CHAPTER 4: WATER SUPPLY SYSTEM

4.1 General

The rapid economic and population growth in Bangkok Metropolitan and its surrounding suburbs caused a concern from the view point of water management to cope against environmental degradation. In addition, natural uncertainty like recent drought remind the water shortage crisis in the Metropolitan Area as well as in the Kingdom. The expansion of urbanization towards suburbs of BMA brought realization to the MWA for expansion of water distribution system to the newly grown urbanized area.

The projects recommended through the second Master Plan has been implementing but the rapid urban development in Bangkok Metropolitan and its surrounding suburbs are become necessary to include in the plan and update the Master Plan to meet with the present and future forecasting developments. Parallel to the reviewed development plans, there should have some water saving policy which may include extensive water saving campaigns and educate people to make aware of the users about value and necessity of water.

4.2 Assessment on Present Conditions

As a first step for exploring the water supply system in BMA, 5 years data were taken into consideration for study. On the basis of data, findings are as follows.

(1) Present Situation on Water Service in BMA

The Metropolitan Waterworks Authority (MWA), responsible for supplying water to the customers provides in the half of the BMA area through two different systems, namely, central or main system and separate system. The main system supplies water to the center core of Bangkok Metropolitan and parts of Nontaburi and Samut Prakarn provinces and the separate system consists in Minburi, and Bang Bua Thong water supply systems. MWA organizes the whole BMA into 16 service blocks for its water service systems covering about 893 km2 as a whole.

The water production in 1995 was about 1405 million cubic meter of which about 1318 million cubic meter or 94 % was provided from surface water and 87 million cubic meter or 6 % was yielded from groundwater.

Total number of MWA customers are 1,241,000 connections of which 903,000 connections are domestic water users and 338,000 connections are other business water users including commercial, industries, state enterprises, government agencies, etc. Total amount of water sold to the customers was 870 million cubic meter of which 445 million cubic meter or 51 % was domestic water use and 425 million cubic meter or 49 % was consumed by the other business users. The water consumption per connection reach at 41 m3/month and 105 m3/month for domestic use and other business use respectively whereas an average water consumption is 58 m3/month per connection.

(2) Main System and Separate System

The MWA withdraw raw water from the Chao Phraya River for the main waste source. Utilization of ground water is very less compared to surface water. The raw water from Chao Phraya river is pumped at the rate of 3.6 million m3/day at Sam Lae pumping station located 90 km upstream from the estuary of the river and convey for production to the Bang Khen and Sam Sen water treatment plants in the East Bank of Main System and Thon Buri Water Treatment Plant in the West Bank of Main System. Raw water is pump-up to the Khlong Prapa of capacity 3.6 million cubic meter per day which feeds Bang Khaen Treatment Plant first at km 19, then feeds to Bang Sue pumping station at km 30 for feeding Sam Sen and Thonburi Treatment Plant.

Table 4.1 shows capacity of the existing water supply system in MWA's Main Service System. The largest water treatment plant at Bang Khen produce 3.2 million cubic meter per day (mcmd) followed by Sam Sen 0.70 mcmd, Mahasawat 0.4 mcmd and Thonburi Treatment Plant 0.17 mcmd. Total water treatment capacity including the separate system is 4.8 mcmd as of 1995.

There are eleven main distribution pump stations, namely, Bang Khen 0.80 mcmd, Pahon Yothin 0.48 mcmd, Lat Phrao 0.48 mcmd, Lumpini 0.64 mcmd, Samrong 0.64 mcmd and Khlong Toei 0.48 mcmd are used to distribute water to the East Bank. Thapra and Ratburana pumping stations receive treated water from Bang Khen Water Treatment Plant to supply 0.64 and 0.48 mcmd respectively in the West Bank of Metropolitan area. In addition, Mahasawat pumping station distribute water 0.48 mcmd to the West Bank. Total water distribution capacity including other smaller system reach at 6.3 mcmd.

Underground water is the major source of Separate System followed by the smaller surface water systems. This system is totally isolated from the main system, hence named separate system. Water production capacity of the separate system is 0.33 mcmd as of 1995. But in future the separate system will be connected with the main system.

Table 4.1 Existing Water Supply System Capacity

Water Treatment Plant	Plant Capacity (cum/day)			Pumping Station	Pumping Capacity (cum/day)
	Present	A.D.2005	A.D.2017		Present
1. Bang Khaen	3,200,000	3,600,000	4,000,000	1.1 Bang Khaen	800,000
				1.2 Phon Yothin	480,000
				1.3 Lat Phrao	480,000
				1.4 Lumpini	640,000
				1.5 Thapra	640,000
				1.6 Samrong	640,000
				1.7 Khlong Toei	480,000
				1.8 Ratburana	480,000
				Subtotal	4,640,000
2. Sam Sen	700,000	700,000	700,000	2. Sam Sen	700,000
3. Thonburi	170,000	170,000		3. Thonburi	170,000
4. Mahasawat	400,000	1,200,000	3,200,000	4. Mahasawat	480,000
5. Nong Chok	1,200	1,200		5. Nong Chok	1,200
6. Bang Bua Thong	4,500	4,500		6. Bang Bua Thong	4,500
7. Mobile Plant				7. Mobile Plant	
7.1 Rama VI	50,000	50,000		7.1 Rama VI	50,000
7.2 Khlong Tawee Watana	10,000	10,000		7.2 Khlong Tawee Watana	10,000
7.3 Maha Sawat	15,000	15,000		7.3 Maha Sawat	15,000
7.4 Bang Bua Thong	5,000	5,000		7.4 Bang Bua Thong	5,000
				Subtotal	80,000
8. Deep Well (80 units)	240,000	(emergency use)		8. Deep Well (80 units)	240,000
Total Production Capacity	4,795,700	5,755,700	7,900,000		6,315,700
East Bank Total	3,951,200	4,351,200	4,700,000	East Bank Total	4,271,200
West Bank Total	604,500	1,404,500	3,200,000	West Bank Total	1,804,500
Deep Well	240,000	(emergency use)		Deep Well	240,000
Total	4,795,700	5,755,700	7,900,000		6,315,700

Table 4.2 gives some idea about the water production in two systems as well as percentage of surface and ground water uses. Total MWA water production is 1405 million cubic meter already mentioned, of which 98.37% is in the Main System and 1.63% is in the Separate System. In the Main System, 95% production comes from surface water and 5% production from underground water. On the other hand, in Separate System, 19% production comes from surface water and 81% production from underground water

Table 4.2 Water Production in Main and Separate Systems in 1995

Fiscal Year	Main System			Separate System			Grand Total
1995	Plant	Deep Well	Total	Plant	Deep Well	Total	
Oct-Dec	314.11	18.01	332.12	1.112	4.78	5.892	338.012
Jan-Mar	317.73	16.63	334.36	1.058	4.48	5.538	339.898
Apr-Jun	333.85	16.26	350.11	1.086	4.56	5.646	355.756
Jul-Sep	348.21	17.52	365.73	1.069	4.76	5.829	371.559
Whole year	1313.9	68.42	1382.32	4.325	18.58	22.905	1405.225
% Within System	95.1%	4.9%	100%	18.9%	81.1%	100%	
% Inter System			98.4%	(1.63%)		1.6%	100%

(3) Water Service Blocks and Location

To provide overall speedy service to the customers MWA divide 16 service zones under 12 branch offices. Ten branch offices in Nontaburi, Bang Khen, Phayathai, Phrakanong, Samut Prakarn, Bangkok Noi, Phasicharoen, Taksin, Toongmahamek, and Mansri to serve the Main System. Other two branch offices, Minburi and Bangbuathong are serving water to the Separate System.

(4) Water Production and Consumption in the Last 5 Years

Water production data in the last 5 years shows that yearly water production is increasing though consumption rate per connection is decreasing as indicated in Table 4.3. This is simply because of rate of increase of connection is higher than the rate of increase of production needed for the increased service. Increased rate of water production over previous year for the last 5 Fiscal Years are calculated in Table 4.3. From the Table, it is found that in the 1994 Fiscal Year over the previous 1993 Fiscal Year water production increase is very less (0.76%) and that in this year over previous year is very high (13.85%). This is because of serious drought in the 1994 Fiscal Year and heavy rainfall with demand in this year. During the period from 1991 to 1993 increase rate varies from 4% to 6% annually. Percentage of water sold to water production is clearly decreasing during the last 5 years which indicates that the system loss is increasing.

Block-wise average water production and sales are shown in Table 4.4. At present, the highest water production in the Main system is in Samut Prakarn branch office of 0.492 mcmd and the lowest in Bangkok Noi branch office of 0.221 million mcmd. The total average production is 3.85 million mcmd and it is 26.64% higher over the Fiscal Year 1991. The increase rate of water production is very high in both blocks of the Separate System compared to Main System Blocks. Among the blocks in the Main System, the increase of production in Phasicharoen, Toongmahamek and Samut Prakarn blocks are higher, varying from 59- 61%. Production in Phayathai and Mansri blocks are decreased by 23% and 0.62%, respectively. In other 5 blocks- Nontaburi, Bang Khen, Phrakanong, Bangkok Noi and Taksin water production are increased by 27-33%.

Table 4.3 Summary of Water Consumption in 1991 - 1995

Fiscal Year	Water Production	Water Sold	Rate of Water Sold	Number of Connection	Water Consumption per Connection
	million m3	million m3	%	pcs.	m3/month
1991	1109.2	781.5	70.5	1,027,623	63.4
	(5.7)	(8.7)			
1992	1175.5	823.4	70.0	1,090,995	62.9
	(6.0)	(5.4)			
1993	1224.9	836.1	68.3	1,139,299	61.2
	(4.2)	(1.5)			
1994	1234.3	816.1	66.1	1,194,161	57.0
	(0.8)	(-2.4)			
1995	1405.2	870.3	61.9	1,241,380	58.4
	(13.9)	(6.6)			

Note : Figures in parenthesis indicate increase or decrease over the previous year

Table 4.4 Block-wise Water Production and Consumption (1991 - 1995)

	1991		1992		1993		1994		1995		IncreaseRatio	
	Prod	Sold	Prod	Sold	Prod	Sold	Prod	Sold	Prod	Sold	Prod	Sold
Nonthaburi	0.273	0.211	0.328	0.229	0.293	0.205	0.306	0.198	0.349	0.216	27.68%	2.19%
BangKen	0.291	0.211	0.330	0.227	0.340	0.234	0.346	0.236	0.385	0.253	32.46%	19.74%
Phayathai	0.387	0.261	0.385	0.266	0.343	0.232	0.326	0.222	0.314	0.229	-18.94%	-12.21%
PhraKanong	0.328	0.224	0.316	0.235	0.341	0.242	0.338	0.234	0.418	0.248	27.54%	10.64%
Samut Prakarn	0.308	0.215	0.338	0.240	0.370	0.257	0.410	0.271	0.492	0.301	59.64%	39.77%
BangBo	0.014	0.010	0.013	0.008	0.006	0.003	---	---	---	---	---	---
Min Buri (Sep.)	0.026	0.021	0.029	0.023	0.029	0.027	0.035	0.028	0.045	0.033	74.14%	56.86%
Bangkoknoi	0.166	0.133	0.180	0.139	0.199	0.142	0.195	0.138	0.221	0.146	33.13%	9.77%
Phasicharoen	0.223	0.157	0.231	0.163	0.269	0.174	0.301	0.171	0.360	0.188	61.63%	19.60%
Taksin	0.328	0.232	0.357	0.245	0.360	0.253	0.369	0.254	0.434	0.271	32.43%	16.63%
Toongmahamek	0.196	0.130	0.190	0.132	0.289	0.184	0.279	0.171	0.312	0.178	59.06%	36.98%
Mansri	0.481	0.323	0.493	0.324	0.486	0.317	0.440	0.266	0.478	0.291	-0.60%	-9.79%
BangBua Thong(Sep.)	0.019	0.014	0.023	0.017	0.030	0.022	0.036	0.026	0.041	0.032	116.89%	125.83%
Total (mcm/year)	3.040	2.142	3.212	2.250	3.356	2.291	3.381	2.236	3.650	2.384	26.64%	11.30%
Total	1109.6	781.8	1172.3	821.1	1224.9	836.1	1234.1	816.2	1405.2	870.2		

Note: Figures in the column "increase ratio" indicates a increase or a decrease of water amount between 1991 and 1995.

(5) Water Consumption by Types of Water Users

Water consumption data on the type of water users are not clear but categorized by the available data and shown in Table 4.5. The first category domestic water users and the second category business users including commercial, state enterprises, government agencies, industries, etc. consume almost the same amount of water since 1991.

Though total consumption during the last 5 years is increasing which is quite natural except the Fiscal Year 1995. This exception is due to serious drought flow of the Chao Phraya River in 1994. In 1995, 444.5 million cubic meter per year or 51 % is consumed by domestic purpose and that by business, industry and others are 321.57 million cubic meter per year or 49 %.

Table 4.5 Water Consumption by Type of Water Users(1991 - 1995)

Fiscal Year	Domestic Water Consumption			Business Water Consumption			Total Water Consumption (million m3)
	Water Consumption (million m3)	Increase or Decrease over Previous Year (%)	Rate to Total Water Consumption (%)	Water Consumption (million m3)	Increase or Decrease over Previous Year (%)	Rate to Total Water Consumption (%)	
1991	391.70	6.00	50.13	389.60	11.50	49.87	781.30
1992	405.40	3.50	49.23	418.00	7.29	50.77	823.40
1993	413.90	2.10	49.50	422.20	1.00	50.50	836.10
1994	415.80	0.46	50.95	400.30	-5.19	49.05	816.10
1995	444.50	6.90	51.08	425.78	6.37	48.92	870.28

Note : Business water consumption include commercial, state enterprises, government agencies, industries, public water supply & others

4.3 On-going and Future Development Plans

Development projects of water supply facilities of MWA are carried out based upon the Master Plan formulated in October 1990 with the target year 2017 covering about 3,080 sq. km including the entire BMA area and the neighboring Nonthaburi and Samut Prakarn provinces.

Major current and future development projects are described herein and in Table 4.6 for the benefits to study on urban environmental Improvement program for BMA area from the viewpoint of the major urban facilities to maintain satisfactory public health and sanitation. Figure 4.1 shows water service area, water transmission projects and expansion plan of the current Master Plan.

(1) On-going Projects

1) The Fourth Bangkok Water Supply Improvement Project (1991-1996)

This project aimed at the increase of water production capacity of Bang Khen Water Treatment Plant by 400,000 m3/day, accompanied by distribution pipes and a pumping station at Lat Krabang. The project will expand the service area by an additional 180 km2 into Sukhaphiban 3, Sri Nakarin, Bangna -Trad, Rom Klao, Theparak and King Kaew roads.

2) The Fifth Bangkok Water Supply Improvement Project (1992-1996):

This will provide a new Mamasawat Water Treatment Plant located on the West Bank of Metropolitan Bangkok to supply sufficient water to the people in Thonburi area and Nonthaburi province. This project will extend service by 400,000 cubic meters of water per day and that will increase service area and population by 80 km2 and 800,000 person, respectively. After completion of this project MWA total capacity will be 4.5 million cubic meter per day to the service area 930 km2. And hence 85.1% population will be beneficiaries from MWA. The total project cost is 7,663.5 million Baht.

3) The Sixth Bangkok Water Supply Improvement (1994-1999)

This project will provide additional production capacity to the Mamasawat Water Treatment Plant by 400,000 cubic meters per day. The project includes construction of pumping station at Pechakasem Road, construction of transmission line approximate length of 34 km and installation of distribution pipes to extend the service area by about 80 km2. After completion of this project MWA total production capacity will be raised to 4.9 million cubic meter per day to the service area 1,030 km2. As a result 90.5% population will be served from MWA. The total project cost will be about 10,113.0 million Baht.

4) The West Bank Raw Water Canal Project (1995-1999), Phase II

This project aimed at construction of upstream portion of raw water canal from Mae Khlong River upper Vajiralongkorn Dam, Kanchanaburi Province to Tha Chin River approximately 70 km. The total project cost will be about 4,885.5 million Baht.

5) The Network System Improvement Project (1994-1997)

To improvement and develop water pipe system and distribution system for the increase of pumping capacity and distribution efficiency to cope with the rising demand in central business and high rise districts. Total project cost will be about 4,690.1 million Baht.

(2) Future Project (1997-2001)

- Installation of raw water pump at Mamasawat Water Treatment Plant
- Increased production capacity of Mamasawat Water Treatment Plant by 400,000 cubic meter per day. Construction of clear water reservoir of 60,000 cubic meter capacity with other appurtenant facilities.
- Construction of distribution pumping system, surge tower, and transmission line in both East and West Bank of Metropolitan Bangkok. Construction of transmission system in the East Bank.
- Increase facilities in Minburi service area by purchasing land, construct pump station, clear water reservoir and appurtenant facilities.
- Installation of an additional water pump to increase pumping capacity at Pechakasem pump station.
- Installation of various sizes of pipelines approximately 600 km in whole service area.

After the completion of the project in the year 2001, total MWA water production capacity will be 5.7 million cubic meter per day to cover the service area 1,090 km2. Total number of customer will be increased to 1.6 million for 8.2 million population. And hence, 93% population will be served by MWA. Total project cost will be about 12,431.0 million Baht.

Table 4.6 List of Water Supply Development Projects

	Projects	Type	Purpose	Location	Cost (million Baht)	Completion Year
On-GoingProjects						
1	TheFourthBWSIP	Pumpingstation& distributionpipeat Krabang	Increasewater productioncapacityof BangKhaenWater Treatmentplantby 400,000cmd	BangKhaenEast suburb	7,798.10	December1996
2	TheFifthBWSIP	MahaSawatWater TreatmentPlant, additionalpipeline	Increasesystem capacityby400,000 cmd	BangKruai, Nontaburi	7,663.50	1996
3	TheSixthBWSIP	PhetKasemPumping station,additionalpipe line	Increasecapacityof MahaSawatTreatment Plantby400,000cmd	PhetKasemRoad,	10,113.00	1998
4	TheWestBankRaw WaterProject	Rawwatercanal	Rawwatersupply	MaeKhlongRiver to Tha Chin River	4,885.50	1999
5	TheNetworkSystem Improvement	Monitoringpipe system & repair	improvepumping capacityanddistribution efficiency	Wholesystem	4,690.10	1997
FutureProjects						
1	MinburiProject	Pumpingstationwith otherfacilities	Increasecapacity	Minburi,EastBank	-	2002
2	BangPleeProject	Pumpingstationwith otherfacilities	Increasecapacity	BangPlee,East Bank	-	2006
3	Thonburi&ThaPhra Project	Transmissionpipeline fromMahaSawatto ThonburiandTha PhraPS	Increasecapacity	westBank	-	2017

Figure 4.1

Water Service Area Expansion Plan

Legend

- Water Service Area in 1995
- Water Service Area before 1997
- Water Service Area before 1997
- Water Service Area bofore 2007
- Water Service Area before 2017
- Chaopraya River
- River
- Road
- MWA Boundary
- Rail
- BMA Boundary
- District Boundary
- Subdistrict Boundary

N
W E
S

SCALE 1:250000

5 0 2 4 6 8 10

KILOMETERS

THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

4.4 Policy Directions and Planning Issues

Planning of water supply system is not dealt in the scope of work of the study concerned since water supply system does not directly related with the issues as it is discussed the urban environmental improvement program for the city. However, in view of a key role of water supply system composing the urban facilities to maintain sanitary environment in daily life, the study was made in brief to evaluate the water supply system of Metropolitan Waterworks Authority(MWA).

The suggestions described in the following paragraphs will be beneficial to the MWA to strive for solving the planning issues for accomplishment of effective water supply system. Moreover, it is expected that the suggestions are also effective for BMA to create a water-saving or energy-saving society for sustainable development of the city of Bangkok.

(1) Review of Water Supply Master Plan

MWA is carrying out the development projects steadily based on the Water Supply Master Plan set forth the phased development plans up to the final target year in 2017.

Currently, the 4th expansion plan is underway to complete the project by the end of 1997. The 5th and 6th expansion projects are scheduled for the period 1992 - 1997 and 1994 -1999 respectively. Upon completion of the final phase, the MWA water supply system will be made available with the water consumption amount of 5.3 million m3/day or equivalent to the served population 15.5 million in the year 2017 in whole service area and the population in BMA area accounts for 10.6 million or approximately 70 % amongst in MWA service area. For individual water consumers, the amount of water will be secured at the least by about 60 m3/month per connection in average for every consumers or 30-40 m3/month per connection for domestic water user.

It is understood that implementation of the projects proposed in the water supply Master Plan would make it possible to supply sufficient amount of water to the people in the service area. However, the recent phenomena taking place in urbanization such as the direction and speed of urban growth, change of life style, quality of life, etc. shall need review of the water supply development projects to accommodate better service of water to the consumers.

Tendency of urbanization in the recent years has changed the population distribution pattern toward suburban area, besides the decentralization project having been promoted by the government. In relation with the current urban renewal plan of Bangkok and that of the neighboring provinces, review of the Water Supply Master Plan will be necessary for coordinating with the city development plans to perform water supply onward target for continuous service of safe and sufficient water to the people.

Prediction of future water consumption, location of distribution pump stations, restructuring of water transmission pipes, distribution pipe network and water service blocks, and phasing of the development projects are the important issues as the Master Plan is reviewed in connection with the urban renewal plan.

(2) Water Leakage Protection and Pipeline Information System

Unaccounted water amount reached at 38 % or 534 million m3/year in 1995 statistic. Most of the unaccounted water amount is caused of water leakage from the pipeline system composed of water transmission, water distribution and water service to the consumers. Distribution water is produced through the physical and chemical processes with spending a lot of expenses for purification of water meeting with the drinking water standards. Water leakage from the pipeline system is something like a waste of investment or loss of energy in other word.

It is recommended to set a provisional target of water leakage protection at 20 % in consideration of the least water leakage ration at 30 % performed in 1992.

Firstly, inventory survey of the pipelines and networks will be useful to work with as - built drawings and site survey using the advanced underground explore equipment. Then, all the data and information shall be input in the graphic information system for constructing the pipeline information system covering entire water service area. Secondary, field investigation shall be carried out in the water leakage investigation block divided properly into smaller blocks by the data obtained from the pipeline information system. After analysis of the zonal water leakage amount and ratio, detail investigation shall be conducted to search for the water leaking pipelines for design and for immediate measures. The third step work shall be conducted to repair, renew or replace the damaged pipelines based on the design. Final step of this program is to renew the data and information of the pipeline information system to input the repair records. The water service area controlled by each branch office shall be divided into smaller blocks for block-wise operation to implement the leakage protection program one by one.

(3) Improvement of Water Quality

West Bank Raw Water Canal Project is under way to withdraw raw water from the Tachin River to Mahasawat Water Treatment Plant by the end of 1997 and complete the project after extending the raw water intake site further to the Maeklong River Basing in future. Completion of the project will make available to increase the rated capacity of Mahasawat Water Treatment Plant up to 3.2 million m3/day.

The past and on-going projects aimed at securing sufficient quantity of water and MWA is materializing the plan successfully up to now. Now, the people in Bangkok is achieving stability in his livelihood and his consciousness in daily life is changing to obtain rather the quantitative than the qualitative things. Movement of environmental conservation activities in the recent years is an example that people is asking for better quality of life.

To cope with the changes of the society, MWA have to set up the program to improve water quality in purification and water distribution processes.

Fortunately, raw water in the Chao Phraya River is not yet contaminated with hazardous matters but there is a phenomena of water contamination with organic matters especially in drought period. Organic contamination by fumic acid have a potentiality to generate Tri-haro-methane which is known as one of a carcinogenic substances produced as residual fumic acid contact to chlorine in disinfection process. Chemical dosing, sedimentation and filtration processes must be controlled carefully to produce better filtered water quality before chlorination .

Turbid water is observed frequently when tap water is contained in sink or in bath tub. Turbids from the service pipes occurs as sediments or scale in the pipe float caused by shock flow, pipe repair work, insufficient blow-off operation, and so forth. Those cause mentioned above can be improved easily through strengthening operation and maintenance works of distribution pipe network.

Deterioration of raw water quality will be the problem being afraid in near future as long as pollution loading increase continuously in future. Water pollution control projects must be carried out soon by the authority concerned to avoid probable water pollution problem in the area of water resources in future.

Accordingly, it is recommended to start up the program for water quality improvement of MWA water supply system with strengthening water purification process control and operation & maintenance of the distribution pipe network through utilizing the existing function of MWA.

CHAPTER 5: FLOOD PROTECTION AND DRAINAGE SYSTEM

5.1 General

Devastating flood in October - November, 1995 reminded the citizens and the official agencies concerned with flood protection that the flood problem is one of the major disaster in the urbanized comfortable civic life.

There are many arguments came from the implementing agencies concerned are suggesting the method of solutions to improve and enhance the flood protection facilities in BMA and its neighboring areas. Those suggestions include stormwater diversion directly to the seashore, storm water retention to cut peak flow period, dredging of the existing canals to secure enough carrying capacity, construction of the retaining wall of 2.5 m high along both sides of the Chao Phraya River and so forth.

A cause of flooding in BMA in 1995 may be the excessive discharge from the upstream reaches was interrupted by the backflow from the sea which raised water level in the Chao Phraya River to exceed the embankment level and caused of flooding in Tonburi, Nontaburi and the low-lying area along the Chao Phraya River.

However, the flood problem in BMA can not be concluded simply by the cause mentioned above but it is related to some other factors such as the flat terrain, land subsidence, capacities of flood protection and drainage facilities, etc., and increase of stormwater run off coefficients caused by the current urbanization in suburban area.

Planning of flood protection system was not dealt with a major scope of works in the Study aiming at formulating the urban environmental improvement program since the phenomena of flooding is not deemed as an element categorized in environmental deterioration as compared with air pollution, water pollution, etc.

However, the flood protection system is one of the important infrastructures in BMA Area to provide disaster-free comfortable life to the citizen and the planning of the system is influential factors as the city planning and/or land use plan is discussed. Accordingly, the study was conducted aiming at suggesting only the approach to solve the flood problems based on an angle of restructuring the city of Bangkok to cope with improvement of urban environment in the BMA Area.

5.2 Assessment on Present Condition

(1) Current Flood Protection Work

1) Implementing Agency

Department of Drainage and Sewerage (DDS), BMA undertake the services of flood protection in BMA Area. Drainage System Development Division take charge of the services from planning to construction work while. Drainage System Control Division take charge of operation and maintenance of the khlongs, pumping stations and control gates.

Royal Irrigation Department(RID) take charge of the flood protection work in the

eastern suburbs, outside of the King's Dike, in cooperation with DDS to control flood water entering to the inner core area of Bangkok.

2) Existing Facilities

Figure 5.1 shows the location of the existing flood control facilities including pumping stations and control gates. The total pumping capacity reach at 863.4 cum/sec and the breakdown of each area is 422.6 cum/sec in east bank, 239.8 cum/sec in west bank and 201 cum/sec in the coastal area in Samut Prakarn.

(2) Floods in October - November ,1995

The Chao Phraya River recorded the highest water level of 2.27 m MSL at the Memorial Bridge in October, 1995, which is higher water level than that was observed in 1983 when most part of the BMA Area suffered a very heavy flooding for several weeks.

Since the severe floods in 1983, the flood protection facilities such as polders, pumping stations and control gates have been in the central area of Bangkok. Major development projects have now shifted to Tonburi side to construct the flood protection and drainage facilities.

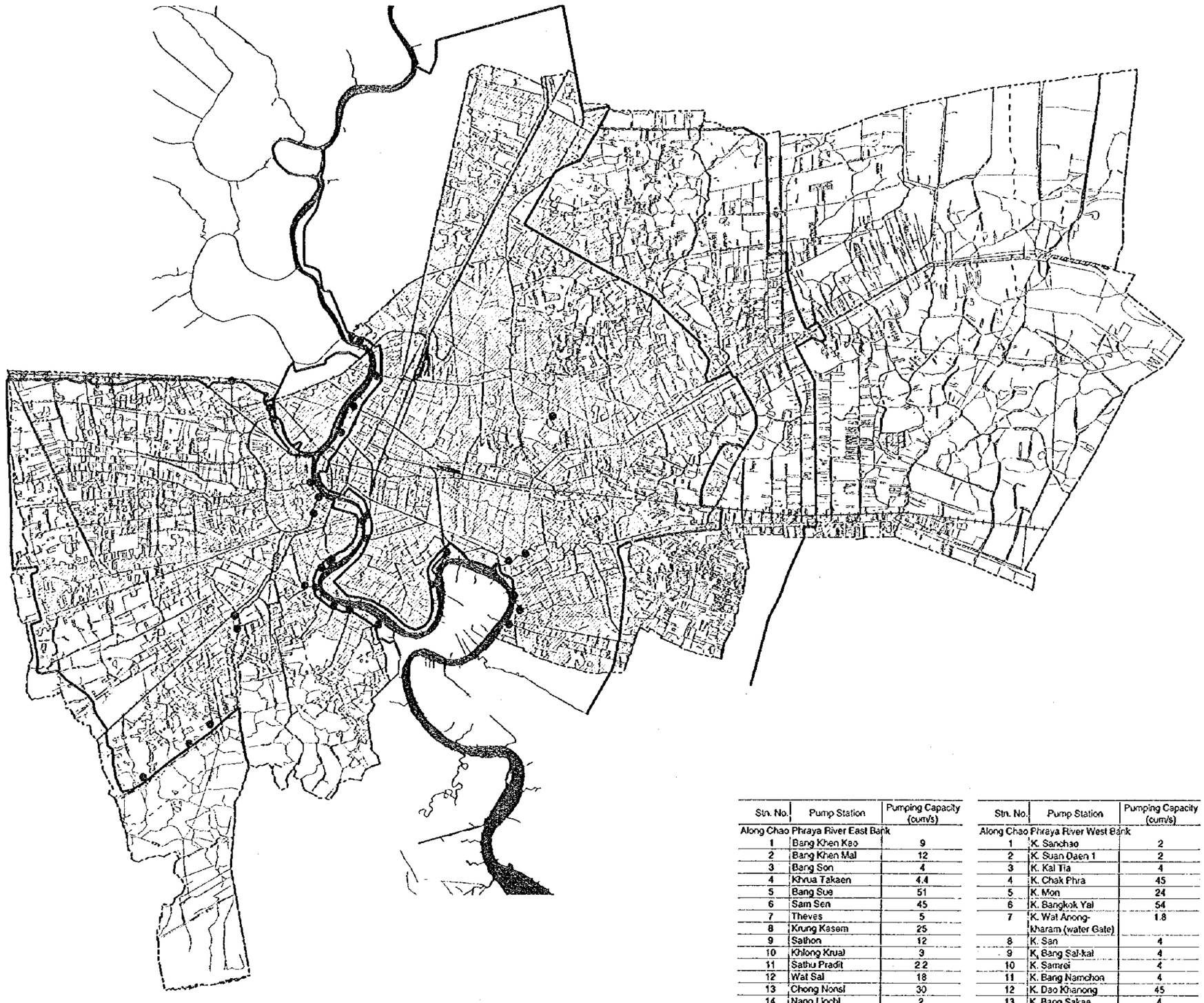
However, ironically, heavily inundated area in 1995 flood occurred outside of the flood protection area in the low lying area along the Chao Phraya River caused by overflow from the river. The area damaged by the flood extended to the municipality area of Nonthaburi, Pakkred in Nonthaburi Province, Bang Yai, Bang Bua Thong, Bang Kruay, Khlong San, Bang Phlat, Taling Chan, Bangkok Noi, Bang Khuntien, and Lat Krabang in Bangkok.

Figure 5.2 and 5.3 show inundation area during floods in 1983 and 1995 respectively in BMA Area.

(3) Inundation-prone Roads in Bangkok

In wet season, inundation damage extended to many roads and sois and cause of traffic congestion chaos in many sections in BMA Area. Figure 5.4 shows inundation records on major roads recorded by DDS during 1993 to 1995. Inundation-prone roads were picked out and listed in Table 5.1 for the inundation records more than 20 times in two years. Those roads include Phahon Yothin, Lat Phrao, Sukhmvit, Charoen Krung, Charoen Nakhon, Charan Sanitwong, etc.

Figure 5.1



Existing Flood Protection Facilities

Legend

- Buildup Area
- Chaopraya River
- River
- Rail
- Road
- Flood Protection Barier
- BMA Boundary
- District Boundary
- Subdistrict Boundary
- Pumping Station
- Watergate

N
W E
S

SCALE 1:235000

6 0 2 4 6 8 10

KILOMETERS

Stn. No.	Pump Station	Pumping Capacity (cum/s)
Along Chao Phraya River East Bank		
1	Bang Khen Kao	9
2	Bang Khen Mai	12
3	Bang Son	4
4	Khrua Takaen	4.4
5	Bang Sue	51
6	Sam Sen	45
7	Theves	5
8	Krung Kasem	25
9	Sathon	12
10	Khlong Krual	3
11	Sathu Pradit	22
12	Wat Sal	18
13	Chong Nonsi	30
14	Nang Linchi	2
15	Rama IV	24
16	Khlong Toei	30
17	Phra Khanong	105
18	Khlong Chak	6
19	Bang Chak	2
20	Bang Or	18
21	Bang Na	15

Stn. No.	Pump Station	Pumping Capacity (cum/s)
Along Chao Phraya River West Bank		
1	K. Sanchao	2
2	K. Suan-Daen 1	2
3	K. Kal Tia	4
4	K. Chak Phra	45
5	K. Mon	24
6	K. Bangkok Yai	54
7	K. Wat Anong-kharam (water Gate)	1.8
8	K. San	4
9	K. Bang Sai-kai	4
10	K. Samrei	4
11	K. Bang Namchon	4
12	K. Dao Khanong	45
13	K. Bang Sakae	4
14	K. Bang Pakok	6
15	K. Ratburana	9
16	K. Chaeng Ron	9
17	K. Sakae-ngam	6
18	K. Lain-pain	6
19	K. Ra-ham	6

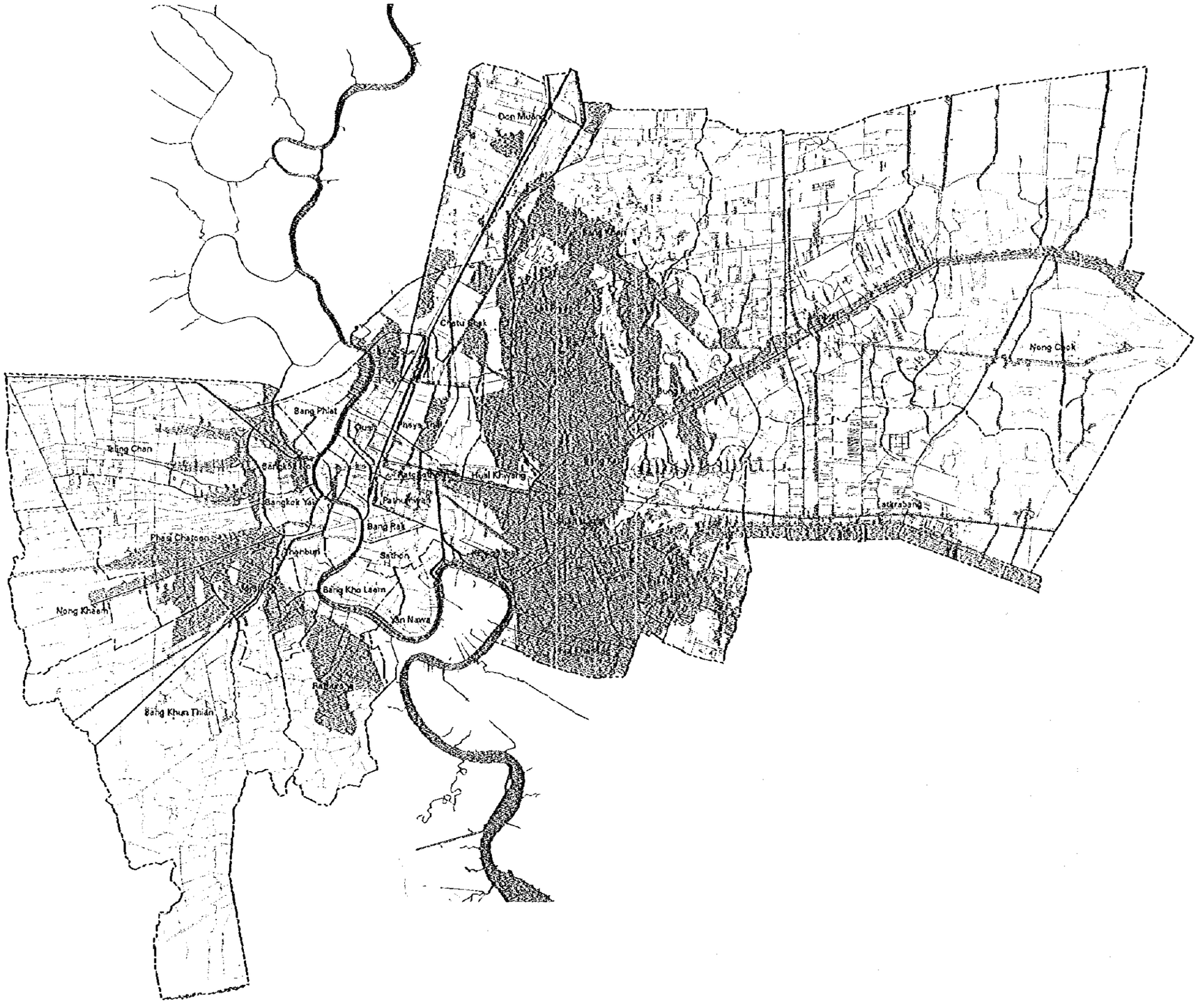
THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

Figure 5.2

Inundated Area in 1983



Legend

- Flooded Area in 1983
- Roads
- Chaopraya River
- Khlongs
- Railways
- BMA Boundary
- District boundary

N
W E
S

SCALE 1:235000

5 0 2 4 6 8 10

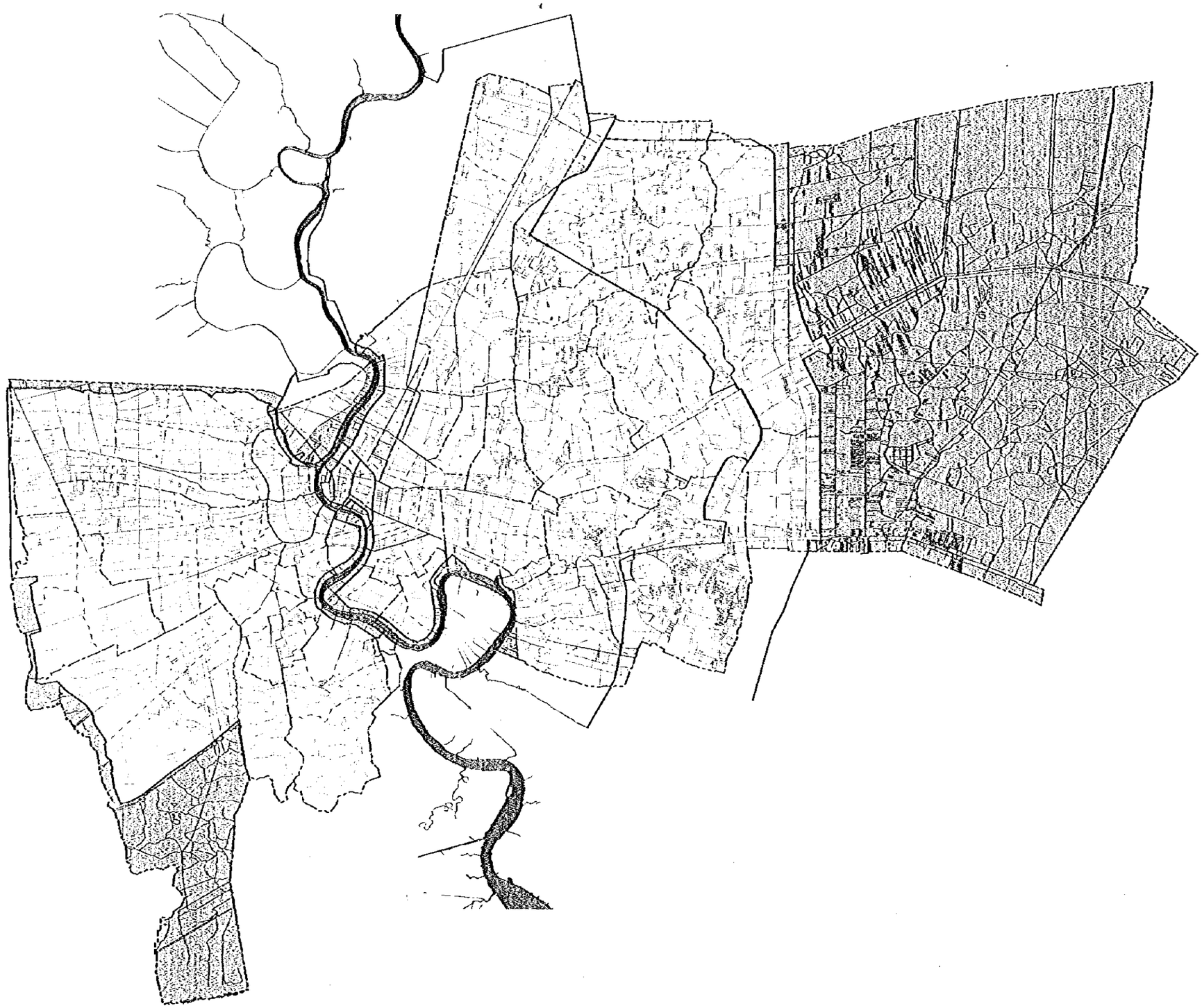
KILOMETERS

THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

Figure 5.3



Inundated Area in 1995

Legend

- Flooded Area
- Temporarily Flooded Area
- Chaopraya River
- BMA Boundary
- District Boundary
- Subdistrict Boundary
- Flood Protection Barier

N
W E
S

SCALE 1:235000

5 0 2 4 6 8 10

KILOMETERS

THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

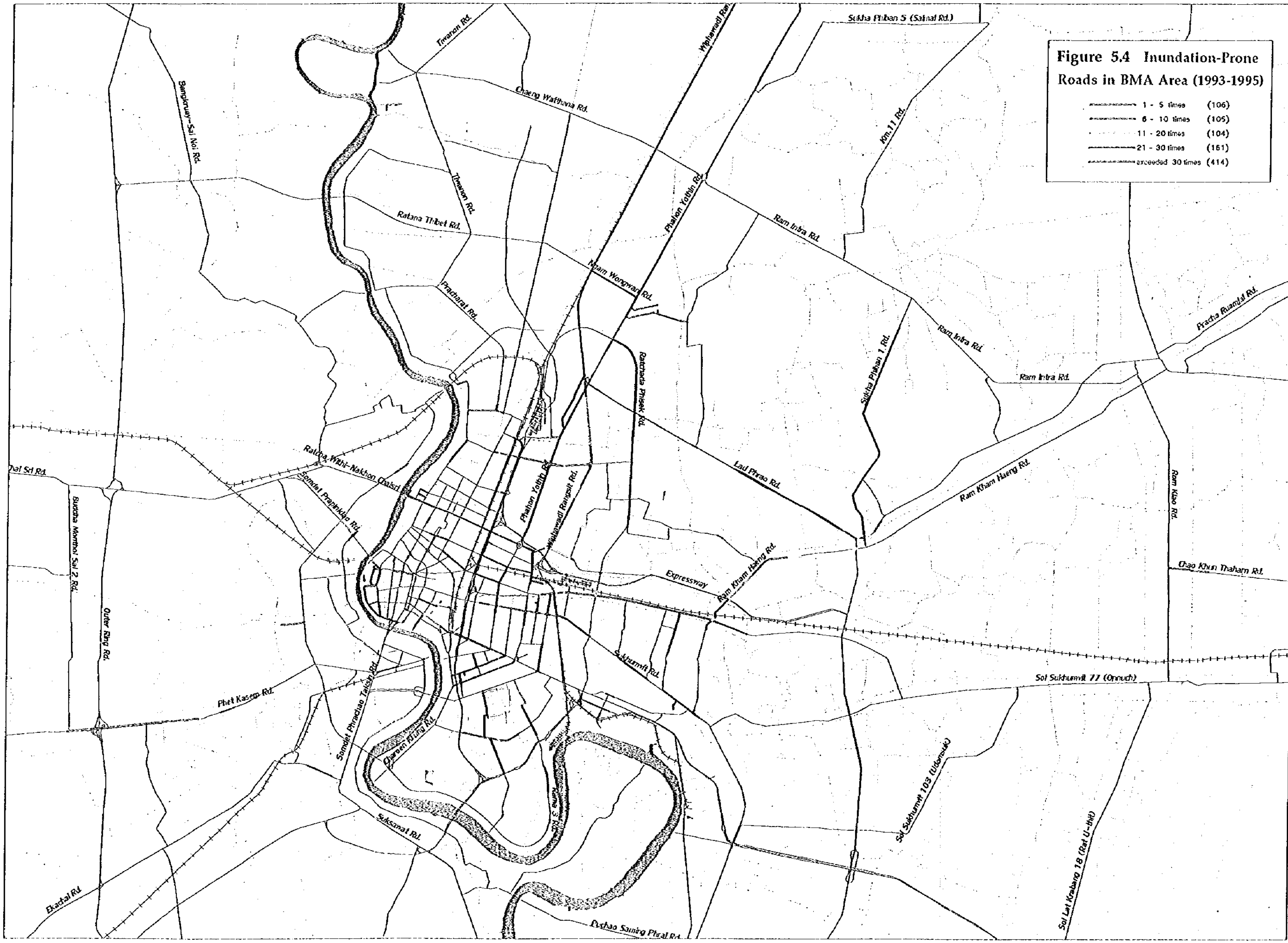


Figure 5.4 Inundation-Prone Roads in BMA Area (1993-1995)

Table 5.1 Frequent Inundation Roads in BMA Area

No	Name of Road	From	To
Inundated More Than 30 times During 1993-1995			
1	Phetchakasem	BuddhaMonthonSai2	Phetchakasem64
2	PhahonYothin	PhahonYothin32	PhahonYothin46(K.BangBua)
3	PhahonYothin32	PhahonYothinRd.	WatLadPlakao
4	PhahobYothin34	PhahonYothinRd.	ThaiCottonIndustrialFactory
5	PhahonYothin	PhumiphoHospital	
6	PhahonYothin	PhahonYothin24	Ratchadaphisek
7	Ratchadaphisek	PhahonYothinRd.	K.BangSue
8	LatPhrao	Chokchai4(junction)	
9	LatPhrao	LatPhrao86	BangKapi
10	SukhaPhiban2	BangKapi	
11	PhahonYothin1	AnusawarChaisamoraphum	LatPhrao
12	Ratchawithi	AnusawarChaisamoraphum	DinDaengJunction
13	Ratchawithi	AnusawarChaisamoraphum	RamaVI
14	RamaVI	Ratchawithi	Phetchaburi
15	Phetchaburi	RamaVI	PhayaThai
16	Phetchaburi	Phetchaburi	SoiNanaNua
17	SoiNanaNua	K.SaenSaep	Phetchaburi
18	RamKhamhaeng	RamKhamhaeng27	RamKhamhaeng65
19	Sukhumvit	Sukhumvit39	Sukhumvit55
20	Sukhumvit	Sukhumvit63	Sukhumvit71
21	Sukhumvit	Sukhumvit103	BangNa-Trad
22	Ratchadaphisek	nearbySoonthornKosa	
23	Chan	K.ChongNonsi	ExpressWay
24	NangLinchi,SoiSuanPhlu	Chan Rd.	SathonTai
25	CharoenKrung	nearbyTokRd.(intersection)	
26	RamaIII	SoiWatKlongPhum,nearbyintersection	
27	CharoenNakhon	CharoenNakhon40	
Inundated 21 - 30 times During 1993-1995			
No	Name of Road	From	To
1	SukhaPhiban1	BangKapi	SuanSiamRd.
2	SukhaPhiban2	BangKapi	KlongChanFlat
3	RamKhamhaeng	KlongTan	RamaIX(Junction)
4	Sukhumvit	nearbyPhraKhanongintersection	
5	SathuPradit	ChongNonsiRd.	ChanRd.(infrontofYannawaPostOffice)
6	SathuPradit		PublicHealthCenter7
7	Chidlom	K.SaenSaep	PloenchitRd.
8	Ratchadamri	nearbyRatchaprasongintersection	
9	Ratchaprarop	Pratu-nam(IndhaHotel)	DinDaengJunction
10	SriAyudthaya	Ratchaprarop	RamaVIRd.(junction)
11	SriAyudthaya	RamaVRd	PhitsanulokRd.
12	Ratchawithi	nearbyTukChaiintersection	
13	Ratchadaphisek	nearbySoonthornKosaintersection	
14	ArunAmmarin	SomdejPhraPinklaoRd.	K.BangkokYai
15	CharanSanitwong	Soi96/2	K.BangkokNoi
16	SomdejChaoPhraya	PrachathipokRd.	LadYaRd.
17	CharoenNakhon	CharoenNakhonSoi1	ChomThongRd.
18	Ratburana	ChomThongRd.	NakhonKhuanKhinRd.(WatRuak)

(4) Flood Protection and Drainage Plans in the Past

A historical map dated 1690 of the Chao Phraya River shows that the original Chao Phraya River meandering system and secondary connecting khlong system. It shows a diversion channel to the west of Bangkok which cut the shortest path from the Chao Phraya River near Nonthaburi to the sea. Secondary diversion khlongs are also shown connecting other meanders to the river. Many of the wide meanders of the Chao Phraya River had been shortcut by 1960's and the main river had been shortened significantly to carry more flow. Currently, the only large meander remain in the section of Yannawa and Phra Phradaeng.

Flood control planning has been conducted for several decades in the Bangkok area. However, the flood damages have become catastrophic state as to the expansion of urban area. In the past ten years multiple plans have been developed and implemented to different degrees. The severe flood in 1983 in Bangkok was a turning point to tackle with flood protection and drainage works in planning and in construction of the facilities.

The following paragraphs provides a summary of the flood control and drainage studies performed for the Bangkok area.

1) Greater Bangkok Plan (1960)

Litchfield, Whiting, Bowne & Ass. Adams Howard and Greely proposed the Greater Bangkok Plan in 1960. This plan consist primarily of two perimeter canals on the East and West banks of the Chao Phraya River. The plan also laid out several zones in the city on both sides of the Chao Phraya River to install flood protection barriers. This concept is a type of polder system functioned together with pumps to drain stormwater to the Chao Phraya River.

Priority was given to the down town areas of Dusit, Phra Nakhon, Pom Prap Suttru Phai and Pathumwan Districts.

2) Camp, Dresser McKee Plan (1968)

The Camp, Dresser McKee Plan proposed the polder systems divided considerably large area of Bangkok into 11 zones ranging the area size from 11 to 100 km2 to cover the East and West banks of the Chao Phraya River. The proposed polder systems intend to protect the city from flood inflow from the surrounding area of Bangkok. Roads, concrete walls and embankments structure the flood protection barriers for each polder, while the khlongs and the Chao Phraya River function as main drains. Stormwater inside of the polders is drained to the Chao Phraya River through drain pipes, pump station, and the khlongs.

The khlongs proposed for the main drain drains in the plan consist of Khlong Bang Sue, Khlong Lat Phrao, Khlong Saen Saep, Khlong Phra Khanong, and Khlong Samrong on the East Bank. In the West Bank, Khlong Maha Sawat, Khlong Bangkok Noi, Khlong Phasicharoen, and Khlong Sanam Chai are proposed for predominantly use for the main drains.

3) City Core Project (1984)

An area of 86 km2 on the East Bank of the Chao Phraya River is covered in this plan. The plan consist of feasibility study and detail design and conducted by NEDECO in joint venture with NECCO and Land Marine/Span. The polder system was endorsed in the plan to protect the central from flooding from outside area. The polders were subdivided into 6 drainage based on the previous studies and protected by a secondary flood barrier installed around the area. The secondary flood barrier, called inner dike, is installed by raising level of the roads for flood wall. Stormwater inside the polders is drained directly to the Chao Phraya River from the drainage pump stations. In addition to 5 existing pump station at the time, 11 drainage pump stations were

proposed with the capacity ranging from 10 to 35 m3/s.

4) Master Plan and Feasibility Study on Flood Protection/Drainage Project in Eastern Suburban - Bangkok, JICA (1986)

This master plan consisted of structural and non structural measures to provide adequate flood protection and drainage methods and to study Bangkok's flood management organization and management structure. Based on the recommendation in this study, many projects were carried out for the area of 260 km2 located in the east side of the central area of Bangkok.

The structural elements of the plan consist of endorsing the polder system, strengthening drainage system by pumps and diversion gates, and non-structural measures to mitigate flood flow by the idea of flood plain management by the retention ponds and natural retardation area such as swamps, ponds, borrow pits and other open fields scattered in the east side of the polder. Most of the existing flood protection and drainage facilities in the East Bank are were developed based on this plan.

Also implemented from this plan is the Bangkok Metropolitan Flood Control Center (FCC) now operated by DDS in BMA 2 City Hall. The FCC was designed to establish on-line monitoring of the information such as water level etc. related with flooding condition in the central area of Bangkok. Twenty five monitoring stations are now in function at the major drainage pump stations and water gates in the area covering about 600 km2. Each monitoring station equipped with a) rain gauge, b) water level gauge, c) pump operation gauge, d) water-gate opening detector, and e) water quality meter. Data from the monitoring station is recorded and transmitted automatically to FCC by telemetering system utilizing TOT leased line. FCC receives data telemetricaly from the 25 monitoring stations. The data are processed and displayed on the graphic panel to monitor the flood situation in all over the monitoring area.

5) The RID-Plan (1985)

The Royal Irrigation Department (RID) encompassed a regional flood control in the west side of the Chao Phraya, extending from north of Ayutthaya and continuing south to the Gulf of Thailand and extending west to the Tha Chin River. The system consist of construction of dikes enclosing the area between the Chao Phraya and Tha Chin rivers along the Khlong Phraya Banlu and Khlong Phra Pimon. The plan proposed to construct 2 control gates, 12 pumping stations and dredging of canals in the area between the Chao Phraya River and the Tha Chin River.

6) Study on Tawee Wattana by AIT (1985)

This study encompassed the planning in the western side of the Chao Phraya River expanded to the Tha Chin River in the south of the Khlong Maha Wawat covering 500 km2. The plan intended to strengthen drainage capacity by connecting the Khlong Tawee Wattana with the Khlong Khoon Ratpinidjai and drain to the sea. Result of the study shows that the plan is not feasible because of a lack of hydraulic gradient and a polder system was proposed even in the this area. The polder dikes were proposed in line with the 1985 RID Plan.

7) Alternative Flood Control Schemes Proposed by AIT (1985)

AIT conducted a study of several alternative flood control measures and recommended several measures. The study examined the change in water levels and flood periods in the Chao Phraya River assisted by the proposed alternatives. These alternatives include;

- Cutoff channel for the Chao Phraya River at Phra Pradaeng to shorten the length of the river to increase carrying capacity and lower water level as well.
- Construction of by-pass floodway with the carrying capacity 500 cum/s along the East Bank of the Chao Phraya River from Ban Mai to the sea in the east of Samut

Prakan, and

- Construction of dikes along the Chao Phraya River from Bangsai to the estuary and dredging the river from Pakkret to the estuary.

The study concluded that a by-pass channel with a 500 cum/s capacity is the best alternative although it was projected to improve the flood peak condition by a small amount because of the strong tidal influence.

8) Chao Phraya 2 (1986)

The Chao Phraya 2 study formally named the Bangkok Flood Protection, Chao Phraya 2 Feasibility study was prepared by the Thai Austrian Consortium in cooperation with the Asian Institute of Technology in July 1986. This study aimed at developing an integrated flood control plan by reviewing all the previous flood protection and drainage plans and developed a comprehensive flood control program. The study covered the area including Bangkok and the vicinity area.

This plan recommended to lower the water levels in the Chao Phraya River by constructing a diversion channel around the western side of the city. Water levels in the city would be controlled with two control structures. The upper control structure would be located at Bangsai and divert peak flows into the diversion channel to carry flood flow nearby the estuary nearby estuary of the Chao Phraya River in the West Bank. The control structure located in the down-stream side consist of a sea-barrier structure. The structure prevent sea water intrusion to the Chao Phraya river and to the khlongs in high tide period.

9) Master plan for Flood Protection and Drainage of Thonburi and Samut Prakan West by NEDECO and SPAN CO, Ltd. (1987)

The NEDECO study cover the study area of 432 km2 on the west side of the Chao Phraya River. This study analyzed multiple alternatives and developed a plan maximizing flood protection inside of the protected area while minimizing impacts on the areas outside of the flood protection dikes. The aim of the recommendations is to control inflow of flood water from outside the polder and to drain excess stormwater inside of the polder.

The master plan was developed to cover 135 sq.km of the study area and recommended alternatives including construction of new or raising existing flood barriers around and throughout the study area, and construction or rehabilitation of regulation water gates in the khlongs.

The study determined the best alignment for the surrounding flood barrier onto the Southern Railway in the north side, the Chao Phraya River in the east side and generally along the Khlong Sanam Chai in the south side. Two locations were investigated for the western boundary. The first location was recommended to set the flood barrier along the Tha Chin River, however, the plan was not adopted because of the urgency to improve the flood situation and construction cost of the barrier along the Tha Chai River. Instead, the interim barrier along Phutthamonthon sai 4 Road and Soi Bang Bon 3 was recommended and constructed. Approximately seven kilometers of the inner flood barriers were recommended located along the Khlong Dan in Bang Khun Thian, along the Khlong Bang Khun Thian, along the Chao Phraya River, and across Amphoe Phra Pradaeng.

Regulators and flood control gates were also recommended on the Khlong Maha Sawat, along the Khlong Chak Phra, on the Khlong Sanam Chai, on the Khlong Bang Khun Thian, along the Khlong Ratburana, and on the Khlong Lat Luang.

5.3 Policy Direction and Planning Issues

To formulate the urban environmental improvement program for BMA Area, the following issues are raised for discussion to attain the role of the flood protection and drainage faciliitiies in the area.

(1) Flood Control Plan in Low Area Along the Chao Phraya River

Low lying area along the Chao Phraya River suffer floods problem as the river water overflow from the low sections of the embankment walls. Arguments is now being raised to raise the flood protection walling, embankment, to the level at 2.5 m MSL along both sides of the banks of the Chao Phraya River in the section from Bang Khaen to Bang Na.

This plan shall be carefully studied together with the comprehensive flood control analysis in the river basin against the probable influence to the upper stream reaches and the countermeasures, periodical dredging plan for the Chao Phra River, etc.

(2) Flood Control Plan in BMA Area

Installation of the drainage facilities in Bangkok side has been completed with the major facilities and shifted to development of the facilities in the subdrainage areas. In Tonburi side, construction projects of the main pumping stations have started development since merely in 10 years ago and the projects shall be continued and be accelerated from now on.

Structural measures have took an effect on flood protection with the capacity as it is. Flood flow increase in the recent years tend to exceed the capacity of the existing facilities. Destruction of the tropical forest and land development projects cause more stormwate flow discharge in nowadays. Flood protection and drainage plan in future shall be associated with the non-structural, soft measures, to control stormwater run off in the river basin planning.

Vacant areas or the occupied areas squatters exist along both sides of the khlongs can be developed for retention ponds. Development of the retention pond in small area may be constructed a deeper pond by diaphragm wall method.

Abandoned sand borrow pits scattered in the north east of Bangkok, Min Buri, Nong Chok districts are also expectable for the retention ponds. The borrow pit of the area 100 rai, or 16 ha, can store water more than 1 million cum since , generally, the pit is dug to the sand stratum which lies at the level approximately 20 to 25 m below the ground level. The stored flood water may be discharged back to the khlongs or utilized for groundwater recharging purpose. Those deep retention pond plan shall be required to design by gravity inflow and pumping out flow systems.

Bangkok Plan presented 14 places of the existing and proposed retention area having the total area of approximately 400 ha or the storage volume of 16 million cubic meter. The plan envisage the retention area using as the public parks in dry season.

Those retention area will be functioned effectively to cut the peak flow discharge in the subdrainage area to minimize an excessive investment as designed by the peak flow. The main drainage system shall be reviewed to maximize the flood water carrying capacity by the network of khlongs and the pumping stations. A comprehensive flood control management system shall be established including the flood plain management covering each subdrainage area.

DDS, BMA is conducting a review study over the whole BMA Area except for the eastern part of the King's Dike by the contract with a associated group of the consultant companies. Points of reviewing the flood control system shall include review of the runoff coefficient, the capacity of existing canals and pumping stations of the main drainage systems and subdrainage systems, coordination with the on-going sewage projects, introduction of flood plain management plan, selection of feasible

stormwater retention areas or ponds, review of the flood protection polders in connection with the flood protection plan in outer area, etc.

(3) Flood Control Plans in Eastern Suburbs and Western & Northern City Boundaries

Applying the concept of hierarchy system into the planning, the primary drain and the tirtially drain may be located with the Chao Phraya River and the khlong network in the city area. However, the effective secondary drain can not be located in both of the East and West banks. The Khlong Thanon, Khlong Lat Phrao, Khlong Saen Saep, Khlong Tan and Khlong Prakanong line in the East Bank and the Khlong Tawee Wattana, Khlong Phasicharoen, Khlong Sanam Chai, Khlong Maha Chai or, Khlong Khoon Ratpinidjai line may be functioned as the secondary drain. However, these floodways do not function well due to the scale and the installations against flood control measures.

Installation of the secondary drain or called the floodway holds a key to solve the flood problem in BMA Area drastically. The Gham Ling project in the West Bank and the floodway project targeted for the conservation in the East Bank and New Bangkok International Airport can be developped to have a function for the secondary drain. What is called the Chao Phraya River 2 Plan has been in discussion from time to time for more than 20 years but the plan was not implemented due to difficulty in land acquisition and financial burden. It is about the time to spotlight onto this plan as to attain a sustainable development of the city of Bangkok in the next centuries.

The Royal Irrigation Department (RID) is conducting study and construction of the facilities in cooperation with DDS, BMA, Public Works Department(PWD), Ministry of Interior and other government agencies concerned. These projects mentioned above, initiated by the King, basically consist of securing the floodways connected to the sea and the flood plain management by the retention ponds, are the main subjects to be studied in detail. with the topics including as follows.

Widening and improvement of the existing khlongs will be the practical way to secure the flood ways running to the coastal area at Samut Prakarn in the East Bank and at Samut Sakhon in the West Bank.

In the eastern suburbs, Khlong Nguhao and Khlong Jorake Yai have high potential conditions to achieve the objectives. These khlongs are running across the site of new international airport, Nong Nguho, however these alignment of the khlongs will be replaceable by designing the ditches surrounding the airport to carry stormwater discharge from the eastern suburbs.

(4) Strategic Plan in The 5th BMA Five Year Development Plan

The programs were drafted by the Department of Drainage and Sewerage, BMA to develop, operate and maintain the flood protection and drainage facilities to protect the city from flood damages. The coming Five Year Plan is emphasized on construction of flood protection and drainage facilities in Thonburi side since the major part of the system in Bangkok side has been constructed in the previous and current Five Year Plans. In Bangkok side, flood control is practiced by introducing the flood plain management to retard stormwater runoff to cut peak flow and release in low water level period of the floodway. The major development projects in the Five Year Plan were listed below and summarized in the following paragraphs.

Program 1:	Flood Plain Management
Program 2:	Construction of Drainage System in Phra Nakhon (Bangkok) Side
Program 3:	Construction of Drainage System in Thonburi Side
Program 4:	Construction of Embankment along the Chao Phraya River in Bangkok Section and Khlong Bangkok Noi
Program 5:	Construction of Flood Protection Barrier in Southern Thonburi

Program 6: Construction of Flood Protection and Drainage in Bang Phlat and Bangkok Noi Districts
Program 7: Survey, Study and Preparation of Master Plan for Sub-Polder System in Bangkok and Thonburi
Program 8: Development and Improvement for Cleansing and Beautification of Khlongs in Whole Bangkok Area

Activities of the Strategic Plan

Program 1: Flood Plan Management

1) Procurement of Public and Private Lands for Stormwater Retention
2) Improvement of the Existing Flood Wall, Ponds, etc. to dam up water for Flood Protection
3) To specify the Preservation Areas for Stormwater Retention
4) To install Signboards at the Flood Risk Areas
5) To mark Flood Water Levels in the Past
6) To Prepare Flood Risk Area and Flooded Area Maps

Program 2: Construction of Drainage System in Phra Nakhon(Bangkok) Side

1) To support Main Drainage System in Urgent Period by providing stormwater retention areas at Nong Bon Pond,, Phibulwattana Pond, Krom Prachasamphan Pond and Phong Krathiam Pond to save budget for reducing the scale of Pump Station, Large Drainage Pipes and Gates
2) To improve inner drainage system by dredging and construction of Drainage Tunnel to discharge stormwater efficiently to the River and Sea

Program 3: Construction of Drainage System in Thonburi Side

1) To improve drainage system in Phetkasem Road, Buddha-Monthol Road, Pinklao-Nakhon Chaisri Road, Charoen Nakhon Road, etc. where suffering flood damages every year
2) To improve main drainage khlongs by constructing concrete retaining wall, pump stations, gates and drainage pipes
3) To provide retention area for supporting and increasing efficiency of drainage system

Program 4: Construction of Embankment along the Chao Phraya River in Bangkok Section and Khlong Bangkok Noi

1) Construction of Embankment approximately 37 km including appurtenances such as walkway etc. in East Bank of the Chao Phraya River
2) Construction of Embankment approximately 18.3 km including appurtenances such as walkway etc. in West Bank of the Chao Phraya River
3) Construction of Embankment approximately 5.6 km including appurtenances such as walkway etc. in along the Khlong Bangkok Noi in Thonburi

Program 5: Construction of Flood Protection Barrier in Southern Thonburi

1) Construction of 18 water gates and one pumping station in Bang Khun Thian, Nong Khaem and Ratburana areas
2) Construction of Embankment approximately 4 km in Nong Khaem
3) Construction of 4 water gates in Bang Khun Thian
4) Construction of flood wall approximately 6 km in Bang Khun Thian to prevent waste water flowing into animal farms

Program 6: Construction of Flood Protection and Drainage Facilities in Bang Phlat and Bangkok Noi Districts

1) Construction of embankment approximately 17.3 km along the Chao Phraya River and the Khlong Bangkok Noi
2) Construction of 51 gates and pumping station
3) Improvement of the khlongs approximately 33.9 km
4) Installation of drainage pipes approximately 47.4 km
5) Improvement of drainage pipes approximately 48.8 km

Program 7: Survey, study and preparation of Master Plan for sub-polder system in Bangkok and Thonburi

1) Study and formulation of Master Plan for sub-polders in BMA area except some part of Bang Phlat and Bangkok Noi
2) Feasibility Study of the projects and prioritization
3) Detail design of sub-polders including water gates, pumping stations, improvement of the khlongs, etc.
4) Preparation of tender documents for construction works
5) Preparation of existing and proposed drainage system maps

Program 8: Development and Improvement for cleansing and Beautification of the khlongs in BMA Area

1) Development, cleansing and improvement of the khlongs not less than 933 khlongs in 38 districts
2) Beautification, provision of relaxation spots, water transportation and drainage functioning

5.4 Planning Targets and Framework

(1) Planning Targets

Establishment of the system of "Flood-Free Urbanization" is not achieved simply by installing the flood control facilities but it will be required to take measures for overflow problem from the Chao Phraya River and urban growth control measures to minimize increase of run off coefficient. The planning issues discussed earlier including development of flood protection and drainage facilities, land use control and urban growth management are the key elements to take comprehensive measures against flooding in BMA Area.

Accordingly, the target for planning of the flood protection and drainage system shall be put basically on the point to take measures against the causes of man-made flooding as well as against the natural-cause flooding to create " Flood-free Urbanization " for

the next centuries and the drainage facilities may be designed to 5 year probability rainfall intensity for practical means.

(2) Proposed Action Plan to Achieve the Targets

As described earlier, the action plans for flood protection work shall be prepared on the view point to take measures for both natural and artificial causes to create " Flood-free Urbanization " for BMA Area and the surrounding provinces. To this target, the Study Team proposed the action plans presented as follows.

1) For Development of Flood Protection and Drainage Facilities

Action Plan 1 : Flood Control Plan in Low Area along the Chao Phraya River

Present Situation as of 1995

- Due to increase in stormwater run-off and high tide, the flowrate of the Chao Phraya River exceeded the maximum carrying capacity, thereby resulting in water level rise and overflow
- Embankment along the lower Chao Phrarya River section is not always high enough to protect the area from inundation in high water period in the end of wet season

Action Plan during 1997 - 2001

- Implementation of the urgent projects to raise the embankment level along the Cho Phraya River and Khlongs in Bang Phat, Bangkok Noi, and Bangkok Yai districts
- Formulation of Comprehensive Water Management and Flood Control Master Plan in the Lower Chao Phraya River Basin in collaboration with RID/PWD
- Start construction of the floodwall water diversion project based on the recommendations of the Master Plan in collaboration with RID/PWD

Action Plan during 2002 - 2006

- Continuation of the flood water diversion project based on the recommendations of the Master Plan in collaboration with RID/PWD

Action Plan 2 : Flood Control Plan in the Polder System (Draft Plan)

Flood protection and drainage facilities inside of the polder system have been developped for its major facilities and have functioned for drainage in the central part of the city. Construction works is shifting to the development projects in the sub-drainage area and improvement of the existing facilities as well.

Action Plan 2 endorse those strategic plans proposed for the 5th Five Year Plan and at the same time add the non-structural measure projects to be developped together with the future land use planning. The flood plain management planning shall be implemented in collaboration with the authorities concerned with the city planning and land procurement.

Note) Action Plan 2 will be adjusted waiting for the on-going study reviewing the Master Plan in Eastern Suburbs expected to be finalized in two moths

Present Situation as of 1995

- Main part of the BMA Area is protected by the polder systems
- Major drainage facilities in the East Bank have almost completed and the development projects are underway in the East Bank
- Stormwater run-off tend to increase caused by urbanization
- The Flood Control Master Plan for the East Bank is now being reviewed to meet with future urbanization condition and land use patterns

- Settlements and foreign matters sometimes block the drainage system and cause of flooding in local areas

Action Plan during 1997 - 2001

- Complete the projects in sub-drainage areas in the East Bank
- Accelerate the development projects in the West Bank
- Land inventory survey and procurement of sites for flood water retardation purpose
- Implementation of the urgent projects proposed in the master plan for Flood Protection and Drainage Systems in Eastern Suburban
- Review of the flood control Master Plan in the West banks
- Implementation of the flood plain management projects in suburban areas and drainage control linking with the main drain system in the East Bank
- Strengthening of the flood control center for regional level flood monitoring and forecasting
- Strengthening of cleaning and dredging work for drain pipes and khlongs

Action Plan during 2002 - 2006

- Implementation of the flood plain management projects based on the proposed plan in the revised Master Plan for the West Bank linking with the main drain system
- Completion of the flood plain management facilities in the East Bank
- Continuous operation and maintenance of the flood protection and drainage facilities both in the East and West banks

Action Plan during 2007 - 2011

- Completion of the flood plain management facilities in the West Bank
- Operation and maintenance of the total flood control system supported by the facilities developed for the structural and non-structural measures

Action Plan 3 : Flood Control Plans in Green Area and City Boundary Area

Present Situation as of 1995

- Drainage system in the Green Area and out side of the polder system in the surrounding area the BMA city boundary are not adequate and ineffective
- Stormwater flow is interrupted by the dikes and flood control gates and thereby causing severe flooding problems in outside of the polders

Action Plan during 1997 - 2001

- Land inventory survey along the routes of the floodways based on the comprehensive flood control Master Plan
- Design of the floodways in the East Bank
- Planning and design of the flood management facilities
- Review of the Gham Ling Project and strengthening the system if necessary

Action Plan during 2002 - 2006

- Design of the floodways in the West Bank
- Start construction of the floodways in the East Bank
- Start construction of the flood plain management facilities in the East Bank

Action Plan during 2007 - 2011

- Start construction of the floodways in the West Bank
- Completion of the floodways and full system operation & maintenance
- Completion of the flood plain management facilities in the West Bank

- **For Rational Priority of Urbanization Process**

Action Plan 4 : Control of Land Development Projects to Minimize Stormwater Run Off

Present Situation as of 1995

- Stormwater run-off is increasing due to uncontrolled land development without flood protection measures
- The current standards are not enforced effectively to regulate stormwater flow

Action Plan during 1997-2001

- To study the Building Code and the relevant Laws, Royal Decree, regulations, standards to add, alter or modify the articles to cope with increase of run-off coefficient caused of land development projects
- Enforcement of the Building Code for the land development projects to obligate installation of stormwater regulation facilities

Action Plan during 2002 - 2006

- Review of the situation of enforcement of the Building Code and adjustment if necessary
- Continuous administrative control for the land development projects
- **For Control of Environmentally Preserved Land**

Action Plan 5 : Urbanization Control in the Green Area to Conserve Stormwater Retention Area

Present Situation as of 1995

- Urbanization is in progress in the Green Area
- Current Bangkok City Plan or the General Plan, is not always effectively enforceable to control land development projects in the Green Area

Action Plan during 1997-2001

- Authorization of the land use plan in the Bangkok City Plan
- Establishment of a standardized control system for land development projects in respect of flood control
- Restriction of land development projects in the Green Area

Action Plan during 2002- 2006

- Review of the land use plan and adjustment if necessary
- Review of the land development regulations and adjustment if necessary
- Maintenance and conservation of stormwater retention area

CHAPTER 6: WATER QUALITY

6.1 General

Water quality survey was carried out to document a state of current water pollution problems in the Khlongs in BMA Area. In addition, water samples were collected from waste water discharge points and from drainage pipes to make a use of water pollution load analysis. Actual survey works for sampling and water quality tests were sublet to the Thai environmental consultant company to conduct the services under the direction of the JICA Study Team with a support and cooperation provided by Department of Drainage and Sewerage (DDS), BMA.

The first survey, Water Quality Investigation on Major Khlongs in BMA were carried out through water sampling from 28 points out of the khlongs and the Chao Phraya River for wet and dry season, started in November 1995 and finished in February 1996 Meanwhile, the other survey, Investigation on Prediction of Water Pollutants Loads in BMA Area, was carried out during from January to March 1996 with 53 sampling points by which the water samples can represent the source of each type of wastewater.

In addition to the field surveys conducted in connection the study concerned, past datum were collected for water quality in the city khlongs and the Chao Phraya River respectively from DDS, BMA and Pollution Control Department (PCD), Ministry of Science, Technology and Environment.

The results of the survey were analyzed and presented the summary as shown in the following sections.

6.2 Water Quality Survey in the Major Khlongs in BMA Area

(1) Purpose

This water quality test was conducted at the representing points of the major khlongs running in both banks of the Chao Phraya River. The survey is aiming at investigate distribution of the water pollution area in the city and check the seasonal differences between the wet and the dry seasons. In addition, the existing past test records were collected from DDS and analyzed for searching the tendency of the elapsed-time changes of water pollution from the past to the present days.

(2) Conditions of Investigation

Water sampling, test and analysis are conducted based on the following conditions:

1)Sampling Points

Khlongs in Bangkok Side	: 13 points
Khlongs in Tonburi Side	: 10 points
Chao Phraya River	: 5 points
Total	: 28 points

2) Frequency of Sampling

Wet Season 1 time and Dry Season 1 time

Water sampling in dry season was conducted during 7 to 20 November, 1995 in consideration to avoid the abnormal high water level conditions in this year. Meantime, Water sampling for the dry season was carried out during 6 to 16 January ,1996.

3) Water Quality Parameters

pH/ DO/ PO4/ NH4/ NO3-N/ Tr/ COD/ T-Cr,T-CN/ Pb for each water sample

4) Test Device

Water Test Kit, KYORITSU Model M-WAL-M

(3) Water Quality Test Results

Fig. 6.1 (1/2) & (2/2) show the summary results of the surveys conducted by the Study team. The figures show the relative level of water contamination expressed with DO and COD observed in wet and dry seasons.

1) Test results in Wet Season

From the test results, the higher concentration areas are spreading considerably over the central areas in Bangkok and Tonburi sides judging from the indices of Dissolved Oxygen (DO) less than 5 mg/lit and of Chemical Oxygen Demand(COD)more than 30 mg/lit. Out of the total 28 water sampling points, 17 points shows less than 5 mg/lit in DO and 8 points exceed 30 mg/lit in COD. All the 8 higher COD points coincided with the lower DO points.

Sampling points in the north-east of Bangkok , Lat Krabang, Min Buri, etc. and the north city boundary of Tonburi in Taling Chan, do not show remarkable water contamination in wet season.

In the previous years, the khlong water quality in the eastern suburbs of Bangkok had been improved in wet season and this is because of the inflow from the eastern khlongs. But water quality in this year deteriorated because of control of water gates in the eastern suburbs to stop inflow to the minimum extent for protection of the central area of Bangkok from flooding or due to increase of water pollution loading. Whatever may be the causes, it seems that the water pollution area is expanded to the suburbs gradually by keeping the same direction and pace of urbanization.

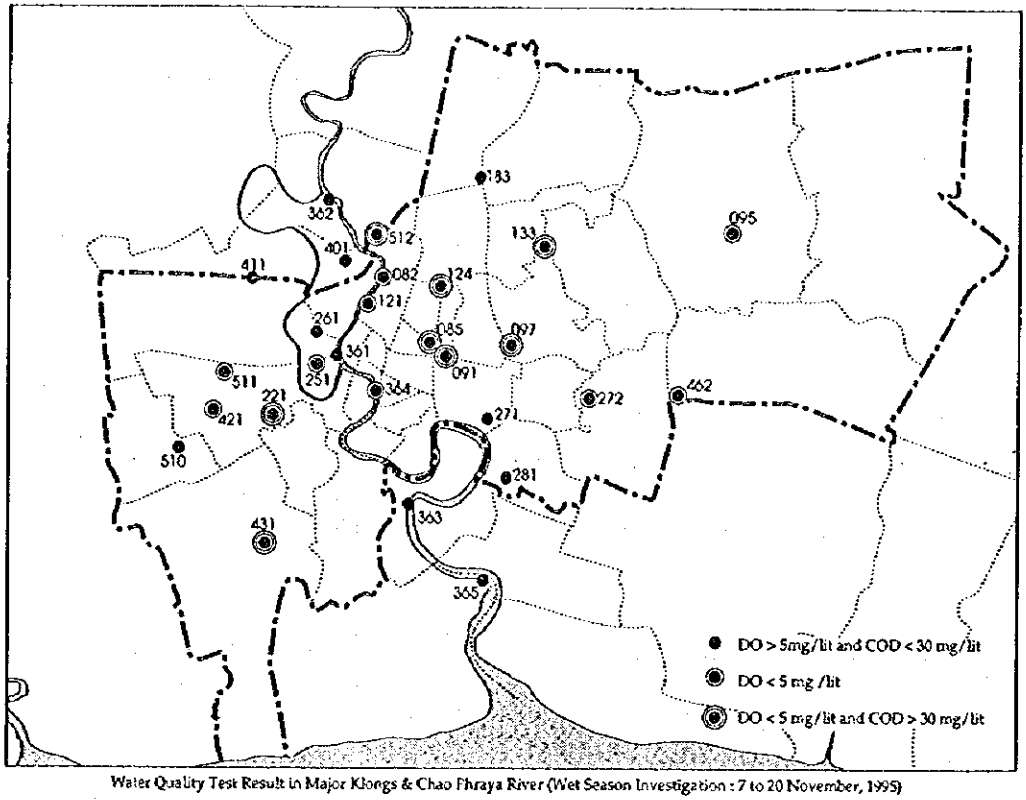
2) Test Results in Dry Season

The water quality survey in dry season was conducted by the Study Team at the same sampling points conducted in wet season. Out of the total 28 water sampling points, 20 points shows less than 5 mg/lit in DO and 10 points exceed 30 mg/lit in COD. All the 10 higher COD points coincided with the lower DO points.

As well as the results in dry season, the sampling points in the north-east of Bangkok, Lat Krabang, Min Buri, etc. and the north city boundary of Tonburi side in Taling Chan, do not show a sign of serious water contamination in dry season.

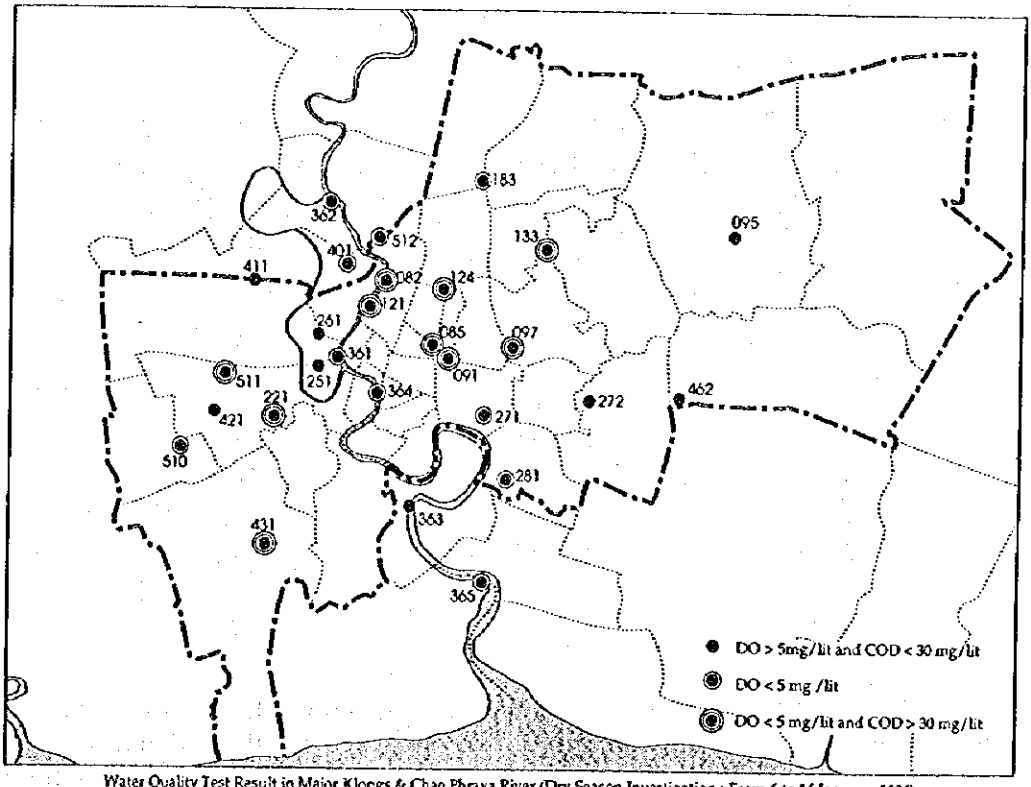
3) Comparison of Water Quality in Wet Season and Dry Season

Water quality test results conducted by the study shows that 10 sampling points are in worse condition in dry season compared with 8 sampling points in wet season. The result do not indicate any significant improvement in wet season through rainfall. But, on the contrary, unlike the normal phenomena observed in BMA, water quality in the far eastern part of the BMA Area is improved in dry season. This phenomena may be due to control of water gates close in wet season and open in dry season and water pollutants are diluted by the flow entering from the eastern khlongs in dry season but the flowrate may be too low to be effective for entire zone.



Water Quality Test Result in Major Klongs & Chao Phraya River (Wet Season Investigation : 7 to 20 November, 1995)

Fig. 6.1 (1/2) Water Quality Test Result in Major Khlongs and the Chao Phraya River(Wet Season)



Water Quality Test Result in Major Klongs & Chao Phraya River (Dry Season Investigation : From 6 to 16 January, 1996)

Fig. 6.1 (2/2) Water Quality Test Result in Major Khlongs and the Chao Phraya River(Dry Season)

6.3 Investigation for Prediction of Water Pollution Loads in BMA Area

(1) Purpose

The investigation is intended to make use the results for prediction of the amount of pollutants generated from different types of watstewater sources at present and in future in BMA Area by means of BOD which is one of the major water pollutants to represent the state of pollution in the Study area.

(2) Conditions of Investigation

Sampling Points and Frequency of Sampling

Fifty three (53) sampling points were chosen from the entire study area for different types of wastewater sources . Water sampling was conducted in the dry season to avoid the influence of rain water dilution. Three water samples were taken from each sampling point.

1) Wastewater Sources

Residential Area/ Commercial Area/ Mixed Areas/ Factories or Industrial Estates/ Office Buildings/ Restaurants/ Hotels/ Condominiums/ Fresh Food Markets/ Hospitals/ Department Stores/ Schools/ Others

2) Water Quality Parameters

pH/ BOD/ COD/ SS/ DO/ T-N/ T-P/ Flowrate

3) Sampling Period

From 17 January, 1996 to 1 February, 1996.

4) Water Quality Test Results

Summary of the BOD Loading survey is shown in the following Table 6.1.

Table 6.1 Summary of BOD Loading for Different Wastewater Sources

Sampling Point No.	Wastewater Sources	Average BOD Loading (g/m3)
1	Industrial Area	91
2-6	Hotel	193
7-9	Hospital	83
10-12	Condominium	85
13-17	Restaurant	617
18-22	Office Building	228
23-25	Department Store	556
26-28	Fresh Food Market	771
29-41	Mixed Area	105
42-53	Residential Area	130

Unit BOD loading for various types of waste water ranges from 83 g/m3 to 771 g/m3 from hospitals and from fresh food markets respectively. Mixed land use area including commercial area, offices, hotels, department stores, etc., shows 105 g/m3 in terms of unit BOD loading in average. Meanwhile, waster water discharged from residential area including housing estates, town houses and single houses indicate 130 g/m3. Table 6.2 tabulate the process of unit BOD loading calculation.

Table 6.2 Calculation of BOD Loading for Different Wastewater Sources

Sampling Point No.	Flowrate (m3/day)	BOD5 (mg/lit.)	BOD Loading (kg/day)	Waste Water Sources		Avg. Unit BOD Loading (g/m3)	Remarks	
1	15850	91	1442.350	Industrial Area		91		
2	320	230	73.600	Hotel		193		
3	517.8	360	186.408	Hotel				
4	650	140	91.000	Hotel				
5	703.6	47	33.069	Hotel				
6	511.6	270	138.132	Hotel				
7	150	190	28.500	Hospital		83		
8	6000	80	480.000	Hospital				
9	305.3	96	29.309	Hospital				
10	225	49	11.025	Condominium		85		
11	252.7	44	11.119	Condominium				
12	272.8	154	42.011	Condominium				
13	69.4	650	45.110	Restaurant		617		
14	46.6	617	28.771	Restaurant				
15	48.6	800	38.880	Restaurant				
16	54.4	470	25.568	Restaurant				
17	68.7	572	39.296	Restaurant				
18	96.2	53	5.099	Private Office		228		
19	223.7	68	15.212	Private Office				
20	481.2	58	27.910	Private Office				
21	304.6	720	219.312	Private Office				
22	158.3	130	20.579	Private Office				
23	174.8	480	83.904	Department Store		556		
24	413	530	218.890	Department Store				
25	450	610	274.500	Department Store				
26	128.7	910	117.117	Fresh Foods Market		771		
27	20.5	388	7.954	Fresh Foods Market				
28	20.4	280	5.712	Fresh Foods Market				
29	51.4	140	7.196	Mixed Area I	(-)	71		105
30	73.5	100	7.350	Mixed Area I			Avg. of Mixed Area	
31	11.6	260	3.016	Mixed Area I				
32	16.7	24	0.401	Mixed Area I				
33	179.5	64	11.488	Mixed Area II	(-)	58		
34	222.6	66	14.692	Mixed Area II				
35	123	31	3.813	Mixed Area II				
36	430	126	54.180	Mixed Area II	(-)			
37	468	126	58.968	Mixed Area II				
38	34	110	3.740	Mixed Area III		154		
39	47.2	154	7.289	Mixed Area III				
40	51	190	9.690	Mixed Area III				
41	21	140	2.940	Mixed Area III				
42	1300	144	187.200	NHA		130		
43	5000	100	500.000	NHA				
44	2161	190	410.590	NHA				
45	108	112	12.096	School		107		
46	45	119	5.355	School				
47	99	97	9.603	School				
48	0.58	111	0.064	Town House		85		
49	0.47	61	0.029	Town House				
50	0.68	79	0.054	Town House				
51	1.8	120	0.216	Single House		146		130
52	2.07	250	0.518	Single House			Avg. of Residential Area	
53	1.9	58	0.110	Single House			NHA,Town House, Single House	

(3) Khlong Water Quality Monitoring Data by DDS

Water quality monitoring data of the khlongs in BMA area during the last 6 years from 1990 to 1995 was collected from DDS, BMA for more than 228-550 water samples from 73 monitoring stations located in major khlongs in BMA Area and analyzed for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD5) as indicated in the following paragraphs.

1) Trend of Annual Water Quality Change

Fig. 6.2 indicate annual changes of average DO and BOD values for all the data in each year. In the last 6 years, DO change from 0.66 to 1.88 mg/lit and BOD change from 24.45 to 23.43 mg/lit with the highest value at 29.94 mg/lit in 1992. in the last 6 years. Judging from these values, water pollution level is high but there is a sign of water quality improvement in the city khlongs in BMA Area.

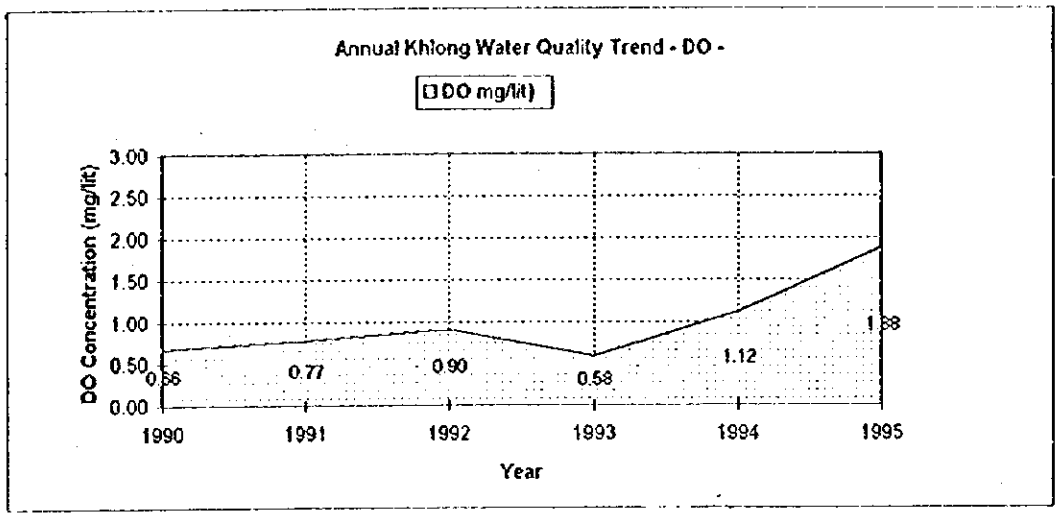
2) Water Quality in the East and West Banks

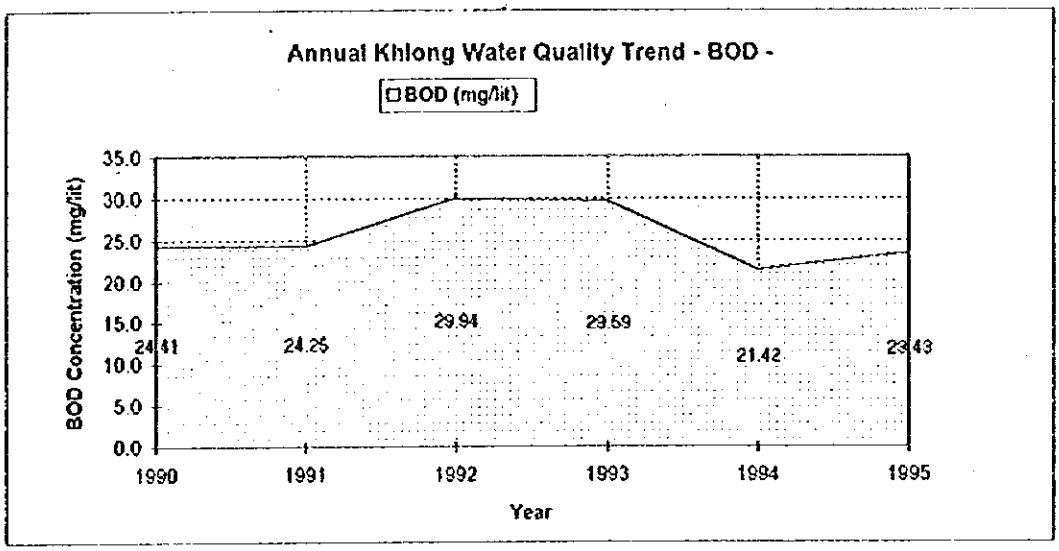
Difference of water quality in the khlongs between the East Bank, Bangkok side and the West Bank is indicated in Fig. 6.3. DO in the East Bank change from 0.43 to 1.70 mg/lit, whereas DO in the West Bank changes from 1.09 to 2.56 mg/lit with the lowest annual average value at 0.80 in 1993. Meanwhile, BOD in the East Bank changes from 27 to 24 mg/lit and it changes from 19 to 22 mg/lit in the West Bank. Representative water quality parameters, DO and BOD, shows that the water quality in the East Bank is slightly worse than that in the West Bank. Water quality shows somewhat improvement in both Bangkok and Tonburi sides but the level of water pollution is still high for the people residing along the khlongs to live a comfortable life.

3) Water Quality in Wet and Dry Seasons

Trend of water quality differences between the wet and dry seasons were analyzed and summarized in Fig. 6.4. As learned it from the graphs, there is no distinctive difference between the seasons. That means, even in the wet season the level of water quality does not improved from high pollution level throughout the BMA Area. However, on the contrary, close observation on the khlongs in Rathanakosin Area show that the water quality in dry season is improved with the effect of introduction of the Cho Phray river water into the khlongs operated by DDS since 1990 for flushing or dilution of water pollutants. In other words, the Khlong Water Quality Improvement Project is effective to keep a possible water quality deterioration in dry season to almost the same water pollution level in wet season.

Fig.6.5 (1/2) & (2/2) show the water quality test data analyzed for the seasonal change for the year 1995. Four teen (14) points out of twenty (20) points show less than 2 mg/lit in DO and higher than 15 mg/lit in BOD in dry season. In wet season, the number of water contamination point increased by one(1) point and become fifteen (15) points. As well as the results mentioned above, seasonal change is not clearly shown in the figure but the water pollution areas are observed over the widely spreaded area in both Bangkok and Tonburi area.

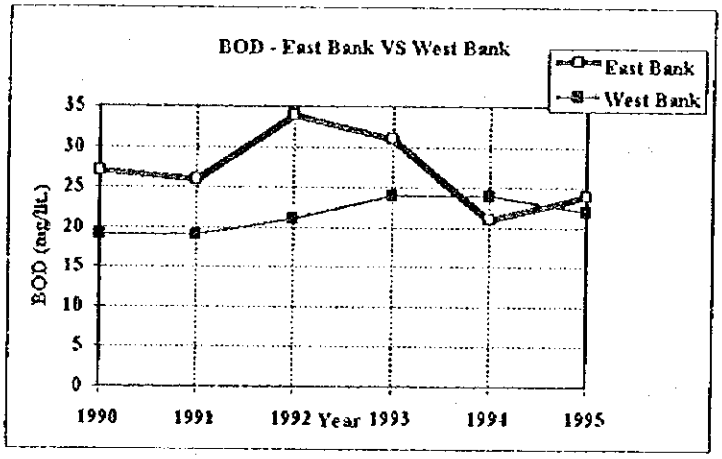




Year	Water Quality Parameters DO (mg/lit)	BOD (mg/lit)	Nos. of Sampling Points	Nos. of Samples for DO	for BOD
1990	0.66	24.41	73	514	550
1991	0.77	24.25	73	473	476
1992	0.90	29.94	73	288	301
1993	0.58	29.59	73	228	231
1994	1.12	21.42	73	234	240
1995	1.88	23.43	73	342	345

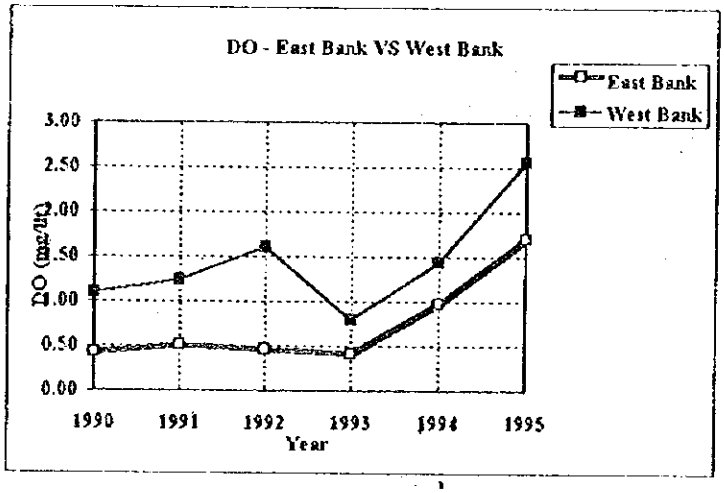
Note : BOD stand for Biochemical Oxygen Demand
DO stand for Oxygen Demand

Fig. 6.2 Trend of Water Quality in the Major Khlong of BMA Areas during 1990-95



BOD (mg/lit.)

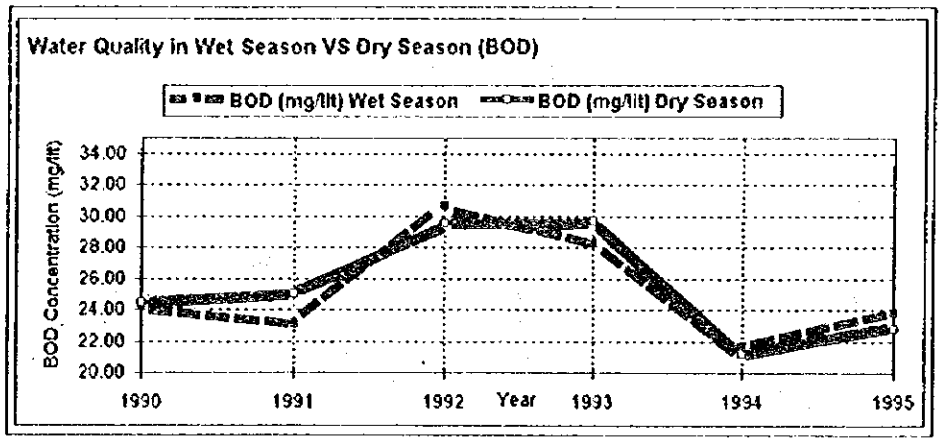
Year	East Bank	West Bank
1990	27	19
1991	26	19
1992	34	21
1993	31	24
1994	21	24
1995	24	22

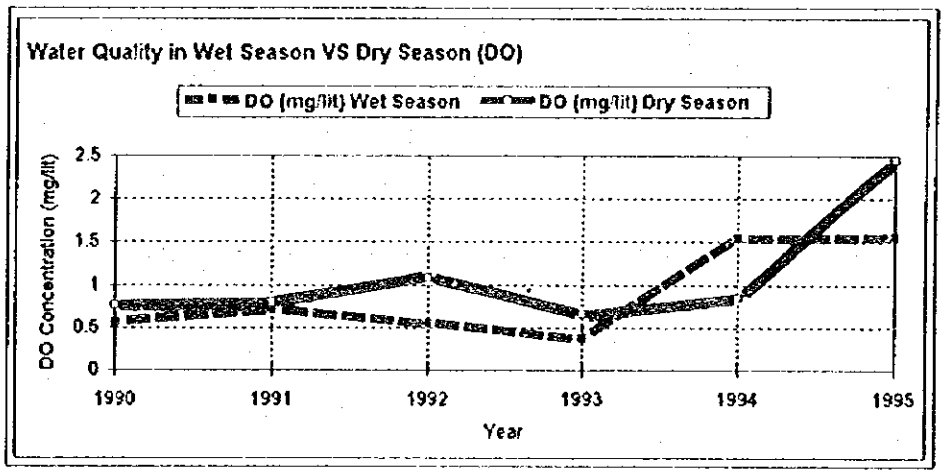


DO (mg/lit.)

Year	East Bank	West Bank
1990	0.43	1.09
1991	0.51	1.24
1992	0.47	1.61
1993	0.42	0.80
1994	0.98	1.44
1995	1.70	2.56

Fig. 6.3 Water Quality Changes in Major Khlongs in East and West Banks





Year	BOD (mg/lit)		DO (mg/lit)		Numbers of Samples BOD		Numbers of Samples DO	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
1990	24.34	24.48	0.56	0.76	302	248	286	228
1991	23.14	25.01	0.71	0.80	193	283	193	280
1992	30.64	29.59	0.55	1.08	99	202	97	191
1993	28.29	29.70	0.37	0.66	59	172	58	170
1994	21.73	21.20	1.54	0.84	98	142	95	139
1995	23.80	22.78	1.56	2.45	219	126	216	126

Note : BOD stand for Biochemical Oxygen Demand
DO stand for Oxygen Demand
Wet Season : May - October
Dry Season : November - April

Fig. 6.4 Trend of Water Quality in Wet Season & Dry Season in the Major Khlong of BMA Areas during 1990-1995

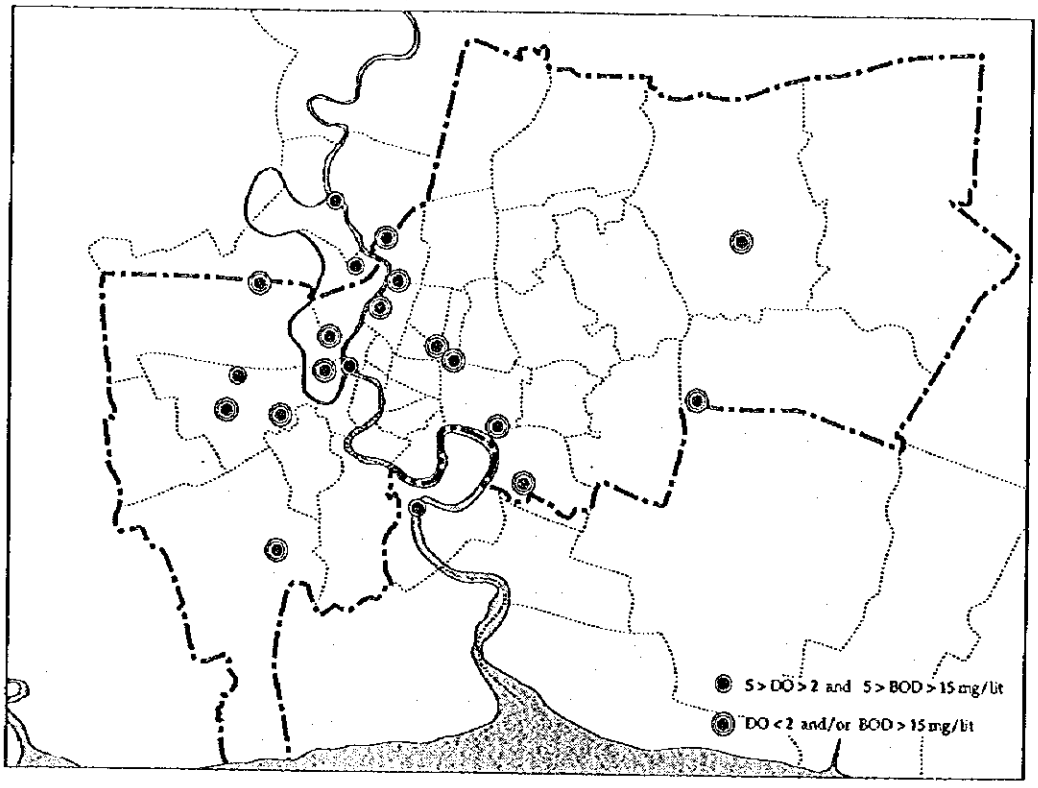


Fig. 6.5 (1/2) Annual Average BOD/DO in Major Khlongs (Wet Season-1995)

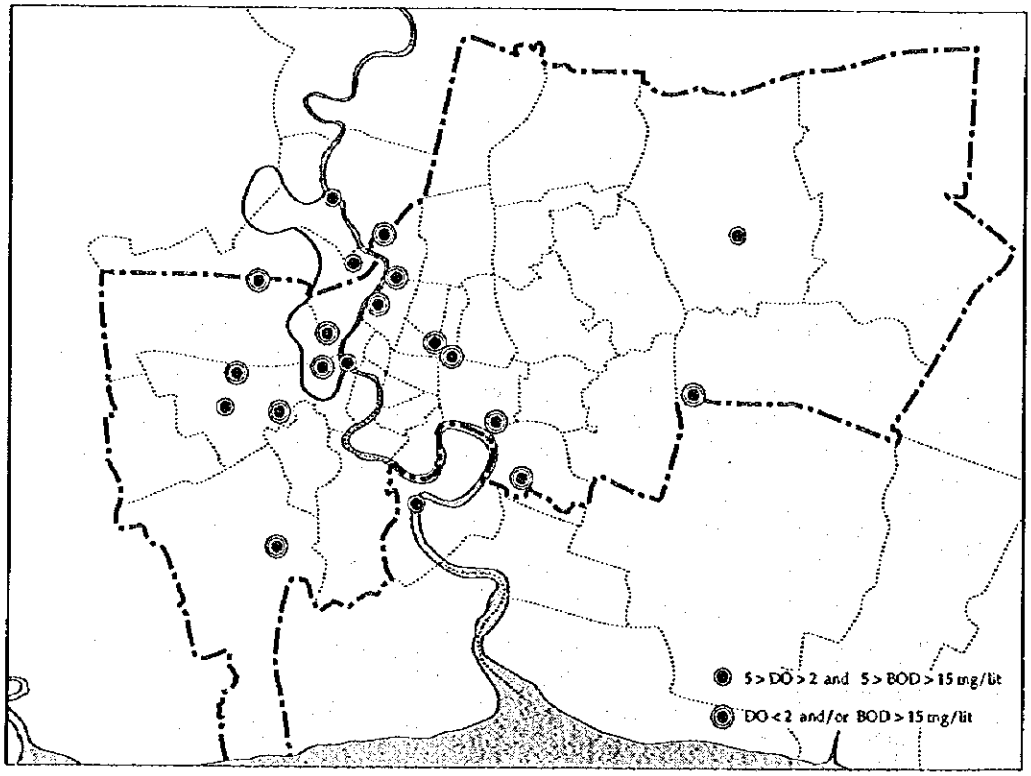


Fig. 6.5 (2/2) Annual Average BOD/DO in Major Khlongs (Dry Season-1995)

(4) The Cho Phraya River Water Quality Monitoring Data by PCD

An analysis of water quality was made on the basis of the data collected from Pollution Control Department, Ministry of Science, Technology and Environment for the last 17 years from 1978 to 1994. Three monitoring points, from the up stream reach, Rama 7 Bridge, Krungthep Bridge, and confluence with the Khlong Prakanong, were picked out to show the water contamination level along the river in Bangkok section and each monitoring point locate 58 km, 41.5 km and 27 km respectively from the estuary of the Chao Phraya River.

Average values of DO and BOD in the last 17 years were calculated to show the water pollution level along the stream and found that the water pollution level is increasing gradually from the up stream to the down stream reaches as tabulated in the following Table 6.3.

Table 6.3 Water Pollution Trend along the Cho Phraya River

Item	Confluence with Khlong Phrakanong (27 km)	Khrungthep Bridge (41.5 km)	Rama 7 Bridge (58 km)
Avg. DO (mg/lit)	0.97	1.33	2.46
Nos. of DO Samples	13	16	16
Avg. BOD (mg/lit)	2.76	2.60	1.90
Nos. of BOD Samples	13	15	15

Data Source : PCD, MOSTE

Annual change of DO and BOD was shown in Fig. 6.6 for the three monitoring points from 1978 to 1994. Change of annual water pollution level is not clear because of the missing datum and fluctuation of the data but the trend line of DO declines from around 2 mg/lit in 1978 to 1 mg/lit in 1994, whereas the trend line of BOD ascending from around 2 mg/lit in 1978 to 3 mg/lit in 1994. BOD level is still lower than that noticed by the environmental standard, 4 mg/lit in the Bangkok section. The state of water pollution level on the basis of DO and BOD can be mentioned that it would not take long time as the water pollution level exceed the environmental standards in the lower reach of the Bangkok section unless water pollution control projects, such as the development of sewage systems are immediately implemented by the authorities concerned.

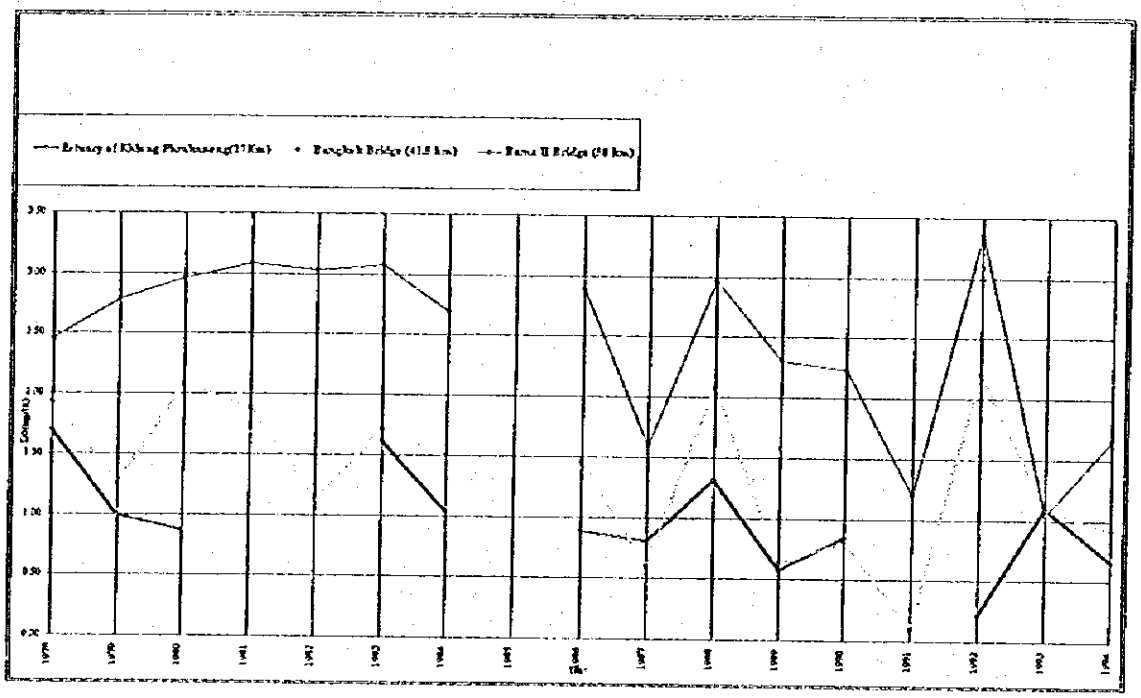


Fig. 6.6 (1/2) Annual Changes of DO in the Chao Phraya River

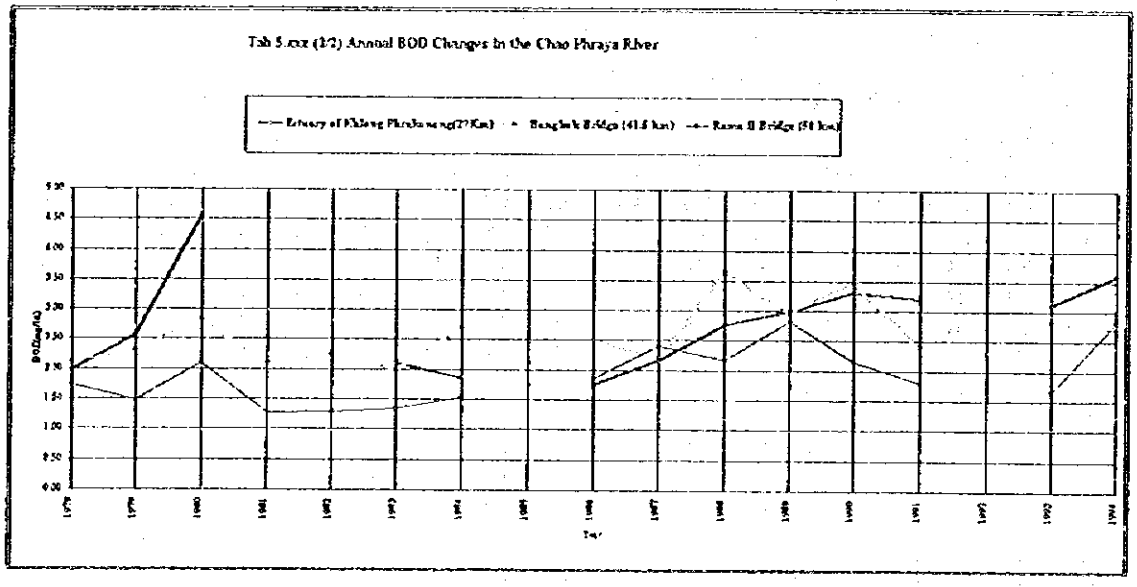


Fig. 6.6 (2/2) Annual Changes of BOD in the Chao Phraya