projects;

(4) Conduct of a public awareness campaign on environmental issues; and

(5) Creation of a tripartite organization (involving communities, enterprises and the government) to act as environmental overseer.

3.2.2 Special Committee for the Formulation of Policies and Countermeasures to Control Water, Air and Noise Pollution in Thailand

This committee formulated a number of policies and countermeasures to control environmental pollution not only in the area of water resources, but also in the area of air and noise. These policies and countermeasures are envisaged to be implemented and enforced by relevant agencies which have been duly designated. Succeeding discussions will only focus on water pollution-related areas.

(1) Policies and Guidelines

1) Strict enforcement of existing laws and regulations for the planning and management of pollution control systems, strict application of land use plans, and adequate control over project implementation;
2) Set-up of monitoring and inspection systems to evaluate environmental quality vis-a-vis the set standards as well as environmental parameters defined in project environmental analyses;
3) Reduction of pollution load through wastewater management planning and construction of appropriate wastewater treatment systems;
4) Utilization of financial mechanisms to support government investments in pollution control and management, and promotion of private investments in the same aspect; and
5) Promotion of public awareness and involvement in pollution control and management.

Specific countermeasures formulated by the committee are presented in Tables 3.2.1 to 3.2.2.

Table 3.2.1 Short-Term Water Pollution Countermeasures

FORMULATED COUNTERMEASURES	Start of Implemen.	Concerned Agencies
A. LEGAL COUNTERMEASURES		
1. Effectively enforce all domestic wastewater standards. Local administrations, the Bangkok Metropolitan Authority (BMA) and other concerned agencies shall integrate the wastewater standards with existing laws and regulations, e.g. building control law, BMA and municipal regulations, etc.	1990	ONEB, PWD, BMA, municipal governments, MOPH
2. Set penalties for violations of water pollution laws and regulations. Existing penalties shall be fully applied and fines shall be set higher.	1991	ONEB, DIW, DOL, MOPH
3. Establish livestock wastewater treatment standards	1991	ONEB, MOI, DOL, MOPH, DOF
4. Develop regulations to control construction /land use near the banks of rivers, canals, and other public water resources.	1991	HD, municipalities, province
5. Inclusion in project contracts of clauses/ conditions to prohibit discharge of refuse, wastewater, oil, chemical agents to rivers	1990	HD
6. Set higher qualities for the discharge of wastewater to and obstruction of water resources	1990	HD
B. INVESTMENT COUNTERMEASURES		
1. Construct wastewater treatment facilities at:		
a) Rattanokosin Island	1991	BMA
b) See Phraya	1991	BMA
c) Yannawa	1991	BMA
d) Tourism seaboard areas. i.e. Jomthien, Naklua, Pattaya, Bangsaen, Sirracha and Hua Hin	1991	PWD
e) Chonburi	1991	PWD, Chonburi Municipality
f) Surat Thani and Songkhla	1992	PWD, concerned municipality
g) 108 government hospitals	1991	MOPH
h) University-run government hospitals	1991	Office of University Affairs
i) Cold/Fishery storages at Yannawa, Samut Prakarn, and Samut Sakorn	1991	Gov't Cold Storage Organ. Fish Marketing Organization
j) Tobacco factory	1991	Tobacco Monopoly

....cont'd

Table 3.2.1 Short-Term Water Pollution Countermeasures (cont'n)

FORMULATED COUNTERMEASURES	Start of Implemen.	Concerned Agencies
k) Bangkok Port	1991	Port Authority of Thailand
l) Provincial/municipal slaughter houses	1991	Concerned municipalities
m) Correctional facilities	1991	Department of Corrections
n) Local administration markets	1991	LAD,MOI,local administration
2. Construct central wastewater treatment plants at industrial projects in Samut Prakarn :		
a) Sukhasawasdi Project	1992	DIW
b) Phoochao Samingprai Project	1991	DIW
c) Thepharak Project	1991	DIW
3. Construct hazardous waste treatment and disposal center at Bang Plee, Samut Prakarn	1993	DIW
4. Construct refuse disposal and transport center at Onnuch, Ram Indra and Nongkham	-	-
5. Install refuse disposal systems in public transportation, i.e., buses, trains, etc.	1991	Ministry of Communications
6. Construct 2-3 refuse disposal areas (sanitary landfill). Private sector shall support the investment and operations	1991	BMA
7. Install an incinerator for pathogenic refuse from hospitals	1991	BMA
C. OTHER MANAGEMENT COUNTERMEASURES:		
1. Conduct a Master Plan of wastewater treatment for Bangkok Metropolis and its vicinities	1990	BMA, PWD
2. Conduct a study and master plan of wastewater treatment along canals in Bangkok	1991	BMA
3. Acquire land for future wastewater treatment and refuse disposal facilities near water resources		
4. Conduct a feasibility study of wastewater treatment plants for Chiang Mai, Hat Yai, Nong Harn, Ban Pae, and the eastern seaboard of Phuket	1991	PWD
5. Conduct a study of wastewater management for Pathum Thani and Ayutthaya municipalities	1990	ONEB

....cont'd

Table 3.2.1 Short-Term Water Pollution Countermeasures (cont'n)

FORMULATED COUNTERMEASURES	Start of Implemen.	Concerned Agencies
6. Conduct a study of wastewater collection and drainage system for the municipality of Samut Prakarn	1990	ONEB
7. Establish a database system for industrial environmental information and monitoring	1991	DIW
8. Immediately prepare guidelines/measures for economical refuse disposal in small and medium size communities	1991	MOI, ONEB
9. Conduct a study of suitable methods to drain agricultural wastewater	1992	Department of Agriculture
10. Conduct a study of methods to dispose aquaplants	1990	HD
D. PUBLIC AWARENESS CAMPAIGN		
1. Conduct `1991 is wastewater treatment year' campaign	1991	ONEB

Table 3.2.2 Long-Term Water Pollution Countermeasures

FORMULATED COUNTERMEASURES	Start of Implemen.	Concerned Agencies
1. Monitor and control activities on the banks, e.g. operations of floating restaurants, transportation ships/boats/etc.	-	HD
2. Monitor and control environmental protection measures as defined in project proposals and environmental impact assessment studies.	-	ONEB
3. Undertake land use planning specifically in the identification of suitable drainage areas	1991	DTCP, MOI
4. Define suitable industrial areas as well as prohibit industries from locating in poor drainage areas		
5. Promote and support private industrial estates	1991	DIW
6. Promote private sector investments in centralized wastewater treatment plants	1991	DIW
7. Promote private sector investments in hazardous waste disposal facilities in high-density industrial areas.	1991	DIW
8. Establish organizations for the effective management of both effluent discharge and wastewater treatment systems	1991	ONEB
9. Undertake master planning of solid waste disposal in major cities/provincial centers	1991	LAD, PWD
10. Amend Ship Transportation Act. Establish additional penalty-setting regulations	1991	HD
11. Continuously monitor water quality and public sanitation	1991	ONEB
12. Study reuse/recycling of treated wastewater	1991	
13. Undertake long-term public awareness campaign	1991	

3.3 Environmental Water Quality Standards, and Relevant Laws and Regulations

Numerous standards, laws and regulations have been decreed in Thailand for purposes of environmental quality management. Summarized hereunder are the standards, laws and regulations pertinent to water quality management.

3.3.1 Effluents

(1) Industrial Effluent

Table 3.3.1 presents the standards set for industrial effluents, and the applicable penalty for non-compliance. Other regulations relevant to industrial water pollution control are shown in Tables 3.3.2 to 3.3.4.

(2) Domestic Effluent Guidelines

Table 3.3.5 presents domestic effluent guidelines for different community groups classified according to population size, while Table 3.3.6 shows the guidelines for wastewater analysis.

(3) Building Effluent Standards

Table 3.3.7 presents the proposed effluent standards for different building types of various size classifications.

(4) Waste Dumping into Public Water Courses

Navigation in Thai Water Act BE 2456 (1913), Article 119, as amended under the Announcement of the Revolutionary Party No. 50, dated January 19 BE 2515 (1972) stipulates that "it is forbidden to dump rocks, gravels, silt, soil, mud, detritus, solid wastes, sewage, oil and chemicals in public water courses such as rivers, canals, swamps, reservoirs, and lakes used for navigation or for other utilization".

Table 3.3.1 Industrial Effluent Standards

Items	Units	Standard values	Remarks	
BOD (5 days, at 20°C)	mg/l	20-60	Fishery canning	Max. 100
			Starch industry	
			Centrifugal	Max. 60
			Sedimentation	Max. 100
			Noodle industry	Max. 100
			Tanning industry	Max. 100
			Pulp industry	Max. 100
			Frozen food industry	Max. 100
Suspended solids (SS)	mg/l	Depend on dilution	Ratio	
		ratios of wastewater	1/8 to 1/150	Max. 30
		and receiving water	1/151 to 1/300	Max. 60
			1/301 to 1/500	Max. 150
Dissolved solids (DS)	mg/l	Max. 2,000 or under office's consideration but not more than 5,000	If salinity of receiving water is higher than 2,000 mg/l, DS in the effluent should not be higher than 5,000 mg/l of the DS in the receiving water	
pH	-	5-9		
Permanganate value	mg/l	Max. 60		
Sulfide as H_2S	mg/l	Max. 1.0		
Cyanide as HCN	mg/l	Max. 0.2		
Tar	mg/l	none		
Oil & Grease	mg/l	Max. 5.0	Refinery & Lubricant oil industry Max. 15.0	
Formaldehyde	mg/l	Max. 1.0		
Phenol & Cresol	mg/l	Max. 1.0		
Free Chlorine	mg/l	Max. 1.0		
Insecticides	mg/l	none		
Radioactivity	Bq./l	none		
Heavy metals				
Zinc (Zn)	mg/l	Max. 5.0	Zinc industry	Max. 3.0
Chromium (Cr)	mg/l	Max. 0.5	Zinc industry	Max. 0.2
Arsenic (As)	mg/l	Max. 0.25		
Copper (Cu)	mg/l	Max. 1.0		
Mercury (Hg)	mg/l	Max. 0.005	Zinc industry	Max. 0.002
Cadmium (Cd)	mg/l	Max. 0.03	Zinc industry	Max. 0.1
Barium (Ba)	mg/l	Max. 1.0		
Selenium (Se)	mg/l	Max. 0.02		
Lead (Pb)	mg/l	Max. 0.2		
Nickel (Ni)	mg/l	Max. 0.2	Zinc industry	Max. 0.2
Manganese (Mn)	mg/l	Max. 5.0		
Silver (Ag)	mg/l	-	Zinc industry	Max. 0.02

Penalty: A license for operation a factory who does not comply with this notification shall be punished by fine not exceeding ten thousand Baht.

Source: (1) Notification of the Ministry of Industry No. 12 B.E 2525 (1982) issued under the Factory Act B.E. 2521 (1978) published in the Royal Government Gazette, Vol. 99, Part 33, dated March 5, B.E. 2525 (1982)

(2) Notification of the Ministry of Industry No. 10 B.E 2521 (1978) issued under the Factory Act B.E. 2521 (1978) published in the Royal Government Gazette, Vol. 95, Part 132, dated November 28, B.E. 2521 (1978)

Table 3.3.2 Industrial Water Pollution Control Regulations (I)

I. Industrial plants which shall require machine operators/supervisors of water pollution control systems with qualifications specified in Table 3.3.3

1. An industrial plant discharging wastewater at higher than 60 cubic meters/hour (with the exception of cooling water), or having the BOD load of influent at higher than 100 kilogram/day.

2. An industrial plant using heavy metals in the production process discharging wastewater at higher than 50 cubic meter/day, and having the content of heavy metals in the discharge water at the following values:

   (a) Zinc at higher than 25,000 milligrams/day
   (b) Chromium at higher than 25,000 milligrams/day
   (c) Arsenic at higher than 12,500 milligrams/day
   (d) Copper at higher than 50,000 milligrams/day
   (e) Mercury at higher than 250 milligrams/day
   (f) Cadmium at higher than 1,500 milligrams/day
   (g) Barium at higher than 50,000 milligrams/day
   (h) Selenium at higher than 1,000 milligrams/day
   (i) Lead at higher than 10,000 milligrams/day
   (j) Manganese at higher than 250,000 milligrams/day

3. An industrial plant dealing with iron and steel:

   (a) Using during furnace or acids or other substances which may be polluting the environment in the production process, with production capacity of higher than 100 tons/day.

   (b) Using steel smelters with the total capacity of 5 tons/batch.

4. An industrial plant producing petrochemicals from the raw materials obtained as by-products of the Oil refinery in the production process at higher than 100 tons/day.

5. An industrial plant of any size separating or processing the natural gas.

6. An industrial plant producing chlor-alkali, using sodium chloride (NaCl) as raw material in the production of soda ash (Na_2CO_3) caustic soda (NaOH), hydrochloric acid (HCl), chlorine (Cl_2) and bleaching (NaOCl each or several combined at higher than 100 tons/day.

7. An industrial plant of any size producing cement.

8. An industrial plant engaged in ore smelting or production of metals at higher than 50 tons/day.

9. An industrial plant producing paper pulp at higher than 50 tons/day.

10. An industrial plant of any size engaged in crude oil refinery.

Table 3.3.3 Industrial Water Pollution Control Regulations (II)

Qualification requirements of supervisors and machine operators of water pollution control systems.
1. The supervisors are holders of bachelor degree in engineering, or science in chemistry, or other branches or study with experiences in the field of environment, and who has been approved by the Industrial Factory Department. In the case of an engineering consulting firm, it must be operated by person(s) having the qualifications mentioned above.
2. The machine operators must be graduates of the secondary education, lower level, with the certification from the persons as mentioned in (1).
3. The persons stated in (1) and (2) must register themselves with the Industrial Works Department, and comply with the regulations and procedures as prescribed by the Industrial Works Department.

Table 3.3.4 Industrial Water Pollution Control Regulations (III)

Monitoring Reporting Requirements
1. Factories mentioned in Table 3.3.2 must arrange to make Poisonous Matter Analysis Reports and submit them to the Industrial factories Department every 3 months on the form and according to the procedures prescribed by the Industrial Factories Department. The analysis of the qualities of poisonous matter must be performed by a government analysis laboratory or a private analysis laboratory approved by the Industrial Factories Department in accordance with the regulations and procedures prescribed by the Industrial Factories Department.

Penalty: a licensee for operating a factory who does not comply with this notification shall be punished by fine not exceeding ten thousand baht.

Source: Notification of the Ministry of Industry No.1 13 B.E. 2525 (1982), as amended in No. 22 B.E. 2528 (1985), issued under the Factory Act B.E. 2512 (1969), published in the Royal Government Gazette, Vol. 99 Part 89, dated June 29, B.E. 2525 (1982).

Table 3.3.5 Domestic Effluent Guidelines

Parameters	Units	Domestic Effluent Classification for Community Group (persons)			
		A(>2500)	B(501-2500)	C(101-500)	D(<1010)
1. BOD (20°C at 5 days)*	mg/dm^3	20	30	60	90
2. Solids					
2.1 SS	mg/dm^3	30	40	50	60
2.2 Settleable S.	mg/dm^3	0.5	0.5	0.5	0.5
2.3 TDS ***	mg/dm^3	+500	+500	+500	+500
3. Sulfide	mg/dm^3	1.0	1.0	3.0	4.0
4. Free residual Chlorine ****	mg/dm^3	0.3	0.3	-	-
5. Nitrogen					
5.1 TKN	mg/dm^3	-	-	40	40
5.2 ORG-N	mg/dm^3	10	10	15	15
5.3 NH_3-N	mg/dm^3	-	-	25	25
5.4 NO_3-N	mg/dm^3	-	-	-	-
6. pH	mg/dm^3	5-9	5-9	5-9	5-9
7. Oil & Grease	mg/dm^3	20	20	20	20
8. Fecal coliform	MPN/100cm^3	-	-	-	-
9. Phosphate	mg/dm^3	-	-	-	-

Remarks: A,B,C,D size of community with more than 2500, between 501-2500, between 101-500 and less than 1010 persons respectively.

* Settled BOD (30 min)

** more than TDS of used water

*** Maximum allowance under epidemic condition only

Source: Proposed by the Sub-Committee on Domestic Effluent under the Environmental Committee on Water (May 27 BE 2527 (1984)) and approved by the National Environment Board (Jan. 31 BE 2528 (1985))

Table 3.3.6 Wastewater Quality Analysis Guidelines

Parameters	Methods of Analysis
1. BOD (20°C at 5 days)	- Azide Modification; 20°C; 5 days
2. Solids	
2.1 Suspended solids	- Non-filterable residue through glassfiber filter discs
2.2 Settleable solids	- 60 min-settled in 1,000 cc Imhoff cone
2.3 Total dissolved solids	- Filtrate from 2.1 and evaporate at 103-105°C 1hr.
3. Sulfide	- Titration for total sulfide
4. Free residual	- Orthotolidine Azenide
5. Nitrogen	
5.1 TKN	- Kjeldahl
5.2 ORG-N	- Kjeldahl after NH3-N separation
5.3 NH_3-N	- Nesslerization after distillation
5.4 NO_3-N	
6. pH	- Electrometric pH meter
7. Oil & Grease	- Soxhlet extraction

Method of Analysis: Standards Methods for the Examination of Water and wastewater set by American Public Health Association, American, Waterworks Association and Water Pollution Control Federation

Source : Proposed by the Sub-Committee on Domestic Effluent under the Environmental Committee on Water (May 27, B.E 2527 (1984), and approved by the National Environment Board (Jan. 31, B.E 2528 (1985))

Table 3.3.7 Proposed Building Effluent Standards

Building type	Size	Min. Require.	Remarks
1. Government offices	2,000-10,000 m^2	C	working area only
State enterprises	10,000-55,000 m^2	B	(excluding central
International agencies,	>55,000 m^2	A	service area)
Bank, Office buildings			
(except those specified			
otherwise in this Table)			
2. Condominium	< 100 units	C	all sizes
	101-500 units	B	
	>500 units	A	
3. Hotels	60-200 rooms	B	
	>200 rooms	A	
4. Hospitals	10-30 beds	B	
	> 30 beds	A	
5. Massage parlors	>5,000 m^2	B	
(or equivalent)			
6. Fresh-food markets	500-1,000 m^2	D	
	1,001-1,200m^2	C	
	1,501-2,500m^2	B	
	>2,500m^2	A	
7. Housing estate	<20 households	D	all sizes
	20-100 households	C	
	100-500 households	B	
	>500 households	A	
8. Food service operations	50-100 m^2	D	dining area
	101-500 m^2	C	
	501-2,500 m^2	B	
	> 2,500 m^2	A	
9. Department Stores	5,000-25,000 m^2	B	
	> 25,000 m^2	A	
10. Schools, Universities	5,000-25,000 m^2	B	
Colleges, Institute	> 25,000 m^2	A	
11. Dormitories	10-50 rooms	D	
	51-250 rooms	C	
	> 250 rooms	B	
12. Fishing Piers	> 300 m^2	B	- loading, unloading sorting area - excluding nitrogen parameter

Remarks : Concentration of all parameters are the same as those stated in Table 3.3.5 Domestic Effluent Guidelines

Source : Proposed by the sub-committee on Domestic Effluent (Apr. 10, B.E 2532 (1989) under consideration of the Environment Committee in laws

3.3.2 Surface Water

(1) Water Quality Classification

Table 3.3.8 defines the classification criteria used for surface water. Table 3.3.9 and Figure 3.3.1 show the classification of the Chao Phraya river using aforementioned criteria.

Table 3.3.8 Water Classification Criteria

Classifications	Objectives, Conditions and Beneficial Usages
Class 1	Extra clean fresh surface water resources used for: (1) consumption (not necessary to pass through water treatment processes, require only ordinary process for pathogenic destruction) (2) ecosystem conservation, where basic living organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption (require ordinary water treatment process before use) (2) aquatic organism conservation (3) fishery (4) recreation
Class 3	Medium clean fresh surface water resources used for: (1) consumption (need to pass through an ordinary treatment process before use) (2) agriculture
Class 4	Fairly clean fresh surface water resources used for: (1) consumption (require special water treatment process before use) (2) industry (3) other activities
Class 5	The resources which are not classified in class 1-4 and used for: (1) navigation

Source : Notification of the Ministry of Science, Technology and Energy (B.E 2528 (1985)), published in the Royal Government Gazette, Vol. 103, Part 60, dated April 15, B.E 2529 (1986).

Table 3.3.9 Chao Phraya River Water Quality Classification

Control Areas (km. from River Mouth)	Water Classification	Water Quality Standard point
7-62	Class 4	
62-142	Class 3	Pompetch, Ayutthaya
142-379	Class 2	beside Nonthaburi p. office

Source: Notification of the Office of the National Environment Board (January 17. B.E 2529 (1986), published in the Royal Government Gazette, Vol. 103, No. 60 dated April 15, B.E 2529 (1986)

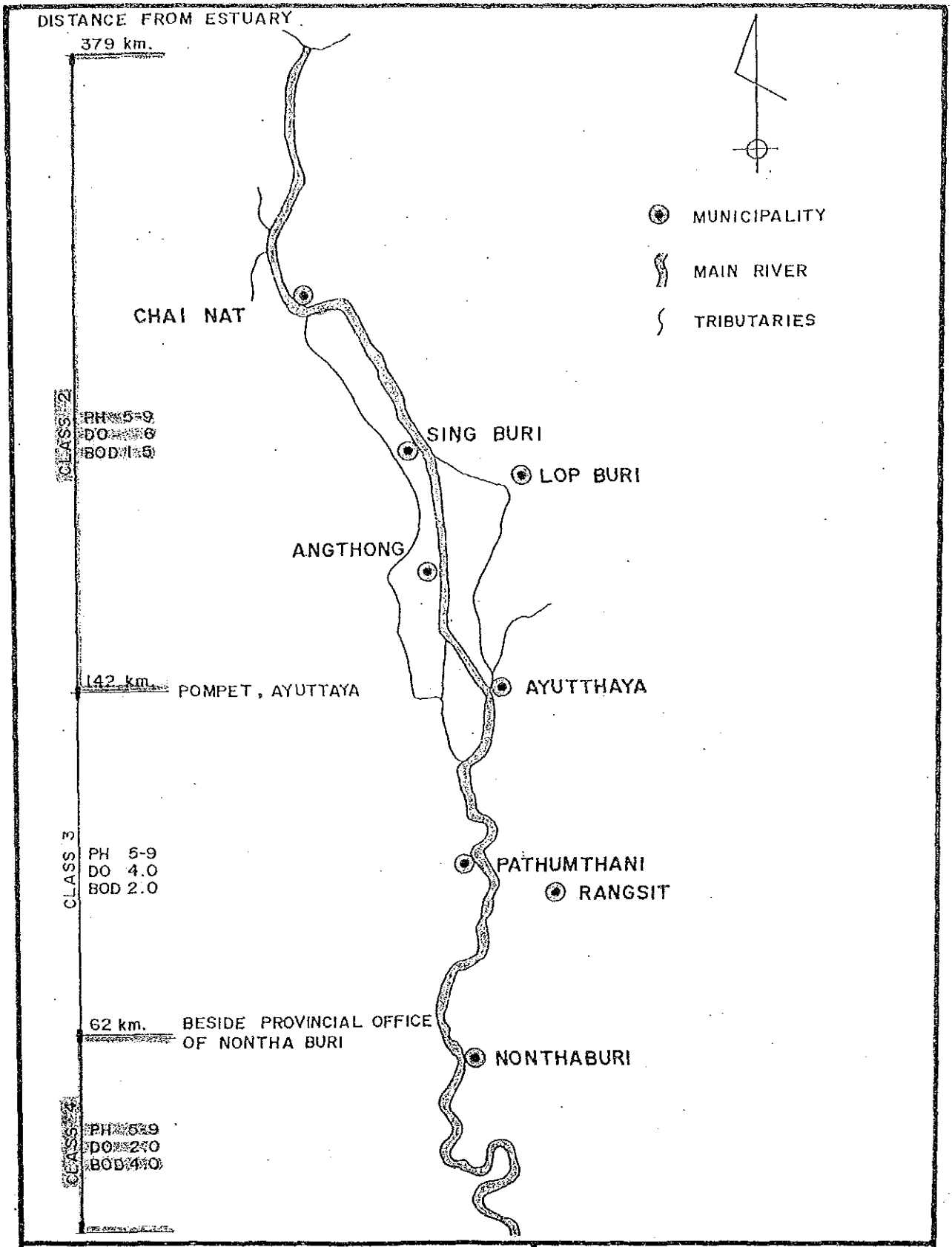


FIG. 3.3.1 CHAO PHRAYA RIVER WATER CLASSIFICATION

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

(2) Surface Water Quality Standards

Table 3.3.10 defines the surface water quality standards according to water classification.

(3) Restricted Zone for Protecting the Source of the Bangkok Metropolitan Region Water Supply (Cabinet Resolution, January 12, B.E 2531 [1988])

To ensure the quality of the Bangkok Metropolitan Region (BMR) water supply source, a 350 km^2 restricted zone was placed in the immediate vicinity of the Sam Lae water intake. This regulation specifically requires that within the restricted zone, building and expansion of factories which discharge wastewater containing toxic substances listed below or organic matter exceeding one kilogram of BOD per day will not be permitted. The toxic substances referred to are as follows:

Heavy metals: Zinc, Chromium, Copper Mercury, Manganese, Cadmium, Lead, Selenium, Nickel, Barium, Iron, etc.

Other toxic substances: Polychlorinated Biphenyl (PCB), Cyanide, Arsenic, Phenol, etc.

Figure 3.3.2 shows the restricted zone.

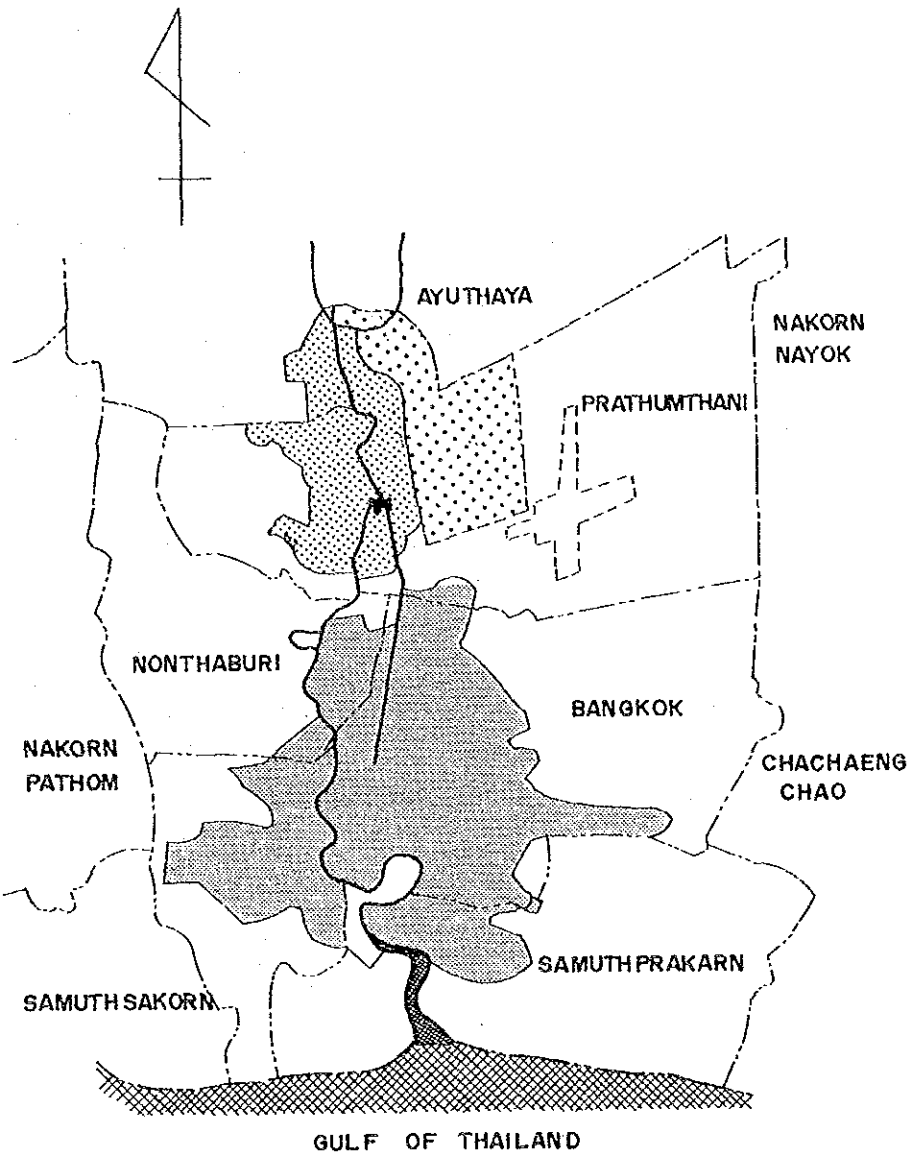
Table 3.3.10 Surface Water Quality Standards

Parameter	Unit	Statistic	Standard values for class ***				
			1	2	3	4	5
1. Temperature	°C	-	n	n	n	n	n
2. pH Value	-	-	n	5-9	5-9	5-9	-
3. Dissolved oxygen	mg/l	P20	n	6	4.0	2.0	-
4. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-
5. Coliform bacteria							-
- total coliform	MPN/100ml	P80		5,000	20,000	-	-
- Fecal coliform	MPN/100ml	P80		1,000	4,000	-	-
6. NO_3-N	mg/l	Max. allowance	n	5.0	5.0	5.0	-
7. NH_3-N	mg/l	Max. allowance	n	:	0.5	:	-
8. Phenols	mg/l	Max. allowance	n	:	0.005	:	-
9. Cu	mg/l	Max. allowance	n	:	0.1	:	-
10. Ni	mg/l	Max. allowance	n	:	0.1	:	-
11. Mn	mg/l	Max. allowance	n	:	1.0	:	-
12. Zn	mg/l	Max. allowance	n	:	1.0	:	-
13. Cd	mg/l	Max. allowance	n	:	0.005*, 0.05**	:	-
14. Cr (hexavalent)	mg/l	Max. allowance	n	:	0.05	:	-
15. Pb	mg/l	Max. allowance	n	:	0.05	:	-
16 Hg (total)	mg/l	Max. allowance	n	:	0.002	:	-
17 As	mg/l	Max. allowance	n	:	0.01	:	-
18 CN	mg/l	Max. allowance			0.005		-
19 Radioactivity							-
- Gross α	Bq./l	Max. allowance	n	:	0.1	:	-
- Gross β	Bq./l	Max. allowance	n	:	1.0	:	-
20. Pesticides (total)	mg/l	Max. allowance	n	:	0.05	:	-
- DDT	µg/l	Max. allowance	n	:	1.0	:	-
- β BHC	µg/l	Max. allowance	n	:	0.02	:	-
- Dieldrin	µg/l	Max. allowance	n	:	0.1	:	-
- Aldrin	µg/l	Max. allowance	n	:	0.1	:	-
- Heptachlor & Heptachlor epoxide	µg/l	Max. allowance	n	:	0.2	:	-
- Endrin	µg/l	Max. allowance	n	:	None	:	-

Note :

P = Percentile value
n = natural
n' = natural, but changing not more than 3°C
* = when water hardness not more than 100 mg/l as $CaCO_3$
** = when water hardness more than 100 mg/l as $CaCO_3$
*** = Water Classification

Source: Notification of the Ministry of Science, Technology and Energy (B.E 2528) (1985)



LEGEND :

- PROVINCE BORDER
- CHAO PHRAYA RIVER
- WATER SUPPLY PUMPING STATION
- RAW WATER CANAL
- WATER SUPPLY SERVICE AREA OF MWA (MASTER PLAN UNTIL 1991)
- EXPANDED AREA OF SURFACE WATER SUPPLY (INSTEAD OF DEEP WELL WATER PUMPING)
- PREVIOUS RESTRICTED ZONE FOR PROTECTION OF WATER SUPPLY SOURCE IN 1979 (200 KM^2)
- EXPANDED RESTRICTED ZONE (150 KM^2)

FIG. 3.3.2 RESTRICTED ZONE FOR THE PROTECTION THE BMR WATER SUPPLY SOURCE

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

3.4 Water Pollution Status

The traditional agriculture-oriented society of Thailand has been urbanized and industrialized in the course of recent economic development. On the process, environmental pollution has been accelerated.

Lower Chao Phraya river basin where agriculture is a major economic activity and where population is still relatively scattered does not exhibit significant water pollution owing to its assimilation capacity over the in-flowing pollution load from mainly domestic wastewater discharge. However, rapid urbanization in the Bangkok Metropolitan area coupled with its expansion to the subject area has increased the discharge of pollution load beyond the environmental capacity of the Chao Phraya river. This resulted to serious water pollution in the downstream portion of the river.

The on-going water quality surveillance systems and water pollution status of the main river and its tributaries are presented in this section. Available data were obtained from relevant authorities supplemented by a series of four field investigations conducted by the JICA Study Team.

3.4.1 Concerned Agencies Undertaking Water Quality Examination

There are four agencies undertaking water quality examination at the central government level; PCD (former ONEB), MWA, PWD and DOH. Detailed information is incorporated in section 3.4.1, Part I of Volume IV - Data Report.

Water quality in public water bodies has been examined mainly by the ONEB. The ONEB established 32 water quality surveillance stations between the river mouth of the Chao Phraya river and 376 km upstream therefrom (refer to location of points in section 3.4.1, Part I of Volume IV - Data Report). Of the 32 established points, only 17 have been water sampled. Water quality indices that has to be examined by the ONEB is reflected in Table 3.4.1. However, only a few indices are regularly examined, about three times a year, as reflected in Table 3.4.2.

The PWD, MWA and DOH are also carrying out water quality surveillance in Chao Phraya river corresponding to their objectives. The present set-up of these water quality surveillances is summarized in Table 3.4.3.

Table 3.4.1 Parameters for Water Quality Monitoring Program (ONEB)

Monitoring Parameters				
Physical	Chemical		Biological	Radioactivity
1. pH	1.DO		1.Total Coliform Bacteria	-Gross(Becquerel/l)
2. Water Temperature	2.BOD		2.Fecal Coliform Bacteria	β-Gross(Becquerel/l)
	3.NO_3-N			
	4.NH_3-N			
	5.Total-P			
	6.Phenols			
	Heavy Metals	Pesticides		
	-Cd	-DDT		
	-Cr	-BHC		
	-Cu	-Dieldrin		
	-Pb	-Aldrin		
	-As	-Heptachlor		
	-Cn	-Heptachlor		
	-Ni	-epoxcides		
	-Mn	-Endrin		
	-Zn			
	-Total-P			

Table 3.4.2 Common Water Quality Indices Examined by ONEB

Physical	Chemical	Biological
1 pH	1 NH_4-N	1 BOD
2 Water Temperature	2 NO_2-N	2 COD
3 Conductivity	3 T-P	3 DO
4 Total Solid	4 Cl-	
5 Suspended Solid	5 Alkalinity	
	6 Hardness	
	7 Acid	

Table 3.4.3 Water Quality Monitoring by Concerned Agencies

Agencies	PCD	PWD	MWA	DOH
Objective	1) Monitoring of water sources and policy making for pollution control 2) Monitoring of water pollution in rivers 3) Monitoring of tributary and khlong 4) Reporting to the national government	1) Monitoring of main drainage channel and discharged pollution load 2) Monitring to assess water pollution in river by waste-water from drainage channel	1) Monitoring of water sources for waterworks	1) Monitoring from view point of public hygine 2) Monitoring by toxic sub-stances, i.e., heavy metals
Location & Number of Surveillance Stations	1) 32 points between Samut Prakan and Nakhon Sawan 2) 17 points out of 32 points are for periodical monitoring	1) 18 points between Nonthaburi and Chai Nat 2) Main drainage channels in each province	1) 4 points along main river in Chai Nat, Sing Buri, Ang Thong and Ayutthaya 2) 8 points in raw water convey-ance channel	1) 26 points between Samut Prakan and Chai Nat
Frequency/ Interval	3 times a year (rainy, summer and winter season	Not established	Once a year	2 to 8 times a year depending on stations
Water Quality Indices	pH, Temp., DO, SS, BOD, COD, NH4-N, NO2-N, T-P, cl-, Alkalinity, Heavy Metals, Coliform Group Bacteria	DO, BOD, Coliform Group Bacte-ria	Color, Odor, pH, Temp., DO, BOD NH4-N, NO3-N, Ca, Mg, Fe, Mn F, S, cl-, Hadness, Conductivity	pH, Hardness, DO, BOD, cl-, NO3-N, Fe, Mn, Cu, Zn, Pb, Cr, Cd

Note: Flow rate in main river and main drainage channel is not measured by these agencies.

Although these agencies are periodically monitoring water quality, their frequency/interval, surveillance stations and water quality indices are not consistent with each other. Inter-agency coordination is necessary to achieve an efficient surveillance activity and smooth implementation of environment management and administration.

3.4.2 Water Pollution Status in Rivers

From the field investigation results and data gathered from the different concerned agencies, the present water pollution conditions in Chao Phraya river, its tributaries and khlongs/drains within the study area were reviewed and analyzed. The study effort focused on the achievement of water quality standards viz-a-viz water use and conservation of public water bodies. Seasonal fluctuations, (rainy and dry seasons) and historical trends of water quality were also evaluated.

A summary of the water pollution conditions in terms of organic and toxic/hazardous substances content are presented below.

(1) Organic Substances Pollution

1) Chao Phraya River

Table 3.4.4 reflects the field measurements data on water quality along the Chao Phraya river at the sampling points where investigations were conducted by the Study Team (from No.1 Chai Nat to No.5 Nonthaburi). Water quality data of the same sampling points gathered from concerned agencies were also incorporated.

Table 3.4.5 summarizes BOD, DO, Coliform Group Bacteria and heavy metals content by sectional classification of the river. Figure 3.4.1 shows the weighted average of water quality based on the field investigation results conducted four times (2 each in June 1992 and in January 1993). The detailed data are presented in section 3.4.2, Part I of Volume IV - Data Report.

Table 3.4.4 Summary of Water Quality Data at Major Five Points

(unit: mg/l)

LOCATION & ST. No.			CHAI NAT No.1			SING BURI No.2			AYUTTHAYA No.3			AYUTTHAYA No.4			PATHUM THANI No.5			NONTHABURI No.6		
SOURCE	SEASON	ITEMS	BOD	SS	DO	BOD	SS	DO	BOD	SS	DO	BOD	SS	DO	BOD	SS	DO	BOD	SS	DO
PCD	Dry Season	Avg.	0.85	147	5.3	1.27	144	7.2	1.36	78	5.6	-	-	-	2.33	54	3.7	3.04	32	1.3
		Max.	1.24	262	5.8	1.50	209	7.8	2.35	174	6.6	-	-	-	4.4	91	5.5	8.05	44	3.5
		Min.	0.27	78	4.6	0.95	32	6.8	0.09	34	4.4	-	-	-	0.8	28	2.6	1.56	10	0.4
	Rainy Season	Avg.	0.94	28	5.8	1.10	34	7.7	1.16	61	5.9	-	-	-	2.00	35	5.1	1.53	109	2.7
		Max.	1.40	35	5.8	1.60	39	7.8	2.30	122	7.0	-	-	-	3.80	58	5.8	2.00	207	4.5
		Min.	0.48	20	5.8	0.60	30	7.6	0.20	33	4.7	-	-	-	0.80	23	4.1	1.05	28	1.2
PCD	Rainy Season	-	0.75	-	-	0.80	-	-	1.05	-	-	0.85	-	-	0.85	-	-	1.15	-	-
PWD	All Season	Avg.	0.65	-	5.3	1.00	-	6.6	1.27	-	4.6	0.63	-	5.5	1.50	-	4.6	6.23	-	2.9
		Max.	1.10	-	6.2	2.40	-	7.6	2.50	-	7.4	1.30	-	7.6	5.40	-	7.6	23.0	-	6.5
		Min.	0.20	-	4.0	0.10	-	5.6	0.20	-	2.5	0.20	-	4.0	0.4	-	3.2	0.6	-	1.0
DOH	Dry Season	Avg.	1.0	-	-	1.0	-	6.5	1.10	-	6.4	1.00	-	5.5	1.15	-	6.0	2.54	-	1.4
		Max.	1.0	-	-	-	-	-	1.30	-	6.8	1.00	-	8.0	1.30	-	-	5.10	-	3.6
		Min.	1.0	-	-	-	-	-	1.00	-	6.0	1.00	-	5.0	1.10	-	-	1.00	-	0.0
	Rainy Season	Avg.	1.25	-	-	1.0	-	6.0	1.12	-	6.0	1.43	-	4.0	1.13	-	4.8	2.08	-	2.6
		Max.	1.30	-	-	-	-	-	1.30	-	6.2	1.50	-	5.0	1.40	-	5.0	4.70	-	4.8
		Min.	0.20	-	-	-	-	-	0.99	-	5.8	1.30	-	3.0	0.99	-	4.5	0.99	-	1.2
This Study	First Time (13-14,June)	Avg.	1.5	2	7.0	2.1	23	7.8	2.3	23	8.0	1.8	16	4.9	-	-	-	4.7	62	2.9
		Max.	1.9	9	4.7	2.6	26	8.8	2.1	26	8.5	2.9	18	7.3	-	-	-	6.6	99	4.5
		Min.	1.1	0.5	8.0	1.5	20	6.5	1.6	9	6.0	1.2	10	5.6	-	-	-	4.1	27	0.3
	Second Time (20-21,June)	Avg.	3.2	11	6.8	2.6	27	7.9	1.3	13	6.9	2.1	21	5.6	-	-	-	4.4	23	2.7
		Max.	4.6	26	7.0	3.6	29	8.7	2.0	17	7.3	2.3	23	7.6	-	-	-	5.5	65	3.4
		Min.	2.2	7	6.2	1.4	25	6.9	1.2	7	5.6	1.5	15	6.0	-	-	-	2.2	28	0.3
Total	Dry Season	Avg.	1.42	77	6.1	1.6	85	7.2	1.4	48	6.6	1.5	19	5.4	1.74	54	4.9	3.4	37	1.8
		Max.	4.6	262	8.0	3.6	209	8.8	2.35	174	8.5	2.9	23	8.0	4.4	91	6.0	8.05	99	4.5
		Min.	0.2	0.5	4.6	0.95	20	6.5	0.09	7	4.4	1.0	10	5.0	0.8	28	2.6	1.00	10	0.3
	Rainy Season	Avg.	0.98	28	5.8	0.95	34	6.9	1.1	61	6.0	1.14	-	4.0	1.33	35	5.0	1.59	109	2.1
		Max.	1.40	35	5.8	1.6	39	7.8	2.3	122	7.0	1.50	-	5.0	3.9	58	5.8	4.70	207	4.8
		Min.	0.48	20	5.8	0.8	30	6.0	0.2	33	4.7	1.30	-	3.0	0.8	23	4.1	0.99	28	1.2

Note: (1) PCD : dry season (Feb. & May) in 1988-1990, rainy season (Aug. & Nov.) in 1988-1990 (2) PCD (Rainy season) : Oct. 1984
(3) PWD : All season in 1989 - 1991 (4) DOH : Jan. 1991 - Jan. 1992 (5) This study : June, 1992

Table 3.4.5 Average Water Quality in Chao Phraya River by Classified Section

Distance Classifications	Items		PCD Standard	PCD			PWD	DOH	MWA	This Time Avg.	Total Avg.
				Dry Seasons	Rainy Seasons	Avg.					
7-62 km	BOD	(mg/l)	4.0	3.71 (9.40)	2.39 (4.00)	3.05	4.0 (23.0)	3.58 (13.5)	-	-	3.54
Water Quality	DO	(mg/l)	2.0	1.12 (0.0)	1.5 (0.0)	1.3	3.1 (1.0)		-	-	1.5
Class 4	Coli.G.	(MPN/100ml)	-	$1,225 \times 10^3$	$2,178 \times 10^3$	$1,702 \times 10^3$	682×10^3	$4,828 \times 10^3$	-	-	$2,404 \times 10^3$
	Cd	(mg/l)	0.05-0.005	-	-	0.00068	-	0.005	-	-	0.0028
	Pb	(mg/l)	0.05	-	-	0.0056	-	0.0062	-	-	0.0059
	Hg	(mg/l)	0.002	-	-	0	-	-	-	-	0
	Cu	(mg/l)	0.1	-	-	0.02	-	0.03	-	-	0.025
	Zn	(mg/l)	1.0	-	-	0.05	-	0.17	-	-	0.11
67-142 km	BOD	(mg/l)	2.0	1.56 (4.40)	1.32 (3.80)	1.44	1.96 (28.0)	1.59 (7.6)	1.7	4.6 (6.6)	2.3
Water Quality	DO	(mg/l)	4.0	3.9 (2.0)	4.8 (2.4)	4.4	4.6 (0.1)	4.1 (1.3)	5.5	2.8 (0.3)	4.3
Class 3	Coli.G.	(MPN/100ml)	20,000	20,000	17,100	18,600	192,000	45,600	32,000	26,000	62,840
	Cd	(mg/l)	0.05-0.005	-	-	0.00062	-	0.0015	-	0.002	0.001
	Pb	(mg/l)	0.05	-	-	0.0032	-	0.02	-	0.01	0.01
	Hg	(mg/l)	0.002	-	-	0.00016	-	-	-	-	0.00016
	Cu	(mg/l)	0.1	-	-	0.0096	-	0.008	-	0.045	0.016
	Zn	(mg/l)	1.0	-	-	0.044	-	0.13	-	0.01	0.06
142-379 km	BOD	(mg/l)	1.5	0.89 (1.84)	1.08 (2.00)	0.99	1.32 (9.2)	1.42 (5.9)	1.13 (1.6)	2.15 (4.6)	1.4
Water Quality	DO	(mg/l)	6.0	6.5 (5.4)	6.6 (5.2)	6.6	5.2 (0.1)	6.6 (3.0)	7.7 (7.2)	7 (5.6)	6.6
Class 2	Coli.G.	(MPN/100ml)	5,000	20,800	6,800	13,800	428,000	27,000	21,000	13,100	100,580
	Cd	(mg/l)	0.05-0.005	-	-	0.00068	-	0.0026	-	0.001	0.002
	Pb	(mg/l)	0.05	-	-	0.003	-	0.02	-	0.005	0.008
	Hg	(mg/l)	0.002	-	-	0.0001	-	-	-	-	0.0001
	Cu	(mg/l)	0.1	-	-	0.01	-	0.06	-	0.04	0.04
	Zn	(mg/l)	1.0	-	-	0.049	-	0.11	-	0.01	0.056

Note : BOD ( ) : Max.
DO ( ) : Min.

Source :
1) PCD : average between 1988 and 1990
2) PWD : 1989-1991
3) DOH : Average in 1991
4) MWA : April, 1991
5) This study : Average of two times survey

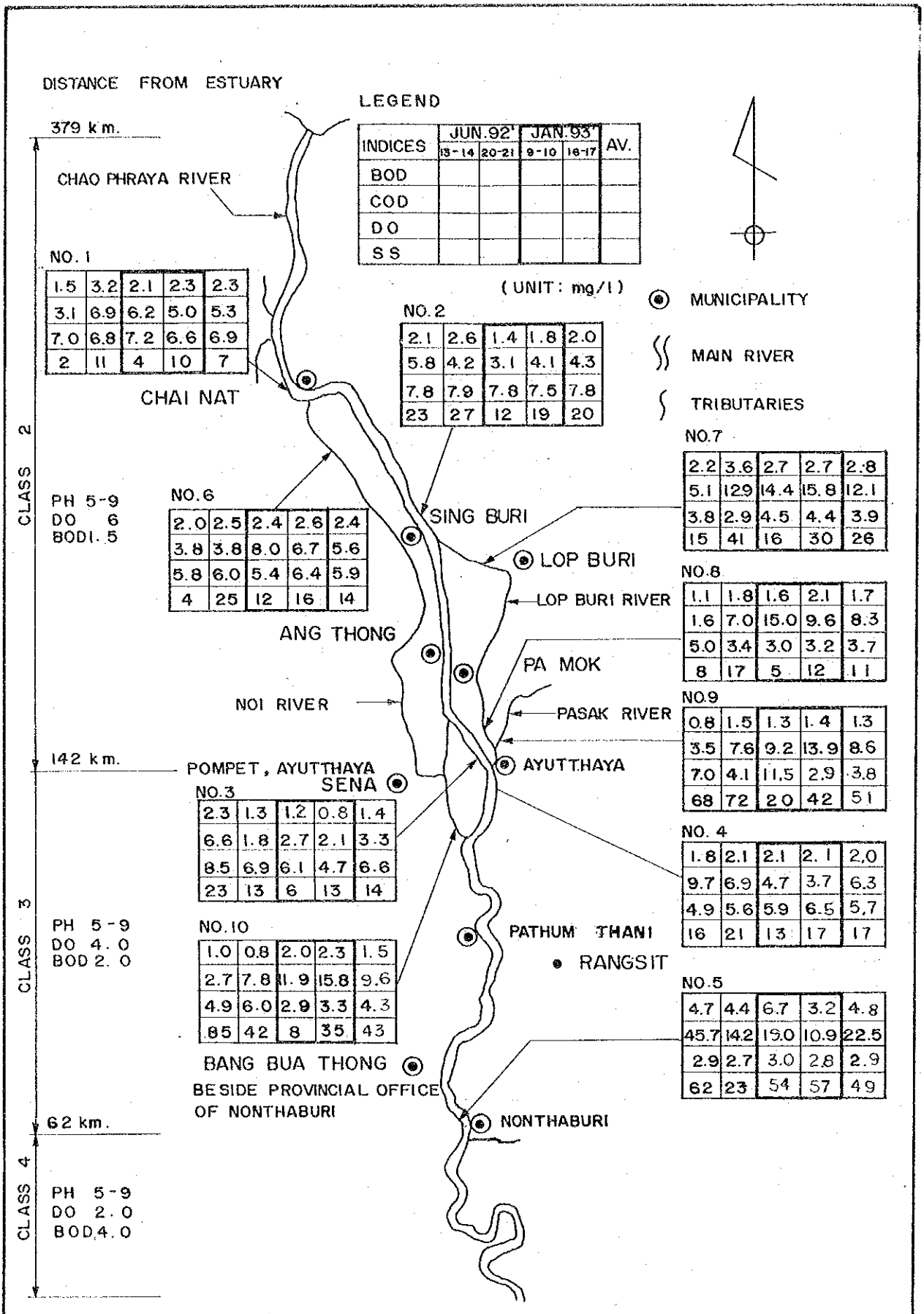


FIG.3.4.1 WEIGHTED AVERAGE OF WATER QUALITY ON THE FOUR SAMPLING DAYS (CHAO PHRAYA RIVER)

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Comparison with Environmental Water Quality Standards

Class 4: BOD 4 mg/l, DO 2.0 mg/l, pH 5 - 9

Serious water pollution was caused by wastewater inflow from Bangkok, Nonthaburi, etc. in the downstream portion of Chao Phraya river. Achievement of environmental water quality standards has become difficult throughout the year.

BOD: average 3.54 mg/l which met the quality standard, but the max. value exceeded the standard.

DO: average 1.5 mg/l which met the quality standard, but zero value was confirmed.

Coliform Group: average 2.4×10^6 MPN/100 ml (very high value).

Class 3: BOD 2 mg/l, DO 4 mg/l, pH 5 - 9 and Coliform Group Bacteria 4,000 MPN/100 ml as fecal and 20,000 MPN/100 ml as total

Water pollution was in progress in this classification, especially in Nonthaburi downstream of Chao Phraya river. Although average figures of existing data collected from PCD, PWD, etc. still met the quality standard, the max. value considerably exceeded the standard.

BOD: Average 2.2 mg/l which slightly exceeded the standard (Nonthaburi point is critical at max. 6.6 mg/l).

DO: Average 4.2 mg/l which met the standard, but 0.1 mg/l was confirmed.

Coliform Group: Average 5.8×10^4 MPN/100 ml which was about 3 times of the standard.

Class 2: BOD 1.5 mg/l, DO 6 mg/l, pH 5 - 9, and Coliform Group Bacteria 1,00 MPN/100 ml as fecal and 5,000 MPN/ml as total

Water pollution was not as serious in comparison with Classes 3

and 4 areas. In general, the environmental water quality standard was met. However, average figures were almost at the limit of standard. The field investigations by the Study Team revealed that average figures obtained between Chai Nat and Ayutthaya exceeded the standard, especially at Ayutthaya and its neighboring area. This area is densely populated and needs urgent countermeasures against generated wastewater.

BOD: Average 1.3 mg/l which met the standard, but max. value exceeded the standard.

DO: Average 6.4 mg/l which met the standard, but 0.1 mg/l was confirmed.

Coliform Group: 1.0×10^5 MPN/100 ml which exceeded the standard.

Seasonal Fluctuation of Water Quality

Figure 3.4.2 presents seasonal fluctuations of water quality based on data collected from PCD and obtained from field investigations by the Study Team. Although the field surveys were carried out 2 times intentionally for each different seasons (June, 1992 and January, 1993), these results were considered to represent water quality in dry season due to specific climatic conditions.

BOD: In Classes 3 and 4, values in dry season showed 0.5 to 2 mg/l higher than those in rainy season, which clearly indicated the status of water pollution. Those in the section of Class 2, on the other hand, did not show significant difference in seasonal fluctuations. The overall average of existing data shown in Table 3.4.4 also indicated similar tendency of water quality between Chai Nat and Nonthaburi.

DO: All classes showed higher DO values in rainy season than dry season.

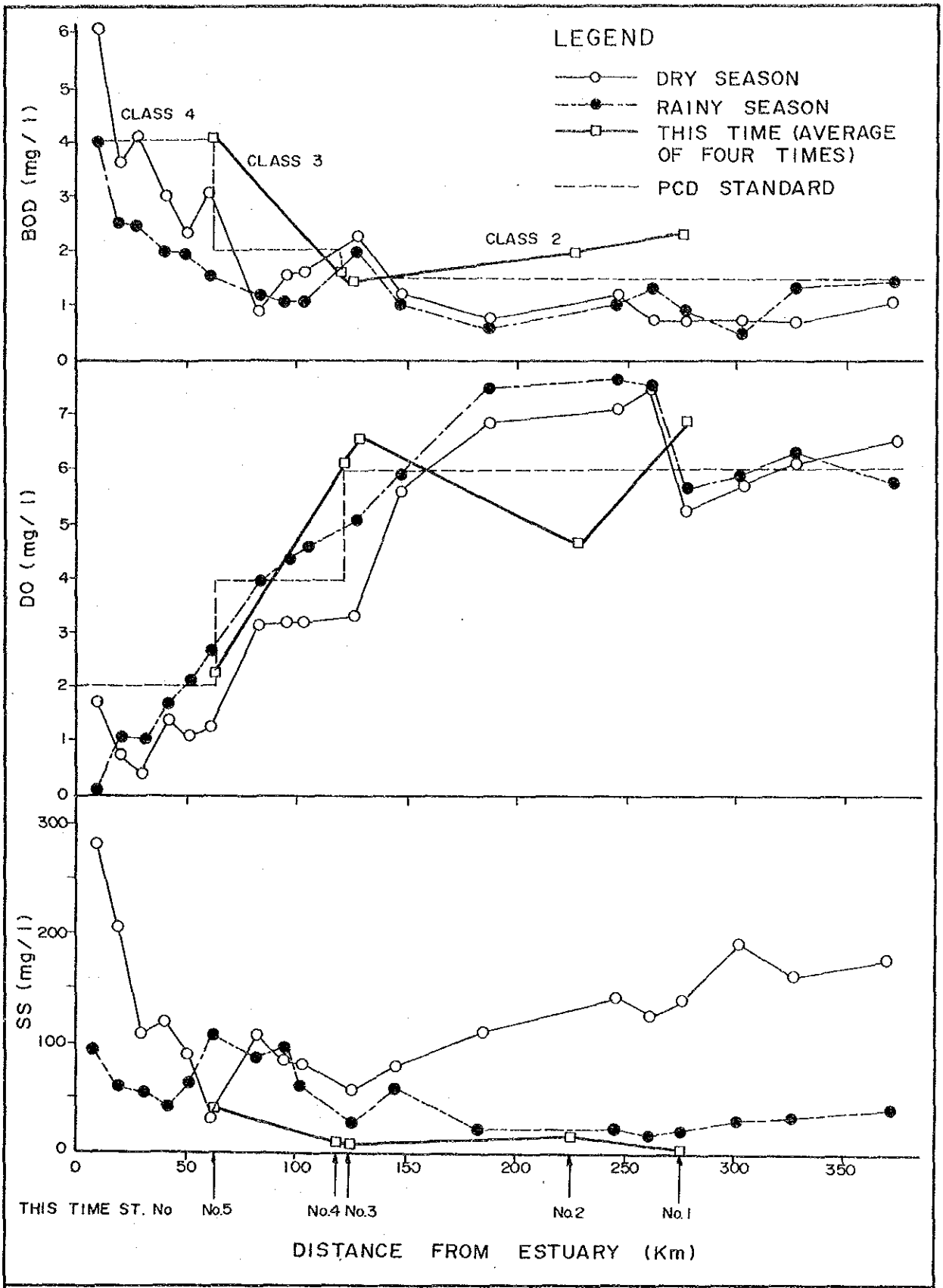

FIG. 3.4.2 AVERAGE WATER QUALITY IN DRY SEASON AND RAINY SEASON (PCD AND THIS STUDY DATA)

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SS: Values in Class 4 in the downstream of Chao Phraya river showed higher SS values in dry season similar to that of BOD. Those in Class 2 showed the same tendency as Class 4, but was not corresponding to the characteristics of BOD.

Annual Change of Water Quality

Increased discharge of pollution load to rivers because rapid urbanization and industrialization in the Bangkok Metropolitan and its expansion areas has triggered fast deterioration of aquatic environment. Figure 3.4.3 exhibits annual change of water quality in the past 3 years (1988 to 1990) based on the data collected from PCD. Water quality in 1988 was already deteriorated, but no significant change was observed in this period.

2) Tributaries

There are three major tributaries in the Study Area, namely; Noi river, Lop Buri river and Pasak river. According to the investigation done by the JICA Study Team, a BOD of 2.4 mg/l was measured at Chai Nat upstream of Noi River and exceeded the BOD environmental water quality standard by 1.5 mg/l.
Downstream of Noi River, BOD content was decreased to 1.6 mg/l by the effect of the river's self-purification process. Consequently, 6.6 mg/l of DO was detected in the downstream, while 5.9 mg/l was measured in the upstream.

In Lop Buri river, 2.8 mg/l of BOD was observed in the upstream wherein the pollution load from Lop Buri City area was inflowing. In the downstream, BOD decreased to 1.7 mg/l owing to self-purification effect like in Noi river. Downstream of Pasak river showed 1.3 mg/l of BOD slightly satisfying the environmental water quality standards.

BOD in the main stream of Chao Phraya river before the confluence point with Lop Buri river and Pasak river was 1.6 mg/l, slightly exceeding the standards, while it increased to 2.2 mg/l at the downstream from the said confluence point.

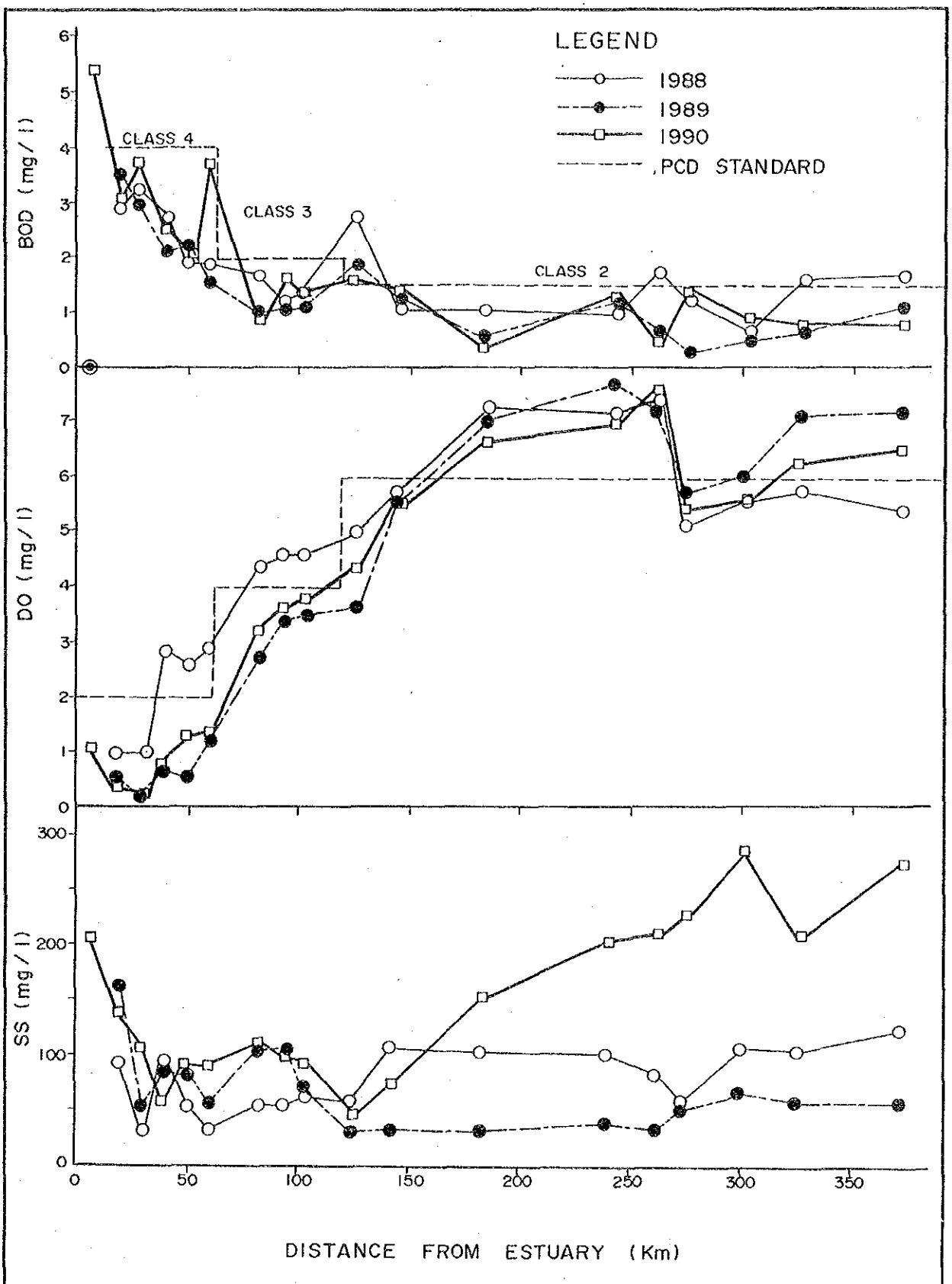

FIG. 3.4.3 VARIATION OF YEARLY WATER QUALITY
(PCD DATA)

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3) Drainage Channel, Khlong and Irrigation Canals

Results of average values of water quality research at the drainage channels in Nonthaburi and Pathum Thani conducted by PWD and PCD are shown in Table 3.4.6. Detailed data are presented in section 3.4.3, Part I of Volume IV. These data and ocular observations taken in the course of the field surveys revealed that in the urban areas, the appearance of water at the drainage channels was black. There was also accumulated sludge at the bottom and was emitting offensive odor, like sewage itself.

TABLE 3.4.6 Average Values of Water Quality in Pathum Thani and Nonthaburi (PWD)

Index		SS (mg/l)			BOD (mg/l)			Coliform (MPN/100ml)		
Sampling Point	Year	1989	1990	1991	1989	1990	1991	1989	1990	1991
Pathum Thani	Market (Pathum Thani Municipality)	118	-	-	39	-	-	1.4x10	-	-
	Slaughter House (Pathum Thani Municipality)	271	-	178	212	-	58	1.5x10	-	6.7x10
	Ban Pak Khlongz Canal (Amphoe Sam Khok)	53	95	71	1.3	1.4	1.8	9.3x10	4.8x10	6.2x10
	Khlong Ban Prao (Amphoe Sam Khok)	59	134	96	0.8	1.3	1.9	4.1x10	3.1x10	1.0x10
Nonthaburi	Market (Nonthaburi Manicipality)	62	100	64	37	24	48	1.2x10	4.2x10	1.8x10
	Slaughter House (Nonthaburi Municipality)	232	571	390	356	294	257	1.9x10	2.1x10	6.2x10

Source: PWD

The PWD survey determined 260 to 360 mg/l of BOD at drainage channels in Nonthaburi and was validated by the field investigation results of the Study Team which also detected 133 mg/l of maximum BOD in Nonthaburi. Analysis results including the presence of high content of NH_4-N, Coliform Group Bacteria and Cl^- were strongly indicative of inflow of untreated nightsoil.

Water quality of khlongs in some locations shows serious water pollu-

tion like the drainage channels. Specifically, khlongs in Bangkok are becoming heavily polluted that no aerobic organism can survive in its aquatic environment. The survey of BMA in 1985 showed that the khlong running in the city proper along with Chao Phraya river had the worst condition having a 50 mg/l of BOD. Khlongs lovated even in the suburban areas showed 10 to 20 mg/l of BOD.

Water quality data of irrigation canals was scarce. Field investigations by the Study Team were repeated 4 times covering 5 locations in Ayutthaya and its surrounding area. These irrigation canals are small-size with width of 1 to 3m. Water was stagnant showing yellowish brown color. Analysis results of some parameters, e.g., BOD, COD, and pesticides are presented in Table 3.4.7. BOD values varied from 2.3 to 13 mg/l which were relatively high than that of ordinary irrigation canals. Analysis of Cl-, NH_4-N, Coliform Group Bacteria, etc. indicated that there were partial inflows of domestic nightsoil and livestock wastewater in the surrounding area.

Table 3.4.7 Water Quality of Irrigation Channel

Parameter	St. No.	I-1		I-2		I-3		I-4		I-5	
	Date	Jun.92	Dec.92	Jun.92	Dec.92	Jun.92	Dec.92	Jun.92	Dec.92	Jun.92	Dec.92
	Unit										
Water Temperature	deg.C	32.6	26.6	32.6	27.0	31.4	26.8	30.6	28.0	33.7	27.0
pH	-	7.2	6.2	7.0	6.6	7.7	7.0	8.2	6.6	7.7	7.7
DO	mg/l	5.7	1.2	4.7	0.5	5.4	4.5	2.9	2.1	6.7	7.1
SS	mg/l	281	7	104	8	376	82	72	15	134	171
Alkalinity as CaCO3	mg/l	80	70	115	180	115	170	295	190	110	105
Chloride as Cl-	mg/l	7.3	15.5	8.6	36.7	7.0	13.2	308	45.5	15.9	8.0
Nitrate as NO3	mg/l	0.18	<0.01	0.22	0.15	0.31	0.04	0.22	0.04	0.44	0.11
Sulfate as SO4 2-	mg/l	30.1	62.8	12.9	6.5	15.2	3.7	115	21.4	24.9	23.3
Ammonia as NH3-N	mg/l	1.79	<0.01	0.05	<0.01	0.08	<0.01	<0.01	<0.01	0.06	<0.01
BOD	mg/l	8.9	2.3	10.4	6.2	10.0	5.5	3.3	6.7	13	5.8
COD	mg/l	52.4	21.3	59.3	59.7	63.3	26.6	26.7	23.9	69.3	31.0
Coliform Bacteria	MPN/100ml	16,000	940	540	7,900	2,200	700	2,800	4,600	630	330
Pesticides											
Dieldrin	µg/l	0.011	<0.002	0.022	<0.002	0.012	<0.002	0.009	0.003	0.012	0.003
Aldrin	µg/l	0.067	0.040	0.080	0.026	0.058	0.027	0.059	0.040	0.059	0.026
Heptachlor	µg/l	0.003	0.010	0.019	0.105	0.003	0.002	0.003	0.003	0.005	0.003
Heptachlor Epoxide	µg/l	<0.002	0.004	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Lindane +											
Hexachlorobenzene	µg/l	<0.002	0.125	<0.002	1.642	<0.002	0.004	<0.002	0.006	<0.002	0.004
DDT	µg/l	<0.002	<0.002	0.009	<0.002	0.008	<0.002	<0.002	<0.002	0.007	<0.002
Methoxychlor	µg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chlordane	µg/l	0.092	0.032	0.186	0.021	0.095	0.031	0.080	0.034	0.016	0.033

Pesticides Total	µg/l	0.181	0.217	0.322	1.802	0.182	0.072	0.159	0.092	0.105	0.075

Date of Investigation First: June 18-19, 1992
Second: December 23-24, 1992

(2) Toxic Substance Contamination

Heavy metals in Chao Phraya river surveyed by PCD are indicated in Table 3.4.8, which all satisfyied the environmental water quality standards. On the other hand, the results of the field investigation by the Study Team revealed that the drainage channels especially in Nonthaburi were highly contaminated.

Table 3.4.8 Heavy Metals of the Chao Phraya River Water (1980-1990 average)

Station No.	Distance from Estuary (km)	Ni '88-'90 AVG. (ppb)	Zn '88-'90 AVG. (ppb)	Cu '88-'90 AVG. (ppb)	Hg '88-'90 AVG. (ppb)	Mn '88-'90 AVG. (ppb)	Pb '88-'90 AVG. (ppb)	Cd '88-'90 AVG. (ppb)	Cr '88-'90 AVG. (ppb)
1	7.0	9.00	100	28.14		340	1.09		
3	18.0	11.56	57	44.52	0.00	416	17.05	0.71	9.0
5	27.0	9.53	45	12.99	0.00	309	4.95	0.59	6.4
8	41.5	6.61	37	11.62	0.00	210	4.43	0.96	5.9
10	48.0	7.71	39	13.38	0.00	200	3.88	0.42	4.8
12	58.0	5.39	36	8.98	0.00	117	1.93	0.72	3.5
15	83.0	4.37	33	9.77	0.00	133	3.99	0.40	7.8
16	93.0	1.00	27	2.50	0.20	101	3.60	0.59	6.8
16.1	95.7	3.63	70	9.60		120	5.26	2.20	10.7
17	101.0	3.95	30	6.30	0.62	95	2.50	0.38	5.5
18	123.6	4.13	37	7.23	0.00	107	1.90	0.27	5.0
19	127.8	3.90	25	12.00	0.00	72	3.10	0.10	9.4
20	142.4	1.50	87	19.52		86	2.00	0.40	1.8
21	183.0	6.48	42	10.04	0.00	149	1.45	0.36	6.0
24	244.0	5.41	66	11.36	0.00	118	3.11	1.72	5.6
25	263.5	8.17	36	9.52	0.00	117	3.26	0.65	4.3
28	280.0	5.98	39	8.01	0.00	112	3.14	0.52	5.2
29	305.6	6.87	61	10.70	0.00	146	4.65	0.43	6.8
30	331.0	4.90	48	12.06	0.25	154	3.18	0.70	6.6
32	376.4	4.60	48	9.47	0.46	178	1.71	0.38	5.4

Considering the high contamination rate downstream of Chao Phraya river, there is a possibiliry of exceeding the environmental water quality standards at the downstream portion in the near future. To avoid such contamination, various preventive measures shall be taken up to possible pollution sources, such as water quality surveillance

of industrial wastewater, administrative guidance of national and local governments, etc.

Hazardous chemical substances such as pesticides were widely present in the river system, but within the limit of environmental water quality standards. The PCD survey detected presence of BHC, Aldrin, Dieldrin, etc. It shall be noted that concentrations of these chemicals during dry season are 3 to 10 times higher than that during rainy season. Due attention shall be paid to water contamination by these traces of hazardous chemical substances. There is a possibility that these traces will be absorbed by the human bodies through food chain and biological concentration/magnification. Nowadays such chemical substances are not detected in the rivers of Japan.

Irrigation canals were also investigated on contamination levels by the Study Team. Most of the pesticides were detected. It is considered that pesticides drained into irrigation canals from farmlands are largely contributing to the presence of pesticides in the main stream of Chao Phraya river. In 1989, 20 types of pesticides were banned from usage, but the survey results showed their existence up to the present.

The irrigation systems are under the jurisdiction of RID, but the responsible agency to handle water pollution problems in the agricultural field is not clear within the national government including the said RID. Therefore, strict compliance on the said ban seems to be not properly enforced by the government. In this regard, it is recommended that an agency in the Thai Government be designated who will be responsible in the proper administration of this problem and enforce/implement governmental controls on the use of pesticides and fertilizers.

CHAPTER 4

SANITATION CONDITIONS AND SEWERAGE SYSTEMS AT PRESENT AND IN THE FUTURE

CHAPTER 4 SANITATION CONDITIONS AND SEWERAGE SYSTEMS AT PRESENT AND IN THE FUTURE

4.1 Sanitation Conditions

The Government of Thailand prepared the "Thailand Country Profile on Drinking Water Supply and Sanitation" in 1989. This sub-section presents the present status of water supply and sanitation conditions and recommendations for future improvements, some of which are gathered from the aforementioned report.

(1) Background Information

Population

The population in the urban and rural areas from 1986 to 1991 is presented the table below.

Table 4.1.1 Population of Thailand

Unit : Million

Area	1986	1987	1988	1989	1990	1991
Urban*	13.77	14.29	14.7	15.18	15.65	16.12
Rural	38.88	39.32	39.83	40.27	40.69	41.08
Total	52.65	53.61	54.53	55.45	56.34	57.2
% of Urban area	26.2	26.6	27	27.4	27.8	28.2

Note : * Area includes Bangkok, Pattaya, 130 municipalities and 330 SDs
Source : Human Resources Planning Division, NESDB

Health Conditions

Many people in the rural areas suffered from health problems caused by inadequate and low quality health services as compared with those in the urban areas. In particular, the northeastern region has been affected because of poor water supply and sanitation.

It was reported that a high incidence of water-borne diseases affected about one-third of the population. Intestinal infection diseases, which include cholera, typhoid and diarrhea, have been one of the ten major causes of mortality for many years.

The national statistics revealed that the mortality rate for these diseases had dropped from 14.8/100,000 in 1977 to 4.8/100,000 in 1984. Communicable diseases (e.g. malaria, tuberculosis) have given way to non-communicable diseases as the main cause for concern.

Through the Fourth National Health Plan (1977-1981), rural health improvement had been performed in areas such as maternal and child health, sanitation, water supply, and nutrition. In the Fifth Plan (1982-1986), primary health care was introduced as the key strategy.

(2) Present Situation and Improvement Needs

1) Nationwide Water Supply

Urban public water supply in Thailand is provided by either MWA or PWA or concessions. For rural areas, water supply is mostly from point sources such as wells, ponds and rainwater containers. Piped water supply exists as general economic condition improves.

The nation-wide population coverage of drinking water in 1988 is shown in the table below.

Table 4.1.2 Population Coverage of Drinking Water

Type of Water Supply	Population Coverage	
	Million	Percent
Piped water	14.4	26.3
Rain water	25.7	47.2
Total	40.1	73.5

Note : Total population in 1988 : 54.5 million
Unknown water sources : 26.5 %

The DOH established a nation-wide drinking water quality surveillance network at the provincial level in 1985. The following is a comparative evaluation of water quality obtained from the provincial network (1987) as against the WHO Drinking Water Quality Standard (1971).

Table 4.1.3 Evaluation of Water Quality

Type of Systems	Satisfaction Ratio (%)	
	Physical & Chemical	Bacteriological
Piped Water Supply		
large scale	84	51
intermediate scale	79	41
small scale	73	38
Deep Well	56	51
Shallow Well	52	26
Rain Water Container	90	29
Pond	64	7

Source : Department of Health (DOH)

A rough assessment of population coverage with respect to both quantity and quality revealed that drinking water satisfaction level in quantity was 73%, while in quality (bacteriological index), it was 26%. Therefore, due attention should be paid to the improvement in water quality (reduction of bacteria levels), which is a primary public health concern.

2) Nationwide Sanitation Conditions

Sanitation in Thailand includes the provision of latrine and other facilities such as waste disposal, vector and pest control, drainage and sewerage, household and food sanitation and the like.

The 1980 population and housing census reported that 95% of the households in urban areas was served by latrines, while in the rural areas it was only 49%. It was envisaged that urban coverage would become almost 100% in 1992.

a) Urban sanitation

There is no municipality in Thailand with a complete sewerage system (service percentage in Pattaya is less than 50%). Nightsoil in urban areas is through a toilet connected to septic tank and leaching pit. In Bangkok, there is one nightsoil treatment

plant with a capacity of 600 m^3/day. Large establishments like hospitals, hotels, commercial and residential complexes usually operate and maintain their own wastewater treatment facilities.

The Bangkok Metropolitan Administration had prepared many plans in the past to the solve sewerage and drainage problems. In 1982, the JICA prepared a Master Plan of sewerage systems for Bangkok Metropolis. As of 1992, six sewerage sub-projects are being constructed and will start operation of the facilities in 1993.

In other urban areas, the National Excreta Disposal Plan was formulated in 1983 with a general plan and guidelines for the efficient planning of sewerage systems in urban areas other than Bangkok.

Presently, 73 wastewater facilities are operated at public hospitals by the MOPH. The DOH employed formally stabilization pond and oxidation ditch treatment systems for public hospitals. Upflow anaerobic filter has been used recently and the Department intends to introduce water reuse for some projects.

Open dumping is commonly employed for solid waste disposal in urban areas. Presently, most local authorities can collect only 60-95% of generated solid wastes in their service areas. Only the BMA has composting plants and incinerators as other means of disposal.

The DIW and ONEB have plans to control industrial or hazardous wastes. To ameliorate the problems, primary focus on integrated planning is recommended.

b) Rural sanitation

In the past, the annual increase of the number of latrines was rather low with a the range of 1-2%. However a marked increase to 6% was observed at the end of 1986 (refer to Figure 4.1.1). This was primarily due to the following:

- Non-governmental organizations were introduced into the DOH sanitation improvement program; and
- Stepping up of program demonstration activities.

Water-sealed type is a very common latrine in use. The DOH reported that as of 1988, 63% of the rural households had latrines installed. The distribution status of latrines is shown in Figure 4.1.1.

The DOH also reported in 1988 that in the process of refuse collection, 42% of the households used DOH refuse containers and about 13% of the rural communities had access to DOH small-scale incinerators.

The aim of the domestic vector control program has yet to be realized. In 1988, fly and cockroach proliferation were far beyond acceptable levels. The population of rats and mice were also beyond tolerable levels.

3) Study Area

Table 4.1.4 shows the number of household within the Study Area which are provided with latrine, safe water, and refuse disposal facilities as of January 1991. The average household coverage for the aforementioned facilities were 92.22%, 91.51%, and 80.92%, respectively. Ayutthaya Province has the least favorable conditions with regard to provision of latrine, 79.69% and safe water, 82.5%. For refuse disposal, Pathum Thani had the lowest coverage at 69.77%, and it may be noted that Ayutthaya was the second worst at 77.84%. Provinces which had the best coverage were Chai Nat with a 100% latrine coverage, Ang Thong with a 99.45% safe water coverage, and Sing Buri with a 91.95% refuse disposal coverage.

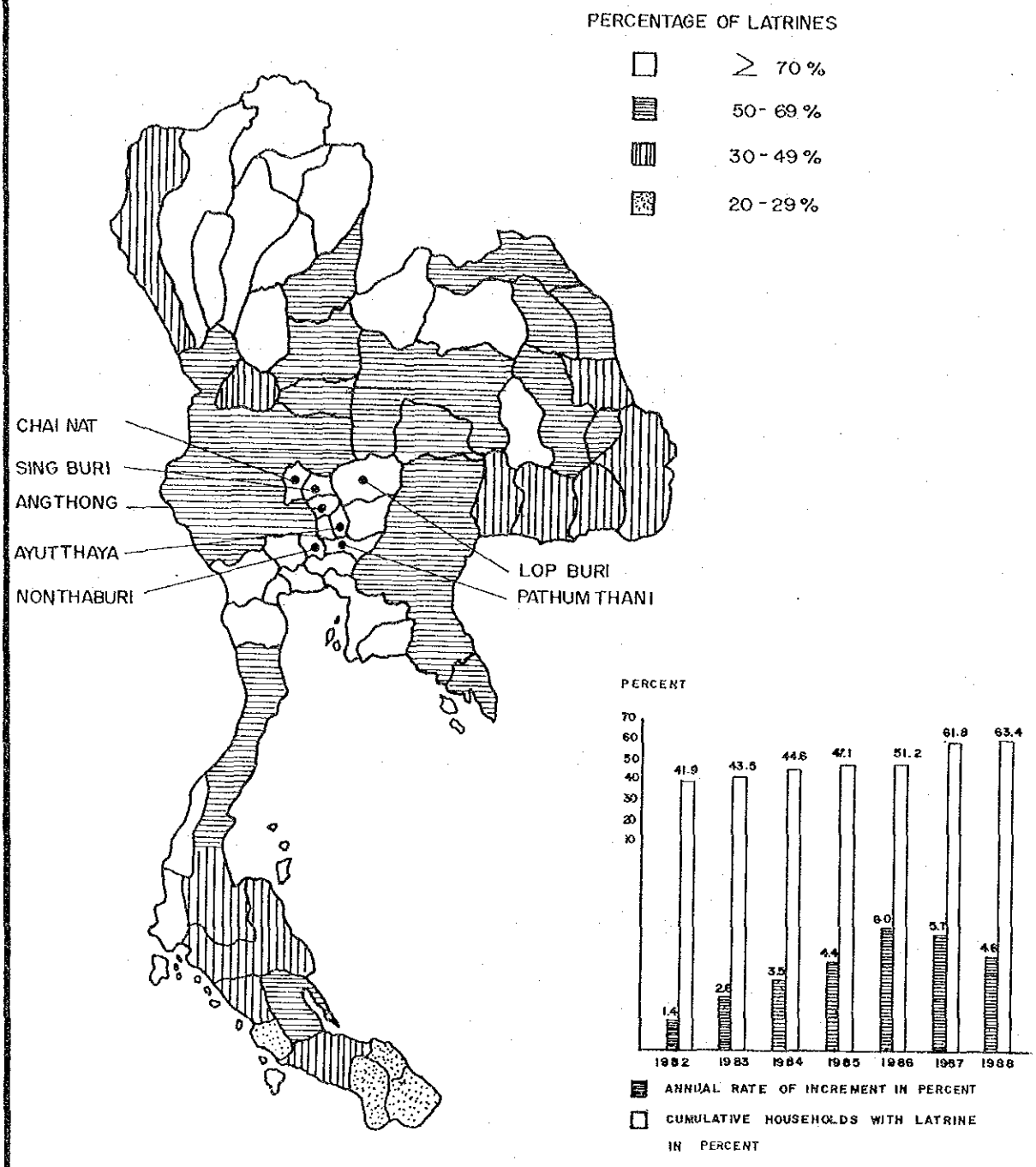


FIG. 4.1.1 NUMBER AND PERCENTAGE OF HOUSEHOLDS WITH LATRINE (1982 - 1988) AND LATRINE DISTRIBUTION IN THAILAND (1987)

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Table 4.1.4 Service Coverage by Province for latrine, Safe Water, and Refuse Disposal

Province	No. of Households	Latrines		Safe Water		Refuse	
		Served	%	Served	%	Served	%
Chai Nat	65,549	65,549	100.00	61,927	94.47	59,039	90.07
Sing Buri	46,062	44,403	99.81	41,228	96.02	42,355	91.95
Lop Buri	140,663	133,462	94.83	135,363	96.23	117,159	83.29
Ang Thong	55,550	53,507	96.32	55,246	99.45	47,203	84.97
Ayutthaya	126,991	101,195	79.69	104,786	82.51	98,853	77.84
Pathum Thani	88,627	74,976	84.60	77,117	87.01	61,838	69.77
Nonthaburi	139,543	138,318	99.12	131,016	93.89	110,039	78.86
Total	662,985	611,410	92.22	606,683	91.51	536,486	80.92

Source : Sanitary Division, Health Department

(3)Relevant Institutions

Institutional arrangements for urban water supply are as follows:

MWA

Bangkok Metropolitan Region : Metropolitan Bangkok, and Nonthaburi and Samut Prakan provinces

PWA

Urban areas except for MWA jurisdiction

Concessional waterworks operated by municipalities/SDs

Technical assistance is provided by PWD.

Various government agencies involved in rural water supply are shown in Tables 4.1.5 and 4.1.6. Agencies responsible for sanitation are shown in Tables 4.1.6 and 4.1.7.

(4) Recommended Future Plans

Future plans for the improvement of water supply and sanitation are summarized in the country profile report, as follows:

1) Public participation in the rural areas; strengthening of national system to effectively integrate the key strategy into the system; and reassessment of the bottom up approach;

2) Integrated planning on macro- and micro-scale considering sanitation, water quality and water for domestic and agricultural uses;

3) Intersectoral collaboration with roles of coordination bodies;

4) Expansion of services in all segments of water supply and sanitation;

5) Programs for promotion of continuous services including O & M, rehabilitation schemes and social acceptability;

6) Promotion of water supply for small-scale integrated farming;

7) Focus on rural areas in water supply and sanitation improvement; research and development in unknown environments or supporting programs of health education and public relations to create awareness;

8) Incorporation of human resources development wherever new concepts/technology are introduced; and

9) Institutional development to cope with the increase of service coverage.

Table 4.1.5 Implementation Institutions and Their Physical Output in Water Supply

	Physical Output				
	Pond	Shallow Well	Deep Well	Water Container + Jar	Piped Water Supply System
Ministry of Agriculture and Cooperatives					
The Royal Irrigation Department	v	o	o	o	o
The Land Development Department	v	o	o	o	o
Ministry of Interior					
Department of Local Administration	v	v	o	v	o
Department of Public Works	o	o	v	o	v
Department of Public Welfare	v	v	o	v	o
The Community Development Department	v	v	o	v	o
The Office of Accelerated Rural Development	v	v	v	v	o
Metropolitan Waterworks Authority	o	o	o	o	v
Provincially Waterworks Authority	o	o	o	o	v
Ministry of Public Health					
Department of Health	o	v	v	v	v
Ministry of Industry					
Department of Mineral Resources	o	o	v	o	o
Ministry of Defense					
National Security Command Headquarters	v	v	v	o	o

v: Implement o: Not Implement

Remark: Implementation includes provision of water through two means only: direct service and promotion of public participation

Source: Thailand Country Profile on Drinking Water Supply and Sanitation

Table 4.1.6 Institution for Planning in Water Supply and Sanitation

Ministry	Agencies and Coordinating Bodies	Specific Area of Interest
Water Supply		
Office of the Prime Minister	National Economic and Social Development Board	National Development Plan
	Bureau of Budget	Budget allocation
	Civil Services Commission	Personnel
	National Rural Water Supply Program Executive committee (Office of Policy and Planning, MOI)	National rural water supply
	National Water Resources Committee	National water resources
	Coordinating of Royal Inception Projects Committee	Royal inception projects
Sanitation		
Office of the Prime Minister	National Economic and Social Development Board	National Development Plan
	Bureau of Budget	Budget allocation
	Civil Services Commission	Personnel
Ministry of Interior	Department of Local Administration	Development of major cities
	Municipalities	Municipal development
	Department of Public Works	Control of construction
	Office of Policy and Planning	Planning
Ministry of Public Health	Office of the Permanent Secretary	Health promotion in urban and rural areas
	Department of Health	Environmental quality monitoring
Ministry of Science and Technology	National Environment Board	Environmental policy

Source : Thailand Country Profile on Drinking Water Supply and Sanitation (1989)

Table 4.1.7 Institution for Implementation in Sanitation

Ministry	Agencies and Coordinating Bodies	Specific Area of Interest
Ministry of Interior	Department of Local Administration	Comprehensive plan of action
	Department of Public Works	Consulting services in sewerage system
	Local Authorities	Provision of sanitary services
Ministry of Public Health	Department of Health	Promotion of latrine and consulting services in wastewater treatment system in hospital etc.
	Office of the Permanent Secretary	Operating body of the Ministry

Source : Thailand Country Profile on Water Supply and Sanitation (1989)

4.2 Existing Sewage Works in Thailand and On-going Pollution Control Plans in the Study Area

4.2.1 Existing Sewage Works and Plans in Thailand

Public sewage works in the local areas of Thailand were started in the middle of 1980, while the sewerage projects in Bangkok just started in 1992 and will commence operation of treatment facilities in 1993. Presently, the sewage works in Thailand is still under the initial stage of development for the improvement of living standard and water pollution control in the public water bodies.

The on-going sewerage projects in Bangkok comprise six(6) sub-systems under the responsibility of DDS-MWA. Table 4.2.1 shows the outline of the different projects. The total service area is 155.3 km^2 with an aggregate service population of 1,995,000 (service population of each sub-project ranges between 70,000 and 800,000). The treatment method determined for three of the six sub-projects is the modified activated sludge treatment method. The treatment capacity of each 6 plants is between 30,000 and 350,000 m^3/d for a total treatment needs of 776,000 m^3/d (250-570 lpcd). The huge construction cost required will be arranged by BMA supported by the central government.

For the local areas, the PWD is responsible from planning to construction supervision of the sewerage projects. Municipalities/local governments will undertake operation and maintenance of the sewerage systems. Table 4.2.2 presents implementation arrangements for sewage works.

There is a total of 34 sewerage systems in the local areas. Of these, 13 systems were constructed or under construction, while 7 treatment plants are in operation. Other systems are still under planning or design stage (D/D for 3 systems are already completed). Table 4.2.3 and Figure 4.2.1 indicate the location of sewage works in the local areas. The capacity of the treatment plant in local areas is small to medium size with a range of 2,200-32,000 m^3/d. The treatment methods include RBC (3 systems), OD (4 systems) and SP (5 systems). Unit construction costs by different treatment method are; SP B/ 3,600 m^3/d, RBC B/ 8,300 m^3/d,

Table 4.2.1 Sewerage Project by BMA

as of Dec.1991

Project Name	Area (km^2)	Population (x 1,000)	Sewage Treatment Plant: Treatment Method	Sewage Treatment Plant: Capacity ($1000m^3/d$)	Sewage Treatment Plant: Construction Cost (BB)	Interceptor: Length (km)	Interceptor: Cost (BB)	Total Cost (BB)	Finance	Remarks
1. Si Phraya	2.7	120	Contact Stabilization (Activated Sludge)	30	0.28	3.1	0.11	0.39	BMA	STP: Under Construction (~'93) Sewer D/D Completed
2. Rattanakosin	4.1	70	2 Stages (Activated Sludge)	40	0.51	16.5	0.35	0.86	Governmental Subsidy	D/D completed, Preparatory for tendering To be constructed from '92 to '95
3. Yan Nawa (Stage 1)	28.5	485	Contact Stabilization (Activated Sludge)	195	2.20	45.0	0.7	2.9	BMA	D/D Stage To be constructed from '93 to '95
4. Nong Khaem (Stage 1)	42.0	310	-	106	-	-	-	-	BMA	Under basic designing to be constructed from '93 to '95
5. Lard Burana (stage 1)	41.0	170	-	60	-	-	-	-	BMA	Under basic designing To be constructed from '93 to '95
6. Lumphini Huay Khwang (Stage 1)	37.0	800	-	350 2 plants	3.95	49.4	3.55	7.5	Governmental Subsidy (3/4) BMA (1/4)	Turn Key Project under evaluation of contractor To be constructed from '93 to '97
Total	155.3	1,955		776 7 plants						

Table 4.2.2 Implementation Arrangements for Sewage Works

Item	Government		
	Nation	Province	Municipality/S.D
Establishment of sewerage plan Decision on the priority projects	- Investigation & planning by PWD - Approval by cabinet meeting 100 %	0 %	- Willingness on participation 0 %
Land acquisition	- Recommendation on location and land size by PWD 0 % 70 % 1/ 60 % 2/ 75 % 3/	0 %	100 % 30 % 1/ 40 % 2/ 25 % 3/
Design & engineering work	Design Committee PWD staff Designing (by consultants) 100 %	Representative 0 %	Representative 0 %
Construction	Advisory Committee PWD staff Supervision work 100 % 70 % 1/ 60 % 2/ 75 % 3/	Representative 0 %	Representative 0 % 30 % 1/ 40 % 2/ 25 % 3/
Staff training	Training Plan by PWD 100 %	0 %	0 %
Operation and Maintenance of facilities	Technical assistance 0 %	0 %	Responsible 100 %

Note: percentage (%) indicates budgetary arrangements
1/ Fifth National Economic and Social Development Plan
2/ Sixth National Economic and Social Development Plan
3/ Seventh National Economic and Social Development Plan (NESDB)

Capital construction cost sharing between central and local government in 5 categories

Traffic	65 : 35	Piped water supply	45 : 55
Drainage	65 : 35	Sewerage system	75 : 25
Solid Waste	70 : 30		

Table 4.2.3 Sewerage System in Local Areas

No.	STP	Construction Year	Cost (M.B)	Treatment Capacity (m^3/day)	Treatment Methods	Remarks
1.	Pattaya Kasem Suwan	First :1984-1986	27.5	4,000	RBC	Operated
		Second :1989-1991	31.0	4,000	RBC	Operated
2.	Pattaya, #17	1989-1991	38.8	5,000	RBC	Operated
3.	Patong Beach, Phuket	First :1988	15.5	2,250	OD	Operated
		Second :1990-1992	22.3	3,000	OD	Under Construction
4.	Hua Hin	First :1989-1991	43.3	4,000	RBC	Operated
5.	Khon Kaen	1988	59.0	25,000	SP	Operated
6.	Nakhon Ratchasima	1989	88.5	32,000	SP	Operated
7.	Nakhon Phathom	1991	36.7	15,000	SP	Under Construction
8.	Sakhon Nakhon	1991-1993	85.9	5,250	SP	Under Construction
9.	Phanat Nikhom	1992	15.0	2,200	SP	Under Construction
10.	Leam Chabang	1992-1993	110	20,000	OD	Under Construction
11.	San Suk, North	1992-1994	439	14,000	OD	Under Construction
12.	San Suk, South	1992-1994	380	9,000	OD	Under Construction
13.	Jomthien Beach, Pattaya	1992-1994	359	20,000	Combined Fix Film	Under Construction
14.	Chiang Mai					M/P, F/S, D/D
15.	Chonburi					M/P
16.	Had Yai					M/P, F/S
17.	Nakhon Sawan					M/P, F/S
18.	Surat Thani					M/P, F/S
19.	Udon Thani					M/P, F/S
20.	Rachaburi					M/P, F/S
21.	Pitsanulok					M/P, F/S
22.	Phuket					Under Construction
23.	Nonthaburi					Under Construction
24.	Samui Island					Under Construction
25.	West Area of Phuket					M/P, F/S
26.	Cha Am					M/P, F/S
27.	Samut Sakhon					M/P, F/S
28.	Kanchanaburi					M/P, F/S
29.	Ayutthaya					M/P, F/S
30.	Ban Pae, Rayong					M/P, F/S, D/D
31.	Pathum Thani					M/P, F/S
32.	Sri Pacha					M/P, F/S, D/D
33.	Song Khla					M/P, F/S
34.	Samut Prakarn					M/P, F/S

Note: M/P : Master Plan
F/S : Feasibility Study
D/D : Detailed Design
RBC : Rotating Biological Contacter
OD : Oxidation Ditch
SP : Stabilization Pond

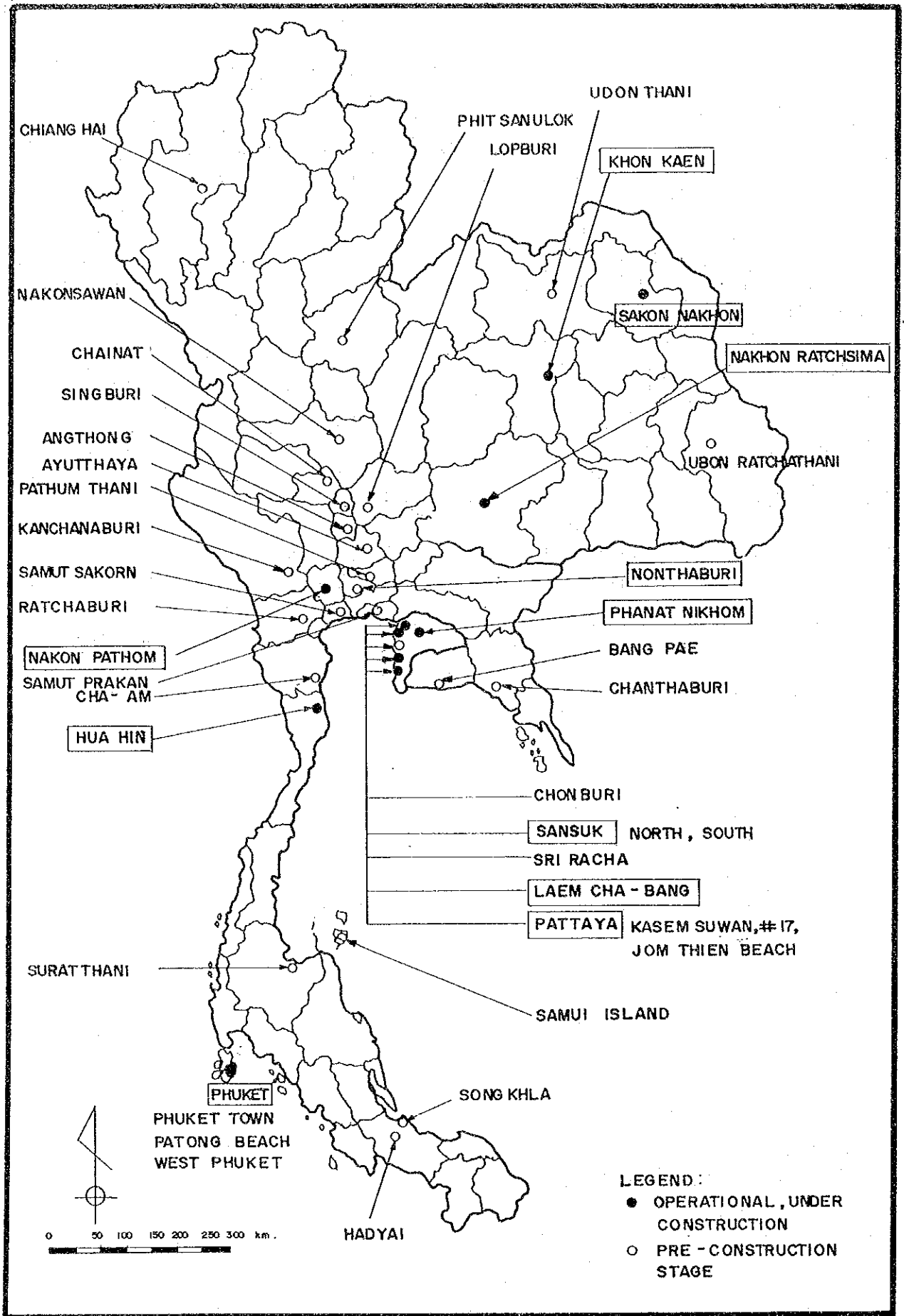


FIG. 4.2.1 SEWERAGE SYSTEM IN LOCAL AREA

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Reference information on the community plant constructed by NHA in Bangkok and its surrounding area are included in Table 4.2.4. Of the 18 plants, the oldest was in Huay Khwang constructed in 1975. The capacity of the treatment plant ranges from 400 to 6,500 m^3/d (200 lpcd). Most of the treatment methods used are activated sludge treatment method (11 T.Ps). Others are OD (3 T.Ps), aerated lagoon (2 T.Ps) and SP (2 T.Ps).

4.2.2 On-going Pollution Control Plans in the Study Area

The PCD, PWD and DIW are the major central government agencies undertaking sewerage projects for water pollution control in the Chao Phraya river basin. As of July 1992, the following plans and designs were prepared or under preparation for the specified priority areas in the subject basin.

(1) Lower Chao Phraya River Basin Water Pollution Control Master Plan, ONEB, 1991

(2) Comprehensive Study of Sewerage Systems for the First Group Area (5 provinces), PWD, 1992

(3) Flood Control, Drainage and Sewerage Systems for Nonthaburi Province, PWD, 1992

(4) Pre-Feasibility Study of Domestic Wastewater Management for Muang Pathum Thani Municipality, ONEB (PCD), 1992

(5) Pre-Feasibility Study of Domestic Wastewater Management for Muang Ayutthaya Municipality, ONEB (PCD), 1992

(6) Detailed Design of Wastewater Treatment Plant for Rangsit Area, DIW, 1992.

The areas covered for sewerage planning/design in the subject basin are three municipalities; Ayutthaya, Pathum Thani and Nonthaburi, and Rangsit area. Detailed design work for the industrial wastewater treatment plant in Rangsit area was recently completed. Other projects are still under feasibility study stage waiting for the allocation of the budget from the central government.

Table 4.2.4 Community Plant Constructed by NHA

as of December, 1991

Housing Estate	Construction Year	No.of Household and Population	Capacity (m^3/d)	Treatment Method
Huai Khwang	1975	3,360 16,800	3,400	AS
Tasai	1978	1,419 7,095	1,400	AS
Hua Mark	1978	588 2,940	600	OD
Ram Indra	1978	812 4,060	800	AS
Phibun Watana	1979	410 2,050	400	AS
Din Daeng	1979	1,020 5,100	1,000	AS
Khlong Chan	1979	6,438 32,190	6,500	AS
Bang Bua	1980	1,214 6,070	1,200	OD
Bang Na	1981	1,656 8,280	1,650	OD
Khlong Toei	1983	1,440 7,200	1,450	AS
Bon Kai	1983	380 1,900	400	AS
Tung Song Hong	1984	3,003 15,015	3,000	Aerated L.
Tung Song Hong	1984	1,111 5,555	1,100	AS
Rom Klao	1985	3,830 19,150	3,800	Aerated L.
Sub-Total (14 T.Ps)		26,681 133,005	26,700	
Rangsit	1977	1,428 7,140	1,400	SP
Prachaniwes 3	1979	3,709 18,545	3,700	SP
Prachaniwes 2/3	1979	642 3,210	640	AS
Bang Phli	1987	4,307 21,535	6,000	AS
Sub-Total (4 T.Ps)		10,086 50,830	11,740	
Total (18 T.Ps)		36,767 183,835	38,440	

Note: AS - Activated Sludge, OD - Oxidation Ditch,
Aerated L. - Aerated Lagoon, SP - Stabilization Pond

CHAPTER 5

SOCIO–ECONOMIC PROFILE AND LAND USE AT PRESENT AND IN THE FUTURE

CHAPTER 5 SOCIO-ECONOMIC PROFILE AND LAND USE AT PRESENT AND IN THE FUTURE

5.1 Socio-Economic Perspective

5.1.1 National Perspective

(1) Socio-Economic Development

The national economy had grown considerably during the past few years with the gross domestic product (GDP) increasing by an average of 10.5 percent during the 6th Plan Period (1987-1991), the highest average growth rate attained in the past twenty five years. Particular sectors which had exhibited high growth rates were export, investment and tourism sectors.

The rapid economic growth had helped bring about a stable and secure fiscal and monetary position. In 1991, international reserves reached nearly US$ 17 billion. For the same year, the ratio of debt payments to export earnings declined from 20.6 percent in 1986 to 10.15 percent. The ratio of external debt to GDP was 16.9 percent in 1989 and declined to 13.6 percent in 1990. In the balance of payments, the trade balance on goods and services recorded minus 40,998 million baht in 1988 and minus 193,539 million baht in 1991. The minus current account of goods and services was offset by net capital account. The net capital account was 72,623 million baht in 1988 and 294,734 million baht in 1991.

The current labor force is defined as all persons 13 years and over, who are either employed or unemployed. The employed person is then defined as the one who worked at least one hour for remuneration, cash or kind. On the other hand, the unemployed person is one who was looking for work or who had not been looking for work due to illness or other reasons. This definition of employment is too broad in concept, compared with that of developed countries. There are many underemployed part time workers in this definition. Should the labor force survey on hours worked become available, the proportions of full time employment, part time employment and of unemployment to the employed, the underemployed, and the unemployed, respectively, will contribute to a better understanding of the labor force utilization.

In the absence of such breakdown of labor force utilization, employment, as defined as the ratio of those who worked at least one hour to those who are in the labor force, is extremely an overestimation of the employment situation. The unemployment rates, as defined in the above, were 1.1 percent and 1.7 percent in 1989 and 1990, respectively.

Per capita GNP grew from 22,960 baht in 1987 to 36,032 baht in 1990. Since these figures are in current prices, the real growth rate is the growth rate in current prices minus the average of the consumer price index and the producer price index. The consumer price index (CPI) between 1986 and 1990 was 18.8 percent while the producer price index (PPI) was 23.5 percent between 1985 and 1990. Taking the annual average of CPI, 4.7 percent, and of PPI, 4.7 percent, we assume that the average rate of 4.7 percent be deducted from the current per capita GNP growth rate of 56.9 percent between 1987 and 1990. The real growth rate of per capita GNP becomes 42.8 percent or the annual average real growth of 14.2 percent. Such an increase is substantially high.

The agricultural sector, nonetheless, continues to be a very important sector in the Thai economy. At present, the sector employs around 64% of the country's total work force, and also, it plays a major role in the export market. Including agri-processed products, the sector's share in the export market reaches around 60 percent.

Despite the unprecedented economic success, income disparities among households of different socio-economic status and between rural and urban areas have increased. The income share of the top twenty percent of the income strata has increased from 49.3 percent in 1975-76 to 54.9 percent in 1987-88, while that for the lowest twenty percent declined from 6.1 percent to 4.5 percent during the same period. Table 5.1.1 shows the major socio-economic indicators during the 6th Plan Period (1987-1991) and the economic targets for the 7th Plan Period (1992-1996).

(2) National Economic and Social Development Plan

The present framework for national development is the 7th National Economic and Social Development Plan covering the years 1992-1996. Outlined hereun-

Table 5.1.1 Major Development Targets of Economic and Social Development During the Seventh Plan (1992-1996)

	6th Plan (1987-1991)	7th Plan Target (1992-1996)
1 Economic growth (% per year at constant prices)	10.5	8.2
1.1 Agriculture sector	3.4	3.4
1.2 Non-agriculture sector	12.1	8.6
- Industry	13.7	9.5
- Construction	18.7	8.9
- Services and Others	11.0	8.1
2 Per capita income (baht/year)*	41,000	71,000
3 Expenditures (% per year at constant prices)		
3.1 Private sector		
- Consumption	9.1	5.7
- Investment	26.0	8.8
3.2 Public sector		
- Consumption	2.0	3.3
- Investment	6.5	8.5
4 Export of goods		
4.1 Average (billion baht)	496.0	1,063.0
4.2 Average growth rate per year (%)	24.5	14.7
5 Import of goods		
5.1 Average value (billion baht)	664.3	1,358.0
5.2 Average growth rate per year (%)	32.6	11.4
6. Inflation (%)	4.7	5.6
7. Number of population (million)	56.9	61.0
Population growth rate (%)	1.4	1.2
8. Transition rate to secondary school (%)	46.2 **	73.0
9. Employment (million persons)	32.0	34.9
Unemployment rate (%)	0.6	0.5
10. Infant mortality rate (per 1,000 live births)	29.0	23.0
11. Proportion of people under poverty line (%)	23.7 ***	20.0

* Figures of the last year (1991 and 1996) of the Sixth and Seventh Plans respectively

** Year 1989/1990 *** Year 1988

Source : The 7th National Economic and Social Development Plan (1992-1996), National Economic and Social Development Board (NESDB)

der are the salient plan features.

1) Main Development Objectives

a) Maintain economic growth rates at appropriate levels to ensure sustainability and stability

b) Redistribute income and decentralize development to the regions and rural areas more widely

c) Accelerate the development of human resources and upgrading of quality of life, the environment and natural resource management.

2) National Development Targets

To attain the above development objective, national development targets have been set forth. Table 5.1.1 shows the major economic and social development targets for the seventh plan period.

5.1.2 Study Area

(1) Economic Activities

The economic profile of the study area is characterized by a predominantly agricultural economy in the five provinces in the Upper Central Region (UCR) and a high concentration of industry in Pathum Thani and Nonthaburi.

The reliance of the UCR provinces in agriculture stems from the fact that the region has vast land with relatively good soil quality and abundant water resources like the Chao Phraya, Noi, Lop Buri and Pasak rivers. These water resources are optimized through irrigation systems like the Chai Nat Dam, the Channasut, Phraya Banlue, Chao Chet-Bang Yi Hon, Brom That, and Sam Chuck projects.

The main agricultural products of the UCR are rice, maize, sorghum, peanut and cotton. Major rice-producing provinces or changwats are Chai Nat, Sing Buri, Ang Thong, and Ayutthaya. With high average yields, the whole UCR supplies around 10 percent of the total national rice production. In 1988-1989, the region produced 1,397,335 tons of rice with an average yield of

447 kg/rai (1 rai = 1,600 m^2), much higher than the national average yield of 343 kg/rai. For sorghum, it was estimated that the whole UCR produced around 45 percent of the total national production. Also, the UCR accounted for around 15 percent of the total national production of maize, much of which was produced in Lop Buri.

The region is also endowed with mineral resources like iron, kaolin, limestone, marble, shale and pyrophyllite mostly found in Lop Buri and Chai Nat.

Industrial based economy in Nonthaburi and Pathum Thani is basically a fringe part of a greater industrial mass concentrated in the BMR area, which has served as the hub of the Thai economy. In 1989, the manufacturing sector contributed 69.8 percent of the gross provincial product (GPP) to Pathum Thani and 53.1 percent of the GPP to Nonthaburi.

Table 5.1.2 presents the GPP in 1989 at current prices, and the per capita GPP of the provinces within the study area. Pathum Thani province had the largest GPP at 44,825 million baht, while Sing Buri province, the smallest at 5,082 million baht. On a per capita basis, Pathum Thani still was the highest among the provinces with 100,279 baht per capita and Lop Buri province, the lowest with 20,980 baht per capita.

The whole study area contributed around 7.4 percent of the gross domestic product (GDP) to the GDP of Thailand in 1989. The 1989 average per capita GPP for the study area was 40,341 baht per capita, 26 percent higher than the national average of 32,028 baht per capita.

(2) Social and Infrastructure Profile

1) Education

Based on the National Statistics Office (NSO) regional reports, there were around 26,800 teachers and 452,620 students (up to secondary level) in 1987 in the whole UCR with an average teacher-student ratio of 1:16.9. Sing Buri had the best teacher-student ratio at 1:14.6, while Ayutthaya had the least at 1: 17.2.

Table 5.1.2 1989 Gross Provincial Product (GPP) at Current Prices
Unit: Million Baht

PROVINCES / SECTOR	CHAI NAT GPP	%	SING BURI GPP	%	LOP BURI GPP	%	ANG THONG GPP	%	AYUTTHAYA GPP	%	PATHUM THANI GPP	%	NONTHABURI 1 GPP	%
Agriculture	2,765	33.5	1,323	26.0	4,456	30.0	1,288	.	2,746	17.6	2,312	5.2	1,464	3.9
Mining and Quarrying	118	1.4	22	0.4	372	2.5	118	.	1,922	12.3	886	2.0	0	0
Manufacturing	539	6.5	656	12.9	710	4.8	819	.	2,149	13.8	31,274	69.8	19,763	53.1
Construction	659	8.0	118	2.3	699	4.7	129	.	587	3.8	1,450	3.2	3,764	10.1
Electricity and Water Supply	69	0.8	83	1.6	329	2.2	136	.	740	4.7	2,090	4.7	1,037	2.8
Transportation and Communication	283	3.4	392	7.7	891	6.0	469	.	988	6.3	470	1.0	1,224	3.3
Wholesale and Retail Trade	1,592	19.3	1,069	21.0	3,296	22.2	1,309	.	3,012	19.3	2,979	6.6	4,981	13.4
Banking, Insurance and Retail Trade	210	2.5	220	4.3	459	3.1	226	.	589	3.8	832	1.9	1,374	3.7
Ownership of Dwellings	356	4.3	229	4.5	721	4.9	289	.	650	4.2	454	1.0	685	1.8
Public Administration and Defense	604	7.3	268	5.3	1,563	10.5	227	.	653	4.2	419	0.9	507	1.4
Services	1,048	12.7	702	13.8	1,358	9.1	697	.	1,550	9.9	1,659	3.7	2,416	6.5
TOTAL GPP	8,243	100	5,082	100	14,854	100	5,707	100	15,586	100	44,825	100	37,215	100
PER CAPITA GPP (bt/cap)	24,316		23,100		20,980		21,536		24,052		100,279		58,791	
POPULATION (1,000 per)	339		220		708		265		648		447		633	

Source: Gross Regional and Provincial Products, 1981-89
Office of the National Economic and Social Development Board
Office of the Prime Minister, Bangkok, July 1991

In the same year for the whole UCR, student population was estimated at 16.54 percent of the whole regional population. Sing Buri had the highest student-population percentage at 17.8 percent, while Chai Nat had the lowest at 15.2 percent.

For Nonthaburi and Pathum Thani, the educational sector was characterized by a student and teacher population of 9,811 and 182,011, respectively. These figures corresponded to an average teacher-student ratio of 1:18.5.

2) Health

In 1986 there was a total of 59 hospitals in the UCR with a combined bed capacity of 4,728 and a complement of 344 physicians. The bed-population ratio (BPR) was estimated at 1:576 while the physician-population ratio (PPR) was placed at 1:7,918. Health facilities of Sing Buri were the most adequate among the UCR provinces as it had the most favorable BPR and PPR at 1:323 and 1:4,975, respectively. On the other hand, Ayutthaya had the least favorable ratios: 1:1,167 BPR and 1:12,301 PPR.

There were 13 hospitals in Nonthaburi and Pathum Thani in 1988. The hospitals had a combined capacity of 582 beds and a staff of 127 physicians. Pathum Thani was better off than Nonthaburi in terms of bed-population ratio as the former had a 1:1,340 BPR, while the latter had a 1:2,321 BPR. However, it was the other way around with regard to physician-population ratio (PPR): Pathum Thani had 1:11,458 PPR, while Nonthaburi had 1:6,701 PPR.

From the 1986 statistics, 11,234 persons died of various diseases in the central region. The number one cause of mortality was heart diseases with 1,139 persons, followed by malignant neoplasms and nutritional deficiency with 810, accidents and poisonings with 758, and tuberculosis with 208. The disease index, like the consumer price index, is indicative of which disease is rising or under control. The base year was 1975 with the initial index of 100 for each of the major diseases. While the overall disease index declined from 100 in 1975 to 85 in 1986 in the central region, the indexes of heart disease and of malignant neoplasms of 392 and 169, respectively were still

higher than 100. Any disease index above 100 indicates that the disease is not under control.

The malaria index fell from 100 in 1975 to 20 in 1986, while the nutritional deficiency index dropped to 10 in 1986. The accidents and poisonings index was 85 and the tuberculosis index, 59.

3) Urbanization

Of the estimated 3.3 million study area's population in 1990, around 37.7 percent lived within the boundaries of municipalities and sanitary districts.

Nonthaburi had the highest percentage of urban population to total population at 65.4 percent. Pathum Thani followed with 45.9 percent and Ayutthaya at 33.7 percent. Chai Nat had the lowest percentage at 10.1 percent.

As for urban development, it is projected that the urban area and its population in Nonthaburi and Pathum Thani will continue to increase as it will continue to absorb spill-over industrialization from the Bangkok Metropolis. The 1990 JICA UCR Master Plan Study concluded that the "concentration of economic activities and population in the BMR will continue to be a predominant trend in national development". It also stressed that cities in other regions are too small to absorb and support industrialization and that some factors like higher levels of living amenities and urban services will further attract migration. Of the 24,510 and 20,216 population growth recorded in 1987-1988 for the provinces of Nonthaburi and Pathum Thani, respective percentages of 87.7 and 98.1 may be attributed to net migration to these provinces.

Rapid urban development is likewise projected in some areas of the UCR. The Department of Town and Country Planning (DTCP) has identified Chai Nat, Ang Thong, Sing Buri, Lop Buri, Phraphutthabat and Ayutthaya municipalities as secondary urban centers. The municipality of Saraburi will serve as the main regional urban center. The JICA UCR Master Plan Study likewise gives importance to these municipalities, although it emphasized Ayutthaya which may serve as a main regional urban center on the same level as Saraburi in the future.

It may, however, be noted that urban development in the UCR will focus on Saraburi, which as aforementioned will be the main regional urban center. Saraburi is not within the study area but is adjacent. It has a significant economic influence on the study area as it is bounded by Lop Buri on the north and Ayutthaya on the southeast. Furthermore, the 7th National Economic and Social Development Plan calls for the development of Saraburi province as a new economic base in the UCR to serve as a center for relocation of industrial activities from Bangkok Metropolis and vicinity areas. Saraburi shall also serve as the trade connecting point of the region to Laem Chabang, Chonburi province. Laem Chabang in Chonburi Province will be developed as a modern seaport town with an international commercial seaport for containerized cargoes, industrial estates, and an export processing zone. It is part of the Eastern Seaboard economic development zone.

4) Infrastructure and Utilities

As per the 1990 JICA UCR Master Plan Study, the UCR road system had a total length of 7,084 km broken down as follows: 587 km (8%)of arterial roads; 1,636 km (23%), collector roads; and 4,861 km (69%), local roads. The main roads of the UCR are national highway number 1 and 32, which connect to the Bangkok Metropolis and northern region, respectively. National highway number 2 and 205 connect to the northeastern region while national highway number 35, to the eastern region. For the other two provinces in the BMR, the major roads are highway number 1 which passes Pathum Thani and highway number 304 which leads to Nonthaburi coming from highway number 1.

The provinces of Pathum Thani, Ayutthaya and Lop Buri are served by the railway systems. A total of 240,759 passenger-trips originated from Pathum Thani in 1988, while in the UCR provinces, a total of 6,058,829 passenger-trips were made in 1986. As for freight, it seems that Pathum Thani does not utilize the railway system significantly based on the 1988 figures. Only 4 metric tons of cargoes originated from Pathum Thani. Railway freight was more pronounced in the UCR where in 1986, a total of 845,350 metric tons were carried therefrom.

In 1987, there were a total of 94 telephone exchanges in the whole 7 provinces in the study area. These exchanges had a total capacity of

65,201 lines, although only 46,622 (71.5%) were utilized. Nonthaburi accounted for 59.6 percent of the total line capacity.

There were 90 power plants within the UCR in 1986. For the same year, electricity sales through the PEA totaled 1,226 million kWh, 73.2 percent of which were consumed by the business and industry, while the remaining 26.8 percent were used by residential consumers. In Pathum Thani, a total of 1,271 million kWh of electricity were sold in 1988. Business and industry accounted for a large 91.3 percent of these sales.

5.2 Present and Future Land Use

Land use in the Chao Phraya river basin is broken into agricultural land, forestry and swamp land, and or residential and economic-related use. The present land use in the whole study area is covered and presented in this section. On the other hand, the future land use with reference to city planning is limited to municipalities concerned on this Study.

The DTCP prepares land use plans for only municipalities covering the entire Thailand. These plans generally consist of four reports: (1) general; (2) engineering; (3) research; and (4) development plan together with three kinds of maps (general, land use plan and road development plan).

5.2.1 Overall Land Use in the Past and at Present

At the country level, approximately 74 percent of the total land were used for agriculture (46%) and forestry (28%) purposes as of 1988. Paddy field share to total agricultural land area over the years was almost constant at about 23 percent, while lands for field crops and fruits had increased remarkably.

In 1988, agricultural land share of 1,516,515ha to total land area of the seven provinces within the study area was a high 83 percent. Paddy fields occupied about 52% (797,670ha) of the total land area.

Comparing the 1981 figures with the composition of the present land use, attention may be given to the fact that agricultural land has been increasing moderately, while forest land has decreased. Residential and economic-

related land uses have likewise increased. Development of towns is expected to be accelerated in the future, especially in Pathum Thani and Nonthaburi provinces. The overall land use in Thailand and the study area are shown in Table 5.2.1 and Table 5.2.2, respectively.

5.2.2 City Planning for the Municipalities

Based on the plans prepared by the DTCP, the land use plan for the subject eight municipalities and SDs is summarized in Table 5.2.3.

Table 5.2.3 Land Use Plan of the Subject Municipalities & Sanitary Districts

Area Unit: Km^2

Municipality	Present Pop. in Muni./SD (1991)	Present Area of Muni./SD	Future Exp. area	Other area	DTCP Area
1 Chai Nat	13,983	6.06	0.84	49.54	56.49
2 Sing Buri	22,570	9.02	2.89	19.42	31.33
3 Lop Buri	36,832	6.85	3.38	2.62	12.85
4 Ang Thong	9,607	3.73	1.45	18.80	23.98
5 Pa Mok	10,686	6.89	0.24	19.73	26.86
6 Sena	4,607	1.20	0.79	24.11	26.10
7 Rangsit	100,600	33.30	-	-	33.30
8 Bang Bua Thong	45,786	1.60	14.04	-	9.85
Total	244,671	68.65	23.63	134.27	220.76

Table 5.2.1 Overall Land Use in Thailand

Change of Land Use in Thailand (unit: 1,000 ha)

Year	Total Land	Forest Land	Farm Holding Land							Unclassified Land
			Paddy Land	Field Crops	Fruits & Tree Crops	Vege. & Flowers	Others	Housing area	Total	
1975	51,312	20,922	11,398	3,192	1,666	57	1,187	454	17,954	12,436
1976	51,312	19,842	11,411	3,418	1,646	57	1,131	435	18,098	13,372
1977	51,312	18,653	11,440	3,732	1,612	53	939	431	18,207	14,452
1978	51,312	17,522	11,723	3,801	1,668	56	965	418	18,631	15,159
1979	51,312	17,024	11,657	4,041	1,767	50	902	399	18,816	15,472
1980	51,312	16,547	11,770	4,121	1,783	50	913	403	19,040	15,725
1981	51,312	16,094	11,764	4,382	1,826	48	989	398	19,407	15,811
1982	51,312	15,660	11,716	4,686	1,900	55	1,004	413	19,774	15,878
1983	51,312	15,403	11,782	4,708	1,905	55	1,013	414	19,877	16,032
1984	51,312	15,151	11,826	4,805	1,930	66	979	444	20,050	16,111
1985	51,312	14,905	11,824	5,057	2,154	76	980	485	20,577	15,830
1986	51,312	14,665	11,877	5,132	2,226	86	962	492	20,775	15,872
1988	51,312	14,220	11,871	5,715	3,126	135	2,267	535	23,648	13,283

Change of Land Use Composition in Thailand (%)

Year	Total Land	Forest Land	Farm Holding Land							Unclassified Land
			Paddy Land	Field Crops	Fruits & Tree Crops	Vege. & Flowers	Others	Housing area	Total	
1975	100.00	40.77	22.21	6.22	3.25	0.11	2.31	0.88	34.99	24.24
1980	100.00	32.25	22.94	8.03	3.47	0.10	1.78	0.79	37.11	30.65
1985	100.00	29.05	23.04	9.85	4.20	0.15	1.91	0.95	40.10	30.85
1988	100.00	27.71	23.13	11.14	6.09	0.26	4.42	1.04	46.09	25.89

Table 5.2.2 Land Use in the Study Area

unit: ha

Year	Province	Total Land	Forest Land	Farm Holding Land: Paddy Land	Field Crops	Fruits & Tree Crops	Veget.& Flowers	Others	Housing area	Total	Unclassified Land
1981	Whole Kingdom (1,000 ha)	51,312	16,093	11,764	4,382	1,826	48	989	398	19,407	15,811
	Share (%)	100.00	31.36	22.93	8.54	3.56	0.09	1.93	0.78	37.82	30.81
	Chai Nat	246,975	1,047	149,500	21,737	4,953	82	620	344	180,343	65,585
	Sing Buri	82,248	0	65,874	1,057	1,985	88	324	1,474	70,802	11,446
	Lop Buri	619,975	29,776	191,406	191,406	249,562	4,614	35	7,179	458,932	131,267
	Ang Thong	96,837	0	79,937	0	2,528	306	471	2,777	86,019	10,818
	Ayutthaya	255664	0	214,175	1,442	3,513	429	421	4,136	224,115	31,549
	Pathum Thani	152,586	0	111,853	286	6,672	1,887	3,797	2,225	126,720	25,865
	Nonthaburi	62,230	0	24,320	0	7,443	388	638	982	33,766	28,459
	Total	1,516,515	30,823	837,065	215,928	276,658	7,793	6,305	19,117	1,180,697	304,990
	Share (%)	100.00	2.03	55.20	14.24	18.24	0.51	0.42	1.26	77.86	20.11
1985	Whole Kingdom (1,000 ha)	51,312	14,905	11,824	5,057	2,154	76	980	485	20,577	15,830
	Share (%)	100.00	29.05	23.04	9.86	4.20	0.15	1.91	0.95	40.10	30.85
	Chai Nat	246,975	900	144,312	21,632	5,384	265	693	4,233	176,519	69,556
	Sing Buri	82,248	0	63,228	1,342	2,202	126	125	3,663	70,686	11,562
	Lop Buri	619,975	27,900	181,584	253,324	5,747	594	7,239	6,552	455,040	137
	Ang Thong	96,837	0	75,188	308	2,939	194	429	3,046	82,104	14,733
	Ayutthaya	255,664	0	199,191	2,397	5,352	652	886	6,622	215,100	40,564
	Pathum Thani	62,230	0	25,752	0	6,023	362	350	1,105	33,593	28,637
	Nonthaburi	152,586	0	96,334	0	20,045	1,594	2,460	2,775	123,209	29,377
	Total	1,516,515	28,800	785,588	279,002	47,693	3,787	12,182	27,997	1,156,250	194,567
	Share (%)	100.00	1.90	51.80	18.40	3.14	0.25	0.80	1.85	76.24	12.83
1988	Whole Kingdom (1,000 ha)	51,312	14,220	11,871	5,715	3,216	135	2,267	535	23,648	13,283
	Share (%)	100.00	27.71	23.13	11.14	6.27	0.26	4.42	1.04	46.09	25.89
	Chai Nat	246,975	802	158,480	19,163	5,502	348	15,857	3,787	203,137	43,035
	Sing Buri	82,248	0	64,815	1,237	3,717	104	3,599	1,808	75,279	6,968
	Lop Buri	619,975	27,540	188,108	265,196	9,400	380	47,181	5,523	515,789	76,647
	Ang Thong	96,837	0	73,065	2,970	3,711	100	5,479	2,071	87,396	9,441
	Ayutthaya	255,664	0	202,153	1,478	4,888	709	7,071	6,101	222,399	33,265
	Pathum Thani	62,230	0	27,603	0	8,468	1,410	1,584	763	39,827	22,403
	Nonthaburi	152,586	0	83,446	591	22,590	953	4,784	2,311	114,674	37,911
	Total	1,516,515	28,342	797,670	290,635	58,275	4,004	85,555	22,363	1,258,502	229,671
	Share (%)	100.00	1.87	52.60	19.16	3.84	0.26	5.64	1.47	82.99	15.14
Ratio 1988/1981											
	Whole Kingdom	1.000	0.884	1.009	1.304	1.761	2.812	2.291	1.343	1.219	0.840
	Study Area	1.000	0.920	0.953	1.346	0.211	0.514	13.568	1.170	1.066	0.753

CHAPTER 6

POPULATION, INDUSTRY, AGRICULTURE AND FISHERY AT PRESENT AND IN THE FUTURE

CHAPTER 6 POPULATION, INDUSTRY, AGRICULTURE AND FISHERY AT PRESENT AND IN THE FUTURE

6.1 Population Projection

6.1.1 Methodology

Population of the subject seven provinces was projected for target years 1996, 2001, and 2011 with 1990 as base year 1990.

The base data are registered population investigated by the DOLA which are used for comprehensive basin-wide water pollution control plan from the macro-level viewpoint. On the other hand, non-registered population may be considered for sewerage planning as practiced by the PWD in its on-going sewerage plans.

Projection is made on provincial and amphoe levels and for municipalities and sanitary districts. The study area is categorized into two groups: the Upper Central Region (UCR), and the extended development area of Metropolitan Bangkok.

By group area, recent projections made by the authorities in Thailand are basically employed as follows:

(1) UCR related provinces: Chai Nat, Sing Buri, Lop Buri, Ang Thong and Ayutthaya - Upper Central Region Study, Master Plan, NESDB, prepared by JICA in 1990.

(2) Metropolitan Bangkok extension area: Pathum Thani and Nonthaburi - Comprehensive Study of Sewerage Systems for First Group Area (5 Provinces), 1992, PWD; Flood Control, Drainage and Sewerage Systems for Nonthaburi Province, 1992, PWD; Lower Chao Phraya River Basin Water Pollution Control Master Plan, 1991, ONEB.

Further description was made in the application of the above-mentioned projections by categorized area.

UCR Related Provinces

(1) Population projection on provincial and amphoe levels

Total population of the UCR is projected in the Report by the year 2010 with the following growth rates:

Duration	Growth Rate
1988-1996	0.8%
1996-2001	1.3%
2001-2010	1.3%

Population in the year 2011 was projected using the growth rate of 1.3% between the years 2010 and 2011. To get the total population of the Study area by target year (5 provinces), projected population of Saraburi province was deducted by using the present proportion among the provinces. Population projection by target year for respective provinces and amphoe was made using percentages to the total population of the study area considering past trends up to 1990.

(2) Population projection for municipalities and sanitary districts

Projection by 2010 in the Report was employed for the municipalities and SDs concerned. The figures for the year 2011 were projected using the same growth rate between 2001 and 2010 for respective municipalities/SDs.

The projections for province, amphoe, municipality and SD were also examined by the Study Team based on collected data in 1970, 1980, 1985 and 1990. For details, refer to Section 6.1.1 of Volume III-Supporting Report. Average growth rate method is employed both for adopted projection and conducted study. The study results and projected figures by aforementioned authorities are within allowable ranges. Accordingly, projections by the authorities are employed.

Extension Area of Metropolitan Bangkok

In the Report, population projections by amphoe for Pathum Thani and Nontha-

buri provinces were made for the years 2000, 2010, and 2020 using 1990 as the base year and past records in 1970, 1980, 1983 and 1990.

(1) Population projection on provincial and amphoe levels

The growth rates used in the Report are employed for population projection for years 1996, 2001 and 2011.

(2) Population projection for municipalities and sanitary districts

Future population for the municipalities and SDs are projected as follows:

a) Bang Bua Thong municipality

The DTCP projected population under the following conditions as shown in the "Municipality Bang Bua Thong Development" report.

- growth rate: 1.8% between 1988 and 1987
- average growth rate projection method

However, recent trend between 1985 and 1990 revealed that the average annual growth rate was 2.8%. Applying the average growth rate method, and considering the present development of housing areas as confirmed through field survey, the growth rate of 2.8% is used.

b) Prachatipat and Khu Kot sanitary districts

Using the annual growth rate of 2.8% (1985-1990), projection was made applying the average growth rate method with 1990 as base year.

c) Pathum Thani and Nonthaburi municipalities and Pak Kret SD

The projections made in the study on development of sewerage systems by PWD were adopted.

d) Other municipalities and SDs

The projections made in the Lower Chao Phraya River basin Water Pollution Control Master Plan were adopted.

6.1.2 Population Projection in Provincial and Amphoe Levels

Projection by target year are presented by province in Table 6.1.1.

6.1.3 Population Projections for Municipalities and Sanitary Districts

Tables 6.1.2 and 6.1.3 show projections for both municipalities and SDs. Population by target year in the study basin is also shown in Table 6.1.4.

6.2 Industrial Development

6.2.1 General

Projection of wastewater discharged from factories both in quality and quantity is imperative for water pollution analysis covering the Study area.

Suitable frame value shall be selected common to the parameter to be used for projection of unit pollution quality and quantity.

Present industrial development and its features were analyzed and previous studies/plans were studied for a comprehensive approach entailing socio-economic aspects. This is in line with the national policy and wide area/regional coverage (macro-level consideration).

Methodology for the projection was established on a practical basis using fully previous studies within the limited data available.

In principle, the Upper Central Region (UCR) and the adjacent area of Bangkok Metropolitan Region (BMR) are dealt with separately as practiced for the population projection.

Table 6.1.1 Projected Population of Provinces and Amphoes

Provinces / Amphoes	Past Record				Estimation	Projection		
	1970	1980	1985	1990	1992	1996	2001	2011
Chai Nat	261,513	318,068	339,478	355,151	359,098	370,091	387,556	416,009
** Muang Chai Nat	50,866	70,620	69,114	73,110	72,957	72,652	73,037	75,611
Manorom	27,971	31,640	34,829	35,453	35,943	36,944	38,639	40,402
Wat Sing	35,453	42,679	42,478	45,154	45,256	45,460	46,200	48,879
* Sankhaburi	52,475	61,753	66,319	68,684	69,530	71,255	74,248	77,065
* Sanphaya	41,375	47,515	51,785	52,888	53,548	54,892	57,220	59,436
Hankha	53,353	63,861	74,953	79,862	82,764	88,888	98,212	114,616
Sing Buri	165,371	196,574	215,021	229,816	234,635	244,669	260,869	290,239
** Muang Sing Buri	38,651	43,463	49,581	53,118	54,600	58,326	63,738	74,318
* Khai Bang Rachan		25,633	27,516	30,180	30,904	32,406	34,758	39,043
* Tha Chang	12,636	14,575	15,313	16,059	16,228	16,571	17,193	18,074
* Bang Rachan	45,635	32,333	35,418	38,984	40,110	42,460	46,087	53,013
* Prom Buri	20,372	26,112	24,942	25,925	25,657	25,130	24,752	23,445
* In Buri	47,877	56,458	62,251	65,550	66,936	69,796	74,341	82,346
Lop Buri	463,933	571,713	695,992	704,432	727,260	778,746	856,653	1,014,708
** Muang Lop Buri	146,045	192,780	234,442	251,391	267,289	302,165	352,978	461,681
Khok Samrong	107,009	118,436	133,518	81,119	75,827	66,256	56,093	38,535
Chai Badan	69,621	85,208	101,462	86,280	87,211	89,103	91,720	93,154
Tha Luang		17,312	21,284	23,743	25,500	29,415	35,239	48,475
* Tha Wung	39,613	43,469	49,617	50,628	52,627	56,864	62,777	73,337
Ban Mi	65,317	70,318	83,016	86,524	90,934	100,439	113,971	140,660
Patlana Nikom	36,328	44,190	50,003	53,467	56,003	61,442	69,136	83,902
Sa Boat			22,650	24,480	24,682	25,092	25,668	25,745
Khok Charoen				23,788	23,985	24,383	24,942	25,018
Lam San Thi				23,012	23,202	23,587	24,129	24,201
Ang Thong	217,014	256,706	270,941	278,168	280,307	284,702	293,700	305,950
** Muang Ang Thong	34,610	44,571	46,100	47,992	48,288	48,884	50,199	51,736
* Chaiyo	17,261	22,336	22,466	22,730	22,613	22,381	22,344	21,764
** Pa Mok	24,377	28,087	29,113	29,068	29,016	28,913	29,108	28,834
* Pho Thong	43,939	49,937	55,523	57,290	58,379	60,618	64,254	70,557
* Wiset Chai Chan	59,298	65,227	66,941	68,078	68,072	68,059	68,809	68,739
* Samko	12,362	15,032	16,678	17,443	17,815	18,583	19,810	22,003
* Sawaengha	25,167	31,516	34,120	35,567	36,124	37,264	39,176	42,317
Ayutthaya	497,737	602,021	652,977	681,920	693,210	716,748	755,973	823,196
** Muang Ayutthaya	76,658	99,620	115,107	120,102	123,553	130,757	141,839	162,824
** Tha Rua	35,643	45,690	50,112	51,434	52,192	53,740	56,330	60,380
* Nakhon Luang	24,505	27,164	31,477	32,918	33,899	35,949	39,096	45,112
* Bang Sal	17,501	19,559	18,637	19,553	19,375	19,025	18,793	17,868
* Bang Sai	33,549	39,770	41,838	43,838	44,297	45,229	46,913	49,239
* Bang Ban	28,494	32,707	34,043	34,599	34,675	34,826	35,387	35,644
* Bang Pahan	25,579	33,050	35,420	36,649	37,077	37,948	39,479	41,684
* Bang Pa-In	41,685	52,023	58,568	63,032	64,908	68,829	74,849	86,352
* Ban Phraek	8,183	9,332	9,272	9,377	9,301	9,152	9,063	8,671
* Phak Hai	41,442	46,302	45,849	45,674	45,138	44,086	43,258	40,631
Phachi	22,023	26,990	28,572	29,444	29,691	30,190	31,152	32,360
* Maha Rat	18,351	21,222	22,965	23,373	23,614	24,103	24,989	26,206
Lat Bua Luang	21,772	28,172	30,072	32,632	33,302	34,684	36,878	40,674
Wang Noi	26,704	33,137	37,946	42,269	43,977	47,604	53,116	64,513
** Sena	48,095	54,568	57,914	59,918	60,499	61,677	63,850	66,757
Uthai	27,353	32,715	35,183	37,108	37,712	38,949	40,981	44,261
Pathum Thani	233,861	319,674	–	446,431	479,195	547,552	647,635	909,416
** Muang Pathum Thani	46,104	59,238	–	90,272	96,546	110,433	130,632	182,792
* Sam Khok	26,235	28,910	–	38,947	40,517	43,848	48,401	58,972
* Lat Lum Kaeo	23,500	27,672	–	36,211	36,664	39,752	43,981	53,836
* Thanyaburi	38,358	57,657	–	82,325	88,858	103,522	125,301	183,566
* Lam Luk Ka	37,141	48,381	–	62,831	69,749	105,365	128,760	192,287
* Khlong Luang	37,271	66,849	–	78,817	84,946	98,672	118,989	173,034
Nong Sua	25,252	30,967	–	40,028	41,915	45,960	51,571	64,929
Nonthaburi	269,067	369,777	–	652,462	715,310	861,168	1,089,195	1,757,962
** Muang Nonthaburi	99,359	164,038	–	286,560	318,579	393,746	513,121	871,414
Krueal	39,092	43,331	–	76,364	81,652	93,353	110,364	154,252
Bang Yai	26,052	27,828	–	40,299	42,096	45,934	51,226	63,712
** Bang Bua Thong	30,550	34,530	–	63,572	68,406	79,203	95,127	137,225
* Pak Kret	50,650	75,337	–	152,010	169,669	211,378	278,217	481,981
Sai Noi	23,364	24,713	–	33,657	34,908	37,552	41,140	49,378
Total of 7 Provinces	2,108,498	2,636,533	–	3,350,380	3,489,915	3,803,695	4,291,581	5,517,480
Other	(1972)	(1977)		(1987)				
Sara Buri	425,189	506,544	–	509,750	523,255	537,024	579,249	608,898
Muang Sara Buri	88,942	130,710	–	118,866	124,852	129,857	141,490	148,317
Kaeng Khoi	59,251	66,600	–	69,423	69,790	70,085	73,086	70,179
Don Phunt	7,986	6,299	–	6,292	5,541	5,006	4,573	3,370
Ban Mo	40,921	43,076	–	46,259	45,952	45,707	47,099	44,158
Phra Phutthabat	59,353	46,498	–	47,100	41,582	37,636	34,467	25,525
Muak Lek	28,757	51,418	–	60,052	73,194	85,750	108,419	153,036
Wihan Daeng	27,340	28,485	–	31,245	31,150	31,075	32,137	30,351
Saohai	25,926	26,300	–	25,498	24,180	23,174	22,797	19,478
Nong Khae	58,427	76,505	–	75,736	78,744	81,237	87,618	89,995
Nong Saeng	14,365	15,331	–	15,820	15,579	15,388	15,719	14,483
Nong Don	13,919	13,122	–	13,459	12,691	12,109	11,844	10,006
7 Prov + Sara Buri	2,533,685	3,143,077	–	3,860,130	4,013,170	4,340,720	4,870,830	6,126,378

Note: "***" refers to amphoes that have a municipality within the basin.
" **" refers to amphoes that have sanitary district/s within the basin.
"– " means data is not available

Table 6.1.2 Projected Population of Municipality

Province / Municipality	Area (km2)	Pop.Dens. 1990 (c./km2)	Past Record 1970	1980	1985	1990	Estimation 1992	Projection 1996	2001	2011
Chai Nat	8.06	2,255.6	13,329	17,854	19,624	18,182	18,754	19,991	21,196	23,681
Muang Chai Nat	6.06	2,307.0	9,944	13,906	15,215	13,983	14,618	15,977	17,203	19,765
Wat Sing	2.00	2,099.5	3,385	3,948	4,409	4,199	4,136	4,014	3,993	3,916
Sing Buri	7.81	2,889.9	9,050	18,537	20,784	22,570	23,379	25,085	28,375	35,973
Muang Sing Buri	7.81	2,889.9	9,050	18,537	20,784	22,570	23,379	25,085	28,375	35,973
Lop Buri	9.03	5,672.5	35,711	42,511	53,540	51,223	52,967	56,646	60,842	70,011
Muang Lop Buri	6.85	5,376.9	23,112	29,815	38,238	36,832	37,871	40,036	42,918	49,320
Khok Samrong	1.50	6,081.3	8,353	8,507	9,447	9,122	9,576	10,553	11,363	13,056
Ban Mi	0.68	12.0	4,246	4,189	5,855	5,269	5,520	6,057	6,561	7,635
Ang Thong	15.73	1,290.1	15,871	19,843	20,579	20,293	21,275	23,413	25,387	29,753
Muang Ang Tong	3.73	2,575.6	7,267	9,520	9,593	9,607	10,283	11,782	13,327	16,896
Pa Mok	12.00	890.5	8,604	10,323	10,986	10,686	10,992	11,631	12,060	12,857
Ayutthaya	18.20	4,316.1	47,113	57,765	72,150	78,553	84,742	98,627	115,942	158,840
Muang Ayutthaya	14.00	4,713.6	37,213	47,189	59,214	65,991	71,273	83,138	98,140	135,531
Sena	1.20	3,839.2	4,640	4,209	4,867	4,607	4,867	5,432	6,145	7,790
Tombon Wat Sing	3.00	12.0	5,260	6,367	8,069	7,955	8,602	10,057	11,657	15,519
Pathum Thani	7.10	1,690.4	4,365	6,254	12,618	12,002	14,486	21,104	24,910	32,521
Muang Pathum Thani	7.10	1,690.4	4,365	6,254	12,618	12,002	14,486	21,104	24,910	32,521
Nonthaburi	40.50	6,139.8	33,974	39,985	49,371	248,661	312,883	383,191	483,924	774,761
Muang Nonthaburi	38.90	6,126.1	27,465	32,425	40,350	238,307	265,778	330,584	423,528	695,157
Bang Bua Thong	1.60	6,471.3	6,509	7,560	9,021	10,354	47,105	52,607	60,396	79,604
TOTAL	106.43	4,242.0	159,413	202,749	248,666	451,484	528,486	628,057	760,576	1,125,540

Source:

Municipalities in UCR: Upper Central Region Study, Sector Report Vo. 1, 1990, JICA

Muang Lop Buri: Average growth rate of Amphoe Muang Lop Buri between '85 and '90 (1.4% p.a.) was adopted.

Muang Pathum Thani: Projected in the Comprehensive Study of Sewerage Systems for First Group Area (5 Provinces), 1992, PWD

Muang Nonthaburi: Projected in the Flood Control, Drainage and Sewerage Systems for Nonthaburi Province, 1992, PWD

Bang Bua Thong: Average population growth rate of present municipality between '85 and '90 (2.8% p.a.) was adopted.
The population from 1992 is based on expanded municipality area (15.64 km2).

Table 6.1.3 Projected Population of Sanitary Districts

Provinces / Amphoes	Sanitary Districts	Area (km2)	Pop.Dens. 1988 (c /ha)	Past Record 1981	Past Record 1988	Estimation 1992	Projection 1996	Projection 2001	Projection 2011
Chai Nat		8.31	25.6	19,611	21,246	22,152	23,104	24,059	25,909
Manorom	Khung Sam Phao	1.83	15.6	2,931	2,855	2,857	2,859	2,825	2,735
Sanphaya	Sanphaya	1.27	24.6	2,225	3,130	3,351	3,587	3,857	4,419
	Pho Nang Dam	0.77	33.2	2,507	2,560	2,671	2,786	2,900	3,117
Sankhaburi	Prake Sriracha	2.50	23.4	5,619	5,854	6,116	6,389	6,663	7,184
Hankha	Hankha	0.58	88.4	4,567	5,127	5,410	5,709	6,028	6,660
	Sam Ngam Tha Bot	1.36	12.6	1,762	1,720	1,747	1,774	1,786	1,794
Sing Buri		67.40	7.2	46,000	48,248	50,860	53,633	56,620	62,669
In Buri	In Buri	2.00	36.1	6,597	7,215	7,849	8,539	9,367	11,172
Bang Rachan	Sing	22.80	8.8	18,875	20,078	21,321	22,641	24,098	27,059
Prom Buri	Bang Nam Chaeo	15.00	2.7	4,020	4,062	4,196	4,334	4,456	4,669
	Pak Bang	8.00	3.9	3,118	3,094	3,184	3,276	3,352	3,479
Tha Chang	Thon Samo	18.10	5.6	9,810	10,091	10,573	11,077	11,593	12,592
Khai Bang Rachan	Pho Sang Kho	1.50	24.7	3,560	3,708	3,737	3,766	3,754	3,698
Lop Buri		65.54	12.5	68,380	81,772	90,463	100,734	114,836	151,984
Muang Lop Buri	Khok Toom	1.50	139.6	22,655	20,943	20,721	20,502	19,976	18,792
Khok Samrong	Nong Muang	2.00	41.9	7,113	8,380	9,573	10,935	12,750	17,188
Sa Boat	Sa Boat	6.00	12.2	6,501	7,291	8,059	8,908	9,968	12,370
Chai Badan	Chai Badan	2.54	16.5	3,998	4,203	4,458	4,728	5,025	5,627
	Lam Na Rai	12.60	20.9	17,862	26,344	31,744	38,250	47,678	73,465
Tha Luang	Ban Tha Luang	13.00	2.5	1,311	3,232	3,604	4,018	4,544	5,762
Tha Wung	Tha Wung	1.60	15.2	2,537	2,432	2,374	2,317	2,272	2,167
	Tha Khlong	5.95	4.5	2,736	2,669	2,676	2,683	2,658	2,587
Pattana Nikom	Pattana Nikom	4.00	8.7	1,735	3,460	3,858	4,301	4,865	6,167
	Kang Sua Ten	16.35	1.7	1,932	2,818	3,396	4,092	5,100	7,859
Ang Thong		116.30	4.6	56,325	53,375	55,823	58,570	63,002	73,382
Chaiyo	Charakerong	11.50	9.4	10,562	10,754	10,987	11,225	12,697	16,097
	Ked Chaiyo	0.70	20.5	1,412	1,433	1,489	1,548	1,604	1,709
Pho Thong	Pho Thong	36.00	2.0	7,893	7,163	7,087	7,012	6,832	6,428
Wiset Chai Chan	San Chao Rong T.	2.50	38.4	8,260	9,600	10,846	12,253	14,090	18,475
	Bang Chak	10.00	10.4	15,113	10,427	10,317	10,208	9,945	9,356
Samko	Samko	53.00	1.9	8,664	10,113	11,253	12,521	14,128	17,832
Sawaengha	Sawaengha	2.60	14.9	4,421	3,885	3,844	3,803	3,706	3,485
Ayutthaya		133.96	11.3	137,485	151,444	165,741	181,873	202,413	251,445
Muang Ayutthaya	Ayothaya	8.40	12.2	10,735	10,281	11,463	12,780	14,456	18,327
Tha Rua	Tha Luang	2.50	55.9	11,374	13,976	16,322	19,061	22,848	32,529
Nakhon Luang	Nakhon Luang	4.31	16.8	6,656	7,245	7,862	8,532	9,330	11,065
Bang Sai	Bang Sai	5.57	11.5	7,096	6,424	6,356	6,289	6,127	5,764
Bang Shai	Bang Shai	2.50	42.3	8,991	10,571	11,422	12,341	13,422	15,732
Bang Ban	Bang Ban	7.13	14.2	9,183	10,140	11,099	12,149	13,429	16,271
Bang Pahan	Bang Pahan	5.98	9.4	4,312	5,629	6,692	7,956	9,752	14,524
Bang Pa-In	Ban Len	3.78	22.5	6,844	8,507	9,880	11,475	13,660	19,190
	Pra Intharacha	1.20	30.3	3,940	3,633	3,827	4,031	4,248	4,675
	Ban Sang	9.80	2.6	–	2,578	2,874	3,205	3,625	4,595
Ban Phraek	Ban Phraek	8.00	3.3	3,157	2,669	2,641	2,613	2,546	2,395
Phak Hai	Phak Hai	4.00	33.7	13,430	13,467	13,916	14,381	14,794	15,517
	Lad Chado	15.53	6.2	9,110	9,584	10,083	10,607	11,158	12,244
Phachi	Kok Muang	5.00	13.1	6,745	6,526	6,590	6,655	6,651	6,583
Maha Rat	Maha Rat	5.84	4.6	2,759	2,810	2,889	2,971	3,038	3,151
Lat Bua Luang	Lat Bua Luang	3.80	5.7	2,617	2,181	2,158	2,135	2,080	1,957
Wang Noi	Lum Tha Sao	19.50	6.5	10,805	12,739	14,704	16,973	20,050	27,725
Sena	Hua Wiang	7.00	12.1	7,625	8,480	9,301	10,202	11,306	13,762
	Chao Chet	10.69	9.8	9,148	10,494	11,712	13,071	14,805	18,831
Uthai	Uthai	3.43	10.2	2,958	3,510	3,950	4,446	5,088	6,608
Pathum Thani		171.24	11.4	113,083	195,187	207,615	220,872	247,601	290,025
Muang Pathum Thani	Bang Luang	3.90	13.1	2,560	5,096	5,470	5,872	6,694	8,034
Sam Khok	Bang Toei	7.29	11.6	5,874	8,429	8,578	8,729	9,079	9,832
Lat Lum Kaeo	Rahaeng	18.22	3.0	3,864	5,528	5,867	6,227	6,967	8,211
Thanyaburi	Phrachatipat	20.80	22.3	21,675	46,426	49,946	53,732	61,344	73,097
	Thanyaburi	30.78	8.7	15,659	26,720	28,746	30,925	35,306	42,070
	Sanunrak	38.40	3.1	8,775	11,900	12,802	13,773	15,724	18,736
Lam Luk Ka	Khu kot	12.48	24.8	–	30,984	32,885	34,903	38,963	45,408
	Lam Luk Ka	11.45	6.1	5,428	6,975	7,403	7,857	8,771	10,222
	Lam Sai	3.64	12.8	4,756	4,651	4,936	5,239	5,849	6,816
Khlong Luang	Khlong Luang	10.50	44.6	42,967	46,870	49,281	51,816	56,947	65,353
Nong Sua	Nong Sua	13.78	1.2	1,525	1,608	1,701	1,799	1,957	2,246
Nonthaburi		57.28	31.1	73,322	177,957	181,563	192,835	221,536	294,826
Muang Nonthaburi	Bang Si Muang	6.36	27.4	–	17,438	17,944	18,464	19,749	22,842
Kruai	Wat Chalow	1.53	119.9	18,240	18,351	9,236	4,648	4,958	5,853
	Bang Kruai	4.90	27.7	–	13,572	19,778	28,821	30,772	36,470
Bang Yai	Bang Yai	7.23	5.6	3,759	4,055	4,339	4,642	5,296	6,429
	Bang Muang	1.67	35.2	–	5,874	6,309	6,777	7,733	9,388
Pak Kret	Pak Kret	34.59	33.7	50,328	116,415	121,623	127,064	150,402	210,727
Sai Noi	Ratniyom	1.00	22.5	995	2,252	2,334	2,419	2,626	3,117
TOTAL		620.03	11.8	514,206	729,229	774,217	831,621	930,067	1,150,240

Source: Amphoes in UCR; Upper Central Region Study, Sector Report Vol. 1, 1990, JICA
Pathum Thani and Nonthaburi; Lower Chao Phraya Basin Water Pollution Control Master Plan, 1991, ONEB
(Past Records of both provinces are for the year 1980 and 1990)

Table 6.1.4 Area and Projected Population in the Basin

Provinces/ Amphoes	Area (km2)			Population in 1992			Population in 1996			Population in 2001			Population in 2011		
	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin	Total	Within Basin	Out of Basin
Chai Nat	2,469.7	624.3	1,845.4	359,998	151,628	208,370	370,091	154,680	215,411	387,556	159,934	227,622	416,009	166,847	249,162
** Muang Chai Nat	255.4	147.0	108.4	72,957	47,594	25,363	72,652	48,013	24,639	73,037	48,763	24,274	75,611	51,332	24,279
Manorom	225.6	0.0	225.6	35,915	0	35,943	36,914	0	36,914	36,639	0	36,639	40,402	0	40,402
Wat Sing	606.3	0.0	606.3	45,256	0	45,256	45,450	0	45,450	46,200	0	46,200	49,879	0	49,879
* Sankhaburi	354.8	249.0	105.8	69,539	50,466	19,014	71,255	51,775	19,480	74,248	53,051	20,297	77,065	56,079	20,986
* Sanphaya	226.3	226.3	0.0	53,548	53,548	0	54,802	54,802	0	57,220	57,220	0	59,436	59,436	0
Hankha	799.5	0.0	799.5	82,764	0	82,764	88,668	0	88,668	98,212	0	98,212	114,616	0	114,616
Sing Buri	822.5	822.5	0.0	234,635	234,635	0	244,589	244,589	0	260,869	260,869	0	290,239	290,239	0
** Muang Sing Buri	112.4	112.4	0.0	54,600	54,600	0	58,326	58,326	0	63,738	63,738	0	74,318	74,318	0
* Khai Bang Rachan	88.4	88.4	0.0	30,904	30,904	0	32,406	32,406	0	34,758	34,758	0	39,043	39,043	0
* Tha Chang	34.4	34.4	0.0	16,228	16,228	0	16,571	16,571	0	17,193	17,193	0	18,074	18,074	0
* Bang Rachan	190.5	190.5	0.0	40,110	40,110	0	42,460	42,460	0	46,087	46,087	0	53,013	53,013	0
* Prom Buri	82.5	82.5	0.0	25,657	25,657	0	25,130	25,130	0	24,752	24,752	0	23,445	23,445	0
* In Buri	314.3	314.3	0.0	66,936	66,936	0	69,796	69,796	0	74,341	74,341	0	82,346	82,346	0
Lop Buri	6,199.8	649.5	5,550.3	727,260	292,658	434,602	778,746	325,844	452,902	856,653	373,889	482,764	1,014,708	474,053	540,645
** Muang Lop Buri	565.8	426.8	139.0	267,289	215,307	51,982	302,185	241,980	60,185	352,978	280,723	72,255	481,681	383,651	98,030
Khok Samrong	982.5	17.5	965.0	75,827	1,013	74,814	56,256	800	55,456	56,093	572	55,521	38,535	148	38,387
Chai Badan	1,253.0	0.0	1,253.0	87,211	0	87,211	89,103	0	89,103	91,720	0	91,720	93,154	0	93,154
Tha Luang	538.9	0.0	538.9	25,500	0	25,500	29,415	0	29,415	35,239	0	35,239	48,475	0	48,475
* Tha Wung	242.8	242.8	0.0	52,627	52,627	0	56,864	56,864	0	62,777	62,777	0	73,337	73,337	0
Ban Mi	585.7	162.4	423.3	90,934	23,711	67,223	100,439	26,200	74,239	113,971	29,917	84,154	140,850	38,927	103,733
Pattana Nikom	517.0	0.0	517.0	56,003	0	56,003	61,442	0	61,442	69,135	0	69,135	83,902	0	83,902
Sa Boet	304.7	0.0	304.7	24,082	0	24,082	25,092	0	25,092	25,668	0	25,668	25,745	0	25,745
Khok Charoen	317.1	0.0	317.1	23,965	0	23,965	24,393	0	24,393	24,942	0	24,942	25,018	0	25,018
Lam Sen Thi	447.0	0.0	447.0	23,202	0	23,202	23,597	0	23,597	24,129	0	24,129	24,201	0	24,201
Nang Muang	445.5	0.0	445.5	-	0	-	-	0	-	-	0	-	-	0	0
Ang Thong	968.4	868.2	60.2	280,307	262,613	17,694	284,702	266,821	17,881	293,700	275,292	18,408	305,950	287,019	18,931
** Muang Ang Thong	102.9	102.0	0.9	48,268	47,943	345	48,884	48,547	337	50,199	49,864	335	51,756	51,420	336
* Chaiyo	72.3	72.3	0.0	22,613	22,613	0	22,381	22,381	0	22,344	22,344	0	21,764	21,764	0
** Pa Mok	80.9	80.9	0.0	29,016	29,016	0	28,913	28,913	0	29,108	29,108	0	28,834	28,834	0
* Pho Thong	219.4	212.4	7.0	58,379	55,421	1,958	60,618	58,572	2,046	64,254	62,062	2,192	70,557	68,109	2,448
* Wiset Chai Chan	224.7	189.3	35.4	68,072	60,246	7,826	68,059	60,452	7,607	68,809	61,340	7,469	68,739	61,915	6,824
* Samko	86.9	50.0	36.9	17,815	10,250	7,565	18,583	10,692	7,891	19,010	11,398	6,412	22,003	12,660	9,343
* Sawaengha	181.3	181.3	0.0	36,124	36,124	0	37,264	37,264	0	39,176	39,176	-0	42,317	42,317	0
Ayutthaya	2,556.6	1,907.5	649.1	693,210	557,651	135,559	716,748	575,221	141,527	755,973	604,803	151,170	823,195	654,556	168,640
** Muang Ayutthaya	130.6	130.6	0.0	123,553	123,553	0	130,757	130,757	0	141,839	141,839	0	162,824	162,824	0
** Tha Rua	105.2	105.2	0.0	52,192	52,192	0	53,740	53,740	0	56,330	56,330	0	60,360	60,360	0
* Nakhon Luang	198.9	198.9	0.0	33,599	33,599	0	35,949	35,949	0	39,096	39,096	0	45,112	45,112	0
* Bang Sai	150.7	119.3	31.4	19,375	16,558	2,817	19,025	16,269	2,756	18,793	16,053	2,740	17,088	15,265	2,023
* Bang Sai	219.7	219.7	0.0	44,297	44,297	0	45,229	45,229	0	46,913	46,913	0	49,239	49,239	0
* Bang Ban	135.3	135.3	0.0	34,675	34,675	0	34,826	34,826	0	35,387	35,387	0	35,644	35,644	0
* Bang Pahan	121.9	121.9	0.0	37,077	37,077	0	37,948	37,948	0	39,479	39,479	0	41,684	41,684	0
* Bang Pa-In	229.1	189.1	40.0	64,908	55,888	9,020	68,829	59,475	9,354	74,849	64,898	9,951	86,352	75,547	10,805
* Ban Phraek	39.1	39.1	0.0	9,501	9,501	0	9,152	9,152	0	9,069	9,069	0	8,671	8,671	0
* Phak Hai	189.0	189.0	0.0	45,138	45,138	0	44,095	44,095	0	43,258	43,258	0	40,831	40,831	0
Phachi	184.5	0.0	184.5	29,691	0	29,691	30,190	0	30,190	31,152	0	31,152	32,350	0	32,350
* Maha Rat	120.1	120.1	0.0	23,614	23,614	0	24,103	24,103	0	24,989	24,989	0	26,206	26,206	0
Lat Bua Luang	199.9	136.9	63.0	33,302	21,742	11,560	34,684	22,723	11,961	36,878	24,293	12,585	40,674	27,029	13,645
Wang Noi	219.2	0.0	219.2	43,977	0	43,977	47,604	0	47,604	53,116	0	53,116	64,513	0	64,513
** Sena	205.6	198.9	6.7	60,499	59,257	1,242	61,677	60,494	1,183	63,850	62,716	1,134	66,757	65,811	946
Uthai	186.8	2.5	184.3	37,712	460	37,252	38,949	470	38,479	40,981	489	40,492	44,281	513	43,748
Pathum Thani	1,525.9	485.5	1,040.4	472,195	296,315	182,880	547,552	326,008	221,544	647,635	372,455	275,180	909,416	477,017	432,399
** Muang Pathum Thani	120.2	120.2	0.0	98,548	98,548	0	110,433	110,433	0	130,632	130,632	0	182,792	182,792	0
* Sam Khok	95.0	95.0	0.0	40,517	40,517	0	43,848	43,848	0	48,401	48,401	0	58,972	58,972	0
* Lat Lum Kaeo	188.1	188.1	0.0	36,664	36,664	0	39,752	39,752	0	43,981	43,981	0	53,836	53,836	0
* Thanyaburi	112.1	8.7	103.4	88,058	39,957	48,901	103,522	42,986	60,536	125,801	49,075	76,226	183,566	58,478	125,088
* Lam Luk Ka	297.7	6.0	291.7	89,749	26,308	63,441	105,365	27,922	77,443	128,760	31,170	97,590	192,287	36,326	155,961
* Khlong Luang	299.2	67.5	231.7	84,946	56,323	28,623	98,672	61,007	37,665	118,989	69,196	49,793	173,034	86,613	86,421
Nong Sua	413.6	0.0	413.6	41,915	0	41,915	45,960	0	45,960	51,571	0	51,571	64,929	0	64,929
Nonthaburi	622.3	273.6	348.7	715,310	449,979	265,331	881,168	553,429	307,739	1,089,195	714,281	374,914	1,757,962	1,192,834	565,128
** Muang Nonthaburi	77.0	42.3	34.7	318,579	202,595	115,984	393,748	252,632	141,116	513,121	329,631	183,490	871,414	559,451	311,963
Kruei	57.4	0.0	57.4	81,652	0	81,652	93,353	0	93,353	110,364	0	110,364	154,252	0	154,252
Bang Yai	96.4	25.9	70.5	42,926	9,309	32,767	45,934	10,216	35,718	51,226	11,306	39,920	63,712	14,177	49,535
** Bang Bua Thong	116.4	116.4	0.0	68,406	68,406	0	79,203	79,203	0	95,127	95,127	0	137,225	137,225	0
* Pak Kret	89.0	89.0	0.0	169,669	169,669	0	211,378	211,378	0	278,217	278,217	0	491,981	491,981	0
Sai Noi	186.1	0.0	186.1	34,908	0	34,908	37,552	0	37,552	41,140	0	41,140	49,378	0	49,378
Total of 7 Provinces	15,165.2	5,851.1	9,314.1	3,489,915	2,245,479	1,244,436	3,869,696	2,446,692	1,357,004	4,291,581	2,761,523	1,530,058	5,517,480	3,542,575	1,974,905
Other															
Saraburi	3,576.6	186.3	3,390.3	523,255	30,792	492,463	537,024	29,724	507,300	579,249	29,554	549,695	608,898	25,941	582,957
Muang Saraburi	503.8	0.0	503.8	124,852	0	124,852	129,857	0	129,857	141,490	0	141,490	148,317	0	148,317
Kaeng Khoi	871.1	0.0	871.1	69,790	0	69,790	70,085	0	70,085	73,066	0	73,066	70,179	0	70,179
Don Phut	65.6	65.6	0.0	5,541	5,541	0	5,005	5,005	0	4,573	4,573	0	3,370	3,370	0
Ban Mo	279.0	93.7	185.3	45,952	15,433	30,519	45,797	15,350	30,357	47,009	15,818	31,281	44,158	14,830	29,328
Phra Phutthabat	324.6	0.0	324.6	41,592	0	41,592	37,636	0	37,636	34,467	0	34,467	25,525	0	25,525
Muak Lek	752.5	0.0	752.5	73,194	0	73,194	65,750	0	65,750	108,419	0	108,419	153,036	0	153,036
Wihan Daeng	228.8	0.0	228.8	31,150	0	31,150	31,075	0	31,075	32,137	0	32,137	30,351	0	30,351
Seohai	125.1	0.0	125.1	24,180	0	24,180	23,174	0	23,174	22,797	0	22,797	19,478	0	19,478
Nong Khae	293.8	0.0	293.8	78,744	0	78,744	81,237	0	81,237	87,618	0	87,618	89,995	0	89,995
Nong Saeng	97.4	0.0	97.4	15,579	0	15,579	15,388	0	15,388	15,719	0	15,719	14,483	0	14,483
Nong Don	34.9	27.0	7.9	12,091	9,818	2,673	12,109	9,368	2,741	11,844	9,163	2,681	10,006	7,741	2,265
7 Prov + Sara Buri	18,741.8	6,037.4	12,704.4	4,013,170	2,276,271	1,736,899	4,340,720	2,476,416	1,864,304	4,870,830	2,791,077	2,079,753	6,126,378	3,568,516	2,557,862

Note: "**" refers to amphoes that have a municipality within the basin.
" * " refers to amphoes that have sanitary district/s within the basin.
"-- " means data is not available

6.2.2 Situation of Industries

The study area is divided into two major sub-areas, the adjacent area to Bangkok (Pathum Thani and Nonthaburi), and the UCR (Chai Nat, Sing Buri, Lop Buri, Ang Thong, Ayutthaya and Saraburi).

The leading industries in Nonthaburi and Pathum Thani are apparel, textiles and electrical machinery industries. Further development in the area is obvious because of its locational advantage and is within the expansion area of the BMR. The core area of industrialization in Pathum Thani is situated in the Rangsit area.

In the UCR, resource-based industries such as food processing and cement/ceramic industries are the major industries. Cement/ceramic industries are concentrated in Saraburi, which is the national production center of cement and ceramics. However, some linkage type industries such as textiles, precision machinery and electronic industries are being developed in the southern part of the UCR, especially in Ayutthaya, because of its proximity to the BMR and the international airport. These are mostly direct investments by foreign enterprises.

A comprehensive development study for the UCR, "the Upper Central Region Study (UCRS)", was carried out by JICA for the National Economic and Social Development Board (NESDB) from December 1988 to July 1990. The targets of future industrialization are summarized in the UCR reports as follows:

- Saraburi will be highlighted as an industrial area.
- Ayutthaya is not an appropriate area for industrialization but aims to preserve the town and for environmental conservation.
- Highlighted industry types will be: agro-processing, construction materials, and urban support industries.

6.2.3 Methodology of Projection

(1) Frame Value

In general, production amount of factory is favorable as a frame value (parameter) with reference to the parameter of unit pollution loading.

In Thailand, however, it is difficult to obtain such data at the present time due to lack of related regular statistical works.

Area of factory premises is also one of the practical parameters. The data is available from the Department of Industry (DIW) only for registered factories. However, it was not adapted in this study, because the parameter is strongly influenced by the locational features of each factory, i.e, land price, scale of factory, etc. Added to these is the difficulty in projecting land use areas.

In this study, the Gross Regional Product (GRP) in the industrial sector that has been recorded in the statistics of NESDB is used as a basic factor for projection of the frame value. The GRP under industrial sector may be regarded to be closely related with the production amount of factories. The number of employees derived from the projected GRP was selected as the frame value.

(2) Methodology

Projection of the frame value was carried out by aforementioned group area using fully the data and study results.

Upper Central Region

1) GRP by industrial group was projected in UCRS for the whole UCR: data-(a). The results of this projection was used as basic data.

2) Allot projected GRP: data-(a) to each province and each industrial group using the present share in number of employees by province and by industrial type: data-(b).

   This employed share was assumed to be stable through out the future.

3) Compute number of employees of each province by industrial group: data-(d) using data-(b) and the labor productivity

(number of employees per GRP): data-(c), which was derived from the data presented in the JICA study report.

Pathum Thani and Nonthaburi

1) Project GRP under industrial sector for each province: data-(e) using the trend of past data recorded by NESDB.

2) Compute number of employees by industrial group: data-(f) using data obtained from the DIW.

3) Project GRP by industrial group by province: data-(g) using data-(c), (e) and (f).

4) Compute number of employees of each province by industrial group: data-(h) using data-(c) and (g).

6.2.4 Upper Central Region

(1) GRP by industrial group

In the UCR, GRP projection was conducted by using the following data:

- estimated labor productivity derived from estimated GRP and registered number of employees
- estimated annual increase of GRP derived from estimated increase of employees and labor productivity
- assumed adjustment factor for growth

The equations used for projection and results are shown in Table 6.2.1, the result of which is used for this Study.

Table 6.2.1 Projected GRP in UCR

Industrial Group	GRP in 1987 (a)	GRP Annual Increase (b)	Estimated GRP in 1991 (c)	Projected GRP in 1992 (d)	Projected GRP in 1996 (e)	Projected GRP in 2001 (f)	Projected GRP in 2010 (g)	Projected GRP in 2011 (h)
Food Processing	2,040	454	3,856	4,310	6,126	9,032	14,571	15,116
Min/Cement/Ceramic	6,220	46	6,404	6,450	6,634	7,510	10,457	10,641
Light Processing	1,768	477	3,555	4,002	5,789	8,024	12,045	12,522
Machine/Elect.	2,155	1,129	6,670	7,799	12,313	16,376	22,922	23,825
Others	617	98	1,010	1,108	1,500	1,991	2,875	2,973
Total	12,800		21,495	23,668	32,363	42,932	62,870	65,077

Equation: (c) = (a) + (b) x 4 x (Af1) (f) = (a) + (b) x 14 x (Af3)
(e) = (a) + (b) x 9 x (Af2) (g) = (a) + (b) x 23 x (Af4)
(d) = (c) + ((e) -(c)) / 5 (h) = (a) + (b) x 24 x (Af4)

Adjustment Factor for Growth (Af):

	Af1	Af2	Af3	Af4
Food	1.0	1.0	1.1	1.2
Min.	1.0	1.0	2.0	4.0
Light	1.0	1.0	1.0	1.0
Machine	1.0	1.0	0.9	0.8
Others	1.0	1.0	1.0	1.0

Industrial Types in Each Group:
Food Processing; food and beverages
Min/Cement/Ceramic; mining and non-metallic products
Light Processing; textile, apparel and leather/footwear
Machine/Elect.; basic metal, fabricated products, machinery, electrical machinery, transport equipment and precision instrument
Others; all industrial types except above four groups

Source: UCRS, Sector Report NO.5, Nov. 1990, NESDB, JICA. (e) and (h) are calculated by Study Team

(2) GRP by province

Allotment of projected GRP to each province was carried out by using the composition ratio of employee number by each industrial group by province. Number of employees of registered factories in each province is presented in the UCRS report as shown in Table 6.2.2. Based on these figures, the composition ratio of employee number by each industrial group by province was computed as shown in Table 6.2.3.

Table 6.2.2 Number of Employees by Industrial Group in 1988

unit: person

Industrial Group	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	9,398	760	1,066	1,018	411	3,158	2,985
MIN/CEMENT/CERAMIC	13,713	48	190	519	991	1,462	10,503
LIGHT PROCESSING	11,505	32	124	107	1,256	1,635	8,351
MACHINE/ELECT.	15,010	34	95	695	60	11,774	2,352
OTHERS	5,081	49	86	199	297	2,991	1,459
TOTAL	54,707	923	1,561	2,538	3,015	21,020	25,650

Source: UCRS, Sector Report No.5

Table 6.2.3 Composition Ratio of Employee Number

unit: %

Industrial Group	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	100	8.1	11.3	10.8	4.4	33.6	31.8
MIN/CEMENT/CERAMIC	100	0.4	1.4	3.8	7.2	10.7	76.6
LIGHT PROCESSING	100	0.3	1.1	0.9	10.9	14.2	72.6
MACHINE/ELECT.	100	0.2	0.6	4.6	0.4	78.4	15.7
OTHERS	100	1.0	1.7	3.9	5.8	58.9	28.7
TOTAL	100	1.7	2.9	4.6	5.5	38.4	46.9

GRP was alloted by using the data presented in Tables 6.2.1 and 6.2.3. Computation results are shown in Table 6.2.4.

Table 6.2.4 Projected GRP by Province by Industrial Group

(1992) unit: MB

INDUSTRIAL GROUP	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	4,310	349	489	467	188	1,448	1,369
MIN/CEMENT/CERAMIC	6,450	23	89	244	466	688	4,940
LIGHT PROCESSING	4,002	11	43	37	437	569	2,905
MACHINE/ELECT.	7,799	18	49	361	31	6,117	1,222
OTHERS	1,108	11	19	43	65	652	318
TOTAL	23,668	411	689	1,153	1,187	9,474	10,754

(1996) unit: MB

INDUSTRIAL GROUP	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	6,126	495	695	664	268	2,059	1,946
MIN/CEMENT/CERAMIC	6,634	23	92	251	479	707	5,081
LIGHT PROCESSING	5,789	16	62	54	632	823	4,202
MACHINE/ELECT.	12,313	28	78	570	49	9,658	1,929
OTHERS	1,500	14	25	59	88	883	431
TOTAL	32,362	577	952	1,597	1,516	14,130	13,589

(2001) unit: MB

INDUSTRIAL GROUP	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	9,032	730	1,024	978	395	3,035	2,869
MIN/CEMENT/CERAMIC	7,510	26	104	284	543	801	5,752
LIGHT PROCESSING	8,024	22	86	75	876	1,140	5,824
MACHINE/ELECT.	16,376	37	104	758	65	12,846	2,566
OTHERS	1,991	19	34	78	116	1,172	572
TOTAL	42,933	835	1,352	2,173	1,996	18,994	17,583

(2011) unit: MB

INDUSTRIAL GROUP	WHOLE UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	15,116	1,222	1,715	1,637	661	5,079	4,801
MIN/CEMENT/CERAMIC	10,641	37	147	403	769	1,134	8,150
LIGHT PROCESSING	12,522	35	135	116	1,367	1,780	9,089
MACHINE/ELECT.	23,825	54	151	1,103	95	18,689	3,733
OTHERS	2,973	29	50	116	174	1,750	854
TOTAL	65,077	1,377	2,198	3,376	3,066	28,432	26,627

Number of Employees

Number of employees was computed by using projected GRP and labor productivity. Labor productivity in 1987 was calculated in UCR based on the estimated GRP and number of employees. Projection of future labor productivity was conducted applying the decreasin average annual growth rates of 6%, 5.5%, 5% and 4.5% for projected years, 1991, 1996, 2001 and 2011. These figures are assumed based on the corresponding rate of 6.07% in Japan duri 1965 to 1975. Results of calculation are shown in Table 6.2.5.

6.2.5 Projection of Labor Productivity

unit: B/year/head

Industrial Group	Labor Productivity 1987 (a)	1991 (b)	1992 (c)	1996 (d)	2001 (e)	2010 (f)	2011 (g)
FOOD PROCESSING	57,466	72,550	76,649	93,044	113,780	158,157	165,274
MIN/CEMENT/CERAMIC	74,802	94,436	99,771	121,111	148,103	205,867	215,131
LIGHT PROCESSING	40,683	51,361	54,263	65,870	80,549	111,966	117,005
MACHINE/ELECT.	55,159	69,637	73,571	89,307	109,211	151,806	158,638
OTHERS	16,757	21,155	22,350	27,131	33,177	46,117	48,193

equation: (b) = (a) x 1.06^4
(c) = ((d) - (b)) /5 + (b)
(d) = (a) x 1.055^9
(e) = (a) x 1.05^{14}
(f) = (a) x 1.045^{23}
(g) = (a) x 1.045^{24}

Source: UCRS, Sector Report No.5; (c) and (g) are calculated by the Study Team.

By using figures presented in Tables 6.2.4 and 6.2.5, the number of employees in UCR in the future can be obtained for each province as shown in Table 6.2.6.

Table 6.2.6 Projected No. of Employees by Province by Industrial Group

(1992)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	56,230	4,547	6,378	6,091	2,459	18,895	17,860
MIN/CEMENT/CERAM.	64,648	226	896	2,447	4,672	6,892	49,515
LIGHT PROCESSING	73,749	205	795	686	8,051	10,481	53,531
MACHINE/ELECT.	106,001	240	671	4,908	424	83,148	16,610
OTHERS	49,575	478	839	1,942	2,898	29,183	14,235
TOTAL	350,203	5,696	9,579	16,074	18,504	148,599	151,751

(1996)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	65,839	5,324	7,468	7,132	2,879	22,124	20,912
MIN/CEMENT/CERAM	54,777	192	759	2,073	3,959	5,840	41,954
LIGHT PROCESSING	87,885	244	947	817	9,594	12,490	63,793
MACHINE/ELECT.	137,872	312	873	6,384	551	108,148	21,604
OTHERS	55,288	533	936	2,165	3,232	32,546	15,876
TOTAL	401,661	6,605	10,983	18,571	20,215	181,148	164,139

(2001)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	79,382	6,419	9,004	8,599	3,472	26,675	25,213
MIN/CEMENT/CERAM	50,708	177	703	1,919	3,665	5,406	38,838
LIGHT PROCESSING	99,616	277	1,074	926	10,875	14,157	72,307
MACHINE/ELECT.	149,948	340	949	6,943	599	117,621	23,496
OTHERS	60,011	579	1,016	2,350	3,508	35,326	17,232
TOTAL	439,665	7,792	12,746	20,737	22,119	199,185	177,086

(2011)

Industrial Group	Whole UCR	Chai Nat	Sing Buri	Lop Buri	Ang Thong	P. N. Si Ayutthaya	Saraburi
FOOD PROCESSING	91,459	7,396	10,374	9,907	4,000	30,733	29,049
MIN/CEMENT/CERAM	49,462	173	685	1,872	3,575	5,273	37,884
LIGHT PROCESSING	107,021	298	1,153	995	11,684	15,209	77,682
MACHINE/ELECT.	150,187	340	951	6,954	600	117,808	23,534
OTHERS	61,690	595	1,044	2,416	3,606	36,315	17,714
TOTAL	459,819	8,802	14,207	22,144	23,465	205,338	185,863

6.2.5 Pathum Thani and Nonthaburi

(1) GRP in the future

Projection of GRP under industrial sector for each province was made based on average GRP growth rate during the last 3 years, 1987 to 1989, which was the latest data recorded by NESDB. Reduced growth rate was applied the same way as the UCR. Reduction factors applied for projection were 100% until 1992, 75% until 1996, 50% until 2001, and 45% from 2002. The results are shown in Table 6.2.7.

Table 6.2.7 Gross Regional Products under Industrial Sector (past trend and future projection)

(unit: 1,000 BAHT in 1972 constant price)

Province	GRP	1981	1982	1983	1984	1985	1986	1987
Pathum Thani	Min. & Quarry.	8,586	9,246	8,989	9,673	38,261	32,742	201,517
	Manufacturing	3,974,565	3,905,954	5,472,748	6,184,281	6,036,082	7,111,620	7,155,308
	Total	3,983,151	3,915,200	5,481,737	6,193,954	6,074,343	7,144,362	7,356,825
Nonthaburi	Min. & Quarry.	0	0	0	0	0	0	0
	Manufacturing	2,211,286	2,287,402	2,246,719	2,432,730	2,480,842	2,663,887	2,993,831
	Total	2,211,286	2,287,402	2,246,719	2,432,730	2,480,842	2,663,887	2,993,831

Province	GRP	1988	1989	1992	1996	2001	2011
Pathum Thani	Min. & Quarry.	204,464	242,736	320,900	397,900	429,800	624,400
	Manufacturing	7,503,658	8,703,038	11,674,400	14,641,800	15,887,000	23,550,400
	Total	7,708,122	8,945,774	11,995,300	15,039,700	16,316,800	24,174,800
Nonthaburi	Min. & Quarry.	0	0	0	0	0	0
	Manufacturing	4,271,423	5,067,193	6,794,500	8,518,900	9,242,200	13,692,900
	Total	4,271,423	5,067,193	6,794,500	8,518,900	9,242,200	13,692,900

Source: National Economic and Social Development Board. Study team (projection)

(2) GRP by industrial group

Estimation of GRP by industrial group can be obtained by using number of employees and labor productivity. Number of employees of registered factories in Pathum Thani in 1991 w investigated and reported by the Department of Industrial Works (DIW) as shown in Table 6.2.8.

Table 6.2.8 Number of Employees in Pathum Thani

Industrial Type	Number of Factories	Number of Employees (head)
Beverage	8	99
Food	60	2,562
FOOD PROCESSING TOTAL	68	2,661
Non-Metallic	38	4,557
MIN/CEMENT/CERAMIC TOTAL	38	4,557
Apparel	24	13,215
Footwear	10	6,147
Leather	13	2,076
Textiles	35	22,292
LIGHT PROCESSING TOTAL	82	43,730
Basic Metal	17	2,130
Electrical Machinery	68	36,730
Fabricated Products	45	3,658
Machinery	28	1,376
Transport Equipment	29	2,735
Others	43	7,612
MACHINE/ELECT. TOTAL	230	54,241
Chemical	41	1,762
Furniture	24	1,368
Paper	10	1,772
Petrol Refineries	1	0
Plastics	30	3,265
Printing	4	423
Rubber	15	3,194
Tobacco	1	70
Wood	43	1,391
Others	2	47
OTHERS TOTAL	171	13,292
GRAND TOTAL	589	118,481

Source: Department of Industrial Works

GRP by industrial group in Pathum Thani including non-registered factories can be estimated by using assumed labor productivity, projected GRP and actual number of employees of registered factories presented in Tables 6.2.5, 6.2.7 and 6.2.8, respectively. Results of computation are shown in Table 6.2.9. Based on the composition ratio of estimated GRP, the composition of projected GRP was computed as shown in Table 6.2.9.

Projection of GRP in Nonthaburi was also conducted by using projected GRP shown in Table 6.2.7 and the assumed composition ratio shown in Table 6.2.10. Computation results are shown in Table 6.2.10.

Table 6.2.9 Projection of GRP Breakdown in Pathum Thani

Industrial Group	Reg'd No. of Employees (head)	Est'd 1991 Labor Product. (B/head)	Calc'd GRP in 1991 (MB)	Revised Est'd GRP in 1991 (MB)*	Est'd GRP Share (%)	Est'd GRP in 1992 (MB)*	Est'd GRP in 1996 (MB)*	Est'd GRP in 2001 (MB)*	Est'd GRP in 2011 (MB)*
FOOD PROCESSING	2,661	72,550	193.1	297.7	2.8	325.3	408.0	442.7	656.3
MINING/CEMENT/CERAMIC	4,557	94,436	430.3	958.5	6.2	1,046.1	1,307.4	1,416.7	2,087.3
LIGHT PROCESSING	43,730	51,361	2,246.0	3,463.8	32.4	3,784.9	4,746.9	5,150.6	7,635.1
MACHINE/ELEC. EQUIP.	54,241	69,637	3,777.2	5,825.1	54.5	6,365.1	7,983.0	8,661.9	12,840.2
OTHERS	13,292	21,155	281.2	433.7	4.1	473.9	594.3	644.8	955.9
TOTAL	118,481	58,472	6,927.8	10,978.8	100.0	11,995.3	15,039.7	16,316.8	24,174.8

*: including GRP by mining sector

Table 6.2.10 Projection of GRP Breakdown in Nonthaburi

Industrial Group	Est'd GRP Share (%)*	Est'd GRP in 1992 (MB)	Est'd GRP in 1996 (MB)	Est'd GRP in 2001 (MB)	Est'd GRP in 2011 (MB)
FOOD PROCESSING	2.8	189.3	237.4	257.6	381.6
MINING/CEMENT/CERAMIC	6.2	422.1	529.2	574.1	850.6
LIGHT PROCESSING	32.4	2,202.8	2,761.9	2,996.4	4,439.3
MACHINE/ELEC. EQUIP.	54.5	3,704.5	4,644.7	5,039.0	7,465.7
OTHERS	4.1	275.8	345.8	375.1	555.8
TOTAL	100.0	6,794.5	8,518.9	9,242.2	13,692.9

*: assumed to be same as the one of Pathum Thani

(3) Number of employees

Number of employees of each province by industrial group was computed by using assumed labor productivity shown in Table 6.2.5 and projected GRP shown in Tables 6.2.9 and 6.2.10 Computation results are as shown Table 6.2.11.

Table 6.2.11 Projected No. of Employees in Pathum Thani and Nonthaburi

Industrial Group	Pathum Thani				Nonthaburi			
	1992	1996	2001	2011	1992	1996	2001	2011
FOOD PROCESSING	4,244	4,385	3,891	3,971	2,470	2,551	2,264	2,309
MIN./CEM./CERAMIC	10,485	10,795	9,565	9,703	4,230	4,369	3,876	3,954
LIGHT PROCESSING	69,751	72,065	63,944	65,255	40,595	41,929	37,199	37,941
MACHINE/ELEC.	86,517	89,389	79,314	80,940	50,353	52,008	46,140	47,061
OTHERS	21,201	21,905	19,436	19,835	12,339	12,745	11,307	11,532
TOTAL	192,198	198,539	176,150	179,704	109,987	113,602	100,786	102,797

6.3 Livestock and Fishery Development

6.3.1 General

Excreta of cattle and swine, and floor washing water from pigsty have a possibility to be pollution sources to public water bodies. However, through field work, it was confirmed that pollution load generated by cattle and buffalo does not usually reach to channels in the dry season.

Wastewater discharged from fresh fish cultivation pond, mainly situated on the southern part of the study area, is also one of the pollution contributors as revealed in the ONEB report.

The projection of these frame values was made to estimate potential pollution load generated in the study area.

6.3.2 Livestock

Dominant livestock reared in the study area with reference to water pollution are water buffalo, cattle and swine. According to the record by the Department of Livestock Development, Ministry of Agriculture and Cooperatives, the number of water buffalo is moderately decreasing, while other livestocks are increasing.

Although the recorded number of livestock fluctuated yearly, projection was made employing a linear trend method using data during the last 5 years. Due to data limitation, the ranges of growth rate are assumed as follows:

1990 to 1992; 10% per annum

1990 to 1996; 8% per annum

1990 to 2001; 6% per annum

1990 to 2011; 4% per annum

Past records and projection of livestock frame values are shown in Table 6.3.1.

Table 6.3.1 Number of Livestock (past record and future projection)

Province	Livestock	Past Record 1986	1987	1988	1989	1990	Projection 1992	1996	2001	2011
Chai Nat	Buffaloes	22,408	20,581	19,948	20,887	23,052	22,000	22,700	23,400	25,000
	Cattle	50,171	50,979	51,378	54,278	51,136	53,700	55,800	58,400	63,600
	Swine	38,361	38,970	36,573	33,830	39,573	36,400	35,300	33,900	31,200
Sing Buri	Buffaloes	6,924	4,987	4,713	4,454	3,075	2,500	1,900	1,600	1,300
	Cattle	17,026	17,340	21,251	27,758	26,934	32,600	42,700	51,100	61,400
	Swine	40,483	32,252	26,675	31,337	28,237	22,900	17,100	14,300	12,000
Lop Buri	Buffaloes	40,292	25,612	24,202	22,212	19,910	16,100	12,100	10,100	8,400
	Cattle	156,899	159,797	164,750	172,157	166,569	176,700	189,400	205,200	236,900
	Swine	82,019	84,215	97,123	87,726	77,672	83,700	81,600	79,000	73,800
Ang Thong	Buffaloes	12,381	9,170	7,442	5,924	7,547	6,100	4,600	3,800	3,200
	Cattle	32,689	33,293	32,639	33,651	36,057	36,500	39,300	42,900	50,000
	Swine	28,878	29,143	28,132	36,432	40,903	45,200	57,800	73,400	93,200
Ayutthaya	Buffaloes	31,882	34,277	29,043	26,997	27,872	23,900	17,800	14,100	11,800
	Cattle	33,008	33,618	34,265	35,527	33,249	34,900	35,800	37,000	39,400
	Swine	25,827	25,980	25,612	40,273	43,362	52,000	68,800	82,300	98,800
Pathum Thani	Buffaloes	4,207	5,086	4,806	5,846	6,923	7,900	10,300	13,400	15,800
	Cattle	4,528	4,612	4,701	7,117	9,178	10,700	14,600	17,400	20,900
	Swine	3,195	13,316	34,435	39,949	37,395	45,200	59,300	71,000	85,200
Nonthaburi	Buffaloes	1,012	1,175	1,442	1,318	1,383	1,600	2,000	2,400	3,200
	Cattle	3,156	3,334	3,322	3,313	3,340	3,400	3,600	3,700	4,100
	Swine	1,897	1,989	3,770	2,831	3,751	4,500	6,000	7,100	8,500
Saraburi	Buffaloes	41,737	33,890	27,485	24,432	20,920	16,900	12,700	10,600	8,900
	Cattle	63,398	64,569	66,389	68,260	60,075	63,400	62,200	60,700	57,700
	Swine	53,558	54,719	98,225	88,759	87,322	105,700	138,600	165,800	199,000
TOTAL	Buffaloes	160,843	134,778	119,081	112,070	110,682	97,000	84,100	79,400	77,600
	Cattle	360,875	367,542	378,695	402,061	386,538	411,900	443,400	476,400	534,000
	Swine	274,218	280,584	350,545	361,137	358,215	395,600	464,500	526,800	601,700

Source: Office of Agricultural Economics and Department of Livestock Development, Ministry of Agriculture and Cooperatives (MOAC)
JICA Study Team (projection)

6.3.3 Fishery

Fish cultivation is popular in Thailand not only for marine water shrimps and prawns in coastal area but for freshwater fishes in inland area. Fresh water fish cultivation has been done using several types of culture such as pond culture, paddy-field culture, ditch culture and cage culture as shown in Table 6.3.2. Area of fresh water fish cultivation ponds has been decreasing, while the number of farms is slightly increasing.

Table 6.3.3 shows the area of fishpond for each province and amphoe in the study area. About 75% of fishponds in the study area is located in Ayutthaya and Pathum Thani owing to their geographical feature. The present figures shown in Table 6.3.3 will be employed as a frame value through out the future. Average depth of ponds is assumed to be 1.5m by the Department of Fisheries.

Table 6.3.2 Number of Farms and Area of Fresh Water Fishes Cultivation in Thailand by Type of Culture

Number of Farms

	Pond	Paddy-field	Ditch	Cage
1985	36,508	6,443	528	842
1986	39,015	6,990	554	710
1987	48,027	7,034	490	617
1988	51,025	7,162	582	670
1989	52,126	7,242	442	686

Area (ha)

	Pond	Paddy-field	Ditch	Cage
1985	12,957	23,788	197	5
1986	14,511	23,842	231	4
1987	23,501	23,524	188	5
1988	22,954	22,639	249	6
1989	18,810	22,668	147	9

Source: Department of Fisheries, MOAC

Table 6.3.3 Area of Fish Pond by Municipality and Amphoe in 1990

Province / Amphoe	Area (m^2)
Chai Nat	
Muang Chai Nat	276,237
Manorom	136,588
Wat Sing	138,400
Sankhaburi	383,200
Sanphaya	165,236
Han Kha	231,785
Total	1,331,446
Ratio to G. Total	6.4%
Sing Buri	
Muang Sing Buri	90,776
Khai Bang Rachan	90,730
Tha Chang	32,452
Bang Rachan	109,148
Phrom Buri	75,613
In Buri	62,155
Total	460,874
Ratio to G. Total	2.2%
Lop Buri	
Muang Lop Buri	263,113
Khok Samrong	131,055
Chai Badan	37,360
Tha Wung	79,015
Ban Mi	279,477
Phatthana Nikhom	412,975
Sa Boat	1,600
Total	1,204,595
Ratio to G. Total	5.8%
Ang Thong	
Muang Ang Thong	124,986
Chaiyo	15,804
Pa Mok	75,745
Pho Thong	173,318
Wiset Chai Chan	277,756
Samko	2,800
Sawaengha	25,010
Total	695,419
Ratio to G. Total	3.3%
Ayutthaya	
Muang Ayutthaya	37,200
Tha Rua	14,100
Nakhon Luang	56,050
Bang Sai	1,886,350
Bang Shai	481,900
Bang Ban	46,209
Bang Pahan	135,931
Bang Pa-in	146,676
Ban Phraek	33,148
Phak Hai	1,580,472
Phachi	43,370
Maha Rat	307,044
Lat Bua Luang	633,520
Wang Noi	4,700
Sena	2,689,554
Uthai	22,400
Total	8,118,624
Ratio to G. Total	38.9%
Pathum Thani	
Muang Pathum Thani	470,150
Sam Khok	740,590
Lat Lum Kaeo	1,864,051
Thanyaburi	545,914
Lam Luk Ka	1,456,540
Klong Laung	1,534,756
Nong Sua	440,760
Total	7,052,761
Ratio to G. Total	33.8%
Nonthaburi	
Muang Nonthburi	653,600
Kruai	150,670
Bang Yai	133,140
Ban Bua Thong	589,764
Pak Kret	94,000
Sai Noi	378,140
Total	1,999,314
Ratio to G. Total	9.6%
Grand Total	20,863,033

Source: Department of Fisheries, MOAC

6.4 Slaughterhouse and Fresh Market

6.4.1 General

Slaughterhouse and fresn market are major point sources of water pollution in the study area. These pollution sources are usually located in the vicinity of municipalities/SDs. At present, there is at least one or two of these facilities in each municipality/SDs.

The projection of frame value on these pollution sources was undertaken.

6.4.2 Slaughterhouse

The number of livestock slaughtered by province was recorded by the Department of Livestock Development, MOAC as shown in Table 6.4.1.

The number of cow and swine was computed using the linear trend by applying a least square method on the data during the last 4 years. The following growth rates were derived:

1990 to 1992; 10% per annum
1990 to 1996; 8% per annum
1990 to 2001; 6% per annum
1990 to 2011; 4% per annum

Results of computation are also shown in Table 6.4.1. The location of the slaughterhouse is assumed to be in the vicinity of each municipality/SD through out the future.

6.4.3 Fresh Market

A large-size fresh market is located in the urban area. These markets located in the municipalities are considered as one of the major pollution point sources, while pollution load discharged from small-size markets commonly found in residential area is regarded as part of the domestic load.

The population size/economic activities and market area size can be suitable parameters to estimate pollution load. However, due to limited available

data, a constant and uniform pollution load is assumed for each municipality through out the future.

The following are reference information from sewerage projects conducted in Thailand.

- Domestic wastewater and water pollution problems in Bangkok and its vicinity

  Market area: 691 m^2
  Wastewater : 37.39 m^3/d

- Comprehensive Study of Sewerage System for the First Group Area, Pathum Thani Municipality

  Market area: 282 m^2 (2 markets)
  Wastewater : 42 m^3/d

The average wastewater volume of the above municipalities is regarded as a representative figure for local municipalities which is 40 m^3/d.

Table 6.4.1 Number of Slaughtered Livestock (past record and future projection)

Province	Livestock	Past Record 1986	1987	1988	1989	Projection 1992	1996	2001	2011
Chai Nat	Buffaloes	892	1,811	1,943	1,689	1,570	1,330	1,020	690
	Cattle	2,337	1,179	944	692	500	390	330	280
	Swine	16,062	14,937	15,674	16,866	17,300	18,560	20,140	23,280
Sing Buri	Buffaloes	255	252	122	120	90	70	60	50
	Cattle	2,249	1,857	1,019	695	510	390	330	280
	Swine	17,478	14,528	10,634	9,071	6,610	5,060	4,320	3,700
Lop Buri	Buffaloes	401	298	276	275	240	190	130	110
	Cattle	8,226	8,017	8,094	7,493	7,000	6,150	5,090	3,050
	Swine	23,899	24,408	26,190	24,447	26,280	27,650	29,360	32,790
Ang Thong	Buffaloes	1,286	1,188	1,463	1,115	1,160	1,060	940	700
	Cattle	3,933	3,422	2,909	1,971	1,440	1,100	940	800
	Swine	17,741	22,474	23,879	20,675	25,790	29,870	34,970	45,180
Ayutthaya	Buffaloes	3,680	4,031	4,000	5,314	6,450	8,400	10,690	12,590
	Cattle	4,998	5,558	4,871	6,947	7,920	9,980	12,560	16,460
	Swine	43,307	44,196	43,321	47,525	49,890	54,600	60,490	72,270
Pathum Thani	Buffaloes	33,802	35,306	33,905	31,233	29,460	25,820	21,270	12,720
	Cattle	28,228	26,113	25,345	25,743	22,660	19,370	15,260	10,490
	Swine	64,733	72,790	64,418	79,391	86,350	100,590	118,400	154,000
Nonthaburi	Buffaloes	11,580	11,559	9,404	8,607	6,270	4,800	4,100	3,510
	Cattle	8,585	8,357	7,531	7,294	5,830	4,070	3,470	2,970
	Swine	33,494	35,645	37,719	37,390	42,250	47,760	54,640	68,400
Saraburi	Buffaloes	1,474	1,706	1,878	1,576	1,870	2,060	2,300	2,780
	Cattle	4,761	4,466	4,460	4,348	3,950	3,450	2,830	1,770
	Swine	40,004	42,150	46,464	45,286	52,550	60,610	70,690	90,850
TOTAL	Buffaloes	53,370	56,151	52,991	49,929	47,110	43,730	40,510	33,150
	Cattle	63,317	58,969	55,173	55,183	49,810	44,900	40,810	36,100
	Swine	256,718	271,128	268,299	280,651	307,020	344,700	393,010	490,470

Source: Office of Agriculture Economics, MOAC
JICA Study Team (Projection)

CHAPTER 7

WATER USE AND HYDROLOGICAL CONDITIONS OF RIVERS THROUGH THE FUTURE

CHAPTER 7 WATER USE AND HYDROLOGICAL CONDITIONS OF RIVER THROUGH THE FUTURE

7.1 Water Use in the Chao Phraya River

Water of Chao Phraya river and its tributaries is utilized for domestic, industrial, irrigation and fishery purposes. The following sub-sections describe the major water uses.

7.1.1 Domestic and Industrial Water Supply

Domestic and industrial water uses are mostly concentrated on the lower part of the basin from Pathum Thani to Samut Prakarn provinces. The respective amount of industrial and domestic water is not identified. However, the consumption for both purposes is estimated at about 2.65 million m^3/day, which is much less than that for irrigation use. Sources of these water supply are surface water and groundwater.

Major water source of the MWA is the Chao Phraya river. Raw water intake facilities with a pump station is located at Tambon Samlae, Pathum Thani. The intake amount at the pump station is about 1.25 million m^3/day (maximum at 3.0 million m^3/day).

Groundwater is also used by MWA and private sectors. The amount for MWA and private sector is about 0.5 million m^3/day and 0.9 million m^3/day, respectively. A total amount of groundwater extraction of 1.4 million m^3/day results to the problem of land subsidence.

7.1.2 Irrigation Water Use

Water from Chao Phraya river is taken through irrigation channels. Several intake gates and pump stations are located in the basin from Ang Thong to the upper part of Bangkok Metropolis.

The amount of water used during the wet season that starts from the mid-July until November, is estimated at about 1,100 million m^3/month for farmland use in the whole basin. For the lower part from Chai Nat to Nonthaburi, about

20% of the total amount or 200 million m^3/month is utilized, mainly for paddy field. During the dry season, from December to June, the water is also used for other agricultural production such as corn, sugar cane, potato and fruits. The amount of water used is estimated at 700 million m^3/month for the whole basin and 120-130 million m^3/month in the lower part.

RID is in-charge of water management for irrigation use, and is classified into 2 types, water management in non-irrigated areas, and irrigated areas.

Non-irrigated areas are those outside the irrigation project areas, and water sources are from natural water reservoirs. Water management to support cultivated areas is to utilize local pumps and not pumping stations. The amount of available water depends on the condition of natural water reservoirs. Flow rate in these areas are not observed directly by RID.

Irrigated areas are those covered by irrigation projects which mostly have water storage reservoirs in their own basins. Water management covering water use activities such as paddy farming, vegetable and perennial plant cultivation, etc. is to control and manage the amount of water through hydraulic facilities along Chao Phraya river and its tributaries.

Efforts have been devoted by RID to ensure required water for irrigation use throughout the year for both irrigated and non-irrigated areas by providing irrigation canal networks, intakes gates and pumping stations. Location of these facilities is shown in Figure 7.1.1 while Table 7.1.1 presents the intake amount at major gates and pumping stations.

In the lower part of the river, from Chai Nat to Nonthaburi, about 50 to 130 million m^3/month is used through out the year even during the dry season. Water intake in Ayutthaya (in Jao Jed Project, from Noi river) is not so high between August and January but is negligible between February and July, although the period of paddy cultivation usually starts from June. This is because the water from Tha Chin and Suphan rivers is utilized in the west bank area and upstream of Pasak river, and the east bank area of Pasak river, respectively.

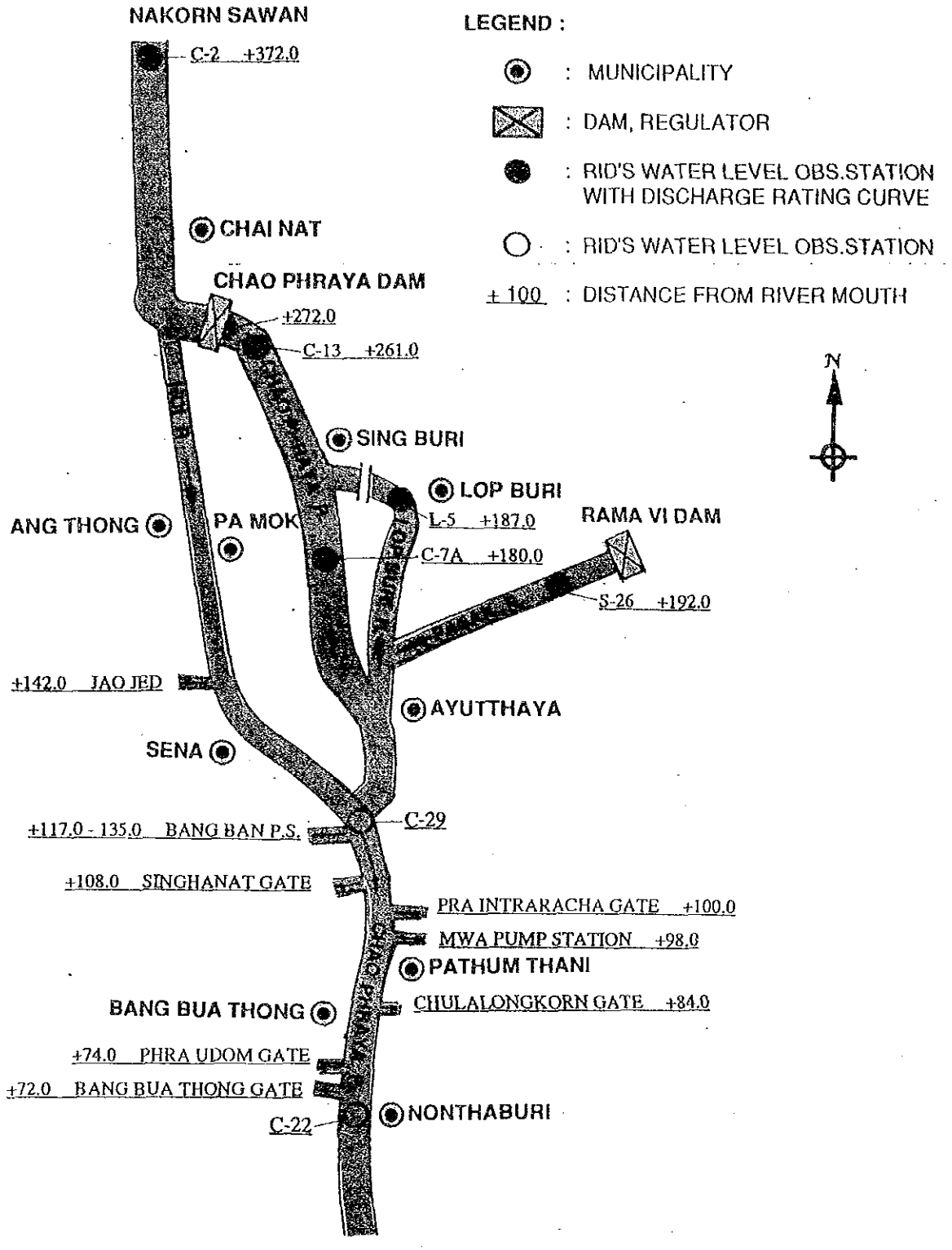


FIG. 7.1.1 FLOW PATTERN IN THE STUDY AREA

STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

TABLE 7.1.1 WATER INTAKE BY GATES AND PUMPING STATIONS IN CHAO PHRAYA RIVER AND ITS TRIBUTARIES
(Averaged between 1988-1992)

Gate/ Pumping St.	Dist. (km)	Monthly average flow rate (m3/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Bang BuaThong	72.0	-17.75	-20.42	-19.66	-20.07	-16.25	-10.61	-10.39	-14.24	-12.62	-23.92	-15.83	-11.20
Pra Udom	74.0	-9.22	-12.64	-10.98	-11.76	-10.05	-9.94	-5.39	-4.50	-4.75	-5.91	-3.77	-3.68
Chulalongkorn	84.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pra Intraracha	100.0	1.16	0.63	0.24	0.13	0.17	0.71	0.83	1.52	1.88	7.44	4.99	1.64
Singhanat	108.0	2.26	2.43	0.82	-0.25	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jao Jed	136.0	-8.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.33	-0.07	-1.32	-1.57	-19.89

Note :
- "-" refers to water intake and "+" refers to water release from gates
- Bang Ban Pumping Station, data is not available for whole year, but is estimated that water intake is less than 1.0 m3/s
- PWA Pumping Station, water intake varies very slightly whole year, therefore it is assumed that water intake is constant at 30.0 m3/s
- Chulalongkorn gate, data by gravity and pumping station in the recent years are not available, therefore water intake is assumed 0.0 m3/s

Water intake in Pathum Thani (from Chulalongkorn, Pra Intraracha and Singhanat Gate) is not so high because the area has been developed as an industrial area especially in the west side. In the east side of the border area between Nonthaburi and Pathum Thani, water intake (from Bang Bua Thong and Pra Udom Gate) is considerably high through out the year but the peak is in February to March, and September to October because paddy cultivation is done 2 times a year during these periods. After paddy cultivation period ends, some other cultivation or farming is also done, so that water demand is also high.

7.2 Hydrological Conditions of the Rivers

7.2.1 Rainfall Observation

A total of about 600 gauging stations is distributed in the Chao Phraya river basin. About half of these belongs to RID, another half belongs to other agencies including MD, former ONEB, EGAT, PWD, etc.

The MD's gauging stations are distributed uniformly in the basin, while the RID's gauging stations are concentrated in nearby irrigation structures. Consequently, about 400 gauging stations for irrigation and flood control are located in the lower reaches that covers an area of about 50,000 km^2, while about 200 gauging stations for mainly flood control are in the upper reaches with an area of about 110,000 km^2.

Gauging stations equipped with telecommunication system are scarcely distributed in the basin. The MD also operates radar gauging stations at Bangkok and Chiang Mai, but the information is limited for qualitative analysis of precipitation.

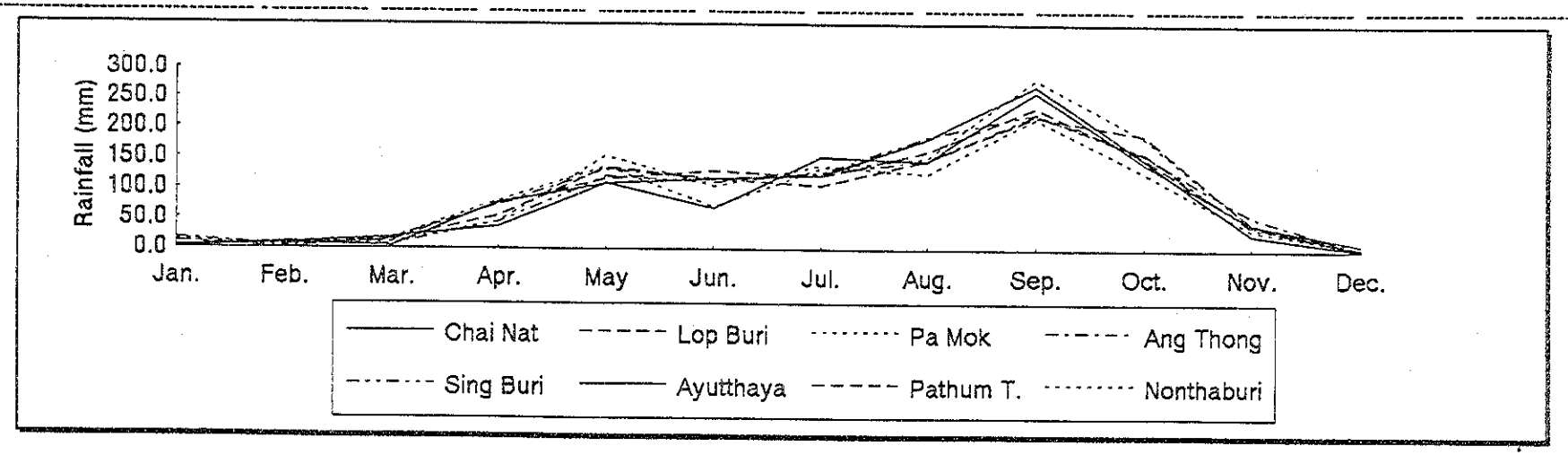
Rainfall observation is undertaken by almost all stations using a brass cylinder with 18 inch diameter. Observation time is 7:00 A.M. by MD and 6:00 A.M. by RID.

Monthly average rainfall for the past 10 years is shown in Table 7.2.1.

The area coverage of each rainfall station is 400-500 km^2/station in the upper reaches and about 120 km^2/station in the lower reaches.

TABLE 7.2.1 AVERAGE MONTHLY RAINFALL IN CHAO PHRAYA RIVER BASIN
(Averaged between 1980-1989)

Station	Monthly average rainfall (mm)											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chainat, Chao P. Dam	3.4	7.9	18.1	37.2	109.7	68.1	152.5	145.4	260.1	143.5	44.0	8.4
Lop Buri, A. Muang	0.9	10.5	16.0	74.0	116.3	129.1	120.9	160.9	233.7	151.9	42.0	0.2
Ang Thong, Pa Mok	10.3	5.4	9.4	44.8	153.6	104.3	137.9	125.0	216.0	128.6	33.7	2.6
Ang Thong, A. Muang	16.1	4.7	12.7	75.0	132.3	116.1	126.6	146.7	222.5	157.4	56.2	2.1
Sing Buri, A. Muang	2.3	9.7	6.0	44.3	121.1	111.2	126.5	185.3	224.0	159.8	38.5	2.4
Ayutthaya, A. Muang	0.4	7.6	3.5	76.8	108.9	116.5	122.2	182.0	270.7	148.9	25.8	0.3
Pathum Thani, A. Muang	10.6	0.0	14.3	54.5	134.9	117.5	105.8	146.6	219.1	189.5	44.4	2.9
Nonthaburi, A. Muang	14.4	2.7	16.1	79.7	136.2	71.2	134.1	150.8	282.0	184.9	43.5	0.0
Total	58.40	48.50	96.10	486.30	1,013.00	834.00	1,026.50	1,242.70	1,928.10	1,264.50	328.10	18.90



Rainfall in Chao Phraya river basin is affected by the monsoon from southern part in wet season. Monthly maximum rainfall in the whole basin occurs in September with a range from 200 to 300mm and minimum rainfall occuring in December to February with a range from 0 to 20 mm. The amount of rainfall varies from high in the lower basin to low in the upper basin.

7.2.2 Rainfall Intensity by Return Period

Rainfall data are analyzed by stochastic method for different return period. Maximum rainfall on daily, monthly and yearly periods are shown in Table 7.2.2.

Rainfall data is normally utilized for run-off analysis. In this study, hourly rainfall data is analyzed stochastically by Gumbell's method. Results of the rainfall intensity and time duration analysis for the area in the lower reaches including Chai Nat, Lop Buri, Ayutthaya, Pathum Thani and Nonthaburi are shown in Section 7.2.1 of Volume IV-Data Report.

Time duration means run-off time of the water between 2 specified points of the river. Using Manning's formula for average velocity, time duration can be estimated with a formulae that is generally used, the ratio of river length to slope of the basin.

7.2.3 Flow Pattern

Flow pattern in the lower Chao Phraya river basin is controlled by major dams, regulators and gates. Chao Phraya river branches off to main and Noi river at Chai Nat. Noi river also branches into several tributaries which are connected to irrigation channels and again merges with Chao Phraya river at Bang Sai, Ayutthaya. Chao Phraya river, after branching off at Chai Nat, is controlled by Chao Phraya dam. Details on the operation of Chao Phraya Dam are mentioned in the previous section. Downstream of Chao Phraya Dam, the river merges again with Pasak river in Ayutthaya and flows downstream.

The watershed of Lop Buri river is divided into 2 parts; one area directly connected to the main river basin, and the other, the Lop Buri river basin. Lop Buri river merges with Pasak river at the upper part of Ayutthaya. Flow rate in Pasak river is controlled by Rama VI barrage. After the con-

Table 7.2.2 Stochastic Consecutive Maximum Rainfall in the Chao Phraya River Basin

	unit	Return Period (Year) 1/5	1/10	1/20	1/50	1/100
Nakhon Sawan (Amphoe Muang)						
Daily Max. Rainfall	mm/day	94.7	106.6	117.4	130.8	140.5
Monthly Max. Rainfall	mm/month	333.2	358.5	379.5	403.5	419.7
Yearly Max. Rainfall	mm/year	1,267.5	1,373.8	1,467.6	1,580.2	1,659.8
Chai Nat (Chao Phraya Dam)						
Daily Max. Rainfall	mm/day	94.9	110.9	126.3	146.4	161.6
Monthly Max. Rainfall	mm/month	322.1	354.1	380.8	411.3	431.9
Yearly Max. Rainfall	mm/year	1,089.3	1,187.6	1,276.2	1,384.7	1,462.9
Ayutthaya (Amphoe Muang)						
Daily Max. Rainfall	mm/day	104.1	117.9	130.0	144.3	154.3
Monthly Max. Rainfall	mm/month	355.0	410.4	461.0	523.9	569.6
Yearly Max. Rainfall	mm/year	1,352.5	1,551.7	1,734.3	1,961.5	2,127.4
Bangkok (Meteorology Dept.)						
Daily Max. Rainfall	mm/day	114.6	129.6	143.4	160.5	173.1
Monthly Max. Rainfall	mm/month	460.8	514.5	563.2	623.2	666.5
Yearly Max. Rainfall	mm/year	1,704.9	1,837.7	1,950.8	2,081.9	2,171.8

Source : Meteorology Department, Bangkok, Thailand

fluence, Pasak river joins Chao Phraya river at the middle part of Ayutthaya. Before the confluence of Chao Phraya river and Noi river at the lower part of Ayutthaya, there are some natural and man-made canals but water intake amount is not significant. Considerable amount of river water is utilized for agricultural purposes between Ayutthaya and Nonthaburi through several pump stations, intake gates and irrigation channels.

7.2.4 Flow Rate and Water Level Observation

Daily water level in the Chao Phraya river is observed at RID's observation stations. Flow rate at each stations is generally calculated by a "Rating Curve" which is a calibration curve of water level and flow rate at respective stations. However, in the downstream part of the river from Amphoe Bang Sai, Ayutthaya to the Gulf of Thailand, rating curves are not applicable due to tidal effect. Thus, only water level is available in this area. An effort has been made to determine rating curve and flow rate estimation in the lower part from Amphoe Bang Sai, Ayutthaya to the river mouth by JICA and AIT by formulating a dynamic flow model. The model is applicable for prediction of flow rate in wet season but may not be utilized for dry season.

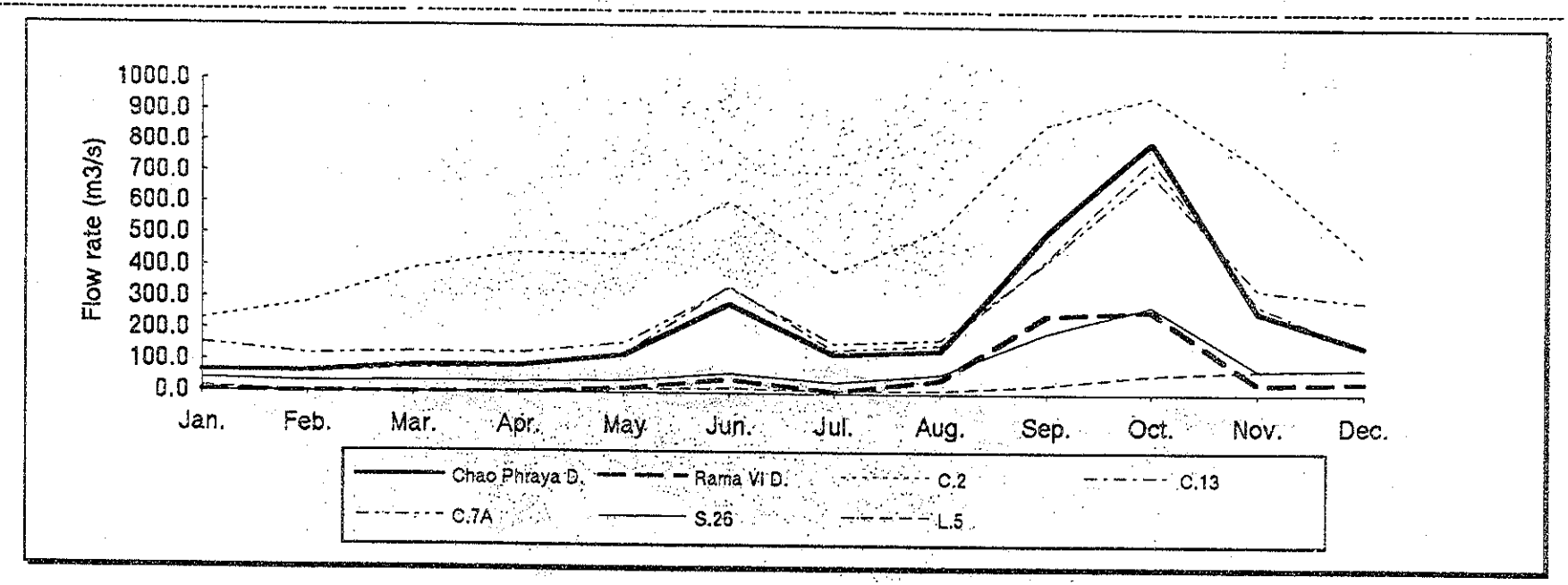
Flow rate and water level observation stations managed and controlled by RID in the Chao Phraya river basin are shown in Section 7.2.2 of Volume IV-Data Report. In this study, all data from these flow rate observation stations are used for flow rate estimation in the basin. Location of these stations are shown in Figure 7.1.1.

7.2.5 Flow Rate and Water Level along the river in Dry and Wet Season

Flow rate at observation stations by RID is shown in Table 7.2.3 and Section 7.2.3 of Volume IV-Data Report. Flow rate in the river is high from May to November and is low from January to May at all the observation stations which coincides with seasonal changes.

TABLE 7.2.3 FLOW RATE IN CHAO PHRAYA RIVER AND ITS TRIBUTARIES OBSERVED BY RID
(Averaged between 1988-1992)

Station	Dist (km)	Average flow rate (m3/s) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
C.2, A.Muang, Nakorn Sawan	372.0	230.7	284.9	392.5	442.5	438.5	605.2	386.2	519.0	860.4	951.2	727.8	436.8
C.7A, A.Muang, Ang Thong	180.0	152.5	119.9	128.6	125.5	157.2	334.7	159.4	173.5	422.0	700.9	334.6	297.4
C.13, A.Sanphaya,Chai Nat	261.0	60.6	58.5	75.9	78.0	123.5	340.2	137.5	155.8	428.0	747.9	266.3	147.3
S.26, A.Tha Rua,Ayutthaya	192.0	40.2	33.0	34.8	34.6	38.6	63.0	34.8	63.1	196.4	282.6	78.9	81.3
L.5, A.Ban Phreak,Ayutthaya	187.0	14.6	0.9	0.9	2.7	11.6	16.0	8.5	11.4	29.0	62.4	77.6	82.5
Chao Phraya Dam, Chai Nat	272.0	63.4	64.2	84.0	84.0	118.4	283.6	123.2	137.2	510.4	803.2	263.2	153.2
Rama VI Dam, Ayutthaya	-	0.6	0.0	0.0	0.0	11.8	42.4	4.7	43.8	251.4	267.0	32.6	37.6



Although flow rate in the river basin is mainly controlled by Chao Phraya Dam and Rama VI Dam, water releases by these dams depend heavily on the rainfall in the basin since the storage basins in the upper part of these dams are small. The operation of these dams therefore, has to follow the yearly meteorological condition.

Average water release from Chao Phraya during dry season is about 64 m^3/s but in recent years, due to the drought, water release is limited to 50 m^3/s which is the least flow rate for control of saltwater intrusion from the river mouth.

Recorded peak discharges by RID in wet season are as follows:

TABLE 7.2.4 Peak Flow Rate Observed by RID

Observation Station	Peak Discharge (m3/s) 1978	1980	1983
Chao Phraya River			
C.2 Nakhon Sawan	3,540	4,320	2,290
Downstream of Chao Phraya River	3,740	3,795	3,290
Pasak River			
S.26 Ayuttaya	3,206	886	851

Flow capacity differs from section to section because the river is still a natural stream. Results of some investigations on the river capacity are shown below.

River capacity : At downstream of Chao Phraya dam, 3,300 m^3/s

At Ayutthaya, Wat Panun Choeng, 2,200 m^3/s

Water level observed during the last 5 years is shown in Table 7.2.5. In Nakhon Sawan, the fluctuation of maximum water level is not so high because the flow at this station is not directly controlled by any dams. Downstream of Chao Phraya Dam, maximum water level varies from low during the dry

season to high during the wet season due to the water release by the dam and the fluctuation is gradually attenuated downstream. Fluctuation in the downstream from Amphoe Bang Sai is almost nil throughout the year.

Water level by return period investigated in previous sewerage projects in Thailand is shown below.

Ayutthaya area :	2 year return period, 3.76 m, msl
	10 year return period, 4.63 m, msl
Pak Kret, Nonthaburi:	2 year return period, 1.72 m, msl
	5 year return period, 1.98 m, msl
	10 year return period, 2.16 m, msl

7.2.6 Flow Rate Estimation and Balance of Flow

Water is released from Chao Phraya dam and other dams in the Chao Phraya river basin basically for domestic, agricultural and industrial uses as well as salinity control and wastewater flushing. In general, the run-off model during the rainy period is complicated due to the mechanism and quantity of flow, rainfall and tidal effect. But during dry season, it is much simpler with the flow controls at dams, regulators and gates.

Respective flow models during wet and dry periods have been formulated to estimate flow rate in the basin. The model study for wet period prepared by AIT divides the basin into 2 parts; upstream area from Amphoe Bang Sai in Ayutthaya, and downstream area therefrom up to the Gulf of Thailand. The model in the upper part is a flood routing model, while in the lower part is a harmonic model due to tidal effect.

The now defunct ONEB also made a model for the dry period by neglecting the unsteady condition of tide but considering the average condition instead. Total flow in the model is a balance of inflows, outflows and losses due to the existence of major pump stations and gates in the basin.

TABLE 7.2.5 WATER LEVEL IN CHAO PHRAYA RIVER AND ITS TRIBUTARIES OBSERVED BY RID
(Between 1988-1992)

Station		Water level (m, msl.) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
C.2, A.Muang, Nakorn Sawan	Max.	19.03	19.41	19.85	19.95	20.89	21.72	21.11	21.78	22.46	23.81	22.65	20.43
	Min.	17.73	18.32	18.10	18.54	17.95	17.61	17.38	18.16	19.12	19.83	19.42	18.00
C.13, A.Sanphaya, Chai Nat	Max.	7.82	6.42	6.79	6.80	9.48	10.51	10.24	9.84	13.91	14.90	13.24	8.41
	Min.	5.93	5.91	6.10	6.09	5.94	5.94	5.78	5.80	6.10	6.41	6.09	5.94
C.7, A.Muang, Ang Thong	Max.	1.70	0.78	0.88	0.90	2.80	3.79	3.58	3.00	6.88	7.55	6.87	2.55
	Min.	0.55	0.22	0.22	0.27	0.22	0.15	0.19	0.16	0.23	0.55	0.50	,63
S.26, A.Tha Rua, Ayutthaya	Max.	3.66	3.36	3.38	3.45	4.32	4.60	3.65	9.22	9.65	12.04	7.81	5.03
	Min.	2.67	2.55	2.48	2.57	2.44	2.62	2.59	2.58	2.63	2.83	2.77	2.85
L.5, A.Ban Phreak, Ayutthaya	Max.	3.80	0.56	0.80	2.07	3.05	3.03	2.63	3.05	4.86	5.54	5.50	4.78
	Min.	0.00	-0.15	-0.18	-0.13	-0.04	0.10	-0.24	-0.08	0.42	0.79	2.51	2.97
C.29, A.Bang Sai Ayutthaya	Max.	1.48	1.17	1.17	1.09	1.35	1.76	1.24	1.57	2.01	3.06	3.05	2.84
	Min.	-0.14	-0.94	-0.95	-0.85	-1.00	-1.20	-1.14	-0.52	-0.87	-0.28	-0.30	-0.24
C.22, A.Pak Kret Nonthaburi	Max.	1.27	1.19	1.12	1.11	1.36	1.12	1.10	1.26	1.61	1.88	1.85	1.44
	Min.	-0.56	-0.79	-0.84	-0.72	-0.90	-1.05	-1.13	-0.84	-1.08	-0.80	-0.53	-0.42