3.6 Water Sources in Surrounding Area

The existing and prospective water sources in the surrounding area of Pattaya are shown in Fig-3.9 and tabulated in Table-3.9. In Fig-3.10, the progress of studies on the eastern seaboard area's water development plan is shown chronologically.

Existing are four reservoirs, namely, Nong Kho, Bang Phra, Dog Krai and Bang Bung. In the planning stage are, construction of the Nong Pla Lai Reservoir and expansion of the Bang Bung Reservoir and construction of the Huai Kong Dai Intake. Basic information on these water sources are summarized hereunder.

1) Nong Kho Reservoir

The Nong Kho Reservoir was built in 1983 with a primary purpose to supply water to the Laem Chabang Industrial Complex and the supplementary to Pattaya City having an active storage of 18.8 MCM. The distance between the reservoir and Pattaya is about 25 km northeast of the city, and the Nong Kho-Laem Chabang Pipeline Project is under way. However, the activity of Laem Chabang Industrial Estate is behind the schedule. Therefore, the allocation of water is available for Pattaya Waterworks at Laem Chabang Receiving Well at about 17 km north-northeast of Pattaya City. The Nong Kho-Laem Chabang Pipeline Project is now under construction to be completed in 1988, following the plan shown in Fig-3.11.

2) Bang Phra Reservoir

The Bang Phra Reservoir is located about 30 km north of Pattaya City, having an active storage of 104 MCM. It was completed in 1975 with a primary purpose to supply water to the irrigation and Chonburi Municipality. Water demands for Chonburi Municipality namely as public water supply, and industry are increasing. The distance between the reservoir and Pattaya is at about 30 km. It seems almost impracticable to convey raw water from this reservoir to Pattaya City.

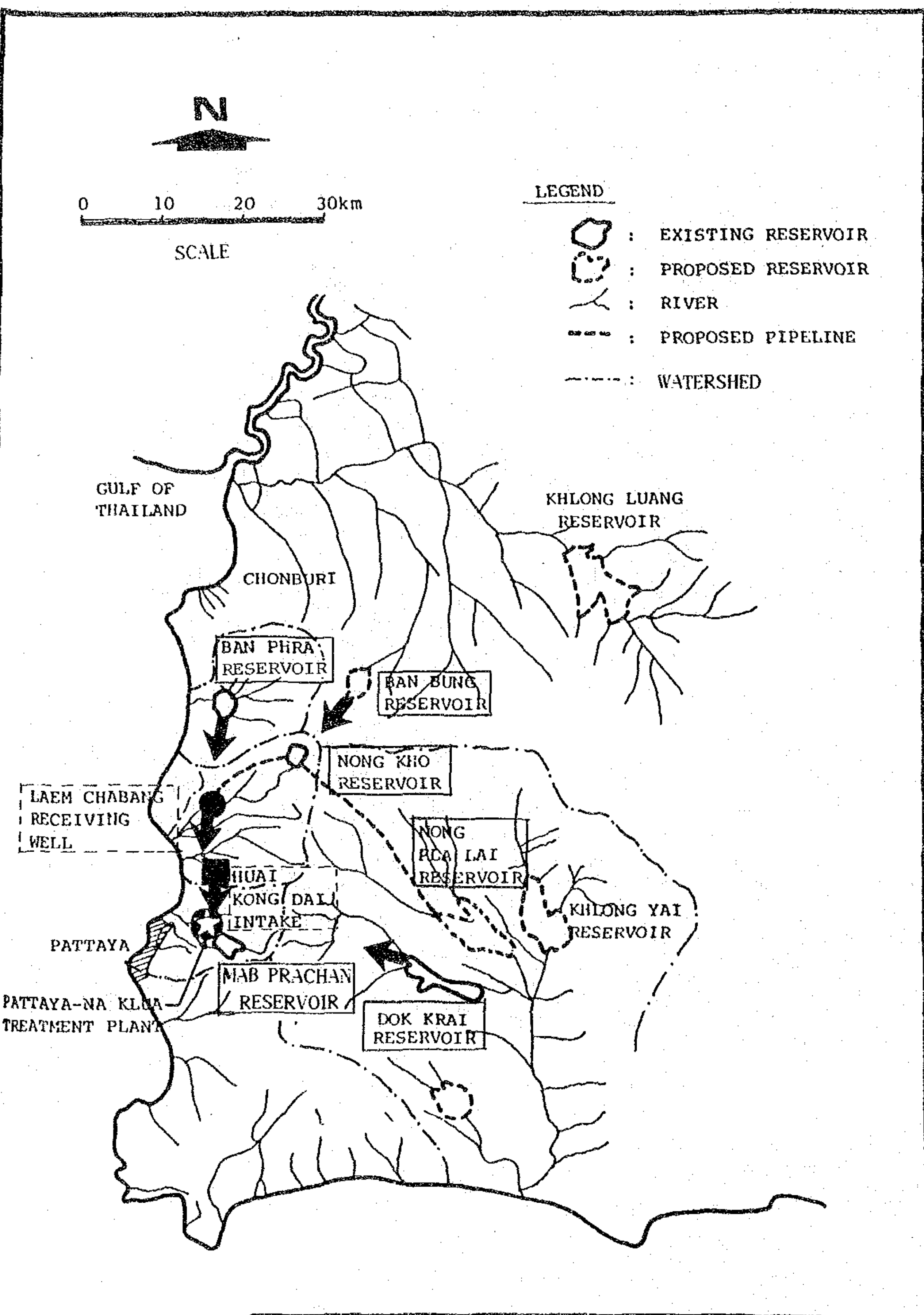

FIGURE	ALTERNATIVES OF WATER SOURCES
3.9	

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Table-3.9 EXISTING WATER SOURCES SURROUNDING PATTAYA BASIN

No.	Water Source	Construction Year	Catchment Area (Km^2)	Average Annual Inflow (MCM)	Gross Storage (MCM)	Active Storage (MCM)	High Water Surface (m)	Low Water Surface (m)	Reservoir Surface Area H.W.L (Km^2)	Net Draft (MCM/year)	Present & Future Utilization
1.	Mab Prachan Reservoir	1979	37.9	14.5***	14.8**	14.0	45.0	36.0	2.8	9.4***	Main Source for Pattaya and Some Industrial Use
2.	Nong Kho Reservoir	1983	59.0**	24.7**	21.1**	18.8**	65.6**	58.9**	4.7**	16.0**	Main Source for Leam Chabang Basin and Supplymentary Source for Pattaya
3.	Bang Phra Reservoir	1975	123	43.9	120.0	104.0	30.0	18.8	15.8	34.7	Main Source for Chonburi Area and Irrigation Use
4.	Dok Krai Reservoir	1975	291	103.8	70.8	46.8	50.6	38.6	8.8	56.8	Main Source for Map Ta Phut Area and Irrigation Use
5.	Ban Bung Reservoir	1958	51.2	12.2	2.9	0.4	76.3	75.8	1.2	2.2	Only Irrigation Use (Small Capacity)
6.	Huai Kong Dai Intake	planned	117*	44.7***	-	-	-	-	-	5.0 (Rainy Season)	Planned Supplymentary Source for Pattaya, however unstable River Flows
7.	Nong Pla Lai Reservoir	planned	408	126.1	200.7	144.4	45.0	33.3	20.2	102.5	Planned Future Main Source for Pattaya & Leam Chabang Basins and Irrigation Use
8.	New Ban Bung Reservoir	planned	51.2	12.2	21.9	12.5	82.1	76.1	3.2	11.7	Under Planning Source for Irrigation and Pattaya & Leam Chabang Basins

Data : RID, JICA, 1983

Revised, PWD, JICA, 1984 *

Revised, PWD, SANYU-Team, 1985 **

Revised, 1986 ***

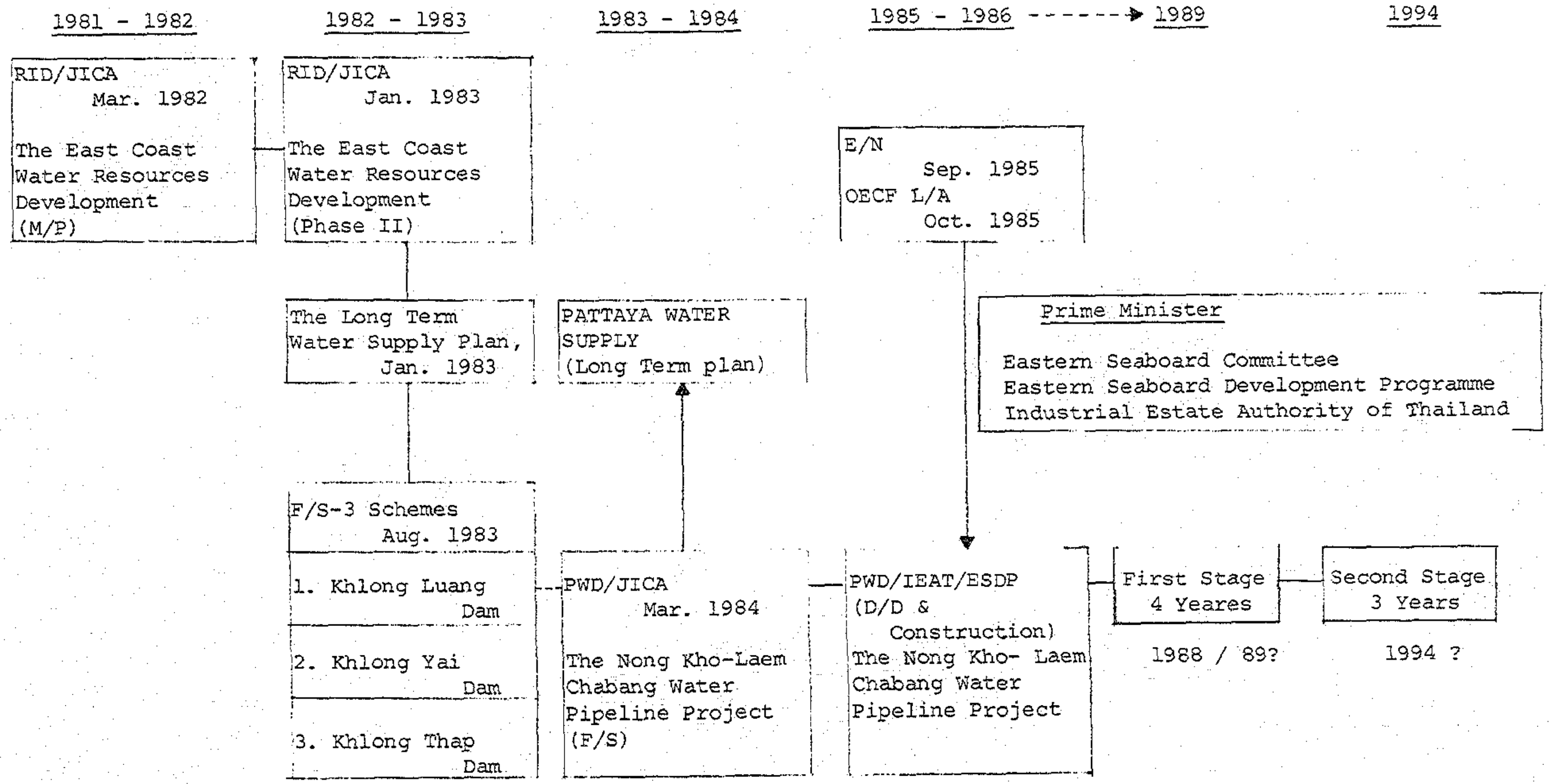

FIGURE 3.10 HISTORICAL WATER RESOURCES DEVELOPMENT STUDY IN THE EASTERN SEABOARD AREA

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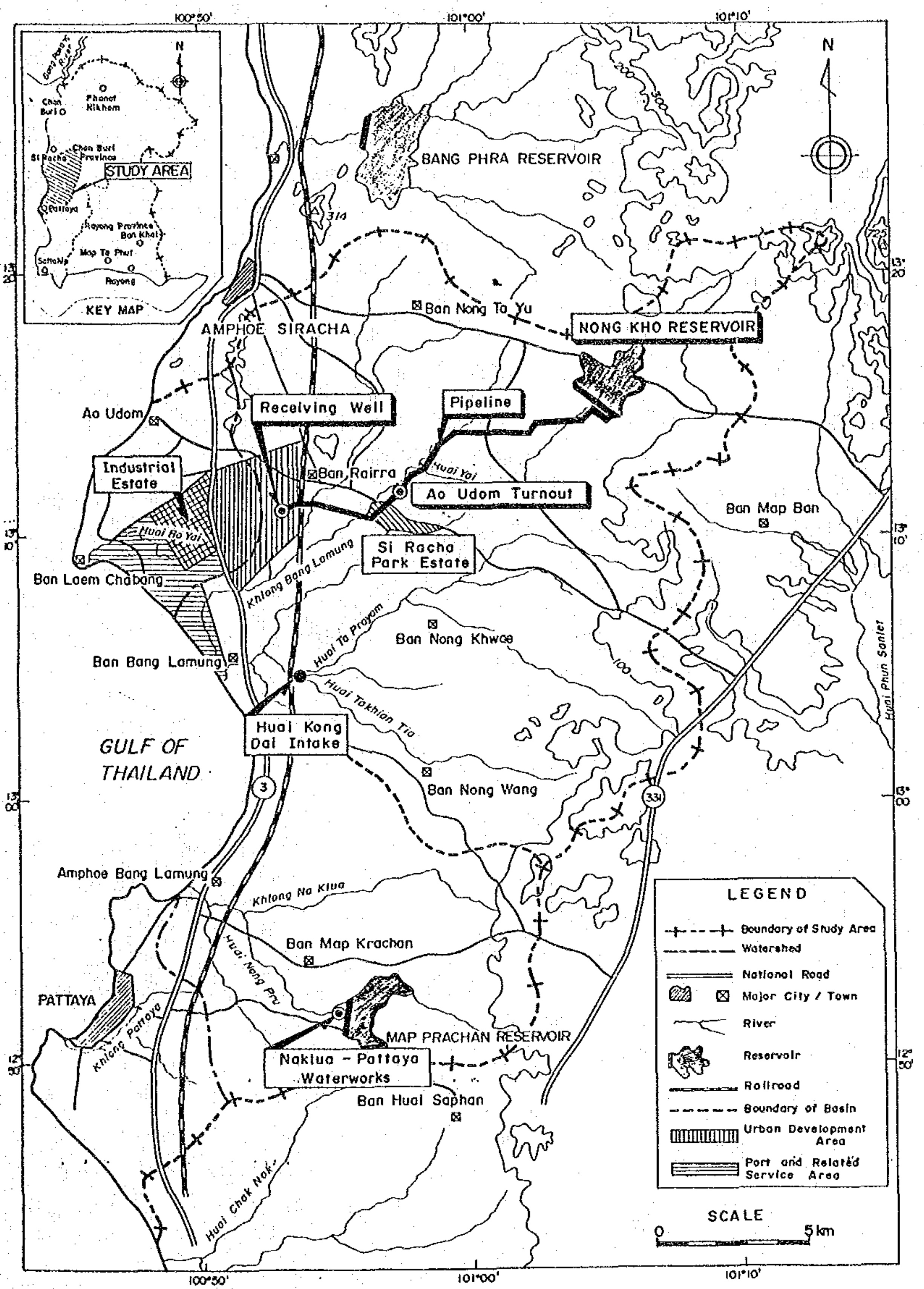

DATA : PWD
JICA,1984

FIGURE 3.11 NONG-KHO-LAEM CHABANG WATER PIPELINE PROJECT

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3) Dok Krai Reservoir

The Dok Krai Reservoir, completed in 1975 with a primary purpose for irrigation and water supply for Map Ta Phut Industrial Estate, is located about 35 km east of Pattaya City, having an active storage of 46.8 MCM. A new allocation for Pattaya is difficult because of the existing large demands, in addition, the construction cost of a transmission pipeline will be too high due to the topographic conditions between the reservoir and Pattaya City.

4) Ban Bung Reservoir

The Ban Bung Reservoir located about 37 km northeast of Pattaya City has an active storage of 0.4 MCM. It was completed in 1958. RID has an intention to expand its storage capacity and to convey raw water to the Nong Kho Reservoir by open canal. Despite its small storage capacity, successful implementation of this plan may contribute to the realization of effective water resource management in the area.

5) Nong Pra Lai Reservoir

The Nong Pra Lai Reservoir is planned at about 40 km east of Pattaya City. It is expected to have an active storage of 126.1 MCM which is the most attractive future water source for not only Pattaya but also Eastern Seaboard Area. The Nong Pra Lai Reservoir Project includes the transmission pipeline from Nong Pra Lai to Laem Chabang/Pattaya water conveyance system. According to the study of PWD/Sanyu, 1985 and JICA, 1983, the water diversion from Nong Pra Lai Dam using the Nong Kho-Laem Chabang water pipeline via Nong Kho Reservoir is concluded technically and economically the most promising plan. The raw water is planned to be supplied to Nong Kho reservoir for easing the supply shortage in the Laem Chabang and Pattaya Basins, and the water conveyance systems will be implemented taking into account the growth of the domestic and industrial demands.

6) Huai Kong Dai Intake

One of the promising water resources in the area discussed in Nong Kho Laem Chabang Pipeline Project Report is the Huai Kong Dai Intake at the confluence of the Huai Takhian Thai and Huai To Proyom Rivers. The Rivers have a total catchment area of 117 sq km, almost three times as large as that of the Mab Prachan Reservoir. An average annual inflow estimated from this figure and the data of the Mab Prachan Reservoir is around 40 MCM. This estimated inflow may be large enough as one of the water sources of Pattaya water supply. However, the alternative study carried out in the Appendix 7 shows this plan is uneconomical as compared with the alternative plan of extracting raw water from the Nong Kho Reservoir.

3.7 Water Sources Development Plan

Fig-3.12 shows the water demand and supply conditions, up to 2010.

3.7.1 Present Water Source

The present water source for Pattaya, the Mab Prachan Reservoir, can supply water at the maximum draft rate of 8.71 MCM/year, or 23,900 cu m/day in average and 28,800 cu m/day in maximum.

The rate is marginal to manage the water demand in 1988 and new sources shall be developed to meet the demand in and after 1989. (Fig-3.13)

3.7.2 Water Source Development up to 2000

The Stage I Project planned under this study plans to take water from the receiving well at the down stream end of the Nong Kho - Laem Chabang Pipeline, starting the operating in 1992.

From 1989 to 1991, if a severe drought occurs, it will cause water shortage, as seen in Fig-3.13.

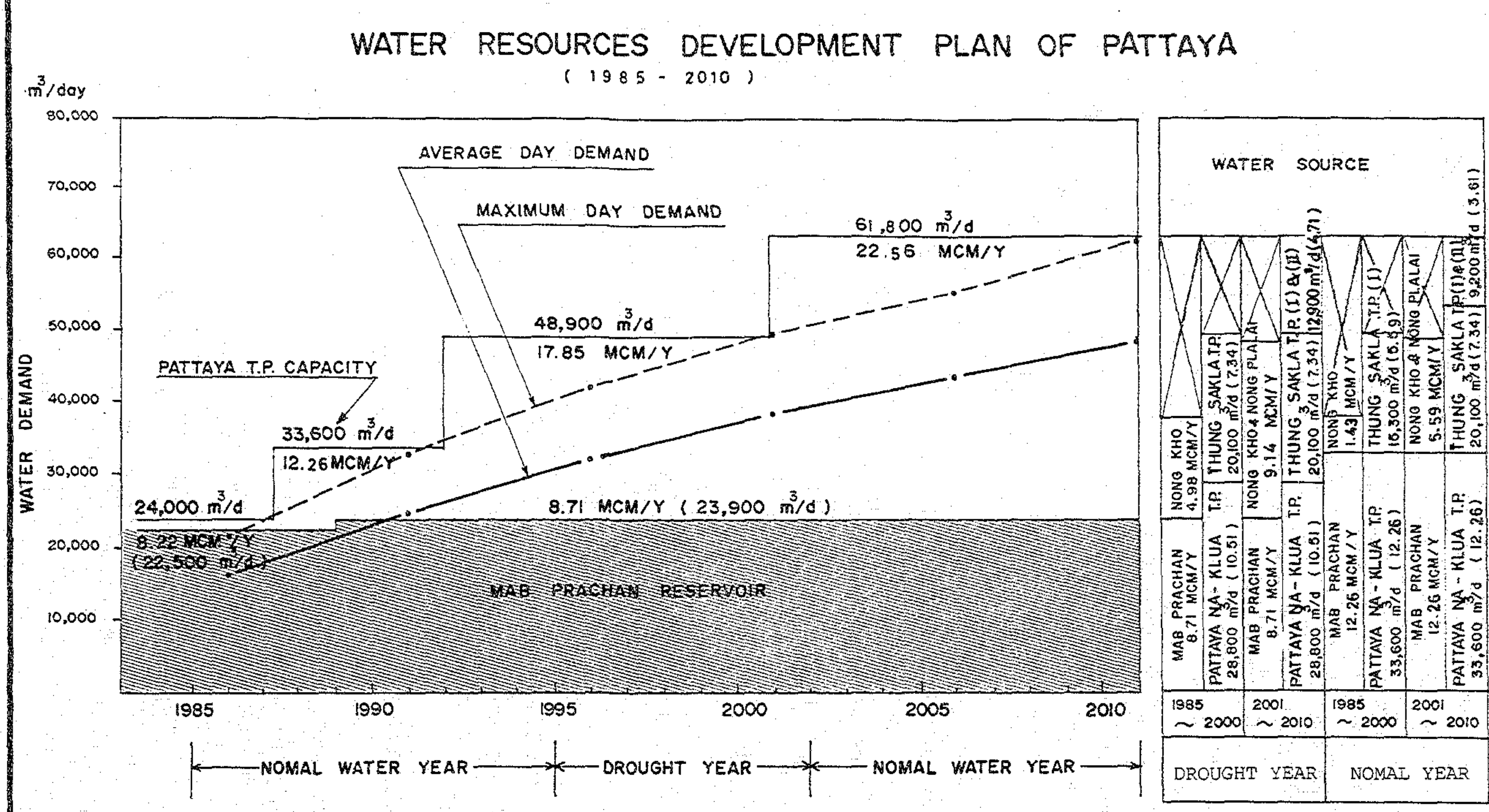

FIGURE 3.12 WATER RESOURCES DEVELOPMENT PLAN OF PATTAYA (1985 - 2010)

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WATER RESOURCES DEVELOPMENT PLAN OF PATTAYA

(1985 - 2000)

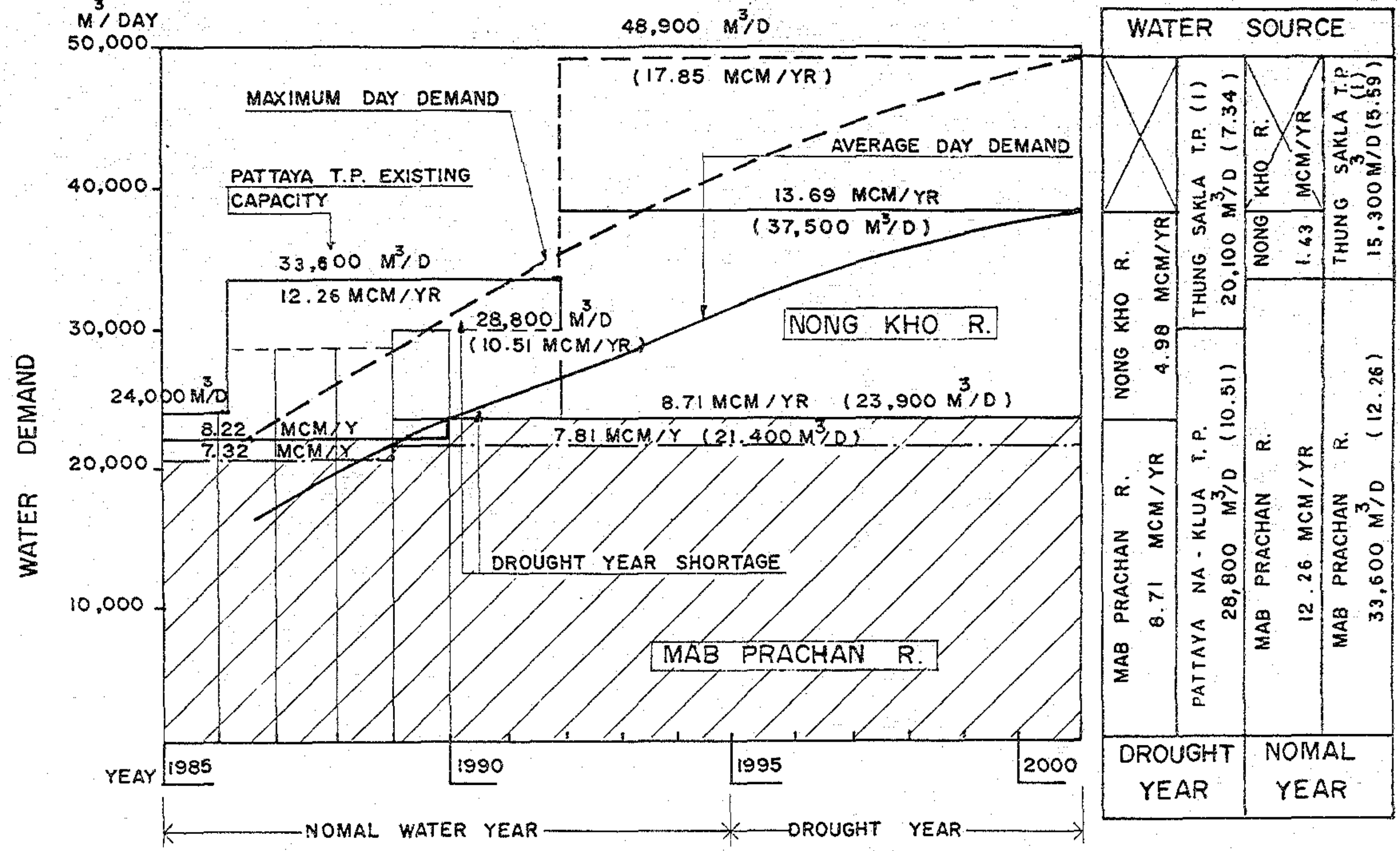

FIGURE 3.13	WATER RESOURCES DEVELOPMENT PLAN OF PATTAYA (1985 - 2000)

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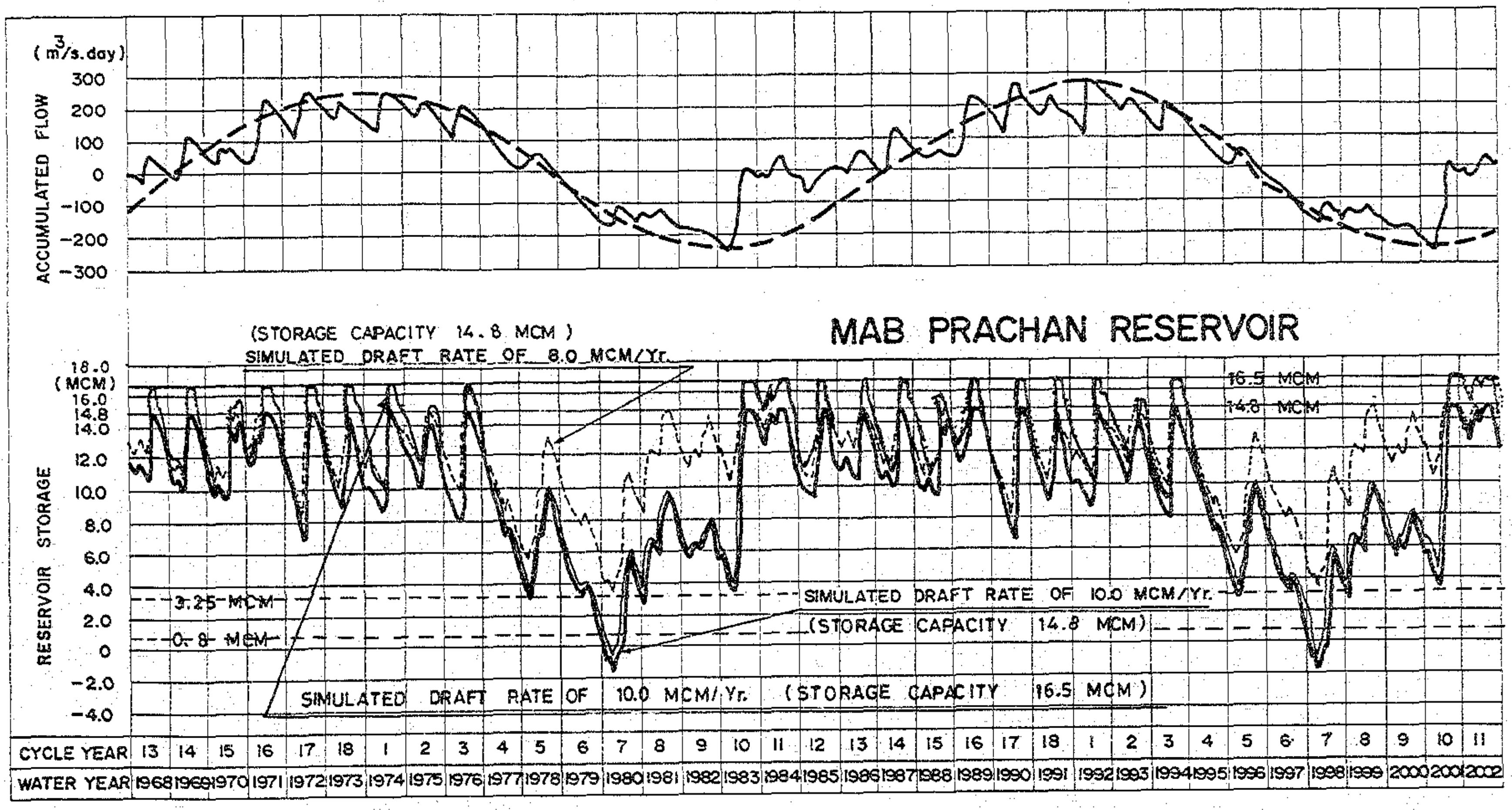
CLIMATICAL 18 YEARS CYCLE



DATA : BANG PHRA RUNOFF MODEL (1968 - 1984) , RID
MODIFIED MAB PRACHAN RUNOFF MODEL (1968 - 1984)

FIGURE 3.14	CLIMATICAL 18 YEARS CYCLE AND MAB PRACHAN RESERVOIR OPERATION ANALYSIS

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To study the probability of drought occurrence, the climatical data in the past were analyzed and it was found that there was a 18 years' climatical cycle and the cycle would recur in the future. The cyclic pattern is shown in Fig-3.14.

The mass curve shown in Fig-3.7 for 1968 - 1984 period was plotted, with a different scale, in Fig-3.14. For 1985 - 2001, the 1968 - 1985 pattern was assumed to recur. Noticeable in Fig-3.14 is that the trend is on the rise presently and 1992 will be the peak, suggesting the coming years until 1992 will be not severe drought years.

Table-3.10 was prepared to forecast the reservoir storage fluctuation from 1976 to 1994, a 18 year's climatical cycle.

Table-3.10 is a table showing fluctuation of the reservoir's storage, or a simulation model of the reservoir operation providing that draft rate from the reservoir be 10 MCM/year. The inflow, draft and evaporation in the coming years were assumed on the past data.

The lower half of Fig-3.14 shows the fluctuation of the reservoir water storage capacity, as the result of simulation. In the figure, two storage capacity lines, of 14.8 and 16.5 MCM, are drawn, as they represent the water levels before and after the spillway raising work to be completed in 1989. Two draft rate lines, of 8 and 10 MCM/year, are plotted as they approximate the water demand 1988 and 1992, respectively.

A dotted horizontal lines, of 3.25 MCM represents the dead storage that is not available for water supply, without any improvement of present PWA intake level of 39 m MSL. The figure indicates that under the raised draft rate and raised storage capacity, the critical situation will not occur before 1996.

Conclusively, as 1989 - 1992 period is foreseen to be not severe drought years, water shortage is unlikely to occur. However, Pattaya will probably have to experience water shortage in the latter half of 1990's, water development works are to be implemented at an early stage as planned by this study.

Table-3.10 SIMULATION OF MAB PRACHAN RESERVOIR OPERATION (DRAFT RATE 10.0 MCM/YEAR)

Year	M	Water Level (m)	Reservoir Surface (Km2)	Storage (MCM)	Inflow (MCM)	Draft (MCM)	Evaporation (mm)	Evaporation (MCM)	Fluctuation (MCM)	Spillway (MCM)
1976										
	11	45.5	3.06	16.50	2.26	0.80	50.6	0.15	Full	1.31
	12	45.5	3.06	15.68	0.37	0.90	96.0	0.29	-0.82	
	1	45.3	3.00	14.72	0.29	0.94	101.8	0.31	-0.96	
	2	45.0	2.80	13.88	0.26	0.84	75.2	0.21	-0.84	
	3	44.8	2.75	12.76	0.11	0.99	86.5	0.24	-1.12	
1977										
	4	44.5	2.61	12.18	0.47	0.78	102.5	0.27	-0.58	
	5	44.2	2.55	11.42	0.29	0.79	101.1	0.26	-0.76	
	6	43.9	2.40	10.80	0.39	0.75	108.5	0.26	-0.62	
	7	43.7	2.40	9.97	0.18	0.79	91.5	0.22	-0.83	
	8	43.2	2.24	9.21	0.26	0.82	88.2	0.20	-0.76	
	9	42.9	2.10	8.64	0.34	0.45	74.7	0.16	-0.57	
	10	42.7	2.03	8.85	1.18	0.80	83.2	0.17	0.21	
	11	42.8	2.10	8.02	0.13	0.80	75.9	0.16	-0.83	
	12	42.3	1.95	7.00	0.05	0.90	88.3	0.17	-1.02	
	1	41.8	1.80	5.95	0.03	0.94	78.5	0.14	-1.05	
	2	41.1	1.60	5.71	0.74	0.89	55.2	0.09	-0.24	
	3	41.0	1.57	4.69	0.11	0.99	90.6	0.14	-1.02	
1978										
	4	40.2	1.39	4.20	0.42	0.78	95.8	0.13	-0.49	
	5	39.9	1.35	4.89	1.60	0.79	91.6	0.12	0.69	
	6	40.3	1.45	5.98	1.97	0.75	89.8	0.13	1.09	
	7	41.1	1.60	8.37	3.31	0.79	81.1	0.13	2.39	
	8	43.7	2.00	8.20	0.81	0.80	80.6	0.16	-0.17	
	9	42.5	2.00	10.27	9.97	0.75	73.7	0.15	-2.07	
	10	43.4	2.35	9.80	1.84	0.80	95.1	0.22	-0.47	
	11	43.2	2.20	9.34	0.55	0.80	93.4	0.21	-0.46	
	12	43.0	2.20	8.28	0.03	0.90	84.9	0.19	-1.06	
	1	42.5	2.00	7.27	0.08	0.94	75.0	0.15	-1.03	
	2	41.9	1.80	6.69	0.45	0.89	80.2	0.14	-0.58	
	3	41.7	1.70	5.55	0.05	0.99	115.8	0.20	-1.14	
1979										
	4	40.9	1.53	4.99	0.37	0.78	100.2	0.15	-0.56	
	5	40.5	1.45	4.19	0.16	0.79	118.2	0.17	-0.80	
	6	39.9	1.35	4.09	0.76	0.75	82.9	0.11	-0.10	
	7	39.8	1.30	3.64	0.45	0.79	86.7	0.11	-0.45	
	8	39.5	1.25	3.29	0.58	0.82	85.5	0.11	-0.35	
	9	39.0	1.10	3.73	1.26	0.75	61.7	0.07	0.44	
	10	39.5	1.20	3.44	0.63	0.80	102.5	0.12	-0.29	
	11	39.2	1.15	2.69	0.16	0.80	99.3	0.11	-0.75	
	12	38.5	1.00	1.74	0.03	0.90	76.8	0.08	-0.95	
	1	37.6	0.80	0.77	0.03	0.94	77.4	0.06	-0.97	
	2	36.1	0.55	-0.05	0.11	0.87	79.3	0.04	-0.82	
	3	33.0	0.10	-0.96	0.09	0.99	107.2	0.01	-0.91	
1980										
	4	33.0	0.10	-0.94	0.81	0.78	123.2	0.01	0.02	
	5	33.0	0.10	-1.65	0.11	0.77	133.6	0.01	-0.71	
	6	33.0	0.10	-0.86	1.55	0.75	98.0	0.01	0.79	
	7	33.0	0.10	-0.44	1.24	0.79	112.7	0.01	0.42	
	8	33.0	0.10	-0.40	0.87	0.82	103.4	0.01		
	9	33.0	0.10	1.76	2.92	0.75	96.5	0.01	2.16	

(cont'ed)

Year	M	Water Level (m)	Reservoir Surface (Km2)	Storage (MCM)	Inflow (MCM)	Draft (MCM)	Evaporation (mm)	Evaporation (MCM)	Fluctuation (MCM)	Spillway (MCM)
	10	37.6	0.80	5.41	4.52	0.80	90.9	0.07	3.65	
	11	40.8	1.50	5.52	1.02	0.80	74.0	0.11	0.11	
	12	40.8	1.50	4.68	0.18	0.90	77.5	0.12	-0.84	
	1	40.2	1.39	3.75	0.11	0.94	74.2	0.10	-0.46	
	2	39.5	1.20	3.29	0.42	0.80	70.3	0.08	-0.69	
	3	39.0	1.10	2.60	0.39	0.99	98.6	0.09		
1981										
	4	38.5	1.00	4.78	3.09	0.78	113.6	0.11	2.18	
	5	40.2	1.40	6.35	2.50	0.79	103.4	0.14	1.57	
	6	41.3	1.65	6.26	0.84	0.75	107.5	0.18	-0.09	
	7	41.2	1.62	6.10	0.81	0.79	108.1	0.18	-0.16	
	8	41.2	1.60	5.75	0.63	0.82	97.4	0.16	-0.35	
	9	41.0	1.58	8.27	3.42	0.75	93.6	0.15	-2.52	
	10	42.5	2.00	9.02	1.73	0.80	92.0	0.18	0.75	
	11	42.8	2.10	9.60	1.52	0.80	68.8	0.14	0.58	
	12	43.1	2.22	8.89	0.39	0.90	89.2	0.20	-0.71	
	1	42.8	2.10	7.97	0.31	0.94	92.2	0.19	-0.92	
	2	42.2	1.95	6.99	0.08	0.89	88.5	0.17	-0.98	
	3	41.8	1.80	6.03	0.39	0.99	188.5	0.34	-0.96	
1982										
	4	41.1	1.60	5.82	0.76	0.78	118.0	0.19	-0.21	
	5	41.0	1.60	5.56	0.71	0.79	113.5	0.18	-0.26	
	6	40.8	1.50	5.90	1.24	0.75	102.9	0.15	0.34	
	7	41.0	1.60	6.40	1.47	0.79	112.1	0.18	0.50	
	8	41.4	1.68	5.81	0.39	0.82	94.5	0.16	-0.59	
	9	41.0	1.60	6.12	1.18	0.75	76.0	0.12	0.31	
	10	41.2	1.60	7.20	2.02	0.80	85.6	0.14	1.08	
	11	41.9	1.80	8.09	1.84	0.80	82.4	0.15	0.89	
	12	42.4	1.95	7.61	0.60	0.90	90.5	0.18	-0.48	
	1	42.1	1.90	6.49	0.00	0.94	95.7	0.18	-1.12	
	2	41.5	1.70	5.52	0.08	0.89	93.6	0.16	-0.97	
	3	40.6	1.50	5.65	1.21	0.90	120.5	0.18	0.13	
1983										
	4	41.0	1.55	4.78	0.11	0.78	131.5	0.20	-0.87	
	5	40.2	1.40	4.35	0.53	0.79	119.6	0.17	-0.43	
	6	40.0	1.36	3.65	0.18	0.75	95.7	0.13	-0.70	
	7	39.5	1.20	3.75	1.02	0.79	108.3	0.13	0.10	
	8	39.5	1.25	7.19	4.39	0.82	104.1	0.13	3.44	
	9	41.9	1.80	11.36	5.07	0.75	81.2	0.15	4.17	
	10	43.9	2.40	16.50	11.43	0.80	70.6	0.17	Full	5.32
	11	45.5	3.06	16.50	7.49	0.80	73.8	0.23	Full	6.46
	12	45.5	3.06	16.50	1.84	0.90	78.3	0.24	Full	0.70
	1	45.5	3.06	16.50	1.24	0.94	87.0	0.27	Full	0.03
	2	45.5	3.06	15.98	0.63	0.89	86.4	0.26	-0.52	
	3	45.4	3.00	14.91	0.26	0.99	112.1	0.34	-1.00	
1984										
	4	45.0	2.85	14.37	0.55	0.78	107.4	0.31	-0.54	
	5	45.0	2.80	15.72	0.44	0.79	108.3	0.30	1.35	
	6	45.3	3.00	16.04	1.39	0.75	99.3	0.30	0.32	
	7	45.4	3.01	15.25	0.29	0.79	95.9	0.29	-0.79	
	8	44.2	2.95	15.91	1.79	0.82	104.7	0.31	0.66	
	9	45.4	3.00	16.50	9.15	0.75	88.8	0.27	Full	0.54
	10	45.5	3.06	16.50	3.07	0.80	89.4	0.27	Full	2.00
	11	45.5	3.06	16.50	3.29	0.80	92.6	0.28	Full	2.21
	12	45.5	3.06	15.31	0.00	0.90	96.2	0.29	-1.19	
	1	45.2	2.95	14.12	0.00	0.94	86.3	0.25	-1.19	
	2	44.9	2.75	12.98	0.00	0.89	91.0	0.25	-1.14	
	3	44.5	2.65	11.70	0.00	0.99	110.5	0.29	-1.28	
1985										
	4	44.0	2.45	11.35	0.71	0.78	112.4	0.28	-0.35	

(cont'ed)

Year	M	Water Level (m)	Reservoir Surface (Km2)	Storage (MCM)	Inflow (MCM)	Draft (MCM)	Evaporation (mm)	Evaporation (MCM)	Fluctuation (MCM)	Spillway (MCM)
	5	43.9	2.40	11.16	0.87	0.79	111.2	0.27	-0.19	
	6	43.8	2.40	11.12	0.95	0.75	101.4	0.24	-0.04	
	7	43.8	2.40	10.80	0.71	0.79	101.2	0.24	-0.32	
	8	43.7	2.40	10.85	1.10	0.82	95.4	0.23	0.05	
	9	43.7	2.40	13.61	3.71	0.75	81.8	0.24	2.76	
	10	44.7	2.70	16.50	4.70	0.80	88.5	0.25	Full	0.77
	11	45.5	3.06	16.50	1.87	0.80	81.8	0.25	Full	0.82
	12	45.5	3.06	15.88	0.53	0.90	82.5	0.23	-0.62	
	1	45.3	3.00	14.97	0.26	0.94	78.0	0.23	-0.91	
	2	45.0	2.85	14.15	0.29	0.84	78.5	0.22	-0.82	
	3	44.9	2.75	13.14	0.26	0.94	101.9	0.28	-1.01	
1986										
	4	44.6	2.65	12.68	0.63	0.78	117.7	0.31	-0.46	
	5	44.4	2.60	12.80	1.94	0.79	127.5	0.33	0.12	
	6	44.5	2.63	13.20	1.52	0.75	141.3	0.37	0.40	
	7	44.6	2.65	12.51	0.47	0.79	139.6	0.37	-0.69	
	8	44.3	2.55	12.09	0.77	0.82	135.0	0.34	-0.42	
	9	44.1	2.55	13.95	2.84	0.75	91.7	0.23	1.86	
	10	44.9	2.75	16.50	6.28	0.80	93.4	0.26	Full	2.65
	11	45.5	3.06	16.50	1.39	0.80	96.2	0.29	Full	0.30
	12	45.5	3.06	15.61	0.32	0.90	100.3	0.31	-0.89	
	1	45.3	3.00	14.92	0.50	0.94	82.6	0.25	-0.69	
	2	45.0	2.85	13.93	0.13	0.89	79.0	0.23	-0.99	
	3	44.8	2.75	13.03	0.59	0.99	108.3	0.30	-0.90	
1987										
	4	44.5	2.65	12.24	0.34	0.76	130.7	0.35	-0.79	
	5	44.2	2.55	11.96	0.84	0.79	129.5	0.33	-0.28	
	6	44.0	2.50	12.24	1.31	0.75	113.5	0.28	0.28	
	7	44.2	2.55	11.39	0.18	0.79	93.5	0.24	-0.85	
	8	43.9	2.40	11.66	1.29	0.82	82.0	0.20	0.27	
	9	44.0	2.45	16.50	10.64	0.75	84.4	0.21	Full	4.74
	10	45.5	3.06	16.50	4.52	0.80	98.3	0.30	Full	3.42
	11	45.5	3.06	16.50	1.21	0.80	87.4	0.27	Full	0.14
	12	45.5	3.06	15.49	0.16	0.90	88.7	0.27	-1.01	
	1	45.2	2.95	14.40	0.16	0.99	104.0	0.31	-1.09	
	2	44.9	2.80	13.46	0.18	0.87	83.3	0.23	-0.94	
	3	44.7	2.70	12.29	0.13	0.97	116.1	0.31	-1.17	
1988										
	4	44.2	2.55	11.72	0.50	0.78	113.5	0.29	-0.57	
	5	44.0	2.45	11.18	0.55	0.77	120.9	0.30	-0.54	
	6	43.8	2.40	11.86	1.66	0.75	97.4	0.23	0.68	
	7	44.0	2.50	11.44	0.63	0.79	105.3	0.26	-0.42	
	8	43.9	2.40	10.89	0.47	0.82	83.9	0.20	-0.55	
	9	43.7	2.40	11.00	1.05	0.75	77.2	0.19	0.11	
	10	43.8	2.40	15.12	5.10	0.80	74.4	0.18	4.12	
	11	45.1	2.90	14.52	0.45	0.80	85.9	0.25	0.60	
	12	45.0	2.80	15.79	2.39	0.90	70.1	0.20	1.27	
	1	45.3	3.00	14.93	0.26	0.94	58.8	0.18	-0.86	
	2	45.0	2.85	14.17	0.84	0.89	73.1	0.21	-0.76	
	3	44.9	2.75	13.05	0.13	0.99	93.4	0.26	-1.12	
1989										
	4	44.5	2.65	12.81	0.84	0.78	112.6	0.30	-0.24	
	5	44.5	2.63	13.43	1.68	0.79	101.2	0.27	0.62	
	6	44.7	2.70	14.43	2.02	0.78	99.2	0.27	1.00	
	7	44.9	2.79	14.26	0.89	0.79	91.0	0.25	-0.17	
	8	44.9	2.75	16.40	3.21	0.82	90.8	0.25	2.14	
	9	45.4	3.05	16.50	9.93	0.75	87.7	0.27	Full	8.81
	10	45.5	3.06	16.50	7.86	0.80	80.7	0.25	Full	6.81
	11	45.5	3.06	16.50	1.34	0.80	76.4	0.23	Full	0.31
	12	45.5	3.06	15.62	0.29	0.90	89.6	0.27	-0.88	

(cont'ed)

Year	M	Water Level (m)	Reservoir Surface (Km2)	Storage (MCM)	Inflow (MCM)	Draft (MCM)	Evaporation (mm)	Evaporation (MCM)	Fluctuation (MCM)	Spillway (MCM)
	1	45.3	3.00	14.54	0.03	0.94	57.5	0.17	-1.08	
	2	45.0	2.80	13.65	0.21	0.89	76.5	0.21	-0.89	
	3	44.7	2.70	12.52	0.13	0.99	101.1	0.27	-1.13	
1990										
	4	44.3	2.55	12.08	0.60	0.78	101.4	0.26	-0.44	
	5	44.1	2.55	10.94	0.03	0.79	147.7	0.38	-1.14	
	6	43.7	2.40	10.07	0.13	0.75	102.8	0.25	-0.87	
	7	43.2	2.25	9.14	0.11	0.79	112.8	0.25	-0.93	
	8	42.8	2.18	8.14	0.05	0.82	107.0	0.23	-1.00	
	9	42.4	1.95	11.93	11.68	0.75	69.4	0.14	3.79	
	10	44.0	2.50	16.50	6.91	0.80	96.7	0.24	Full	1.3
	11	45.5	3.06	16.50	4.89	0.80	81.3	0.25	Full	3.84
	12	45.5	3.06	16.50	1.52	0.90	72.8	0.22	Full	0.4
	1	45.5	3.06	15.61	0.29	0.94	80.0	0.24	-0.89	
	2	45.3	3.00	14.63	0.16	0.89	81.8	0.25	-0.98	
	3	45.0	2.80	13.71	0.34	0.99	97.3	0.27	-0.92	
1991										
	4	44.8	2.73	12.66	0.08	0.78	127.9	0.35	-1.05	
	5	44.4	2.60	12.02	0.39	0.79	93.0	0.24	-0.64	
	6	44.1	2.55	11.42	0.59	0.75	85.3	0.22	-0.60	
	7	43.9	2.40	10.60	0.18	0.79	88.8	0.21	-0.82	
	8	43.6	2.37	10.65	1.13	0.82	107.6	0.26	-0.05	
	9	43.6	2.37	12.33	2.60	0.95	72.9	0.17	1.68	
	10	44.2	2.55	16.02	4.73	0.80	93.5	0.24	3.69	
	11	45.4	3.01	15.49	0.47	0.80	66.6	0.20	-0.53	
	12	45.2	2.95	14.53	0.13	0.70	64.3	0.19	-0.96	
	1	45.0	2.80	13.55	0.11	0.94	54.6	0.15	-0.98	
	2	44.7	2.70	12.61	0.13	0.89	65.0	0.18	-0.94	
	3	44.3	2.55	11.62	0.21	0.99	82.3	0.21	-0.99	
1992										
	4	44.0	2.45	11.74	1.13	0.78	93.8	0.23	0.12	
	5	44.0	2.45	11.83	1.10	0.79	88.0	0.22	0.09	
	6	44.0	2.45	11.07	0.21	0.75	90.0	0.22	-0.76	
	7	43.8	2.40	10.24	0.18	0.79	91.5	0.22	-0.83	
	8	43.4	2.25	9.82	0.58	0.82	78.0	0.18	-0.42	
	9	43.2	2.23	11.11	2.23	0.75	85.6	0.19	1.29	
	10	43.8	2.40	16.50	11.96	0.80	83.9	0.20	Full	5.57
	11	45.5	3.06	16.50	1.84	0.80	78.5	0.24	Full	0.80
	12	45.5	3.06	15.89	0.53	0.90	77.1	0.24	-0.61	
	1	45.3	3.00	15.68	0.92	0.94	63.1	0.19	-0.21	
	2	45.3	3.00	15.03	0.50	0.89	85.3	0.26	-0.65	
	3	45.1	2.85	14.19	0.45	0.99	104.3	0.30	-0.84	
1993										
	4	44.9	2.75	13.92	0.81	0.78	109.3	0.30	-0.27	
	5	44.8	2.75	13.30	0.42	0.79	92.5	0.25	-0.62	
	6	44.6	2.65	12.39	0.08	0.75	89.1	0.24	-0.91	
	7	44.2	2.55	11.74	0.37	0.79	88.9	0.23	-0.65	
	8	44.0	2.45	11.61	0.89	0.82	83.3	0.20	-0.13	
	9	44.0	2.45	13.77	3.10	0.75	77.0	0.19	2.16	
	10	44.8	2.73	15.13	2.42	0.80	96.8	0.26	1.36	
	11	45.1	2.90	15.73	1.71	0.80	107.9	0.31	0.60	
	12	45.3	3.00	14.98	1.34	0.90	62.4	0.19	-0.75	
	1	45.0	2.85	14.04	0.16	0.94	57.3	0.16	-0.94	
	2	44.9	2.75	13.41	0.45	0.89	70.8	0.19	-0.63	
	3	44.7	2.70	12.36	0.21	0.99	99.1	0.27	-1.05	
1994										
	4	44.2	2.55	11.64	0.34	0.78	111.7	0.28	-0.72	
	5	44.0	2.45	10.94	0.32	0.79	95.9	0.23	7.00	
	6	43.7	2.40	10.16	0.26	0.75	119.8	0.29	-0.78	
	7	43.3	2.27	9.40	0.29	0.79	112.4	0.26	-0.76	

(cont'ed)

Year	M	Water Level (m)	Reservoir Surface (Km2)	Storage (MCM)	Inflow (MCM)	Draft (MCM)	Evaporation (mm)	Evaporation (MCM)	Fluctuation (MCM)	Spillway (MCM)
	8	43.1	2.20	9.18	0.81	0.82	95.9	0.21	-0.22	
	9	42.9	2.10	15.13	6.91	0.75	98.9	0.21	5.95	
	10	45.1	2.90	16.50	3.84	0.80	78.3	0.23	Full	1.44
	11	45.5	3.06	16.50	2.26	0.80	50.6	0.15	Full	1.31
	12	45.5	3.06	15.68	0.37	0.90	96.0	0.29	-0.82	
	1	45.3	3.00	14.72	0.29	0.94	101.8	0.31	-0.96	
	2	45.0	2.80	13.88	0.26	0.89	75.2	0.21	-0.84	
	3	44.8	2.75	12.76	0.11	0.97	86.5	0.24	-1.12	

END

3.7.3 Water Source Development up to 2010

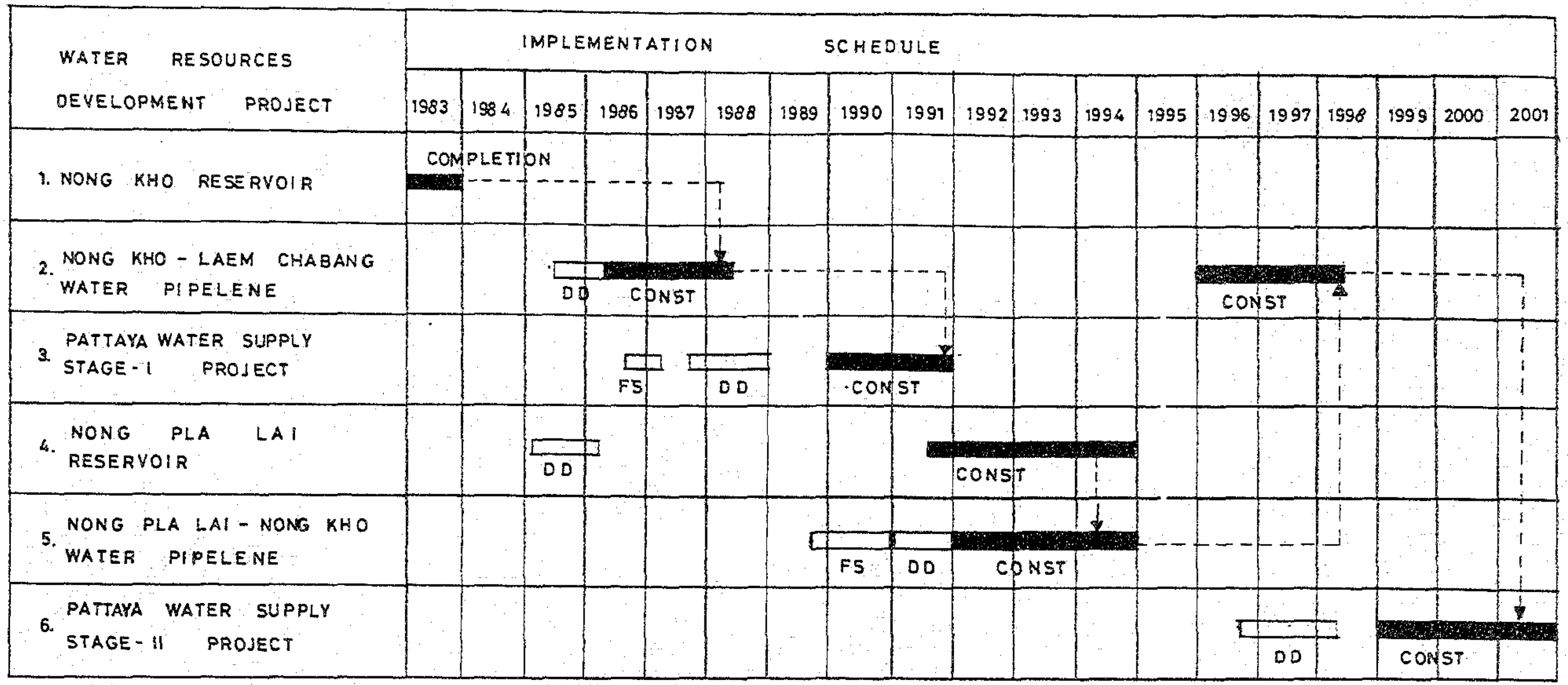
The Nong Pla Lai Reservoir, now under planning, will be recommended as the water source to meet the demand in 2010, the target year of the Stage II Project.

Besides the reservoir's construction, a Nong Plan Lai - Nong Kho pipeline and additional Nong Kho - Laem Chabang pipeline are needed to introduce the reservoir water to Pattaya.

3.7.4 Schedule of Water Sources Development

Fig-3.15 shows the schedule of developing water sources in the Stage I and II Projects.

PATTAYA WATER SUPPLY & WATER RESOURCES DEVELOPMENT



FS: FEASIBILITY STUDY
DD: DETAIL DESIGN
CONST: CONSTRUCTION

FIGURE	SCHEDULE OF WATER SOURCES DEVELOPMENT
3.15	

JAPAN INTERNATIONAL COOPERATION AGENCY

3.8 List of Reference

1) JICA/RID, March 1982
The East Coast Water Resources Development Project
- Main Report & Supporting Report

2) JICA/RID, Jan. 1983
The East Coast Water Resources Development Project (Phase II)
Study Report on Long-Term Water Supply Plan

3) JICA/RID, Aug. 1983
The East Coast Water Resources Development Project (Phase II)
Vol-2, Main Report, Feasibility Study on Khlong Luang Dam Scheme

4) JICA/PWD, March 1984
Feasibility Study on The Nong Kho-Laem Chabang Water Pipeline Project, Main Report & Supporting Report

5) GTZ/PWA, Jan. 1985
Chonburi Water Supply Project
Vol-II, Phase II, Master Plan Report
Vol-I, Phase III, Feasibility Study Report (July 1985)
Vol-I, Phase I, Immediate Improvements (Sep. 1984)

6) JICA, Nov. 1983
The Study on The Development Project of the Industrial Port on the Eastern Seaboard in the Kingdom of Thailand
Final Report

7) NSC/Embassy of Japan, Bangkok, June 1985
Identification Survey of the Provincial Waterworks Authority, Pattaya-Na Klua Water Supply Expansion project

8) JICA , Aug. 1983
The East Coast Water Resources Development Project (Phase II)
Vol-4, main Report, Feasibility Study on Khlong Thap Ma Dam Scheme.

9) JICA, Aug. 1983
The East Coast Water Resources Development Project (Phase II)
Vol-3, Main Report, Feasibility Study on Khlong Yai Dam Scheme
Pattaya-(2)

10) JICA, TAT Dec. 1977
Pattaya Tourism Development, Thailand, Final Report

11) PWD, Sanyu/Team, Oct. 1985
Nong Kho-Laem Chabang Water Pipeline Project
Report of Review of previous Studies (Draft)

12) National Statistical Office, 1983
Statistical Reports of Changwat, Chonburi

13) NEA (National Energy Administration, Ministry of Science), 1983
1981 Hydrologic Data Vol-I (River Discharge)
1981 Hydrologic Data vol-II (Meteologic Data)

14) RID Nov. 1983
Thailand Hydrological Yearbook, Water Year vol-24

15) EGAT, July 1985
Guide Book for Accessing Hydrologic Data

16) EGAT, August 1984
Kley Maps of River Basins in Thailand

17) EGAT, December 1980
Surface Runoff and Specific Yield of River Basins in Thailand

18) RID, April 1983
Mean Annual Flow, Instantaneous Peak Discharge, Average Yield of
Runoff and Specific Yield of flood Flow for Rivers in Thailand

19) Royal Thai Survey Department, 1974
Hydrography (Atlas of Thailand)
Mean Monthly Discharge (1951-1870)

20) Royal Thai Survey Department, 1974
Daily Discharge of the Mayor Rivers, 1965/66-1969/70
- Ping River at Ban Tha Sala, Chiangmai
- Muin river at Seri Prachathipatai Bridge, Ubon Ratchathani

APPENDIX 4

STUDY ON WATER QUALITY

APPENDIX 4

APPENDIX 4 WATER QUALITY

APPENDIX 4 WATER QUALITY

4.1 Water Sources

4.1.1 Water Sources for Pattaya-Na Klua Treatment Plant

The results of water quality analysis of the Mab Prachan Reservoir, made by PWA and the study team, are shown in Table-4.1.

1) Characteristics of water

a) Color

The value is low, ranging from zero to 15 Pt-Co units.

b) Turbidity

The value varies from 4.5 to 28 SiO2 units by PWA analysis. As apparent from it, the turbidity is not notably high.

c) pH

The value ranges from 6.9 to 7.85, staying within DWS.

d) Alkalinity

The value, ranging from 32 to 38 mg/l as CaCO3, is rather low and are almost steady.

e) Hardness

The value, ranging from 24 to 54 mg/l as CaCO3, is considered moderate.

f) Iron and Manganese

The value ranges from 0.06 to 0.11 mg/l for iron and less than 0.1 mg/l for manganese. Both of them satisfy DWS.

g) Nitrate

Nitrate, originating possibly from the soil and the dissolved plants, is detected slightly.

Table-4.1 WATER QUALITY OF MAB PRACHAN RESERVOIR

Item	Unit						PWA Standard
Date		16-1-85	26-2-85	23-8-85	21-10-85	11-12-85	
Color	Pt·Co units	2	-	-	-	none	5
Turbidity	SiO_2 units	12	22	28	15	4.5	5
pH		7.7	7.1	7.3	7.4	6.9	6.5-8.5
Conductibity	micromhos/cm	95	-	-	-	82	-
T-Hardness	mg/l as $CaCO_3$	54	50	44	24	24	-
P-Alkalinity	mg/l as $CaCO_3$	nil	nil	nil	nil	nil	-
M-Alkalinity	mg/l as $CaCO_3$	34	38	34	38	36	-
Calcium	mg/l	20.4	8.8	8.0	5.6	9.6	75
Magnesium	mg/l	1.9	6.7	5.7	2.4	nil	50
Chloride	mg/l	8	4	8	5	10	250
Iron	mg/l	0.07	-	-	-	0.38	0.5
Total Solids	mg/l	87	-	-	-	-	500
Nitrate-N	mg/l	-	-	-	-	-	45 as NO_3
A B S	mg/l	-	-	-	-	-	0.5
Manganese	mg/l	0.14	-	-	-	-	0.3
Copper	mg/l	0.022	-	-	-	-	1.0
Zinc	mg/l	0.043	-	-	-	-	5.0
Sulfate	mg/l	2	-	-	-	-	200
Fluoride	mg/l	0.01	-	-	-	-	0.7

DATA SOURCE : PWA

Item	Unit			PWA Standard
Date		26-1-86	13-2-86	
Temperature	°C	28.5	29.8	-
Color	Pt·CO units	8	15	5
Turbidity	N T U	14	10	5
pH		7.5	7.85	6.5-8.5
Conductibity	micromhos/cm	89	93	-
Total Solids	mg/l	171	-	500
Alkalinity	mg/l as $CaCO_3$	32	32	-
Hardness	mg/l as $CaCO_3$	39	27	-
Calcium	mg/l	10	8	75
Magnesium	mg/l	3.1	1.7	50
Iron	mg/l	0.06	0.11	0.5
Manganese	mg/l	<0.1	<0.1	0.3
Chloride	mg/l	8.5	2	250
Sulfate	mg/l	3	<1	200
Ammonia-N	mg/l	<0.2	<0.2	-
Nitrite-N	mg/l	<0.01	<0.01	-
Nitrate-N	mg/l	0.4	0.5	45 as NO_3
Phosphate	mg/l	0.06	0.04	-
Coliform group	N/100ml	0	1400	<2.2
Total colonies	N/ml	54	280	500

DATA SOURCE : STUDY TEAM

2) Evaluation

a) Presently the water quality of the Mab Prachan reservoir is good for water supply purposes.

b) Total Solids are comparatively high, despite a moderate conductivity. Possibly, suspended matters, including abundant plankton, are contained in the solids.

c) Nitrogen and phosphorus are thought to be the governing elements of plankton growth. When more than 0.2 mg/l nitrogen and 0.02 mg/l phosphorus co-exist, the possibility of eutrophication is concerned about generally. The present concentrations of nitrogen and phosphorus, may cause eutrophication in the future, thus resulting in filter clogging and/or odor outbreak. Attention should be paid to plankton growth.

4.1.2 Other Sources

Sea water is thought to be affecting the groundwater in this area. Hotels and households in the served area as well as households in the unserved area presently use shallow wells, though the wells' production is rather limited.

Fig-4.1 shows the location of eight wells and Table-4.2 lists the wells' water analysis.

As seen in the table below, all wells surveyed by the study team were found unsuitable as sources of public water supply, because of the following itemized conditions. If the water is to be used as drinking water, desinfection by chemicals or boiling should be provided to protect the users from a bacteria.

UNACCEPTABLE CONDITIONS OF EIGHT WELLS

	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	ST.7	ST.8
Low pH (<6.5)	*			*			*	
High Conductivity (>500micromhos/cm)			*	*	*	*		*
High Hardness (>300mg/l)			*					*
High Iron (>1.0mg/l)	*			*	*			
High Ammonia (>0.5mg/l)		*		*	*	*		*
Coliform	*	*	*			*	*	*

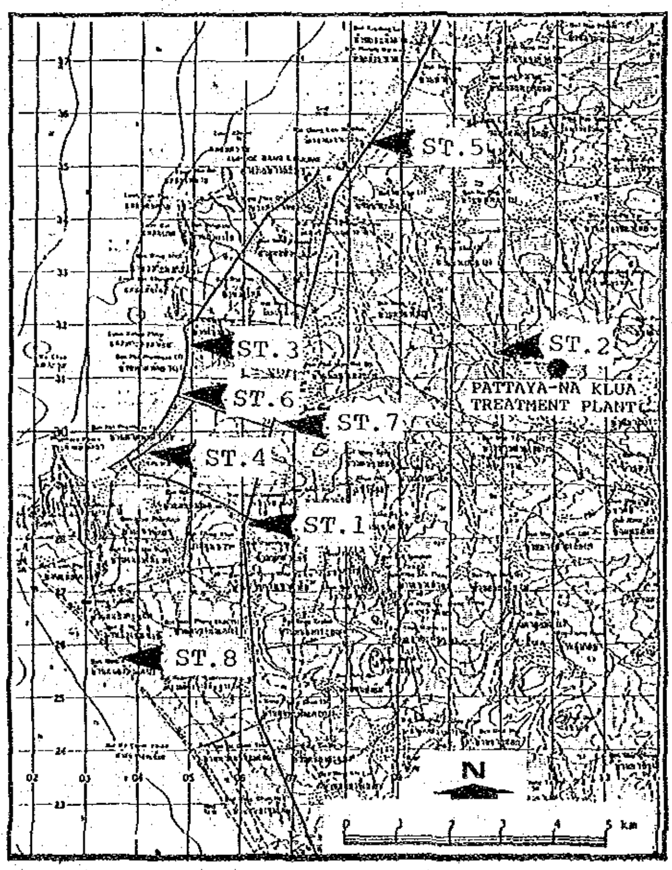
NOTE : ST. : Sampling station
* : Yes

Table-4.2 WATER QUALITY OF GROUNDWATER IN PATTAYA

Item	Unit	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	ST.7	ST.8
Date		12-2-86	12-2-86	12-2-86	12-2-86	14-2-86	14-2-86	14-2-86	14-2-86
Well depth	m	12	6	3.3	6	6	6	8	7
Temperature	°C	29.0	28.0	28.9	28.8	28.1	29.2	30.2	31.2
Color	Pt·Co units	15	<2	<2	120	30	20	<2	12
Turbidity	N T U	10	3	0.5	3	5	<1	<1	3
pH		5.84	6.58	7.14	6.44	6.95	7.10	4.62	7.30
Conductibity	micromhos/cm	270	480	990	770	860	940	92	1090
Total solids	mg/l	-	-	-	-	-	-	-	-
Alkalinity	mg/l as $CaCO_3$	22	148	319	120	184	242	2	225
Hardness	mg/l as $CaCO_3$	32	116	344	131	110	214	3	372
Calcium	mg/l	6.8	38	117	36	28	66	1	110
Magnesium	mg/l	3.9	4.9	13	9.7	10	12	<1	24
Chloride	mg/l	28	20	60	98	96	97	13	171
Sulfate	mg/l	8	20	65	78	1	25	1	19
Iron	mg/l	2.6	0.06	0.02	3.8	1.23	0.40	0.08	0.58
Manganese	mg/l	0.3	<0.1	<0.1	0.2	0.1	<0.1	<0.1	0.4
Ammonia-N	mg/l	<0.2	1.8	<0.2	8.0	0.8	4.0	<0.2	0.7
Nitrite-N	mg/l	<0.01	0.40	<0.01	-	0.90	0.03	<0.01	0.80
Nitrate-N	mg/l	0.2	2.2	4.8	1.5	2.7	2.7	3.4	2.4
Phosphte	mg/l	-	-	-	-	-	0.68	-	-
Coliform group	N/100ml	1900	1000	2000	-	0	200	100	800
Total colonies	N/ml	81	>300	190	-	170	11	>300	120

DATA SOURCE : STUDY TEAM

Fig-4.1 GROUNDWATER SAMPLING POINTS



4.2 Treated Water

4.2.1 Existing Conditions

Table-4.3 shows the result of water quality analysis made by PWA on the raw and treated water. Fig-4.2 shows the monthly average dosage of alum, chlorine and lime.

Condition of treated water quality is described below.

a) Turbidity of the treated water is relatively high despite low turbidity of the raw water. This is possibly due to a break-through of turbidity in the filter because of insufficient backwashing and the downward movement of mud balls in the sand bed.

b) pH of the treated water fell below DWS in some months. pH values of water for distribution must be adjusted to stay within DWS to protect pipes from corrosion.

c) Although a small amount of ABS, indicative of domestic sewage intrusion, is present. This is not anticipated to be a significant problem as it was very low.

d) In Fig-4.2, lime dosage fluctuates in a far higher range than alum dosage. In principle, lime is added to adjust pH for flocculation and to restore alkalinity reduced by alum, as well as to control pH against corrosion. pH of the listed treated water shows fluctuation from 6.3 to 7.6. Alum and lime dosage shall be controlled on the basis of jar test results with the purpose of preventing corrosion.

f) Chlorine dosage fluctuates less and averages 1.78 mg/l through the year. A residual chlorine survey, conducted at consumers' taps in the whole service area, revealed that bactericidal effect was maintained in the system, as seen in Fig-4.3. Several points where low residual chlorine was detected should be investigated to find out the cause.

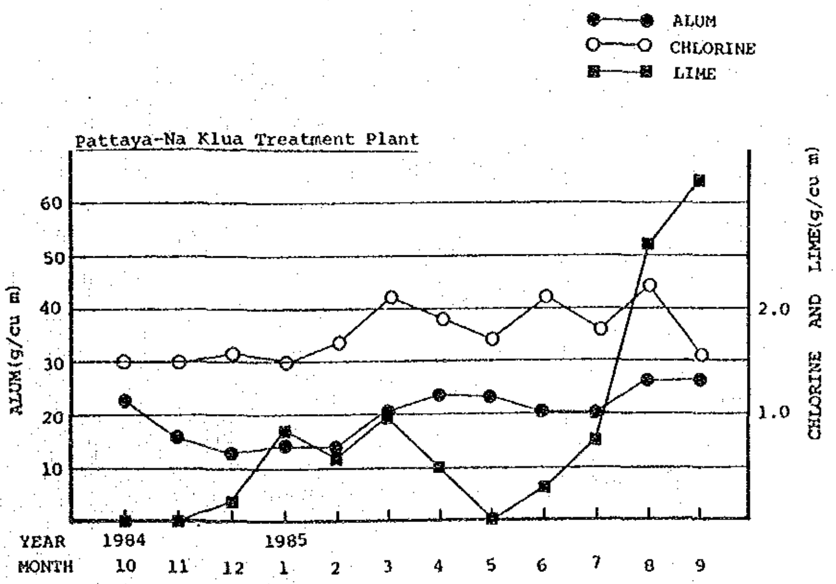
An organized survey of the whole area, as conducted and reported by the study team, should be made periodically for reasonable control of the distributed water quality.

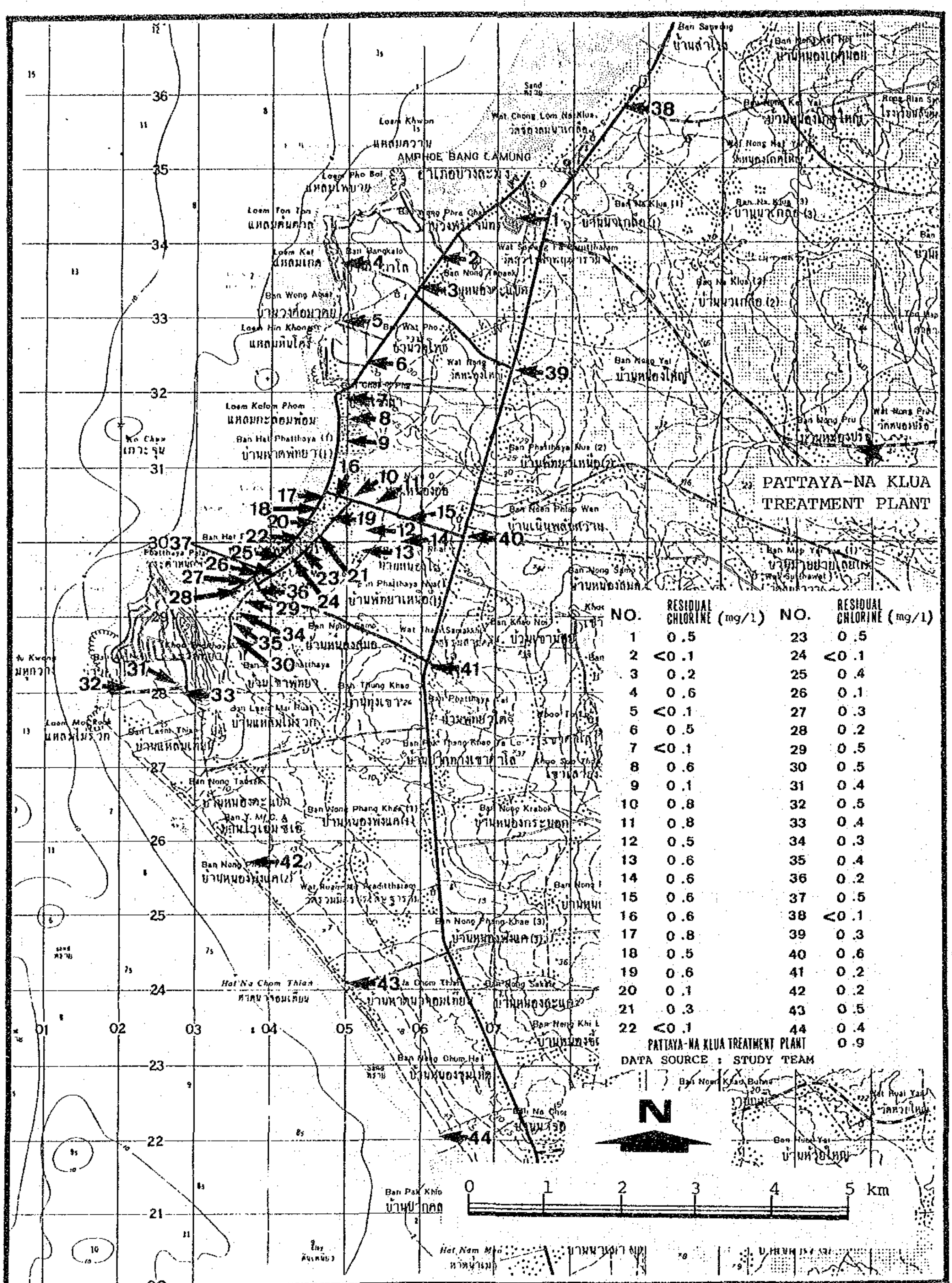
Table-4.3 WATER QUALITY OF PATTAYA-NA KLUA TREATMENT PLANT

Item	Unit	Raw/Treated	Raw/Treated	Raw/Treated	Raw/Treated	Raw/Treated	PWA Standard
Date		16-1-85	26-2-85	23-8-85	21-10-85	11-12-85	
Color	Pt·Co units	2 /none	- / -	- / -	- / -	none/none	5
Turbidity	SiO_2 units	12 /2.5	22 /4.0	28 /5.0	15 /3.5	4.5/4.5	5
pH		7.7/7.4	7.1/6.7	7.3/6.3	7.4/7.6	6.9/6.9	6.5-8.5
Conductivity	micromhos/cm	95 /100	- / -	- / -	- / -	82 /87	-
T-Hardness	mg/l as $CaCO_3$	54 /34	50 /44	44 /40	24 /28	24 /26	-
P-Alkalinity	mg/l as $CaCO_3$	nil/nil	nil/nil	nil/nil	nil/nil	nil/nil	-
M-Alkalinity	mg/l as $CaCO_3$	34 /26	38 /34	34 /24	38 /26	36 /28	-
Calcium	mg/l	20.4/12.4	8.8/7.2	8.0/15.2	5.6/7.2	9.6/6.4	75
Magnesium	mg/l	1.9/1.9	6.7/6.2	5.7/4.8	2.4/2.4	nil/2.4	50
Chloride	mg/l	8 /9	4 /4	8 /7	5 /7	10 /8	250
Iron	mg/l	0.07/nil	- / -	- / -	- / -	0.38/0.06	0.5
Total solids	mg/l	87 /92	- / -	- / -	- / -	- / -	500
Nitrate-N	mg/l	- /0.88	- / -	- / -	- / -	- / -	45 as NO_3
A B S	mg/l	- /0.013	- / -	- / -	- / -	- / -	0.5
Manganese	mg/l	0.14/nil	- / -	- / -	- / -	- / -	0.3
Copper	mg/l	0.022/0.030	- / -	- / -	- / -	- / -	1.0
Zinc	mg/l	0.043/0.197	- / -	- / -	- / -	- / -	5.0
Sulfate	mg/l	2 /6.3	- / -	- / -	- / -	- / -	200
Fluoride	mg/l	0.01/0.08	- / -	- / -	- / -	- / -	0.7

DATA SOURCE : PWA

Fig-4.2 CHEMICAL DOSAGE MONTHLY AVERAGES





NO.	RESIDUAL CHLORINE (mg/l)	NO.	RESIDUAL CHLORINE (mg/l)
1	0.5	23	0.5
2	<0.1	24	<0.1
3	0.2	25	0.4
4	0.6	26	0.1
5	<0.1	27	0.3
6	0.5	28	0.2
7	<0.1	29	0.5
8	0.6	30	0.5
9	0.1	31	0.4
10	0.8	32	0.5
11	0.8	33	0.4
12	0.5	34	0.3
13	0.6	35	0.4
14	0.6	36	0.2
15	0.6	37	0.5
16	0.6	38	<0.1
17	0.8	39	0.3
18	0.5	40	0.6
19	0.6	41	0.2
20	0.1	42	0.2
21	0.3	43	0.5
22	<0.1	44	0.4
		PATTAYA-NA KLUA TREATMENT PLANT	0.9

DATA SOURCE : STUDY TEAM

FIGURE 4.3	RESIDUAL CHLORINE SAMPLING POINTS (PATTAYA)

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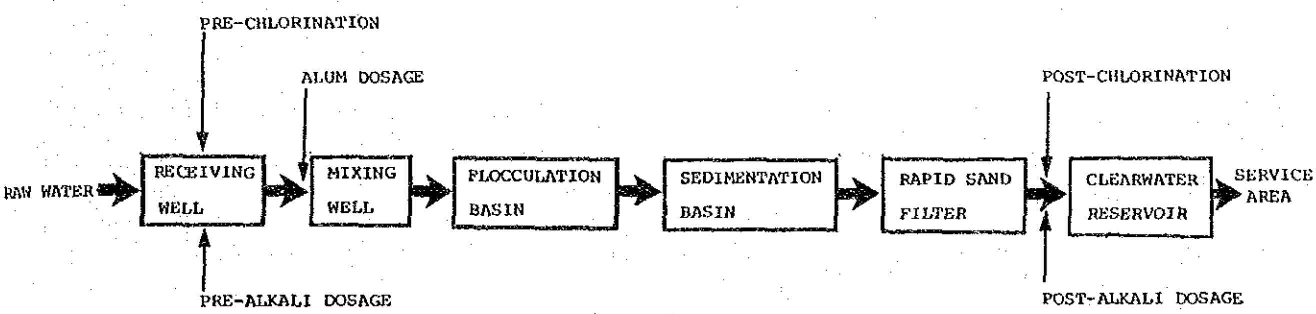
4.2.2 Improvement of Treatment Method

To improve the treated water quality, rectifying chemical dosages and filter-backwashing is needed.

Fig-4.4 shows the present treatment process and the ways of improvement.

Fig-4.4 FLOW SHEET OF TREATMENT PROCESS



a) Pre-chlorination should be made when the algae number is found excessively high. Killed algae in suspension will be partly removed by sedimentation and filtration, and proliferation will be checked.

b) Pre-alkali dosage is useful in optimizing sedimentation effect.

c) Alum and pre-alkali dosage shall be determined by jar testing.

d) The performance post-chlorination is to be checked by surveying residual chlorine.

e) Post-alkali dosage is effective in inhibiting corrosion of pipes.

f) The timing of backwashing filters shall be judged by the head loss and turbidity of filtered water. Filter sand shall be checked of cleaness occasionally, by sampling sand of different depth and scrubbing it by hand in clear water.

4.3 Possible Water Sources in Future

Of the several water sources, Nong Kho is the most promissing for this project, for the reasons related in Chapter 7 of the main report.

Water quality of the reservoir and inflowing river (Khlong Huai Chaew) was studied accordingly and the results are shown in Table-4.4.

Characteristics

Finding of the water quality is characterized as follows:

a) Color is high in spite of the low turbidity both in the reservoir and Khlong Huai Chaew.

b) In the epilimnion and thermocline in 0 - 4 m depth from the surface, plankton is abundant. In the bottom stratum, iron, manganese, phosphorus and ammonia are eluted from the bottom under anaerobic conditions.

   Judging from the vertical distribution of 1) temperature, 2) pH, and 3) dissolved oxygen, stratification is formed in the reservoir indicating the features of a typical eutrophic reservoir. The eutrophication is not considered to be caused by the external influent of the pollutants but by the dissolution of soils and plants in the land and fecal matters of the then-living people (about 4,000) before the land was submerged under water when completion of the dam.

c) In the stratum ranging from 4 to 6 m depth, water quality is good as it is least subject to the influence of the plankton-rich upper layer and the anaerobic lower layer. 6 to 8 m depth water, though inferior, is still acceptable.

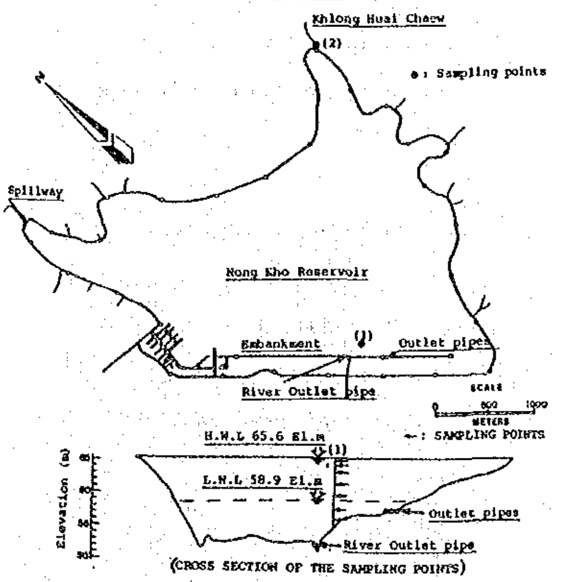
Table-4.4 WATER QUALITY OF THE NONG KHO RESERVOIR AND KHLONG HUAI CHAEW

Item	Unit	NONG KHO RESERVOIR (TRANSPARENCY : 0.8m)							KHLONG HUAI CHAEW
Depth	m	0.5	1	2	4	6	8	9.5	
Temperature	°C	30.0	30.0	29.9	29.1	28.9	28.7	27.9	31.0
Color	Pt·Co units	25	30	25	25	25	30	100	60
Turbidity	N T U	5	5	5	5	2	3	35	10
pH		7.77	7.77	7.73	7.14	7.10	7.04	6.96	7.25
Conductivity	micromhos/cm	105	101	101	102	102	102	122	116
Alkalinity	mg/l as $CaCO_3$	35	35	33	32	36	36	46	36
Hardness	mg/l as $CaCO_3$	28	28	28	25	28	28	37	30
Iron	mg/l	0.04	0.04	0.04	0.05	0.03	0.06	1.70	1.35
Manganese	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	0.3
Chloride	mg/l	4	3	3	3	3	4	4	4
Sulfate	mg/l	2	2	2	2	2	2	6	3
Ammonia-N	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	>1	<0.2
Nitrite-N	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01
Nitrate-N	mg/l	-	-	-	-	-	-	-	0.3
Total Nitrogen	mg/l	0.26	0.27	0.29	0.32	0.38	0.88	1.06	-
Total Phosphorus (Phosphate-P)	mg/l	0.029	0.033	0.034	0.034	0.034	0.047	0.105	(0.08)
A B S	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Dissolved Oxygen	mg/l	7.79	7.63	7.30	4.22	4.22	2.60	0.27	-
$KMnO_4$ consumed	mg/l	16.4	16.4	16.4	5.1	5.1	5.7	15.8	12.0
C O D (Mn)	mg/l	4.1	4.1	4.1	1.3	1.3	1.4	4.0	3.0
Hydrogen Sulfide	mg/l	-	-	-	-	-	-	0.2	-
Coliform group	N/100ml	100	100	0	0	0	-	0	0
Total colonies	N/ml	120	100	110	120	47	-	>300	150

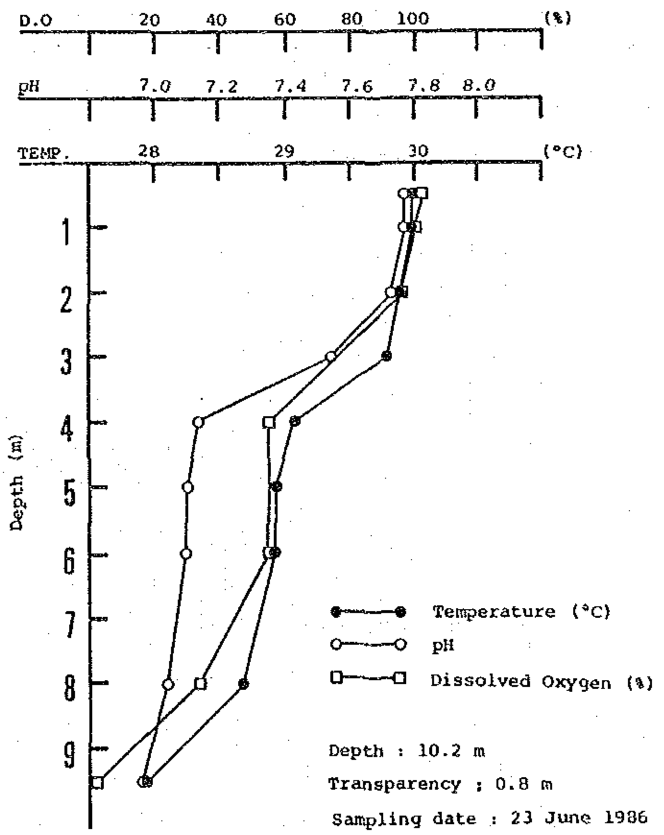
SAMPLING DATE : Nong Kho reservoir June 23, 1986 Khlong Huai Chaew June 24, 1986
NOTE : COD has been caluculated from the results of N/100 $KMnO_4$ consumed.

DATA SOURCE : STUDY TEAM

SAMPLING POINTS



DISTRIBUTION OF TEMPERATURE, pH AND DISSOLVED OXYGEN WITH DEPTH



Recommendation

When the reservoir's water is used for potable supply, the following points shall be paid attention:

a) Plankton-rich water in the upper layer may cause biological problems and anaerobic water in the lower layer chemical problems in treatment. Collecting water from 4 to 8 m depth is most desirable.

b) When the inflow is large in rainy season, say from May to October, disturbance by the inflow will prevent stratification.

c) To check the stratification, periodical investigation of the vertical distribution of water treatment is needed.

d) The high water level of the reservoir is 65.6 EL m and the outlet is positioned at 58 EL m, allowing a 7.6 m depth for collection. As the top 4 m layer is not preferable, only the 3.6 m depth layer of good quality water is calculated to be usable under the stratified condition.

e) The effective storage capability of the reservoir, between 65.6 and 58.9 EL m (Low Water Level), is 19 MCM. According to the plan, the reservoir will begin to receive water from Nong Pla Lai Dam in 1994, and in the same year, the reservoir is required to supply about 16 MCM water to Laem Chabang, Pattaya and other demand.

f) When the supply to Laem Chabang, starting in near future, takes a substantial volume of water constantly, the possibility of stratification will decrease and the supply to Pattaya, expected to start in 1992, will lower the possibility furthermore. Eventually in 1994, the inflow from Nong Pla Lai and the outflow to Laem Chabang/Pattaya will improve the situation considerably.

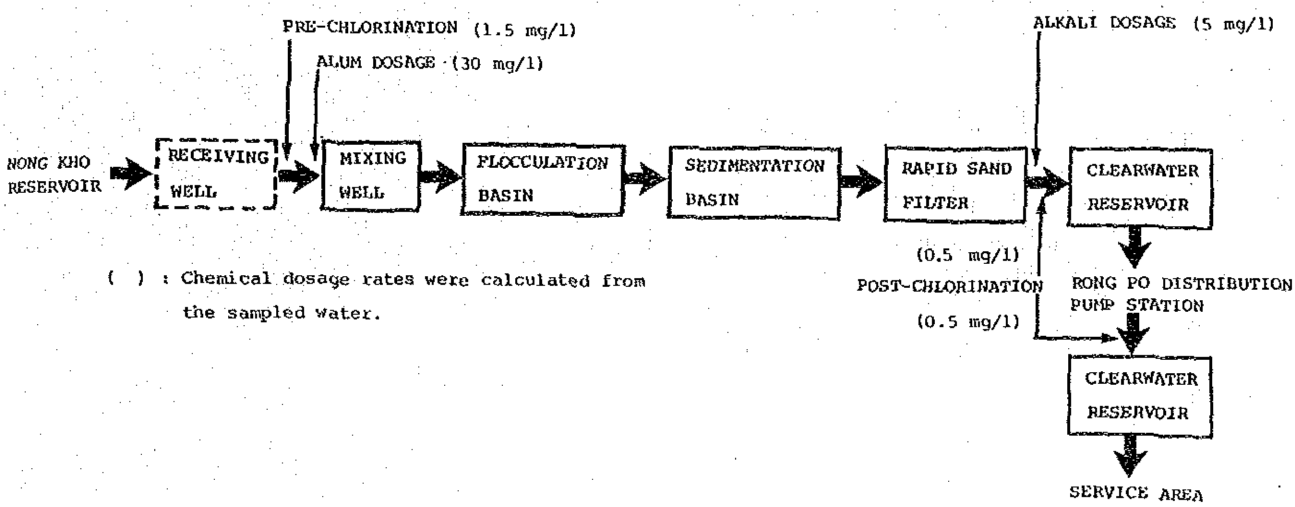
g) For this project, the impact of drawing the eutrophic water may be felt and coped with from 1992 to 1994. However, unless an extraordinary growth of plankton occurs, the treatment method described in 4.2.2 will be able to manage the situation.

Proposed Treatment Process

Fig-4.5 shows the proposed treatment process, made upon consideration of the previously mentioned situation.

The sedimentation basin is of a horizontal flow type and the rapid sand filter is of a conventional type.

Fig-4.5 PROPOSED TREATMENT PROCESS



a) Per-chlorination

Free residual chlorine of about 0.5 mg/l is said to be required to kill plankton and prevent its growth in the treatment process. As chlorine is consumed by inorganic oxygen-demanding substances like ammonia and iron, and partly decomposed by direct sunlight, excessive dosage is usually necessary. To maintain a level of 0.5 to 1.0 mg/l residual chlorine, the shown 1.5 mg/l of chlorine, for instance, is to be added. The dosage shall be determined by measuring the background chlorine demand from time to time.

b) Alum dosage

An alum dosage, higher than usually is added, will be needed here as the water's color value is high. The dosage should be controlled on the result of jar test. Presently, the optimum dosage for a mixed sample of 6 and 8 m depth water has been found to be 30 mg/l.

c) Alkali dosage

The raw water alkalinity, about 30, and pH, from 7.0 to 7.7, will be lowered by the dosed alum. As low alkalinity and pH may cause corrosion, alkali dosage shall be monitored.

When alkali dosage is found to be effective, pre-alkali dosage is to be practiced to improve coagulation/flocculation. The shown 5 mg/l post-alkali dosage is for corrosion control.

d) Post-Chlorination

The post-chlorination is done to ensure the safety of water, to completely remove pathogenic organisms, and protect the distribution system from possible future contamination.

APPENDIX 5

QUESTIONNAIRE SURVEY

APPENDIX 5

APPENDIX 5 QUESTIONNAIRE SURVEY

APPENDIX 5 QUESTIONNAIRE SURVEY

5.1 Objective

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

This survey was intended to obtain the basic and direct information on the present uses of water by the inhabitants in the project areas, and also to obtain the information necessary for estimation of future demand.

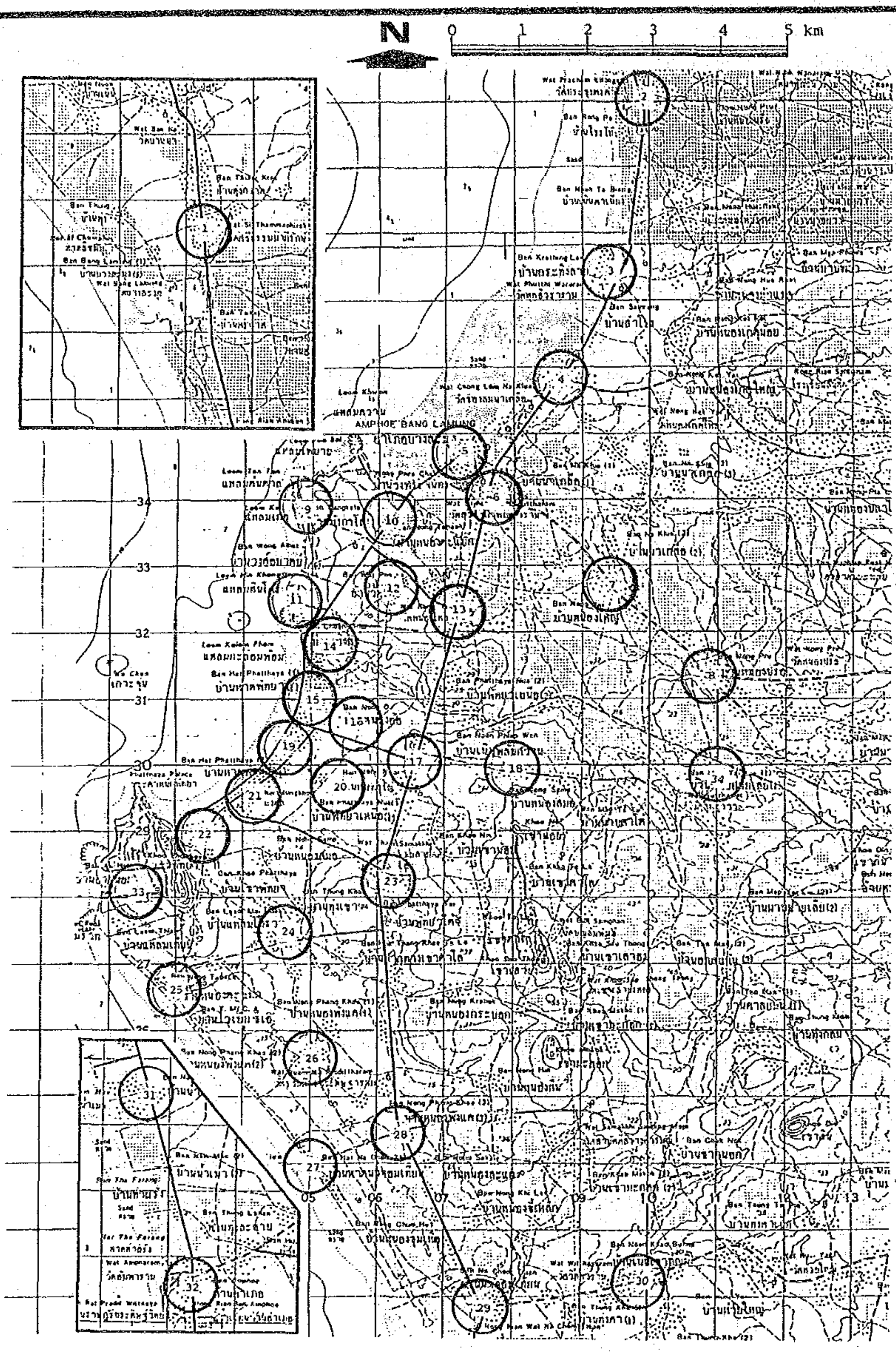
Survey subjects were selected so that the itemized information might clear a whole structure of water supply and that the co-relation of surveyed factors contributed to the analysis of water-demand structure and a systematic approach to water demand forecast.

5.2 Survey Areas and Interviewees

Although the survey area covered to all districts in the project areas, inclusive of both the served and unserved area, emphasis was placed on the busiest parts of the served areas and on the most promising parts of the planned future service areas. In the emphasized area, more samples were taken than in the other areas.

The points where the questionnaire survey was conducted are shown in Fig-5.1.

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



No. Surveyed points

FIGURE 5.1

MAP OF SURVEYED ZONE
PATTAYA

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5.3 Survey Items

The questionnaire form used for the survey is shown is Table-5.1.

The questions consist of the following ten items:

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

5.4 Survey Method

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

The total of 33 local people, employed as interviewers, were engaged in the survey and the interviewees, numbering 774 in total, were selected randomly.

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

The survey was conducted on 12th and 13th of February, 1986.

Table-5.1 QUESTIONNARE FORM

QESTIONNAIRE
FOR
PROVINCIAL WATER SUPPLY PROJECT

Ward No. :
Interviewer :
Date : (a)

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

5.5 Survey Results

The survey results are summarized in Table-5.2 and shown in Fig-5.2 (1) to (6) graphically. All of the listed numbers represent the meaningful and relevant answers.

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

Of the 772 households answering the captioned question, 54.9 % lived in residential-only (purely residential) buildings while 32.9 % in residential-commercial buildings. Altogether 87.8 %, most of the 772, lived in the residential-purported buildings and consumed water for domestic uses.

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

Of the 772 households answering the captioned question, 29.3 % used the municipal system only, 13.2 % the municipal system and other sources and 57.5 % other sources only. (Fig-5.2 (1))

The 13.2 % of users of the municipal system and other sources numbered 102 and the 57.5 % of users of other sources only 444. Fig-5.2 (2) shows how the other sources were used. When the two graphs are combined, the groundwater's share is largest, 259 of the total 546, or 47.4 %, followed by the combined sources' 31.7 %, the rain/river water user's 11.5 % and the water buyer's 9.3 %.

Though water quality of Pattaya's groundwater is not acceptable, 246 of 772, or 31.9 % of the surveyed, depend on it. From a sanitary viewpoint, it is noticeable.

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

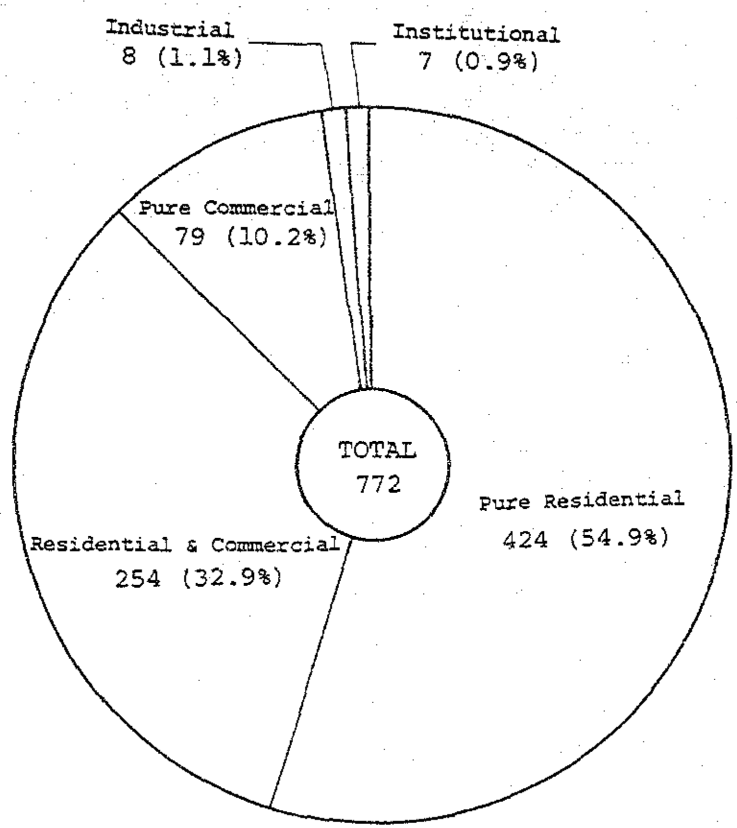
Of the 326 households using the PWA system wholly or partly, 80.7 % were found to be dissatisfied with the service. Of the reasons, 38.8 % of the 263, pointed out costliness, 33.1 % combined reasons, 20.1 % instability of the supply condition and 6.5 % chronic low pressure.

Table-5.2 SURVEY RESULTS

PATTAYA

QUESTIONNAIRE	TOTAL
Q-1 :Type of Building Surveyed	
Pure Residential	424
Residential & Commercial	254
Pure Commercial	79
Institutional	7
Industrial	8
No Anser	2
TOTAL Q-1	774
Q-2 :Type of Water Supply Sources	
A :Municipal System Only	226
B :Municipal System Plus Other Sources	
B-1 : Rain/River Water	61
B-2 : Pond / Reservoir Water	0
B-3 : Water Vender	16
B-4 : Groundwater	13
B-5 : Combined Sources	12
C :Sources Other Than Municipal System	
C-1 : Rain/River Water	2
C-2 : Pond / Reservoir Water	0
C-3 : Water Vender	35
C-4 : Groundwater	246
C-5 : Combined Sources	161
D :No Answer	2
Sub total (A + B)	328
Sub total (C)	444
TOTAL Q-2	774
Q-5 :Current Status of Water Supply (Municipal System)	
A :Satisfactory	63
B :Unsatisfactory	
B-1 : Poor Quality	4
B-2 : Low Pressure	17
B-3 : Unstable	53
B-4 : Expensive	102
B-5 : Combined Reasons	87
C :No Answer	2
TOAL Q-5	328
Q-6 :Average Monthly Water Consumption	
1 :Less than 15 m3	37
2 :15 - 30	81
3 :30 - 50	119
4 :50 - 75	38
5 :75 - 100	25
6 :100 - 150	16
7 :150 - 200	2
8 :200 - 300	3
9 :Over 300	6
10 :No Answer	1
TOTAL Q-6	328
Q-7 :Average Cost of Water Per Month	
1 :Less than 50 Baht	35
2 :50 - 100	51
3 :100 - 150	40
4 :150 - 200	55
5 :200 - 300	57
6 :300 - 500	38
7 :500 -1,000	30
8 :1,000 - 5,000	18
9 :5,000 - 10,000	3
10 :Over 10,000	0
11 :No Answer	1
TOTAL Q-7	328
Q-8 :Willingness to be Connected	
1 :Yes	256
2 :No	184
3 :No Answer	6
TOTAL Q-8	446
Q-9 :Willingness to Pay for Water per Month	
1 :Upto 50 Baht	113
2 : 100	94
3 : 200	21
4 : 500	2
5 : 1,000	0
6 : 2,000	1
7 : 5,000	1
8 : 10,000	0
9 :No Answer	24
TOTAL Q-9	256
Q-10:Average Monthly Income per Household	
A :Sources Other Than Municipl System	
1 :Less than 2,000 Baht	196
2 : 2,000 - 3,000	138
3 : 3,000 - 4,500	64
4 : 4,500 - 6,000	30
5 : 6,000 - 7,500	6
6 : 7,500 -10,000	3
7 : 10,000 -15,000	6
8 : 15,000 -50,000	1
9 :Over 50,000	2
10 :No Answer	0
Sub total Q-10-A	446
B :Municipal System Wholly or Partly	
1 :Less than 2,000 Baht	49
2 : 2,000 - 3,000	94
3 : 3,000 - 4,500	64
4 : 4,500 - 6,000	45
5 : 6,000 - 7,500	17
6 : 7,500 -10,000	27
7 : 10,000 -15,000	15
8 : 15,000 -50,000	14
9 :Over 50,000	2
10 :No Answer	1
Sub total Q-10-B	328
TOTAL Q-10	774

TYPE OF BUILDING SURVEYED



TYPE OF WATER SUPPLY SOURCE

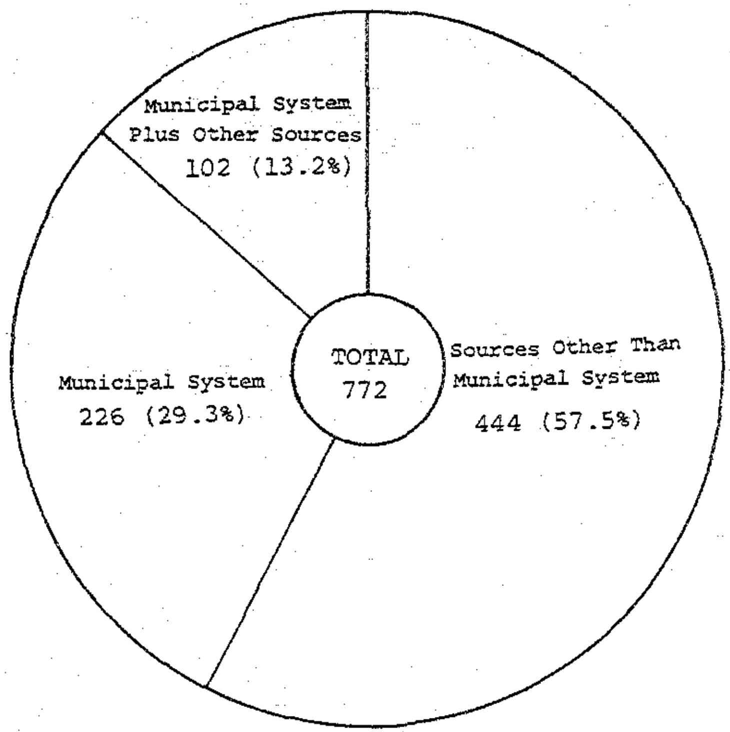


FIGURE	QUESTIONNAIRE SURVEY RESULTS (1) (PATTAYA)
5.2(1)	

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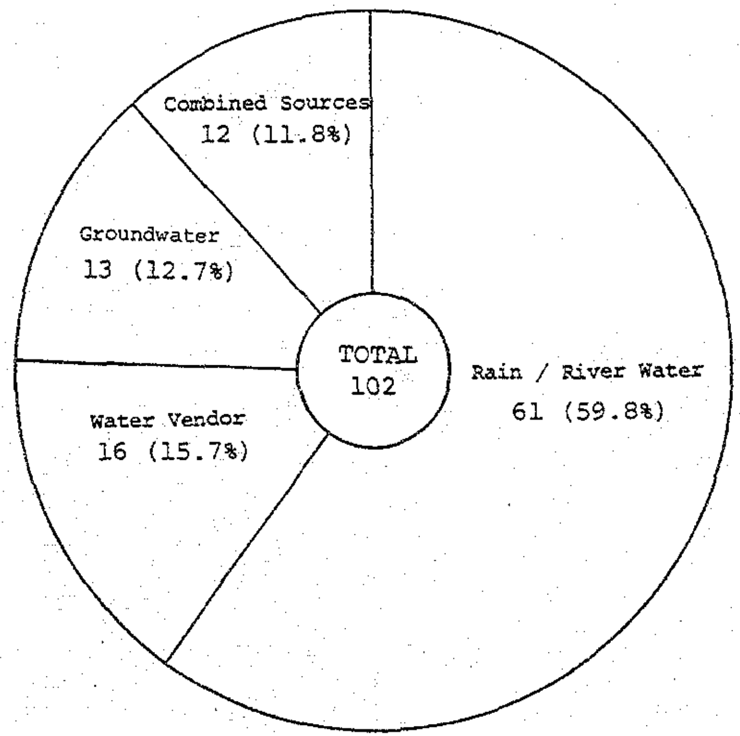
MUNICIPAL SYSTEM PLUS OTHER SOURCES



SOURCES OTHER THAN MUNICIPAL SYSTEM

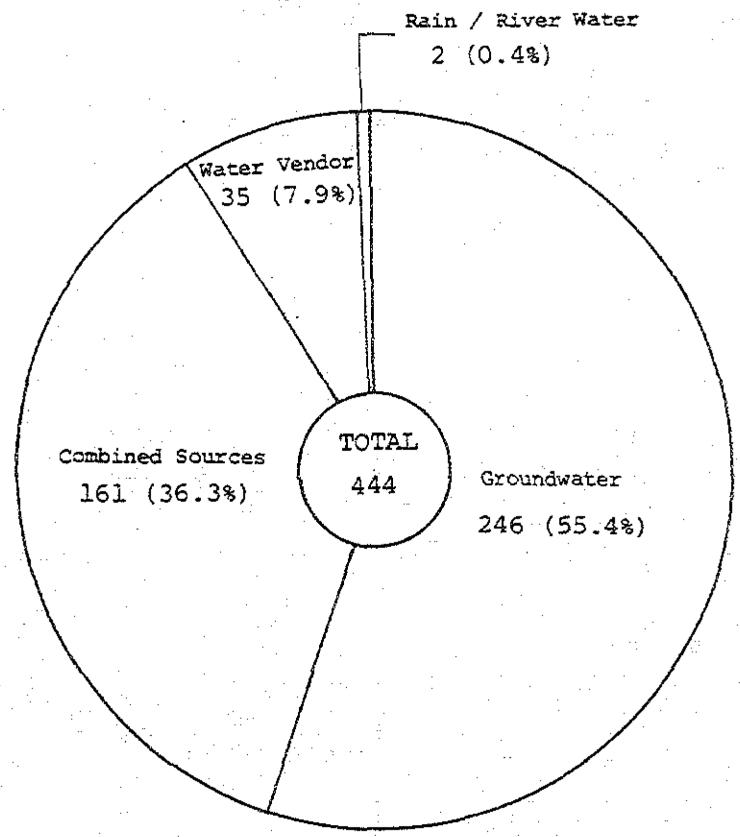


FIGURE	QUESTIONNAIRE SURVEY RESULTS (2) (PATTAYA)
5.2(2)	
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CURRENT STATUS OF WATER SUPPLY
MUNICIPAL SYSTEM

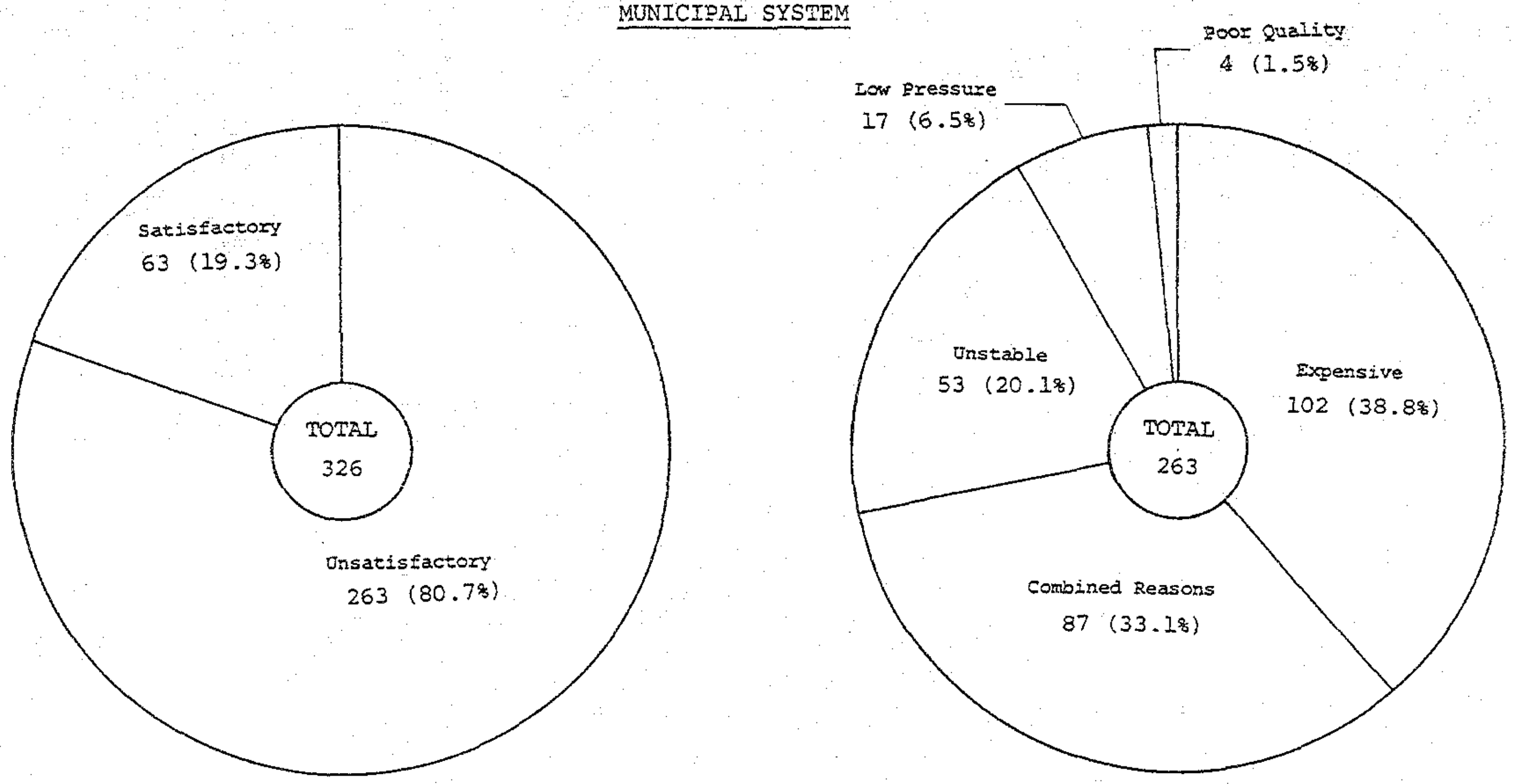

FIGURE	QUESTIONNAIRE SURVEY RESULTS (3)
5.2(3)	(PATTAYA)

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

Consumption and payment are closely related. Of the 327 households surveyed, the less-than-15 cu m/month consumer, numbering 37 and comprising 11.3 %, corresponds the less-than 50 baht payer, numbering 35 and comprising 10.7 %. Likewise, 15-30 cu m/month consumer and 30-50 cu m/month consumer correspond the payer of 50-150 baht and 150-300 baht.

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

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

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

Nearly 60 %, or 256 of 440 of the answer, was positive.

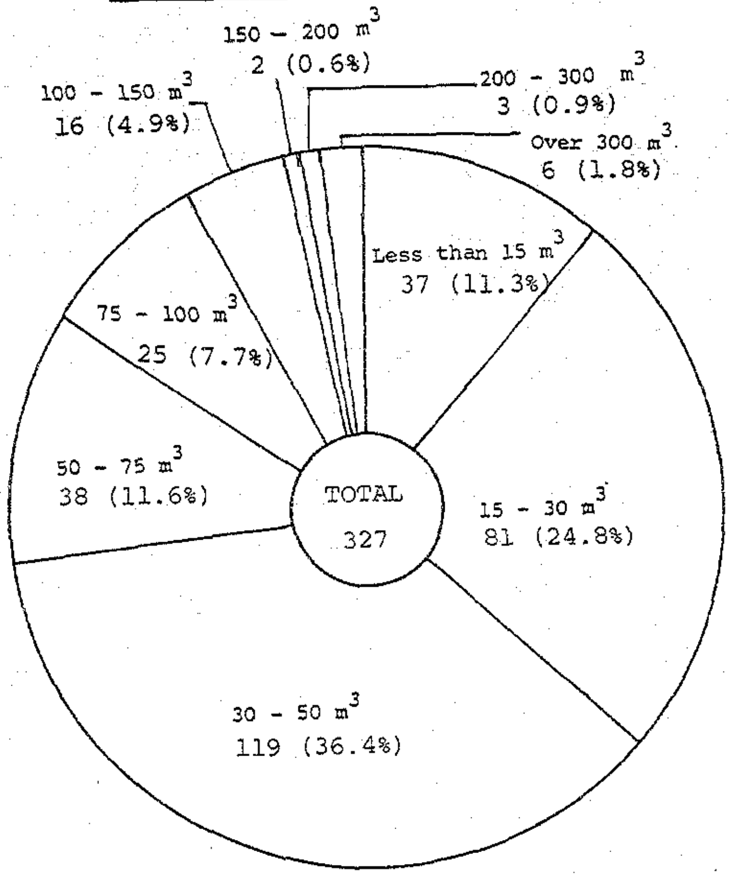
6) Willingness to Pay for Water per Month (Table-5.2, Fig-5.2 (5))

Of the willing-to-be-connected people, how much they are willing to pay was questioned and answered.

Nearly a half, 113 of 232, answered less than 50 baht. This contrasts with the finding that presently the less-than-50 baht paying group comprises only 10.7 % of the total. The portion willing 50-100 baht payment is 40.5 %, contrasting with the present percentage of 15.6 %.

Seemingly, the unserved people are not well informed well about the price of water they would have to pay.

MONTHLY AVERAGE WATER CONSUMPTION



AVERAGE COST OF WATER PER MONTH

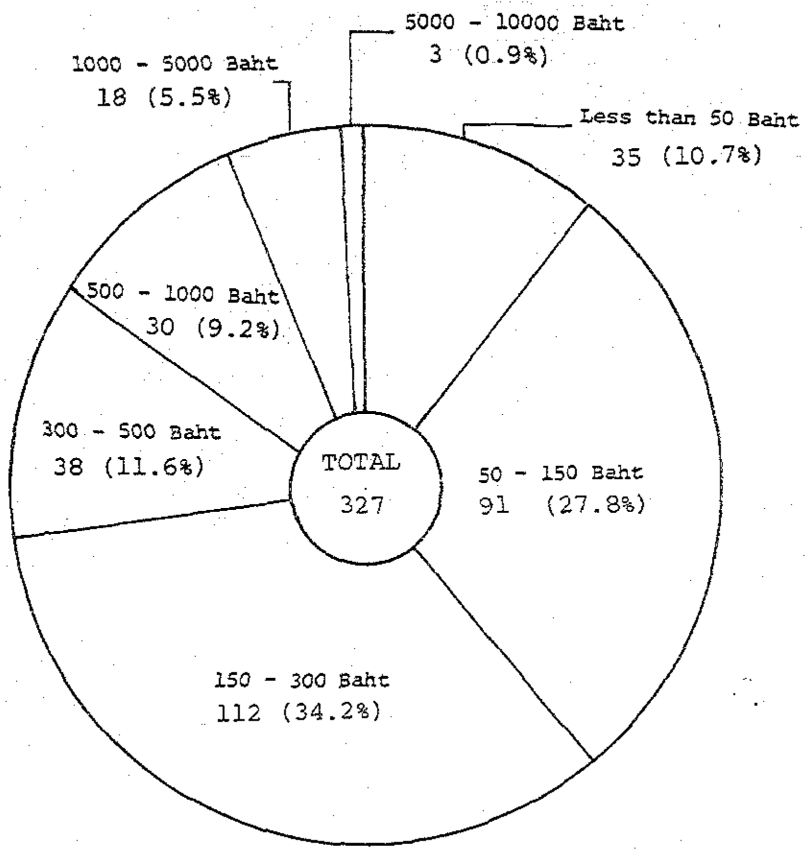


FIGURE	QUESTIONNAIRE SURVEY RESULTS (4) (PATTAYA)
5.2(4)	

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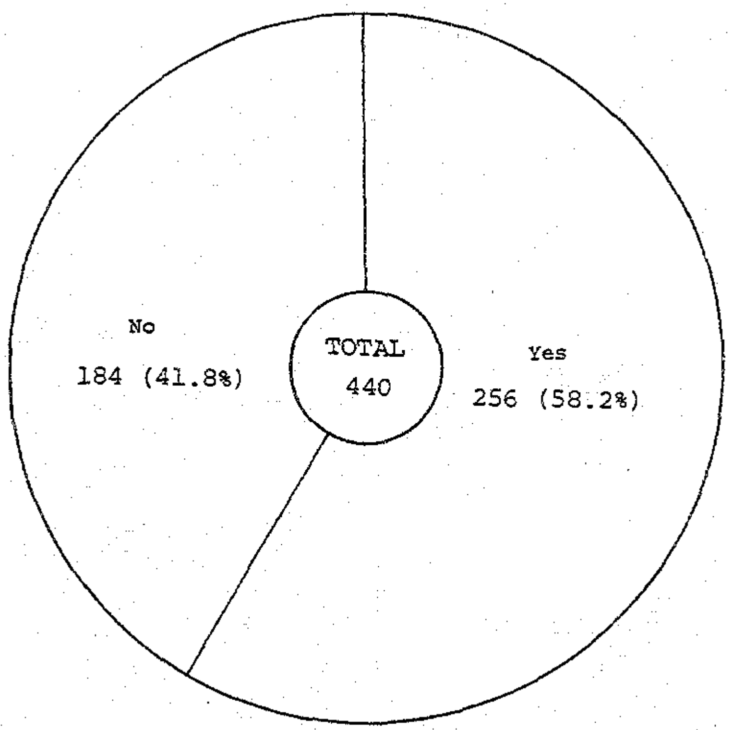

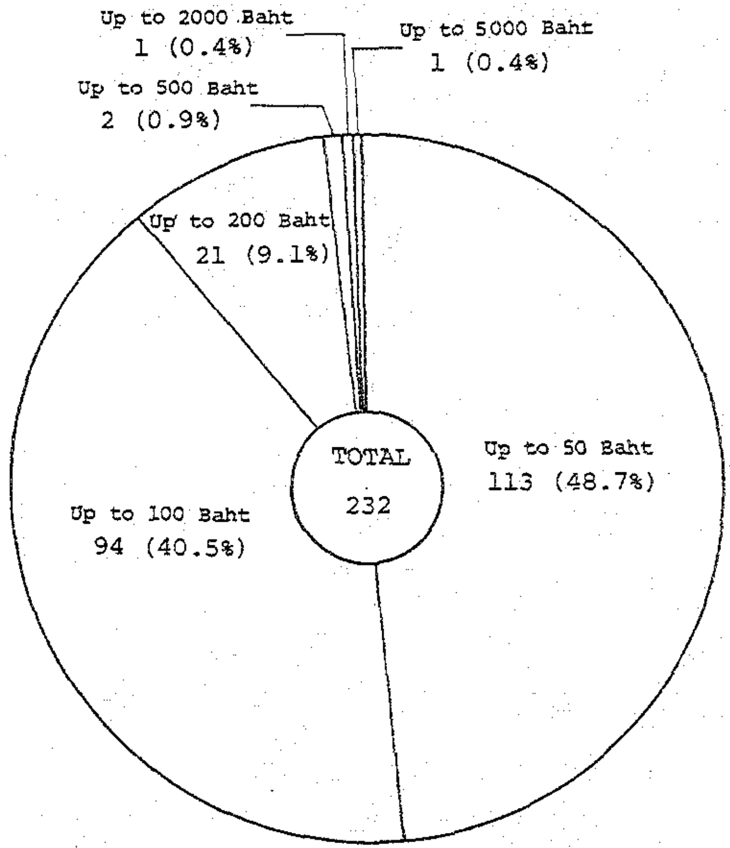

FIGURE	QUESTIONNAIRE SURVEY RESULTS (5)
5.2(5)	(PATTAYA)

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

446 other-sources-than-Municipal system users and 327 wholly-or-partly-Municipal-System users were questioned and the result is shown for each separately.

Obviously, the income range of the two differs. The less-than-2,000 Baht income group comprises 44.0 % of the non-users and 15.0 % of the partial-users. The 2,000-3,000 Baht class is 31.0 and 28.7 % respectively. Seemingly, a separation line of income level between the affordable and not-affordable exists at around 2,000 Baht per month.

8) System Connection by Income Bracket (Fig-5.3)

To find the relationship between per capita income and individual house-connection ratio, screening of data, which was collected during the questionnaire survey, was made by taking the following steps:

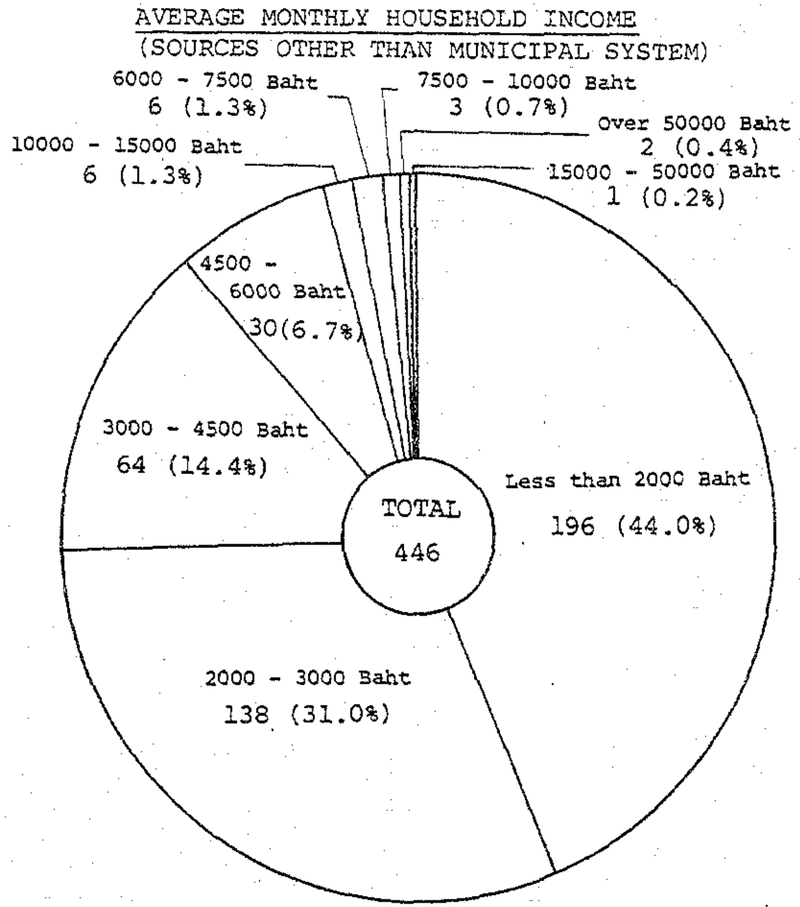
a) Picking up all families having less than 20 family members,

b) Picking up all families in the residential-only dwellings and residential-commercial dwellings from selected families in step a),

c) Classifying the above selected families by per capita income brackets, and

d) Grouping the classified families whether they have services through individual house connections or not.

As shown in Fig-5.3, there is an apparent positive correlation between the per capita income and individual house connection services. It is also observed that more than 80 % of families of higher income than 1,500 Baht have PWA services through individual house connections.



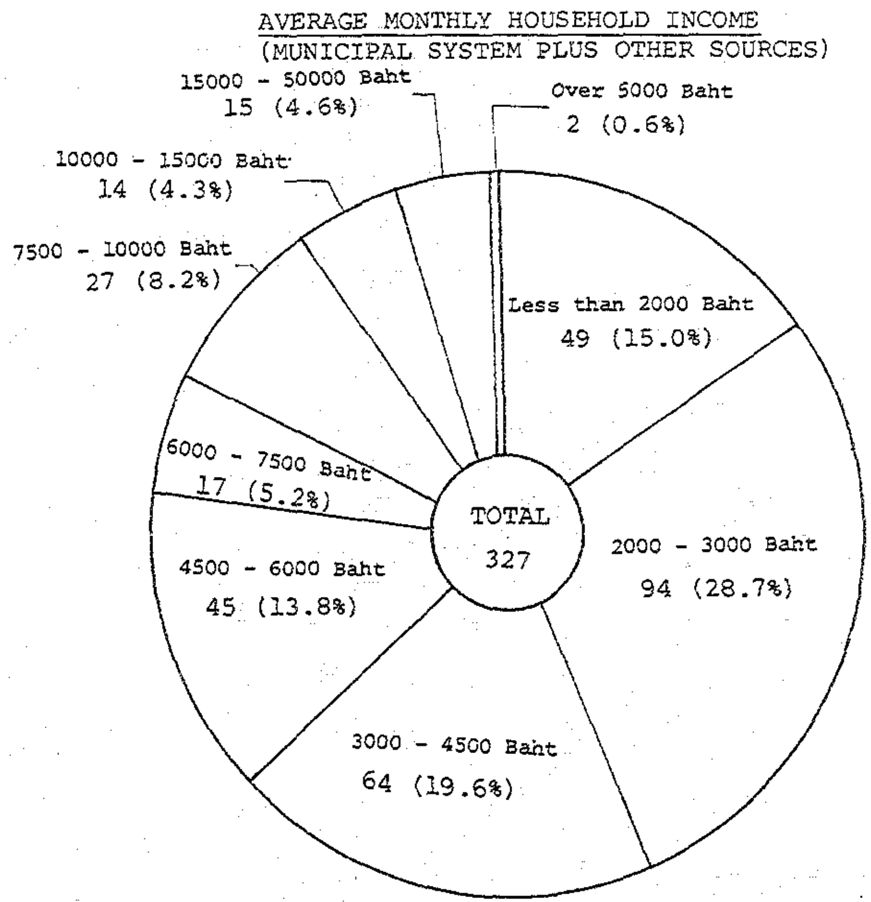


FIGURE	QUESTIONNAIRE SURVEY RESULTS (6)
5.2 (6)	(PATTAYA)

JAPAN INTERNATIONAL COOPERATION AGENCY

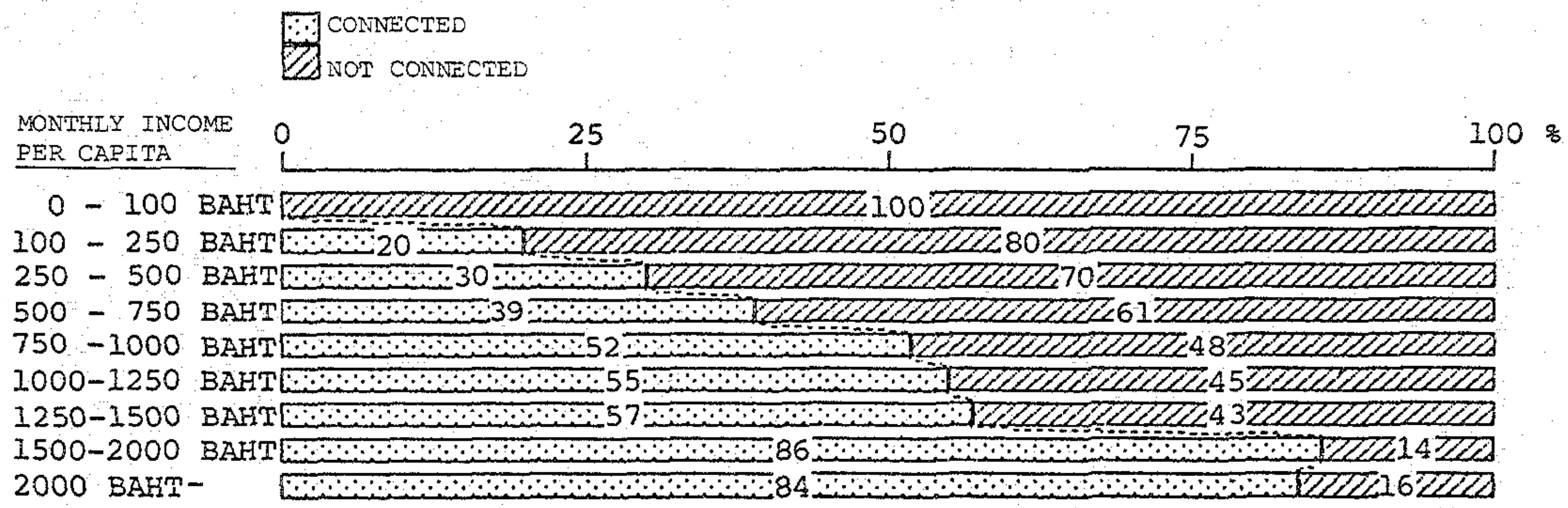


FIGURE 5.3

SYSTEM CONNECTIONS BY INCOME BRACKETS
(PATTAYA)

JAPAN INTERNATIONAL COOPERATION AGENCY

APPENDIX 6

DESIGN CRITERIA

APPENDIX 6

APPENDIX 6 DESIGN CRITERIA

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APPENDIX 6 DESIGN CRITERIA

The design criteria mentioned herein are applied to the preliminary design of the present project. They were concluded after studying the PWA design criteria and the concepts widely accepted in waterworks field and discussing them with PWA.

6.1 Peak Factors

The factors have not been established as criteria and the table below shows the peak factors planned for this project.

City/Town	Peak Factor by Day (Max Day/Ave Day)	Peak Factor by Hour (Max Hour/Ave Hour*)
Chiangmai	1.25	1.30
Ubon, Warin	1.30	1.40
Pattaya	1.30	1.20
Suphanburi	1.35	1.40
Five S.D.s in Chiangmai	1.35	1.50

* Ave Hour = 1/24 Max Day

The peak factor by day was estimated for each of the domestic and tourism demands separately and the listed figure is the average. Using the peak factors, the average day demand, maximum day demand and maximum hour demand are calculated.

These demands are used in making calculation mostly of:

Average Day Demand: financial and economic study
Maximum Day Demand: production facility design
Maximum Hour Demand: distribution facility design.

6.2 Water Loss in Production

Water loss is counted in the design of production facilities. They are assumed to be:

Treatment Plant	:	8 % including filter washing and other in-plant consumptions

6.3 Concrete Structure

Concrete structures for production and distribution must be designed following the practiced design method prevailing in Thailand.

6.4 Pipeline

Pipelines must be designed based on consideration of hydraulic conditions, geologic conditions, pipe and joint material and others.

6.5 Treatment Plant Facilities

1) Flash Mixing

Type of mixing	:	hydraulic
Intensity, G (1/s)	:	500 - 1,000
Time of mixing, t (s)	:	1 - 3

2) Flocculation

Type of mixing	:	hydraulic
No. of stages	:	more than 3
Intensity, G (1/s)	:	10 - 70, tapered
Detention time (min)	:	20 - 40
Others	:	minimum of 2 basins, easy removal of scum and sludge

3) Sedimentation

Type	:	rectangular basin, one direction horizontal flow
Hydraulic loading	:	1 - 2 m3/m2/hr
Flow velocity (m/min)	:	0.3 - 1
Detention time (hr)	:	1.5 - 3
Water depth (m)	:	more than 3 plus sludge deposit thickness estimated on the interval of cleaning
Weir loading (m3/m.d)	:	less than 300 (less than 15 gpm/ft)
Length/width ratio	:	more than 5, dummy wall considered
Sludge collection	:	manual

4) Filtration

Type	:	gravity rapid sand filter
Filt. rate (m/hr)	:	less than 7, for declining rate filtration

<u>Filter Bed</u>

Type	:	single media
Minimum no. of filter	:	4
Minimum size of filter	:	3 m x 4 m
Effective size of sand	:	0.55 - 0.75 mm
Uniformity coefficient	:	1.7
Minimum depth	:	750 mm

Underdrains

Type	:	pipe lateral
No. of gravel layers	:	minimum 4
Thickness of each	:	more than 100 mm

Surface wash

Type	:	fixed nozzle
Rate (m/min)	:	0.12 - 0.17
Head (kg/cm2)	:	more than 1.0
Jet velocity (m/s)	:	6 - 7

Backwash

Rate (m/min)	:	more than 0.6

5) Clear Water Reservoir in Treatment Plant

Function	:	storage for in-plant consumption including backwashing
Type	:	elevated and/or ground level
For backwash	:	minimum storage for 2 filters consecutive backwashing

6) Chemical Feeding

Alum

No. of tank	:	more than 2
Feeder	:	metering pump or manual control with flow meter, recycle bypass, corrosion-resistant pump

Lime

Objective	:	pH control for coagulation and/or pipe protection against corrosion
No. of tank	:	more than 2

At least 1 stand-by feeder is to be provided for alum and lime. Gauges at outside of the tanks are preferable.

7) Chlorination

Chemicals form	:	chlorine gas and/or bleaching powder
Minimum storage	:	1 months
No. of standby chlorinator	:	more than 1
Scale	:	periodical recording of consumptions to be practiced

8) Instrumentation

Flow to be measured	:	raw water and treated water of treatment plant, chemicals, chlorine
Level to be measured	:	clear water reservoir, chemical tank
Weight to be measured	:	chlorine

In selecting the measuring devices, durability, robustness, easiness of operation and maintenance (changing parts, repair) are to be given priority to, for instance, high accuracy.

6.6 Distribution Facilities

1) Service Pressure

The minimum service pressure under the maximum hour flow is set at 1.0 kg/cm2 for general application, except for rural area where 0.7 - 0.8 kg/cm2 be tolerated.

2) Storage of Distribution Reservoir

When sufficient data regarding the characteristics of fluctuation area collected in future, the storage problems are to be studied.

Increasing the existing storage capacity is not considered in the rehabilitation/modification works, but in the expansion works, construction of a reservoir retaining 6 hour production volume for the expanded capacity is planned.

3) Pipe Material

In selecting pipe material, conditions such as strength against internal and external loads, importance of the pipeline, suitability to ground conditions, workability in existing conditions and influence on water quality must be considered.

Asbestos cement pipes, anti-corrosion coated when necessary, are to be used preferably for economic reasons. For cases requiring pipe strength such as road crossing works and the like, ductile cast iron pipes are to be employed.

4) Pipe Size

Pipe size is to be selected pursuant to flow requirements. In this preliminary design, the maximum hour flow is employed for the pipe size selection.

5) Valves

The location of stop valves is selected upon consideration of convenience in operation and maintenance, such as:

- control of flow to equalize distribution or reduce excessive pressure
- isolation of a section of distribution area

- isolation of in-line facilities like railway, riverbed crossing and pipe-bridge

PWA criteria of 1 km minimum distance is observed.

The location of drain valves is selected upon consideration such as:

- emptying a pipeline in emergency like bursting
- draining wastewater in periodical cleaning works

Air valves are to be located at all the peaks in a pipeline's profile.

6) Fire Hydrant

The location of fire hydrants is selected upon consideration such as:

- existence of nearby natural and/or man-made water like streams, canals swamps, etc.
- characteristics of the area to be protected, for instance, existence of factories handling inflammable matters, congested wooden housings, etc.

7) Anchor Block

To prevent displacement or slip-off of bends and tees, anchor blocks are used where necessary.

6.7 Drinking Water Standard

Table-6.1 shows the PWA Drinking Water Standard of Surface Water Source.

The treatment facilities, preliminary designed on the basis of the design criteria in 6.5 for processing raw water of two surface water sources of Pattaya, are required to produce treated water conforming to the standard.

Table-6.1 DRINKING WATER STANDARD OF SURFACE WATER SOURCE

PHYSICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION (mg/l)	MAXIMUM ALLOWABLE* CONCENTRATION (mg/l)
Color (Platinum Cobalt Unit)	5	15
Taste	unobjectionable	unobjectionable
Odour	unobjectionable	unobjectionable
Turbidity (Silica Scale Unit)	5	20
pH	6.5 to 8.5	not over 9.2
CHEMICAL PROPERTIES		
Total Solids	500	1,500
Total Hardness as $CaCO_3$	300	500 (WHO 1971)
Iron (Fe)	0.5	1.0
Manganese (Mn)	0.3	0.5
Iron an Manganese	0.5	1.0
Copper (Cu)	1.0	1.5
Zinc (Zn)	5.0	15
Calcium (Ca)	75**	200
Magnesium (Mg)	50	150
Sulphate (SO_4)	200	250***
Chloride (Cl)	250	600
Fluoride (F)	0.7	1.0
Nitrate (NO_3)	45	45
Alkyl Benzyl Sulfonates (ABS)	0.5	1.0
Phenolic Substances as Phenol	0.001	0.002
TOXIC SUBSTANCES		
Mercury (Hg)	0.001	
Lead (Pb)	0.05	
Arsenic (As)	0.05	
Selenium (Se)	0.01	
Chromium Hexavalent (Cr)	0.05	
Cyanide (CN)	0.2	
Barium (Ba)	1.0	
Cadmium (Cd)	0.01	

Table-6.1 DRINKING WATER STANDARD OF SURFACE WATER SOURCE (cont'ed)

BACTERIOLOGICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION
Standard Plate Count (N/ml)	500
Most Probable Number	
Coliform Organisms (N/100 ml)	less than 2.2
Escherichia Coli	None

Notes:

* The maximum allowable concentration is allowable for waterworks and well used for human consumption temporarily only and the water property is between the maximum acceptable and maximum allowable and will not be entitled to use the standardized trademark.

** If the Calcium (Ca) is higher than the limit and the Magnesium (Mg) is lower, the standard shall be considerd as Ca and Mg in terms of total hardness. If the total hardness calculation in terms of $CaCO_3$ is lower than 300 mg/l, the water is according to the standard classification of water hardness in the following:

0 - 75 mg/l	=	Soft water
75 - 150 mg/l	=	Mean hard water
150 - 300 mg/l	=	Hard water
up 300 mg/l	=	Very hard water

*** If the Sulfate value reached 250 mg/l, the Magnesium (Mg) shall not exceed 30 mg/l.

APPENDIX 7

ALTERNATIVE STUDY

APPENDIX 7

APPENDIX 7 ALTERNATIVE STUDY

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APPENDIX 7 ALTERNATIVE STUDY

In the present Appendix, the most appropriate location of the newly constructed treatment plant is studied. The ATTACHMENTs affixed on the Appendix deals with one of the prospective water sources, Huai Kong Dai Intake, together with Mab Prachan water balance simulation related to the Huai Kong Dai.

7.1 Objective

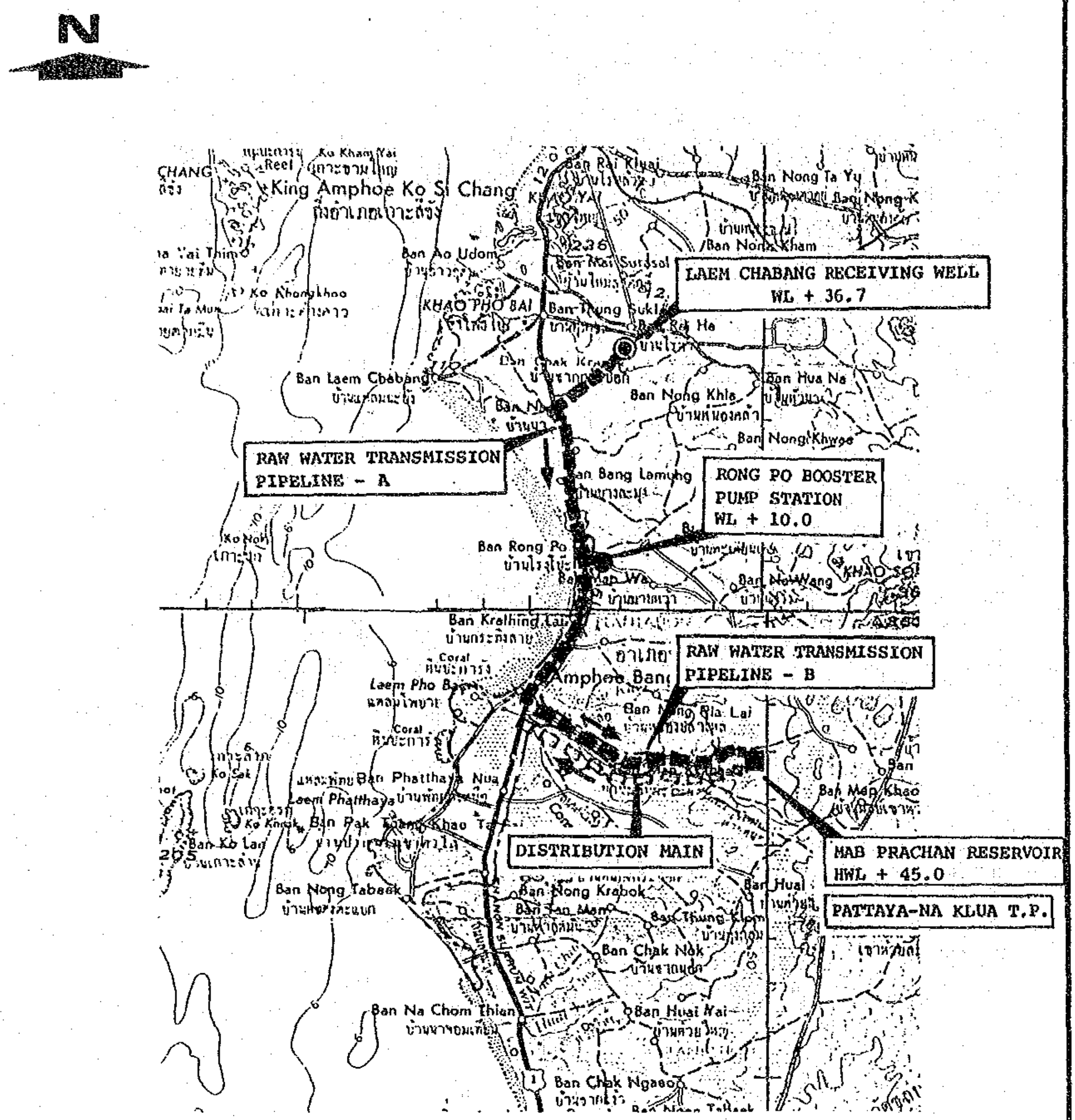
The objective of this study is selecting the optimal location of the new water treatment plant in the long term development plan up to 2010, from technical and economical view point. Requirements or conditions to be met in the water supply plan for Pattaya are described in Chapter 7 of the main report.

7.2 Alternatives

There are several alternatives for the proposed treatment plant location, inclusive of the existing Pattaya-Na Klua treatment plant site. The following three alternatives were selected for further detailed comparison.

Alternatives	Location of Treatment Plant
A	Next to existing Pattaya-Na Klua Plant
B	Laem Chabang
C	Ban Rong Po

It should be noted that all three alternatives were required to take water in from the new source of water of the receiving well at Laem Chabang. General plans of the alternative A, B and C are shown in Figs-7.1, 7.2 and 7.3 respectively and a schematic comparison of the three is shown in Fig-7.4.



	YEAR 2000	YEAR 2010
RAW WATER TRANSMISSION PIPELINE - A (BY GRAVITY)	ø500, 11.4 km	ø500, 2 km ø400, 9.4 km
RONG PO BOOSTER PUMP STATION	1 LS	1 LS
RAW WATER TRANSMISSION PIPELINE - B (BY PUMPING)	ø600, 14 km	ø500, 14 km
PATTAYA-NA KLUA T.P. EXPANSION	15,300 m3/d	12,900 m3/d
DISTRIBUTION MAIN (BY GRAVITY)	ø600, 6.7 km	ø500, 6.7 km

FIGURE 7.1 ALTERNATIVE - A

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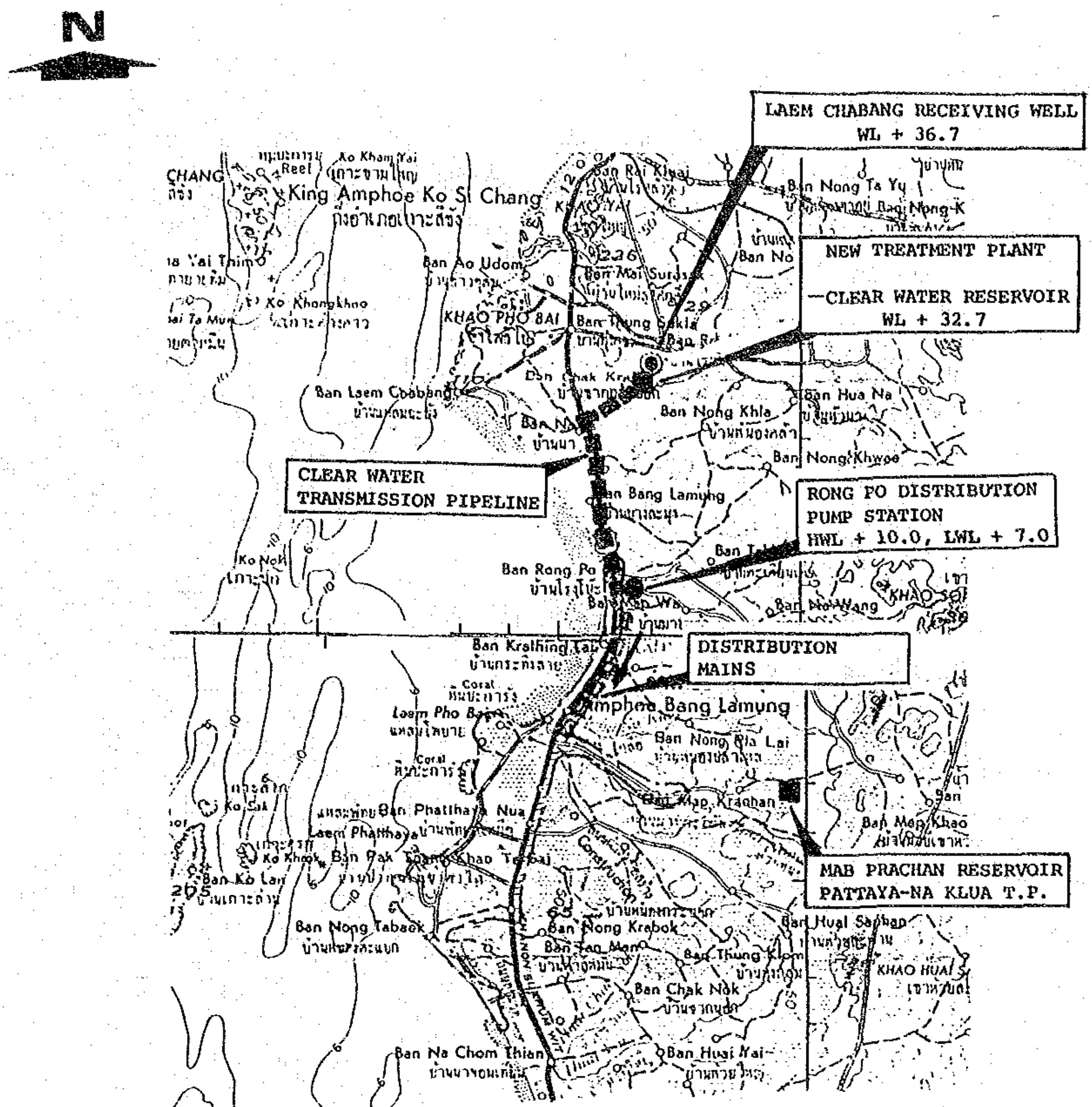

	YEAR 2000	YEAR 2010
RAW WATER TRANSMISSION PIPELINE (BY GRAVITY)	ø700, 0.4 km	ø600, 0.4 km
NEW TREATMENT PLANT	20,100 m3/d	12,900 m3/d
CLEAR WATER TRANSMISSION PIPELINE	ø600, 6 km ø500, 5 km	ø500, 8 km ø400, 3 km
RONG PO DISTRIBUTION PUMP STATION	1 LS	1 LS
DISTRIBUTION MAINS (BY PUMPING)	ø600, 4.2 km ø500, 1.8 km	ø500, 4.2 km ø400, 0.8 km

FIGURE 7.2 ALTERNATIVE - B

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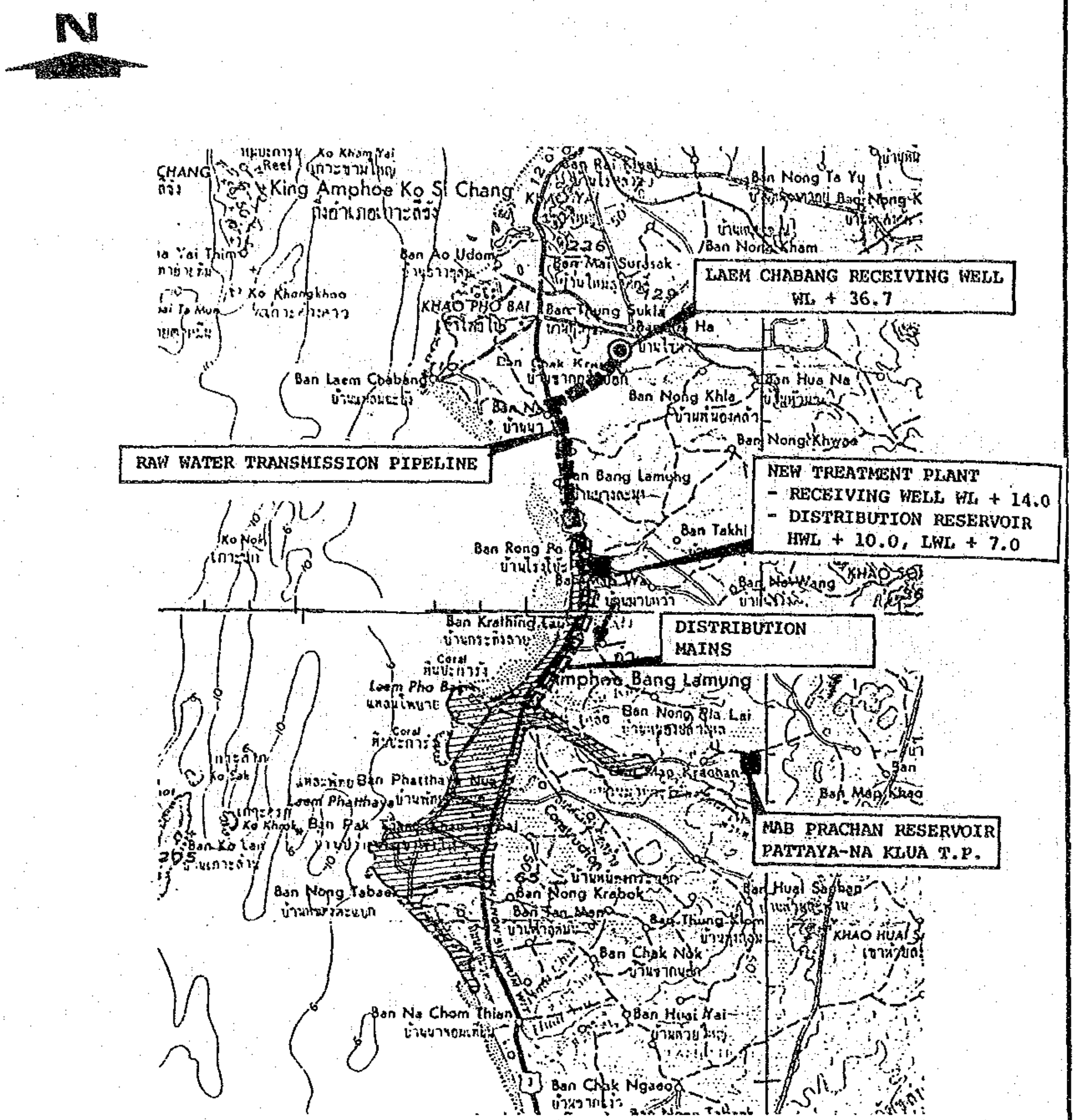

	YEAR 2000	YEAR 2010
RAW WATER TRANSMISSION PIPELINE (BY GRAVITY)	ø600, 9 km ø500, 2.4 km	ø500, 11.4 km
NEW TREATMENT PLANT	20,100 m3/d	12,900 m3/d
DISTRIBUTION MAINS (BY PUMPING)	ø600, 4.2 km ø500, 1.8 km	ø500, 4.2 km ø400, 0.8 km

FIGURE 7.3

ALTERNATIVE - C

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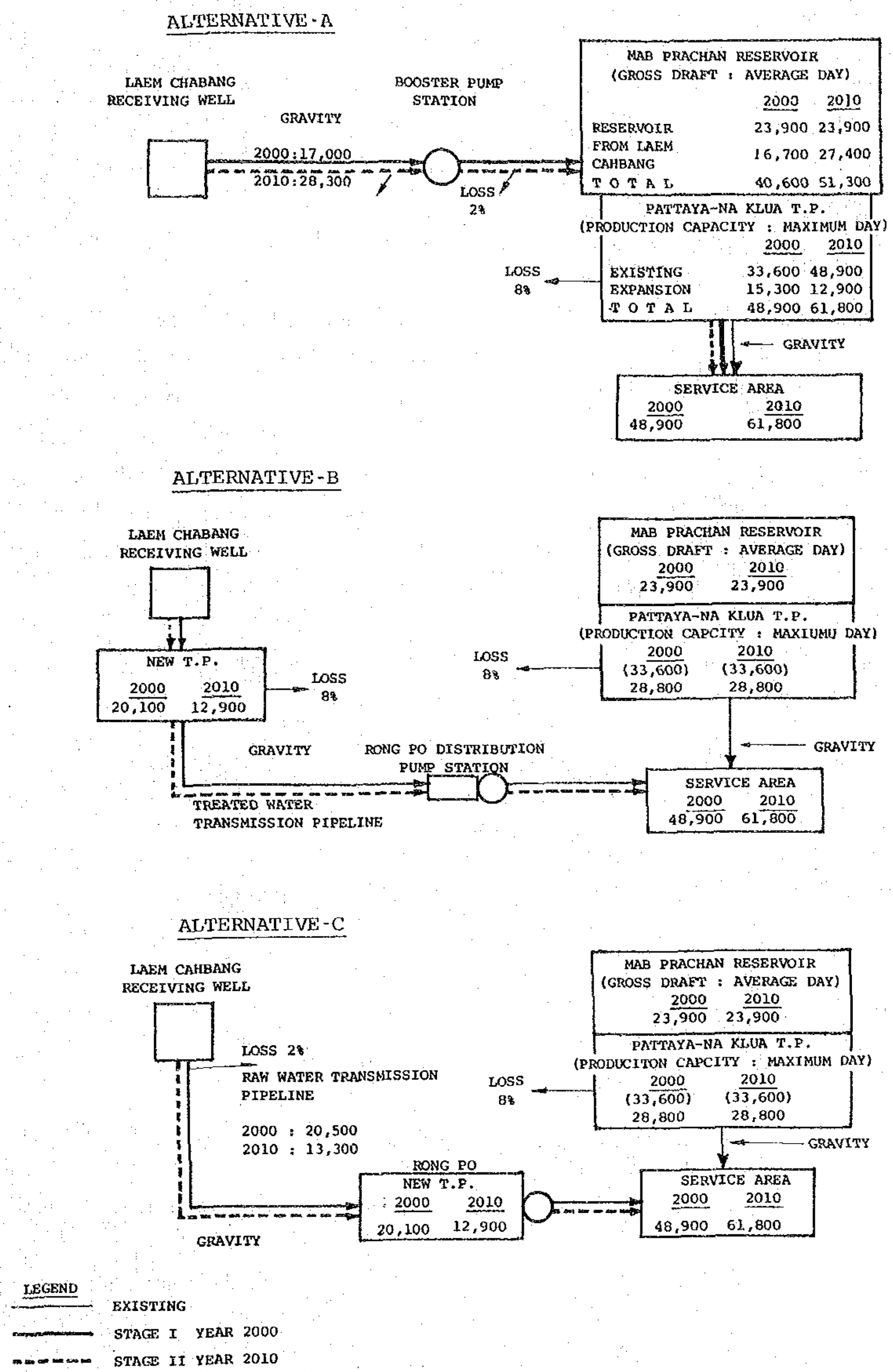

FIGURE 7.4 SYSTEM DIAGRAM FOR ALTERNATIVES

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7.3 Present Value Analysis

Prior to the present value analysis, the construction cost of the three was estimated on the basis of 1986 price, as summarized in Table-7.1. The alternative B was found as the lowest.

The annual operation and maintenance costs (O/M costs) including chemicals and electricity costs were estimated till 2020, 10 years after the project's completion. Raw water charge payable to RID and personnel cost are excluded in the O/M cost estimation, as their costs of Alternatives can be deemed similar to each other.

All the above costs were discounted at 5 %, 10 % and 15 % per annum rate in computing the present value. The result shows that the least cost solution is the Alternative B in the whole range of 5 % to 15 % discount rate. Fig-7.5 shows details of the present worth analysis.

It is concluded that the site of Laem Chabang Receiving Well is most optimal for locating the new treatment plant.

Table-7.1 CONSTRUCTION COST OF ALTERNATIVES

Unit : x 1,000 Baht

ALTERNATIVE - A

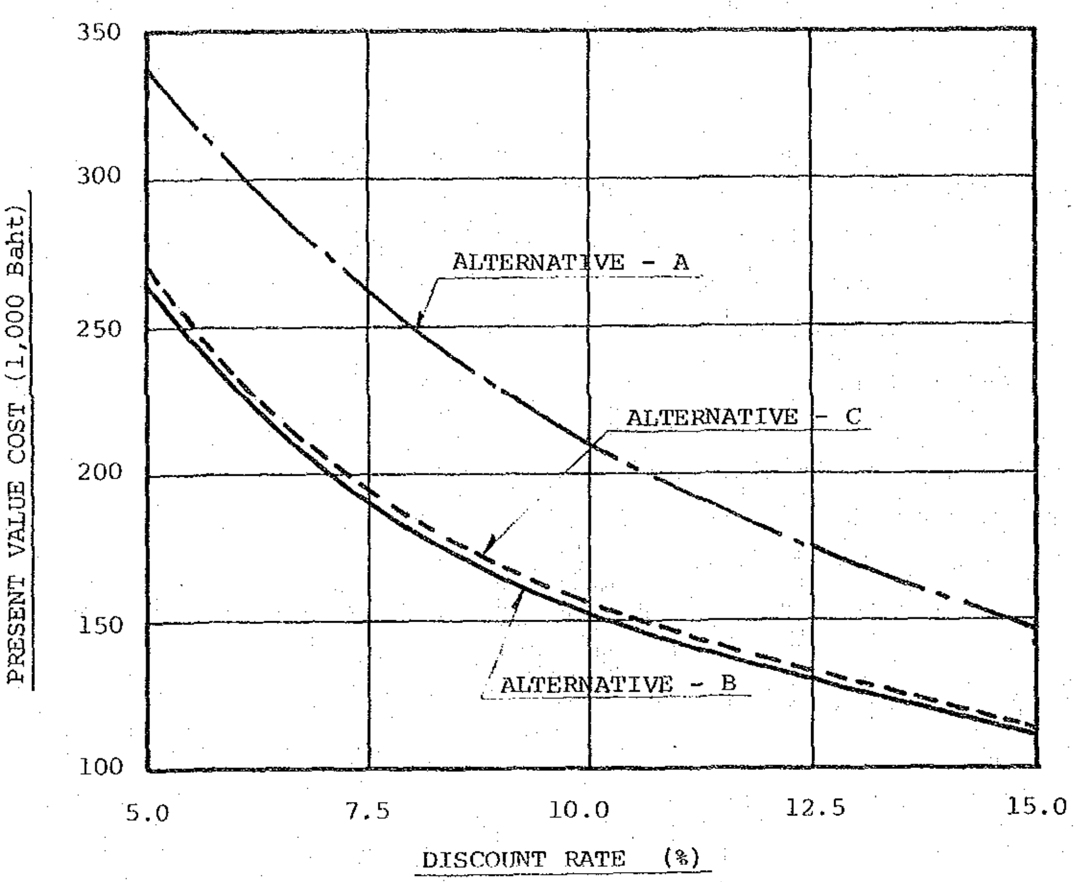
	Year 2000	Year 2010	Total
Raw Water Transmission Pipeline - A (by Gravity Flow)	41,500	28,700	70,200
Rong Po Booster Pump Station	6,800	3,400	10,200
Raw Water Transmission Pipeline - B (by Pumping)	65,400	50,200	115,600
Pattaya-Na Klua T.P. Expansion	47,800	43,100	90,900
Distribution Main Pipeline (by GravityFlow)	31,300	24,000	55,300
T O T A L	192,800	149,400	342,200

ALTERNATIVE - B

	Year 2000	Year 2010	Total
Raw Water Transmission Pipeline (by Gravity Flow)	2,500	2,300	4,800
New Treatment Plant	52,900	39,600	92,500
Clear Water Transmission Pipeline	45,800	36,500	82,300
Rong Po Distribution Pump Station	18,800	9,000	27,800
Distribution Main Pipeline - A (by Pumping)	26,100	17,100	43,200
T O T A L	146,100	104,500	250,600

ALTERNATIVE - C

	Year 2000	Year 2010	Total
Raw Water Transmission Pipeline (by Gravity Flow)	51,200	41,500	92,700
New Treatment Plant	71,700	48,600	120,300
Distribution Main Pipeline - A (by Pumping)	26,100	17,100	43,200
T O T A L	149,000	107,200	256,200



PRESENT VALUE

		DISCOUNT RATE		
		5.0 %	10.0 %	15.0 %
ALTERNATIVE-A	CONSTRUCTION	235,300	166,900	124,500
	O/M	100,800	44,700	23,000
	TOTAL	336,100	211,600	147,500
ALTERNATIVE-B	CONSTRUCTION	174,100	124,200	93,100
	O/M	66,500	30,300	16,000
	TOTAL	240,600	154,500	109,100
ALTERNATIVE-C	CONSTRUCTION	177,700	126,800	95,000
	O/M	66,500	30,300	16,000
	TOTAL	244,200	157,100	11,000

FIGURE 7.5 COST COMPARISON BY PRESENT VALUE METHOD

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ATTACHMENT-1

STUDY OF HUAI KONG DAI INTAKE

ATTACHMENT-1 STUDY OF HUAI KONG DAI INTAKE

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