MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

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

FINAL REPORT FOR PHANG NGA

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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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.

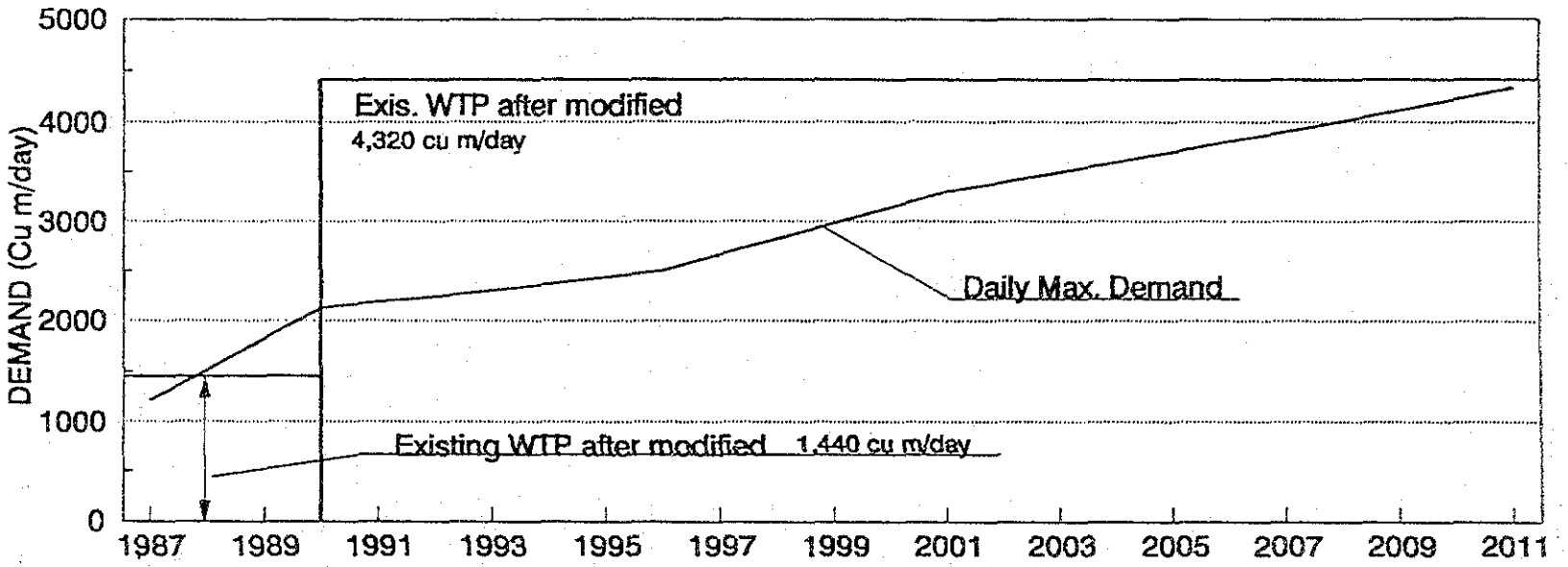
The expansion of the treatment plant is not recommended since the latest modification works has not been evaluated its intended capacity.

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.



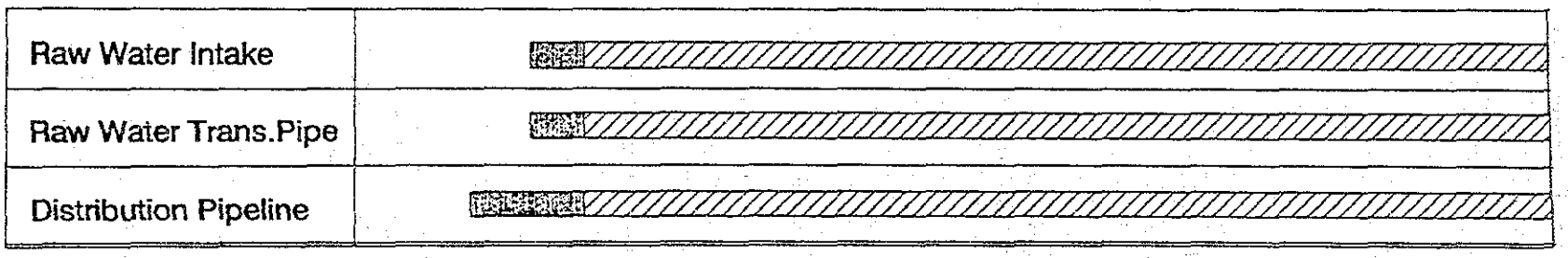


FIGURE S-1

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.

Part 1
GENERAL

Part 1 GENERAL

1 DESCRIPTION OF THE STUDY AREA

1.1 Natural Conditions

1.1.1 General

The Municipality of Phang Nga is the capital of Phang Nga Province, which is located on the western coast in the southern region of Thailand. It is the center of commerce, communication and transportation and a tourist attraction. It is located at longitude 98°31' east and latitude 8°26' north, about 854 km south of Bangkok and 94 km north of Phuket. The Municipality is along Route 4 between the Phang Nga River and the mountains. The Au Phang Nga National Park famous for its beautiful scenery is located 9.5 km south of the Municipality.

1.1.2 Topography

Phang Nga is located 5 km north of the Phang Nga Bay where one will find the Thailand's unique national park. The Municipality is blest with limestone mountains inland and numerous isolated islands offshore. These striking features attract many tourists all year round. The Phang Nga River flows through the west of the Phang Nga Bay with highly seasonal variation in stream flow.

Low-lying or middle terrace occupies a fairly small area surrounding by isolated steep mountains or mudstone mountains the elevation of which ranges from 500 m to 1,000 m.

1.1.3 Geology

Phang Nga is situated along the Phang Nga River consisting of alluvial deposits such as gravel, sand, silt and clay. It is surrounded by isolated steep mountains comprising mainly of limestone (P) by both the west and east side - colluvial deposits (Qt) which are developed below these mountains and form undulating middle terrace. Mudstone or sandstone (CP) are mainly formed on the mountain area. Granite (Kgr) are formed further deeply into the steep mountains on the west coast.

The details of the geological features are given in Table 1-1-1.

Table 1-1-1 Geological Feature

Group	Feature	Location
Qa	Alluvial deposits, Gravel, sand, silt and	Low-laying area along streams
Qb	beach deposits : Sand, silt and shell fragments	Beachside
Qt	Terrace and colluvial deposits; Pebble, gravel, sand, silt and clay	Undulating middle terrace below mountain
P	Linestone, gray and dark gray, thin-bedded to massive, fassiliferous	Isolated steep mountains
Cp	Pebbly mudstone, gray and dark gray, cobble to boulder as clast, thick-bedded to massive laminated mudstone; interbedded siltstone and mudstone, brown and gray, thin-bedded, with sharp based bed, slump structure, bioturbation, load cost, and dropstone like structure; sandstone, white and pale brown, coarse to medium-grained, thick and well-bedded, grade-bedding; conglomeratic sandstone; and shale with aboundant bryozoas brachiopods, gastropods, corals, and crinoid stems	Mountain area
Kgr	Biotite - horn blende granite, fine-to medium - grained, equigranular; biotite granite, coarse - grained and por phynitic	Mountain area on the west coast and at the mountain peak

1.1.4 Meteorology

The annual rainfall in Phang Nga averages 2,500 mm with a highly seasonal distribution. As much as 50% of the total rainfall occurs during the wet season from May to October. Rainfall during the dry season is variable. Rainfall increases in the mountain area.

Average annual pan evaporation level is about 1,800 mm with little monthly variation. Relative humidity is high, ranging from 86.3% in October to 74.3% in February. The mean monthly temperature varies from 28.6°C in April to 26.5°C in December with a range of only 2.1°C. The extreme range is from 37.0°C to 13.9°C. Temperatures inland decline slightly.

Details of the meteorology are given in Table 1-1-2.

Table 1-1-2 Meteorological Data at Phang Nga

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (C.degree)													
Mean	26.7	27.5	28.2	28.6	28.0	27.9	27.5	27.6	26.9	26.7	26.6	26.5	27.4
Mean Max.	31.4	32.6	33.2	33.0	31.5	30.8	30.5	30.4	29.9	30.1	30.5	30.8	31.2
Mean Min.	21.9	22.3	23.0	23.9	24.4	24.7	24.4	24.7	23.9	23.5	23.0	22.5	23.5
Ext. Max.	34.5	36.2	37.0	36.8	36.0	35.0	34.0	34.5	33.3	33.3	33.0	33.3	37.0
Ext. Min.	13.9	15.8	18.3	21.1	21.4	21.2	21.0	20.7	21.2	21.0	17.9	18.4	13.9
Relative Humidity (%)													
Mean	76.1	74.3	75.9	79.7	83.8	82.8	83.0	82.1	85.2	86.3	84.1	79.4	81.1
Mean Max.	92.5	92.4	93.9	95.4	95.4	92.7	93.0	91.8	94.6	96.3	95.5	92.7	93.9
Mean Min.	56.1	53.3	55.2	61.6	69.9	71.8	72.2	72.1	74.5	73.1	68.1	62.5	65.9
Ext. Min.	33.0	32.0	32.0	29.0	34.0	42.0	42.0	43.0	54.0	52.0	46.0	40.0	29.0
Evaporation (mm.)													
Mean - Pan	164.3	155.3	197.6	157.2	135.3	124.0	136.1	167.3	140.2	138.9	133.0	139.8	1789.0
Rainfall (mm.)													
Mean	43.6	26.3	68.0	152.6	345.5	296.2	302.2	267.6	409.8	344.8	186.3	75.0	2517.9
Mean Rainy Days	6.0	4.2	6.3	11.8	21.9	21.0	20.8	19.8	22.8	23.1	16.1	9.3	183.6
Greatest in 24 hr.	65.6	59.0	72.3	156.3	209.4	113.4	151.1	132.0	142.1	197.6	121.5	63.2	209.4
Day / Year	22/66	26/71	23/73	29/83	23/63	23/63	14/66	13/83	24/56	5/71	2/58	16/73	23/64

Source : Meteorological Department
Remark : Sunshine Duration 1957-1985
: Evaporation 1981-1985

1.2 Socioeconomic Conditions

1.2.1 Economic Conditions

In 1983, the total employment in the main study area was 4,374 accounting for 38.5% of the population as in Table 1-2-1.

Table 1-2-1 Population and Labor Force

(Unit : persons (%))

Total population	11,354 (100.0)
Population in work ages	9,001 (79.3)
Labor force	4,815 (42.4)
Employed	4,374 (38.5)
Unemployed	441 (3.9)
Non labor force	4,186 (36.9)
Population not in work ages	2,354 (20.7)

Source : DTCP

Among the employed, laborers account for the largest share of 26.5%, followed by professional workers, commercial workers and service workers.

There are 221 commercial and service establishments in the tertiary sector, and 21 industrial establishments composed of 13 manufacturers and 8 repair/maintenance shops. These establishments are generally characterized as small scale family industries because employees are less than 10 persons. Major types of industries are limestone industry, repair/maintenance of machines or cars and welding.

These are mostly located along the Taichang Road, Route 4 (Petkasaem Road) and Route 4144.

The unique natural features of Phang Nga attracts tourists. An average of 300 tourists start their boat ride around the area daily.

1.2.2 Transportation

The Phang Nga Municipality has been developed along Route 4 (Petkasaem Road) as in Figure 1-3-1. The road is a national artery connecting the Municipality with Bangkok through Ranong and other towns in the southern region. The road also stretches to Hat Yai through Krabi and Trang.

From the road, Route 402 leads to Phuket, and Routes 4090 and 4032 lead to Takua Pa.

At the south of the Municipality, there is a paved branch road to the Phang Nga Bay Resort Area. Inside the Municipality, local road networks are formed on both sides of Route 4 between the mountains on the west and the Phang Nga River on the east. A few bridges connect both sides of the river around the Municipality. For public transport services, large and small buses are available.

At the bay area, boat services are available for local people and tourists.

1.2.3 Education

The education system in Thailand is divided into three levels - primary, secondary and tertiary.

In recent years, pre-primary education, including kindergarten, has become available to children whose ages range from three to five. Children enter primary school when they are anywhere between six to eight years old, depending largely on the locality. Secondary education is divided into lower and upper divisions each consisting of three years such that, typically, those 12-14 years of age attend lower secondary while those 15-17 attend upper secondary.

The government plays a major role in all aspects of Thailand's education system. For the past eight years, 19% to 21% of total government expenditure went to education. It is the highest compared to other developing countries.

In Phang Nga, there are 11 schools. A detailed breakdown of schools, including the number of students is shown in Table 1-2-2.

Table 1-2-2 School in Amphoe Phang Nga

Grade of School	No. of Schools	No. of Students
Kindergarten	2	366
Primary School	7	1,758
Secondary School	2	1,585
College/University	-	-
Total	11	3,709

1.2.4 Sanitation (Water-borne Diseases)

In developing countries, three people out of the five do not have access to clean drinking water. According to WHO, about 80% of sicknesses are caused by unhygienic water and defective sewage treatment. Thus, the quality of drinking water is closely related to human health.

To decrease the incidence of water-borne diseases is one of the more significant purposes of a water supply project. The status of water-borne diseases in relation to the number of patients is shown in Tables 1-2-3 to 1-2-5.

Table 1-2-3 Water-Borne Diseases in Phang Nga Municipality

Year	No. of Patients					
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Cholera	Total
1983	29	3	8	3	-	43
1984	107	5	8	3	-	123
1985	142	5	11	3	1	162
1986	83	1	10	2	-	92
1987	47	1	3	3	-	54
1988	67	5	8	-	-	80

Table 1-2-4 Water-Borne Diseases in Tambon Tam Nam Pud

Year	No. of Patients				
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Total
1983	4	-	2	-	6
1984	18	3	4	1	25
1985	20	-	2	-	22
1986	3	1	3	1	8
1987	9	-	3	-	12
1988	8	2	-	-	10

Table 1-2-5 Water-Borne Diseases in Tambon Kohpanyi

Year	No. of Patients				
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Total
1983	28	1	-	2	31
1984	22	1	-	3	26
1985	30	-	-	2	32
1986	82	-	-	1	83
1987	72	-	1	1	73
1988	26	1	1	-	28

1.3 Land Use

1.3.1 Existing Land Use Pattern

The existing land use pattern of the main study area described in Chapter 4 is as shown in Figure 1-3-1 and Table 1-3-1.

Table 1-3-1 Existing Land Use of Phang Nga Town Planning Area

Land Use Type	Area (ha)	Ratio (%)
Low & medium density residential area	65.2	3.8
Commercial & high density residential area		
Industry & warehouse area	7.1	0.4
Rural & agricultural area	1571.4	91
Vacant land for recreation & environmental protection	11.2	0.7
Educational institute	13.3	0.8
Religious institute	19	1.1
Governmental institute, public utilities & social infrastructure	31.3	1.8
Total	1,726	100

Source : DTCP

(a) The route 4 is the axis of urbanization with the market area in the north as the hub. Along the roads, commercial activities are mainly located in the northern parts, while in the southern parts government offices dominate. Behind the road are belts of residential quarters.

(b) In the area, institutional use holds a considerably large share. The total of educational, religious, governmental, public utility and social infrastructure uses accounts for approximately 41 % of the whole area except rural and agricultural areas. This is due to the Municipality's roles as the provincial center despite its compact town scale.

(c) The east side of the Phang Nga River is sparsely inhabited at present.

1.3.2 Land Value

In the Municipality, official land prices are higher along Route 4 (Petkasaem Road) especially around the commercial center at the northern part, ranging from 1,250 ฿/sq.m (2,000,000 ฿/rai) to 1,750 ฿/sq.m (2,800,000

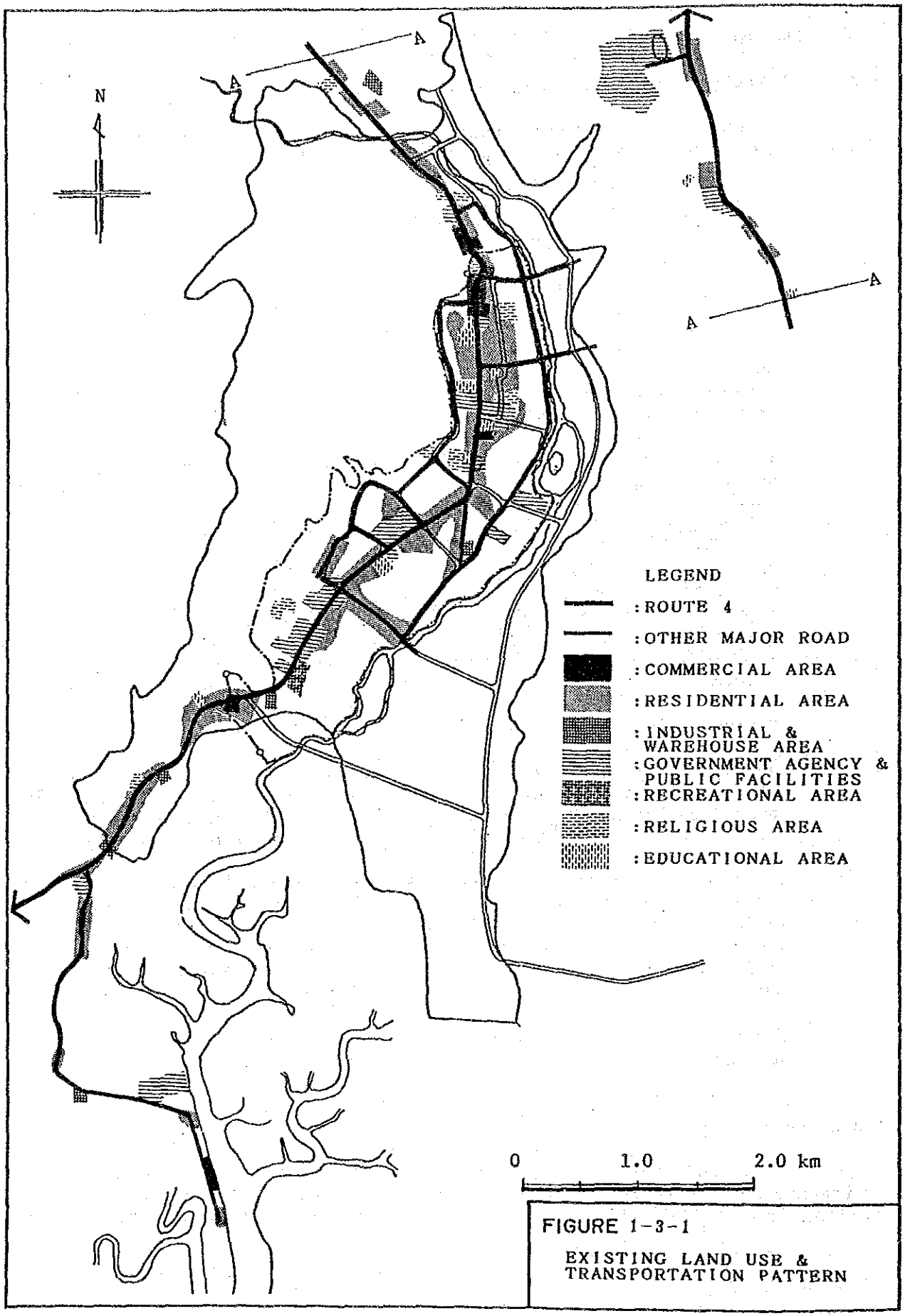


FIGURE 1-3-1

EXISTING LAND USE & TRANSPORTATION PATTERN

฿/rai). On the contrary, at sites far from Route 4 especially in the southern parts, official land prices are lower, ranging between 100 ฿/sq.m (160,000 ฿/rai) and 100 ฿/sq.m (160,000 ฿/rai) and 200 ฿/sq.m (320,000 ฿/rai).

In Tambon Tam Nam Pud, official land prices also depend heavily on accessibility to main roads. The prices range from 5 ฿/sq.m (8,000 ฿/rai) to 125 ฿/sq.m (200,000 ฿/rai).

In Tambon Ko Pangee, official land prices are not more than 5 ฿/sq.m (8,000 ฿/rai).

In general, land is much cheaper outside the Municipality. Reliable data of actual land prices is not available, but they are thought to be higher than official prices at most sites.

1.3.3 Future Land Use Pattern and Development Prospects

According to the town plan by DTCP shown in Figure 1-3-2, expansion of residential zones and recreational and environmental protection zones is remarkably large. Southern and eastern parts including the east side of Phang Nga River will be mostly developed as low and medium density residential areas. "Elephant" mountains on the west side of the Municipality is designated as a recreation and environmental protection area. The population density will be increased accordingly.

The local road network is to be improved to serve new residential areas.

Phang Nga is covered by "the Study on Potential Tourism Area Development for the Southern Region in Thailand" conducted by JICA for the Tourism Authority of Thailand. According to the plan, the Phang Nga Resort Area will be further developed for international and domestic tourists. The Municipality is also expected to develop as a tourism base. The tourism study recommends to establish the "Andaman Resource Center" in front of the Phang Nga Bay Resort Hotel to preserve and display Andaman cultural and natural heritage, train staff for tourism and to promote tourism and research. The provincial office also has a plan to upgrade the area including the following as in Figure 1-3-3.

1) Improving the sewerage system

2) Building a car park

3) Expansion of the hotel

4) Opening the bungalows which are currently used by the hotel staff

5) Opening souvenir shops

6) Opening a festival space in front of the hotel

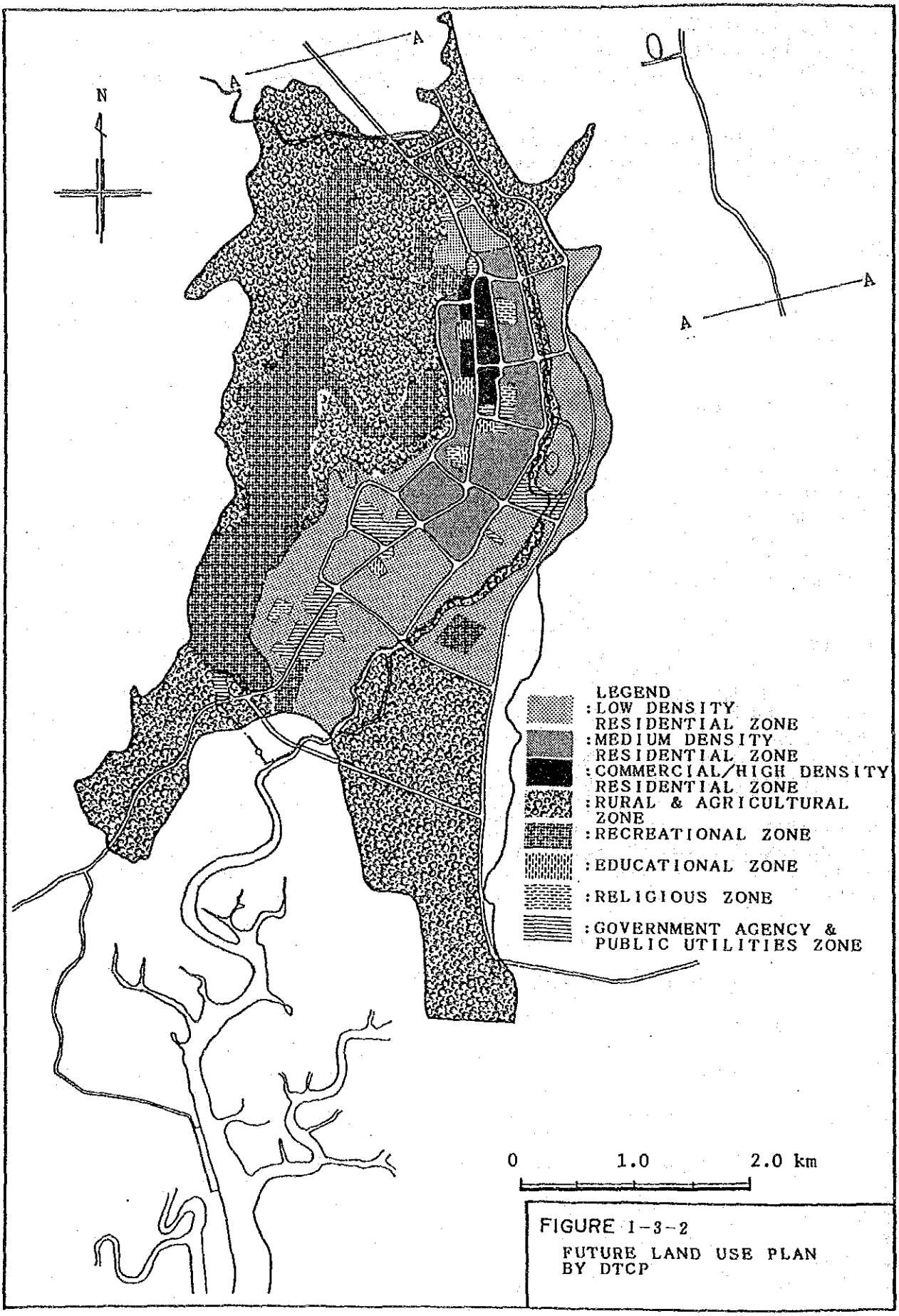
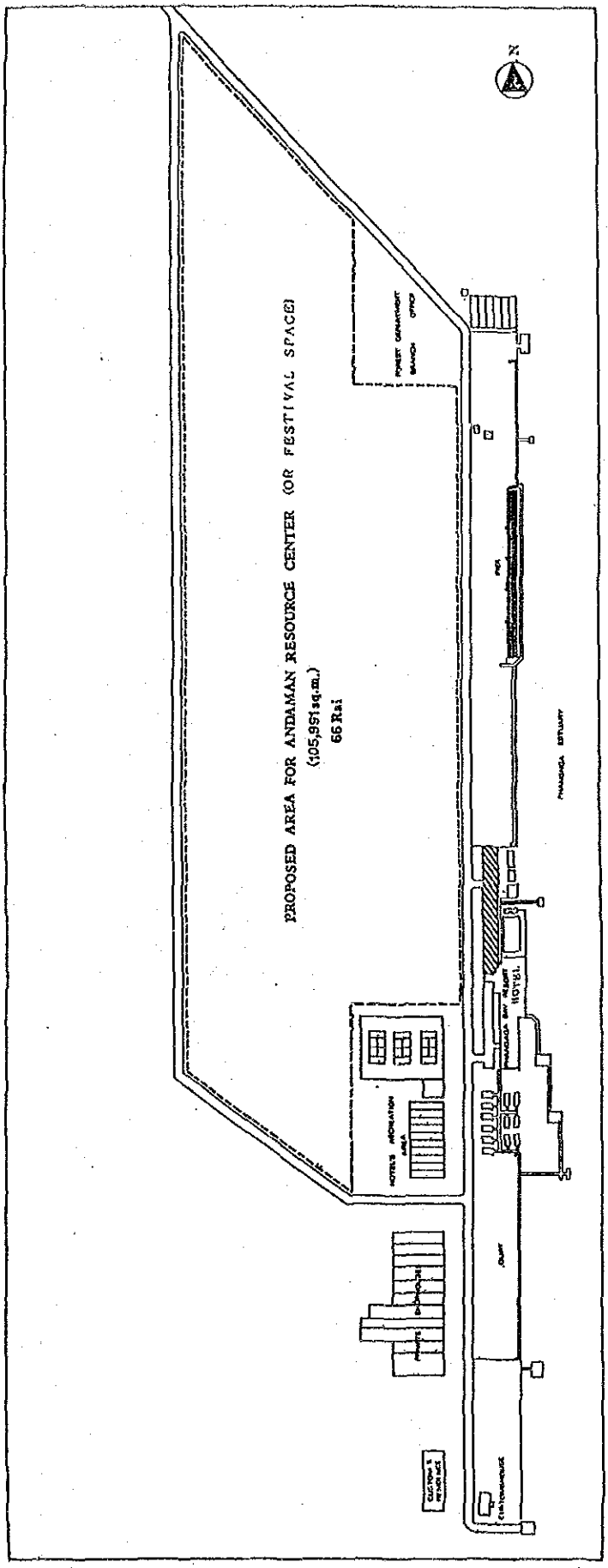


FIGURE 1-3-2

FUTURE LAND USE PLAN BY DTCP



LEGEND

: SPACE FOR THE HOTEL EXPANSION

SOURCE:

STUDY ON POTENTIAL TOURISM AREA DEVELOPMENT FOR THE SOUTHERN REGION IN THAILAND

FIGURE 1-3-3

PHANG NGA BAY RESORT AREA

2 WATER SOURCE

2.1 Existing Water Use Pattern

2.1.1 General

The Phang Nga Municipality is located along the Phang Nga River 6 km upstream of the estuary. The Phang Nga River flows southward collecting an annual rainfall of 2,500 mm falling on the catchment area of 287.5 sq.km. The water source of the waterworks is located upstream of one of the Phang Nga River tributaries. The waterworks are supposed to use a mining pit as an alternative source to supplement water shortage in the dry season. Previously, potable pumps were used for taking supplemental water from the Phang Nga River.

The location of water sources is given in Figure 2-1-1.

2.1.2 Surface Water

(1) Khlong Pa Ko

The present intake point is located upstream of the Khlong Pa Ko, one of the right bank tributaries of the Phang Nga River. The catchment area is approximately 12.4 sq.km having paddy field and some small villages and there are three 200 mm pipes for drainage, irrigation and water supply at the intake weir. The weir is 20 m long and 1.5 m high, too small to store enough water for the demand in the dry season.

(2) Mining Pit

The Phang Nga Waterworks plans to use a mining pit as an alternative source. The mining pit is located 2 km north of the waterworks next to the Phang Nga River. The pit has a storage capacity of approximately 100,000 and expects some inflow from the river in the rainy season.

The quality of raw water sampled during the field survey is given in Table 2-1-1.

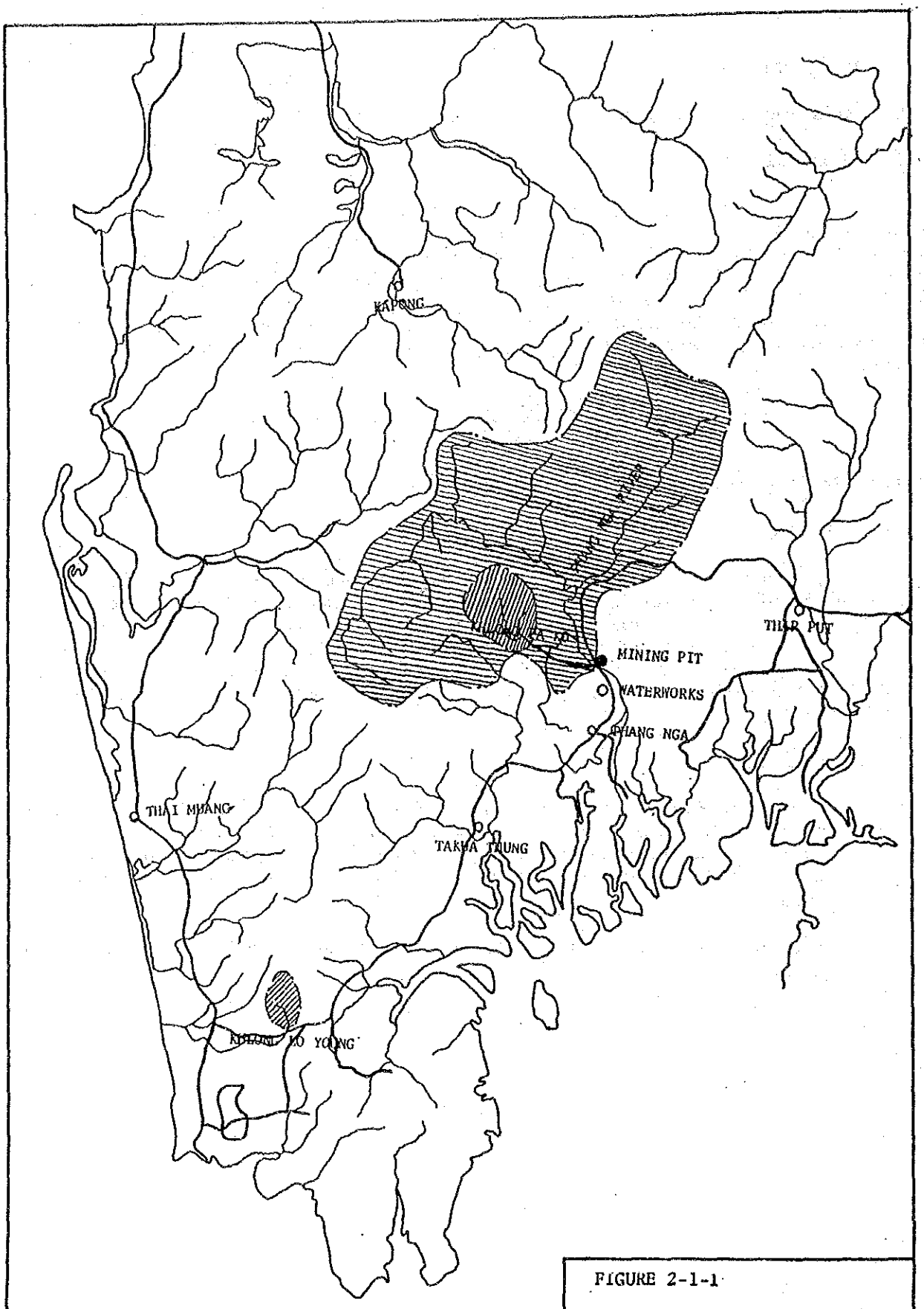


FIGURE 2-1-1

LOCATION MAP OF WATER SOURCE

Table 2-1-1 Water Quality of Water Sources

Item	Khlong Pa Ko	Mining Pit	Phang Nga River
Temperature (°C)	31.3	31.3	31.3
pH	7.5	7.1	7.2
Turbidity	4.0	0.8	8.4
Conductivity (5 x 10)	4.2	3.5	3.7
NH_4-N (mg/l)	<0.4	<0.4	<0.4
NO_2-N (mg/l)	<0.006	<0.006	<0.006
NO_3-N (mg/l)	<0.23	<0.23	<0.23
Coliform	D	ND	D

D : Detected ND : Not Detected

2.1.3 Ground Water

(1) Shallow Well

The Phang Nga Municipality is situated on the alluvium of the river, so shallow wells are often seen in private houses. Most of the wells are hand-dug with brick lining. Water is drawn by a bucket and rope from approximately 3 to 5 m depth.

(2) Deep Well

Deep wells constructed by DMR are listed in Table 2-1-2.

Table 2-1-2 List of Deep Wells by DMR

LOCATION	Year	Depth (ft)	Size (in.)	Aquifer Code	Static (ft)	Yield (gpm)	Drawdown (ft)	Iron (ppm)	Chlorine (ppm)	TDS (ppm)
Ban Wang Mo kaeng	1980	220	5	5	34.30	181.90	39.06	137	18	263
Samyaek Ban Wang Mo Kaeng	1979	100	6	5	23.05	62.24	53.35			
Satri Phang Nga School	1983	190	5	3	32.40	15.85	46.96	2.1	9	276
Changwat Phang Nga Pisen	1983	110	6	21	34.88	65.40	5.72	0.10	13	232
Di Buk Phang Nga Witthaya	1983	70	4	52	18.00	5.00	37.00	6.0	17	172

2.2 Availability of Existing Water Source

2.2.1 Data Available for Study

(1) General

The data required for the hydrological studies are meteorological data as rainfall and evaporation, hydrological data as water level and discharge in the monthly base. MD and RID are responsible for collecting and processing the data on meteorology and hydrology, respectively.

Rainfall data recorded at the amphoe office are sent to the MD headquarter, Bangkok for data processing.

All water level records are sent directly to the RID headquarter, Bangkok for data processing.

Geology and hydrogeology are referred from the maps prepared by DMR.

(2) Monthly Rainfall

Monthly rainfall data are available at five gauging stations controlled by Amphoe Phang Nga, Takua Thung, Thai Muang, Kapong and Tap Put.

The rainfall stations are listed below and monthly rainfall data are given in Tables A2-1-1 to A2-1-5 in Appendix A-2-1.

Table 2-2-1 List of Rainfall Station

Station	Location	Period of Record
Phang Nga	Amphoe Phang Nga	1956 to Present
Takua Thung	Amphoe Takua Thung	1955 to Present
Thai Muang	Amphoe Thai Muang	1952 to Present
Ka Pong	Amphoe Ka Pong	July 1966 to Present
Ta Put	Amphoe Ta Put	1956 to Present

(3) Climatological Data

The data describing the climatology in the Phang Nga area is available at the Phang Nga Municipality. This station observes such climatological data as temperature, atmospheric pressure, humidity, evaporation, sunshine hours and wind. The data are given in Table A2-1-6 in Appendix A-2-1.

(4) Hydrological Data

Four hydrological stations, X-57, X-58, Bang Hin Phu and Ban Bang Song are selected for hydrological analysis because these stations have similar runoff pattern and catchment conditions to the concerned water sources.

The stations are listed below and these data are given in Tables A2-2-1 and A2-2-2 in Appendix A-2-2.

Table 2-2-2 List of Hydrological Stations

Station	Location	Period of Record	Remarks
X-58 (CA=312 sq.km)	Phanom, Surat Thani	1972 to 1980	RID
X-57 (CA= 8 sq.km)	Phanom, Surat Thani	1972 to 1982	RID
Bang Hin Phu (CA=171 sq.km)	Tha Put Phang Nga	1973 to 1983	NEB
Ban Bang Son (Ca= 361sq.km)	Tha Put Phang Nga	1972 to 1983	NEB

2.2.2 Availability of Existing Water Source

(1) Khlong Pa Ko

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

(a) Specific Runoff

There are four gauging stations in the neighborhood of the present intake point on the Khlong Po Ko. Specific runoff adopted by X-67, X-58, Ban Bang son and Bang Hin Phu are given in Tables 2-2-3 and 2-2-4.

(b) Hydrological model

Runoff model is established by Tank Model Method using The observed discharge record at the RID's hydrological gauging stations, X-57 and X-58. As described in Appendix A-2-2, the rainfall is not successfully simulated to the gauged discharge, because the gauged flow does not necessarily respond to rainfall occurrence.This fact reveals that the hydrological model cannot be applied for estimating the available amount of water
Table 2-2-3

Table 2-2-3 Specific Runoff

(Unit : MCM/sq.km)

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1972	×-57									—	0.067	0.094	0.036
	×-58									0.382	0.143	0.106	0.046
1973	×-57	0.013	0.001	—	0.030	0.007	0.165	0.552	0.415	0.222	0.285	0.259	0.044
	×-58	0.022	0.009	0.007	0.012	0.025	0.199	0.464	0.331	0.302	0.278	0.167	0.075
1974	×-57	0.008	0.004	0.004	0.013	0.124	0.321	0.050	1.212	0.279	0.459	0.360	0.060
	×-58	0.044	0.029	0.025	0.035	0.156	0.311	0.193	0.876	0.318	0.489	0.355	0.071
1975	×-57	0.114	0.012	0.013	0.068	0.131	0.959	0.064	0.563	0.194	0.512	0.220	0.037
	×-58	0.067	0.029	0.025	0.020	0.057	0.603	—	0.415	0.182	0.409	0.180	0.043
1976	×-57	0.020	0.013	0.010	0.009	0.375	0.337	0.556	0.348	0.969	0.064	0.139	0.044
	×-58	0.022	0.013	0.015	0.021	0.253	0.227	0.392	0.285	0.603	0.094	0.086	0.043
1977	×-57	0.014	0.012	0.010	0.007	0.074	0.045	—	—	—	0.265	0.253	0.047
	×-58	0.024	0.018	0.025	0.008	0.053	0.061	0.086	0.519	—	0.167	0.116	0.041
1978	×-57	0.027	0.024	0.030	0.032	0.064	0.230	0.589	1.200	0.901	0.204	0.117	0.030
	×-58	0.025	0.016	0.020	0.016	0.071	0.356	0.479	0.742	0.647	0.337	0.003	0.043
1979	×-57	0.040	0.027	0.030	0.062	0.204	0.162	1.460	0.961	0.878	1.025	0.182	0.087
	×-58	0.024	0.014	0.008	0.059	0.181	0.190	0.693	0.488	0.362	0.467	0.066	0.041
1980	×-57	0.074	0.058	0.070	0.068	0.080	0.204	0.817	0.733	0.920	0.268	0.194	—
	×-58	0.028	0.019	0.022	0.026	0.069	0.216	0.547	0.555	0.597	0.312	0.223	0.110
1981	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.061	0.037	0.025	0.033	0.091	0.422	0.211	0.140	0.252	0.161	0.234	0.098
1982	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.055	0.032	0.027	0.051	0.089	0.133	0.622	0.476	0.445	0.212	0.134	0.085
1983	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.059	0.040	0.037	0.026	0.012	0.261	0.329	0.504	0.410	0.419	0.226	0.090
1984	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.019	0.015	0.012	0.047	0.094	0.358	0.313	0.646	0.389	0.366	0.107	0.075
Ave.	×-57	0.038	0.018	0.023	0.036	0.132	0.302	0.584	0.776	0.623	0.349	0.202	0.175
	×-58	0.037	0.022	0.019	0.029	0.095	0.277	0.394	0.508	0.444	0.300	0.153	0.066

Table 2-2-4 Specific Runoff

(Unit : MCM/sq.km)

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	Bang San				0.030	0.072	0.143	0.341	0.352	0.332	0.503	0.457	0.161
	Bang Hin Phu				0.001	0.003	0.010	0.035	0.024	0.022	0.042	0.040	0.016
1974	Bang San	0.047	0.022	0.023	0.012	0.071	0.059	0.038	0.201	0.098	0.193	0.188	0.066
	Bang Hin Phu	0.003	0.008	0.001	0.002	0.007	0.004	0.003	0.014	0.021	0.030	0.054	0.028
1975	Bang San	0.025	0.014	0.008	0.041	0.055	0.251	0.073	0.146	0.109	0.145	0.162	0.040
	Bang Hin Phu	0.008	0.003	0.002	0.013	0.017	0.069	0.031	0.041	0.033	0.051	0.050	0.015
1976	Bang San	0.142	0.029	0.019	0.013	0.075	0.068	0.128	0.083	0.242	0.059	0.096	0.033
	Bang Hin Phu	0.051	0.014	0.008	0.013	0.062	0.076	0.130	0.110	0.291	0.147	0.177	0.077
1977	Bang San	0.018	0.010	0.012	0.004	0.030	0.021	0.020	0.109	0.147	0.120	0.088	0.025
	Bang Hin Phu	0.036	0.016	0.017	0.0008	0.007	0.003	0.006	0.012	0.026	0.038	0.030	0.001
1978	Bang San	0.017	0.010	0.005	0.013	0.054	0.069	0.125	0.217	0.191	0.107	0.049	0.019
	Bang Hin Phu	0.005	0.002	0.008	0.0006	0.029	0.020	0.032	0.027	0.022	0.041	0.016	0.006
1979	Bang San	0.015	0.007	0.010	0.041	0.081	0.064	0.310	0.248	0.192	0.299	0.057	0.030
	Bang Hin Phu	0.004	0.0009	0.001	0.008	0.018	0.017	0.095	0.060	0.069	0.073	0.023	0.010
1980	Bang San	0.011	0.006	0.005	0.018	0.027	0.056	0.145	0.172	0.234	0.137	0.135	0.069
	Bang Hin Phu	0.003	0.0009	0.002	0.006	0.005	0.016	0.041	0.044	0.053	0.052	0.037	0.022
1981	Bang San	0.010	0.008	0.008	0.012	0.034	0.137	0.036	0.018	0.055	0.063	0.109	0.067
	Bang Hin Phu	0.005	0.002	0.002	0.002	0.009	0.031	0.008	0.003	0.017	0.026	0.045	0.028
1982	Bang San	0.022	0.013	0.007	0.013	0.030	0.025	0.162	0.094	0.105	0.064	0.056	0.025
	Bang Hin Phu	0.007	0.005	0.002	0.003	0.011	0.022	0.060	0.035	0.017	0.034	0.035	0.015
1983	Bang San	0.016	0.006	0.007	0.002	0.053	0.064	0.073	0.111	0.121	0.162	0.101	0.027
	Bang Hin Phu	0.005	0.001	0.0009	0.0008	0.009	0.017	0.011	0.032	0.035	0.040	0.024	0.009
Ave.	Bang San	0.032	0.012	0.010	0.018	0.052	0.087	0.131	0.159	0.166	0.168	0.136	0.051
	Bang Hin Phu	0.012	0.005	0.006	0.005	0.016	0.028	0.041	0.036	0.055	0.052	0.048	0.020

(c) Evaluation on Analysis Methods

The correlation among the gauging stations in specific runoff is also shown in Figures 2-2-1 to 2-2-4.

Since the existing intake point on the khlong Pa Ko has catchment area of 12.4 sq.km, the catchment area has a similar topographical features as that of the gauging station X-57. The above mentioned figures show that the correlation between X-57 and X-58 is the highest among the four stations.

The monthly flow estimated by specific runoff at X-57 is shown in Table 2-2-5 and the monthly average flow is shown in Figure 2-2-5.

(d) Availability

Probability analysis is made on the following conditions:

- Return Period is set at once in ten years(1/10).
- The flow estimated by specific runoff at X-57 is applied, but the term of flow data can be prolonged to 11 years by correlation between X-57 and X-58.
- The monthly minimum flow in each year is applied.
- The applied data indicate logarithmic normal distribution as shown in Figure 2-2-5, therefore, the method suitable for analyzing the return period of 1/10 will be adopted.

The monthly minimum flow at the existing intake point on the Khlong Pa Ko is estimated at 0.037 MCM/mo or 1,200 cu.m/d in the return period of 1/10 as shown in Table 2-2-6.

(2) Mining Pit

(a) Evaluation on the Availability

The mining pit is situated on the left bank of the Phang Nga River and fairly close to the river. Some inflow from the river is expected in the wet season, but is considered to be an unknown factor.

The study on the availability is made considering the pit as a reservoir under the following conditions:

- Total and dead storage capacities are 100,000 cu.m and 10,000 cu.m respectively as shown in Figure 2-2-7.
- Evaporation is considered to be 70% of the Class A pan. Average evaporation area is 20,000 sq.m.
- Seepage loss is considered referring the RID's standard.

Clay	1.0 - 1.5 mm/d
Silty clay	1.5 - 2.0
Sand	2.0 - 3.0

The mining pit mainly consists of silty clay. The average seepage area is 20,000 sq.m.

Figure 2-2-1

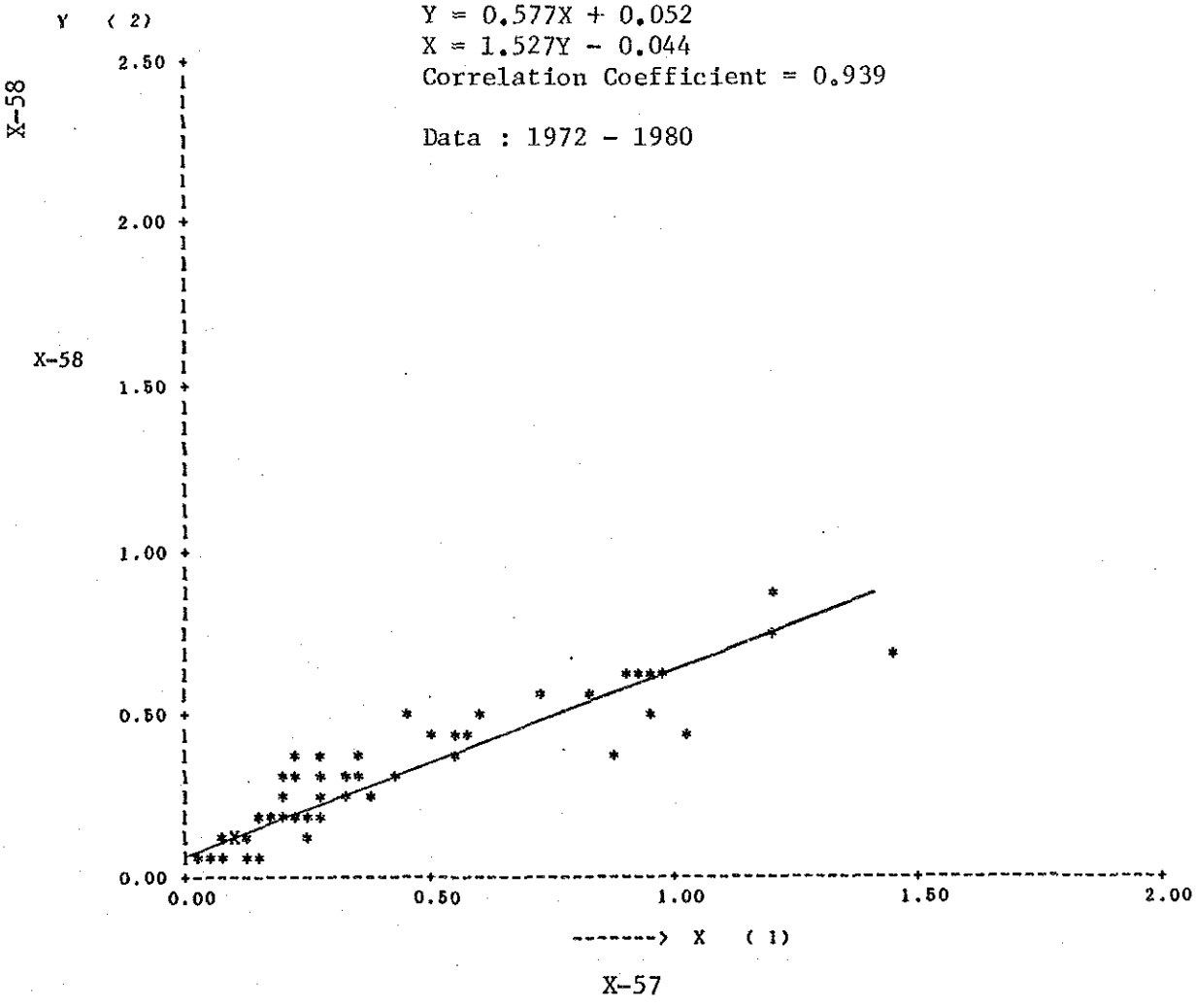


FIGURE 2-2-1
CORRELATION IN RAINFALL
X-57 - X-58

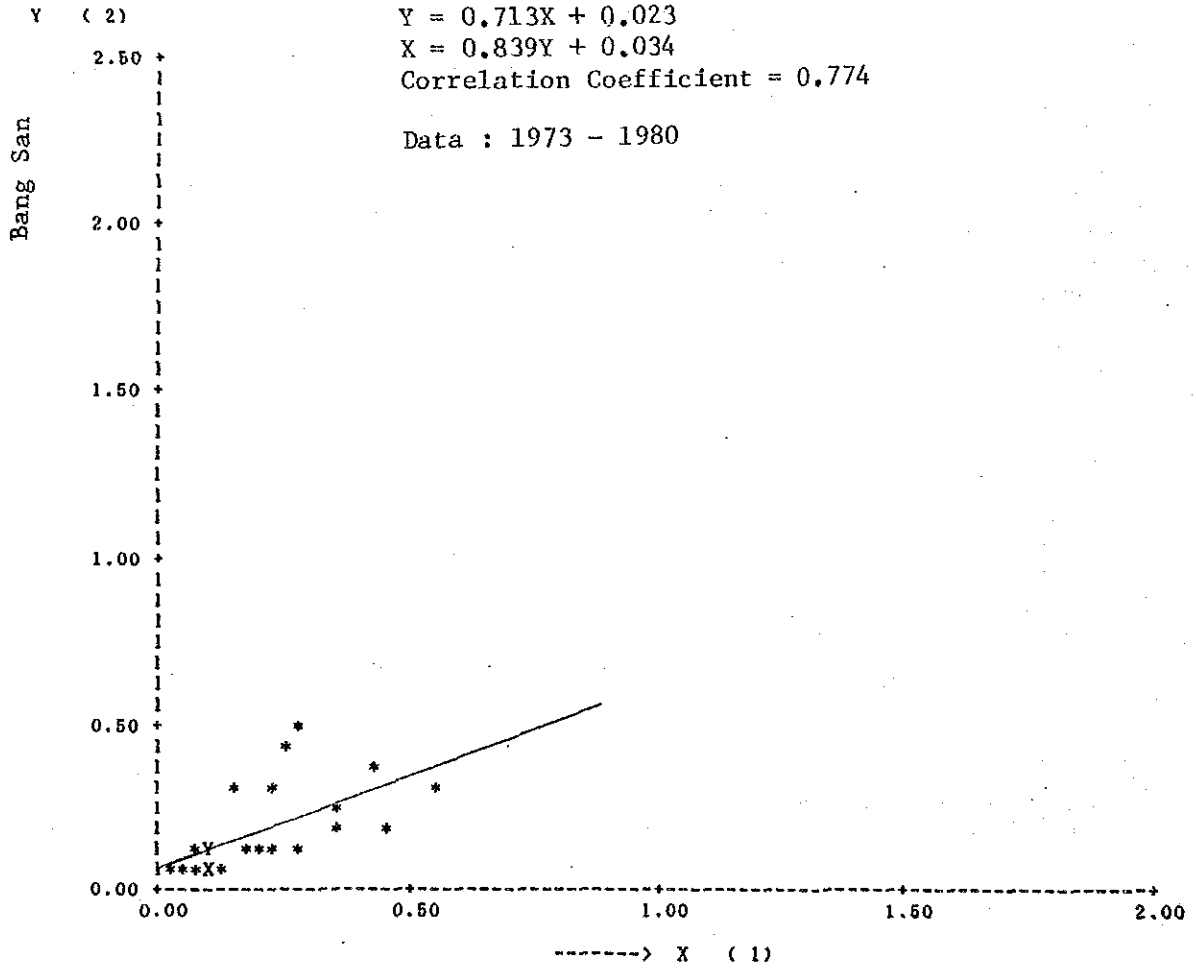


FIGURE 2-2-2
CORRELATION IN RAINFAL
BANG SAN - X-57

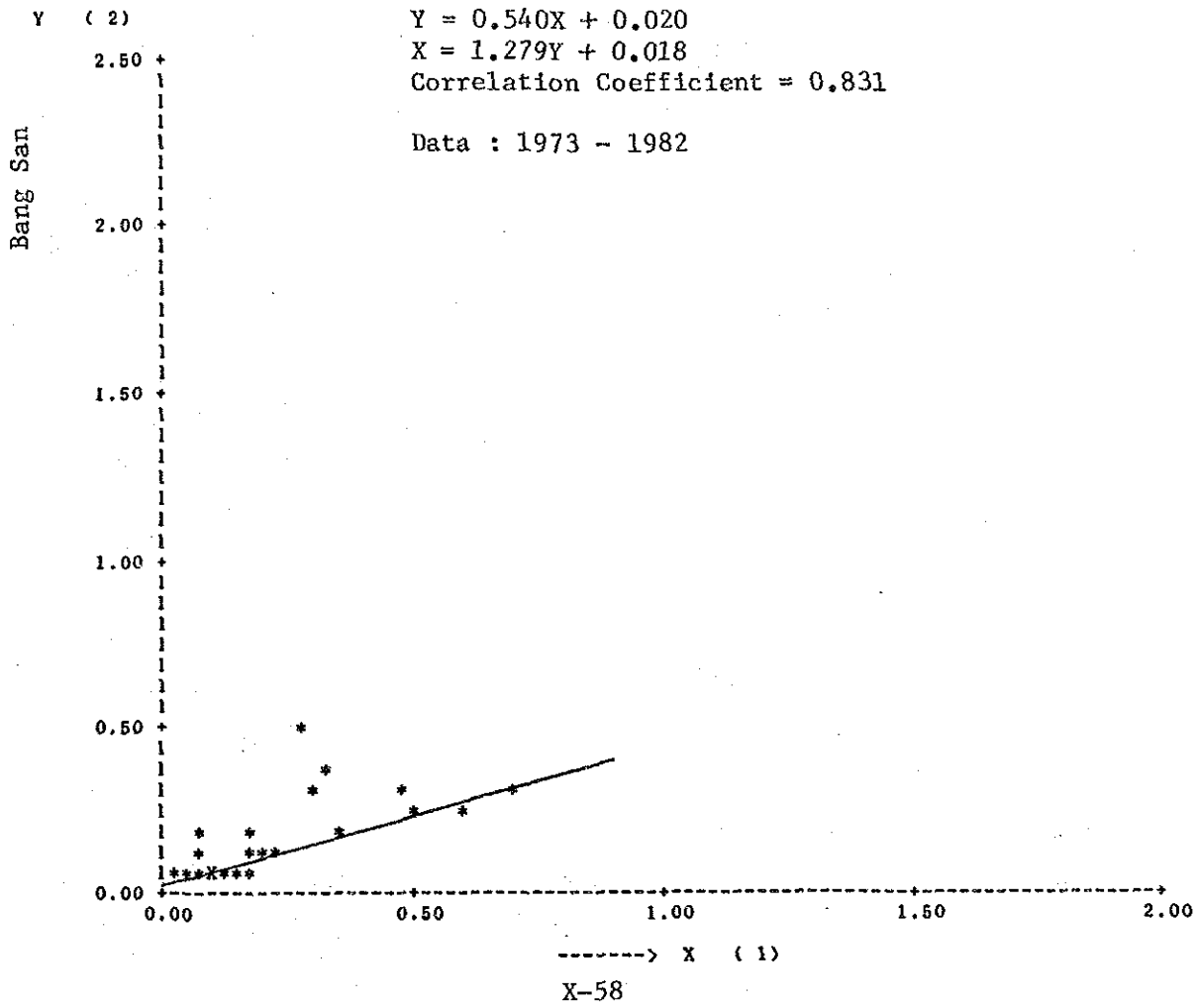


FIGURE 2-2-3
CORRELATION IN RAINFALL
BANG SAN - X-58

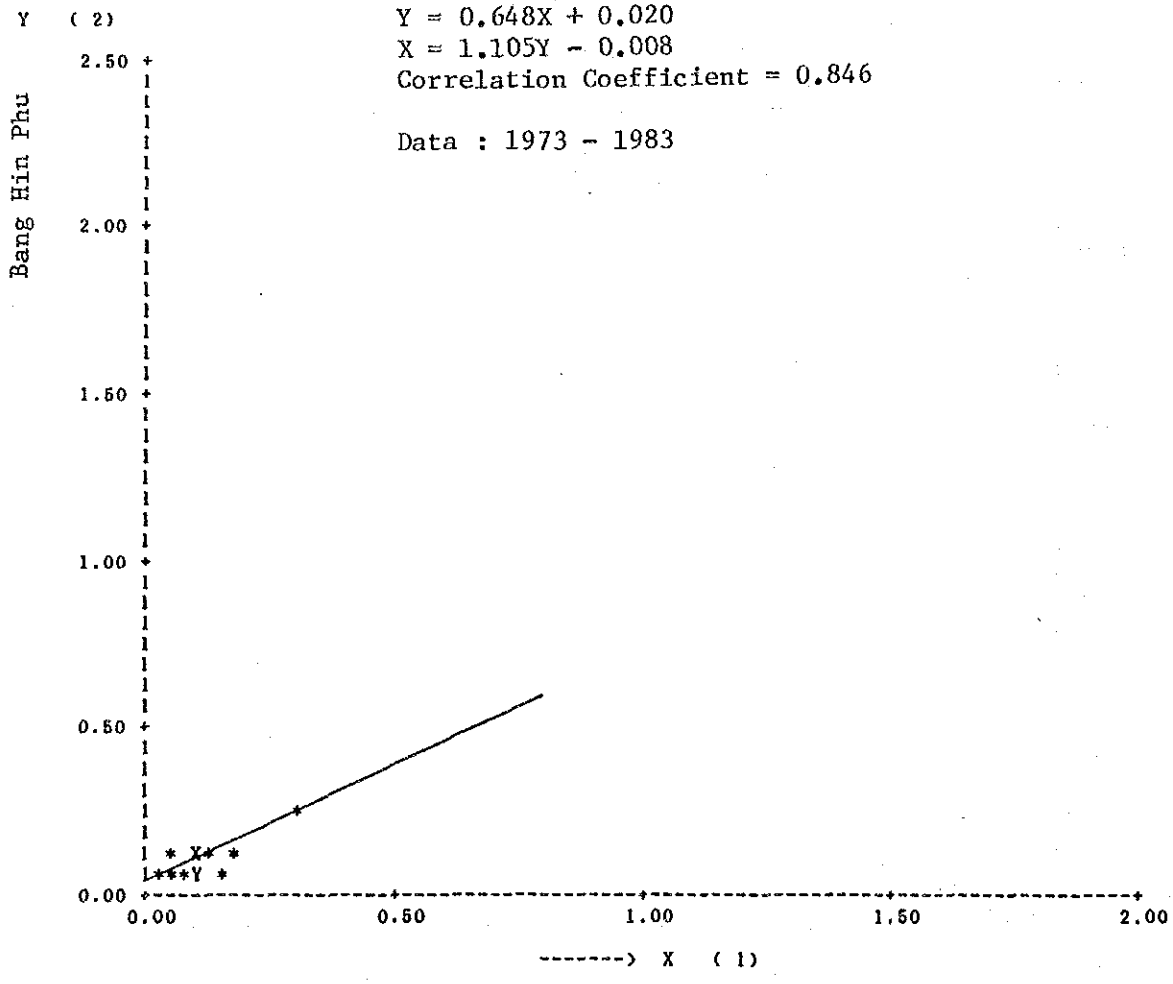


FIGURE 2-2-4
CORRELATION IN RAINFAL
BANG HIN PHU - BANG SAN

Table 2-2-5 Calculated Runoff at Intake Point

(Unit : MCM/sq.km)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1972	—	—	—	—	—	—	0.829	1.165	0.415	0.165	0.007		—
1973	0.365	0.083	2.049	6.840	5.147	2.754	3.529	3.214	0.539	0.103	0.048	0.044	24.715
1974	0.161	1.536	3.977	0.623	15.028	3.454	5.686	4.459	0.747	1.412	0.150	0.161	37.394
1975	0.843	1.619	11.891	0.788	6.975	2.410	6.351	2.732	0.457	0.252	0.161	0.128	34.607
1976	0.113	4.650	4.178	6.891	4.318	12.012	0.788	1.728	0.539	0.178	0.144	0.128	35.667
1977	0.080	0.912	0.562	—	—	—	3.279	3.134	0.581	0.331	0.300	0.289	—
1978	0.401	0.788	2.852	7.306	14.880	11.169	2.532	1.446	0.830	0.497	0.337	0.373	43.411
1979	0.762	2.532	2.008	17.353	11.914	10.887	12.703	2.250	1.078	0.912	0.713	0.871	63.983
1980	0.843	0.996	2.531	10.129	9.092	11.409	3.321	2.410	—	0.996	0.737	0.871	—
1981	0.409	1.177	7.444	3.449	2.105	4.225	2.509	3.885	1.310	0.756	0.458	0.310	28.037
1982	0.632	1.139	1.972	11.231	8.467	7.880	3.468	1.991	1.054	0.682	0.396	0.334	39.246
1983	0.322	0.148	4.396	5.683	8.997	7.217	7.388	3.733	1.158	0.731	0.496	0.458	40.727
1984	0.582	1.234	6.233	5.380	11.686	7.217	6.384	1.480	0.930	0.235	0.186	0.148	41.695
Ave.	0.524	1.699	4.335	7.095	9.171	7.495	3.900	2.735	0.960	0.685	0.410	0.448	39.457

Note : Specific Runoff at Intake Point = Specific Runoff at X-57 x 12.4 (from 1972 to 1980)

= (Specific Runoff at X-58 x 1.527 - 0.044) x 12.4 (from 1981 to 1984)

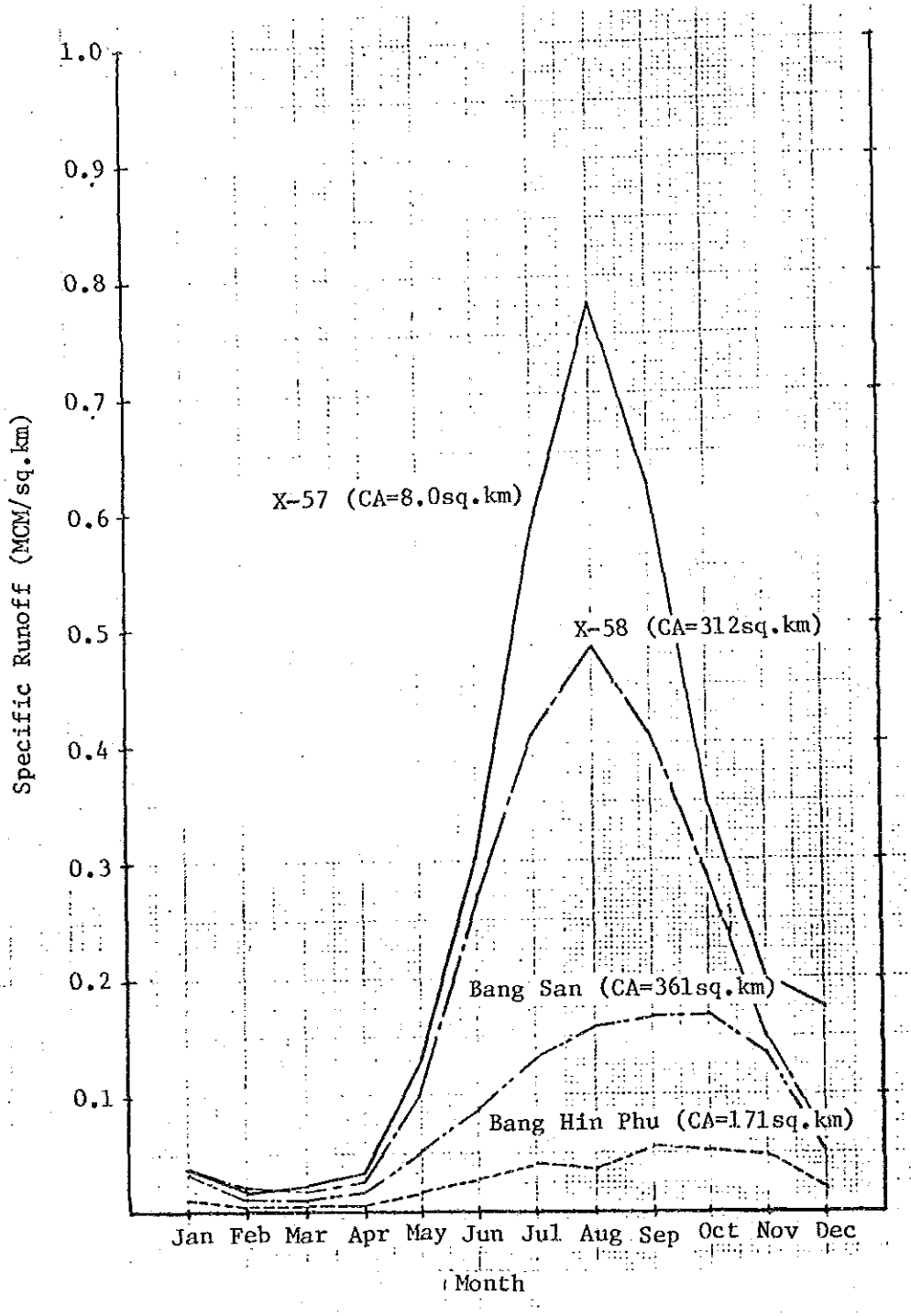


FIGURE 2-2-5

SPECIFIC RUNOFF

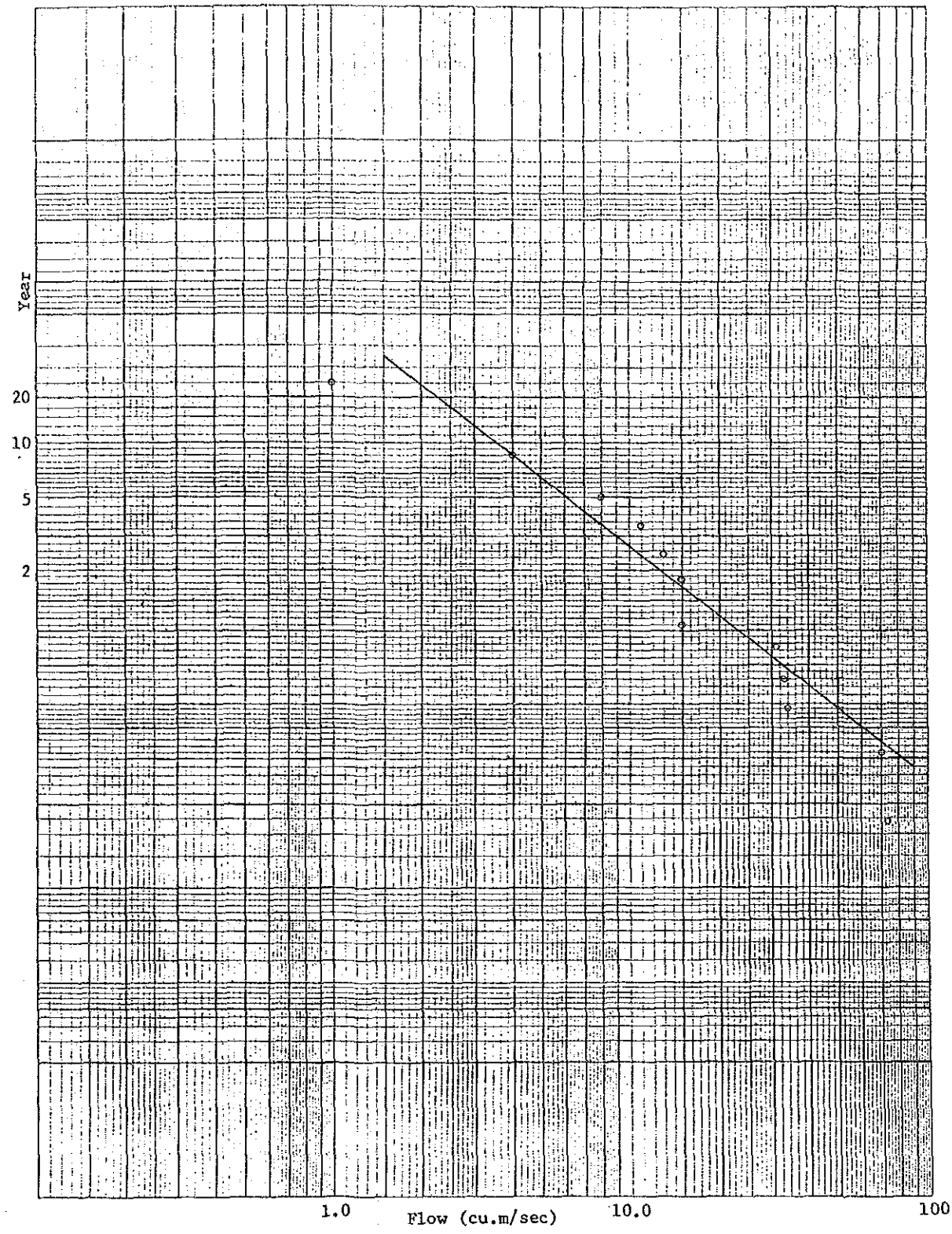


FIGURE 2-2-6
LOGARITHMIC NORMAL
DISTRIBUTION

Table 2-2-6 Monthly Flow of the Pa Ko River by Specific Runoff

********** NON-EXCEEDANCE PROBABILITY BY IWAI METHOD **********

ORDER	YEAR	X	LOG-X	Y=X+B	LOG-Y	(LOG-Y)**2	TOMAS(%)	HAZEN(%)	X**2
1	1972	0.01	-2.15490	0.047	-1.32760	1.76252	92.86	96.15	0.000
2	1973	0.04	-1.35655	0.084	-1.07555	1.15681	85.71	88.46	0.002
3	1977	0.08	-1.09691	0.120	-0.92070	0.84769	78.57	80.77	0.006
4	1976	0.11	-0.94692	0.153	-0.81522	0.66458	71.43	73.08	0.013
5	1975	0.13	-0.89279	0.158	-0.77461	0.60001	64.29	65.38	0.016
6	1983	0.15	-0.82974	0.188	-0.72577	0.52674	57.14	57.69	0.022
7	1984	0.15	-0.82974	0.188	-0.72577	0.52674	57.14	57.69	0.022
8	1974	0.15	-0.82391	0.190	-0.72117	0.52009	42.86	42.31	0.022
9	1981	0.31	-0.50864	0.350	-0.45589	0.20784	35.71	34.62	0.096
10	1982	0.33	-0.47625	0.374	-0.42709	0.18241	28.57	26.92	0.112
11	1978	0.34	-0.47237	0.377	-0.42362	0.17945	21.43	19.23	0.114
12	1979	0.71	-0.14691	0.753	-0.12319	0.01517	14.29	11.54	0.508
13	1980	0.74	-0.13253	0.777	-0.10956	0.01200	7.14	3.85	0.543
TOTAL		3.25	-10.66816		-8.62572	7.20204			1.477
(1/N)		0.25	-0.82063		-0.66352	0.55400			0.114

KHLONG PA KO PHANGA(SPECIFIC RUNOFF)

******* COMPUTATION OF B **********

ORDER	XI	XS	XI*XS	XI+XS	XI*XS-X0**2	2X0-(XI+XS)	BI
1	0.007	0.737	0.005	0.744	-0.018	-0.442	0.040
TOTAL							0.040
						B=	0.040

******* MONTHLY FLOW(MIN) LIST OF RETURN PERIOD**********

RETURN PERIOD YEAR	(MCM)	RETURN PERIOD YEAR	(MCM)
2	0.177	5	0.070
10	0.037	15	0.024
20	0.017		

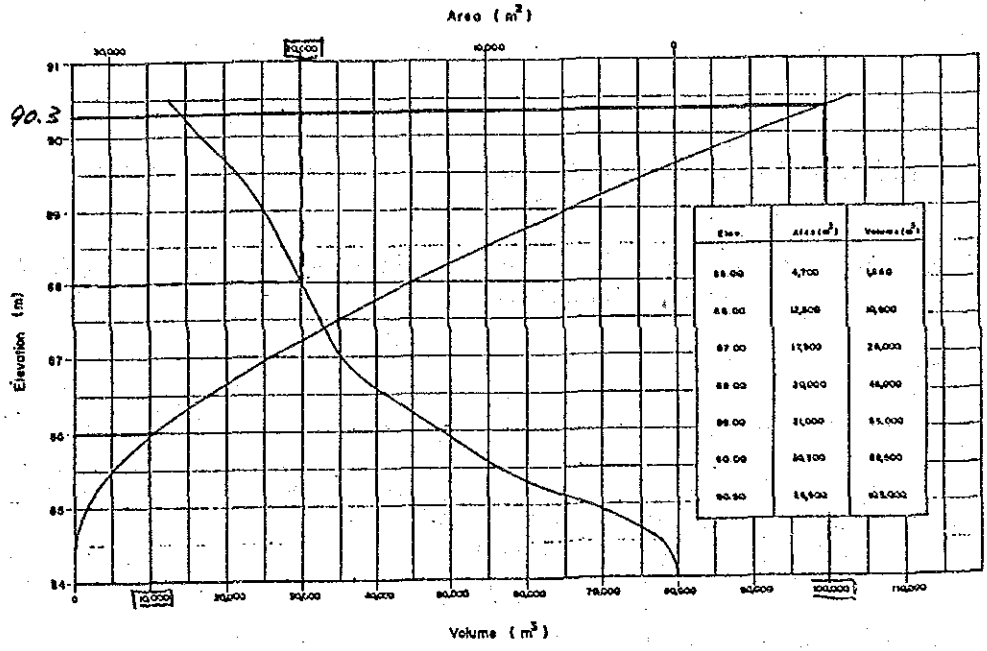


FIGURE 2-2-7
AREA-CAPACITY CURVE FOR
PHANG NGA PIT

- Inflow to the pit from the river will occur when water level rises over EL +90.41 which is the lowest elevation of the bank as shown in Figure 2-2-8. In this case the stream flow of the Phang Nga River will reach at the elevation over 64 m/s which is obtained by multiplying the river cross section area (approximately 80 sq.m) by the velocity 80 cm/s.

  Velocity is obtained from the following Manning's Formula.

  $$V = (1/n) \times R^{2/3} \times I^{1/2}$$

  where,

  V : Velocity
  n : Roughness coefficient (0.035)
  R : Average Depth (1.5 M)
  I : River bed gradient (1/2,000)

  $$V = (1/0.035) \times 1.5^{2/3} \times (1/2,000)^{1/2} = 0.80 \text{ m/s}$$

  $$Q = 0.8 \times 80 = 64 \text{ cu.m/s}$$

- Daily maximum flow can be obtained from specific runoff at X-58 daily data as shown in Table 2-2-7.

  Table 2-2-7 shows that seven months from November to May are considered to be the drawdown period.

(b) Minimum Availability

Accordingly, the minimum available amount for water supply is:

$Q = (100,000-10,000) - 20,000 \times 0.7 \times (0.133+0.139+0.164+0.155+0.198+0.157+0.135) - 20,000 \times 0.002 \times 210$
$= 66,500$ cu.m in seven months
$= 300$ cu.m/d

(3) Total Minimum Availability

A irrigation canal exists downstream of the existing weir with a 200 mm pipe for irrigation purpose. Irrigation requirement is considered to be 50% of the minimum flow. Therefore, the total minimum available flow is:

Khlong Pa Ko	1,200	x 0.5 =	600 cu.m/d
Mining Pit			300
		Total	900 cu.m/d

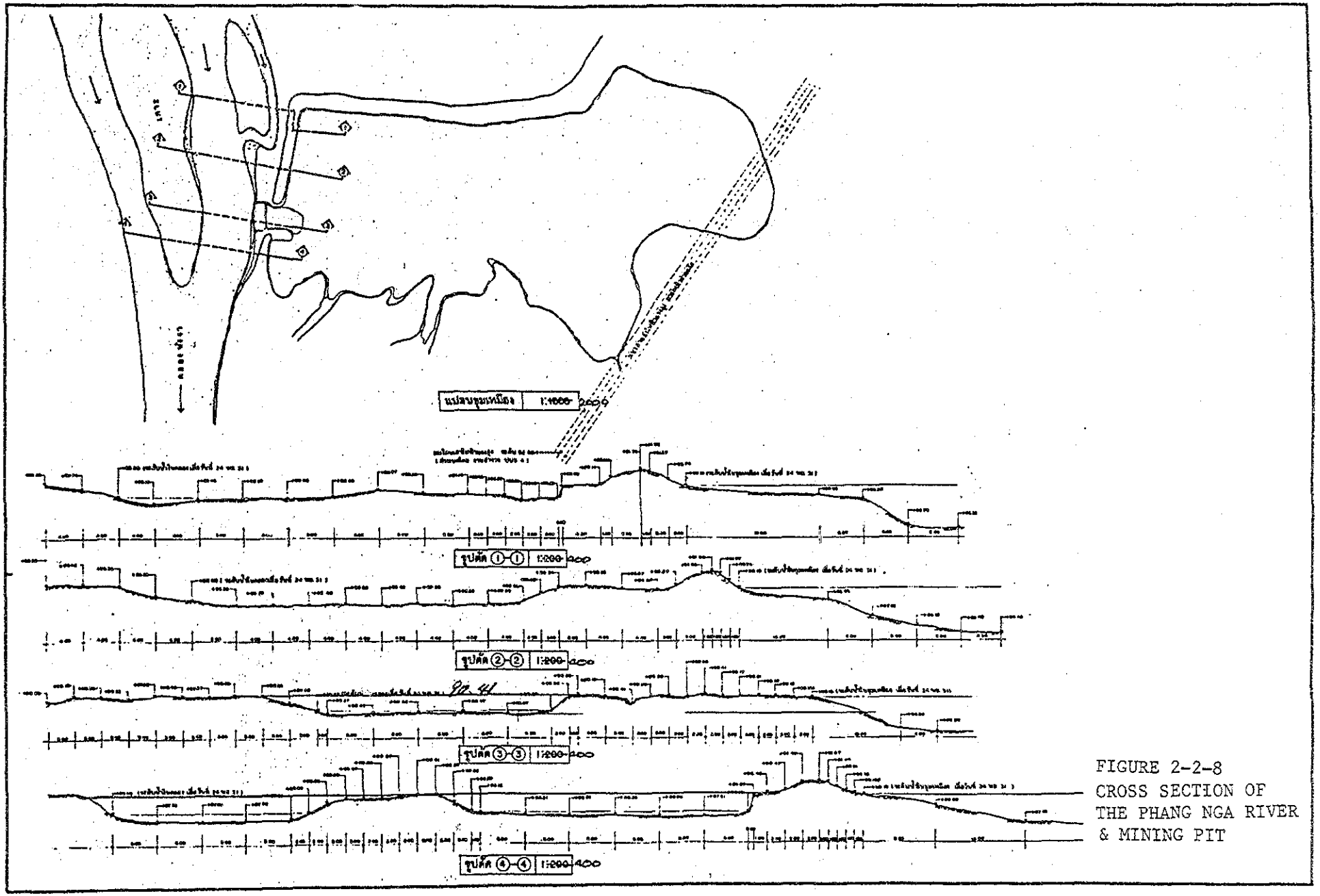


FIGURE 2-2-8
CROSS SECTION OF
THE PHANG NGA RIVER
& MINING PIT

Table 2-2-7 Daily Maximum Flow at Mining Pit along the Phang Nga River

(Unit : cu.m/sq.km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	4.09	1.47	1.47	5.52	11.04	97.52	142.60	184.00	94.76	84.64	35.88	11.96	674.95
1974	7.91	5.24	4.55	8.74	164.35	125.10	44.16	213.40	199.64	187.68	114.08	11.96	1,086.81
1975	17.48	4.14	3.86	4.50	12.88	178.48	—	205.16	50.60	167.44	44.16	6.16	—
1976	2.99	1.84	3.81	6.25	205.16	125.12	230.92	165.60	350.52	16.56	22.08	7.36	1,138.21
1977	3.45	4.00	3.03	3.18	13.80	20.24	14.72	339.48	—	39.56	32.20	6.16	—
1978	3.10	2.18	3.43	4.09	38.78	79.12	176.45	165.41	232.39	116.93	27.50	5.98	855.36
1979	3.68	2.30	1.65	72.86	122.36	47.88	225.86	191.17	204.40	230.00	10.72	5.55	1,118.38
1980	3.49	2.48	5.26	8.46	19.39	79.30	149.50	225.21	188.78	60.90	49.58	16.33	808.68
1981	8.28	5.33	3.49	6.44	18.87	125.23	54.74	66.05	110.03	31.90	85.10	18.87	534.33
1982	7.54	4.46	5.15	14.03	23.77	40.89	236.25	228.52	148.48	31.70	24.80	11.96	777.55
1983	7.80	6.00	9.20	4.40	58.10	98.35	159.75	168.55	222.60	94.30	62.30	13.50	904.85
1984	11.00	7.40	4.85	10.40	34.47	150.95	137.15	261.60	136.64	164.15	18.00	12.40	949.01
Ave.	6.73	3.90	4.14	12.40	60.21	97.34	142.80	183.41	176.19	102.14	43.86	15.20	848.32

Note : The 1973's data is considered to have once in ten-year return period on an annual base.

2.3 *Developability of Alternative Water Sources*

2.3.1 Surface Water

The following alternative water sources are considered in order to meet the future water demand and secure stable water supply:

(1) Raising of the Existing Weir

The existing weir is constructed on the fresh granite rock, but too small to store a sufficient amount of water to meet the demand. The weir should be heightened 10 m or so to store a water volume of more than 150,000 cu.m.

(2) Expansion of the Existing Mining Pit and Construction of Transmission Facilities from the Phang Nga River

Some recharge from the Phang Nga River are expected but unknown. In addition, the mining pit is not sufficient enough in capacity to meet the future water demand.

A transmission facilities to the pit should be constructed and the capacity of the pit should be expanded by digging or heightening the embankment as well.

(3) New Mining Pit Development

A few mining Pit are located 2 km upstream of the existing mining pit. These pit can be used for water supply.

(4) Dam Construction on the Khlong Tham

At present, RID constructed the weir for irrigating an area of 1,200 ha upstream of the Khlong Tham. The point has favorable topographical features for dam construction and an enough catchment area.

A multi-purpose dam should be constructed for the purpose of irrigation, water supply and flood control.

2.3.2 Ground Water Development

According to the survey conducted by DMR, ground water potentiality on the aquifers in the area is described below:

(1) Alluvial Aquifer

Alluvial aquifer consisting of unconsolidated clay sand and gravel of alluvial deposits occurred on the right bank of the Phang Nga River. The aquifer is generally not over 200 ft. The yield is about 20-100 gpm.

(2) *Carbonate Aquifer*

Carbonate aquifer comprising the Permian limestone occurred along the river. The Permian are generally crystalline, cavernous and massive. Ground water occurs mainly in solution cavities, bedding planes, contact zones between limestone and interbedded shale, and fault zones. The yield generally ranges from 50-100 gpm.

3 EXISTING WATER SUPPLY SYSTEM

3.1 Existing Water Supply System

3.1.1 General

The waterworks for the Municipality of Phang Nga was founded in 1963. The treatment plant had a capacity of 20 cu.m/h treating the surface water of the Phang Nga River which flowed through the Municipality. In 1969, the treatment capacity was expanded to 60 cu.m/h with the construction of the 40 cu.m/h new treatment plant and coincidentally the water source was switched from the river to the waterfall at Pak Ton, 5.6 km away from the waterworks. The waterworks was placed under the control of the PWA and put under the jurisdiction of the PWA Regional Office 4 in Surat Thani.

3.1.2 Treatment

Although there are two treatment units with capacities of 20 cu.m/h and 40 cu.m/h, respectively in the treatment plant as mentioned above, the small and old one is no longer used. Elements comprising the treatment plant are summarized in Table 3-1-1.

Raw water transmitted by gravity through the 200 m pipe from the Pak Ton Waterfall is fed into the 40 cu.m/h treatment unit. The treatment process consists of chemical flocculation, sedimentation, rapid sand filtration and chlorination. Clear water stored in the 500 cu.m clear water reservoir is distributed directly by the clear water pumps during high water demand and by gravity from the 50 cu.m elevated water tank during low water demand. Backwash water for rapid sand filters is obtained from a pipeline connected to the clear water pumps. Figures 3-1-1 and 3-1-2 provide the schematic representation and layout of the treatment plant, respectively.

3.1.3 Distribution System

(1) Description of Existing Distribution System

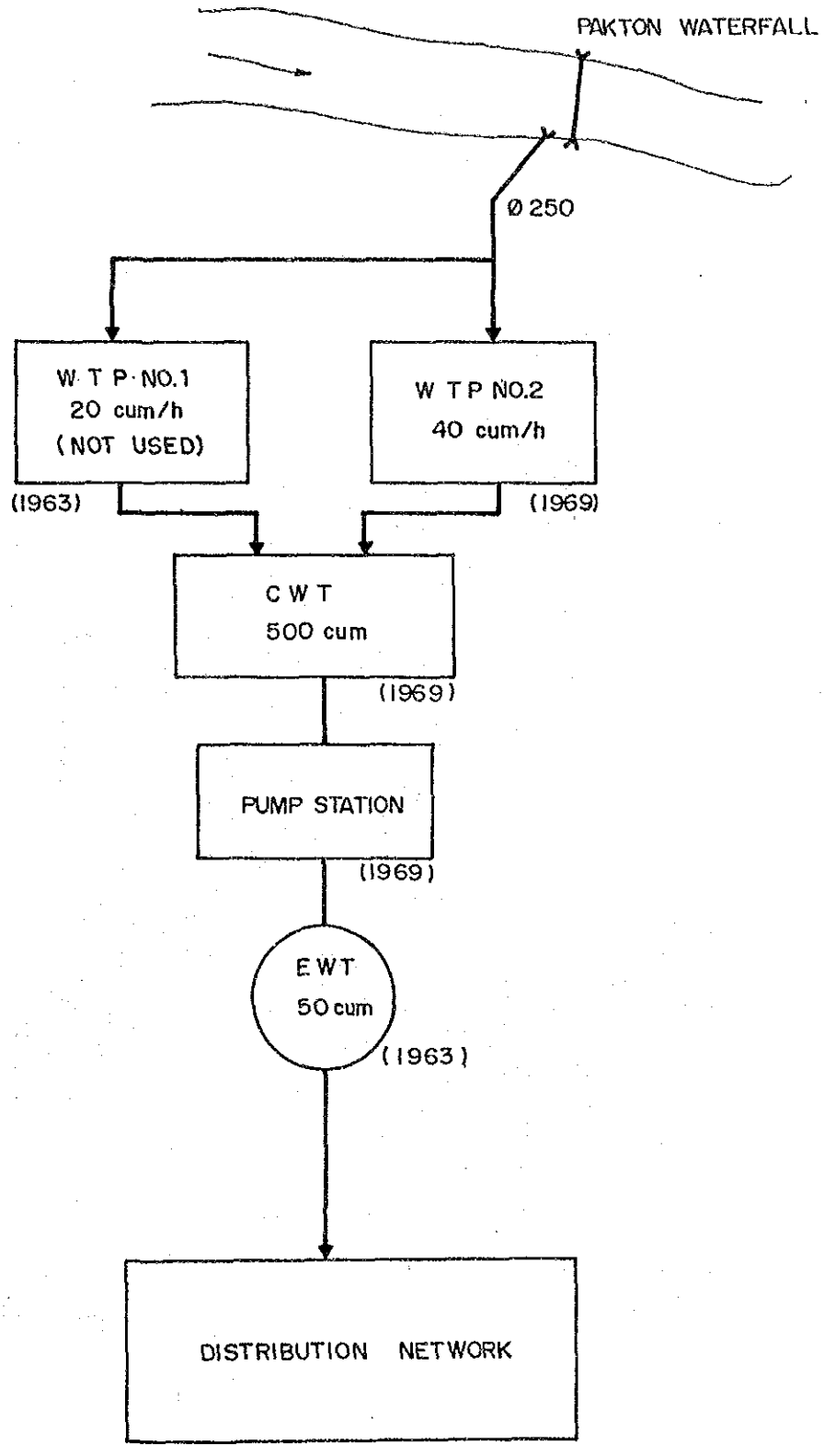
The distribution system of Phang Nga Waterworks covers the most of the town and extends to the Phang Nga Bay Resort Hotel shown in Figure 3-1-3 . Schematic plan of the network is shown in Figure 3-1-4.

Most of the existing distribution pipelines were installed in the 1960's with Class 15 asbestos cement pipes. New developed areas have installed asbestos cement pipes with Class 20 in the year of 1983 and 1984. The year of installation for each pipe is shown in Figure 3-1-4.

The record of the Phang Nga Waterworks shows that 38 cases of leakage problems on the distribution system occurred in 1988. Those were mostly located south of the existing water treatment plant.

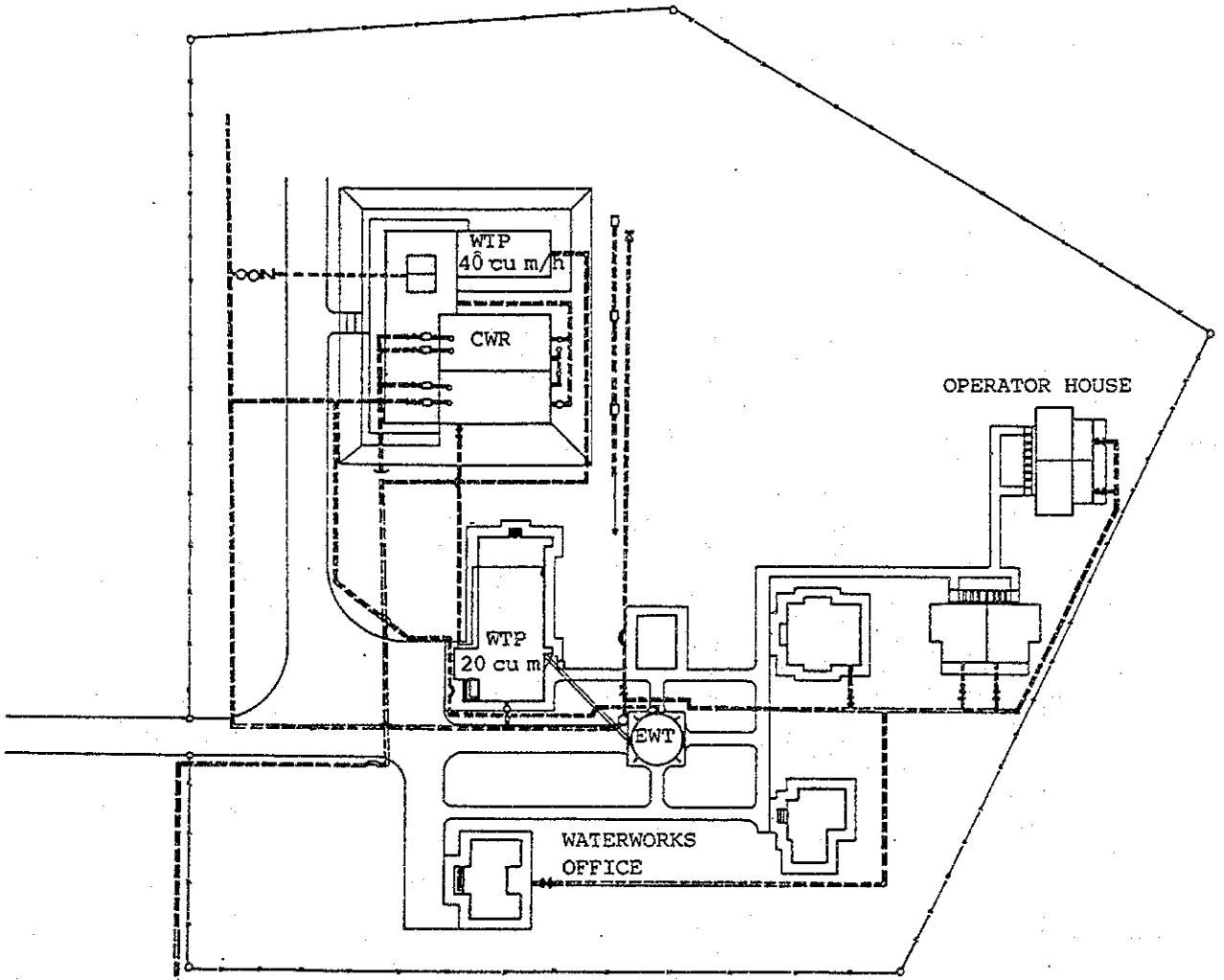
Table 3-1-1 Outline of Treatment Facilities

Water Source	Pak Ton Waterfall
Treatment Capacity	40 cu.m/h
Treatment Facilities	
Rapid Mixing Basin	
No. of Units	1 unit
Dimensions	0.40 m x 13.00 m x 0.60 m
Flocculation Basin	
No. of Units	1 unit
Dimensions	2.50 m x 4.80 m x 4.40 m
Sedimentation Basin	
No. of Units	1 unit
Dimensions	4.8 m x 11.50 m x 4.40 m
Sedimentation Time	6.1 hours
Rapid Sand Filter	
No. of Units	2 units
Dimensions	2.00 m x 3.00 m
Filtration Rate	80 m/d
Chlorination Facility	
Kind of Chemical	Bleaching Powder
Dosage Rate	Approx. 3 mg/l
Chlorine Feed Pump	Metering Pump
Clear Water Reservoir	
No. of Units	1 unit
Capacity	500 cu.m
Detention Time	12.5 h
Water Elevated Tank	
Height	Approx.18 m above the ground level
No. of Units	1 unit
Capacity	50 cu.m
Detention Time	
Clear Water Pump	40 cu.m/h x 40 m x 11 kw x 2 units motor-driven 40 cu.m/h x 40 m x 19 hp x 1 unit engine-driven 100 cu.m/h x 33 m x 35 hp x 1 unit engine-driven



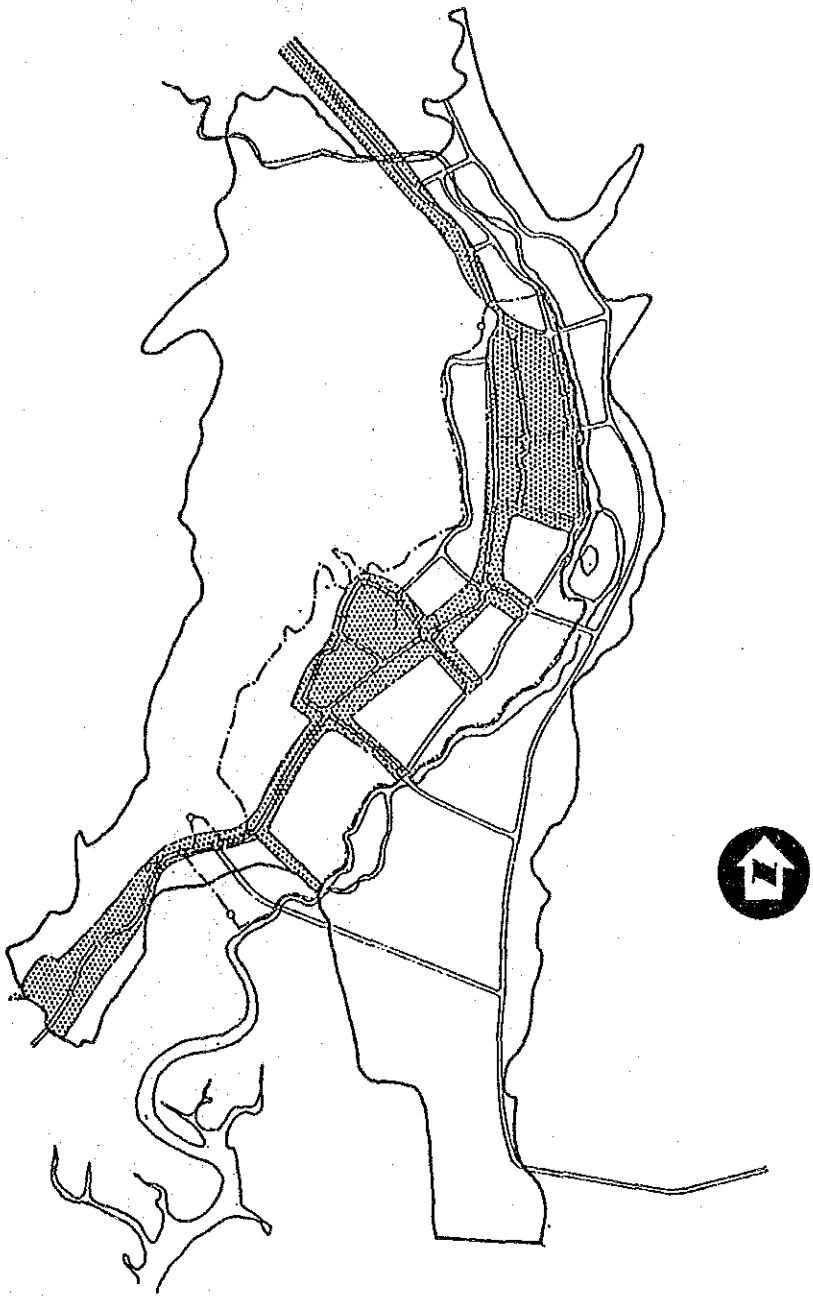
WTP : WATER TREATMENT PLANT
CWR : CLEAR WATER RESERVOIR
EWT : ELEVATED WATER TANK

FIGURE 3-1-1
PHANG NGA
EXISTING WATER
TREATMENT SYSTEM



WTP : WATER TREATMENT PLANT
CWR : CLEAR WATER RESERVOIR (500 cu m)
EWT : ELEVATED WATER TANK (50 cu m)

FIGURE 3-1-2
PHANG NGA
WATER TREATMENT PLANT



: EXISTING SERVICE AREA

FIGURE 3-1-3
PHANG NGA
EXISTING SERVICE AREA

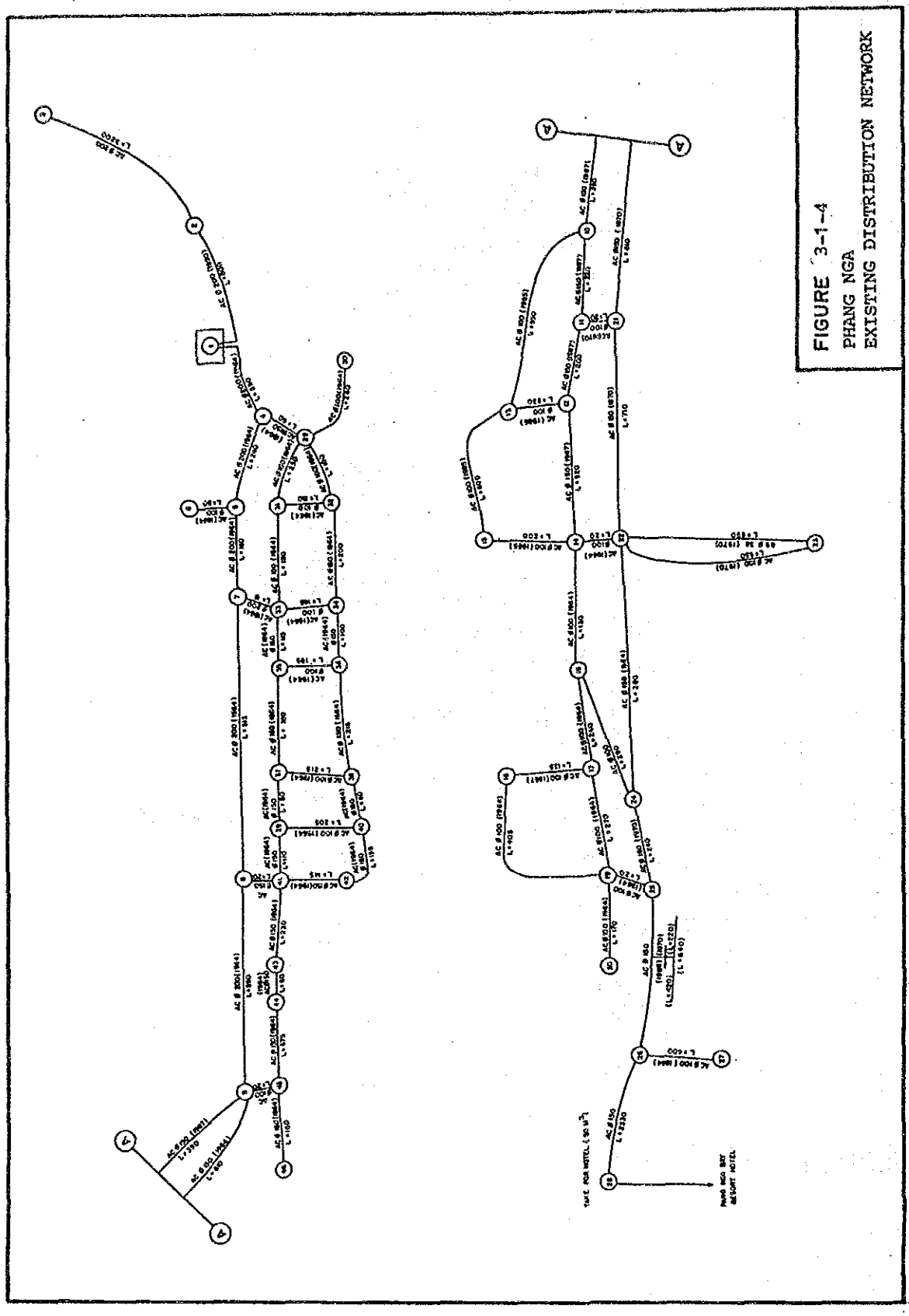


FIGURE 3-1-4
PHANG NGA
EXISTING DISTRIBUTION NETWORK

Breakdown of the pipeline is tabulated in Table 3-1-2.

Table 3-1-2 Distribution Pipe

Dia. (mm)	Length (m)	Material
200	6,460	AC
150	7,430	AC
100	4,480	AC
Total	18,370	

The elevated tank is not actually in use. It is connected to the outflow pipe with a high lift pump and acts like surge tank or stand pipe in the distribution system. Pumps are turned on and off manually. The operators observe the pressure at the delivery side of pumps.

The number of connections of the waterworks are counted as follows:

Table 3-1-3 Number of Connections

Year	No. of Conn.
1980	728
1981	839
1982	887
1983	928
1984	948
1985	979
1986	1,019
1987	1,041

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

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

(2) Distribution Network Analysis

(a) Method of Analysis

A computer model was used to analyze the existing distribution system and to prepare an improvement plan therefore as required. The model uses a standard Hardy-Cross network analysis technique where head losses are calculated using the Hazen-Williams formula. An interactive process is used in the model to balance the hydraulic grade line at each pipe junction in the network, with adjustment made in the hydraulic grade line to satisfy the continuity equation at each junction.

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

Estimates of the Hazen-Williams discharge coefficients for existing pipeline are determined based on the age of pipes which was obtained from the Phang Nga Waterworks during the field survey.

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

(c) Demand Distribution

Based on the water sales records, a demand distribution at each node was prepared. It was assumed for the purpose of the initial analysis that the existing treatment plant can supply enough treated water to meet the daily and hourly maximum demands.

(d) Evaluation of the Existing Distribution System

Using the data described above, a simulation was made to the existing system by the computer model described earlier. This simulation shows that a pressure of about 28m in water column is required at the existing treatment plant. The results indicating pressure contour lines are shown in Figure 3-1-5 . The computer output of distribution network analysis are presented in the separate volume.

The results show that there are adequate pressure throughout the distribution system, and indicates similar pressure conditions to the actual field pressure measurements described in Appendix A-3-1.

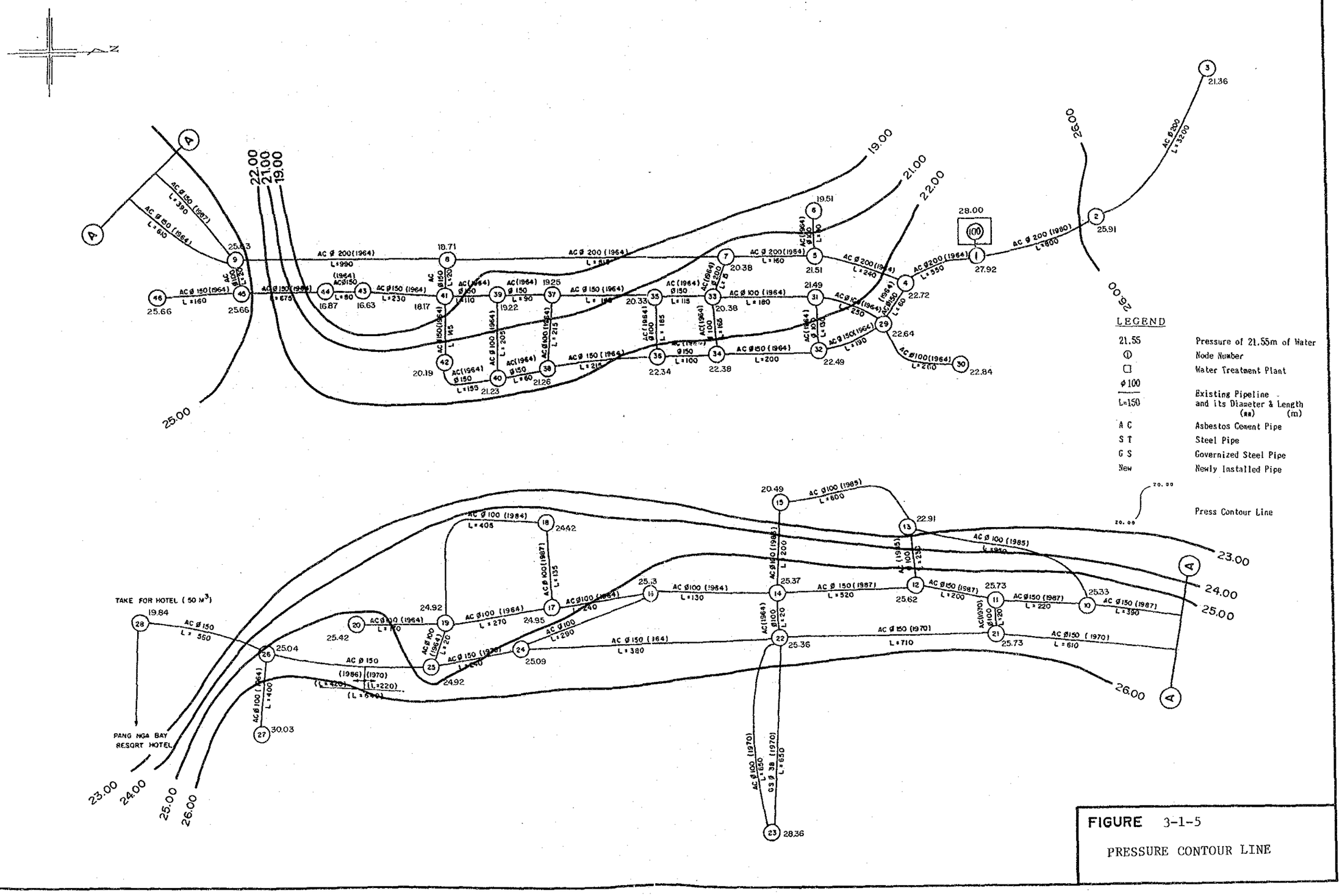


FIGURE 3-1-5

PRESSURE CONTOUR LINE

3.2 Operation and Maintenance

The operations status during the past two year from October 1986 to July 1988 is shown in Table 3-2-1.

The operational condition is remarkably stable for the Phang Nga Waterworks. Although the average daily water production of 50.3 cu.m/h exceeds the nominal treatment capacity by 25.8%, the monthly deviations from the average are within the range of -4.2% and +4.1%, excluding the minimum of -8.4% in September 1987 and the maximum of +7.1% in January 1988. The average treatment loss is 5.8%, and is a reasonable level.

There is no chemical addition for coagulation-sedimentation in the dry season and neither is there a raw water pump.

It should be noted that more than half of the users have complained of color, smell and turbidity from tap water, based on the results of the questionnaire survey as shown in Appendix 3-2. Rapid mixing is conducted with the turbulent flow in the long channel installed above the sedimentation basins but no flocculation basin for slow mixing is provided. The overflow weir in the sedimentation basins is not long enough and is thus always submerged. The mud balls are found in the rapid sand filters.

The chemical solving tanks are installed beneath the staircase at the corner of the clear water pump room. This is so narrow that the chemical dosing works into the chemical solving tanks is troublesome. The chemical storage room is next to the pump room but detouring is required when carrying the chemical bags to the pump room.

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

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	32860	33830	37120	39413	37204	41273	25260	39690	36855	38740	35472	34130	431847	35987
Ground Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water	32860	33830	37120	39413	37204	41273	25260	39690	36855	38740	35472	34130	431847	35987
*Variation	0.913	0.940	1.031	1.095	1.034	1.147	0.702	1.103	1.024	1.076	0.986	0.948	-	-
B) Raw Water Used	100	150	100	193	184	193	120	150	135	240	212	390	2167	181
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	200	200	17
Drainage	100	150	100	100	100	100	120	60	75	150	150	100	1305	109
Waste	0	0	0	93	84	93	0	90	60	90	62	90	662	55
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.003	0.004	0.003	0.005	0.005	0.005	0.005	0.004	0.004	0.006	0.006	0.011	0.005	-
C) Treated Water	32760	33680	37020	39220	37020	41080	37800	39540	36720	38500	35260	33740	442340	36862
*Variation	0.889	0.914	1.004	1.064	1.004	1.114	1.025	1.073	0.996	1.044	0.957	0.915	-	-
D) Treated Water Used	1826	1510	1612	1784	1530	2022	1953	2280	1785	2004	1977	1903	22276	1856
Filter Washing	1240	1200	1240	1240	1120	1550	1400	1550	1200	1550	1550	1500	16340	1362
Chemical Mixing	31	30	31	31	28	31	30	31	30	31	31	150	485	40
Engine	31	30	31	31	28	31	30	31	30	31	31	30	365	30
Sedimentation Basin	128	0	0	0	50	0	0	0	0	0	0	40	218	18
Clear Water Reservoir	0	0	0	50	0	0	0	0	0	0	0	0	50	4
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	396	250	310	432	304	410	493	668	525	482	365	180	4818	402
Used in Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(D)/(C)	0.056	0.045	0.044	0.045	0.041	0.049	0.052	0.058	0.049	0.054	0.056	0.056	0.050	-
E) Distributed Water	30394	32170	35408	37436	35490	39058	35847	37260	34935	36400	33283	31837	419524	34960
*Variation	0.869	0.920	1.013	1.071	1.015	1.117	1.025	1.066	0.999	1.041	0.952	0.911	-	-
F) Sold Water	19116	21020	23451	24345	23882	23396	25811	26824	15977	21774	22903	18438	266845	22245
Connection Meters	19116	21014	23344	24345	23688	23396	25761	26824	15977	21774	22903	18438	266580	22215
Public Meters	0	6	107	0	122	0	30	0	0	0	0	0	265	22
Lump Sum	0	0	0	0	72	0	20	0	0	0	0	0	0	8
*Variation	0.859	0.945	1.054	1.094	1.074	1.052	1.160	1.206	0.718	0.979	1.030	0.829	-	-
G) Unaccounted-for Water	11278	11150	11957	13091	11608	15662	10036	10436	18958	14632	10380	13399	152679	12716
*(G)/(E)	0.371	0.347	0.338	0.350	0.327	0.401	0.280	0.280	0.543	0.402	0.312	0.421	0.364	-
H) No. of Connections	1022	1023	1023	1023	1023	1028	1033	1035	1034	1033	1037	1040	-	-
I) Per Conn. Consumption	NA	32.92	36.19	38.34	36.19	39.96	36.59	38.20	35.51	37.27	34.00	32.44	397.62	33.13
*Variation	NA	0.994	1.092	1.157	1.092	1.206	1.072	1.153	1.072	1.125	1.026	0.979	-	-
J) Chemical														
Alum	2100	2100	1600	1300	1500	1500	2000	1200	1700	1500	1500	1500	19500	1625
Bleaching Powder	120	120	80	80	120	160	160	120	120	120	120	120	1440	120
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	250	100	50	100	0	0	0	50	125	150	125	0	950	79
K) Chemical Dosage Rate														
Alum	64.10	62.35	43.22	33.15	40.52	36.51	52.91	30.35	46.30	38.96	42.54	44.46	-	44.08
Bleaching Powder	3.66	3.56	2.16	2.04	3.24	3.89	4.23	3.03	3.27	3.12	3.40	3.56	-	3.26
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Lime	7.63	2.97	1.35	2.55	0.00	0.00	0.00	1.26	3.40	3.90	3.55	0.00	-	2.15

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

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

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	37790	35680	38260	39525	35466	37680	36320	37749	37530	37206	0	0	373206	37321
Ground Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water	37790	35680	38260	39525	35466	37680	36320	37749	37530	37206	0	0	373206	31101
*Variation	1.013	0.956	1.025	1.059	0.950	1.010	0.973	1.011	1.006	0.997	0.000	0.000	-	-
B) Raw Water Used	710	240	260	255	366	270	170	249	130	150	0	0	2800	280
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	530	150	105	100	250	150	80	125	130	150	0	0	1770	177
Waste	180	90	155	155	116	120	90	124	0	0	0	0	1030	103
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.019	0.007	0.007	0.006	0.010	0.007	0.005	0.007	0.003	0.004			0.008	-
C) Treated Water	37080	35440	38000	39270	35100	37410	36150	37500	37400	37056	0	0	370406	37041
*Variation	1.001	0.957	1.026	1.060	0.948	1.010	0.976	1.012	1.010	1.000	0.000	0.000	-	-
D) Treated Water Used	2028	1815	1577	1973	1821	1847	1964	2138	1892	1218	0	0	18273	1827
Filter Washing	1550	1500	1350	1500	1400	1500	1500	1550	1500	780	0	0	14130	1413
Chemical Mixing	180	30	31	186	132	155	150	150	150	150	0	0	1314	131
Engine	31	30	31	31	29	31	30	31	42	38	0	0	324	32
Sedimentation Basin	0	0	0	0	0	0	0	150	0	0	0	0	150	15
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	267	255	165	256	260	161	284	257	200	250	0	0	2355	236
Used in Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(D)/(C)	0.055	0.051	0.042	0.050	0.052	0.049	0.054	0.057	0.051	0.033			0.049	-
E) Distributed Water	35051	33025	36173	37197	33279	35503	34246	35362	35508	35838	0	0	351842	35184
*Variation	0.996	0.956	1.028	1.057	0.946	1.011	0.973	1.005	1.009	1.019	0.000	0.000	-	-
F) Sold Water	21292	19163	18581	24479	25566	23281	23510	23944	21409	22601	0	0	223826	22383
Connection Meters	21292	19163	18581	24479	25566	23281	23510	23944	21409	22601	0	0	223826	22383
Public Meters	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.951	0.856	0.830	1.094	1.142	1.040	1.050	1.070	0.957	1.010	0.000	0.000	-	-
G) Unaccounted-for Water	13759	14462	17592	12718	7713	12282	10736	11418	14099	13237	0	0	128016	12802
*(G)/(E)	0.393	0.430	0.486	0.342	0.232	0.345	0.313	0.323	0.397	0.369			0.364	-
H) No. of Conn. (nos.)	1040	1048	1049	1053	1053	1061	1066	1064	1068	1050	0	0	-	-
I) Per Conn. Consumption	35.65	33.82	36.22	37.29	33.33	35.26	33.91	35.24	35.02	35.29	0.00	0.00	351.05	35
*Variation	1.016	0.963	1.032	1.062	0.950	1.004	0.998	1.004	0.998	1.005	0.000	0.000	-	-
J) Chemical (kg)														
Alum	1560	1500	400	400	0	0	0	0	800	1200	0	0	5860	586
Bleaching Powder	120	160	120	120	160	160	280	160	240	320	0	0	1840	184
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	25	100	125	150	100	0	0	0	0	0	500	50
K) Dosage Rate (mg/l)														
Alum	42.07	42.33	10.53	10.19	0.00	0.00	0.00	0.00	21.39	32.38			-	15.82
Bleaching Powder	3.24	4.51	3.16	3.06	4.56	4.28	7.75	4.27	6.42	8.64			-	4.07
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00
Lime	0.00	0.00	0.66	2.55	3.56	4.01	2.77	0.00	0.00	0.00			-	1.35

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

3.3 Existing Improvement/Expansion Plan

3.3.1 Improvement/Expansion Plan for Treatment Plant

At present, a concrete plan for improvement/expansion has not been prepared for Phang Nga waterworks. However, the general concept explained in the following sub-section will be applied in improving the existing treatment plant.

3.3.2 General Concept of PWA for Improvement/Expansion for Water Treatment Plant

PWA's general concept for the improvement and expansion of the water treatment plant is based on the recommendations of the UNDP experts, which are well summarized in the article "Improving Water Supply in Thailand" by Messrs. Sawasdi Orvichian, Prasert Chuaphanich, and Susumu Kawamura, Journal of AWWA, Management and Operations, June, 1988.

The concept for improvement and expansion was established to increase the treatment capacity without the addition of new basins and filters. The modification for improvement consists of three phases as listed below:

Stage 1 - Correct existing deficiencies and implement those modifications needing immediate action.

Stage 2 - Expand plant capacity at the earliest possible time.

Stage 3 - Modernize plants and improve safety.

These stages were separated in accordance with the urgency of the measures to be taken, and the cost- effectiveness of the investment.

At present, PWA is implementing the improvement and modification program for various waterworks applying the technology recommended for Stage 1. The facilities and measures for improvement recommended in Stage 1 are summarized below:

(1) Coagulation System (Flush Mixing)

Coagulation and flocculation are the most important process in the treatment system. As most of the existing plants have no proper coagulation and flocculation systems, the sedimentation tank does not work well so that a lot of micro floc are carried over to the sand filter. The improvement proposed is a provision of an in-line static mixer in the raw water main to achieve the proper magnitude of mixing of coagulant.

(2) Flocculation System

Flocculation is a process which most existing plants lack. The recommended flocculation process consists of round-the-end, and flow-type baffled channels (hydraulic flocculation). Mechanical flocculation is not considered because of the unavailability of spare parts and technical manpower to maintain the system.

(3) Filtration Process

Filters require a wide range of modification. Existing underdrains,

gravel beds, filter beds, wash troughs, backwash system and piping are subject for replacement and improvement/modification. For installation is a surface wash system. These modifications may lead to increasing system's treatment capacities by 100%. Dual media filtration is not considered because of the high cost of anthracite.

(4) Sedimentation process

Recognized as the most serious problem in operation is sludge removal. However, sludge withdrawal will be made efficiently by manual cleaning. Therefore, no major modification is considered. Baffled walls are recommended to be installed at the inlet and the intermediate point to prevent short circuit of flow. For overflow troughs, the installation of additional troughs is recommended to decrease weir load and decrease carry- over of micro floc.

As the recommendations stated above are the basis of improvement/expansion work, a similar design for the modification works for the existing water treatment plant may be used.

Stage 2, Expansion of plant capacity will follow the modification works. After modification works are made, the plant will be expected to have a larger treatment capacity (twice the original design rate); therefore, the production amount can be increased to cope with the increased water demand.

Stage 3, Modernization consists of the preparation of proper instrumentation and safety provisions. This stage is recognized as the final step of modification; therefore actual implementation will only be made after steps 1 and 2 are accomplished. This is because of some budgetary constraints for the total implementation of the improvement/expansion program.

3.4 Existing Constraints

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

(1) Water Source

- Flow is insufficient in the dry season.
- Got muddy by paddy field upstream.

(2) Intake and Transmission Pipe

- The weir is insufficient in height.
- The transmission pipe is insufficient in diameter.
- Amount of inflow to the mining pit is uncertain.

(3) Treatment

- Amount of chemical dozing is inadequate in the dry season.
- Flocculation is inadequate.
- The weir of flocculation basins is insufficient in length.
- A chemical solving tank is located in an inconvenient place.

(4) Distribution

- The elevated tank is not being used due to operational defects.

(5) Operation and Maintenance

- Consumers have complaints of color, turbidity and odor in water.

3.5 Organization

3.5.1 Organization of Regional Office

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

The Phang Nga Waterworks is supervised by the Regional Office IV in Surat Thani which covers 13 waterworks in this region. Figure 3-5-1 shows the organization chart of the Regional Office IV. The function of each section is described as follows:

(a) Personnel and Clerical Section

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

(b) Finance and Accounting Section

This section is in charge of finance and accounts of the waterworks including borrowing and depositing of bank accounts.

(c) Procurement and Stores Section

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

(d) Maintenance Section

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

(e) Technical Service Section

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

(f) Water Quality Control Section

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

(g) Survey Section

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

(h) Price Estimation Section

This is responsible for estimating the expansion/ rehabilitation cost of water supply systems for both urban and rural waterworks and for preparing documents, drawings and others for bidding.
Figure 3-5-1

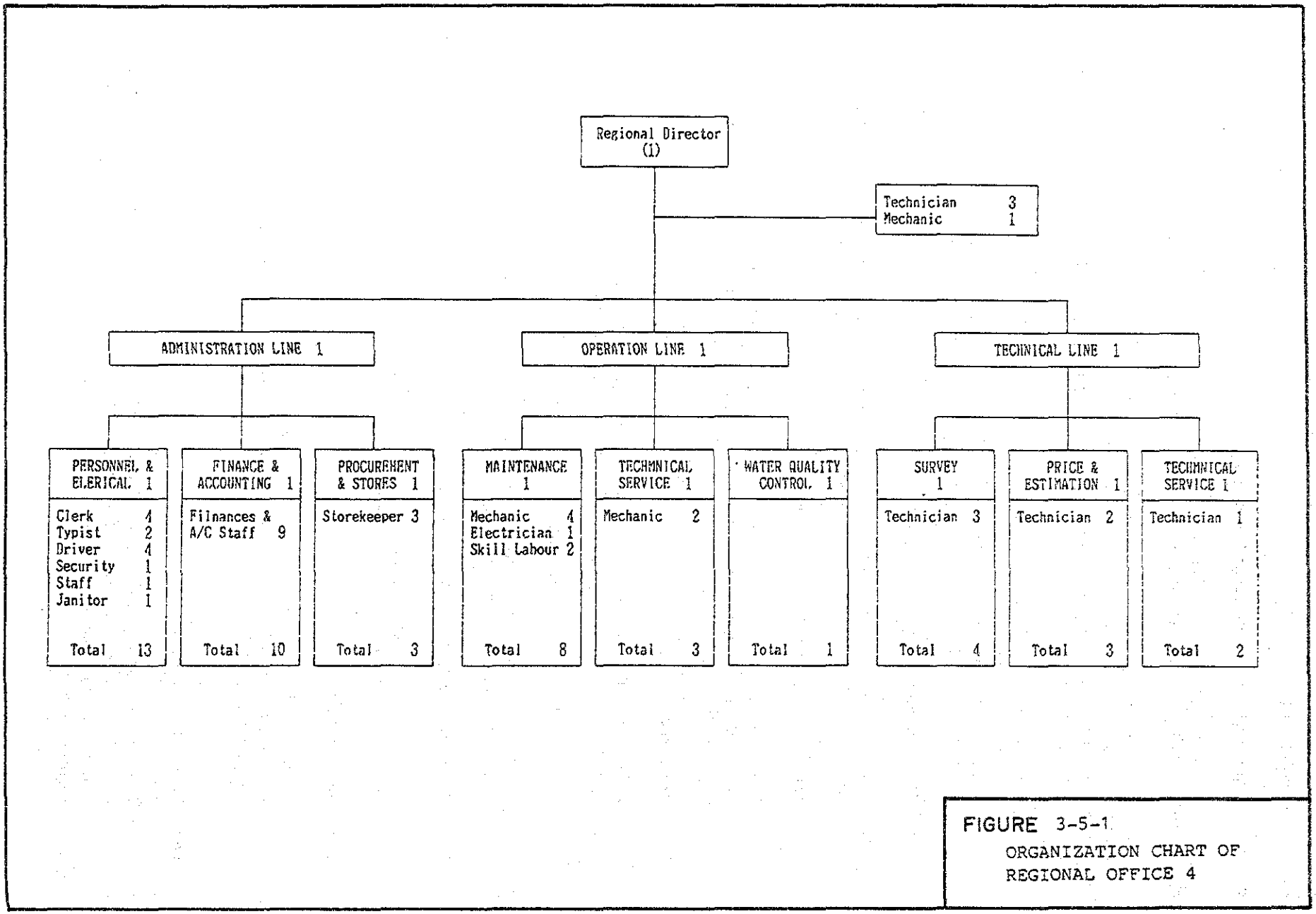


FIGURE 3-5-1
ORGANIZATION CHART OF REGIONAL OFFICE 4

(i) Construction Supervision Section

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

3.5.2 Organization of Waterworks

The organization of the Phang Nga Waterworks consists of three sections; namely, production, services, and administration sections. The organization chart with the number of employees is shown in Figure 3-5-2, and the function of each section is described as follows:

(a) Water Production Section

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

(b) Service Section

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

(c) Administration Section

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

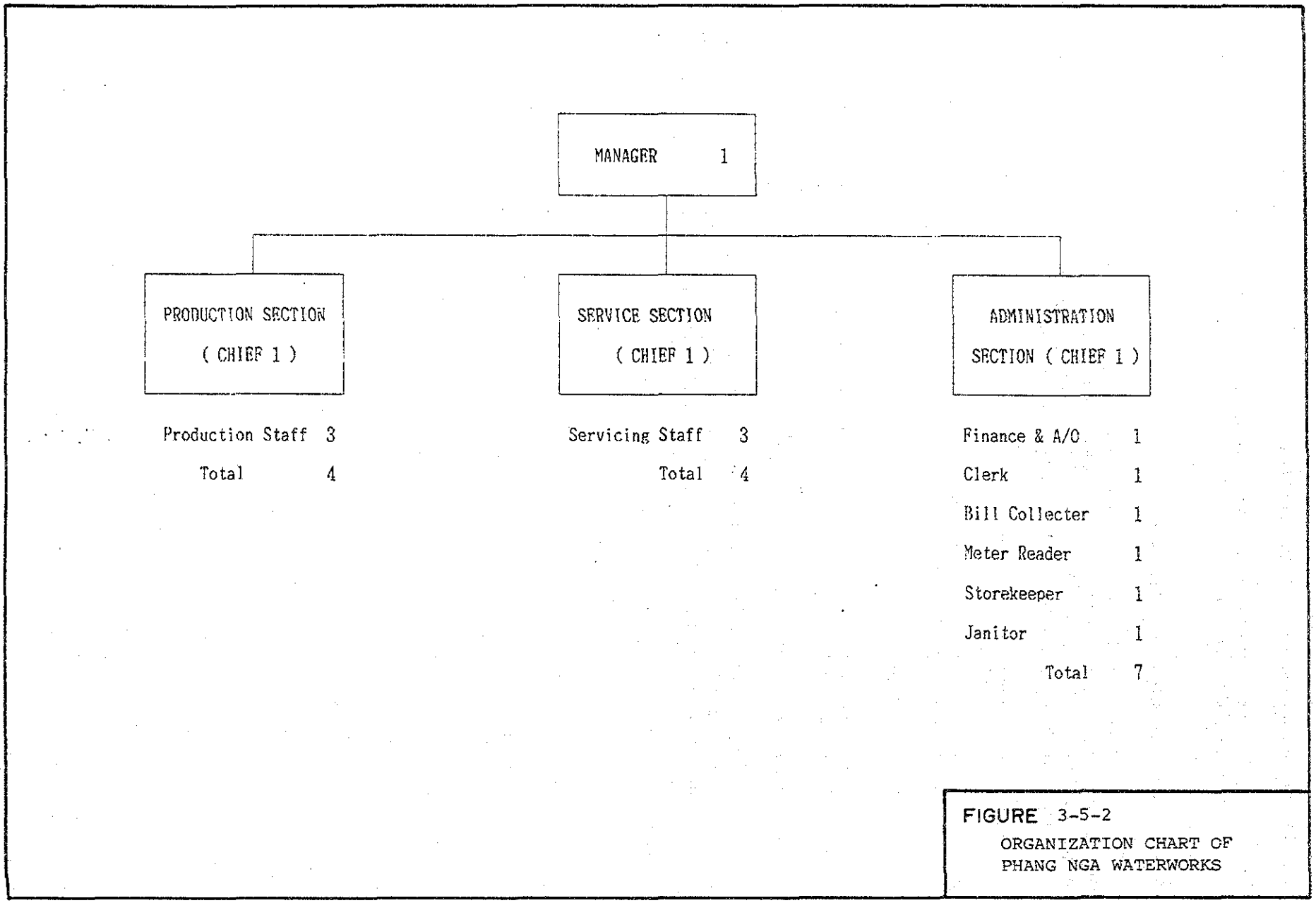


FIGURE 3-5-2
ORGANIZATION CHART OF
PHANG NGA WATERWORKS

3.6 Financial Status

3.6.1 Present System

As of 1987, the Phang Nga Waterworks has 1,041 connections. The annual water production and sales in 1987 were 442,340 cu.m and 267,121 cu.m, respectively.

PWA has three major sources of tariff revenue: namely water sales, service charges and connection fees. These tariffs' contribution to the total revenue of PWA was about 95%. The waterworks has about the same income structure as this. PWA applies same water rate structure to all waterworks.

Details of current levels of tariffs are set out in Tables 3-6-1 to 3-6-3.

Table 3-6-1 Present Water Sales Charges

Consumption (cu.m/mo)	Tariff (฿/cu.m)
0 - 10	3.75
11 - 20	4.50
21 - 30	6.50
31 - 50	7.50
51 - 80	8.00
81 - 100	8.50
101 - 300	9.00
301 - 1,000	9.25
1,100 - 2,000	9.50
2,001 - 3,000	9.75
3,001 and above	10.00

Table 3-6-2 Present Service Charge

(Unit : ฿/mo)

Size of Conn.	Service Charge
1/2"	10
3/4"	15
1"	30
1-1/2"	60
2"	100
2-1/2"	120
3"	160
4" and above	200

Table 3-6-3 Present Connection Charge

Size of Conn.	Basic Connection Fee (฿/Conn.)
1/2"	2,050
3/4"	2,750
1"	3,750
1-1/2"	6,690
2"	9,575
2-1/2"	13,075
3"	15,495
4"	21,455
6"	30,025

Note : The basic connection fee is applied to the connection with an installation length of less than 10 m from a main pipe.

3.6.2 Revenue and Expenditure

The annual revenues and expenditures of the waterworks in the last three years are shown below:

Table 3-6-4 Revenue and Expenditure

(Unit : 1,000 ฿)

Year	Revenue	Expenditure	Profit(Loss)
1985	8,306	3,582	4,724
1986	2,207	1,864	343
1987	2,097	1,899	198

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

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

Table 3-6-5 Ratio of Revenue to Expenditure

Office	1985	1986	1987
PWA Head Office	1.45	1.72	1.76
Phang Nga Waterworks	1.11	1.18	1.10

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

As shown above, the waterworks earned a net profit on its annual operations. The ratio is greater than 1.0, but lower than the average rate for all PWA waterworks.

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

Table 3-6-6 Revenue and Expenditure of Phang Nga Waterworks

(Unit : Baht)

Description	1985	1986	1987
Water Production cu.m	389,670	421,970	442,340
Water Sales cu.m	314,959	287,428	267,121
No. of Connections	979	1,019	1,041
Revenue			
Water Sales	1,631,057.48	1,890,504.60	1,802,075.40
Service Charge	144,595.00	150,262.00	153,130.00
Connection Fee	166,624.00	145,937.00	124,936.00
Other Revenue	28,433.22	20,521.44	17,213.21
Total Revenue (A)	1,970,709.70	2,207,225.04	2,097,354.61
Expenditure			
Salaries	1,016,240.00	1,035,766.42	1,135,580.00
Remuneration	230,799.59	225,901.86	233,275.15
Chemical	100,112.85	82,202.00	96,973.60
Material & Maintenance	43,864.04	87,217.20	71,594.09
Oil & Fuel	32,182.90	29,638.00	20,607.76
Office Supplies	8,856.56	7,098.01	9,863.09
Hired Service	1,680.00	59,549.00	42,234.50
Other Operating Expense	4,564.00	29,132.00	31,782.50
Public Utilities	2,243.75	21,547.50	7,449.00
Electricity	256,927.19	224,193.40	207,042.20
Connection Cost	65,207.54	61,334.77	40,648.93
Material Sold	9,239.99	497.48	2,080.00
Total Expenditure (B)	1,771,918.41	1,864,077.64	1,899,130.82
Profit (Loss)	198,791.29	343,147.40	198,223.79

4 POPULATION AND WATER DEMAND

4.1 Project Horizon

The study area consists of the Phang Nga Municipality, Tambon Tam Nam Pud, the area around the stadium on the north of the Tambon and Phang Nga Bay Resort Area.

The study area has been delineated considering the following conditions:

(1) Urbanization of the Municipality is expanding beyond the boundary to the surrounding tambons. At present the urban expansion is along the Route 4; however in future expansion to other directions such as toward the east side of the Phang Nga River in the tambon is expected.

(2) The urbanization will be limited by the mountains on the east and west sides of the tambon. However urban development of the neighboring communities on the north of the tambon should be studied together, which PWA is currently considering to supply water.

(3) At present the Phang Nga Bay Resort Area is supplied water by PWA while the study is needed to meet the future development of the area.

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

The combined area of the Municipality and Tambon Tam Nam Pud, which shares most of the study area, coincides the town planning area of DTCP, of which area measures as in Table 4-1-1.

Table 4-1-1 Area of Main Study Area

(Unit : sq.km (%))

DTCP town planning area	17.26 (100.0)
Municipality	6.75 (39.1)
Outside Municipality (Tambon Tam Nam Pud)	10.51 (60.9)

Source : DTCP
Note : The main study area consists of the Phang Nga Municipality and Tambon Tam Nam Pud excluding the stadium area and the Phang Nga Bay Resort Area.

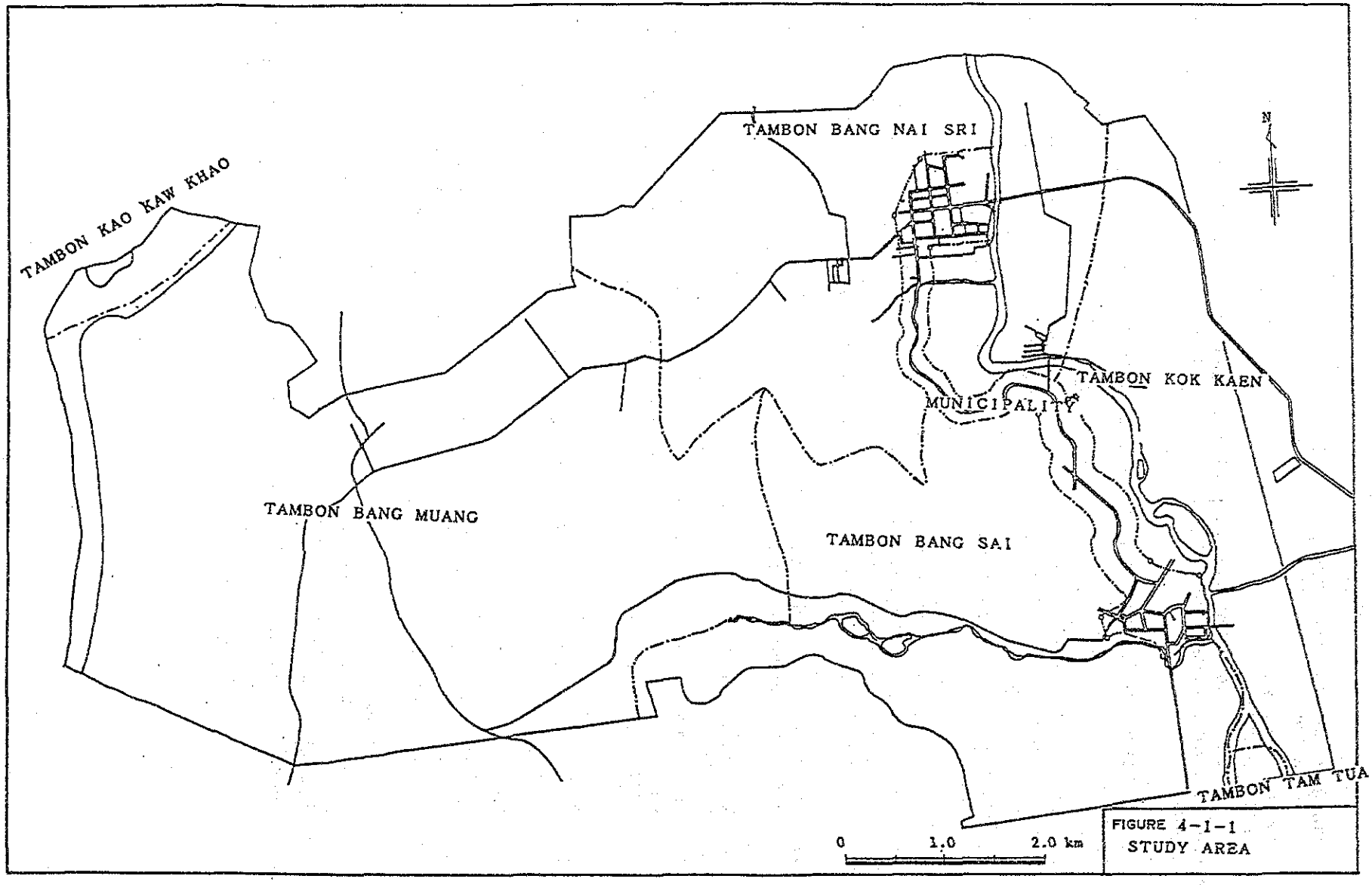


FIGURE 4-1-1
STUDY AREA

4.2 Population

4.2.1 Historical Population

The population of the main study area was 10,740 as shown in Table 4-2-1.

Population trend of the Municipality in 1980's is characterized by rapid growth in the first half of the decade and decline in the following years. The decline is caused by the net out-migration, which exceeds the high natural increase. One of the causes of the out-migration is thought to be the recent sluggish situation of the local economy reflecting the tin industry. Development in the neighboring areas may be absorbing the population of the Municipality as well.

Population of Tambon Tam Nam Pud increased steadily at an average growth rate of 3.2% in recent years.

4.2.2 Future Population

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

A) Arithmetical progression $y = aX + b$

B) Geometrical progression $y = y0 \times (1 + b)^X$

C) Decreasing rate of increase $y = K - ab^X$

D) Exponential $y = y0 + aX^b$

E) Logistic $y = k / (1 + \exp(a - bX))$

Where,

y : Population forecasted

y0 : Population in the base year

X : Years from the base year

a, b, K : Coefficient

Aside from these mathematical models, the annual growth rate was also considered from the socioeconomic conditions of the area. Therefore, mathematical models are used only for comparison.

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

(1) In the Municipality, the natural growth rate will decrease steadily from the present level of 6.5% to 1.5% in 1997 and will remain at the level. The natural increase rate of 1.5% is the national target for 1986, while the rate in the southern region has been higher than the national average.

The net out-migration will decrease steadily from the present level of 8.4% to 0% in 1995 and then the net in-migration of 0.3% will be

maintained, assuming that the economy will be revitalized, of which tourism development is one of the examples.

(2) In Tambon Tam Nam Pud, the growth trend in recent years (approximately 3%) is expected to continue.

(3) Population of the stadium area and the resort area with approximately 40 houses is marginal and is dealt with separately.

The total population of the Municipality and the tambon is estimated at 16,500 in 2011 as shown in Table 4-2-1.

Figures 4-2-1 and 4-2-2 shows the population projection of the Phang Nga Municipality and Tambon Tam Nam Pud for reference. In these figures, legends "A" to "E" correspond to the formulae mentioned above and legend "T" shows the values adopted.

Presently the average family size is approximately 5.06. According to the HOMES Research Report prepared in 1987 for the Seminar on Demographic and Economic Forecast for Thailand, the average household size of the nation in 2011 will be approximately 71% of the 1987 level. Following the general decreasing trend, the figure of the area in 2011 is estimated at 3.61 and the number of families at 4,600 as in Table 4-2-2.

The average population per house is less than the family size. The number of houses in 2011 is estimated at 5,700.

4.2.3 Higher and Lower Growth Cases

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

In the higher growth case, the Municipality's natural growth rate will decrease steadily from the present level of 6.5% to 1.5% in 2007, 10 years after the original case and will remain at the level. The net out-migration will decrease steadily from the present level of 8.4% to 0.5% in 1993 and then the net in-migration of 0.3% will be maintained. The population growth rate of Tambon Tam Nam Pud is assumed to be 4%, that is 1% higher than the original case.

In the lower growth case, the Municipality's natural growth rate will decrease steadily from the present level of 6.5% to 1.5% in 1994, 3 years before the original case and will remain at the level. The net out-migration will decrease steadily from the present level of 8.4% to 0.5% in 1997 and then the net in-migration of 0.3% will be maintained. The population growth rate of Tambon Tam Nam Pud is assumed to be 2%, that is 1% lower than the original case.

Table 4-2-1 Population Projection of Main Study Area of Phang Nga

Year	1980	1981	1982	1983	1984	1985	1986	1987	1991	1996	2001	2006	2011
Population of Phang Nga Municipality													
Population	7,640	7,807	7,939	8,592	8,791	8,908	8,886	8,714	8,624	9,453	10,334	11,709	12,353
Natural Increase (%)		5.393	6.955	7.066	6.716	6.234	7.140	6.471	4.5	2	1.5	1.5	1.5
Social Increase (%)		-3.207	-5.265	1.159	-4.399	-4.903	-7.387	-8.406	-4	0.3	0.3	0.3	0.3
Growth Rate (%)		2.186	1.691	8.225	2.316	1.331	-0.247	-1.936	0.5	2.3	1.8	1.8	1.8
Population of Tambon Tam Nam Pud				1,789	1,826	1,883	1,891	2,026	2,280	2,642	3,063	3,550	4,116
Total Population of Phang Nga Municipality and Tambon Tam Nam Pud				10,381	10,617	10,791	10,777	10,740	10,904	12,095	13,397	15,259	16,469

Estimation of Population Distribution by Land Use Plan Zone

Zone		Area (sq.km)					
Zone 1	Low Density Residential Zone	3.14	3,965	4,340	4,750	5,351	5,717
Zone 2	Medium Density Residential Zone	1.23	4,722	5,284	5,911	6,808	7,435
Zone 3	High Density Resi./Commercial Zone	0.22	2,050	2,190	2,338	2,570	2,680
Zone 4	Industrial Zone	0	0	0	0	0	0
Zone 5	Rural/Agricultural Zone	9.19	90	204	320	449	557
Zone 6	Recreation Zone	2.81	0	0	0	0	0
Zone 7	Education Zone	0.10	11	11	11	12	12
Zone 8	Religious Zone	0.17	19	19	19	20	19
Zone 9	Government Office/Public Utilities	0.40	47	47	48	49	49
Total		17.26	10,904	12,095	13,397	15,259	16,469

Source : "Annual Statistics of Residents Registration" DTCP

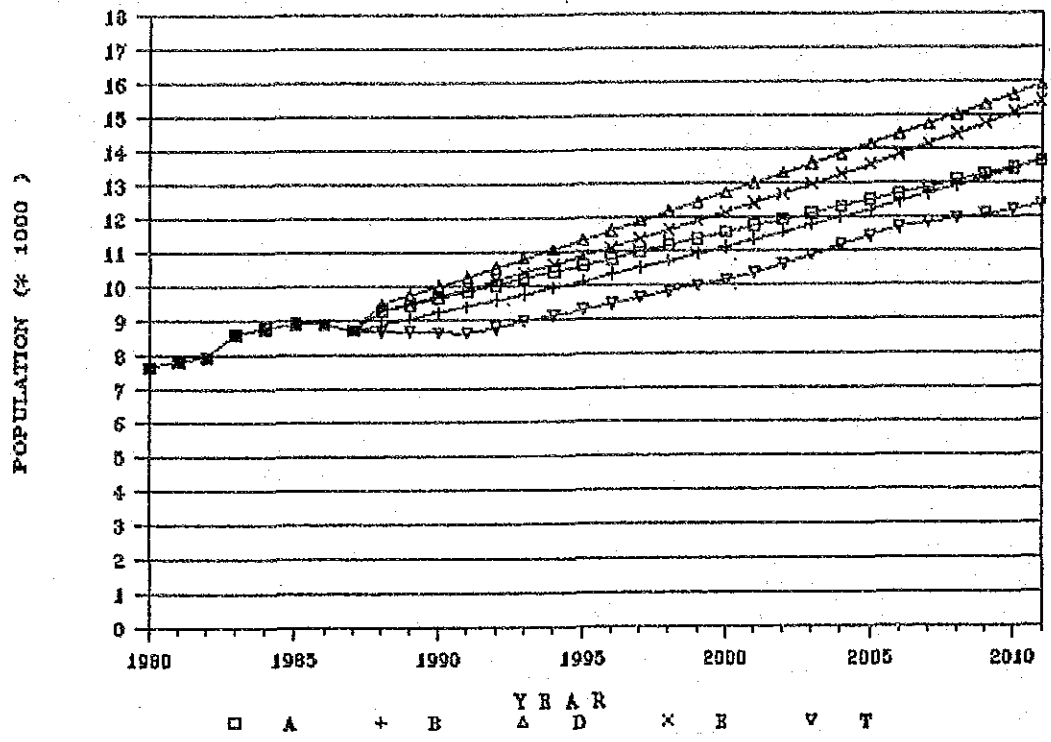


FIGURE 4-2-1
POPULATION PROJECTION OF PHANG NGA MUNICIPALITY

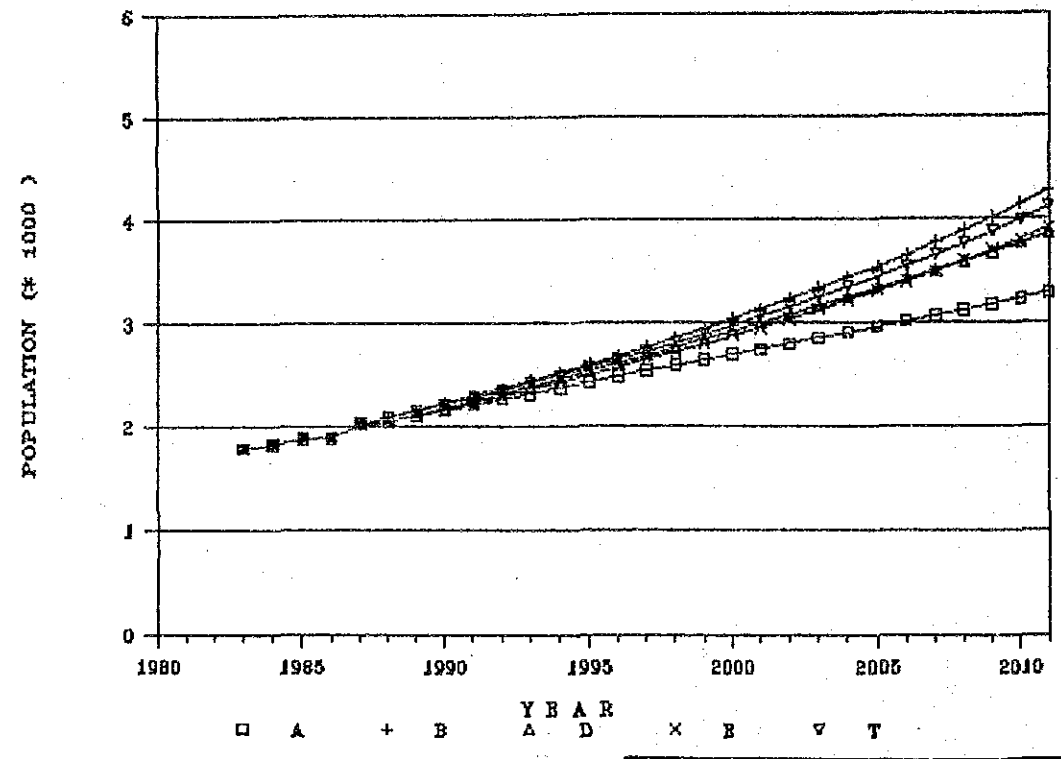


FIGURE 4-2-2
POPULATION PROJECTION OF TAMBON TAM NAM PUD

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

Phang Nga Municipality

Year	1980	1981	1982	1983	1984	1985	1986	1987
Population	7,640	7,807	7,939	8,592	8,791	8,908	8,886	8,714
No. of Houses	1,305	1,414	1,458	2,010	2,055	2,122	2,152	2,201
House Size	5.854	5.521	5.445	4.275	4.278	4.198	4.129	3.959

Nation (Homes Research Report, November 1987)

Year	1985	1990	1995	2000	2005	2010	2015
Household Size	4.98	4.62	4.27	3.96	3.70	3.49	3.31
Year	1987	1991	1996	2001	2006	2011	
Household Size	4.836	4.550	4.208	3.908	3.658	3.454	
Index	1	0.941	0.870	0.808	0.756	0.714	

Phang Nga

Year	1987	1991	1996	2001	2006	2011
Population	10,740	11,187	12,035	13,397	15,259	16,469
Family Size	5.056	4.757	4.399	4.085	3.824	3.611
No. of Families	2,124	2,351	2,749	3,279	3,990	4,560
House Size	4.080	3.839	3.550	3.297	3.086	2.914
No. of Houses	2,632	2,914	3,406	4,063	4,944	5,651

Table 4-2-3 Population of Main Study Area of Phang Nga

Year	1987	1991	1996	2001	2006	2011
Original Case						
Municipality	8,714	8,624	9,453	10,334	11,709	12,353
Tambon Tam Nam Pud	2,026	2,280	2,643	3,063	3,550	4,115
Total	10,740	10,904	12,096	13,397	15,259	16,468
Higher Growth Case						
Municipality	8,714	9,064	11,283	13,594	15,415	16,850
Tambon Tam Nam Pud	2,026	2,369	2,879	3,500	4,256	5,177
Total	10,740	11,433	14,162	17,094	19,671	22,027
Lower Grouwth Case						
Municipality	8,714	8,202	7,835	8,492	9,282	10,147
Tambon Tam Nam Pud	2,026	2,191	2,416	2,666	2,941	3,244
Total	10,740	10,393	10,251	11,158	12,223	13,391

In the higher growth case, the population of the area is 34% more than the original case, while in the lower growth case, it is 19% less.

4.2.4 Population Distribution

At present, population is relatively densely distributed around the market in the northern zone of the Municipality. The southern half of the Municipality and outside the Municipality have less density.

Future population is thought to be distributed reflecting the land use plan of DTCP covering the eastern side of the Phang Nga River.

Population distribution by the land use category expected in 2011 is shown in Table 4-2-1.

The population density of the town planning area is estimated to grow from the present level of 6.2 persons/ha (1.0 person/rai) to 9.5 persons/ha (1.5 persons/rai) in 2001.

Residential zones will considerably increase the population density. The density of the low density residential zones designated by the land use plan is estimated at approximately 18 persons/ha (3 persons/rai) in 2011, that of the medium density residential zones at approximately 61 persons/ha (10 persons/rai), and that of the high density residential/commercial zones at approximately 120 persons/ha (19 persons/rai). The population density of the rural/agricultural zones will remain very low.