1.4 URBANIZATION TREND

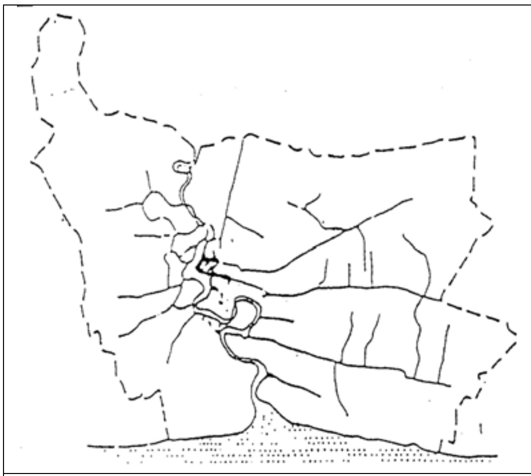
1.4.1 Settlement Pattern

(1) Historical Context

The city of Bangkok was first established in the area called Rattanakosin located on both banks of the Chao Praya River as a result of capital relocation that took place in 1782. Today the area is not only the historical center of Bangkok but the official and governmental center of the country with great symbolic importance.

From an early stage, the city was developed on the eastern side of the Chao Praya River between two canals soon after they were constructed. As shown in the figures below, the development of the central area was almost complete by 1960. This was followed by gradual developments toward the north, east, and then south along with the construction of the road network in the 1970s. In the 1980s, the northeastern part was rapidly developed largely due to many new town and industrial estate development projects. Today, the momentum of urbanization is not limited to the administrative area of BMA but is also sustained in its vicinity.

Figure 1.9: Built-up Area: 1900-1984



Y1900: Population 0.6Million

Y1958: Population 1.6Million

Y1974: Population 4.1Million

Y1984: Population 5.7Million

Source: 1,2 From German Advisory Team, Bangkok Transportation Study
3 From Aerial Photography, 1974
4 From Small Gromal Aerial Photography, 1984

(2) Classification of Districts

The current 50 districts within BMA can be classified into four groups in accordance with the stage of development:

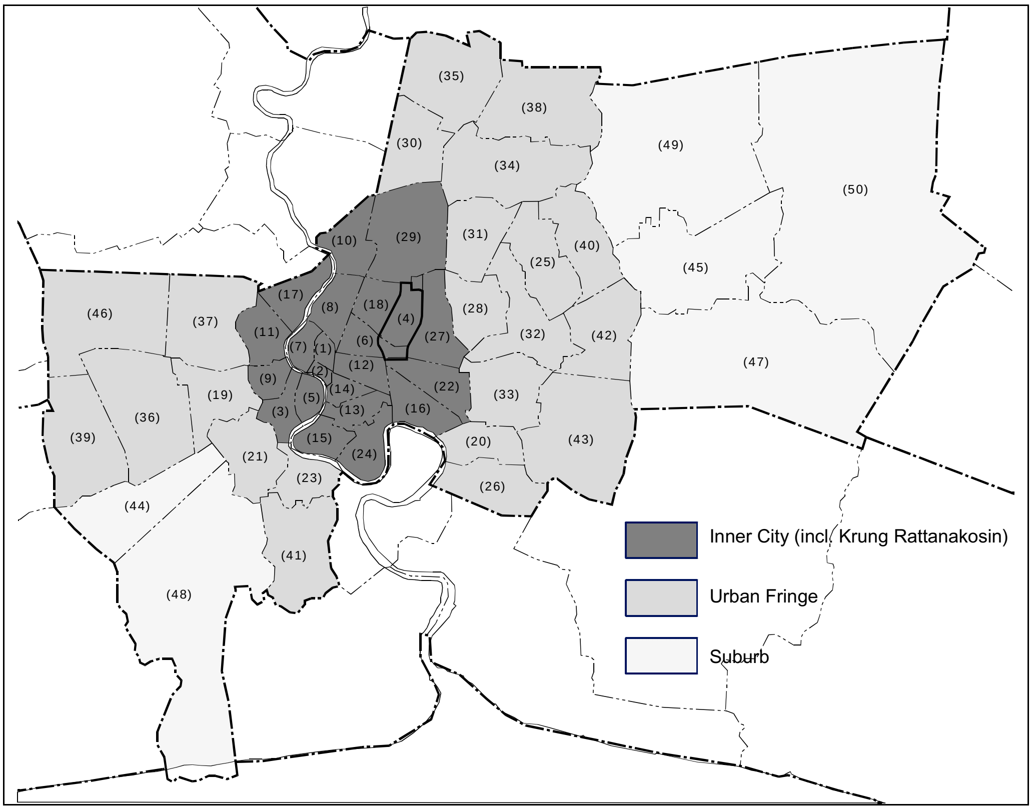
The core of the city: composed of the historical city of Rattanakosin, and contains many symbolic facilities as an old development area.

The inner city: consists of districts of the core of the city area, used by a mixture of business, education, commercial, and residential buildings. (The Study Area belongs to this category of classification)

The suburban area: is located in the range of 10-20 km from the center of the city, and consists of the west side and the east side of the Chao Praya River.

The urban fringe: is on the west and east of the city along the administrative boundary of BMA, and is predominately used as agricultural land.

Figure 1.10: Classification of Districts

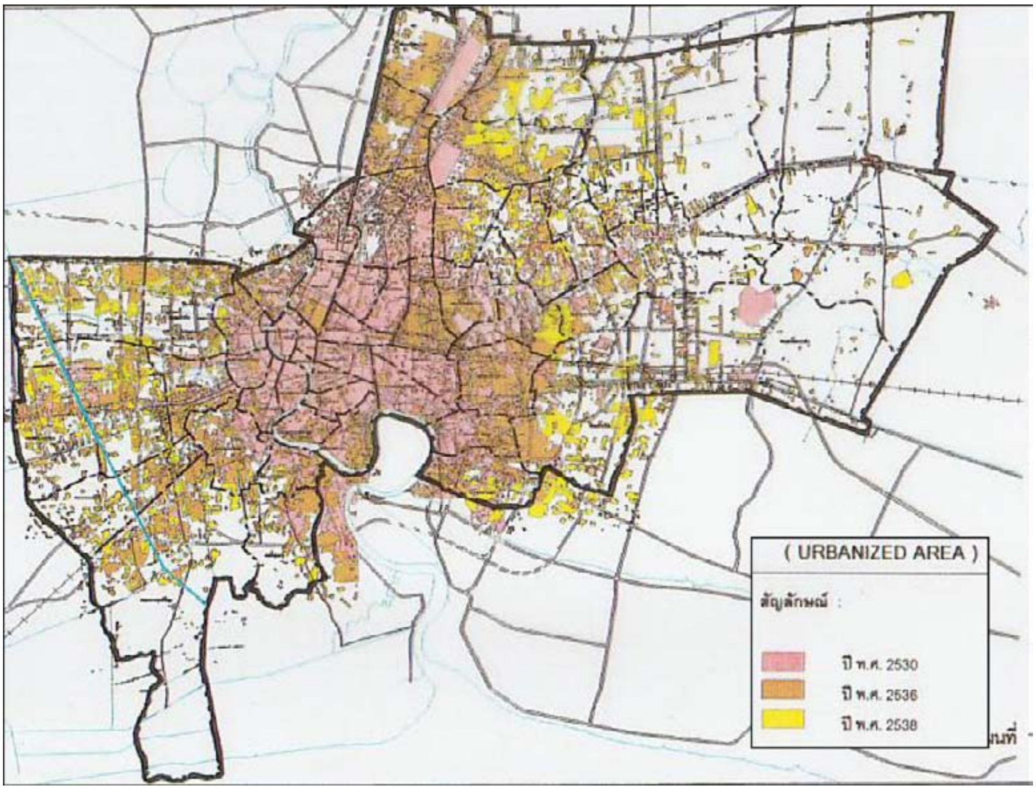


Source: City Planning Dept., BMA

(3) Built-up Area

According to the Department of City Planning, BMA, the built-up area had expanded by nearly 10% per year from 1993 to 1995. From the aerial photograph in 1995, there was about 39% of the built-up area in BMA. Subsequently, there has been no statistical significance in the increase. The built -up area of 700km^2, out of a total 1,568 km^2 of the city's administrative area, is still concentrated in the inner city and in the suburb area. As a result of the economic decline in the past five years, (1996-2000), the pattern of land use in the city of Bangkok has not changed much.

Figure 1.11: Built-up Area in BMA



Source: BMA

1.4.2 Traffic Pattern

(1) Outline of Transport System

As a center of political and economic activities, Bangkok is a hub of air, water, and land transportation means. Within BMA, trips are largely made by private cars and motorcycles (44.7%) and public transport systems (42.4%). Among the public transport systems, buses have an outstanding share of 72%. This fact indicates mass transportation as a striking feature of transportation within BMA.

Table 1.15: Person Trip by Purpose and Means (person/day)

Means	Commute	School	Private	Business	Total
Walk	631,539 (10.9%)	766,952 (21.6%)	481,135 (11.9%)	112,775 (5.2%)	1,992,401 (12.8%)
Bicycle	1,056,735 (18.24%)	299,310 (8.42%)	981,123 (24.28%)	450,581 (20.93%)	2,787,749 (17.94%)
Personal Car	1,297,121 (22.4%)	303,490 (8.5%)	1,301,277 (32.2%)	1,268,848 (58.9%)	4,170,736 (26.8%)
Public Transport System	2,809,052 (48.5%)	2,183,071 (61.4%)	1,276,633 (31.6%)	320,680 (14.9%)	6,589,436 (42.4%)
Total	5,794,447 (37.3%)	3,552,823 (22.9%)	4,040,168 (26.0%)	2,152,884 (13.9%)	15,540,322 (100.0%)

Source: BEIP 1997, JICA

Table 1.16: Share of Public Transport Systems

Description	Share (%)
Bus	72.0
Railway	0.4
Surface Transport	4.2
Others (taxi, etc.)	23.4

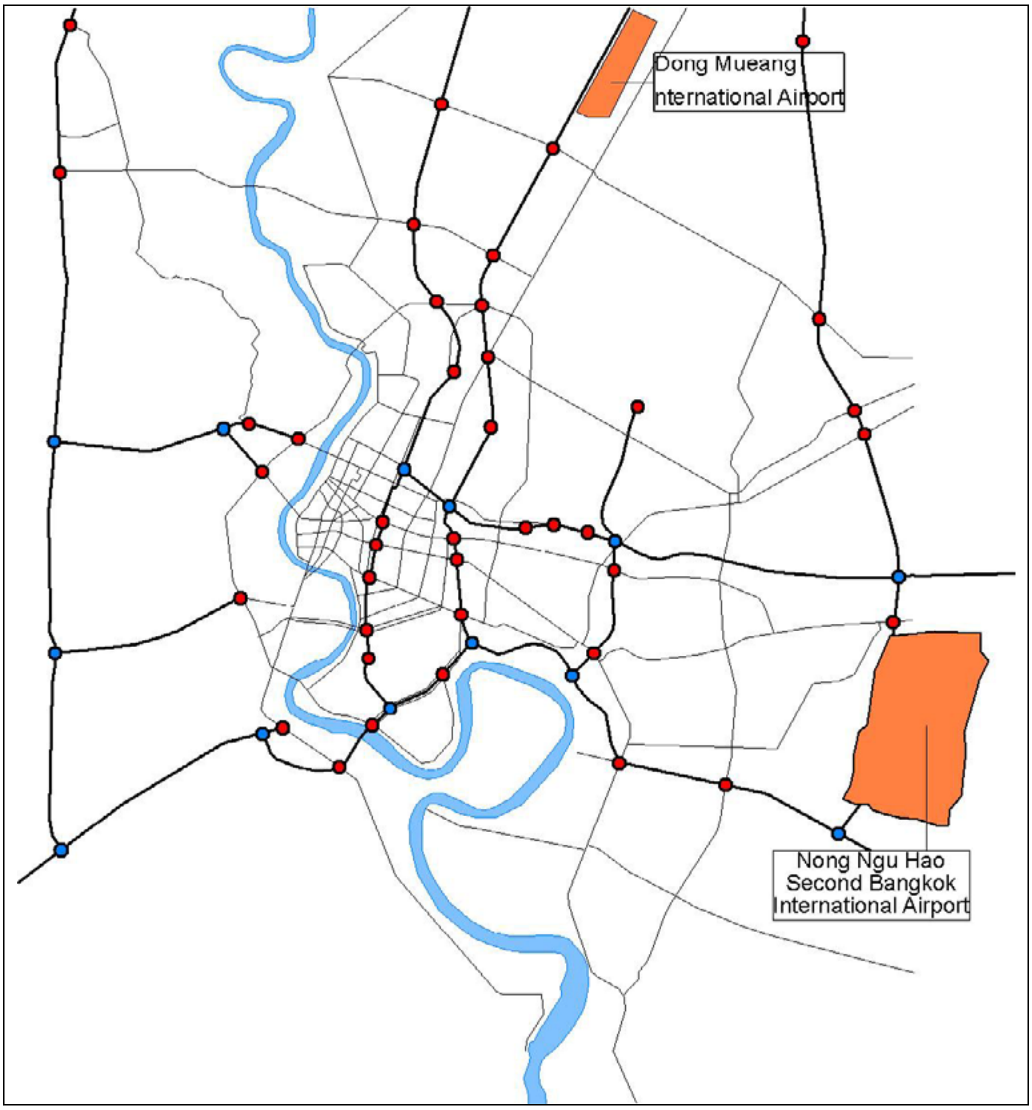
Source: BEIP 1997, JICA

(2) Current Condition of Transportation System

1) Airport

Although air traffic is scarcely used for urban trips inside BMA, the airport is a significant factor due to the importance of Bangkok as a national and international transportation hub. The Bangkok International Airport is located some 30 km north of the city center, connected by a highway and SRT railway. The second Bangkok International Airport is under construction about 30km east of the city center, scheduled to be partly open in 2005. The new airport will be connected by the existing SRT Railway and a toll road presently under construction.

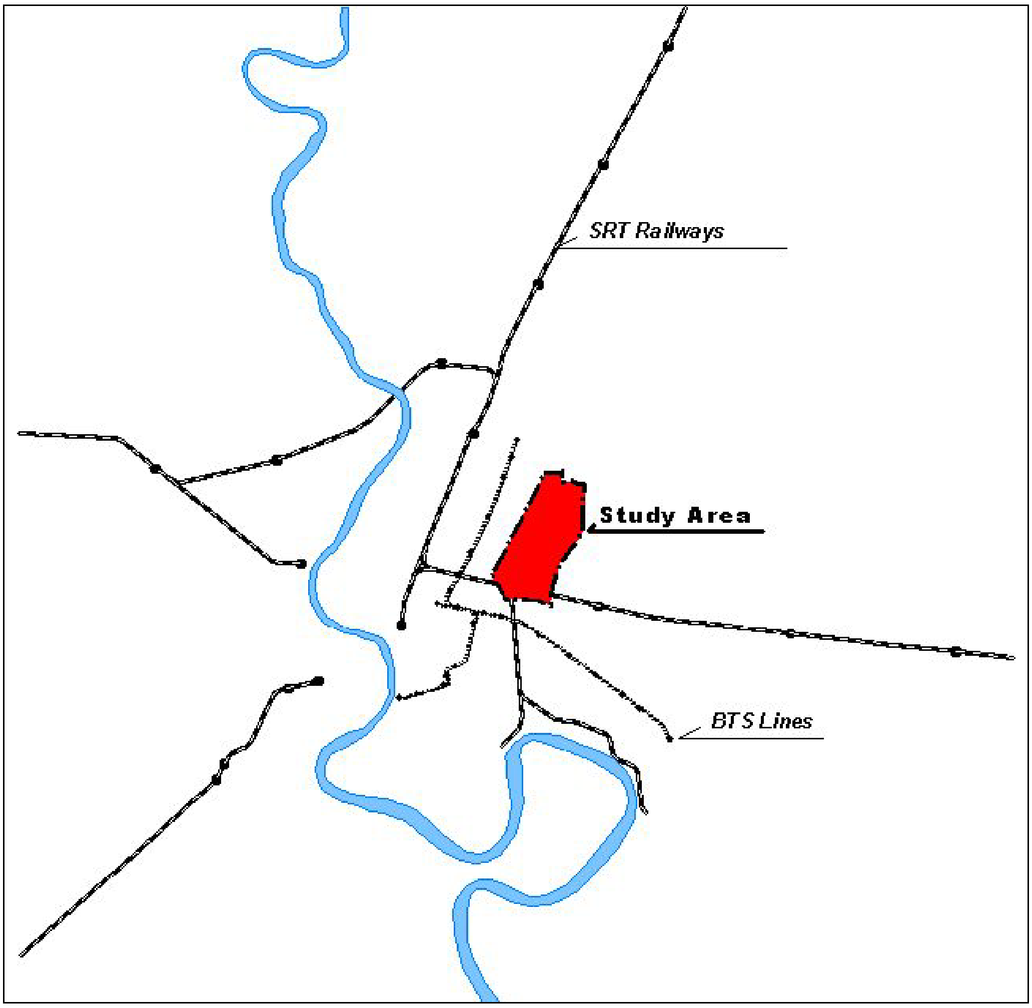
Figure 1.12: Location of Airports in Bangkok



2) Railway/Mass Transit System

Currently, there are SRT railways and two BTS (Bangkok Transit System) lines available in Bangkok. The SRT railways are built to serve for nation wide trip demands while BTS lines aim to serve for intra city transport demands, connecting the city's busy areas. The following figure shows the current network of railway and mass transit systems.

Figure 1.13: Current Railways and Mass Transit Systems



Referring to the table below showing the volume of passenger transport by SRT, the number of passengers, and their travelling distances have been declining in recent years. The average travel distance of around 180 km/person is too long to assume that the system is used to commute. The average interval of stations is 6 km even inside the busy area. This fact implies why the SRT railway is inconvenient for commuters.

Table 1.17: Transport Volume and Average Travel Distance

Year	1995	1996	1997	1998
Passenger (1,000 person)	72,504	67,761	65,348	60,815
Average travel distance per person (km)	179.0	180.1	180.6	180.0

Source: Statistical yearbook Thailand, 1999

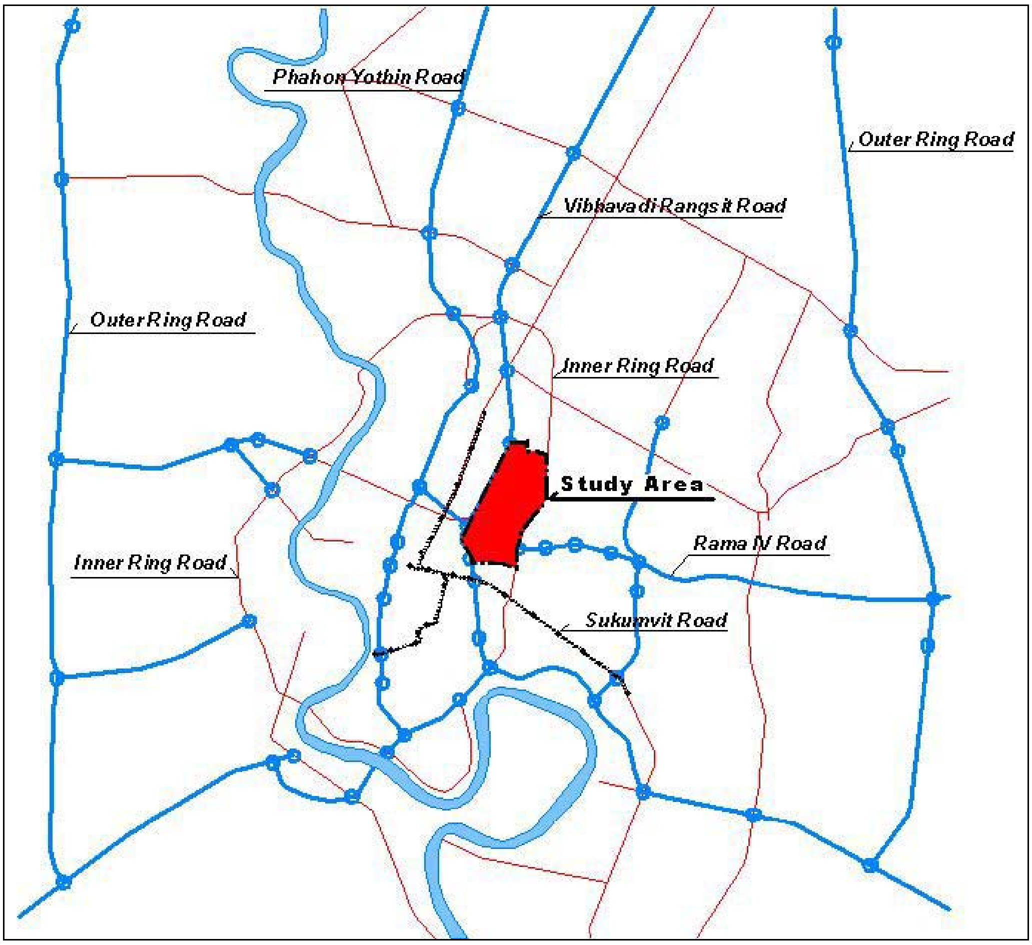
3) Water Transport System

Water transport in Bangkok includes 'public boats' running along Chao Phraya River and 'canal boats' running along canals inside the city. There are three lines in the canal boat systems, namely Phadung Krung Kasem line between Phra Sumen and Hua Lamphong, Saen Saep line between Pampher and Pratu Nam, and Lat Phrao line between Dong Mueang Airport and Sukhumvit 71. Fares are 6, 5-15, and 10-18 baht respectively. Operating hours are from 6:00 am-19:00 pm in general. These systems are frequently used by the citizens for commuting in the morning and evening peak hours owing to traffic jam free features. However, its share remains low at 4.2% of all public transport trips. The prospect of expansion of this system is also dim because of the scarcity of suitable canals.

4) Road Transport System

The road network in Bangkok is characterized by a radial pattern, originating at the old town of Rattanakosin on the east bank of the Chao Phraya River. As radial directions, the primary axes have been formed by a north-south axis represented by Phahon Yothin and Vibhavadi Rangsit roads, and an east-west axis represented by Rama IX, Sukhumvit and Rama IV roads. These radial roads are connected by ring roads: 1) the 'inner ring road' running along Thanon Charan Sanit Wong-Rama III-Ratchadaphisek, and 2) the 'outer ring road' along Thanon Charan Sanit Wong-Thanon Suk Sawat-Sinagarindra-Thanon Lat Phrao. The following figure shows the basic pattern of the primary road network.

Figure 1.14: Primary Road Network in BMA



(3) Current Condition of Road Traffic

Although the importance of mass transit systems will grow in the future, vehicles will remain the primary transport mode for some time in view of the time required to develop new systems. The number of annual new registrations of vehicles declined after the currency crisis in 1997, but has since turned around as shown in the following table.

Table 1.18: Vehicle Registration by Type - Bangkok, 1995-1999

Class of Vehicles	1995	1996	1997	1998	1999
Passenger Car	940,573	1,026,233	1,156,361	1,231,899	1,317,062
Microbus and passenger pick-up truck	321,496	316,580	319,546	317,013	289,116
Van and pick-up truck	402,680	462,803	552,835	594,617	664,080
Motorcycle	1,373,072	1,527,834	1,616,622	1,646,738	1,660,119
Total	3,037,821	3,333,450	3,645,364	3,790,267	3,930,377
New Passenger car registration	106,901	111,143	98,214	34,087	50,664

Source: Thailand Figures 6th Edition

Because of the importance of the road system in Bangkok, the current condition of road traffic is further analyzed below.

1) Traffic Volume

The AM peak hour traffic volume in 2000 was estimated applying the UTDM model developed by the Office of Commission for Management of Land Traffic (OCMLT). The result revealed that the morning peak hour traffic volume is over 4,000 passenger car unit (pcu) on most roads in the central area. Particularly the ring and radial roads have larger traffic volumes and the radial roads have large inflow of long distance traffic. This was even true of the low-grade roads.

Focusing on the traffic toward the inner city, the traffic is concentrated by way of the main radial roads, which form the north-south and east-west axes. These trunk roads intersect at the city center and cause severe traffic congestion due to the absence of appropriate facilities such as, three-dimensional traffic control or secondary road network to accommodate spillover traffic from these intersections.

Figure 1.15: Present Traffic Volume in BMR

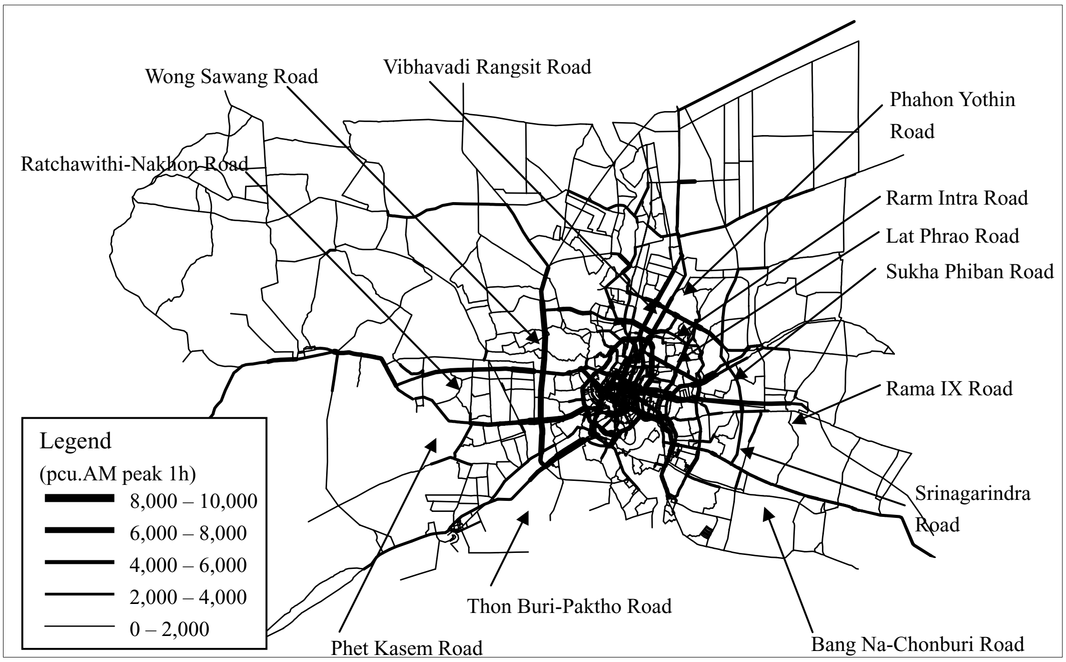
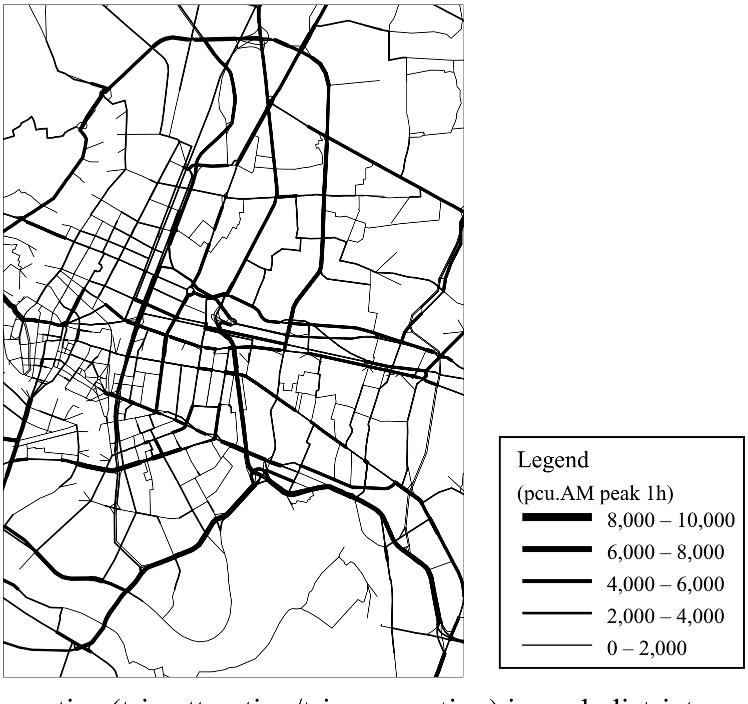


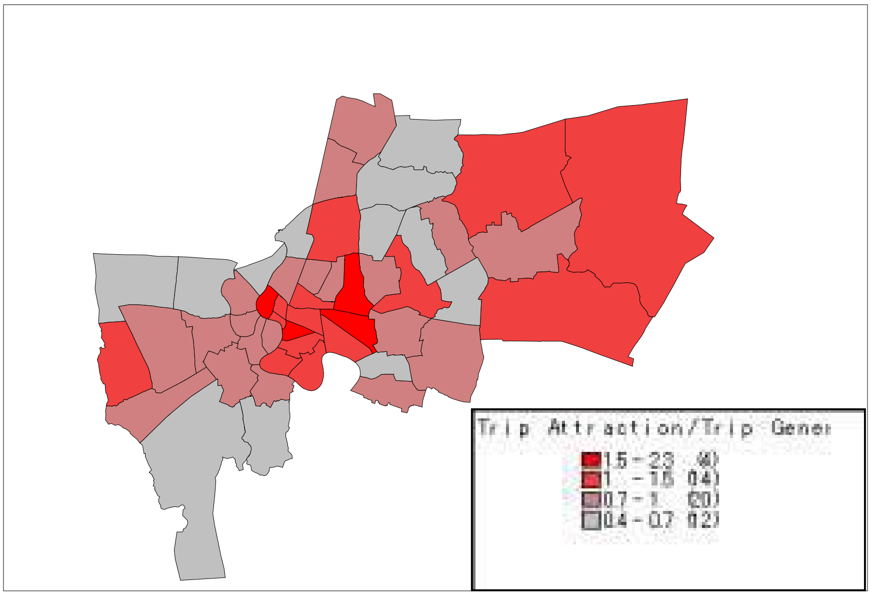
Figure 1.16: Current Traffic Volume in Central Area



Concentration ratios (trip attraction/trip generation) in each district were computed based on the OD table forecasted by UTDM. The result indicate that districts with higher trip attraction than trip generation are distributed in inner city areas, like Bang Rak, Phra Nakhon and their surroundings. There are attraction centers also in the suburbs, such as Khlong Sam Wa, Nong Chok and Lat Krabang.

This concurrently implies that the major traffic flows are not only directed toward the city center but also to suburbs as well.

Figure 1.17: Distribution Map of Trip Attraction

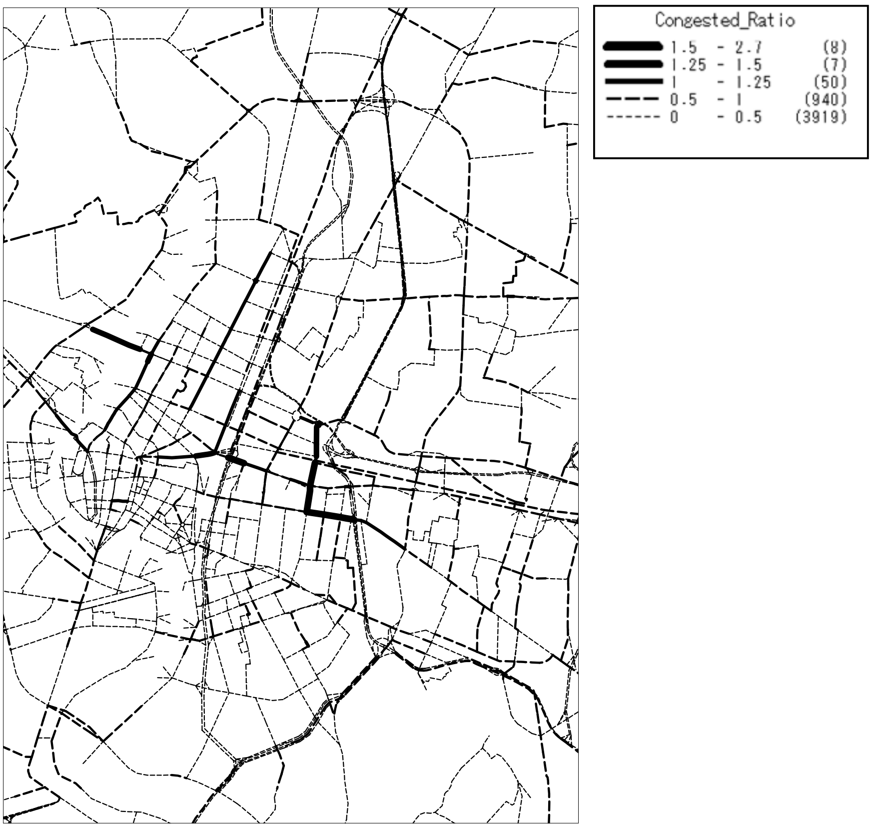


2) Congestion Rate

Figure 1.18 shows the distribution of estimated road congestion ratios in the Central area of Bangkok. Congestion in Bangkok is characterized by the following.

- Most of the roads are serving for traffic within the capacity.
- Severe congestion is observed where north-south and east-west axes meet.
- The Chao Phraya River is a bottleneck factor for the traffic to/from Thonburi side.

Figure 1.18: Estimated Congestion Ratio



3) Traffic Control System

Despite many urban trunk roads developed in the city, the intersections of these roads are not fully facilitated with three-dimensional structures. This is partly because of scarce available space over these roads as they are already used for toll ways, and BTS among others.

The past efforts concentrated on strengthening the capacity of trunk roads by widening and construction of upper structures, but these have only created bottlenecks at crossings.

Many of the primary intersections in Bangkok have been furnished with an automatic signaling system (British SCOOT). However, its capability is not sufficiently demonstrated due to frequent breakdown of sensors installed at the intersections and to their vulnerability to extremely heavy traffic.

At most of the key intersections, traffic is manually controlled by policemen in the morning and evening peak hours. These manual controls tend to create very long cycle times, often extending to over 10 minutes, and resulting in an extremely low service level. This control method often results in reduction of traffic capacity, and is one of the major reasons of traffic congestion. Moreover, there are many one-way traffic controls in the inner city forcing redundant travel to the drivers.

1.5 INFRASTRUCTURE/UTILITIES

1.5.1 Water Supply System

The Metropolitan Water Supply Authority (MWA) was established under the jurisdiction of MOI (Ministry of Interior) in 1967, to supply water in three provinces namely BMA, Nonthaburi and Samut Prakan with a total area of 3,082 km^2. By 1999, its service area has covered 1,148.4 km^2 and the service ratio has reached more than 80% in terms of population. An outline of current service provision in the three service areas is summarized in the table below.

Table 1.19: Service Provision of MWA in 1998 and 1999

Items	Unit	1998	1999
Service Area	km^2	1,129.3	1,148.4
Population in Responsible Area	Population	7,443,584	7,478,916
Unit Daily Water Demand per Person*1	Litter/person/day	374	374
Average Water Demand	Million m^3/day	2.78	2,80
Annual Water Production	Million m^3/year	1,555.2	1,415.2
(Avg. Daily Water Production)	Million m^3/day	4.26	3.88
Annual Water Sales	Million m^3/year	914.8	856.6
(Avg. Daily Water Sales)	Million m^3/day	2.51	2.35
Service Ratio	%	90.2	83.8
Water Sales Ratio	%	58.8	60.5

Source: Annual Report 1999, MWA
Notes - *1: Unit daily water demand is according to the Master Plan by MWA.

(1) Water Resource and Treatment

The water supply by MWA consists of two main systems for BMA and a separate system for each neighboring province. Most raw water is taken 96 km upstream of the mouth of the Chao Phraya River. Another water resource, the Tha Chine River is used on a temporary basis, and will be replaced by the Mae Klong River as a permanent resource. Water quality of the Chao Phraya River is classified into Class 4 of the Surface Water Quality Standards issued by the National Environmental Board, by which the water can be used for consumption after a special treatment process. Water supply for the Study Area is included in the east bank main system. The existing water supply system in BMA is shown in figure1.19.

MWA has four main water treatment plants (WTPs) with the total capacity of 4,470,000 m^3/day. The largest WTP is located at Bang Khen with the capacity of 3,200,000 m^3/day as tabulated in the table below. The groundwater system is being phased out since the 1980s as it has caused ground subsidence. At present the groundwater abstraction is restricted by a regulation set out in the mid-1980s.

Table 1.20: Existing Treatment Capacity

Systems	W.T.P.	Existing Capacity*1 (m³/day)	Annual Water Production in 1999*2 (million m³/year)	Average Actual Production in 1999*2 (m³/day)
East Main	Bang Khen	3,200,000	1,022.8	2,802,192
	Sam Sen	700,000	174.0	476,712
West Main	Thon Buri	170,000	55.1	150,959
	Maha Sawat	400,000	139.3	381,644
Mobile		35,000	9.2	25,205
Deep Well		n/a	8.2	22,466
Separate (surface & ground water)		10,000	6.6	18,082
Total		4,655,000	1,415	3,877,260

Source: *1- The Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok 1999, JICA
*2- Annual Report 1999, MWA*2

(2) Water Distribution

Currently, there are nine pumping stations to supply water through distribution pipelines (12,774 km) and service pipelines (5,320 km). Asbestos cement (AC) pipes of over 20 years, amount to 47% of the total length and cause a large amount of leakage. The MWA annual report claims that it is implementing the pipe network improvement projects to reduce leakage ratio to 30% by the year 2001. Damaged pipes influence water quality and necessitate a reduction of service water pressure in distribution in order to prevent them from bursting.

The water quality meets the World Health Organization standards, according to the analyses of tap water quality by Mahidol University, The main cause of worsening the tap water quality is the rusted old pipes connected to consumers houses.

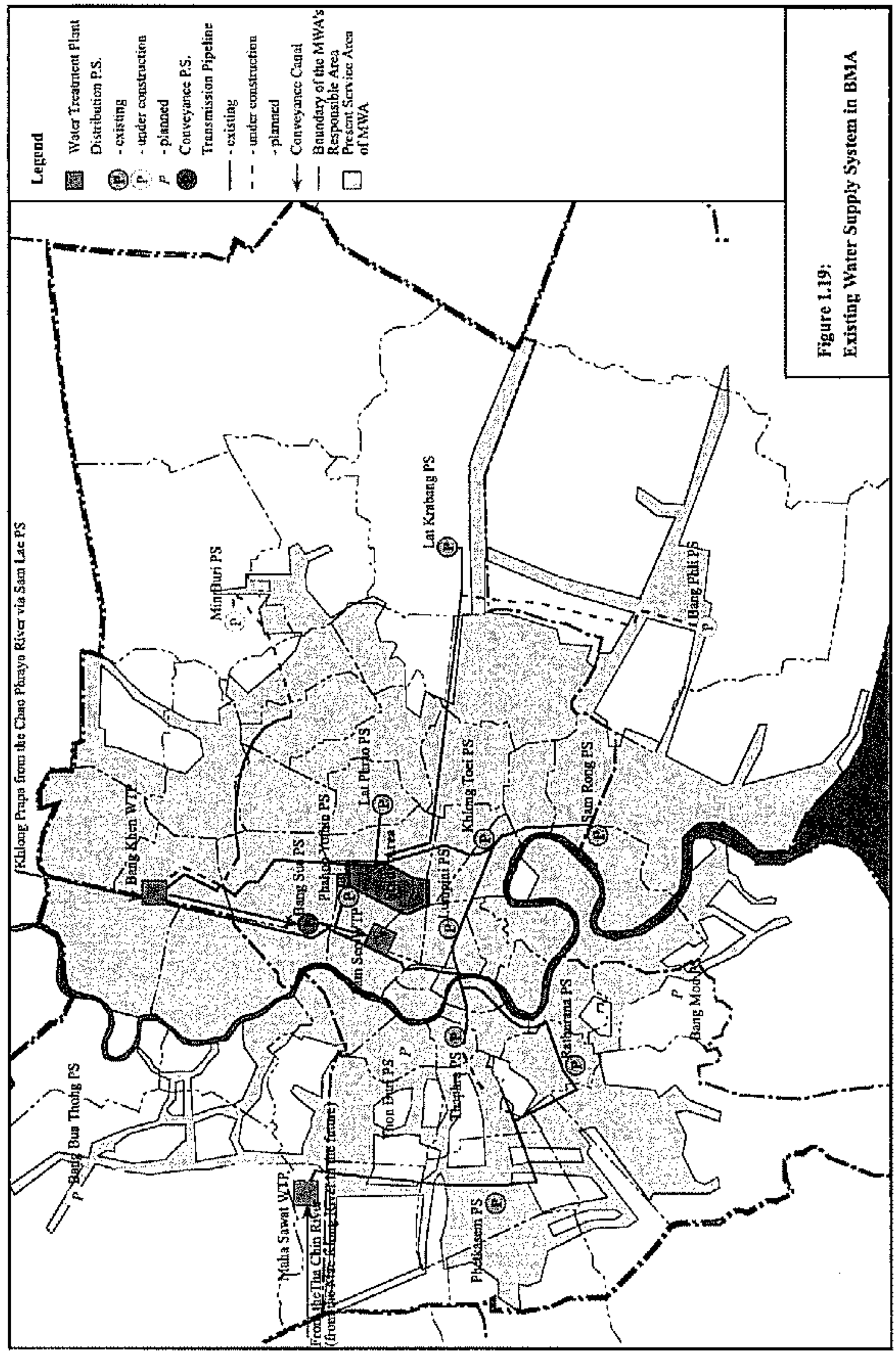


Figure 1.19: Existing Water Supply System in BMA

(3) Future Water Supply System

A master plan was prepared in 1990 covering a 30-year period from 1987 until 2017. It estimates that the service ratio will be 91.4% or 5.32 million m^3/day in 2017 as shown in the table below.

Table 1.21: Water Demand and Supply Forecast

Description	Unit	2007	2017
Urbanized Area	km^2	1,229.6	1,475.2
Population in Responsible Area	Million population	12.5	15.5
Population served	Million population	10.6 (85 %)	14.1 (91 %)
Unit Daily Water Demand	Litter/person/day	374.0	377.0
Avg. Daily Water Demand	Million m^3/day	4.68	5.82
Water Sales by MWA	Million m^3/day	3.96 (85 %)	5.32 (91 %)
Required Production Capacity	Million m^3/day	6.05	7.80
Un-accounted for Water (UFW)	%	28	25
Raw Water Required	Million m^3/day	6.66 (or 77.1 m^3/s)	8.61 (99.6 m^3/s)

Source: Master Plan for Water Supply and Distribution of Metropolitan Bangkok 1990, MWA

MWA has made a new agreement with the Royal Irrigation Department (RID) that additional raw water will be abstracted from the Tha Chine River as a temporary source at the supply rate of 30 m^3/s. This will, later be replaced by the Mae Klong River as a permanent source of 45 m^3/s, as the maximum raw water abstraction from the Chao Phraya River is restricted to 60 m^3/s. The total raw water volume will then be 105 m^3/s.

Following the increase of water demand, MWA will expand water treatment plants to meet the required daily production capacity of 7.8 million m^3/day. Major expansion is planned at Bang Khen WTP and at Maha Sawat WTP. It also plans that the mobile WTP is to be withdrawn from service by the year 2000. The separate systems for Nonthaburi and Samut Prakan will also be integrated into the main systems serving BMA.

Table 1.22: Planned Capacity of Water Treatment Facilities

Systems	W.T.P.	Existing Capacity (m^3/day)	Future Capacity 2007 (m^3/day)	Future Capacity 2017 (m^3/day)
Required Production Capacity	*Total*		*6,050,000*	*7,800,000*
East Main	Bang Khen	3,200,000	3,600,000	4,000,000
	Sam Sen	700,000	700,000	700,000
West Main	Thon Buri	170,000	170,000	-
	Maha Sawat	400,000	2,000,000	3,200,000
Mobile		35,000	-	-
Deep Well		n/a	Emergency use	Emergency use
Separate		10,000	10,000	-
Total		*4,655,000*	*6,480,000*	*7,900,000*

Source: Master Plan for Water Supply and Distribution of Metropolitan Bangkok, 1990, MWA
Note: *1) Actual treatment capacity of Sam Sen WTP is 550,000 m^3/day due to aging.

(4) Current Problems

The following items profile the current condition and problems of the water supply system in BMA:

- Basic water supply system has been developed in the central part of BMA and service ratio will reach 85% by 2007 and 91% by 2017. Production capacity of existing treatment plants is more than required for the volume of water in 2007;
- Shortage of raw water is predicted since 95% of the expanded raw water resources (105 m^3/s) will be consumed by 2017;
- Major programs have been directed to expansion and renovation of the existing system. MWA is implementing replacement of old AC pipes to reduce leakage ratio from 39% to 30%. However the replacement works will take a long time due to the large length of existing pipelines and heavy traffic congestion on the road; and
- As the Chao Phraya River has been being contaminated, MWA plans to withdraw all the mobile WTP along the river.

1.5.2 Sewage Treatment System

(1) Main Sewage Treatment System

Water pollution of khlongs in the central part of BMA have been recognized as a serious environmental issue since the 1960s. However it was not until 1994 that Si Phraya Wastewater Treatment Plant (WWTP), was put into operation as the first plant in BMA. At present, there are three central WWTPs, with a total capacity of 270,000 m^3/day for a population of 840,000, equivalent to 15% of 5,662,500 population in BMA. The location of central WWTPs are shown in the attached Figure 1.20.

Table 1.23: Existing Central Wastewater Treatment Plants in BMA

Plant	Plant Capacity (m^3/day)	Design Population (pop.)	Service Area
Si Phraya	30,000	120,000	Pom Prap Sattru Phai, Samphanthawong, and some part of Bang Rak district
Rattanakosin	40,000	160,000	Phra Nakhon district
Yan Nawa	200,000	560,000	Yan Nawa, Bang Rak, Sathon and Bang Kho Laem district
Total	270,000	840,000	

Source: The Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok 1999, JICA

Apart from the central WWTPs, BMA operates thirteen community WWTPs, which were transferred from the National Housing Authority (NHA), in accordance with an agreement made in 1990. The total capacity of the community WWTPs is 24,700 m^3/d for a population of 128,315.

(2) Other Sewage Treatment Systems

In accordance with regulations, small private houses have to be equipped with septic tanks for toilet wastewater. These systems generally have outlets to drain systems or khlongs after treatment. However there is no regulation for systematic removal of night soil. As a result, khlong water is polluted by wastewater and illegal disposal of night soil.

On the other hand, effluent from larger properties and industrial activities is regulated as tabulated below.

Table 1.24: Effluent Standards for Larger Properties and Others

Category	Required Quality for Effluent	Relevant Laws
Larger Properties and Housing Estates	･Having own treatment facilities ･Less than 50:50 or 20:30 in BOD: SS values (mg/l), depending on size of premises.	Laws and Standards on Pollution Control, Pollution Control Department, MOSTE
Industry	･Less than 20 mg/l in BOD value ･Less than 60 mg/l in BOD value for specific industries*1	Department of Industrial Works, MOI

Source: The Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok 1999, JICA

Notes: *1 The specific industries include animal processing, food products, starch, textiles, tanning, paper, pulp, chemicals, pharmaceuticals and frozen foods.

(3) Night Soil and Sludge Treatment/Disposal Systems

BMA has two Night Soil Treatment Plants (NSTPs), namely, Nong Khaem in the western part and On-Nut in the eastern part. Design capacity of both plants is 600 m^3/day. Yan Nawa and Ratburana central WWTPs also have NSTPs and treat night soil with capacity of 1,000 m^3/d and 400 m^3/d, respectively.

(4) Wastewater Tariff

Wastewater tariff has not been determined yet. It is a matter for discussion after the construction of all seven central WWTPs projected in the Master Plan. The charge for desludging of night soil tanks is set at 50 baht/m^3.

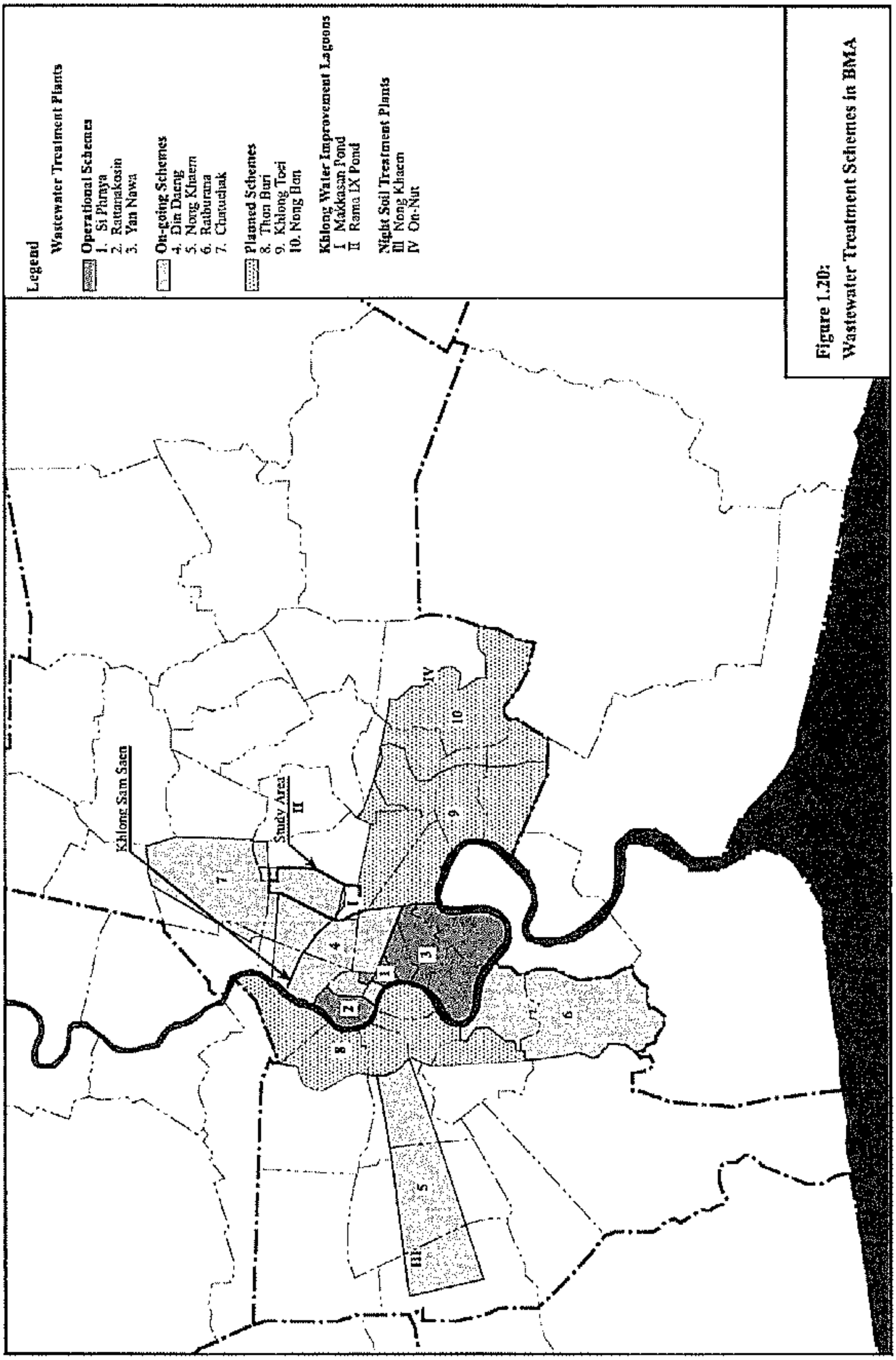
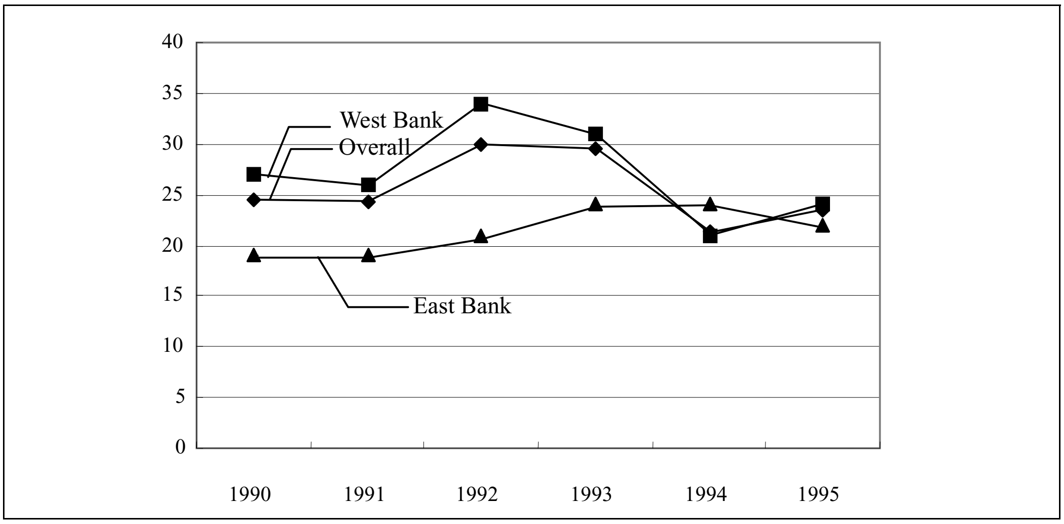


Figure 1.20:
Wastewater Treatment Schemes in BMA

(5) Surface Water Circulation System

The Department of Drainage and Sewerage (DDS), BMA, has been collecting data on water quality in major khlongs at 73 monitoring stations. The water quality is generally improving as witnessed by a tendency of declining BOD values, but the khlong water is still highly contaminated. Water quality of the Chao Phraya River has been around 2 mg/l during 1978-1994, according to the Pollution Control Department (PCD), the Ministry of Science, Technology, and Environment (MOSTE).

Figure 1.21: Trend of BOD in the Major Khlongs in BMA during 1990-1995



Note: No. of sampling points and sampling is 73 and 2,043.

BMA has conducted water quality improvement in khlongs. During the dry season, from December to April, river water is pumped up from the Chao Phraya River to khlongs and then pumped back to the river, at an average of 2,083 m^3/min at Phra Khanong Pumping Station as shown in the following figure. Furthermore there are three lagoons in which aeration systems are installed, namely the Makkasan Pond for Khlong Sam Sen, the Phuttha Monthon Pond for Khlong Ban Jak, and the Rama IX Pond for Khlong Lat Phrao. Consequently, there is no significant difference in the water quality between the dry and rainy seasons.

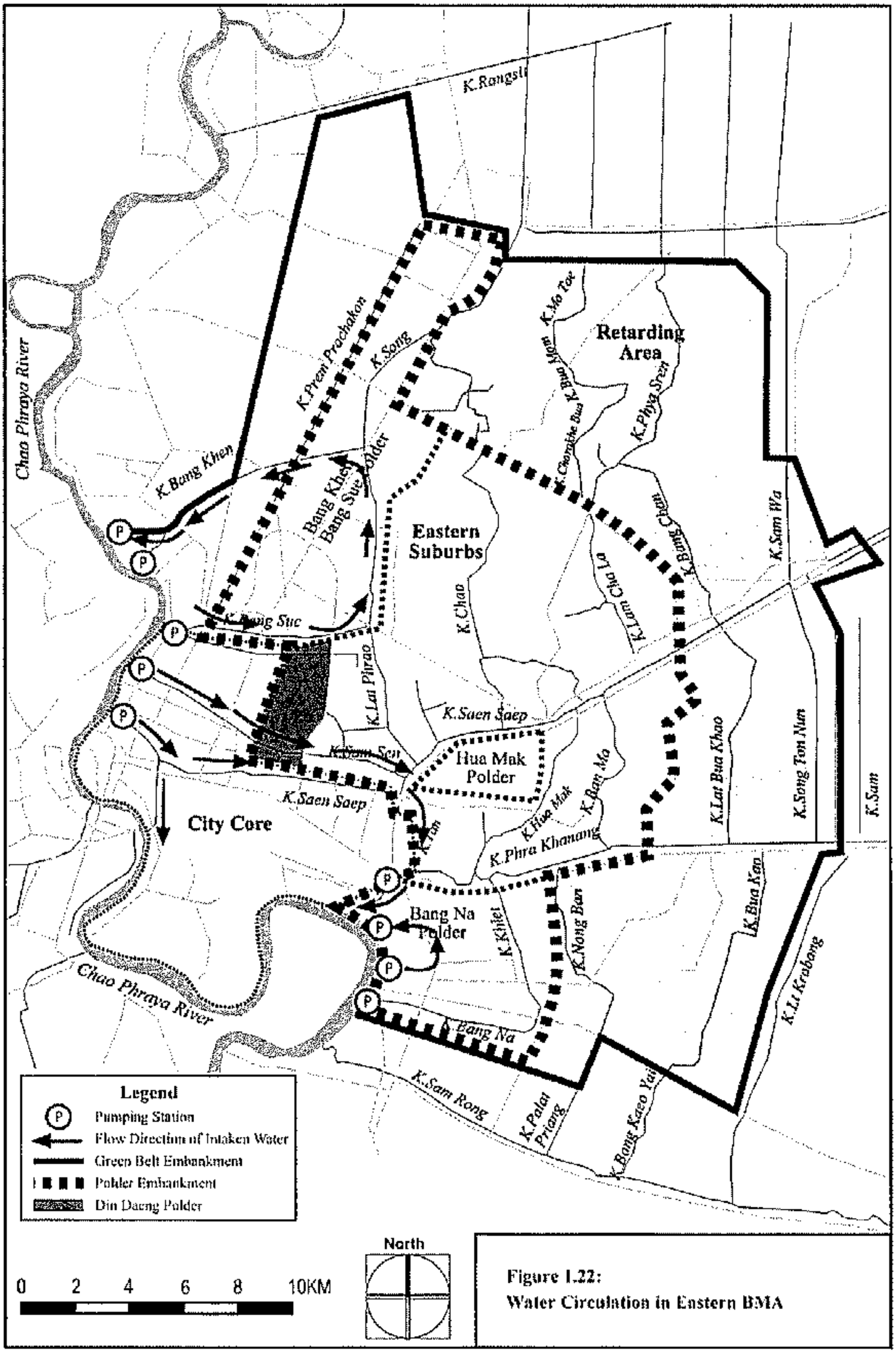


Figure 1.22:
Water Circulation in Eastern BMA

(6) Master Plan for Sewerage System in BMA

The wastewater treatment program by BMA proposes construction of seven central WWTPs by a combined system as tabulated below. These are planned to be completed by 2003 as Phase 1 of the program with a total capacity of 983,000 m^3/day for 2.3 million as population against 8.1 million total population. In later phases the total capacity is planned to reach 1,936,000 m^3/d for 5.1 million population to cover 43 % of total 11.9 million in 2020. Construction of some WWTPs are being delayed from the original schedule.

Table 1.25: Planned Central Wastewater Treatment Plants in Bangkok

Plant	Status	Plant Capacity (m^3/day)	Design Population (1,000 pop.)	Service Area
Si Phraya	Operational	30,000	120,000	Pom Prap Sattru Phai, Samphanthawong, and some part of Bang Rak district
Rattanakosin	Operational	40,000	160,000	Phra Nakhon district
Din Daeng	December, 2002	1) 341,000 2) 463,000	1) 697,000 2) 1,080,000	Pom Prap Sattru Phai, Samphanthawong, Pathum Wan, Ratchathewi, and some part of Phra Nakhon, Dusit, Phya Thai and Din Daeng district
Yan Nawa	Operational	1) 200,000 2) 360,000	1) 560,000 2) 900,000	Yan Nawa, Bang Rak, Sathon and Bang Kho Laem district
Nong Khaem	2002	157,000	1) 178,000 2) 450,000	Nong Khaem district
Rat Burana	2002	1) 65,000 2) 130,000	1) 177,000 2) 375,000	Phasi Charoen district
Chatu Chak	2004	150,000	430,000	Dusit, Phya Thai, Huai Khwang and Chatuchak district

Source: The Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok 1999, JICA

Wastewater loads are derived from an assumed BOD load concentration, such as the 150 mg/l for raw sewage in Phase 1, and 200 mg/l for Phase 2. The BOD of effluent after treatment is to be 20 mg/l.

BMA also has a plan to develop a new sludge treatment center at Nong Khaem, which was scheduled to be put in operation in 2001 but in delay. It will treat sludge generated from the above central WWTPs with a capacity of 120 t/d on a dry weight basis. Treated sludge cakes will be disposed of in landfill sites.

(7) Current Problems

The following items profile the current condition and problems of the sewage treatment system in the BMA area:

- Public sewerage systems are being developed in the central part of BMA and the service ratio will reach 43% in 2020, which is still a rather low level;

- Water in small khlongs is highly contaminated with BOD values exceeding 20 mg/l, while in major khlongs the water of the Chao Phraya River is circulated; and
- The public sewerage system will improve water quality in major khlongs, while the proper maintenance of septic tanks will be required to reduce the water pollution in the minor khlongs.

1.5.3 Storm Drainage System

(1) General

BMA has experienced serious floods in the past because of flat and low topography with ground level of 0–2 m above mean sea level (MSL). The ground subsidence is still progressing at 0.5 cm/year.

A severe inundation that occurred in 1983 prompted flood protection efforts: defining flood protection zones, raising of roads and dikes (polder system) and installation of flood gates and pumping stations to control water levels in the khlongs. BMA now operates a sophisticated control system to minimize chances of flooding in the city. The flood-prone area has shifted to the eastern suburbs of BMA and along the Chao Phraya River in light of the flood experienced in 1995.

(2) Existing storm drainage system in BMA

BMA is divided into three major polders: 1) City Core, 2) Eastern Sub-Urban District, and 3) Eastern Retarding Area. The City Core Polder is further demarcated into five minor polders as shown in Figure 1.23.

According to the master plan study on the flood protection and drainage systems in eastern suburban Bangkok, it was confirmed that the drainage system in the City Core and some of the Eastern Sub-Urban District has met the required capacity. The design rainfall for the City Core and the Eastern Suburban District is set at a rather low 2-year return-period of 61 mm/h, while it is a 5-year return-period for the Eastern Retarding Area.

The general concept of the drainage system is: 1) to cut off inflow from the eastern area, and 2) to drain surface water from each polder to major khlongs, such as Bang Khen, Bang Sue, Saen Saep, Phra Khanong, Bang Na, and on to the Chao Phraya River.

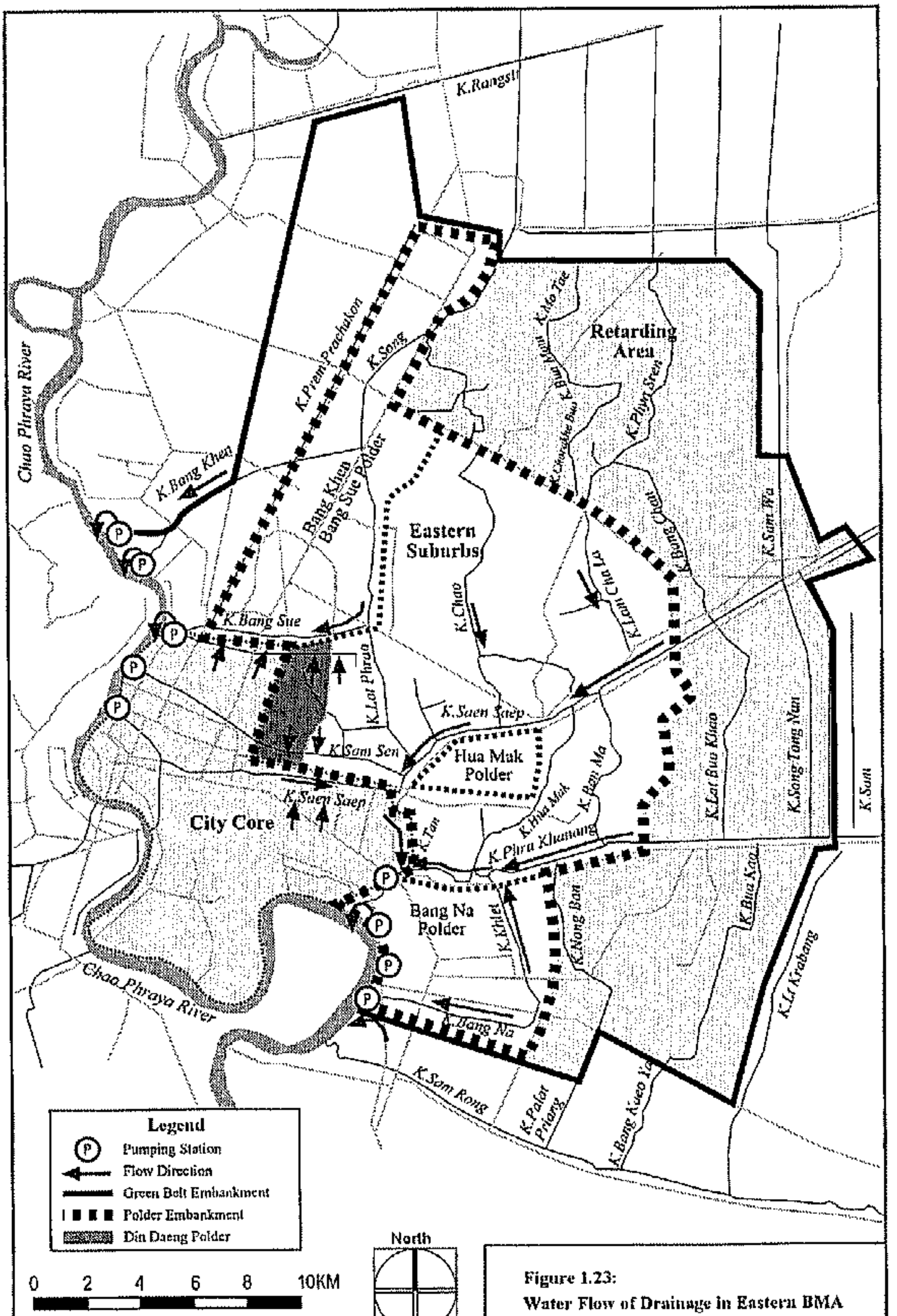


Figure 1.23:
Water Flow of Drainage in Eastern BMA

The major activities for drainage improvement have focused on dredging of khlongs, riverside embankments along the Chao Phraya River, and securing of retention ponds (Monkey Cheeks).

However the flow capacity of the Chao Phraya River was estimated at 3,600 m^3/s, which is only equivalent to run-off from 200 km upstream in only a 3-year return-period, although the flow capacity of the river is required to be a 100-year return-period.

Furthermore, while storm drainage capacity reaches 775 m^3/s combining BMA and Thon Buri there is still remaining rainfall of 13 million m^3 (if rain falls continuously for three hours). To cope with this DDS proposes the private and public retention basin, or Monkey Cheek, with capacity of 7 million m^3, but this still leaves a shortfall in capacity of 6 million m^3.

(3) Current Problems

The following items profile the current condition and problems of the drainage system in BMA:

- The inundation area has shifted from the central area to the riverside of the Chao Phraya River and the east on areas outside the BMA area. Flooding in the central areas now occurs in certain limited locations;
- Shortage of discharging capacity is 6 million m^3 in 3-hour rainfall even if DDS's proposed retaining basins are all secured;
- Flow capacity of the Chao Phraya River is equivalent to the run-off of only a 3-year return period; and
- Open drain ditches are clogged with dumped garbage, stagnant wastewater and silting which hinder water flow and deteriorate water quality.

1.5.4 Electric Power System

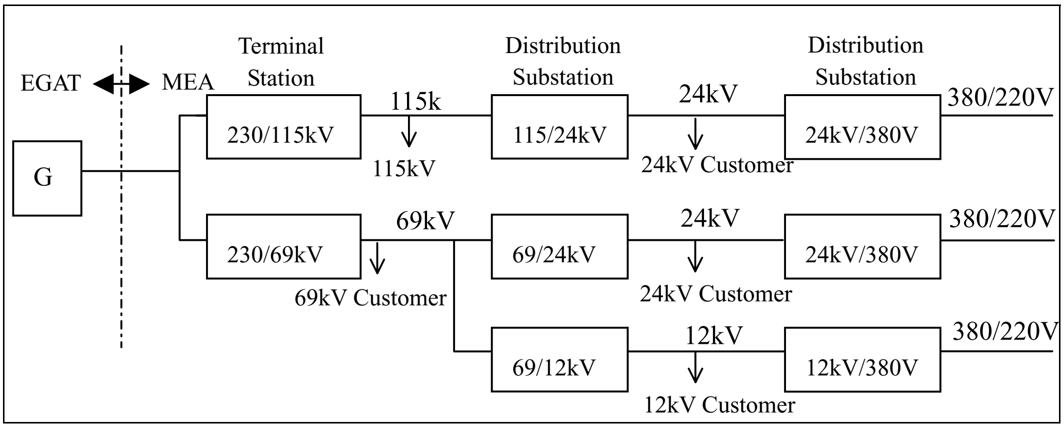
(1) Electric Power System in BMA

Development of power generation facilities has been carried out generally following the feasibility study prepared by JICA in 1995, which targeted the year 2016. The Metropolitan Electricity Authority (MEA) is currently preparing a new master plan. MEA receives electricity from the Electricity Generation Authority of Thailand (EGAT) through 230 kV transmission line, and after stepping down to 115 kV, distributes it to customers.

Substations consist of a combination of 3×40 MVA, 2×40 MVA and 2×60 MVA. According to rated voltage and transmission capacity, transmission lines adopt 230 kV, 115 kV, and 69 kV lines. Distribution lines consist of 12/24 kV and 380/220 V. MEA will implement upgrading of distribution lines from 12 kV to 24 kV. For distribution, overhead cables are used except where space is not available. In such cases cables are laid underground.

The existing capacity of terminal station, substation, and distribution substation is 10,169 MVA, 12,030 MVA, and 12,275 MVA in 1998, respectively

Figure 1.24: General Structure of Power Transmission and Substation



(2) Electric power demand forecast

MEA had prepared a power demand forecast until the year 2011 that was updated in 2000. It awaits approval by Parliament. A development plan for substations targeting the year 2006 has also been prepared.

The power demand forecast predicts the power demand will turn upward again, as economy will recover. The maximum peak demand in 2007 is within the existing capacity of substations, but expansion of substations is required to meet the peak demand of 9,631 MW in 2011.

Table 1.26:

Electric Power Demand Forecast and Loading Ratio to Existing Substations

Fiscal Year	Max. Peak Demand	Energy Received from EGAT	Energy Sales	Number of Customers	Energy Loss	Loading Ratio to Existing Capacity		
						Terminal	Substation	Distribution
	MW	GWh	GWh	Number	%	%	%	%
Actual						(peak demand is within the existing capacity)		
1997	5,938	33,708	32,373	2,004,023	3.96	58	49	48
1998	5,657	32,552	31,258	2,043,901	3.97	56	47	46
1999	5.356	30,837	29,641	2,094,893	3.88	53	45	44
Forecast								
2000	5,799*1	33,367	31,932	2181936	4.30	57	48	47
2001	6,183	35,400	33,807	2,262,721	4.50	61	51	50
2002	6,598	37,460	35,774	2,349,224	4.50	65	55	54
2003	6,891	39,504	37,727	2,437,305	4.50	68	57	56
2004	7,146	41,444	39,579	2,527,369	4.50	70	59	58
2005	7,456	43,378	41,426	2,619,728	4.50	73	62	61
2006	7,787	45,311	43,272	2,706,038	4.50	77	65	63
2007	8,165	47,343	45,213	2,793,049	4.50	80	68	67
2008	8,566	49,427	47,203	2,872,097	4.50	84	71	70
2009	8,871	51,636	49,312	2,962,605	4.50	87	74	72
2010	9,250	53,847	51,424	3,051,721	4.50	91	77	75
2011	9,631	56,077	53,553	3,134,140	4.50	95	80	78

Source: Electricity Demand Forecasting Report 2000, MEA for electricity demand

Note 1): Max. peak demand with *1 in 2000 is actual record.

2) Existing capacity of terminal station, substation, and distribution transformer is 10,169 MVA, 12,030 MVA, and 12,275 MVA in 1998 respectively, according to MEA Annual Report in 1999.

3) Max. loading ratio of terminal station, substation, and distribution transformer is 80%, 75%, and 75%, according to the JICA F/S Report in 1995.

4) Gray-colored ratio means max. peak demand is within the existing capacity.

(3) Current Problems

The following items profile the current condition and problems of the electric power system in BMA:

- Electricity distribution system has been developed to meet the estimated demand in 2007;
- MEA is implementing expansion of the distribution system and updating the master plan for the distribution system to secure adequate capacity. MEA will upgrade distribution line from 12 kV to 24 kV;
- Typical problems are i) difficulty of land acquisition for constructing new substations in built-up areas, ii) energy loss due to the remote location of power generation facilities, and iii) intricate overhead power lines causing disturbance to cityscape and constraints for maintenance.

1.5.5 Telecommunication System

(1) General

The Telecommunication Organization of Thailand (TOT) is responsible for the domestic telecommunication system under the jurisdiction of the Ministry of Communication and Transportation (MOTC), while the Communication Authority of Thailand (CAT) serves for international telecommunication. TOT also covers some international telecommunication to neighboring countries.

Service provision for telecommunication in BMA is sufficient as the diffusion level is 1.84 persons/line for line capacity and 2.87 persons/line for connected lines, compared to the average line capacity of 100 persons/line in the whole country.

Table 1.27: Diffusion Level of Telecommunication in BMA

Area	Population	Line Capacity	Line Connected
Metropolis	8,112,910	4,412,437	2,831,472
Diffusion Level	-	1.84 persons/line	2.87 persons/line

Source: Annual Report 1999, TOT
Note: Metropolis includes BMA, Pathum Thani, Samut Prakan, and Nonthaburi.

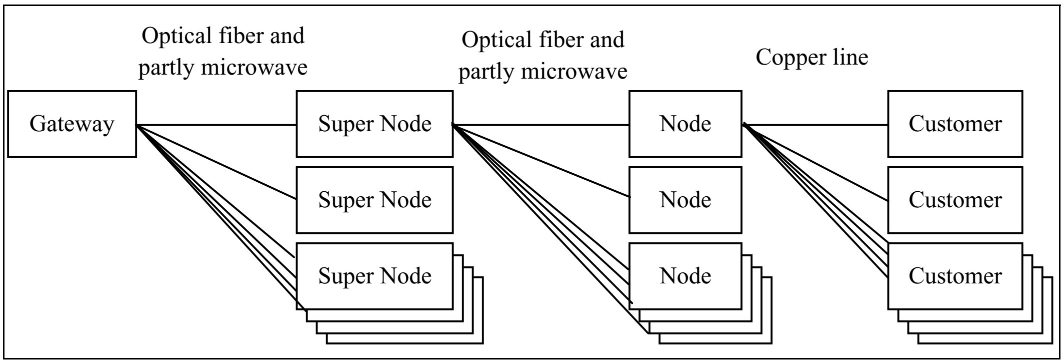
The major improvement works for the telecommunication system is development of an optical fiber network to connect switching stations to achieve high efficiency and capability for huge information traffic.

(2) Existing Telecommunication System in BMA

The telecommunication system in BMA roughly consists of three levels: The highest tier is international communication through the gateway located in Surawong; The second one is regional communication with terminal stations called “Super Node”; and the lowest stratum is the district level operated under terminals called “Nodes”. Intercommunication between these three tiers is mainly born by optical fibers and partly by microwaves. Optical fiber route in BMA is shown in Figure1.26.

TOT has not experienced shortage of telecommunication capacity but understands that the capacity needs to be reinforced to meet the future demand.

Figure 1.25: General Structure of Telecommunication System in BMA



(3) Current Problems

A telecommunication system has already been developed in BMA. TOT is now installing the optical fiber network and expects that sufficient capacity will be available for future demand.

Problem areas are limited to the following items:

- Congestion of overhead telephone cables is making the cityscape unseemly; and
- Difficulty of securing space for setting up exchange stations due to high density urbanization and high land prices.

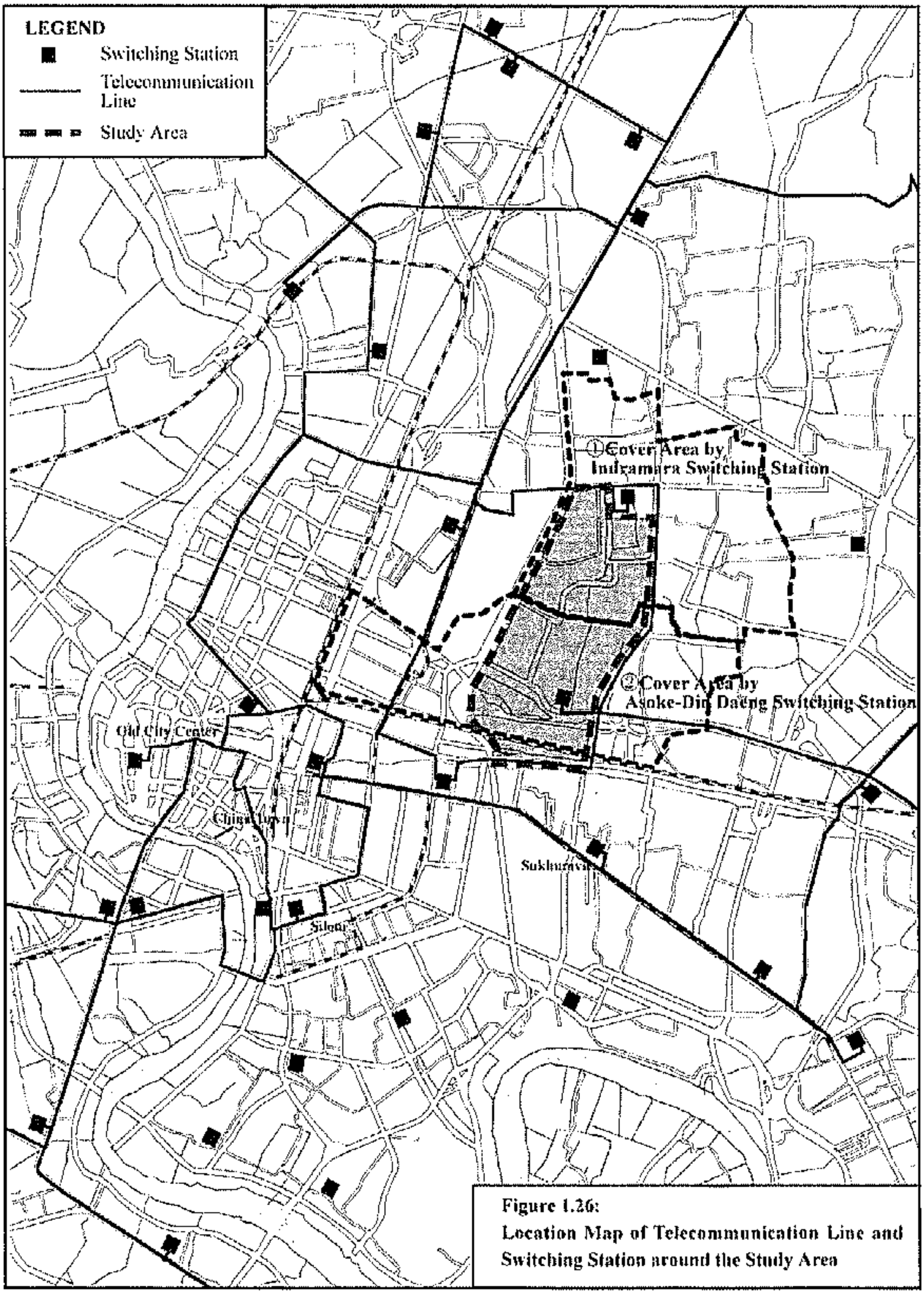


Figure 1.26:
Location Map of Telecommunication Line and Switching Station around the Study Area

1.5.6 Solid Waste Disposal System

(1) General

Solid waste collection and disposal services are conducted by the Department of Public Cleansing (DPC), BMA and district offices. Through three transfer stations, collected solid waste is disposed of in two sanitary landfills. Apart from solid waste, DPC also collects and incinerates infectious wastes from hospitals.

(2) Solid Waste Generation and Collection

Solid waste generated increased twofold in the 10- year period from 4,160 ton/day in 1987 to 7,961 ton/day in 1997 as tabulated below. Medical solid waste amounted to 8,040 kg/day in 1997.

Table 1.28: Collected Solid Waste

Fiscal Year	1987	1989	1991	1993	1995	1997
Collected Solid Waste (ton/day)	4,160	4,598	4,706	6,016	6,963	7,961
Increasing Ratio (%)	-	10.5	2.3	27.8	15.7	14.3

Source: Master Planning Study for Waste Management of Bangkok Metropolis 1999, PCD

DPC has 2,199 collection vehicles with a total capacity of 6,364 ton. The required collection trip of vehicles was only 1.16 trips/day/vehicle to handle the solid waste volume in 1995. However the collection productivity was 6.1 ton/day/vehicle, which was lower than that of Singapore (25.6 ton/day/vehicle) and Kuala Lumpur (24 ton/day/vehicle). The main reason is the long collection time of about 224 minutes on average and travelling time of 85 minutes from the last collection point to a transfer station.

(3) Separation at discharge spots

Solid waste is separated into four types at the discharge spots. According to a questionnaire survey by DPC 64% of respondent inhabitants are in favor of separation of solid waste and they generally follow the separation standard properly. DPC analyzed the composition of solid waste from 1986 to 1997 and reported that moisture content was high at between 45-55% by weight. Dry solid calorific value (DSCV) was 1,600 kcal/kg, which meets the requirement for the proposed On-Nut incineration project.

Infectious waste from medical centers, construction waste, and night soil are separately collected.

Table 1.29: Separation of Solid Waste at Discharge Spots

Type of container	Type of solid waste
Green container	Solid waste from households and buildings including residences, shops, schools and market.
Yellow container	Recyclable waste including glass, plastic, metal and paper wastes.
Grey container With red lids	Household hazardous waste including Light bulbs, batteries, insecticides and sanitation product containers.
Blue container	Ordinary garbage and designated places for trash bags collection.

(4) Intermediate Facilities and Disposal

There are three transfer stations located at On-Nut (3,650 ton/day), Tha Raeng (2,356 ton/day), and Nong Khaem (2,678 ton/day). BMA relies on two private companies for transporting and dumping solid waste. These companies transport from the transfer stations to their own landfill sites at Kamphaeng Saen and Ratchatawa. Solid waste is transferred to Kamphaeng Saen Landfill site from Tha Raeng and Nong Khaem transfer stations, which are located 112 km and 75 km from the landfill site respectively.

Table 1.30: Intermediate and Disposal Facilities

Method	Compost Plant			Sanitary Landfill	
	Nong Khaem	On-Nut	Tha Raeng	Kamphaeng Saen*1	Rachathewa
Area	-	-	-	160 ha	30 ha
Status		Suspended		Operational	Operational
Daily quantity	-	-	-	4,000 t/d	3,500 t/d
Capacity	1,000 t/d	1,200 t/d	1,500 t/d	40 mil. t	7.5 mil. t
Remain. Capacity	-	-	-	38 mill. t	7.5 mil. t
Remain. Life	-	-	-	>30 years	6 years

Source: Master Planning Study for Waste Management of Bangkok Metropolis 1999, PCD

(5) Collection Tariff

The DPC master plan pointed out that collection charges had been set quite lower than the actual cost of collection. A monthly charge of 4 baht per house in 1998 generated revenue of 62.163 million baht, representing only 4.9% of the total collection cost. To cover the total cost of 3,322 million baht, the average monthly charge per household should be only 150 baht, equivalent to 0.58 % of the average income of 25,800 baht for a little over 1.8 million households. Under such circumstances, BMA is contemplating a tariff increase.

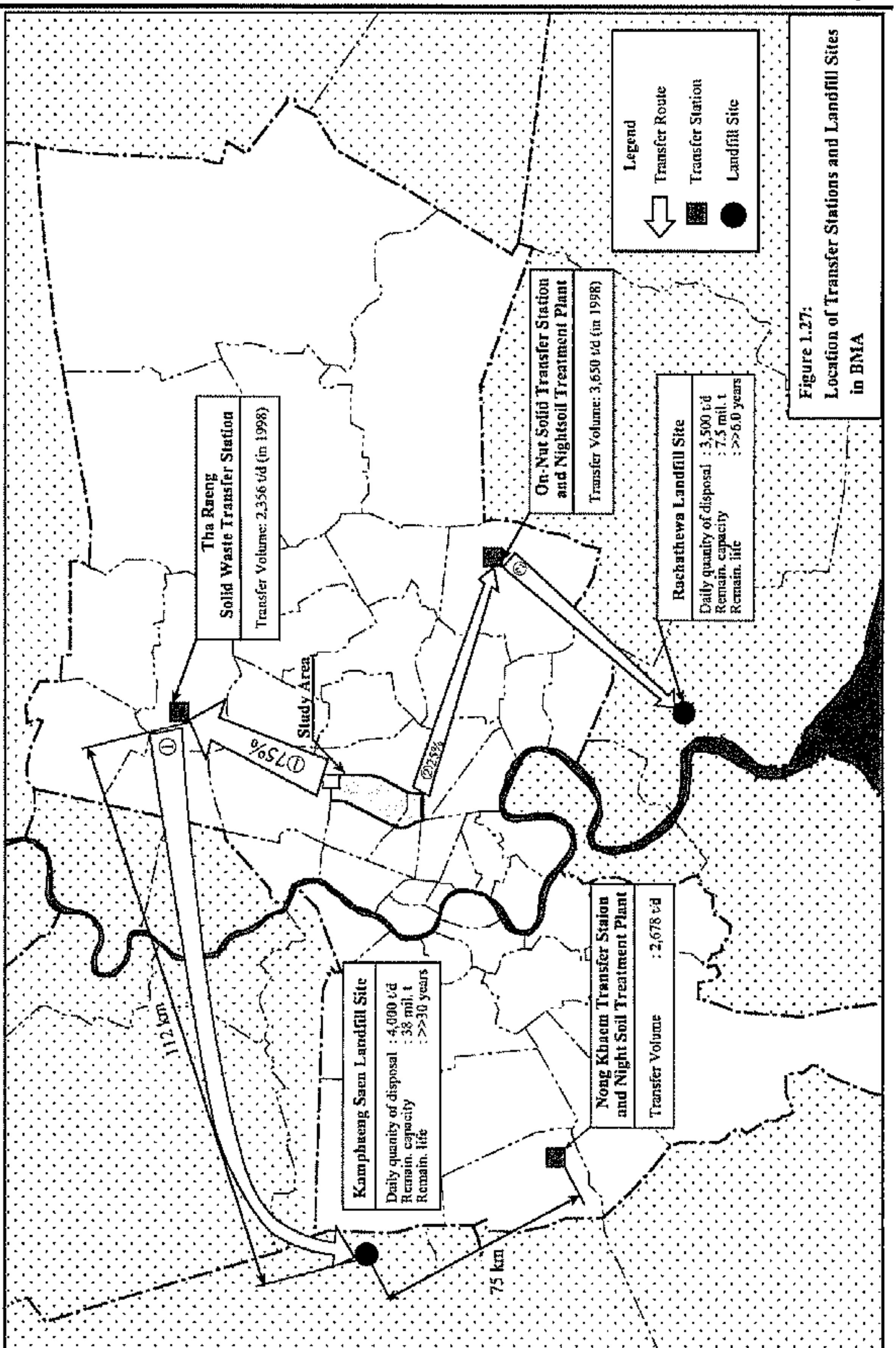


Figure 1.27:
Location of Transfer Stations and Landfill Sites in BMA

(6) Master Plan for Solid Waste Management

DPC formulated a new master plan in 1999 for the next 20 years until 2019. The master plan focused on municipal solid waste (MSW) excluding industrial hazardous wastes, which is the responsibility of the Department of Industrial Works.

The master plan initiates i) reduction of MSW generation, ii) collection system improvement, iii) land acquisition for disposal, iv) promotion of recycle and reuse, v) management of construction waste and medical waste.

MSW generation rate was 1.61 kg/person/day in 1998 and the master plan assumes that the rate will increase to 2.00 kg/person/day by 2019, which was twice the unit generation rate in Japan in the 1990s. Collected MSW is estimated to reach 15.7 ton/day in 2019.

Table 1.31: Estimates of MSW Collected During 1999-2019

Year	Registered Population (persons) (a)	MSW Generation (kg/person/day) (b)	MSW for Collection	
			(tons/day) (c)=(a)*(b)/1,000	(tons/year) (d)=(c)*365
1999	5,778,900	1.593	9,206	3,360,113
2004	6,238,400	1.695	10,574	3,859,542
2009	6,734,500	1.797	12,102	4,417,192
2014	7,269,900	1.898	13,798	5,036,369
2019	7,847,900	2.000	15,696	5,728,967

Source: Master Planning Study for Waste Management of Bangkok Metropolis 1999, PCD

The master plan proposes to enlarge the capacity of transfer stations and to construct one or two new transfer station(s) near the collection areas. This is as follows:

i) On- Nut to be enlarged from 3,650 tons/day to 6,500 tons/day;
ii) Nong Khaem to be expanded from 2,678 tons/day to 4,890 tons/day; and
iii) Tha Raeng to be expanded from 2,356 tons/day to 4,300 tons/day.

The master plan proposes an integrated system including composting, recycling, incineration, and sanitary landfill to minimize land acquisition for disposal sites to 1,920 ha for 51 million ton, otherwise the required area will be 3,286 ha for 94 million ton.

Table 1.32: Proposed Integrated Treatment System

Type of final disposal		Proposed Volume	Proposed Facilities
1)	Turned to compost	11,497,500 tons (12.27%)	Plants at Nong Khaem (1,000 t/d), On-Nut (1,200 t/d), and Tha Raeng (1,500 t/d).
2)	Incinerated	31,043,250 tons (33.12%)	Plants at Nong Khaem (1,350 t/d) and On-Nut (1,350 t/d).
3)	Landfill	51,183,039 tons (54.61%)	At Bang Khun Thian (35 km2, 140 mil. ton for 30 years)

Source: the Master Plan for MSW by DPC

Projects for construction of disposal sites have been facing opposition of local residents all over Thailand. For example, an incineration project in Chiang Mai, a landfill project at Lat Krabang, and a hazardous waste treatment center in Rayong. Since 1992, there have been more than 40 such campaigns opposing similar projects.

(7) Current Problems

The following items profile the current condition and problems of solid waste management in BMA.

- Solid waste generation rapidly increased twofold from 7,961 ton/day to 15,696 ton/day in the past 10 years. The increase of solid waste will require expansion and new construction of transfer stations near the collection areas; and
- Collection system has been developed but sanitary landfill sites have been secured only for the short-term.
- The following measures are required.
  - Reduction of solid waste generation;
  - Raising of efficiency of collection services;
  - Development of integrated system, including incineration and composting with promotion of recycling and reuse systems; and
  - Raising of collection charge to achieve financial soundness.
- DPC has been facing opposition to construction of incineration, landfill site and hazardous treatment center. The opposition by people living in the vicinities and campaign of the opposition groups are constraints to the development of a rational solid waste disposal system.

1.5.7 Evaluation on Infrastructure

The basic infrastructure has already been developed in the central part of BMA and the focus is shifting to renovation and expansion of existing systems, especially for water supply, sewage treatment, and solid waste disposal.

The organizations concerned are struggling to meet future demands and face the following constraints:

- Large amount of existing facilities;
- Intricate road network with cul-de-sac and heavy traffic volumes;
- Continuous urban expansion;
- Difficulties for land acquisition due to the crowded built-up areas and opposition campaigns; and
- Decline of financial conditions due to the economic recession.

The improvement works cannot be completed all at once, and the organizations have to proceed continuously with some means of constructing various kinds of infrastructure jointly and introducing co-location of some utilities in common service ducts.

- On the other hand, the provision of the sewage treatment system, solid waste management, and the transportation system have lagged behind urban growth and in some places are causing deterioration of the living environment through water pollution, noise, odor, air pollution, and traffic congestion. Considering the difficulties of the infrastructure renewal over such a large area, the priority for renovation is recommended to be in areas where the environmental deterioration has progressed due to insufficient infrastructure. In this case a comprehensive development will be necessary in the crowded built-up areas, which will also contribute an improvement to surrounding areas.

1.6 PUBLIC POLLUTION

1.6.1 Ground Water

In 1998, about 681,999 m^3/day of ground water in BMA was used by the business sector (176,611 m^3/day), MWA's tap water (157,763 m^3/day), residential consumption (153,682 m^3/day), the government sector (67,683 m^3/day), and agriculture (3,260 m^3/day). The ground water was intensively pumped up in the districts of Bang Khen, Min Buri, Lat Krabang, Thaling Chan and Bang Khun Thian.

Intensive groundwater abstraction in BMA has resulted in significant land subsidence and lowered the level of groundwater. The rate of land subsidence varies from less than 1 cm/year to more than 3 cm/year, and the rate of ground water level subsidence from less than 2 m/year to more than 3 m/year.

1.6.2 Surface Water Quality

The water quality in the lower part of the river during 1996-1999 was characterized by low DO (0-4 mg/l) and high BOD (0.3-12 mg/l). The major environmental indicators in the same period include: total coliform bacteria (540-16,000,000 MPN/100 ml), phosphorous (non detectable-3.80 mg/l), nitrogen (non detectable-9.75 mg/l), and suspended solids (non detectable-1,008 mg/l). Based on these figures, the lower segment of the river was classified as Class 4 of the water quality standard, meaning that the water is "fairly clean and can be used for consumption and for industrial use after special treatment", according to the Chao Phraya River Water Quality Standard, issued as Notification of MOSTE in 1975.

Most of the khlongs in BMA receive wastewater from built-up areas: housing sector (54.12%), government, state enterprise and business sector (37%), hotels (3.99%), industry (2.19%), shopping centers (1.37%) and other sources such as markets, and restaurants. Such wastewater contains large amounts of organic substances, detergent, oil, and grease, which are the major cause of poor water quality.

The deteriorated water quality has become a serious issue these days and development of Sewerage Treatment System (STS) is urged. However, as STSs require a large investment and a long time to develop, several short-term measures have been taken to improve the water quality of khlongs. Measures include dilution of khlong water, construction of aerated ponds (the Makkasan pond and the Rama IX pond), retaining wall embankments, installation of a direct aeration system, and dredging works.

1.6.3 Air Quality

Air pollution in BMA is mainly caused by exhaust from vehicles, industrial factories, and construction activities. Among them, the exhaust from vehicles is a major cause of air pollution. The air quality has been monitored by several agencies such as the Air Quality and Noise Management Division, the Pollution Control Department, MOSTE, the District Offices of BMA, and the Environmental Health Bureau, the Department of Health, the Ministry of Public Health. MOSTE has monitored air quality along the roadside where the traffic is congested, and in other areas which are not directly affected by traffic, such as residential, educational and governmental areas. The air quality monitored during 1988-1998 indicates that there had been improvement of air quality except for TSP and PM-10, which still exceed allowable limits of air quality standards. The high TSP, especially PM-10, is inhaled through the respiratory system and affects human health.

The results of air quality monitoring in 1998 indicated that the concentration of NO_2, CO, O_3, and PM-10 on the roadsides, and O_3 and PM-10 in non-roadside areas exceeded allowable limits.

Table 1.33: Air Quality in BMA (1998)

Parameter		Unit	Along the Roadsides[1]		The General Area [2]		National Standard[3]
			Range	Average	Range	Average	
SO_2 1-hr. average		ppb	140-0	9.8	177-0	6.2	300
NO_2 1-hr. average		ppb	183-0	32.9	142-0	21	170
CO	1-hr. average	ppm	33.7-0	1.98	13.5-0	0.9	30
	8-hr average	ppm	18.04-0	2.23	6.04-0	0.9	9
O_3 1-hr. average		ppb	112-0	8	191-0	14	100
PM-10 24-hr. average		$\mu g/m^3$	251-9	81.6	225-23	66.4	120
TSP 24-hr. average		mg/m^3	2.71-0.06	0.29	0.33-0.02	0.1	0.33
Pb 1-month average		$\mu g/m^3$	0.25-0.02	0.08	0.49-0.02	0.08	1.5

Remark: 1.Area is directly affected by traffic and is about 10 meters from the main road.
2.Area is not directly affected by traffic and is about 50 meters from the main road, such as community, institutional and governmental area.
3.Notification of the National Environmental Board No. 10 under the Enhancement and Conservation of National Environmental Quality Act B.E. 2535, published in the Royal Government Gazette No. 112 Past 52 dated May 25, B.E. 2538.

Source: Air Quality and Noise Management Division, Pollution Control Department, MOSTE (1998). Situation and management of Air and Noise Pollution.

1.6.4 Noise Level

The noise pollution in BMA is mainly caused by transportation. The noise level near the main roads, along congested roads, in the general area, and along the khlongs were measured by MOSTE in 1998. The results indicate a high impact of noise near the main roads and along highly congested roads.

Table 1.34: Noise Level in BMA (1998)

Area	Range of Leq (24) (dB(A))	Range of Leq (1) (dB(A))
Near to the main roads[1]	79.3 – 64	85.1 – 68.2
Along the congested traffic road[2]	82.3 – 71.4	87.9 – 76.2
The general area[3]	76.4 – 53.1	80.9 – 56.7
Along the khlong[4]	69.1 – 57.5	74.3- 59.4
Standard Values[5]	70	-

Remark: 1/ Near Rama IV Rd., Phahon Yothin Rd., Lat Phrao Rd., Din Daeng Rd., and in Thorn Phi Tak.
2/ Along 18 congested traffic roads.
3/ Area no directly affected by traffic, about 50 meters from main road.
4/ Khlong Saen Saep, Khlong Lat Phrao and Khlong Phra Khanong.
5/ Ambient Noise Standards of Thailand, According to MOSTE

Source: Air Quality and Noise Management Division, Pollution Control Department, MOSTE (1998). Situation and Management of Air and Noise Pollution.

1.7 IDENTIFICATION OF PROBLEMS AND PLANNING IMPLICATIONS

1.7.1 Socio-economic Issues

A hollowing out phenomenon is going on in the inner city area, together with suburbanization in the outskirts. Rapid urbanization of recent years in the northeastern part of the city, such as Bang Kapi and Min Buri has been remarkable.

Population growth is leveling off in BMA as a whole. On the contrary, growth still continues in peripheral provinces resulting in expansion of the urban area, though it has moderated in recent years.

Population growth may turn negative around the year 2015, not only in the inner city area but in BMA as a whole, according to a cohort population growth forecast conducted by the Study as presented below.

Table 1.35: Population Projection in BMA

	1970	1980	1990	2000	2005*	2010*	2015*	2020*
Population	3,908.2	5,965.3	7,470.7	8,026.6	8,202.6	8,289.5	8,319.9	8,302.7
Household	617.1	1,118.7	1,655.6	2,068.4	2,374.7	2,604.4	2,836.8	3,072.3
Household size	6.3	5.3	4.5	3.9	3.5	3.2	2.9	2.7

Source: 1970～2000, result of multiplied Population and Housing Census, NSO by 1.27.
* Projection by the Study Team, based on Year 2000 Census results

1.7.2 Spatial Issues

Major high-level urban activities are concentrated in the areas between physical transport barriers such as the Chao Phraya River, SRT railways, and some outstandingly wide trunk roads such as Vibhavadi Rangsit, Rama IX, Sukhumvit roads.

Due to the natural configuration of the Chao Phraya River, urban axes have been formulated in north-south and east-west directions. Recent population growth has occurred in the periphery of the busy city cores supported by a combination of ring roads and radial roads situated in these urban axes.

Because of the concentration of the movement of goods and passengers, private sector investment tends to be concentrated on these axes resulting in ribbon development. This has encouraged suburbanization of residential areas further to the outer areas.

At the same time, heavy traffic on the arterial roads flows in large volumes into the inner city area and generates severe traffic congestion due largely to the shortage of secondary arterial roads. Living conditions have deteriorated because of congestion and associated pollution such as air, noise and vibrations. This, in turn, has led to the hollowing out of the population inside the inner city.

Figure 1.28: Current Urban Structure in Bangkok