社会開発調査部報告書

No. 52

PUBLIC WORKS DEPARTMENT
MINISTRY OF INTERIOR

FEASIBILITY STUDY
ON
SEWERAGE AND DRAINAGE IMPROVEMENT PROJECT
FOR
PHUKET MUNICIPALITY
IN
THE KINGDOM OF THAILAND

FEASIBILITY STUDY REPORT

AUGUST 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

PUBLIC WORKS DEPARTMENT MINISTRY OF INTERIOR FEASIBILITY STUDY ON SEWERAGE AND DRAINAGE IMPROVEMENT PROJECT
FOR PHUKET MUNICIPALITY IN THE KINGDOM OF THAILAND FEASIBILITY STUDY REPORT

No.

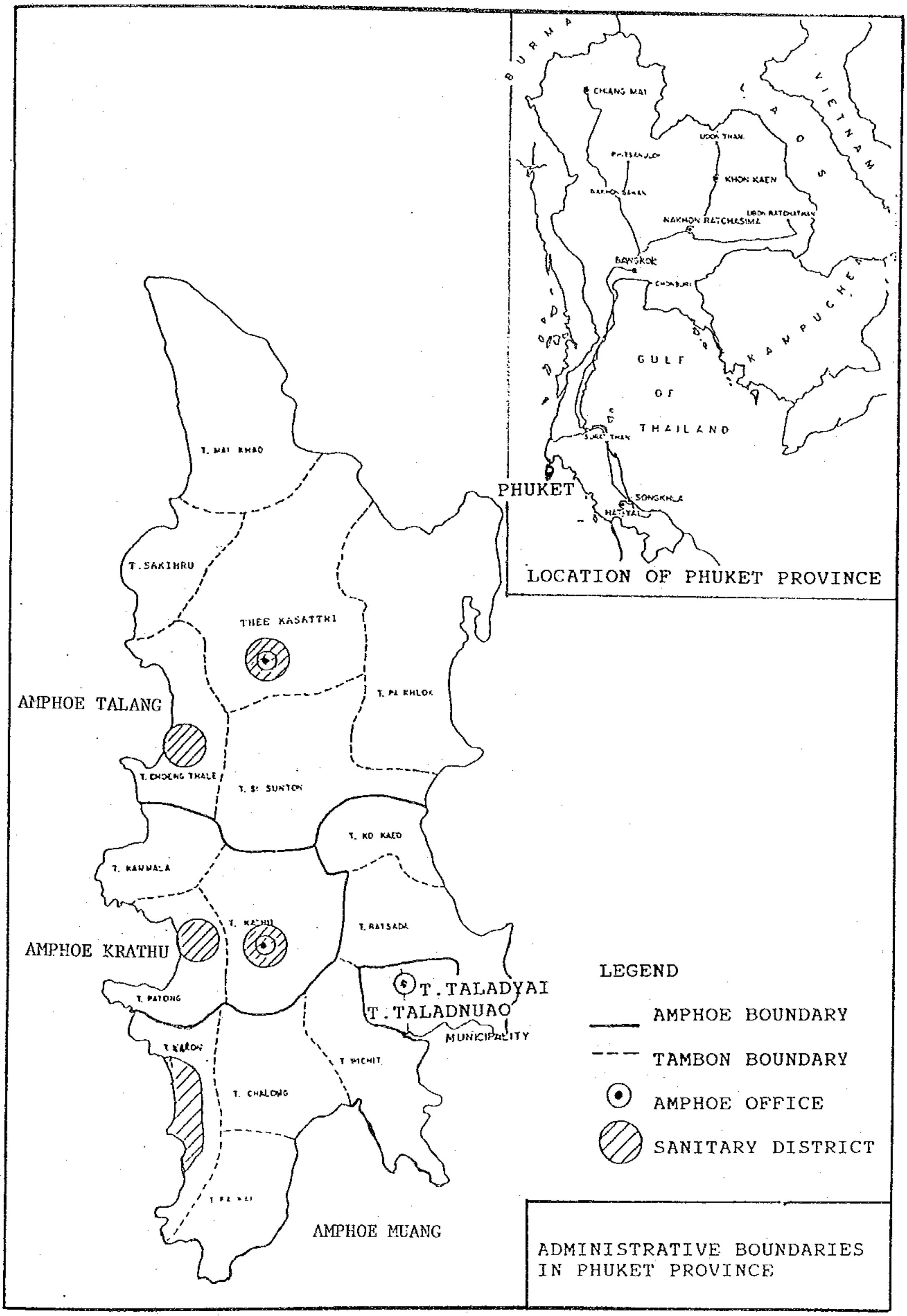
PUBLIC WORKS DEPARTMENT
MINISTRY OF INTERIOR

FEASIBILITY STUDY ON SEWERAGE AND DRAINAGE IMPROVEMENT PROJECT FOR PHUKET MUNICIPALITY IN THE KINGDOM OF THAILAND

FEASIBILITY STUDY REPORT

AUGUST 1990

JAPAN INTERNATIONAL COOPERATION AGENCY



ADMINISTRATIVE BOUNDARIES IN PHUKET PROVINCE

ABBREVIATIONS

The following abbreviations have been adopted in this report.

Thai Government Organizations :

AIT	-	Asian Institute of Technology
BOS or BS	-	Bureau of Sanitation, BMA
BMA	-	Bangkok Metropolitan Administration
CPD	-	City Planning Division, Office of Under Secretary of State for BMA
DPH	-	Department of Public Health
DOH	-	Department of Highways
DOI	-	Department of Industry, Ministry of industry
DOLA	-	Department of Local Administration
DOR	-	Department of Religion
DTCP	-	Department of Town and Country Plannning
DTEC	-	Department of Technical and Economic Cooperation
EGAT	-	Electricity Generating Authority Thailand
FRS	-	Foreign Relations Section, Office of Under Secretary of State for BMA
HWD	-	Highway Department, Ministry of Communication
IEAT	-	Industrial Eastate Authority of Thailand
LD	-	Land Department
LTD	-	Land Transport Department
MD	-	Meteorological Department
MOA	-	Ministry of Agriculture
MOI	-	Ministry of Interior
NEB	-	Office of the Nation Environment Board
NESDB	-	National Economic and Social Development Board
NHA	-	National Housing Authority
NICA	-	National Institute of Coastal Aquaculture
NSO	-	National Statistical Office
OPP	-	Office of Policy and Planning
OUD	-	Office for Urban Development
PAT	-	Port Authority of thailand
PEA	-	Provincial Electricity Authority
PSU	-	Prince Songkhla University
PWA	-	Provincial Waterworks Authority
PWD	-	Public Works Department
RCDP	-	Regional Cities Development Project
RID	-	Royal Irrigation Department
RTG	-	Royal Thai Government
RTSD	-	Royal Thai Survey Department
TAT	-	Tourist Authority Of Thailand
TISTR	-	Thailand Istitute of Scientific and Technological Research
TOCD	-	Techcical Office for Cities Development

Other Organizations :

ADB	-	Asian Development Bank
AIDAB	-	Australian International Development Assistance Bureau
IBRD	-	International Bank for Reconstruction and Development
JICA	-	Japanese International Cooperative Agency
UNDP	-	United Nations Development Programme
WB	-	World Bank

Technical Term :

A/C	-	Asphaltic Concrete
BCR	-	Benefit/Cost Ratio
B.E.	-	Buddhist Era
BOD, BOD5	-	Biochemical Oxygen Demand
DF/R	-	Draft Final Report
CI	-	Castiron, grey
CIF	-	Cost Insurance and Freight
CL	-	Chloride Ion
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
DS	-	Dissolved Solids
DWF	-	Dry Weather Flow
EIRR	-	Economic Internal Rate of Return
FIRR	-	Financial Internal Rate of Return
F/R	-	Final Report
F/S	-	Feasibility Study
FY	-	Fiscal Year
GPP	-	Gross Provincial Product
H2S	-	Hydrogen Sulfide
IC/R	-	Inception Report
IT/R	-	Interim Report
JSWA	-	Japan Sewage Works Agency
IRR	-	Internal Rate of Return
Klong	-	Canal (Thai word)
M/P	-	Master Plan
MPN	-	Most Probable Number
msl, MSL	-	Mean sea Level
NPV	-	Net Present Value
O & M	-	Operating and Maintenance Costs
p.a.	-	Per Annum
pH	-	pH Value
PVC	-	Polyvinyl Choride Pipe
SS	-	Suspended Solids
SW	-	Solid Waste
TOR	-	Terms of Refernce
TS	-	Total Solids
WS	-	Water Supply
WT	-	Water Temperature
WW	-	Wastewater

Units of Measurement :

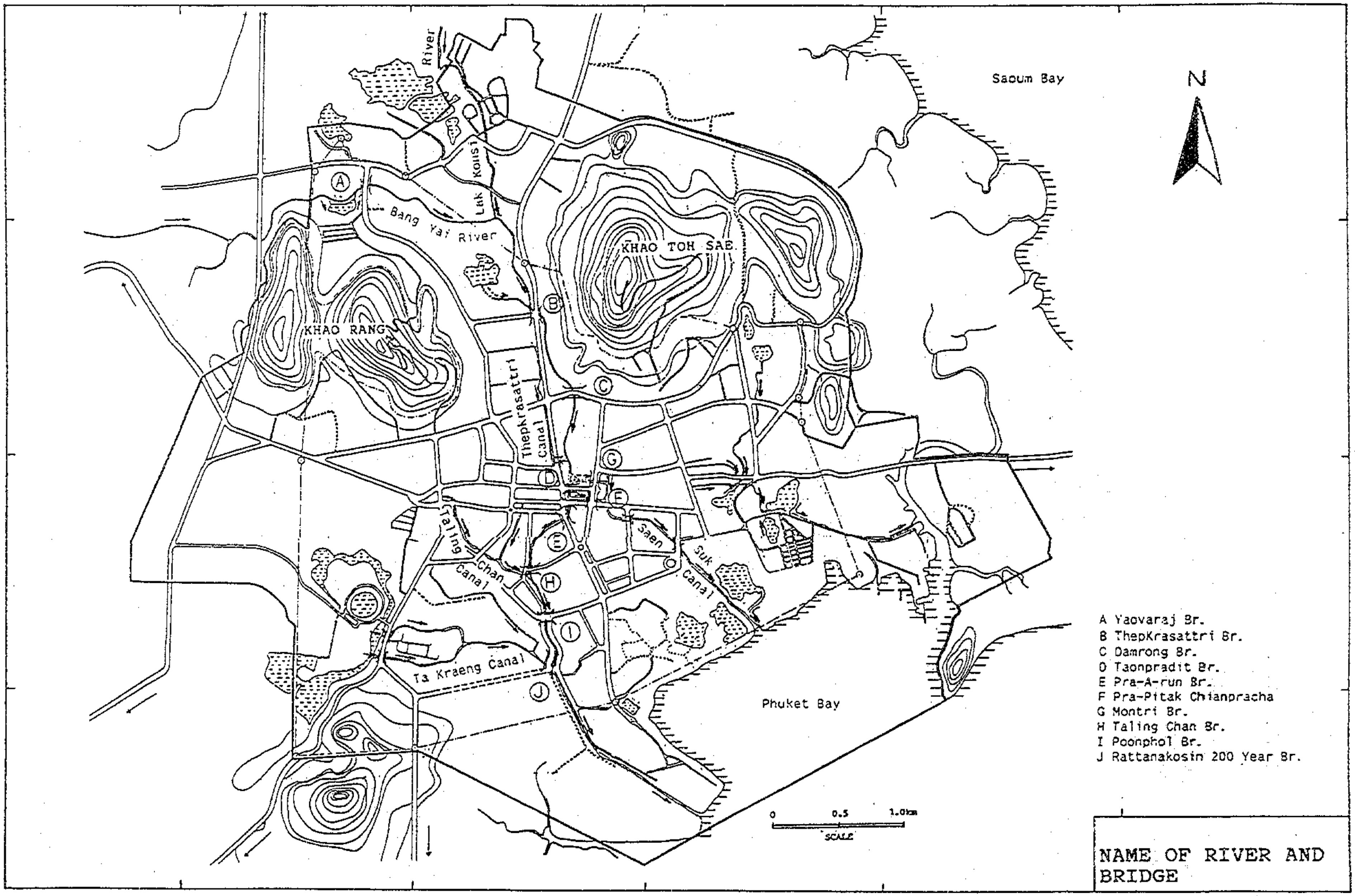
฿, B	-	baht	-	Thai Currency
M฿, MB	-	million baht	-	Thai Currency
°C	-	degree Celsius	-	Temperature Unit
cfs,ft3/s	-	cubic foot per second	-	Flow Rate Unit
d	-	day	-	Time Unit
cm	-	centimeter	-	Length Unit
cms,m3/s	-	cubic meter per second	-	Flow Rate
ft	-	foot	-	Length Unit
gal	-	U S gallon	-	Volume Unit
g, gm	-	gram	-	Weight or Mass Unit
gpcd	-	gram per capita per day	-	Loading Consumption Rate
gpm	-	U S gallon per minute	-	Flow Rate
ha	-	hectare	-	Area Unit
h, hr	-	hour	-	Time Unit
HP	-	horse power	-	Power Unit
Hz	-	hertz (cycle per second)	-	Frequency Unit
kg	-	kilogram	-	Weight Unit
km	-	kilometer	-	Length Unit
kV	-	kilovolt	-	Electric Potential Unit
kW	-	kilowatt	-	Power Unit
kWh	-	kilowatt-hour	-	Energy Unit
l	-	liter	-	Volume Unit
lb	-	pound	-	Weight or Mass Unit
lpcd	-	liter per capita per day	-	Water Consumption Rate
m	-	meter	-	Length Unit
mm	-	millimeter	-	Length Unit
m/sec	-	meter per second	-	Velocity Unit
m2	-	square meter	-	Area Unit
m3	-	cubic meter	-	Volume Unit
m3/s, cms	-	cubic meter per second	-	Flow Rate
m3/day	-	cubic meter per day	-	Flow Rate
m3/min	-	cubic meter per minute	-	Flow Rate
m3/day/m2	-	cubic meter per day per square meter	-	Surface Loading
m3/m2/day	-	cubic meter per square meter per day	-	Surface Loading
mg	-	milligram	-	Weight or Mass Unit
mg/l	-	milligram per liter	-	Density Unit
ppt	-	part per thousand	-	Density Unit
Rai, rai	-	rai	-	Thai Unit Measurement of Area
rpm	-	revolution per minute	-	Angular Velocity
s,sec	-	second	-	Time Unit
sq km	-	square kilometer	-	Unit Measuerment of Area
yr	-	year	-	Time Unit

Conversion Table :

1 acre	=	2.53	rai
1 cfs	=	0.0283	cms
1 cms	=	35.31	cfs
1 ft	=	0.3048	m
1 ft2	=	0.0929	m2
1 ft3	=	0.0283	m3
1 hectare	=	6.25	rai
1 inch	=	2.54	cm
1 inch	=	25.4	mm
1 kg	=	2.205	pounds
1 km	=	0.6214	miles
1 km2	=	100	hectares
1 m	=	3.28	ft
1 m2	=	10.7584	ft2
1 m3	=	35.31	ft3
1 mile	=	1.6093	km
1 ngan	=	400	m2
1 rai	=	1600	m2
1 tarangwa	=	4	m2
1 ton	=	1000	kg
1 wa	=	2	m

Currency Conversion:

1 Baht	=	5.7 Yen
1 U.S. Dollar	=	143 Yen
1 Yen	=	0.175 Baht


N
Saoum Bay
River
Lak Kousi
Bang Yai River
KHAO TOH SAE
KHAO RANG
Thepkrasattri Canal
Taling Chan Canal
Saen Suk Canal
Ta Kraeng Canal
Phuket Bay
A Yaovaraj Br.
B ThepKrasattri Br.
C Damrong Br.
D Taonpradit Br.
E Pra-A-run Br.
F Pra-Pitak Chianpracha
G Montri Br.
H Taling Chan Br.
I Poonphol Br.
J Rattanakosin 200 Year Br.
0 0.5 1.0km
SCALE
NAME OF RIVER AND BRIDGE

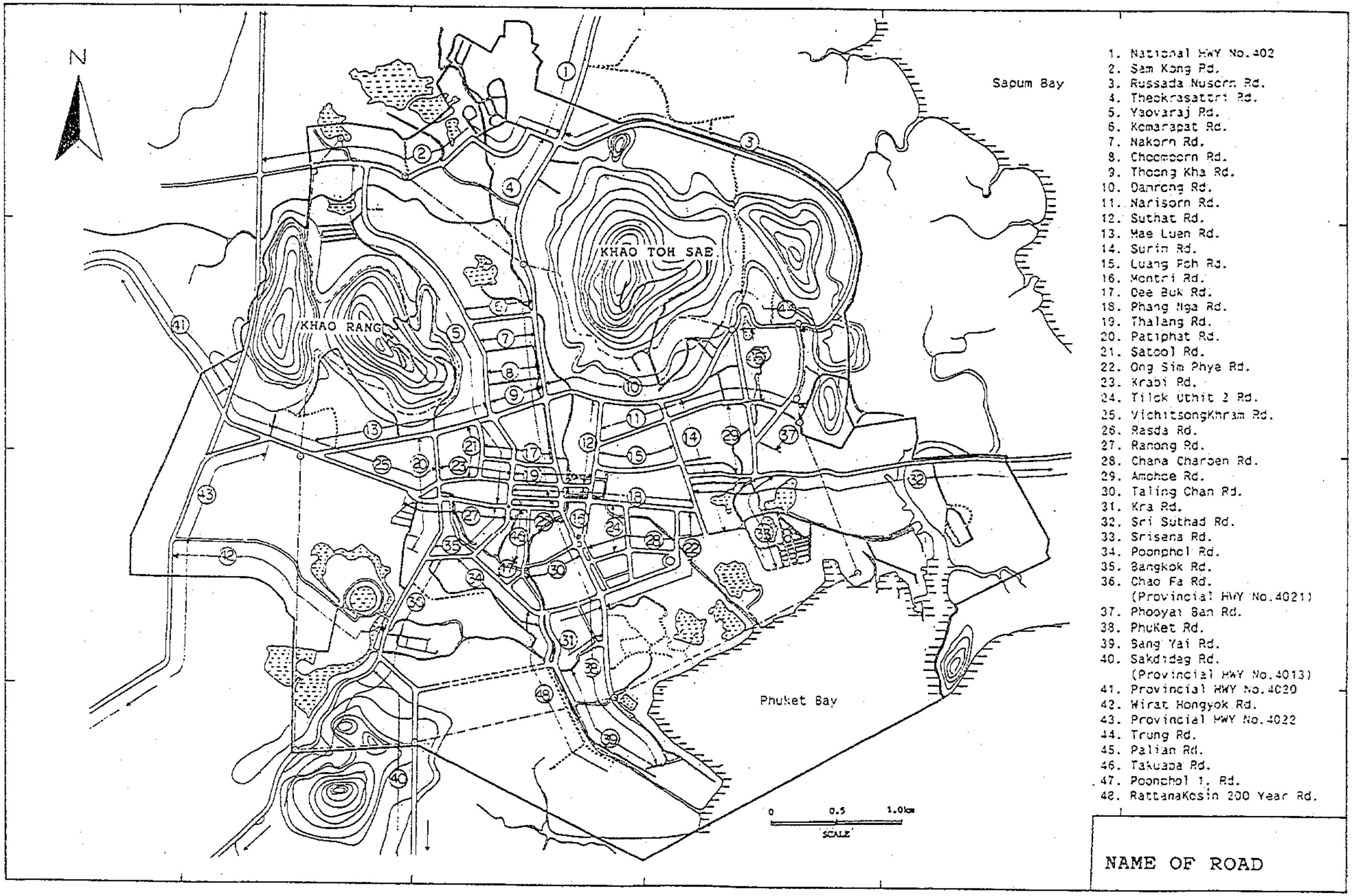

N
Sapum Bay
KHAO TOH SAE
KHAO RANG
Phuket Bay
0 0.5 1.0km
SCALE
1. National HWY No.402
2. Sam Kong Rd.
3. Russada Nusorn Rd.
4. Theokrasattri Rd.
5. Yaovaraj Rd.
6. Komarapat Rd.
7. Nakorn Rd.
8. Choomoorn Rd.
9. Thoong Kha Rd.
10. Damrong Rd.
11. Narisorn Rd.
12. Suthat Rd.
13. Mae Luen Rd.
14. Surin Rd.
15. Luang Poh Rd.
16. Montri Rd.
17. Dee Buk Rd.
18. Phang Nga Rd.
19. Thalang Rd.
20. Patiphat Rd.
21. Satool Rd.
22. Ong Sim Phye Rd.
23. Krabi Rd.
24. Tilok Uthit 2 Rd.
25. VichitsongKhram Rd.
26. Rasda Rd.
27. Ranong Rd.
28. Chana Charoen Rd.
29. Amphoe Rd.
30. Taling Chan Rd.
31. Kra Rd.
32. Sri Suthad Rd.
33. Srisena Rd.
34. Poonphol Rd.
35. Bangkok Rd.
36. Chao Fa Rd. (Provincial HWY No.4021)
37. Phooyai Ban Rd.
38. Phuket Rd.
39. Sang Yai Rd.
40. Sakdideg Rd. (Provincial HWY No.4013)
41. Provincial HWY No.4020
42. Wirat Hongyok Rd.
43. Provincial HWY No.4022
44. Trung Rd.
45. Palian Rd.
46. Takuapa Rd.
47. Poonchol 1. Rd.
48. RattanaKosin 200 Year Rd.
NAME OF ROAD

TABLE OF CONTENTS
FOR
FEASIBILITY STUDY REPORT

LIST OF TABLES

LIST OF FIGURES

ANNEX

LIST OF TABLES

ANNEX

LIST OF FIGURES

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. Objectives and Scope of the Study

(1) The Feasibility Study of the Sewerage and Drainage Improvement Project for Phuket Municipality was executed by Japan International Cooperation Agency (JICA) during the period from July 1989 to February 1990, in response to the request made by the Government of the Kingdom of Thailand (the Government).

(2) The objectives of the Feasibility Study were to formulate plans for immediate improvement of the sewerage, drainage and flood control systems for the study area, and to evaluate the technical, financial and economic viability of the recommended improvement program.

(3) In order to accomplish satisfactorily the above objectives, the Master Plan was undertaken so as to formulate the basic scheme of the improvement project first, which would be submitted to the Government at the same time with this report.

2. Summary of Conclusions and Recommendations

2-1 Sewerage

(1) Like other big cities in Thailand, in Phuket Municipality (the City), there is a public storm drainage system that is also used to remove domestic wastewater. However, there is no public sewage disposal system.

(2) While in the downtown of the city, the sullage from kitchens, washing and bath is discharged to rivers or canals through those storm drainage system, but approximately one-third volume of septage from cesspools and septic tanks is simply allowed to infiltrate into the ground. Therefore, the existing storm drainage system practically refers as the combined sewage collection system, even it was not originally planned for such purpose. This

led to the pollution not only of river and sea water, but also of ground water in the area which is used to one of water supply source. (Refer to Chapter 3.1)

(3) As one of the most accessible southern paradises, name of Phuket is well known in the world with traditional culture and beautiful nature. The tourism in Phuket island consists of hotels accommodations in various resort coasts accompanied with most of their local agriculture, mining, manufacturing and several service industries to jointly cooperate as a whole. As the growing symbol center in Phuket Province in political and economical respect, the city of Phuket has been urgently requested to introduce a sewerage system to improve the conservation of environmental condition not only for impress appealing the natural resources as a famous resort but also for a public health and sanitation.

(4) The evaluation of alternative for planning the sewage collection system for the study area was undertaken. Experience has shown that apparently, for surrounding environmental impact and water pollution control, a separate collection system is advantageous compared with a combined system to the best solution. However, further analysis shows that under the following conditions, combined system may be more desirable to promote the diffusion of sewerage system economically.

- The degree of pollution of the receiving watercourses during rains is acceptable.

- The existing public drainage system, which is collecting both surface runoff and sewage can be intercepted to combined sewers to be constructed thus resulting in a lesser need for lateral sewers.

(5) With regards to the study on sewage collection system, comparison of alternative was undertaken on the improvement of environmental conditions and foreseeable trouble after operation of the project, and cost evaluation including construction cost and operation and maintenance cost.

Result of the cost evaluation the combined system was inexpensive than the separate system in both construction cost and operation and maintenance cost approximately 30% and 40%, respectively. (Refer to Chapter 3.2.2(2))

(6) Sewage treatment process was also discussed to select an optimum treatment process for the project. The following three processes were finally selected as the comparative alternatives.

- Conventional activated sludge process

- Rotating biological contactor process

- Oxidation ditch process

(7) Comparison of the alternatives was elaborated on the construction cost, operation and maintenance cost and various operational characteristics. An overall evaluation was made to select the optimum treatment process. The result was summarized as follows:

	Conventional Activated Sludge Process	Rotating Biological Contactor Process	Oxidation Ditch Process
Construction Cost	A	C	A
Operation and Maintenance Costs	A	C	A
Various Characteristics	C	B	A
Overall Evaluation	B	C	A

Note: The evaluation was made using an "A-B-C" rating system where each alternative was rated accordingly. An "A" rating implies that the alternative considered was the best. A "B" rating fallowed "A", and a "C" rating means that the alternative was least advantageous among those considered.

From result of the evaluation the oxidation ditch process was recommended as the optimum sewage treatment process for the project. (Refer to Chapter 3.2.3)

(8) Preceding the comparison study of alternatives on sewage collection system and sewage treatment process, fundamental design conditions such as target year, study area, future population and future water consumption were studied for the Master Plan, which were outlined below. (Refer to Chapter 2.3)

(i) Design Target year
Year 2006 (B.E. 2549) or 16 years from 1990 was proposed.

(ii) Design Area
The study area for the Master Plan was proposed to be the DTCP town planning area and the area between the DTCP town planning boundary and the Bang Ping river.

(iii) Future Population
Present population of the study area is 61,900. Future population of the area was projected to be 78,200.

(iv) Future Water Consumption
Future water consumption of the study area was estimated 34,500 m^3/day in 2006.

(9) With the end goal of reducing the extent of water pollution and improving the deteriorating sanitary conditions in the study area, the study is developed in order to formulate an appropriate urgent improvement plan as the Feasibility Study Project, taking into account the capital investment required and the desired end results.

As the objective is to introduce a public sewerage system in the city, the most important concerns are to select the optimum design target year and the project study area. Hence the design area is selected taking into account the following:

(i) high population density area as it discharges the biggest volume of pollutants.

(ii) the vicinity of the upstream of the Bang Yai river rather than the downstream as the upstream has a much greater influence in environmental pollution to the river than the downstream areas.

(iii) still-to-be-developed area of street drain as it is easy to intercept wastewater discharged from houses and buildings into sewers to be constructed.

(iv) combined sewage collection area rather than separate collection area as the former requires no or less expense for installation of lateral sewers and house connections, while the letter surely requires it the cost of which is to be shared eventually by the users. (Refer to Chapter 3.3.1)

As to the target year, year 2001 (B.E.2544) is chosen for the following reasons:

(i) The target year of the Master Plan for this project is 2006.

(ii) Assuming a total period of 5 years for detailed design, bidding and construction of this project, the system is scheduled to be operational in 1996.

(iii) Considering the diffusion of house connections into the existing drainage and or intercepting sewers, the system is forecasted to operate under the designed full load in 2001.

(10) After consideration such factors like projected target year and design area, the fundamental design conditions for the Feasibility Study project are made. The result is summarized as follows:

Items	Master Plan	Feasibility Study
-Design Target Year	2006 (B.E.2549)	2001 (B.E.2544)
-Design Area	2,581 ha	396 ha
-Design Population	78,200 in 2006	29,600 in 2001
-Design Flow	34,500 m^3/d	18,300 m^3/d

(11) The investment cost of the Feasibility Study project for sewerage system is estimated as follows. (Refer to Chapter 4.3.2)

(Unit: 10^3 Baht)

	Estimated Construction Cost	Allocation	
		Phase 1	Phase 2
Construction Cost			
-Sewer	109,500	96,130	13,370
-Pump Station	60,600	60,120	480
-S.T.P.	138,600	111,935	26,665
Sub-total	308,700	268,185	40,515
Expense Account			
-Land Acquisition	4,180	4,180	0
-Administration & Engineering Fee	32,238	26,818	4,051
-Physical Contingency	34,512	30,056	4,457
Sub-total	70,930	61,054	8,508
Project Cost	378,262	329,239	49,023

In the above table the cost of land acquisition and compensation includes only for pumping station. The projected land for the sewage treatment plant is a dumping ground belonged to the city and to be applied for this purpose at free of charge, thus such land cost is not included in the investment cost.

(12) The disbursement schedule of the investment cost is prepared as shown below in accordance with the established project implementation schedule. (Refer to Chapter 4.4)

(Unit: 10^3 Baht)

1st Phase				2nd Phase			
Year	Foreign Currency	Local Currency	Total	Year	Foreign Currency	Local Currency	Total
1991	9,667	6,813	16,480	1998	0	2,726	2,726
1992	9,860	1,375	11,235	1999	12,308	38,292	50,600
1993	1,437	70,088	71,525	2000	12,534	36,880	49,413
1994	50,069	99,358	149,427				
1995	73,227	148,981	222,208				
Total	144,260	326,615	470,875	Total	24,842	77,897	102,739

(13) Water quality analyses were conducted periodically during rainy and dry seasons on the river water and sewage. It is not easy to stipulate a river common water quality. In case of the Bang yai river, practically speaking, water quality of the river depends upon the limited river flow for its maintenance or scarce flow in a dry season.

Based on the field survey done during the dry season, the systematic water quality investigation shows that the water quality can be improved as shown in the following table, provided this Feasibility Study project will be fully implemented.

Location	Present as of Jan. 25, 1990	In 2006 without the Project	In 2006 with the Project
R-1 (Yaovaraj Br.)	0.95 mg/l	0.95 mg/l	0.95 mg/l
R-2 (Taonpradit Br.)	3.10	14	6.0
R-3 (Taling Chan Br.)	13.25	30	7.5
R-4 (River Mouth)	12.40	-	-

As being evident in the above table, the river water quality would be considerably improved when the project is carried out on schedule. (Refer to Chapter 2.4.1 (Fig. 2.3) & Chapter 3.3.2(3))

(14) The Economic benefits for sewerage project are principally used to be evaluated by:

1) Health and welfare improvement benefit
Such as improvement of hygiene/health and reduction in those disease

2) Environmental improvement benefit
Such as conservation of agriculture and fishery, development of water resources and preservation of sound environment including leisure and recreation

3) Other economic benefit
Such as decrease of flood damages, development of land use, increase of land value, promotion of local industry and resources including reuse of treated water and saving of water supply costs

Taking those circumstances, in the case of this Project, the particular conditions in Phuket City could afford to scarcely quantify those economic benefits. However, as an institutional nature of infrastructure project, even if those benefits are not awfully enough to conform the project costs namely unprofitable, the project is apt to be implemented from socio-economic and or political viewpoints essentially for a part of basic human needs. Accordingly, the economic analysis is made only for flood control scheme. While the project justifications including financial aspect and indirect benefit and socio-economic impact are conducted for the sewerage schemes. (Refer to Chapter 10.1.1 & 10.1.4)

(15) It is deemed appropriate that the PWD will be responsible for implementation of the project. And PWD need to support and assist the city in the operational initial stage of the sewerage system. Since there is no basic law to implement a sewerage works in both

the central and local level, it is inevitable to enact a bylaw for sewerage works. In this connection, it is recommended that the establishment of the bylaw should be commenced as earlier as possible in which the following contents must be at least included:

- Declaration of service area and time that this bylaw is applied to

- Requirements to persons who will construct or improve their house in the service area.

- Installation method of house connection

- Approval of plans for house connection work and inspection of the work

- Requirements to users who discharge wastewater exceeding the acceptable level in quantity and/or quality

- Calculation method and collection of sewage fee

(16) It is strongly recommended that the Government takes a prompt step to implement the sewerage improvement system from the first phase of the program.

2-2 Drainage

(1) The storm drainage system in the city is almost developed except a part of eastern and northern areas in the city. The existing public drainage are widely employed street gutter constructed along the paved streets. The city, however, has been occasionally attacked with large scale of inundation.

Floods within the study area are classified into two types: one is that of flood waters coming from the Bang Yai river (External floods), while the other is that of floods by storm and rains (internal floods).

(2) Internal floods occurred at some areas several times a year are mainly caused by insufficient drainage facilities and their improper cleaning and maintenance.

(3) The existing storm drainage system in the study area can be classified roughly into four zones. Since these areas have no particular names, the Study Team arbitrarily named them as follows: Central drainage area, Taling Chan canal area, Ta Kraeng canal area and Tajin river area. (Refer to Chapter 5.2.1)

(4) Computerized analysis is carefully undertaken in order to evaluate the capacity of the existing drainage facilities. It was estimated that the central drainage area seemed to have a capacity to meet 1 to 1.5 year probable rainfall as a whole and less than 1 year probable rainfall for Taling Chan canal area.

(5) Improvement of drainage facilities is studied to manage the probable rainfall of 5 year return period for main drains and canals, and 2 year return period for lateral drains, except Tajin river area in which the public drainage system is not yet developed.

The major improvement facilities and construction cost for the central drainage area are summarized as follows:

Unit: 10^3 Baht

Improvement Facility	Length	Construction Cost
Drainage		64,300
ϕ300 - ϕ1500	4,520m	
Box culvert 4.0 - 6.0m^2	1,700	

The estimated construction cost includes the tax to be levied on the construction work, but excludes the cost for administration, engineering services and physical contingency. (Refer to Chapter 6.2.1)

(6) In order to solve the inundation in the Taling Chan canal area due to heavy rain, drainage system with retarding pond and with both pumping station and retarding pond are studied to provide an appropriate drainage system. From a result of the construction cost evaluation the drainage system with retarding pond is recommended. Moreover, it is imperative for the existing drainage system to improve the facility for the distance of 540m. The project cost of the proposed retarding pond and drainage facilities for the Taling Chan canal area is summarized as follows:

Unit: 10^3 Baht

Item	specification	Cost
Drainage Improvement	ϕ800 - ϕ1,200 x 540m	2,013
Retarding Pond	114,000m^3	20,030
Project Cost		22,043

(Refer to Chapter 6.2.2)

(7) As to the Ta Kraeng canal area, it is recommended to construct diversion canal to connect the Bang Ping river to discharge the rain water of 5 year probable rainfall. The canal construction cost and drainage improvement cost are estimated as follows:

Unit: 10^3 Baht

Item	specification		Cost
Drainage Improvement			20,344
	ϕ500 - ϕ800	925m	
	Bx.C 1,600H x 3,200W	550	
Diversion Canal			4,580
Project Cost			24,924

(Refer to Chapter 6.2.3)

2-3 Flood Control

(1) Phuket city has been developed rapidly in recent years and its assets are also increasing and concentrating in the city. However, social infrastructures such as water supply, sewerage and flood control have not caught up with economic development in the city. The magnitude of flood damage will increase remarkably and economic growth will be disturbed if no flood control measures are implemented.

The provisional plan is formulated taking into consideration the above conditions.

(2) Probable basin rainfall was recalculated adding latest data in 1989 and the results are same as those of the Master Plan as shown below:

Return period(year)	Basin rain(mm)
100	196
50	183
30	173
20	164
10	150
5	134
2	108

Probable flood is derived from the probable one-day rainfall, whose pattern is applied from that of the 1986 September 27 flood, since the pattern would give the most serious flood. Peak discharge by probable flood at the branching point of the proposed floodway was derived as shown below:

Return period (year)	Peak discharge (m^3/s)
50	132
30	121
20	112
10	98
5	85
2	65

(Refer to Chapter 7.2.1)

(3) In order to estimate inundation area and depth by the probable floods, flood damage analysis was carried out. The results show that Phuket city might be inundated entirely by floods which occur once in five years or more.

The highest inundation depth is expected at 1.5 m by the flood in the recurrence period of 5 years and 1.7 m by the flood in the recurrence period of 30 years. The difference of inundation depth among probable floods is not so much but it will take longer inundation time by the magnitude of probable floods.

For the economic evaluation of the proposed flood control plan, flood damage by probable flood is assessed taking into consideration the land use and the results of interview survey carried out in Aug. 1989. The results are as follows:

Unit: 1,000 Bahts

Peak Flood (m^3/s)	Return Period (years)	Exceedance (%)	Probability Range	F L O O D Damage	Mean	Annual	Cumulated
72	2	50	0.500	0	0	0	0
94	5	20	0.300	68,300	34,150	10,200	10,200
108	10	10	0.100	70,600	69,450	6,900	17,100
123	20	5	0.050	77,200	73,900	3,700	20,800
133	30	3	0.0167	79,300	78,250	1,300	22,100
Total			0.967			22,100	

(4) Urgent flood control plan is formulated from the viewpoint of socio-economic effects such as the stability of civil life and economic activity in Phuket city in addition to cost effectiveness to flood damage reduction.

Design scale of urgent flood control plan is studied in comparison with cost effectiveness of alternative schemes which are formulated to control 5 year, 10 year, 20 year or 30 year probable flood. Cost estimate was made for each alternative scheme. These project costs are compared with flood reduction benefit by probable flood in terms of total net present value. Annual flood damage by probable flood is estimated by the flood damage analysis. Project cost, annual cumulated benefit and economic internal rate of return (EIRR) for each scheme is shown below.

Unit: 1,000 Bahts

Return Period	Project Cost	Annual Benefit	EIRR (%)
5	147,400	10,200	6.2
10	149,900	17,100	10.4
20	155,500	20,800	12.1
30	160,200	22,100	12.5

EIRR for return period of 30 years are the highest among the alternative schemes. Therefore the development scale for 30 year probable flood is recommended to implement. (Refer to Chapter 7.4.2)

(5) Flood control facilities are designed under proposed flood distribution plan. The design discharge at the diversion inlet is 121 m^3/s. Out of 121 m^3/s, 116 m^3/s is diverted to the Sapam bay completely by the floodway and the discharge from the diversion point into the town is limited to 5 m^3/s.

(6) The location of diversion inlet is determined at 400 m downstream from the Yaovaraj bridge under agreement with the city office.

Trapezoidal cross section is employed for the floodway. Diversion inlet is constructed as concrete structure with side slopes of 1:0.5. The floodway after the diversion inlet is designed as trapezoidal cross section with side slopes of 1:2.0. The side slopes are protected by revetments. The design river bed width is 11 m. Bed slope of the floodway is designed at 1/1,000 for smooth connection between the floodway diversion inlet and outlet.

Design discharge is adopted for 116 m^3/s which is 30 year probable flood. The design high water depth is determined for 4.2 m. The design velocity is 1.9 m/s. Freeboard for the floodway bank is adopted at least 60 cm from the design high water level. (Refer to Chapter 8.2.2)

(7) In order to divert the design discharge of 121 m^3/s, river improvement work is necessary for the Bang Yai river between the Bypass highway and the diversion inlet. Excavation of river will be made to meet the design discharge. Side slopes of the Bang Yai river is excavated to make slopes 1:0.5. The river bed is excavated to make the bed width at least 8 m.

The high water depth will be 4.7 m for the design discharge of 121 m^3/s. Since the water level is higher than bank elevation, levee is constructed along the river at 1,700 m in length. The design velocity is estimated at 2.5 m/s. Retaining wall will be constructed along the upstream and downstream of the diversion point for 25 m in length respectively.

Replacement of the bridges in the city will be required to mitigate local floods from the residual basin. Six bridges are recommended to be reconstructed. It is recommended to reconstruct the diversion inlet of the Saen Suk canal to release local flood from residual basin effectively.

(8) Assuming that the construction of the floodway will be completed by April 1995 (BE 2538), implementation schedule is expected as follows:

1) Preparation of budget, loan agreement and selection of consultants
   - 1 year from October 1990 (BE 2533) to September 1991 (BE 2534)

2) Additional field investigation, detailed design and preparation of tender documents
   - 15 months from October 1991 (BE 2534) to December 1992 (BE 2535)

3) Tender call and contract
- 9 months from March 1993 (BE 2536) to September 1993 (BE 2536)

4) Commencement of construction
- October 1993 (BE 2536)

5) Completion of construction
- April 1995 (BE 2538)

(9) The project cost is composed of (i) the construction cost, (ii) land acquisition and compensation cost, (iii) engineering service fee, (iv) government administration cost, (v) physical contingency and (vi) price contingency.

The project cost is estimated as follows:

Unit: ฿ 1,000

WORK ITEM	F.C.	L.C.	Total
1. Preparatory Works	6,870	2,440	9,310
2. Floodway	62,290	21,960	84,250
3. River Improvement	6,440	2,390	8,830
Direct Cost	75,600	26,790	102,390
4. Land Acquisition & Compensation Cost	-	17,900	17,900
5. Engineering Service & Government Administration	7,560	5,680	13,240
6. Physical Contingency	16,630	10,080	26,710
Sub-total	99,790	60,450	160,240
7. Price Contingency	8,740	26,870	35,610
Total	108,530 55%	87,320 45%	195,850 100%

Total project cost excluding price contingency is estimated at ฿ 160 million. It comprises of ฿ 100 million of the foreign currency portion and ฿ 60 million of the local currency portion.

The maintenance cost for the floodway is assumed to be 0.5 % of the direct construction cost including its physical contingency. Annual O&M cost is estimated at ฿ 614,000. (Refer to Chapter 8.4)

(10) Economic internal rate of return (EIRR) of the project for 30 year probable flood is the highest among the alternative schemes. In addition, the difference of the project costs between the scheme for 30 year probable flood and that for 5 year probable flood is 12,800,000 Bahts and 8 %. It is not so much different. Therefore it is recommended to implement the project to control 30 year probable flood which is the target flood for Master Plan.

(11) Work quantities of the floodway and river improvement were estimated from the preliminary design drawings which was made based on the topographic map in a scale of 1: 4,000 prepared by DTCP. It is recommended to carry out topographic survey and geological and soil mechanical survey for floodway route to estimate more accurate work quantities.

(12) It is expected that the project will not bring about negative environmental impact, according to field reconnaissance which was made along the floodway route to assess environmental impact. However, it is recommended to carry out detailed environmental impact study to get understanding and cooperation of the citizens in the project area.

Principal Features of Proposed Flood Control Plan

I. <u>River improvement</u>

Location: between the Bypass highway and the inlet of floodway

- Channel excavation : 18,400 m^3 (length = 1,700 m)
- Levee Embankment : 10,470 m^3 (length = 1,700 m x 2)

Reconstruction of bridge :

1. Phoonphol bridge
2. Phang Nga bridge
3. Tuanpradit bridge
4. Thepkrasattri 3 bridge
5. Damrong bridge
6. Thepkrasattri 1 bridge

Reconstruction of Saen Suk intake

II. <u>Floodway</u>

East floodway

Location: from 400 m downstream of Yaovaraj Bridge (Sam Kong Village) to Sapam bay

- Length : 3,430 m
- Bed width : 11.0 m
- Side slope : 1:2.0 with revetment
- Excavation volume : 442,000 m^3

CHAPTER 1

INTRODUCTION

CHAPTER 1 : INTRODUCTION

1.1 Background of the Study

This Feasibility Study (the Study) contains the recommended program for the sewerage and drainage improvement of Phuket City (the Study Area) in the Kingdom of Thailand. It is in accordance with the scope of Work of the Contract Agreement signed on February 3, 1989 by the Japan International Cooperation Agency (JICA), an official agency responsible for the implementation of technical cooperation programs of the Government of Japan, and the Public Works Department (PWD), Ministry of Interior, an executing agency of the Government of the Kingdom of Thailand (the Government).

JICA entrusted the Study to Nippon Jogesuido Sekkei Co., Ltd., in association with Nippon Koei Co., Ltd. (the Study Team).

Field survey and investigation for a period of 2.5 months works for this project were conducted in two stages: the first stage was from July to October 1989, while the second stage was from January to February 1990. Counterpart support was provided for by the Government. This report was prepared on the basis of the study for the Master Plan of development of the same project, both of which would be submitted to the Government at the same time.

1.2 Objectives of the Study

The objectives of the Study are:

- to formulate a plan for the immediate improvement of the sewerage, drainage and flood control systems for the Study Area; and

- evaluate the technical, financial and economic viability of the recommended improvement program

1.3 Scope of Work

As defined in the Contract of Agreement between JICA and the Government, the Scope of Work of this Study covers the following:

(i) Review of topographic survey for flood way
(ii) Review of hydrological data for flood control
(iii) Investigation of sewage quality for dry season
(iv) Review of existing drainage facility
(v) Formulation of improvement plans
(vi) Preliminary designs and cost estimates
(vii) Economic and financial evaluation

CHAPTER 2

THE STUDY AREA

CHAPTER 2 : THE STUDY AREA

2.1 Delineation of the Study Area

The provincial capital, Phuket City, is located in the southeastern corner of the Phuket island. The present population is about 50,000. The city is developed on the coastal plain of the Bang Yai river.

The catchment area of Bang Yai river is around 56 km^2 at the entrance of the city. The minimum discharge is about 0.4 m^3/s. Since the flow capacity of the Bang Yai river is quite small, say more or less 35 m^3/s which is much less than the surface runoff particularly during periods of heavy rains, Phuket City often suffers from perennial flooding ever after a few hours of continuous raining. Phuket City has a generally flat except for two mountains in the area, namely Mt. Toh Sae and Mt. Rang, which are 285 meters and 160 meters high, respectively.

The study area for sewerage improvement project covers approximately 2,000 ha (12,500 rais) of the DTCP town planning area including the whole of Phuket City and the area between the DTCP town planning boundary and the Bang Ping river. The study area for the flood control and drainage project additionally covers 56 km^2 of the Bang Yai river basin as shown in Fig. 2.1.

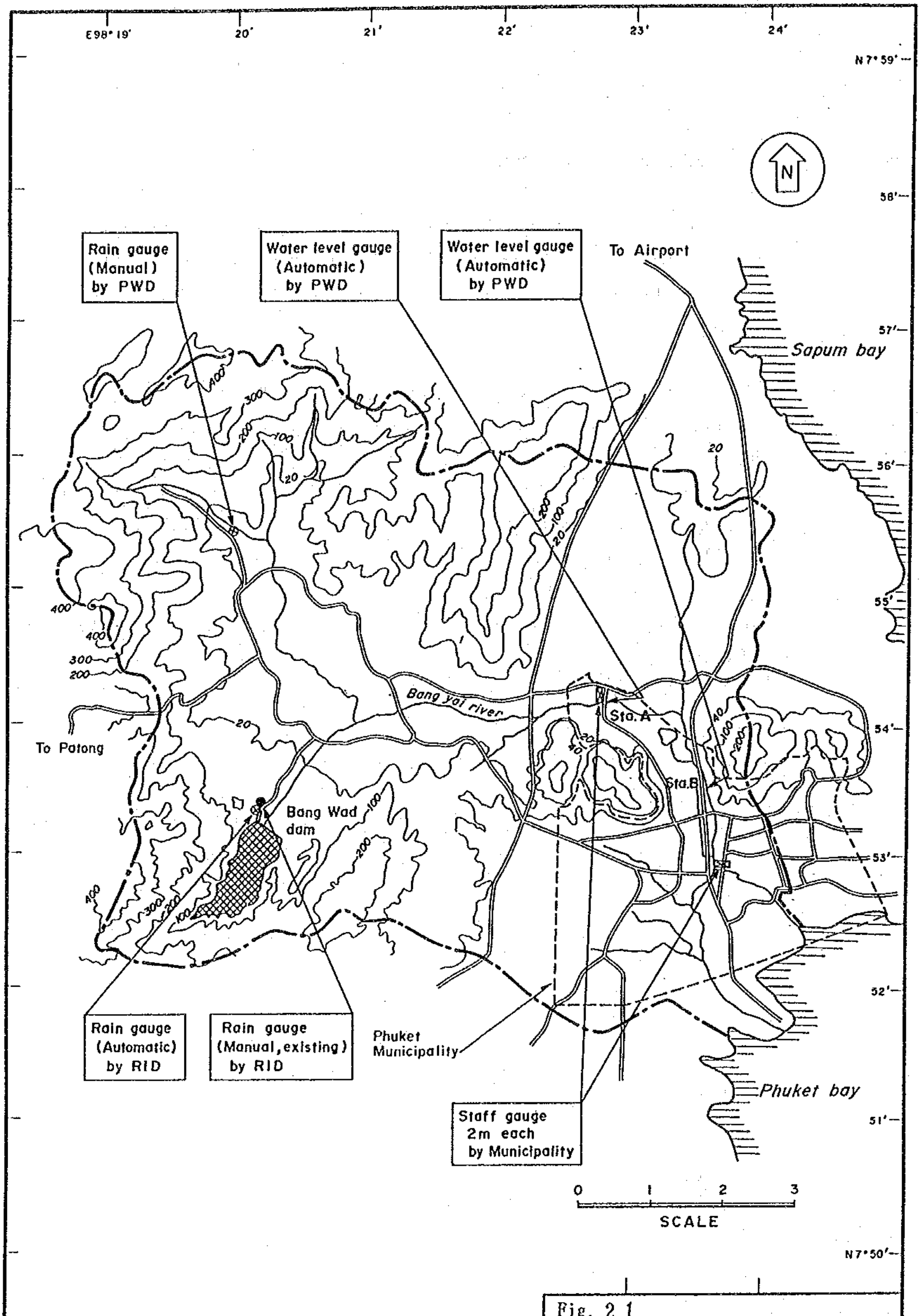


Fig. 2.1 LOCATION MAP OF METEO-HYDROLOGICAL OBSERVATORIES NEWLY ESTABLISHED

2.2 Hydrological Characteristics

There are three meteorological stations in the island. One is in the city, another one is at the Phuket airport in the northern part of the island and the third is at the Bang Wad dam in the Bang Yai river basin. However, there was no available data at all for the river stream flow of the Bang Yai river.

JICA provided one set each of automatic and manual rain gauges and two sets of automatic water level gauges. The data collected after the installation of these gauges in September, 1989 proved very useful in analyzing the flow capacity of the Bang Yai river and on the potentiality of a flood retarding basin. These are described more in Sections 7.1 and 7.2.

2.3 Population and Water Consumption Projection

2.3.1 Future Population

(1) Projection of Future Population

The methods used to project the future population in the study area are as follows:

1) Regression method

Arithmetic, geometric and logarithmic regression analyses were tried. By extrapolating the past population trend using this method, the city's population in the project target year 2006 was to be around 55,000. This does not take account, however, the current economic and commercial growth of the area so the results tend to be below normal expectations.

2) Expected fixed growth rate

By applying the annual growth rate of 1.3%, which is the national target for 1991, and the net balance of in and out migration, the city's population for year 2006 was projected to be 60,000.

Likewise, the study area's population also for year 2006 was projected to be 78,000.

3) Simplified cohort analysis

By using the simplified cohort analysis which takes into account the combined population change by births, deaths and migration between 1980 and 1988, a slow population growth was projected for the city at 50,000 in year 2004. This is predicted to decrease further due to the increasing out-migration and aging population. This analysis assumed that the past pattern of out-migration especially of the young generation would not change in the future.

4) Bottom-up approach

In order to incorporate the current housing boom and the long term land use plan, the following bottom-up approach was applied.

(i) The population increase considering the on-going and planned building projects could be estimated at approx. 5,400 as shown below:

2,686 units x 4 persons x 50 % = 5,372 persons

Where:
2,686 = Number of housing units to be built
4 = Average family size for the new units
50 % = Ratio of residents from outside come into the study area assumed by the Study Team

(ii) To project the minimum planned population by zone in 2006 consistent with the land use plan, the population density for each land use category as shown in Table 2.1 was assumed as follows:

Low density residential zone	=	25 persons/ha
Medium density residential zone	=	55 persons/ha

Commercial and		
high density residential zone	=	110 persons/ha
Industrial zone	=	15 persons/ha
Rural and agricultural zone	=	5 persons/ha
Other zones	=	0 person

(iii) By comparing the results of the above (i) and (ii), and assuming the larger population for each zone, the city's population could be approximated at 60,000, while 78,200 was projected for the study area as shown in Table 2.3.

Results of the above estimates are summarized in the following Table 2.2.

Table 2.2 City's Population by Various Methods for Year 2006

Method	Estimated Population	Remarks
1. Regression Analysis		
	persons	
a) Arithmetic	54,490	P = -689,067 + 370,667 x year
b) Geometric	55,016	P = 0.00859574 x 1.007843 x year
c) Logarithm	46,592	P = -129,900 + 23,210.7 x year
2. Fixed Growth Rate	59,564	1.3%/year
3. Cohort Analysis	50,140	in 2004
4. Bottom-up Approach	59,734	in-City + S.Zone
		(56,689) (3,045)

5) Selected method and results of estimation

Among the above methods, the bottom-up approach reflects the current housing boom and the long-term land use plan, being consistent with the macroscopic trend shown using the expected fixed growth rate method.

Table 2.1 Area by Land Use Plan Category and
Minimum Planned Population by Land Use Plan in Each Zone (Unit : ha, persons)

Zone	LU1	LU2	LU3	LU4	LU5	Others	Total Area	Population by Land Use Plan
A1	0	0	13.472	0	0	1.12	14.592	1482
A2	0	0.28	5.352	0	0	0	5.632	604
A3	0	0	8.192	0	0	0	8.192	901
A4	0	0	6.656	0	0	0	6.656	732
A5	0	0	11.776	0	0	0	11.776	1295
A total	0	0.28	45.448	0	0	1.12	46.848	5015
B1	0	0	13.904	0	0	2.48	16.384	1529
B2	0	0	33.28	0	0	0	33.28	3661
B3	0	0	20.2	0	0	0.28	20.48	2222
B4	0	0	9.88	0	0	0.36	10.24	1087
B5	0.2	9.32	0	0	0	0.72	10.24	518
B6	20.744	9.2	0	0	0	1.8	31.744	1025
B total	20.944	18.52	77.264	0	0	5.64	122.368	10041
C1	0	22.232	0	0	0	1.32	23.552	1223
C2	23.72	10.8	0	0	0	1.32	35.84	1187
C3	35.84	0	0	0	0	0	35.84	896
C4	14.68	0	0.68	0	0	0	15.36	442
C5	31.04	0	0	0	0	24	55.04	776
C6	70.624	0	0	0	0	20	90.624	1766
C7	0	52.16	0	0	0	13.12	65.28	2869
C total	175.904	85.192	0.68	0	0	59.76	321.536	9158
D1	0	20.48	0	0	0	0	20.48	1126
D2	0	17.24	0	0	0	10.92	28.16	948
D3	38.68	0	0	0	0	2.28	40.96	967
D4	53.76	0	0	0	0	0	53.76	1344
D5	4.8	14	29.36	0	0	0.48	48.64	4120
D6	34	79.384	20.4	0	0	5.48	139.264	3730
D total	131.24	131.104	49.76	0	0	19.16	331.264	12235
E1	2.4	62.16	0	0	0	7.12	71.68	3479
E2	72.192	0	0	0	0	0	72.192	1805
E3	79.64	0	7.2	0	0	15.56	102.4	2783
E4	39.32	0	0	0	0	40.04	79.36	983
E total	193.552	62.16	7.2	0	0	62.72	325.632	9050
In-Munici.	521.64	297.256	180.352	0	0	148.4	1147.648	45499
T.Rasada	184	21.2	0	102	136	331.752	774.952	7952
T.Vichit	184.92	0	0	0	0	145.32	330.24	4623
F zone	4	0	0	0	0	109	113	100
Out-Munici	372.92	21.2	0	102	136	586.072	1218.192	12675
DTCP Area	894.56	318.456	180.352	102	136	734.472	2365.84	58174
S zone	0	0	0	0	0	95.5	95.5	-
Bang Ping	0	0	0	0	0	120	120	-
Study Area	894.56	318.456	180.352	102	136	949.972	2581.34	-

Note

LU1 : Low density residential zone
LU2 : Medium density residential zone
LU3 : Commercial & high density residential zone
LU4 : Industrial zone
LU5 : Agricultural and rural zone

Others
Recreational and environmental protection zone
Educational zone
Religious zone
Government office and public service zone
Outside the Town Plan Area

Source : Analysis Report for Phuket Town Plan, DTCP 1989
Analysis and Estimation by the Study Team

Table 2.3 Comparison of Population Changes by On-Going Projects and by Land Use Plan

Zone	Present Population (a)	No. of Units of Projects (b)	Population after Projects (c)	Population by Land Use Plan (d)	Larger Population between c & d (e)
A1	1530	0	1530	1482	1530
A2	970	0	970	604	970
A3	1383	0	1383	901	1383
A4	1640	0	1640	732	1640
A5	1303	24	1351	1295	1351
A total	6826	24	6874	5015	6874
B1	1638	36	1710	1529	1710
B2	1870	0	1870	3661	3661
B3	1900	108	2116	2222	2222
B4	1466	153	1772	1067	1772
B5	1221	0	1221	518	1221
B6	1631	270	2171	1925	2171
B total	9726	567	10860	10041	12757
C1	1120	0	1120	1223	1223
C2	1691	75	1841	1187	1841
C3	1688	100	1888	896	1888
C4	1023	0	1023	442	1023
C5	1643	0	1643	776	1643
C6	1754	0	1754	1766	1766
C7	1698	20	1738	2869	2869
C total	10617	195	11007	9158	12252
D1	1772	37	1846	1126	1846
D2	1035	100	1235	948	1235
D3	1339	0	1339	967	1339
D4	1558	0	1558	1344	1558
D5	1634	306	2246	4120	4120
D6	1876	50	1976	3730	3730
D total	9214	493	10200	12235	13828
E1	4023	566	5155	3479	5155
E2	1128	0	1128	1805	1805
E3	1637	262	2161	2783	2783
E4	1236	0	1236	983	1236
E total	8024	828	9680	9050	10979
In-Munici.	44407	2107	48621	45499	56689
T.Rasada	12600	143	12886	7952	12886
T.Vichit	1530	169	1868	4623	4623
F zone	0	0	0	100	100
Out-Munici	14130	312	14754	12675	17609
DTCP Area	58537	2419	63375	58174	74298
S zone	2511	267	3045	-	3045
Bang Ping	860	0	860	-	860
Study Area	61908	2686	67280	-	78203

Note : No.of Units of Projects
= Known No.of Housing Units - Outside Study Area
+ Estimate of Unkown No.of Units
= 2579-53+160 = 2686

Source : Analysis Report for Phuket Town Plan, DTCP 1989
Analysis and Estimation by the Study Team

The bottom-up approach method was accordingly selected in projecting the city's future population.

Area outside Phuket City that are included in the study area are T. Rasada, T. Vichit, F Zone and Bang Ping in which total population is projected to be 18,469 in 2006. As a result, future total population of the study area in 2006 could be estimated to be 78,203, say 78,200.

(2) Population Distribution in Intermediate Phase

Allocation of the zonal population to each land use category is made according to the share of the assumed density as shown in Table 2.4 and in Fig. 2.2.

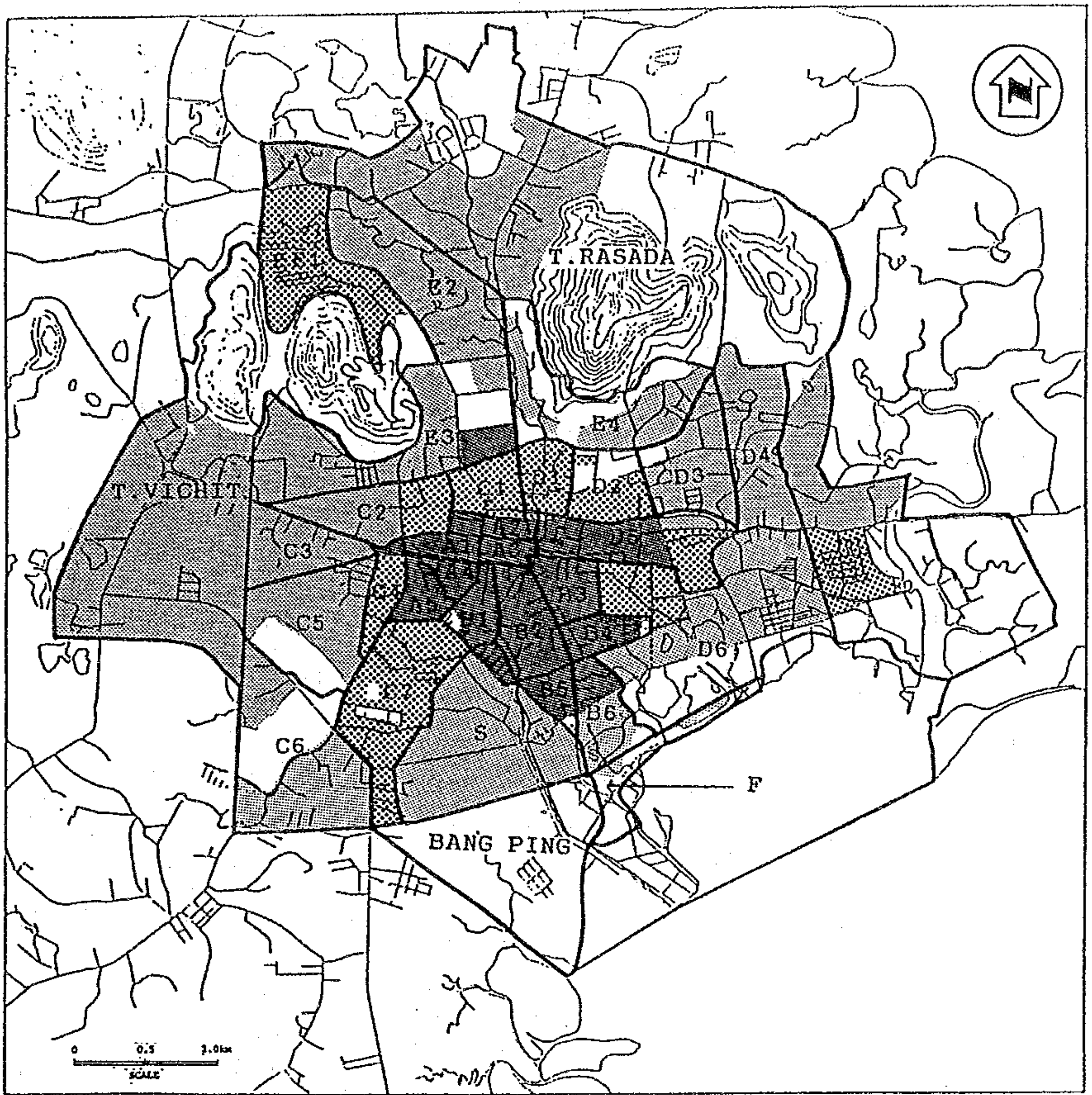
The population distribution in the intermediate phase of 2001 is also made assuming a 1.3% growth rate per annum as it matches closely with the value obtained using the bottom-up approach method adopted for population projection for year 2006. The result is given in Table 2.5.

Table 2.4 Summary of Population Distribution in 2006

Unit :Population density = persons/ha

	Population		Population Density
Low density residential zone	28,900	(37%)	32.3
Medium density residential zone	20,300	(26%)	63.8
Commercial and high density residential zone	21,500	(28%)	119.4
Industrial zone	2,500	(3%)	24.3
Rural and agricultural zone	1,100	(1%)	7.8
Other areas	3,900	(5%)	18.1
Study Area	78,200	(100%)	30.3

Source: Estimation by Study Team



LEGEND

Population Density

- 110 Persons/ha (17.6 Persons/Rai) or More
- 55 - 110 Persons/ha (8.8 - 17.6 Persons/Rai)
- 25 - 55 Persons/ha (4 - 8.8 Persons/Rai)

Fig. 2.2
ESTIMATED
POPULATION DENSITY
DISTRIBUTION IN 2006

Table 2.5 Estimated Population Distribution in 2001

Zone	Total	LU1	LU2	LU3	LU4	LU5
A1	1530	0	0	1530	0	0
A2	970	0	25	945	0	0
A3	1383	0	0	1383	0	0
A4	1640	0	0	1640	0	0
A5	1351	0	0	1351	0	0
A total	5874	0	25	6849	0	0
B1	1710	0	0	1710	0	0
B2	2926	0	0	2926	0	0
B3	2116	0	0	2116	0	0
B4	1772	0	0	1772	0	0
B5	1221	12	1209	0	0	0
B6	2171	1099	1072	0	0	0
B total	11916	1111	2281	8524	0	0
C1	1120	0	1120	0	0	0
C2	1841	920	921	0	0	0
C3	1888	1888	0	0	0	0
C4	1023	850	0	173	0	0
C5	1643	1643	0	0	0	0
C6	1754	1754	0	0	0	0
C7	2293	0	2293	0	0	0
C total	11562	7055	4334	173	0	0
D1	1846	0	1846	0	0	0
D2	1235	0	1235	0	0	0
D3	1339	1339	0	0	0	0
D4	1558	1558	0	0	0	0
D5	3293	96	615	2581	0	0
D6	2981	340	1745	897	0	0
D total	12252	3333	5441	3478	0	0
E1	5155	89	5066	0	0	0
E2	1442	1442	0	0	0	0
E3	2224	1591	0	633	0	0
E4	1236	1235	0	0	0	0
E total	10058	4359	5066	633	0	0
In-Munici.	52661	15856	17148	19657	0	0
T.Rasada	12886	7454	1889	0	2479	1063
T.Vichit	3695	3695	0	0	0	0
F zone	80	80	0	0	0	0
Out-Munici	16661	11229	1889	0	2479	1063
DTCP Area	69322	27085	19037	19657	2479	1063
S zone	3045					
Bang Ping	860					
Study Area	73227					

LU1 : Low density residential zone
LU2 : Medium density residential zone
LU3 : Commercial and high density residential zone
LU4 : Industrial zone
LU5 : Agricultural and rural zone

Source : Analysis Report for Phuket Town Plan, DTCP 1989
Analysis and Estimation by the Study Team

2.3.2 Water Consumption

(1) Historical Water Consumption

The city area of Phuket is being supplied by the Phuket City Waterworks. The people unserved by the city water system mainly rely on shallow wells for water source. Estimated number of shallow wells are 5,000, however, some of it are not used due to water pollution problems.

Historical record of water supply and consumption is summarized in Table 2.6. The breakdown of the number of connections is 74.6% for residential, 22.8% for commercial, 1.4% for governmental and remaining 1.2% for industrial use in 1988.

Table 2.6 Historical Water Consumption

Year	Consumption (m^3/y) (A)	Connection (Number) (B)	Per Connection (m^3/d) (C) = (A)/(B)	Per House (pers) (D)	Per Capita (lpcd) (E) = (C)/(D)
1984	2,541,287	4,506	1.54	4.58	336
1985	2,899,247	4,774	1.66	4.55	366
1986	3,276,722	5,014	1.79	4.50	398
1987	3,759,885	5,404	1.91	4.42	431
1988	4,207,750	5,867	1.96	4.30	456

Source : Phuket Municipal Waterworks

(2) Per Capita Consumption

Since the per connection consumption has been steadily increasing in spite of the decreasing per house population, the apparent per capita consumption has been rapidly increasing from 336 lpcd in 1984 to 456 lpcd in 1988 as shown in the preceding Table 2.6.

Generally speaking, when the per capita domestic consumption is discussed as compared with other cities, water consumption for governmental offices and business use are excluded.

Table 2.7 shows the distributions of the number of connections and water consumption as categorized into domestic, commercial, governmental, industrial, hotel and other use in 1988. As can be seen, domestic and commercial consumption comprise 55.96% and 24.35% of the total, respectively. These water consumption varies widely from as low as 100 m^3/y to as high as 2,000 - 3,000 m^3 /y, which is hard to categorize them all into common domestic consumption.

The inadequacy of water consumption data makes the projection of future water consumption difficult. Providing that, to address this problem, water consumers of 100 to less than 1,500 m^3/y among categorized as domestic and commercial use are assumed to be common domestic consumers, 2,061,616 m^3/y with connection number of 4,521 is estimated for the use of the consumers, which is marked with four-cornered frame in the preceding Table 2.7. These consumers can be estimated as the common domestic consumers such as residential houses and houses holding small restaurant, which will be hereinafter referred to as "basic consumers/consumption" in domestic and commercial consumption and by contrast "additional consumers/consumption" for other bigger consumers for convenience in this report.

The present per capita basic consumption is accordingly calculated to be 291 lpcd by means of a per house population of 4.30.

(3) Future Water COnsumption

The future water consumption is projected by category. These classifications are:

(1) domestic and commercial use; (2) governmental use;
(3) school's use; (4) hospitals' use; (5) hotels' use;
(6) industrial use; and (7) restaurants' use.

Table 2.7 Water Consumption and Number of Connections by Scale

Upper : No. of Conn.
Lower : Consump. (cu. m/y)

Scale	Dom.	Com.	Gov.	Sch.	Hos.	Fac.	Hot.	Res.	Total	Share (%)
30.000 -	1 92191	1 62199	2 70670		1 76712	2 103508	1 30431		8 435711	0.14 10.37
10.000 - 30.000	2 36177	4 66813		3 49126		6 112725	3 54105		18 318946	0.31 7.59
5.000 - 10.000	18 117562	17 120234	5 32173	4 28754		3 23238	4 29954	6 40695	57 392610	0.97 9.34
3.000 - 5.000	39 147746	36 136698	6 24931	3 10789	1 3216	3 10015	3 11446	6 22174	97 367015	1.65 8.73
2.000 - 3.000	63 149649	39 92753	4 9429	2 4254			1 2398	7 17113	116 275596	1.98 6.56
1.500 - 2.000	92 159775	54 93508	1 1551				2 3630	4 6719	153 265183	2.61 6.31
1.000 - 1.500	257 306445	99 120812	6 7503	1 1242	1 1277			6 6545	370 443824	6.31 10.56
500 - 1.000	874 604473	279 195886	12 8891	5 3997	1 823			11 8442	1182 822512	20.16 19.57
100 - 500	2574 703824	438 130176	25 6746	2 475	2 483		1 218	2 855	3044 842777	51.91 20.06
100	712 33646	102 4139	1 34	1 44	1 75		1 46	1 94	819 38078	13.97 0.91
Total	4632 2351488	1069 1023218	62 161928	21 98681	7 82586	14 249486	16 132228	43 102637	5864 4202252	100.01 100.00
Share (%)	78.99 55.96	18.23 24.35	1.06 3.85	0.36 2.35	0.12 1.97	0.24 5.94	0.27 3.15	0.73 2.44	100.00 100.00	

Source : Phuket Municipal Waterworks

1) Domestic and commercial consumption

(i) Basic consumption

The per capita consumption was 291 l/d in 1988 as discussed in the preceding section. This value seems to be considerably high to those of other similar cities in Thailand. In the forecast of future water demand, it is assumed that the per capita consumption will not increase much, that will increase to only as much as 300 lpcd by the design year 2006.

(ii) Additional consumption by big consumers

In 1988, 1,275,305 m^3 was consumed used by 366 big consumers for domestic and commercial purposes. This is assumed to be remain constant until the target year 2006.

2) Governmental consumption

161,928 m^3 was consumed for governmental purposes in 1988 in the government agencies for administrative population which was 61,048 persons. This gives an average consumption for each government employee of 2.65 m^3/y. This is equivalent further to 7.3 lpcd for government users which is assumed to increase to only 10 lpcd in the target year.

3) School consumption

As stated in the Master Plan report, the per student consumption was 11.7 l/d, say 12 l/d in 1988. It is assumed that this value will remain constant up to the future.

At present there are 23,631 students in the Study Area. On the assumption that the ratio of the number of pupils and students to the total population is to be equal to the present ratio, the number of pupils and students by the year 2006 is estimated to increase to 30,000 as shown below.

$$\frac{\text{No. of Pupils \& Students}}{\text{Total Population}} = \frac{23{,}631}{61{,}908} = 38\%$$

78,200 prs x 38% = 29,720 Say 30,000 prs

4) Hospital consumption

According to the Public Health Statistics Office, the average population to hospital bed ratio was at the provincial level 862 persons/bed in 1986, and the administrative target is 700 in 1991 and 600 in 2006. However, in Phuket City, there is one public hospital with 207 beds, four private hospitals with 149 beds and 39 private clinics as of August 1989. The per bed population of the public hospital is reported at 560.7 persons which is lower than the year 2006 target. Therefore, the Phuket City is regarded as sufficient as to its hospital beds needs thus the construction of new hospitals is not expected.

Since the per bed water consumption in the future is assumed to be not much more than the present average value of 818 l/d, it is assumed to be 1.0 m^3/d by the year 2006, which is also the current water consumption level in the public hospital in the city.

5) Hotel consumption

According to the Tourist Authority of Thailand, as of August 1989, there are 30 hotels and bungalows with 1,881 rooms in the city, and at least 1,432 hotel rooms are under construction or planned for construction.

In projecting water demand for use by the hotels, it is assumed that there is a hotel construction boom which is expected to continue in the future, with 1,600 new rooms to be constructed by the year 2001. The per room consumption is assumed to remain constant at 1.2 m^3/d in the future.

6) Industrial consumption

249,486 m^3/y of water was consumed by 14 factories in 1988.

However, some of these factories have already been closed. The area along both sides of the Thachin river is regard as an industrial zone by the DTCP. The existing factories are mostly small and the development of new industrial zones and factories is hardly foreseen in the future. Therefore, industrial consumption is also assumed to remain constant in the future.

7) Restaurant consumption

The restaurant consumption was 102,637 m^3/y which is equivalent to 5% of the basic consumption in 1988. Since the restaurant business is considered to grow with the development of the city, it is assumed that this percentage will remain constant in the future. The future water demand which is calculated to be 34,500 m^3/d is presented in Table 2.8.

(4) Maximum Daily and Hourly Water Consumption

As shown in Table 2.9, the maximum daily peaking factor which is basically the ratio of the maximum daily consumption to the average daily consumption range between 1.09 and 1.16.

Since the past peak factors are relatively constant, a peaking factor of 1.20 shall be used for the calculation of future maximum daily water consumption.

Therefore, the maximum daily water consumption is:

$$34{,}500\ m^3/d \times 1.20 = 41{,}400\ m^3/d \text{ in } 2006$$

There is no data on the ratio of the maximum hourly consumption to the maximum daily consumption. A peaking factor of 1.40 for the peak hour consumption is assumed taking into account the factor of the similar cities. Therefore, the peak hour water demand is:

$$41{,}400\ m^3/d \times 1.40 = 57{,}960\ m^3/d \text{ in } 2006$$

Table 2.8 Future Water Consumption in 2006

1. Domestic and Commercial Consumption		
(1) Basic Consumption		23,460 m^3/d
- Population	78,200 pers.	
- Per capita consump.	300 lpcd	
(2) Additional Consumption		3,494
-Actual result in 1988	1,275,305 m^3/y	
2. Governmental Consumption		782
- Per capita consump.	10 lpcd	
3. School Consumption		360
- No. of students	30,000 pers.	
- Per student comsump.	12 lpcd	
4. Hospital Consumption		356
- No. of beds	356 beds	
- Per bed consump.	1.0 m^3/d	
5. Hotel Consumption		4,200
- No. of hotel rooms	3,500 rooms	
- Per room consump.	1.2 m^3/d	
6. Industrial Consumption		684
- Actual result in 1988	249,486 m^3/y	
7. Restaurant Consumption		1,164
- Rate of consump. against basic consump.	5 %	
Total		34,500 m^3/d

Table 2.9 Peak Factor

Item	1984	1985	1986	1987	1988
Maximum Daily (m^3/hr)	400	410	480	520	580
Average Daily (m^3/hr)	350	380	420	450	520
Peaking Factor	1.14	1.09	1.14	1.16	1.12

Source : Phuket Municipal Waterworks

2.4 Water Quality of River and Drainage

2.4.1 Water Quality of River and Sea

Water sampling and quality tests were conducted periodically through field investigations during rainy and dry seasons in collaboration with the Songkla University and the Marine Biological Research Center in Phuket. The results of the tests are shown in Table 2.10.

The tests were conducted to determine the extent of the existing water pollution of the river as well as sea water.

The emphases of these tests were on the concentration change of BOD, COD, SS T-P and T-N which indicate the degree of water pollution of the Bang Yai river as shown in Fig. 2-3.

The major findings are as follows:

(i) There were significant differences between the water quality of the Bang Yai river during rainy and dry seasons due to the pollution by surface runoffs of the river water during rainy season.

Table 2.10 Results of Analysis (Rainy season and Dry season)

Station	Data		Time	pH	EC (μS/cm)	CL (mg/l)	SS (mg/l)	BOD (mg/l)	COD (mg/l)	SS (mg/l)	T-P (mg/l)	T-N (mg/l)		
												NH-N	Org.	Total
R-1	1989	8/24	8:40	7.0	88.1	13	16	1.20	22.56	62.00	0.10	0.45	0.87	1.11
	1990	1/25	10:13	6.9	75.8	-	0	0.95	7.60	5.00	0.05	-	-	2.94
R-2	1989	8/24	9:05	6.8	115.4	17	11	0.65	10.24	19.50	0.16	5.52	3.90	9.42
	1990	1/25	10:45	6.9	131	-	2	3.10	15.20	8.50	0.04	-	-	4.34
R-3	1989	8/24	9:30	6.9	216	40	22	2.70	50.70	51.00	0.45	6.30	4.96	11.28
	1990	1/24	15:00	7.2	620	-	43	13.25	79.80	52.00	0.84	-	-	7.77
R-4	1989	8/24	9:50	7.0	2630	980	27	2.20	24.44	23.00	0.20	4.68	6.18	10.87
	1990	1/24	14:55	9.2	13000	-	50	12.40	273.60	80.00	0.49	-	-	7.84
B-1	1989	8/24	8:56	7.0	165	17	121	5.20	45.12	91.00	0.37	6.13	3.84	9.97
	1990	1/25	10:30	7.2	700	-	102	50.0	186.20	118.00	0.87	-	-	17.36
B-2	1989	8/24	9:20	6.8	518	73	72	6.00	54.52	48.50	1.60	10.09	6.24	16.33
	1990	1/25	10:05	7.0	717	-	27	6.80	32.30	25.50	0.35	-	-	5.11
B-3	1989	8/24	9:35	6.8	5270	1870	65	1.20	56.40	38.00	0.11	2.51	5.18	7.69
	1990	1/24	14:45	9.2	12600	-	45	13.00	136.80	61.50	0.38	-	-	3.92
B-4	1989	8/24	10:00	8.9	1947	1200	37	3.76	41.36	26.50	0.26	6.46	5.07	11.53
	1990	1/24	15:09	7.1	17270	-	45	20.00	182.40	56.00	1.04	-	-	12.74
B-5	1989	8/24	10:10	7.6	11540	16400	19	1.90	165.44	51.00	0.13	1.00	0.96	1.96
	1990	1/24	15:15	8.2	52750	-	26	7.80	965.50	197.50	0.18	-	-	0.84
D-1	1989	8/24	8:50	7.5	553	40	50	11.00	120.32	60.00	1.64	21.29	14.49	35.77
	1990	1/25	10:20	7.6	720	-	99	220.00	444.60	239.00	4.66	-	-	6.72
D-2	1989	8/24	8:59	7.2	548	49	117	15.00	139.12	75.50	1.40	18.94	16.16	35.10
	1990	1/25	10:35	7.0	470	-	90	150.00	228.00	51.00	2.85	-	-	21.14
D-3	1989	8/24	9:10	7.2	270	24	36	7.00	26.32	70.00	0.54	6.46	1.00	7.47
	1990	1/25	11:40	7.5	534	-	51	29.50	144.40	30.50	2.31	-	-	28.98
C-1	1989	8/24	7:48	8.2	1050	-	-	185.00	308.32	128.25	8.67	60.46	36.22	96.67
	1990	1/25	7:58	8.3	1000	-	-	275.00	418.00	103.00	4.88	-	-	62.72
C-2	1989	8/24	7:55	6.9	3240	-	-	670.00	2068.00	563.00	10.10	222.88	130.94	353.82
	1990	1/25	8:04	6.8	3300	-	-	975.00	1612.30	367.00	12.65	-	-	222.32

SS : Simplified method by HACH
pH, EC, Cl, SS : Analyzed by Study Team
BOD, COD, SS, T-P, T-N : Analyzed by Songkhla Uniersity
weather : 1989 8/22 , 8/23 fine
8/24 - 8/25 rain (78 mm)
1990 1/22 , 1/23 , 1/24 fine.

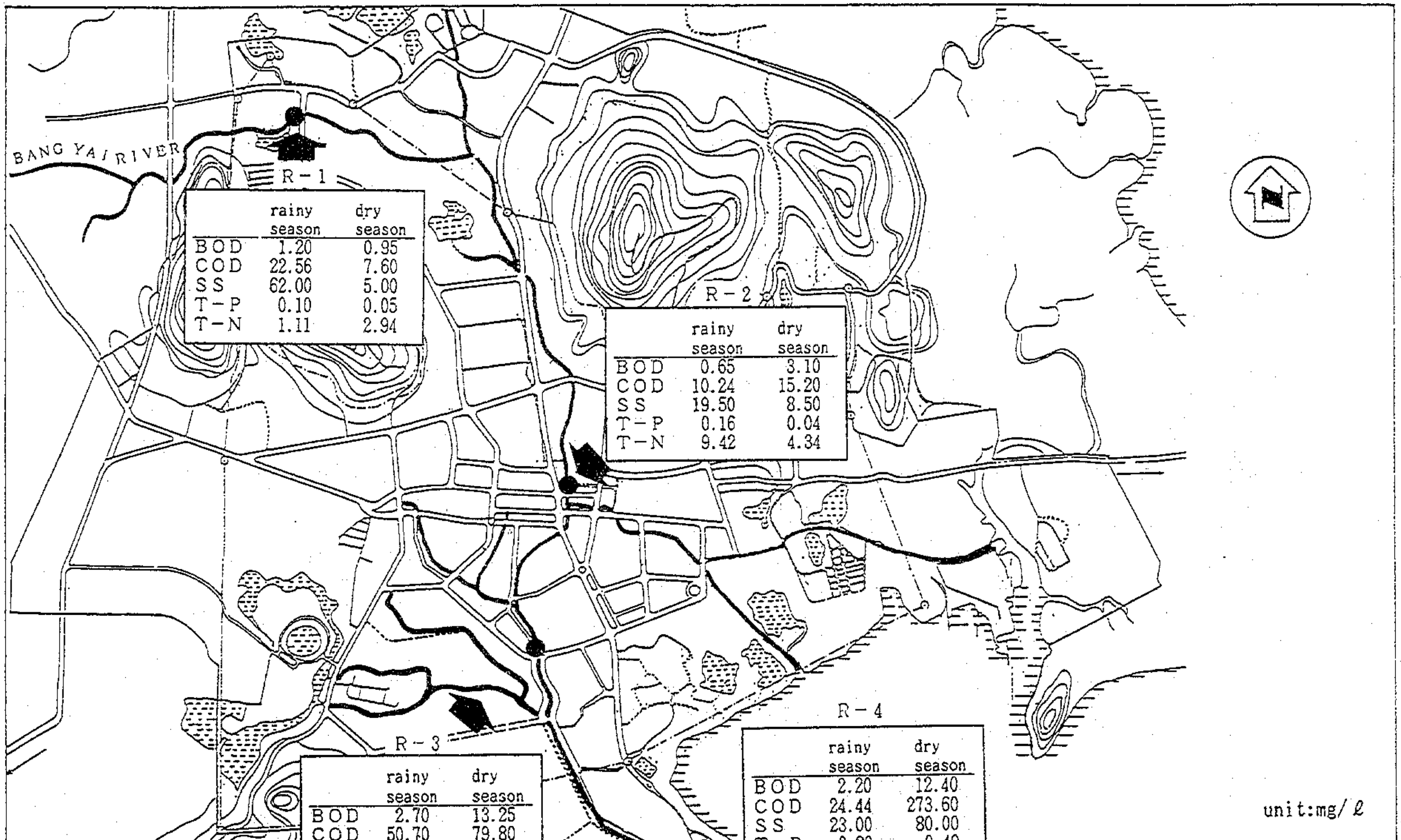


Fig. 2.3
WATER QUALITY OF THE BANG YAI RIVER

(ii) The BOD value at station R-1, located on the Bang Yai river at the entrance of the city, was the same during rainy and dry seasons, probably due to little or no inflow of domestic sewage and wastewater into the station from the upstream.

(iii) The Bang Yai river was mostly polluted at the section between R-2 and R-3 which is located downtown of the city. The BOD value in that section increased from 3.10 mg/l to 13.25 mg/l in dry season.

(iv) The BOD value near the estuary of the river, station R-4, was slightly lower than that in station R-3 due perhaps to effects of tide charges.

According to the results of the water quality tests, the pollution of the river may be mainly caused by domestic sewage and wastewater discharged by commercial establishments. Domestic sewage from these sources are being disposed using only cesspools or septic tanks. It is expected that the volume of sewage would increase largely in the future due to economic and population growth.

2.4.2 Water Quality of Drainage

Three points within the study area were chosen and their BOD values were determined to evaluate the water quality of common domestic sewage. The stations where samples were taken for investigation are shown in Fig. 2.4 and the results are given in Table 2.11. These stations are existing in the area where there are no institutions discharging much wastewater such as hotels and public offices.

Samples were taken after breakfast-time and lunch-time, when the dirtiest water is expected to flow in a day. Additional samples were taken again at the same time a week later.

The tests show that the BOD was approximately more than 100mg/l as it is presented in Table 2.11. As the exact BOD of the samples could not be obtained from the Marine Biological Center in Phuket

Table 2.11 Result of BOD Analysis

Station	Date	Time	pH	BOD (mg/L)	EC (μS/cm)	SS(by HACH) (mg/L)
X	01/27/'90	9:38	7.6	> 100	720	62
X	01/27/'90	12:32	7.6	> 100	960	96
X	02/02/'90	9:43	7.2	58.0	477	162
X	02/02/'90	12:35	6.9	> 100	662	138
Y	01/27/'90	9:50	7.3	> 100	835	91
Y	01/27/'90	12:40	7.4	> 100	980	80
Y	02/02/'90	9:50	7.3	88.5	739	64
Y	02/02/'90	12:45	7.0	> 100	712	93
Z	01/25/'90	10:35	7.0	150.0*	470	90
Z	01/27/'90	10:00	7.2	> 100	614	91
Z	02/02/'90	10:00	7.2	96.5	538	74

pH, EC, SS ; Analyzed by Japan Study Team
BOD ; Analyzed by Marine Biological Centre
*) Analyzed by Songkla University

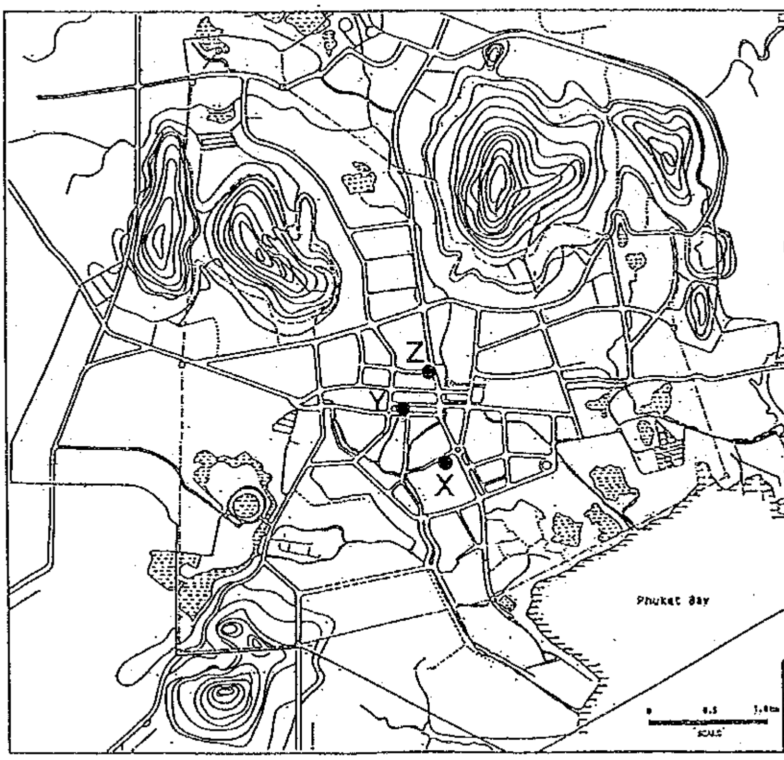


Fig. 2.4
LOCATION OF STATION

were these tests were conducted, the extent of the pollution based from these BOD tests could not be fully ascertained. However, the following can be observed:

(i) The highest BOD value of samples which were taken at each station was more than 100mg/l.

(ii) There is not much variation in the BOD value of the samples more particularly for those taken at 12:30 in the afternoon.

(iii) BOD values of samples taken after breakfast-time were lower than those taken after lunch-time at the stations X and Y.

After all, wastewater flowing through drainage channels within the downtown in the city is deemed to have a BOD value of more than 100 mg/l around 12:30 p.m., if not affected by discharge of wastewater from hotels and schools where the BOD value of wastewater discharged is estimated to be lower than that discharged from the domestic users or households.

CHAPTER 3

FORMULATION OF SEWERAGE IMPROVEMENT PLAN

CHAPTER 3 : FORMULATION OF SEWERAGE IMPROVEMENT PLAN

3.1 Summary of Existing Sewerage System

Sewerage systems refer to structures and facilities designed for the removal and disposal of domestic and industrial waste and storm water. In Phuket city, there is a public storm drainage system that is also used to remove domestic wastewater. However, there is no public sewage disposal system.

In the newly developed area in the city, the wastewater from house kitchens and washrooms, and the septage from excreta disposal are discharged to the rivers or the sea through the existing street gutters and storm drainage system. While in the center of the town, the wastewater is also drained through the street gutters, but approximately one-third volume of the domestic septage is simply allowed to infiltrate into the ground.

The existing storm drainage system, therefore, practically refers as the combined sewage collection system, even it was not originally designed for such purpose. This led to the pollution not only of the rivers and the sea water, but also of groundwater in the area.

Other pertinent findings are as follows:

(1) Almost all storm drains or sewers in the city are presently polluted basically by domestic wastewater and sewage from houses and buildings. This does not only endanger the environment but also threaten human health. The city is now facing various environmental and sanitation problems. For instance, a recent monitoring team reported that at the Bang Yai river and the Saen Suk canal water is being polluted especially from the central part of the city up to its estuary. This is highly suspected to be caused by the domestic wastewater discharged from the city.

(2) Phuket city presently has a drainage system that is mainly a combination of closed conduits, open conduits and excavated ditch-

es. However, open conduits are not only eyesores but are also unsanitary. Likewise, street gutters and canals are widely used as illegal dumping grounds of local garbage.

(3) The daily inflow and ouflow of tidewater also leads to the stagnation of wastewater more particularly at the outlets of drains and canals in low-lying areas. This is experienced not only during high tide but also after heavy rains.

(4) In Thailand, cesspools and septic tanks are widely used in the disposal and treatment of human waste. However, more modern and newer systems like anaerobic filters are being increasingly used particularly for newly constructed buildings like hotels and condominiums.

As for domestic wastewater, it is commonly found in all households that the human waste itself is collected from restrooms and then discharged to on-site treatment units. The remaining fluid portion is drained into public sewers nearby or simply allowed to infiltrate into the ground. This may lead to groundwater contamination which endangers human health.

(5) Settled sludge at the bottom of septic tanks or cesspools is presently collected by the city's concerned so-called "nightasoil" authorities once or twice a year for proper treatment and eventual disposal.

3.2 Outline of Proposed Master Plan

3.2.1 Foundamental Planning Condition

(1) Target Year

The target year for the sewerage improvement project is 2006 (B.E.2549) or 16 years from 1990.

This master plan takes into account the following:

(i) Typical planning periods for long-term sewerage projects in Japan are 15 to 20 years.

(ii) The town plan of Phuket currently prepared by DTCP involves a future land use plan for 2008, which can be a base for the study.

(iii) Quite a few plans relevant to the study set target years in the Christian Calendar with 1 or 6 as the last digit of the years such as 2001 for the Study on Potential Tourism Area Development for the Southern Region in Thailand by JICA, year 2001 of the Phuket City Development Project by AIDAB, year 2011 of the Provincial Water Supply Project by JICA and year 2006 of the 9th National Economic and Social Development Plan by NESDB.

(2) Project Area

The project area for the sewerage improvement program covers those sections included in the DTCP town planning area and the area between the DTCP town planning boundary and the Bang Ping river as shown in Fig. 3.1.

(3) Population of Project Area

The population of the project area in 2006 is projected and assumed to be 78,200. The distribution of the population in 2006 was shown earlier in Table 2.2.

(4) Design Sewage Flow

The design sewage flow in 2006 is assumed and projected as follows:

Design sewage flow = (Collected sewage into sewer) + (Ground Water infiltration into sewer)

= Water consumption x (sewage collection rate + ground water infiltation rate)

$= 34,500 \ m^3/d \times (0.8 + 0.2)$
$= 34,500 \ m^3/d$

(5) Design BOD Loading

The design BOD loading is assumed and projected as follows:

1) In case of separate collection system

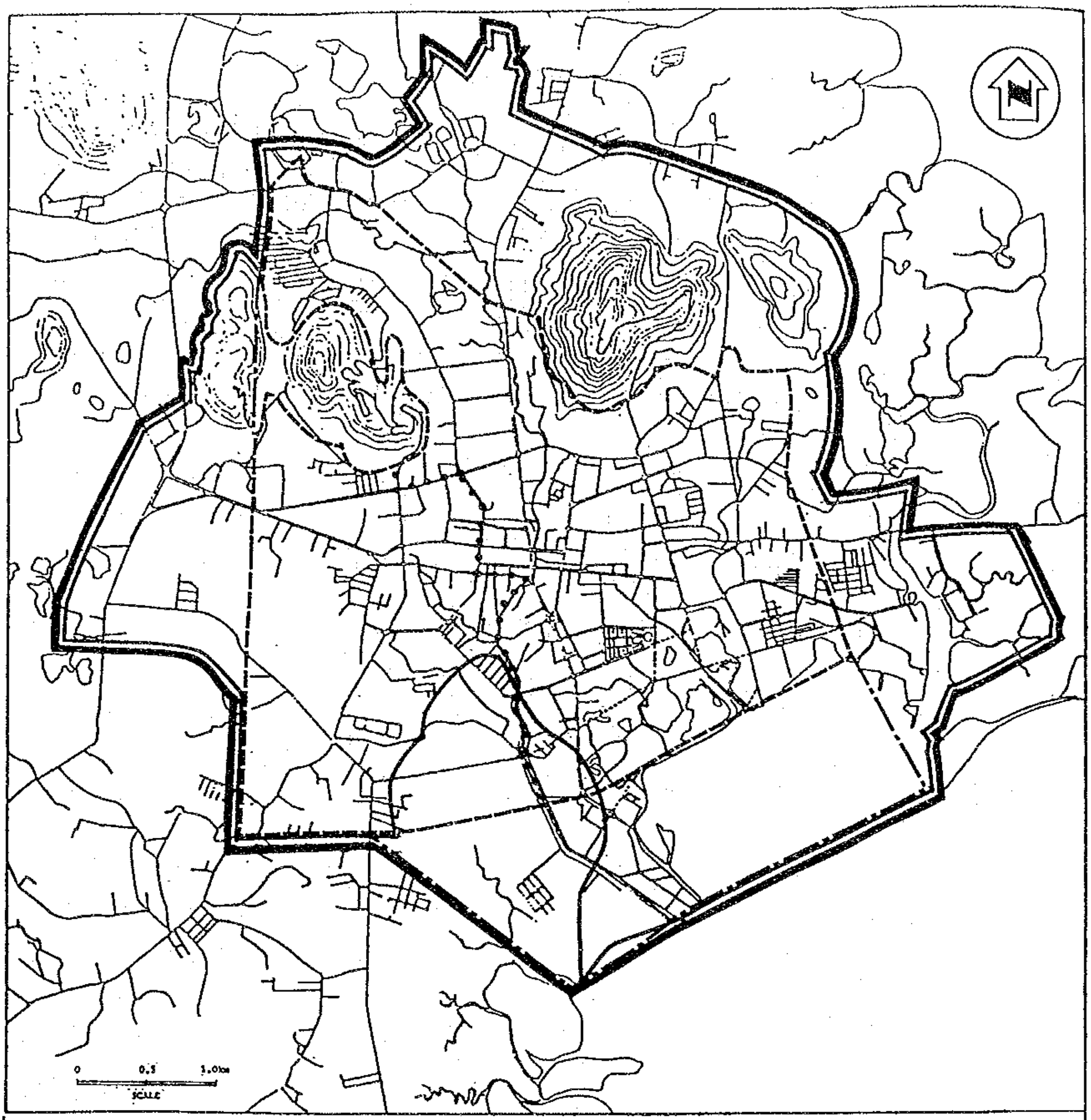
Unit : gpcd

Description	1989	1996	2001	2006
Toilet	22	22	23	23
Sullage	20	23	27	31
Total	42	45	50	54

2) In case of combined collection system

Unit : gpcd

Description	1989	1996	2001	2006
Toilet	4	7	10	12
Sullage	20	23	27	31
Total	24	30	37	43



LEGEND

Study Area for Sewerage Improvement

DTCP Town Plan Area

Present Municipal Boundary

Expanded Municipal Boundary in Future

Tambon Boundary

Fig. 3.1
STUDY AREA FOR
SEWERAGE IMPROVEMENT

3.2.2 Selected Sewage Collection System

The two widely used sewage collection systems were considered for comparison: the separate sewer system and combined sewer system. Experience has shown that taking into account the impact on the environment and water pollution control, a separate system is more advantageous of the two. However, further analysis shows that under the following conditions, a combined sewer system may be more desirable to promote the introduction of a public sewerage economically.

a. The degree of pollution of the receiving watercourses during rains is acceptable.

b. The existing public drainage system, which collects both surface runoff and sewage, can be intercepted easily to combined sewers to be constructed thus resulting in a lesser need for lateral sewers.

(1) Comparison of Alternatives

The evaluation of alternatives for planning the sewage collection system for the study area was undertaken, taking into consideration the possibility of retaining and utilizing the existing drainage facilities as much as possible. The advantages and disadvantages of these systems were evaluated in consideration of the following factors:

(i) Performance for environmental and sanitary improvement between the separate and combined sewer systems.

(ii) Potential problems foreseen after completion of the project.

(iii) Construction cost, and operation and maintenance cost.

(iv) Other factors affecting the selection of the sewage collection system.

Shown under Table 3.1 is a brief comparison of these two alternative sewer systems, taking further into consideration their impact or effect on the environment. Other factors considered included the relevant costs of construction and operation and maintenance costs, the temporary disruptive effects of construction works to both human and vehicular traffic or to the business community or the economy as a whole during the construction period. These matters are elaborated further in the next section.

Table 3.1 Comparison of Alternative Sewage Collection Systems

	Separate Sewer System	Combined Sewer System
Definition	(1) Sanitary sewage and storm water are collected principally by sewers and storm drains separately.	(1) Sanitary sewage and storm water are collected together by the combined sewers.
Method of Sewage Collection	(1) Sanitary sewage is discharged into sanitary sewers while storm water is discharged into the existing street drains as presently practice. (2) Domestic waste and watercloset and other industrial wastewater will be connected with sanitary sewers to be newly constructed.	(1) Sanitary sewage is discharged into the existing street drains just like storm water as is into presently practiced. (2) Domestic waste and watercloset and other industrial wastewater will be connected with the existing street drains or sewers to be newly constructed.
Improvement of Environmental Conditions	(1) Environmental conditions in the City as well as at the rivers and the sea will be upgraded. (2) No septic tank and cesspool will be required to construct for new house and buildings after completion of the project. To reduce the environmental effects the existing pour-flush toilet should be changed to flush-type unit. (3) Groundwater pollution caused by wastewater infiltration can be overcome.	(1) Environmental conditions of the rivers and the sea will be upgraded. (2) In the area where the existing street drains are poorly flowed mainly because insufficient slope has been provided, environmental impacts can be easily reduced by reconstruction these street drains. (3) The surface water of initial period of rain will contain high level of pollutants, being discharged to the street drains and conveyed into sewage treatment plants.
Foreseen Trouble Issues	(1) Without issuing of regulations on sewerage and upgrading of public comprehensions and awareness on environment, to connect house drains with the public sewer system may not be done smoothly. (2) For separate sewage system, if the existing open drains are connected with sanitary sewer, overloading of the sewer system may take place, particularly during rain period. (3) Since the sanitary sewers are rather small, clogging by litter may be a serious problem in the future without upgrading a public environmental understanding.	(1) It is foreseen that the existing cesspools will be remained even after the completions of the project. Hopefully, however water pollution in canals and the sea is reduced whether or not environmental conditions in the study area are improved. (2) Users will be double charged for both sewerage and septic tank cleaning services. (3) Since the existing street drains are used for combined sewer as presently practice, clogging by litter may be a serious problem in interceptors and at pumping station without upgrading public understanding of this problem. (4) Earth and sand will flow into interceptors and also into a sewage treatment plant during rain, which will pile in the bottom of the channels, sedimentation tanks and so on for a long time.
Construction	(1) Installation of lateral sewers and house connections is required in the City side.	(1) It has been experienced before that, in general, wherever storm sewers have already been existed to employ a combined sewerage system is much more considerate than a separate system. By contrast, with some constraints such as the necessity of interception system and observed high tide as for this study, this statement is reliable. (2) Fewer or limited amount of lateral sewers and lesser house connections will be required in the City side.

(2) Cost Comparison of Alternatives

1) Outline of facility

The following table presents a description of the major facilities to be installed and constructed for each alternative. The routes of the trunk sewers in each alternative are shown in Figs. 3.2 and 3.3 in a simplified manner.

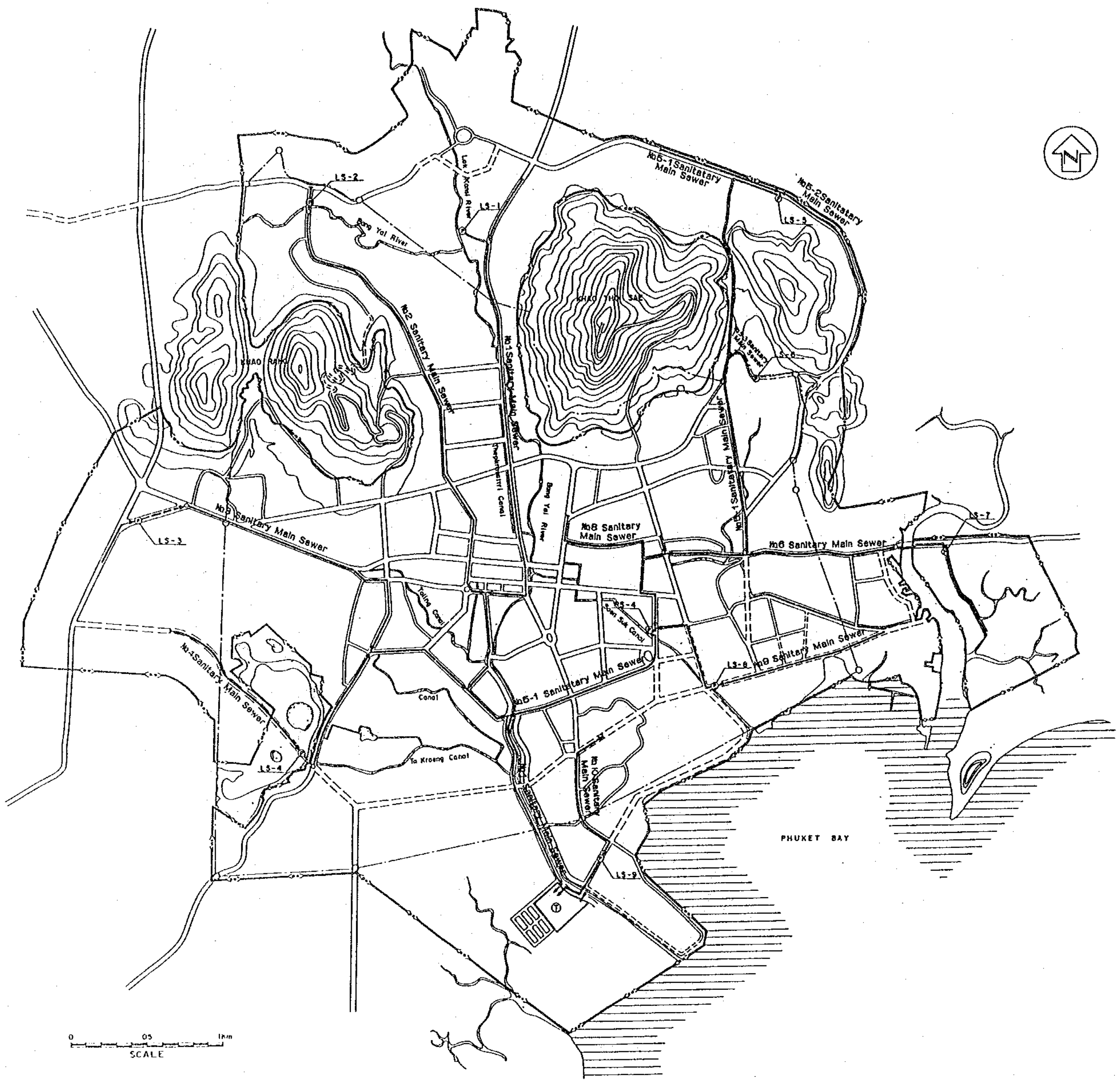
Comparison of Major Sewer Facilities

Item	Size	Length of Sewer Separate System	Length of Sewer Combined System	Remarks
-Main Sewer				
Open cut	ϕ100-1,200 mm	21,280 m	15,750 m	PVC,RCP
Jacking	ϕ600-1,500	1,820	1,290	RCP
Pressure	ϕ100- 500	2,420	2,570	CIP
-Lateral Sewer				
	ϕ200- 250	53,750	15,450	PVC
Sewer Total		79,290 m	35,060 m	
-Inverted Siphon				
	ϕ200-1,200 mm	8 unit	13 unit	
-Pump Station				
Lift station		9 unit	10 unit	
Pump Station		1	2	
Pump Station Total		10 unit	12 unit	

2) Study and cost evaluation

Unit costs were established first. The estimated unit costs for sewer construction are presented in Annex Figs. 3.1 to 3.4. Unit costs were prepared for the following:

- -sewer construction cost (open cut method)
- -sewer construction cost (normal jacking method)
- -pumping station cost
- -annual operation & maintenance cost



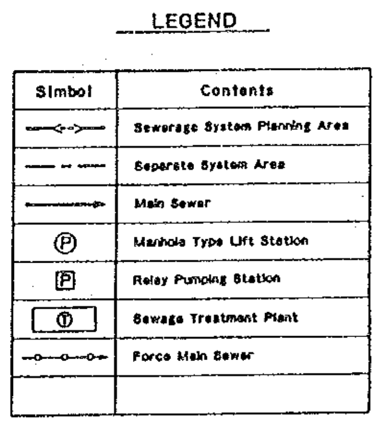


Fig. 3.2
ROUTE MAP OF SEWER SYSTEM
(SEPARATE SYSTEM)

LEGEND

Simbol	Contents
	Sewerage System Planning Area
	Separate System Area
	Main Sewer
N	Intersepting Point (Diversion Facility)
P	Manhole Type Lift Station
P	Relay Pumping Station
T	Sewage Treatment Plant
	Force Main Sewer
	Combined Sewer

Fig. 3.3
ROUTE MAP OF SEWER SYSTEM
(COMBINED SYSTEM WITH PARTIALLY SEPARATE SYSTEM)

The estimated total capital cost and operation and maintenance costs of each alternative are summarized in the following Tables 3.2 and 3.3.

Table 3.2 Comparative Construction Costs for the Separate and Combined Systems (Direct Cost)

Unit: Million Baht

Item	Separate system	Combined system
Direct Cost		
Sewer installation	159.4	152.5
Lateral Sewer installation	69.9	20.1
Inverted siphon	7.7	10.8
Pump station	8.0	9.1
Others	——	0.5
Total (Rate)	245.0 (127%)	193.0 (100%)

Table 3.3 Comparative Operation and Maintenance Costs for the Separate and Combinedd Sewer Systems

Unit: Million Baht

Item	Separate system	Combined system
Cleaning of sewer (every three years)	0.82	0.35
Operations Cost (for pumps)	1.05	0.95
Total	1.87 (144%)	1.30 (100%)

The comparative cost estimates indicate that the separate system would be more expensive than the combined system considering both capital cost and operation and maintenance costs. The total estimated capital cost of the separate system is about 27 percent higher that the cost of the combined system. Besides, the operation and maintenance cost of the former also exceeds by about 44 percent the cost of the latter. This is mainly due to the difference of the length of lateral sewers to be provided.

On the basis of the various studies and field surveys on the existing drainage facilities, it was initially recommended that the original sewer system should be basically a separate system, but in response to immediate needs, existing public drains should be used as temporary combined sewers until such time when financing for a complete separate system is possible.

The interceptor sewer of the recommended combined system would be adaptable for conversion as a trunk sewer of a separate system considering not only the diameter of the sewer but also considering the design or lay-out of the pipe network itself.

3.2.3. Selected Sewage Treatment Process

With regard to the selection of an optimum treatment process, the commonly used processes were comparatively considered first.

a. Activated Sludge Process

- Conventional Activated Sludge Process
- Modified Aeration Process
- Oxidation Ditch Process
- Extended Aeration Process
- Step Aeration Process
- Contact Stabilization Process
- Modified Aeration Process
- High-Rate Activated Sludge Process

b. Rotating Biological Contactor Process

c. Trickling Filter Process

- Low-Rate Trickling Filter Process
- High-Rate Trickling Filter Process

d. Stabilization Pond Process

- Aerated Lagoon Process

- Aerobic Pond Process
- Facultative Pond Process

In line with the basic purpose of this project, the trickling filter process and stabilization pond process were not considered because the site provided for the construction of the sewage treatment plant was as small as 30 rais (approximately 5 ha). This is insufficient for such processes.

Therefore, the following three processes were selected for comparative study.

- Conventional Activated Sludge Process
- Oxidation Ditch Process
- Rotating Biological Contactor Process

(1) Preliminary Design Considerations

- Design wastewater flow	35,000 m^3/day (Design mean dry weather flow)
- Design water quality	Influent BOD: 120 mg/l Influent SS : 100 mg/l
- Removal efficiency	BOD target : 90% SS target : 75 to 80%
- Design value of each facility	Refer to design criteria
- Site area	approx. 5 ha
- Design ground height	+2.50 m (Existing ground height: +1.0 m)

- Design receiving water level height — +2.0 m

- Dewatering procedure — Drying sand beds for each process

(2) Comparison of Alternatives

1) Outline of designed facilities

Preliminary designs of the three sewage treatment processes selected above were made for cost comparison purposes. Their typical layout drawings are shown in Figs. 3.4 to 3.6.

2) Study and cost evaluation

Cost considerations were focused on the following items:

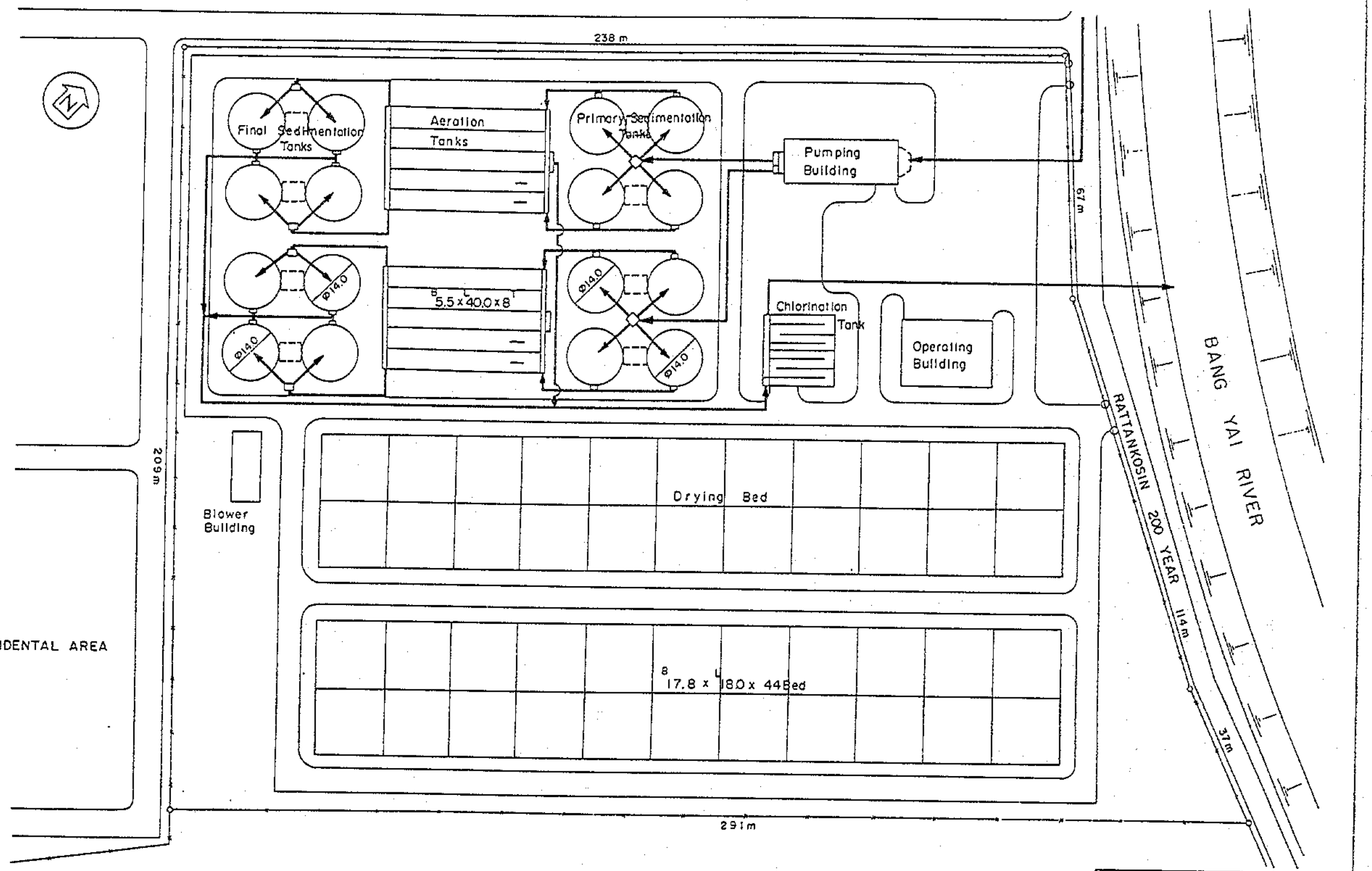
- Construction cost
- Operation and maintenance costs
- Other factors/characteristics
  . Ordinary characteristics
  . Flexibility
  . Workability

The evaluation was made using an "A-B-C" rating system where each alternative is rated accordingly. The "A" rating implies that the alternative considered is the best. A "B" rating means that the alternative is second best. Lastly, a "C" rating means that the alternative is least advantageous among those considered.

a. Construction cost

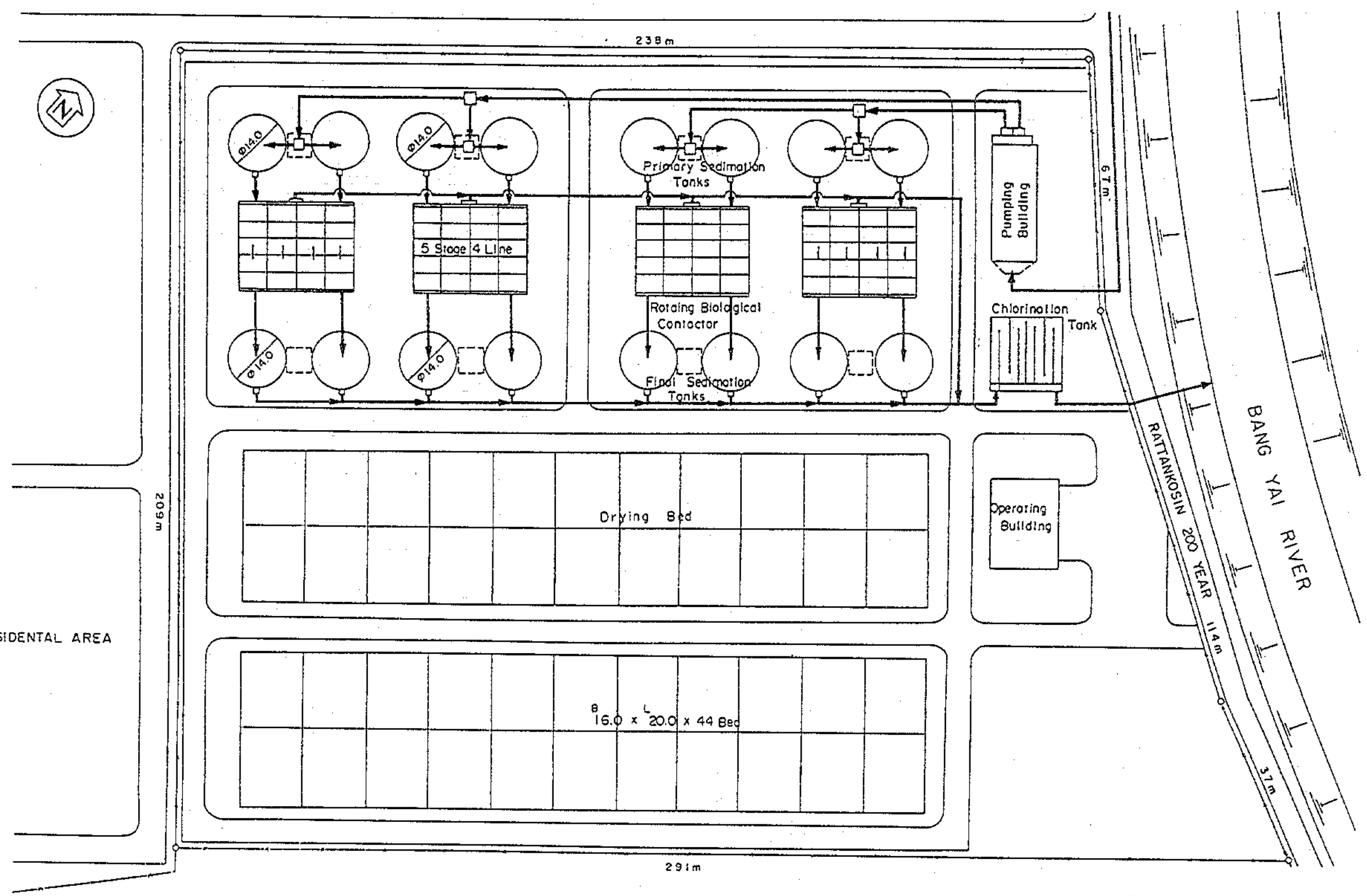
Based on the direct construction cost of the three processes selected above which are shown in Table 3.4, the following ratings were made:

Process	Rating
- Conventional Activated Sludge Process	"A"
- Rotating Biological Contactor Process	"C"
- Oxidation Ditch Process	"A"



Scale = 1:1000

Fig. 3.4
TYPICAL LAYOUT OF CONVETIONAL ACTIVATED SLUDGE PROCESS



Scale = 1:1000

Fig. 3.5
TYPICAL LAYOUT OF ROTATING
BIOLOGICAL CONTACTOR PROCESS

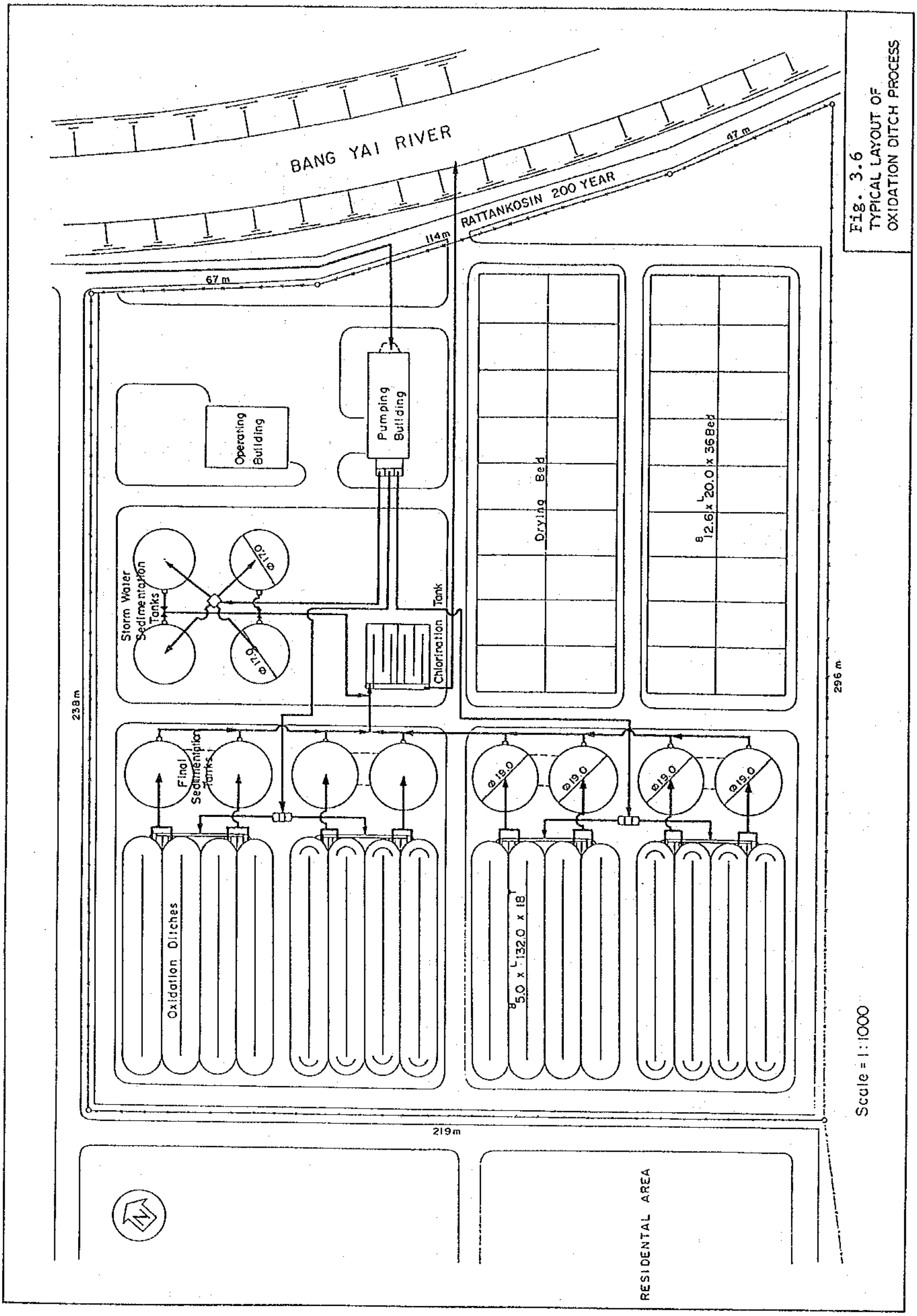


Fig. 3.6
TYPICAL LAYOUT OF
OXIDATION DITCH PROCESS

Table 3.4 Direct Construction Cost of Treatment Processes Considered

Unit: Thousand Baht

Item	Conventional Activated Sludge Process	Rotating Biological Contactor Process	Oxidation Ditch Process
1. Structures	83,801	78,193	79,390
2. Mechanical installation	88,637	192,870	94,390
3. Electrical installation	50,980	51,785	51,007
Total	223,418 (100%)	322,848 (144%)	224,701 (101%)

b. Operation and maintenance costs

The ratings considering the operation and maintenance costs comparatively shown in the Table 3.5 are as follow:

Process	Rating
- Conventional Activated Sludge Process	"A"
- Rotating Biological Contactor Process	"C"
- Oxidation Ditch Process	"A"

Table 3.5 Comparative Operation and Maintenance Costs for Various Treatment Processes

(Unit: Thousand Baht)

Item	Conventional Activated Sludge Process	Rotating Biological Contactor Process	Oxidation Ditch Process
Personal Expense	890	678	599
Civil Structure Repair Expense	563	513	547
Mechanical Equipment Repair Expense	2,106	3,895	2,025
Electrical Equipment Repair Expense	411	417	411
Expense of Electricity	3,465	5,017	4,211
Expense of Chlorine	593	593	593
Expense of Fuel	85	85	85
Total	8,112 (100%)	11,197 (138%)	8,471 (104%)

Note: For the detailed calculations of the operation and maintenance costs, see Section 9.3 in the Master Plan Report on this project.

c. Other factors / Characteristics

Attempts were made to evaluate these alternatives considering various non-monetary or cost-related criteria . The details are given in Table 3.6.

Table 3.6 Evaluation on Various Characteristics

	Conventional Activated Sludge Process	Rotating Biological Contactor Process	Oxidation Ditch Process
i) General Characteristics			
Amount of Sludge Production	much	much	slightly small
Action of Nitrification of nitrogenous compounds	good to some extent	good	good
Influence to Surrounding Environment	some problems on odor	some problems on odor and trams- parency of treated water	comparatively good
(Evaluation on Items)	(B)	(C)	(A)
ii) Flexibility			
Stability against Shock Load	a little unstable	good	good
Stability against Loading Fluctuation	a little unstable	a little unstable	good
Stability against Toxic Substances	possible to cope with	possible to cope with	possible to cope with
Stability against Fluctiation of Water Temperature	a little unstable	a little unstable	stable
(Evaluation on Items)	(C)	(B)	(A)
iii) Workability			
Difficulties of Operation Control	comparatively hard	comparatively easy	comparatively easy
Establishment of Operation System	complete	complete	complete
Number of Inspection Points	many	few	extremely few
Necessity of high Grade Technique	necessary to skill operation	not necessary	not necessary
(Evaluation on Items)	(C)	(B)	(A)
Overall Evaluation	C	B	A

(3) Recommendation

After considering such factors like the construction costs, operation and maintenance costs and various characteristics of each treatment process, an overall evaluation is made to select the optimum treatment process. The result is summarized as follows under Table 3.7.

Table 3.7 Result of Evaluation for Alternatives

	Conventional Activated Sludge Process	Rotating Biological Contactor Process	Oxidation Ditch Process
Construction Cost	A	C	A
Operation and Maintenance Costs	A	C	A
Various Characteristics	C	B	A
Overall Evaluation	B	C	A

Table 3.7 above the Oxidation Ditch Process is recommended as the optimum sewage treatment system for the project.

3.3 Formulation of Urgent Improvement Plan

3.3.1 Study of Urgent Improvement Plan

(1) Current Environmental Situation

A review of existing environmental problems in the study area is discussed herein focusing on water pollution and the surroundings of the Bang Yai river so as to formulate the urgent improvement project. The current environmental situation in the study area is as follows:

1) Almost all public sewers in the study area are presently polluted basically by domestic and business wastewater. Consequently, this not only results into the degradation of the environment and polution of riverwater but it also endangers the area as a whole.

2) As a proof of the above, water in the Bang Yai river and its tributaries is getting gradually polluted. The BOD value of the riverwater near the entrance to the city in dry season was 0.95 mg/l, but going as high as 13.25 mg/l at mid-downtown as described in the preceding sub-section 2.4.1. At the Thepkrasattri canal before the junction with the Bang Yai river at sampling station B-1, the BOD value is higher at 50 mg/l.

3) The average population density of the study area is assumed to be 30.3 prs/ha in year 2006. However, it was assumed that there would be higher density areas with as much as 55 to 119 prs/ha especially at the city's central area and a part along the Bang Yai river. It is foreseen that the increasing population similarly mean increased wastewater up to such extent that it would cause more uncomfortable living conditions in the area.

(2) Study of Urgent Subject Area

With the end goal of reducing the extent of water pollutions and checking and improving the deteriorating conditions in the area, the study would be developed formulating first an appropriate urgent improvement plan taking into account the capital investiment required and the desired end results. As the objective is to introduce a public sewerage system in the city, the most important concerns are to select the optimum design target year and the project study area. The design study area is selected taking into account the following:

(i) high population density area as it discharges the biggest volume of pollutants.

(ii) the vicinity of the upstream of the Bang Yai river rather than the downstream as the upstream has a much greater influence in environmental pollution to the river than the downstream areas.

(iii) still-to-be-developed area of street drain as it is easy to intercept wastewater discharged from houses and buildings into sewers to be constructed.

(iv) combined sewage collection area rather than separate collection area as the former requires none if not lesser expense for installation of lateral sewers and house connections, while the latter surely requires it, the cost of which is to be shared eventually by the users.

The selection of the design area and population in 2006 by land use plan category in each zone are shown in Table 3.8, which are prepared intensively for 16 blocks considering planning population density. This is illustrated in Annex Figure 3.5.

The basis of the selection of the areas to be included in the urgent improvement area is elaborated in Table 3.8.

Based on the above study, blocks Nos. 2, 3 and 10 are selected for inclusion in the feasibility study area. However, it is recommended that block No. 2 be incorporated in the second stage of the construction as the present drainage facilities along the street in the area is not yet completely developed. The Feasibility Study Area including Phase 1 and Phase 2 is showing in Fig. 3.7.

Table 3.8 Selection of Urgent Area to Introduce Sewerage System

Block No.	Prerequisite Item: High Population Density Area more than 55 prs/ha	Prerequisite Item: Combined Sewage Collection Area	General Requisite Item: Up-stream Area of Bang Yai river	General Requisite Item: Street Drain Developed Area	Selected area for Feasibility Study
1		o	o	o (partial)	
2	o	o	o	o (partial)	o
3	o	o	o	o	o
4		o			
5		o		o	
6					
7	o		o	o	
8					
9		o	o	o (partial)	
10	o	o	o	o	o
11				o (partial)	
12					
13					
14					
15					
16					

(3) Target Year

The target year for the urgent sewerage improvement project is 2001 (B.E.2544) which is only 11 years from 1990.

Year 2001 is chosen for the following reasons:

(i) The target year of the Master Plan for this particular project is 2006 (B.E.2549).

(ii) Assuming a total period of 5 years for detailed design, bidding and construction of this project, the system is slated to be operational in 1996.

(iii) Considering the diffusion of house connections into the existing drainage and or intercepting sewers including sullage and domestic wastewater, the system is forecasted to operate under the designed full load in 2001.

3.3.2 Optimum Improvement Plan

Through the project optimization study in the previous section, the optimum improvement plan is summarized as follows.

(1) Target year

The target year for the urgent sewerage improvement project is 2001 (B.E.2544).

(2) Design Area

The proposed design area is selected as an urgent subject area for mitigation of water pollution of the Bang Yai river and for the improvement of the sanitary condition. This brings the central area of the city into focus. The project implementation will be divided into two stages. System capacity of the first stage development will be designed solely for commercial and high density residential zone in the city, being population of 22,900. The second stage development will deal with the new developing area of northern part of the city in which population is estimated at 6,700 in 2001.

(3) Justification of the Urgent Improvement Plan

Aiming at reducing water pollution in the Bang Yai river and recovering its amenity, the provisional plan was discussed in the preceding sections. In this line an attempt will be made on justification of the proposed urgent improvement plan as the Feasibility Study hereunder.

1) The following tables, Table 3.9 and Table 3.10, show the relative population, designed flow and comparative BOD load between the Master Plan and the Feasibility Study Plan by year 2006 for comparision.

Table 3.9 Comparison of Population and Sewage Flow between Master Plan and Feasibility Plan

	Master Plan Area	Feasibility Study Area
Population	78,200 prs (100%)	31,900 prs (41%) (29,600 prs in 2001)
Sewage Flow	34,500 m3/d(100%)	19,160 m^3/d(56%) (18,300 m^3/d in 2001)

Table 3.10 Comparison of BOD Load to be generated from Master Plan Area and Feasibility Study Area in 2006

Items	Master Plan Area		Feasibility Study Area	
	Total Area	Discharging Area into Bang Yai River Upstream of Tailing Chan Br.	Discharging Area into Bang Yai River Upstream of Tailing Chan Br.	First Stage Construction Area among the Preceding column
1. Population (prs)	78,200	34,000	25,000	18,000
2. Sewage Flow (m3/d)	34,500	16,500	13,000	10,500
3. Assumed BOD (mg/l)	120	120	120	110
4. BOD Load (kg/d) = (2) x (3)	4,140	1,980	1,560	1,155
5. Ratio of BOD Load Against Total	(100%) -	(48%) 100%	- 79%	- 58%