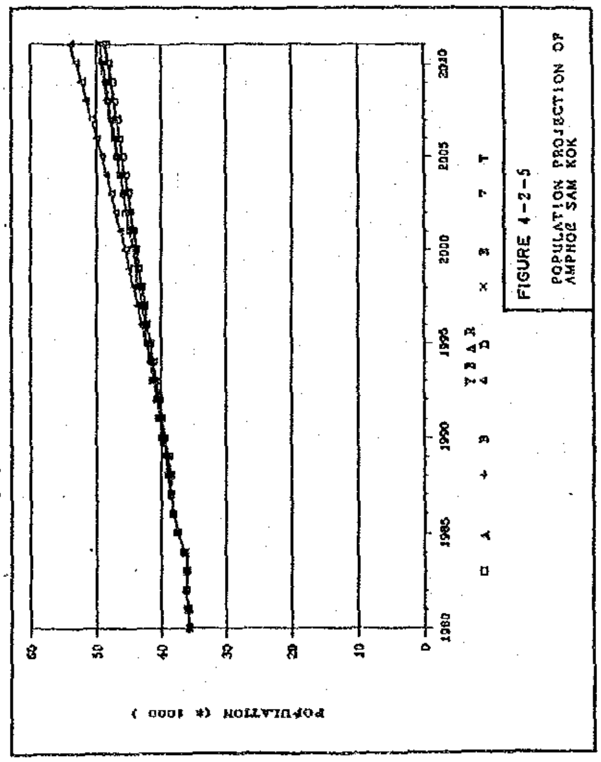


FIGURE 4-2-5
POPULATION PROJECTION OF AMPHOE SAM KOK

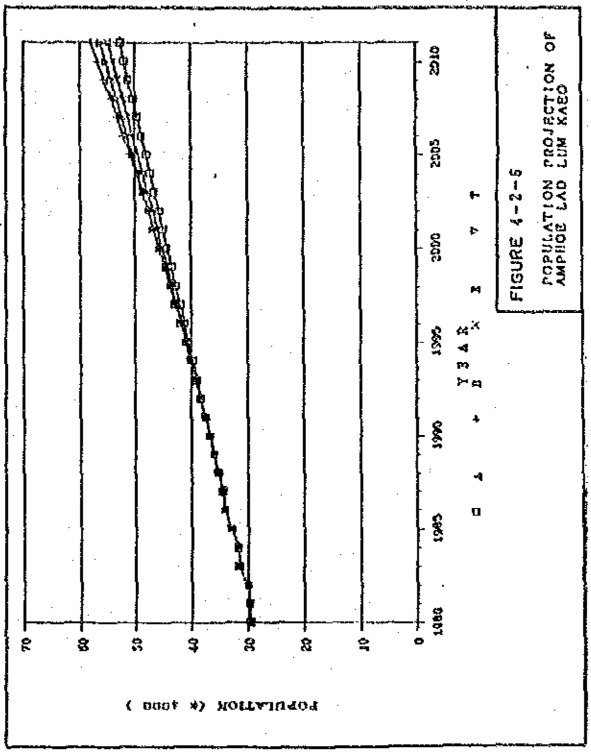


FIGURE 4-2-6
POPULATION PROJECTION OF AMPHOE LAD LUM KAEO

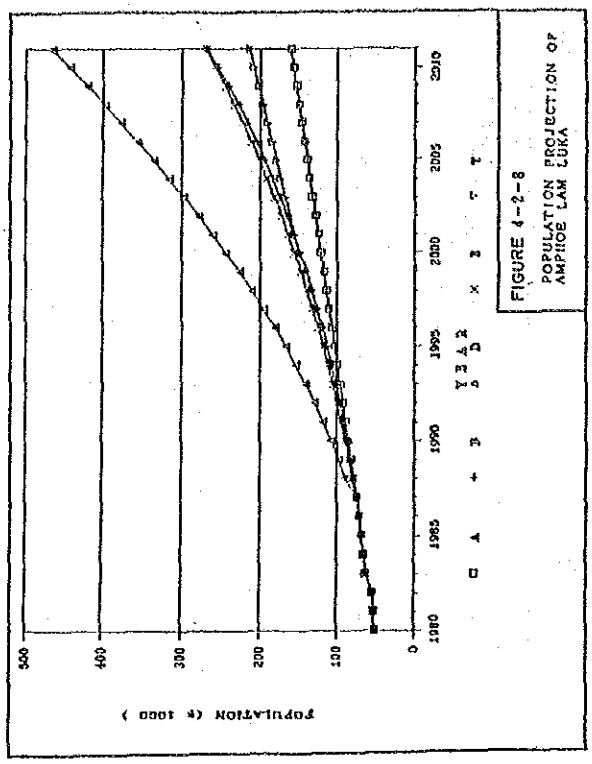


FIGURE 4-2-8
POPULATION PROJECTION OF AMPHOE LAM LUKA

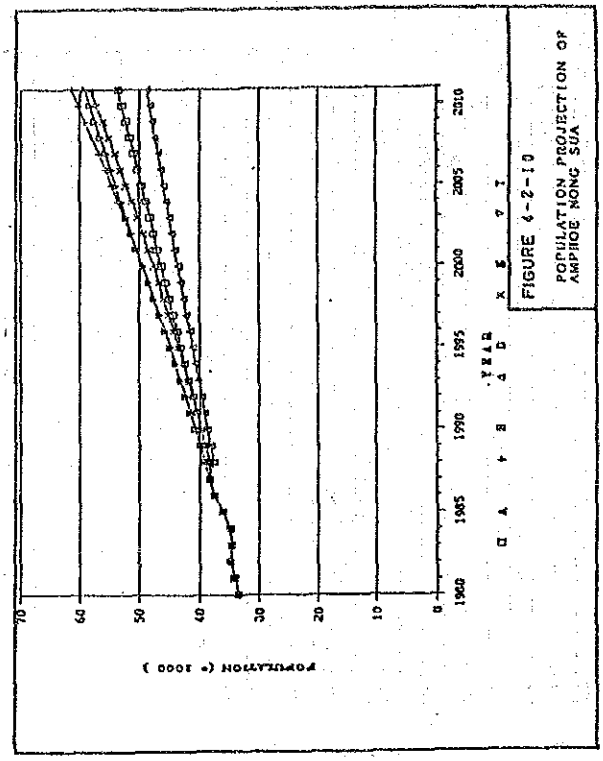


FIGURE 4-2-10
POPULATION PROJECTION OF AMPHOE NONG SUA

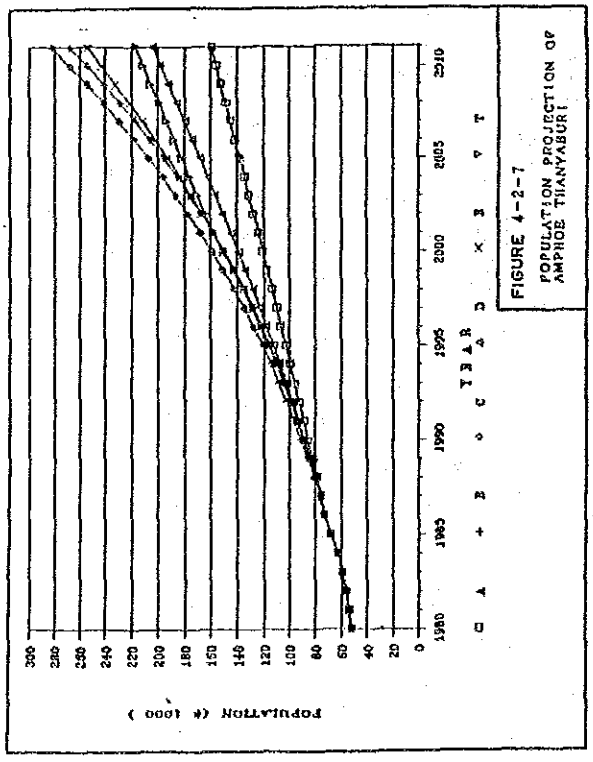


FIGURE 4-2-7
POPULATION PROJECTION OF AMPHOE THANYABURI

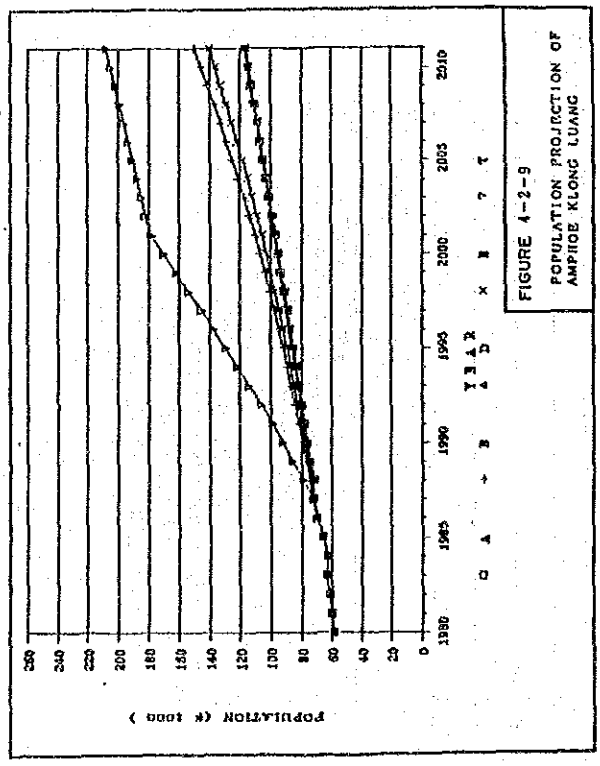


FIGURE 4-2-9
POPULATION PROJECTION OF AMPHOE KLONG LUANG

Table 4-2-2 Projection of Number of Families and Houses

Nation (HOMES Research Report, November 1987)							
Year	1985	1990	1995	2000	2005	2010	2015
Household Size	4.98	4.62	4.27	3.96	3.70	3.49	3.31
Year	1987	1991	1996	2001	2006	2011	
Household Size	4.84	4.55	4.21	3.91	3.66	3.45	
Index	1	0.94	0.87	0.81	0.76	0.71	

Patum Thani and Prachatipat						
Year	1987	1991	1996	2001	2006	2011
Population	376,801	455,919	579,670	731,274	835,103	938,919
Family Size	5.61	5.28	4.88	4.54	4.25	4.01
No. of Families	67,126	86,325	118,677	161,209	196,680	234,191
House size	5.55	5.23	4.83	4.49	4.20	3.97
No. of Houses	67,850	87,257	119,957	162,948	198,801	236,717

4.2.3 Higher and Lower Growth Cases

In order to compare effects of the assumption adopted in the method of estimation, higher and lower growth cases are shown in Table 4-2-3.

In the higher growth case, annual population growth rate of the municipality and each amphoe is 1% higher than the original case by the year 2001 and in the lower case, the growth rate is 1% lower. After the year 2001, the annual increment is changed according to the original method.

In the higher case, the population of the study area is 24% more than the original case, while in the lower case, it is 12% less.

4.2.4 Population Distribution

Population distribution in 1987 is presented in Figure 4-2-11.

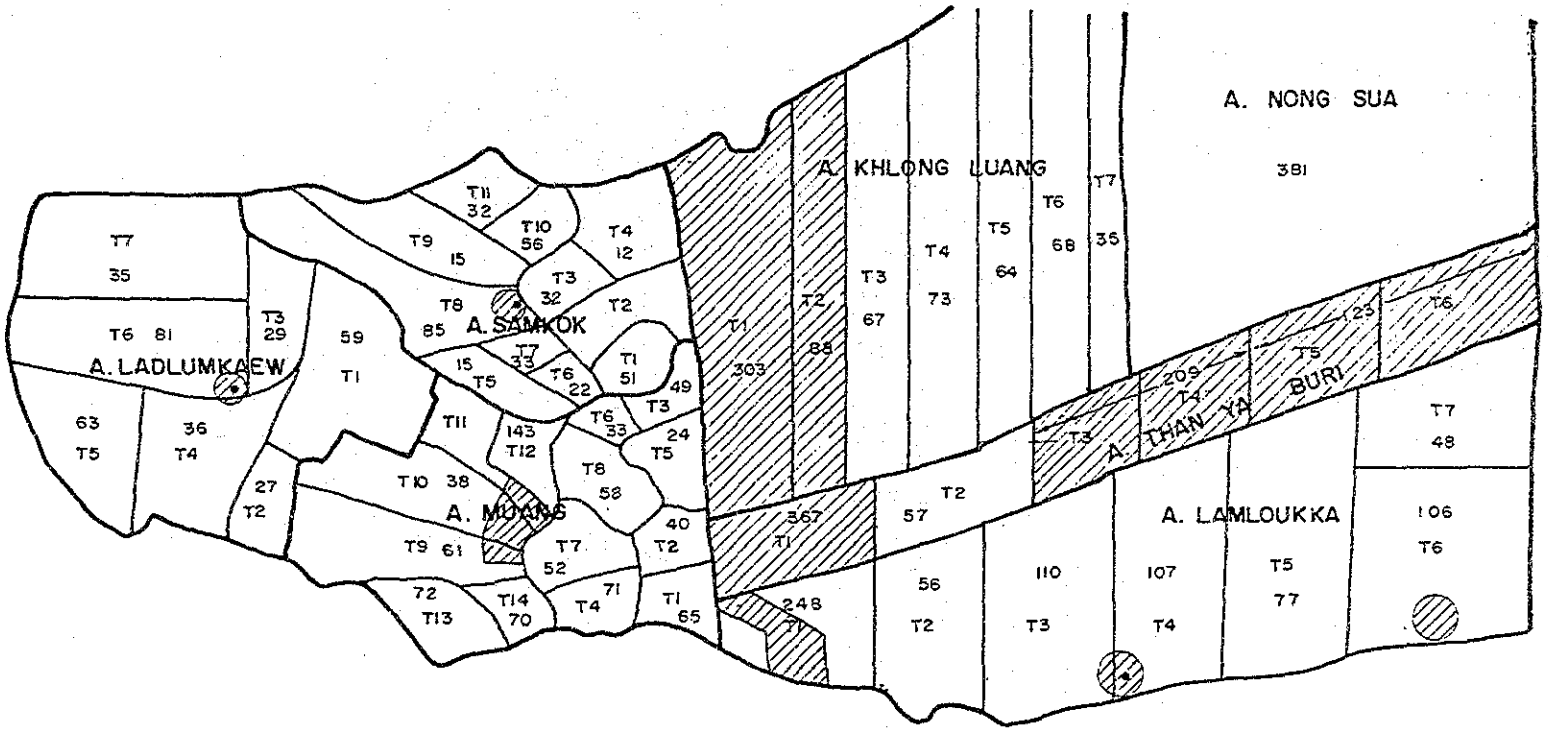
The population of Amphoe Thanyaburi accounts for 20.1% of the total population in the study area and has the largest share followed by Amphoe Lam Luka, Khlong Luang and Amphoe Muang which accounts for 22.0% together with the municipality .

Tambons with over 10,000 population are the municipality, tambons along the Phaholyothin Road, Tambons Rangsit and Lam Phak Kut of Amphoe Thanyaburi (the total population of the two tambons exceeds 20,000), and Tambons Bung Khum Proy, Lam Luka and Lum Sai of Amphoe Lam Luka.

In future, Amphoes Lam Luka, Thanyaburi, and Khlong Luang are expected to increase their shares of population in the study area as shown in Figure 4-2-12. Tambons expected to increase the shares in the study area are seen along Route 1 (Phaholyotin Road), Route 305 (Thanyaburi Road), Route 3312 (Lam Luka Road) and also in southern parts of Amphoe Muang.

Table 4-2-3 Population Projection in Higher and Lower Growth Cases

Name of Area	1987	1991	1996	2001	2006	2011
High Growth Case						
Patum Thani Province	415,193	513,799	675,029	892,979	1,063,618	1,234,253
Patum Thani Municipality	14,297	16,725	20,349	24,757	28,493	32,228
A. Muang	68,579	84,587	109,950	142,918	169,468	196,017
A. Sam Khok	38,567	41,885	46,437	51,484	56,097	60,710
A. Lat Lum Kaeo	34,341	38,968	45,639	53,451	60,276	67,101
A. Thanyaburi	75,679	97,040	132,411	180,674	218,172	255,670
A. Lam Luka	73,158	94,320	129,577	178,014	215,463	252,911
A. Khlong Luang	72,180	97,090	140,643	203,735	250,719	297,703
A. Nong Sua	38,392	43,184	50,023	57,946	64,930	71,913
Study Area	376,801	470,615	625,006	835,033	998,688	1,162,340
Low Growth Case						
Patum Thani Province	415,193	475,938	568,379	683,631	779,502	875,371
Patum Thani Municipality	14,297	15,475	17,086	18,864	20,495	22,126
A. Muang	68,579	78,346	92,535	109,293	123,834	138,374
A. Sam Khok	38,567	38,698	38,863	39,028	39,193	39,357
A. Lat Lum Kaeo	34,341	36,034	38,269	40,642	42,892	45,143
A. Thanyaburi	75,679	89,948	111,626	138,527	160,973	183,418
A. Lam Luka	73,158	87,435	109,262	136,537	159,172	181,808
A. Khlong Luang	72,180	90,076	118,809	156,707	186,895	217,083
A. Nong Sua	38,392	39,926	41,929	44,033	46,048	48,062
Study Area	376,801	436,012	526,450	639,598	733,454	827,309



UNIT : 100 PERSONS

▨ : SANITARY DISTRICTS

FIGURE 4 - 2 - 11

POPULATION DISTRIBUTION IN 1987

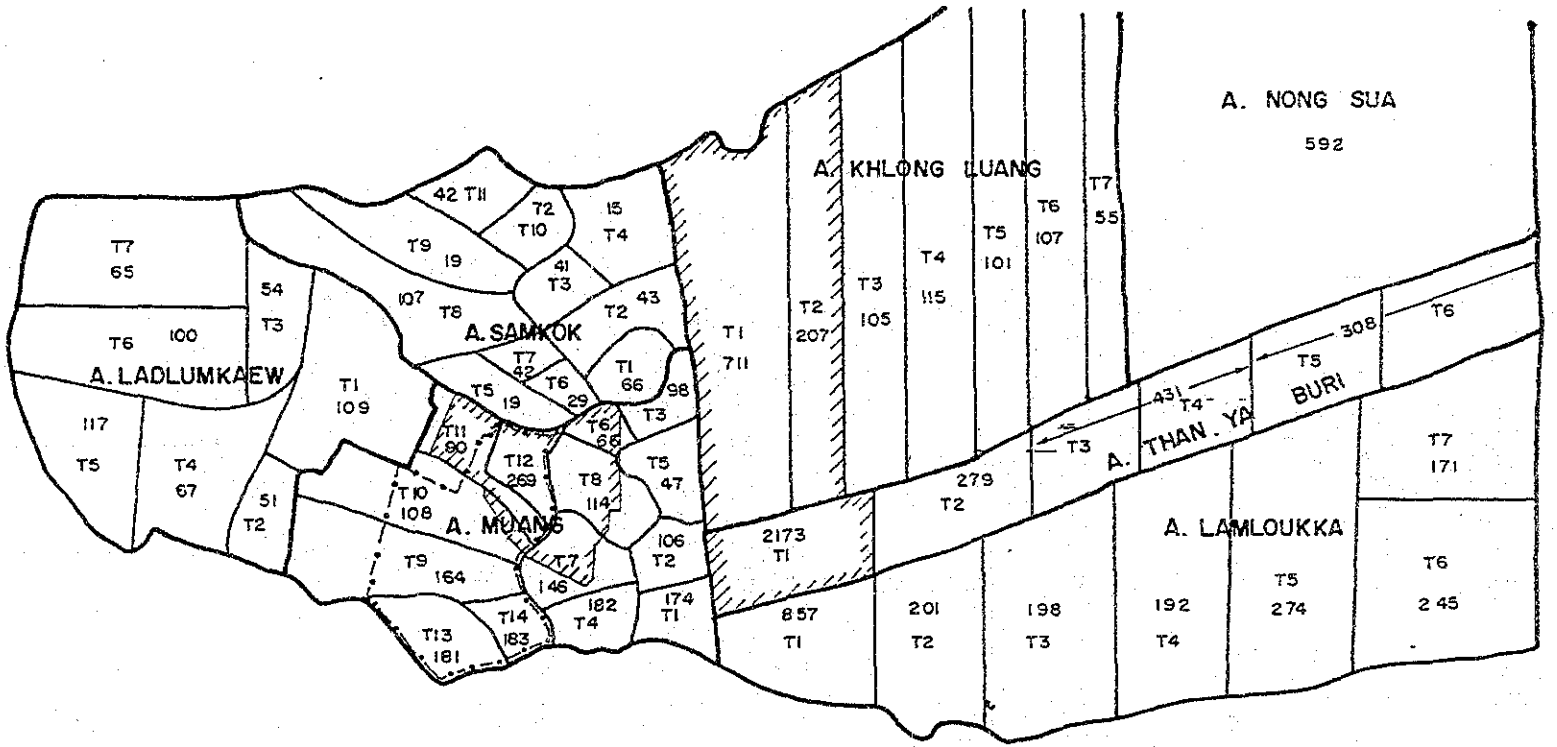


FIGURE 4-2-12
POPULATION DISTRIBUTION IN 2011

4.3 Service Area and Served Population

4.3.1 Service Area

The present service areas of Patum Thani and Prachatipat Waterworks consist of the Municipality of Patum Thani, a part of Amphoe Muang, Thanyaburi, Lam Luka and Khlong Luang with a total area of about 30 sq.km.

For the expansion of the services area in the future, taken into account are the DTCP's development plan and the PWA's development strategy. Consideration is made with future land use, population growth, industrial prospect and housing estates.

The extent of the service area in years 2001 and 2011 are proposed as shown in Figure 4-3-1 with areas of about 39 sq.km and 51 sq.km, respectively.

4.3.2 Served Population

(1) Past and Present Served Population

Past and present served population is estimated from the number of connections and the number of members per household. Prior to this, the number of connections for domestic use is calculated from the number of connections in the past, and the ratio of the connection for domestic use against the total connection. As the ratios of residential user are 0.944 and 0.963 for Patum Thani and Prachatipat, respectively (see Table 4-4-3), this ratio is applied to each year's number of connections to calculate the number of connections for domestic use.

Table 4-3-1 shows the result of estimation of served population in each year.

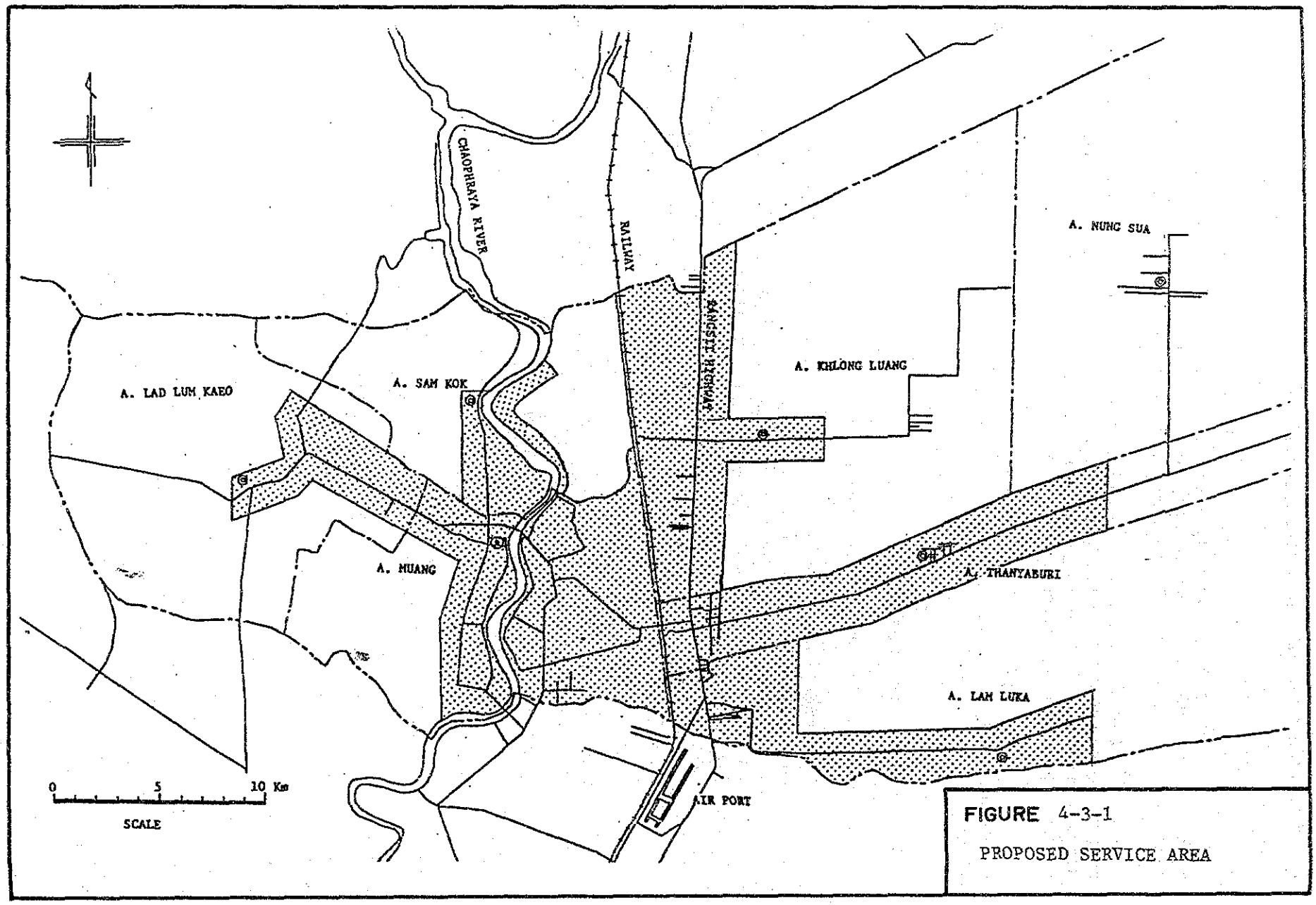


FIGURE 4-3-1

PROPOSED SERVICE AREA

Table 4-3-1 (a) Served Population in Patum Thani

Year	No. of Conn. (a)	No. of Conn. for Domestic Use (b)	Pop./ No. of Houses (c)	Population Served (d)
1980	822	776	6.02	4,672
1981	842	795	5.90	4,691
1982	954	901	5.77	5,199
1983	999	943	5.53	5,215
1984	1,060	1,001	6.19	6,196
1985	1,180	1,114	5.81	6,472
1986	1,255	1,185	5.78	6,849
1987	1,445	1,364	7.54	10,285

(b) = (a) x 0.944
(c) from Table 4-2-2 (a)

Table 4-3-1 (b) Served Population in Prachatipat

Year	No. of Conn. (a)	No. of Conn. for Domestic Use (b)	Pop./ No. of Houses (c)	Population Served (d)
1983	230	221	4.29	948
1984	1,121	1,080	3.77	4,072
1985	1,295	1,247	3.02	3,766
1986	1,516	1,460	3.20	4,672
1987	1,735	1,671	4.19	7,001

(b) = (a) x 0.963
(c) from Table 4-2-2 (b)

(2) Past and Present Service Ratio

Past and present service ratio is given as shown in Table 4-3-2.

Table 4-3-2 (a) Service Ratio in Patum Thani

Year	Total Population in Service Area	Population Served	Service Ratio (%)
1980	7,755	4,762	61.41
1981	10,583	4,691	44.33
1982	10,898	5,199	47.71
1983	11,583	5,215	45.02
1984	13,238	6,196	46.80
1985	13,123	6,472	49.32
1986	13,577	6,849	50.45
1987	13,805	10,285	74.50

Table 4-3-2 (b) Service Ratio in Prachatipat

Year	Total Population in Service Area	Population Served	Service Ratio (%)
1984	28,045	4,072	14.52
1985	29,797	3,766	12.64
1986	31,912	4,672	14.64
1987	36,732	7,001	19.06

(3) Future Service Ratio Forecasting

The future service ratio is defined by tambon since the proposed service area, consisting of 34 tambons, is rather large and varying in the level of development, population density and characteristics.

The future service ratio by tambon are scheduled considering the present service ratio, development strategy for water supply and land use plan.

In the projection of the service ratio, the definition of the areas are made as follows:

(a) High Density Area

Tambon 12 in Amphoe Muang and Tambon 1 in Thanyaburi

This area presently forms a core in the service area and has high density. This role is to be continued in the future, therefore, the service ratio should be highest in the area.

The service ratio in the target year of 2011 is 90%.

(b) Medium Density Area

Areas other than the high and low density areas

The service ratio in the target year of 2011 is 60%.

(c) Low Density Area

Tambons 1, 2, 3, 5, 6 and 7 in Amphoe Sam Khok and Tambons 1, 3 and 6 in Lad Lum Kaeo

The service ratio in the target year of 2011 is 50%.

(4) Future Served Population

Future served populations are summarized by area using the future service ratios and projected population therein as shown in Table 4-3-3. The breakdown of the served population is shown in Table 4-3-4.

Table 4-3-3 Future Served Population

Year	Population Density of Service Area				Average Service Ratio (%)
	High	Medium	Low	Total	
1991	28,183 (62,412)	12,478 (52,385)	0 (3,434)	40,661 (118,231)	34.4
1996	45.492 (80,554)	41,280 (151,128)	0 (3,635)	86,772 (235,317)	36.9
2001	69,986 (104,343)	85,340 (234,664)	976 (4,878)	156,302 (343,885)	45.5
2006	97,452 (123,384)	160,358 (351,091)	7,882 (22,522)	265,692 (496,997)	53.5
2011	128,182 (142,424)	236,073 (393,458)	12,016 (24,027)	376,271 (559,909)	67.2

Upper : Served population in the service area
Lower : Total population in the service area

Table 4-3-4 Breakdown of Population by Tambon

Amphoe & Tambon	Type of Area	1991 Pop. in Study Area	1991 Ratio (a)	1991 Pop. in Service Area	1991 Ratio (b)	1991 Served Pop.	1996 Pop. in Study Area	1996 Ratio (a)	1996 Pop. in Service Area	1996 Ratio (b)	1996 Served Pop.	2001 Pop. in Study Area	2001 Ratio (a)	2001 Pop. in Service Area	2001 Ratio (b)	2001 Served Pop.	2006 Pop. in Study Area	2006 Ratio (a)	2006 Pop. in Service Area	2006 Ratio (b)	2006 Served Pop.	2011 Pop. in Study Area	2011 Ratio (a)	2011 Pop. in Service Area	2011 Ratio (b)	2011 Served Pop.
Muang																										
T1	Med.	7870	0	0	10	0	10056	0	0	20	0	12848	0	0	25	0	15126	100	15126	40	6050	17404	100	17404	60	10442
T2	Med.	4814	0	0	10	0	6148	0	0	20	0	7852	0	0	25	0	9243	100	9243	40	3697	10633	100	10633	60	6380
T3	Med.	5610	0	0	0	0	6597	0	0	0	0	7757	0	0	25	0	8767	50	4384	40	1754	9777	50	4889	60	2933
T4	Med.	8532	0	0	0	0	10757	0	0	0	0	13562	0	0	25	0	15874	60	9524	40	3810	18186	60	10912	60	6547
T5	Med.	2688	0	0	0	0	3160	0	0	0	0	3716	0	0	25	0	4200	60	2520	40	1008	4683	60	2810	60	1686
T6	Med.	3798	0	0	0	0	4466	0	0	0	0	5251	0	0	25	0	5935	75	4451	40	1780	6618	75	4964	60	2978
T7	Med.	6386	0	0	0	0	8269	0	0	0	0	10707	0	0	25	0	12676	70	8873	40	3549	14645	70	10252	60	6151
T8	Med.	6558	0	0	0	0	7712	0	0	0	0	9068	0	0	25	0	10249	60	6149	40	2460	11430	60	6858	60	4115
T9	Med.	7452	0	0	0	0	9510	0	0	0	0	12135	60	7281	25	1820	14279	60	8567	40	3427	16422	60	9853	60	5912
T10	Med.	4773	60	2864	10	286	6413	60	3848	20	770	8616	60	5170	25	1293	10347	60	6208	40	2483	12078	60	7247	60	4348
T11	Med.	3552	60	2131	10	213	4777	60	2866	20	573	6424	60	3854	25	964	7718	60	4631	40	1852	9011	60	5407	60	3244
T12	High	16091	100	16091	60	9655	18654	100	18654	68	12685	21625	100	21625	75	16219	24242	100	24242	83	20121	26859	100	26859	90	24173
T14	Med.	8417	0	0	0	0	10684	0	0	0	0	13562	70	9493	25	2373	15922	70	11145	40	4458	18281	70	12797	60	7678
Sam Khok																										
T1	Low	5316	0	0	0	0	5628	0	0	0	0	5958	0	0	20	0	6272	50	3136	35	1098	6585	50	3293	50	1647
T2	Low	3444	0	0	0	0	3646	0	0	0	0	3860	0	0	20	0	4063	50	2032	35	711	4266	50	2133	50	1067
T3	Low	3330	0	0	0	0	3525	0	0	0	0	3732	0	0	20	0	3928	50	1964	35	687	4124	50	2062	50	1031
T5	Low	1531	0	0	0	0	1621	0	0	0	0	1716	60	1030	20	206	1806	60	1084	35	379	1896	60	1138	50	569
T6	Low	2320	60	1392	0	0	2456	60	1474	0	0	2600	60	1560	20	312	2737	60	1642	35	575	2873	60	1724	50	862
T7	Low	3403	60	2042	0	0	3602	60	2161	0	0	3813	60	2288	20	458	4014	60	2408	35	843	4214	60	2528	50	1264
T8	Med.	8841	75	6631	0	0	9290	75	6968	0	0	9761	75	7321	20	1464	10212	75	7659	35	2681	10663	75	7997	60	4798
Lad Lum Kaeo																										
T1	Low	6620	0	0	0	0	7638	0	0	0	0	8813	0	0	20	0	9852	50	4926	35	1724	10890	50	5445	50	2723
T2	Low	3291	0	0	0	0	3797	0	0	0	0	4381	0	0	20	0	4897	50	2449	35	857	5413	50	2707	50	1354
T3	Low	8422	0	0	0	0	8809	0	0	0	0	9213	0	0	20	0	9602	30	2881	35	1008	9990	30	2997	50	1499
Thanyaburi																										
T1	High	46321	100	46321	40	18528	61900	100	61900	53	32807	82718	100	82718	65	53767	99142	100	99142	78	77331	115565	100	115565	90	104009
T2	Med.	7978	0	0	0	0	12189	60	7313	10	731	18623	60	11174	25	2794	23244	60	13946	40	5578	27865	60	16719	60	10031
T3+T4	Med.	24003	70	16802	0	0	28505	70	19954	0	0	33852	70	23696	20	4739	38471	70	26930	40	10772	43089	70	30162	60	18097
Lam Lu Ka																										
T1	Med.	31943	75	23957	50	11979	43895	75	32921	53	17448	60319	75	45239	55	24881	73015	75	54761	58	31761	85710	75	64283	60	38570
T2	Med.	7306	0	0	0	0	10138	70	7097	10	710	14069	70	9848	25	2462	17086	70	11960	40	4784	20103	70	14072	60	8443
T3	Med.	12287	0	0	0	0	14072	0	0	0	0	16116	0	0	25	0	17935	70	12555	40	5022	19753	70	13827	60	8296
T4	Med.	11933	0	0	0	0	13666	0	0	0	0	15651	0	0	25	0	17417	70	12192	40	4877	19183	70	13428	60	8057
Khlong Luang																										
T1	Med.	55181	0	0	0	0	87701	80	70161	30	21048	122108	80	97686	40	39074	130602	80	104482	50	52241	139095	80	111276	60	66766
T2	Med.	10427	0	0	0	0	12822	0	0	0	0	15767	60	9460	25	2365	18242	60	10945	40	4378	20717	60	12430	60	7458
T3	Med.	7227	0	0	0	0	8012	0	0	0	0	8883	50	4442	25	1111	9679	50	4840	40	1936	10475	50	5238	60	3143
Total		347665	34.0	118231	34.4	40661	450115	52.3	235317	36.9	86772	575076	59.8	343885	45.5	156302	656794	75.7	496997	53.5	265692	738496	75.8	559909	67.2	376271
breakdown																										
High		62412		62412		28183	80554		80554		45492	104343		104343		69986	123384		123384		97452	142424		142424		128182
Med.		247576		52385		12478	328839		151128		41280	426647		234664		85340	486239		351091		160358	545821		393458		236073
Low		37677		3434		0	40722		3635		0	44086		4878		976	47171		22522		7882	50251		24027		12016

4.4 WATER DEMAND

4.4.1 Historical Water Consumption

(1) Water Production and Sales

The annual water production and sales from 1980 to 1987 are shown in Figure 4-4-1 and Table 4-4-1

Table 4-4-1 (a) Annual Water Production and Sales in Patum Thani

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. per Conn. (cu.m/d)
1980	343,110	309,498	822	1.029
1981	652,770	613,437	842	1.996
1982	765,459	416,541	954	1.196
1983	1,015,835	460,700	999	1.263
1984	982,852	472,424	1,060	1.218
1985	811,318	516,575	1,180	1.199
1986	1,071,769	530,103	1,255	1.157
1987	1,031,440	570,319	1,445	1.081

Table 4-4-1 (b) Annual Water Production and Sales in Prachatipat

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. per Conn. (cu.m/d)
1983	84,068	63,033	230	0.751
1984	614,620	396,624	1,121	0.967
1985	1,255,873	585,518	1,295	1.239
1986	1,166,847	621,016	1,516	1.122
1987	1,204,972	707,649	1,735	1.117

(2) Classification of Consumption

The PWA Annual Reports from 1985 to 1987 show the consumption by categorized major consumer as listed in Table 4-4-2. Table 4-4-3 shows the average share of each group after being regrouped into five groups for convenience of estimating the future water demand.

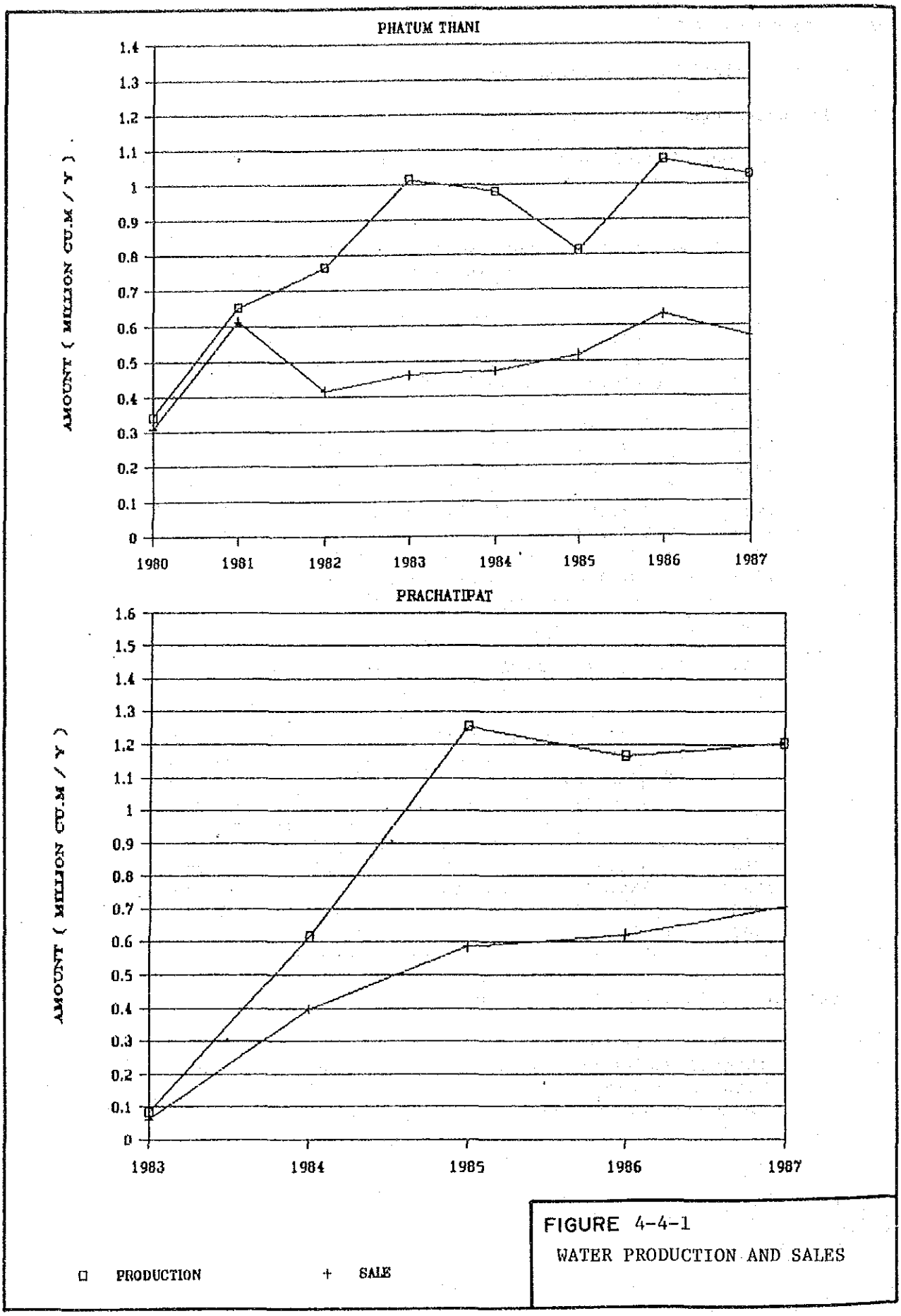


FIGURE 4-4-1
WATER PRODUCTION AND SALES

Table 4-4-2 (a) Major Consumers by Category in Patum-Thani

Code	Category	1985		1986		1987		Total		Average		Share	
		No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.
1	Residential	13	1314	14	1709	7	1357	34	4380	11.3	1460	0.87	3.22
2	Residential(Rental)	7	937	5	762	3	674	15	2373	5	791	0.38	1.74
3	Commercial	16	2439	28	3737	18	3579	62	9755	20.7	3252	1.59	7.16
4	Restaurant	12	1626	9	1273	5	1165	26	4064	8.7	1355	0.67	2.98
5	Government Agency	17	5116	14	4091	13	4814	44	14021	14.7	4674	1.13	10.29
6	School	5	2528	5	2060	5	2231	15	6819	5	2273	0.38	5.01
7	Temple	2	592	2	801	2	654	6	2047	2	682	0.15	1.5
8	Bangalow							0	0	0	0	0	0
9	Industrial	9	2073	6	1691	6	0	21	3764	7	1255	0.54	2.76
10	Hotel	2	430	3	356	2	332	7	1118	2.3	373	0.18	0.82
11	Hospital	1	0	1	0	0	0	2	0	0.7	0	0.05	0
12	Service							0	0	0	0	0	0
13	Others	4	764	3	1478	13	2477	20	4719	6.7	1573	0.51	3.46
	Sub-total	88	17819	90	17958	74	17283	252	53060	84	17687	6.45	38.95
	Percentage	7.42	39.96	7.06	40.49	5.12	38.55	6.45	38.95				
14	Other than Major Consumer	1098	26771	1185	26394	1371	30008	3654	83173	1218	27724	93.55	61.05
	Sub-total	1098	26771	1185	26394	1371	30008	3654	83173	1218	27724	93.55	61.05
	Percentage	92.58	60.04	92.94	59.51	94.88	63.45	93.55	61.05				
	Total	1186	44590	1275	44352	1445	47291	3906	136233	1302	45411		
	Percentage	100	100	100	100	100	100	100	100			100	100

Table 4-4-2 (b) Major Consumers by Category in Prachatipat

Code	Category	1985		1986		1987		Total		Average		Share	
		No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.
1	Residential	9	1569	11	2176	14	3052	34	6797	11.3	2266	0.74	4.27
2	Residential(Rental)	3	466	3	460	1	320	7	1246	2.3	415	0.15	0.78
3	Commercial	30	4687	30	5127	29	5900	89	15714	29.7	5238	1.94	9.86
4	Restaurant	8	1639	6	1291	6	1176	20	4106	6.7	1369	0.44	2.58
5	Government Agency	5	1849	2	1209	5	2031	12	5089	4	1696	0.26	3.19
6	School	1	210	3	900	1	294	5	1404	1.7	468	0.11	0.88
7	Temple	0	0	0	0	0	0	0	0	0	0	0	0
8	Bangalow	0	0	0	0	0	0	0	0	0	0	0	0
9	Industrial	6	812	7	871	6	1298	19	2981	6.3	994	0.41	1.87
10	Hotel	1	332	1	274	1	317	3	923	1	308	0.07	0.58
11	Hospital	0	0	1	261	0	0	1	261	0.3	87	0.02	0.16
12	Service	0	0	0	0	0	0	0	0	0	0	0	0
13	Others	2	357	9	1398	2	1038	13	2793	4.3	931	0.28	1.75
	Sub-total	65	11921	73	13967	65	15426	203	41314	67.7	13771	4.42	25.93
	Percentage	4.92	25.84	4.75	25.32	3.75	26.58	4.42	25.93				
14	Other than Major Consumer	1257	34205	1464	41205	1670	42604	4391	118014	1463.7	39338	95.58	74.07
	Sub-total	1257	34205	1464	41205	1670	42604	4391	118014	1463.7	39338	95.58	74.07
	Percentage	95.08	74.16	95.25	74.68	96.25	73.42	95.58	74.07				
	Total	1322	46126	1537	55172	1735	58030	4594	159328	1531.3	53109		
	Percentage	100	100	100	100	100	100	100	100			100	100

Table 4-4-3 (a) Water Consumption by Category in Patum Thani (after Re-grouping)

Code	Category	1985		1986		1987		Total		Average		Share	
		No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.
	Domestic												
1	Residential	13	1314	14	1709	7	1357	34	4380	11.3	1460	0.87	3.22
14	Other than Major Consumer	1098	26771	1185	26394	1371	30008	3654	83173	1218	27724	93.55	61.05
	Sub-total	1111	28085	1199	28103	1378	31365	3688	87553	1229.3	29184	94.42	64.27
	Institutional												
5	Government Agency	17	5116	14	4091	13	4814	44	14021	14.7	4674	1.13	10.29
6	School	5	2528	5	2060	5	2231	15	6819	5	2273	0.38	5.01
7	Temple	2	592	2	801	2	654	6	2047	2	682	0.15	1.5
11	Hospital	1	0	1	0	0	0	2	0	0.7	0	0.05	0
	Sub-total	25	8236	22	6952	20	7699	67	22887	22.3	7629	1.72	16.8
	Commercial												
3	Commercial	16	2439	28	3737	18	3579	62	9755	20.7	3252	1.59	7.16
4	Restaurant	12	1626	9	1273	5	1165	26	4064	8.7	1355	0.67	2.98
8	Bangalow							0	0	0	0	0	0
10	Hotel	2	430	3	356	2	332	7	1118	2.3	373	0.18	0.82
	Sub-total	30	4495	40	5366	25	5076	95	14937	31.7	4979	2.43	10.96
	Industrial												
9	Industrial	9	2073	6	1691	6	0	21	3764	7	1255	0.54	2.76
	Sub-total	9	2073	6	1691	6	0	21	3764	7	1255	0.54	2.76
	Others												
2	Residential(Rental)	7	937	5	762	3	674	15	2373	5	791	0.38	1.74
12	Service							0	0	0	0	0	0
13	Others	4	764	3	1478	13	2477	20	4719	6.7	1573	0.51	3.46
	Sub-total	11	1701	8	2240	16	3151	35	7092	11.7	2364	0.9	5.21
	Total	1186	44590	1275	44352	1445	47291	3906	136233	1302	45411	100.01	100

Table 4-4-3 (b) Water Consumption by Category in Prachatipat (after Re-grouping)

Code	Category	1985		1986		1987		Total		Average		Share	
		No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.	No. of Conn.	Consump.
	Domestic												
1	Residential	9	1569	11	2176	14	3052	34	6797	11.3	2266	0.74	4.27
14	Other than Major Consumer	1257	34205	1464	41205	1670	42604	4391	118014	1463.7	39338	95.58	74.07
	Sub-total	1266	35774	1475	43381	1684	45656	4425	124811	1475	41604	96.32	78.34
	Institutional												
5	Government Agency	5	1849	2	1209	5	2031	12	5089	4	1696	0.26	3.19
6	School	1	210	3	900	1	294	5	1404	1.7	468	0.11	0.88
7	Temple	0	0	0	0	0	0	0	0	0	0	0	0
11	Hospital	0	0	1	261	0	0	1	261	0.3	87	0.02	0.16
	Sub-total	6	2059	6	2370	6	2325	18	6754	6	2251	0.39	4.24
	Commercial												
3	Commercial	30	4687	30	5127	29	5900	89	15714	29.7	5238	1.94	9.86
4	Restaurant	8	1639	6	1291	6	1176	20	4106	6.7	1369	0.44	2.58
8	Bangalow	0	0	0	0	0	0	0	0	0	0	0	0
10	Hotel	1	332	1	274	1	317	3	923	1	308	0.07	0.58
	Sub-total	39	6658	37	6692	36	7393	112	20743	37.3	6914	2.44	13.02
	Industrial												
9	Industrial	6	812	7	871	6	1298	19	2981	6.3	994	0.41	1.87
	Sub-total	6	812	7	871	6	1298	19	2981	6.3	994	0.41	1.87
	Others												
2	Residential(Rental)	3	466	3	460	1	320	7	1246	2.3	415	0.15	0.78
12	Service	0	0	0	0	0	0	0	0	0	0	0	0
13	Others	2	357	9	1398	2	1038	13	2793	4.3	931	0.28	1.75
	Sub-total	5	823	12	1858	3	1358	20	4039	6.7	1346	0.44	2.54
	Total	1322	46126	1537	55172	1735	58030	4594	159328	1531.3	53109	100	100.01

4.4.2 Future water consumption

The five categories of consumption listed in Table 4-4-3 are forecasted separately for future as they are different in nature.

(1) Domestic Water Consumption

Table 4-4-3 shows that the domestic water consumption in Patum Thani and Prachatipat are accounted to be 64.3% and 78.3% of the total on average in 1985 to 1987, respectively. Assuming that this ratio has been constant from 1980 to 1987, the domestic water consumption is calculated as shown in Table 4-4-4.

Table 4-4-4 (a) Domestic Water Consumption
Patum Thani

Year	Water Sales			Pop. Served	Per Capita Consump.
	Total (cu.m/y) (a)	Total (cu.m/y) (b)	Domestic (cu.m/d) (c)	(d)	(lpcd) (e)
1980	309,498	846	544	4,672	116
1981	613,437	1,681	1,081	4,691	230
1982	416,541	1,141	734	5,199	141
1983	460,700	1,262	811	5,215	156
1984	472,424	1,291	830	6,196	134
1985	516,575	1,415	910	6,472	141
1986	530,103	1,452	934	6,849	136
1987	570,319	1,563	1,005	10,285	98

(c) = (b) x 0.643

Table 4-4-4 (b) Domestic Water Consumption
Prachatipat

Year	Water Sales			Pop. Served	Per Capita Consump.
	Total (cu.m/y) (a)	Total (cu.m/y) (b)	Domestic (cu.m/d) (c)	(d)	(lpcd) (e)
1983	63,033	173	135	948	142
1984	396,624	1,084	849	4,072	208
1985	585,518	1,604	1,256	3,766	334
1986	621,016	1,701	1,332	4,672	285
1987	707,649	1,939	1,518	7,001	217

(c) = (b) x 0.783

The estimated per capita consumption for 1991 is 170 lpcd in the high density area. Considering the socioeconomic feature of Patum Thani Province, Master Plan of MWA for Bangkok Metropolis, and living standard of people, an arithmetical progression curve which comes up to 230 lpcd in 2011 is selected.

For the medium and low density areas the per capita consumption is assumed to be 100 and 80 lpcd, respectively, in 1991. These figures

are assumed to then increase as shown below:

Table 4-4-5 Future Unit Water Consumption

(Unit : lpcd)

Year	High Density Area	Medium Density Area	Low Density Area
1991	170	100	80
1996	185	120	95
2001	200	140	110
2006	215	160	125
2011	230	180	140

Table 4-4-6 shows the domestic water consumption in every five years to 2011.

Table 4-4-6 Domestic Water Consumption

(Unit : cu.m/d)

	Area Category by Population Density			Total
Year	High	Medium	Low	
1991	8,724	-	-	8,724
1996	19,140	-	-	19,140
2001	36,266	5,905	2,011	44,182
2006	56,363	13,166	4,443	73,972
2011	80,816	23,756	7,818	112,390

(2) Governmental/Institutional Water Consumption

The governmental/institutional water consumption includes the consumption of such institutions as governmental offices, hospitals, schools and temples.

Water consumption of each institution is predicted separately as they are different in nature.

(a) Governmental Offices

It is assumed that the activities of governmental facilities correlate the population in the service area where these facilities are governing. For example, the staff of the police department will increase as the population grows up.

Considering this concept, the future water consumption of the governmental facilities is predicted from the ratio to the population in the service area of each year. Present data gives the following figures for the water consumption of governmental offices.

	Patum Thani	Prachatipat
Average consump. (cu.m/mo) (1985-1987)	4,674	1,696
Population in the service area (1987)	13,805	36,732
Average daily consump. (lpcd)	11.3	1.5

Larger amount of Patum Thani is derived from the fact that Patum Thani is the capital of the province and has more number of governmental offices than in Prachatipat.

The unit consumption per population in the future is assumed to be 5 lpcd and constant.

(b) School

Prediction of water consumption of schools is made by assuming the number of students from the proportion of that against the population in the service area.

Table 4-4-7 Share of Students

Amphoe	Population (a)	No. of Students (b)	Share (%) (c)
Patum Thani Mun.	14,297	18,817	
Muang Patum Thani*	68,579	24,075	35.1
Sam Khok	38,567	4,882	12.7
Lam Luka	73,158	15,008	20.5
Lad Lum Kaeo	34,341	5,529	16.1
Total/Average	214,645	49,494	23.0

(a) from Table 4-2-2
(b) from Tables 1-2-2 to 1-2-7
* Excluding the Patum Thani Municipality

As shown in Table 4-4-7, the number of students shares 23.0% in the total population in Patum Thani Province in 1987. This high rate of students is expected to continue in the future in consideration of the population structure by age group in 1988. Therefore, the ratio of the number of students to the total population is assumed at 20%.

The average number of students per school in Amphoes Muang, Lad Lum Kaeo and Lam Luka is 398 persons, while the average consumption per school from 1985 to 1987 is 13.705 cu.m/d. The average water consumption per student is accordingly given as follows:

13.705 / 398 = 34.4 lpcd

Considering this value, the future unit consumption is set to be 20 lpcd and constant through years.

(c) Hospital

Major consumer data contains no hospital in Patum Thani and Prachatipat.

Regarding the statistical data of the number of beds against the total population, the "Population and Health" report of TDRI shows the following historical data with predictions in 1991 and 2006.

Table 4-4-8 Ratio of Population to Hospital Bed

(Unit : pop./bed)

Year	Whole Kingdom	BMA	Provincial Area
1980	805.85	341.48	955.66
1981	801.35	361.22	952.75
1982	793.46	365.63	934.51
1983	761	376	888
1984	749	354	879
1985	748	336	882
1986	744	354	862
1991			(700)
2006			(600)

It is difficult to identify the actual consumption of hospitals because of their use of deep well water, the amount of which are not recorded. Assuming a unit water consumption per bed to be 1.5 cu.m/d/bed until 2011, the total consumption of hospitals is calculated as follows:

Table 4-4-9 Prediction of Number of Beds

Year	Population in Service Area	Population per Bed	No. of Beds
1991	118,231	345	343
1996	235,317	345	682
2001	343,885	345	997
2006	496,997	345	1,441
2011	559,909	345	1,623

(d) Summary of Governmental/Institutional Consumption

Total of governmental/institutional consumption are summarized as shown in Table 4-4-10.

Table 4-4-10 Summary of Governmental/Institutional Consumption

	1991	1996	2001	2006	2011
1. Government					
o per pop. consump. (lpcd)	5	5	5	5	5
o population in service area	118,231	235,317	343,885	496,997	559,909
o consump. (cu.m/d)	591	1,177	1,719	3,485	2,800
2. School					
o per student consump. (lpcd)	20	20	20	20	20
o No. of students*	23,646	47,063	68,777	99,399	111,982
o consump. (cu.m/d)	473	941	1,376	1,988	2,240
3. Hospital					
o per bed consump. (cu.m/d/bed)	1.5	1.5	1.5	1.5	1.5
o No. of beds**	343	682	997	1,441	1,623
o consump. (cu.m/d)	515	1,023	1,496	2,162	2,435
Total Consump. (cu.m/d)	1,579	3,141	4,591	6,635	7,475

* 20% of population in the service area
** (Population in the service area)/(345 pop./bed)

(3) Commercial Water Consumption

Commercial water consumption is defined to be the consumption of private businesses such as shops, restaurants, bars, and markets. The consumption for commercial use is assumed to be related to the population in the service area with a constant unit consumption of 10 lpcd.

Table 4-4-11 Commercial Water Consumption

Year	1991	1996	2001	2006	2011
Population in Service Area	118,231	235,317	343,885	496,997	559,909
Per Capita Consump. (lpcd)	10	10	10	10	10
Consump. (cu.m/d)	1,182	2,353	3,439	4,970	5,599

(4) University/College

Universities/colleges are known as one of big consumers of water, especially in case that those have scientific, engineering and medical faculties. The questionnaire survey was conducted to six universities/colleges in Patum Thani Province. The results are shown in Table 4-4-11. The total number of students/teachers/staff is approximately 21,600 persons at present and is expected to double to 42,800 persons in 2001, though some universities give the near future figures only (at Thammasat in 1994 and Rangsit in 1992, respectively).

The water consumption is approximately 4,500 cu.m/d at present and will be over 6,900 cu.m/d in 2011. In consideration of the fact that some universities cannot give the future water demand as mentioned above, the water consumption in those educational/institutional facilities is assumed at 10,000 cu.m/d in 2011 and is allocated to each university/college in proportion to the total number of students/teachers/staff.

Table 4-4-12 University/College

University	No. of Students (pers.)	No. of Teachers (pers.)	No. of Staff (pers.)	Total (pers.)	Comsump. (cu.m/d)
AIT					
Present	700	150	600	1,450	1,550
Future	850	175	700	1,725	2,440
Thammasat					
Present	4,883	189	80	5,152	1,600
Future	6,593	846	4,988	12,427	3,500
Bangkok					
Present	6,580	200	90	6,870	600
Future	10,000	400	150	10,550	
Teachers					
Present	4,200	201	70	4,471	500
Future	5,500	300	100	5,900	1,000
Rangsit					
Present	2,700	191	225	3,116	200
Future	10,000	700	300	11,000	
Agricultural					
Present	431	68	49	548	50
Future	1,000	100	100	1,200	
Total					
Present	19,494	999	1,114	21,607	4,500
Future	33,943	2,521	6,338	42,802	6,900

(5) Industrial Water Consumption

(a) Existing Factories

Most of factories in the area are using groundwater from their own deep well. Although factories which are supplied water from PWA are recorded six and twenty two in Patum Thani and Prachatipat, respectively, the water consumption of these factories are too small to represent the industrial water consumption pattern in this area.

According to the data on industrial wastewater in the Rangsit Area surveyed by the Ministry of Industry, 31 factories outside the Nava Nakorn Industrial Estate presently discharge wastewater with an amount of 30,413 cu.m/d as indicated in Appendix A-4-5. It is assumed that the water consumption in these factories is equal to the amount of wastewater and has no change up to 2011.

(b) Nava Nakorn Industrial Estate

The Nava Nakorn Industrial Estate has a total area of 960 ha (6,000 rai) and has been developed by Nava Nakorn Co., Ltd. 35% of the whole area is allocated to housing and commercial zones in accordance with the BOI regulations, therefore remaining 65% or 624 ha is available for industrial purpose.

As shown in Appendix A-4-6, data regarding the water consumption, type of industry, number of employees, and factory land area in the estate were collected through Nava Nakorn Co., Ltd. Water consumption at the present 70 factories in the estate is approximately 6,000 cu.m/d. The Water demand is calculated as follows:

624 x 30 = 18,720 cu.m/d

Nava Nakorn Co., Ltd has a plan to expand its area, the scale of which is expected to be about a quarter the existing area. The water demand in this expansion area is calculated with the same unit consumption as follows:

624 x 1/4 x 30 = 4,680 cu.m/d.

(c) Bangkadi Industrial Park (BIP)

BIP has been developed by Bangkadi Industrial Park Co., ltd. with a total area of 180.4 ha (1,127.4 rai) near the boundary with Bangkok Metropolis west of Prachatipat. the available area for industrial purpose is also 65% of the whole area or 93.6 ha. the water demand is estimated as follows:

93.6 x 30 = 2,808 cu.m/d

(d) Bangkadi Area

The area is located west of BIP along the Chao Phraya River and designated the industrial area by DTCP. The available area for industrial use is 145 ha in consideration of the BOI regulation. The water demand is calculated as follows:

145 x 30 = 4,350 cu.m/d

(e) Ransit Area

The area is located between the Phaholyothin Rd. and the railway and designated the industrial zone by DTCP. 104 ha is available for industrial purpose. The water demand is estimated as follows:

104 x 30 = 4.160 cu.m/d

(f) Others

Other industrial water consumption by factories to be constructed in the future is predicted by surveying the vacant area available for industrial use along the major roads excluding those included in the above.

Table 4-4-13 Available Land Area for Factories

Name of Road	Length of Road (km)	Available Length of Road (km)	Effective Length of Road (km)	Land Area for Factory (ha)	Remarks
R1-E	21.5	0	0	0	Ransit HW
R1-W	21.5	0	0	0	
R305-S	20.0	0	0	0	Tanyaburi
R305-N	20.0	4.0	1.00	50.0	
R306-E	6.0	0	0	0	BKK-Muang
R306-W	6.0	0	0	0	
R307-E	9.5	1.0	0.25	12.5	BKK-Muang
R307-W	9.5	1.0	0.25	12.5	
R3015-S	11.5	0	0	0	Lam Luka
R3015-N	11.5	0	0	0	
R31-E	1.7	0	0	0	Phaholyothin
R31-W	1.7	0	0	0	
R3100-S	6.8	1.0	0.25	12.5	R306-R346
R3100-N	6.8	1.0	0.25	12.5	
R3111-E	6.0	1.0	0.25	12.5	Muang-
R3111-W	6.0	2.0	0.50	25.0	Sam Khok
R3112-S	13.5	4.0	1.00	50.0	Muang-
R3112-W	13.5	4.0	1.00	50.0	Lad Lum Kaeo
R3214-S	7.9	1.0	0.25	12.5	Khlong Luang
R3214-N	7.9	1.0	0.25	12.5	
R346-S	12.8	2.0	0.50	25.0	Ransit-
R346-W	12.8	1.0	0.25	12.5	Muang
Total	234.4	24.0	6.00	300.0	

In Table 4-4-13, the effective length of a factory facing the road is assumed to be a quarter the available length and the depth of a factory is 500 m.

Unit consumption per land area : 30 cu.m/ha/d
Land available for factories : 300 ha
Water demand : 30 x 300 = 9,000 cu.m/d

Table 4-4-14 shows the summary of the industrial water consumption.

Table 4-4-14 Industrial Water Consumption

(Unit: cu.m/d)

Category	1991	1996	2001	2006	2011
Nava Nakorn (Present)	0	18,720	18,720	18,720	18,720
Nava Nakorn (Future)	0	4,680	4,680	4,680	4,680
Existing	0	6,083	21,289	30,413	30,413
BIP & Bang Krabi	0	435	4,331	6,070	7,157
Rangsit	0	416	1,456	3,120	4,160
Others	0	900	3,150	6,750	9,000
Total	0	31,234	53,626	69,753	74,130

(5) Others

Other water consumption is counted from the percentage to the total of the domestic and institutional consumption of each year. The percentages of this category in the PWA's statistics from 1985 to 1987 are 6.4% and 3.1% for Patum Thani and Prachatipat, respectively, and 4.6% on an average.

For the future prediction of water consumption, 4.6% of the total of domestic and institutional consumption is used.

Table 4-4-15 Other Water Consumption

(Unit: cu.m/d)

Year	Domestic (a)	Institutional (b)	Total (c)	Others (d)
1991	6,319	1,579	7,898	363
1996	14,205	3,141	17,346	798
2001	26,529	4,591	31,120	1,432
2006	47,595	6,635	54,230	2.495
2011	73,657	7,457	81,132	3,732

(d) = (c) x 0.046

(6) Unaccounted-for Water Ratio

Historical unaccounted-for water ratios of Patum Thani and Prachatipat Waterworks are shown in Table 4-4-16.

Table 4-4-16 (a) Unaccounted-for Water Ratio in Patum Thani

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	Unaccounted-for Water Ratio (%)
1980	343,110	309,498	9.80
1981	652,770	613,437	6.03
1982	765,459	416,541	45.58
1983	1,015,835	460,700	54.65
1984	982,852	472,424	51.93
1985	811,318	516,575	36.33
1986	1,071,769	530,103	49.46
1987	1,031,440	570,319	44.71

Table 4-4-16 (b) Unaccounted-for Water Ratio in Prachatipat

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	Unaccounted-for Water Ratio (%)
1983	84,068	63,033	25.02
1984	614,620	396,624	35.47
1985	1,255,873	585,518	53.38
1986	1,166,847	621,016	46.78
1987	1,204,972	707,649	41.27

This ratio is supposed to be improved lower by implementing the daily maintenance works such as replacement of old pipes, leakage detection and replacement of water meters with more sensitive and anti-reverse rotation type.

PWA set a target of reducing the unaccounted-for water as one of measures for cost recovery at 25% and 20% in 1995 and 2010, respectively. Implementing program of leakage control is presently ongoing at various waterworks under PWA.

The said target is adopted for the existing service area with intermittent figures and a constant ratio of 20% is applied to the area to be newly developed due to good installation of new pipes and use of good pipe materials as shown in Table 4-4-17.

Table 4-4-17 Future Unaccounted-for Water Ratio

(Unit : %)

Year	Zones 1 & 7	Other Zones
1991	26	20
1996	25	20
2001	23	20
2006	21	20
2011	20	20

Note : Refer to Section 8.1 regarding the zone.

4.4.3 Future Water Demand

(1) Peak Factor

The number of connections rose by 20.9% to 1,747 in Patum Thani and by 189.4% to 5,021 in Prachatipat, respectively at the end of September 1988. In such situations it is difficult to identify the typical daily fluctuation of water supply from the daily records due to the influence by the increase in the number of connections. According to the study in MWA, the peak factors for daily and hourly maximum demand are 1.20 and 1.50 to daily average demand, respectively.

In general, the fluctuation in water supply tends to be alleviated by enlarging the scale of water supply. The scale of a integrated water supply in Patum Thani and Prachatipat is not so big as Bangkok Metropolis, but it also has the tendency to alleviate the fluctuation in water supply due to the big share of industrial water demand. Provided that the peak factors are 1.0 for industrial use and 1.30 for those other than industrial use, a weighted average peak factor is 1.17 based on each water demand.

Accordingly, a value of 1.20 is adopted as the peak factor for daily maximum water demand estimation.

(2) Future Water Demand

Future water demand is calculated from the water consumption, unaccounted-for water ratio, and peak factors.

Table 4-4-18 shows the daily average and maximum water demands.

Table 4-4-18 Daily Average Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic	2,560	6,319	14,205	26,529	47,595	73,657
Gov't/Inst'l	338	1,578	3,141	4,590	6,634	7,474
Commercial	505	1,182	2,353	3,439	4,970	5,599
University/College	0	0	3,547	4,289	8,627	10,000
Industrial	0	0	28,100	39,851	69,753	74,130
Others	156	363	798	1,431	2,495	3,732
Sub-Total	**3,559**	**9,443**	**52,144**	**80,129**	**140,073**	**174,592**
Breakdown to Zone						
Zone 1		5,923	13,418	26,494	39,511	50,334
Zone 2		0	31,218	38,282	44,135	49,383
Zone 3		285	1,211	2,486	4,594	7,799
Zone 4		610	1,137	2,084	5,390	8,481
Zone 5		0	0	0	9,808	10,822
Zone 6		0	0	0	17,787	23,239
Zone 7		2,626	5,159	10,784	15,967	20,518
Zone 8		0	0	0	2,880	4,015
Zones 1 & 7		8,549	18,577	37,278	55,478	70,852
Other Zones		895	33,566	42,852	84,594	103,739
Unaccounted-for Water Ratio						
For Zones 1 & 7	43	26	25	23	21	20
For Other Zones	20	20	20	20	20	20
Unaccounted-for Water	2,685	3,227	14,584	21,848	35,896	43,648
Daily Average	**6,244**	**12,670**	**66,728**	**101,977**	**175,969**	**218,240**
Peak Factor		1.20	1.20	1.20	1.20	1.20
Daily Maximum		**15,204**	**80,074**	**122,372**	**211,163**	**261,888**

Note : Refer to Section 8.1 regarding the zone.

5. DESIGN CRITERIA

5.1 Raw Water Intake

Raw water intake capacity : 110 % of daily maximum demand

5.2 Treatment and Pipe Design

Design criteria for the design of the treatment system and pipeline was established on the basis of the various design standards having been employed in Thailand or other countries, and with consideration on the conditions of the project site and raw water quality to be taken from the Chaophraya River.

The design criteria is summarized in the followings:

(1) Water Loss

Intake Loss : 10 %

Treatment Loss : 8 % of production capacity for filter washing and in-plant use

(2) Pipeline

Formula for Flow Rate Calculation :

Hazen-William's Formula, C = 110

C-value for pipes are usually defined as 130 for new pipes. For planning purpose, 110 is adopted considering miscellaneous loss in line at valves, bends etc.

Velocity : Maximum 3.0 m/s
Minimum 0.3 m/s

Pipe Material: Material should be decided considering pressure, soil condition, pipe profile, etc. However, material is generally selected in accordance with the principle below:

Steel Pipe:for diameter 400 mm or larger

A/C Pipe: for diameter 300 mm or smaller

(3) Treatment Plant Facilities

a. Receiving Well

Retention Time : 1.5 min

b. Mixing Tank

Type of mixing : Mechanical Flush Mixer
Mixing time (min) : 1 - 5
Intensity, G (1/sec) : 500 - 1,000

c. Flocculation

Type of mixing	:	Mechanical Flocculator
Stage	:	3 or more
Intensity, G (1/sec)	:	10 - 75
Flocculation time (min)	:	20 - 40

d. Sedimentation Basin

Type of sedimentation	:	by Gravity
Type of basin	:	Rectangular with Inclining Plate
Flow velocity (cm/min)	:	less than 60
Retention time (hour)	:	more than 20 minutes
Effective depth (m)	:	4 - 5
Sludge removal	:	Mechanical scraper

e. Filter

Type of filtration	:	Rapid sand filtration Gravity down flow
Surface loading (m/d)	:	120 - 150
Filter media		
type	:	Single media
depth (cm)	:	60 - 70
effective size (mm)	:	0.45 - 0.70
Underdrain		
gravel layer	:	100- 150 mm x 4 layers
underdrain type	:	Bored pipe
Surface washing		
type	:	fixed nozzle
jet pressure(kg/cm2)	:	1.5 - 2.0
washing time (min)	:	4 - 6
rate (m3/m2/min)	:	0.2
Backwashing		
rate (m3/m2/min)	:	0.6 or larger
washing time (min)	:	5 - 10

f. Clear Water Reservoir

Retention time (hour)	:	3.0

Daily fluctuation of water demand will also be absorbed in each distribution reservoir.

Depth (m)	:	3 - 6

g. Chemical feeding

Alum		
coagulant	:	Solid aluminum sulfate
mixing	:	Batch mixing
dosage rate	:	5 - 10
Lime		
objective	:	pH control for coagulation
chemical type	:	Slaked lime (Ca(OH)2)

h. Chlorination

Chemical type	:	Chlorine gas

Minimum storage	:	1 month
Type of injector	:	Vacuum type injector
Dosage rate (ppm)	:	2.0

i. Instrumentation

General concept

Centralized operation not to be introduced except for emergency measures;

Various measurements to be monitored at central board with proper alarm system;

Automatic operation to be introduced at each facility site.

Flows to be measured	:	Raw and treated water Chemical amount
Levels to be measured	:	Receiving well Clear water reservoir All pump pits Chemical tanks
Weights to be measured	:	Chlorine gas cylinder
Head to be measured	:	Filter loss

(4) Distribution Facilities

a. Service pressure

Minimum pressure (kg/cm2)	:	1.0 (for hourly maximum demand)

b. Distribution reservoir

Retention time	:	6 hours of daily maximum demand

(5) Foundation Structure for Treatment Plant and Distribution Reservoir

a. Foundation type	:	Centrifugal Prestressed Concrete Pile (Dia 500mm)
b. Depth of bearing layer	:	25 m - Ground level
c. Bearing strength of pile	:	60 ton each

6. BASIS OF COST ESTIMATES

6.1 Construction Cost

(1) General

Construction cost of facilities to be built is calculated with prices in 1989 on the basis of the various unit costs.

The construction cost is calculated by different items in the manner as described below:

a. Pipelines : by linear meter for
- o Transmission pipes
- o Distribution pipes

b. Water Treatment Plant and Distribution Reservoir: by quantities for
- o Civil works (structures and earth works)
- o In-plant pipings
- o Mechanical works
- o Electrical works

c. Land Acquisition

These costs are separated in Foreign and Local Cost portion with the percentage by item as shown below:

Work Item	Foreign Currency	Local Currency
Pipeline	(%)	(%)
A/C pipes	30	70
Steel pipes	80	20
Structural/Architectural	30	70
Mechanical Works	80	20
Electrical Works	80	20
Land Acquisition	0	100

(2) Pipeline Construction

Pipelines are firstly separated into two major groups: (i) transmission pipeline for either raw water or clear water, but not for distribution, and (ii) distribution pipeline.

Unit costs for construction of transmission pipeline are calculated by linear meter, consisting of the material, transportation (two cases as more than 800 km, or smaller) and installation costs. Cost for fittings are assumed as 10 and 15 percent of pipe material cost for asbestos cement and steel pipes, respectively. These ratios are set smaller compared to that of the distribution pipes because of the simplicity in the pipeline components.

Unit costs of distribution pipeline are calculated in the same manner as that for the transmission pipeline. The ratios for fittings are set as 25 and 35 percent of the pipe material cost for asbestos cement and steel pipes, respectively.

(3) Structural Works

Unit costs for the structural works are assumed for the major items as follows:

- o Concrete works by concrete volume, including related works as reinforcement (assuming 100 kg/cu m of concrete), forming, scaffolding, supporting.
- o Earth works by soil volume for excavation and fill
- o Architectural works by unit area of building
- o Concrete piles by each pile, including material, transportation and driving cost

(4) Mechanical Works

Costs for the plant facilities included in the mechanical works are calculated on the basis of the number of unit of each equipment such as pump, flocculator, sludge remover, or chemical and chlorination dosage equipment. Additional percentage is assumed for the miscellaneous items as pipings and fittings.

(5) Electrical Works

Cost for the electrical works substantially varies depending on the magnitude of the instrumentation system. The records in the construction of the advanced water supply system shows it would share as much as 40 percent of the total construction cost if the sophisticated computer control system is employed. Employing the more simple system could reduce this cost much.

The system to be recommended in this study should be the simple one as described in the Design Criteria in the Chapter 5 so that the cost for the system could be lowered. It is a practical way to assume that the cost of the electrical works closely related to the cost of the mechanical works. In this study, the cost is therefore, calculated by percentage of the mechanical works.

(6) Land Cost

The land cost in the study area has been increasing very rapidly because of the booming investment therein. The escalation ratio is said to be more than 300 to 500 percent in one or two years. Considering this situation, the unit land cost is adopted to be 2,000,000 Baht per rai (1,600 sq m) for the intake and treatment plant site, and 5,000,000 Baht per rai for the distribution reservors.

The details of the unit costs are shown in Appendix A-6-1.

6.2 Operation and Maintenance Cost

(1) General

Operation and maintenance cost is calculated on the basis of the price and rate in 1989, and consists of the following factors:

- o Energy Cost

- o Chemical Cost
- o Manning Cost
- o Repair Cost
- o Replacement

This cost is calculated in local currency only.

(2) Energy Cost

It is expected that the energy for the operation will be provided by the Provincial Electricity Authority (PEA).

The Energy cost is calculated separately for the demand charge and energy charge with the PEA rate in 1989 which are:

Demand Charge : Baht 229 /KW/month

Energy Charge : Baht 1.23 /KWH

(3) Chemical Cost

Unit chemical costs are as follows:

Alum : Baht 3.9 /kg

Lime : Baht 1.25 /kg

Chlorine Gas : Baht 15.6 /kg (excluding gas container)

(4) Manning Cost

The unit manning costs of each year are calculated from the average manning cost in 1987, which is Baht 7,129 per person per month. The annual increment of the monthly salary is set to be 5 percent.

(5) Repair Cost

Repair cost should be counted for repairing and maintaining the plant equipment. This cost is assumed as 0.3 percent of the construction cost of the mechanical and electrical works.

(6) Replacement

Each facility to be constructed should have a certain life time. The span for the life time is varying depending on its nature of the facility. The followings are the life time of the facilities to be taken in this study and concept for replacement:

Item	Life time span	To be replaced after life time
Pipeline		
A/C pipes	20 years	50 percent
Steel Pipes	30	50
Concrete Structures		
Treatment Plant	50	100
Reservoir	50	100
Mechanical Equipment	20	100
Electrical System	20	50

Part 2
DEVELOPMENT PLAN

7. Consideration for the Development Plan

An extensive expansion of the service area and the water supply system should be required to cope with the rapid development in this area. This factor is the most important in considering a facility planning in the development plan.

The large service area in 2011 with a total area of approximately 344 sq km needs a careful consideration on the distribution system to achieve, in any point in the service area, a proper supply pressure and to avoid too high pressure. To keep supply pressure in the proper range is important not only to protect pipes from burst or leakage but also to save water by preventing unnecessary discharge of tap water caused by high pressure.

A distribution system should also be well organized so that economical operation be done in pump operation for water transmission as well as distribution.

Another factor to be taken into account is a selection of the proposed raw water intake and the treatment system. Since these are quite large facilities and have intensive role in the development of this area, they should have an efficient and reliable operation in any case of water demand pattern. As well as the capacity and characteristics in its operation, expansion step should be considered to make an effective financing plan.

Facility planning should therefore aim at the cost effectivity in terms of both construction and operation.

Land acquisition is realized as a serious problem in this region as the investment by private sector has been increasing and it made the land price to uprise substantially. Therefore, the land requirement should be minimized in the planning so that the implementation of the project would not be hampered by the land acquisition problem.

Considering the factors above, the concept for facility planning is established as follows:

(1) Zoning the service area;
(2) Maximum use of the land of the existing deep well plants;
(3) Minimizing the water treatment plant site; and
(4) Economical implementation plan.

(1) Zoning of the service area

The service area is separated into several blocks consisting of the several Tambons, where the water will be distributed from the service reservoir with proper range of the service pressure. A service reservoir will be provided as a water source for one or two zones depending on the water demand pattern and pipeline features. Treated water will be transmitted from the treatment plant to these reservoirs, and then delivered to each distribution network by pumping.

The zoning method is introduced since it has several advantages, such as:

(i) Distribution of the water demand

The service area will consist of the separated zones which have the separated water demand depending on the characteristics of the

population and social aspects. This will help the implementation to be easily established by considering the priority of each zone.

(ii) Stable water transmission

As the total service area is quite large, it is difficult to maintain the water pressure within the suitable range if the water is directly transmitted to the consumers from the treatment plant. To supply water with the suitable supply pressure, Treated water will be firstly conveyed to the distribution reservoirs from the treatment plant. The distribution to the consumers will then be made from these reservoirs.

(iii) Cost effectivity in the pipeline design

Transmission pipes from the treatment plant to the distribution reservoirs are designed not for the hourly maximum demand but for daily maximum demand since hourly fluctuation can be absorbed in the retention of the reservoirs. Pipe sizes are therefore designed smaller than for the direct distribution.

(iv) Easy operation and maintenance

Operation and maintenance of the distribution system will be easier sine each block is isolated.

The organization of waterworks will also become simple by the separated staff and responsibility which could be clearly separated into water production and distribution.

The service area is divided into eight zones considering its topography, administrative borders, and road networks. Separated zones are numbered as shown in Figure 7-1 which also shows maximum daily water demand in 2011 in each zone. Table 7-1 presents the features of each zone.

Table 7-1 Characteristics of Zones

Zone No.	Tambon	Served Population (in 2011)	Water Demand (in 2011) (cu m/day)	Characteristics of Zone	Distribution Reservoir
1	Thanyaburi-1 Khlong Luang-1 Lam Luka -1	141,023	62,917	High density Commercial area	D-1
2	Khlong Luang-1 -2 -3	67,352	61,729	Industrial area	D-2
3	Thanyaburi -1 -2 -3 -4	28,129	9,749	Residential area	D-3
4	Lam Luka -1 -2 -3 -4	36,367	10,602	Residential area	D-4
5	Muang -3 -6 Sam Kok -1 -2 -3	9,656	13,528	Low density Residential area	None
6	Muang -1 -2 -4 -5 -7 -8	35,321	29,049	Low density Industrial area	D-5
7	Muang - 9 -10 -11 -12 -13 -14 Sam Kok -5 -6 -7 -8	52,849	25,648	Provincial capital Commercial and residential area	D-7
8	Lad Lum Kaeo-1 -3 -6	5,575	5,019	Low density Residential area	None

Note: Water Demand is shown in daily average.

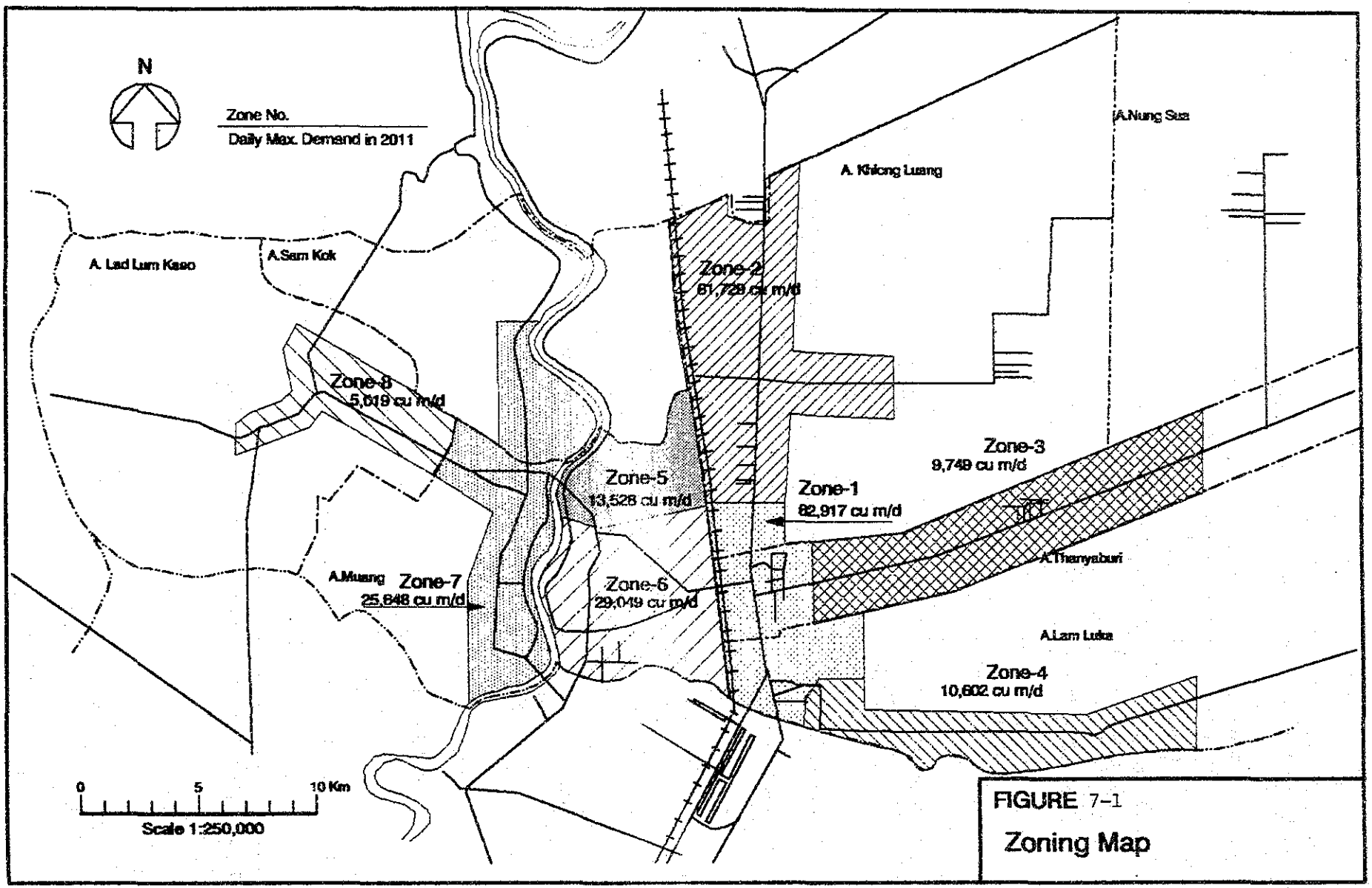


FIGURE 7-1

Zoning Map

(2) Maximum use of the land of the existing deep well plants

The land acquisition is the critical problem in this area because of the uprising land price. The facility plan should therefore be established with the land requirement limited minimum. The available land in the PWA's existing deep well plants should be utilized utmost.

(3) Minimizing the water treatment plant site

This is related to the problem of the land acquisition. The treatment plant will need the huge land area in the difficult situation of the land acquisition. Therefore, it should be the important target to reduce the land requirement for the treatment plant as much as possible as long as the technical and economical feasibility are satisfied.

(4) Economical implementation plan.

The water supply project of Patum Thani and Prachatipat will need the substantial investment since the project is regarded as the new construction of the big scale municipal water supply system. The expansion strategy should be carefully established so that the most economical effect will be achieved.

8. Definition and Evaluation of Alternatives

8.1 Water Sources

8.1.1 General

As previously described in Chapter 2, the land subsidence and groundwater level drop are going on due to the overpumping of groundwater for water supply. As far as groundwater will be drawn at the high rate as being done presently, these problems will become worse to such a critical situation that buildings will be seriously damaged by differential settlement caused by the land subsidence.

It is dispensable to divert its water source from groundwater to surface water at the earliest time. However, it will take at least five years to start utilizing surface water for water supply, even after this feasibility study is completed. In the meantime, its water source will have to rely on the groundwater.

8.1.2 Comparative Study

(1) Selection of the Intake Site

For the raw water intake for water supply, three sites are proposed as shown in Figures 8-1-1 to 8-1-3, the situation of which are tabulated in Table 8-1-1.

Table 8-1-1 Situation of the Proposed Raw Water Intake Points

Item	Intake Point No. No. 1	No.2	No.3
Main stream stable and near the intake point	Good	Good	Good
Industries or institutions discharging wastewater upstream	Fair	Fair	Fair
Space for the treatment plant near intake	Good	Poor	Fair
Foundation condition	Fair	Fair	Fair
Accessibility	Good	Fair	Fair

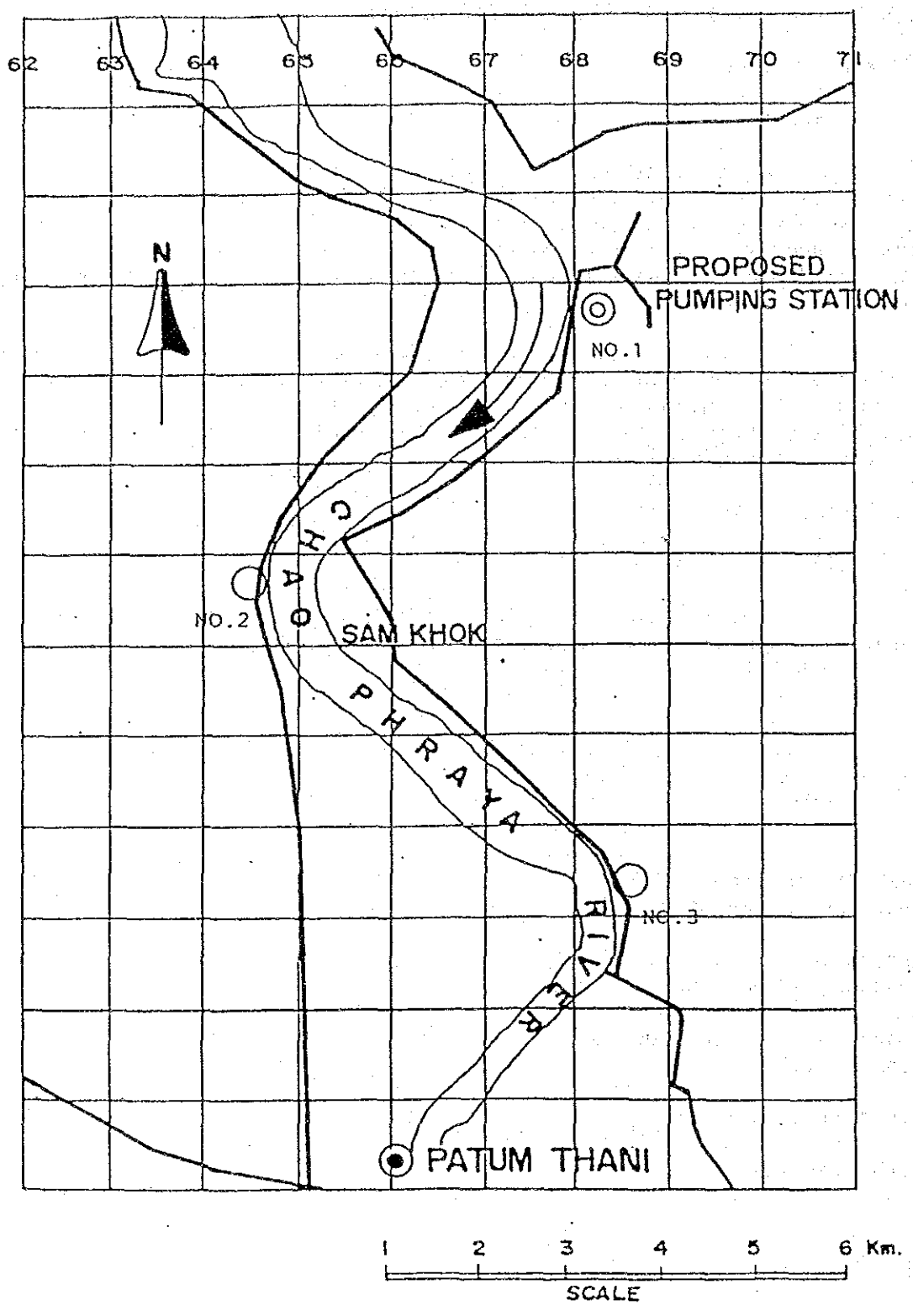


FIGURE 8-1-1

Location of Proposed Raw Water Intake POints

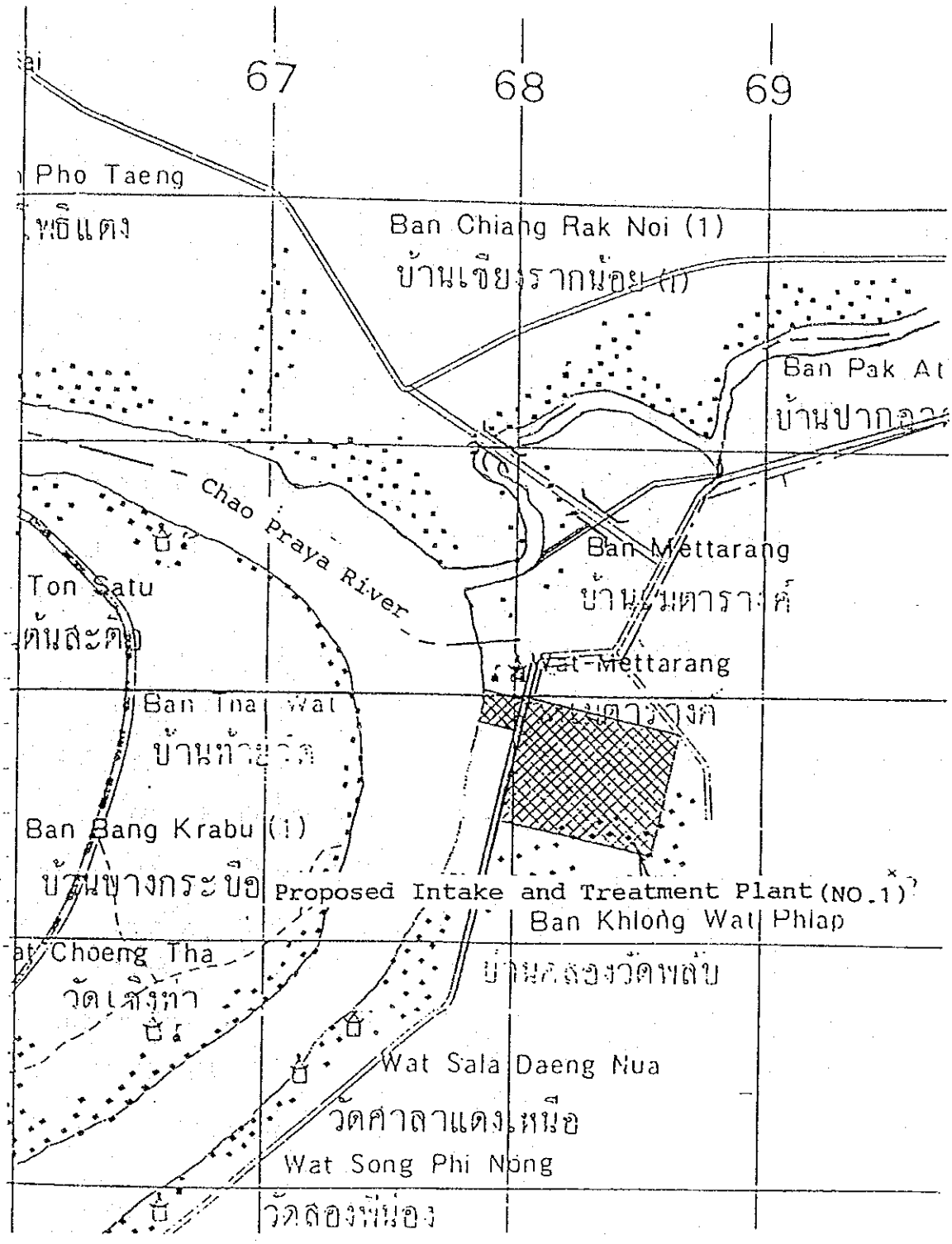


FIGURE 8-1-2

Location of the Proposed Raw Water Intake (No.1)

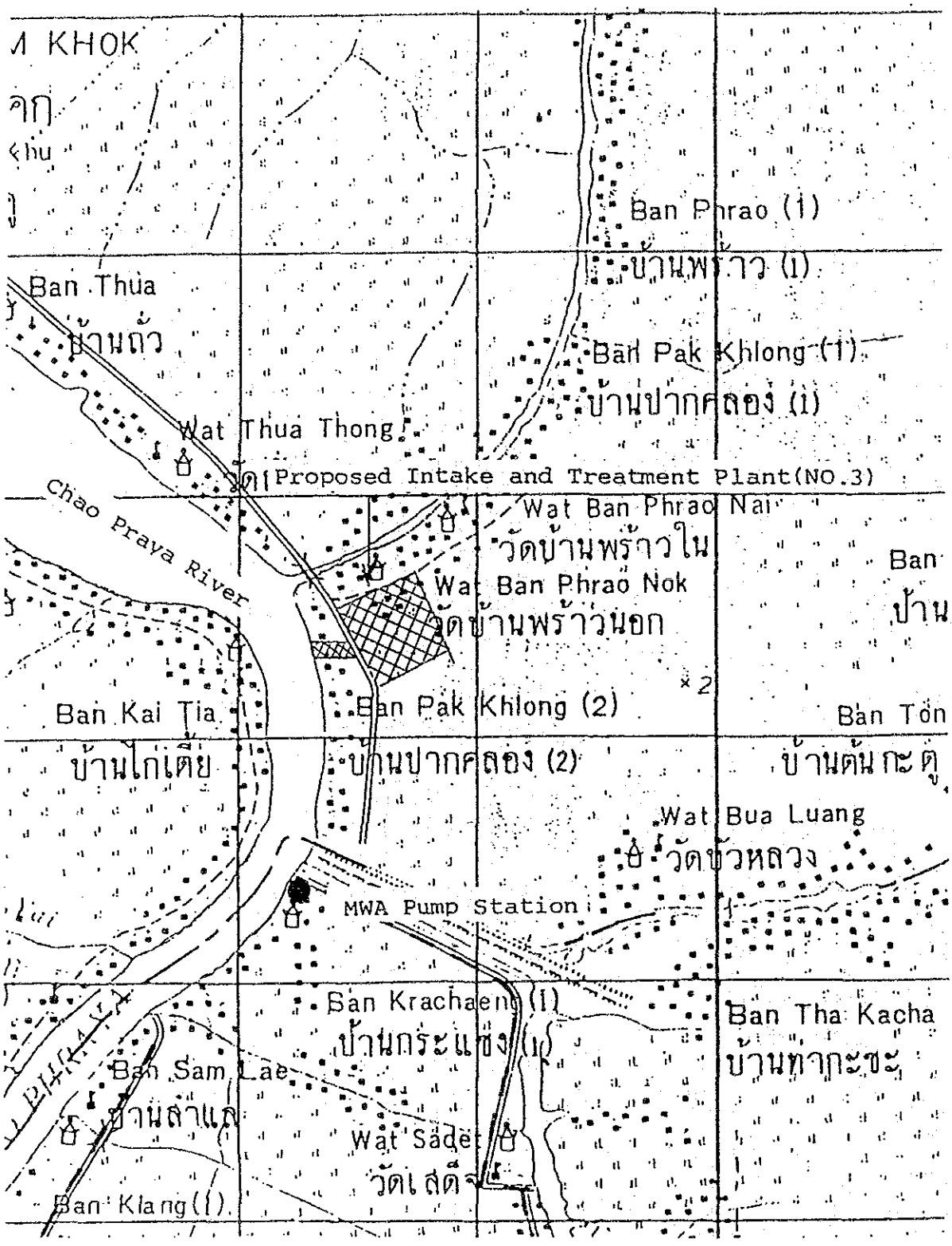


FIGURE 8-1-3
Location of the Proposed Raw Water Intake (No.3)

The water quality of surface water of the Chaophraya River close to each site has been analyzed by PWA, MWA, and NEB. The sampling points and results of these analysis are shown in Figure 8-1-4, and Tables 8-1-2 and 8-1-3, respectively. Raw water was sampled at the proposed intake site (W-1) on January 31, 1989 and analyzed by PWA. MWA is taking samples every month at Samlae Intake while NEB is sampling at W-3 and W-4 every month. Any distinguished difference is not seen in the result of the water quality analysis so that no difficulty is expected in treatment.

It is comprehensively considered that No.1 point is the most suitable site for raw water intake from the view point of raw water quality. However, the differences in total characteristics between Nos.1 and 3 are technically less. The further study is conducted in the subsequent section considering the total cost comparison including construction, operation, and land costs.

As described in details in Section 8.3, No. 3 point is consequently recommended as the intake point because of the lowest cost and easy operation.

Table 8-1-2 Water Quality of W - 1

Point : Wat Mettarang (W-1)
Date : January 31, 1989

Parameter	Value
Color	12
Turbidity	60 FTU
pH	7.86
Conductivity	276
Total Solid	268 mg/l
Total Hardness	98 mg/l
Temporary Hardness	98 mg/l
Permanent Hardness	nil
Phenolic Acid	nil
Alkalinity	112 mg/l
Ca	30 mg/l
Mg	5.3 mg/l
Cl	18 mg/l
Fe	2.66 mg/l
Mn	0.43 mg/l
Cu	0.03 mg/l
Zn	0.03 mg/l
SO_4	18 mg/l
NO_3	0.25 mg/l
NO_2	0.01 mg/l
F	-

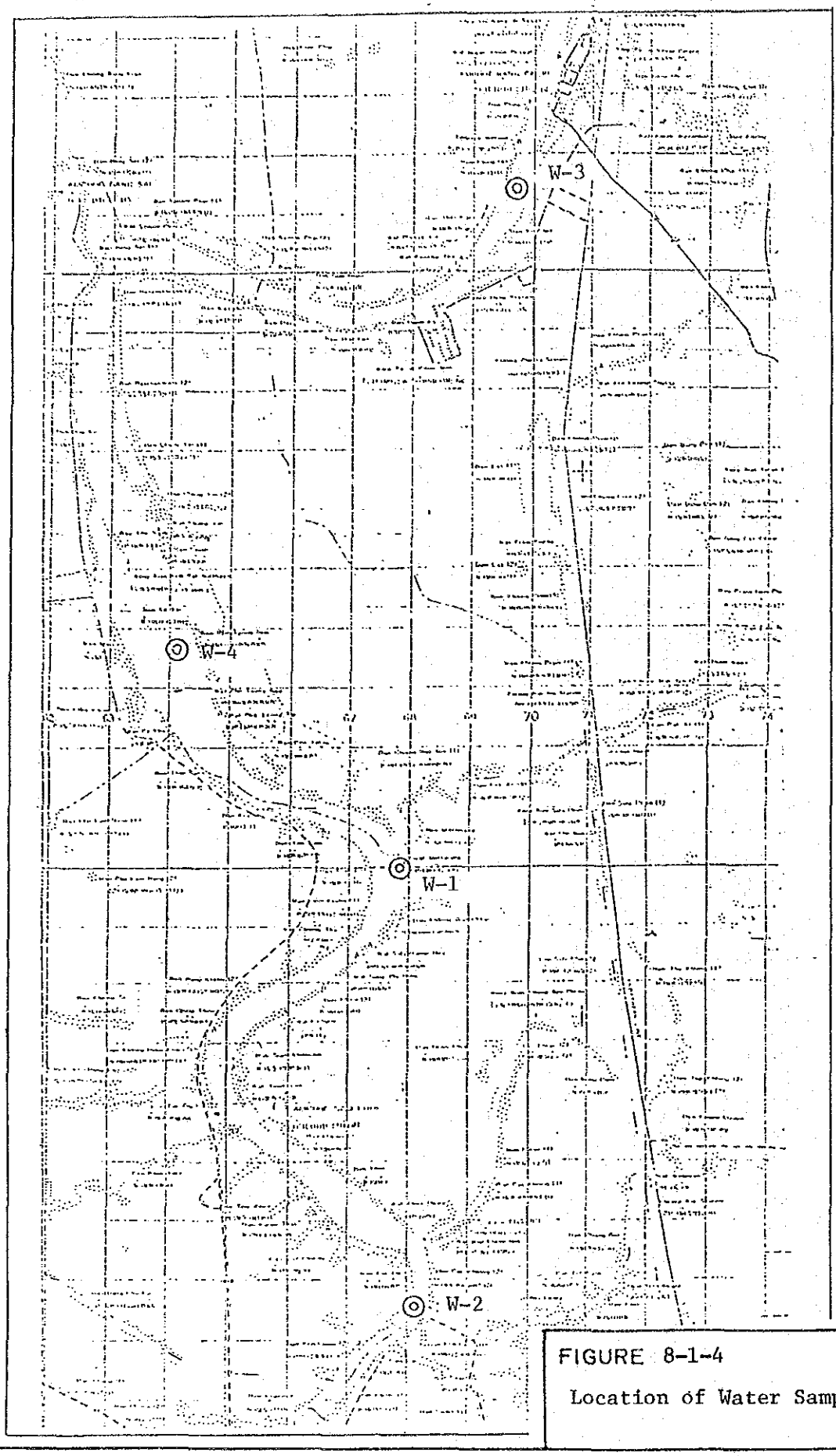


FIGURE 8-1-4

Location of Water Sampling

Table 8-1-3 Water Quality Analysis by MWA

Chaophraya River Samloe Intake (W-2)

Item	Standard	21 Jan	23 Feb	18 Mar	15 Apr	20 May	24 Jun	16 Jul	27 Aug	23 Sep	7 Oct	11 Nov	21 Dec	Remarks
1. Physical														
o Color	5	5.0	5.0	5.0	5.0	5	8	5	5	5	9	5	7	
o Odor		little clay	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	
o Turbidity	5	20.0	43	67	58	42	63	88	65	125	47	35	22.5	
o PH	6.5-8.5	7.08	7.72	6.56	7.46	7.19	7.38	7.0	7.76	6.55	7.13	7.19	6.95	
o Condactivity		270	250	250	220	270	250	250	270	290	195	219	236	
o Appearance		Clear	Slightly clear	Slightly turdid	ditto	Lather Clear	Slightly Clear	Moderate turbid	Slightly turbid	High turbid	Rather Clear	Rather Clear	Clear	
2. Chemical														
o Total Alkalinity		108	92	86	86	80	82	92	88	74	78	80	94	
o Alkalinity		nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	
o Total Solids	500	191	224	229	197	213	228	234	244	331	159	173	153	
o Dissolved Solids		162	156	150	132	162	150	168	162	174	118	131	142	
o Suspended Solods		29	68	79	65	51	78	116	82	157	41	42	11	
o Total Hardness	300	114	124	90	86	94	84	108	88	74	72	78	86	
o Temporary Hardness		108	92	86	86	80	82	82	88	74	72	78	86	
o Permanent Hardness		6	32	4	nil	14	2	26	nil	nil	nil	nil	nil	
o Chloride	250	14	18	12	12	12	13	18	14	7	11.5	11	43	
o SO 4	200	12.5	14.4	14.4	11.3	4.4	9.4	8.1	11.3	14.4	12.5	11.3	16.3	
o Oxygen consumed		4.72	2.48	3.12	2.64	3.68	3.04	3.68	3.52	5.36	4.56	3.92	5.04	
o NH3 - N (Fra)		0.33	0.151	nil	nil	0.112	0.015	0.06	nil	0.026	nil	0.116	nil	
o NH3 - N (A		0.42	0.036	0.3	0.1	0.132	0.226	0.416	0.356	0.6	0.32	0.536	0.464	
o NO3	45	0.9471	0.39	1.2539	1.0521	1.1008	1.0162	1.613	1.3396	0.7522	0.4833	0.9135		
o NO2		0.0428	0.0109						0.0138	0.0586	0.0234	0.0263	0.0406	
o Ca	75	26.4	23.2	24	23.2	25.6	26.4	24	26.4	23.2	23.2	24	25.6	
o Anionic Surfactant	0.5											0.05		
o Fe	0.5	0.41	0.735	0.19	0.31	0.55	0.83	0.79	0.706	1.38	0.88	0.55	0.407	
o F	0.7	0.34	0.19	0.27	0.6	0.09	0.15	0.1	0.25	0.04	0.12	0.28	0.19	
o Mn	0.3	0.076	0.047	0.028	0.058	0.047	0.058	0.018	nil	0.16	0.104	0.028	0.01	
o Mg	50	11.52	15.84	7.2	6.72	7.2	4.32	11.52	5.28	3.84	3.36	4.32	5.28	
o Co														
o Silica														
o Na		33.8	25.1			16.8	25.1	28.8	29.1	20.2	15.4	20.5	22.3	
o K		2.9	2.7			2.7	2.5	3.8	3.1	2.7	2.9	2.4	2.2	
o DO		3	3.5	3.6	3.2	2.6	3	3.4	3	3.7	3.6	2.9	5	
o BOD		1.9	1.7	1.3	1.7	2.1	1.3	0.9	0.7	0.8	1	1.7	1.2	

8.1.3 Design of Facilities

(1) Location

The proposed raw water intake and pumping station is located about 1,000 m upstream of the existing MWA's intake as shown in Figure 8-1-3.

(2) Pumping Station

Pump Specification :
- Type : Horizontal Axial Flow Pump
- Discharge : 195 cu m/min
- Head : 12 m
- No. of Unit : 4 units (including 1 stand-by)
  - 3 units for Phase 1 (1995-1999)
  - 1 unit for Phase 2 (2000-2011)

Pumping Station :
- Building : 12.0 m x 9.0 m

Intake Canal : W L
- Dimension : 20.0 m x 50.0 m

(3) Raw Water Transmission Pipe

Conveyance of raw water is proposed to be made through a transmission pipe since it is the most convenient measure in terms of cost, maintenance, and land requirement (open channel requires land acquisition).

Transmission pipe : Dia. 1,500 mm, Steel Pipe
No. of Pipeline : 1

(4) Water Level

As shown in Table 8-1-4, the highest water level occurred on October 27, 1980 at both of the C-29 and C-22 Gauging Stations, while the lowest water level was observed on May 16, 1979.

From the figures available in these data, the highest and lowest water levels at the proposed intake point are estimated as follows:

Highest Water Level :

$$(3.15 - 2.21) \times 25/(22 + 25) + 2.21 = 2.71 \text{ m AMSL}$$

Lowest Water Level :

$$(0.94 - 1.09) \times 25/(22 + 25) - 1.09 = -1.01 \text{ m AMSL}$$

Table 8-1-4 Water Level of Chaophraya River

Year	Sta. C - 29		Sta. C - 22	
	High	Low	High	Low
1978	-	-	2.22 (Oct.19)	-0.90 (Jun.12)
1979	1.60 (Oct. 6)	-0.94 (May 16)	1.52 (Oct. 6)	-1.09 (May 16)
1980	3.15 (Oct.27)	-1.06 (May 17)	2.21 (Oct.27)	-1.05 (May 17)
1981	1.85 (Nov.27)	-0.58 (Jul.30)	1.60 (Dec.13)	-0.89 (Jul 30)
1982	1.80 (Dec. 4)	-0.74 (Jun.23)	1.50 (Dec. 4)	-1.17 (Jun.23)
1983	3.06 (Oct.30)	-0.84 (Jun.27)	2.17 (Nov.11)	-1.16 (Jun.27)
1984	-	-	1.34 (Dec.24)	-1.02 (Jul.27)
1985	2.19 (Nov.10)	-0.74 (Jun.18)	1.68 (Dec.13)	-1.10 (Jul.12)
1986	1.44 (Dec.17)	-0.96 (Jun.18)	1.40 (Dec.20)	-0.92 (Jul.12)
1987	1.89 (Oct. 4)	-1.20 (Jun.26)	1.56 (Oct. 4)	-1.11 (Jul.12)

Source : RID

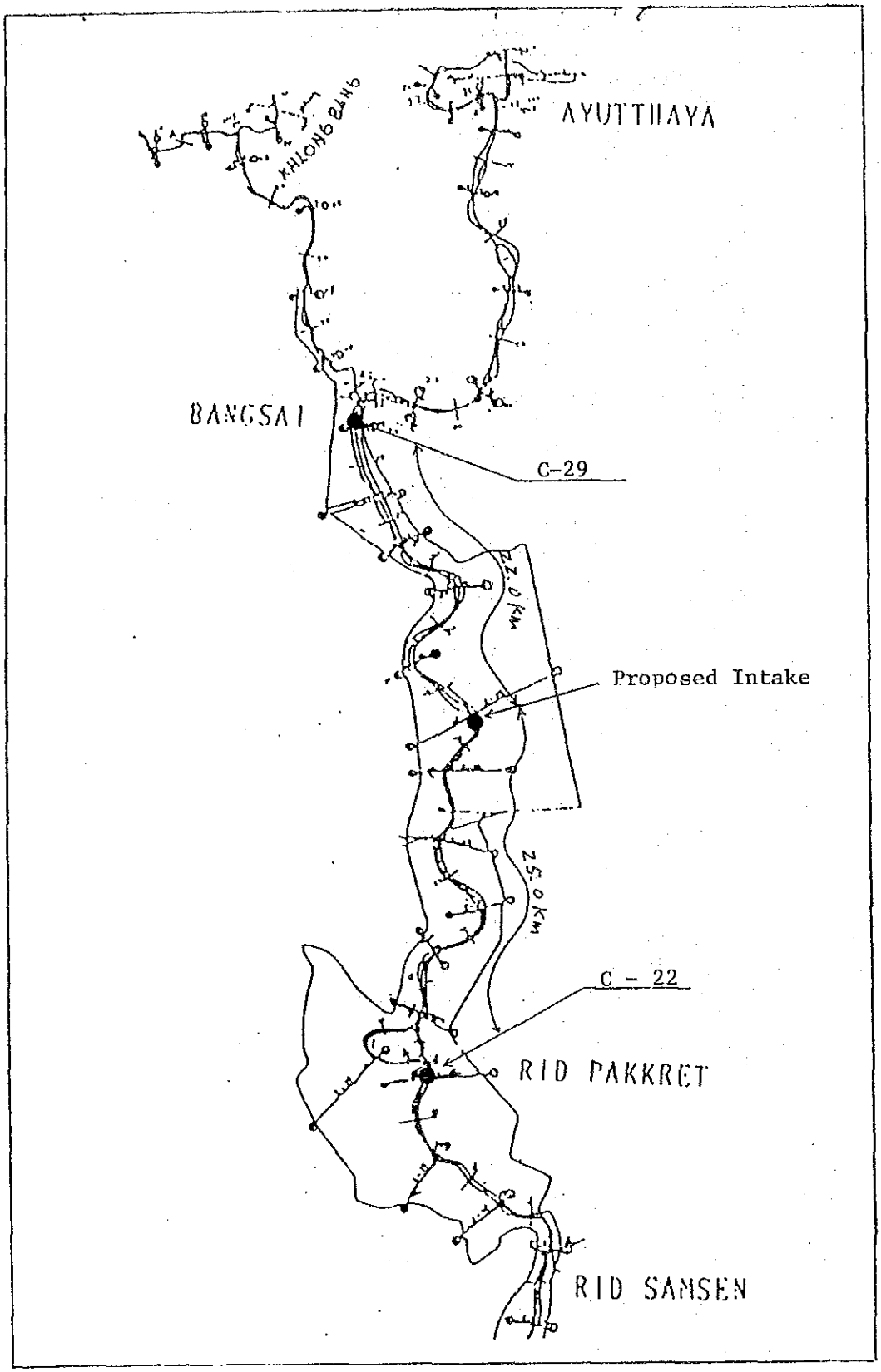


FIGURE 8-1-5

Location of Gauging Station

8.1.3 Water Source Development Plan

The chronological water source development plan is shown in Figure 8-1-6. This figures shows that PWA should maintain the existing wells until the new treatment plant has been completed.

Table 8-1-5 indicates that water demand will exceed the safety yield before 1 in most of the Zones.

Table 8-1-4 Zone-wise Safety Yield and Water Demand

Zone	Area (sq.km)	Safety Yield (cu m/d)	Exis. Well (cu m/d)	Daily Maximum Water Demand (cu m/day) 1991	1996	2001	2006	2011
1	45.0	4,678	8,640	7,400	18,418	36,447	52,727	66,432
2	68.1	7,080	-	0	46,692	56,930	64,193	72,460
3	53.5	5,560	2,880	436	1,903	3,814	6,635	11,699
4	34.7	3,607	5,760	3,110	5,378	10,233	14,433	21,791
5	23.3	2,420	-	0	2,722	9,791	14,656	16,233
6	46.8	4,860	-	0	6,646	18,857	27,573	36,473
7	45.0	4,680	6,720	4,349	8,978	17,040	24,017	30,777
8	28.3	2,940	-	0	0	2,059	4,320	6,023
Total	344.8	35,820	24,000	15,295	90,737	155,171	208,554	261,888

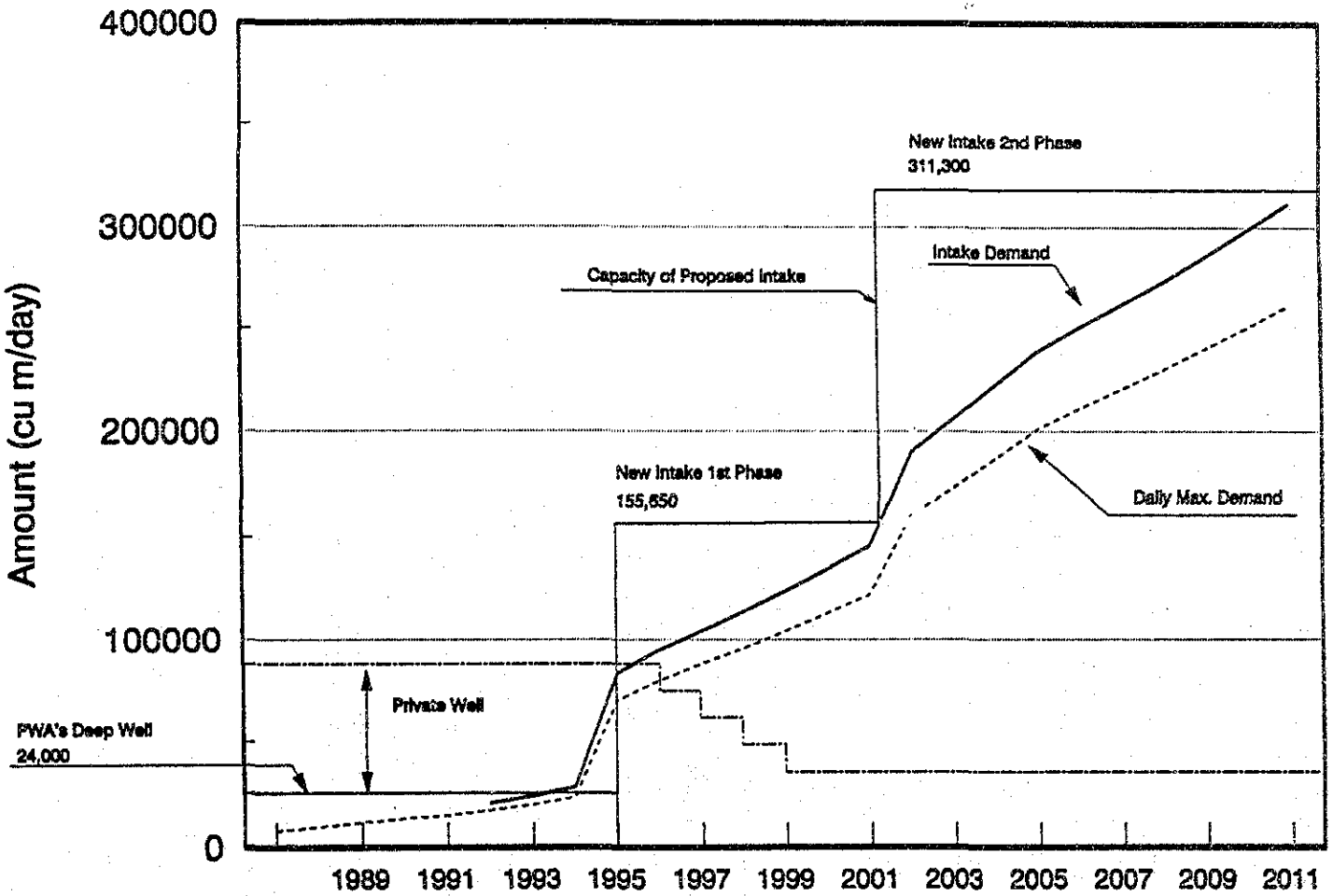
Note : "Exis.Well" shows the capacities of the existing deep well plants of PWA.

As shown in the Table 8-1-5, the capacities of the existing deep well plants exceeds the safety yield capacity of the area in Zones 1, 4, and 7, while Zone 3 still has a room for well development.

On the other hand, there are many deep wells operated in the factories and industrial estates in Zone 2, 5 and 6. The total capacity of these wells is considererd to be exceeding the safety yields of each zone.

Considering the situation above, the development of more deep wells is not recommended except in Zone 8 from the view point of the prevention of land subsidence. The development of the proposed water supply system depending on the surface water of Chaophraya River is, therefore an urgent need with the highest priority.

Figure 8-1-6 shows a water resource development plan.



Groundwater Source		Phasing Out (120 cu m/hr, or 11,520 cu m/d per year)
Raw Water Pumping Station	Construction	
Raw Water Pump Capacity		108 cu m/min / 216 cu m/min

FIGURE 8-1-6.

Water Source DEvelopment Plan

8.2 Water Supply System

In consideration of alternatives of the water supply system, there are three major items to be studied: (i) Water demand prediction by zone, (ii) the total facility layout, and (iii) the facility planning of each component. These issues are studied separately as follows:

8.2.1 Water Demand Prediction by Zone

Water demand in each zone is calculated from the served population and unit consumption, assuming the water supply service ratio of each Tambon in every year. Various kind of other demands such as industrial, commercial, and governmental use are calculated in the same manner of predicting the water demand in the total service area.

Figures 8-2-1 shows a water demand prediction by zone. Detailed calculation is shown in Appendix A-8-1.

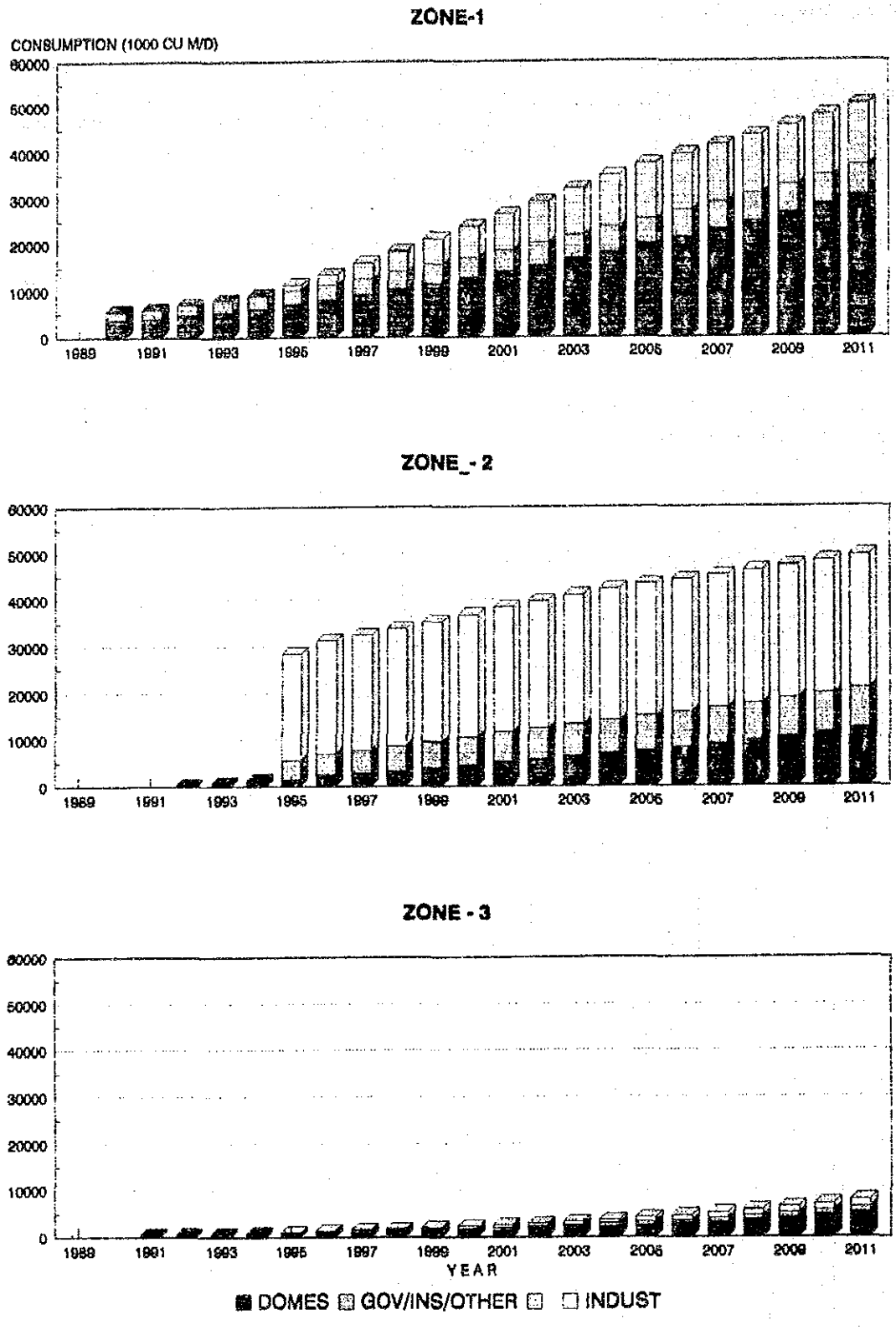


FIGURE 8-2-1
Water Demand Prediction
(Zones 1,2,& 3)

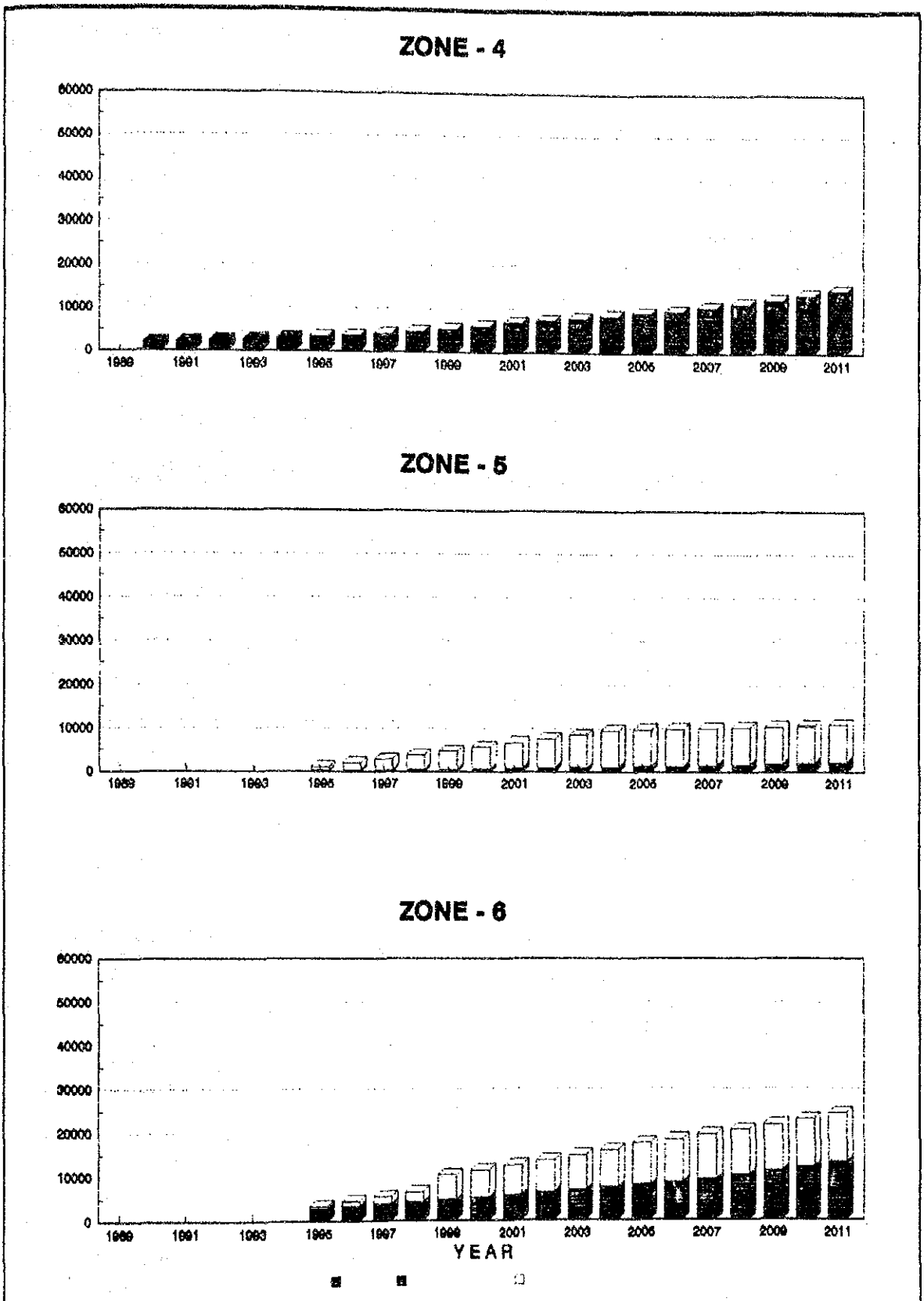
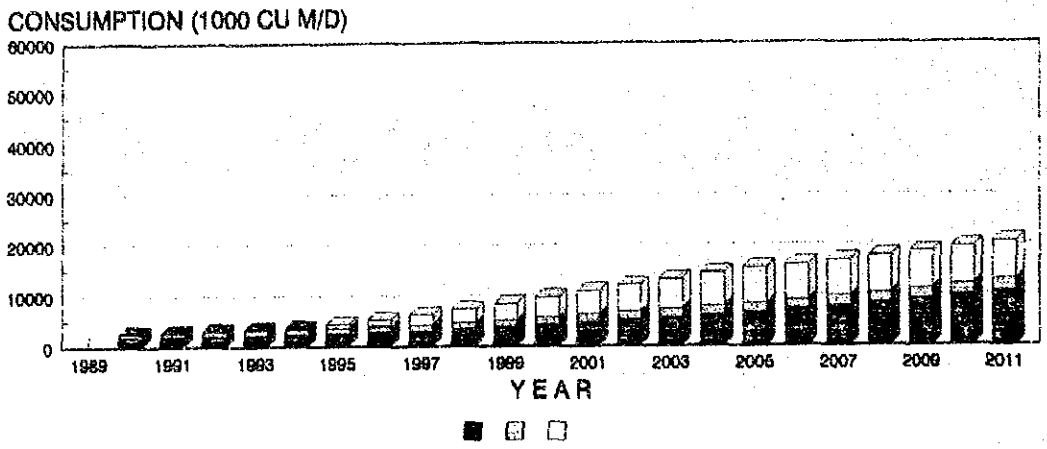


FIGURE 8-2-1

Water Demand Prediction
(Zone 4, 5, & 6)

ZONE - 7



ZONE - 8

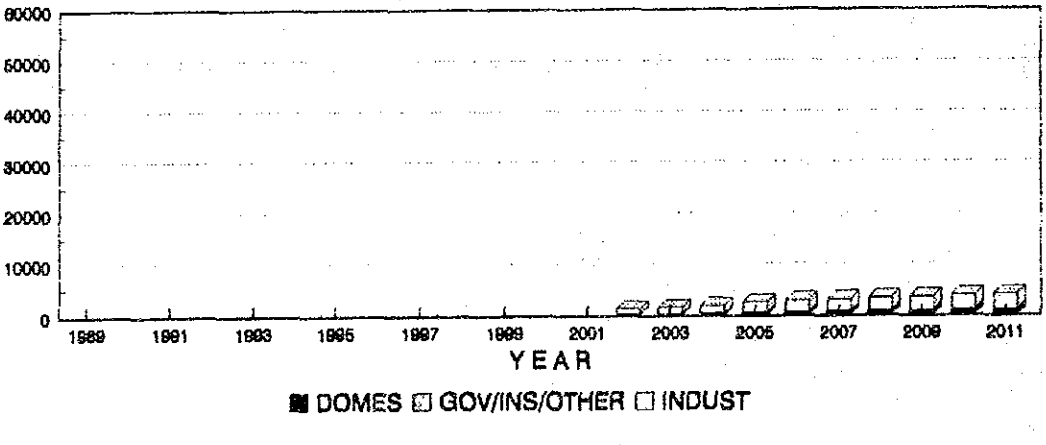


FIGURE 8-2-1
Water Demand Prediction
(Zones 7 & 8)