APPENDIX G

WASTEWATER SURVEY

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WASTEWATER SURVEY

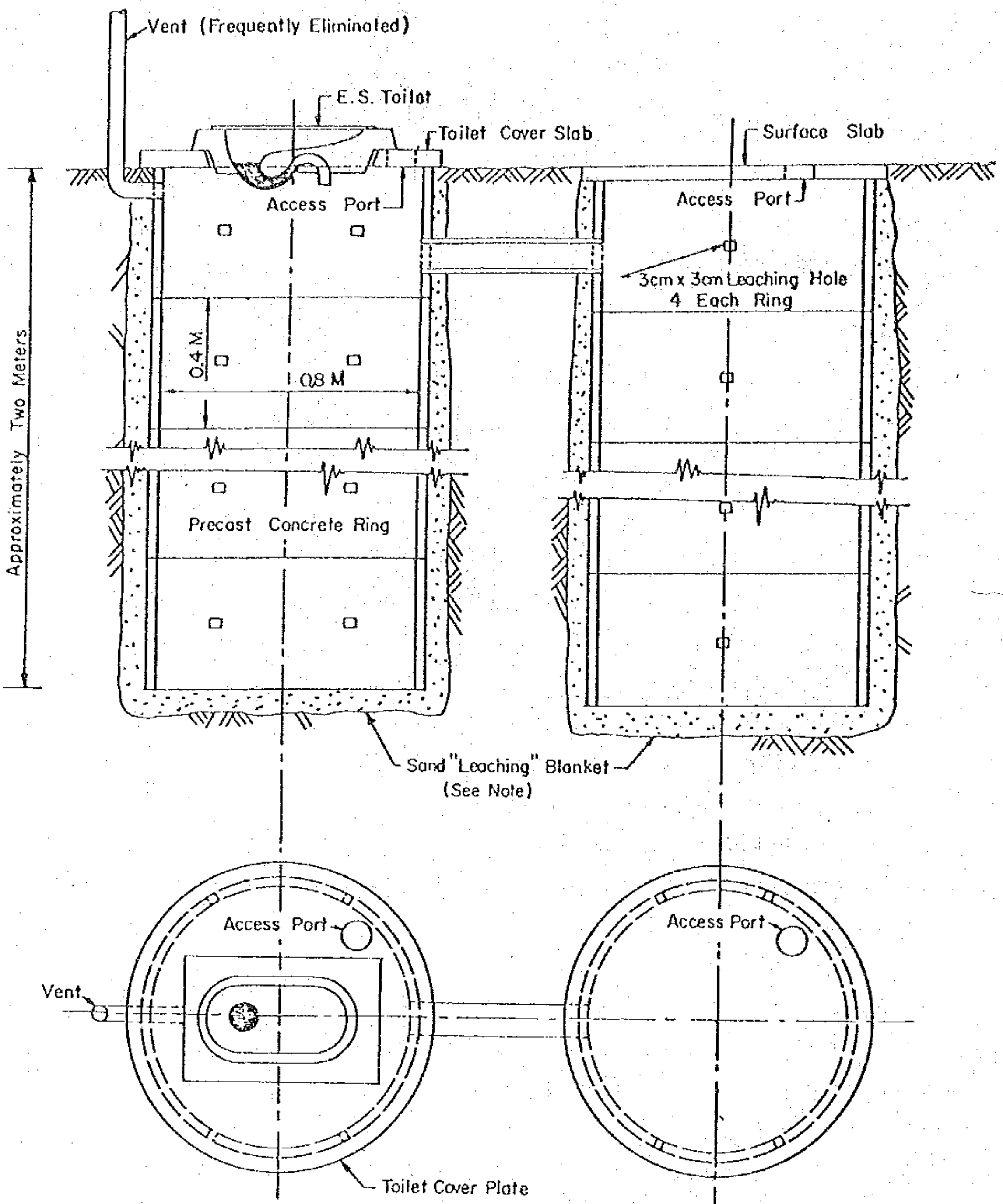
Wastewater surveys were made to obtain the data on per capita wastewater flows and BOD loadings originating from domestic and commercial activities, and additionally to collect the information of the wet-weather BOD loadings discharged into the klongs through the drain system in the town area.

In Bangkok the wastewater disposal system consists of the drainage system which collects and conveys storm water and sullage water originating from each house, and the septic tank system which receives toilet wastes and treats them by on-site digestion and permeation as a rule. Some of toilet wastes are discharged into the drains and/or surface waters. Typical wastewater systems are shown in Figures G.1 through G.3.

In the Master Plan Area, most areas of residential and/or commercial are recognized as mixed ones, but the former is residential dominant and the latter is commercial dominant. So, the "domestic wastewater" is, in this report, defined as the wastewater discharged from residential areas, so that it includes the wastewater from neighbouring shops and/or institutes as its portion.

On the other hand, in the commercial area which widely spreads over the central Bangkok, it is considered that commercial waste-discharge would be almost free from the number of residents, but characterized by the day time activities, namely trading. Therefore, the wastewater from the commercial area should be estimated based on the sum of house wastes and commercial wastes. The former can be estimated from the number of residents as domestic wastewater. And the "commercial wastewater" is defined as the wastewater originating from the trading in the central commercial area.

To obtain the data on existing wastewater production two field sampling and chemical analysis of wastewater were carried out. The sampling points were selected from the each category, i.e. residential and/or commercial areas.

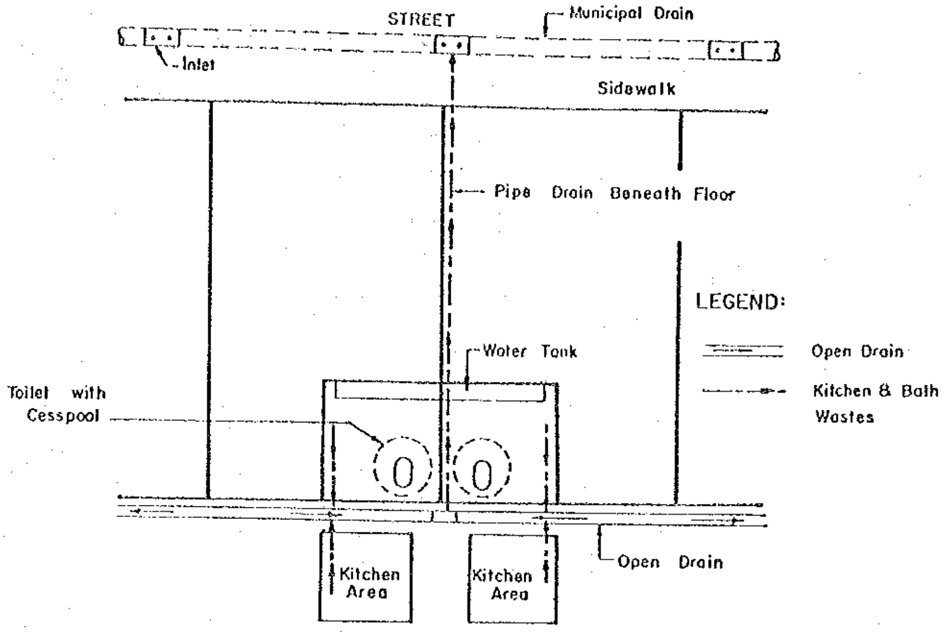


NOTE

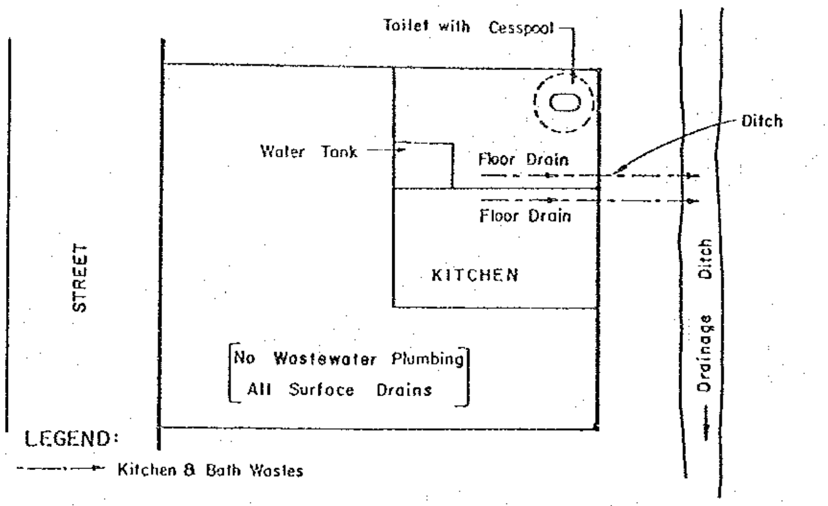
MUNICIPAL PLAN CALLS FOR PROVIDING A SAND LEACHING BLANKET AROUND EACH TANK. IN FACT THIS IS SELDOM DONE. THE RINGS ARE USUALLY INSTALLED BY "CAISSON " TYPE EXCAVATION, OR EXCAVATION FROM WITHIN, ALLOWING THE RING TO SLIDE INTO THE GROUND.
THE CAPACITY CAN BE INCREASED BY THE ADDITION OF RINGS BUT THE USE OF 5 RINGS (2.0 M DEPTH) SEEMS TO BE STANDARD. IF MORE CAPACITY IS REQUIRED A SECOND TANK IS ADDED AS SHOWN.

Scale 1 : 20
1cm = 0.20 meter
1in = 1.66 feet

Figure G·1 Typical Leaching Cesspool

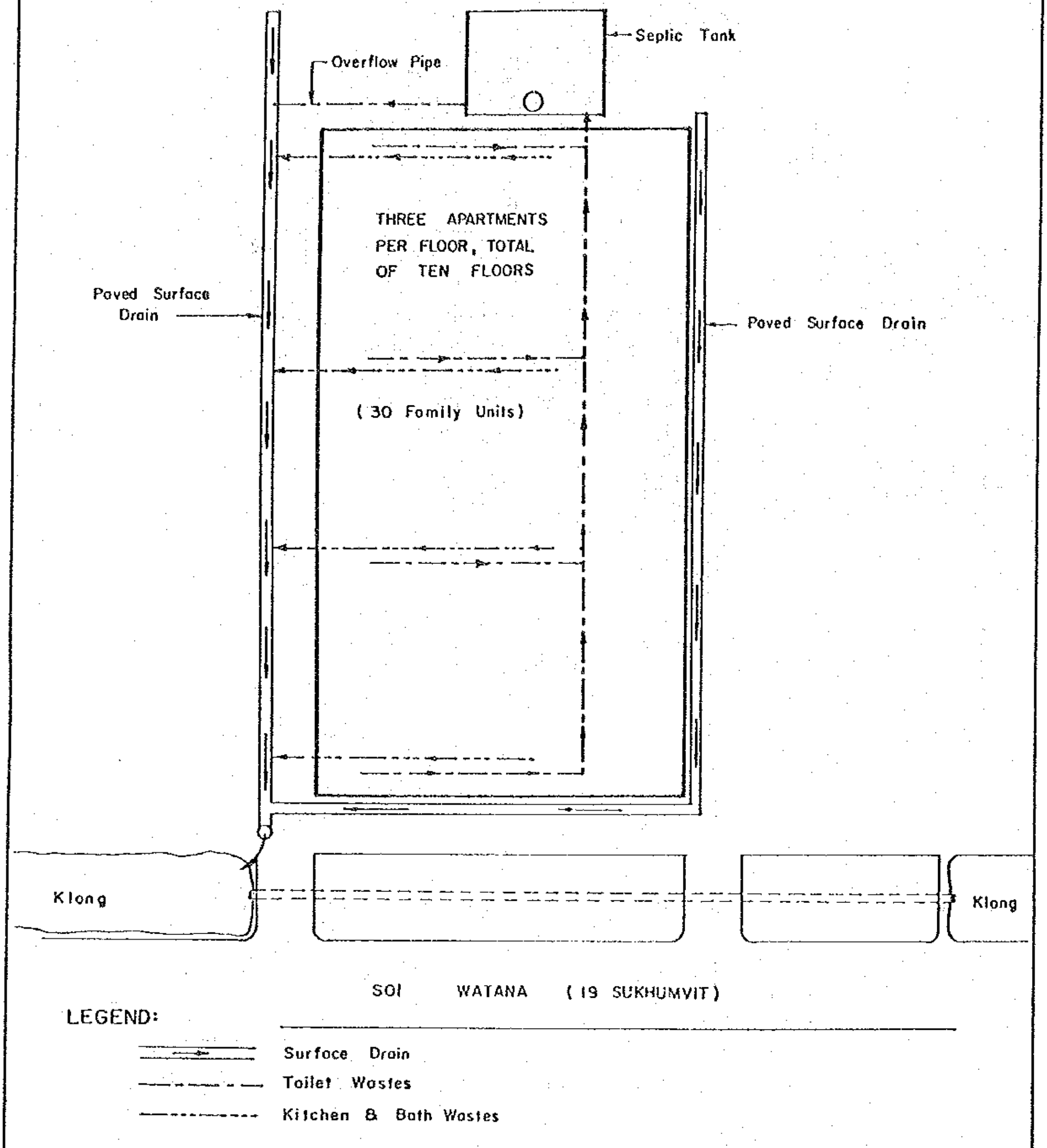


Row Housing Wastewater System



Small Single Family Unit Wastewater System

Figure G.2 Typical Wastewater System (I)



Apartment Wastewater System

Figure G.3 Typical Wastewater System (2)

Prior to the selection of sampling points, existing drainage condition such as flow direction, discharge points, connection from the neighbouring areas and water retention in the sewers were checked up. And then the Huay Kwang Housing Estate and Wang Burapa were selected.

1. Survey Area

<u>Huay Kwang</u>

The Huay Kwang Housing Estate was constructed by National Housing Authority (NHA) as a link of settlement projects for slum people. The sewerage system in the area is a most modernized one in Bangkok, which is composed a separate collection system (partly combined) and a treatment facility consisting of activated sludge wastewater treatment process and sludge digestion process together with a machinery dewatering system.

There are 38 buildings of multistoried residence including 3,360 units, super market including many retail stores and restaurants, primary school, 3 Government offices, and open space as a sports ground.

The outline of the estate is as follows:

* Served Area	:	about 13 ha
* Population	:	25,000 persons
* Number of Units	:	3,360 units (38 buildings)
* Super Market	:	1
* School	:	1 (2,700 pupils)
* Government Office	:	3

<u>Wang Burapa</u>

The area is a central commercial area containing 137 shop houses (shop on ground floor and residence on upper floor). Most of the shops are retail stores, restaurants, etc. and in the area theaters and super markets are also located.

The outline of the area is as follows:

* Survey Area : 3.2 ha
* Population : 647 persons
* Number of Unit : 137
* Theater : 2
* Super Market : 6
* Bank : 1

The area used to be the biggest shopping center before construction of Siam Square. The drainage system in the surveyed area is independent from neighbouring drain network as shown in Figure G.4. The wastewater is discharged into Klong Ong Ang by gravity flow. The water level of the klong can be controlled by the Kasem Pump Station through other klongs.

During the sampling the water level was controlled to prevent the klong water backing up into the drain sewer.

2. Methods

2.1 Flow Rate Measurement

At the Huay Kwang Community the wastewater flow rate was continuously measured by the Parshall measuring flume attached to the treatment facility The records of the Parshall flume was corrected by the cross-section-velocity method during the survey.

At the Wang Burapa commercial center the wastewater flow rate was measured by the cross-section-velocity method at one hour interval and at 5 to 10 minutes interval during initial runoff if rained. The measuring point was the outlet of the drains network in the block of the commercial center.

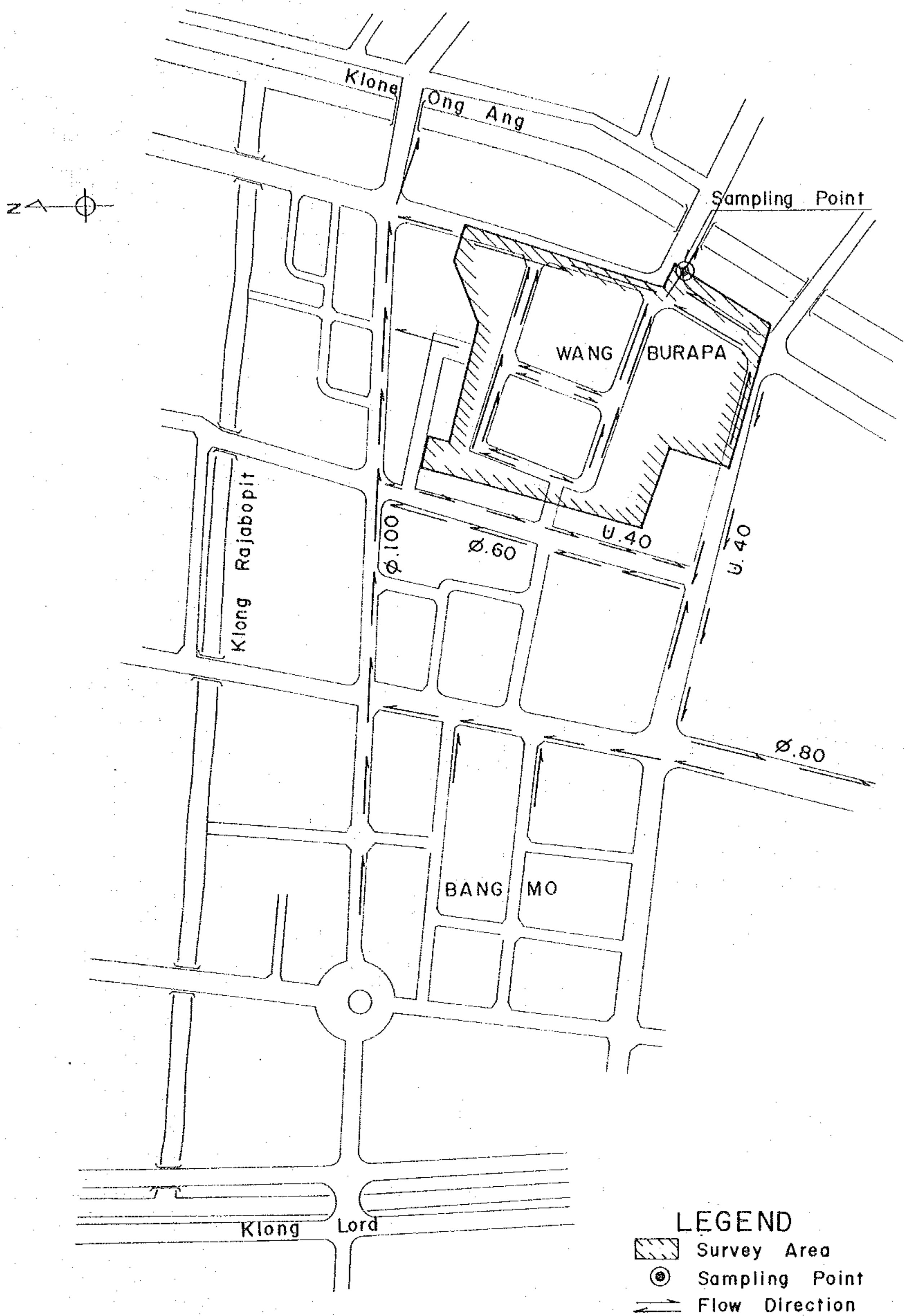


Figure G-4 Drain Network and Sampling Point at Wang Burapa

2.2 Sampling and Chemical Analysis

The wastewater samples were bi-hourly collected at the point of the inlet flow gauge of the Huay Kwang treatment facilities and/or at the outlet point of the drain network in Wang Burapa. And, if rained, the water samples were taken at 10 minutes interval during initial runoff. All the samples were stored in an ice packed cooler and refrigerator until analyzed.

The chemical analyses of the wastewater were made by the laboratories of Chulalongkorn University and Bureau of Drainage and Sewerage, BMA.

The parameters analyzed are pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and chloride ion (Cl).

The findings of the surveys are shown in Tables G.1 through G.3.

In Table G.1, the data on 26 August shows wet-weather discharge from a typical drainage system in Bangkok, and the data on 27 August is dry-weather wastewater. The average dry-weather wastewater flow rate, BOD and SS at Wang Burapa are 28.2 l/sec, 74 mg/l and 24 mg/l respectively.

At Huay Kwang the average vlaues are 68.8 l/sec of flow rate, 147 mg/l of BOD, 151 mg/l of SS. Comparing the data obtained from two surveyed areas, it is considered that in the sewer system of Wang Burapa, i.e. a typical drainage system in Bangkok, dilution of wastewater by ground water infiltration and deposition of suspended solids are dominant.

2.3 Home Visit

To obtain the background information a home visit survey was carried out at each surveyed area by BDS staff conducted by the survey team.

Table G.1 Findings of Wastewater Survey at Wang Burapa

2523 (1980)

Date	Time	Flow Rate l/sec	pH	BOD mg/l	COD mg/l	SS mg/l	CL mg/l
26 Aug.	10:00	24.2	7.18	89	147	53	52
	11:00	26.4	-	-	-	-	-
	12:00	26.4	7.21	82	143	48	53
	13:00	32.8	-	-	-	-	-
	14:00	29.7	7.25	96	171	47	52
	15:00	28.9	-	-	-	-	-
	16:00	32.5	7.54	88	151	52	57
	17:00	33.9	-	-	-	-	-
	:45	34.7	-	-	-	-	-
	:55	75.4	7.42	125	1,047	359	52
	18:00	299.6	7.40	145	1,321	584	42
	:05	221.7	-	-	-	-	-
	:10	212.0	7.42	142	936	573	31
	:15	216.9	-	-	-	-	-
	:20	212.0	7.44	114	403	253	24
	:30	163.4	7.39	71	210	91	22
	:40	160.9	7.34	54	250	94	29
	19:00	125.4	7.37	48	70	63	22
	20:00	42.7	-	-	-	-	-
	21:00	55.5	7.13	74	111	69	47
	:00	68.9	7.22	86	145	108	45
	:20	72.4	7.26	77	170	70	44
	:30	71.4	7.24	69	123	146	43
	:40	65.9	7.31	66	36	72	44
	22:00	64.6	7.28	92	111	74	44
	24:00	39.8	7.24	32	51	21	38
27 Aug.	2:00	37.6	7.34	23	25	11	39
	4:00	35.2	7.24	16	45	8	38
	6:00	29.5	7.27	16	20	6	37
	8:00	30.4	6.71	100	565	66	79
	9:00	28.6	-	-	-	-	-
	10:00	29.5	7.41	93	138	25	59
	11:00	31.3	-	-	-	-	-
	12:00	34.2	7.04	102	166	40	88
	13:00	35.7	-	-	-	-	-
	14:00	25.1	7.10	120	182	23	63
	15:00	30.9	-	-	-	-	-
	16:00	27.1	7.20	89	154	26	56
	17:00	30.8	7.20	121	213	31	110
	18:30	25.7	7.16	107	182	28	74
	20:00	30.7	7.45	107	170	33	69
	22:00	26.9	7.46	100	265	47	66
	24:00	29.1	7.27	50	988	17	43
28 Aug.	2:00	28.3	7.29	32	36	6	37
	4:00	27.8	7.37	24	36	12	38
	6:00	28.1	7.37	22	36	15	36
	8:00	20.1	7.29	35	44	11	42
	10:00	25.1	7.12	89	136	29	58

Table G.2 Flow Rate, BOD and SS of Wastewater at Huay Kwang

2523 (1980)

Date	Time	Flow Rate	BOD		SS	
		l/sec	mg/l	g/s	mg/l	g/s
29 Jan.	9:00	71.1	303	21.5	339	24.1
	11:00	88.9	160	14.2	213	18.9
	13:00	80.0	136	10.9	168	13.4
	15:00	71.1	123	8.7	144	10.2
	17:00	71.1	137	9.7	114	8.1
	19:00	71.1	164	11.7	160	11.4
	21:00	80.0	152	12.2	148	11.8
	23:00	72.9	136	9.9	140	10.2
30 Jan.	1:00	65.8	98	6.4	71	4.7
	3:00	56.9	69	3.9	74	4.2
	5:00	56.9	68	3.9	62	3.5
	7:00	64.0	280	17.9	27	17.2
	9:00	71.1	220	15.6	208	14.9
	11:00	74.7	159	11.9	154	11.5
	13:00	71.1	126	9.0	141	10.0
	15:00	67.6	123	8.3	144	9.7
	17:00	69.4	137	9.5	148	10.3
	19:00	71.1	157	11.2	152	10.8
	21:00	74.7	154	11.5	170	12.7
	23:00	71.1	117	8.3	118	8.4
	1:00	65.8	103	6.8	78	5.1
	3:00	56.9	63	3.6	50	2.8
	5:00	51.6	77	4.0	68	3.5
	7:00	56.9	294	16.7	292	16.6
	9:00	71.1	165	11.7	172	12.2
Average		68.8	147	10.1	151	10.4

Table G.3 Flow Rate at Huay Kwang Wastewater Treatment Facilities

2523 (1980)

Date	Time	Flow Rate (l/sec)
27 Aug.	17:00	53.4
	19:00	58.7
	21:00	85.4
	23:00	81.8
28 Aug.	1:00	60.5
	3:00	42.7
	5:00	35.6
	7:00	92.5
	9:00	85.4
	11:00	67.6
	13:00	53.4
	15:00	49.8
	17:00	58.7
	19:00	64.0
	21:00	80.0
	23:00	76.5
29 Aug.	1:00	56.9
	3:00	40.9
	5:00	35.6
	7:00	71.1
	9:00	97.8
	11:00	96.0
	13:00	85.4
	15:00	72.9

Date	Time	Flow Rate (l/sec)
8 Sept.	15:00	67.6
	17:00	67.6
	19:00	72.9
	21:00	80.0
	23:00	74.7
9 Sept.	1:00	49.8
	3:00	35.6
	5:00	28.5
	7:00	94.3
	9:00	74.7
	11:00	58.7
	13:00	49.8

Data on family composition, mean water consumption rate, monthly income, etc. were collected from each house selected by the random sampling method.

The findings of home visits are shown in Tables G.4 and G.5. The average household population in Huay Kwang is 5.9 persons per unit, and their monthly income is 3,700 baht per unit per month, so they are classified to the middle or low income group in Bangkok.

The per capita water consumption is estimated at 184 liters per capita per day in Huay Kwang. The water bills show that their expenditure for water is about 1 percent of their income.

3. Results and Discussion

3.1 Per Capita Flows and BOD Loadings

The results of the dry-weather wastewater survey are summerized in Table G.6.

The domestic wastewater flow is strongly affected by living condition of residents, especially water consumption rate. According to "Water Use Study" (MWWA, 2520), water uses for high or low income groups are varied between more than 350 l/day/cap and less than 200 l/day/cap, and average to 230 l/day/cap.

As the Huay Kwang community surveyed belongs to comparatively low income groups, the per capita flow of 157 l/day/cap (Table G.6) is corrected to the average flow of residential area of 184 l/day/cap by the factor of 1.17.

Strength of BOD and SS of wastewater is usually almost same if the wastewater is collected by sanitary sewers which are provided for both sullage water and nightsoil as seen at Huay Kwang (Table G.6).

Table G.4 Findings of Home Visiting Survey in Huay Kwang Housing Estate

(Household Population and Monthly Income)

Flat No.	Surveyed			Monthly Income	
	Units	Persons	Persons/Unit	Baht / Month/Unit	Baht / Month/Capita
5	20	108	5.40	4,635	858
7	8	50	6.25	3,363	538
12	21	123	5.86	3,824	653
13	21	142	6.76	4,367	646
22	20	145	7.25	3,470	479
26	23	119	5.17	2,665	515
31	6	41	6.83	3,783	554
34	21	104	4.95	3,476	702
	140	832	5.94	3,700	623

Date: 28 Jan. 2523 (1980)

Table G.5 Findings of Home Visiting Survey in Huay Kwang Housing Estate
(Water Expenditure and Water Consumption)

Flat No.	Surveyed		Water Expenditure		Water Consumption	
	Units	Persons	Baht/Month/Unit	Baht/Month/Capita	M^3/Month/Unit	1/day/cap
5	-	-	-	-	-	-
7	6	39	44.0	6.77	28.8	148
12	16	102	45.7	7.16	36.0	188
13	18	127	47.7	6.75	41.0	193
22	13	80	37.4	6.08	33.1	179
26	2	7	22.8	6.50	25.3	240
31	-	-	-	-	-	-
34	2	7	18.3	5.21	15.8	150
	57	362	42.2	6.64	35.1	184

Date : 28 Jan. 2523 (1980)

On the other hand, low SS value comparing with BOD, as seen at Wang Burapa, indicates that some portion of loading produced in the area may be reduced in the sewers by deposition.

From above, it is estimated that about 30 percent of BOD produced in Wang Burapa would be reduced in sewers. Therefore, total BOD load of 181 kg/day (Table G.6) is corrected to 235 kg/day of BOD production in the area by the factor of 1.30.

Following the definition of the "domestic" and "commercial" wastewaters, both of them are estimated as shown in Table G.7 on the basis of land use pattern, "residential" and "commercial". BOD contents of each wastewater are assumed at 260 mg/l as can be calculated from the figures shown in Table G.6.

Table G.6 Summary of Domestic Wastewater Survey

	Unit	Wang Burapa	Huay Kwang
Date	-	Aug. 2523(1980)	Jan. 2523(1980)
Area	ha	3.2	13
Population	Capita	647	19,958
Population Density	Capita/ha	202	1,535
Total Discharge	m^3/day	2,441	5,587
Infiltration*	"	1,737	2,462
Sewage Flow	"	704	3,125
Per Capita Flow	l/day/cap	1,088	157
Total Load BOD	kg/d	181**	821***
Total Load SS	kg/d	59**	844***
Per Capita BOD	g/day/cap	280**	41***
Per Capita SS	g/day/cap	91**	42***

* It is assumed that minimum flow equals to infiltration.
** Septic tanks are applied to nightsoil removal in this area.
*** Both sullage water and nightsoil are collected by sanitary sewers.

Table G.7 Per Capita Wastewater

2523(1980)

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

* Value of per capita correspondent.

3.2 Wet Weather Wastewater Survey

During field sampling at Wang Burapa there was heavy rainfall of which pattern could be seen quite frequently in Bangkok during rainy season. The rainfall pattern is characterized by strong intensity and short duration. The rainfall intensity changed as shown in Figure G.5 (100 mm/hr for first 10 minutes, 20 mm/hr for successive 30 minutes).

Figure G.5 shows a typical initial runoff pattern of storm-water from the town area in Bangkok. In the town area the initial runoff is very quick because of high density roof cover and pavement and small tributary area (in this case about 3.2 ha).

BOD and SS contents of the storm-water increases up to about 20 times of dry weather averages in a short time and then quickly decreases less than the averages. The initial increasing may be caused by flushing deposits from the sewer system, and the successsive decreasing may be caused by dilution of wastewater by the storm-water.

This characteristics of the initial runoff and loadings would be considered to determine the effects of intercepting of wastewater on the water pollution control of the receiving waters.

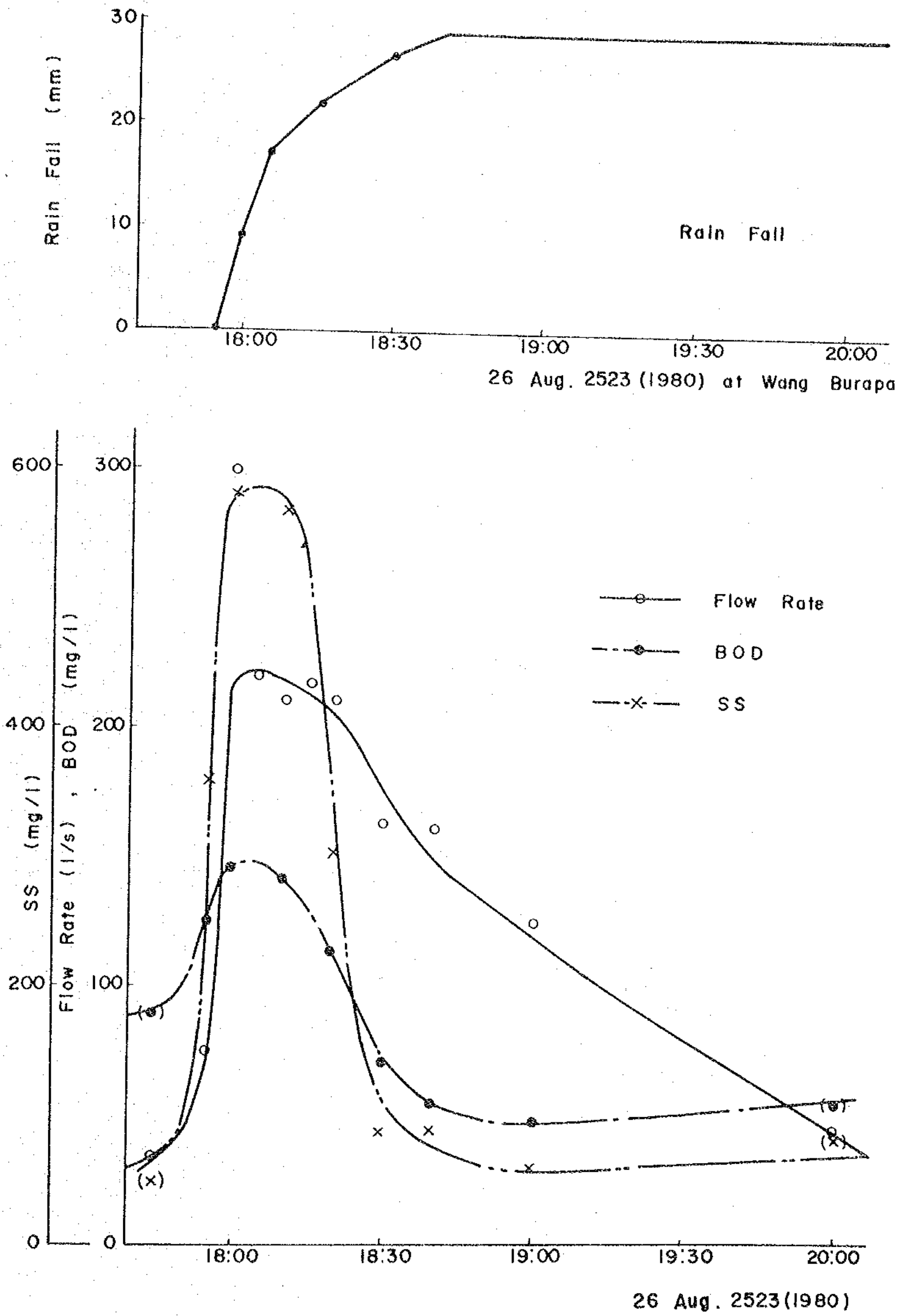


Figure G·5 Typical Initial Runoff Pattern of Storm Water

APPENDIX H

WATER POLLUTION SURVEY

APPENDIX H

WATER POLLUTION SURVEY

In the Master Plan Area there are many klongs which were constructed in ansewer to navigation, drainage and irrigation needs and have been known as a symbol of Bangkok for tourists. However, in the last decade the klongs, especially in the central Bangkok, have been heavily polluted owing to wastewater discharge.

1. Sampling and Chemical Analysis

During this Master Planning water quality analyses on the klongs in the Master Plan Area were made by the Laboratory of Bureau of Drainage and Sewerage (BDS), BMA, from March 2523 (1980) through September 2523 (1980). The water samples were collected once a month from 56 locations in 34 klongs at surface of each klong. The sampling points are shown in Table H.1 and Figure H.1.

2. Findings of the Survey

The findings of the survey are shown in Table H.2. These findings confirmed the existing condition of klong pollution in the Master Plan Area, especially in the central area. The nuisance conditions such as foul odor and black color of water have occurred in these klongs. The water quality of the polluted klongs located in the central Bangkok is similar to that of wastewater as described below.

<u>Temperature</u>

The water temperature of the klongs varied from 28°C to 32°C. It would be more than 26°C even in December which is the coldest season in Thailand and not included in this survey period.

These comparatively higher temperatures cause to increase the rate of decomposition of biodegradable matter such as BOD, and to decrease DO content of the water.

Dissolved Oxygen (DO)

The DO content of the klongs was in the range of zero to 6.7 mg/l. Even the highest DO content was less than the saturation of oxygen. The DO content of the klong located in the town area of Bangkok and Thonburi are always zero or nearly zero. Klongs Rajabopit, Watteptida, Ong Ang, Bang Lam Poo, Nahanak and Padung Krung Kasem in Bangkok, and Klongs San, Bang Sai Kai and Bang Nam Chong in Thonburi are the examples of these.

Klongs Bangkok Noi, Bangkok Yai, Dao Kanong, Rat Burana, Bang Prokok, etc. have also very low DO content sometimes in a year even though these klongs receive comparatively small amount of pollutants such as BOD. This is caused by backing up of the Chao Phya River water of which DO contents have been reduced by assimilation of pollutants originating from industrial and/or domestic wastewater.

Biochemical Oxygen Demand (BOD)

The highest BOD content of the klong waters surveyed was 240 mg/l in Klong Rajabopit of which average BOD content was also the highest, 154 mg/l, among the klongs surveyed. These figures closely represent domestic wastewater.

The lowest BOD contents, 2 to 4 mg/l, were measured in Klongs Chaeng Ron, Rat Burana, Bang Prakok, and Bang Pa Kaeo. These klongs are almost free from the domestic wastes.

The klongs receiving domestic wastewaters from town area are about 50 mg/l of BOD and almost zero of DO content. It is supposed that these klongs may be contributing as an anaerobic pond for stabilization of domestic wastewater discharged from the central area.

Suspended Solids (SS)

In temperate countries SS content of surface waters is used as an index of pollutants from municipal or industrial activities. However, in tropical countries such as Thailand, surface waters often include high SS content even in the dry weather.

Klongs Rat Burana, Bang Prakok, and Bang Pakaeo have markedly higher SS content than the other klongs in spite of less pollution. This can be considered to be caused by backing up of the river water of which SS content is very high because of flooding of the up streams of the Chao Phya River.

As shown in Table H.1, the klong waters polluted by the wastewater have less SS content than comparatively clean waters in the Master Plan Area.

Chloride Ions (Cl)

During low flow of the Chao Phya River seawater intrudes acrossing the Memorial Bridge.

And, the chloride content of the klong waters is also affected by the seawater intrusion. As the rainfall of the Chao Phya basin was very small in 2522 (1979), Klong Bangkok Noi which is located around 50 km from the river mouth contained more than 1,000 mg/l of chloride in April 2524 (1980).

Hydrogen Sulfide (H_2S)

Odor nuisance have occurred from the klongs located in the central Bangkok, especially Klongs Ong Ang, Mahanak and Drung Kasem, and from the Pumping Stations of Krung Kasem and Rama IV which are furnished to discharge combined storm-water and wastewater from the central area.

Hydrogen sulfide is a main source of the odor nuisance from the polluted waters, and is toxic for human body and errosive for city structures. High concentration of hydrogen sulfide was observed in the heavily polluted klong waters, especially during low tide and the water running.

Coliforms

Coliforms which is an indication of contamination of human fecal material were detected in quite high concentration from the almost all of the klongs in the central area. This indicates that the klong waters are potentially hazardous on the public health especially for the people associated with the use of the water for washing, bathing and other uses.

From these figures of coliforms it is suspected that the toilet systems, septic tanks and/or cesspools, of which liquid effluents are soaked into the ground as a rule are functional to remove toilet wastes from each house in Bangkok.

Table H.1 List of Klongs Surveyed and Sampling Points

Name of Klong	Point No.	Sampling Point
1. Klong Lord	011	Outside Gate near Rechinee School
	012	Gate near Rachinee School
	013	In front of Department of Land
	014	In front of Royal Hotel
	015	Pra Pin Klae Bridge
2. Klong Wat Tep Tida	021	Behind BMA Office
3. Klong Wat Rajabopit	031	Tre Tong Road Cross
4. Klong Bang Lam Poo	041	In front of Talat Nana
	042	Rachadamnon Road Cross
5. Klong Ong Ang	051	Chalerm Krung Road Cross
6. Klong Mahanak	061	Chakra Padipong Road Cross
	062	Talat Mahanak
7. Klong Padung Krung Kasem	071	Outside Pump Station
	072	Krung Kasem Pump Station
	073	In front of Bangkok Railway Station
	074	In front of DTEC
	075	Talat Tevaraj
8. Klong Sam Sen	081	Boat Maepra
	082	Sam Sen Road Cross
	083	Savia Housing Community
9. Klong San Saep	091	Din-Daeng Asoka Road Cross
	092	Mit Mahad Thai Bridge
	093	Bang Kapi Bridge
10. Klong Tan	101	Klong Tan Pump Station
11. Klong Prem Prachakorn	111	Sri Ayuthaya Road Cross
	112	Srad Satien School
	113	Talat Bang Sue
	114	Cook Bang Ken
12. Klong Bang Sue	121	Pibool Song Kram Bridge
	122	Mear by Jatujak Park

- to be continued -

continued

Name of Klong	Point No.	Sampling Point
13. Klong Sathon	131	YWCA
14. Klong Chong Nonsi	141	Ling Road Cross
15. Klong Bang Sai Kai	151	Taksin Road Cross
16. Klong San	161	Ta Din Daeng Bridge
17. Klong Huay Kwang	171	Near NHA community
18. Klong Lad Prao	181	Soi Sena Nikom I
	182	Pibool Upatan School
19. Klong Bang Nam Chon	191	Taksin Road Cross
20. Klong Dao Kanong	201	Taksin Road Cross
21. Klong Bang Kun Tien	211	Tod Thai Road
22. Klong Pasi Jaroen	221	Wat Rang Bua School
23. Klong Bangkok Yai	231	Fire Police Station
24. Klong Rama VI	241	Rama VI Engineering School
25. Klong Mon	251	Charan Sanit Wong Road Cross
	252	Bang Sao Tong Police Station
26. Klong Bangkok Noi	261	Soi Wat Gaitee
	262	Suwan Naram School
27. Klong Pra Kanong	271	Wat Yang Sutaram
	272	Sukumvit Road Cross
28. Klong Bang Na	281	Sukumvit Road Cross
29. Klong Toey	291	Near pig geed factory
30. Klong Pai Sin Toe	301	Vittayu Road Cross
31. Klong Chaeng Ron	311	Sukusawad Road Cross
32. Klong Rat Burana	321	Sukusawad Road Cross
33. Klong Bang Prakok	331	Sukusawad Road Cross
34. Klong Bang Pa Kaeo	341	Sukusawad Road Cross

The name of the sampling points are shown in Table H.1.

Fig. H.1 Sampling Points for Klong Survey

Table H.2 Findings of the Water Quality Survey (BDS, 2523)

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
011	5 Mar.	14:15	30	-	2.1	-	5	-	-	-	-	Klong Lord
	1 Apr.	10:40	31	-	0	-	14	137	1,129	-	-	
	25 Apr.	9:40	31	-	1.6	-	20	135	746	-	-	
	19 May	14:00	31	7.3	0	-	42	45	1,050	-	-	
	3 June	11:00	30	7.6	1.1	-	6	-	-	-	-	
	2 Sep.	-	29.5	7.4	4.5	11	6	32	16	0	-	
	Average				1.6	11	16	87	735	0	-	
012	5 Mar.	14:17	30	-	1.9	-	9	-	-	-	-	
	1 Apr.	-	-	-	-	-	-	-	-	-	-	
	25 Apr.	9:50	31	-	0.9	-	17	18	169	-	-	
	19 May	14:25	31	7.2	0	-	51	81	250	-	-	
	3 June	11:05	30	7.4	0	-	19	-	-	-	-	
	2 Sep.	-	30	7.3	0	23	15	62	26	0.2	-	
	Average				0.6	23	22	54	148	0.2	-	
013	5 Mar.	14:30	30	-	1.2	-	9	-	-	-	-	
	1 Apr.	10:45	30.5	-	0	-	28	115	968	-	-	
	25 Apr.	10:00	31	-	0	-	11	13	88	-	-	
	19 May	14:30	30	7.2	0	-	82	3	108	-	-	
	3 June	11:10	30	7.4	0.3	-	12	-	-	-	-	
	3 Sep.	-	30.2	7.1	0	94	55	20	62	0	210,000	
	Average				0.3	94	33	38	307	0	210,000	
014	5 Mar.	14:40	30	-	0	-	32	-	-	-	-	
	1 Apr.	-	31	-	0	-	42	123	663	-	-	
	25 Apr.	10:10	31	-	0	-	21	7	79	-	-	
	19 May	14:45	30	7.2	0	-	72	4	76	-	-	
	3 June	11:15	30	7.3	0.1	-	10	-	-	-	-	
	2 Sep.	-	31	7.3	0	25	14	18	43	0	-	
	Average				0	25	32	38	215	0	-	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
015	5 Mar.	14:50	30	-	1.6	-	6	-	-	-	-	Klong
	-	-	-	-	-	-	-	-	-	-	-	Lord
	25 Apr.	9:27	31	-	1.5	-	9	22	587	-	-	
	19 May	14:00	31	7.3	0	-	44	30	510	-	-	
	3 June	11:30	29	7.4	0.1	-	8	-	-	-	-	
	2 Sep.	-	30	7.5	4.5	15	7	12	12	0	-	
	Average				1.5	15	15	21	370	0	-	
021	5 Mar.	15:15	30	-	0	-	50	-	-	-	-	Klong
	1 Apr.	11:15	30	-	0	-	68	118	331	-	-	Watteptida
	25 Apr.	10:30	31	-	0	-	18	23	70	-	-	
	19 May	15:00	29	7.3	0	-	100	40	72	-	-	
	3 June	10:55	29	7.0	0	-	112	-	-	-	-	
	3 Sep.	-	30.5	7.3	0	101	48	29	61	0	72,000	
	Average				0	101	66	53	134	0	72,000	
031	5 Mar.	15:00	30	-	0	-	240	-	-	-	-	Klong
	1 Apr.	10:50	30	-	0	-	144	162	495	-	-	Rajabopit
	25 Apr.	10:20	31	-	0	-	175	54	210	-	-	
	19 May	14:50	30	6.9	0	-	150	45	104	-	-	
	3 June	10:30	29	7.3	0	-	46	-	-	-	-	
	2 Sep.	-	30	7.3	0	303	168	43	115	0.5	1,700,000	
	Average				0	303	154	76	231	0.5	1,700,000	
041	12 Mar.	10:05	30	-	2.5	-	9	-	-	-	-	Klong
	2 Apr.	10:35	29	-	0	-	40	102	227	-	-	Bang Lam Poo
	25 Apr.	13:45	32	7.3	0	-	30	13	-	-	-	
	21 May	10:45	30	7.5	0	-	17	-	600	-	-	
	4 June	9:30	29	7.5	0	-	9	-	-	-	-	
	2 Sep.	-	31	7.6	0	105	73	40	64	0	1,700,000	
	Average				0.4	105	30	52	297	0	1,700,000	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
042	12 Mar.	10:15	30	-	2.5	-	5	-	-	-	-	Klong
	2 Apr.	10:45	29	-	0	-	45	97	223	-	-	Bang Lam Poo
	25 Apr.	14:00	33	7.2	0	-	56	47	-	-	-	
	21 May	10:55	29	7.5	0	-	25	-	320	-	-	
	4 June	9:50	29	7.4	0	-	18	-	-	-	-	
	2 Sep.	-	31	7.2	0	116	67	20	65	0.2	-	
	Average				0.4	116	36	55	203	0.2	-	
051	12 Mar.	10:45	29	-	0	-	4	-	-	-	-	Klong
	2 Apr.	11:10	29	-	0	-	42	60	196	-	-	Ong Ang
	25 Apr.	14:30	33	7.1	0	-	72	13	-	-	-	
	21 May	11:30	29	7.4	0	-	51	-	270	-	-	
	4 June	10:00	29	7.3	0	-	51	-	-	-	-	
	2 Sep.	-	30.5	7.1	0	122	69	21	58	0	-	
	Average				0	122	48	31	175	0	-	
061	12 Mar.	10:35	29	-	0	-	4	-	-	-	-	Klong
	2 Apr.	10:50	29	-	0	-	83	115	100	-	-	Mahanak
	25 Apr.	14:15	33	7.2	0	-	53	-	-	-	-	
	21 May	11:00	28	7.4	0	-	54	-	170	-	-	
	4 June	9:55	29	7.3	0	-	45	-	-	-	-	
	2 Sep.	-	30.5	7.3	0	89	56	29	69	0	-	
	Average				0	89	49	66	113	0	-	
062	13 Mar.	10:05	30	-	0	-	15	-	-	-	-	
	3 Apr.	10:05	30.5	-	0	-	15	53	587	-	-	
	28 Apr.	11:20	30	7.3	0	92	44	63	109	-	-	
	22 May	10:40	29	7.4	0	-	22	-	350	-	-	
	5 June	10:00	30	7.4	0	-	19	-	-	-	-	
	3 Sep.	-	30	7.2	0	74	27	22	65	0.5	640,000	
	Average				0	83	24	46	278	0.5	640,000	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
071	13 Mar.	9:35	29	-	0.8	-	4	-	-	-	-	Klong
	3 Apr.	9:30	30	-	0	-	38	127	-	-	-	Krung Kasem
	28 Apr.	10:40	31	7.4	2.1	35	14	103	420	-	-	
	22 May	10:15	30	7.6	2.1	-	7	-	215	-	-	
	5 June	9:45	30	7.4	0.5	-	4	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	Average				1.1	35	13	115	618	-	-	
072	13 Mar.	9:30	29	-	0	-	37	-	-	-	-	
	3 Apr.	9:25	30	-	0	-	48	39	197	-	-	
	28 Apr.	10:46	31	7.3	0	98	47	79	110	-	-	
	22 May	10:05	29	7.4	0	-	41	-	240	-	-	
	5 June	9:30	29	7.4	0	-	33	-	-	-	-	
	3 Sep.	-	30	7.1	0	68	45	26	61	0	5,400,000	
	Average				0	83	42	48	150	0	5,400,000	
073	13 Mar.	9:55	29	-	0	-	48	-	-	-	-	
	3 Apr.	9:45	30	-	0	-	45	73	147	-	-	
	28 Apr.	11:10	30	7.7	0	89	43	63	109	-	-	
	22 May	10:30	29	7.4	0	-	43	-	85	-	-	
	5 June	9:55	30	7.4	0	-	31	-	-	-	-	
	13 Sep.	-	30	7.1	0	55	35	20	59	0.5	-	
	Average				0	72	41	52	100	0.5	-	
074	13 Mar.	10:15	29	-	0	-	23	-	-	-	-	
	3 Apr.	10:15	30	-	0.5	-	100	60	312	-	-	
	28 Apr.	12:45	31	7.7	4.4	81	44	83	138	-	-	
	22 May	11:00	29	7.4	0	-	25	-	160	-	-	
	5 June	10:10	29	7.5	0.5	-	15	-	-	-	-	
	3 Sep.	-	29.5	7.3	0	48	20	30	65	0.5	-	
	Average				0.9	65	38	59	169	0.5	-	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/1)	COD (mg/1)	BOD (mg/1)	SS (mg/1)	CL (mg/1)	H_2S (mg/1)	Coliforms (MPN/100 ml)	Remarks
075	13 Mar.	10:30	30	-	1.8	-	21	-	-	-	-	Klong Krung Kasem
	3 Apr.	10:30	30.5	-	0.3	-	85	63	397	-	-	
	28 Apr.	12:25	32	7.8	9.5	81	47	76	140	-	-	
	22 May	11:20	29	7.3	0	-	23	-	205	-	-	
	5 June	10:15	29	7.4	0	-	25	-	-	-	-	
	3 Sep.	-	30	7.0	0	96	44	29	85	0	40,000	
	Average				0.4	89	41	56	207	0	40,000	
081	19 Mar.	9:30	29	-	0	-	33	-	-	-	-	Klong Sam Sen
	4 Apr.	9:55	29	-	0	-	42	72	130	-	-	
	29 Apr.	9:55	29	7.3	0	77	68	10	-	-	-	
	20 May	12:35	29	7.2	0	-	56	94	80	-	-	
	10 June	13:35	29	7.3	0	-	22	-	-	-	-	
	10 Sep.	-	29	7.4	0	66	32	5	78	4	6,800	
	Average				0	72	42	45	96	4	6,000	
082	20 Mar.	10:45	31	-	0.7	-	15	-	-	-	-	
	8 Apr.	10:35	31	-	3.2	-	17	195	360	-	-	
	30 Apr.	10:30	30.5	7.3	0	-	26	143	-	-	-	
	23 May	11:45	29	7.6	0.9	-	20	-	180	-	-	
	11 June	12:15	28	7.4	0.9	-	13	-	-	-	-	
	8 Sep.	-	30	7.2	0	24	34	94	27	0	-	
	Average				1.0	24	21	144	189	0	-	
083	21 Mar.	9:20	29	-	0	-	20	-	-	-	-	
	22 Apr.	11:45	-	-	0	-	-	28	44	-	-	
	6 May	10:20	31	7.2	0	-	41	24	44	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	3 Sep.	-	29	7.2	0	79	50	39	71	0.5	31,300	
	Average				0	79	37	30	53	0.5	31,300	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
091	19 Mar.	9:45	30	–	0	–	25	–	–	–	–	Klong San Sep
	4 Apr.	10:00	30	–	0	–	95	92	125	–	–	
	29 Apr.	10:10	30	7.6	1.5	92	47	9	–	–	–	
	20 May	12:45	30	7.4	0	–	59	124	70	–	–	
	10 June	13:40	31	7.8	6.7	–	21	–	–	–	–	
	10 Sep.	–	29	7.3	0	58	18	4	77	0.6	6,100	
	Average				0.3	75	44	57	91	0.6	6,100	
092	19 Mar.	10:15	29	–	0	–	23	–	–	–	–	
	4 Apr.	10:25	30.5	–	0	–	38	96	118	–	–	
	29 Apr.	10:45	30	7.7	2.8	18	14	57	–	–	–	
	20 May	11:36	30	7.4	0	–	76	120	165	–	–	
	10 June	14:00	30	6.9	2.7	–	11	–	–	–	–	
	10 Sep.	–	30	6.8	0.9	12	7	4	42	0	1,060	
	Average				1.0	15	28	69	108	0	1,060	
093	19 Mar.	10:30	30	–	2.1	–	22	–	–	–	–	
	4 Apr.	10:40	30.5	–	0	–	25	86	128	–	–	
	29 Apr.	11:00	32	7.8	0.6	102	–	10	–	–	–	
	20 May	12:00	29	7.5	0	–	37	104	155	–	–	
	10 June	14:10	30	6.9	2.1	–	9	–	–	–	–	
	10 Sep.	–	30	6.8	1.5	4	9	13	40	0	161	
	Average				1.1	54	20	53	108	0	161	
101	19 Mar.	11:00	30	–	0	–	13	–	–	–	–	Klong Tan
	4 Apr.	11:00	32	–	0.3	–	60	100	398	–	–	
	29 Apr.	10:25	29	7.6	0	69	45	33	–	–	–	
	20 May	12:25	29	7.5	0	–	32	94	234	–	–	
	10 June	14:30	30	7.2	0.1	–	9	–	–	–	–	
	10 Sep.	–	29	7.4	0	47	15	26	67	0	5,205	
	Average				0.1	58	29	63	230	0	5,205	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
111	20 Mar.	10:00	30	-	4.0	-	26	-	-	-	-	Klong Prem Pracha-korn
	8 Apr.	9:48	31	-	6.3	-	24	97	248	-	-	
	30 Apr.	9:50	30	7.5	0.7	66	31	15	-	-	-	
	23 May	10:30	29	7.7	5.2	-	31	100	-	-	-	
	11 June	11:20	29	7.6	4.3	-	9	-	-	-	-	
	3 Sep.	-	30	7.2	1.5	48	13	38	40	0	-	
	Average				3.7	57	22	50	129	0	-	
112	20 Mar.	10:00	30	-	1.5	-	18	-	-	-	-	
	8 Apr.	10:00	30	-	1.1	-	6	98	96	-	-	
	30 Apr.	9:55	30	7.3	0	36	18	20	-	-	-	
	23 May	10:45	30	7.6	0	-	48	-	175	-	-	
	11 June	11:40	28	7.3	1.5	-	8	-	-	-	-	
	3 Sep.	-	30	7.2	0.7	52	22	31	55	0	-	
	Average				0.8	44	21	50	109	0	-	
113	20 Mar.	10:20	30	-	0.9	-	9	-	-	-	-	
	8 Apr.	10:10	-	-	1.6	-	23	108	223	-	-	
	30 Apr.	10:05	31	7.4	0.6	40	15	20	-	-	-	
	23 May	11:10	29	7.5	0	-	36	-	85	-	-	
	11 June	11:45	28	7.3	0.5	-	10	-	-	-	-	
	3 Sep.	-	30	7.2	0.6	52	18	19	58	0	1,700,000	
	Average				0.7	46	19	49	122	0	1,700,000	
114	27 Mar.	12:40	29	-	2.0	-	8	-	-	-	-	
	18 Apr.	10:00	28	-	1.0	-	7	42	-	-	-	
	30 Apr.	11:30	30	7.5	1.7	-	14	46	55	-	-	
	30 May	11:00	30	7.6	2.6	-	9	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	12 Sep.	-	29	7.0	0.3	32	6	4	43	0	60,000	
	Average				1.5	32	9	31	49	0	60,000	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
121	20 Mar.	10:30	30	-	0.9	-	9	-	-	-	-	Klong Bang Sue
	8 Apr.	10:20	32	-	3.3	-	22	95	200	-	-	
	12 Apr.	10:20	30.5	7.4	0.4	-	16	30	-	-	-	
	23 May	11:30	30	7.6	1.9	-	29	-	185	-	-	
	11 June	12:00	28	7.3	0.7	-	12	-	-	-	-	
	3 Sep.	-	30	7.1	0	24	18	39	38	0	7.100	
	Average				1.2	24	18	55	141	0	7,100	
122	21 Mar.	9:35	29	-	0	-	35	-	-	-	-	
	22 Apr.	12:00	31	-	0	-	-	38	68	-	-	
	6 Apr.	10:35	31	7.2	0	-	55	27	66	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	8 Sep.	-	29	7.3	0	48	20	19	56	0.5	-	
	Average				0	48	37	28	63	0.5	-	
131	27 Mar.	11:50	29	-	0	-	91	-	-	-	-	Klong Sathon
	9 Apr.	12:45	31	-	0	-	40	36	72	-	-	
	9 Apr.	13:20	32	7.2	0	-	75	-	85	-	-	
	27 May	9:50	30	7.6	0	-	40	-	90	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	31	7.4	0	101	38	17	107	0	19,500	
	Average				0	101	57	27	89	0	19,500	
141	27 Mar.	11:30	29	-	2.6	-	31	-	-	-	-	Klong Chong Nonsi
	9 Apr.	12:45	31	-	2.9	-	11	27	1,000	-	-	
	9 Apr.	13:30	32	7.4	2.5	-	55	-	745	-	-	
	27 May	10:05	30	7.6	0	-	48	-	285	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	30	7.3	3.5	39	3	230	11	0	1,340	
	Average				2.3	36	30	129	510	0	1,340	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
151	25 Mar.	10:20	29	-	0	-	45	-	-	-	-	Klong
	10 Apr.	9:45	30	-	0	-	26	40	78	-	-	Bang Saikai
	1 Apr.	10:00	32	7.1	0	128	-	2	175	-	-	
	27 May	11:15	30	7.2	0	-	63	-	85	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	17 Sep.	9:50	29.5	7.3	0	133	62	44	107	0	60,000	
	Average				0	131	50	29	111	0	60,000	
161	25 Mar.	10:10	29	-	0	-	39	-	-	-	-	Klong
	10 Apr.	9:25	31	-	-	-	84	46	100	-	-	San
	1 Apr.	9:30	32	7.2	0	92	55	21	108	-	-	
	27 May	11:30	30	7.2	0	-	98	-	80	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	17 Sep.	9:35	30	7.2	0	133	55	95	118	0	42,526	
	Average				0	63	66	54	102	0	42,526	
171	21 Mar.	10:40	29	-	0	-	24	-	-	-	-	Klong
	22 Apr.	10:50	32	-	0	-	21	30	62	-	-	Huay Kwang
	6 Apr.	11:30	31	7.7	0	-	62	6	87	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	9 Sep.	-	28.5	7.3	0	19	8	20	68	0	19,550	
	Average				0	19	29	19	72	0	19,550	
181	21 Mar.	9:50	29	-	0	-	28	-	-	-	-	Klong
	22 Apr.	12:20	32	-	0	-	13	30	72	-	-	Lad Prao
	6 May	10:45	30	7.5	0	-	39	-	86	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	9 Sep.	-	30	7.0	0	20	11	19	30	0	950	
	Average				0	20	23	25	63	0	950	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
182	21 Mar.	10:10	31	-	0.1	-	29	-	-	-	-	Klong Lad Prao
	22 Apr.	12:35	32	-	0	-	24	30	62	-	-	
	6 May	11:00	31	7.5	0	-	48	49	84	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	9 Sep.	-	30	7.1	0	23	9	21	33	0	4,740	
	Average				0	23	28	33	60	0	4,740	
191	25 Mar.	10:25	29	-	0	-	34	-	-	-	-	Klong Nam Chong
	10 Apr.	9:55	29.5	-	0	-	56	55	92	-	-	
	1 May	9:40	30	7.2	0	138	50	11	145	-	-	
	27 May	11:05	30	7.3	0	-	84	-	185	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	17 Sep.	9:55	29	7.3	0	144	42	6	124	0	35,000	
	Average				0	141	53	24	137	0	35,000	
201	25 Mar.	10:25	30	-	0	-	3	-	-	-	-	Klong Dao Kanong
	10 Apr.	10:15	31	-	2.1	-	21	93	1,000	-	-	
	1 May	9:45	30	7.3	0	142	21	77	1,190	-	-	
	27 May	10:05	30	7.4	0	-	23	-	425	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	17 Sep.	10:05	30.5	7.4	4.8	10	7	272	117	0	300	
	Average				3.5	76	15	147	683	0	300	
211	25 Mar.	10:55	30	-	0	-	6	-	-	-	-	Klong Bang Kun Tien
	15 Apr.	9:50	31	-	3.2	-	13	84	-	-	-	
	1 May	10:35	31	7.3	0	-	14	78	154	-	-	
	28 May	12:00	30	7.4	0	-	6	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	11 Sep.	-	29	7.2	0.7	38	8	64	67	0	4,850,000	
	Average				0.8	38	9	75	80	0	4,850,000	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
221	25 Mar.	11:05	30	-	0	-	8	-	-	-	-	Klong
	15 Apr.	10:00	31	-	3.1	-	34	129	-	-	-	Pasijaroen
	1 May	10:40	31	7.4	0	-	10	17	308	-	-	
	28 May	12:30	30	7.4	0.5	-	7	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	11 Sep.	-	30	7.3	0.8	51	11	3	216	0	10,400,000	
	Averege				0.9	51	14	50	262	0	10,400,000	
231	25 Mar.	11:25	30	-	0	-	9	-	-	-	-	Klong
	15 Apr.	9:30	31	-	2.6	-	22	106	-	-	-	Bangkok Yai
	1 May	10:45	31	7.3	0	-	13	59	167	-	-	
	28 May	11:40	29	7.3	1.4	-	7	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	11 Sep.	-	29.5	7.3	3.8	24	4	30	17	0	420	
	Average				1.6	24	11	65	92	0	420	
241	26 Mar.	12:15	29	-	0	-	24	-	-	-	-	Klong
	18 Apr.	9:45	29	-	0.5	-	18	49	-	-	-	Rama VI
	12 May	12:15	31	7.5	0	-	12	46	175	-	-	
	30 May	10:35	30	7.5	0	-	25	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	11 Sep.	-	30	7.4	2.5	20	5	58	22	0	1,050	
	Average				0.6	20	17	51	99	0	1,050	
251	26 Mar.	10:30	30	-	6.4	-	6	-	-	-	-	Klong
	10 Apr.	9:30	31	-	2.8	-	10	102	-	-	-	Mon
	15 May	10:40	31	7.7	2.4	-	15	40	720	-	-	
	28 May	10:30	29	7.3	1.3	-	6	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	18 Sep.	-	30.5	7.3	4.0	13	6	127	49	0	500	
	Average				3.4	13	9	90	385	0	500	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/1)	COD (mg/1)	BOD (mg/1)	SS (mg/1)	CL (mg/1)	H_2S (mg/1)	Coliforms (MPN/100 ml)	Remarks
252	26 Mar.	10:40	30	-	3.9	-	7	-	-	-	-	Klong Mon
	10 Apr.	9:40	31	-	2.7	-	16	93	503	-	-	
	15 May	11:00	31	7.8	3.0	-	16	126	1,075	-	-	
	28 May	10:35	29	7.3	1.4	-	4	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	18 Sep.	-	30	7.2	3.0	18	4	89	55	0	350	
	Average				2.8	18	9	103	544	0	350	
261	26 Mar.	11:20	30	-	6.2	-	5	-	-	-	-	Klong Bangkok Noi
	16 Apr.	10:10	31	-	2.8	-	19	67	652	-	-	
	9 May	9:45	32	-.5	3.0	-	14	64	250	-	-	
	28 May	11:00	30	7.4	2.2	-	6	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	18 Sep.	-	31	7.3	4.3	19	9	147	32	0	155	
	Average				3.7	19	9	93	311	0	155	
262	26 Mar.	12:00	30	-	5.8	-	5	-	-	-	-	
	16 Apr.	10:30	31	-	2.3	-	29	101	1,102	-	-	
	9 May	10:05	32	7.5	3.3	-	11	20	572	-	-	
	28 May	11:15	29	7.5	2.5	-	6	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	18 Sep.	-	31	7.3	4.3	5	4	154	44	0	1,300	
	Average				3.6	5	11	92	573	0	1,300	
271	27 Mar.	10:15	29	-	0	-	186	-	-	-	-	Klong Prakanong
	23 Apr.	9:30	31	-	0	-	20	42	598	-	-	
	8 May	10:15	32	7.7	3.1	-	134	-	1,344	-	-	
	16 May	9:50	30.5	7.8	1.3	-	54	26	885	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	30	6.9	1.2	23	4	18	66	0	174	
	Average				1.1	23	80	29	723	0	174	

To be continued

Continued

Sampling Point No.	Date	Time	Temp. (°C)	pH	DO (mg/l)	COD (mg/l)	BOD (mg/l)	SS (mg/l)	CL (mg/l)	H_2S (mg/l)	Coliforms (MPN/100 ml)	Remarks
272	27 Mar.	10:30	29	-	0	-	50	-	-	-	-	Klong Prakanong
	23 Apr.	9:45	31	-	0	-	27	20	798	-	-	
	8 May	10:20	31	7.5	0	-	-	-	1,418	-	-	
	16 May	-	30	7.7	0	-	46	6	1,535	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	30	7.0	0.9	23	4	17	53	0	1,260	
	Average				0.2	23	32	14	951	0	1,260	
281	27 Mar.	10:50	29	-	3.1	-	42	-	-	-	-	Klong Bang Na
	23 Apr.	10:30	31	-	0	-	22	56	1,968	-	-	
	8 May	10:30	31	7.5	4.1	-	44	-	5,004	-	-	
	16 May	10:30	30.5	7.4	0.9	-	61	195	5,423	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	30	7.4	0.9	43	11	88	150	0	800	
	Average				1.8	43	36	113	3,136	0	800	
291	27 Mar.	11:05	29	-	0	-	48	-	-	-	-	Klong Toey
	23 Apr.	10:30	31	-	0	-	25	26	2,162	-	-	
	8 May	11:20	32	7.4	0	-	124	-	2,631	-	-	
	16 May	10:50	30.5	7.6	0	-	45	18	2,119	-	-	
	-	-	-	-	-	-	-	-	-	-	-	
	16 Sep.	-	31	-	-	37	9	19	59	0	1,600	
	Average				0	37	50	21	1,743	0	1,600	
301	16 Sep.	-	33	7.1	0.3	90	28	18	130	0	12,700	Klong Pai Sin Toe
311	17 Sep.	10:20	29	7.4	1.3	22	4	81	89	0	700	Klong Chaeng Ron
321	17 Sep.	10:30	31	7.4	5.1	10	2	330	64	0	285	Klong Rat Burana
331	17 Sep.	10:35	31	7.3	4.3	6	4	311	57	0	1,000	Klong Bang Prakok
341	17 Sep.	10:45	30.5	7.4	5.0	12	2	339	44	0	340	Klong Bang Pa Kaeo

APPENDIX I

SEWER DESIGN FOR HYDROGEN SULFIDE CONTROL

APPENDIX I

SEWER DESIGN FOR HYDROGEN SULFIDE CONTROL

In the design of sewerage system for where strong and/or high temparature occurs, the consideration should be given to the question of potential sulfide problems as well as to the provision of self-cleansing sewer velocities.

1. Hydrogen Sulfide Generation

The presence of sulfides in wastewater flows is usually caused by the bacterial reduction of sulfates normally found in the originating water supply and augmented through human use. This bacterial activity is concentrated within a layer of slimes which typically develops on the submerged surfaces of the sewer. Generation of sulfides within the body of wastewater is very small and can safely be ignored.

Bacteria require oxygen to consume organic matter and when free oxygen is not available, certain species obtain oxygen from the sulfate ion ($SO_4^{=}$), leaving the sulfide ion ($S^{=}$). Through reaction of the sulfide ion with water there results a mixture of the ion HS^- and hydrogen sulfide H_2S. At pH 5, it is nearly all H_2S; at pH 9 it is nearly all HS^-. After the formation of H_2S within the flowing wastewater, the following actions can be do take place when corrosion of sewer pipelines occurs:

(1) Significant amounts of the hydrogen sulfide gas (H_2S) escapes from the flowing wastewater into the sewer air.

(2) A significant quantity of this H_2S is transferred to the surfaces of the sewer pipeline above the water surface.

(3) The H_2S reaching the non-submerged surfaces is oxidized (through bacterial action) with the resulting formation of sulfuric acid.

The process is shown diagramatically in Figure I.1.

When sewers are constructed of materials not immune to sulfuric acid attack, such as concrete, asbestos cement or steel, gradual corrosion results.

Inasmuch as sulfide is formed by the reduction of sulfate in the absence of dissolved oxygen, the oxygen balance of the stream is the determining factor. This is the balance between the quantity of oxygen initially avaialble in the stream plus the rate that oxygen is supplied by aeration at the surface of the stream, as related to the rate of oxygen demand by bacterial action in the wastewater. As the wastewater flows through the collecting network, the dissolved oxygen concentration is gradually diminished by a demand which exceeds supply. At some points in the system, dissolved oxygen is exhausted and sulfides appear. When dissolved sulfides reach average concentrations exceeding 0.1 mg/l and 1.0 mg/l produce attack of ordinary concrete at rates of one inch per century to one inch per decade respectively.

2. Sulfide Controlling Method

Hydrogen sulfide associated with the operation of sanitary sewers is produced in anaerobic environment as defined above. The key to their control is, therefore, keeping the wastewater aerobic by maintaining sufficient flow velocity in sewer. On the other hand, in flat areas the control of sulfides by providing adequate sewer slopes may require excessive costs of excavation. In such cases pipe materials which are inert to sulfide attack should be considered. Taking the concept mentioned above into account, the following three methods are brought up for sulfide control.

a. Keep sufficient flow velocity to prevent sulfide build-up without special sulfide corrosion protection measures.

b. Use anti-sulfide corrosion pipe or linning pipe without special velocity control where sulfide build-up is expected.

c. Inject air to keep wastewater aerobic without special considerations on flow velocity and pipe material.

In the majority of cases the problem may be economically resolved by selection of proper sewer slopes and pipe diameters which produce sulfide controlling velocities.

3. Formulas for Sulfide Build-up

The fundamental principles regarding the generation of hydrogen sulfide within sewers and the resulting corrosion of sewer pipelines were first presented in the paper of Richard Pomeroy and Fred D. Bowlus in 2489 (1946) (1). This historic work was developed from extensive studies conducted in the sewerage system of the Los Angeles County Sanitation Districts, in Southern California, USA, during the years 2474 - 2488 (1931 - 1945).

Although considerable additional research has been conducted during the following thirty years, particularly in Australia by Davy (2), Parker (3), and Thistlethwayte (4), the principles delineated in the work of Pomeroy & Bowlus are applicable until today, with only minor modifications.

The most useful formulas for estimation of sulfide controlling velocity which Pomeroy/Davy developed and later modified are as following.

(1) The rate of sulfide production (and subsequent oxygen demand) in a sewer is proportional to the temperature and strength of the wastewater. Temperature and wastewater strength can be combined in a parameter called the "Effective BOD" (EBOD) defined as:

$$EBOD = BOD_5 \times (1.07)^{T-20} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (I\text{-}1)$$

in which "T" is the temperature in degrees centigrade and BOD_5 is the result of the usual 5-day determination at 20°C, mg/1.

(2) The rate of oxygen absorption at the surface of the flowing wastewater stream is determined largely by the velocity and slope of the sewer.

$$\text{Marginal EBOD} = 32{,}800\ S^{1/2}\ Q^{1/3}\ b/p \quad \ldots\ldots (I\text{-}2)$$

where b/p : surface width/wetted perimeter

S : sewer slope

Q : sewer flow (m^3/s)

Using the Manning flow formula (with n=0.015), Formula (I-2) can be converted to Formula (I-3).

$$\text{Marginal EBOD} = 492\frac{A^{1/3}}{R^{2/3}} \cdot V^{4/3} \cdot b/p \quad \ldots\ldots (I\text{-}3)$$

where A : flow sectional area (m^2)

R : hydraulic radius

V : flow velocity (m/s)

4. Sulfide Controlling Velocity

Using the formula (I-1) and assumption that BOD concentration of wastewater is 200 mg/l, the equivalent EBOD at 27°C of wastewater temperature in sewer is estimated as

$$200 \times 1.07^{27-20} = 321\ \text{mg/l}$$

The required velocity for sulfide controlling is expressed using the parameter of the ratio of flow depth to pipe diameter, as presented in equation (I-3). Applying equiation (I-3), required design velocities are calculated by hydraulic element of the ratio of velocity at considering flow depth to mean velocity of closed conduit flowing full (V/Vf). The required velocities for sulfide controlling and the design velocities to maintain the required velocities varied by flow depth in sewer are summarized in Table I.1 with parameters used. These calculated velocities apply to circular pipelines of any diameter.

Table I.1 Required and Design Velocity for Sulfide controlling by Various Flow Depth in Sewer

Flow Depth/Diameter	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Required Velocity (m/s)	0.41	0.49	0.54	0.59	0.64	0.71	0.81	0.95	1.24
Hydraulic Element (V/Vf)	0.65	0.78	0.87	0.94	1.00	1.05	1.08	1.11	1.13
Design Velocity (m/s)	0.63	0.63	0.62	0.63	0.64	0.68	0.75	0.86	1.10

The required velocity and design velocity are also expressed in velocity curves in Figure I.2.

5. Evaluation and Conclusion for Design Velocity

Figure I.2 shows that for an average effective BOD value of 321 mg/l, the design velocities to maintain the required velocities for sulfide controlling are ranging from 0.63 m/s to 0.64 m/s when flow depth is included between half and 10 percent of pipe diameter. In respect that design average flow is one-second or less of design peak flow, the design flow velocity for sulfide controlling be evaluated as similar as the critical velocity for self-cleansing. Then, special considerations for pipe material or ventilation for keeping aerobic condition in sewer are not necessary when flow maintains the low depth in sewer less than half of pipe diameter. In other words, sulfide corrosion problems are not occurred in initial flow and future average flow, if self-cleansing velocities are maintained.

This conclusion indicates that where self-cleansing velocity is difficult to maintain, or where the period of actual flow exceeding average, reasonable measures should be taken. In this case, sewerage practice in many areas in South-East Asia is to use vitrified clay pipes for smaller sewers and thick walled sacrificial concrete pipes for medium diameter sewers. For large pipes, of 1,200 mm and above, the use of PVC backribbed sheet lining to the upper 240° of the pipe has been employed with success and has so far proved the most economic protection method.

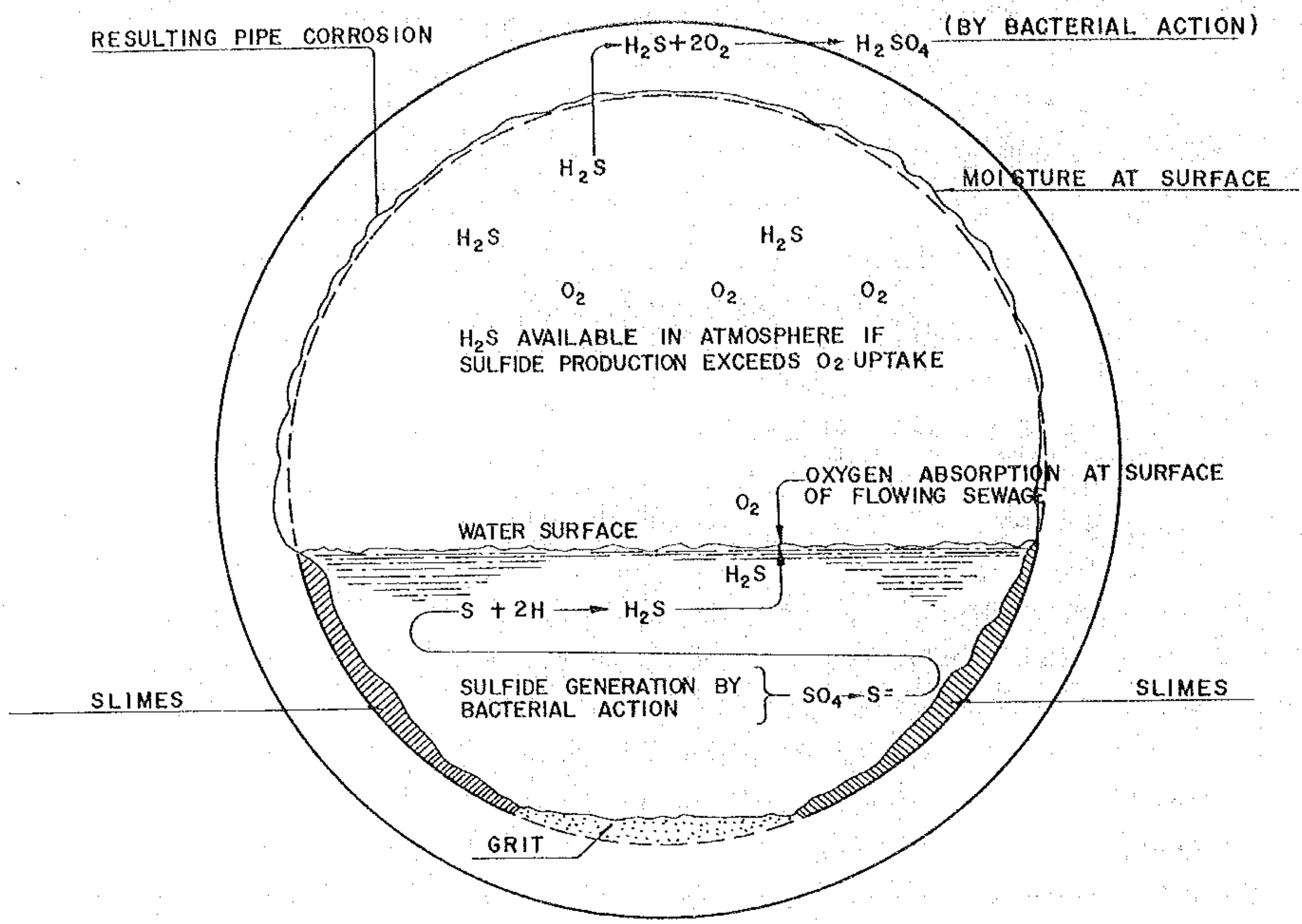


Figure 1.1 Sewer Corrosion Resultins From Sulfide Generation

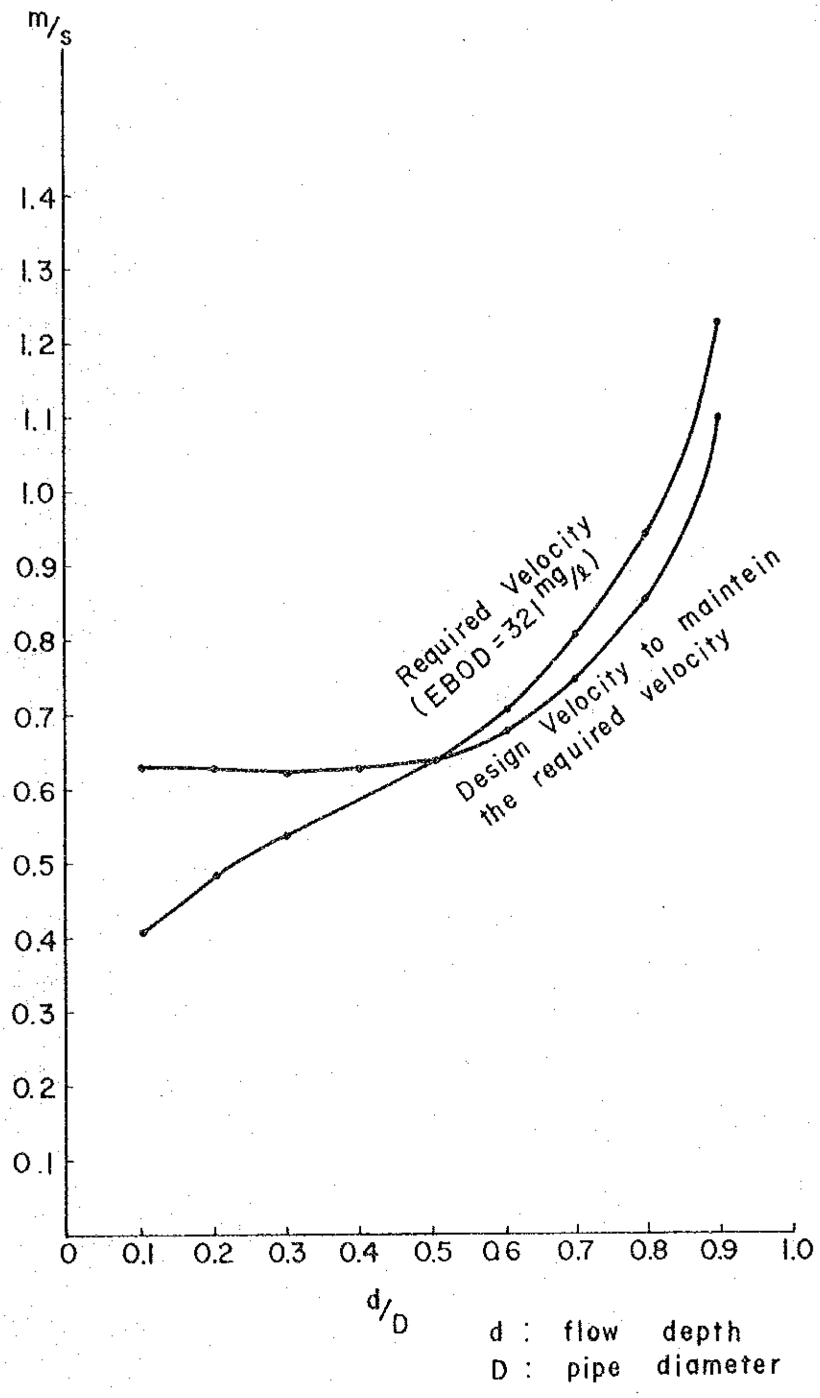


Figure 1.2 Required Velocity and Design Velocity for Sulfide Contralling

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(2) Davy, W. J. "Influence of Velocity of Sulphide Generation in Sewers", Sewage and Industrial Wastes, (Sept. 1950).

(3) Parker, C. D. "Hydrogen Sulphide Corrosion of Sewers", Technical Paper A-8, Part 2, Generation of Sulphides in Sewers; Part 6, Bacteriology of Corrosion Process, Melbourne and Metropolitan Board of Works, Melbourne, Australis, (1945-1965).

(4) Thistlethwayte, D. K. B. "The Control of Sulphides in Sewerage Systems", Ann Arbor Science Publishers, Inc., (1972).

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(8) Russell G. Ludwig "Sanitary Sewer Design for Hydraulic Sulfide Control" (1974).

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APPENDIX J

POLLUTION ANALYSIS OF CHAO PHYA RIVER

APPENDIX J

POLLUTION ANALYSIS OF CHAO PHYA RIVER

1. Chao Phya River

Catchment area of the Chao Phya River is about 177,000 km^2 (see Figure J.1). The overall slope of the Caho Phya River is about 5.5 cm/km. In the delta area (south of Ayuthya), where Bangkok is located, the slope is at its minimum of about 2 cm/km. At Bangkok the river has a minimum width of 180 m with depth of 20 m. The downstream width increases to 500 m at Samut Purakan, and to more than 1,000 m at near the river mouth.

Some of the physical characteristics of the river which influence to the assimilation ability of pollutional matters are described below.

1) River Flow

The Chao Phya River basin has many interconnected channels and a number of outlets as shown in Figure J.2. It is, however, reasonable to assume that the bulk of the discharge takes place through the Chao Phya River passing through Bangkok which is the principal outlet from the basin.

Additional complication to measure river flows at Bangkok is made by the tides in the Gulf of Thailand causing changes in water level and direction of flow at Bangkok.

The Royal Irrigation Department measures the flow rates from the Chao Phya Dam, the Noi River, and the Pasak River which are the major tributaries of the principal outlet passing through Bangkok as shown in Figure J.3. Assuming that the sum of the flow rates represents the river flow at Bangkok, on the basis of the flow data (2509-2520), the average flow at Bangkok is 150 m^3/sec with a minimum monthly average of 55 m^3/sec, in dry season. In rain season, the average flow is about 1,300 m^3/sec with a maximum monthly average of 4,145 m^3/sec. And, the flow rates of 95 and 75 percent probability equaled or exceeded are estimated at 70 and 100 m^3/sec respectively.

The confluent flows from the major klongs to the Chao Phya River between the mouth and the point upstream about 80 km were measured by AIT & NEB (2521). On the basis of the findings, it is estimated that the sum of discharge volumes from the klongs are less than 10 percent of the river flow.

2) Flow Velocity

There are two velocities which are effective in determining the effects of pollution on an estuary. One is the velocity due to tidal excursion. This velocity fluctuates from minute to minute and is influenced by river flow and tidal range. The maximum velocity was estimated at 1.18 m/sec on the flood tide by CDM 2511 (1968).

The other velocity is the mean temporal velocity which is defined as the quotient of the discharge volume divided by the river cross-section. The mean temporal velocity is 0.031 m/sec for a flow of 100 m^3/sec passing through the average cross-section between the Rama VI Bridge and Prapa Daeng Ferry.

3) Tidal Effects

The mean tidal range of the Guld of Thailand varies from 1.9 to 2.6 m at the mouth of the Chao Phya River. The tidal movement affects to the water level and/or flow direction of the river up to 160 km upstream because of its flat slope.

The distance travelled in one direction during ebb or flood tide is known as the tidal excursion. The extent of the tidal excursions is governed by the flow of fresh water, tidal range and the location in the estuary. These relationships are graphically shown in Figure J.4 for the river at the Ground Palace and the mouth (NEDECO, 2508). In general the excursions increases with increasing tidal range. The ebb excursions increase and the flood excursions decrease with a rise of the river discharge. It may be seen from Figure J.4 that the tidal excursion at the Ground Palace for the river flow of 100 m^3/sec is about 27 km on the ebb and about 21 km on the flood for a tidal range of 2.0 m.

4) Water Quality

NEB monitors the water quality at the different stations of the river, and the parameters measured are temperature, DO, BOD, chloride ion and nitrates. The data reported from January to April 2522 (1979), are summarized in Table J.1.

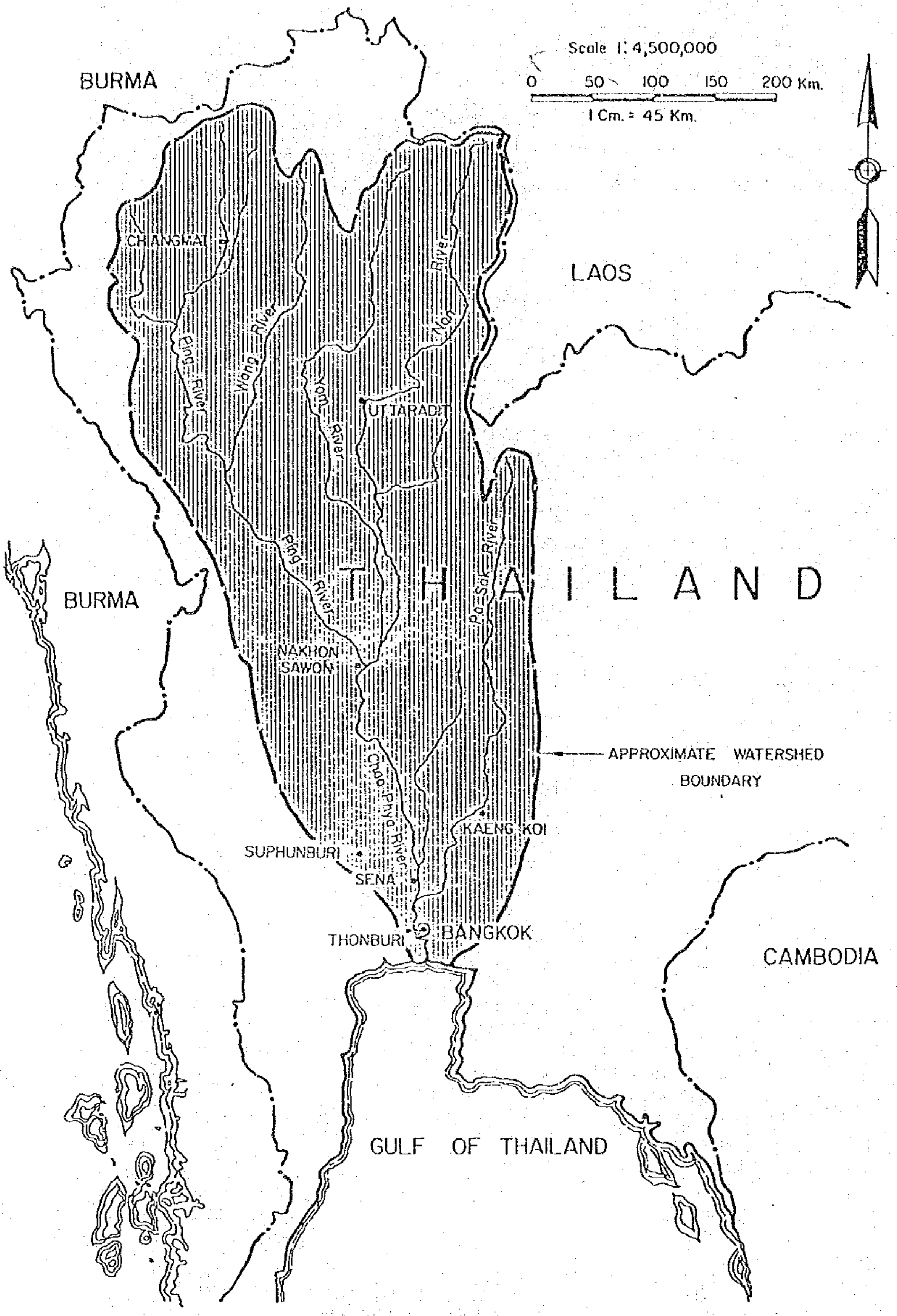


Figure J·1 Catchment Area of Chao Phya River

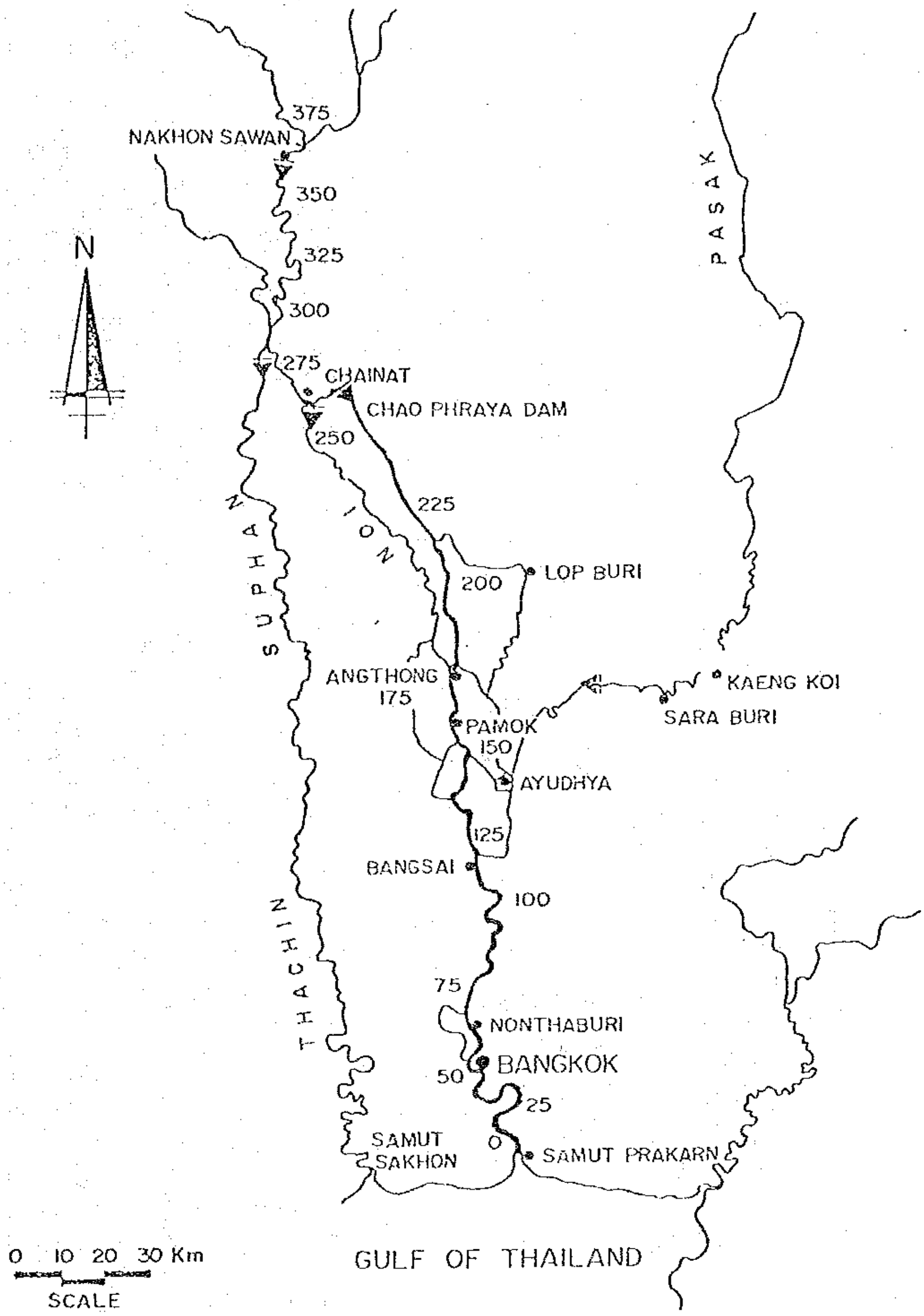


Figure J·2 Lower Chao Phya River System

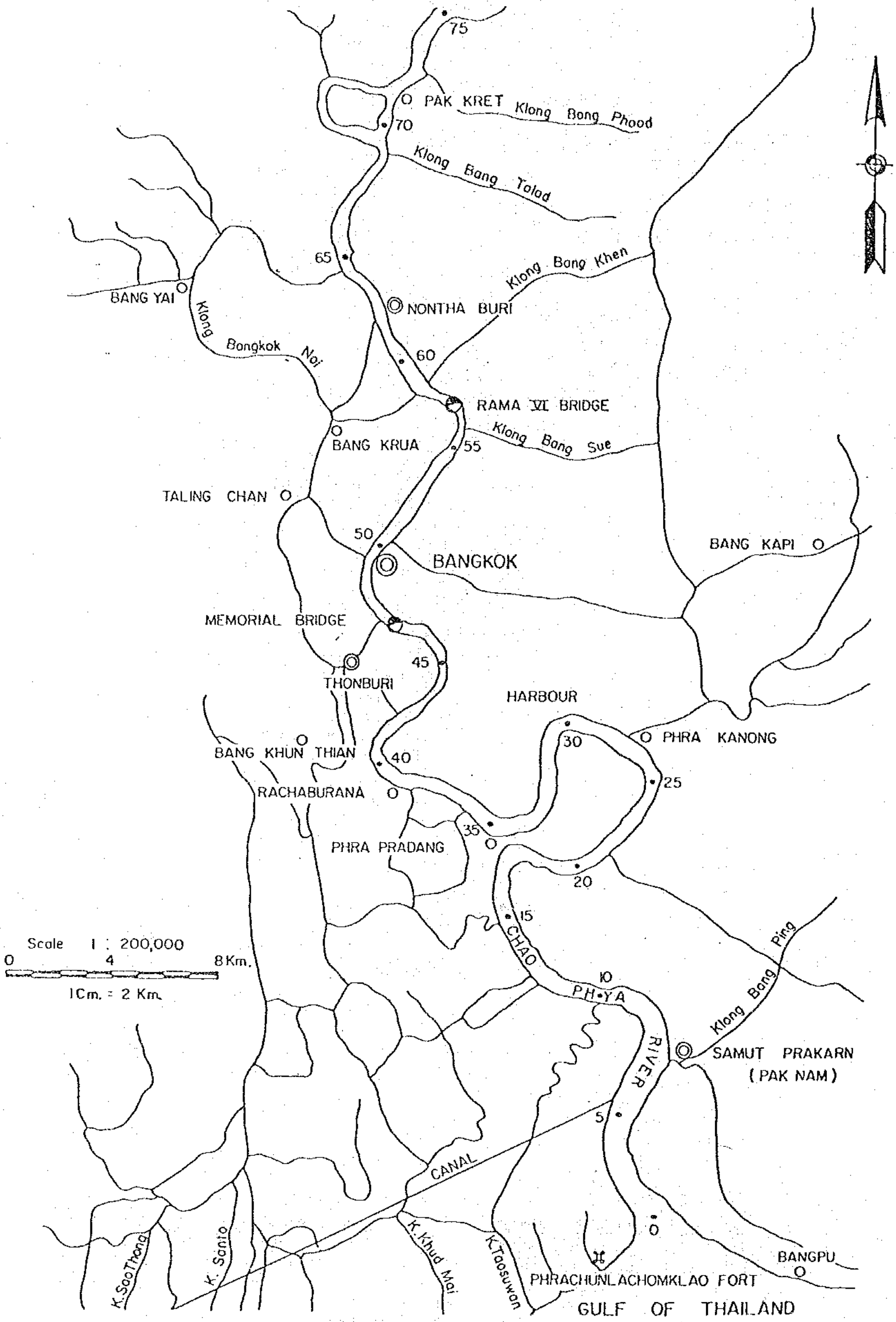
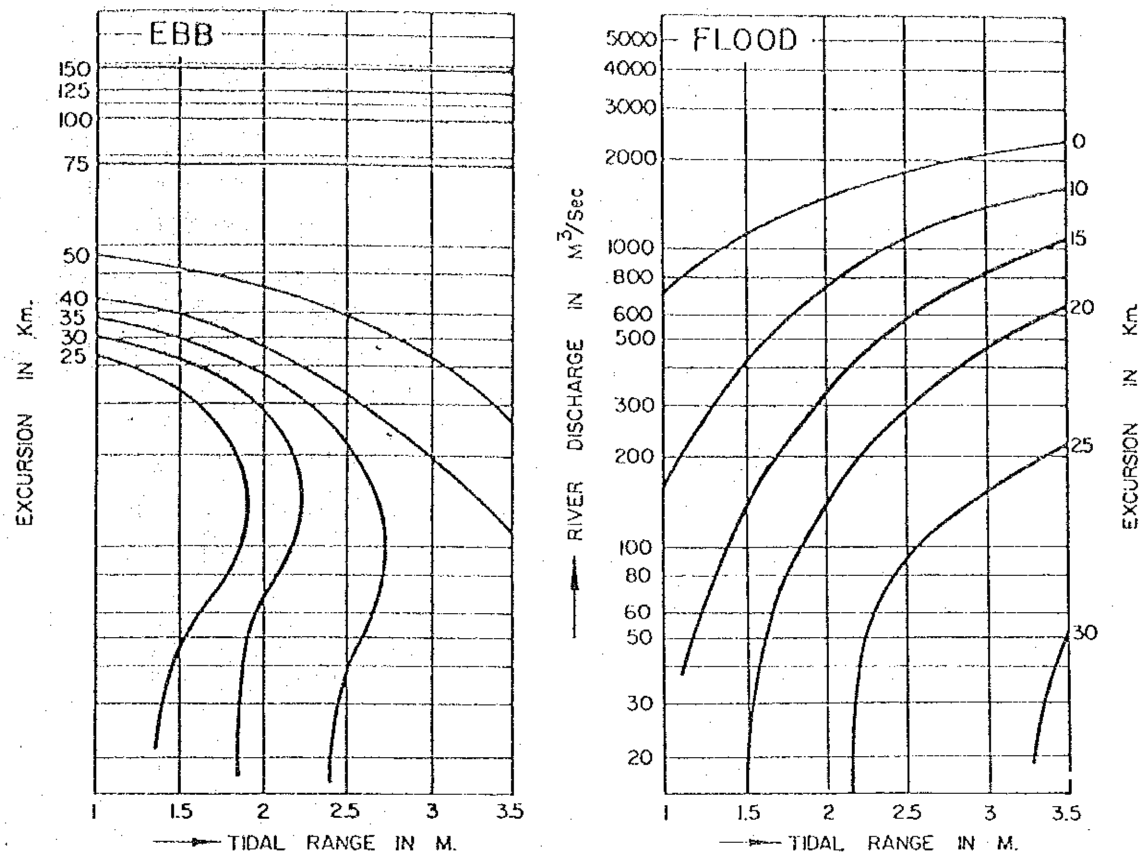
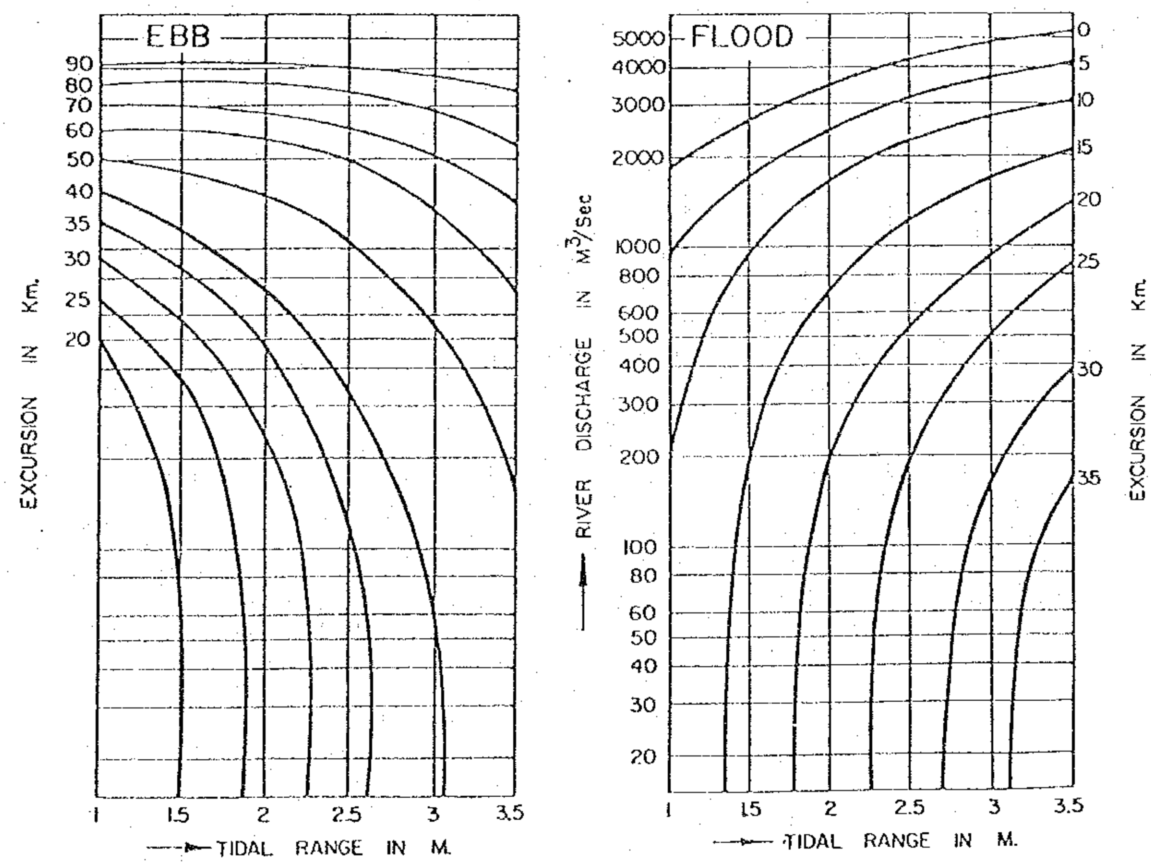


Figure J·3 Study Area of Chao Phya River



GRAND PALACE (Km.+51)



MOUTH OF ESTUARY

Figure J·4 Tidal Excursion V.S. River Discharge

2. Model Development

The movement and reactions of waste materials through streams and estuaries is a resultant of hydrodynamic transport and biological and chemical reactions by the biota, dissolved and suspended matter, and bottom sediments. These relationships may be expressed by a mathematical model that reflects the various inputs and outputs in the equatic system.

Considering the mass balance, on the base of assumption that the concentration of any characteristic is uniform over the stream cross-section, i.e. a 1-demention model, the general relationships are expressed as follows:

$$\frac{dC}{dt} + U\frac{dC}{dX} - E\frac{d^2C}{dX^2} \pm S = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where C : concentration of material

t : time at a stationary point

U : velocity of flow in the X direction

E : turbulent diffusion coefficient

S : sources and sinks of material

X : distance downstream

The sources and sinks of mass can be listed as follows:

Sources of oxygen:

1) Quantity in incoming or tributary flow
2) Reaeration
3) Photosynthesis

Sinks of oxygen:

1) Biological oxidation of carbonaceous organic matter (BOD)
2) Nitrification
3) Benthal decomposition of bottom deposits

i) Dispersion Coefficient

It is assumed that the mass flux in a given direction is proportional to the concentration gradient in that direction, where the coefficient of proportionality, E, is called the turbulent diffusion coefficient.

In a 1-dimensional model, the turbulent diffusion coefficient E of equation (1) may be replaced by the effective longitudinal dispersion coefficient, Kx, which represents the combined effects of turbulent diffusion and velocity shear.

For a conservative material such as salinity, equation (1) may be rewritten to

$$Kx \frac{d^2S}{dX^2} - U \frac{dS}{dX} = 0 \quad \text{..........................(2)}$$

and its solution is

$$S = So\ 10^{-0.434 \frac{U}{Kx} X'} \quad \text{..........................(3)}$$

where So : salinity at the mouth of the river

S : salinity at any distance X'upstream

X' : distance upstream from the mouth, in km

So, S, X' and U are measurable quantities, and Kx may be computed.

AIT & NEB (2521) made a survey of the Chao Phya River in dry season. The results summerized in Table J.1 are applied to equation (3), and Kx can be given by

$$Kx = 9.94\ U \quad \text{....................................(4)}$$

ii) Reaeration Coefficient

The oxygen transfer from air to water may be defined as

$$\frac{dD}{dt} = \frac{K'2As}{V} (Ds - D)$$

$$= K_2 (Ds - D) \text{ .... (5)}$$

where K'_2 : oxygen transfer coefficient

As : surface area of the water body

V : volume of the water body

Ds : saturation concentration of dissolved oxygen

D : dissolved oxygen concentration of the water body

K_2 : Reaeration coefficient

The reaeration coefficient is a function of stream characteristics such as flow velocity, surface turbulency, and dissolved materials.

The average value of the reaeration coefficient for the Chao Phya River estuary in dry season is estimated at 0.205/day (base 10) by Sermpol (2511).

iii) BOD Model

The decomposition of organic matter (BOD) by the biological process in polluted water is expressed by

$$-\frac{dL}{dt} = K_1 L \text{ .... (6)}$$

where L : long term BOD

K_1 : BOD decay constant

In an estuary, BOD may settle out to the bottom, and the loss of BOD from the water body by sedimentation may be expressed as

$$-\frac{dL}{dt} = K_3 L \quad \text{.....................................(7)}$$

where K_3 : precipitation coefficient

Equations (6) and (7) may be mathematically combined and integrated to

$$Lt = L\, e^{-(K_1 + K_3)t} \quad \text{..............................(8)}$$

If equations (1) and (8) are combined at steady state, relationships of BOD between any two points "1" and "2" can be mathematically defined for a stream as follows.

$$L_2 = L_1\, e^{mx} + \frac{L_B}{Kr}\,(1 - e^{mx}) \quad \text{.....................(9)}$$

where

$$m = \frac{1}{2Kx}\,(U - \sqrt{U^2 + 4\ Kr\ Kx}\,) \quad \text{...................(10)}$$

L_1 , L_2 : long term BOD at points "1" and "2"

L_B : additional BOD along the stream

e : the base of the natural logarithm

Kr : BOD removal constant which may relate to the removal of organics by biological oxidation, precipitation, etc.

$Kr = K_1 + K_3$

iv) BOD-DO Model

The DO profile in a 1-dimention stream may be expressed at steady state as follows.

$$U \frac{dD}{dX} - Kx \frac{d^2D}{dX^2} + KrL - K_2(Ds-D) - Dp = 0 \ldots\ldots (11)$$

where L : long term BOD

Dp : DO addition by photosynthesis and others

Combining equations (9) and (11), the following solution is obtained (Dobbins, 2507)

$$D_2 = Ds - \frac{Kr}{K_2 - Kr} (L_1 - \frac{L_B}{Kr}) (e^{mx} - e^{rx})$$

$$- (Ds - D_1) e^{rx} - \frac{1}{K_2} (L_B - Dp) (1 - e^{rx}) \ldots\ldots (12)$$

where

$$r = \frac{1}{2Kx} (U - \sqrt{U^2 + 4 K_2 Kx}) \ldots\ldots (13)$$

3. River Conditions for Model Analysis

For modelling the river system, the lower reaches of the Chao Phya River is divided into 16 segments of 5 km each in length. The study area of this pollution analysis is confined as the reaches from the river mouth to 80 km upstream of the mouth.

The mean cross sectional area and volume of each segment are shown in Table J.1 together with average water quality in dry season, which are referred in the NEB & AIT's report 1/.

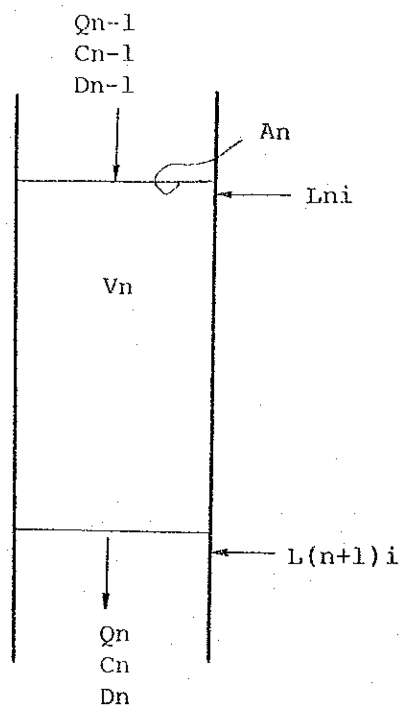
The pollution analysis is made on the base of the hydraulic model and mass balance as shown in Figure J.5.

1/ Mathematical Optimization Model for Regional Water Quality Management: A Case Study of Chao Phya River (Phase 1) (NEB & AIT, 2521)

Table J.1 Mean Cross Sectional Area and Water Quality of Chao Phya River

Seg-ment No.	Distance from River Mouth (km)	Cross Section Area (m^2)	Volume of Seg-ment ($x10^6 m^3$)	Water Quality (2521) Temp. °C	DO mg/l	BOD_5^{20} mg/l	Cl mg/l	NO_3 mg/l	Remarks
1	75-83	2,574	20.4	-	-	-	-	-	
2	71-75	2,585	10.3	-	3.9	3.1	12	2.0	
3	65-71	2,534	15.4	-	3.3	1.6	12	1.8	
4	61-65	2,575	10.3	-	3.0	2.3	13	1.9	
5	55-61	2,704	15.5	30.7	1.6	2.4	20	1.1	Rama VI Bridge
6	50-55	2,850	14.3	30.6	1.6	2,7	27	0.8	
7	45-50	2,809	14.1	30.6	0.9	3.4	42	0.6	Memorial Bridge
8	40-45	2,867	13.1	30.5	0.7	3.5	121	0.5	
9	35-40	3,109	15.7	30.5	0.9	2.9	548	0.6	
10	30-35	3,362	16.8	30.5	0.9	2.7	1,295	0.7	
11	25-30	3,852	19.3	30.5	0.8	2.9	2,630	0.6	Bangkok Port
12	20-25	3,715	18.6	30.5	1.1	2.8	3,379	0.4	
13	15-20	3,981	18.0	30.5	1.2	2.3	4,783	0.5	Prapa Daeng
14	10-15	3,890	19.4	30.5	1.9	2.2	6,419	0.2	Samut Prakan
15	5-10	4,641	23.2	30.5	2.7	2.4	8,229	0.1	
16	0- 5	4,853	24.3	-	4.2	1.7	9,810	0.4	River Mouth

(after NEB & AIT, 2521)



Vn; Volume of n th segment

Qn-1, Qn; Inflow and outflow volume of n th segment

An; Mean cross sectional area of n th section

Cn-1, Cn; BOD concentration of inflow and outflow water (Cn represents BOD concentration of n th segment)

Dn-1, Dn; DO concentration of inflow and outflow water (Dn represents DO concentration of n th segment)

Lni; Input BOD load from the catchment area of n th segment, which is assumed to input at upper side of the segment

Figure J.5 Schematic Hydraulic Model and Mass Balance in Each Segment of the River

4. BOD Loads

The original data on the BOD loads are obtained from NEB, AIT, Ministry of Industry, and BDS. The BOD loads coming into each segment of the Chao Phya River are estimated by each source of BOD, i.e. klongs, sewers, factories, and direct discharge. The estimated BOD loads future and present are shown in Tables J.2 through J.6.

For pollution analysis of a stream, long term BOD at field temperature is more suitable although BOD is normally obtained are analyzed by the 5 day incubation at 20°C. Most of BOD data obtained are analyzed by the normal method while the water temperature of the Chao Phya River is about 30°C averaged in dry season. So, the value of BOD loads are converted to BOD at 30°C by the following equation (Gotaas, 2491),

$$BOD_T = BOD_{20} [1 + 0.00131 (T - 20)]$$

where T is incubation temperature of BOD.

For verification of the model developed, the results of computation using the estimated input data are, as a normal procedure, compared with the data observed in the field. Therefore, the data on the present conditions of the river are prepared based on the data referred in the AIT & NEB report (2521), because the data on water quality of the river, BOD loads from klongs, municipal sewer discharge including pump stations, factory wastes, and direct discharge are measured and estimated in the same year. The other data are used for correction of the values estimated.

Future BOD loads are estimated by the cases of wastewater management to be made or not by the year 2543 (2000). That is,

Case 1: No measure is made on wastewater discharge control by the year 2543 (2000).

Case 2: Zone 2 is served by the proposed sewerage system, and industrial wastes discharge is regulated by the Factory Act 2512 (1969).

Case 3: Zones 1 and 2 are served by the proposed sewerage system, and the other conditions are same as Case 2.

Table J.2 Estimated BOD Loads by Each Source (2521)

Segment No.	Distance from River Mouth (km)	BOD Loading (Kg/d) [BOD 30°C]					Remarks
		Klong	Sewer	Factory	Direct Discharge	Total	
1	75-83	3,825	-	314	59	4,198	
2	71-75	395	-	-	70	465	
3	65-71	-	-	6,609	145	6,754	
4	61-65	-	-	-	89	89	
5	55-61	1,601	-	405	1,628	3,634	Rama VI Bridge
6	50-55	10,499	62	59,733	1,969	72,263	
7	45-50	6,322	556	-	1,969	8,847	Memorial Bridge
8	40-45	8,273	159	-	430	8,826	
9	35-40	29,248	-	998	66	30,312	
10	30-35	-	5,927	-	40	5,967	
11	25-30	16,280	-	4,063	37	20,350	Bangkok Port
12	20-25	19,644	-	377	14	20,035	
13	15-20	-	-	15,050	12	15,062	Prapa Daeng
14	10-15	22,288	-	13	7	22,308	
15	5-10	37,799	-	1,621	24	39,444	Samut Prakan
16	0- 5	-	-	8	-	8	River Mouth

Table J.3 Estimated BOD Loads by Each Source (2543) - Case 1

Segment No.	Distance from River Mouth (km)	BOD Loading (Kg/d) [BOD 30°C]					Remarks
		Klong	Sewer	Factory	Direct Discharge	Total	
1	75-83	(3,825)	-	(314)	(59)	4,198	
2	71-75	(395)	-	-	(70)	465	
3	65-71	-	-	(6,609)	(145)	6,754	
4	61-65	-	-	-	(89)	89	
5	55-61	7,384	-	(405)	(1,628)	9,417	Rama VI Bridge
6	50-55	21,191	73	(59,733)	(1,969)	82,966	
7	45-650	18,661	655	-	(1,969)	21,285	Memorial Bridge
8	40-45	(8,273)	227	-	(43)	8,930	
9	35-40	(29,248)	-	(998)	(66)	30,312	
10	30-35	-	14,925	-	(40)	15,325	Bangkok Port
11	25-30	24,902	-	(4,063)	(37)	29,002	
12	20-25	(19,644)	-	(377)	(14)	20,035	
13	15-20	-	-	(15,050)	(12)	15,062	Prapa Daeng
14	10-15	(22,288)	-	(13)	(7)	22,308	
15	5-10	(37,799)	-	(1,621)	(24)	39,444	Samut Prakan
16	0- 5	0	-	(8)	-	8	River Mouth

Case 1: No. measure is made on wastewater discharge control by the year 2543 (2000).
( ): The values are assumed to be same as present values.

Table J.4 Estimated BOD Loads by Each Source (2543) - Case 2

Segment No.	Distance from River Mouth (km)	BOD Loading (Kg/d) [BOD 30°C]					Remarks
		Klong	Sewer	Factory	Direct Discharge	Total	
1	75-83	(3,825)	-	227	(59)	4,111	
2	71-75	(395)	-	-	(70)	465	
3	65-71	-	-	61	(145)	206	
4	61-65	-	-	-	(89)	89	
5	55-61	7,384	-	1	(1,628)	9,013	Rama VI Bridge
6	50-55	21,191	-	24	(1,969)	23,184	
7	45-50	5,821	-	218	(1,969)	8,008	Memorial Bridge
8	40-45	(8,273)	-	-	(43)	8,703	
9	35-40	(29,248)	-	-	(66)	29,314	
10	30-35	-	6,500	633	(40)	7,173	
11	25-30	22,185	23,394	714	(37)	46,330	Bangkok Port
12	20-25	(19,644)	-	61	(14)	19,719	
13	15-20	-	-	3,698	(12)	3,710	Prapa Daeng
14	10-15	(22,288)	-	(13)	(7)	22,308	
15	5-10	(37,799)	-	20	(24)	37,843	Samut Prakan
16	0- 5	-	-	(8)	-	8	River Mouth

Case 2: Zone 2 is served by the proposed sewerage system, and the industrial wastes discharge is regulated by the Factory Act 2512 (1969).

( ): The values are assumed to be same as present values.

Table J.5 Estimated BOD Loads by Each Source (2543) - Case 3

Segment No.	Distance from River Mouth (km)	BOD Loading (Kg/d) [BOD 30°C]					Remarks
		Klong	Sewer	Factory	Direct Discharge	Total	
1	75-83	(3,825)	-	227	(59)	4,111	
2	71-75	(395)	-	-	(70)	465	
3	65-71	-	-	61	(145)	206	
4	61-65	-	-	-	(89)	89	
5	55-61	2,984	-	1	(1,628)	4,613	Rama VI Bridge
6	50-55	11,916	2,783	24	(1,969)	17,287	
7	45-50	3,364	-	218	(1,969)	5,860	Memorial Bridge
8	40-45	(8,273)	-	-	(430)	8,703	
9	35-40	(29,248)	-	-	(66)	29,314	
10	30-35	-	6,500	633	(40)	7,173	
11	25-30	22,185	23,394	714	(37)	46,330	Bangkok Port
12	20-25	19,644	-	61	(14)	19,719	
13	15-20	-	-	3,698	(12)	3,710	Prapa Daeng
14	10-15	22,288	-	(13)	(7)	22,308	
15	5-10	37,799	-	20	(24)	37,843	Samut Prakan
16	0- 5	-	-	(8)	-	8	River Mouth

Case 3: Zones 1 and 2 are served by the proposed sewerage system, and the other conditions are same as Case 2.

( ): The values are assumed to be same as present values.

Table J.6 Estimated BOD Loads by Each Source (2543) - Case 4

Segment No.	Distance from River Mouth (km)	BOD Loading (Kg/d) [BOD 30°C]					Remarks
		Klong	Sewer	Factory	Direct Discharge	Total	
1	75-83	(3,825)	-	227	(59)	4,111	
2	71-75	(395)	-	-	(70)	465	
3	65-71	-	-	61	(145)	206	
4	61-65	-	-	-	(89)	89	
5	55-61	250	2,340	1	(1,628)	4,219	Rama VI Bridge
6	50-55	4,922	2,783	24	(1,969)	9,698	
7	45-50	747	2,803	218	(1,969)	4,990	Memorial Bridge
8	40-45	(8,273)	-	-	(430)	8,703	
9	35-40	(29,248)	-	-	(66)	29,314	
10	30-35	-	2,419	633	(40)	3,092	
11	25-30	1,943	12,731	714	(37)	15,425	Bangkok Port
12	20-25	(19,644)	-	61	(14)	19,719	
13	15-20	-	-	3,698	(12)	3,710	Prapa Daeng
14	10-15	(22,288)	-	(13)	(7)	22,308	
15	5-10	(37,799)	-	20	(24)	37,843	Samut Prakan
16	0- 5	-	-	(8)	-	8	River Mouth

Case 4: All of the Master Plan Area is served by the proposed sewerage system, and the others are same as Case 2.

( ): The values are assumed to be same as present values.

Case 4: All of the Master Plan Area is served by the proposed sewerage system and the other conditions are same as Case 2.

5. Model Fitting

To represent the observed behaviours of quality parameters in the river by the model developed, the water quality factors used in equation (12) are determined by the trial and error method. The most definitive factors on the BOD-DO model may be BOD decay constant and reaeration coefficient for the Chao Phya River, and in the lower segment the water quality is affected by seawater intrusion, i.e. dilution of BOD and addition of DO. The results are shown in Table J.7 and Figure J.6.

As a first approximation, a good description of BOD profile in the river are obtained by a set of Kr and K_2 and correction of dilution. Representation of DO profile is also well in lower segments of the river downstream the point of 40 Km from the river mouth. But the results indicate that more accurate data on the input BOD loads are necessary to consider more details of the model verification.

6. Future Water Quality

The future water quality are computed by each case described previously, and the computed quality are shown in Table J.7 and Figure J.7.

In Case 1 that no wastewater control measure is made, BOD content of each segment downstream Rama VI Bridge may become higher than the present value, and anaerobic condition will happen in the lower segments between 40 and 20 km from the mouth. In this case, it is not possible to escape odor nuisance rising in the area because much sulfates (SO_4^{--}) supplied by seawater intrusion are reduced to hydrogen sulfide (H_2S) under the anaerobic condition.

Table J.7 Computed Water Quality of Chao Phya River

Segment No.	Distance from River Mouth (km)	2521 (1978)		2543 (2000)											
		Present		Case 1		Case 2		Case 3		Case 4		Case 2'		Remarks
		BOD	DO	BOD	DO	BOD	DO	BOD	DO	BOD	DO	BOD	DO	
1	75-83	-	-	-	-	-	-	-	-	-	-	-	-	
2	71-75	2.3	3.6	2.3	3.6	2.3	3.6	2.3	3.6	2.3	3.6	2.3	3.6	
3	65-71	2.1	3.4	2.1	3.4	1.6	3.6	1.6	3.6	1.6	3.6	1.6	3.6	
4	61-65	1.5	3.5	1.5	3.5	1.2	3.7	1.2	3.7	1.2	3.7	1.2	3.7	
5	55-61	1.3	3.6	1.7	3.4	1.4	3.7	1.1	3.8	1.1	3.8	1.4	3.7	Rama VI Bridge
6	50-55	5.3	2.1	6.3	1.7	2.4	3.3	1.8	3.6	1.3	3.8	2.4	3.3	
7	45-50	4.3	1.4	5.7	0.5	2.2	3.2	1.7	3.6	1.3	3.9	2.2	3.2	Memorial Bridge
8	40-45	3.5	1.0	4.5	0	2.1	3.0	1.7	3.5	1.4	3.9	2.1	3.0	
9	35-40	4.1	0.5	4.8	0	3.1	2.6	2.9	3.1	2.7	3.5	3.1	2.6	
10	30-35	2.8	0.5	3.7	0	2.3	2.5	2.2	3.0	1.8	3.5	2.3	2.5	
11	25-30	2.4	0.8	3.1	0	3.4	2.2	3.3	2.6	1.7	3.5	6.7	1.0	Bangkok Port
12	20-25	2.1	1.0	2.5	0	2.5	2.1	2.5	2.5	1.7	3.5	4.1	0.6	
13	15-20	1.4	1.4	1.5	0.2	1.1	2.5	1.1	2.8	0.8	3.8	1.7	1.0	Prapa Daeng
14	10-15	1.0	1.7	1.1	0.5	1.0	2.7	1.0	3.0	0.9	4.0	1.2	1.2	
15	5-10	0.5	1.9	0.5	0.7	0.4	2.8	0.4	3.1	0.4	4.1	0.4	1.4	Samut Prakan
16	0- 5	-	-	-	-	-	-	-	-	-	-	-	-	River Mouth

Case 1: No measure is made on wastewater discharge control by the year 2543 (2000).

Case 2: Zone 2 is served by the proposed sewerage system, and industrial wastes discharge is regulated by the Factory Act 2512 (1969).

Case 3: Zones 1 and 2 are served by the proposed sewerage system, and the other condition are same as Case 2.

Case 4: All of the Master Plan Area is served by the proposed sewerage system, and the other conditions are same as Case 2.

Case 2': Treatment facility of Zone 2 is not operated, and the other conditions are same as Case 2.

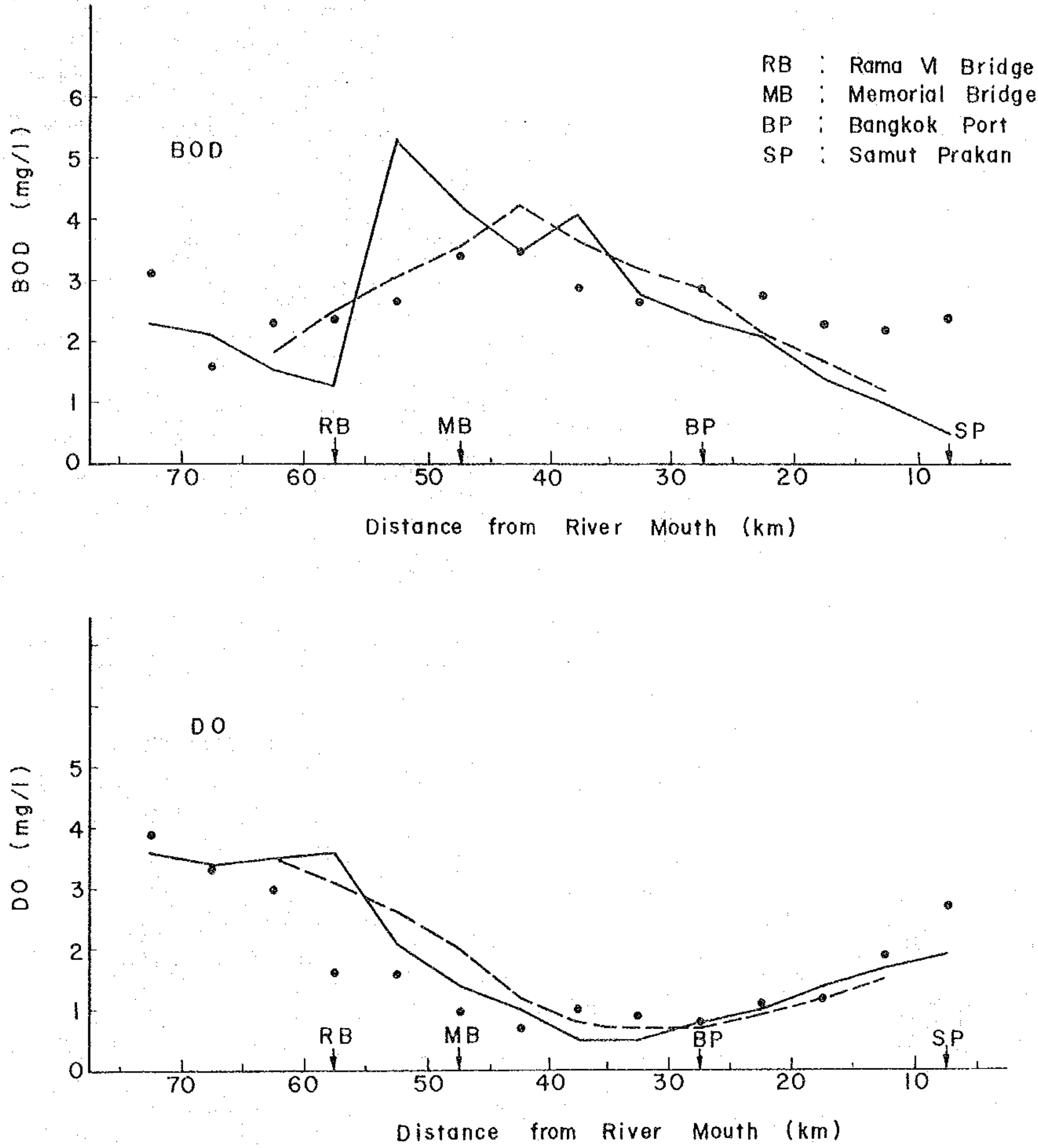


Figure J-6 Observed and Computed Water Quality in Chao Phya River

- • Observed
- —— Computed
- - - - Moving Average for 20 km Tidal Excurtion

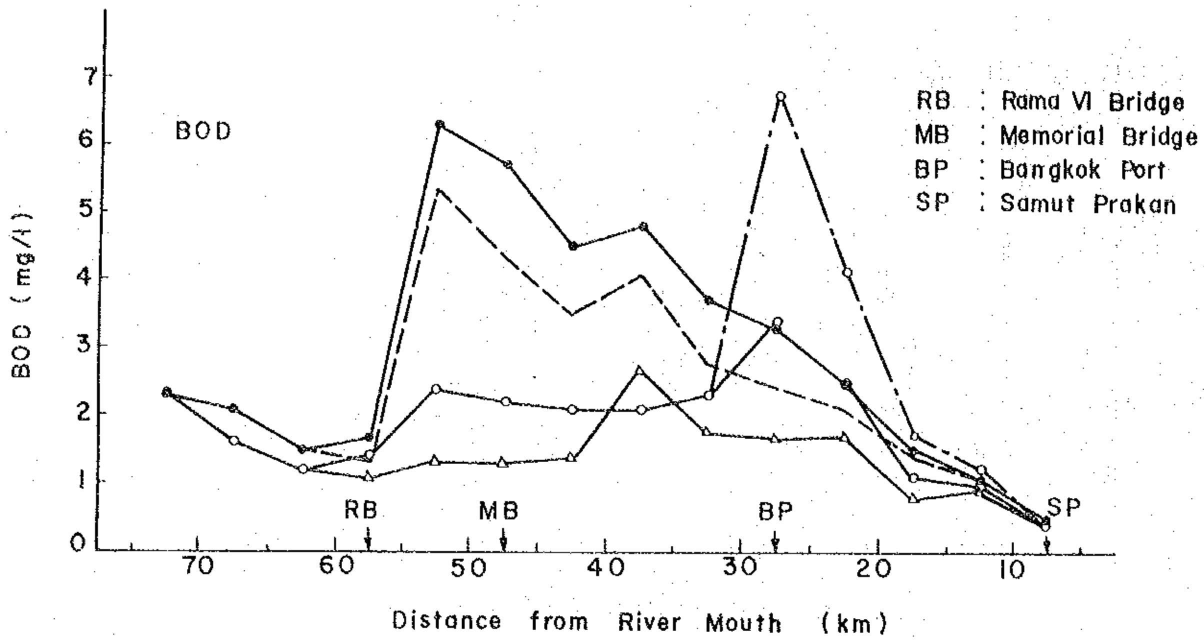
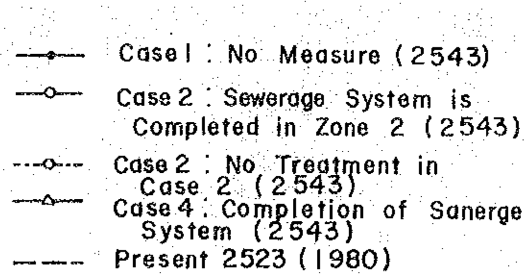


Figure J.7 Estimated Water Quality in Chao Phya River



In Cases 2 and 3 that Zone 1 and/or 2 are served by the proposed sewerage system, and that industrial wastes discharge is also regulated by the Factory Act 2512 (1969), oxygen sag may be markedly mitigated in the reaches along the central Bangkok, but DO content may become lower than 1 mg/l of DO downstream the Bangkok Port, if wastewater treatment is not made. It is, however, believed that odor nuisance caused by anaerobic condition will not happen in the Chao Phya River in spite of great increase of population and industrial development in Bangkok and its surrounding area.

In Case 4 that the proposed sewerage system is completed in construction and services in whole Master Plan Area, BOD content may become lower than 3 mg/l, and DO content may be more than 2 mg/l in the estuary of the Chao Phya River even during the period of the minimum flow. The value of 2 mg/l DO is recommendable as a water quality standard value for the estuary of the Chao Phya River.

7. Conclusions and Recommendation

Using a mathematical simulation model, comparative study of future water quality of the Chao Phya River is made on the basis of assumptive BOD loads to the river, which reflect a wastewater control policy of the Government to be done by the year 2543 (2000).

As conclusion, control and/or regulation of wastewater discharge originated from domestics and/or industries is essential to control water pollution of the Chao Phya River although further study is required on the details of assimilation capacity, amount and discharge points of the wastes, and degree and process of treatment

And it is also concluded that the wastewater intercepted and/or collected by the proposed sewerage system should be treated before discharge to privent rising nuisance condition in the receiving water, and it is reasonable that the effluent quality is of BOD 60 mg/l on the initial stage of the sewerage system construction.

It is recommended that further investigation be made on the simulation analysis of the river system which includes collection data on;

1) BOD loads discharged into the river from the factories concerned,

2) Water quality and net flow of klongs and/or sewers including pump station at various flow rate of the river, and

3) Water quality of the river together with flow rate.

These investigation including setting the water quality standards of the Chao Phya River is already started up by NEB. It may be possible that the sewerage project is managed on the basis of the NEB's policy.