BANGKOK SEWERAGE SYSTEM PROJECT
IN
KINGDOM OF THAILAND

MASTER PLAN REPORT
VOLUME II
MAIN REPORT

AUGUST 2524 (1981)

JAPAN INTERNATIONAL COOPERATION AGENCY

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MAIN REPORT

ON

BANGKOK SEWERAGE SYSTEM PROJECT

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MASTER PLAN REPORT

Guide to the Reports

The Reports consist of the following,

VOLUME I	:	EXECUTIVE SUMMARY
VOLUME II	:	MAIN REPORT
VOLUME III	:	DRAWINGS
VOLUME IV	:	APPENDICES

VOLUME II - MAIN REPORT

ORDER OF PRESENTATION

TABLE OF CONTENTS

Table of Contents

Volume II

Chapter | Page

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

INTRODUCTION

As of 1980, except in some of the newly developed housing areas, there is no comprehensive sewerage system in Bangkok Metropolitan Area. Excreta disposal is conducted almost entirely through septic tank, cesspool or storage tank. Wastewater from washing, baths and kitchens is collected separately from human excreta and discharged to the nearest drain or water course. Although the overflows from septic tanks and cesspools are prohibited to be discharged into drains by law, such overflows are discharged into drains either through illegal connection pipes or ground surface due to the impermeable soil of clay type. The system of klongs which extends throughout the area serves as a receiving body for a large portion of the all sort of wastes generated in Bangkok Metropolitan Area.

The situation as described above has provoked the pollution of the klongs and the Chao Phya River to a degree that constitutes a deplorable aesthetic nuisance and potential health hazard to the general public.

In the past 20 years, several master plans for sewerage, drainage and flood protection were prepared. On the basis of those plans, drainage and flood protection facilities have been partly constructed. Since the problems caused by lack of drainage and flood protection facilities have been more apparent than those caused by lack of sewerage, the priority has been given to the program of drainage and flood protection.

However, the condition of the increased pollution of both the Chao Phya River and the klongs has made the government and the general public aware of the importance of and need for sewerage facilities in addition to drainage and flood protection program.

In order to meet with such requirement, the area urbanized or to be urbanized in Bangkok Metropolitan Area of approximately 37,000 hectares defined as attached Figure, is designated as the Study Area, for the purpose of establishing the comprehensive regional sewerage master planning on the basis of the review of the previous studies on the subject matter.

The Area is comprised by 18 administrative districts of Bangkok Metropolitan Area, namely Phra Nakhon, Pom Prap Sattru Pai, Pathumwan, Sampanthawong, Bang Rak, Yan Nawa, Dusit, Phaya Thai, Huai Khan, Phra Khanong, Bang Khen, Bang Kapi, Thonburi, Khlong San, Bangkok Noi, Bangkok Yai, Bangkhun Thian and Rat Burana, with a population of some 4.0 million as of 2522 (1979).


KLONG BANGSUE
LAT PRAO ROAD
KLONG LAT PRAO
CHAO PHAYA RIVER
KLONG SAN SEP
RAMA VI ROAD
CHAHOL YOTHIN ROAD
MITTAPHAP ROAD
KLONG WONG ROAD
SAMSEN ROAD
KLONG BANG KOK NOI
KLONG LAMPOO
KLONG HUA DUAK
KLONG BANG
KLONG MAHANAK
KLONG SAN SAEP
RAM KAMHENG ROAD
PETCHABURI ROAD
RAMA I ROAD
CHARAN SANIT
KLONG MON
KLONG KAI
KLONG BANG KOK
KLONG KASEM
SRI WONG ROAD
SILOM ROAD
RAMA IV ROAD
SUKHUMVIT ROAD
PRAKANONG - KLONG TAN ROAD
KLONG TAN
KLONG SATHON
TAKSIN ROAD
CHAROEN KRUNG ROAD
KLONG CHONG NONSI
KLONG TOEY
KLONG PRAKE NONG
CHAO PHAYA RIVER
LEGEND
Master Plan Area
Study Area

CHAPTER 1

SUMMARY

1.1 Purpose and Scope of the Study

The main purposes of the study on sewerage system for Bangkok Metropolitan Area are to:

(a) Develop a comprehensive master plan on sewerage system in which the major elements of the relevant subject matters are properly forecast and generally define for implementation in successive phases to meet the present and future needs in the Study Area up to the year 2543(2000) on the basis of the sound technical and socio-economic consideration, compatible with proper projection of population increase, housing development, water consumption and water supply services, income growth, and other national and local socio-economic factors affecting the future of the Study Area.

(b) In particular, identify sewerage implementation area, develop implementation program and explore funding arrangement for construction, operation and maintenance with due consideration on the available financial resources.

(c) Undertake studies and formulate recommendations regarding the proper organization to effectively carry out the planning and designing, construction, operation, management and administration of the sewerage system, together with consideration on proper legislative provisions, which may be required for establishment and activities of the proposed organization.

(d) Suggest interim measures to improve the existing environmental conditions by identifying sources of pollution and establishing control program, economical but best suited for each case, until the sewerage system is completed and sources of pollution become under control.

1.2 Summary of Findings and Recommendations

1.2.1 Findings

(a) The Chao Phya River Basin, in which the Study Area is situated, is essentially a flat alluvial plain, lying below equal or less than one meter above mean sea level.

(b) Temperature is relatively constant throughout the year and the average monthly temperature varies between about 26 and 30°C. (Refer to Chapter 2)

(c) Heavy rain was recorded from May to October. According to the rainfall records obtained in ten years from 2513(1970) through 2522(1979), the mean annual rainfall during these months was 1,215 mm, accounting for 87 percent of the average annual rainfall of 1,402 mm. (Refer to Chapter 2)

(d) Prior to this project, the master plan for "Sewerage, Drainage and Flood Protection Systems, Bangkok and Thonburi" was established by Camp Dresser & McKee (Consulting Engineers, U.S.A. - hereinafter calls CDM) in 2511(1968). (Refer to Chapter 3)

Drainage and flood protection project has partly been commenced already on the basis of the Master Plan prepared by CDM. However, no sewerage construction has been implemented yet.

(e) From 60 to 70 percent of the population in the Study Area use pour-flush toilet on site permeation and about 30 percent of population use flush toilet with cistern septic tank on site permeation.

Sludge from septic tank is transported by vacuum lorries to the dumping site of solid waste for lagooning (at Nong Khem) or for treatment (at On Nooch). (Refer to Chapter 4)

(f) In the central area of Bangkok, public storm sewers contributing to surface drain and sullage water disposal are installed. This sullage water disposal is one of the causes of water pollution of klongs and the river. A part of public storm sewers has presently insufficient flow capacity owing to accumulation of deposit. (Refer to Chapter 4)

(g) To solve the problem of shortage of housing due to population migration to Metropolitan Area, the Central Government has established "National Housing Authority (NHA)" and has been undertaking housing development program. Some of the housing complexes built by NHA have modernized wastewater treatment facilities and are well operated. (Refer to Chapter 4)

(h) Housing developments by the effort of private sectors are also being undertaken actively, and their wastewater treatment is conducted mainly through individual septic tank system.

(i) The migration of population to Bangkok Metropolitan Area has caused several infrastructural problems including heavy traffic resulting in consequent air pollution and noise problems.

(j) Water supply condition in Bangkok Metropolitan Area is generally satisfactory in terms of quantity and quality. The entire Area is already covered by main pipe lines and therefore, all of the population in the Area may soon be covered in the foreseable future. (Refer to Chapter 5)

(k) Water supply system of Bangkok Metropolitan Area is managed by "Metropolitan Water Works Authority (MWWA)". According to their plan, per capita water demands are estimated at 210 l/day/cap for domestic use and 124 l/day/cap for commercial and institutional use in the year 2543(2000). (Refer to Chapter 5)

(l) The influx of people into Metropolitan Area is significant particularly during the current decade. The population of the Area of 1,568.7 km^2 was approximately 5.0 million according to the residence register record of 2522(1979). (Refer to Chapter 7)

(m) The results of the surveys indicate that the effect of pollution by domestic, commercial and other sources of wastes has been evident in waterways of the area surrounded by commercial and residential zones, suggesting the need for implementation of the comprehensive sewerage program. (Refer to Chapter 6)

(n) The proposed project area of Bangkok is administered by the Bangkok Metropolitan Administration (BMA). BMA is organized into 11 bureaus and 24 district offices directly responsible for the activities of local interests. Among 11 bureaus, Bureau of Drainage and Sewerage (BDS) is a recently established unit with primary objective to alleviate or possibly eliminate the recurrent flooding and to control ever-increasing wastewater, both of which have recently been the major concerns of BMA. The duty naturally includes maintenance of existing drainage system and klongs.

The other organizational unit related to waste control is the Bureau of Sanitation (BOS) mainly responsible for the desludging of the widely prevalent cesspools, septic tanks and collection and disposal of solid waste.

BMA's activities are under the control of the central government agencies, especially, the Ministry of Interior. The central government agencies under Prime Minister and Council of Ministers having direct or indirect bearings on the proposed project are:

. National Economic and Social Development Bureau (NESDB)
. Budget Bureau
. Ministry of Finance
. Ministry of Interior

. Ministry of Public Health
. National Environmental Board (NEB)
. Ministry of Industry

The existing organization charts are presented in Figures 16.1, 16.2 and 16.3 of Chapter 16. (Refer to Chapter 16)

(o) The present financial situation of BMA, the agency proposed to administer the project, is reviewed. The magnitude of the most recent annual expenditure of BMA is approximately 3,000 million baht and about 75 percent of the revenue to meet such expenditure is derived from the taxation. The present taxation system is not necessarily satisfactory, having extensive exemption elements resulting in a limited tax revenue. The attempt is understandably being made to amend the present taxation system for the purpose of raising greater amount of revenue.

BMA has been receiving annual subsidy approximately 10 percent of the total revenue from the central government to support its financial viability. (Refer to Chapter 16)

(p) The availability of existing regulations for the proposed sewerage system operation has been reviewed.

The existing regulations related in the different degrees to the sanitary control activities are as follows:

. Public Health Act B.E. 2484 (1941)
. Act for the Cleanliness and Orderliness of the Country B.E. 2503 (1960)
. Building Control Act B.E. 2522 (1979) and its By-Law
. Bangkok Metropolitan Administration Act B E. 2518 (1975)
. City Planning Act B.E. 2518 (1975)
. National Environmental Quality Act (No. 2) B.E. 2521 (1978)

. Notification of the Ministry of Industry issued under Factories Act B.E. 2512 (1969)

. By-Law of Bangkok Metropolis on Control of Trade which is objectionable or may be dangerous to Health B.E. 2519 (1976)

Most of the above regulations stipulate the matters on sanitary control, but they remain to be conceptual and limited in terms of legal definition and its implication. Further provision on the emphasis for practical application are considered desirable. (Refer to Chapter 16)

1.2.2 Conclusions

Out of the field investigation on the existing wastewater disposal, basic design basis for the system to be developed in relation to project implementation is considered. The basic aspect of such consideration are summarized in the following:

(a) The Master Plan will be based on estimated served population in the Area by the year 2543 (2000).

(b) On the basis of 2513 (1970) National Census, population projection by the Working Group on Population, population projection by MWWA, and by summation of present survey, the population of the Study Area is assumed to be 5.6 million for the year 2543 (2000). (Refer to Chapter 7)

(c) Because drainage and flood protection project is already partly initiated on the basis of the existing open drains (including klongs), and the water pollution control of public watercourses have been recognized as very important pending matter, a separate sewerage system will basically be suitable for implementation in Bangkok.

However, in the central area, there exists public storm sewers which drain surface water together with sullage water. In such a area, utilizing these existing pipes to the fullest extent for a new sewerage plan, a combined system will be considered on temporary basis.

(d) The klongs, especially in the central Bangkok, have been polluted by domestic, commercial and other wastes. Therefore, to improve this condition, wastewaters should be treated before discharge to the klongs and/or the river. (Refer to Chapter 11)

(e) To reduce sludge volume and break down the organic matter into simple compounds and also to reduce coliforms, digestion facility in the sludge treatment process should be provided. Digested sludge is useful as fertilizer and advantageous in dumping and transporting. (Refer to Chapter 11)

(f) Taking into account of the drainage basins, topographical conditions, land use pattern with due note of the financial capability, whole Study Area of 37,000 ha will be divided into several zones, with priorities of implementation. (Refer to Chapter 12)

(g) For commemoration of the 200th anniversary of the transfer of the national capital to Bangkok to be held in 2525 (1982), sewerage construction project has started early 2524 (1981) to improve water quality of klongs in Rattanakosin area. Therefore, in this Master Plan, Rattanakosin area will be identified as a single zone (Zone 4) but no plan for sewerage facilities to avoid unnecessary duplication. (Refer to Chapter 12)

(h) Followings are proposed for sewerage designing. (Refer to Chapter 9)

Description	Criteria
Per capita wastewater	246 l/day in 2543 (2000)
Per capita BOD load	64 g/day in 2543 (2000)
Extraneous water to be infiltrated into sewer	7.6 m^3/day/ha
Peak flow vs. average flow	5 : 1 - 2 : 1
Design capacity of pumping station	Expected peak flow
Design capacity of wastewater treatment facilities (including sludge treatment)	Average daily flow

(i) Followings are proposed for sewer designing. (Refer to Chapter 9)

Description	Criteria
Minimum diameter for public sewer	200 mm
Minimum diameter for house connection sewer	150 mm
Flow friction formula adopted	Manning equation
Minimum velocity of public sewer	0.6 m/sec
Maximum velocity of public sewer	3.0 m/sec

(j) The new or modified administrative system with adequate legal and financing supports is considered necessary to facilitate the implementation of the proposed project

Such administrative arrangement should, however, be considered on the basis of the existing organizational set up to do fullest extent possible and should avoid any drastic and complicated modification which will incur time-consuming effort and unnecessary confusion on the part of the existing ones. (Refer to Chapter 16)

The basic requirements for consideration will be as follows:

(i) To identify the agency who will be responsible for the execution of the project
(ii) To establish an adequate administrative structure with functions clearly defined and requirement of the qualified staff specifically membered.
(iii) To ensure legal supports for the executive agency, legally authorizing the construction and management of the sewerage system.

1.2.3 Recommendations

(1) Proposed Sewerage System

(a) The sewerage system should basically be a separate system but to meet with the immediate needs, partially combined sewers are suggested for the areas where public drains are already provided, until such time when financing of the complete separate system is possible. (Refer to Chapter 10)

(b) For the purpose of sewerage planning, whole Study Area is divided into ten (10) sewerage zones. (Refer to Chapter 12)

(c) The physical facilities recommended for sewerage system to be developed includes, (i) system of sanitary main, submain, branch and lateral sewers, (ii) pumping stations, and (iii) wastewater treatment facilities in the form of aerated lagoon process. However, in Zones 1, 2 and 3 because the required site area for aerated lagoon process is not available, modified aeration process is recommended. (Refer to Chapter 12)

(d) Because of the resistance to corrosion from sulfide acids, alkalies, and virtually all corrosive substances, as well as resistance to erosion and scour, although it is not available in Thailand at present, vitrified clay or plastic pipes are recommended for smaller sizes up to 300 mm in diameter. Sewers more than 300 mm in diameter should be concrete pipes either coated or lined by suitable materials. (Refer to Chapter 13)

The area, estaimated population and estimated wastewater flow for all ten (10) zones are summarized in Table 1.1. A plan of these zones is shown in Figure 12.3 of Chapter 12.

Table 1.1 Area, Estimated Population and Estimated Wastewater Flow, 10 Sewerage Zones

Sewerage Zone	Area (ha)	Year: 2543(2000)	
		Population Served	Average Wastewater Flow (m^3/day)
1	3,400	1,018,700	274,700
2	3,600	823,800	375,100
3	2,500	499,600	119,400
4	200	23,000	14,800
5	3,100	457,300	115,500
6	2,600	245,600	69,200
7	6,400	742,200	197,800
8	4,200	336,700	100,200
9	4,600	368,100	109,600
10	5,500	1,085,000	276,700
Total Study Area	36,100 *	5,600,000	1,653,000

* Excluding water surface area of 900 ha.

(2) Proposed Priority of Implementation and Other Related Arrangement

(a) To establish the priority for implementation of sewerage construction program, rating procedure for evaluation of each of ten (10) zones is applied with the following assessment elements:

1. Environmental water pollution aspect
2. Population density
3. Waste load
4. Flooding, drainage system, etc.

The results of the rating indicate that Zone 2 is given the highest priority for the immediate implementation of construction followed by Zones 1 and 3. (Refer to Chapter 15)

(b) Taking the existing budgetary condition into account, it is concluded that the implementation of construction will not be extended out of Zone 2 by the year 2543 (2000). Accordingly, dividing Zone 2 into several sub-zones, total program is divided into four construction stages, namely, 1st Stage (2526 - 2530), 2nd Stage (2531 - 2535), 3rd Stage (2536 - 2540), and 4th Stage (2541 - 2545). (Refer to Chapter 15)

(3) Cost of Proposed Program

The proposed plan for implementation calls for construction in the four stages. Table 1.2 shows the construction costs for each completion period, including both local currency and foreign currency. All the construction costs include land acquisition costs operation and maintenance, contingency of 20 percent and engineering fee of 10 percent. All costs are estimated on the basis of the end of 2523 (1980) price levels and no escalation is considered. (Refer to Chapter 15)

Table 1.2 Cost of Proposed Program at the End of 2523 (1980) Price Level

Million Baht

Stage	1st 2526 - 2530 (1983 - 1987)		2nd 2531 - 2535 (1988 - 1992)		3rd 2536 - 2540 (1993 - 1997)		4th 2541 - 2545 (1998 - 2002)		Total	
Area Served	Sub-zone 2-A		Sub-zones 2-B and 2-C		Sub-zones 2-D, 2-E and Part of 2-F		Rest of Sub-zone 2-F		Zone 2	
Items of Cost	Sub-total		Sub-total		Sub-total		Sub-total		Sub-total	
	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency	Local Currency	Foreign Currency
Government Contribution	687		601		697		747		2,732	
	327	360	239	362	355	342	526	221	1,447	1,285
Private Contribution	0		0		193		247		440	
	0	0	0	0	193	0	247	0	440	(
Total	687		601		890		994		3,172	
	327	360	239	362	548	342	773	221	1,887	1,28

Note: In estimating the construction costs for foreign component, it is assumed that all equipment and materials which are not manufactured in Thailand will be imported. These include pumps, engines, valves, controlling devices, tunnel boring machine, and other equipment required for sewer, pumping station and treatment facilities. Engineering costs for the implementations of the prepared programs include the cost both detailed engineering design and construction supervision services. Foreign portion of engineering costs are assumed at 60 percent of total engineering fee. Twenty percent of the estimated construction and engineering fee is considered as contingency allowance for the completion of the project safely. These percentages are assumed on the basis of similar nature of project experienced in Asian countries and also taking various factors in the project area into accout.

(4) Administration, Financing and Regulation

In order to achieve the satisfactory implementation of the proposed Master Plan for the sewerage system development the administrative, financial and legal supports should be ensured. (Refer to Chapter 16)

(a) Administration

The formation of the Project Steering Committee involving various government agencies mostly concerned to the sewerage project is suggested to serve as a coordinating body to the high ranking officers concerned in the Central Government and to contribute to the expeditious implementation of the project including administration and legal proceedings.

BMA is recommended to be delegated to undertake the project designating BDS as its implementing unit

BDS is suggested to develop new sewerage functions with pertinent qualified engineers in accordance with sewerage system development program. The practical step-wise organizational development is designed with initial organizational set up to deal with the sewerage system construction and operation for the first ten years assuming full utilization of existing staff as indicated by Figure 16.5, which will further strengthen its functional alignment after ten years up to the year around 2543 (2000) as indicated by Figure 16.6.

The staffing plan over the project master plan is presented by Table 16.1 of Chapter 16.

(b) Financing

The preliminary financing plan is considered to estimate the future funding requirements and potential revenue sources over the period of Master Plan.

The project costs required to be met by the funding arrangements of the sewerage executive agency are largely divided in two categories, namely the construction costs and recurrent costs consisting of annual maintenance and operation costs as well as financing capital cost for loan repayments.

The foreign currency portion of the construction costs is suggested to be financed by less burdensome soft loan with low interest and long term of repayment among those from multilateral and bilateral loans.

The local currency portion of the construction costs and recurrent costs are suggested to be partly funded by the central government, BMA and individual resident who will receive direct and indirect benefits from the sewerage system by levying the charges pro rata to their water consumption.

The costs versus funding are summarized as below.

at the end of 2523(1980) price level

Estimated Required Costs (million baht)			Suggested Sources of Fund
Capital Costs in Foreign Currency	1st Stage	360	to be financed by multilateral loan (Loan Alternative I) or bilateral soft loan (Loan Alternative II)
	2nd Stage	362	
	3rd Stage	342	
	4th Stage	221	
Capital Costs in Local Currency	1st Stage	327	to be financed by central government contribution, BMA's budget allocation and customers capital contribution
	2nd Stage	239	
	3rd Stage	355	
	4th Stage	526	
Annual Recurrent Costs:			
Debt Service Costs	Loan Alt. II	Max. 86	to be recovered by sewerage user charge to be imposed pro rata to water consumption
	(Loan Alt. I	Max. 152)	
Operation & Maintenance Cost		65	

Note: Above costs do not include private house connection costs which are funded by individual house holders.

(c) Regulations

In order to meet the future legal requirements pertinent to establish modern sewerage system, basic principles normally employed for sewerage ordinance with exemplified legal provisions as well as necessary definitions are presented so as to be utilized as the guideline for the establishment of new laws or ordinances by the legislative agency.

In addition to the above stated legal recommendation on the sewerage system management, a regulation to control the private wastewater disposal system including septic tank is also proposed assuming the significant portion of area with such systems would remain under the BMA's jurisdiction within the Master Plan period.

(5) Benefits of the Proposed Program

Significant benefits to public health and economy can be derived from the proposed sewerage system program, including both direct and indirect benefits. All anticipated benefits have been evaluated on the basis of either quantifiable or non-quantifiable benefits. Although the quantifiable benefits are likely to be appreciated, non-quantifiable benefits should be emphasized in the overall economic justification of the program.

Evaluation of the major benefits includes avoidance of productivity losses caused by water-borne diseases and avoidance of the much higher cost of controlling water pollution by other means, but, it is not possible to quantify all the benefits expected in monetary terms, and therefore benefit to cost ratio has not been estimated. (Refer to Chapter 17)

Although no B/C analysis is made health and sanitation benefits, water pollution control benefit, benefit derived from increasing land value, and other benefits are emphasized. If no sewerage system were provided in the Area, sanitary conditions, which are already deplorable in many areas in the Study Area, will become progressively worse.

(6) Interim Measures

Since it takes long time to complete adequate sewerage system for the city as proposed in Master Plan, implementation of practical interim measures would be required to help improving environmental condition during the immediate future by removing major sources of pollution with effective minimum capital expenses through proper administrative measures by Government Agencies concerned. On the basis of the evaluation of existing and expected environmental or sanitary problems, interim measures are proposed as follows. (Refer to Chapter 18)

(a) The existing incomplete types of individual excreta removal facilities are recommended to be remodelled to the septic tank system proposed by BDS.

(b) Desludging service is recommended to be actively performed for the facilities particularly in the houses located in the tributary area of deteriorated klongs

(c) The capacity of dredging and cleaning of the drains is recommended to be increased.

(d) Maintenance responsibilities for all existing sewerage treatment facilities which are dispersed in district offices of NHA by location of facilities are recommended to be centralized in one office.

(e) The provision of temporary treatment facilities for both human excreta and sullage water is recommended for every new housing scheme.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

2.1 Location of the Study Area

Thailand is located at the central part of Southeast Asia (see Figure 2.1), occupying a land area of approximately 514,000 km^2 and inhabited by more than 44 million persons. The country is bordered on the west by Burma, on the south by Malaysia, on the east by Cambodia and northeast by Laos. It has no common frontier with China.

The capital city of Thailand, Bangkok is the subject of this study. One of the largest cities in Southeast Asia, with a population of 5.0 million as of December, 2522 (1979), and land area of 1,568.7 km^2. Bangkok is located at north latitude 13°44' and east longitude 100°30'.

The area selected for the study (herein referred to as the "Study Area" and/or "Master Plan Area") in order to alternate pollution problem in the klongs and the river for planning public sewerage system. It consists of urbanized or to be urbanized area of Bangkok Metropolitan Area of approximately 37,000 ha. (See Figure in Introduction)

2.2 Topography

The Study Area lies within the central valley of Thailand and is part of the delta of the Chao Phya River, its primary water course (see Figure 2.2). The general terrain is flat alluvial soil, characteristic of the delta area. The maximum ground elevations in the Study Area is about 2 m above mean sea level. Most of the Study Area is about 0.8 m above mean sea level.

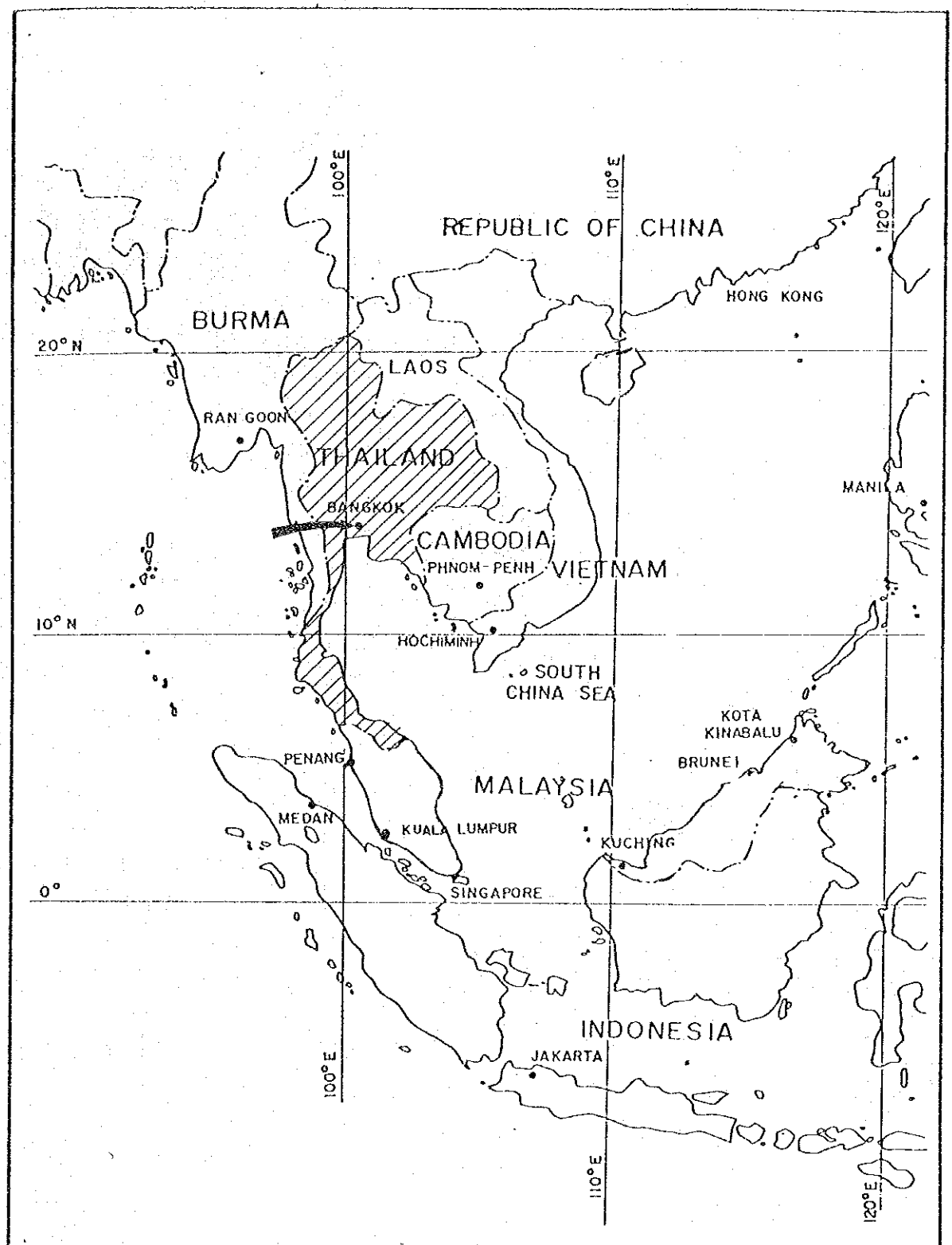


Figure 2.1 Location of Bangkok

Location of Bangkok	FIGURE 2.1

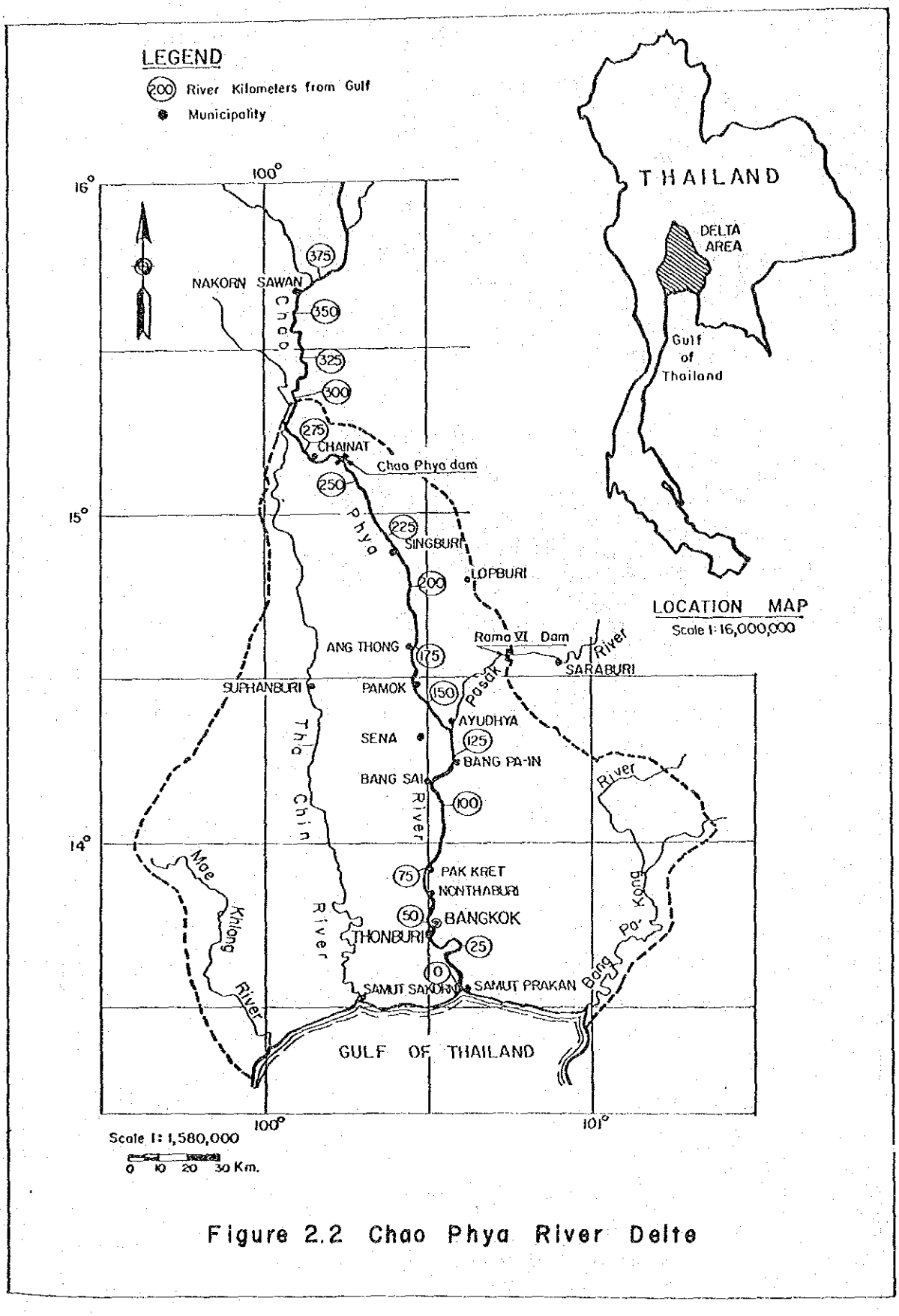


Figure 2.2 Chao Phya River Delta

2.3 Geology

The Chao Phya River basin, coincided with the Study Area, consists of alluvial flood plain formed over the year by the deposit of silt and sand carried down by the river. According to the existing data, it is considered that the soil structure in the area is mainly alluvial clay with fine sand. Borings to a depth of 30 m recently made indicate that there are basically two types of clay, one soft and one stiff. 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. During the dry season, however, the upper 1 or 2 m of the natural ground surface dries and turns to a relatively stiff brown clay.

2.4 Claimate

It is generally recognized that Thailand has three seasons: the "Cold Season" which includes November, December and January; "Hot Season" extending from February to May, and the "Wet Season" covering the other five months from June to October. The relatively dry period extends from November to April with most dry period in December and January.

The mountains around Bangkok dissipate the forces of the typhoons or cyclones originated in the South China Sea and the Bay of Bengal. While velocity of most breezes is more than 1.5 km/hr, about two thirds of the these breezes seldom exceed 12 km/hr. Maximum winds up to 122 km/hr have been recorded, however. The prevailing winds are either from the north or from the south.

Table 2.1 summarizes the climatic condition in Bangkok, including temperature, relative humidity, day of rainfall, and wind velocities.

Table 2.1 Climatic Conditions in Bangkok

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature, ^{o}C (Avg.)												
Max.	32.0	32.5	33.5	34.7	34.0	33.2	33.0	32.5	32.4	32.3	31.5	31.4
Min.	21.2	23.0	24.9	25.9	25.4	25.3	25.1	24.9	24.7	24.3	22.4	20.8
Mean	26.3	27.4	28.8	29.9	29.4	29.0	28.6	28.3	28.2	28.0	26.6	25.8
Relative Humidity,												
Percent	74.9	76.7	77.6	77.0	78.8	78.1	78.5	79.3	82.1	80.7	75.7	72.8
Rainfall Record (Avg.)												
No. of days/month	2	3	3	7	16	17	19	21	22	16	5	2
Rainfall, mm/month	14	30	20	59	200	159	144	181	343	188	46	18
Wind Velocity,												
Avg., km/hr	3.5	5.9	7.9	7.0	5.3	5.8	5.8	5.6	3.7	3.3	4.1	3.9

Period of record: 2513 - 2522 (1970 - 1979), Mean annual rainfall = 1,402 mm

Data Source: Division of Climatology, Meteorological Department

CHAPTER 3

PREVIOUS STUDIES

In the past several studies of varying scope and magnitude have dealt with its problems caused by the lack of a sewerage system, inadequate drainage and flood protection systems, and the resulting pollution in the klongs and the Chao Phya River.

The most recent study was made in 2511 (1968) by the consulting firm, Camp Dresser & McKee, U.S.A. (CDM), to establish a master plan up to the year 2543 (2000), with sufficient reference to other previous studies such as Litchfield Plan, Husband Report and Tholin Study.

3.1 Description of Previous Studies

LITCHFIELD PLAN

"Greater Bangkok Plan - 2533 (1990)", Litchfield Whiting Browne & Associates (International Architects and Engineers, New York City, N.Y., U.S.A.) and Adams, Howard and Greeley (City Planning Consultants, Cambridge Mass., U.S.A.), was submitted on August 13, 2503 (1960).

The purpose of the project was (1) to prepare a comprehensive general plan which would provide a rational, consistent framework within which specific physical plans for regional services and facilities could be developed, (2) to develop general, practical plans, including programs for their implementation, for water supply, drainage, sewerage, land use, transportation, schools, etc., and (3) to institutionalize planning as a continuing program in the Greater Bangkok - Thonburi Metropolitan Area.

The general recommendation of this plan covers six categories inclusive of population, land use, circulation, services and facilities, utilities, and effectuation.

Recommended sewerage system in this plan was a separate system with 2 wastewater treatment facilities.

HUSBAND REPORT

"Report on Sewerage and Sewage Disposal for the Central Area of Bangkok, Including Reference to Associated Problems of Surface Water Drainage", Husband & Co. (Consulting Engineers, London, England), was submitted in September 10, 2505 (1962).

The purpose of the project was, (1) to review the present and future problems of sewerage and wastewater disposal for Central Bangkok, (2) to make recommendations and provide cost estimates for sewerage and wastewater disposal schemes, (3) to study the existing storm-water drainage system and (4) to recommend facilities to overcome the periodic flooding.

In this report a separate system with a wastewater treatment facilities was recommended in Bangkok Central Area.

THOLIN STUDY

"A Study of Drainage and Sewerage for Bangkok, Thailand", A.L. Tholin (Technical Consultant, sponsored by the United Presbyterian Church in the United States and the Church of Christian Thailand), was submitted in October 12, 2505 (1962) to the Bureau of Public Works of the Bangkok Municipality. This study was presented approximately one month after the Husband Report.

In this study a combined sewerage system was recommended on the basis of the cost savings and considering that (a) drainage and sewerage were of equal priority and (b) the early conversion of several klongs into roadways would be necessary for the relief of traffic congestion.

Camp Dresser & McKee (CDM) Plan

"Sewerage, Drainage and Flood Protection Systems, Bangkok and Thonburi, Thailand", Camp Dresser & Mckee (Consulting Engineers, Boston, Massachusetts, USA), was presented on February 29, 2511 (1968). This report was the result of a one and half year study financed by the Government of Thailand.

(a) The purpose of the project was:

1. To review previous investigations,
2. To consider alternative schemes for the solution of existing problems and
3. To prepare a Master Plan which would present the consultants recommendations for effecting the selected scheme.

(b) Recommended Sewerage System

The basic factors and assumptions adopted in the CDM Plan for the design of the sewerage system were as follows:

1. The Master Plan Area was the municipal area of both Bangkok and Thonburi plus certain additional developing areas. The total area encompassed 37,000 hectares.

2. The Master Plan was established with an objective to serve the people expected to be residing in the Area by the year 2543(2000).

3. Estimated population in the Master Plan Area was 5.4 million for the year 2543 (2000).

4. The population expected to be connected to the sewers was be 40 percent (1,800,000) by the year 2528 (1985) and 60 percent (3,240,000) by the year 2543 (2000).

5. The estimated average per capita wastewater flow was 154 l/day/cap in 2528 (1985) and 238 l/day/cap in 2543 (2000). These flows would include allowances for commercial, institutional and scattered factory wastes, in addition to domestic wastewater.

6. The per capita contribution of BOD would be 65 g/day/cap in 2528 (1985) and 85 g/day/cap in 2543 (2000).

7. The total industrial wastewater flow would represent the waste load equivalent to organic wastes from about 120,000 people.

8. Infiltration was estimated to be 2.8 m^3/day/ha.

9. The relationships between peak flows and average daily flow of wastewater were taken as 5 : 1 to 2 : 1.

10. The sanitary wastewater was generally recommended to be separated from the surface water in the future, with adequate treatment before discharge to the river.

11. The minimum diameter for a public wastewater sewer was 200 mm and the minimum size for a building connection sewer was 150 mm.

12. Lateral sewers were designed at a minimum depth to the crown of the sewer of one meter.

13. Public wastewater sewers were designed to carry the peak design flow at a minimum velocity of 0.60 m/sec when the pipe was flowing full.

14. The crowns of sewers were matched at junctions of sewers of different diameters.

15. The design capacity of pumping stations was determined by the expected peak wastewater flow.

(c) Proposed Sewerage System

Accordance to CDM plan, the Master Plan Area was divided into 10 sewerage districts taking account of general type of development and existing pattern of drainage potential future network of trunk sewer.

The area, estimated population and estimated wastewater flow for all 10 districts were summarized in Table 3.1. A plan of these districts was shown on Figure 3.1.

These 10 districts of the Master Plan Area would be served by a system of wastewater sewers which, with the exception of the Thonburi District, would flow by gravity to a main pumping station across the Chao Phya River from the southern tip of Bangkok.

The main trunk sewers would be constructed partly as tunnels and partly as conduits in open cut trenches.

The main trunk sewers which were proposed to be constructed as tunnels and the pumping stations proposed to serve the Master Plan Area are shown for general reference on Figure 3.1.

As areas outside the Master Plan Area develop and require wastewater disposal facilities, the tendency would be to make these areas tributary to the system within the Master Plan Area. Expansion of this type, either by pumping stations and force mains or by gravity sewer connection, would require to proceed without proper planning.

The wastewater sewerage system proposed for the entire Master Plan Area was expected to serve population of about 3.2 million persons at a construction cost of about 3.9 billion baht.

Treatment would be required by about 2518(1975) and it would be required to effectuate a BOD removal of about 90 percent.

Because of high land costs in the Master Plan Area it seemed reasonable to assume that the eventual location of wastewater treatment facilities would be at the south of Bangkok.

For the purposes of considering the required financing for the recommended programs, a somewhat arbitrary estimate of 150 million baht had been assumed as the cost of wastewater treatment facilities.

(d) Proposed Storm-water Drainage System

The basic factors and assumptions adopted for the design of storm-water drainage system in the CDM Plan were as follows:

1. The intensity-duration-frequency curves were used with the following design storm frequency intervals for different land use designations:
   1) 5-year frequency storm for high and low density commercial, manufacturing, utility and institutional areas
   2) 2-year frequency storm for residential areas of high, medium and low density
   3) 1-year frequency storm for "green" areas, such as parks and recreational areas
2. The Rational Method was used in designing storm-water drains.
3. All storm-water drains were designed for self cleansing velocities of 0.9 m/sec when flowing full. In a few rare instances an absolute minimum of 0.75 m/sec was used because of special considerations, mostly in the upper sections of the drainage system.

Table 3.1 Estimated Future Population and Wastewater Flow, 10 Sewerage Districts

	Sewerage District	Area (km^2)	Year: 2523 (1985) Population Served	Year: 2523 (1985) Wastewater Flow, m^3/day Average	Year: 2523 (1985) Wastewater Flow, m^3/day Peak	Year: 2543 (2000) Population Served	Year: 2543 (2000) Wastewater Flow, m^3/day Average	Year: 2543 (2000) Wastewater Flow, m^3/day Peak
1.	Thonburi	61	235,000	36,200	90,600	432,000	103,000	224,000
2.	Construction-Government	12	170,000	26,200	72,500	295,000	70,000	173,000
3.	Sathorn-Rama IV	16	180,000	27,700	77,700	319,000	76,000	177,000
4.	Chan Road	24	190,000	29,200	82,000	349,000	83,000	181,500
5.	North West	43	250,000	38,500	95,000	460,000	109,500	242,000
6.	Sukhumvit	23	130,000	20,000	60,500	223,000	53,000	147,000
7.	North Central	48	230,000	35,400	88,000	416,000	99,000	225,000
8.	North East	50	130,000	20,000	60,500	235,000	56,000	155,500
9.	South East	67	195,000	30,000	83,700	346,000	82,500	180,000
10.	South	26	90,000	13,900	43,200	165,000	39,200	95,000
	Total Master Plan Area	370	1,800,000	277,100	554,000[1)]	3,240,000	771,200	1,382,000[1)]

1) Total peak flow is not the sum of the peak flow of each area.

4, The storm drains were designed to insure that the 0.8-depth flow line would be continuous, on the principle that it represents the line of maximum velocity.

5. The slope of the improved drains was designed to provide a maximum velocity of 0.75 m/sec. A velocity of 0.6 m/sec was considered the absolute minimum acceptable for an improved box drain.

6. The peak capacity of storm-water pumping station, with all pumps in operation would be theoretically required only once during a five year period.

7. The use of diesel engine drives was recommended for the pumps in all of the storm-water pumping station.

The recommended drainage system for the Master Plan Area was divided into 11 districts, each one of which was a protected area or polder.

Storm-water runoff was pumped from the interior drainage klongs into the major multipurpose klongs or directly into the Chao Phya River. Each polder would require from one to eight pumping stations.

The proposed system for the entire Master Plan Area incorporated approximately 300 km of flood barriers or embankments to keep the flood waters of the Chao Phya River out of the protected Area.

The storm-water flow in the klongs would be pumped out of the protected area, either directly to the Chao Phya River or to the large multipurpose klongs which connect directly to the river.

(e) Proposed Flood Protection System

The proposed flood protection systems were as follows:

1. In order to provide flood protection it was recommended that the Master Plan Area be divided into smaller flood protected enclosures or polders.

2. Each recommended polder would be protected from external flood waters by a flood protection barrier consisting of a combination of earth embankments, perimeter highways and concrete walls.

3. Each polder would be surrounded either by the river or by a multipurpose klong. The interior storm-water runoff from each polder would be discharged into these multipurpose klongs by gravity, or by pumping when the exterior water levels were high.

4. The multipurpose klongs would be suitable for navigation and for carrying the drainage water, not only from irrigated lands outside the Master Plan Area but also from the protected polders.

5. In order to prevent exterior flood waters from entering the protected polders it would be necessary to control flows in all the interior klongs by constructing control facilities at the flood barrier. Several large navigable klongs would be provided with navigation locks capable of handling river barges and boats under almost any hydraulic conditions. Sluice gates would be installed on other klongs. The porposed flood protection improvement systems were shown on Figure 3.2.

(f) Recommended Construction Program

The priority of systems, priority of areas, and construction costs were as follows:

1. Priority of systems

The recommended priorities were as follows:

1) The sewerage system should have first consideration in a new construction program.

2) The flood protection system should be considered as the next most important system.

3) The drainage facilities were accorded the lowest priority of the three systems.

2. Priority of Areas (Refer to Figure 3.3)

1) That portion of Bangkok delineated by the Chao Phya River and Klong Padung Krung Kasem was recommended for the first stage of construction.

2) The central part of Thonburi was suggested for the second stage of construction.

3) The Sathorn Triangle Area was proposed for stage three construction.

4) Pathum Wan a somewhat similar to above area was proposed for the fourth stage of construction.

5) As Bangkok's most highly developed residential area, the Bang Kapi Area was proposed for the fifth construction stage.

3. Construction Costs

The estimated cost of providing these five priority areas with sewerage, drainage and flood protection facilities was summarized as follows:

at 2510 (1967) price level

Name of Area	Estimated Cost (million baht)			
	Sewerage	Drainage	Flood Protection	Total
Construction-Government	177.9	138.2	186.7	502.8
Thonburi	335.7	68.5	164.9	569.1
Sathorn Triangle	249.2	55.3	92.4	396.9
Pathum Wan	68.2	80.9	49.3	198.4
Bang Kapi	220.5	115.5	199.5	535.5
Total	1,051.5	458.4	692.8	2,202.7

For the entire Master Plan Area, the estimated costs were as follows:

at 2510 (1967) price level

Item	Million Baht
Sewerage System	3,900
Storm-Water Drainage System	3,500
Flood Protection System	3,900
Total	11,300

Table 3.2 Recommended Stages of Construction

Stage Number	Name of Area	Population Served		Area Served (km^2)		Estimated Total Cost[1] (million baht)
		2528 (1985)	2543 (2000)	Sewerage and Drainage	Flood Protection	
1.	Construction-Government	464,000	500,000	12	19	503
2.	Thonburi	89,000	115,000	7	10	569[2]
3.	Sathorn Triangle	170,000	200,000	5	17	397[3]
4.	Pathum Wan	303,000	345,000	9	0[4]	198
5.	Bang Kapi	254,000	290,000	15	20	536
	Total	1,280,000	1,450,000	48	66	2,203

Note:

1) Including sewerage, drainage and flood protection, at 2510 (1967) price level.

2) Including the main sewer tunnel and pumping station.

3) Including wastewater treatment facilities.

4) Including in Stages 1 and 3.

(g) Recommended Operation and Administration Arrangement

It was recommended that the responsibility for construction, operation and administration of the proposed sewerage system and flood protection facilities be vested in a Metropolitan Water, Sewerage and Flood Protection Authority.

Because of the low priority assigned to the drainage facilities, it was proposed that the responsibility for the construction, operation and administration of the drainage system be retained by the municipalities.

(h) Recommended Financing Arrangement

In order to arrive at a total cost to be financed, the following assumptions were made:

1. That street drainage facilities would be financed separately, under other program established for street or highway construction.
2. That flood protection facilities would be considered only for the five priority areas.
3. That the sewerage and flood protection facilities for the five priority areas would be completed in 14 years and that the remainder of the Master Plan Area would be provided with sewerage facilities by the year 2543 (2000).

To carry out such a program the average capital requirements for the first 14 years were 125 million baht per year and for the remaining years until 2543 (2000), the capital required would be 170 million baht per year. An additional capital requirement of about 162 million baht should also be added. This amount, distributed over a period of 11 years, would be required to establish a involving fund out of which loans can be made to owners of private property for the installation of building connection. These loans would be payable in 10 years and would bear an interest rate of about seven and one half percent.

If financing was obtained and if construction got underway in 2513(1970), the average annual cost to finance the project would be 53 million baht per year during the first five year period. These annual costs would increase as shown below:

at 2510(1967) price level

Five Year Period	Average Annual Cost During This Period (million baht)
2513(1970)-2517(1974)	53
2518(1975)-2522(1979)	132
2523(1980)-2527(1984)	192
2528(1985)-2532(1989)	262
2533(1990)-2537(1994)	310
2538(1995)-2542(1909)	334

(i) Recommended Revenue Arrangement

1. It was recommended that these costs be paid by those who benefit from the services provided by the Authority.
2. It was recommended that 40 percent of the flood protection portion of the annual costs be paid by the National Government and 60 percent be paid by the property owners in accordance with the value of their property.
3. The sewerage system portion of the annual costs should be paid for in three ways.

A suggested schedule of the portion of the costs to be paid as follows:

Category	Share of Annual Sewerage Costs
National Government	20 percent
Private Owner, Direct Benefits	56 (70% of private sector share)
Private Owner, Indirect Benefits	24 (30% of private sector share)
Total	100 percent

4. In addition, a private property owner would also be responsible for repayment of any loan received to pay for the cost of installation of his building connection.
5. For the average costs to be paid for the sewerage system during the period 2528(1985) to 2532(1989) the direct benefit charge would amount to about 48 baht per month for a family of seven persons using one sewer connection.
6. For the private owner whose property is protected against flooding; his share of the average annual flood protection costs during this same period would amount to about 172 baht per rai per month.
7. For the private owner who receives indirect benefit from the sewerage system; his share of the average annual cost of the sewerage system during this period would amount to 33 baht per rai per month.
8. It was suggested that consideration be given to making these charges a part of the existing Land Development Tax.

(j) Recommended Legislative Arrangement

For optimum effectuation of the recommendation of the Master Plan, CDM proposed new legislation as follows:

1. An act creating a National Water Resources Authority which would have responsibility for the control and allocation of the use of all of the water resources of Thailand.
2. Amendment of the Metropolitan Waters Works Authority Act of 2510 (1967) to include the functions of a Sewerage and Flood Protection Authority, granting the specific powers necessary to enable the Authority to accomplish its stated purposes.
3. Amendment of the Act for Expropriation of Immovable Properties of 2497(1954) to include eminent domain procedures similar to those contained in the Highway Act of 2482(1939).
4. That an appropriate set of ordinances governing the use of the facilities of the Sewerage and Flood Protection Authority be established.

5. That a plumbing code applicable to the special conditions which are expected to exist in the Master Plan Area in the next few years be established.
6. That a Cimmittee to study the Problems of solid wastes disposal in Bangkok and Thonburi be appointed.

3.2 Comments by Review of the Previous Studies

In consequence of review and appraisal of the previous studies referred above, it is considered that CDM Plan is basically reasonable and acceptable in many respects, and is fully worthy of implementing the program with certain modification which may become necessary according to the lapse of time. Nevertheless, since the completion of the report, the sewerage project has been withheld.

The reasons for delay the sewerage construction in Bangkok would be assumed as follows:

(a) Although the authorities concerned have recognized the necessity of sewerage system in Bangkok, flooding problems have been given the first priority so far, and therefore no particular steps have been taken, including budgetary provision, for sewerage facilties.

(b) The general public was not yet sufficiently aware of the importance of the sewerage facilities for pollution control program.

(c) Existing septic tanks and drains have kept the living condition of people from disastrous deterioration.

While the delay of implementation occurred due mainly to constraints including the items stated above, it is unfortunate that the CDM Plan has now become to be incompatible with present condition of Bangkok owing to the lapse of time of approximately 13 years as indicated in the followings:

(a) As the general public have been increasingly aware of the necessity of public water pollution control, proposed disposal system without any treatment facilities will hardly be acceptable even it is suggested as a tentative measure.

(b) Proposed centralized sewerage system with large size long trunk sewers needs high initial investiment from the beginning of the project implementation. Such proposed system will be difficult to justify financial viability and will hardly be able to initiate funding arrangement to begin with.

(c) Since the present traffic condition may be more critical than that assumed when the previous report was prepared, proposed construction of some large sized trunk sewers would not be practical.

(d) All costs based on 2510(1967) prices are no longer valid, and the size of the investment greatly escalated. The realistic costing for proper evaluation of the project is essential.

On the basis of the review and evaluation of the previous studies, including particularly CDM Report, as briefly described above, data collection and field investigation have been undertaken to reasonably reflect the existing condition in the Study Area at Bangkok and its immediate needs, and they are included in the present report throughout the followings chapters.

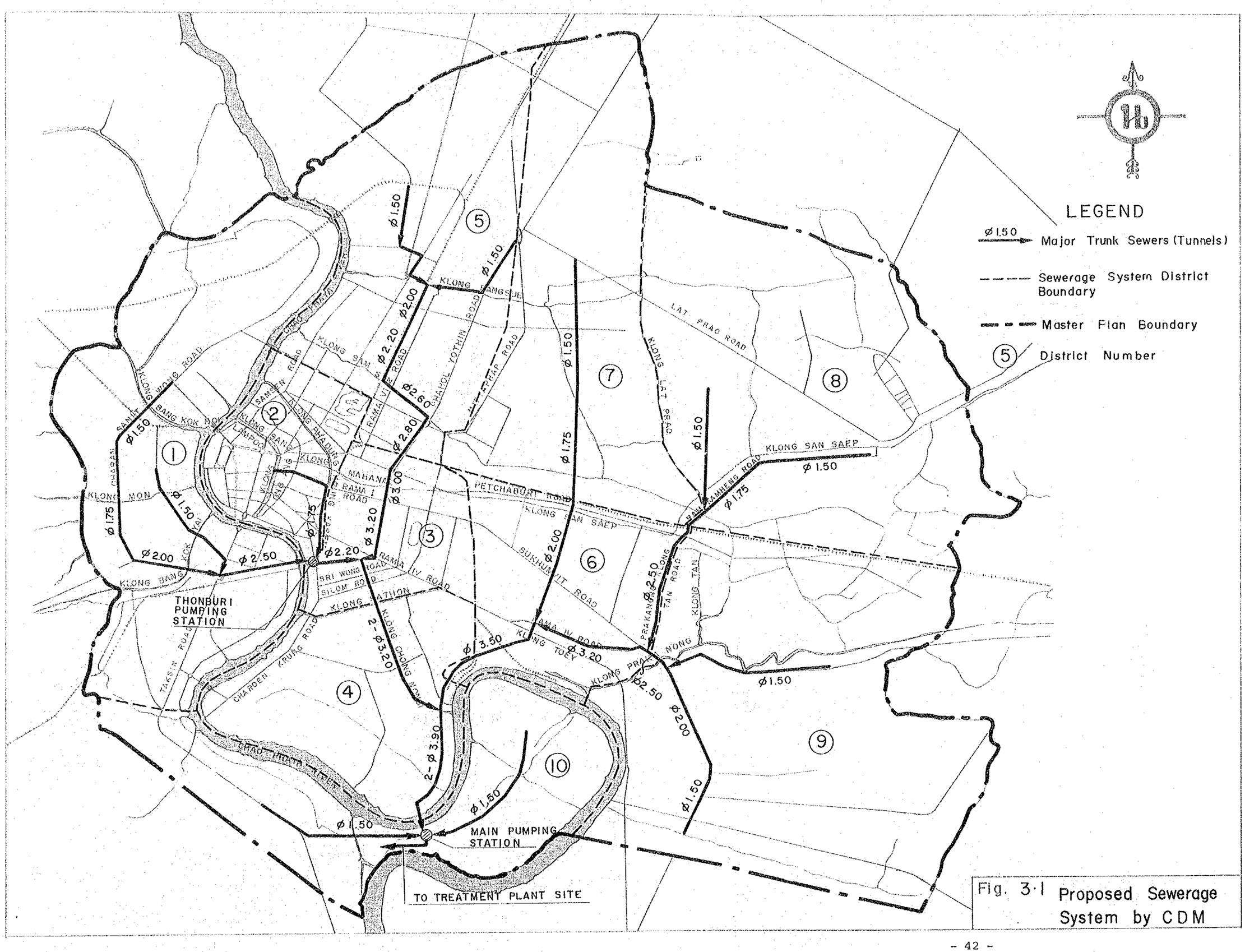


Fig. 3·1 Proposed Sewerage System by CDM

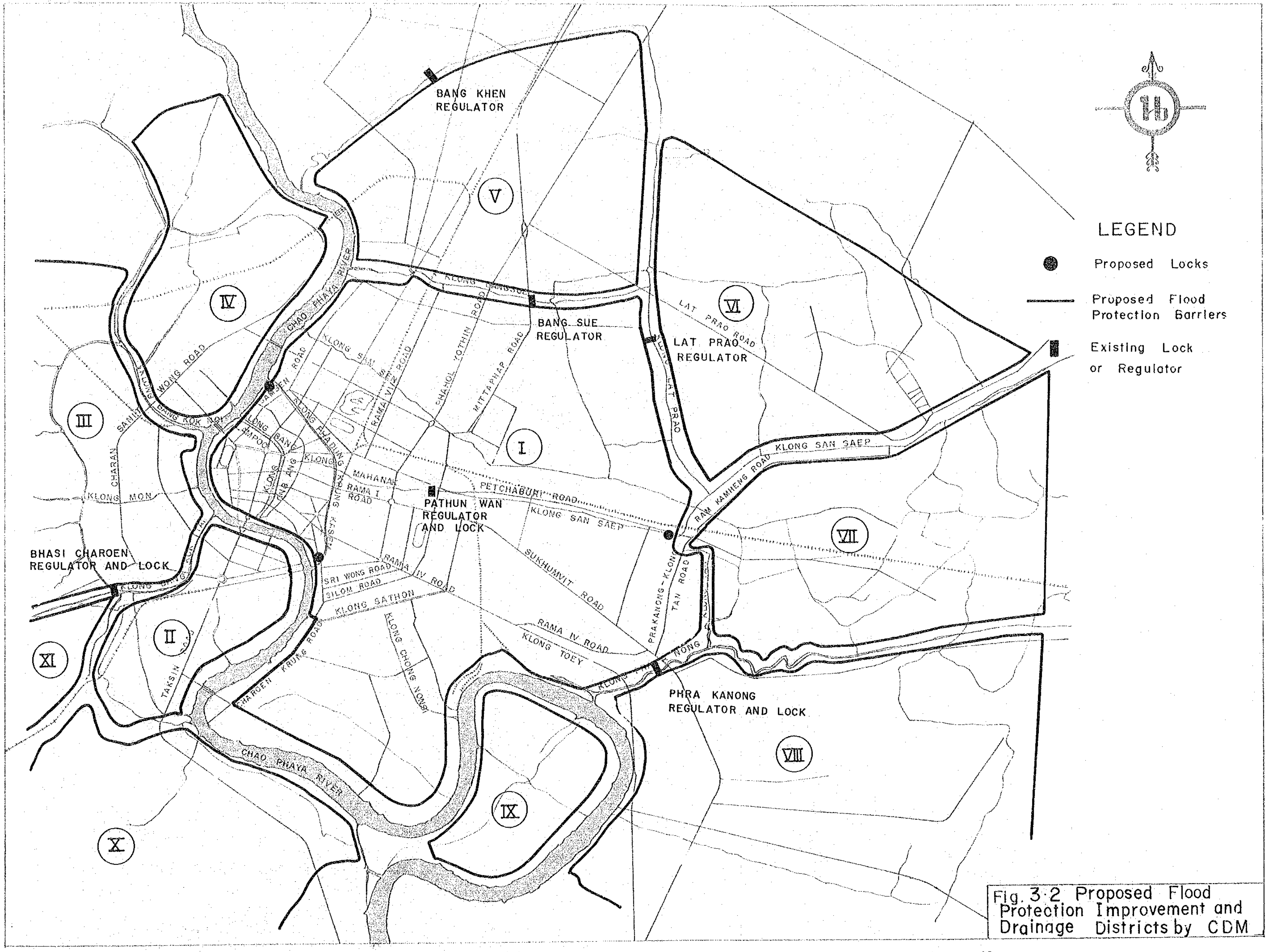
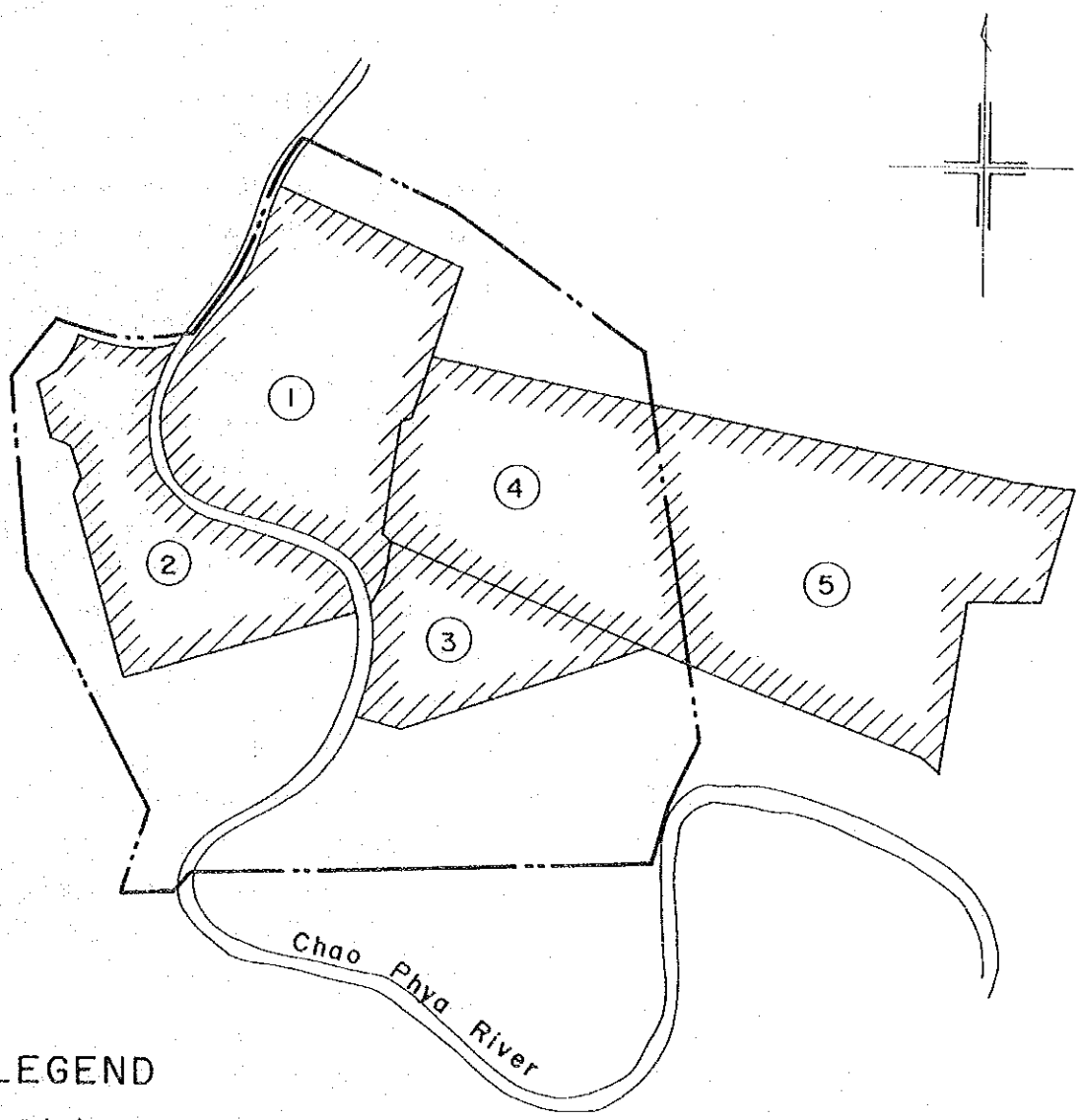


Fig. 3·2 Proposed Flood Protection Improvement and Drainage Districts by CDM



LEGEND

Priority Areas

(1) Construction – Government

(2) Thonburi

(3) Sathorn Triangle

(4) Pathum Wan

(5) Bang Kapi

Central Area Boundary

Figure 3·3 Recommended Priority Construction Areas by CDM

CHAPTER 4
EXISTING SYSTEM

In this chapter, existing practices of wastewater disposal including human excreta disposal, wastewater control, and storm-water disposal are described and evaluated.

A storm-water drain system in Bangkok has been planned and designed on the basis of a network of canals, called "klong", which convey storm-water to the Chao Phya River. The drain system was originally constructed with the "U" shape open channels along with the development of the town of Bangkok. As the population density increased, the open channel system has been gradually converted to the existing underground conduits which presently serve for both storm-water and wastewater in the central Bangkok and newly developed housing estates.

Modernized sewerage systems which consist of both collection and wastewater treatment systems are at present constructed in the housing communities developed by the National Housing Authority (NHA). Each sewerage system of the NHA's communities was designed by different systems of collection and/or wastewater treatment in each community.

In urbanized area including private developers' housing communities the sullage water from kitchens, sinks, washing, and baths is collected separately from toilet wastes, and discharged to the nearest storm-water drain or klongs. The existing storm drain system therefore serves as combined sewerage system, although it was not originally constructed for such purpose.

Septic tanks and/or cesspools are commonly used in Bangkok for human excreta disposal or toilet system. The liquid effluent from them is soaked into the ground or discharged to the storm drain, and the sludge accumulated in the tanks is collected and dumped into the lagoon or treated in the sludge treatment facilities newly constructed by BMA.

4.1 Existing Toilet System

The human excreta disposal systems in Bangkok have been constructed successively during the last 4 decades since the public health act was established in 2484 (1941). The systems are classified to 6 categories as shown in Table 4.1.

Categories A and B are applied only in the communities which have been constructed by NHA. In the project area there are 8 community wastewater treatment facilities of NHA, ranging 2,500 - 45,000 persons served.

Categories C and D are most common type of excreta disposal system not only in Bangkok but also in whole Thailand. Namely, septic tank and cesspool are the most dominant systems.

In this report, septic tank is defined as a device which has a unit process, anaerobic fermentation or digestion of excreta and separation of liquid effluent from sludge. The simple excreta disposal tanks which are called "cesspool" or "storage tank" in Bangkok are called "cesspool" in this report. Those are simpler in structure, with lower cost for construction and less water consumption for flushing than a typical septic tank. Some types of those in Bangkok have function as a septic tank although cesspool and/or storage tank does not have function of neither "digestion" nor "separation", but only storage in general terminology.

In Bangkok, approximately 70 percent of population are served by cesspools, and the remainings are served by septic tanks.

The cesspool tank volumes of the system, which are calculated from standards for approval of BMA for toilet construction, are shown in Table 4.2. Typical structure of toilet system in Bangkok is shown in Appendix G.

Table 4.1 Excreta Disposal Systems in Bangkok

Category	System Flow	Popularity in Bangkok
A	Sanitary Sewer → Wastewater Treatment Facilities	New type NHA Community
B	Septic tank or Cesspool → Drain → Wastewater Treatment Facilities Septic tank or Cesspool → Desludge → Lagooning/Sludge Treatment *1	Transition type to A of NHA Community
C	Septic tank or Cesspool → On-site Permeation Septic tank or Cesspool → Desludge → Lagooning/Sludge Treatment *1	Common in Bangkok
D	Septic Tank or Cesspool → Drainage/Surface water Septic Tank or Cesspool → Desludge → Lagooning/Sludge Treatment *1	Illegal discharge of effluent
E	Pour-flush *2 → Surface water	Very seldom
F	Direct Defecation to surface water/on earth	Quite very seldom

*1 Sludge treatment is just on-going at On Nooch, BMA.

*2 Pour-flush toilet is popularly applied to toilets of each category.

Table 4.2 Tank Volume of The Toilet System in Bangkok (After BMA Approval Standard)

Size (persons/day)	Digestion & Separation Tank	Permeation Tank
Smallest	0.9 m^3	0.9 m^3
5 - 10	3.0	0.9
11 - 14	6.3	1.4
15 - 20	8.6	1.4
21 - 24	9.0	1.6
25 - 80	11.0	2.8

The effluent of the digestion tank is, as a rule, soaked into ground through a permeation tank. It cannot, however, be considered that sub-soil in Bangkok is likely to soak the effluent in high efficiency because of soft clay covered almost whole Bangkok, and because of high ground water level.

The sludge is removed from the septic tank and transported to the public sludge disposal sites, On-Nooch and Nong Khem, by BOS, BMA. Served population and activity of the public services of BOS are shown in Table 4.3.

Table 4.3 Data on Present Activities for Desludging

(BOS, 2522)

Served Area	1,500 km^2
Served Population	5,000,000 persons
Transportation Vehicles	41 suction vehicles (2 or 5 m^3 each)
	24 carriage vehicles (5 m^3 each)
Collection Volume	350 - 400 m^3/day (7 day service a week)
Personnels	433 persons

Nightsoil sludges are collected from septic tanks and/or cesspools by vacuum lorries, and lagooned at the Nong Khem Dump Site or treated by the sludge treatment facilities at On Nooch.

The above lagoon is located in the Nong Khem Solid Waste Disposal Site, and covered by solid wastes later on. The overflow of leachate and/or supernatant water from the site is anticipated during the rainy season, and klong waters nearby are likely to be polluted.

The On Nooch Sludge Treatment Facilities have been constructed, and are under preliminary operation. The facilities are 600 kl/d in capacity, with which it is possible to accommodate daily average quantity of the present collection activity of Bureau of Sanitation, BMA. The treatment process is a chemical treatment followed by an activated sludge process as shown in the process flow sheet, Figure 4.1.

The sludge collection and disposal services mentioned above are supposed to be carried out under the control of BMA. However, according to the field reconnaissance, it is evident that un-licensed private firms also engage in the sludge collection and dump it into the public drains and/or klongs. Furthermore, it is observed that the bulk of existing septic tanks are not properly operated and/or illegally connected to drainage pipes or surface waters for effluent discharge. It is considered that the illegal discharge of the effluent are resulting in fecal pollution of receiving waters in the drainages as mentioned in Chapter 6.

Categories E and F are very seldom in Bangkok. They can be seen as a special case in very low density suburban area and/or slums. Therefore, the population served by the toilet system of categories E and F is negligible.

Pour-flush toilet is very common in Thailand. This toilet is hand-flushed with a small volume of water, 1 - 2 liters, after use, and equipped with shallow trap to provide a water seal between the privy and the pertinent devices. This is quite adequate from the hygienic and water saving viewpoint, as even in the houses where piped water is not available they can be used properly.

In conclusion, the existing excreta removal system in Bangkok is satisfactory to some extent in the comprehensive view of comfortableness of daily life and public health. But such existing system is required to be improved in respects of desludging services for fecal pollution of environmental water.

The elements of existing excreta removal systems in Bangkok are evaluated on the views of hygienics, comfortableness for residents, collection and disposal engineering, and environmental pollution, and are summarized in Table 4.4.

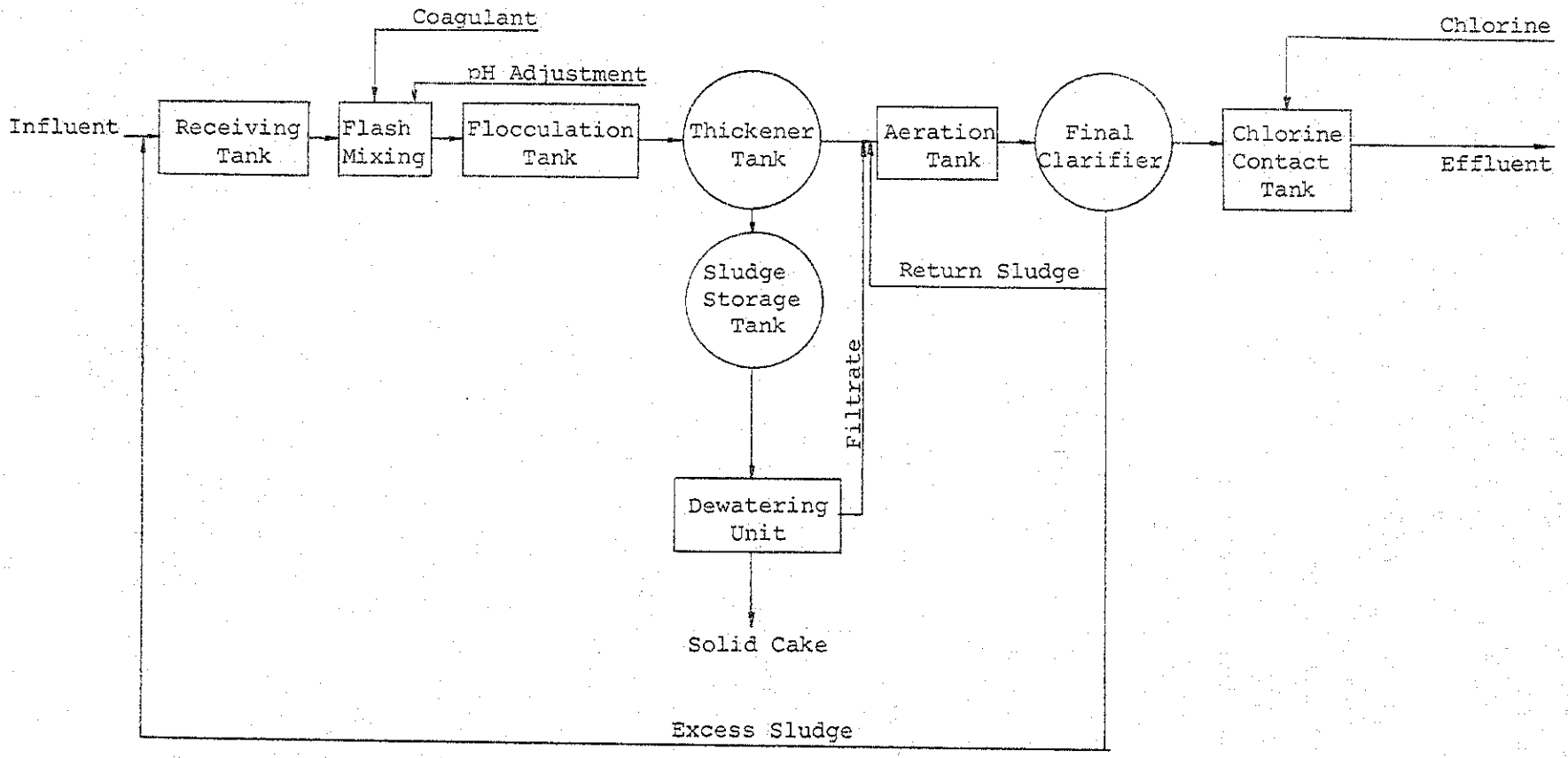


Figure 4.1 Process Flow Sheet of Nightsoil Sludge Treatment Facilities (On Nooch, BMA)

Table 4.4 Evaluation of Elements for Existing Excreta Removal Systems in Bangkok

Element / View Point	Defecation			Storage or Collection					Treatment & Disposal			
	Unsealed	Water Seal		On-site Storage			Collection		On-site Permeation	Discharge into Drains	Drain + Treatment	Sanitary Sewer + Treatment
		Pour or Flush	Flush	Pit	Cess-pool	Septic Tank	Vacuum Suction	Sewerage System				
1. Excreta-Related Disease	-	-	-	X	N	S	-	-	N	X	N	S
2. Comforta-bleness	X	S	S	N	N	N	N	S	N	S	S	S
3. Fly and Insect Segregation	X	S	S	N	N	N	-	S	S	N	N	S
4. Handling for Collection & Disposal	-	-	-	-	-	-	N	S	N	S	S	S
5. Environmen-tal Impacts	-	-	-	-	-	-	-	-	N	X	N	S

S = Satisfied N = Nearly Satisfied X = Should be Improved - = Independent of the Evaluation Point

4.2 Sewerage System

There are 12 sewerage systems with treatment facilities constructed in the housing estates and eight of them are located in the Study Area. Out of these 12 treatment facilities, six are operated by activated sludge method irrespective of the form of ditches or conventional method. Others are operated by aerated lagoon or oxidation ditch process.

In the course of field survey all facilities were visited with the questionnaire on operational conditions and any problems arisen from maintenance activities. This questionnaire consists of items concerned with wastewater collection method, population served, average daily inflow to the treatment facilities, construction and maintenance costs and design criteria.

The results of the investigation are reflected upon the study of treatment process and estimation of cost applicable to the Study Area.

4.3 Drainage System

Existing drainage system is composed of U-shape box and round type drains, klongs, underground conduits, pumping stations installed permanently or temporarily, movable pumps and gates. The runoff from the city area drains into klongs through the collection networks of drains by gravity and eventually is discharged to the Chao Phya River or major klongs mostly by pumps.

Field investigation was performed including confirmation of size, flow direction and invert elevation of existing drains as well as location and scales of flood prone areas and operating conditions of existing pumping stations. As a part of the investigation, ground survey was performed by local surveyor. The results of above investigation are presented in maps of Volume III, "Drawings", which shows location, flow direction and estimated capacity of existing drains for relatively large pipes of 0.6 m and more in diameter. For central area, flood experienced area in 2522(1979) are presented as shown in Figure 4.2.

Generally, drains are well equipped on both sides of streets in the urbanized central area. Particularly in the area surrounded by Klong Padung Krung Kasem and the Chao Phya River, the drains seem to have enough capacity to accommodate the runoff from this area though they are of smaller size than that proposed by CDM because significant inundation caused by inadequate drains has not occurred recently.

Although the drains were not constructed in accordance with a comprehensive drainage plan, and sizes, slopes and invert elevations of those drains vary indiscriminately, capacity and velocity of each drain are relatively sufficient to accommodate the runoff from the area served by each drain as can be seen from the table attached to maps of Volume III, many of these existing drainage systems can be used in the future, provided they are improved partially, when incorporated with new drains to be constructed in accordance with a comprehensive drainage plan.

Wastewaters from sinks, washing, baths and kitchens are collected separately from toilet wastes and discharged to the nearest storm-water drain or watercourse. Thus, the existing drains have become as combined sewers, although they were not constructed as such. Moreover, in spite of the municipal regulations prohibiting overflows from septic tank and cesspools to the drainage system or water course, such discharges seem to be widely practiced even in the central areas.

On the basis of above mentioned situations, the existing drains can be considered to use them as combined sewers. However, the existing drains cannot sufficiently serve as combined sewers which receive sullage water together with toilet wastes, because slope of existing drains cannot maintain the required velocity in low flows and because sand pits installed in every manholes may bring about offensive odor resulting from accumulation of deposit on the bottom drains especially in dry season. If existing drains are used as combined sewers, careful consideration should be given in order to avoid the deposit accumulation and occurrence of offensive odor, taking counter measures such as improvement of manhole or pretreatment of excreta discharges from individual houses.

The biggest existing drainage under Rama IV project starting from Klong Padung Krung Kasem, reaches to Rama IV pumping station through under Rama IV Road and Chuapoeng Road. The size of above drains range from 1.44 x 1.60 m of semielliptic shape to 3.3 m in diameter round shape constructed by tunnel method. The plan and profile of this drain is presented in Volume III, "Drawings" with the calculation table of flow capacity.

Although this drain has insufficient capacity to accommodate the runoff from its served area, it has a high potential to be used temporarily as combined trunk sewer. Detailed survey will be performed in the course of further study such as Feasibility Study, if necessary.

4.4 Flood Protection System

As Bangkok is flat in low-lying area, the flow in klong and down stream of the Chao Phya River are affected by the tide of the Thai Gulf. Consequently, almost all underground piping systems are influenced by back waters. In order to mitigate the effects of back waters klongs located in the central area are usually disconnected from the Chao Phya River water by existing gates or by sand bags, and storm-waters are drained by pumps.

In spite of the various efforts of authorities concerned, flooding frequently occurs in the city area when heavy rain coincides with high tide. In order to mitigate the deteriorated conditions mentioned above, the flood protection and drainage project is under consideration by BMA.

This project covers 6 polders, 82.5 km^2 as shown in Figure 4.3, including construction of embankments and pumping stations, improvements of klongs and drains. This flood protection project will be carried out principally in accordance with the Master Plan prepared by CDM in 2511 (1968). The detailed design is scheduled to start early 2524 (1981). Coordination between sewerage, drainage and flood protection projects has to be carefully maintained during the entire course of the study and implementation of these projects.