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MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

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

FINAL REPORT

SUMMARY

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Thailand, the Japanese Government decided to conduct a Feasibility Study on the Improvement of the Sewerage System in the Southern Part of Lima and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a survey team headed by Mr. Ikuo Miwa, Nippon Jogesuido Sekkei Co., Ltd., from July to October, 1988, from January to March, 1989, and from October to November, 1989.

The team held discussions with concerned officials of the Government of Thailand, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Thailand for their close cooperation extended to the team.

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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1. PATUM THANI AND PRACHATIPAT

EXECUTIVE SUMMARY

Part 1 -GENERAL

THE STUDY AREA

Patum Thani is the capital of Patum Thani province and is located 28 km. north of Bangkok while Prachatipat is 11 km. east of Patum Thani along Phaholyotin Road near Bangkok.

These two areas are rapidly expanding because of the good terrain and accessibility to Bangkok. Now, a portion of the working population in Bangkok is beginning to settle in the fringe areas of Patum Thani and Prachatipat. Housing and factories are being constructed thus generating a lot of employment opportunities.

Both areas occupy a total of 1,153 sq. km. and are bounded on the south by Bangkok Metropolis. The Chao Phraya River lies on the western side of the study area where its average width of 300 m is at Patum Thani discharging 2,200 cu. m/s into the Gulf of Thailand.

Patum Thani and Prachatipat lie in a flat low lying delta plain with average elevations of 1-3 m above mean sea level. The entire study area is covered by thick clay, called Bangkok Clay, to about 30 m thick. This contributes to the presence of a large artesian groundwater basin contained in a series of vast confined aquifers up to a depth of 600 m. This, also, is the cause of land subsidence in the area.

Annual rainfall in the areas average 1,300 mm with highly seasonal distribution. More than 50 percent of this occurs during the rainy season. The average annual pan evaporation level is about 1,780 mm. Humidity is as high as 80 percent in September. Mean temperature show a range of 4.4 °C from 29.9 °C in April to 25.5 °C in December.

Patum Thani Province is economically strong on the manufacturing sector, followed by agriculture and trade. Although the agricultural sector is dominated by rice crops, the live stock subsector showed high growth rates.

Education is an important contribution of the province as many educational institutions are located in the area. Another is its ability to absorb overconcentration of the population in Bangkok. Although the province has its rural characteristics as lack of infrastructure development, an industrial development plan to increase vocational training, agri-production and improve water supply will soon boost the economy of the province.

Urbanization is observed along major transportation routes especially along Phaholyothin Road where even an industrial estate is present. Housing projects are located along this road in Amphoe Muang and neighboring tambons.

Since land prices depend on accessibility, land prices of areas along Phaholyothin Road and of major side roads in Amphoe Muang, Lam Luka and Thanyaburi are high.

Two town planning areas, Patum Thani and Prachatipat have high commercial and population densities. These areas have also planned as industrial centers where factories are being put up. But to avoid inefficient investment and possible traffic congestion along a "linear urbanization" trend, measures for contracted development within planned areas should be made.

WATER SOURCE

With the remarkable industrial and residential development in the two areas ground water supply withdrawal needs government approval.

The aquifers in the area is divided into eight layers from top to bottom as follows:

1.	Bangkok Aquifer -	(500 m zone)
2.	Phra Prading Aquifer -	(100 m zone)
3.	Nakhon Luang Aquifer -	(150 m zone)
4.	Nonthaburi Aquifer -	(200 m zone)
5.	Sam Khok Aquifer -	(250 m zone)
6.	Phaya Thai Aquifer -	(300 m zone)
7.	Thon Buri Aquifer -	(450 m zone)
8.	Pak Nam Aquifer -	(550 m zone)

In the Prachatipit area, eight deepwells are owned by the PWA while other privately owned deepwells also exist. In the Patum Thani area, the PWA owns three deepwells although only two are in operation. Presently, however, some 65 deepwells are in the areas withdrawing groundwater from four different aquifers.

According to statistics, the present withdrawal or water production in the Bangkok Metropolis and adjacent provinces is 1.4 million cu.m/d. where 94 percent of the water is withdrawn from the Lower Chao Phraya Basin. This has caused serious land subsidence and saline intrusion into the groundwater so that land subsidence in Bangkok has averaged 5-10 cm in recent years. Saline intrusion is serious in the Southern part of Bangkok where high pumping continues.

As a result, a limit for groundwater withdrawal should be set 800,000 cu. m/d. in the whole Lower Chao Phraya Basin.

For the proposed water supply system, no other water source can be considered except the Chao Phraya River itself.

After the Mae Khlong Diversion Project is completed, RID's increased allocation for water supply will be 145 cu. m/s against which water demand in the service area at the intake level is:

1996	1.30 cu. m/s
2001	2.60
2006	3.38
2011	4.16

EXISTING WATER SUPPLY SYSTEM

(1) Patum Thani

The waterworks system of Patum Thani, founded in 1962, is under the jurisdiction of PWA Regional Office 3 in Bangkok.

Water for the system comes from two deepwells with the combined capacity of 100 cu. m/h. A third deepwell is still under construction. Treatment is by chlorination after which the water distributed by clear water pumps either directly or through the elevated tank by gravity to some 1,445 concessionaires (as of 1987).

Water production and sales of the waterworks in the past are tabulated as follows:

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Connection	Consumption 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

Actual water intake exceeds proper intake capacity by an average of 50 percent. Although the number of connections has increased to 1,713 in 1988, the increase in water sales remains unclear with the system having a rate of unaccounted water at a high 45.1 percent. This could have been caused in part by a big crack found at the pump foundation due to ground subsidence.

Expansion plans are underway especially for distribution pipelines the most recent of which was towards the north and southwest along the major roads.

(2) Prachatipat

The waterworks system of Prachatipat, founded in 1982, is under the jurisdiction of the PWA Regional Office 3 in Bangkok.

Water for the system comes from two deepwells with a combined capacity of 290 cu. m/d. Two new deepwells with the intake capacities of 120 cu. m/h and 240 cu. m/h are still under construction as of September 1988.

Water is treated by chlorination and is distributed to the 1,735 connection (as of 1987) by clear water pumps along the Rangsit Highway and its adjacent areas.

Water production and sales of the waterworks in the past are tabulated as follows:

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Connection	Consumption 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	1,168,847	621,016	1,516	1.122
1987	1,204,972	707,649	1,735	1.117

Because of the boom in the industrial development and housing estates, the distribution pipelines have been expanded every year. This, however, resulted in operational inconsistencies because of the existence of many elevated tanks and deepwells for the housing estates. This caused pressure and flow control difficulties especially when all the pipelines are connected and in use.

Operation of the Prachatipat waterworks system improved when the water supply systems of two housing estates were put under its control. The number of connection has increased by 41.2 percent since 1987 reflective of the development in the area. But the average rate of unaccounted for water is as high as 42.1 percent.like in Patum Thani.

Constraints exist for both the Patum Thani and Prachatipat water works systems. These are land subsidence, saline intrusion and declining groundwater levels. As for constraints in the existing facilities, these are on the unevenness of intake and clear water pumps capacities, the ineffective use of the elevated tanks and the high unaccounted for water ratio.

Both systems are directly supervised by the regional office of PWA and are assisted technically by the same. The organization of the two waterworks systems consists of the water production, services and administration sections.

POPULATION AND WATER DEMAND

Future service ratios forecasting is made by tambon since each of them has varying levels of development, population densities and characteristics.

Thus high density areas are Tambon 12 in Amphoe Muang and Tambon 1 in Thanyaburi; low density areas are Tambons 1, 2, 3, 5, 6 and 7 in Amphoe Sam Khok and Tambons 1, 3 and 6 in Lad Sum Kaeo. The rest of the 34 tambons are medium density areas.

Future served population is summarized as follows:

Year	Population Density of Service Area				Average Service Ratio (%)
	High	Medium	Low	Total	
1991	28,183	12,478	0	40,661	34.4
	(62.412)	(52,385)	(3,434)	(118,231)	
1996	45,492	41,280	0	86,772	36.9
	(80,554)	(151,128)	(3,635)	(235,317)	
2001	69,986	86,340	976	156,302	45.5
	(104,34)	(234,664)	(4,878)	(343,885)	
2006	97,452	160,358	7,882	265,592	53.5
	(123,384)	(351,091)	(22,522)	(496,997)	
2011	128,182	236,073	12,016	376,271	67.2
	(142,424)	(393,458)	(24,027)	(559,909)	

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

For future water consumption, forecasts are made on five categories:

a) domestic water consumption

b) governmental/institutional consumption

c) commercial water consumption

d) university/colleges consumption

e) industrial water consumption

The future water demand was calculated and summarized as the table below:

Water Demand Prediction Summary

Category	1991	1996	2001	2006	2011
Domestic	6,319	14,205	26,529	47,595	73,657
Gov'l/Inst'l	1,578	3,141	4,590	6,634	7,474
Commercial	1,182	2,353	3,439	4,970	5,599
University/College	0	3,547	4,289	8,627	10,000
Industrial	0	28,100	39,851	69,753	74,130
Others	363	798	1,431	2,495	3,732
Sub-Total	9,443	52,144	80,129	140,073	174,592
Unaccounted for Water	3,227	14,584	21,848	35,896	43,648
Daily Average	12,670	66,728	101,977	175,969	218,240
Daily Maximum	15,204	80,074	122,372	211,163	261,888

Daily maximum demand = (Daily average demand) x 1.20

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality of Chao Phraya River.

The design criteria is summarized as follows:

1. Water loss - intake loss is 10%; treatment loss is 8% of production

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 3.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

5. Foundation Structure for Treatment Plant and Distribution Reservoir - Use of centrifugal prestressed concrete pile with a 500 mm diameter to a strength of 60 ton each is proposed

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant and distribution reservoirs - by quantities for civil/architectural, mechanical, and electrical works. This method was adopted since there was no reference of the cost estimates for the system with this large capacity.

c) Land acquisition - land cost was calculated on the basis of the unit land costs which are Baht 2 million per rai (1,600 sq m) for the intake and water treatment plant, and Baht 5 million per rai for the distribution reservoirs.

The cost estimates are separated into foreign and local cost portions as shown here:

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

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

PART 2 DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

The future service area is divided into eight zones as shown in Figure S-1 to facilitate the efficient and economical water transmission and distribution. The alternative study was made to determine the most reasonable scheme in the comparison of the six alternatives. The recommended scheme consist of the following features:

a. Water treatment plant with the maximum capacity of 283,000 cu m/day will be constructed at the upstream of the existing MWA's raw water intake.

b. A total of six distribution reservoirs will be constructed. The characteristics of the proposed reservoirs are summarized as follows:

Proposed Distribution Reservoirs

Reservoir No.	Zone No.	Location	Volume (cu m)	Structure	Land Requirement
D-1-1	1	Exis.(New)	5,000	PC	-
D-1-2		Exis.(Old)	13,000	PC	-
D-2	2	New	19,100	PC	6,500 sq m
D-3	3	Exis.	2,000	RC	-
D-4	4	Exis.	2,200	RC	-
D-6	6	New	13,000	PC	6,000 sq m
D-7	7	Exis.(New)	9,000	RC	-

In the table above, Prestressed Concrete (PC) is proposed for some reservoirs. This is derived from the prospective constraints for the land acquisition. However, Reinforced Concrete (RC) structure is preferred if the enough size of the land is purchased with inexpensive cost and in time not to delay the the implementing schedule. The comparison of two structures are shown in Appendix A-8-6.

c. Water distribution to consumers will not be made directly from the treatment plant, but made from the distribution reservoirs provided in the zones.

d. Water transmission to the distribution reservoirs will be separated from the operation of water distribution to consumers. Figure S-2 shows a schematic diagram of the proposed system.

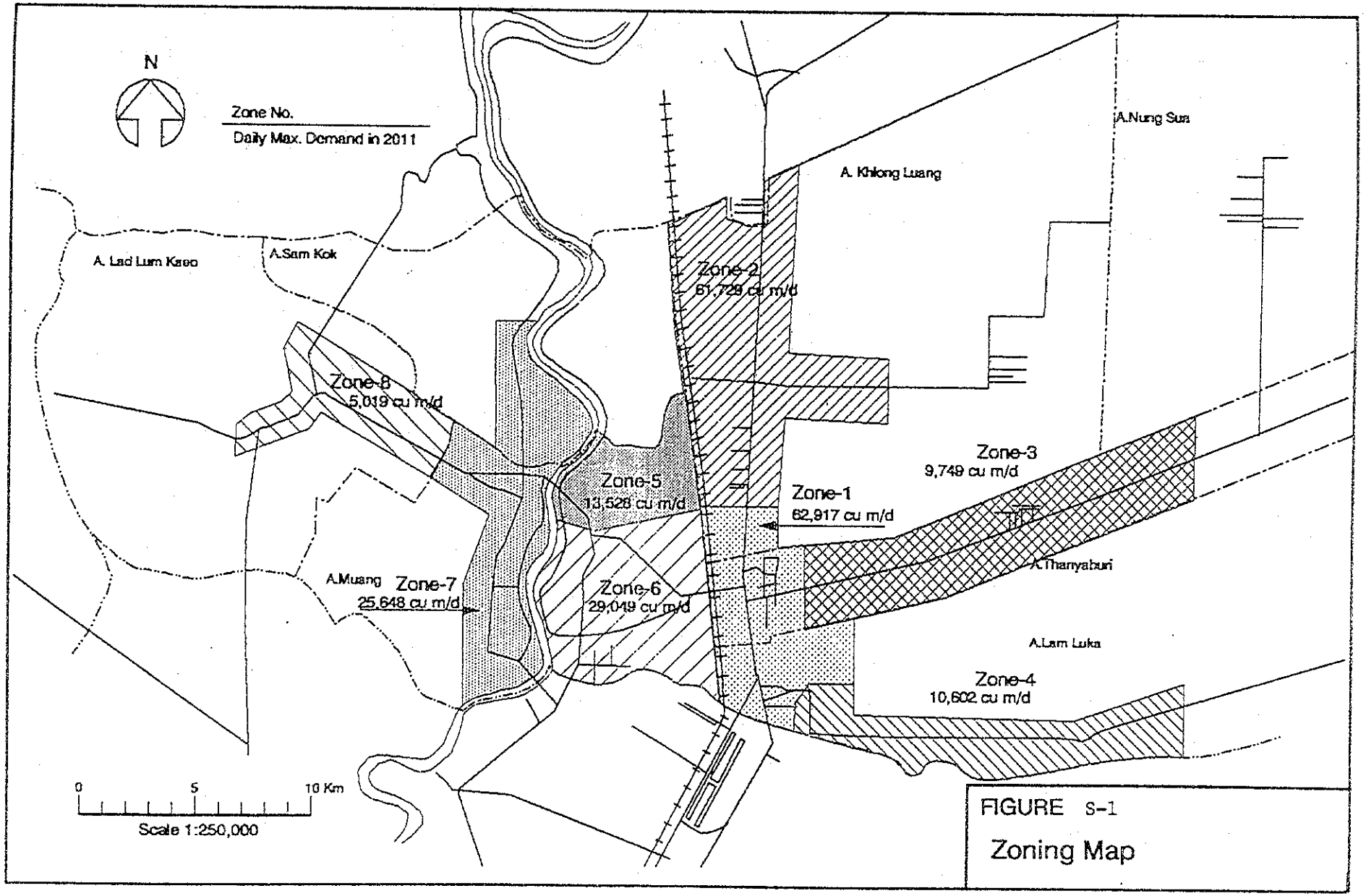


FIGURE S-1

Zoning Map

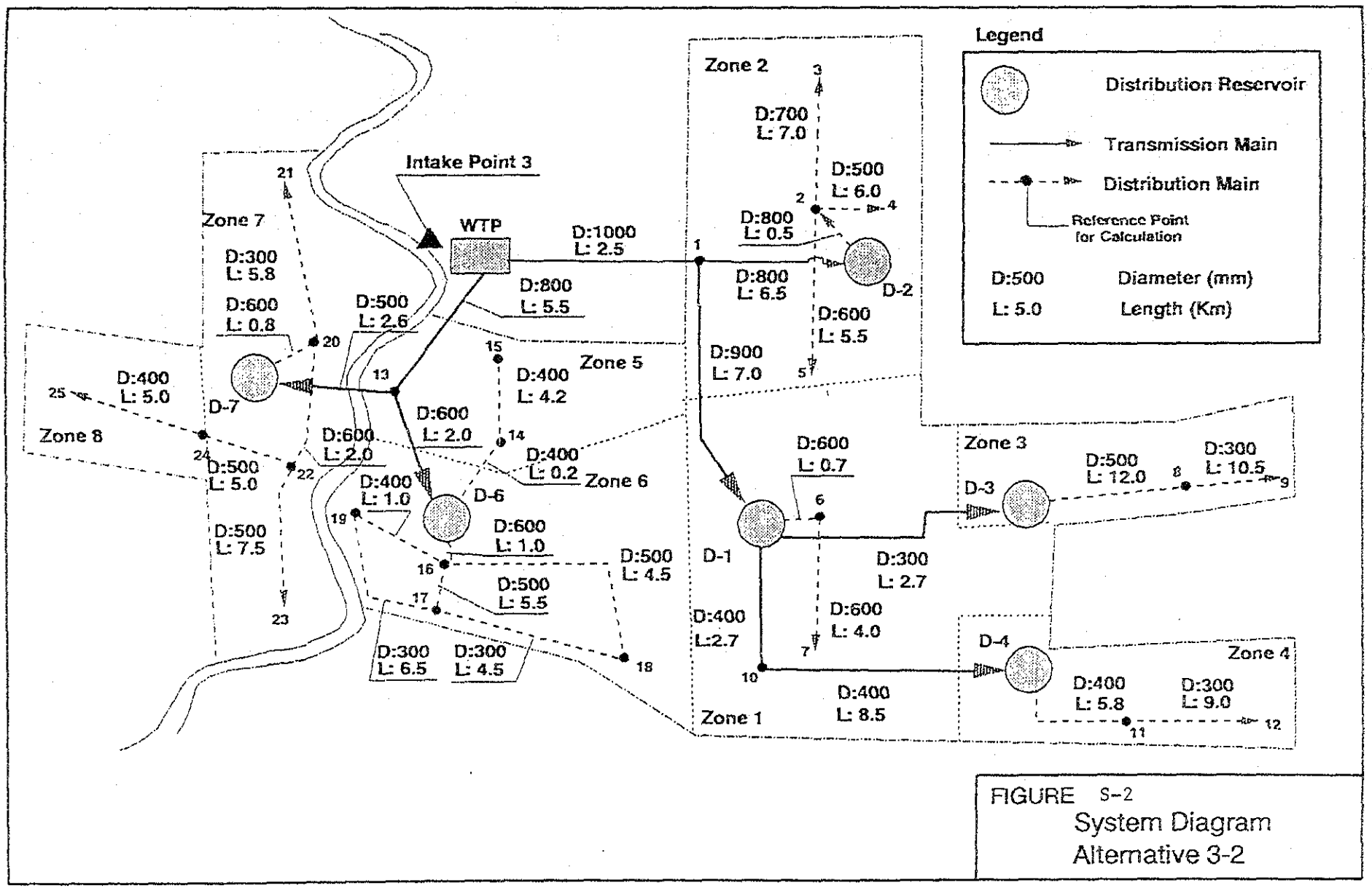


FIGURE S-2
System Diagram
Alternative 3-2

IMPLEMENTATION PLAN

The implementation plan of the total project will follow projections on water demand. The construction of the treatment plant is proposed to be carried out in two phases: (1) the first phase in 1993-1995, and (2) the second phase in 1998-1999. The construction of the distribution reservoirs, and the transmission and distribution pipelines will be constructed in two years in each phase. Figure S-3 shows the water demand, the treatment capacity and the construction schedule of the facilities.

ORGANIZATION OF WATERWORKS

The organization of the waterworks system will have to be expanded to include sections on administration, water production, operation of the distribution reservoirs and the number of staff needed to run the system depend on water demand. Figure S-4 shows a proposed organization for the new system.

PROJECT COST ESTIMATES

(1) Construction Cost

Construction cost summary was based on the 1989 prices and was calculated for each facility component as shown in the Table below.

Summary of Construction Cost

(unit : Baht 1000)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	72,195	50,549	21,646
2.Treatment Plant	656,017	305,705	350,312
3.Distribution Reservoirs	367,487	147,426	220,061
4.Transmission Pipeline	287,027	227,610	59,417
5.Distribution Pipeline	600,223	424,969	175,254
Sub Total	1,982,949	1,156,259	826,690
6.Land Cost	177,000	0	177,000
Total	2,159,949	1,156,259	1,003,690

(2) Operation and Maintenance Cost

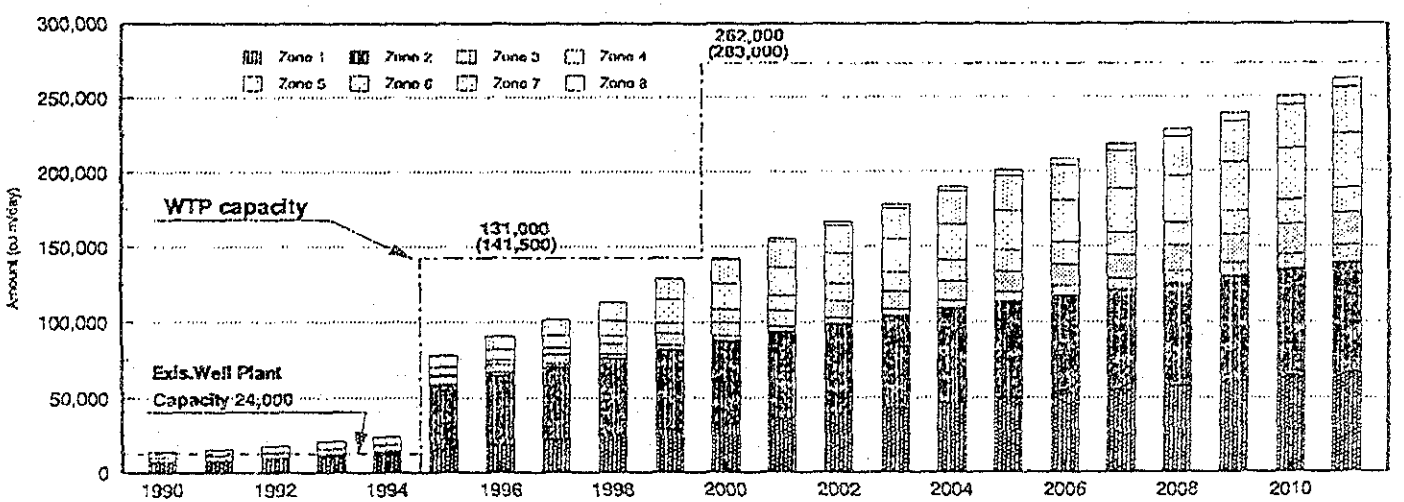
Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement

costs.

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Total
1990 :	0	132	4,566		4,698
1991 :	0	145	5,178		5,324
1992 :	0	169	5,840		6,009
1993 :	0	196	6,555		6,751
1994 :	0	228	7,327		7,555
1995 :	21,740	3,204	8,793		33,737
1996 :	24,015	3,725	11,718	921	40,379
1997 :	27,170	4,166	13,433	921	45,689
1998 :	29,289	4,625	15,290	921	50,124
1999 :	33,954	5,275	17,298	921	57,449
2000 :	36,457	5,833	20,279	921	63,490
2001 :	40,169	6,369	22,665	921	70,124
2002 :	42,667	6,832	25,668	921	76,088
2003 :	46,364	7,304	28,603	1,365	83,636
2004 :	49,584	7,785	31,767	1,365	90,502
2005 :	52,511	8,249	36,381	1,365	98,506
2006 :	54,731	8,561	40,112	1,769	105,172
2007 :	56,689	8,956	45,232	1,769	112,646
2008 :	58,752	9,372	50,167	1,769	120,061
2009 :	60,925	9,810	55,482	1,769	127,986
2010 :	63,211	10,269	61,204	1,769	136,452
2011 :	65,612	10,750	67,359	1,769	145,490



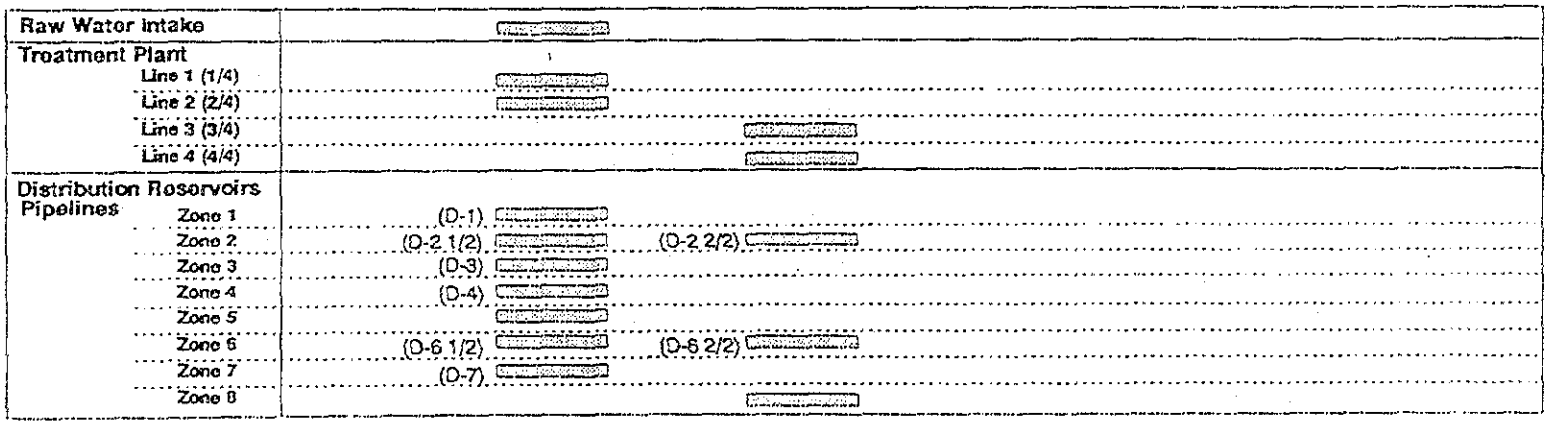


FIGURE S-3

Implementation Plan

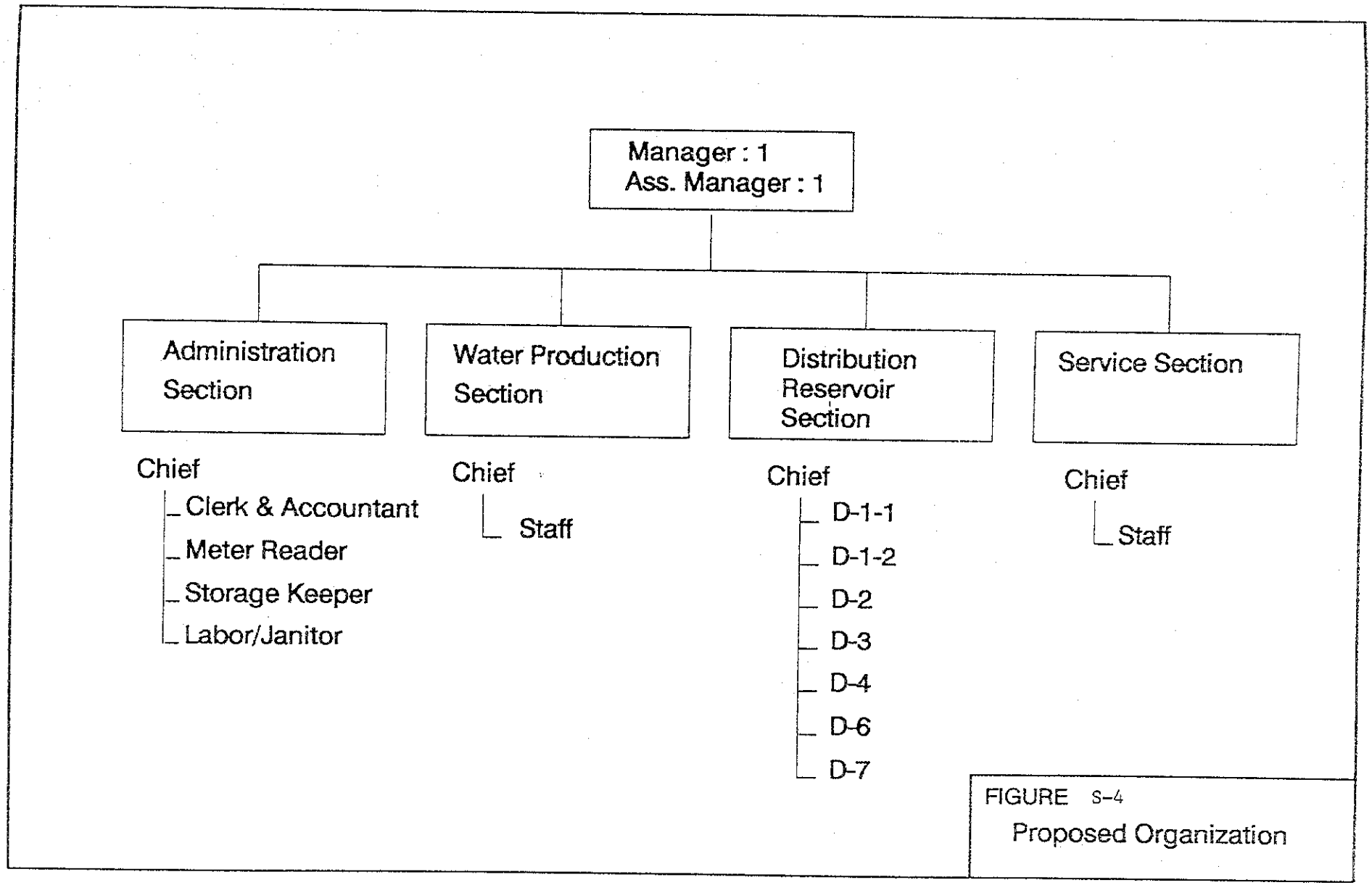


FIGURE S-4
Proposed Organization

PART 3 FEASIBILITY STUDY

Preliminary Design

The preliminary design was prepared for the proposed facilities. The characteristics of the major facilities of the treatment plant are summarized as follows:

a. Receiving Well
   Type : Circular
   Dimension : Dia. 9.0 m x D 5.0 m
   No. : 1

b. Mixing Basin
   Type : Square
   Dimension : L 4.0 m x W 4.0 m x D 3.0 m
   No. : 4

c. Flocculator
   Type : Mechanical flocculation
   Dimension : L 3.6 m x W 10.0 m x D 3.6 m x 3 stages
   No. : 16

d. Sedimentation Basin
   Type : Rectangular with Inclining Plate
   Dimension : L 18.0 m x W 18.0 m x D 4.5 m
   No. : 8

e. Sand Filter
   Type : Rapid Sand Filter, Inter-filter backwashing type
   Dimension : L 15.0 m x W 10.0 m
   No. : 16

f. Clear Water Reservoir
   Type : Rectangular
   Dimension : L 60.0 m x W 60.0 m x D 5.0 m
   No. : 2

g. Sludge Lagoon
   Type : Open Cut, Rectangular
   Dimension : L 68.0 m x W 33.0 m x D 3.0 m
   No. : 2

h. Sludge Drying Bed
   Type : Concrete Bed, Rectangular
   Dimension : L 30.0 m x W 20.0 m x D 1.0 m
   No. : 4

As shown in Figure S-3, the construction will be divided in two phases. The seven zones (Zones 1-7) will be covered in the first phase project while Zone 8 will be covered by the second phase. The project component is accordingly divided in two phases as shown below:

Project Component in Two Phases

Facility	Phase 1	Phase 2
Raw Water Intake		
	Intake Channel	
	Pumping Station	
	Pump : 3 units	Pump : 1 unit
	Raw water pipe	
Treatment Plant		
	Capacity : 141,500 cu m/day	Capacity : 141,500 cu m/day
	Receiving well	
	Mixing tank : 2 units	Mixing tank : 2 units
	Flocculator : 2 lines	Flocculator : 2 lines
	Sedimentation basin: 8 basins	Sedimentation basins: 8 basins
	Sand filter : 8 units	Sand filter : 8 units
	Cleat water reservoir: 1 unit	Clear water reservoir: 1 unit
	Sludge lagoon : 2 units	
	Sludge drying bed : 2 units	Sludge drying bed : 2 units
	Clear water pump: 6 units	Clear water pump : 2 units
Distribution Reservoir		
	D-1-1 : V = 5,000 cu m	
	D-1-2 : V = 13,000 cu m	
	D-2 : V = 9,550 cu m	D-2 : V = 9,550 cu m
	D-3 : V = 2,000 cu m	
	D-4 : V = 2,200 cu m	
	D-6 : V = 6,500 cu m	D-6 : V = 6,500 cu m
	D-7 : V = 9,000 cu m	
Transmission Pipelines		
	Steel pipes	
	1,000 mm, L = 2,500 m	
	900 mm, L = 7,000 m	
	800 mm, L = 12,000 m	
	600 mm, L = 3,800 m	
	400 mm, L = 11,200 m	
	AC Pipe	
	300 mm, L = 2,700 m	
Distribution Pipelines		
	(for Zones 1 to 7)	(for Zone 8)
	Steel Pipes	Steel Pipes
	1,000 mm, L = 200 m	400 mm, L = 3,900 m
	900 mm, L = 3,190 m	
	800 mm, L = 4,540 m	A/C Pipes
	700 mm, L = 1,200 m	300 mm, L = 1,750 m
	600 mm, L = 14,720 m	250 mm, L = 1,000 m
	500 mm, L = 30,710 m	200 mm, L = 2,300 m
	400 mm, L = 30,170 m	150 mm, L = 500 m
	A/C Pipes	
	300 mm, L = 39,480 m	
	250 mm, L = 19,255 m	
	200 mm, L = 13,300 m	
	150 mm, L = 3,270 m	
	100 mm, L = 8,050 m	

Financial Study

Project Cost Estimates

Total Project cost is estimated at 2,291,633 Baht, with a foreign exchange requirement of 1,385,231 Baht and local cost component of 906,402 Baht. The breakdown of cost estimates by phase is as follows:

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	1,300,752	682,200	1,982,952
Phase 1	1,032,226	512,664	1,544,890
Phase 2	268,526	169,536	438,062
b. Engineering Cost			
Design, 4% of (a)	55,974	31,276	87,250
Phase 1	50,377	28,148	78,525
Phase 2	5,597	3,128	8,725
Supervision, 2% of (a)	28,505	15,926	44,431
Phase 1	17,310	9,671	26,981
Phase 2	11,195	6,255	17,450
c. Land Cost (Phase 1)	0	177,000	177,000
TOTAL	1,385,231	906,402	2,291,633
Phase 1	1,099,913	727,483	1,827,396
Phase 2	285,318	178,919	464,237

Financing Plan

The following financing schemes were considered:

Alternative 1: Total project cost financed from multilateral loan

Alternative 2: Foreign cost portion financed from bilateral loan; local cost from multilateral loan

Alternative 3: Foreign cost portion financed from bilateral loan; local cost equally financed from domestic loan and from PWA equity

Alternative 4: 86% of total project cost consisting of all foreign cost and 593,670 million Baht of local cost financed from bilateral loan; the remaining 312,732 million Baht of local cost equally financed from domestic loan and from PWA equity

Alternative 5: 86% of total project cost, consisting of all foreign cost and 593,670 million Baht financed from bilateral loan; 312,732 million Baht of local cost from domestic loan

Alternatives 3 and 4 are more desirable in view of lower funding burden for PWA. However, Alternative 4 is recommended over Alternative 3 due to lower fund requirements during construction stage.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on Alternative 4 financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials, collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on Alternative 4 financing scheme, O&M, and connection expenses (50% of connection fees).

Results of cash flow analysis show deficits ranging from -24.626 million Baht to -411.268 million Baht for the period 1990 to 1994. These are expected to be covered with PWA equity. However, large surpluses during the subsequent years (1995-2020) are forecasted. For year 2020, cumulative cash surpuls is estimated at 2,339.3 Million Baht.

Financial Internal Rate of Return (FIRR)

The project's internal rate of return on equity (IRROE), based on Alternative 4 financing scheme, was assumed to represent the FIRR. The IRROE, unlike the internal rate of return on investment (IRROI), takes into account the debt payments that have to be made each year. Also considered in the analysis was the salvage value of capital assets which was added to the benefit flows. Results indicate that the project is financially viable, with an FIRR of 11.5%, which is greater than the 9% opportunity cost of capital.

ECONOMIC STUDY

The benefits were represented by the following: a) economic value of water, assumed to be 20% higher than the average rate per volume of water used in the financial analysis; b) health benefits, expressed as the reduction in cost of time lost and reduction in medical expenses (assuming 50% of waterborne diseases are caused by poor water supply system); c) increase in land values, assuming an increase of 50% up to year 2011 (7 years after construction of the project) and assuming that 5% of the increase in land values is attributed to the availability of water supply system. Other expected benefits such as increased employment opportunities, intensified land use, increaed government tax revenues were not quantified.

The econoimc costs were calculated based on financial costs adjusted for the following: a) import duties and domestic tax assumed to be 10% and 5%, respectively; b) shadow prices for foreign and local currency of 1.00 and 0.95 respectively, and for unskilled labor of 0.5.

The project was found to be economically viable, with an economic internal rate of return (EIRR) of 9.5%, which is greater than the 9% opportunity cost of capital.

2. PHUKET

EXECUTIVE SUMMARY

Part I - GENERAL

THE STUDY AREA

Phuket is the only island province in Thailand. It is in the Indian Ocean about 867 km from Bangkok and stretches 49 km from north to south and 19 km from east to west.

Phuket is quite mountainous and has many small streams and mining pits. It also has beautiful beaches along the western and southern side of the island that have become major tourist attractions.

Tin ore is the major mining resource in Phuket. Among its agricultural resources are coconut, rubber and fisheries. The promotion of the island as a tourist destination has generated new job opportunities. The average income per person in Phuket is considerably higher than the national average.

Phuket can be reached by land, air or sea. Recently, a Deep Sea Port in Tambon Wichit was constructed, the only one in the west coast of Thailand. Phuket Municipality is the hub of urbanization in the province where expansion is moving beyond its present administrative boundary.

Future land development trends points to the western coast for tourism oriented establishments and industrial complexes because of the Deep Sea Port. Development of an industrial estate is being planned near the airport at Tambon Mai Khao.

The development of Phuket is not without problems. These are unemployment, environmental deterioration, lack of roads, water shortages, high cost of living and land use controversies.

WATER SOURCE

Although Phuket is blessed with an annual average rainfall of 2,500 mm, this is carried away by small streams. Ground water potential is low due to shallow bed rock.

Water supply thus comes from waterfalls, abandoned mining pits and the Bangwad reservoir. Rainwater is used as an alternative to shallow wells.

Phuket Municipal Water Supply sources, for example, are from five mining pits that produce high quality water.

About 3,000 shallow wells, are all over the island and are mostly seen on the western coast or in the northeastern villages. These wells are often contaminated by waste water or seawater. Deepwells are also in use for private water supply.

New water sources are being eyed for development such as dams, other mining pits and the tapping of streams. The potential yield of ground water is still limited.

EXISTING WATER SUPPLY SYSTEM

There are five independent water supply systems in Phuket island. It is the PWA Phuket Waterworks that could supply the entire island while the Phuket Municipal Waterworks supplies the municipality of Phuket. The rest are small community waterworks.

The PWA's waterworks now covers the areas which are Patong Beach, Kathu, and the area along the distribution pipeline stretched to the Deep Sea Port from the Bangwad Water Treatment Plant. The waterworks has also started in 1989 to supply treated water to the Phuket Municipality to help the water shortage in the municipality.

It is the PWA Regional Offices (IV) that directly supervise the urban and rural waterworks. The Phuket Waterworks, which has 666 connections, itself functions with three sections - water production, service and administration.

Water production and sales of the Phuket waterworks in 1987 are 805,878, and 394,314 cu m/day, respectively.

POPULATION AND WATER DEMAND

The study area is the main island of Phuket Province consisting of Ampoes Thalang, Kathu and Muang Phuket and Phuket Municipality with a total of 17 tambons.

The population of the study area was 153,600 in 1987 with a growth rate of 2.3 percent.

The future served population was calculated by tambon in the service area density, i.e., high density, medium, low as shown in the following table:

Year	Population Prediction				Average Service Ratio
	Municipality	Tourism Spot	Other Area	Total	
1991	34,428	3,254	0	37,682	33.24
	(60,400)	(21,684)	(31,292)	(113,376)	
1996	42,055	7,053	5,095	54,203	44.37
	(64,700)	(23,507)	(33,960)	(122,167)	
2001	50,589	9,998	9,029	69,616	53.38
	(69,300)	(24,993)	(36,115)	(130,408)	
2006	60,926	14,477	15,216	90,619	65.35
	(74,300)	(26,319)	(38,040)	(138,659)	
2011	71,550	19,167	19,797	110,514	75.45
	(79,500)	(27,380)	(39,588)	(146,468)	

As Phuket has a large number of the tourists, the tourist population is taken into consideration when plotting future water consumption aside from domestic, institutional, commercial and industrial consumption.

The number of tourist was predicted referring to "the Study on Potential Tourism Area Development for Southern Region in Thailand" for the Tourism

Authority of Thailand (TAT). The latest status of the hotel development plan in the Phuket municipality was also considered. The predicted number of tourist is tabulated in the table below:

Prediction of the Number of Tourist

Area	1991	1996	2001	2006	2011
Inside Municipality	3,780	3,780	3,780	3,780	3,780
Outside Municipality	13,698	17,466	19,895	19,895	19,895
Northern Area					
High Class	2,244	4,830	6,067	6,067	6,067
Low Class	12	275	324	324	324
Sub-total	2,256	5,105	6,391	6,391	6,391
Southern Area					
High Class	7,312	7,978	8,677	8,677	8,677
Low Class	4,130	4,383	4,827	4,827	4,827
Sub-total	11,442	12,361	13,503	13,503	13,503

The predicted total water demand is summarized as shown below:

Water Demand Prediction

(Unit : cu.m/d)

Item	1991	1996	2001	2006	2011
Domestic	13,889	17,054	20,516	25,139	29,993
Inside Mun.	13,564	15,900	18,544	21,772	25,138
Outside Mun.	325	1,154	1,972	3,367	4,855
Governmental	2,251	2,409	2,556	2,701	2,838
Inside Mun.	1,392	1,453	1,518	1,589	1,663
Outside Mun.	859	956	1,038	1,112	1,175
Tourism	12,387	14,727	16,212	16,212	16,212
Inside Mun.	4,200	4,200	4,200	4,200	4,200
Outside Mun.	8,187	10,527	12,012	12,012	12,012
Commercial	3,707	4,690	5,371	5,533	5,701
Inside Mun.	678	795	927	1,089	1,257
Outside Mun.	3,029	3,895	4,444	4,444	4,444
Industrial	1,684	1,684	1,684	1,684	1,684
Inside Mun.	684	684	684	684	684
Outside Mun.	1,000	1,000	1,000	1,000	1,000
Sub-Total	**33,918**	**40,564**	**46,339**	**51,269**	**56,428**
Inside Mun.	20,518	23,032	25,873	29,334	32,942
Outside Mun.	13,400	17,532	20,466	21,935	23,486
Municipality & New Service Area					
Water Demand	23,753	33,406	38,393	43,043	47,882
Unaccounted-for Water Ratio (%)	20	20	20	20	20
Unaccounted-for Water	5,938	8,352	9,598	10,761	11,971
PWA Existing Service Area (Kathu & Patong)					
Water Demand	6,465	7,155	7,945	8,225	8,546
Unaccounted-for Water Ratio (%)	37	33	28	24	20
Unaccounted-for Water	3,797	3,524	3,090	2,597	2,137
Daily average	**39,953**	**52,437**	**59,026**	**64,626**	**70,536**
Peak Factor	1.30	1.30	1.30	1.30	1.30
Daily Maximum	**51,939**	**68,168**	**76,734**	**84,014**	**91,697**

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality.

The design criteria is summarized as follows:

1. Water loss - a total of intake and treatment loss is 5 %

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 8.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant - PWA's data for the unit cost is used for the civil structures of the treatment plant. For the mechanical works, major items are counted individually. The cost of the electrical works are calculated by the percentage to the mechanical works.

c) Land acquisition - land cost was calculated on the basis of the unit land costs as follows:

Flat area in the island	:	Baht 2,000,000 per rai (1,600 sq m)
Hill side area near the beach	:	Baht 5,000,000 per rai
Rubber plantation are at the hill side	:	Baht 500,000 per rai
Hill side area in and outside the island	:	Baht 300,000 per rai

The cost estimates are separated into foreign and local cost portions as shown here:

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

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

Part 2 - DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

In proposing the alternative solutions to the water problem in Phuket, the following factors were taken into consideration:

a) the water supply expansion should cope with present and future development of resorts in the island;

b) a balanced layout of facilities should be made as the service area is scattered into 11 blocks;

c) land acquisition should be seriously considered as land is becoming expensive due to increased private sector investments.

Five dams are proposed to be constructed with a maximum intake capacity of 58,400 cu.m./d. The characteristics of each dam is shown as follows:

Dam	Reservoir Volume	Supply Capacity
Bang Tho Sung	4,300,000 cu m	9,600 cu m/day
Khlong Katha	5,000,000	10,900
Bang Nieo Dam	3,100,000	8,900
Khao Che Tra	3,000,000	7,600
Khlong Lo Yung	11,500,000	21,400

While the dams are being constructed, temporary water sources should be made available. The tapping of Khlong Bang Yai Stream is proposed to supplement the intake capacity of the Bangwat Reservoir. Two mining pits at Khao Na Bon and Ban Tan Muang can be utilized as well.

For establishing the water supply system, the total service area is divided in 11 zones as shown in Figure S-1. As the water sources and service areas are scattered, the layout of the water supply system is limited by the geographical condition.

It is recommended that a total service area is divided into five systems and that several treatment plants are constructed close to the proposed dam sites as shown in Figure S-2 and the following table.

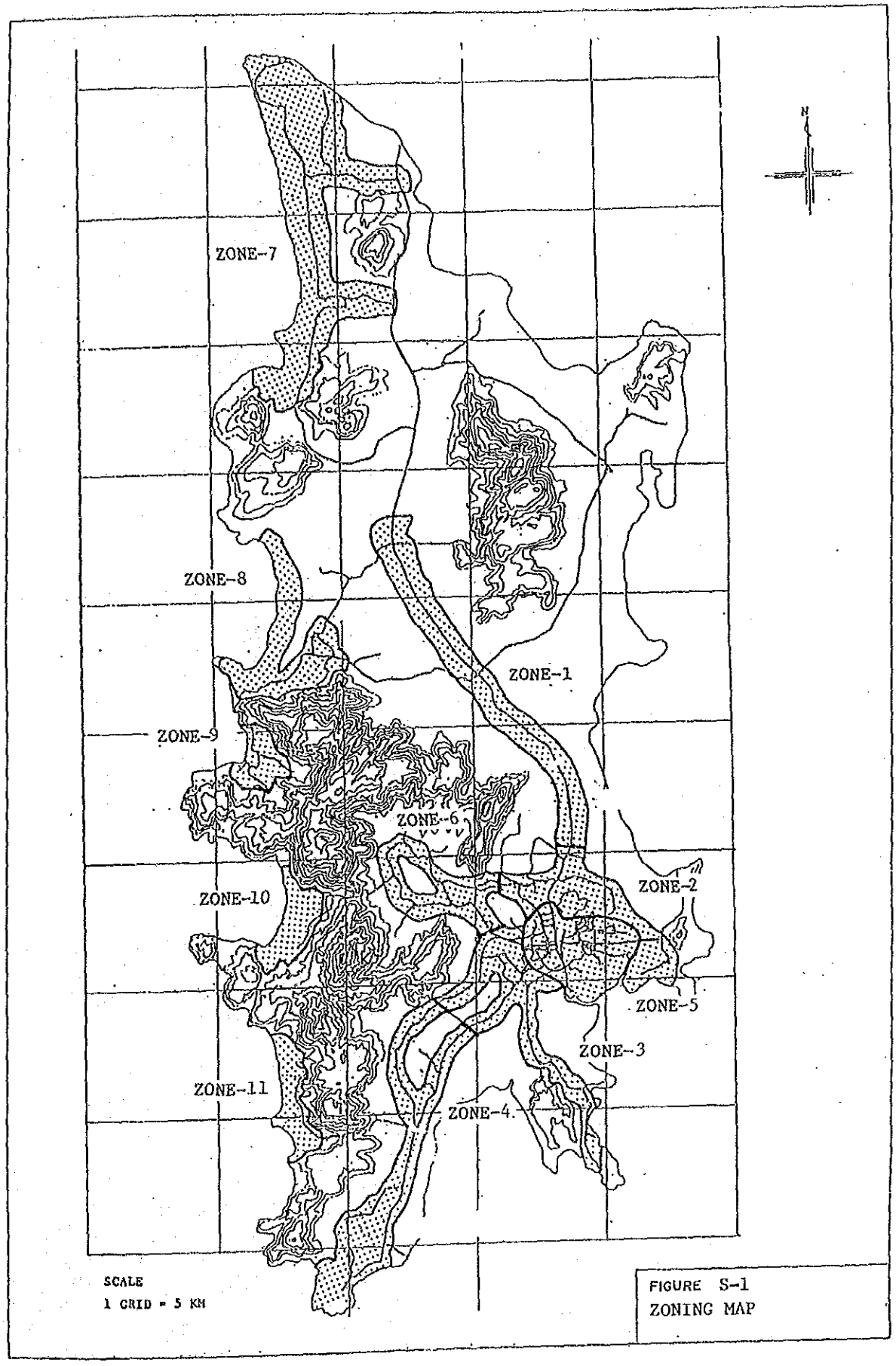


FIGURE S-1
ZONING MAP

Proposed Group of Treatment Plants and Dams

Treatment Plant	Raw Water Source: Dam	Supply Capacity (Day Ave.)	Zone Supplied	Amount Supplied (Day Ave.)
(1) Bangwat System				
T1 (Exis.)	Bangwat	11,700 cu m/d	Zone 6	893 cu m/d
(Bangwad)	Bang Tho Sung	9,600	10	9,788
			11	3,159
			5	4,622 2)
	(total)	21,300		18,462 1)
(2) Municipality System				
T2 (Exis.)	Mining Pits	13,900	Zone 5	13,200 1)
(Municipality)				
(3) Khlong Katha System				
T3	Khlong Khata	10,900	Zone 3	2,700
			4	1,670
			5	6,010 2)
	(total)	10,900		10,380 1)
(4) Bang Nieo Dam System				
T4	Bang Nieo Dam	8,900	Zone 1	1,103
	Che Tra	7,600	2	943
			8	2,476
			9	1,065
			5	10,127 3)
	(total)	16,500		20,954 4)
(5) Zone 7 System				
T5	Khlong Lo Yung	21,400	Zone 7	5,700
			to T4 System	7,078 5)
	(total)	21,400		12,778
			Balance for Thai Muang	8,622

Note : 1) (Supplied Amount) : Calculated from the treatment capacity of Bangwat WTP as follows:
Maximum Effective Capacity (Qmax) = 24,000 cu m/d
Equivalent Daily Average Capacity = 18,462 cu m/d (Qmax/1.3)
2) (Amount for Zone 5) =
(Total Supplied Amount, 1).) - (Other Zone's Amount)
3) (Amount for T4 System) = Total of Zone 5 demand (41,037 cu m/d) minus total of supplied amounts from T1 to T4

It is also proposed, as the immediate improvement project, that additional pipelines having 300 mm. size be laid from Patong side to Karon and Katha areas as well as three reservoirs. This will help reduce the problems arising from the high pressure from the Bangwat Treatment Plant. Of the three reservoirs, the first is a high level reservoir to receive water from the existing booster pumping station to supply water to two distribution reservoirs: one for Patong, and one for Karon and Katha. These distribution reservoirs will regulate distribution pressure.

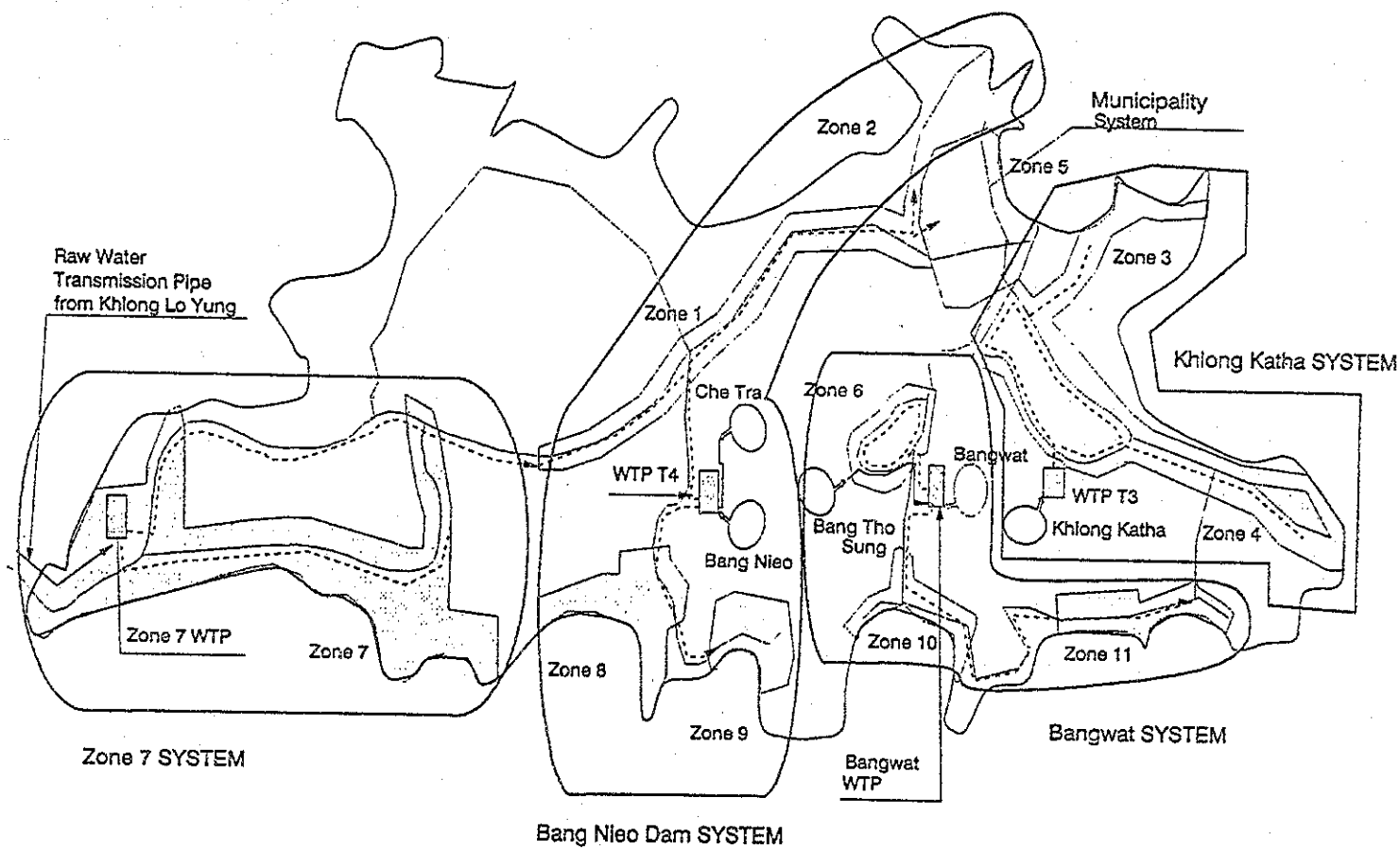


FIGURE S-2

TOTAL WATER SUPPLY SYSTEM

IMPLEMENTATION PLAN

The implementation of the plans depend on the most economical implementation of the water supply development taking into consideration water demand since the existing sources can only supply part of the demand in Bangwat and Phuket municipality. It also takes into consideration raw water sources which will depend on the existence of the dams.

Thus, a dam construction schedule is proposed according to phases with the following giving the last economic efficiency:

Phase I	(1990-1993)	-	Khlong Katha
			Bang Nieo Dam
Phase II	(1991-1994)	-	Khlong Lo Yung
Phase III		-	Khao Che Tra (2003-2006)
			Bang Tho Sung (2006-2009)

Aside from this dam construction schedule, the project implementation schedule is divided into two phases, components of which is described as follows:

Immediate Improvement Project (1990-1991)

* Temporary Water Source Development at Khlong Bang Yai
* Improvement of Beach Area Water Supply for Patong, Karon, and Katha

Main Project (1993-1995)

* Bangwat System
* Khlong Katha
* Bang Nieo Dam System
* Zone 7 System

The implementation schedule and projected water demand is shown in Figure S-3.

ORGANIZATION OF WATER WORKS

A new and improved organization for the size of the proposed water supply system is proposed. The organization will consist of the administration, the water production of the operation of raw pumping station at Khlong Lo Yung and the service section. The Figure S-4 shows a proposed organization chart.

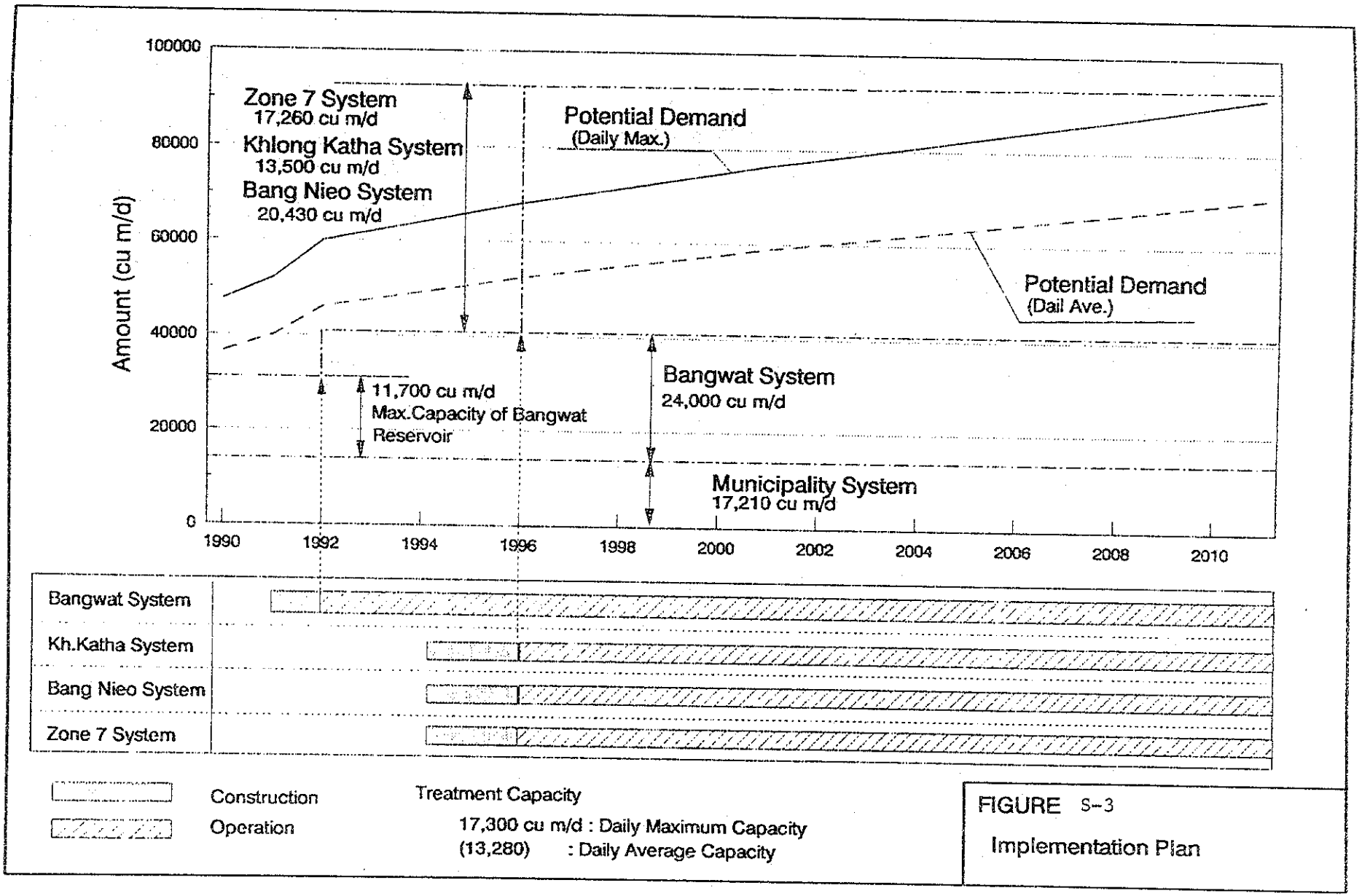


FIGURE S-3

Implementation Plan

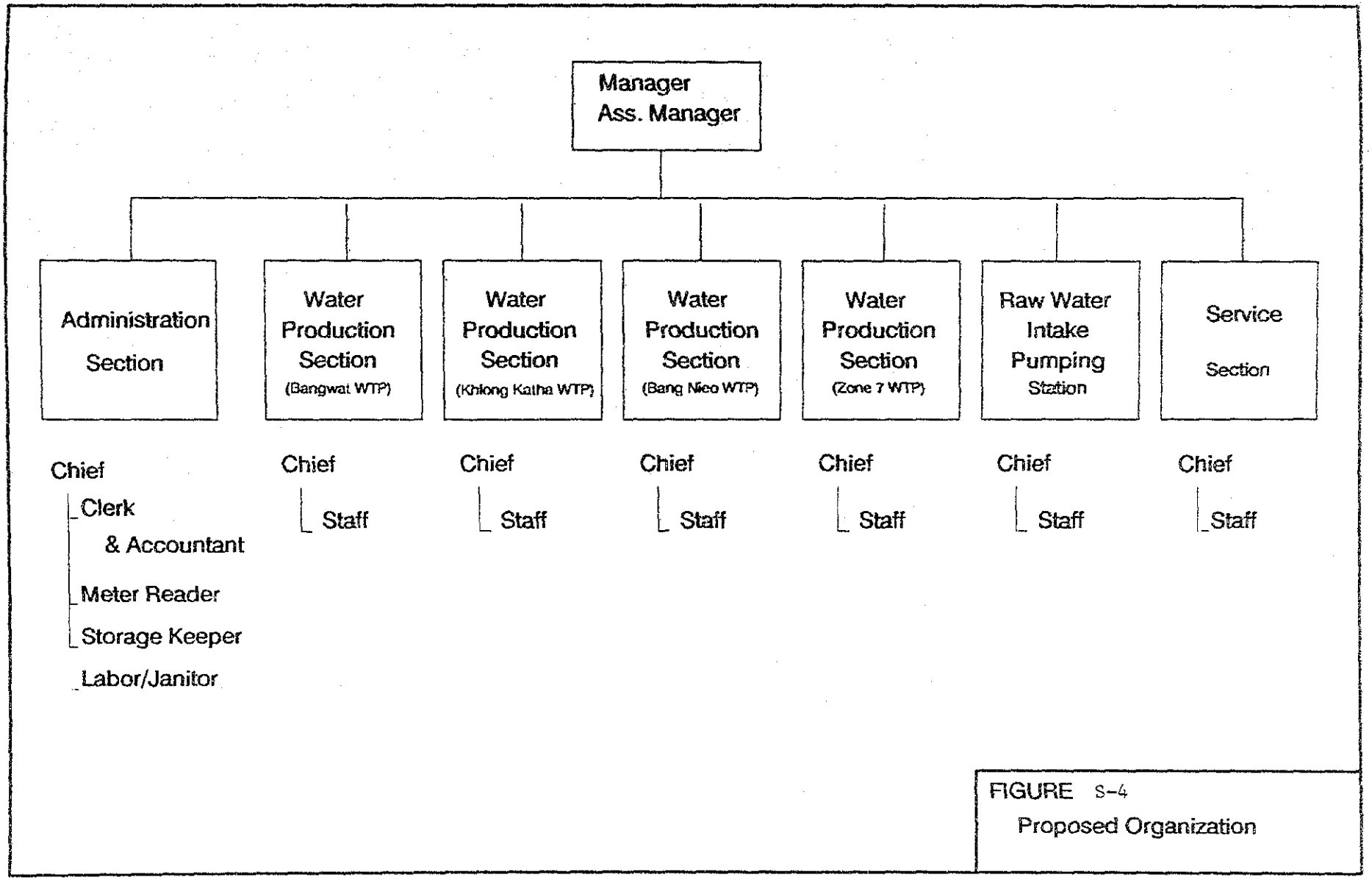


FIGURE S-4
Proposed Organization

PROJECT COST ESTIMATES

(1) Construction Cost

Construction cost summary was based on the 1989 prices and was calculated for each facility component as shown in the Table below.

Summary of Construction Cost

(unit : Baht 1000)

Item	Total Cost	Foreign Cur. Portion	Local Cur. Portion
A. Raw Water Development			
A-1. Construction Cost			
1. Bang Tho Sung Dam	514,307	334,660	179,647
2. Khlong Katha Dam	459,544	297,317	162,227
3. Bang Nieo Dam and Che Tra Dams	440,745	275,527	165,218
4. Khlong Lo Yung Dam	474,757	310,100	164,657
Total of A-1.	1,889,354	1,217,604	671,750
A-2. Land Cost			
1. Bang Tho Sung Dam	93,750	0	93,750
2. Khlong Katha Dam	125,000	0	125,000
3. Bang Nieo Dam and Che Tra Dams	343,750	0	343,750
4. Khlong Lo Yung Dam	375,000	0	375,000
Total of A-2.	937,500	0	937,500
Total of A.	2,826,854	1,217,604	1,609,250
B. Water Supply Development			
B-1. Construction Cost			
1. Bangwat System - Immediate Improvement	104,142	63,065	41,078
2. Bangwat System	36,320	29,056	7,264
3. Khlong Katha System	83,774	44,809	38,965
4. Bang Nieo Dam System	321,010	221,873	99,137
5. Zone 7 System	284,193	193,706	90,487
Total of B-1.	829,439	552,508	276,931
B-2. Land Cost			
1. Bangwat System - Immediate Improvement	7,031	0	7,031
2. Bangwat System	0	0	0
3. Khlong Katha System	7,500	0	7,500
4. Bang Nieo Dam System	11,250	0	11,250
5. Zone 7 System	94	0	94
Total of B-2.	25,875	0	25,875
Total of B.	855,314	552,508	302,806
Grand Total of A. B.	3,682,168	1,770,112	1,912,056

(2) Operation and Maintenance Cost

Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement costs.

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	OPERATION COST					Sub-Total
	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replacement	
1990	3,152	497	2,077	14		5,738
1991	4,165	497	2,180	14		6,855
1992	5,418	621	2,289	14		8,341
1993	5,433	621	2,404	14		8,471
1994	7,874	996	2,524	14		11,408
1995	8,089	1,012	2,761	14		11,876
1996	8,397	1,045	5,450	14		14,905
1997	8,708	1,070	5,722	65		15,565
1998	9,025	1,096	7,414	65		17,600
1999	9,346	1,122	7,785	65		18,318
2000	9,576	1,149	8,174	65		18,964
2001	9,890	1,176	8,583	65		19,713
2002	10,115	1,197	9,012	65		20,389
2003	10,288	1,218	11,584	65		23,155
2004	10,518	1,241	12,334	103		24,196
2005	10,726	1,261	12,951	103		25,041
2006	10,292	1,287	13,599	103		25,281
2007	10,528	1,310	14,279	103		26,220
2008	10,772	1,333	15,201	103		27,409
2009	11,023	1,356	16,180	103		28,661
2010	9,089	1,380	16,989	103		27,560
2011	9,332	1,405	17,838	103		28,678

PART 3 FEASIBILITY STUDY

Preliminary Design

The preliminary design was prepared for the proposed facilities. The characteristics of the major facilities of the treatment plant are summarized as follows:

Major Facilities of the Treatment Plants

Facility	T3 (Khlong Katha)	T4 (Bang Nieo Dam)	T5 (Zone 7)
a.Receiving Well			
Type	Circular	Circular	Circular
Dimension	Dia.3.0 x D 2.5	Dia.3.0 x D 3.0	Dia.3.0 x D 3.0
No.	1	1	1
b.Mixing Basin			
Type	Square	Square	Square
Dimension	L 1.2 x W 1.5 x D 1.5	L 1.5 x W 2.0 x D 1.5	L 1.5 x W 2.0 x D 2.0
No.	4	4	2
c.Flocculator			
Type	Hydraulic flocculation	Hydraulic flocculation	Hydraulic flocculation
Dimension	L 1.5 x W 20.0 x D 2.5	L 2.0 x W 24.0 x D 2.5	L 2.0 x W 20.0 x D 2.5
No.	4	4	4
d.Sedimentation Basin			
Type	Rectangular	Rectangular	Rectangular
Dimension	L 5.0 x W 30.0 x D 4.0	L 6.0 x W 38.0 x D 4.0	L 6.0 x W 32.0 x D 4.0
No.	4	4	4
e.Sand Filter			
Type	Rapid Sand Filter,	Rapid Sand Filter,	Rapid Sand Filter,
Dimension	L 3.0 x W 4.5	L 4.0 x W 5.0	L 3.5 x W 5.0
No.	8	8	8
f.Clear Water Reservoir			
Type	Rectangular	Rectangular	Rectangular
Dimension	L 32.0 x W 15.0 x D 5.0	L 35.0 x W 20.0 x D 5.0	L 30.0 x W 20.0 x D 5.0
No.	2	2	2

As shown in Figure S-3, the construction will be divided in two phases. The project components are accordingly divided in two phases as shown below:

Project Component in Each Phase

1. Immediate Improvement Project (1990-1991)

A. Temporary Water Source Development
   A-1. Construction of a Pumping Station at Khlong Bang Yai

B. Improvement of Beach Area Water Supply
   B-1. Construction of a high level reservoir
   B-2. Construction of service reservoirs
   B-3. Construction of transmission pipe from the high level reservoir to Karon beach
   B-4. Replacement of distribution pipes in Patong beach
   B-5. Construction of distribution pipes in Patong, Karon, and Katha beaches
   B-6. Construction of additional distribution pipes in Kathu area

2. Main Project (1994-1996)

A. Khlong Katha System

   Preceding dam project : Khlong Katha Dam

   A-1. Construction of a raw water pipe
   A-2. Construction of a treatment plant
   A-3. Construction of a distribution pipe

B. Bang Nieo Dam System

   Preceding dam project : Bang Nieo Dam
   (Khao Che Tra Dam is to be completed in 2006)

   B-1. Construction of a raw water pipe
   B-2. Construction of a treatment plant
   B-3. Construction of a distribution pipe

C. Zone 7 System

   Preceding dam project : Khlong Lo Yung Dam

   C-1. Construction of a raw water pumping station
   C-2. Construction of a raw water pipe
   C-3. Construction of a treatment plant
   C-4. Construction of a distribution pipe

Financial Study

Project Cost Estimates

Total Project cost is estimated at 928,303 Baht, with a foreign exchange requirement of 538,063 Baht and local cost component of 390,240 Baht. The breakdown of cost estimates by phase is as follows:

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	489,443	339,996	829,439
Phase 1	0	104,142	104,142
Phase 2	489,443	235,854	725,297
b. Engineering Cost			
Design, 6% of (a)	36,464	18,278	54,742
Phase 1	1,823	914	2,737
Phase 2	34,641	17,364	52,005
Supervision, 2% of (a)	12,156	6,091	18,247
Phase 1	1,216	608	1,824
Phase 2	10,940	5,483	16,423
c. Land Cost (Phase 1)	0	25,875	25,875
TOTAL	538,063	390,240	928,303
Phase 1	3,039	131,539	134,578
Phase 2	535,024	258,701	793,725

Financing Plan

The following financing schemes were considered:

Alternative 1: Total project cost financed from multilateral loan

Alternative 2: Foreign cost portion financed from bilateral loan; local cost from multilateral loan

Alternative 3: Foreign cost portion financed from bilateral loan; local cost equally financed from domestic loan and from PWA equity

Alternative 4: 83% of total project cost consisting all foreigncost. and 230,599 million Baht of local cost financed from bilateral loan; the remaining 159,641 million Baht of local cost equally financed from domestic loan and from PWA equity

Alternative 5: 86% of total project cost, consisting of all foreign cost and 230,599 million Baht financed from bilateral loan; 159,641 million Baht of local cost from domestic loan

Alternatives 3 and 4 are more desirable in view of lower funding burden for PWA. However, Alternative 4 is recommended over Alternative 3 due to lower fund requirements during construction stage.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on Alternative 4 financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials, collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on Alternative 4 financing scheme, O&M, and connection expenses (50% of connection fees).

Results of cash flow analysis show deficits ranging from -1.195 million Baht to -30.566 million Baht for the period 1990 to 1991 and 2000 to 2001. These are expected to be covered with PWA equity. However, large surpluses during the subsequent years (1995-2020) are forecasted. For year 2020, cumulative cash surplus is estimated at 268.6 Million Baht.

Financial Internal Rate of Return (FIRR)

The project's internal rate of return on equity (IRROE), based on Alternative 4 financing scheme, was assumed to represent the FIRR. The IRROE, unlike the internal rate of return on investment (IRROI), takes into account the debt payments that have to be made each year. Also considered in the analysis was the salvage value of capital assets which was added to the benefit flows. Results indicate that the project is financially viable, with an FIRR of 12.67%, which is greater than the 9% opportunity cost of capital.

ECONOMIC STUDY

The benefits were represented by the following: a) economic value of water, assumed to be 20% higher than the average rate per volume of water used in the financial analysis; b) health benefits, expressed as the reduction in cost of time lost and reduction in medical expenses (assuming 50% of waterborne diseases are caused by poor water supply system); c) increase in land values, assuming that land value increase for 7 years after construction of the project and 5% of the increase in land values is attributed to the availability of water supply system. Other expected benefits such as increased employment opportunities, intensified land use, increaed government tax revenues were not quantified.

The econoimc costs were calculated based on financial costs adjusted for the following: a) import duties and domestic tax assumed to be 10% and 5%, respectively; b) shadow prices for foreign and local currency of 1.00 and 0.95 respectively, and for unskilled labor of 0.5.

The project was found to be economically viable, with an economic internal rate of return (EIRR) of 15.52%, which is greater than the 9% opportunity cost of capital.

3. SU NGAI GOLOK

EXECUTIVE SUMMARY

Part 1 - GENERAL

THE STUDY AREA

The Municipality of Su Ngai Golok is one of the centers of Narathiwat Province. Narathiwat is situated on the southeastern crest in the southern region of Thailand. Su Ngai Golok is a border town and enjoys commerce and tourism with Malaysia.

As the southernmost town in Thailand, Su Ngai Golok is bounded by the Golok River. The river originates from Malaysia and flows into the Gulf of Thailand with an average annual discharge of 2,000 MCM, flooding the low-laying areas during the rainy season. Alluvial deposits formed in the areas along small streams that flow into the Golok River.

Average annual rainfall in the areas is 2,600 mm while average annual pan evaporation level is 1,700 mm. Mean monthly temperature varies from 28.5 °C in April to 26.1°C in January.

In 1986, there were 9,877 people gainfully employed in rubber plantations, industrial, commercial, service and other establishments in the study area.

Tourism is a booming economic activity in the area. At present, there are 57 hotels with a total of 2,063 rooms. These are located mostly at the central commercial district of the municipality.

Land transportation is the major means of travel in the area, where two inter-city roads meet. One is Route 4056 which connects the town and Narathiwat and the other is Route 4057 which leads to Tak Bai and Waeng. Boat services across the Golok River is also an important means of daily transportation for people and commodities in the area.

The government plays a vital role in all aspects of Thailand's educational system, which is divided into three levels - primary, secondary and tertiary. There are 17 schools in Su Ngai Golok.

Existing land use shows that most commercial facilities including hotels and restaurants and high density residential areas are concentrated between Route 4056 and the Prachavivat Road. Forests including rubber plantations abound in the southwestern areas.

WATER SOURCE

Main water sources in the study area are the Golok River, shallow wells and a few deep wells.

The Golok River originates from the highland region southwest of Su Ngai Golok. The catchment area is 774 sq. km.

Rainwater collection, which is a traditional source for water supply in Thailand, is rarely utilized in the study area.

Shallow wells and deep wells are commonly used as alternative water sources in the study area, especially by private houses and institutional

establishments, respectively.

Monthly rainfall data were recorded at four gauging stations in the Thai side of the catchment area of the Golok River. Climatology data area available at Narathiwat.

Hydrological data were available both at the station on the Thai side and on the Malaysian side. For hydrogeological data, the only ones available are the map prepared by the DMR, the Golok River Basin Development Study Report and the Bang Nara Irrigation and Drainage Project Feasibility Study Report.

Several methods such as rating curve plotting and gauging were used for estimating the discharge capacity of the water sources at Rantau Panjang, Mu No and Waeng.

Low flow analysis as reported in the Golok River Basin Development Study showed 2.5 cu.m/s once in 10 years, 30-day low flow.

Water demand in the target year 2011 was estimated at 0.137 cu.m/s in intake level including the intake loss. Thus, the existing and proposed water sources have sufficient flows even in the return period of 10 years.

Studies made on groundwater or alternative source for water supply showed that groundwater can be developed for private household's use but not feasible for public water supply because of unreliable quantity during the day season and contamination of source throughout the year.

EXISTING WATER SUPPLY SYSTEM

The waterworks for the municipality of Su Ngai Golok was founded in 1964. The system initially had a treatment plant with a capacity of 20 cu.m./h, treating raw water from the Golok River. In 1969, the treatment capacity was increased to 180 cu.m./h with the construction of a new 160 cu.m./h treatment plant.

The treatment process consists of chemical flocculation, sedimentation, rapid sand filtration and chlorination. Treated water stored in a 1,500 cu.m. reservoir is pumped into a 250 cu.m. elevated tank before it is distributed to the service area by gravity.

The distribution system of the waterworks covers the center of the municipality.

The number of connections increased from 1,531 in 1980 to 1,926 in 1983 and 2,550 in 1987. Although all house connections were metered, numerous meters were found to be defective or show measuring errors.

A detailed design has been prepared for the improvement of the existing sedimentation basin and sand filters in order to increase a treatment capacity to 240 cu.m./hour.

In 1987, Su Ngai Golok Waterworks had 2,550 connections. In this year, the total water production was 1,226,207 cu.m. while total water sale over 1,461,269 cu.m.

The annual water production and sales from 1980 to 1987 are shown in the following table:

Annual Water Production and Sales

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. per Conn. (cu.m/d)
1980	928,880	730,376	1,531	1.303
1981	1,076,460	807,851	1,595	1.427
1982	1,123,816	833,094	1,712	1.371
1983	1,357,506	951,165	1,926	1.391
1984	1,613,456	1,071,329	2,072	1.413
1985	1,527,501	1,081,895	2,253	1.353
1986	1,374,478	1,158,101	2,366	1.379
1987	1,461,269	1,266,207	2,550	1.399

POPULATION AND WATER DEMAND

Future served populations are calculated by area using the future service ratios and projected population therein as shown below:

Future Served Population

Year	Population in Service Area				Average Service Ratio (%)
	High Dens. Area	Med. Dens. Area	Low Dens. Area	Total	
1991	8,581 (12,258)	2,532 (12,660)	0 (7,268)	11,113 (32,186)	34.5
1996	10,318 (13,757)	4,575 (13,865)	1,461 (9,743)	16,354 (37,365)	43.8
2001	12,262 (15,327)	6,783 (15,073)	3,241 (12,965)	22,286 43,365)	51.4
2006	14,399 (16,940)	9,429 (16,257)	6,846 (17,115)	30,674 (50,312)	61.0
2011	16,709 (18,566)	12,170 (17,385)	11,202 (22,404)	40,081 (58,355)	68.7

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

For future water consumption, forecasts are made on five categories:

a) domestic water consumption

b) governmental/institutional consumption

c) tourism water consumption

d) commercial water consumption

e) industrial water consumption

The future water demand was calculated and summarized as the table below:

Daily Average Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic	1,652	1,750	2,535	3,490	4,793	6,333
Gov't/Inst'l	447	612	659	712	775	847
Tourism	98	995	1078	1,114	1,130	1,136
Commercial	128	129	140	145	147	148
Industrial	27	28	38	50	67	86
Others	248	267	361	475	629	811
Sub-Total	**3,489**	**3,781**	**4,811**	**5,986**	**7,541**	**9,361**
Unaccounted-for Water Ratio (%)	13	13	13	13	13	13
Unaccounted-for Water	521	565	719	894	1,127	1,399
Daily Average	**4,010**	**4,346**	**5,530**	**6,880**	**8,668**	**10,760**
Peak Factor		1.30	1.30	1.30	1.30	1.30
Daily Maximum		**5,650**	**7,189**	**8,944**	**11,268**	**13,988**

DESIGN CRITERIA

The Design Criteria for the treatment system and pipeline was established based on the various design standards employed in Thailand and other countries, taking into consideration the conditions of the project site and raw water quality.

The design criteria is summarized as follows:

1. Water loss - a total of intake and treatment loss is 10 %; treatment loss is 8 %

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 8.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant - PWA's data for the unit cost is used for the civil structures of the treatment plant. For the mechanical works, major items are counted individually. The cost of the electrical works are calculated by the percentage to the mechanical works.

The cost estimates are separated into foreign and local cost portions as shown here:

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

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

Part 2 - DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

Evaluations made on several alternatives for the development of the Su Ngai Golok Waterworks revealed the following:

a. The PWA's plan to construct a new pumping station 7 km upstream of the existing intake, where raw water is less contaminated, is appropriate.

b. Construction of a new treatment plant with a maximum treated capacity of 9,400 cu.m./day is necessary to meet water demand by 2011.

Water source development plan calls for the construction of a pumping station at the proposed intake point. The work will be done in three stages, Phases 1, 2 and 3, as shown in the following table:

Water Source Development Plan

(Unit : cu.m/min)

Project	Year	Water Intake Capacity	Daily Maximum Water Demand
(1) Phase I Intake Pit Pump Sta.	1990	6,340	5,333 *)
(2) Phase II add Pump	1995	11,510	6,853
(3) Phase III add Pump	2003	16,700	9,814

*) : Maximum capacity of the existing treatment plant

New treatment plant with a maximum capacity of 9,400 cu m/day is proposed to be constructed at the PWA's land near the new raw water intake. The existing plant will also be in use in the future so that the total treatment capacity will be 15,160 cu m/day. An additional transmission pipeline is proposed to be laid from the new treatment plant to the service area. The pipe should be of steel with a diameter of 400 mm and a length of 6 km.

The proposed system is schematically shown in the Figure S-1.

IMPLEMENTATION PLAN

The implementation plan of the total project will follow projections on water demand. The construction of the treatment plant is proposed to be carried out in one phase. The construction of the transmission and distribution pipelines will be constructed in two years. Figure S-2 shows the water demand, the treatment capacity and the construction schedule of the facilities.

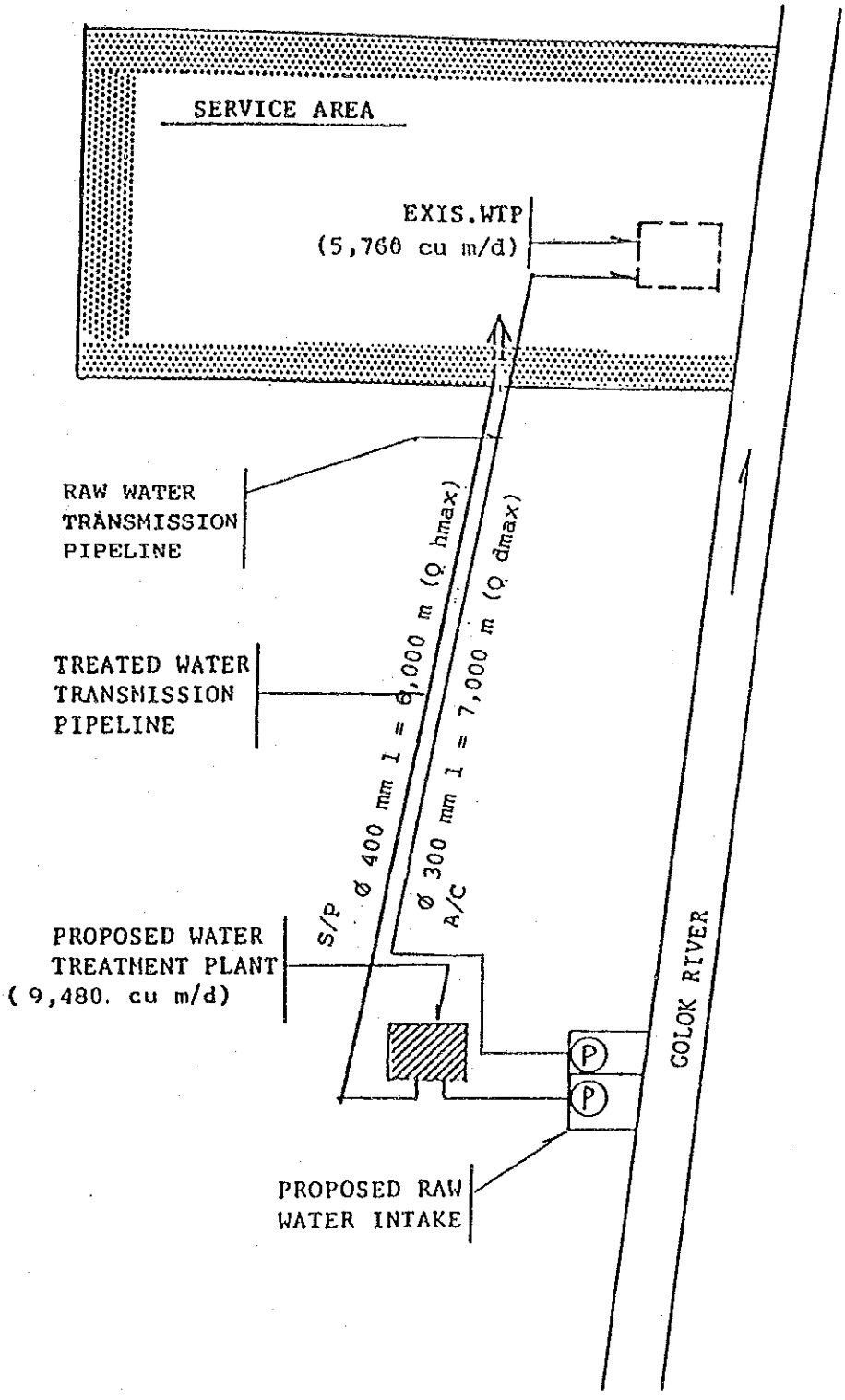
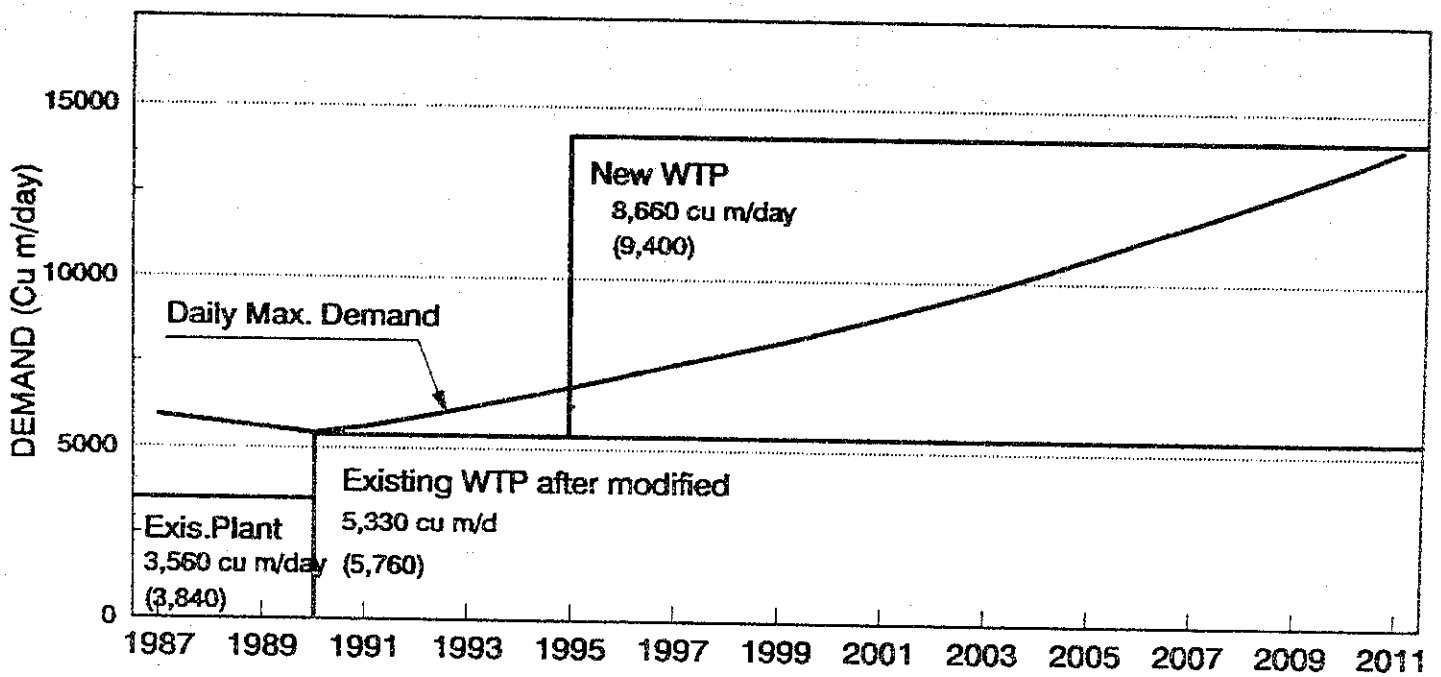
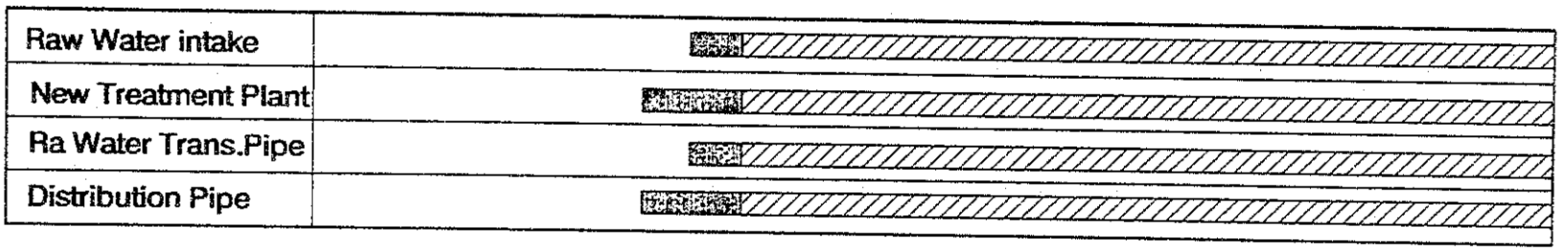


FIGURE S-1
SCHEMATIC PLAN FOR PROPOSED
TREATMENT PLANT SYSTEM
(ALTERNATIVE 3)





Construction

Operation

Water Treatment Plant Capacity

4,330 cu m/day : Net Treatment Capacity

(4,700) : Design Capacity (incl.Treatment loss)

FIGURE S-2

Implementation Plan

ORGANIZATION OF WATERWORKS

The organization of the waterworks system will have to be expanded to include sections on administration, water production at new and existing plant, and the number of staff needed to run the system depending on water demand. Figure S-3 shows a proposed organization for the new system.

PROJECT COST ESTIMATES

(1) Construction Cost

Construction cost summary was based on the 1989 prices and was calculated for each facility component as shown in the Table below.

Summary of Construction Cost

(unit : Baht Million)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	4,320	2,192	2,128
2.Treatment Plant	35,944	26,172	9,772
3.Transmission Pipeline	17,400	5,220	12,180
4.Distribution Pipeline	26,787	8,036	18,751
Sub Total	84,451	41,620	42,831
5.Land Cost	0	0	0
Total	84,451	41,620	42,831

(2) Operation and Maintenance Cost

Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement costs.

Total operation and maintenance cost is tabulated as follows:

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Total
1990	479		2,034		2,513
1991	1,302	164	2,136		3,602
1992	1,318	172	2,243		3,733
1993	1,335	180	2,467		3,982
1994	1,352	189	2,590		4,131
1995	1,646	199	3,833		5,678
1996	1,698	208	4,284	921	7,111
1997	1,748	218	4,498	921	7,385
1998	1,800	227	4,723	921	7,671
1999	1,855	238	5,109	921	8,123
2000	1,912	248	5,365	921	8,446
2001	2,080	259	5,633	921	8,893
2002	2,147	272	6,089	921	9,429
2003	2,216	284	6,941	1,365	10,806
2004	2,288	298	7,480	1,365	11,431
2005	2,418	312	8,055	1,365	12,151
2006	2,496	327	8,458	1,769	13,050
2007	2,575	341	9,103	1,769	13,788
2008	2,766	356	10,024	1,769	14,915
2009	2,850	372	11,015	1,769	16,007
2010	2,938	388	11,566	1,769	16,661
2011	3,029	405	12,414	1,769	17,618

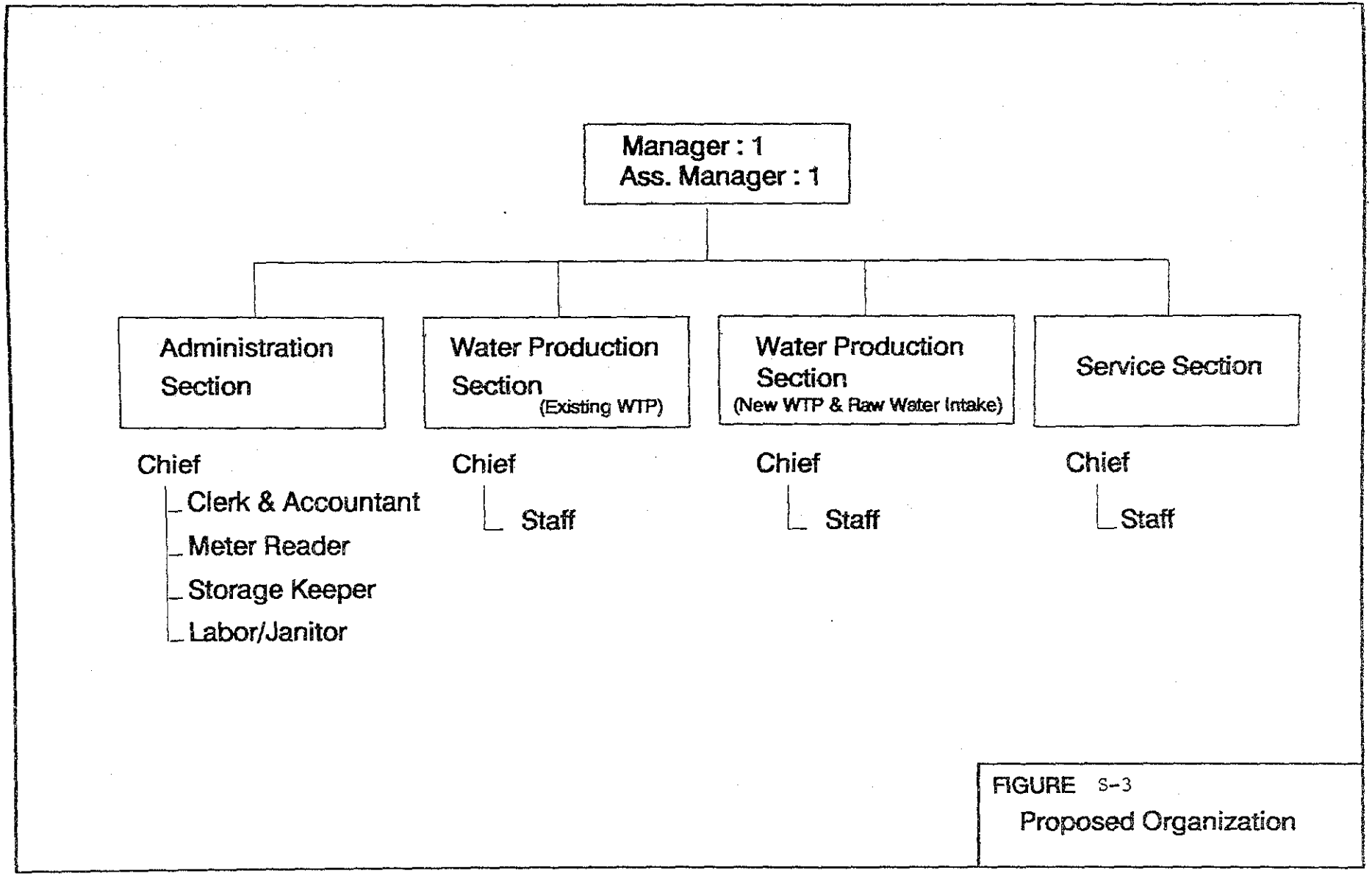


FIGURE S-3
Proposed Organization

Part 3 - FEASIBILITY STUDY

Preliminary Design

The preliminary design was prepared for the proposed facilities. T characteristics of the major facilities of the treatment plant are summariz as follows:

a. Receiving Well
   - Type : Circular
   - Dimension : Dia. 2.5 m x D 2.0 m
   - No. : 1

b. Mixing Basin
   - Type : Square
   - Dimension : L 1.5 m x W 1.5 m x D 1.5 m
   - No. : 2

c. Flocculator
   - Type : Mechanical flocculation
   - Dimension : W 1.7 m x L 12.0 m x D 2.5 m
   - No. : 4

d. Sedimentation Basin
   - Type : Rectangular with Inclining Plate
   - Dimension : W 4.0 m x L 25.0 m x D 4.0 m
   - No. : 4

e. Sand Filter
   - Type : Rapid Sand Filter,
   - Dimension : L 2.5 m x W 4.0 m
   - No. : 8

f. Clear Water Reservoir
   - Type : Rectangular
   - Dimension : L 30.0 m x W 22.0 m x D 5.0 m
   - No. : 1

g. Sludge Lagoon
   - Type : Open Cut, Rectangular
   - Dimension : L 10.0 m x W 8.0 m x D 2.0 m
   - No. : 2

h. Sludge Drying Bed
   - Type : Concrete Bed, Rectangular
   - Dimension : L 5.0 m x W 15.0 m x D 1.0 m
   - No. : 2

Financial Study

Project Cost Estimates

Total Project cost is estimated at 928,303 Baht, with a foreign exchange requirement of 538,063 Baht and local cost component of 390,240 Baht. The breakdown of cost estimates by phase is as follows:

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	41,616	42,833	84,449
Phase 1	41,327	42,552	83,879
Phase 2	289	281	570
b. Engineering Cost			
Design, 6% of (a)	3,663	3,768	7,431
Phase 1	3,663	3,768	7,431
Phase 2	0	0	0
Supervision, 2% of (a)	1,832	1,833	3,715
Phase 1	1,832	1,833	3,715
Phase 2	0	0	0
TOTAL	47,111	48,484	95,595
Phase 1	46,822	48,203	95,025
Phase 2	289	281	570

Financing Plan

The following financing schemes were considered:

Alternative 1: Total project cost financed from multilateral loan

Alternative 2: Foreign cost portion financed from bilateral loan; local cost from multilateral loan

Alternative 3: Foreign cost portion financed from bilateral loan; local cost equally financed from domestic loan and from PWA equity

Alternative 4: 70% of total project cost consisting all foreigncost. and 20,190 million Baht of local cost financed from bilateral loan; the remaining 28,294 million Baht of local cost equally financed from domestic loan and from PWA equity

Alternative 5: 70% of total project cost, consisting of all foreign cost and 20,190 million Baht financed from bilateral loan; 28,294 million Baht of local cost from domestic loan

Alternatives 3 and 4 are more desirable in view of lower funding burden for PWA. However, Alternative 4 is recommended over Alternative 3 due to lower fund requirements during construction stage.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on Alternative 4 financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials, collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on Alternative 4 financing scheme, O&M, and connection expenses (50% of connection fees).

The result of this cash flow statement reveals that the annual net cash flow will not continuously raise profit surpluses throughout after 1994. The cumulative deficit will be 32,822 thousand Baht in 2010 and 85,833 thousand Balt in 2020, respectively.

Financial Internal Rate of Return (FIRR)

The project's internal rate of return on equity (IRROE), based on Alternative 4 financing scheme, was assumed to represent the FIRR. The IRROE, unlike the internal rate of return on investment (IRROI), takes into account the debt payments that have to be made each year. Also considered in the analysis was the salvage value of capital assets which was added to the benefit flows. Results indicate that NPV is -77,663 and B.C. Ratio is 0.31 so more soft loan or government subsidy are required to proceed the project.

ECONOMIC STUDY

The benefits were represented by the following: a) economic value of water, assumed to be 20% higher than the average rate per volume of water used in the financial analysis; b) health benefits, expressed as the reduction in cost of time lost and reduction in medical expenses (assuming 50% of waterborne diseases are caused by poor water supply system); c) increase in land values, assuming that land value increase for 7 years after construction of the project and 5% of the increase in land values is attributed to the availability of water supply system. Other expected benefits such as increased employment opportunities, intensified land use, increaed government tax revenues were not quantified.

The econoimc costs were calculated based on financial costs adjusted for the following: a) import duties and domestic tax assumed to be 10% and 5%, respectively; b) shadow prices for foreign and local currency of 1.00 and 0.95 respectively, and for unskilled labor of 0.5.

The project was found to be economically viable, with an economic internal rate of return (EIRR) of 11.63%, which is greater than the 9% opportunity cost of capital.

4. PHANG NGA

EXECUTIVE SUMMARY

Part 1 - GENERAL

THE STUDY AREA

The Municipality of Phang Nga, which is the capital of Phang Nga Province, lies on the western coast in the southern region of Thailand. A center of commerce, communication and transportation and a tourist destination, Phang Nga is located along the Phang Nga River, 854 km south of Bangkok and 5 km north of Phang Nga Bay, site of Thailand's unique national park.

The municipality is dominated by limestone mountains with low-lying or middle terrace occupying a fairly small area. Alluvial deposits formed in low-lying areas along the river.

Annual rainfall in Phang Nga averages 2,500 mm while average annual pan evaporation level is 1,500 mm. Mean monthly temperature varies from 28.6°C in April to 26.5°C in December.

In 1983, 4,374 or 38.5 percent of Phang Nga's population of 11,354 were gainfully employed as laborers, professional workers, commercial workers and service workers in 221 commercial and service establishments and 21 industrial concerns.

Transportation in the area is mainly through land, with the national road connecting Phang Nga with Bangkok through Ranong and other towns in the southern region. A paved branch road leads to the Phang Nga Bay Resort area where boat services are available.

The government plays a vital role in all aspects of Thailand's education system, which is divided into three levels -- primary, secondary and tertiary. There are 11 schools in Phang Nga.

WATER SOURCE

Presently, Phang Nga's water source consists mainly of surface water from one of the Phang Nga River's tributaries, with a mining pit located at 2 km north of the waterworks. Groundwater is mostly utilized as water source by private houses with the use of shallow wells.

The present intake point of the waterworks is located upstream of the Khlong Pa Ko, a tributary of the Phang Nga River. The catchment area is about 12.4 sq km with the weir, which is 20 m long and 1.5 m high, too small to store enough water for the water demand during the dry season.

Shallow wells are often utilized by private houses, most of which are hand-dug with water being drawn by buckets and rope from about 3 to 5 m. under ground.

Four hydrological stations, x-57, x-58, Bang Hin Phu and Ban Bang Song were selected for hydrological analysis as they have similar runoff patterns and catchment conditions.

Several methods such as specific runoff and hydrological model were used for estimating the available amount of water at the existing source, the Khlong Po Ko which has a catchment area of 12.4 sq. km.

Probability analysis showed that the minimum flow at the existing intake point at Khlong Bang I is 0.037 MCM/mo. or 1,200 cu.m./day in the return period of 10 years.

Evaluation made on the availability of water at the alternative source, the mining pit, which has an average seepage area of 20,000 sq.m., revealed a minimum available amount of 300 cu.m./day for water supply. The study thus showed that the combined minimum flow available for water supply, excluding irrigation requirements, is 900 cu.m./day.

The study also considered the development of several alternative measures to meet the future water demand and secure stable water supply in the area. These include the raising of the existing weir in the Khlong Pa Ko; enlargement of the existing mining pit and construction of feeder facilities from the Phang Nga River; development of a new mining pit as water source; construction of a dam on the Khlong Tham; and development of groundwater sources.

EXISTING WATER SUPPLY SYSTEM

The waterworks for the Municipality of Phang Nga, which was founded in 1963, initially had a treatment plant with a capacity of 20 cu.m./h, treating surface water from the Phang Nga River. The treatment capacity was increased to 60 cu.m./h in 1969 with the construction of another treatment plant and the switching of the water source from the river to a waterfall at Pak Ton, 5.6 km away from the waterworks.

The modification works were made in 1990 for the sedimentation basin and the sand filter by introducing the inclining plate and high rate filtration, respectively. The intended capacity after modification is said by PWA to be 180 cu m/day.

The distribution system of the waterworks covers most of the town and extends to the Phang Nga Beach Resort area. Most of the existing pipes are ACP Class 15, installed in the 1960s and ACP Class 20, installed in 1983 and 1984. In 1988, numerous cases of distribution pipe leakages were discovered, mostly in south of the existing treatment plant.

The number of connections increased from 728 in 1980 to 948 in 1984 and 1,041 in 1987. Although all house connections are metered, some meters are found to be defective or have measuring defects.

The total water production and sales of the Phang Nga waterworks in 1987 were 442,340 cu.m and 267,121 cu.m, respectively. The waterworks has three major sources of revenue, namely: water sales, service charges and connection fees.

The annual water production and sales from 1980 to 1987 are shown in the following table.

Annual Water Production and Sales

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. Per Conn. (cu.m/d)
1980	316,620	269,411	728	1.011
1981	335,250	302,290	839	0.987
1982	350,480	308,494	887	0.953
1983	391,300	299,746	928	0.885
1984	394,210	283,746	948	0.818
1985	398,670	314,959	979	0.881
1986	421,970	287,428	1,019	0.773
1987	442,340	267,121	1,041	0.703

POPULATION AND WATER DEMAND

The population of the study area in 1987 was 10,740. Population trend in the municipality is characterized by rapid growth in the first half of the decade and decline in the following years. The decline was caused by outmigration due to the sluggish situation in the tin mining industry.

Future served populations are calculated by area using the future service ratios and projected population therein as shown below:

Future Served Population

Year	Population in Service Area by Density				Average Service Ratio (%)
	High	Medium	Low	Total	
1991	1,025	2,361	595	3,981	37.1
	(2,050)	(4,722)	(3,965)	(10,737)	
1996	1,226	2,959	1,302	5,487	46.4
	(2,190)	(5,284)	(4,340)	(11,814)	
2001	1,473	3,724	1,900	7,097	54.6
	(2,338)	(5,911)	(4,750)	(12,999)	
2006	1,773	4,698	2,943	9,414	63.9
	(2,570)	(6,808)	(5,351)	(14,729)	
2011	2,010	5,576	4,002	11,588	73.2
	(2,680)	(7,435)	(5,717)	(15,832)	

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

The total water demand is calculated as follows:

Daily Average Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic	416	410	614	828	1,139	1,462
Gov'l/Inst'l	163	386	400	416	438	453
Tourism	131	294	294	559	559	559
Commercial	9	107	118	130	147	158
Industrial	11	15	19	24	30	36
Sub-Total	730	1,212	1,445	1,957	2,313	2,668
Unaccounted-for Water Ratio (%)	39.61	26	25	23	21	20
Unaccounted-for Water	479	426	482	585	615	667
Daily Average	1,209	1,638	1,927	2,542	2,928	3,335
Peak Factor	1.30	1.30	1.30	1.30	1.30	1.30
Daily Maximum		2,129	2,505	3,305	3,806	4,336

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality.

The design criteria is summarized as follows:

1. Water loss - intake loss is 10 %; treatment loss is 8 %

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 8.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant - PWA's data for the unit cost is used for the civil structures of the treatment plant. For the mechanical works, major items are counted individually. The cost of the electrical works are calculated by the percentage to the mechanical works.

The cost estimates are separated into foreign and local cost portions as shown here:

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

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

PART 2 - DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

The provision of a raw water intake from the Phang Nga River and the expansion of the present mining pit is recommended as the most appropriate alternative since the river has sufficient flow even during the dry season.

Water source development plan calls for the construction of an intake pumping station close to the Phang Nga River, together with a sedimentation basin.

The expansion of the treatment plant is not recommended since the latest modification works has not been evaluated its intended capacity.

The distribution system, in order to respond to water demand in 2011, was considered in optimizing the system's capacity. The proposed system includes the installation of 21.3 km mains of 100 mm to 150 mm diameters.

IMPLEMENTATION PLAN

The implementation plan of the total project will include the construction of a raw water intake tower and a pumping station which will be carried out in one phase. The plan also includes the replacement of the aged pipes, and construction of new pipes.

THe implementation schedule of the proposed project is shown in Figure S-1.

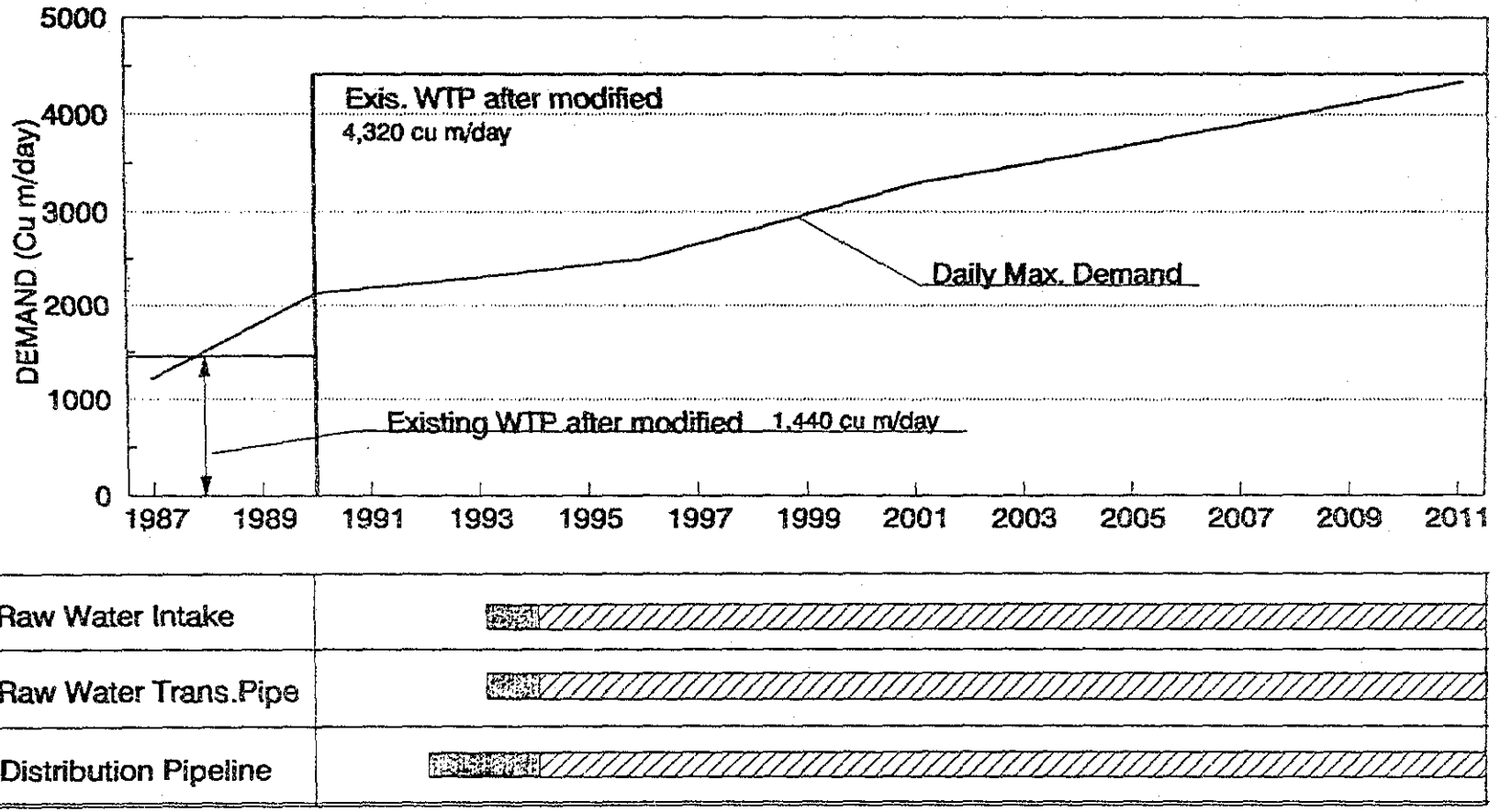


FIGURE S-1

Implementation Plan

ORGANIZATION OF WATER WORKS

The proposed organization is based on the existing functional chart of the waterworks and will consist of the following:

a. Administrative Section - This will be responsible for handling the administrative and financial operations of the waterworks.

b. Water Production Section - Responsible for the operation and maintenance of the treatments and other facilities.

c. Service Section - Responsible for setting and repair of house connections.

PROJECT COST ESTIMATES

(1) Construction Cost

The construction cost of the water supply system was calculated for each component of facility. The following table shows a summary of the construction cost based on the 1989 price.

Summary of the Construction Cost

(unit : Baht 1000)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	2,761	1,200	1,561
2.Transmission Pipeline	373	112	261
3.Distribution Pipeline	13,809	4,143	9,666
Sub-Total	16,943	5,455	11,488
4.Land Cost	0	0	0
Total	16,943	5,455	11,488

(2) Operation and Maintenance Cost

Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement costs.

Total operation and maintenance cost is tabulated in the following table.

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replace-ment	Total
1990	197	45	1,509			1,751
1991	334	46	1,585			1,965
1992	337	48	1,664			2,049
1993	340	49	1,747			2,136
1994	460	50	1,834			2,344
1995	469	52	1,926	18		2,465
1996	478	53	2,275	18		2,824
1997	499	56	2,389	18		2,962
1998	521	60	2,787	18		3,386
1999	564	63	2,926	18		3,571
2000	584	67	3,073	18		3,742
2001	631	70	3,710	18		4,429
2002	643	72	3,896	18		4,629
2003	655	74	4,091	18		4,838
2004	668	76	4,295	18		5,057
2005	681	78	4,510	18		5,287
2006	694	81	5,147	18		5,940
2007	707	83	5,404	18		6,212
2008	719	85	6,129	18		6,951
2009	733	87	6,435	18		7,273
2010	746	90	6,757	18		7,611
2011	760	92	7,095	18		7,965

Financial Study

Project Cost Estimates

Total Project cost is estimated at 19,180,000 Baht, with a foreign exchange requirement of 6,176,000 Baht and local cost component of 13,004,000 Baht. The breakdown of cost estimates is as follows (in thousand Bahts):

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	5,456	11,488	16,944
b. Engineering Cost			
Design, 4% of (a)	480	1,011	1,491
Supervision, 2% of (a)	240	505	745
TOTAL	6,176	13,004	19,180

Financing Plan

The total foreign cost and 2.648 million Baht of local cost (approximately 50% of project cost) is recommended to be financed from bilateral loan, the remaining 5.178 million Baht of local cost to be equally financed from domestic loan and PWA equity.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on recommended financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on recommended financing scheme, O&M, and connection expenses (50% connection fees).

Results of cash flow analysis show deficits throughout the project life. Cumulative cash deficits for years 2011 and 2020 are estimated at 60.732 million Baht and 105.309 million Baht, respectively.

The results suggest that PWA equity shall be infused and/or water rates increased to cover the expected deficits. It is projected that the unit cost of water would stand at 11.38 Baht per cubic meter in year 2011 and average unit water cost from 1990 to 2020 is 11.37 Baht with the implementation of the project. These rates are almost equal to the maximum level of PWA's present water tariff structure.

5. TAKUA PA

EXECUTIVE SUMMARY

Part I - GENERAL

THE STUDY AREA

The Municipality of Takua Pa is one of the centers in the Phang Nga Province which is situated on the western coast of the northern region of Thailand. Takua Pa has two centers, Ban Talad Takua Pa and Ban Yan Yao. Ban Talad is the residential area while Ban Yan Yao serves as the institutional and commercial center.

The study area is located at the left bank of the Takua Pa River which originates from the mountains and flows into the Andaman Sea in the north. The low-laying areas consist of alluvial deposits while the estuary of the river is covered with mangrove in blackish water.

Average annual rainfall in the area is 3,600 mm while average annual pan evaporation level is 1,800 mm. Mean monthly temperature varies from 28.6 °C in April to 26.5°C in December.

The major economic bases in and around the Takua Pa Municipality are tin mining and rubber plantation. Recent surveys show that a total of 4,144 people are gainfully employed in 225 industrial and 657 commercial establishments in Amphoe Takua Pa. The mining sub-sector alone accounts for 70.6 percent or 155 establishments and 1,368 employees in the industry sector.

Transportation in the study area is mainly through land, with the main road leading southwards to Kapong and Phang Nga Municipality. Travel through the river is possible only during the rainy season as the river bed has become heavily silted and shallow.

The present community may be divided into three development areas, namely: the north core, which is a modern sector with wide roads and many government offices; south core, which is relatively old with narrow roads and concentrated housing and small scale commercial and service establishments; and the corridor connecting the two cores and which remains unurbanized.

WATER SOURCE

The water sources of the Takua Pa waterworks consist of a waterfall located upstream of the Khlong Bang I, one of the right bank tributaries, and a mining pit located at 300 meters north of the existing treatment plant. Groundwater is mostly utilized as water source by private houses with the use of hand dug shallow wells.

The present intake point of the waterworks is located upstream of the Khlong Bang I and has a catchment area of 2.7 sq. km. The existing concrete weir is too small to store sufficient water to meet demand during the dry season.

Shallow wells are often utilized by private houses in the study area. Most of the wells are hand-dug, with water being drawn by a bucket and a rope from about 3 to 5 meters under ground.

Monthly rainfall data were recorded at four gauging stations at Amphoe Takua Pa, Khuru Buri, Phanom and Takua Pa MD Station. Climatology data in the

study area were available at the Takua Pa Municipal office.

Two hydrological stations, both in Phanom, Surat Thani were selected for hydrological analysis as they have similar runoff patterns and catchment conditions.

Several methods such as specific runoff and hydrological model were used for estimating the available amount of water at the existing water source, the Khlong Bang I, which has a catchment area of 2.7 sq. km.

Probability analysis showed that the minimum flow at the existing intake point at Khlong Bang I is 0.01 MCM/mo or 300 cu.m./day in the return period of 1/10.

Evaluation made on the availability of water at the alternative source, the mining pit, which has a catchment area of 11.7 sq. m. and a seepage area of 32,000 sq.m., revealed a minimum available amount for water supply of 1,600 cu.m./day.

The study thus showed that the combined minimum flow available for water supply is 1,900 cu.m./day.

The study also considered the development of several alternative measures to meet future water demand and serve stable water supply. These include the raising of the existing weir at Khlong Bong I; enlargement of the existing mining pit and rehabilitation of inlet and outlet channels; provision of a direct intake from the Takua Pa River; development of a new mining pit; and groundwater development.

EXISTING WATER SUPPLY

The waterworks for the municipality of Takua Pa was founded in 1961. Raw water originated from the Bang Ee Waterfall and distributed after chlorination without further treatment. In 1969, a new 40 cu.m./h treatment plant was constructed at the same time the abandoned mining pit was added as water source.

The treatment process consists of chemical sedimentation, rapid sand filtration and chlorination. The treated water from the mining pit, mixed with untreated water from the Bang Ee Waterfall, is stored in a 500 cu.m. reservoir. Water from this reservoir is in turn pumped into a 120 cu.m. elevated tank and distributed by gravity to the service areas.

The distribution system of the water works covers the municipality of Takua Pa and the Ban Yan Yao area. The service area consists of two major areas in the north and south, with connection pipes in between. Although replacement of old pipes installed in 1961 and 1969 was implemented in recent years, high percentage of unaccounted for water still occurs due to deterioration of pipes.

The number of connections increased from 791 in 1980 to 965 in 1984 and 1,077 in 1987. Although all house connections are metered, some meters are found to be defective or have measuring defects.

The total water production and sales of the Takua Pa waterworks in 1987 were 563,505 cu.m. and 247,121 cu.m., respectively. The waterworks has three major sources of revenue, namely: water sales, service charges, and connection fees.

Annual water production and sales in the past years are shown as follows:

Annual Water Production and Sales

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. per Conn. (cu.m/d)
1980	230,988	200,460	791	0.692
1981	388,274	254,690	812	0.859
1982	429,356	289,772	851	0.933
1983	421,818	299,975	911	0.902
1984	443,250	304,744	965	0.863
1985	483,900	290,114	987	0.805
1986	496,050	265,973	1,063	0.686
1987	563,505	247,415	1,077	0.629

POPULATION AND WATER DEMAND

The future population in the study area was placed at 29,979 in 1991, 32,633 in 1996, 35,592 in 2001, 38,891 in 2006 and 42,574 in 2011. Future population was based on the following assumption:

a) Population in the municipality will have the same growth rate as in the four years since 1983.

b) Population outside the municipality will have the same growth rate as that of Amphoe since 1980.

The future served population was calculated by service area density, i.e., high density, medium, low as shown in the following table.

Table 4-3-4 Future Served Population

Year	Population in Service Area			Average Service Ratio (%)
	Existing Service Area	Area to be Expanded	Total	
1991	5,660	-	5,660	41.1
	(9,434)	(4,338)	(13,772)	
1996	6,240	729	6,969	48.2
	(9,600)	(4,863)	(14,463)	
2001	6,838	1,636	8,474	55.7
	(9,769)	(5,452)	(15,221)	
2006	7,456	2,444	9,900	61.7
	(9,941)	(6,111)	(16,052)	
2011	8,093	3,427	11,520	67.9
	(10,116)	(6,851)	(16,967)	

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

Future water demand is calculated from the water consumption, unaccounted-for water ratio and peak factor as summarized in the following table.

Future Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic		623	787	986	1,212	1,476
Gov't/Inst'l		589	601	613	628	643
Commercial		138	145	152	161	170
Industrial		30	35	40	46	53
Others		6	7	8	9	11
Sub-total		1,386	1,575	1,799	2,056	2,353
Unaccounted-for Water Ratio (%)	56.1	50	43	35	28	20
Unaccounted-for Water		1,386	1,188	969	800	588
Daily Average	1,551	2,772	2,763	2,768	2,856	2,941
Peak Factor		1.35	1.35	1.35	1.35	1.35
Daily Maximum		3,742	3,730	3,737	3,856	3,970

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality.

The design criteria is summarized as follows:

1. Water loss - intake loss is 10 %; treatment loss is 8 %

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 8.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant - PWA's data for the unit cost is used for the civil structures of the treatment plant. For the mechanical works, major items are counted individually. The cost of the electrical works are calculated by the percentage to the mechanical works.

The cost estimates are separated into foreign and local cost portions as shown here:

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

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

PART 2 - DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

Evaluations made on several alternatives for the development of the Takua Pa Waterworks, revealed the following:

a. It is recommended to install an additional pipe for transmission of the raw water from the existing weir to the treatment plant. This is to increase the intake capacity from the weir.

b. Groundwater development is not practical due to poor quality and quantity of water.

c. The western part of the existing mining pit may be enlarged by excavating the area over 84.00 m in elevation to increase the capacity to 300,000 cu.m.

d. The development of new mining pits located in the flood plain is required to serve as additional water sources.

e. The construction of an intake at the Takua Pa River is also needed.

Water source development plan calls for the construction of a raw water intake tower and a pumping station near the bridge about 2.0 km upstream of the waterworks.

The construction of a new treatment plant with a capacity of 4,300 cu m/day is proposed to be constructed in the existing plant site. The existing plant units are planned to be abandoned.

The estimated water demand in 2011 was used as basis in planning the improvement of the distribution system, which will involve the replacement of old pipelines and the construction of about 9,000 m mains with diameters of 100 and 250 mm.

IMPLEMENTATION PLAN

The implementation plan of the total project will include the construction of a treatment plant which will be carried out in one phase. The plan also includes the replacement of the aged pipes and construction of new pipes to be constructed in two years.

The water demand, plant capacity, and the implementation schedule are shown in Figure S-1.

ORGANIZATION OF WATER WORKS

The proposed organization of the Takua Pa Waterworks is based on the existing functional chart of the waterworks and will consist of the following:

a. Administrative Section - This will be responsible for handling the administrative and financial operations of the waterworks.

b. Water Production Section - Responsible for the operation and maintenance of the treatment plant and other facilities.

c. Service Section - Responsible for setting and repair of house connections.

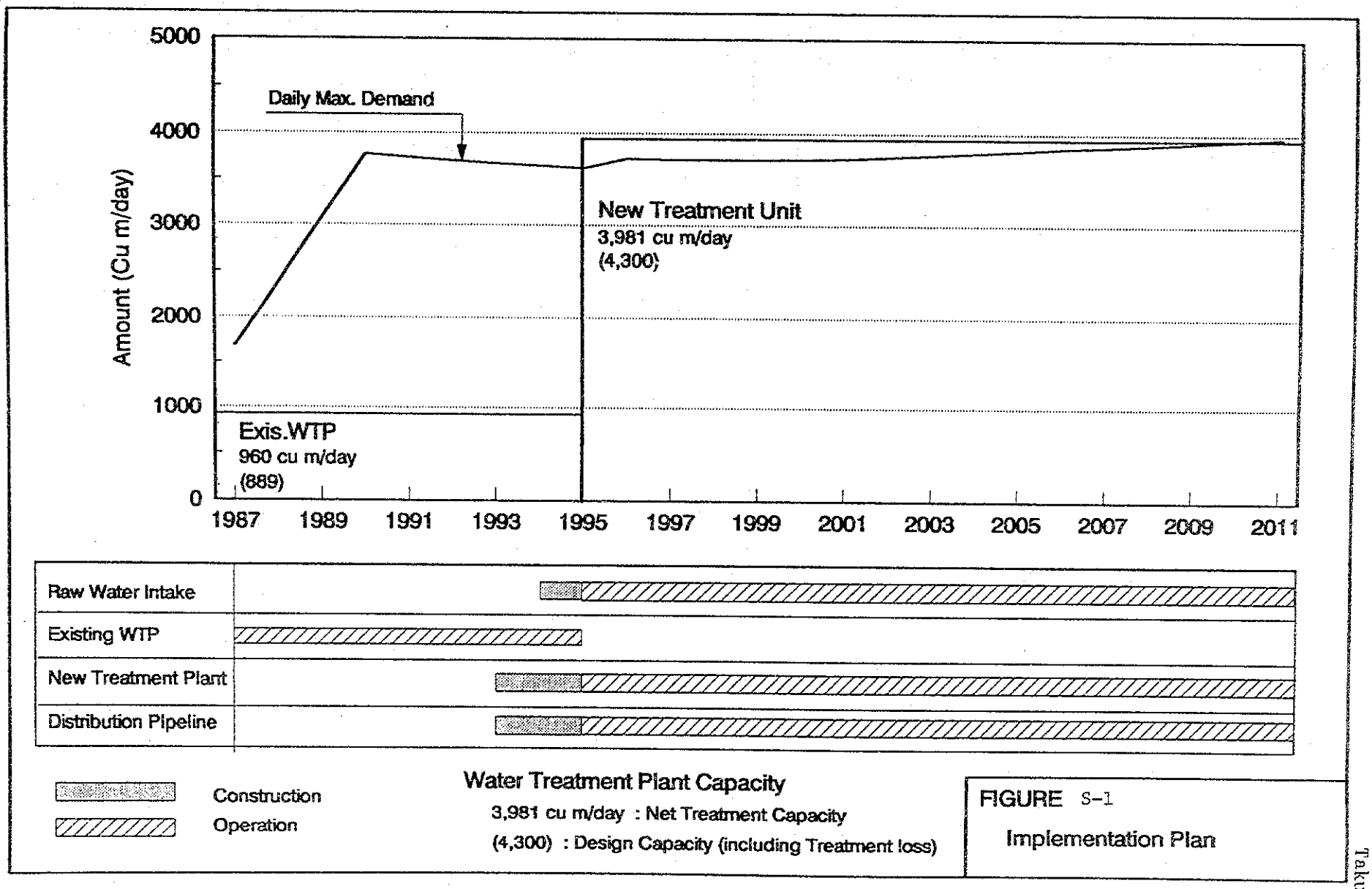


FIGURE S-1

Implementation Plan

PROJECT COST ESTIMATES

(1) Construction Cost

The construction cost of the proposed water supply system was calculated for each component of the facility. The Table below shows a summary of the construction cost based on 1989 prices:

Summary of the Construction Cost

(unit : Baht 1000)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	4,493	1,843	2,650
2.Usage of the Existing Mining Pit	2,675	1,050	1,625
3.Treatment Plant	16,661	6,680	9,980
4.Distribution Pipeline	16,003	4,801	11,202
5.Transmission Pipeline (Intake Weir to WTP SP, Dia.200 mm, 2 km)	3,540	2,832	708
Sub Total	43,372	17,206	26,165
5.Land Cost	100	0	100
Total	43,472	17,206	26,265

(2) Operation and Maintenance Cost

Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement costs.

Manning cost is based on the prediction of the staff number of water-works as proposed in Chapter 10.

Replacement of the mechanical and electrical equipment is considered to be made 20 years after the installation so that they are not included in the period of the development plan.

Total operation and maintenance cost is tabulated below:

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	OPERATION COST					
	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replace-ment	Total
Total	14,015	1,521	61,212	271	0	77,019
1990	462	69	1,590			2,121
1991	460	68	1,669			2,198
1992	458	68	1,753			2,278
1993	457	67	1,840			2,365
1994	660	67	1,932			2,659
1995	657	66	2,029	16		2,768
1996	669	68	2,130	16		2,883
1997	668	68	2,237	16		2,989
1998	668	68	2,349	16		3,101
1999	668	68	2,466	16		3,218
2000	668	68	2,589	16		3,342
2001	670	68	2,719	16		3,473
2002	672	69	2,855	16		3,612
2003	675	69	2,998	16		3,758
2004	678	70	3,148	16		3,911
2005	681	70	3,305	16		4,072
2006	684	71	3,470	16		4,241
2007	686	71	3,644	16		4,416
2008	689	71	3,826	16		4,602
2009	692	72	4,017	16		4,797
2010	695	72	4,218	16		5,001
2011	698	73	4,429	16		5,215

Financial Study

Project Cost Estimates

Total Project cost is estimated at 19,180,000 Baht, with a foreign exchange requirement of 6,176,000 Baht and local cost component of 13,004,000 Baht. The breakdown of cost estimates is as follows (in thousand Bahts):

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	17,207	26,166	43,373
b. Engineering Cost			
Design, 4% of (a)	1,514	2,303	3,817
Supervision, 2% of (a)	757	1,151	1,908
c. Land Cost	0	100	100
TOTAL	19,478	29,720	49,198

Financing Plan

The total foreign cost and 8.348 million Baht of local cost (approximately 50% of project cost) is recommended to be financed from bilateral loan, the remaining 21.372 million Baht of local cost to be equally financed from domestic loan and PWA equity.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on recommended financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on recommended financing scheme, O&M, and connection expenses (50% connection fees).

Results of cash flow analysis show deficits throughout the project life. Cumulative cash deficits for years 2011 and 2020 are estimated at 65.068 million Baht and 96.985 million Baht, respectively.

The results suggest that PWA equity shall be infused and/or water rates increased to cover the expected deficits. It is projected that the unit cost of water would stand at 8.46 Baht per cubic meter in year 2011 and average unit water cost from 1990 to 2020 is 10.44 Baht with the implementation of the project. These rates are almost equal to the maximum level of PWA's present water tariff structure.