4.5 Underground Structures

Sewers are usually constructed under public roads. Normally, these exist several facilities already laid often require the change of sewer routes.

Existing underground structures in Bangkok include drains, electric cables, telephone cables and water pipes. These are laid crossing each other especially under the sidewalk paths of main streets. The space for sewerage is therefore extremely limited under the main streets.

Figure 4.4 illustrates the typical distribution of the underground structures under the main/submain street.

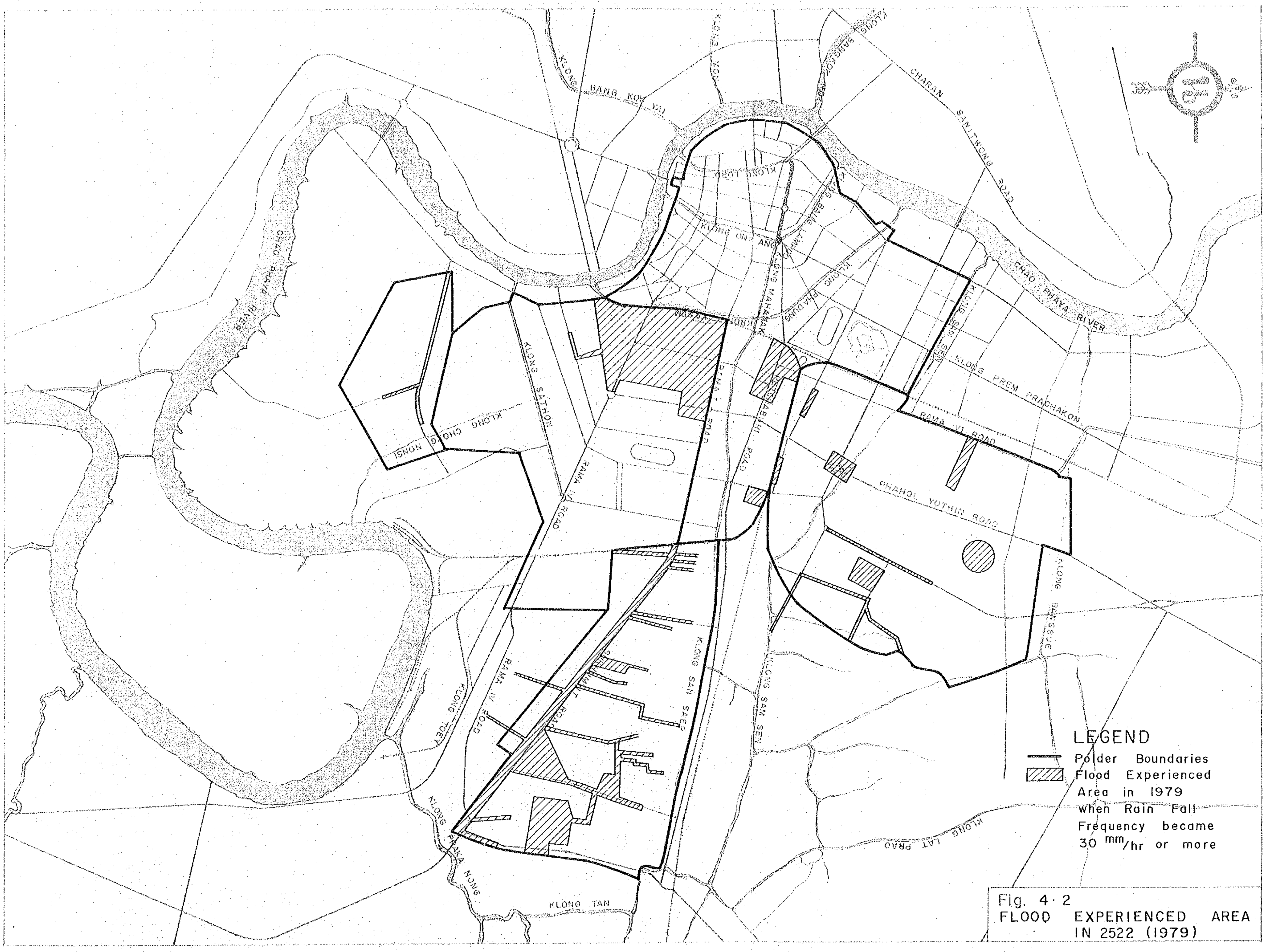


Fig. 4·2
FLOOD EXPERIENCED AREA IN 2522 (1979)

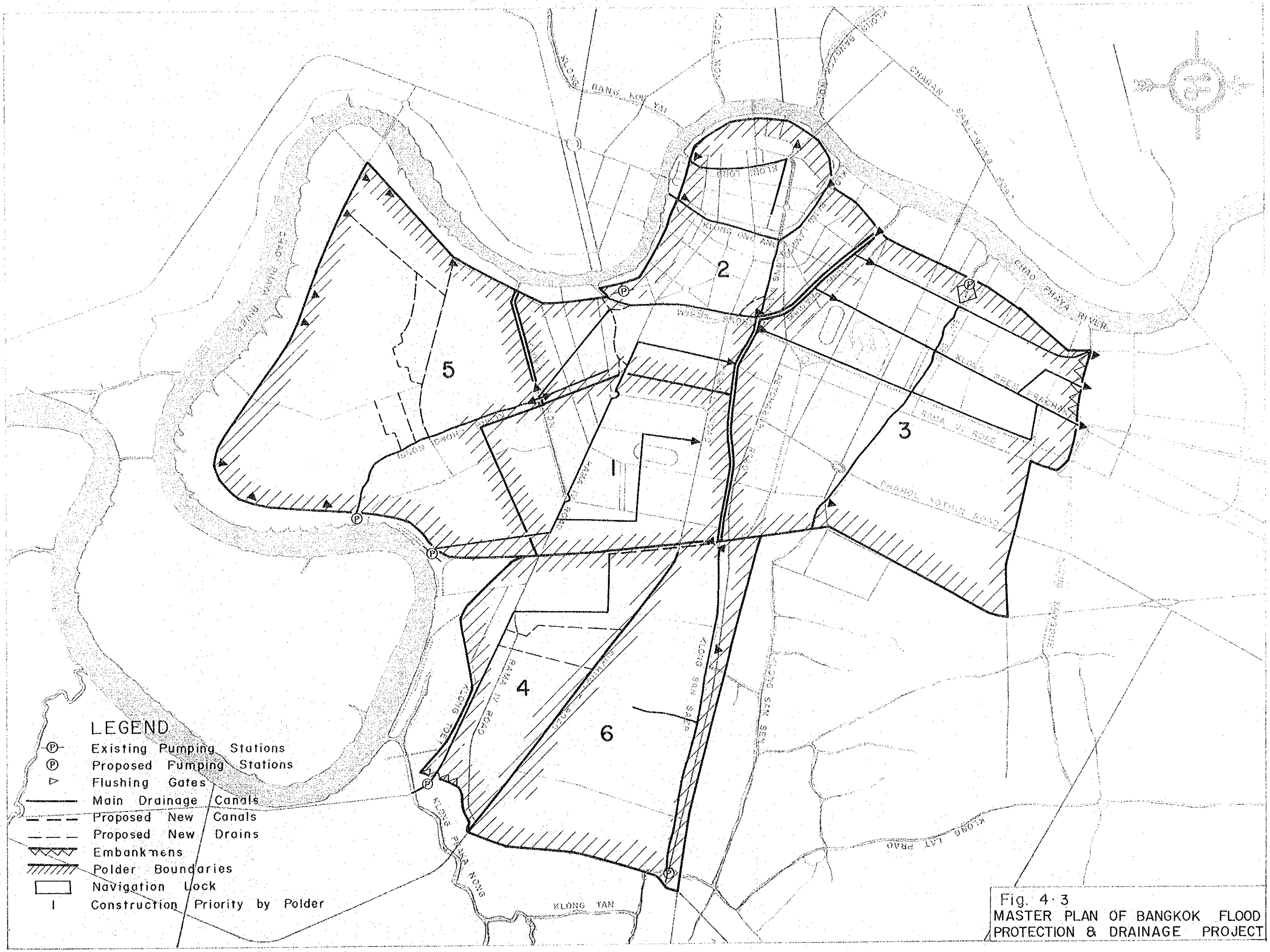


Fig. 4·3
MASTER PLAN OF BANGKOK FLOOD PROTECTION & DRAINAGE PROJECT

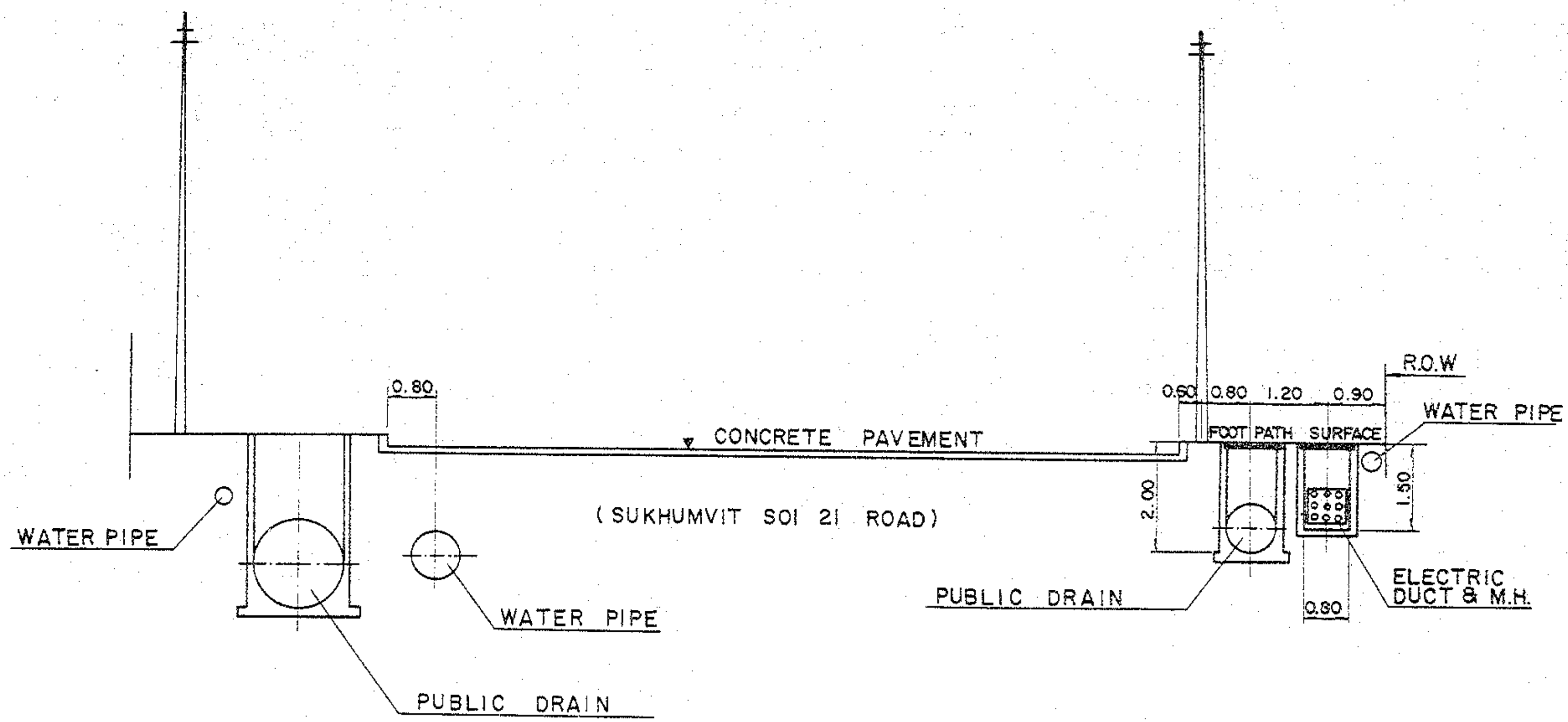


Figure 4.4 Typical Distribution of Underground Structures

CHAPTER 5

WATER SUPPLY SYSTEM

5.1 Water Works Agency

In 2510 (1967) the Thai Government combined the 4 municipal water supply systems of Bangkok, Nonthaburi and Samut Prakarn to form a state enterprise under the mane of "Metropolitan Water Works Authority (MWWA)" administratively under the Ministry of Interior. The total responsible area is 3,100 km^2. MWWA is presently performing a major effort, supported by the Central Government, to expand its services, strengthen its organization and management and improve its operation and financial performance. Continuation of this effort to achieve acceptable levels of service with financial viability as a self-supporting organization will be a prime and most demanding objective of its activities during the immediate future.

5.2 Existing Water Supply System

The source of Bangkok's surface water supply is depending on the Chao Phya River at Sam Lae about 35 km north of Bangkok. The river water has relatively low level of organic contaminants and is alienated from the reach of sea tides. The water is taken to canals which run to the Bang Sue pumping station. From there raw water is pumped by pipeline to the Thonburi Purification Plant and by canal to the Sam Sen Purification Plant in Bangkok.

In 2521 (1978) about 850,000 m^3 of treated water were produced in the two plants. Water from the purification plants and an additional 350,000 m^3/day from deep wells amount to a total production of 1,200,000 m^3/day. This production is equivalent to average 400 l/day/person served without consideration on unaccounted for water.

5.3 Water Supply Improvement Program

In 2511 (1968) MWWA retained Camp, Dresser & McKee (consulting engineers, Boston, Massachusetts, USA) to develop a Master Plan for Water Supply and Distribution covering the thirty years from 2513 (1970) to 2543 (2000). Under the Master Plan water production capacity will grow from the current 1,200,000 m^3/day to about 5,000,000 m^3/day. The percentage of the served population of water supply is expected to increase from 40 percent to 80 percent.

The construction program described in the Master Plan will be implemented in phases. The completion of all construction phases will take until the year 2543 (2000).

The first phase to increase the water supply at 800,000 m^3/day was completed in 2522 (1979). According to the demand, the second phase improvement would be completed by the end of 2524 (1981). Tables 5.1 and 5.2 show estimated water demand.

Stage I - Phase 1

The project was the first major construction stage 2518 (1975) - 2522 (1979) of a long-range program proposed by the Master Plan to increase the water supply capacity by 800,000 m^3/day, extend the water distribution system and improve the water supply operations of MWWA.

The principal project components were as follows:

(a) A new raw water pumping station at Sam Lae, improvements of the open raw water transmission channel (Bang Luang Reservoir and Klong Prapa) and a new siphon at Klong Rangsit.

(b) A new water treatment plant at Bang Khen of maximum reliable capacity about 800,000 m^3/day. The plant includes the transmission pumping station.

(c) Transmission tunnels, two 40,000 m^3 ground level reservoirs and pumping stations, and new storage tank with capacity of 40,000 m^3 in three reservoirs at the existing Sam Sen Water Treatment Complex, trunk mains, distribution mains, etc.

Stage I - Phase 2

To meet the increasing demand of water supply, the Phase 2 construction program was proposed to be implemented and accomplished around the end of 2524 (1981).

The service area after completion of Phase 2 will be 430 km^2 or an increase of 157 km^2 over the Phase 1 service area and the production capability will totally be 2,400,000 m^3/day or increase of 400,000 m^3/day over the Phase 1 capacity. Those design capacity will be enough to serve 4.4 million people up to the year 2528 (1985).

Works according to the plan comprise:

(a) Excavation of raw water canal from Sam Lae pumping station to be connected with the existing Klong Prapa at Bang Poon.

(b) Construction of Bang Luang siphon.

(c) Improvement of existing raw water canal from Bang Khen Purification plant to Sam Sen purification plant.

(d) Expansion of purification facilities at Bang Khen purification plant.

(e) Construction of additional water transmission tunnels, Phahol Yothin (Huay Kwang), Klong Toey and Rat Burana distribution pumping stations, filtered water reservoirs at Phahol Yothin (Huay Kwang), Klong Toey and Rat Burana.

(f) Installation of trunk mains, distribution pipelines and deep wells.

Figure 5.1 shows area to be served by Phase 2 project.

Figure 5.2 shows MWWA water supply flow diagram.

5.4 Water Sources

The part of the central service system which serves Bangkok Metropolitan Area is the only part which uses surface water source. Groundwater is a supplementary source for this area and the only source for the remaineded areas.

About one-third (variously estimated at 330,000 to 400,000 m^3/day) of MWWA's present water supply is groundwater. MWWA now has about 130 operational tubewells. Private tubewells are estimated to be pumping additional 250,000 to 300,000 m^3/day. This large scale withdrawal of groundwater by public and private tubewells exceeds the natural recharge capability of the aquifers with attendant problems of falling groundwater levels and increasing chlorides and iron content of the water.

This has led to abandonment of many wells, particularly in concentrated areas of pumping in the southern portions of Bangkok Metropolitan Area. However, properly designed, constructed and spaced, tubewells can still be expected to supply water in northern and eastern areas of Bangkok Metropolitan Area.

Table 5.1 Per Capita Water Demand

Year	Domestic Use (l/day/cap)	Commercial & Institutional (l/day/cap)	Industrial (l/day/cap)	Public Use (l/day/cap)	Leakage (l/day/cap)
2523 (1980)	180	138	39	21	77
2528 (1985)	190	135	50	16	74
2533 (1990)	200	131	61	12	71
2538 (1995)	205	127	75	10	62
2543 (2000)	210	124	92	8	48

Table 5.2 Water Demand

Year	Total Population (1,000 persons)	Population Served (1,000 persons)	Average Water Demand (m^3/day)						Maximum Water Demand* (m^3/day)
			Domestic Use (A)	Commercial & Institutional (B)	Industrial (C)	Public Use (D)	Leakage (E)	Total	
2523(1980)	5,173.8	3,669.4	660,492	506,376	74,094	77,057	282,544	1,600,563	1,765,686
2528(1985)	6,024.7	4,839.9	919,581	653,386	103,518	77,438	358,150	2,112,073	2,341,971
2533(1990)	6,628.2	5,669.1	1,133,820	742,654	139,453	68,028	402,510	2,486,465	2,769,915
2538(1995)	7,325.4	6,601.2	1,353,245	838,352	191,628	66,012	409,277	2,858,514	3,196,825
2543(2000)	7,890.5	7,492.5	1,573,425	929,070	215,599	59,940	359,640	3,173,674	3,567,030

Note : * Maximum Water Demand = (A) x 1.25 + (B) + (C) + (D) + (E)

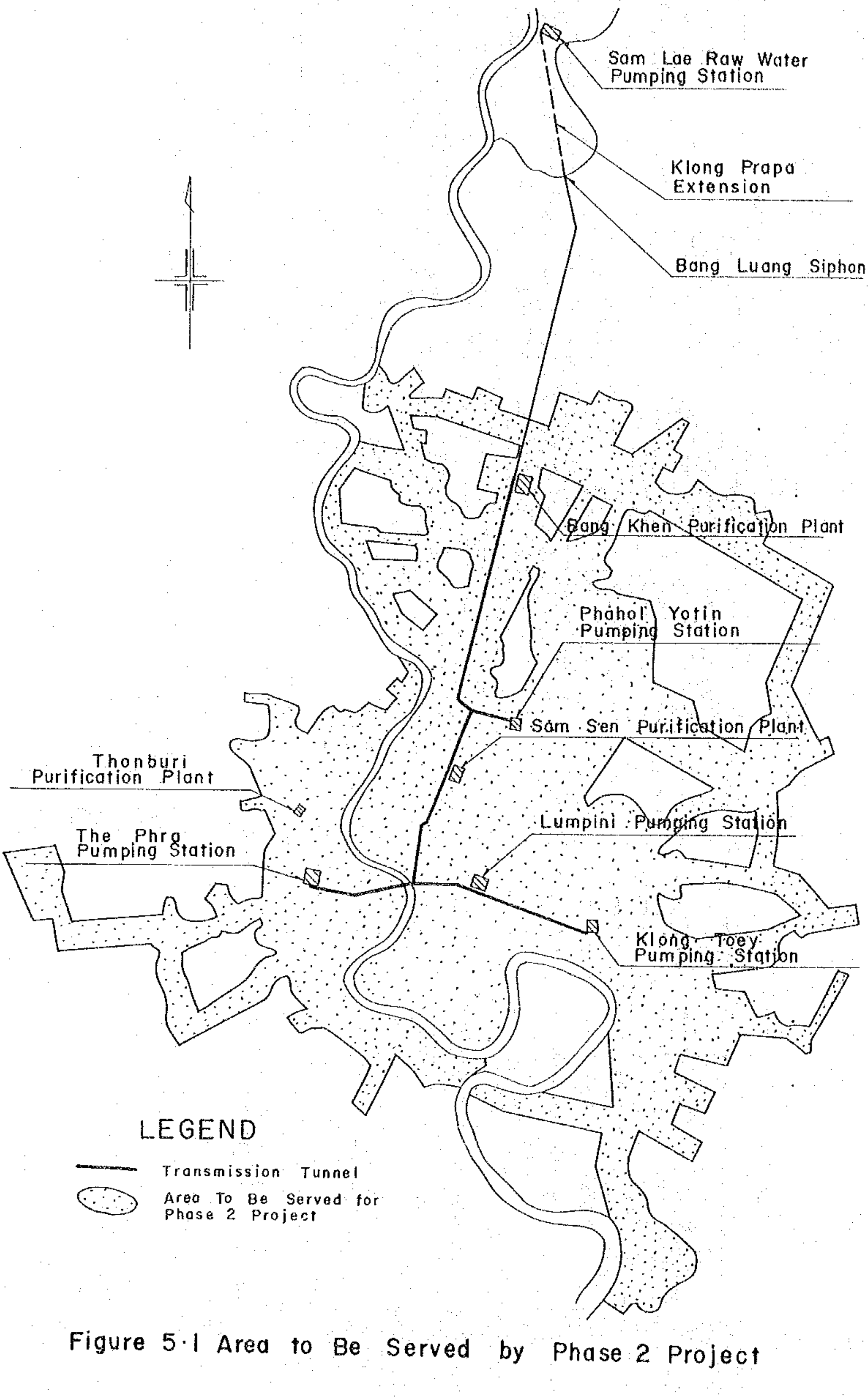
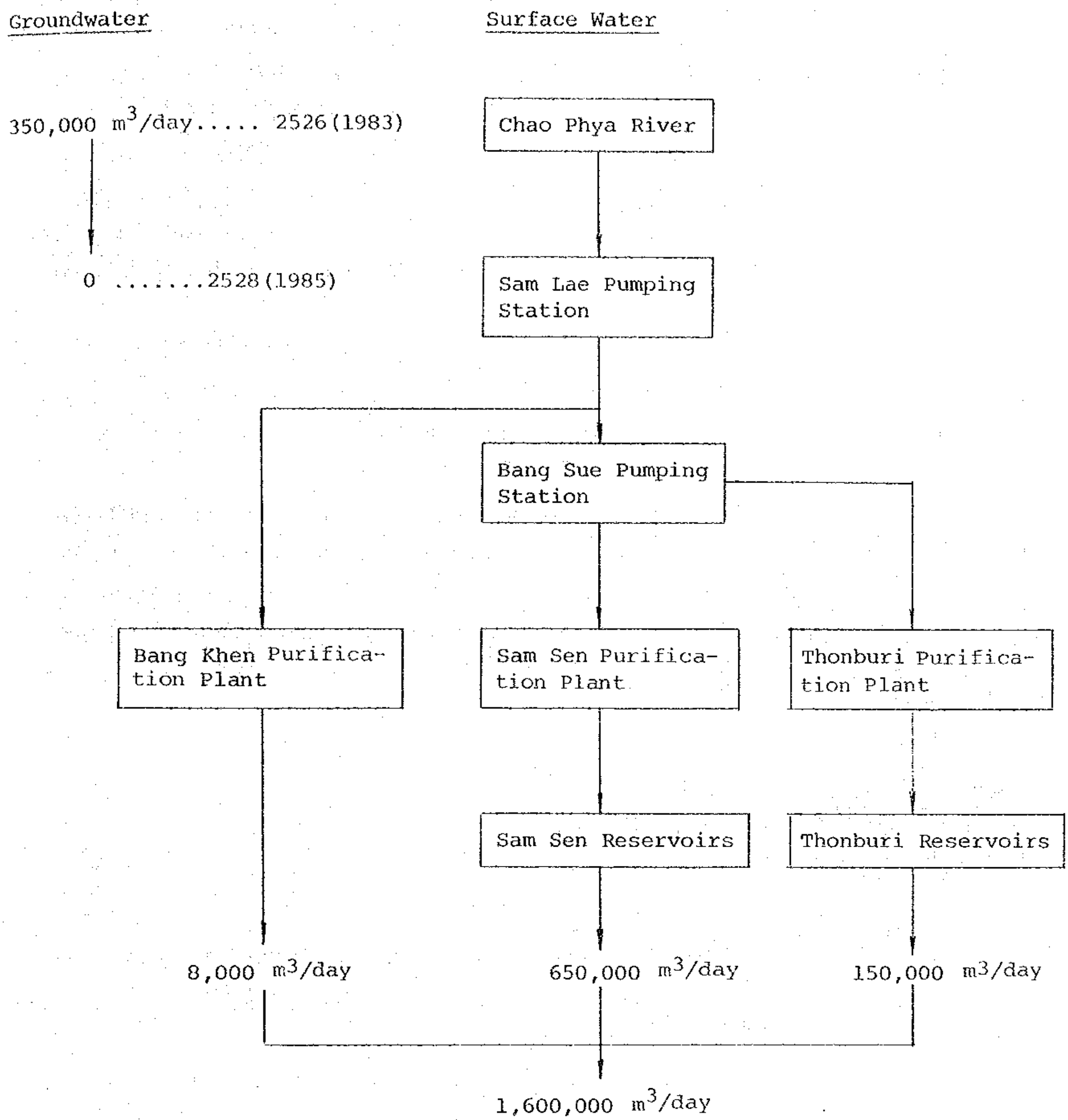


Figure 5·1 Area to Be Served by Phase 2 Project

Figure 5.2 MWWA Water Supply Flow Diagram



CHAPTER 6

CHAO PHYA RIVER AND KLONGS

6.1 Chao Phya River

The Chao Phya River flows through Thailand from the North to the South, of which basin area is about 177,000 km^2. The lower basin of the river is in the flat delta in which Bangkok is located, and its water level flucuates by the tidal effects from the Thai Gulf up to 160 km point from the river mouth.

The Chao Phya River water is used for many purposes such as power generation, irrigation, water supply, fishing and for wastewater disposal.

In this two decades, population growth and industrial development in Bangkok and the surrounding areas have caused water pollution more severe in the lower reach, especially in dry season the dissolved oxygen content becomes less than 0.2 mg/l, and the duration of the low dissolved oxygen content is estimated to become longer as the years go by.

(a) River Flows

The flow of the Chao Phya River is gauged by the Royal Irrigation Department. The minimum discharge measured is less than 50 m^3/sec which is observed in April to June at Bangkok. The flow normally exceeds 1,000 m^3/sec during the period from August to December and a maximum flow rate is more than 4,000 m^3/sec.

(b) Tidal Fluctuation

Tides of the Thai Gulf of Thailand are of a mixed type, i.e. diurnal and semi-diurnal tides. From November to January, the tidal range varies greatly from about 3.5 m at spring tide to about 1.5 m at neap tide above mean sea level. From February to April the tidal range does not fluctuate significantly within 2.5 m and 1.8 m.

(c) Cross Sectional Data

According to the CDM Report, at Bangkok the river has a minimum width of 180 m, with depths of as much as 20 m or more. Down stream width increases to 500 m at 10 km point from the Gulf, and to more than 1,000 m near its mouth. This cross sectional data coincide with the data recently reported by the Asian Institute of Technology (AIT, 2523).

(d) Water Quality

The National Environmental Board has monitored the river water quality at different stations, with the parameters of the components are temperature, DO, BOD, Chloride ion, and Nitrates

Temperature

Water temperature of the river is in the range of 28°C to 34°C. The lowest temperature is observed in February which is in the cold season of Thailand, and the highest temperature is observed in April which is the end of dry season with low flow rate of the river and the hottest season in a year.

Dissolved Oxygen (DO)

The longitudinal variation of DO content is shown in Figure 6.1. The variation pattern is different depending on the variation of the river flow. When the river flow is about 200 m^3/sec, DO content of the river water quickly decreases from approximately 3 mg/l to 1 mg/l in the reaches between Rama VI Bridge and Memorial Bridge, and then gradually increases as flow goes down. This DO variation may be caused by DO consumption owing to assimilation of organic matter originating from domestic and industrial wastewaters discharged from Bangkok and surrounding areas, and caused by DO supply due to reaeration and seawater intrusion. When the flow rate is more than 800 m^3/sec DO content remains more than 2 mg/l at Prapa Daeng.

The data surveyed by AIT in 2521 (1978) shows that DO contents near Memorial Bridge vary in the range of 5.3 mg/l to almost zero during January through April, and are seldom observed to be more than 2 mg/l in the period.

Biochemical Oxygen Demand (BOD)

BOD contents of 1.1 mg/l to 7.9 mg/l in the range were observed at the central area of Bangkok (see Figure 6.1). BOD loads and their corresponding assimilation cause decrease of DO contents and such BOD loads reach or slightly exceed to critical point for aquatic life conservation at the time of the low flow rate.

Chloride Ion (Cl)

Chloride content in the lower reaches of the Chao Phya River is shown in Table 6.1, which is referred from the findings of the survey carried out in 2521 (1978) by NEB and AIT in dry season. The river water at the river mouth includes about 50 percent of the Cl content of a standard seawater, and at Bangkok Port (25 - 30 km upstream the river mouth) about 15 percent.

The Cl contents of the reaches between the Bridges of Rama VI and Memorial are slightly higher than those of the upstream reaches (see Table 6.1). This indicates that the seawater intrusion may be observed crossing the 50 km point from the river mouth in dry season.

Nitrates (NO_3)

Nitrates concentration of the river is in the range of almost zero to 2.6 mg/l at Momorial Bridge. This indicates that nitrification of ammonium originating from wastewater and denitrification may occur in the river. The former causes the decrease of DO, and the latter has a buffer action to offensive odor caused by anaerobic decomposition of organic matter (BOD). The lack of DO and nitrates indicates that the buffer action may be also in a critical condition.

6.2 Klongs

In the lower reaches of the delta, there exist many klongs, some of which are natural but the majority of them are artificial. Most of them presently contributes to navigation, drainage and irrigation needs.

In the central area of Bangkok, the klongs, lined or unlined, which are of various sizes of 1 m to 30 m in width, receive all surface runoffs and convey them to the Chao Phya River. The flow of the klongs is affected by backing up of the Chao Phya River at the time of the high tide. Some of them have stand-bag barrages or various types of gates such as sluice gate and navigation lock for the purposes of controlling water levels of the klongs.

The primary responsibility for maintenance of the major existing klongs is delegated to the Royal Irrigation Department. The smaller klongs within the administrative area are maintained by BMA.

Many klongs in the central area of Bangkok have become heavily polluted by offensive wastewater.

(a) Pollution Survey

To obtain the comprehensive information on water pollution in the klongs in the Study Area, from March 2523 (1980) through September 2523 (1980), smapling and chemical analysis were made by the Laboratory of the Bureau of Drainage and Sewerage (BDS), BMA. The water samples were collected once a month in principle from 56 locations in 34 klongs at surface of each.

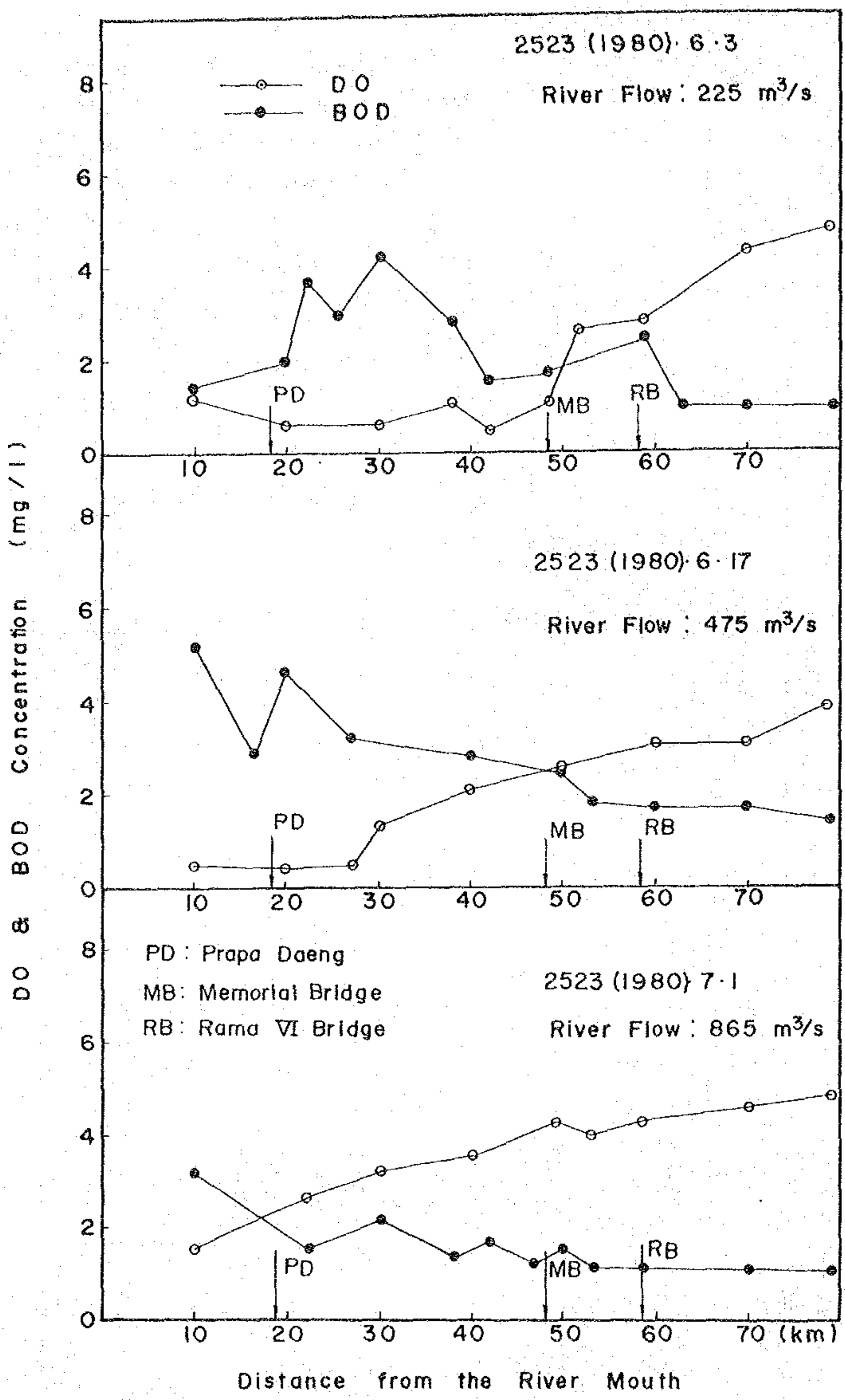
The principal bases used for finding sanitary condition of the surface waters are Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Coliforms, and Hydrogen Sulfide (H_2S). BOD is a measure of the oxidizable matter in the water which is an indication of carbonaceous (organic) and nitrogenous pollution originating from wastewater discharge. DO is an indication of the ability of assimilation of organic matter discharged and of survival of aquatic life. Coliforms is an indication of the contamination of human fecal coliform: i.e. the potential health hazard associated with the use of the water for drinking, washing, bathing, and other uses. Hydrogen Sulfide is an indication of severe pollution of the water receiving waste-waters causing odor nuisances.

The details of the survey are described in Appendix H, and the existing conditions of the klongs surveyed are summarized in Table 6.2.

Table 6.1 Water Quality of Chao Phya River in Dry Season

Segment No.	Distance from River Mouth (km)	Water Quality (1978)					Remarks
		Temp. (°C)	DO (mg/l)	BOD_5^{20} (mg/l)	CI (mg/l)	NO_3 (mg/l)	
1	75-83	-	-	-	-	-	
2	71-75	-	3.9	3.1	12	2.0	
3	65-71	-	3.3	1.6	12	1.8	
4	61-65	-	3.0	2.3	13	1.9	
5	55-61	30.7	1.6	2.4	20	1.1	Rama VI Bridge
6	50-55	30.6	1.6	2.7	27	0.8	
7	45-50	30.6	0.9	3.4	42	0.6	Memorial Bridge
8	40-45	30.5	0.7	3.5	121	0.5	
9	35-40	30.5	0.9	2.9	548	0.6	
10	30-35	30.5	0.9	2.7	1,295	0.7	
11	25-30	30.5	0.8	2.9	2,630	0.6	Bangkok Port
12	20-25	30.5	1.1	2.8	3,379	0.4	
13	15-20	30.5	1.2	2.3	4,783	0.5	Prapa Daeng
14	10-15	30.5	1.9	2.2	6,419	0.2	Samut Prakan
15	5-10	30.5	2.7	2.4	8,229	0.1	
16	0-5	-	4.2	1.7	9,810	0.4	River Mouth

(after NEB & AIT, 2521)



Figure· 6·1 DO and BOD Contents in the Chao Phya River
(Surveyed by NEB)

Table 6.2 Existing Conditions of the Major Klongs

Name of Klong	Point No.	DO	BOD	H_2S	Coliforms
1. Klong Lord	011	C	C	A	-
	012	D	C	C	-
	013	E	D	A	D
	014	E	D	A	-
	015	C	C	A	-
2. Klong Wat Tep Tida	021	E	E	A	C
3. Klong Rajabopit	031	E	E	D	A
4. Klong Bang Lam Poo	041	E	D	A	E
	042	E	D	C	-
5. Klong Ong Ang	051	E	D	A	-
6. Klong Mahanak	061	E	D	A	-
	062	E	C	D	D
7. Klong Padung Krung Kasem	071	C	C	-	-
	072	E	D	A	E
	073	E	D	D	-
	074	D	D	D	-
	075	E	D	A	C
8. Klong Sam Sen	081	E	D	E	B
	082	C	C	A	-
	083	E	D	D	C
9. Klong San Sep	091	E	D	D	B
	092	C	C	A	B
	093	C	C	A	A
10. Klong Tan	101	E	C	A	B
11. Klong Prem Prachakorn	111	B	C	A	-
	112	D	C	A	-
	113	D	C	A	E
	114	C	B	A	C
12. Klong Bang Sue	121	C	C	A	B
	122	E	D	D	-
13. Klong Sathon	131	E	D	A	C
14. Klong Chong Nonsi	141	B	D	A	B
15. Klong Bang Sai Kai	151	E	D	A	C
16. Klong San	161	E	E	A	C
17. Klong Huay Kwang	171	E	C	A	C
18. Klong Lad Prao	181	E	C	A	A
	182	E	C	A	B
19. Klong Bang Nam Chon	191	E	D	A	C
20. Klong Dao Kanong	201	B	C	A	A
21. Klong Bang Kun Tien	211	D	B	A	E
22. Klong Pasi Jaroen	221	D	C	A	E
23. Klong Bangkok Yai	231	C	C	A	A
24. Klong Rama VI	241	D	C	A	B
25. Klong Mon	251	B	B	A	A
26. Klong Bangkok Noi	261	B	B	A	A
	262	B	C	A	B
27. Klong Pra Kanong	271	C	E	A	A
	272	E	D	A	B

- to be continued -

- continued -

Name of Klong	Point No.	DO	BOD	H_2S	Coliforms
28. Klong Bang Na	281	C	D	A	A
29. Klong Toey	291	E	B	A	B
30. Klong Pai Sin Toe	301	E	C	E	C
31. Klong Chaeng Ron	311	C	A	A	A
32. Klong Rat Burana	321	A	A	A	A
33. Klong Bang Prakok	331	B	A	A	B
34. Klong Bang Pa Kaeo	341	B	A	A	A
The range of the parameters	A	≥ 5	<5	0	$<10^3$
	B	2-5	5-10	<0.1	10^3-10^4
	C	1-2	10-30	0.1-0.5	10^4-10^5
	D	0.5-1	30-60	0.5-1	10^5-10^6
	E	<0.5	≥ 60	≥ 1	$\geq 10^6$

Notes: 1) DO, BOD and H_2S contents are presented in mg/l.

2) Coliforms are in colonies per 100 ml.

(b) Existing Situation of Water Pollution

The klongs in the central Bangkok are in the worst condition among the surveyed klongs. In these klongs, DO content is zero through all sampling period except for the period when the flushing water is coming through Klong Bang Lam Poo and/or Klong Prem Prachakorn. In Klong Rajabopit the average BOD is 154 mg/l and coliforms is more than 1 million per 100 milliliters. Klongs of Watteptide, Ong Ang, Nahanak, Padung Krung Kasem, Sam Sen, and San Sep are in the group of the worst water quality. The nuisance conditions such as foul odor and black color caused by the septic condition have occurred in these klongs. Hydrogen sulfide which is toxic for human body and erosive for city structures are often observed in high concentration in the water. And the complaint about odor of hydrogen sulfide is also often made while the klong water is pumped out.

BOD content comparatively low in Klong Lord because the water of the klong is flushed by the river water. However, flushing is not an ideal measure for pollution abatement as the Chao Phya River has almost reached a critical point of oxidation capacity of loadings as described in the previous section.

The small klongs in the town area of Thonburi side such as Klongs San, Bang Nam Chon, and Bang Kun Tien are also polluted by the wastewaters originating in the area. On the other hand large klongs such as Klongs Bangkok Noi, Bangkok Yai, and Dao Kanong are comparatively clean because the tidal flushing volume in these klongs is substantial. However, even in these klongs, zero of dissolved oxygen content is observed during the low flow of the Chao Phya River.

CHAPTER 7

POPULATION, LAND USE AND TRANSPORTATION

The population and the land use in the Study Area are essential factors of the sewerage planning, especially for estimation of wastewater quantity generated in the Area. Consequently, a projection at present and in the future population as well as land use is carried out on the basis of data and information obtained from NESDB, Ministry of Interior, MWWA and City Planning Division, BMA. Transportation also affects the sewerage planning in terms of sewer route selection and sewer construction methods.

7.1 Population

(a) Population of Thailand

Eight National censuses have been conducted since 2454 (1911). The most recent census was made in 2523 (1980), but the result is under analysis. The result of census in 2513 (1970) is the newest available one. Department of Local Administration, Ministry of Interior, has estimated population in each year on the basis of residence register records as shown in Table 7.1.

Table 7.1 Population of Thailand and Bangkok

Year	Population of Thailand (1,000 persons)	Annual Growth Rate (percent)	Population of Bangkok (1,000 persons)	Percentage to National Population
2513 (1970)	34,397	-	2,972	8.6
2515 (1972)	38,359	5.6	3,169	8.3
2516 (1973)	39,950	4.1	3,967	9.9
2517 (1974)	41,334	3.4	4,130	10.0
2518 (1975)	42,391	2.5	4,350	10.3
2519 (1976)	43,214	1.9	4,546	10.5
2520 (1977)	44,273	2.4	4,743	10.7

The future population of Thailand was estimated in "The Fourth National Economic and Social Development Plan (2520-2524)" by NESDB.

It states that the Fourth Plan's objective is to reduce the national population growth rate from 2.5 percent per annum at the beginning of the Plan period to 2.1 percent per annum in the last year of the Plan. The Working Group on Population which is consisted of the representatives of Government agencies and institutions concerned has made estimation of future population of Thailand as shown in Table 7.2. It is apparent that the estimation is based on the Fourth Plan's objective of reducing the growth rate to 2.1 percent in 2524 (1981).

Table 7.2 Population Projection of Thailand

Year	Population (1,000 persons)	Annual Growth Rate (percent)
2523 (1980)	46,455.0	2.33
2528 (1995)	51,301.5	2.00
2533 (1990)	55,344.6	1.53
2538 (1995)	59,579.2	1.49
2543 (2000)	93,771.0	1.37

(d) Population of Bangkok

The result of population census in 2513 (1970) and the population data based on residence register records indicate that, as the city area has expanded, the population in Bangkok has increased by 68 percent in this decade. Table 7.3 illustrates the variation of population of Bangkok.

Table 7.3 Population of Bangkok

Year	Metropolitan Area (km^2)	Population (persons)	Annual Growth Rate (percent)
2513(1970)	874.116	2,971,753	-
2514(1971)	874.116	3,045,300	-
2515(1972)	1,032.897	3,169,091	-
2516(1973)	1,558.405	3,967,081	-
2517(1974)	1,558.405	4,129,609	-
2518(1975)	1,558.405	4,349,494	-
2519(1976)	1,568.737	4,545,608	-
2520(1977)	1,568.737	4,742,774	4.3
2521(1978)	1,568.737	4,870,509	2.7
2522(1979)	1,568.737	4,999,515	2.6

The future population is estimated by MWWA in 2521 (1978) with the growth rate of 2.6 - 1.5 percent as shown in Table 7.4.

Table 7.4 Population Projection of Bangkok

Year	Future Population by MWWA (1,000 persons)	Annual Growth Rate (percent)
2523 (1980)	5,173.8	-
2528 (1985)	5,887.9	2.6
2533 (1990)	6,628.2	2.4
2538 (1995)	7,325.4	2.0
2543 (2000)	7,890.5	1.5

(c) Population of Master Plan Area

On the basis of Bangkok's population projected, the population of the Study Area is estimated and is distributed in each district taking into consideration the past trend and land use.

There is a trend with which people in congested area migrate towards suburban area of moderate density.

The population of the Study Area is projected to be 5.6 million as a whole (see Table 7.5 and Figure 7.1) and the population of individual district is shown in Table 7.6.

Table 7.5 Population of Master Plan Area

Year	Population (1,000 persons)	Annual Growth Rate (percent)
2523 (1980)	4,040	-
2528 (1985)	4,430	1.9
2533 (1990)	4,820	1.7
2538 (1995)	5,210	1.6
2543 (2000)	5,600	1.5

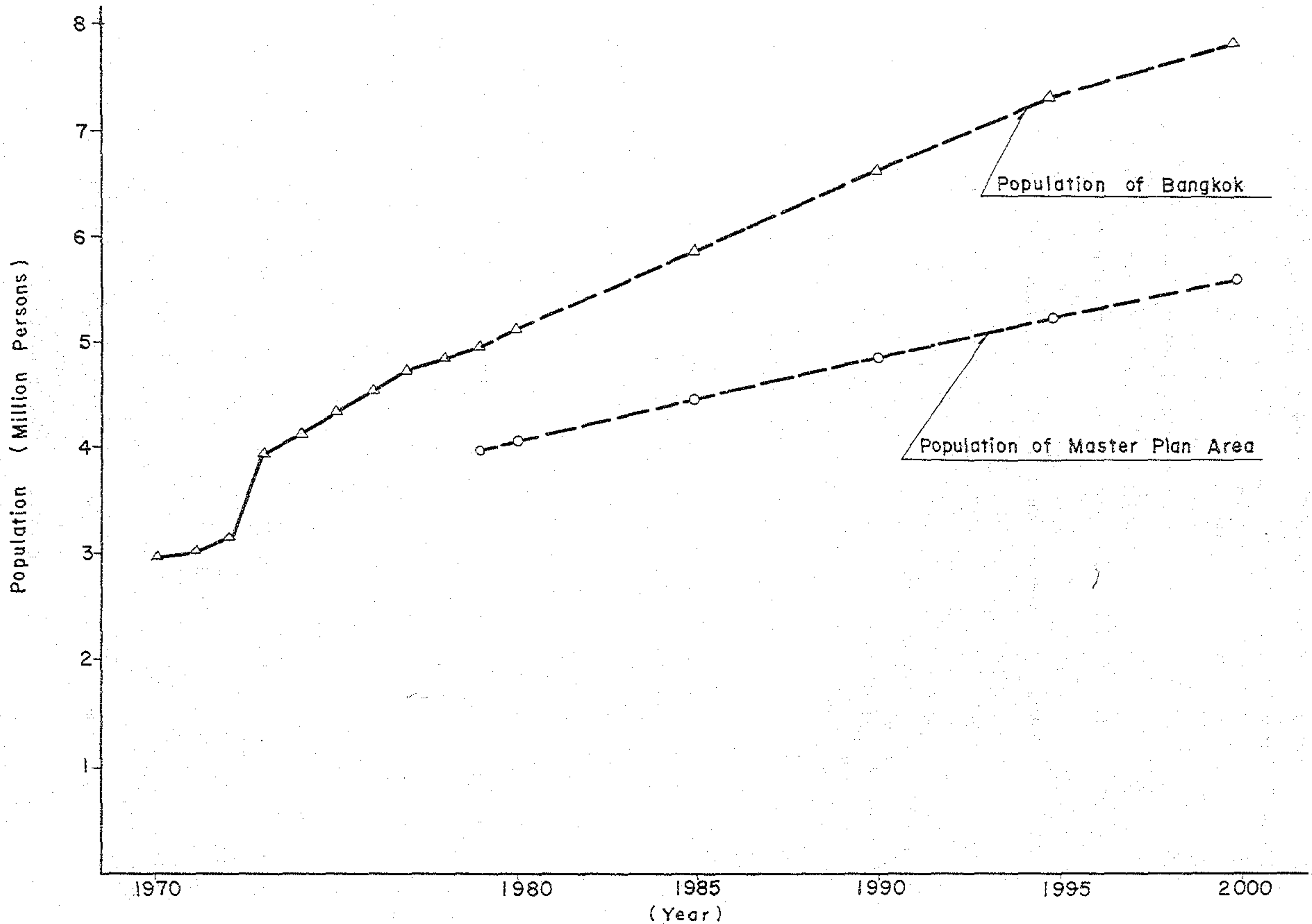


Figure 7·1 Population Projection

Table 7.6 Population and Population Density by District in Master Plan Area

	Name of District	Area (ha)	in 2522 (1979) Population (persons)	Population Density (persons/ha)	in 2543 (2000) Population (persons)	Population Density (persons/ha)
1.	Phra Nakhon	476	124,854	262	108,000	227
2.	Pom Prap	248	194,299	783	161,000	649
3.	Pathumwan	790	233,050	295	233,000	295
4.	Sampanthawong	122	78,151	640	67,000	549
5.	Bang Rak	385	126,487	328	134,000	348
6.	Yan Nawa	2,512	375,213	149	502,000	200
7.	Dusit	2,347	462,210	196	586,000	250
8.	Phaya Thai	1,686	514,177	304	590,000	350
9.	Huay Kwang	2,402	195,112	81	480,000	250
10.	Phra Khanong	10,497	447,953	43	840,000	80
11.	Bang Khen	3,220	148,606	46	289,000	90
12.	Bang Kapi	5,915	145,783	25	525,000	90
13.	Thonburi	826	256,740	310	289,000	350
14.	Klong San	523	140,943	269	104,000	200
15.	Bangkok Noi	2,257	378,817	123	456,000	200
16.	Bangkok Yai	605	100,051	165	121,000	200
17.	Bangkhun Thian	385	8,188	21	34,000	90
18.	Rat Burana	904	35,305	39	81,000	90
	Total	36,100	3,965,939	-	5,600,000	-

7.2 Land Use

The categories of land use in Bangkok are residential, mixture of commercial and residential, industrial and public areas. The central areas which are consisted of historically old area and its periphery, are highly developed as the business and commercial center which serve administrative and economic functions of not only Metropolis but whole of the country. Surrounding area of the central part, is predominantly used for residential purposes. The city has been expanded along main access to the central area, resulting in the form of finger development directing towards low density and agricultural area. The existing land use situation is shown in Figure 7.2.

Studies were performed to recommend the orderly development of the city. A "Greater Bangkok Plan-2533 (1990)", (Litchfield Plan) was submitted in 2503 (1960). Although it had not been officially accepted, it serves as principal guide for city planning.

The government agencies concerned including City Planning Division, Office of the Under Secretary of BMA and Planning Division, Office of Town and Country Planning, Ministry of Interior, reviewed the plan and developed anticipated future land use. However, it has not yet been officially accepted so far. It is likely the plan would be principal guide line for future development (see Figure 7.3).

It is understood from the Figure, that although some urban modification is expected, the old central portion would remain as mixed commercial and residential areas with high population density. Bangrak district would be a business center with modern building in orderly layout. The most part of public area including the Royal Palace, the government buildings, military areas, features with historical value, areas for offices of international organizations as well as parks and stadiums would remain intact.

The expansion and growth of the city has continued along major inter-regional highways and/or the Chao Phya River. The recent predominant trend of urban growth is directed toward the north along transport axes and the river. The topographical advantages of being slightly higher in ground elevation than other parts of the city would accelerate the development of Nakhon Pathom, however, the development would be considerably discouraged if the water supply system does not reach to the area. The southward development towards Samuthprakarn has been extended yearly due to high suitability of land for industrial development induced by the easy access to the port and the river. The expansion to eastward is also under progress, however, its future urban development will be dependent on the solution of chronical flooding problems in the eastern area.

The categories of the proposed land use are as follows.

(a) Residential

Residential areas are divided into three classes namely low density, medium density and high density.

These are described as follows:

Low density area which is predominant in the periphery of urban areas with population density ranging from 100 to 70 persons per hectare, covers single family houses, each on its own lot, with lawns between.

Medium density area with the population density of 250-100 persons per hectare extends in the area surrounding the central highly developed area. It covers the raw houses and garden apartments or courts.

High density area with the population density more than 250 persons per hectare is in zones of the central core and covers high apartment developments and closely spaced with low rise units.

(b) Commercial

Commercial areas comprise of central area, outlying commercial and neighborhood commercial facilities. The central commercial area can be further broken down into a old center between Klong Padung Krung Kasem and Klong Lord and an expansion area east of Bangkok Railway Station in Amphur Bangrak. The outlying commercial area consists of various types of shopping center developed or planned in outlying areas. The neighborhood or strip commercial area is not shown graphically, but is included in residential areas.

(c) Public

Public area is identified as the area used for public facilities. This category includes government buildings, military area, the Royal Palace, railway station, offices of international organization, etc.

(d) Industrial

Industrial area includes the sites of existing industries and planned future sites.

7.3 Transportation

Transportation in Thailand is by air, navigation, rail and road. Among them, air, navigation and rail are, those concerned with land use and population distribution. Road system is the one which affects directly upon the design of the sewerage in terms of sewer routes.

In urbanized area, the road system is almost completed, while in the suburbs there are numerous proposed highways and arterial streets, and some of them are under construction. Figures 7.4 and 7.5 illustrate road and street networks including proposed ones. Because of high population density and commercial activities, there is heavy traffic on every road in the urbanized area all day long. Therefore, sewer routes should be determined so as not to obstruct traffic in this area during the course of construction.

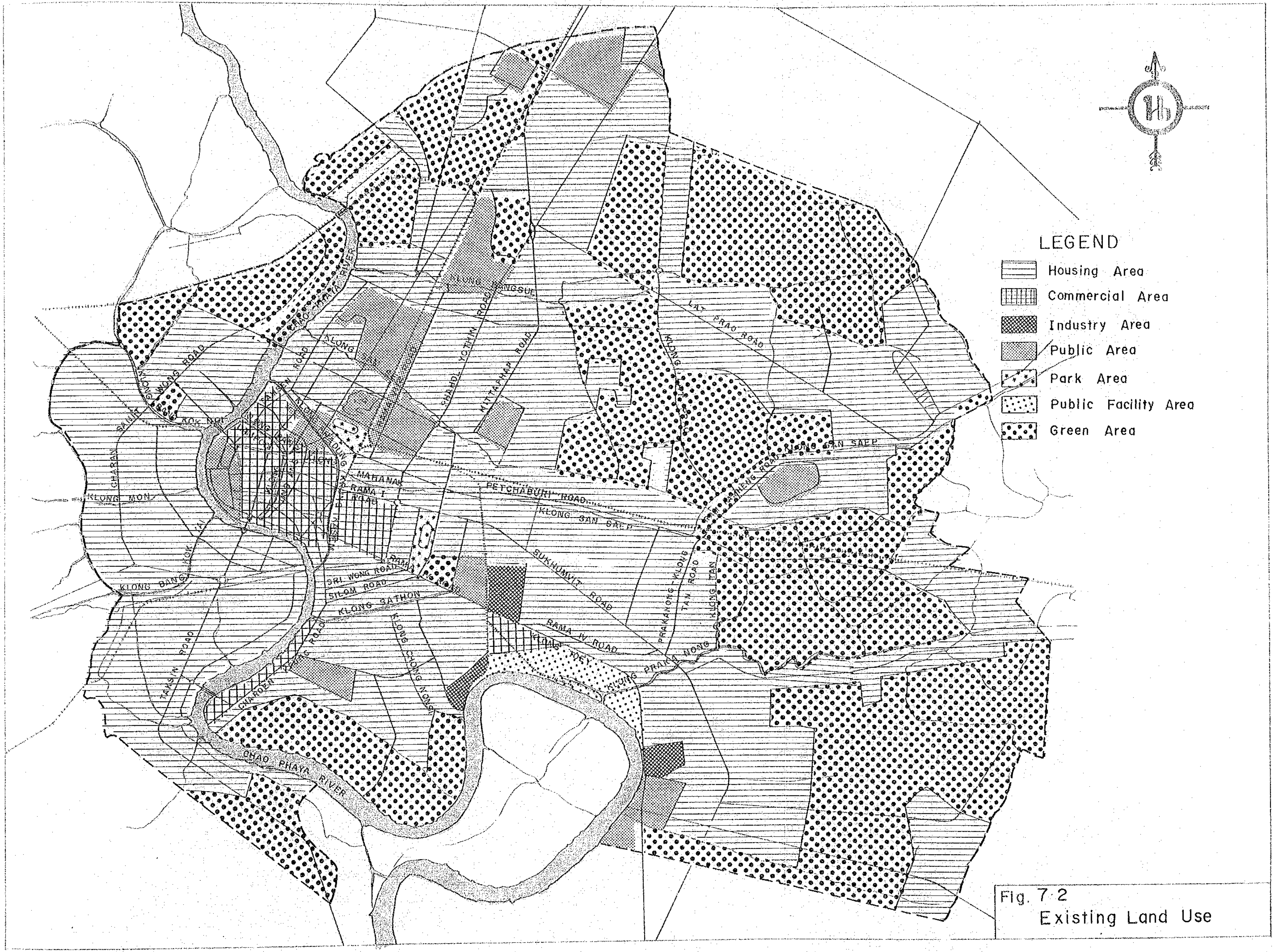


Fig. 7·2
Existing Land Use

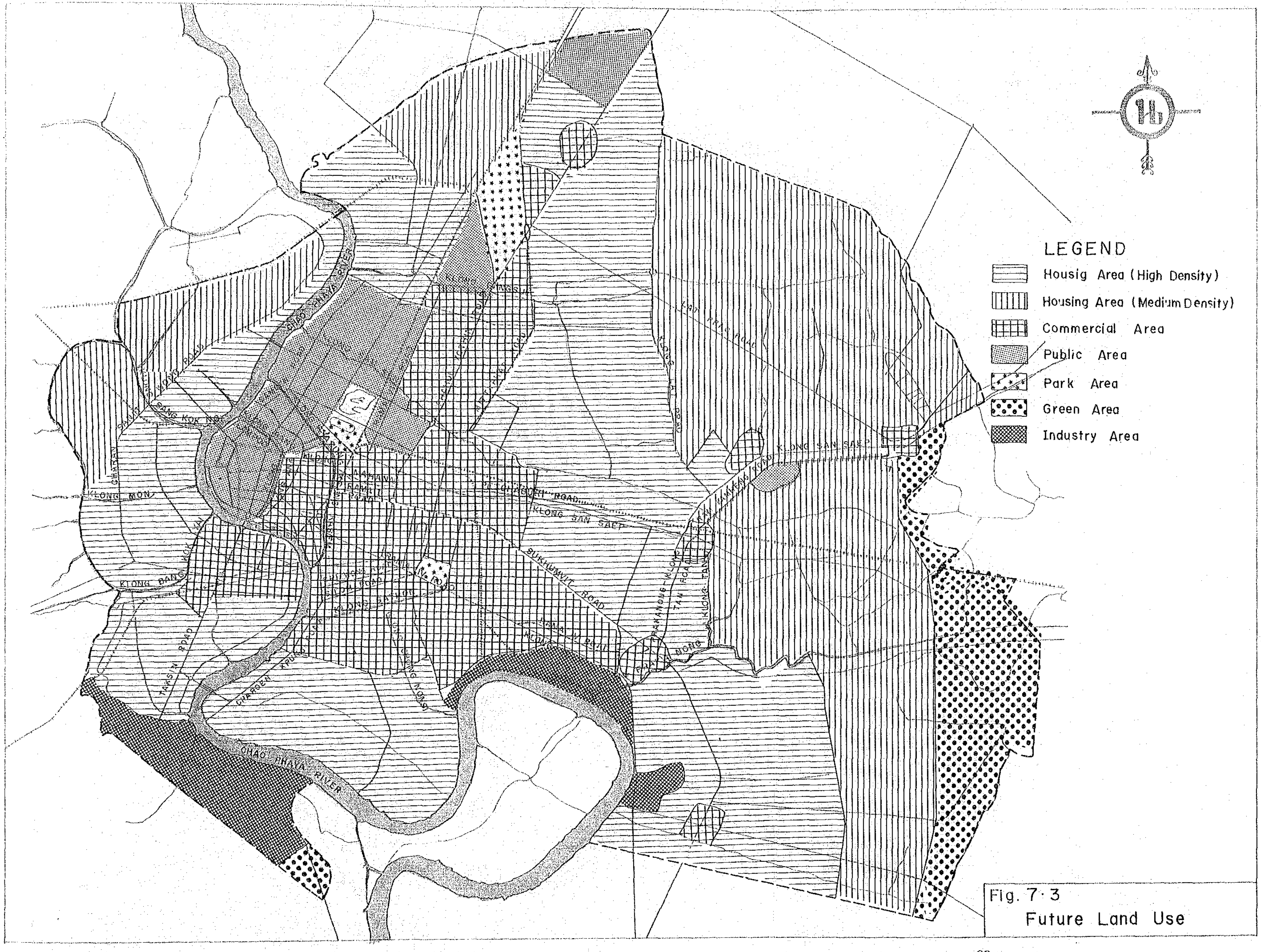


Fig. 7·3
Future Land Use

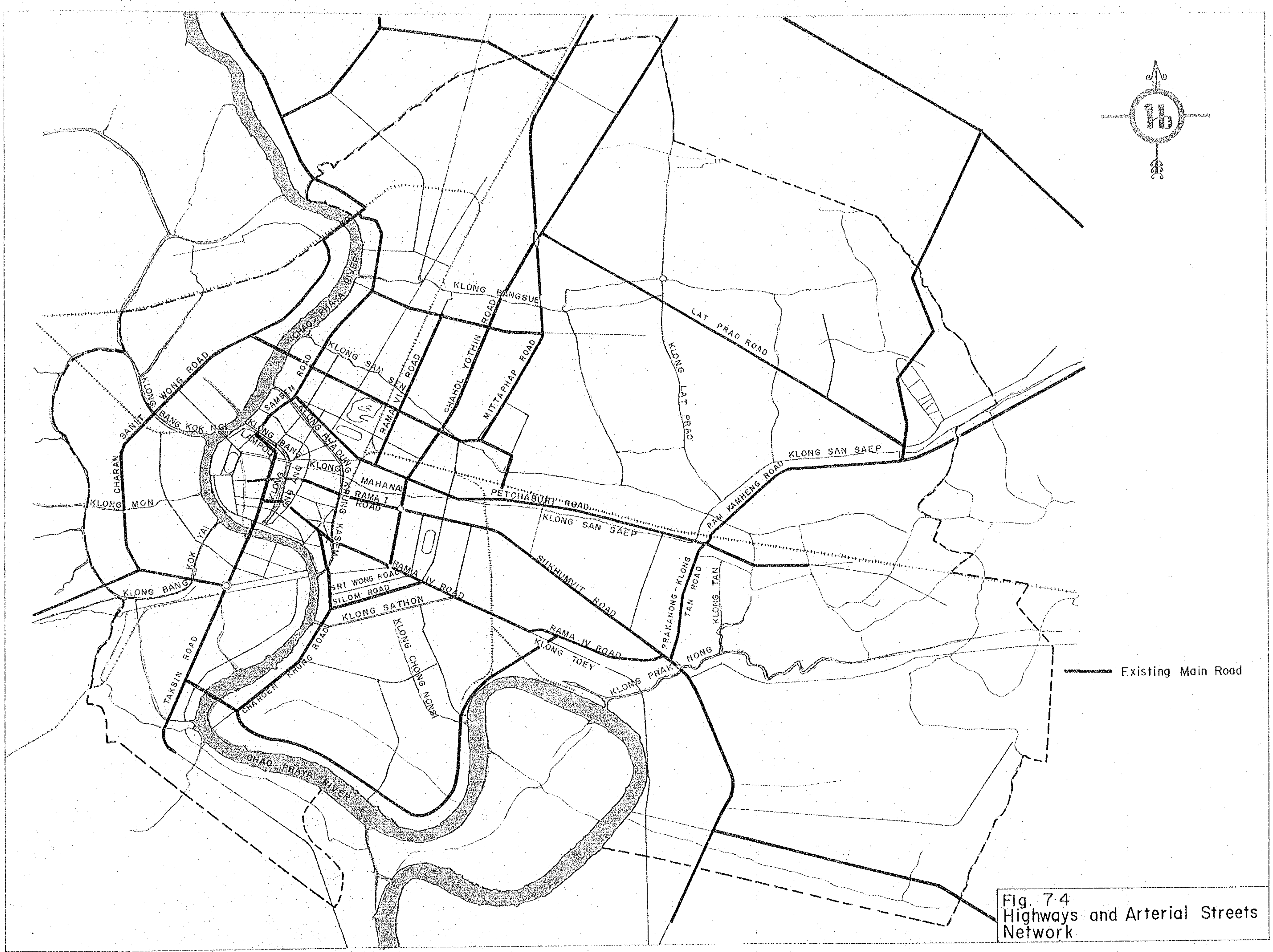


Fig. 7·4
Highways and Arterial Streets Network

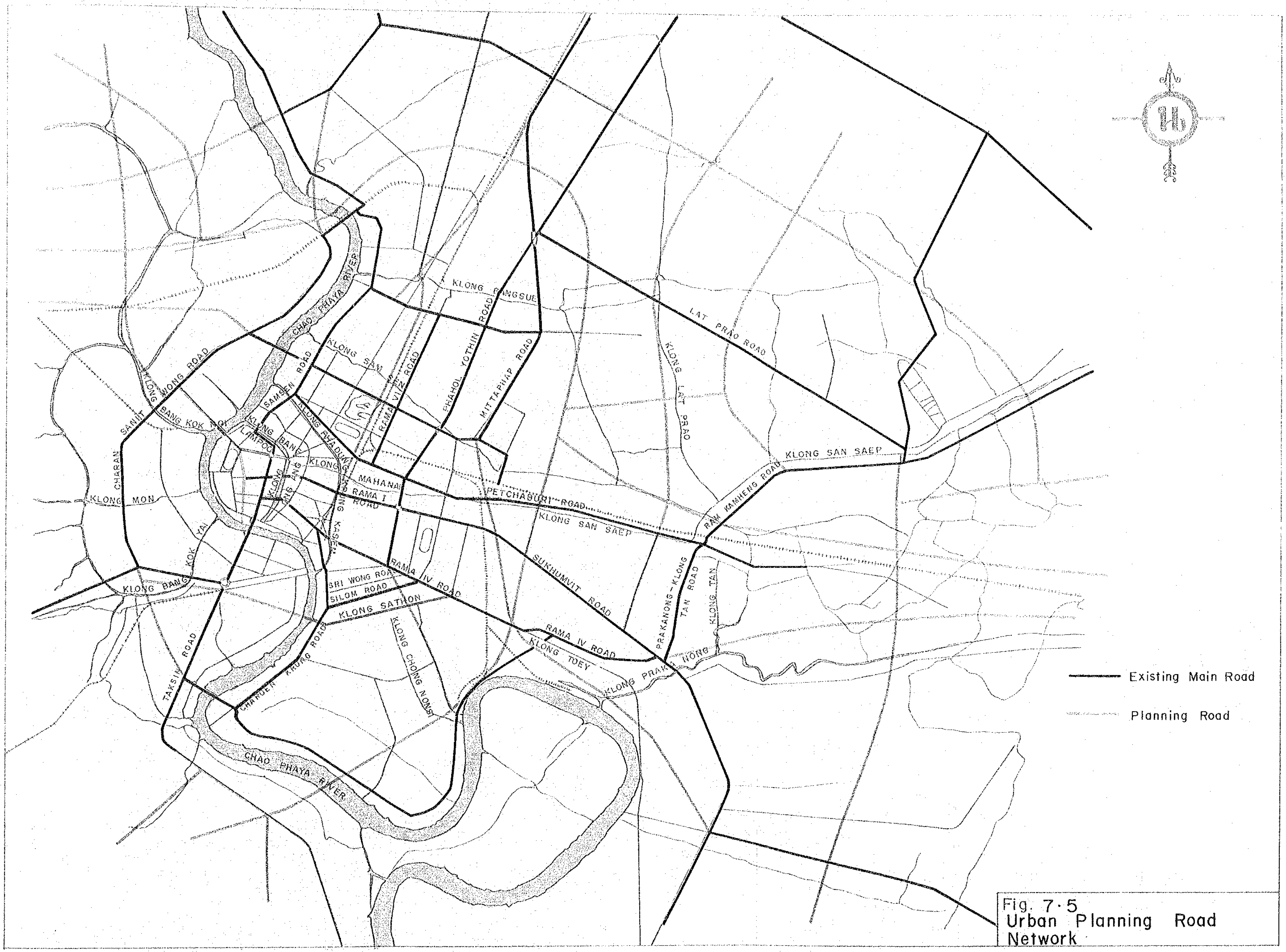


Fig. 7·5
Urban Planning Road Network

CHAPTER 8

QUANTITY AND QUALITY OF WASTEWATER

For design of wastewater collection system and treatment facilities, the quantity and quality of wastewaters generated from different sources would be one of the most basic factors to be determined at the beginning of planning.

In this report, wastewater originating from residential area including neighbouring commercial and institutional establishments are referred to as "domestic wastewater" and those originating from central commercial area are referred to as "commercial wastewater". "Industrial wastewater" are those originating from factories and "extraneous water" are those flowing into the sewers either as ground water infiltration through defective joints and cracks in the pipe or as surface water through faulty connections.

8.1 Domestic and Commercial Wastewater

(a) Present Per Capita Wastewater Flow and its Strength

To obtain data on existing wastewater flow and its strength, field surveys were conducted in 2523 (1980) at Huay Kwang and Wang Burapa by the Survey Team for the Master Plan. Huay Kwang is in a residential area and has a modernized sanitary sewerage system which is the most sophisticated one in Bangkok. The Huay Kwang community and the sewerage system have been constructed by the National Housing Authority (NHA). Wang Burapa is in a typical central commercial area in Bangkok, where municipal drianage system and individual septic tank system are provided.

During the surveys home visits were also made to collect data on income level, water consumption, etc. of the residents in the surveyed areas.

After the surveys (see Appendix G), present wastewater flow and its BOD loads were estimated on the domestic and/or commercial wastewater, and summarized in Table 8.1.

Table 8.1 Present Per Capita Wastewater Flow 2523(1980)

		Residential Area	Commercial Area	Total
Per Capita Flow	(l/day/cap)	184	50*	234
BOD	(mg/l)	260	260	260
Per Capita BOD Load	(g/day/cap)	48	13*	61

* value of per capita correspondent

(b) Future Domestic and Commercial Wastewater

While wastewater flow is heavily dependent on the amount of water used in the area, the future wastewater flow in the Study Area can be estimated on the basis of the water demand projection which had been finalized by the Motropolitan Water Works Authority (MWWA) in 2520 (1977). The water demand projection (MWWA, 2520) is shown in Tables 5.1 and 5.2 of Chapter 5.

Assuming the quantity of domestic and commercial wastewater flow varies in parallel with respective water use, the quantity of future domestic and commercial wastewater in the Study Area are estimated and summerized in Table 8.2.

Table 8.2 Estimated Wastewater Flow and BOD in The Study Area

(x 1,000)

Year	Domestic		Commercial		Total			
	Flow	BOD*	Flow	BOD*	Flow		BOD*	
	(m^3/day)	(kg/day)	(m^3/day)	(kg/day)	(m^3/day)	(l/day/cap)	(kg/day)	(g/day/cap)
2523 (1980)	743	193	202	53	945	234	246	61
2528 (1985)	842	219	217	56	1,059	239	275	62
2533 (1990)	950	246	226	59	1,176	244	305	63
2538 (1995)	1,032	268	240	62	1,272	244	330	63
2543 (2000)	1,126	293	252	66	1,378	246	359	64

* assuming the BOD content be 260 mg/l

8.2 Industrial Wastewater

In accordance with the plan of the government agencies inclusive of City Planning Division, BMA, and Town and Country Planning Office, Ministry of Interior, industrial estates such as Samut Prakan, Rat Burana, Klong Toey, Bang Poo, Lad Kra Bang, Nawa Nakon, and Rang Sit are developed as a part of the policy of decentralization of the central Bangkok area. Most of those estates are located out of the Study Area. Factories to be newly established in Bangkok and its surrounding area would be built in the estates, and the factories including home size industry located in the old central Bangkok are also expected to be relocated in the estates.

In view of water pollution control, industrial wastewater discharge is regulated by Ministry of Industry on the basis of the "Factory Act 2512 (1969)". Wastewater is prohibited to be discharged from any factory unless it satsifies the effluent quality standards for discharge as shown in Table 8.3, with necessary treatment as required, which can be discharged directly into the receiving water. The Ministry of Industry actually ordered the closure of the factories in the past that discharged offensive wastewater against the effluent standards.

Under such condition, it is assumed that the factories scattered in the Study Area will undertake the required treatment of their own industrial wastes by their own individual treatment facilities prior to the completion of the proposed sewerage system. On the other hand, home and cottage industries scattered in the Study Area would not able to facilitate such treatment facilities on each factory site because of their own limitation on land space and financial capability.

According to the Ministry of Industry's data (Table 8.4), there are 248 of major factories along the Chao Phya River between Ayuthaya and Samut Prakan through Bangkok, and about 10 percent of them in number are located in the Study Area. And about 52.4 percent of BOD originated from the factories are removed by their own waste treatment facilities under the regulation of the Factory Act.

Major factories in the Study Area are listed in Table 8.5 together with BOD loads estimated by Ministry of Industry (2522) and others. The type of industry of them are distillery, brewery, cooling bevarage, manufacturing of meats and seafoods, tanning, tobaccos, cement, etc.

Table 8.3 Effluent Criteria for Industrial Wastewater, Ministry of Industry, 2513 (1970)

Parameters	Limits*	Remarks
pH	5 - 9	
Permanganate Value	60 mg/l	
Dissolved Solids	2,000 mg/l	
Sulfide	1 mg/l	as H_2S
Cyanide	0.2 mg/l	as HCN
Heavy Metals	1 mg/l	Zn,Cr,As,Ag,Cu,Hg,Cd,Ba,Se,Pb, and Ni together or separately
Tar	No content	
Oil and Grease	No concent	
Formaldehyde	1 mg/l	
Phenols and Cresols	1 mg/l	
Free Chlorine	1 mg/l	
BOD	20 mg/l or 60 mg/l	The limit may differ in accordance with the judgement and decision of the officials in charge, but must not exceed the maximum.
Temperature	40°C	
Color and Smell	Not objectionable	

* Each content must not exceed the limits.

Table 8.4 Type of Industry, Number, and BOD Loadings of Major Factories along the Chao Phya River between Ayuthaya and Samut Prakan (Ministry of Industry, 2522)

Type of Industry	Number of Factory	BOD Load		Removal percent
		Original (kg/day)	Discharge (kg/day)	
Distillery	5	68,000	36,030	47.0
Brewery	2	10,932	5,813	10.2
Paper Mill	12	31,875	27,995	12.2
Dyeing	26	2,833	1,203	57.5
Beverage	11	-	330	95.4
Vegitable Oil	10	548	524	4.5
Others	182	50,000	4,500	91.0
Total	248	168,590	70,595	52.4

The flows and loadings of wastewater discharged from the industries in the Area are estimated at around 50,000 m^3/day and 15,000 kg/day of BOD, which are respectively corresponding to approximately 13 l/day/cap and 4 g/day/cap of BOD of present population in the Study Area.

The home and cottage industries engaged in manufacturing, processing, assembling, repairing, maintaining, testing, demolishing, packing, and other trades are possibly over 10,000 in number located in the Study Area. The flows and loadings discharged from the home and cottage industries are estimated including in the domestic wastewaters as it is impossible to isolate them from domestic ones. Considering the volume and characteristics of the wastewater, joint treatment of domestic and small industrial wastewaters may offer greater removal efficiencies and economic merits.

However, discharge of some components of wastewater such as flammables, oil and grease, settlables, toxic wastes, and high or low pH of wastewater should be restricted within allowable contents and adequately pretreated before discharging into the sewers if necessary because of their objectionable nature to the operation and maintenance of the sewerage system.

Table 8.5 Major Factories in the Study Area

Name of Factory	BOD Loading		Water Consumption			Remarks
	Generated (kg/day)	Discharged (kg/day)	Process Washing (m3/day)	Cooling etc. (m3/day)	Total (m3/day)	
1. Mekong Whisky	30,000	57,700	1,500	-	-	(1)
2. Singha Beer	10,500	1,350 1,260	2,150 2,800	303 -	2,453 -	(2)
3. Tanning Organization	6,500	825	1,400	-	-	-
4. Thai Dry Wood	- 5,349	655 10	2,400 -	- -	2,400 -	(3)
5. Coca Cola	1,995	35	700	-	-	(3)
6. Thai Ind. Paper	- 1,800	720 420	6,000 -	- -	6,000 -	- (3)
7. Sermsook	1,563	4	80	-	-	-
8. Summit Ind.	1,140	852	1,400	-	-	(3)
9. Foremost	1,100	3	60	-	-	-
10. Bangkok Freezer	1,050	1,050	2,600	-	-	-
11. Sakol Freezer	1,050	1,050	2,600	-	-	-
12. Thai Seree Freezer	974	795	2,400	-	-	-
13. Asia Freezer	900	900	2,200	-	-	-
14. Pranakorn Freezer	900	900	2,200	-	-	-
15. Nakorn Loung Freezer	900	900	2,200	-	-	-
16. Green Spot	765	5	100	-	-	(3)
17. Thai Freezer	750	750	1,800	-	-	-
18. Arlee Freezer	600	600	1,500	-	-	-
19. Tobacco Monopoly	-	-	1,500	-	-	-
20. Amarit Beer	- 432	400 3	472 200	- 83	472 283	(2) -
21. Thai Cement	-	60	2,000	-	-	-
22. Thonburi Clothes	200	200	1,000	-	-	(3)
23. Varun	138	2	40	-	-	(3)
24. Lion Bangkok	120	2	40	-	-	-
25. Thailand Iron Works	-	-	40	2	42	(4)
26. Safcal	60	20	407	30	437	(2)
27. Saha Union	-	38	2,573	2,157	4,730	(5)
28. Osotsapa	-	-	490	100	590	(6)
29. Bangkok Oil Refinery	-	2,160	8,200	-	8,200	-
30. Bangna Glass Authority	-	735	3,500	-	3,500	-
		14,639 - 16,071	52,480 - 53,402			

(1) Dumped into the Gulf

(2) Activated Sludge Treatment

(3) Biological Treatment

(4) Flocculation, Neutralization, and Sand Filtration

(5) Rotary Disc Contactor

(6) Trickling Filter

8.3 Extraneous Flow

The volume of extraneous waters will bring about extra expenses to provide additional capacities of sewers, pumping stations and treatment facilities and operating costs for the excess volume of the waters. Therefore, pipe joints have to be designed to minimize ground water infiltration, and the proposed sewerage system will be constructed with pipelines having water-tight joints. In case the existing sewers are to be incorporated in the new system, it should be planned to prevent inflow of surface water (klongs, and/or rivers), and then, to improve cracked pipes, defective joints, and leaking manholes in accordance with the progress of construction.

The capacity allowance to provide for infiltration should be determined based on the physical characteristics of the tributary area, the type of pipe and joint to be used, and the type and condition of the joints and pipes in the existing contributory sewers. For small to medium-sized sewers, it is common to allow 71 m^3/day/km for the total length of main sewers, laterals, and house connections, without regard to sewer size. Other make an allowance of from 24 to 95 m^3/day/km depending on sewer size and job conditions (ASCE-WPCF Manual, 1974).

The values are equivalent to 4.8 - 19 m^3/day/ha, assuming total length of sewers is 200 m/ha. According to the guideline for sewerage design in Japan, the extraneous flow allowed in the sewers is 10 - 20 percent of the design wastewater flow. The value of such extraneous flow to be added to the peak wastewater flow are ranged from 3.8 to 7.6 m^3/day/ha.

For the proposed sewerage system, taking into consideration high groundwater level in Bangkok, the proposed type of pipe and joints, existing pipes and joints, and their improvement to be done an average infiltration rate of 7.6 m^3/day/ha, maximum figure available in Japan's guideline is used as design allowance. This rate is estimated assuming no inflow of klong water into the proposed sewerage system.

8.4 Design Flows and BOD or Organic Loads

The design flows and loads are computed on the basis of values in the year 2543 (2000) as shown in Table 8.2, and described in the previous sections which are summarized in Table 8.6.

The domestic wastewater including neighbouring commercial and institutional wastewaters is estimated on the basis of per capita values, and applied to whole of the Study Area.

The commercial wastewater is estimated to supplement domestic wastewater for the central commercial area as shown in Figure 8.1.

The industrial wastewater from small or home industries are included in the neighbouring commercial wastewater, and those from the factories inspected by Ministry of Industry are excluded from the study of this Sewerage Master Planning.

The extraneous water is an allowance for unavoidable amounts of groundwater infiltration in addition to the estimated peak wastewater flows.

Table 8.6 Design Flows and BOD Loads at 2543 (2000)

Domestic Wastewater		Commercial Wastewater		Extraneous Water
Flow* (l/day/cap)	BOD (g/day/cap)	Flow* m^3/day/ha)	BOD (kg/day/ha)	Flow (m^3/day/ha)
201	52	116	30	7.6

* Daily average flow

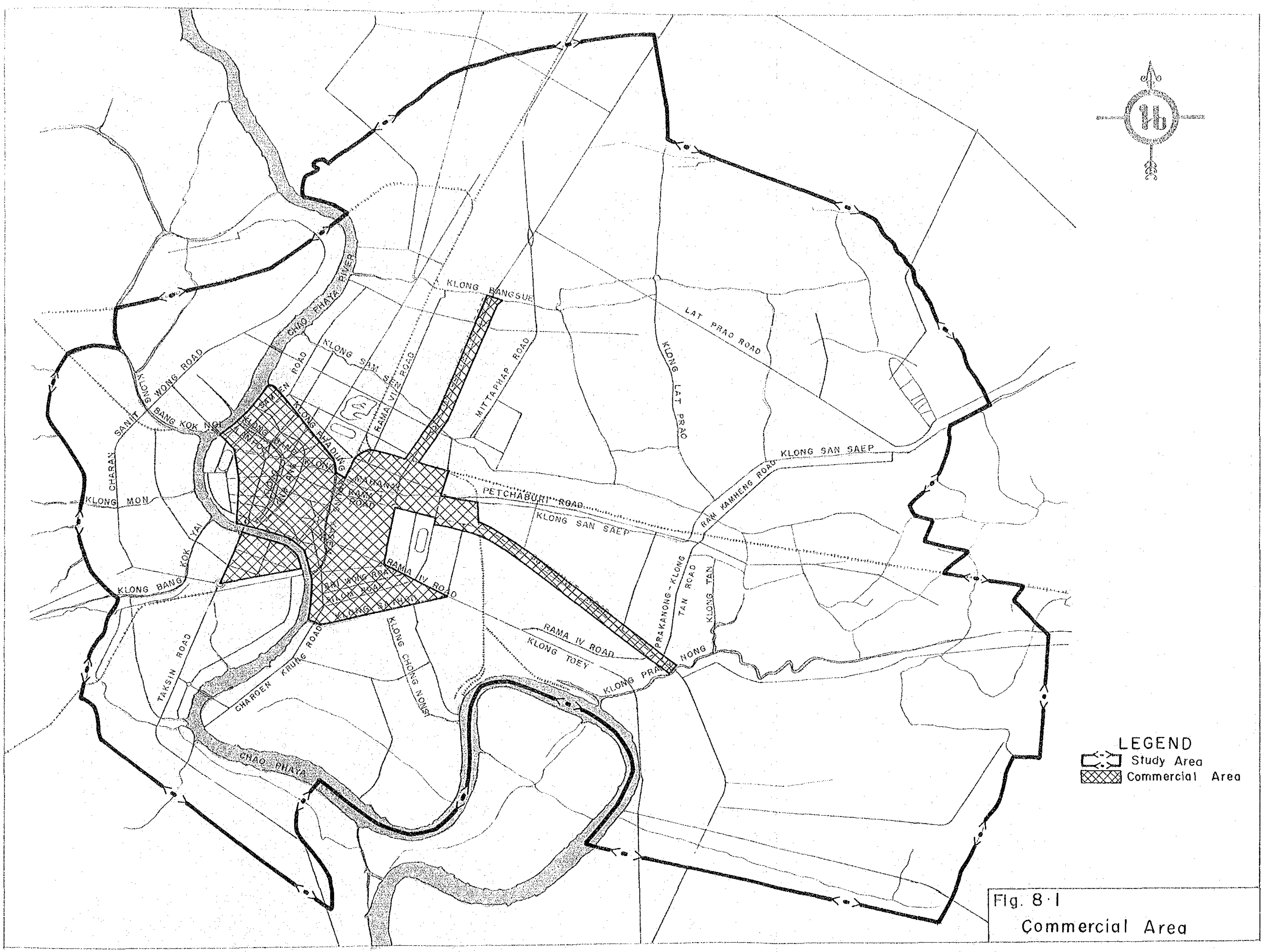


Fig. 8·1 Commercial Area

CHAPTER 9
DESIGN BASIS

9.1 Design Period

The sewerage system to be proposed is designed on the basis of the studies on land use, population growth, and wastewater flow expected by the year 2543(2000), with due consideration on other infrastructure projects including those of drainage, flood protection and water supply.

9.2 Hydraulic Criteria

For the engineering design of sewerage facilities, following criteria have been developed to determine the scale of facilities.

(a) Minimum Size of Sewer

The minimum diameter for a public sanitary sewer is 200 mm and the minimum size for a building sewer is 150 mm dia.

(b) Design Flow

The sanitary wastewater flow is expected to vary throughout the day, with extreme low flow usually occuring between 2 and 6 a.m. and peak flow concentrated during morning and evening.

The design of wastewater sewers is based on the peak flow expected from tributary areas in the year 2543(2000). The relationship between peak wastewater flow and average wastewater flow in Bangkok had been developed by CDM, and illustrated in Figure 9.1.

The ratio of peak flow to average daily flow developed in other countries is illustrated in Figure 9.2 for the reference and comparison purposes. The reference data are as followings:

i) "Design and Construction of Sanitary and Storm Sewers", Water Pollution Control Federation, Washington D.C., U.S.A. (1970), "Ratio of extreme flows to average daily flow in New England, U.S.A."

ii) "Master Plan of Water Supply, Sewerage and Drainage Project", Southwest Coastal Area, Ceylon, prepared for WHO by Howard Humhreys & Sons, England, June 1972.

iii) "Master Plan for the Water Supply and Sewerage of Greater Kathmandu and Bhaktapur", prepared for WHO by Binnie & Partners, England.

iv) "Master Plan for Sewerage and Sanitation Project in Republic of Indonesia", prepared for WHO by Nihon Suido Consultants, Tokyo, Japan.

As a result of comparison the ratio developed by CDM has been considered reasonable to form the basis for predicting the future wastewater peaking factors in designing sanitary sewers of Bangkok.

(c) Flow Friction Formula

The Manning's equation shall be adopted for sewers and conduits in the form:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

where V = velocity of flow, in m/sec

n = coefficient of roughness

R = hydraulic radius, in m

S = slope

Table 9.1 Coefficient of Roughness for Various Pipe Materials

Pipe	Coefficient of Roughness, n
Asbestos Cement Pipe	0.013
Vitrified Clay Pipe	0.013
Plastic Pipe	0.010
Concrete Pipe	0.015

(d) Velocity of Flow

Public sanitary sewers are designed to carry the peak design flow at a minimum velocity of 0.60 m/sec when the pipe is flowing full.

Velocity shall not exceed 3.0 m/sec in any type of sewer to protect sewer erosion.

(e) Slope of Sewer

The slope necessary to produce minimum self-cleansing velocities are summarized in Table 9.2.

Table 9.2 Minimum Slopes Required for Self-Cleansing Velocity in Various Pipe Sizes

Minimum Velocity of 0.60 m/sec			Required Slope Meters per Meter
Pipe Diameter (mm)		Capacity (m^3/sec)	
200 (A.S.P)	(1)	0.019	0.00320
200 (P.P)	(2)	0.019	0.00190
300 (C.P)	(3)	0.043	0.00256
400 "		0.076	0.00175
500 "		0.118	0.00130
600 "		0.170	0.00102
800 "		0.302	0.00069
1,000 "		0.471	0.00051
1,200 "		0.679	0.00040
1,500 "		1.061	0.00030
1,800 "		1.527	0.00023
2,000 "		1,885	0.00020
2,400 "		2.714	0.00016
2,800 "		3.695	0.00013
3,000 "		4.241	0.00012
3,400 "		5.447	0.00010

Note: (1) A.C.P : Asbestos Cement Pipe

(2) P.P : Plastic Pipe

(3) C.P : Concrete Pipe

(f) Sulfide Control

For anti-sulfide corrosion, the followings shall be considered in designing and constructing all sewers:

- The design velocities to maintain the required velocities for sulfide controlling shall be more than approximately 0.60 m/sec.
- Furthermore, sewer shall be vitrified clay pipe and/or plastic pipe for smaller sized sewer and thick walled sacrificial concrete pipe for medium diameter sewer. For large sized pipe of 1,200 and above, anti-sulfide sheet lining shall be employed. (Refer to Appendix I)

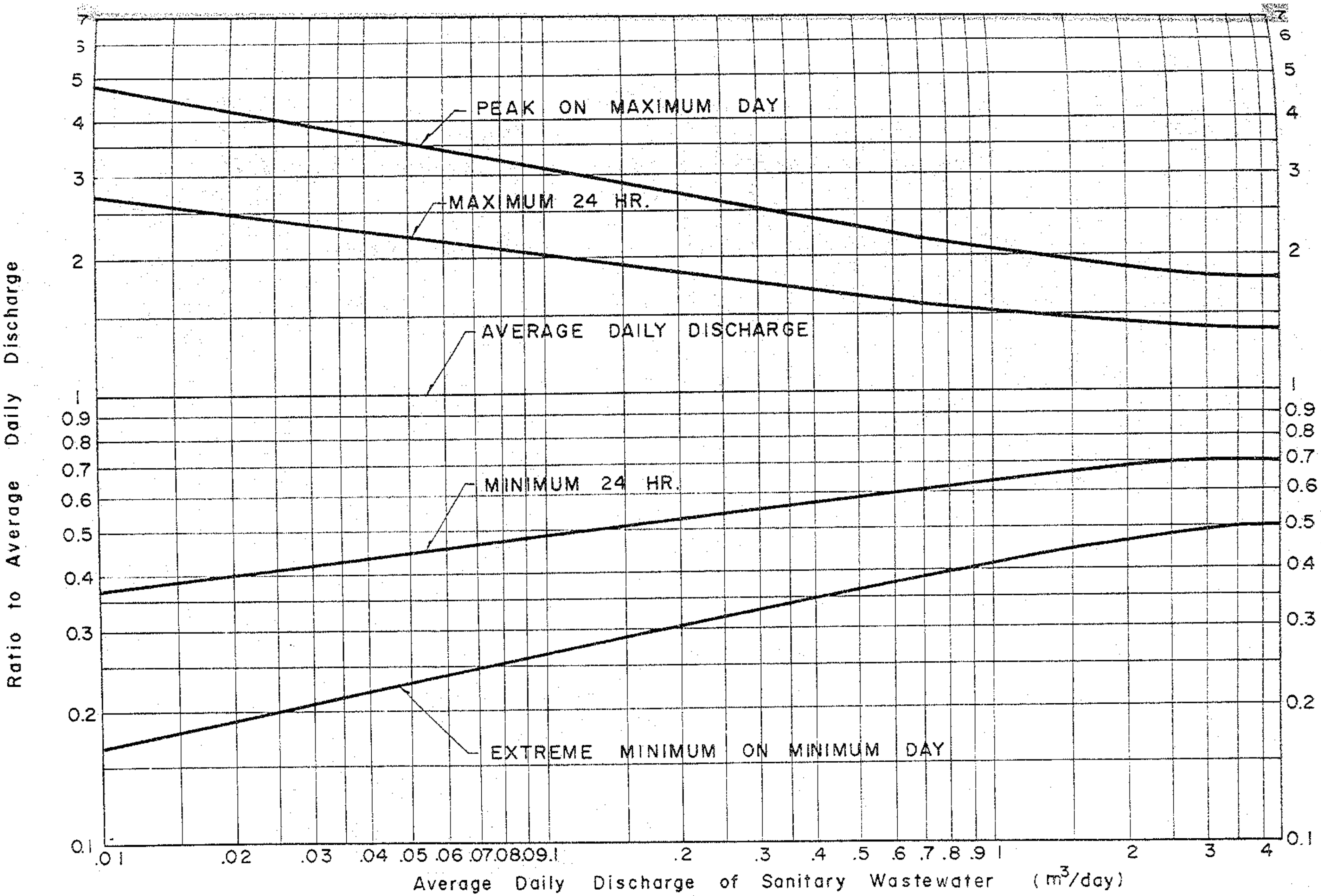


Figure 9·1 Sanitary Wastewater Flow Variation

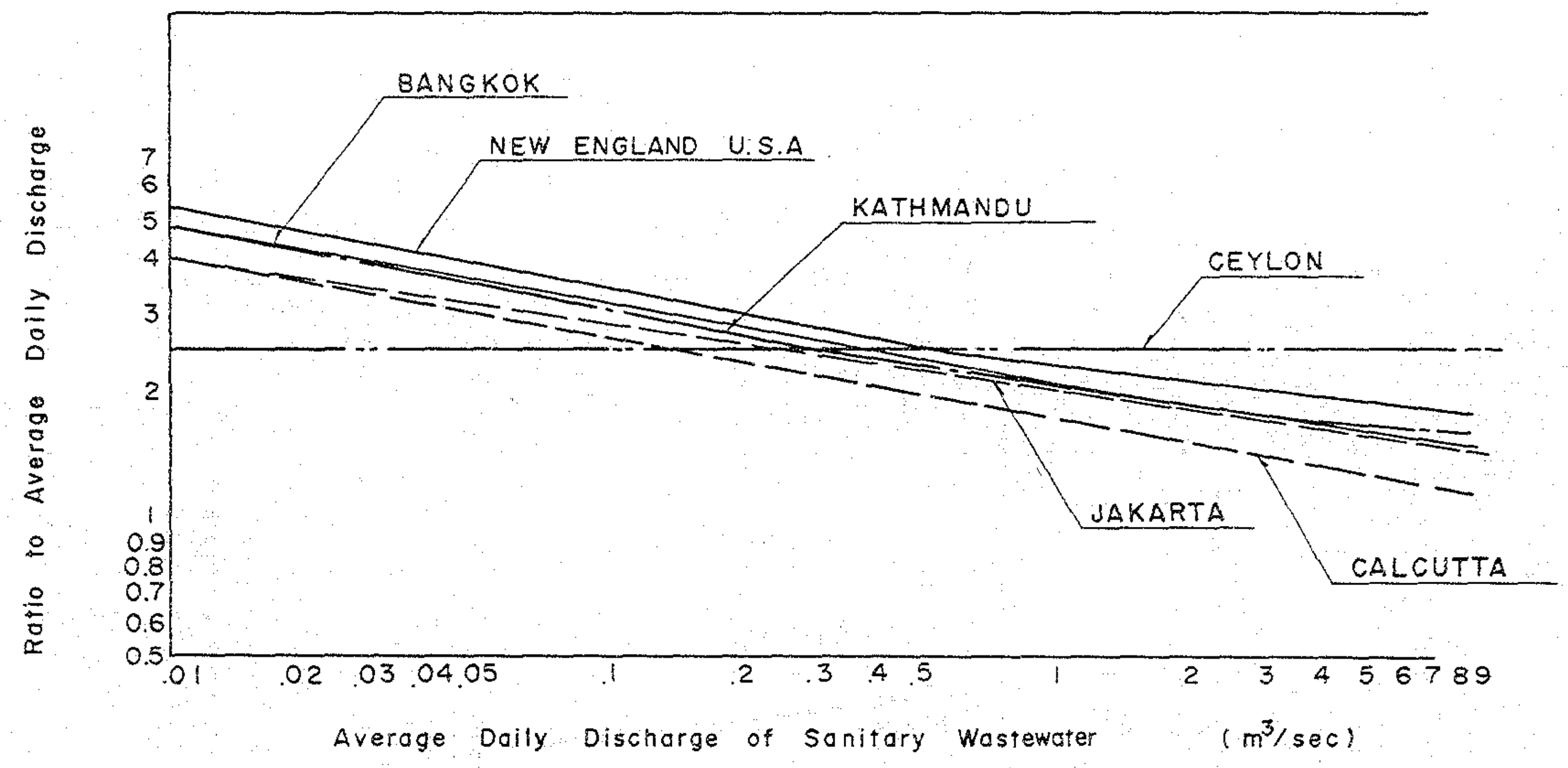


Figure 9·2 Ratio of Peak Flows to Average Daily Flow

9.3 Criteria for Manhole

Manholes are provided at all junctions and at all changes of sewer size, slope and direction. The recommended maximum spacing of manholes in the sewerage system is the followings:

Pipe Diameter (mm)	Maximum Manhole Spacing (m)
200 to 500	60
600 to 800	90
1,000 to 1,500	120
over 1,500	200

9.4 Pumping Stations

The design of pumping stations is based on the peak flow rate. All piping and conduits are designed to carry the expected peak flow rate. For all stations, pumps and motors designed easy for maintenance is provided. Structures are designed for the ultimate size, but pumps, accessory mechanical equipment, and electrical facilities will be purchased and installed in accordance with development of system's construction.

Bar screen are commonly provided ahead of wastewater pumpings to protect the pumps. For sanitary wastewater pumping station, the provision of grit-removal is not required. The main reason is that this is to be a separate sanitary sewerage system into which grit intrusion will be minimal. Furthermore grit-removal installed at depth are expensive to provided, difficult and expensive to maintain, creating both odor nuisance and the necessity to dispose of grit.

As long as the pumps are properly designed and constructed, the replacement of impellers from time to time will be cheaper than the cost of providing and maintaining grit removal facilities.

Typical pumping station structures are illustrated in Figures 9.3 and 9.4.

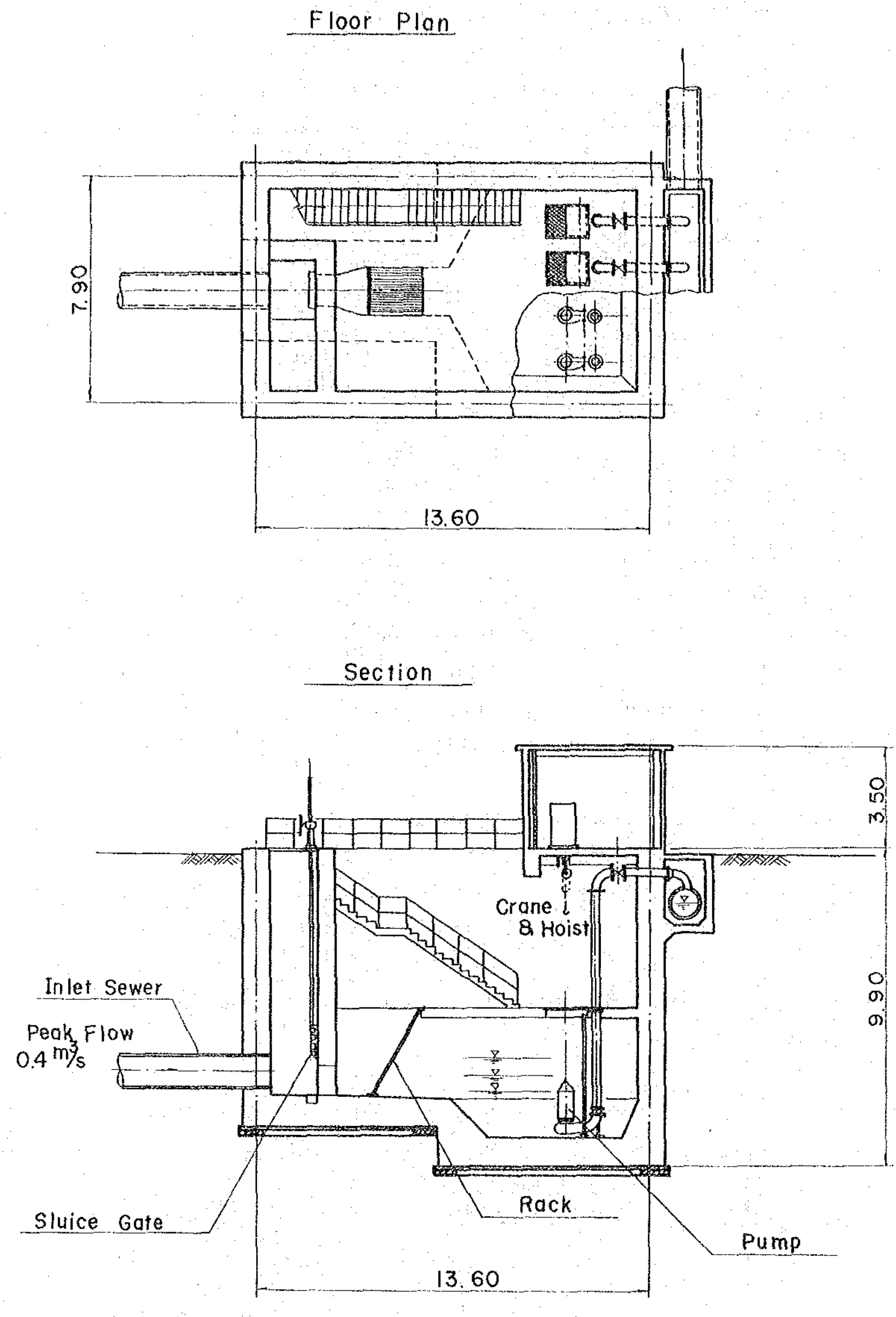


Figure 9·3 General Plan of Wastewater Pumping Station

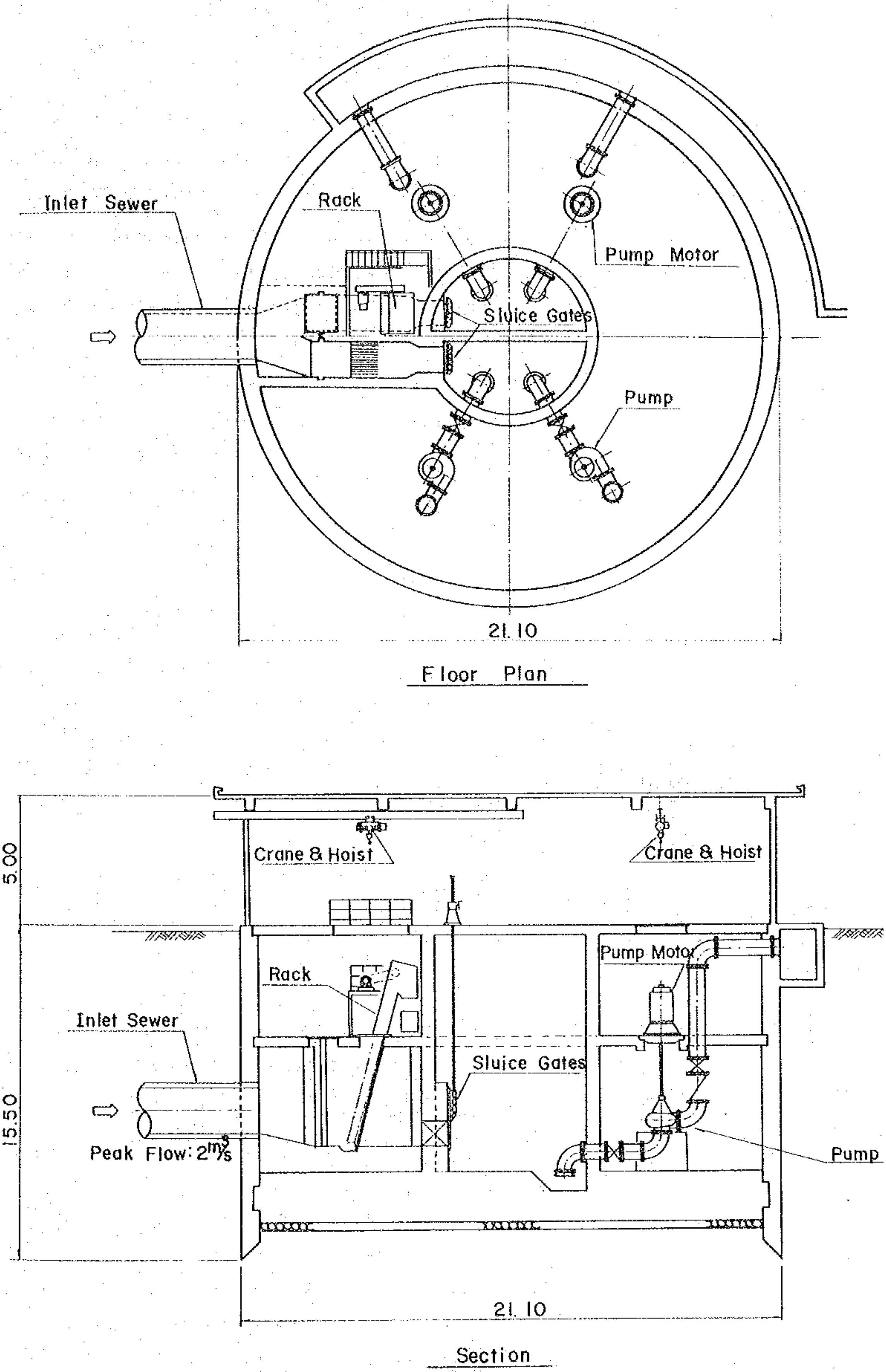


Figure 9·4 General Plan of Wastewater Pumping Station

CHAPTER 10

COMBINED VS. SEPARATE SYSTEM

10.1 General

It is apparent that, for water pollution control, a separate sewerage system will give the best solution. However, under the following conditions, a combined system may be more desirable than a separate system:

(a) Space for parallel laying of sanitary sewer and drain is limited.

(b) Amount of pollution of receiving water courses during rainfalls is acceptable.

(c) Existing public storm sewers which drain surface water together with sullage water can be converted to combined sewers.

In this chapter, the advantages and disadvantages of both separate and combined systems for Bangkok are evaluated. Then, the possibility of utilizing any of the sewerage system is considered, taking into account the followings:

(a) Differences in performance between the separate and combined sewerage system.

(b) Cost comparison.

(c) Combined wastewater overflow and suitable intercepting capacity.

(d) Other factors affecting the selection of the sewerage system.

10.2 General Advantages and Disadvantages of Separate and Combined System

A combined system is not designed to collect and deliver all combined flow to treatment facilities, because the volume of the combined flow at times of storm is too enormous to be treated economically. Therefore, only a portion of the combined flow, up to the capacity of treatment facility, may be delivered to the wastewater treatment facility and the excess is diverted to be discharged directly into the river or other receiving waters. The overflow is a mixture of wastewater which is relatively high in concentration of organic materials with storm-water which contains some organic materials at lower concentrations. If the wastewater flow is diluted by relatively large volumes of storm-water flow (as is usually the case in Bangkok), the resulting pollution of the receiving waters will be minimized. In Bangkok, due to high intensity of rainfall, the flow of diluting water is relatively large.

A separate system carries sanitary wastewater and other water-borne wastes from residence, commercial buildings, industrial plants and institutions. The system also may carry small quantities of storm and surface waters infiltrated. This system permits collection of sanitary wastewater with minimum dilution by infiltration of ground and surface waters; hence, the total volume is quite limited and amenable to treatment for removal of pollutants prior to discharge.

Another type of sewerage system is a combination of separate and combined systems, wherein sanitary wastewaters are collected by the storm drains in some areas and by sanitary sewers in other areas. The advantages and disadvantages of this type of system are principally same as those of combined system, but such a partially combined/separate system will be effective especially for the areas where sanitary wastewater is discharged into existing drains, causing constant water pollution in the nearby waterways. By collecting the wastewater flow from existing drains through interceptors, this system can conduct all dry weather flow to the final disposal places, thus eliminating such wastewater burden from the water cources, without causing large expenditures for branch and lateral sewers which are dominating portions of the separate sewer system costs. Additionally, a partial combined/separate system is especially effective when it is impractical to provide branch and lateral sewers due to physical conditions of an area or to timing of a development plan. Furthermore, unlike a combined system, the partial system can easily be converted to a complete separate system when the conditions change favorably or funds become available for branch and lateral sewer construction.

10.3 Basic Considerations for Selection of the Sewerage System

To determine the most suitable sewerage system for Bangkok, various relevant factors are taken into consideration, including the method of wastewater disposal, rainfall characteristics, topography, water uses, mode of living, and other physical limitations. In order to select the best suited sewerage system following evaluations have been made taking into account above factors.

(a) A basic factor influencing the selection of the sewerage system in Bangkok is the existence of drainage system, as pointed out in the Master Plan for Drainage and Flood Protection prepared by CDM. There is no sufficient justification to build another different combined system of major closed conduits to handle storm runoff, because the extensive existing river and klongs, when improved, will serve adequately for handling storm runoff. It is normally considered that for any urban areas which have a flood control and storm drainage system, the concept of combined system is hardly acceptable.

(b) However, in central area, existing drains discharge storm runoff together with sanitary wastewater, exclusive of night soil, to the river and klongs directly. This means, although it is not satisfactory, combined system is in operation in that area, and conversion of these existing facilities to the separate system will not be practicable at least for the time being.

(c) A study of existing conditions of water pollution in Bangkok shows clearly that the Chao Phya River and klongs are heavily polluted with sanitary wastewater and that only the establishment of separate system, to keep sanitary wastewater out of the river and klongs, can be expected to change the present gross pollution situation and set the basis for progressive cleanup of Bangkok.

(d) Since Bangkok traffic conditions, especially in central area, are often critical, excessive disruption of traffic and normal activities during construction of sewers has to be considered. Such disruption is greater in the construction of a combined sewerage system.

(e) Generally speaking, the most significant disadvantage of a combined sewerage system is that, when it rains, the system causes pollution in the receiving water due to overflow of untreated wastewater. However, in case of Bangkok, sanitary wastewater discharged to sewer will generally be greatly diluted at the time of rain. The overflows from combined sewers will therefore be greatly diluted and thus will have a minimum impact on river and klongs which receive the overflow.

With an intercepting capacity 1 x D.W.F.(dry weather flow), about 2.7 percent of sanitary wastewater, and with a capacity 6 x D.W.F. about 0.7 percent of sanitary wastewater will be lost through combined overflows. The difference in the percentage of sanitary wastewater lost between 1 x D.W.F. and 6 x D.W.F. is only 2.0 percent. (Refer to Appendix B)

(f) The groundwater table in Bangkok is generally high ranging between the surface level to 1 m below during the rainy season. This factor will cause difficulty in construction of deep and large sewers.

(g) Other factors to be considered for Bangkok are immediate needs for sanitary sewer construction for high population density areas, urgency of implementation and funds available for the Project, all of which may seriously affect final selection of the type of the system.

10.4 Cost Analysis of the Systems

Although it is generally more favourable to provide a separate system than to provide a combined system, the cost advantage of both systems may vary depending upon the various conditions of the areas in which the systems are to be provided. Hence, cost analysis is made to compare both systems, considering Bangkok local conditions influencing the sewerage costs. Construction aspects involved in comparing combined versus separate system are as follows:

1) For a separate system, both sanitary sewers and storm drain pipes are needed.

2) For a combined system, only one pipe is needed, however the depth of pipe must be sufficient to suit the house sewer connections, therefore, the required depth will often be more than the depth required for storm drains.

(a) Model Study

Cost of alternative system are calculated by using model layout of central Bangkok. (Refer to Appendix C of Volume IV)

The result is obtained as shown in Table 10.1.

Table 10.1 Cost Comparison of Sewerage System by Model Layout

(million baht)

Alternative	Description	Total Construction Cost
1	Separate system. There are existing public drains. All existing drains are fully used as separate storm sewers.	303
2	Separate system. There is no existing drain.	1,695
3	Combined system. There are existing public drains. All of them are fully used as combined sewers.	191
4	Combined system. There is no existing drain.	1,738

Note: Area of Model is 900 ha.
Intercepting capacity is 1x D.W.F.

Result of cost comparison by model

The cost estimates indicate that the bombined system would be more expensive than the separate system. (Compare Alt. 2 with 4) However, the difference of construction cost between the separate and the combined systems is not so significant. If klongs are not used and large scale drains for separate system are required, the cost for separate system may be higher than combined system. Therefore, judging only from the cost comparison, it can not be said in general which system is more preferable. The superiority of separate or combined system would turn over case by case or area by area.

The most inexpensive case is that existing public drains are used as combined sewers and construction required is interceptor only (Alt. 3). This alternative is followed by Alternative 1 which has the existing public sewers converted to storm sewers and construction of sewerage facilities are required.

(b) Comparative Study by CDM

Alternative schemes comparisons among combined and separate wastewater sewerage and storm-water drainage system were studied by CDM for selected typical urban areas namely, Construction-Government Area, Sathorn Triangle Area, Pathum Wan Area, Bonkai Urban Redevelopment Project, Bang Kapi Area, and Thonburi Area in the Master Plan Report prepared by CDM.

The detailed studies of separate and combined systems, in the six typical areas mentioned above, used the estimated total capital cost of each type of system for the purpose of comparison. The estimated total capital cost of each type of system, for each of the six typical areas, is summarized in Table 10.2.

Table 10.2 Summary of Cost Comparison of Combined System vs. Separate System by CDM

At 2510 (1967) Price Level

Area	Estimated Capital Cost, Million Baht		A Percentage of Combined System Cost to Separate Systems' Costs
	Separate System	Combined System	
1. Construction-Government	464.0	532.5	115%
2. Sathorn Triangle	229.5	184.9	81
3. Pathum Wan	306.5	498.0	163
4. Bonkai	4.5	9.4	210
5. Bang Kapi	242.8	312.0	129
6. Thonburi	126.6	168.3	132
	1,373.9	1,705.1	124%

Result of cost comparison by CDM

According to the study of CDM, the total estimated capital cost of the combined systems is exceeding by about 24 percent over the cost of the separate systems. However, in Sathorn Triangle Area, combined system is cheaper than separate system. That means the superiority of separate or combined system would depend on area by area.

(c) Conclusion of Cost Analysis

Where klongs may be used for storm drainage, the separate system will be more economical than the combined system and also will provide better control of pollution. However, for purposes of economy, it may be desirable to use the existing drains for carrying sanitary flow to the sanitary sewer interceptors until separate sanitary sewers can be afforded.

10.5 Recommendations

On the basis of the various studies and field surveys on the existing drainage facilities, it is recommended that the regional sewerage system be basically a separate system, but in answer to immediate needs, existing public drains be adopted as temporary combined sewers in the central area, until such time when financing of a complete separate system is possible.

The recommended regional sanitary sewerage system for the use up to the year 2543 (2000), consists of interceptors, networks of branch and lateral sewers with 1x peak D.W F. capacity, to discharge the collected wastewater to the treatment facilities. When feasible public drains would be used for transporting sullage water to interceptors, i.e., the house wastewater would discharge into the public drains (where the elevations permit) and be carried by them to the sanitary interceptors with provision for overflow to water courses during rain storms.

CHAPTER 11

WASTEWATER TREATMENT AND DISPOSAL

In Thailand various types of wastewater treatment process such as stabilization pond, aerated lagoon, oxidation ditch, trickling filter, rotating disc contactor, extended aeration, and conventional activated sludge method have already been studied and evaluated by the institutes and/or Government, and applied to industrial and/or domestic wastewater treatment in some of major factories and/or housing communities.

To select the most appropriate treatment process for the proposed sewerage system, followings should be considered as the basic factors;

(a) Condition of receiving waters,
(b) Characteristics of wastewater,
(c) Condition of treatment facility site,
(d) Costs for construction, operation and maintenance, and
(e) Engineering requirements for operation and maintenance.

In this chapter, the requirements of treatment and disposal of wastewater collected in the Master Plan Area and the general features of alternative treatment process are discussed. The matters discussed are engineering aspect related to wastewater disposal, operation and maintenance, land area necessary for treatment facilities, and cost for construction and maintenance.

11.1 Receiving Waters

The wastewater generated in the central Bangkok area is ordinally discharged into the klongs through the municipal drainage system without treatment. This results in the heavy pollution and nuisance conditions of the klongs in the central area. If wastewaters are intercepted before discharging into the klongs, it is evident that the pollution and nuisance conditions in klongs will be mitigated, but at the disposal sites of intercepted wastewaters in the river and/or klongs pollution will be accelerated if such wastewater is discharged without treatment.

It is estimated that about 50 percent of pollutants generated are accumulated in the drainage systems including klongs, and the remainders are discharged to the Chao Phya River 1/. The above percentage will be changed by the sewerage system, for instance, 100 percent of pollutants will be discharged in case of no treatment, and high grade treatment such as conventional activated sludge treatment discharge 10 percent of pollutants. The amount of pollutional matter to be discharged may affect the water quality of the receiving waters. It is evident, therefore, that wastewater treatment is seriously required to prevent increasing nuisance of above water courses. And the degree of treatment should be determined on the balance between the damage to be caused by the effluents and the economy to maximize benefit for the largest number of persons in the metropolitan area.

As mentioned in Chapter 6 and Appendix H, the existing pollution of the Chao Phya River reduces the dissolved oxygen content to nearly zero during low flows. And the nitrate which is effective to prevent nuisance conditions were also reduced to nearly zero in March according to the most recent survey (NEB, 2521), although the CDM Report (2511) insisted the nitrate content of the Chao Phya River was sufficient to receive additional loading of 100,000 kg BOD/day without causing nuisance odor.

It was also mentioned in the CDM Report that nuisance conditions would probably occur when the population of the Master Plan Area reaches 3.5 million. While the present population of the Master Plan Area was estimated at 4.04 million in the year 2523 (1980) as described in Chapter 7.

For the development of water quality management of the Chao Phya River mathematical models have been developed by the National Environmental Board (NEB) and Asian Institute of Technology (AIT) (2521 and 2523). The computer program includes the computation models of BOD and DO concentration and optimal BOD loading to the river system. It is, however, not possible to apply the program to this Master Planning as the model is not completed yet. It cannot be considered that the computer program developed by NEB and AIT is representing the observed behaviour of the quality paramaters in the river system.

1/ Suwanarat, K., "Pollution Study of Chao Phya River and Sources of Pollution" Department of Health, Ministry of Public Health, Thailand: 2512 - 2513 (1969 - 1970)