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No. 9

FEASIBILITY STUDY OF BANGKOK SEWERAGE SYSTEM PROJECT
(SUB - ZONE 2 - A)
IN
KINGDOM OF THAILAND

VOLUME II
MAIN REPORT

JULY 2525 (1982)

JAPAN INTERNATIONAL COOPERATION AGENCY

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CHAPTER 1
INTRODUCTION

The present Feasibility Study of Bangkok Sewerage System dealing with wastewater has been carried out under the request of the Government of the Kingdom of Thailand to the Government of Japan.

Prior to the present study, the Government of Japan decided to grant a technical assistance in response to the request of the Government of the Kingdom of Thaialnd, and the Japan International Cooperation Agency (JICA), an executing agency of the technical cooperation program of Japan, sent a preliminary survey team to Bangkok from 2522 (1979) through 2523 (1980), to perform a preliminary field reconnaissance. On the basis of the results of the preliminary survey, JICA undertook a master plan and a feasibility study of sewerage project since 2523 (1980), to provide a sewerage system suitable for the present condition of Bangkok.

The Master Plan was prepared during the period from 2523 (1980) through 2524 (1981), and a final report on master plan covering the Metropolitan Area was submitted in October 2524 (1981) to the Government of the Kingdom of Thailand.

Based on the findings and recommendations of the master plan report, and with due considerations of basic requirement of the Government of the Kingdom of Thailand, the feasibility study was undertaken from August 2524 (1981) through July 2525 (1982) as the second step of the technical cooperation.

The feasibility study examines, first, the project proposed by the Master Plan in respect to appropriateness for immediate implementation, secondly prepares preliminary engineering design of all the required facilities, and then estimates the project costs consisting of local and foreign components. In preparing the preliminary engineering design, data additionally required are collected and field investigations are made, the results of which are all taken into the design.

Based on the costs estimated, the financial feasibility of the project is studied under various practical assumptions of necessary fund, in connection with implementing the project, establishment of an adequate organization of the executing agency and legislative improvements are indispensable, and, besides, these two factors compose an important element for the financial examination of the project. These factors, therefore, are considered in detail in the report. Further, benefits of the project on the public are also considered to ascertain the feasibility thereof.

Data collection and field investigations for preparation of the present report were performed in cooperation with officials of Department of Drainage and Sewerage (DDS), Bangkok Metropolitan Administration (BMA) and government agencies concerned for the Project. Also, necessary arrangements were made by DDS to discuss various matters as to the Project with officials concerned for the Project.

CHAPTER 2

SUMMARY

Major features of the present feasibility study report are summarized as follows.

1. Study Area

   The study area taken up for the present feasibility study is Sub-zone 2-A of Zone 2, as recommended by the Master Plan as the top priority area for implementation.

   The study area covers a part of Pa Thum Wan District and the whole of Bang Rak District, and has an area of 970 hectares.

   The plan of the study area is roughly rectangular; its western end is bounded by the Chao Phya River and other three sides by klongs and main roads.

2. Features of the Study Area

   Present total population is 252,000, with a population density, within the inhabited area, 350 persons/ha. The area is considered to be an almost saturated urban area developed for commercial, residential and institutional purposes.

   Roads in the area are well developed, including such main roads as Rama I, Rama IV, Silom and others. All the area is served with piped water.

   The existing drainage system is composed of mainly klongs, pumping stations and gates. Domestic wastewater is discharged presently into the storm sewers to be used as combined sewers; for human excreta, cesspools and septic tanks are provided, effluent of which is also discharged in the existing storm sewers.

3. Proposed Sewerage System

A combined sewerage system is proposed for the Study Area in the first stage because existing storm sewers and klongs are easily convertible to the combined sewerage system with minimum cost.

The proposed sewerage system consists of collection system, intermediate pumping stations and treatment plant. The collection system utilizes the existing storm sewers as much as possible and will have an addition of four interceptors. Three intermediate pumping stations will be constructed. The treatment plant will consist of pumping station, wastewater treatment of the modified aeration process and sludge treatment.

For the treatment plant, the existing pond near Thai Tobacco Monopoly which was already proposed by the Master Plan and approved will be utilized.

4. Design Period

Sewers will be capacitated for the flow in the year 2543 (2000), and the facilities for wastewater treatment will be capacitated for the flow in the year 2535 (1992).

5. Preliminary Engineering Design

Designed sewers are 8,405 m in length, ranging from 300 mm to 2,400 mm in diameter including diversion chambers of 27 units. Designed intermediate pumping stations are three small stations with no grit chamber. Designed treatment plant includes an operating and pumping building, grit chamber, aeration tanks, final sedimentation tanks, a chlorination chamber, thickening tanks, digestion tanks, a gas holder, drying beds and others.

6. Materials and Equipment

Most materials needed for the project are locally available; major equipment for the treatment plant and pumping stations have to be imported.

7. Construction Method

Local contractors are considered capable to carry out almost all the construction work. The construction of some interceptors and facilities of the plant will require special civil works machines to be imported.

8. Estimated Cost

The estimated total project cost is 883.1 million Baht at 2524 (1981) price of which the foreign component is 250.1 million Baht and the local component 633.0 million Baht.

9. Financing

The necessary financial plans for the capital costs for the construction as well as annual costs for the operation of the completed sewerage system has been developed to identify the potential sources of fund and adequate revenue raising plan. The total costs for financing purpose is estimated taking account of assumed annual price escalation in order that the executive agency may abide in project implementation under current economic situation realistically estimated. As a result of the study the equal amount of funding of 345.79 million Baht from the central government and BMA are recommended for local currency funding with 461.05 million Baht from concessionary bilateral loan for foreign currency costs of the construction. The required sewerage charges per month per one household are estimated 88 Baht from 2532 (1999) to 2536 (1993) and 136 Baht from 2537 (1994) to 2541 (1998)

10. Organization

The existing Department of Drainage and Sewerage (DDS) of Bangkok Metropolitan Administration (BMA) is recommended to be responsible for the project implementation instituting a new sewerage functional unit, Sewerage Control Division with staffing schedule under maximum mobilization of existing manpower. The ultimate number of new staff to be required at full operation of the proposed sewerage systems is 55.

11. Legal Arrangement

As a result of review of the existing regulation, some legal amendments and new legal provisions are recommended to regulate wastewater disposal and quality control in conformity with the proposed project.

12. Project Evaluation

Benefits of the proposed project has so far been considered from the three viewpoints of health, improvement in living environment and contribution to the local economy. Some of the benefits were quantified, but most of them were treated as unquantified. The calculations of the quantifiable benefits show that the monetary values to be gained in the period of twenty years after the completion of the project equal to 1,206.9 million Baht.

13. Recommendation

In order to assure unimpeded implementation of the project as well as appropriate operation and maintenance of the completed facilities, some recommendations for planning, designing, implementation and finance are presented.

CHAPTER 3
STUDY AREA

The present study area is Sub-zone 2-A, one of Sub-zones of Zone 2, which was selected by the Master Plan as the top priority area for the long ranged sewerage development program for Bangkok Metropolis.

The Master Plan divided the entire Master Plan Area into 10 sewerage zones as shown in Figure 3.1, and subdivided Zone 2 into 6 sub-zones, as shown in the same figure. Further, the Master Plan proposed a four-staged construction program to implement all the project in an orderly manner. The present study area corresponds to the proposed first stage construction.

The selection of Sub-zone 2-A as the area for the present feasibility study is agreed on and confirmed by discussions with the Government officials concerned and the findings obtained from the present survey of the existing facilities and environmental conditions. Major reasons, among others, for this selection are that this Sub-zone has the heighest population density; waste load requires most urgent remedial actions; and as the existing storm sewers can be converted, to a combined sewerage system, immediate effects are obtainable with least cost.

The Study Area, Sub-zone 2-A is situated in the central part of Zone 2 and includes a part of Pa Thum Wan District and whole Bang Rak District. Each district comprises several sub-districts[1/], namely Maha Phrut Tharam, Si Phraya, Su Riyawong, Si Lom and Bang Rak of Bang Rak District, and Rong Muang, Wang Mai, Pa Thum Wan and Lum Pinee of Pa Thum Wan District, as illustrated in Figure 3.2.

The Study Area has an area of 970 hectares, surrounded by the Chao Phya River, Klong Padung Krung Kasem and Klong Suan Luang in the west, by Rama I Road in the north, by the railway in the east and by Rama IV Road and Klong Sathorn in the south.

Note: 1/ Sub-district means administrative Tambol of BMA.

The Study Area is composed of institutional area (29 percent), commercial-residential area (29 percent), residential area (24 percent), commercial area (11 percent) and green area (7 percent).

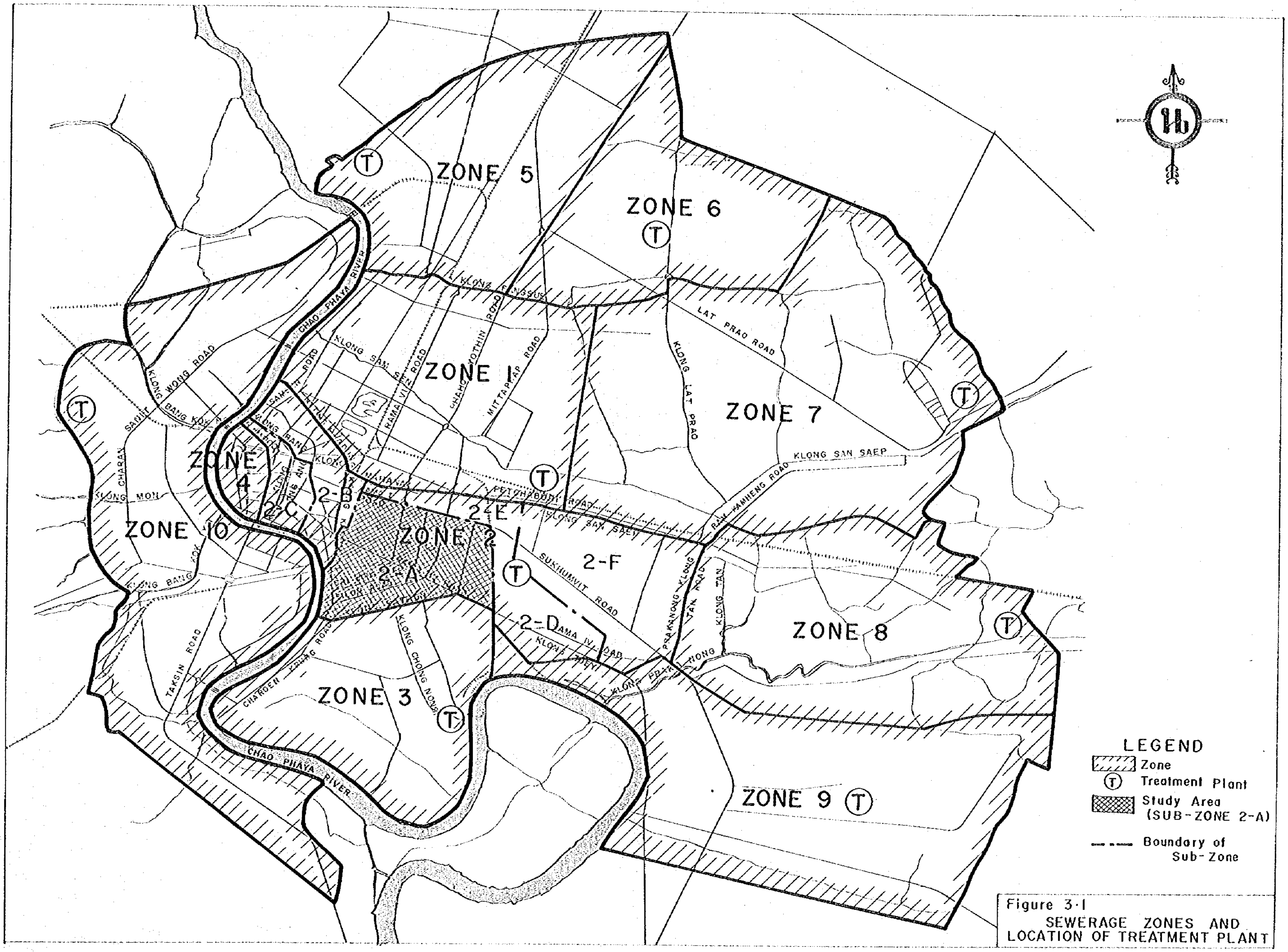


Figure 3·1
SEWERAGE ZONES AND LOCATION OF TREATMENT PLANT

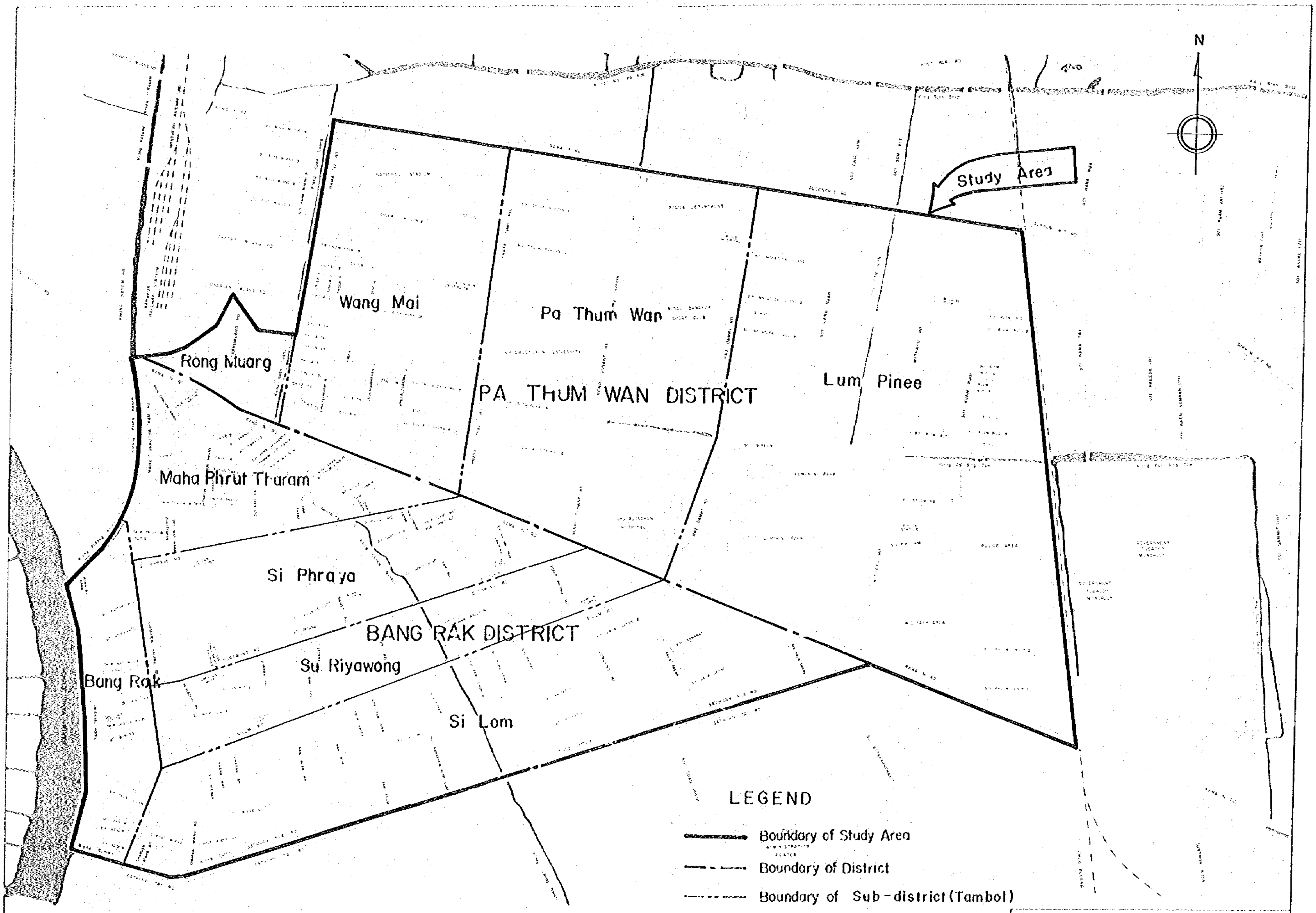


Figure 3·2
STUDY AREA

CHAPTER 4

PRESENT CONDITION OF THE STUDY AREA

4.1 Geology and Topography

The Study Area is on the east bank of the Chao Phya River and at about 50 km from the river mouth. The river basin in which the Area is situated is essentially a flat alluvial plain with ground surface elevation of 36.0 m to 37.0 m. (Mean Sea Level = 35.03 m)

As the Study Area is flat in a low-lying area, the water level of klongs connected with the stream of the Chao Phya River is affected by the tide of the Thai Gulf. Flooding frequently occurs in the Study Area when a heavy rain coincides with such high tide.

According to the existing data, the soil structure in the Area consists mainly alluvial clay with fine sand. Borings to a depth of 30 m indicate that there are basically three types of clay, soft, stiff, and hard. The soft clay is on the upper level. The change from soft layer to stiff layer occurs at an average depth of 14 m and varies from 12 to 18 m. The change from stiff layer to hard layer occurs at around 23 m depth.

Land subsidence in Bangkok Metropolis is recently progressing remarkably. There is a little land subsidence in the Study Area.

4.2 Land Use Pattern

From the field investigation, the existing land use pattern is classfied into (1) commercial area, (2) commercial-residential area, (3) residential area, (4) institutional area, and (5) green area, as identified as follows:

(1) Commercial Area

The commercial areas defined as the area occupied mainly by shops, stores, restaurants, hotels, and business offices, are located along main roads, namely, Surawong, Silom, and Rama I. These are main commercial activity areas in the Bangkok Metropolis.

(2) Commercial-Residential Area

This area is largely composed of buildings for the combined residential and commercial use. In the commercial-residential area, business is usually operated on the first floor of the building, while living quarters are maintained on upper floors. Such areas are located in Rong Muang, Maha Phrut Tharam, Si Phraya, Su Riyawong, and Bang Rak Sub-districts.

(3) Residential Area

This area comprises mainly living quarters including small stores and shops scattered in the Area. Areas of this category are situated in Lum Pinee and Si Lom Sub-districts.

(4) Institutional Area

This area comprises mainly community and public administrative buildings including government offices, hospitals, schools, university, temples, churches, etc. Areas of this category are located mostly in Wang Mai and Pa Thum Wan Sub-districts.

(5) Green Area

Both Lum Pinee Park and cemetery come under this category.

The results of the investigation are summarized in Table 4.1 and illustrated in Figure 4.1.

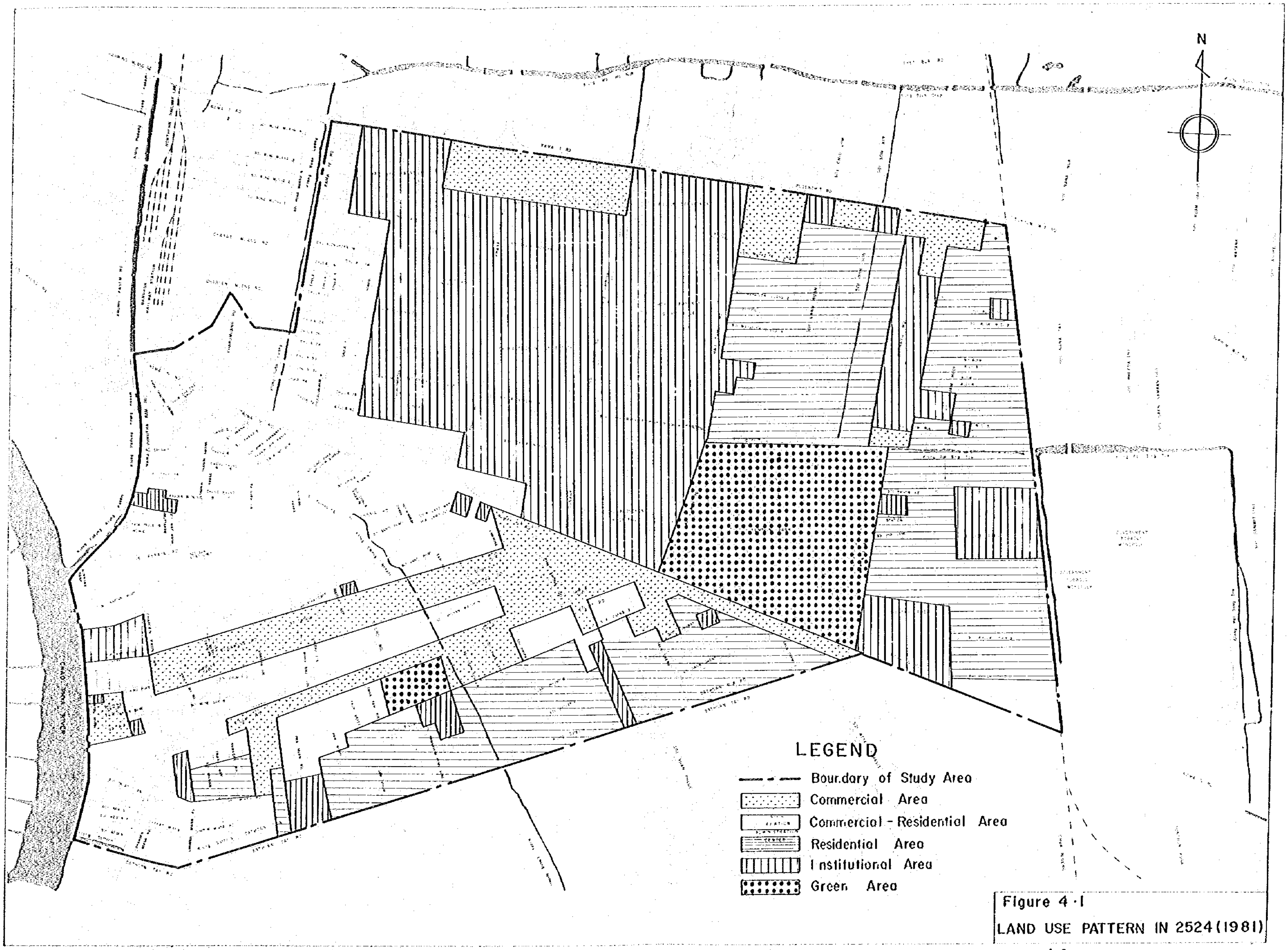


Figure 4·1

LAND USE PATTERN IN 2524 (1981)

Table 4.1 Land Use Pattern as of the year 2524 (1981) in the Study Area

Land Use Pattern	Area (ha)	Percentage (%)
Commercial	113	11.6
Commercial-Residential	277	28.6
Residential	229	23.6
Institutional	285	29.4
Green	66	6.8
Total	970	100.0

4.3 Population

On the basis of the population census record of district and sub-district, the present population of the Study Area is estimated by the population density in connection with the present land use pattern and boundary of the Study Area which occupies a part of Pa Thum Wan District and whole Bang Rak District.

The present population of the whole Study Area in the year 2523 (1980) is estimated at 252,200 persons as described in the following.

4.3.1 Population of District and Sub-district in the Study Area

The population of districts and sub-districts for the past five years is summarized in Table 4.2.

According to the above table, the population of Pa Thum Wan District and Bang Rak District is approximately 235,600 persons and 131,500 persons respectively in the year 2523 (1980).

Table 4.2 Population and Population Density of District and Sub-district in 2519-2523 (1976-1980)

Name of District and Sub-district	Area (ha)	Population and Population Density				Persons (persons/ha)
		2519 (1976)	2520 (1977)	2521 (1978)	2522 (1979)	2523 (1980)
Pa Thum Wan District						
Rong Muang	120	46,568 (388)	39,461 (329)	37,554 (313)	35,948 (300)	35,016 (292)
Wang Mai	130	62,181 (478)	58,917 (453)	57,418 (442)	56,633 (436)	56,160 (432)
Pa Thum Wan	210	102,881 (490)	116,415 (554)	122,148 (582)	124,317 (592)	128,406 (611)
Lum Pinee	330	20,269 (61)	17,762 (54)	17,092 (52)	16,152 (49)	16,065 (49)
Total	790	231,899 (294)	232,555 (294)	234,212 (296)	233,050 (295)	235,647 (298)
Bang Rak District						
Maha Phrut Tharam	60	31,064 (518)	30,824 (514)	30,443 (507)	29,890 (498)	29,639 (494)
Si Phraya	75	20,377 (272)	20,358 (271)	20,449 (273)	20,189 (269)	20,122 (268)
Su Riyawong	60	21,981 (366)	25,857 (431)	29,595 (493)	32,484 (541)	36,969 (616)
Si Lom	155	30,919 (199)	32,432 (209)	33,552 (216)	34,227 (221)	35,467 (229)
Bang Rak	35	8,267 (236)	8,205 (234)	8,148 (233)	9,697 (277)	9,345 (267)
Total	385	112,608 (292)	117,676 (306)	122,187 (317)	126,487 (329)	131,542 (342)

Data Source: Residence register record of Department of Local Administration.

4.3.2 Population of the Study Area

The population of the Study Area is obtained by subtracting the population of northern part of Pa Thum Wan District from the total population of two districts.

Using population densities and areas (ha) of inhabited area composed of residential, commercial-residential and commercial areas excluding institutional and green areas, as illustrated in Figure 4.2, the population of the Study Area is estimated at 252,200 persons as presented in Table 4.3.

4.4 River and Klongs

Klongs related to the Study Area, namely, Klong Pai Sing Tow, Klong Toey, Klong Sathorn, Klong Chong Nonsi, Klong Or Rachorn, Klong Suan Luang and Klong Padung Krung Kasem are used for drainage system, and flow of klongs is finally discharged to the Chao Phya River. These klongs and the river are shown in Figure 4.3.

Among them, Klong Pai Sing Tow and Klong Or Rachorn are covered conduits. And a part of Klong Toey is presently not functioning as klong due to accumulation of soil.

The water level of the klongs is affected by backwater of the Chao Phya River at the time of the high tide. Some of klongs are therefore provided with sand bag barrages or various types of gates such as sluice gate and navigation lock for the purpose of controlling water levels of the klongs.

The results of the water quality analyses of klongs and the Chao Phya River are shown in Table 4.4 and sampling points are shown in Figure 4.3. The klongs in the Study Area have been increasingly polluted by offensive wastewater. Especially, Klong Padung Krung Kasem and Klong Sathorn are among the most polluted klongs in Bangkok.

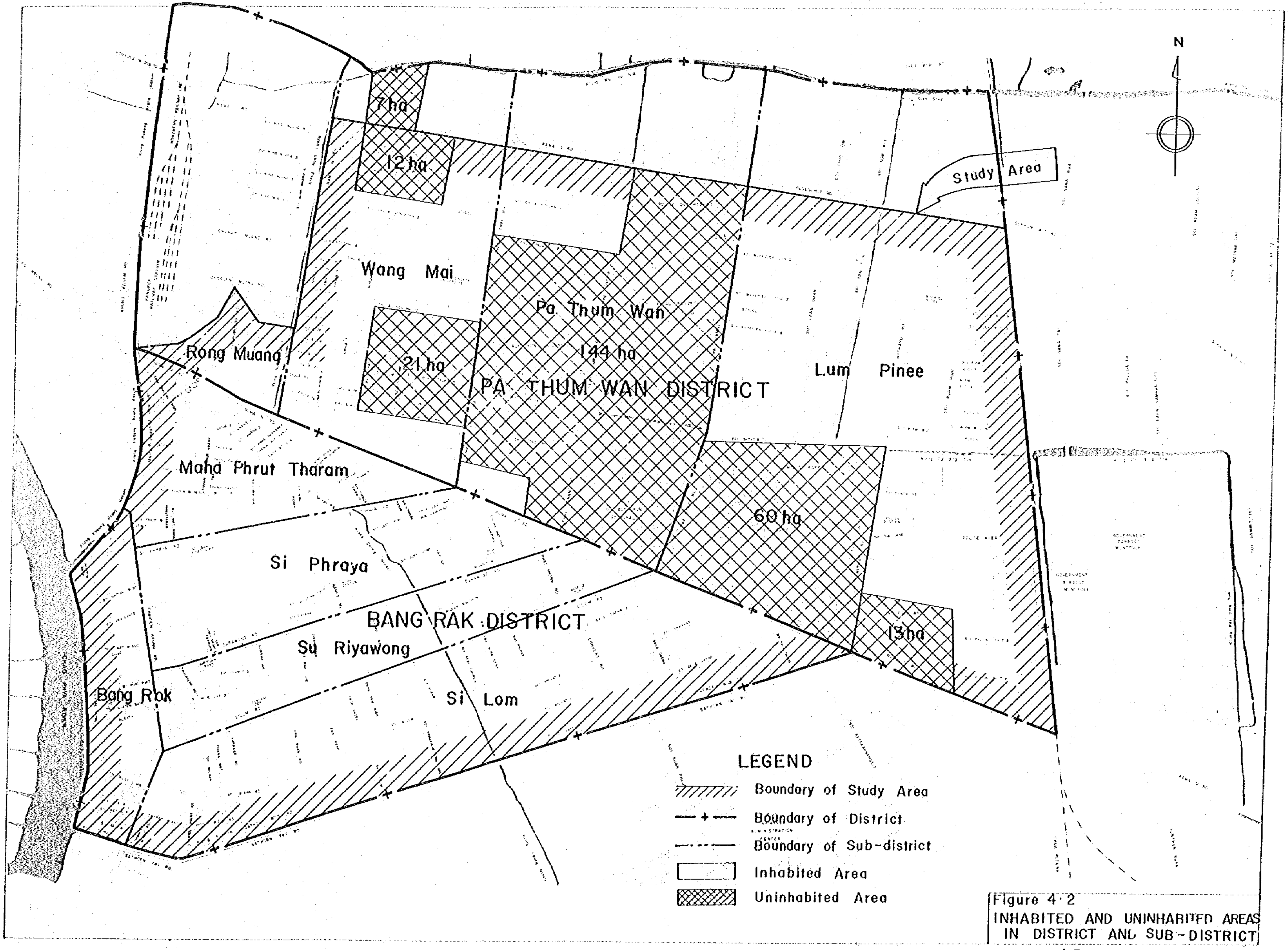


Figure 4·2
INHABITED AND UNINHABITED AREAS IN DISTRICT AND SUB-DISTRICT

Table 4.3 Estimated Population of the Study Area in 2523 (1980)

Name of District & Sub-district	District and Sub-district				Population Density of Inhabited Area (1)	Study Area			
	Population (persons)	Area (ha)				Area (ha)			Population (1)x(2) (persons)
		Inhabited	Uninhabited	Total	(persons/ha)	Inhabited (2)	Uninhabited	Total	
Pa Thum Wan District									
Rong Muang	35,016	120	-	120	292	20	-	20	5,840
Wang Mai	56,160	90	40	130	624	82	33	115	51,170
Pa Thum Wan	128,406	66	144	210	1,946	26	144	170	50,600
Lum Pinee	16,065	257	73	330	63	207	73	280	13,040
Sub-total	235,647	533	257	790		335	250	585	120,650
Bang Rak District									
Maha Phrut Tharam	29,639	60	-	60	494	60	-	60	29,640
Si Phraya	20,122	75	-	75	268	75	-	75	30,120
Su Riyawong	36,969	60	-	60	616	60	-	60	36,970
Si Lom	35,467	155	-	155	229	155	-	155	35,470
Bang Rak	9,345	35	-	35	267	35	-	35	9,350
Sub-total	131,542	385	-	385	342	385	-	385	131,550
TOTAL	367,189	918	257	1,175		720	250	970	252,200

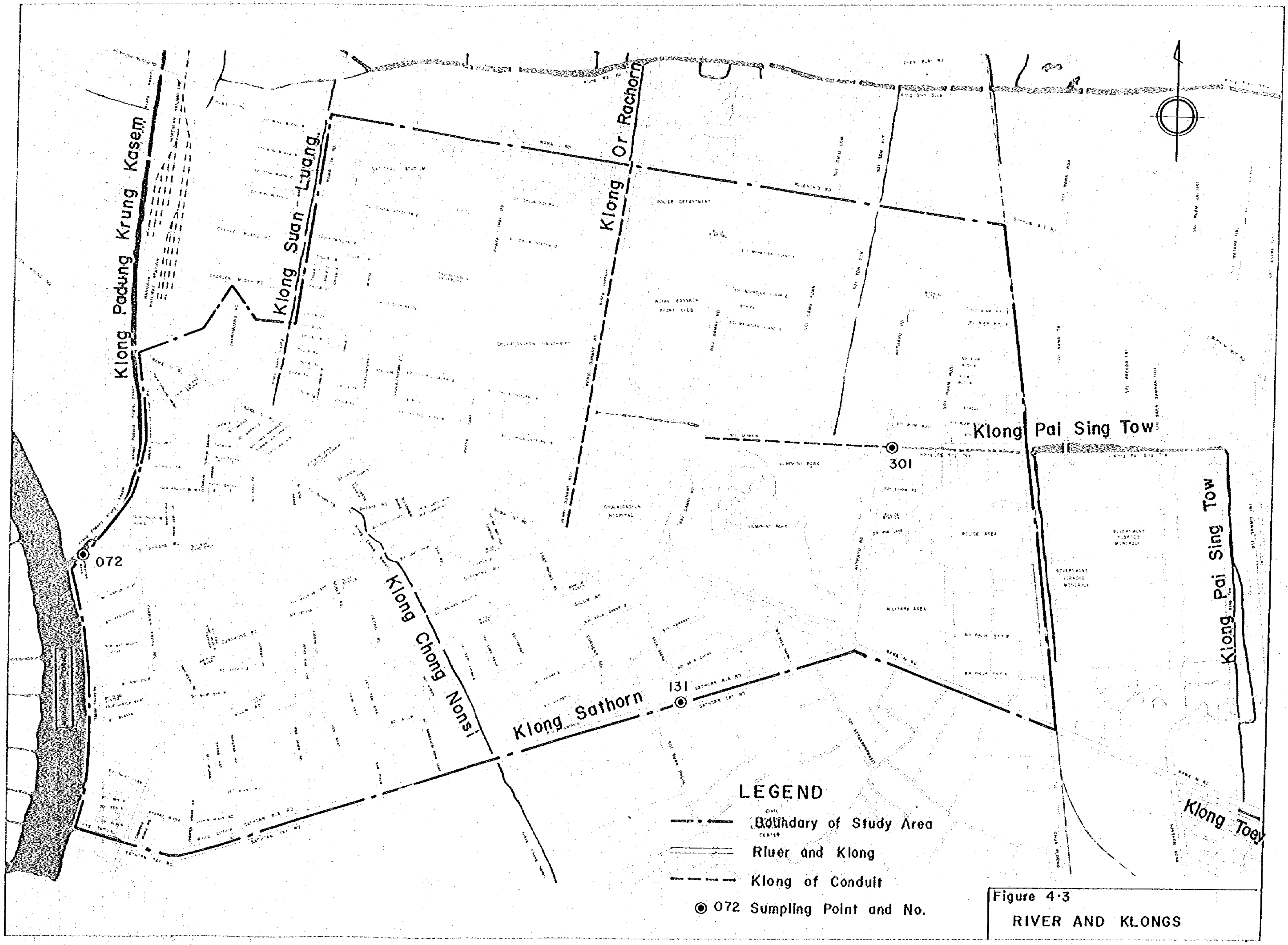


Figure 4·3
RIVER AND KLONGS

Table 4.4 Water Qualities of the Major Klongs and River in the Study Area in 2523 (1980)

Name	Sampling Point No.	Date	Time	DO (mg/l)	BOD (mg/l)	SS (mg/l)	Coliforms (MPN/100ml)
Klong Padung Krung Kasem	No. 072	13 March	9:30	0	37	-	-
		3 April	9:25	0	48	39	-
		28 April	10:46	0	47	79	-
		22 May	10:05	0	41	-	-
		5 June	9:30	0	33	-	-
		3 September	-	0	45	26	5,400,000
Klong Sathorn	No. 131	22 March	11:50	0	91	-	-
		9 April	12:45	0	40	36	-
		9 April	13:20	0	75	-	-
		27 May	9:50	0	40	-	-
		16 September	-	0	38	17	19,500
Klong Chong Nonsi	At near the Chao Phya River	22 March	11:30	2.6	31	-	-
		9 April	12:45	2.9	11	27	-
		9 April	13:30	2.5	55	-	-
		27 May	10:05	0	48	-	-
		16 September	-	3.5	3	230	1,340
Klong Pai Sing Two	No. 301	16 September	-	0.3	28	18	12,700
Klong Toey	At near Klong Phra Kanong	27 March	11:05	0	48	-	-
		23 April	10:30	0	25	26	-
		8 May	11:20	0	124	-	-
		16 May	10:50	0	45	18	-
		16 September	-	-	9	19	1,600

(to be continued)

(continued)

Name	Sampling Point No.	Date	Time	DO (mg/l)	BOD (mg/l)	SS (mg/l)	Coliform (MPN/100ml)
Chao Phya River	Memorial Bridge	3 June	-	1.0	1.7	-	-
		17 June	-	2.7	2.5	-	-
		1 July	-	4.5	1.5	-	-
	Bangkok Bridge	3 June	-	0.5	2.8	-	-
		17 June	-	2.5	2.8	-	-
		1 July	-	3.9	1.7	-	-
	Bangkok Port	3 June	-	1.1	2.9	-	-
		17 June	-	1.7	3.2	-	-
		1 July	-	3.3	2.2	-	-

Data Source: Master Plan Report for Bangkok Sewerage System Project (2524)

Note : Data of klongs were obtained from DDS Laboratory and data of the Chao Phya River were obtained from NEB.

4.5 Road Network

The Study Area is one of the most densely populated urbanized areas and the center of commercial and administrative activities in Bangkok. Under these conditions, the roads in the Study Area, especially Rama I, Rama IV, Phya Thai, Surawong and Si Phraya, are congested by heavy traffic all day. Recently, the klongs such as Klong Sathorn and a part of Klong Pai Sing Tow have been covered with reinforced concrete slab to widen the existing roads and alleviate the traffic jams. An express highway recently opened is located along the east end of the Study Area.

Figure 4.4 shows the existing road network and planned roads in this area.

4.6 Underground Structure

Under public roads, drains, electric cables, telephone cables, and water pipes are laid crossing each other especially under sidewalks of the main streets. (Refer to Figure 4.5)

These underground structures are generally laid at less than 2 m from ground surface. Figure 4.6 illustrates the typical distribution of the underground structures.

4.7 Water Supply

All of the residents in the Study Area are served by the water supply system which is operated by Metropolitan Water Works Authority (MWWA).

Major water supply pipes are laid as shown in Figure 4.5.

According to the water demand projection by MWWA, per capita water demand is anticipated as shown in Table 4.5.

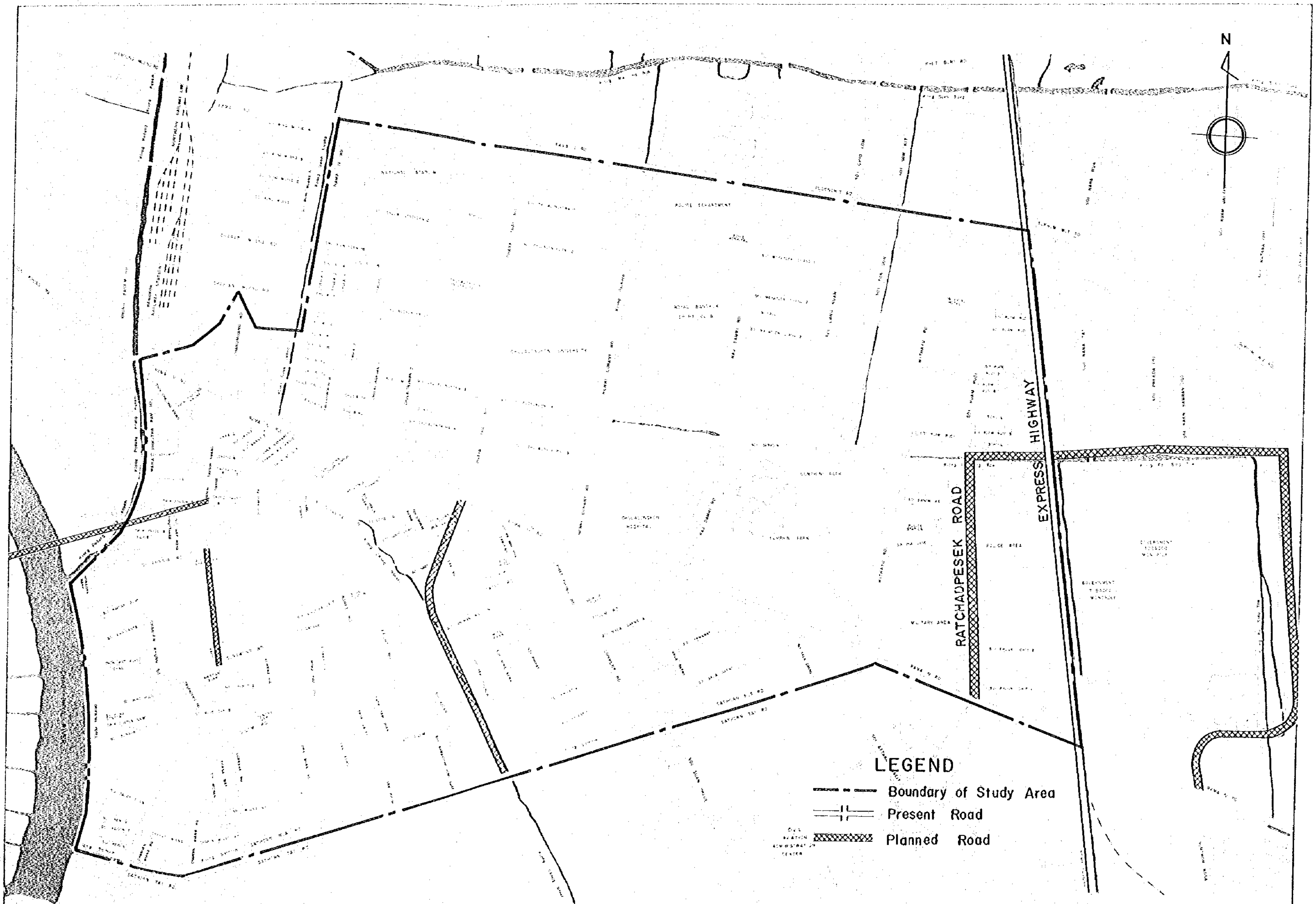


Figure 4·4
PRESENT AND PLANNED ROAD NETWORK

Figure 4·5
MAJOR UNDERGROUND STRUCTURES

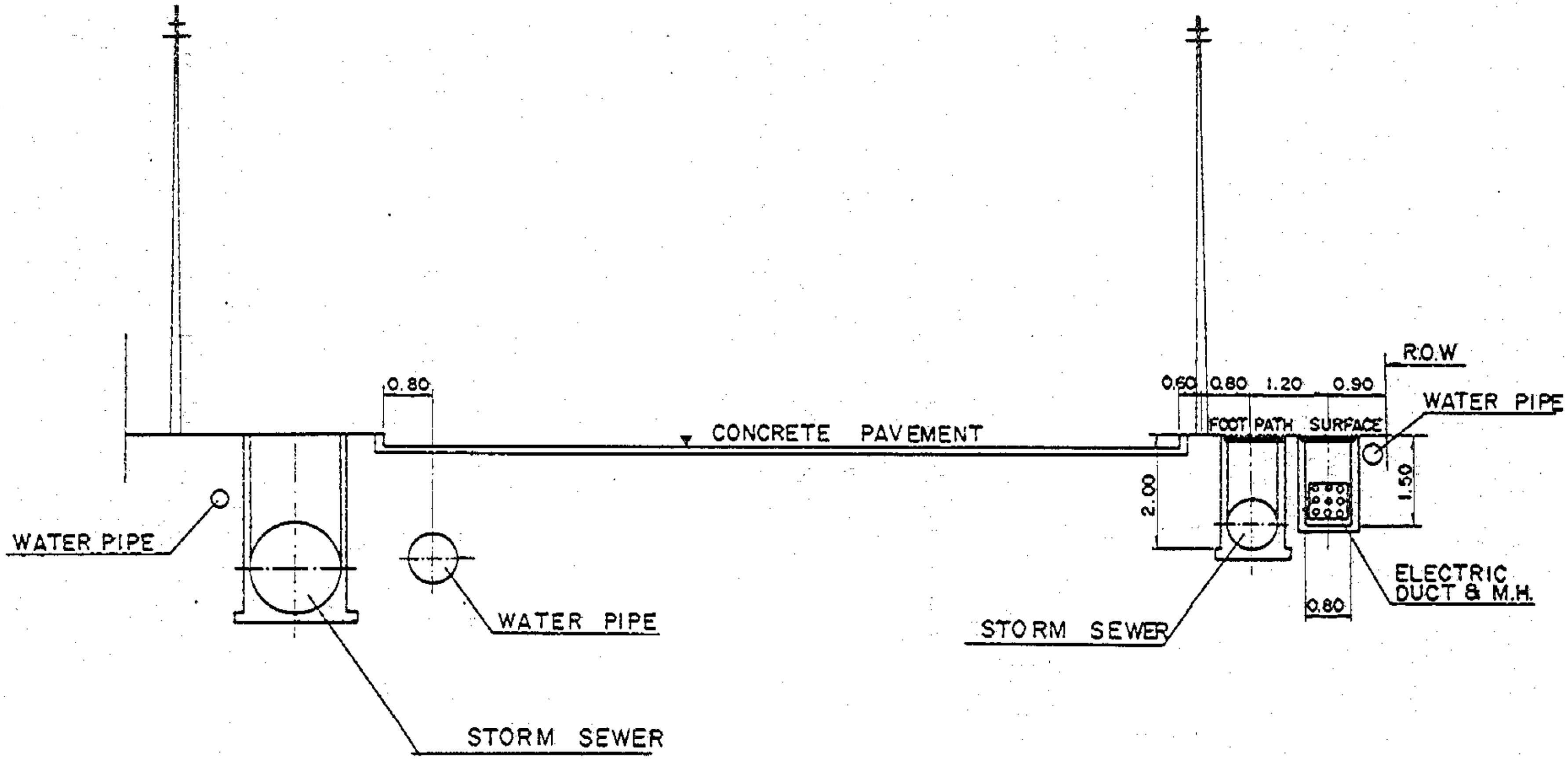


Figure 4.6 Typical Distribution of Underground Structures

Table 4.5 Per Capita Water Demand

Year	Domestic (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

Data Source: Water Supply Master Plan Report, MWWA

4.8 Domestic Wastewater and Solid Waste Disposal

(1) Sullage Water

In the Study Area, there is no adequate sewerage system to cater for sullage water. Sullage water from this area is discharged directly into the nearby waterways without any treatment.

Most of houses are equipped with concrete pipes installed around the house blocks, which are connected to the trunk sewer (Rama IV sewer) or directly to klongs or the river. Maintenance of these pipes is carried out by the Department of Drainage and Sewerage (DDS), however, the maintenance and cleaning works have not been so satisfactory. Unwholesome phenomena such as silting, anaerobic decomposition and mud accumulation have been often observed at the sites where the flow is blocked by garbage and other obstacles.

(2) Excreta

Current practice of excreta disposal in the Study Area is generally classified into two categories, namely, septic tank and cesspool.

In this report septic tank is defined as a device which has a unit process, consisting of anaerobic fermentation of excreta and separation of liquid effluent from sludge. The simple excreta storage tanks are called "cesspool" in Bangkok. These tanks are simpler in structure, with lower cost for construction and less water consumption for flushing than a typical septic tank. Some types of cesspools in Bangkok have function as a septic tank, although cesspool in general terminology does not have function of neigher "digestion" nor "separation".

The liquid effluent from them is soaked into the ground or discharged to the storm sewer, and the sludge accumulated in the tanks is collected and dumped into the lagoon at Nong Khem solid waste disposal site or treated by the On Nooch night-soil treatment plant.

The sludge collection service of septic tanks and cesspools is performed by Department of Sanitation (DOS), BMA. Present activities of DOS for the Study Area are estimated as shown in Table 4.6 on the basis of information obtained from DOS officials during the survey period.

Table 4.6 Present DOS' Activities for Desludging of Septic Tank and Cesspool

Served Area	970 ha (150,000)	
Served Population in 2523 (1980)	252,000 (5,000,000)	
Transportation Vehicles	10 (200)	
Desludging Frequency	1 ~ 2 times/household/year	
Collection Volume	3 m^3/tank/time	
Number of Personnel of 1 crew per Vehicle	7 persons	5 laborers 1 driver 1 foreman

Data Source: Information obtained from DOS

Note : Figures in parentheses are of whole Metropolitan Area.

(3) Solid Waste

Solid waste quantity presently collected and treated by DOS is approximately 2,000 ton/day in the Metropolis. Most part of collected solid waste is treated at the compost plant with total treatment capacity of 1,120 ton/day, and the rest is dumped.

In the Study Area, solid waste quantity is supposed to be about 10 percent of the above figure.

4.9 Drainage System

4.9.1 Existing Drainage System

Storm runoff from the Study Area is drained to the Chao Phya River through Klong Ma Ha Nak, Klong Saen Saep, Klong Sathorn, Klong Padung Krung Kasem, Klong Pai Sing Tow, Klong Chong Nonsi, and Rama IV Sewer as shown in Figure 4.7. Among the above, Klong Padung Krung Kasem and Rama IV Sewer are equipped with pumps.

The Study Area is divided into three drainage basins, that is, an area from which storm runoff is drained directly to the Chao Phya River by gravity flow, an area from which storm runoff is drained through Krung Kasem Pumping Station, and an area from which storm run-off is drained through Rama IV Pumping Station.

As shown in Figure 4.7, there are a lot of gates. Since these facilities are provided to control quantity of storm runoff flowing into or discharging from the Study Area, in case of rain or flooding they are operated complying with storm runoff control program.

At present, these gates are operated as illustrated in Table 4.7, by judgement based on experience of operators taking into account the inflow rate to the pumping station and flooding situation of the area concerned.

As a result of operation of the above system, condition of drainage in the Study Area is relatively saitsfactory.

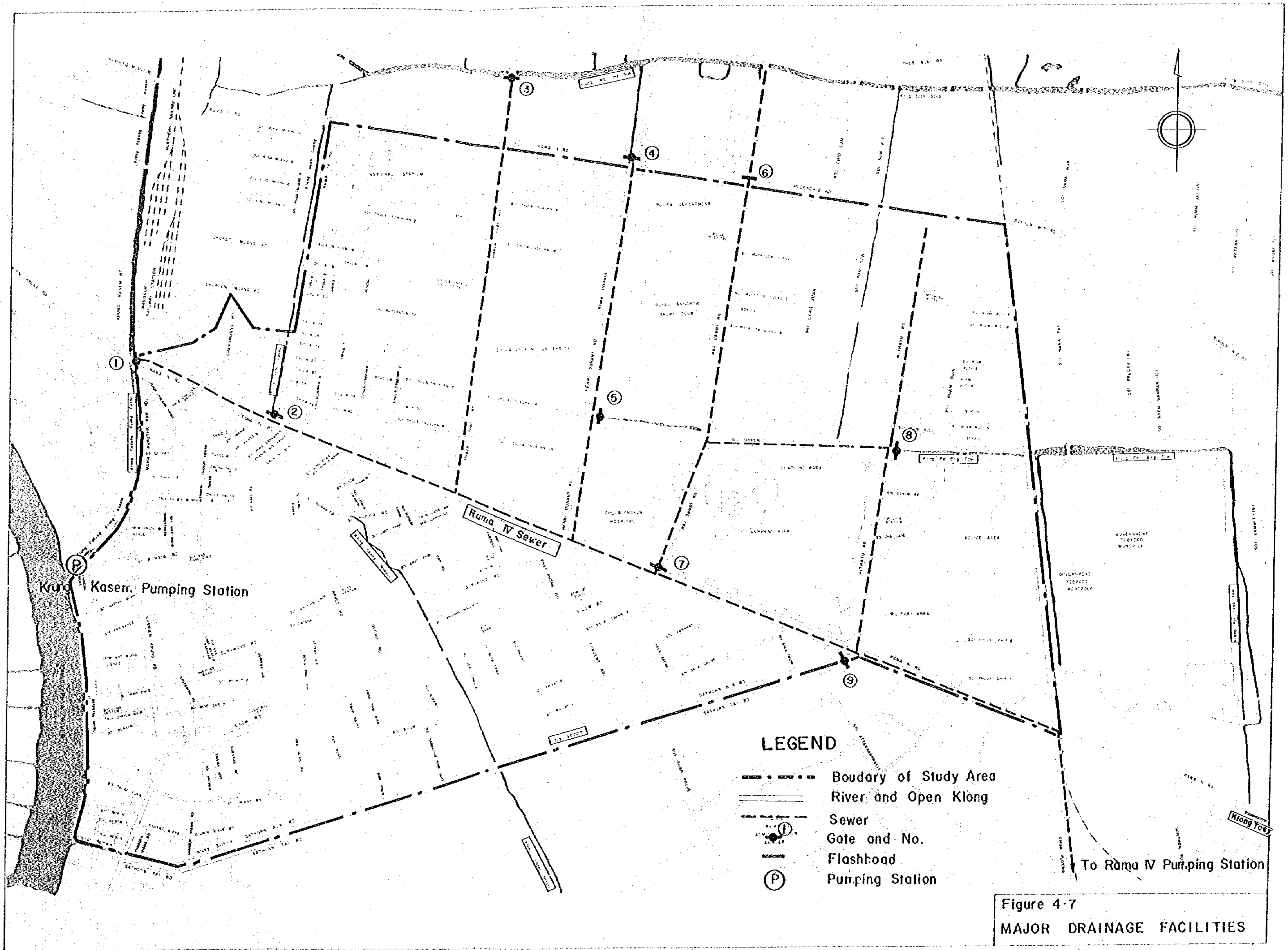


Figure 4-7
MAJOR DRAINAGE FACILITIES

Table 4.7 Gate Control Procedure in 2524 (1981)

Gate No.	In Dry Weather Condition	Gate Type
1	Closed	Sluice and Flap (Manual Drive)
2	Opened	Sluice (Manual Drive)
3	Opened	Sluice (Manual Drive)
4	Closed	Sluice (Electric Drive)
5	Opened	Sluice (Manual Drive)
6	Opened	Flashboard
7	Opened	Sluice (Manual Drive)
8	Opened	Sluice (Manual Drive)
9	Closed	Sluice (Manual Drive)

Data Source: DDS

4.9.2 Relevant Drainage Facilities Proposed by Existing Drainage Plan

The present combined sewerage system which will be described later in Chapter 5, Basic Engineering Consideration on Proposed Sewerage System, is meant to utilize the existing drainage facilities as described in the foregoing section, and to incorporate some drainage facilities planned by the existing drainage plan but not constructed yet. From this viewpoint, relevant drainage facilities formerly proposed by DDS's future drainage program are mentioned as follows, and illustrated in Figure 4.8 and Table 4.8.

(1) Construction of a pumping station at the conjunction of Klong Sathorn with the Chao Phya River.

(2) Reconstruction of Klong Toey and construction of a pumping station at the conjunction of Klong Toey with Klong Phra Kanong.

The item (1) work is considered most effective on reduction of inflow to the Rama IV Pumping Station and alleviation of the flooding problem in Bang Rak District, and the item (2) work will relieve the flooding problem of Rama IV and Sukhumwit roads. The above two works, therefore, will be incorporated in the present project with some necessary modifications, as will be described later in Section 8.1 Layout Plan of Proposed Sewerage System.

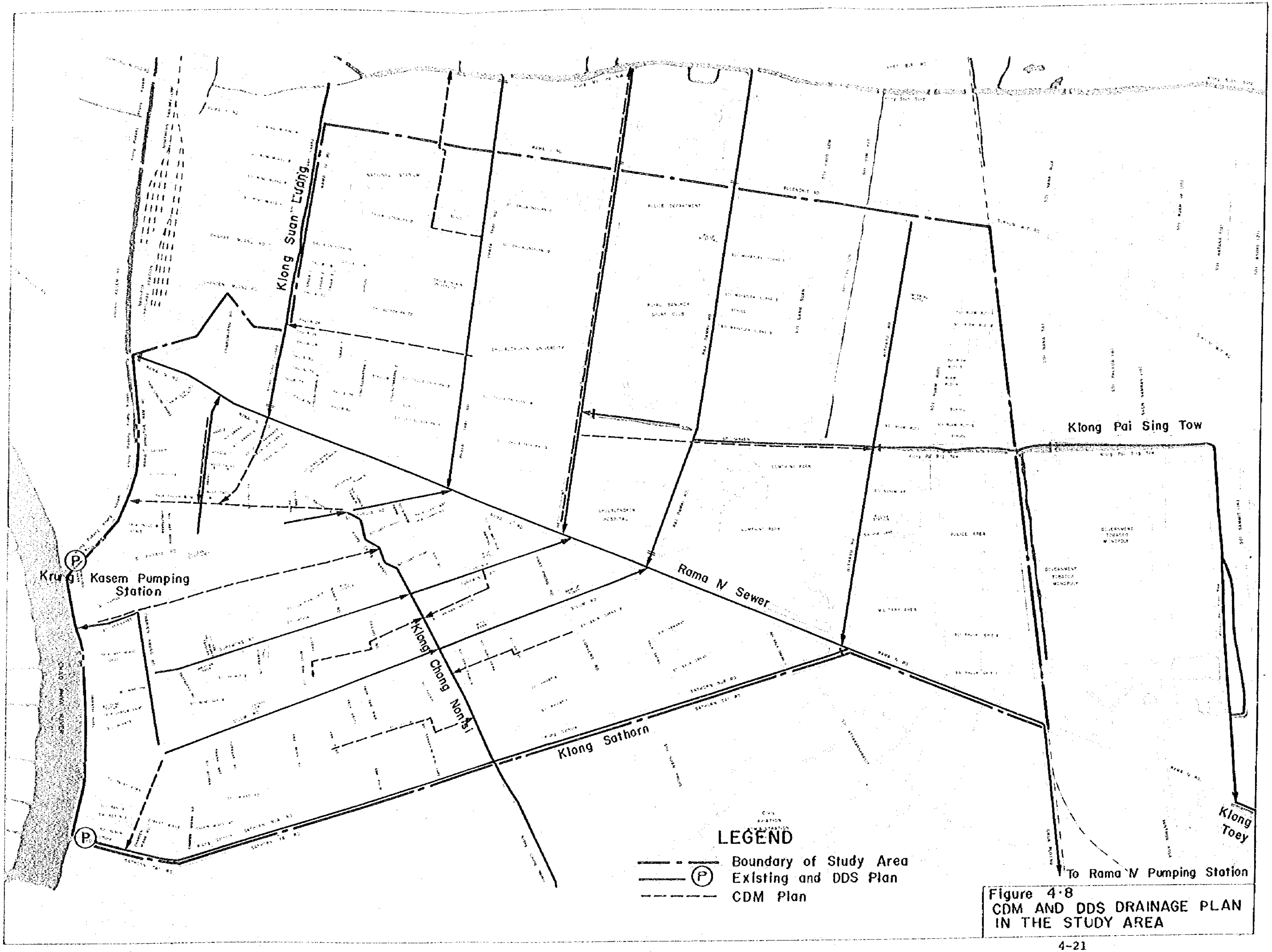


Figure 4·8
CDM AND DDS DRAINAGE PLAN IN THE STUDY AREA

Table 4.8 CDM and DDS Drainage Plan in the Study Area

	CDM Plan	DDS Plan
Rama IV	Service area of Rama IV Sewer is minimized as much as possible. And the rest of area is planned to be service areas of surrounding klongs.	Most of the Study Area is the service area of Rama IV sewer
Klong Chong Nonsi	Service area of Klong Chong Nonsi is connected to the Krung Kasem Pumping Station through new planned canal and Klong Padung Kasem.	Service area of Klong Chong Nonsi is connected to Klong Sathorn. A pumping station is planned at the end of Klong Sathorn
The Direct Service Area to the Chao Phya River	Along the Chao Phya River, a embankment with around 1 m height is planned. Storm water is drained by pump.	Follows the CDM Plan.

Data Source: DDS and CDM Report (1968)

CHAPTER 5

BASIC ENGINEERING CONSIDERATION ON PROPOSED SEWERAGE SYSTEM

The Master Plan, already submitted and approved in 2524 (1981), proposed that the existing storm sewers be used as a combined system. In addition, the Master Plan recommended that a modified aeration process be employed for the present Study Area in the initial period.

In accordance with the proposal of the Master Plan, the present study examined the feasibility of the combined system with a treatment system of modified aeration process. Before proceeding to preliminary design, some basic factors, such as collection system, wastewater treatment and others which are indispensable for the designing of the sewerage facilities, will be discussed in the following sections.

5.1 Basic Conditions of the Present Project

Basic conditions on which the present project was planned by the Master Plan are reiterated below.

(1) Urgency of Water Pollution Control

Water pollution of all klongs, drainage channels and even the Chao Phya River in Bangkok Metropolis has been rapidly intensified in these years, and they are in most deplorable conditions, hygienically and aesthetically. To solve drastically this problem, construction of a comprehensive sewerage system is of vital necessity. Subzone 2-A, in particular, is one of the environmentally deteriorated districts in the whole metropolitan area.

(2) Financial Restraints

Construction of the sewerage system requires a huge amount of fund. Furthermore, operation and maintenance of the constructed facilities on a sound basis raises a financial problem. From these inevitable financial restraints, the project to be implemented must be of a reasonable and moderate size.

(3) Type of Suitable Sewerage System

In consideration of the circumstances as stated above and also of the fact that this area has an extremely high population density, is an important commercial center, and has worst condition of pollution, a combined sewerage system, with the nature of a pilot project, was proposed for this area. Further, with regard to the existing drainage system, this area has storm sewers and klongs which are rather easily convertible to the combined sewerage system with minimum cost.

(4) Utilization of Existing Storm Sewers and Possible Conversion of New Facilities to Separate Sewerage System

To minimize the construction cost of the project, existing facilities of the storm sewers and some appurtenant facilities as well, will be as fully utilized as possible. Due to low flow velocity of the existing storm sewers with very small gradient, discharge of solid matters into the sewers may inavoidably be restricted to some extent.

On the other hand, all the facilities to be constructed by the project will be designed as to be converted to a separate sewerage system when required in the future.

5.2 Wastewater Collection System

The existing storm sewers, covering the whole Study Area, collect not only storm water but also wastewater excluding human excreta of residential, commercial and institutional areas. The wastewater thus collected is discharged into the nearby klongs and the Chao Phya River through sewers or Rama IV Pumping Station.

As regards human excreta, it is treated by individual septic tanks or cesspools, without being thrown directly into sewers. The treated effluent of the septic tanks is discharged into ground or storm sewers. The sludge accumulated in the septic tanks or cesspools is collected and treated at On Nooch Treatment Plant by Department of Sanitation (DOS).

The prevailing conditions, as stated above, of storm sewers being carefully observed in the field, it is considered that the combined system, as proposed by the Master Plan, is most appropriate without requiring construction of lateral sewers and, besides, that Rama IV trunk sewer should be used as the main sewer, as most of the existing storm sewers are presently connected to this trunk sewer. When the combined system is employed as recommended here, wastewater from the Study Area will finally be connected to Rama IV sewer and conveyed to the wastewater treatment plant through diversion chamber planned to divert up to 1 x dry-weather flow from the existing combined sewers.

The existing septic tanks must be kept and waste solid has to be removed, though the existing storm sewer system is to be converted to a combined system, because the gradient of storm sewers is not sufficient to flush away human excreta without clogging.

Open klongs in the Study Area, Klong Sathorn, Klong Chong Nonsi, Klong Suan Luang and Klong Pai Sing Tow, are all heavily polluted due to discharge of sullage water and liquid effluent from the septic tanks or cesspools. If they are utilized as combined sewers, water pollution and environmental destruction will be aggravated. It is, therefore, desirable that wastewater being discharged into klongs be intercepted or the open klongs be remodelled to closed conduits, where possible. Further, gates located around the Study Area should be closed as much as possible in order to prevent back flow of klong water into sewers.

When interceptor as proposed above cannot be connected, by gravity, to an existing storm sewer, an intermediate pumping station should be provided to lift wastewater from the interceptor up to the existing storm sewer.

5.3 Wastewater Treatment Process

In the Master Plan, modified aeration process was recommended for wastewater treatment for the following three reasons: 1) the available site for the treatment facilities is quite limited in area, 2) the effluent BOD from wastewater treatment plant which will be presently permissible in the Study Area is considered to be 60 mg/l and 3) the modified aeration process will easily be converted to conventional activated sludge process when a higher degree effluent is required. Regarding the above recommendation, further consideration will be given below to reflect the presently prevailling local conditions to the design of necessary facilities.

As the site available for treatment facilities is already fixed, the required area for the treatment facilities must be within the available area. The required area is dependent on both wastewater quantity to be treated and process of treatment to be employed. From this standpoint, the inflow and process of treatment in connection with the available area will be considered in detail in the following paragraphs.

The inflow in the first stage is approximately one-third of the anticipated total rate at the final stage. On the other hand, the available site is an existing pond with a surface area of about 20 ha and a depth of 3 to 4 m. This pond can be utilized as a stabilization pond. BOD of the wastewater to be treated is about 160 mg/l, as will be described in Chapter 6. This value is lower than the ultimate value BOD 240 mg/l estimated in the Master Plan.

Taking all the above conditions into account, the possibility for adoption of either 1) stabilization pond process or 2) aerated lagoon process is considered for wastewater treatment in the first stage. Details of the study are presented in Appendix A. The result of the study shows that the available area for the first alternative is not sufficient even for the quantity of wastewater in the first stage.

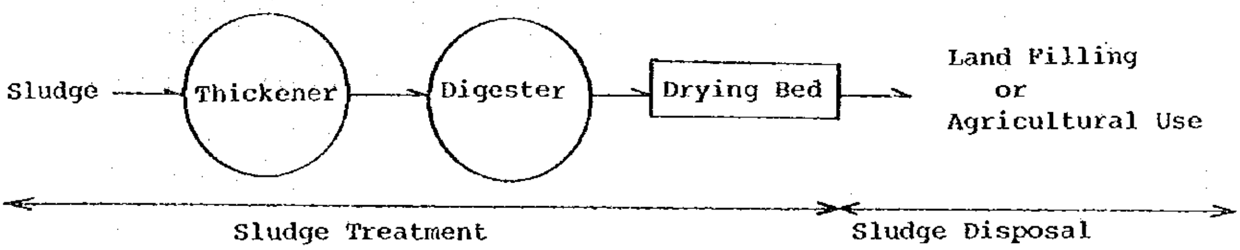
If the above second alternative is adopted, the bottom and wall of the pond have to be strengthened to a large extent, and besides, when a conventional activated sludge process is required in the future, its remodelling will need a sizable investment. Therefore, the aerated lagoon process is not recommended.

Consequently, the modified aeration process is selected as a most appropriate process to meet present conditions. This process can be easily converted to a conventional activated sludge process when a higher degree of effluent such as BOD of 20 mg/l is required.

In the preliminary engineering design, layout of this process will be provided, considering future arrangement for conventional activated sludge process.

5.4 Sludge Treatment and Disposal Process

In the Master Plan, it was recommended that the sludge removed from the sedimentation tanks be treated and disposed of as shown in the following diagram:



For the first part of the above series, the combination of processes as shown in the diagram is considered most appropriate for the First Stage. Regarding the sludge disposal, however, further consideration will be given below by reasons that the sludge is objectionable causing health hazard and odor nuisance, and that on the other hand, it has advantage as fertilizer.

Presently in Bangkok, Bureau of Fertilizer (BOF) is producing and selling two kinds of fertilizer; one of them is by composting garbage and another one is by mixing compost of garbage and digested sludge of septic tanks (refer to Appendix B). The yearly production of fertilizer by the above agency is approximately 25,000 tons against the estimated demand of 40,000 tons in the Metropolitan area.

Therefore, if the components of the sludge from the wastewater treatment plant is found suitable for fertilizer, there is a big potential demand for fertilizer from the wastewater sludge. Such fertilizer is generally recognized to be useful as a result of practical use to be effective.

In spite of the above remarkable advantage of the sludge in agricultural use, there exists a critical pitfall, such as toxic substance harmful to health in the use of the sludge from municipal wastewater. So that, further study based on laboratory tests of sludge to be produced, will be needed before decision on agricultural use of sludge.

In the initial stage, therefore, sanitary land filling would be recommended instead of agricultural use for the final sludge disposal. Dumping sites must be sought for as early as possible.

CHAPTER 6
DESIGN BASIS

Design bases for the project, for which the present feasibility study is to be undertaken, will be discussed and defined in the following. They are the design period for major facilities; land use pattern which governs population and wastewater; population in the area; and quantities and qualities of wastewater to be treated by the project.

6.1 Design Period

The sewerage system proposed in the Master Plan was planned for the capacity needed for the wastewater flow in the year 2543 (2000), namely, the design period up to that year, based on the related studies on land use, population growth and other existing infrastructure projects including water supply.

Major facilities of the sewer system for the first stage will be given capacities as proposed by the Master Plan, in consideration that they are not capable of future expansion or remodelling due to difficulties in construction work and resulting excessively high costs of work. Therefore, the design period of such facilities will be set at the same period as proposed in the Master Plan.

As for the wastewater treatment plant, however, another consideration must be given, because it can be constructed stagewise in accordance with the increasing requirement, leading to avoidance of overinvestment. On one hand, a fairly reliable estimation of wastewater flow is possible for a medium future term, say for about ten years. On the other hand, the timing of operation start-up of the second stage construction, ten years after the commencement of the first stage construction, must be considered, so as for this stage construction to be able to meet the need up to that year. The above two factors being duly considered, ten years for the design period of the wastewater treatment plant is judged most appropriate for the first stage construction.

6.2 Future Land Use Pattern

According to the future land use pattern proposed by City Planning Division, BMA, Sub-zone 2-A, the Study area, is supposed to be a commercial area except Lum Pinee Park. This pattern, however, is considered as an ultimate future picture, not necessarily taking into account the present condition of land use. The Feasibility Study, therefore, applies a more practical land use pattern assumed to actually develop until the year 2543 (2000). The future land use pattern is shown in Table 6.1 and Figure 6.1.

Regarding the above table, the future land use pattern is classified into four categories, namely, residential, commercial, institutional and green areas, and it assumes that the present commercial-residential area will be converted to the commercial area.

Table 6.1 Future Land Use Pattern in 2543 (2000)

Land Use Pattern	Area (ha)	Percentage (%)
Residential	234	24
Commercial	446	46
Institutional	230	24
Green	60	6
Total	970	100

6.3 Population Projection

Future population, one of the basic factors for the feasibility study, will be estimated in two steps, namely, 1) projection of population of the sub-districts concerned, and 2) projection of population of the study area which is a part of the districts concerned. The projection will be made taking into due consideration the future land use pattern, the present population, the present population density, and the condition of urbanization in the area.

Figure 6·1
FUTURE LAND USE PATTERN IN 2543 (2000)

6.3.1 Projection of Population of the Sub-district Concerned

In the Master Plan Report, the future population in the year 2543 (2000) was estimated at 233,000 persons for Pa Thum Wan District and 134,000 persons for Bang Rak District respectively.

On the basis of the above estimated future population of districts and the present population of sub-districts, the future population by sub-district is estimated as shown in Table 6.2.

Table 6.2 Projection of Population of the Sub-districts Concerned

Name of District and Sub-district	Area (ha)	Population (persons) 2523 (1980)	2543 (2000)
Pa Thum Wan District			
Rong Muang	120	35,016	33,500
Wang Mai	130	56,160	54,500
Pa Thum Wan	210	128,406	130,000
Lum Pinee	330	16,065	15,000
Total	790	235,647	233,000
Bang Rak District			
Maha Phrut Tharam	60	29,639	29,000
Si Phraya	75	20,122	20,000
Su Riyawong	60	36,969	39,000
Si Lom	155	35,467	37,000
Bang Rak	35	9,345	9,000
Total	385	131,542	134,000

6.3.2 Projection of Population in the Study Area

The Study Area does not necessarily include the whole area of the 9 sub-districts, and some sub-districts include uninhabited areas, as shown in Figure 4.2.

Therefore, to estimate future population of the Study Area, portions of the sub-districts that belong to the Study Area are, in the first place, taken out. Then, the future population for the year 2543 (2000) is obtained as the product of the taken-out areas and their population densities. In this calculation, the uninhabited areas in the sub-districts are, needless to say, excluded. The future population thus calculated is shown in Table 6.3.

6.4 Design Wastewater Flows and Qualities

Review of the design wastewater flows and qualities to be treated, as estimated in the Master Plan Report, is necessary to ascertain the existing conditions of the Study Area and to project the realistic figures for the design. Therefore, the above matters will be discussed in the following.

6.4.1 Wastewater Flow Rates and Strength

a. Domestic Wastewater

In the Master Plan Report, per capita wastewater production in residential area was estimated at 184 l/day in the year 2523 (1980). Future flows were estimated to increase to 194 l/day/cap. by the year 2535 (1992) and 201 l/day/cap. by 2543 (2000). With respect to BOD productions, they were estimated at 48 g/day/cap. in the year 2523 (1980) and to increase to 50.4 g/day/cap. by the year 2535 (1992) and 52 g/day/cap. by 2543 (2000).

The above per capita wastewater productions are considered reasonable to apply to this study.

Table 6.3 Population of the Study Area (Sub-zone 2-A) in 2543 (2000)

Name of District and Sub-district	District and Sub-district				Population Density of Inhabited Area (1) (persons/ha)	Study Area			
	Population (persons)	Area (ha)				Area (ha)			Population (persons) (1) x (2)
		Inhabited	Uninhabited	Total		Inhabited (2)	Uninhabited	Total	
Pa Thum Wan District									
Rong Muang	33,500	120	-	120	279	20	-	20	5,580
Wang Mai	54,500	90	40	130	606	82	33	115	49,690
Pa Thum Wan	130,000	66	144	210	1,970	26	144	170	51,220
Lum Pinee	15,000	257	73	330	58	207	73	280	12,010
Sub-total	233,000	533	257	790		335	250	585	118,500
Bang Rak District									
Maha Phrut Tharam	29,000	60	-	60	483	60	-	60	29,000
Si Phraya	20,000	75	-	75	267	75	-	75	20,000
Su Riyawong	39,000	60	-	60	650	60	-	60	39,000
Si Lom	37,000	155	-	155	239	155	-	155	37,000
Bang Rak	9,000	35	-	35	257	35	-	35	9,000
Sub-total	134,000	385	-	385		385	-	385	134,000
Total	367,000	918	257	1,175		720	250	970	252,500

On the other hand, as for design BOD loads, since septic tanks and existing excreta disposal facilities in the Study Area are recommended to remain as they are for the time being, design values to be used in the preliminary engineering design must be less than production values. The per capita BOD contribution of excreta has been estimated at 18 g/day from numerous examples in Japan. The BOD load of excreta through septic tanks is estimated at 6 g/day/cap., assuming approximately 70 percent of above BOD value is reduced by the septic tanks.

Therefore, the average per capita BOD loads into sewers from residential area are estimated at 36, 38.4 and 40 g/day in the years 2543 (1980), 2535 (1992) and 2543 (2000) respectively, With respect to SS, the same figures are considered reasonable based on the field survey conducted during the period of the Feasibility Study. These are summarized in Table 6.4.

Table 6.4 Domestic Wastewater Flows and Qualities

	Year 2523 (1980)			Year 2535 (1992)			Year 2543 (2000)		
	Flow	BOD, SS		Flow	BOD, SS		Flow	BOD, SS	
	(l/d/c)	(g/d/c)	(mg/l)	(l/d/c)	(g/d/c)	(mg/l)	(l/d/c)	(g/d/c)	(mg/l)
Domestic Wastewater	194	36	196	194	38.4	198	201	40	199

Note: SS is assumed almost equal to BOD.

b. Commercial Wastewater

Commercial wastewater in the present study is identified with the wastewater from commercial area.

In accordance with the Master Plan, the commercial wastewater flow was estimated at 93 m^3/day/ha in the year 2523 (1980), at 107 m^3/day/ha in 2535 (1992), and at 116 m^3/day/ha in 2543 (2000). BOD concentration for commercial wastewater was estimated to be same values as that of domestic flow based on field survey at commercial-residential area (refer to Appendix G of Master Plan Report).

For the purpose of the preliminary engineering design, the above values for the commercial wastewater flow are applied to this study.

With respect to BOD and SS concentration, the same figures as assumed in the previous section are used for this study.

These are summarized in Table 6.5.

Table 6.5 Commercial Wastewater Flows and Quantities

	Year 2523 (1980)		Year 2535 (1992)		Year 2543 (2000)	
	Flow	BOD, SS	Flow	BOD, SS	Flow	BOD, SS
	(m^3/d/ha)	(mg/l)	(m^3/d/ha)	(mg/l)	(m^3/d/ha)	(mg/l)
Commercial Wastewater	93	196	107	198	116	199

Note: SS is assumed almost equal to BOD.

c. Institutional Wastewater

Institutional wastewater in this study is defined as wastewater discharged from government buildings, hospitals, schools, park, etc. Based on the results of the field survey carried out during this study, the wastewater generated in the sewerage Subzone 2-A for the years 2523 (1980), 2535 (1992) and 2543 (2000) are estimated as summarized in Table 6.6. As for BOD and SS concentration, the same figures as those of domestic are used for the engineering design.

d. Infiltration Flow Allowance

The Master Plan estimated infiltration flow into sewers at 7.6 m^3/day/ha in case a separate sewer system would be employed. This figure, however, has, it is considered, to be adjusted to suit the present project, because the existing storm sewers are to be used as components of a combined sewer system for sanitary waste conveyance. As for such drains, the infiltration flow may possibly be higher than the case of the separate system. Reliable data, however, is not available within the study area to estimate such flow. On account of this, the present study assumes the amount of infiltration taking into consideration the physical characters of the area and conditions of the existing storm sewers, and also the examples of similar cities in Japan.

The rate of infiltration varies with the type and tightness of the construction, the groundwater elevation, and the permeability of the surrounding soil.

The groundwater level in Bangkok is very close to the ground surface during the wet season and it is approximately 35.0 m (almost equal to Mean Sea Water Level of 35.03 m) even in dry season. And further, the existing storm sewers in the Study Area is poorly constructed without water-tight joints.

It is difficult, however, to calculate the accurate amount of infiltration since no reliable data for calculation is available in the present study.

The infiltration flow allowance is therefore estimated in accordance with the figure actually applied in Osaka city and Kawasaki city, etc. in Japan which are under conditions similar to Bangkok. In such cities approximately 20 - 30 percent of average daily wastewater flow is considered as infiltration flow allowance.

Consequently infiltration flow allowance to be applied for the design purpose in the present study is estimated to be 30 percent of average daily wastewater flow.

Table 6.6 Estimated Institutional Wastewater Flow for the year 2535 (1992) and 2543 (2000)

Name of Establishment	*Present Avg. Water Consumption (m^3/day)	Estimated Wastewater Flow (m^3/day)	
		Year 2535(1992)	Year 2543(2000)
1. National Stadium	1,160	1,334	1,450
2. Chulalongkon University	4,192	4,821	5,240
3. Triam Udon Suksa School, College of Education	300	348	380
4. Royal Bangkok Sport Club	62	73	80
5. Police Department	78	91	100
6. Lumpinee Park	155	176	190
7. Military Area	125	146	160
8. Police Hospital	715	820	890
9. Chulalongkon Hospital	2,900	3,339	3,630
10. Bangkok Christian Hospital	525	606	660
11. Loed Sin Hospital	640	736	800
Total	10,852 ≒ 10,900	12,490 ≒ 12,500	13,580 ≒ 13,600

Note: * These are obtained from the results of survey undertaken during the period of the Feasibility Study. The future wastewater flow from the institutional area is estimated by using growth rate of 25 percent from the year 2523 (1980) to 2543 (2000) which rate is derived from MWWA's Water Supply Plan. And, it is assumed that 100 percent of the supplied water will be discharged as the wastewater from the institutional area. Locations of above sources are illustrated in Figure 6.2.

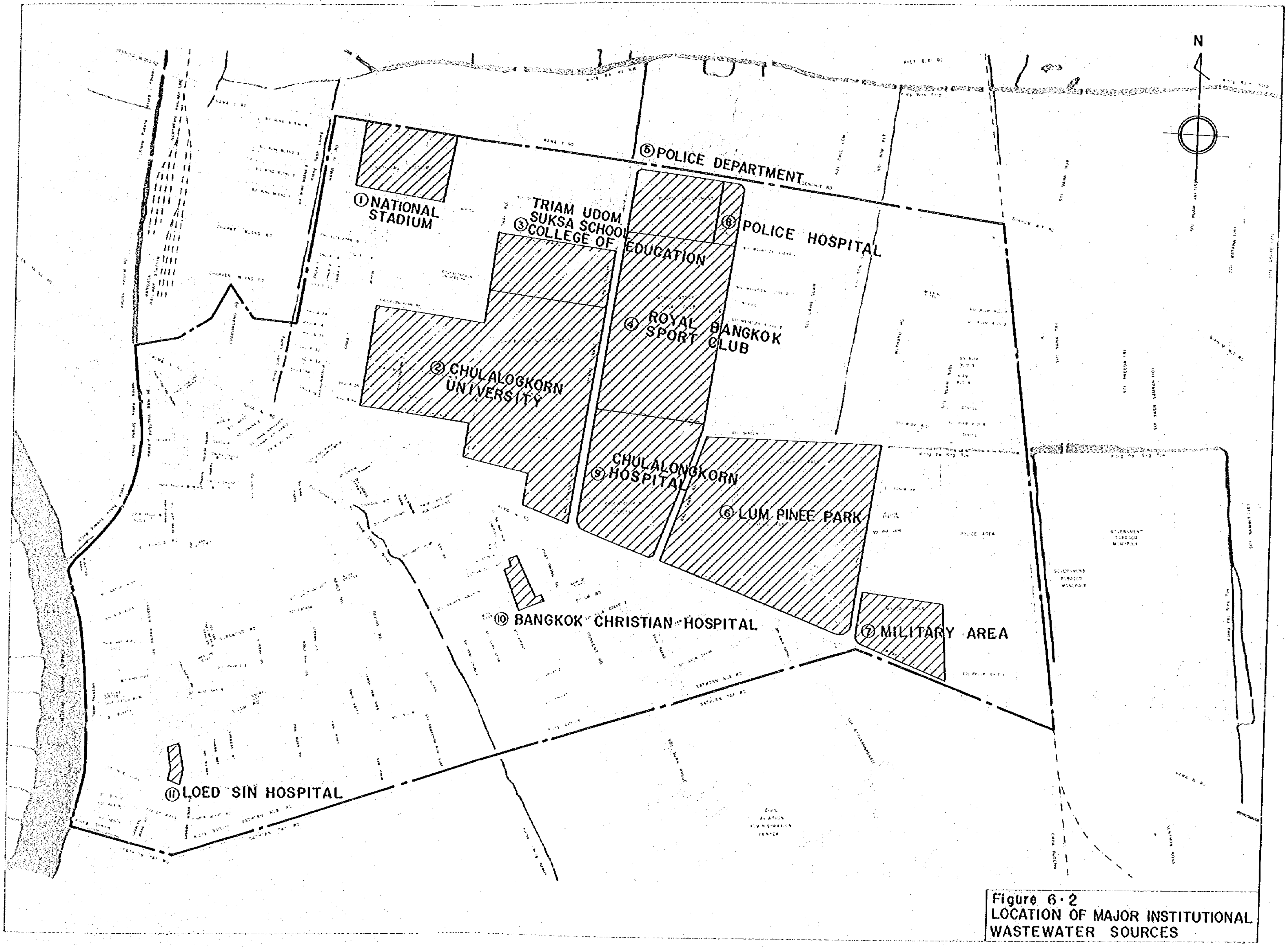


Figure 6·2
LOCATION OF MAJOR INSTITUTIONAL WASTEWATER SOURCES

6.4.2 Wastewater Flows and Qualities to be Treated

a. Wastewater Flows

Wastewater flows, so far described, expected from the Study Area, are summarized in Table 6.7 below. A graphical portrayal is shown on Figure 6.3.

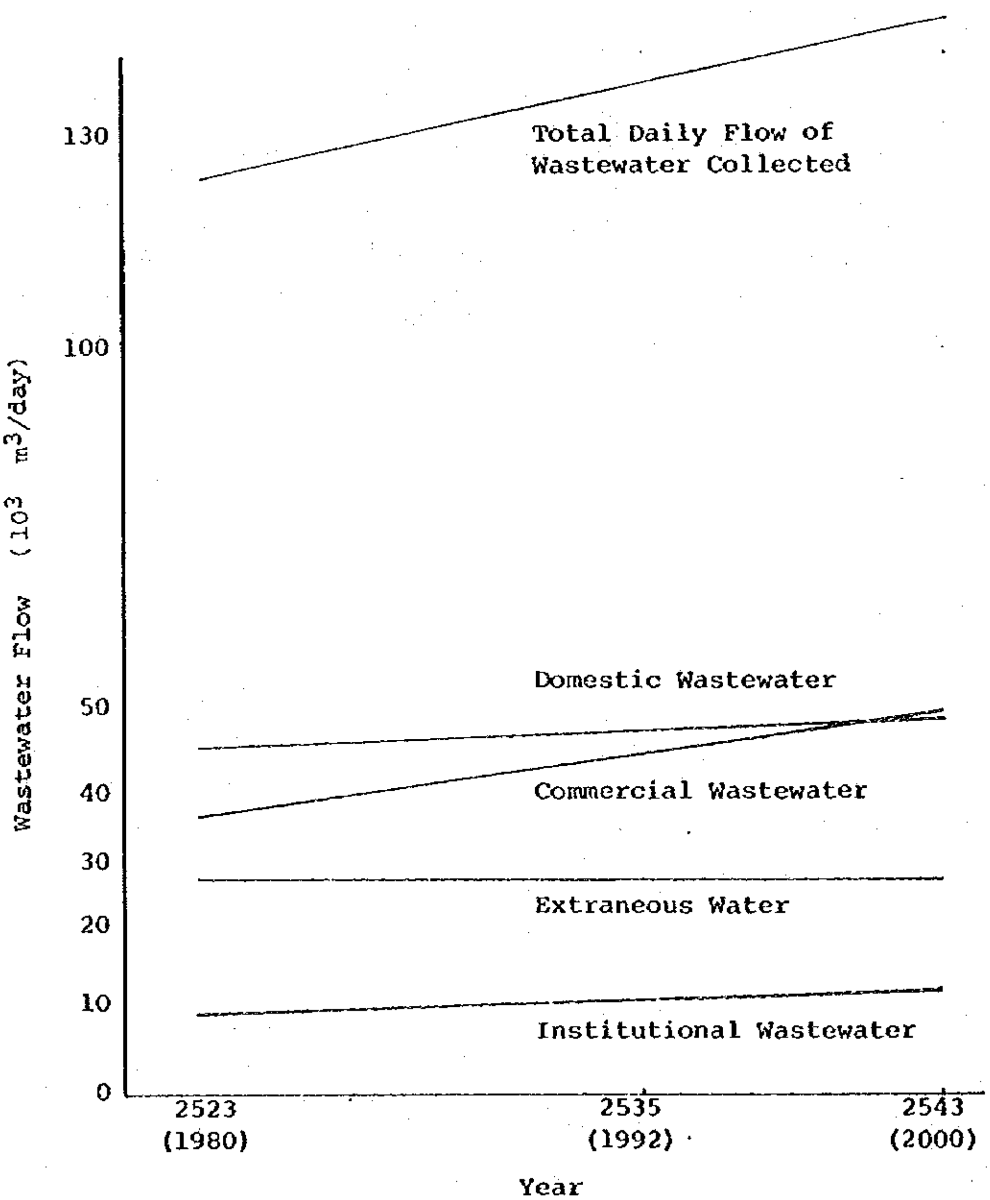
Table 6.7 Summary of Estimated Average Daily Wastewater Flow

	2523(1980)		2535(1992)		2543(2000)	
	Population or Area	Avg. Flow (m^3/d)	Population or Area	Avg. Flow (m^3/d)	Population or Area	Avg. Flow (m^3/d)
Domestic Wastewater	persons 252,000	46,400	persons 252,380	49,000	persons 252,500	50,800
Commercial Wastewater	400 ha	37,200		45,900 1/	446 ha	51,700
Institutional Wastewater 2/		10,900		12,500		13,600
Extraneous		28,400		28,400		28,400
Total		122,900		135,800		144,500

Note: 1/ Medium value between the year 2523 (1980) and 2543 (2000)

2/ Refer to Table 6.6

Figure 6.3 Estimated Daily Wastewater Flow to be Discharged from the Study Area



b. Wastewater Qualities

BOD and SS of wastewater in Rama IV sewer are estimated at approximately 160 mg/l respectively (see Table 6.8) based on the estimation as described in the previous section 6.4.1.

On the other hand, wastewater quality analyses were carried out by DDS Laboratory during field survey for the present Study. The results of such analyses indicated BOD and SS of wastewater in Rama IV sewer were ranged from 50 to 100 mg/l respectively.

The reasons for difference between estimated quality and measured one are considered due to, namely, (1) dilution by inflow of klong water, and (2) solid settling in the lateral sewers.

(1) Dilution by inflow of klong water

Rama IV sewer is connected to several klongs such as Klong Sathorn, Klong Pai Sing Tow, Klong Chong Nonsi, and Klong Ma Ha Nak. The flow directions of these klongs reverse periodically, as a result of gate control at key points for storm runoff control under existing drainage system. However, usually (when no gate control is required) klong water flows into Rama IV sewer by tidal fluctuation. Hence, when klong water flows into Rama IV sewer, wastewater may be attenuated and BOD and SS values may be decreased.

(2) Solid settling in the lateral sewers

Due to insufficient maintenance of lateral sewers or insufficient slope of sewers, the flow velocity in the sewers is usually smaller than designed. Consequently solid settling occurs in the sewers.

As described in a later chapter, if klong water inflowing into Rama IV sewer is shut out and lateral sewers are maintained well, the quality of Rama IV wastewater to be treated must be more than 100 mg/l in BOD and SS. Incidentally, the treatment plant influent

BOD is found to be 150 to 250 mg/l in Huay Kwang housing community in which a separate sewerage system is established. Taking into consideration the above fact, the design BOD of wastewater is calculated, as shown below, based on the anticipated BOD to be generated under conditions that the drainage system is modified and lateral sewers are maintained well. Consequently, the design BOD of wastewater is 160 mg/l for the year 2523 (1992).

Table 6.8 Calculation of Wastewater Qualities

Year	Wastewater Qualities in BOD and SS
2523 (1980)	$\frac{46{,}400\ m^3/d\ ^{1/} \times 196\ mg/l\ ^{2/} + 48{,}100\ m^3/d\ ^{3/} \times 196\ mg/l\ ^{4/}}{122{,}900\ m^3/d\ ^{5/}} \fallingdotseq 150\ mg/l$
2535 (1992)	$\frac{49{,}000\ m^3/d\ ^{1/} \times 198\ mg/l\ ^{2/} + 58{,}400\ m^3/d\ ^{3/} \times 198\ mg/l\ ^{4/}}{135{,}800\ m^3/d\ ^{5/}} \fallingdotseq 160\ mg/l$
2543 (2000)	$\frac{50{,}800\ m^3/d\ ^{1/} \times 199\ mg/l\ ^{2/} + 65{,}300\ m^3/d\ ^{3/} \times 199\ mg/l\ ^{4/}}{144{,}500\ m^3/d\ ^{5/}} \fallingdotseq 160\ mg/l$

Note:

1/ Domestic wastewater flow to be discharged from Study Area.

2/ BOD and SS concentration for domestic wastewater.

3/ Commercial and institutional wastewater flow to be discharged from Study Area.

4/ BOD and SS concentration for commercial and institutional wastewater flow.

5/ Total wastewater flow to be treated.

CHAPTER 7

DESIGN CRITERIA

The Master Plan developed various design criteria which had been used as a basis for design of the proposed sewerage system. This chapter summarizes design criteria to be used for the present preliminary engineering design from the said criteria, with some modifications where necessary.

7.1 Sewers

Sewers will be designed on the basis of the following design criteria:

a. Flow Friction Formula

Use of the Manning Formula is recommended to determine sewer sizes because of its simplicity and worldwide acceptance. This formula gives the velocity as follows:

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

where: V = velocity of flow, in m/sec
n = coefficient of roughness
R = hydraulic radius, in m
S = slope

b. Peak Flow Rate

The relationships of Figure 7.1 should be used for the determination of the peak rates of flow adopted for the design of sewers and pumping facilities.

c. Intercepting Capacity

The design capacity for the intercepting sewers is recommended to use 1 x the peak dry-weather wastewater flow rate. (Refer to Appendix B of Master Plan Report, 2524)

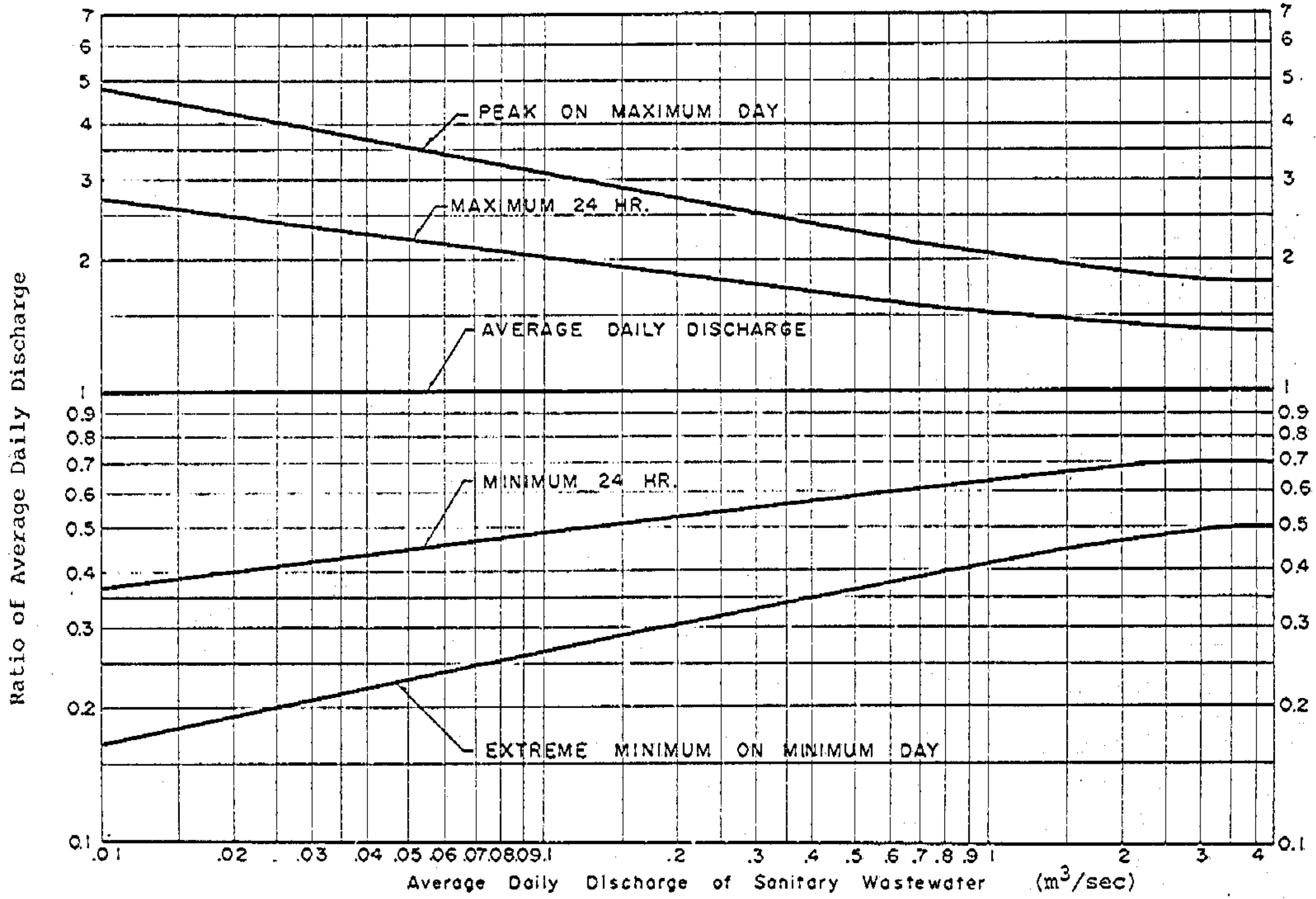


Figure 7.1 Domestic Wastewater Flow Variation

d. Minimum Design Velocity for All Pipes:

0.6 m/sec

All sewers should be designed to have a velocity of not less than 0.6 m/sec to maintain self-cleansing and prevent sulfide corrosion. (Refer to Appendix I of Master Plan Report, 2524)

e. Minimum Size of Public Sewer:

200 mm diameter

Public sewers should be not less than 200 mm in diameter to facilitate satisfactory maintenance.

f. Maximum Manhole Spacing:

- 60 m for sizes up to 0.5 m in diameter
- 90 m for sizes 0.6 m to 0.8 m in diameter
- 120 m for sizes 0.9 m to 1.5 m in diameter
- 200 m for sizes 1.65 m or more in diameter

These manhole spacings should be provided with adequate dimensions for entry and for easy operation of the cleaning rods.

g. Minimum Earth Covering of Sewer Pipes Under Roads:

1.0 m

The external crown of public sewers should be at least one meter below the road surface to receive wastewater from branch and lateral sewers by gravity.

7.2 Intermediate Pumping Stations

The design of pumping stations should be based on the peak flow of wastewater. All pumping stations are recommended to be installed with entrance gates and screens for protection of pump equipment. No grit chamber is recommended to be installed, because it is anticipated that flow rate is low and grit included in wastewater is mostly removed by existing grit-trap of sewers in the Study Area.

7.3 Wastewater Treatment Plant

7.3.1 Wastewater Treatment Facilities

a. Pump

Pump capacity and total number of pumps should be determined based on the design peak flow. Entrance gates, screens, and a stand-by pump should be provided to pumping facilities.

b. Grit Chamber

This facility should be provided ahead of the aeration tanks in order to remove sand, gravel, other minute pieces of minerals, and non-putrescible organics for protection of wastewater and sludge treatment facilities. Design detention time and design flow velocity should be provided as 1.0 minute and 30 cm/sec respectively.

c. Wastewater Treatment Facilities (Modified Aeration Facilities)

A unit of modified aeration process consists of aeration tank, sedimentation tank and chlorination chamber in series.

The design of treatment units should be based on the average rate of wastewater flow per 24 hours except where significant deviation from normal diurnal flow patterns are expected. The capacity of pipes and conduits should be determined based on peak flow rate.

Rates applied for the design of the modified aeration facilities are summarized in Table 7.1.

Table 7.1 Rates Employed for Modified Aeration Process

Design Component	Rate
1. Aeration Tank	
BOD-MLSS Loading	3.0 kg BOD/kg MLSS/day
MLSS	900 mg/l
O_2 Supply	0.35 kg O_2/kg BOD
Aeration Time	1.5 hrs
Return Sludge Ratio	10%
2. Sedimentation Tank	
Overflow Rate	30 m^3/day/m^2
Detention Time	2.0 hrs
3. Chlorination Chamber	
Contact Time	15 minutes
Chlorine Dosage	3 - 5 mg/l

7.3.2 Sludge Treatment and Disposal Facilities

Prior to final disposal, sludge from wastewater treatment process will be digested to reduce organic matters.

A unit of sludge treatment process includes thickener, anaerobic digester, and drying bed in series,

Rates employed for the design of the sludge treatment facilities are summarized in Table 7.2.

Table 7.2 Rates Employed for Sludge Treatment Process

Design Component	Rate
1. Thickener	
Solid Loading	60 kg/day/m^2
2. Anaerobic Digester (Unheated)	
Detention Time	30 days
3. Drying Bed	
Detention Time	10 days
Sludge Depth	20 cm

CHAPTER 8
PRELIMINARY ENGINEERING DESIGN

This Chapter deals with, based on the fundamental conditions so far described in the preceding Chapters 3 through 7, preliminary engineering design of the combined sewerage system to be constructed in the First Stage Area. The design is intended for estimation of the project cost and also for use as a basis for detailed design at a later stage. The estimated cost will be employed for the present financial feasibility study of the project.

In the following sections, first, the skeleton layout of the combined sewerage system will be illustrated, and, secondly, all preliminary engineering designs of sewerage facilities will be presented, together with analyses, calculation and drawings, where required.

8.1 Layout Plan of Proposed Sewerage System

The layout plan of proposed sewerage system in the Study Area is shown in Figure 8.1.

Fundamental facilities of proposed sewerage system consist of existing storm sewers, intercepting sewers to be newly constructed, intermediate pumping stations and wastewater treatment plant.

As shown in Figure 8.1, all of wastewater generated from the Study Area are collected to the existing Rama IV Sewer which is located in the center part of the area, through the existing storm sewers and the interceptors. Then, it is transported to the proposed treatment plant by the trunk interceptor. The collected wastewater is treated at the proposed wastewater treatment plant located along Klong Pai Sing Tow by modified aeration process, and after treatment, effluent is discharged to Klong Pai Sing Tow.

For the First Stage, main intercepting sewers with diversion chambers are proposed to be constructed along Klong Phadung Krung Kasem, Klong Sathorn, and Klong Suan Luang to intercept wastewater being discharged directly and to use fully the existing storm sewers and minimize interruption of the heavy traffic.

Along Klong Chong Nonsi, an interceptor is required, but no sufficient space for such construction is available. Therefore, Klong itself will be used as a sewer after converting its present open type to a conduit type. It will result in aesthetic improvement of the environment.

Three intermediate pumping stations are required to avoid deep excavation of sewers, and to connect with existing storm sewers.

Wastewater treatment plant with a capacity of approximately 140,000 m^3/day is required to be constructed in the First Stage.

To realize most effective functioning of the proposed sewerage system, gates located around the Study Area should be closed as much as possible.

8.2 Proposed Sewerage Facilities

8.2.1 Sewers

A detailed breakdown of the proposed sewer facilities is shown in Table 8.1 For the purpose of identification, each sewer has been named as indicated in the table.

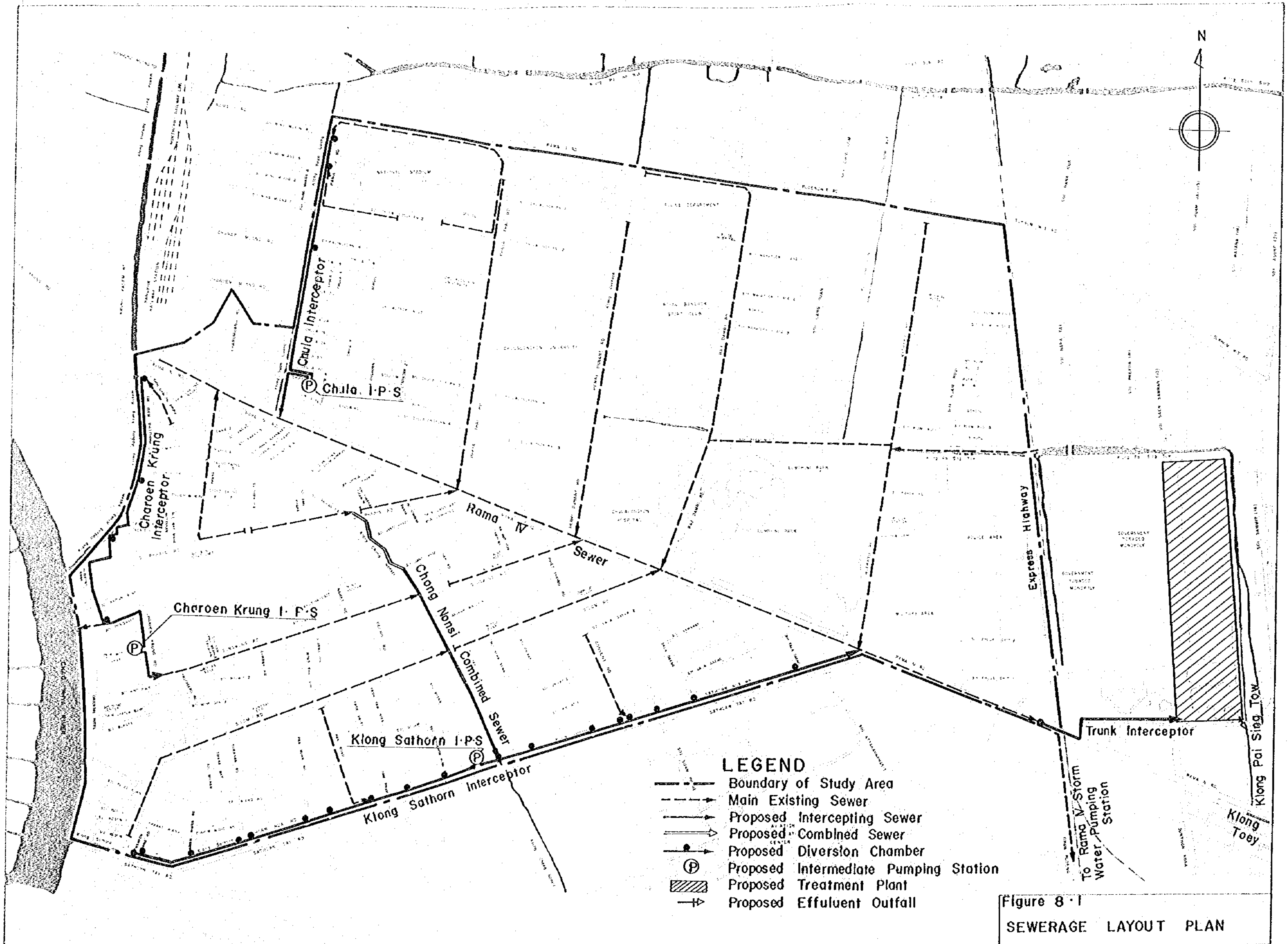


Figure 8·1

SEWERAGE LAYOUT PLAN

Table 8.1 Summary of Proposed Sewer Facilities

Name of Sewer	Pipe Dia (mm)	Ave. Depth of Sewer (m)	Pipe Length (m)	No. of Diversion Chamber	No. of Manhole
Chula Interceptor	600	2.4	140	1	1
	1,000	3.6	1,005	2	8
	Force Main 600	1.7	295	-	1
Charoen Krung Interceptor	400	2.0	295	1	4
	500	3.4	465	2	8
	600	4.2	465	1	6
	1,000	5.4	325	1	4
	Force Main 600	1.7	165	-	1
Klong Sathorn Interceptor	300	1.8	20	1	-
	300	3.5	240	1	4
	400	4.0	260	2	3
	500	4.3	240	1	3
	600	4.5	95	1	-
	600	4.7	220	1	-
	800	5.4	310	2	2
	800	5.6	175	1	2
	1,500	3.5	160	1	2
	1,500	4.7	710	5	1
	1,500	5.3	755	2	4
	Force Main 500	1.6	90	-	-
Chong Nonsi Combined Sewer	□8,500x2,000	3.2	1,275	-	8
Trunk Interceptor	2,400	9.0	450	1	3
	□2,100x2,100	10.0	250	-	3
Total			8,405	27	68

The diversion chambers are provided to divert up to 1 x dry-weather wastewater flow from combined sewers. As for the type of chambers, the leaping type is adopted for Rama IV Sewer and the side over-flow weir type is for the other existing storm sewers. (Refer to Appendix C).

Design calculation of proposed sewers is presented in Appendix D. Details of all sewer facilities, that is (1) plan of sewerage system (2) sewer profile (3) structural drawing of diversion chambers (4) other structural drawings, are presented in Volume III, Drawings.

8.2.2 Intermediate Pumping Stations

Three pumping stations, named provisionally as Chula, Charoen Krung and Klong Sathorn for the purpose of identification, will be constructed in the First Stage.

No grit chamber is proposed for these pumping stations because the inflow into these pumping stations will be not substantial and therefore no grit removal problem will be anticipated. And also by absence of grit chamber easy operation and maintenance and low construction costs are expected.

Two or more screen channels are basically to be provided for each pumping station to facilitate cleansing, repairing, etc of anyone of the channels without interrupting continuous operation of the pumping station. However, for Klong Sathorn Pumping Station, only one channel is proposed, because inflowing rate is extremely small and it is impossible to keep flow velocity more than solid settling velocity to avoid siltation if two channels are provided. In case of emergency, wastewater can be by-passed to the klong directly closing the inlet gate.

As shown in Table 8.2, there is no significant difference between design flows in 2535 (1992) and 2543 (2000). Consequently design flows for the pumping stations based on the year 2543 (2000) is employed since it is sufficient to cover future flows without requiring any surplus investment for the construction.

Table 8.2 Design Flows of Pumping Stations

Name	The Year 2535 (1992)		The Year 2543(2000)	Required Land Area*
	Daily Ave. Flow(m^3/day)	Peak Flow (m^3/min)	Peak Flow (m^3/min)	(m^2)
Chula Pumping Station	10,700	22.7	23.8	300
Charoen Krung Pumping Station	12,900	23.8	24.4	300
Klong Sathorn Pumping Station	6,100	12.6	13.0	300

Note: * open space

Table 8.3 Outline Specifications for Pumps

Name	Total Design Head (m)	Pump Capacity per Unit (m^3/min)	No. of Pump Required (*)	Pump Type
Chula Pumping Station	7.00	12.00	3	Sub-mersible
Charoen Krung Pumping Station	8.00	12.50	3	Sub-mersible
Klong Sathorn Pumping Station	7.00	6.50	3	Sub-mersible

Note: * includes one stand-by.

The design flows of the three pumping stations and outline specifications of the pumps to be provided in the First Stage Program are shown in Tables 8.2 and 8.3. Proposed Plans of these pumping stations are presented in Volume III, Drawings.

8.2.3 Wastewater and Sludge Treatment Facilities

(1) Design Conditions

Basic design factors, previously described in Chapter 6, are recapitulated as shown in Table 8.4.

Table 8.4 Design Conditions of Wastewater Treatment Plant

Item	in 2535 (1992)
Average Daily Flow	135,000 m^3/day
Influent BOD	160 mg/l
Effluent BOD	60 mg/l

In designing the wastewater treatment facilities for the First Stage, arrangement of main facilities, size, and number of units of treatment facilities are determined taking into account both the design of conventional activated sludge process to which the treatment plant may be converted in future and design conditions, namely, flow of approximately 380,000 m^3/day, and effluent BOD of 20 mg/l which are also anticipated in the final stage.

(2) Flow Diagram

The flow diagram for modified aeration process, including pumping and sludge treatment facilities, of the proposed wastewater treatment for the Study Area, is illustrated in Figure 8.2.

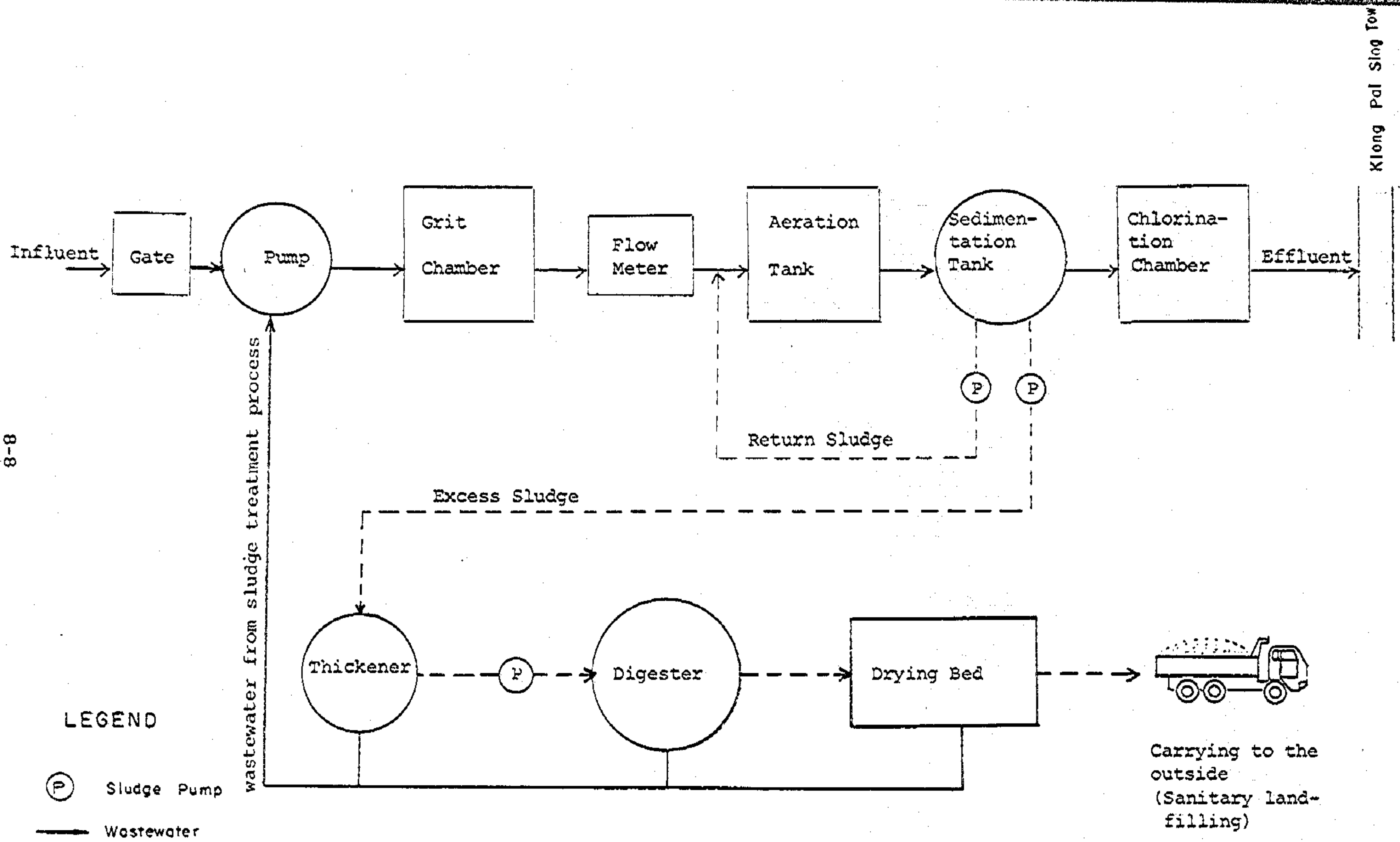


Figure 8.2 Proposed Wastewater Treatment Plant Flow Diagram

Elements indicated in the flow diagram are briefed below.

1) Gate

This is provided to control wastewater flow especially when electric power is out of supply, or overhauling of pump facilities is performed.

2) Pump

This is provided to lift wastewater from Trunk Interceptor to grit chamber. The lift of the pump is determined so that the effluent from the plant can be discharged to Klong Pai Sing Tow by gravity.

3) Grit Chamber

Grit and sand included in wastewater are separated and removed by this facility.

4) Flow Meter

Wastewater flow is measured by this facility.

5) Aeration Tank

Microbial floc particles formed are brought into contact with the organic components of the wastewater in this facility.

6) Sedimentation Tank

Suspended solid particles are removed from wastewater by gravity settling in this facility.

7) Chlorination Chamber

Before discharging to Klong Pai Sing Tow treated water is disinfected by chlorination in this facility.

8) Thickener

This facility is employed for subsequent dewatering to reduce the volumetric loading to related units and to increase the efficiency of the dewatering equipment.

9) Digester

The objectives of anaerobic digestion are to (1) decompose sludge organism to stabilized humus, (2) reduce the mass and volume of sludges, (3) obtain useful by-products, and (4) destory or control pathogenic organisms.

10) Drying Bed

Digested sludge is withdrawn from digester onto this facility to dry.

(3) Size and Number of Main Facilities

Size of the main facilities and number of units are designed taking account of the final scale of plant, space availability, construction program, influence on the environment, operation and maintenance procedure, and economic factors. Design calculation for determination of the above facilities is presented in Appendix D.

In addition to the main treatment facilities, a training room and a laboratory are provided in the operating building, and a room of laborers with workshop and house of workers are planned separately from the operating building.

Size and number of the main wastewater treatment plant facilities proposed for the First Stage are shown in Table 8.5. (Refer to Appendix E)

(4) Arrangement of Main Facilities

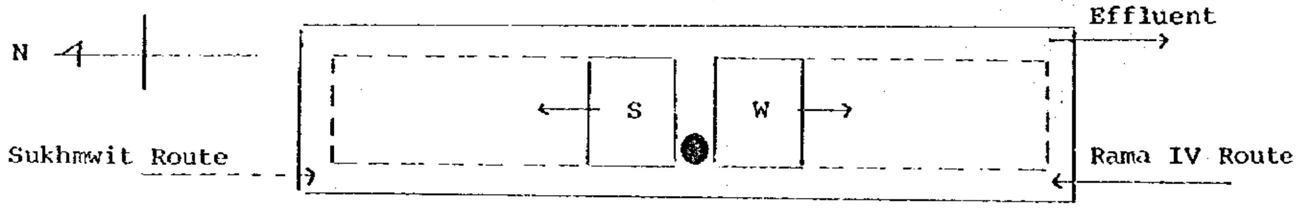
Three alternatives for the arrangement of wastewater treatment plant are conceivable under the following existing conditions of proposed treatment site.

i) The plant site is a pond which consists largely of two parts i.e., northern part with 3 to 4 m depth occupying tow-thirds of the pond and another southern part with about 2 m depth.

ii) Inlet routes into this plant are two, namely, Rama IV Route (presently to be designed) and Sukhumwit Route (in future stage).

Each alternative is briefed below, and comparison of major features of the three follows.

Alternative I: Operating building incorporating pumping station is located at central portion of the proposed plant site, and treatment is largely divided into two processes, namely, wastewater treatment and sludge treatment.



Legend :

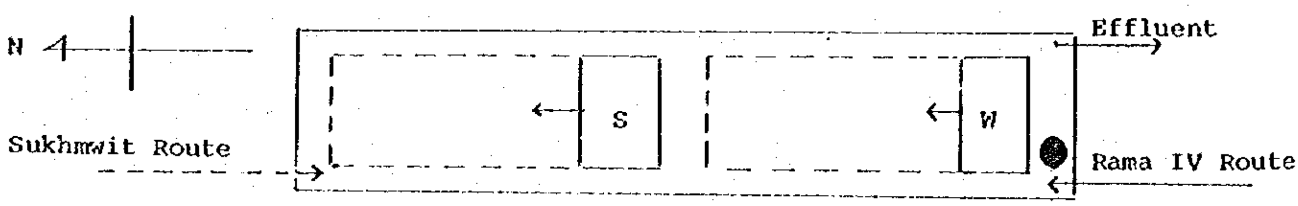
● .... Operating Building incorporating Pumping Station

W .... Wastewater Treatment Facilities

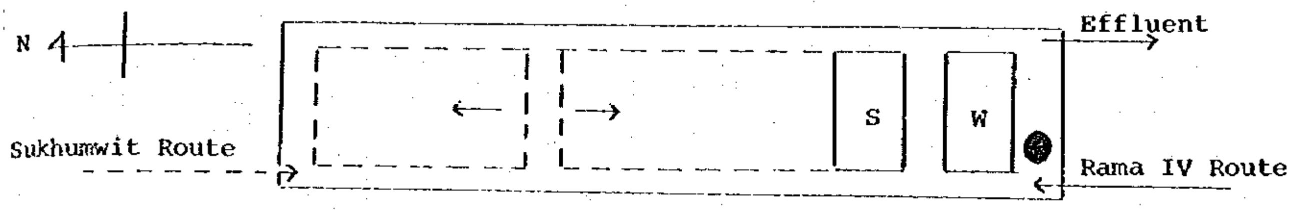
S .... Sludge Treatment Facilities

[ ] .... Future Expansion

Alternative II: Operating building is located at the southern end of the proposed plant site. Wastewater treatment process and sludge treatment process are placed apart from each other.



Alternative III: For the First Stage, treatment facilities are placed at the southern part of the site.



In Alternative I, advantage of arrangement of this type is that less operation and maintenance losses are anticipated in the First Stage and the later stage, because the operating building is located at the central portion of the plant. However, since first stage construction is commenced from the central portion, huge landfilling cost for the ponds is required. And, after the First Stage construction, the remaining plant site is divided into two parts, therefore, less flexibility for future site usage is left.

For Alternative II, initial landfilling cost is less than Alternative I, and flexibility for future site usage is not retained. Disadvantage of this arrangement is that initial investment of piping and conduits for operating facilities is the highest among the three alternatives, because the treatment processes are apart from each other.

For Alternative III, initial landfilling cost is the lowest among the three alternatives, because southern part of the pond is shallow. As for flexibility for incorporating design modifications and expansion of the treatment plant for future needs, this alternative is superior to the other alternatives.

From the above study, Alternative III is recommended. The wastewater treatment plant layout for the First Stage is prepared according to basic arrangement of the above alternative, as shown in Figure 8.3. The treatment plant site required for the First Stage is an area of 12.5 ha.

Table 8.5 Sizes and Numbers of Units of Wastewater Treatment Facilities

Civil & Architectural Works			Major Mechanical Equipment		
Name of Facilities	Number of Unit	Description	Name of Equipment	Number of Unit	Description
Inlet	1	Box: 2,100 mm x 2,100 mm Gradient: 1.1 Vertical: 1,000 Horizontal Invert elevation: $27^{M}090$			
Pumping Building	1	Ø32.0 m Building area: 800 m^2 B2nd Floor: Wet Well Pump Room B1st Floor: Screen Room Motor Room	Influent Gate Influent Pump (No. 1) Influent Pump (No. 2)	2 2 2 (1)	Rectangular sluice gate ${}^{W}1,500$ mm x ${}^{H}1,500$ mm Vertical mixed flow pump Ø600 x 45 m^3/min x 15.0 m x 150 kW Vertical mixed flow pump Ø800 x 80 m^3/min x 15.0 m x 270 kW
Grit Chamber	3	${}^{W}2.0$ m x ${}^{L}27.0$ m x ${}^{H}1.8$ m			
Flow Meter			Parshall Flume	1	${}^{W}182.88$ cm (6 ft) max. capacity 2.93 m^3/sec min. capacity 0.0736 m^3/sec
Aeration Tank	4	${}^{W}13.5$ m x ${}^{L}54.0$ m x ${}^{H}4.0$ m	Aerator	16	Vertical shaft surface aeration: 15 kW/unit
Sedimentation Tank	8	Circular type Ø26.0 m x ${}^{H}2.5$ m	Sludge Collector Return Sludge Pump Excess Sludge Pump	8 4 (2) 4 (2)	Circular clarifier Ø26.0 m x 1.5 kW Horizontal non clog type Ø200 x 5.6 m^3/min x 5 m x 15 kW Horizontal non clog type Ø100 x 1.0 m^3/min x 5.5 kW

(Continued)

Civil & Architectural Works			Major Mechanical Equipment		
Name of Facilities	Number of Unit	Description	Name of Equipment	Number of Unit	Description
Chlorination Chamber	1	$^{W}3.0$ m x $^{L}158.0$ m x $^{H}3.0$ m	Chlorinator	2	Vertical type: 35 kg/hr
			Chlorine Solution Water Pump	2	No. 1 Horizontal shaft multistage pump Ø50 x 280 l/min x 30 m x 5.5 kW
			Neutralization Equipment	1	
			Caustic Soda Pump	1	Horizontal shaft chemical pump Ø80 x 500 l/min x 15 m x 3.7 kW
			Blower	1	Turbo fan (Belt drive) 40 m^3/min x 200 mm Ag x 5.5 kW
			Hoist	1	Motor driven hoist 2 ton x 5.5 kW
			Chlorination Tank, Inlet and Bypass Gate	2	Square type, Manual drive, Cast iron gate $^{W}1,500$ mm x $^{H}1,500$ mm
Thickening Tank	2 (1)	Circular type Ø17.6 m x 3.0 m	Sludge Collector	2	Circular type thickener Ø17.7 m x $^{H}3.0$ m x 1.5 kW
			Concentrated Sludge Pump	2 (1)	Horizontal shaft non clog type Ø100 x 1 m^3/min x 10 m x 5.5 kW
Digestion Tank	2	Anaerobic two-stage Ø22.0 m x $^{H}10.8$ m	Gas Mixing Blower	2 (1)	Rotary blower Ø80 x 4.4 m^3/min x 1.5 kg/cm^2 x 7.5 kW
			Air Compressor	2 (1)	Oil free compressor with pressure switch 300 l/min x 7 kg/cm^2 x 2.2 kW
			Sludge Circulation Pump	1	Horizontal shaft non clog type Ø150 x 2 m^3/min x 5.0 m x 7.5 kW
			Digested Sludge Pump	2 (1)	Horizontal shaft non clog type Ø100 x 1 m^3/min x 5.0 m x 3.7 kW

(to be continued)

(Continued)

Civil & Architectural Works

Name of Facilities	Number of Unit	Description
Gas Holder	1	Dry seal type Ø19.3 m x $^{H}21.5$ m
Drying Bed	60	Drying Bed Area: 1.14 ha $^{W}10.0$ m x $^{L}19.0$ m x $^{H}2.0$ m
Operating Building	1	Ø320 m Building area: 800 m^2 1st Floor: Laboratory Training Room 2nd Floor: Manager Room Office Room Control Room 3rd Floor: Pent House
Room for Laborers	1	Building area: 370 m^2 1st Floor: Room for Labor Work Shop
House of Workers		Site area: 1.1 ha

Note: Figure in the parentheses of Number of Unit Column indicates number of stand-by facilities.
Total energy consumption in full operation is assumed 13,000 kW/hr.
Cake volume with water content of 30% from drying beds is estimated at 15 m^3/day.

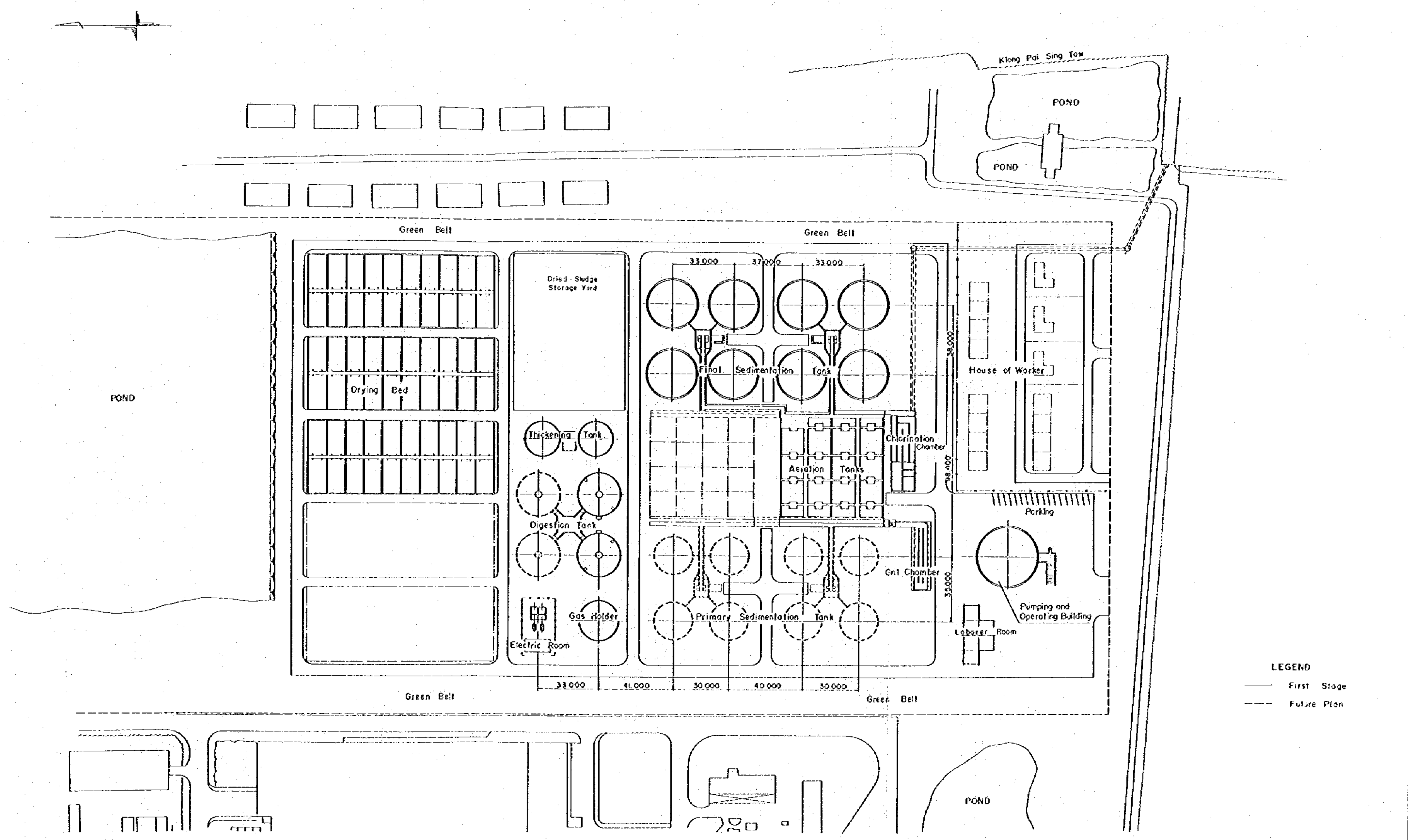


Figure 8·3
TREATMENT PLANT LAYOUT

(5) Plant Hydraulics

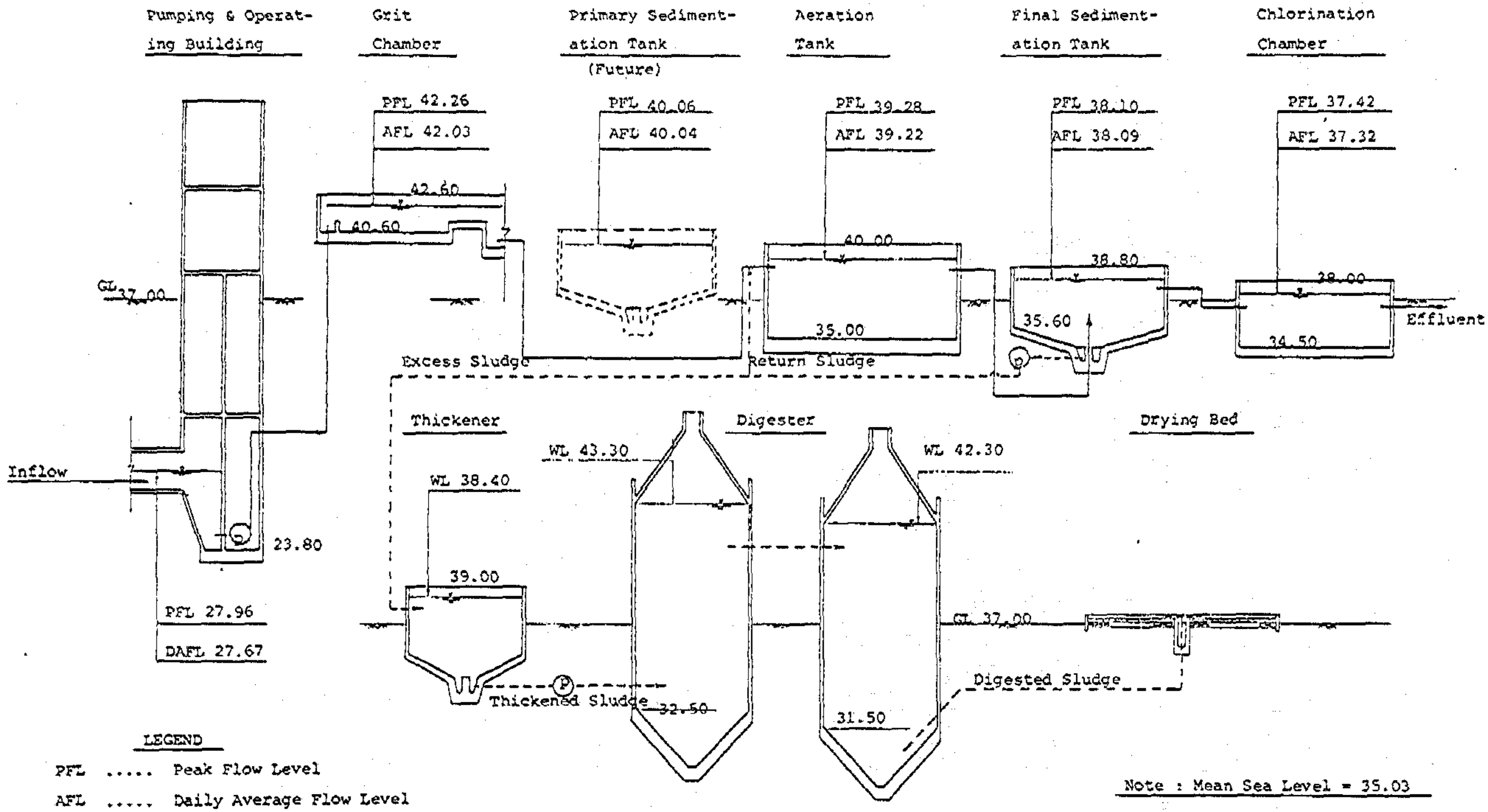
Hydraulic calculation of the treatment plant is conducted to examine the hydraulic profile from the grit chamber through the outlet and determine all the water levels of basins of the treatment facilities. Given basic conditions for this calculation are 1) the H.W.L. of Klong Pai Sing Tow to which the final effluent of the plant is to be discharged by gravity, and 2) throughput of the plant which is determined as the daily average flow, under the condition that the flow through the treatment processes is to be all by gravity.

As for the procedure of the calculation, sizes of all the conduits including pipes are presumed on the basis of preferable velocity of flow 1.0 m/sec. Based on this, losses of head are calculated, and the obtained hydraulic profile is checked about its suitability.

Regarding the water level of Klong Pai Sing Tow, the adopted figure is 36.83 m which is the highest water level of 100-year recurrence frequency of the Chao Phya River, estimated by the CDM report. In the meantime, the corresponding figure for 5-year recurrence frequency is 36.75 m, which has no significant difference from the adopted figure for the design.

The results of the computation are summarized as a hydraulic profile in Figure 8.4.

Details of the wastewater treatment plant, including 1) plan of the plant and 2) structural drawings thereof, are presented in volume III Drawings.



LEGEND

PFL ..... Peak Flow Level
AFL ..... Daily Average Flow Level
WL ..... Water Level
GL ..... Ground Surface Level
(P) ..... Pump

Note : Mean Sea Level = 35.03

Figure 8.4 Hydraulic Profile of Proposed Treatment Facilities

(6) Electric Installations

Basic conditions and concept for the preliminary engineering design of electric facilities are as follows.

1) Power Source

Electric power required for the sewerage system will be taken from the well-established electric power supply system of Metropolitan Electric Authority.

Generation of electric power by digester gas for the use of the treatment plant will be implemented after a detailed study on the actual gas production when the First Stage plant is put into service (refer to AppendiX F).

2) Receiving and Distributing Equipment

The type of receiving and distributing equipment will be that for outdoor, because sufficient open space for the equipment is available and this type requires less construction cost.

3) Distribution Voltage

Primary supply voltage is assumed to be 6.6 kV, considering that the supply systems under construction or to be constructed are to have 6.6 kV, although the existing primary supply voltage is mostly 3.3 kV.

Secondary system voltage will be 380 V, 3-phase for major equipment and 200 V for lighting and small appliances.

4) Instrumentation Equipment

Instrumentation equipment will be installed for measuring, recording, indicating, controlling, etc. of such items as influent flow rate, effluent flow rate, sludge volume generated, gas volume produced, wastewater temperature, dissolved oxygen content, etc.

5) Supervisory Control System

A supervisory control system, consisting of supervisory panels and central operating tables, will be installed at the pumping and operating building which enables the operator to supervise and control the entire wastewater treatment facilities in the plant.

CHAPTER 9

CONSTRUCTION MATERIAL AND METHOD

This chapter studies the availability of, and also the necessity of import for, construction materials for the purpose of estimating the project cost, which is broken down to two components, local and foreign. Construction methods practicable for the present sewerage system construction are also studied, in that the construction cost and the implementation of the project are largely influenced by the method.

9.1 Construction Materials

a. Structural Concrete

Concrete aggregates are sufficiently available. Coarse aggregate is obtained by rock crushing works in the mountainous regions to the north, northeast, and south of Bangkok. Sand is obtained from the north where it is dredged from the rivers.

Portland cement is manufactured in Bangkok, conforming to internationally acceptable standards, suitable for construction of sewerage facilities, such as pressure and non-pressure concrete pipes and civil and building works for pumping stations and treatment facilities.

Since most of the sewerage structures are subject to sulfide attack, high-quality sulphate-resisting portland cement specified as Type II in ASTM, is recommended for under-ground structural works.

b. Steel Bar

Both round and deformed steel bars are manufactured locally in good quality and adequate quantities.

c. Piles

Two types of bearing piles of reinforced concrete and pre-cast concrete piles are manufactured locally in good quality and adequate quantities. Wooden piles are also available locally.

d. Pipes

Pipes currently available in Bangkok are limited both in sizes and materials. Reinforced concrete pipe (RCP) is manufactured locally in good quality and adequate quantities. The pipe is manufactured in a wide range of sizes and classes II, III and IV (ASTM and/or TIS) from 0.30 m to 1.5 m in diameter. After this, the factory may be able to produce pipe of larger size easily to meet future requirement.

Centrifugally cast reinforced concrete pipe (CRCP) is also manufactured locally in both pressure and non-pressure types from 0.40 m to 1.5 m in diameter.

Prestressed concrete pipe is manufactured in Bangkok from 0.6 m to 1.5 m in diameter.

Vitrified clay pipe (VCP) is manufactured up to 0.3 m diameter in Rajburi and the quality is totally suitable for sewerage use.

Asbestos cement pipe (ACP) is manufactured in Thailand in limited sizes conforming to internationally accepted standards.

For the selection of sewer materials, careful consideration should be given to the corrosion problem by sulfide buildup in sewers, and capability of joining the pipe in a manner which prevents ground-water infiltration through the joint.

Taking the above points into account the following pipes are proposed for this project.

1) Vitrified clay pipe of 0.30 m or less in diameter for sewers.

2) Reinforced concrete pipe with an extra thickness of sacrificial concrete on the inner surface for sewers of 0.80 m or less in diameter.

3) Centrifugally cast reinforced concrete pipe with an extra thickness of sacrificial concrete on the inner surface and rubber ring joints for sewers of more than 0.80 m in diameter.

4) Asbestos cement pipe or steel pipe with an extra thickness of sacrificial concrete and/or PVC backribbed sheet lining for pressure sewer.

5) Steel pipe or centrifugally cast reinforced concrete pipe for jacking sewers.

e. Manhole Materials

Manhole materials include frame, cover, brick, precast concrete cone and cast-in-place concrete. The cast iron made manhole frame and cover have been imported from Japan and others. The other materials are available locally in good quality and adequate quantities.

f. Sheet Piles

Timber for sheet piling is sufficiently available in Bangkok. Steel sheet pile has been imported from Japan and Malaysia, etc.

g. Mechanical and Electrical Equipment for Intermediate Pumping Stations and Wastewater Treatment Plant

Almost all machinery and equipment required for intermediate pumping stations and wastewater treatment plant are imported in Thailand except steel pipe, screen, transformer up to 3,000 kVA, and electric cable which are manufactured locally.

The availability of the proposed mechanical and electrical equipment is shown in Table 9.1.

Table 9.1 Availability of Proposed Mechanical and Electrical Equipment

Facilities	Selected Machinery and/or Equipment	Availability	
		Domestic	Import
Intermediate Pumping Station			
Inlet Gate	Cast-Iron made, manual drive		o
Pump	Submergible type		o
Screen	Coarse screen, manual drive	o	
Wastewater Treatment Plant			
Inlet Gate	Cast-Iron made, manual drive		o
Main Pump	Vertical shaft mixed flow volute		o
Screen	Coarse screen, manual drive	o	
Grit Collector	Gate type crane with grab bucket		o
Flow Meter	Parshall flume	o	
Sludge Collector	Circular type	o 1/	o 2/
Sludge Pump	Non clog type		o
Aeration System	Mechanical aerator		o
Disinfection System	Chlorinator		o
Pipe	Cast Iron pipe		o
	Steel Pipe	o	
Transformer	Oil type		o
Breaker	Vacuum type		o
"	Gas Type		o
Condenser	Static capacitor		o

Note: 1/ Collector

2/ Motor

9.2 Construction Methods

The present project includes construction of rather large-scale and complex facilities, covering interceptors, pumping stations and treatment facilities, which all require skill and experience and also civil works machines. Major requirements, therefore, of those construction works and capability of local contractors will first be reviewed, and most suitable methods will be selected in the following. The cost estimate of the project will be made based on the finally recommended methods.

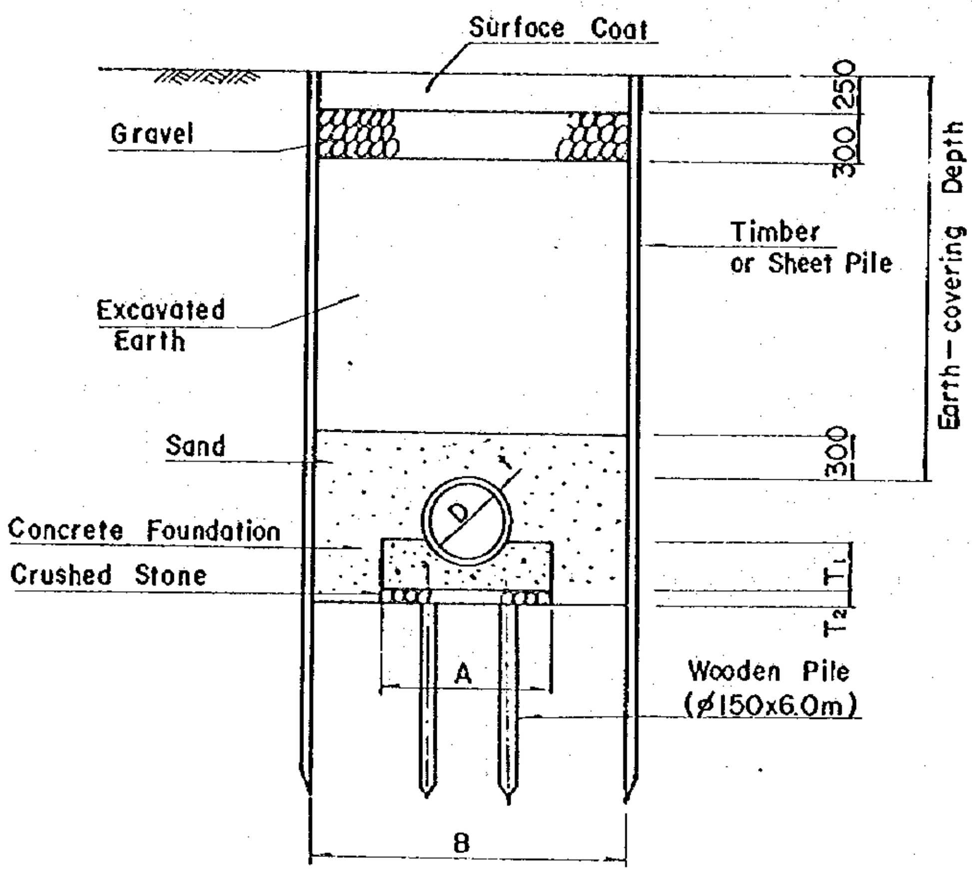
9.2.1 Construction Works

Major construction works of the present project are roughly classified into two categories, namely, laying of sewers and construction of basins and buildings. Salient points regarding such construction works are described below.

a. Sewers

There are, roughly, two applicable methods for laying sewers in the present project: one, the open-cut method and the other, tunneling method. The open-cut method is applicable when the sewer diameter is small and the area concerned is not congested. Most of the sewers of the present project will be laid using this method. Typical crosssection of sewer laying by this method is shown in Figure 9.1.

When the sewer diameter and burial depth are large, and traffic is heavy and cannot be detoured, the tunneling method will be applied. The method includes some sub-classifications, among which the jacking method is recommended for the present project, as it is rather simple and economical. Further, this method is considered appropriate from the diameter and the conditions of the sewer route. The method is schematically shown in Figure 9.2. (Refer to Appendix G)



D	t	B	A	T1	T2
300	50	1,100	500	250	50
400	60	1,100	800	300	50
500	60	1,200	800	300	50
600	70	1 350	900	350	50
800	85	1,600	1,200	500	50
1,000	95	1,950	1,400	500	50
1,200	108	2,150	1,600	550	50
1,500	150	2,500	1,900	600	50

Dimension in mm

Figure 9·1
TYPICAL CONCRETE PIPE BEDDING IN TRENCH

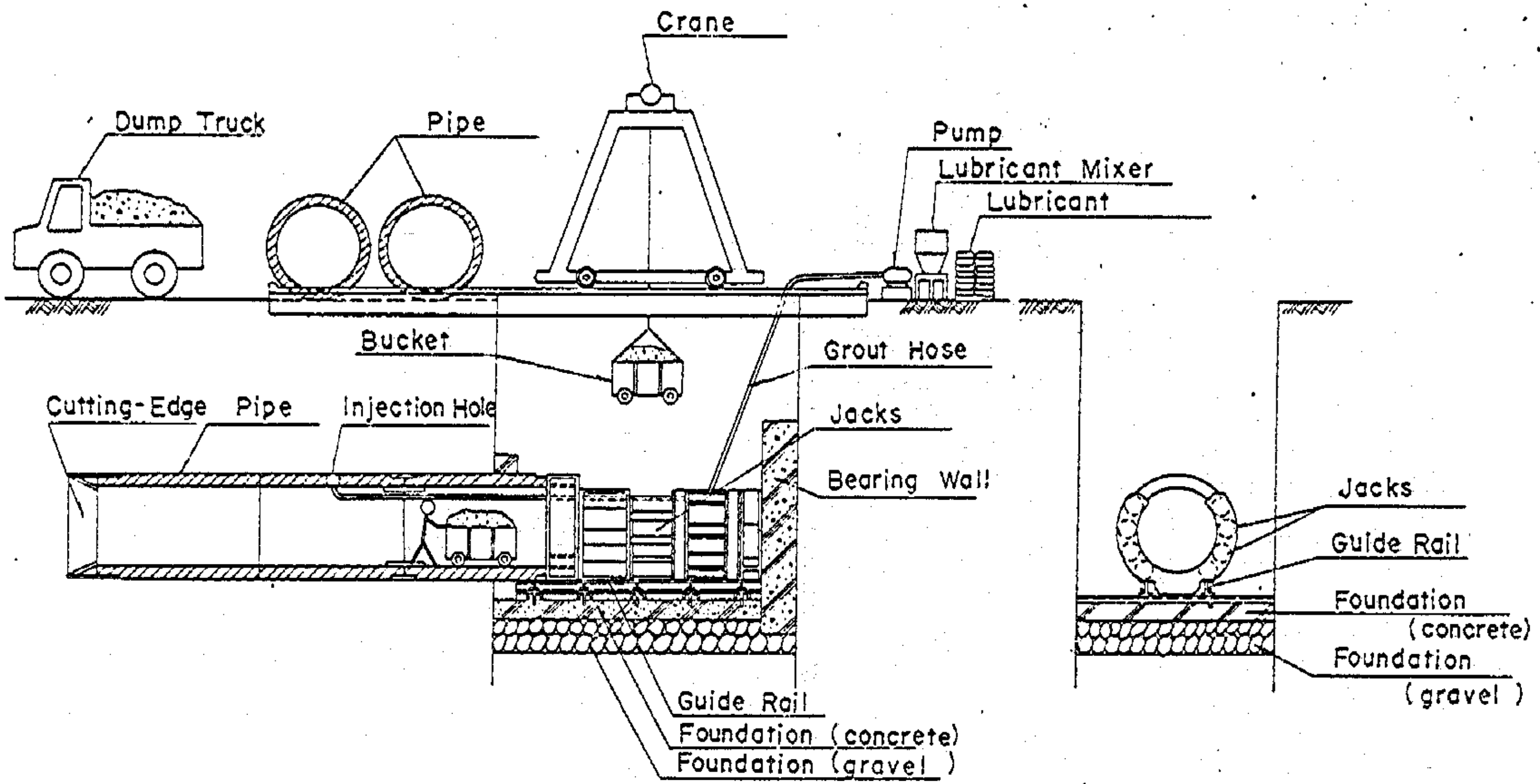


Figure 9·2
TYPICAL PIPE JACKING METHOD

b. Intermediate Pumping Stations

As the intermediate pumping stations are to be built in built-up commercial and residential areas, the available area for their construction is quite limited. Besides, the lowest part of the buildings reaches as deep as GL -5 m to -7 m. Therefore, sheet piling to protect the working area is indispensable to carry out foundation, piping and concrete works by the open-cut method.

c. Treatment Facilities

As the site for the treatment plant is presently ponds, land filling after dewatering is prerequisite for construction work. Bottoms of substructures are generally shallow, -1.0 m to -3.0 m below GL, so the open-cut method without land slide protection is applicable. As the groundwater level is rather high, -0.5 m to -1.0 m below GL, dewatering must be practiced all through the construction work.

The pumping and operation building, among others, has a rather deep foundation. As sheet piling is not suitable because of the soft soil condition, the caisson or diaphragm method (refer to Figure 9.3) will be recommended. Regarding pipes to be connected to this structure, special consideration must be made to protect the pipe from breakage or dislocation due to uneven settlement of the backfilling or the structures. For foundation, cast-in-site piles are recommended for convenience of execution.

9.2.2 Capability and Selection of Contractors

There are many local contractors, large and small. Their capability is widely varied. Large contractors, some of whom are associated with foreign contractors, are experienced in large-scale and complicated civil engineering works, such as speed ways, banks, hotels and drinking water treatment plants, requiring high technology and skill.

On the other hand, the present project includes a wide variety of works, from simple to complicated. The jacking method of sewers and the diaphragm method for the treatment plant, as recommended above, may be new to the local contractors. In view of the nature and variety of the works, selection of contractors is recommended as described below.

Requirements for contractors are different from work to work; simple and small works will be carried out by small contractors, and complex and difficult works may be executed only by large contractors. Before proceeding to tendering, therefore, prequalification of potential contractors is recommendable in order to know the capability of each contractor and classify contractors according to the scale and difficulty of the works, and further to know the necessity to import foreign technology. Competitive tendering should be made among contractors selected by the above prequalification.

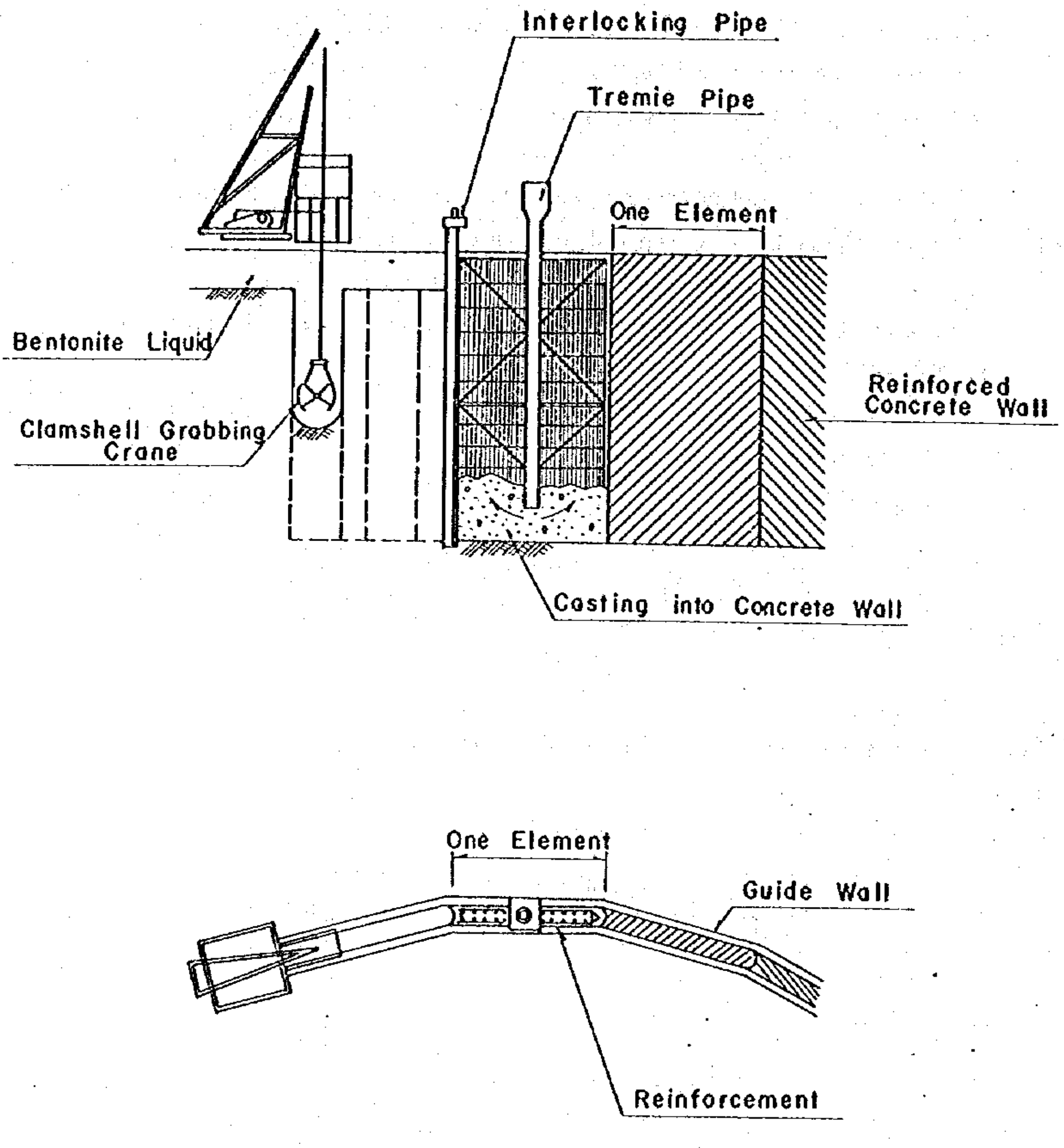


Figure 9·3
CAST IN SITE DIAPHRAGMS METHOD

CHAPTER 10

COST ESTIMATES AND CAPITAL INVESTMENT SCHEDULE

This Chapter deals with, based on the engineering design and construction method so far described in the preceding Chapters 8 and 9, the project cost, operation and maintenance costs and the capital investment schedule of the sewerage facilities to be implemented in the First Stage.

10.1 Project Cost

Procedures for estimating the project cost, and the estimated project cost which is divided into two components: local currency and foreign currency, are described in the following.

The project cost for the First Stage consists of the construction cost of the proposed sewerage facilities: sewers, intermediate pumping stations and the treatment plant, equipment cost of the cleaning machines and laboratory equipment, and consulting services, contingencies and land acquisition costs.

10.1.1 Basis of Project Cost Estimates

For estimating the construction costs of the proposed sewerage facilities, unit prices for labor, materials, equipment, power and transportation, both locally available and imported, have been collected and checked during the course of the present study.

Using the data obtained from various sources in Bangkok, the construction costs are calculated based on three categories, namely, labor costs, basic materials, and unit costs for construction including both labor and materials, as described in detail in Appendix H. All costs are expressed in 2524 (1981) price levels in Bangkok.

Materials for structures of pipe bedding, pumping station and treatment facility are generally available in Bangkok, except mechanical and electrical equipment for the pumping stations and treatment plant.

Values of the land are also estimated on the basis of the information obtained from the Department of Land, Ministry of Interior (MOI). The official price of lands estimated by the said department on the basis of their potential land uses and related frontages of paved or unpaved roads is available. The current official price of the land for proposed treatment plant site is, according to the above estimation, 750 Baht per square meter, and for intermediate pumping stations is, 3,250 Baht per square meter.

The project cost may be defined basically as the sum of all expenditures required to bring the project to completion. The expenditures for the civil works, installation of the equipment, contractor's profits and overhead, and all related construction works are divided into direct items and indirect items.

The project cost is divided into the local currency component and foreign currency component. The local currency component includes costs of labor and materials actually paid in the local currency. Namely, it comprises the costs for local labor and materials locally manufactured or produced, including local handling and transportation charge for imported materials and for expatriate's local expenditure.

The foreign currency component represents the costs to be paid in foreign currency such as those of imported materials and equipment (CIF prices) and foreign currency portion of expatriate service fees.

10.1.2 Estimated Project Cost for the First Stage

Table 10.4 shows the project cost for the First Stage, including consulting services, contingencies and land acquisition costs. Table 10.1 through Table 10.3 show breakdown of construction costs for sewer facilities, intermediate pumping stations and the treatment plant (Refer to Appendix I).

In the estimation, costs of consulting services include the costs both for detailed engineering design and construction supervision services. It is assumed that 10 percent of the construction costs will be needed for the engineering services, approximately 5 percent is considered to be needed for the detailed design and the remaining 5 percent for the construction supervision services.

As contingency allowances, 20 percent of the estimated construction costs including consulting services and procurement of cleaning machines is estimated on the basis of the similar projects experienced and also taking into account physical and price factors.

The total project cost including land acquisition and contingencies amounts to 883.1 million Baht out of which the local currency component is 633.0 million Baht and the foreign currency component, 250.1 million Baht.

Table 10.1 Estimated Construction Costs for the Sewer Facilities

Unit: Million Baht at 2524(1981) Price Level

Name of Sewer	Civil Works		Total
	L.C.	F.C.	
Chula Interceptor	7.73 (0.83)	0.84	8.57 (0.83)
Charoen Krung Interceptor	8.75 (0.94)	0.97	9.72 (0.94)
Klong Sathorn Interceptor	28.80 (4.44)	4.73	33.53 (4.44)
Chong Nonsi Combined Sewer	66.53 (0.01)	0.02	66.55 (0.01)
Trunk Interceptor	20.60 (1.23)	17.19	37.79 (1.23)
Total	132.41 (7.45)	23.75	156.16 (7.45)

Note: L.C. means local currency component.
F.C. means foreign currency component.
Figures in parentheses indicate total amount of import duty, standard profit and business tax.

Table 10.2 Estimated Construction Costs for the Intermediate Pumping Stations

Unit: Million Baht at 2524(1981) Price Level

Name of Pumping Station	Civil & Architectural Works		Mechanical & Electrical Works		Total		
	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	Sub-total
Chula	0.79 (0.02)	0.09	1.22 (0.56)	1.70	2.01 (0.58)	1.79	3.80 (0.58)
Charoen Krung	0.94 (0.02)	0.14	1.22 (0.56)	1.70	2.16 (0.58)	1.84	4.00 (0.58)
Klong Sathorn	0.85 (0.02)	0.12	0.89 (0.44)	1.14	1.74 (0.46)	1.26	3.00 (0.46)
Total	2.58 (0.06)	0.35	3.33 (1.56)	4.54	5.91 (1.62)	4.89	10.80 (1.62)

Note: L.C. means local currency component.
F.C. means foreign currency component.
Figures in parentheses indicate total amount of import duty, standard profit and business tax.

Table 10.3 Estimated Construction Costs for the Treatment Plant

Unit: Million Baht at 2524 (1981) Price Level

Name of Facility	Civil & Architectural Works			Mechaincial Works			Electrical Works			Total		
	L.C.	F.C.	Sub-Total	L.C.	F.C.	Sub-Total	L.C.	F.C.	Sub-Total	L.C.	F.C.	Sub-Total
1. Pumping & Operating Building	47.04 (0.63)	9.82	56.86 (0.63)	11.42 (9.70)	27.35	38.77 (9.70)	5.46 (4.40)	8.40	13.86 (4.40)	63.92 (14.73)	45.57	109.49 (14.73)
2. Grit Chamber	2.11	-	2.11	3.85 (3.43)	7.33	11.18 (3.43)	-	-	-	5.96 (3.43)	7.33	13.29 (3.43)
3. Aeration Tank	19.54	-	19.54	4.97 (4.50)	9.86	14.83 (4.50)	2.77 (2.48)	4.61	7.38 (2.48)	27.28 (6.98)	14.47	41.75 (6.98)
4. Final Sedimentation Tank	22.08	-	22.08	15.95 (5.55)	16.80	32.75 (5.55)	7.13 (4.81)	8.80	15.93 (4.81)	45.16 (10.36)	25.60	70.76 (10.36)
5. Chlorination Chamber	4.28	-	4.28	2.82 (1.95)	4.14	6.96 (1.95)	1.11 (0.97)	1.86	2.97 (0.97)	8.21 (2.92)	6.00	14.21 (2.92)
6. Outlet	3.64	-	3.64	-	-	-	-	-	-	3.64	-	3.64
7. Thickening Tank	3.60	-	3.60	2.63 (1.10)	3.16	5.79 (1.10)	-	-	-	6.23 (1.10)	3.16	9.39 (1.10)
8. Digestion Tank	14.75	-	14.75	3.76 (1.25)	3.22	6.98 (1.25)	1.85 (1.65)	3.07	4.92 (1.65)	20.36 (2.90)	6.29	26.65 (2.90)
9. Gas Holder	0.92	-	0.92	4.32 (4.32)	13.08	17.40 (4.32)	-	-	-	5.24 (4.32)	13.08	18.32 (4.32)
10. Drying Bed	5.06	-	5.06	0.78	-	0.78	-	-	-	5.84	-	5.84
11. Electric Room	0.42	-	0.42	-	-	-	8.71 (8.37)	15.56	24.27 (8.37)	9.13 (8.37)	15.56	24.69 (8.37)
12. Power Receiving	1.18	-	1.18	-	-	-	5.89 (3.67)	7.76	13.65 (3.67)	7.07 (3.67)	7.76	14.83 (3.67)
13. Labor Room	1.57	-	1.57	-	-	-	-	-	-	1.57	-	1.57
14. Earthwork	53.45	-	53.45	-	-	-	-	-	-	53.45	-	53.45
15. Land Scaping	10.16	-	10.16	-	-	-	1.12	-	1.12	11.28	-	11.28
Total	189.80 (0.63)	9.82	199.62 (0.63)	50.50 (31.80)	84.94	135.44 (31.80)	34.04 (26.35)	50.06	84.10 (26.35)	274.34 (58.78)	144.82	419.16 (58.78)

Note: L.C. means local currency component.
F.C. means foreign currency component.
Figures in parentheses indicate import duty, standard profit and business tax.

Table 10.4 Estimated Project Cost for the Proposed Sewerage Facilities in the First Stage

Unit: Million Baht at 2524 (1981) Price Level

Name of Facility	Local Currency	Foreign Currency	Total
1. Sewers	132.41	23.75	156.16
2. Intermediate Pumping Stations			
a) Chula	2.01	1.79	3.80
b) Charoen Krung	2.16	1.84	4.00
c) Klong Sathorn	1.74	1.26	3.00
3. Treatment Plant	274.34	144.82	419.16
4. Cleaning machine & laboratory equipment	4.50	5.10	9.60
5. Sub-total (1+2+3+4)	417.16	178.56	595.72
6. Consulting Services (5x10%)			
a) Engineering Design	14.90	14.90	29.80
b) Supervision	14.90	14.90	29.80
7. Contingencies [(5+6)x20%]	89.40	41.70	131.10
8. Land Acquisition	96.69	-	96.69
9. Sub-total (6+7+8)	215.89	71.50	287.39
10. Total (5+9)	633.05	250.06	883.11

Note: Land acquisition costs are estimated as follows:

For the intermediate pumping stations

Chula : 0.98 million Baht ($300m^2$x3,250 Baht/m^2)
Charoen Krung : 0.98 million Baht ($300m^2$x3,250 Baht/m^2)
Klong Sathorn : 0.98 million Baht ($300m^2$x3,250 Baht/m^2)

For the treatment plant

93.75 million Baht (12.5hax7.5 million Baht/ha)

Total 96.69 million Baht

10.2 Operation and Maintenance Costs

Procedure for estimating the operation and maintenance costs and the estimated costs of operation and maintenance for the proposed sewerage facilities: sewers, intermediate pumping stations and treatment plant, are dealt with below.

Administrative expenses, including personnel cost of all workers are excluded from this operation and maintenance costs. Administrative expenses will be described later in Chapter 11. (Refer to Appendix J)

10.2.1 Sewers

For cleaning the public sewers 200 mm in diameter or larger, a power driven bucket machine will be used. The assumptions made for the estimation are as follows:

Frequency of Cleaning

Public sewers (newly constructed) ... once in every four years

Public sewers (existing) .... once a year

Cleaning Capacity

Public sewers .... 200 m/day

Crew Number

Public sewers .... Six persons

Useful Life Span of Equipment .... Ten years

Cost for Spare Parts, Repairing, Overhauling of Equipment .... 5% of equipment cost (per annum)

Annual rehabilitation cost of sewers .. 0.5% of construction cost

Work Days and Hours

Work days .... 250 days per year

Work hours ...., 6 hours per day

Price of a power driven bucket machine is 4.4 million Baht/set.

Based on the assumptions above, annual operation and maintenance costs per meter of sewer except the administrative expenses are estimated to be 16 Baht at 2524 (1981) price level.

Annual operation and maintenance costs except the administrative expenses for the sewers in the area are shown in Table 10.5.

Table 10.5 Annual Operation and Maintenance Costs for the Sewers

Unit: Million Baht at 2524 (1981) Price Level

Item	Cost	Remarks
Proposed Sewers	0.03	8,400mx1/4yrx16Baht/m=33,600Baht/yr
Existing Sewers	1.60	100,000mx16Baht/m=1,600,000Baht/yr
Total	1.63	

10.2.2 Intermediate Pumping Stations

Operation and maintenance costs for the intermediate pumping stations are derived from labor and material costs including power, fuel, lubrication, screenings removal and disposal, and major repairing of equipments.

Personnel cost is estimated on the assumption that one operator is stationed at each intermediate pumping station for inspection and cleaning of the pumps and removal of screenings which will be made once a day at least.

Annual repairing cost is assumed to be 1 percent per annum of the civil and architectural works costs, and 2 percent per annum of the electrical and machanical works cost. Power cost is estimated at approximately 1.5 Baht/kWh.

Annual operation and maintenance costs except the personnel cost for each intermediate pumping station are shown in Table 10.6.

Table 10.6 Annual Operation and Maintenance Costs for the Intermediate Pumping Stations

Unit: Million Baht at 2524(1981) Price Level

Item \ Name of Pumping Station	Chula	Charoen Krung	Klong Sathorn
Power Cost	0.18	0.36	0.13
Repairing Cost	0.07	0.07	0.05
Total	0.25	0.43	0.18

10.2.3 Treatment Plant

Operation and maintenance costs for the treatment plant are derived from labor and material costs including power, fuel, chemical, and major repairing of equipments.

The number of employees required for operation and maintenance of the treatment plant is assumed to be 25 persons in the First Stage.

Annual repairing cost is assumed to be 1 percent per annum of the civil and architectural works costs, and 2 percent per annum of the electrical and mechanical works costs. Power cost is estimated at approximately 1.5 Baht/kWh.

Annual operation and maintenance costs except the personnel cost for the treatment plant are shown in Table 10.7.