JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND
BANGKOK METROPOLITAN ADMINISTRATION

THE STUDY FOR THE MASTER PLAN ON SEWAGE SLUDGE TREATMENT/DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK IN THE KINGDOM OF THAILAND

FINAL REPORT

Vol. II MAIN REPORT

OCTOBER 1999

NIPPON KOEI CO., LTD.

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LIST OF REPORTS

Vol. I	EXECUTIVE SUMMARY
Vol. II	MAIN REPORT
Vol. III	SUPPORTING REPORT
Vol. IV	DATA BOOK

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(as of October 1998)

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct the master plan study on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Keisuke Okazaki, Nippon Koei Co., Ltd. to the Kingdom of Thailand, four times between September 1998 to October 1999. In addition, JICA set up an advisory committee headed by Mr. Haruki Takahashi, Japan Sewage Works Agency, between September 1998 and October 1999, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared the final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

October, 1999

Kimio Fujita

Kimio Fujita
President
Japan International Cooperation Agency

October, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

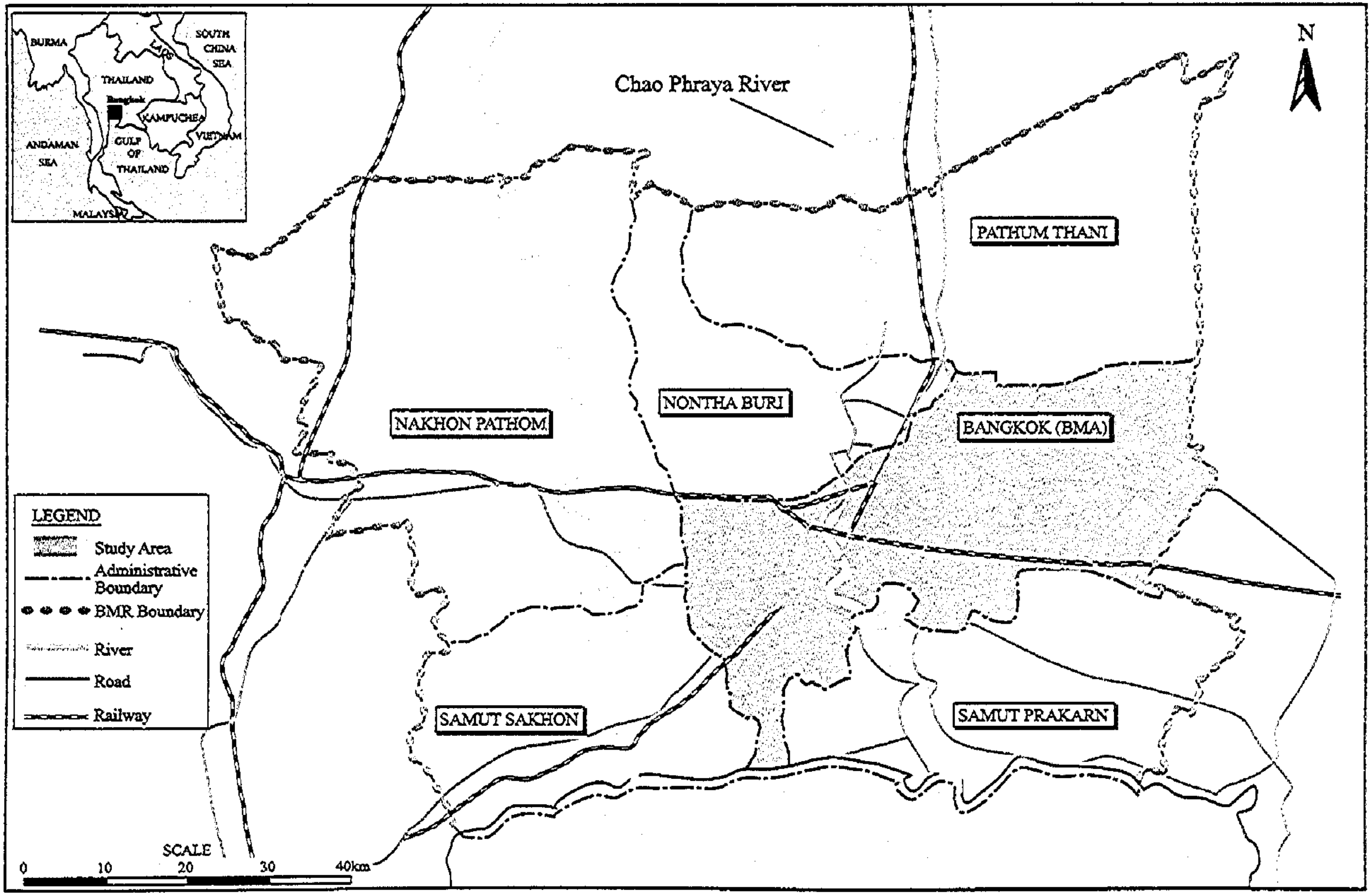
It is with great pleasure that we submit to you the Final Report of the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok completed by the Study Team with cooperative efforts of the Bangkok Metropolitan Administration (BMA) and other parties concerned. The report has been prepared for the Government of the Kingdom of Thailand in implementing the effective sewage sludge treatment/disposal and reclaimed wastewater reuse plan in the BMA area.

The report consists of four volumes of the Executive Summary, Main Report, Supporting Report and the Data Book. The Executive Summary presents the outline of the study results and the Main Report gives all the study results regarding sewage sludge treatment/disposal and reclaimed wastewater reuse. The Supporting Report describes sludge reuse survey for agriculture, proposed wastewater treatment and disposal system, and standards and principles for application of wastewater sludge to agricultural land. The Data Book compiles useful reference data relevant to the Study.

Taking this opportunity, on behalf of the Study Team, I would like to express my heartfelt gratitude to the personnel from JICA, Advisory Committee, Ministry of Foreign Affaires, Ministry of Construction, Embassy of Japan in Thailand and JICA Thai Office and Thai officials from Steering Committee comprised of relevant government agencies who extended the kind assistance and cooperation for the entire study period to the Study Team. The Study Team hopes that the results of this study contribute to the future implementation of sludge treatment/disposal and reclaimed wastewater reuse projects in Thailand and to socioeconomic development of Thailand.

Yours faithfully,

Keisuke Okazaki
Team Leader
The Study for the Master Plan on
Sewage Sludge Treatment/Disposal
and Reclaimed Wastewater Reuse in Bangkok



Location Map of the Study Area

THE STUDY FOR THE MASTER PLAN
ON
SEWAGE SLUDGE TREATMENT/DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK
IN
THE KINGDOM OF THAILAND

FINAL REPORT

MAIN REPORT

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Symbol	Description
AIT	Asian Institute of Technology
AS	Activated Sludge
ASP	Activated Sludge Plant
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Mass Transit Authority
BOD	Biochemical Oxygen Demand
BOO	Build, Operate, and Own
BOT	Build, Operate, and Transfer
BTS	Bangkok Mass Transit System Public Co., Ltd.
C/N	Carbon to Nitrogen Ratio
COD	Chemical Oxygen Demand
CWTP	Central Wastewater Treatment Plant
DDS	Department of Drainage and Sewerage (BMA)
DEQP	Department of Environmental Quality Promotion
DG	Director General
DID	Drainage Information Division
DO	Dissolved Oxygen
DPC	Department of Public Cleansing
DPW	Department of Public Works (in BMA)
DS	Dry Solids
DSD	Drainage System Division
DWF	Dry Weather Flow
EC	E Coil
EIA	Environmental Impact Assessment
F/C	Foreign Currency
FIRR	Financial Internal Rate of Return
F/M	Feed to Micro-organism Ratio
F/S	Feasibility Study
GIS	Geographic Information System
GDP	Gross Domestic Product
GOT	Government of Thailand
GW	Ground Water
ICB	International Competitive Bidding
IEAT	Industrial Estates Authority of Thailand
IEE	Initial Environmental Examination
IFI	International Funding Institution
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
L/C	Local Currency
LS	Lump Sum
MLSS	Mixed Liquor Suspended Solids

Symbol	Description
JV	Joint Venture
MOI	Ministry of Industry
MOSTE	Ministry of Science, Technology and Environment
MSL	Mean Sea Level
MSW	Municipal Solid Waste
MWA	Metropolitan Waterworks Authority
NEB	National Environment Board
NEQA	National Environment Quality Act
NESDB	National Economic and Social Development Board
NHA	National Housing Authority
NS	Night Soil
NSCD	Night Soil Control Division
NSTP	Night Soil Treatment Plant
O&M	Operation and Maintenance
OECF	Overseas Economic Cooperation Fund
PCC	Pollution Control Committee
PCD	Pollution Control Department, Ministry of Science, Technology and Environment
PR	Public Relations
PSP	Private Sector Participation
PV	Permanganate Value
PWA	Provincial Waterworks Authority

Symbol	Description
RID	Royal Irrigation Department
SAPROF	Special Assistance for Project Formation
SBR	Sequential Batch Reactor
SRT	State Railway of Thailand
SS	Suspended Solids
STC	Sludge Treatment Center
TDS	Total Dissolved Solids
TFY	Thai Fiscal Year
TOR	Terms of Reference
TSS	Total Suspended Solids
US EPA	United States Environment Protection Agency
VAT	Value Added Tax
VLR	Vertical Loop Reactor
VS	Volatile Solids
VSS	Volatile Suspended Solids
WMA	Wastewater Management Authority
WQMD	Water Quality Management Division
WW	Wastewater
WWTP	Wastewater Treatment Plant
WWTS	Wastewater Treatment System

List of Units

Symbol	Description
Extent	
ha	hectares
km^2	square kilometers
rai	1 rai = 1,600 m^2
Length	
cm	centimeters
km	kilometers
m	meters
mm	millimeters
Currency	
US$	United State Dollars
	US$ 1.0 = J¥ 120 = Baht 36
J¥	Japanese Yen
B	Thai Bahts
Time	
d	day
h	hour
yr	year
Volume	
l	liter
kl	kiloliters
l/c/d	liter per capita per day
m^3	cubic meters
m^3/d	cubic meters per day
m^3/hr	cubic meters per hour
m^3/min	cubic meters per minute
m^3/c/y	cubic meters per capita per day
Nm^3	Normal cubic meters

Symbol	Description
Weight	
g/c/d	grams per capita per day
kg	kilograms
mg	milligrams
mg/l	Milligrams per liter
t	ton
t/d	ton per day
t DS/d	ton Dry Solid per day
Energy	
kcal	kilocalories
kj/kg	kilo joules per kilogram
kPa	kilo Pascals
kW	kilo Watt
Mj/kg	Mega joules per kilogram
MN/m^2	Mega Newton per square meters
Mpa	Mega pascals
Others	
M or Mil	Million
MD	Man Day
ppm	parts per million
Khlong or klong	Canal
pers.	Persons

CHAPTER 1 INTRODUCTION

1.1 Authorization

Based on the Scope of Work agreed between the Bangkok Metropolitan Administration (BMA) of the Kingdom of Thailand and the Japan International Cooperation Agency (JICA), JICA made a contract with Nippon Koei to conduct the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok (the Study).

JICA, the official agency of the Government of Japan responsible for implementation of technical cooperation programs undertook the Study in accordance with the relevant laws and regulations in force in Japan and in close cooperation with the authorities of the Government of the Kingdom of Thailand. The BMA acted as a counterpart agency to the Japanese Study Team and as a coordinating body in relation to other relevant organizations for smooth implementation of the Study.

1.2 Background of the Study

The metropolitan area of Bangkok plays a role not only of the center for politics and the economy of the nation, but also the center of culture and tourism for the country. However, deterioration of the water environment over the years has brought urban degradation that may even impact on the political issues. In response to this, the improvement in wastewater management has become a key national issue.

Water quality conservation and provision of wastewater facilities were a major commitment of the 7th National Socioeconomic Development Plan, (1992 -1997). This lead to plans for the implementation of wastewater collection and treatment facilities, strengthening of water quality control and canal water quality improvement in the 4th Bangkok Metropolitan Administration Development Plan (1992 - 1996).

The BMA, in compliance with the national and regional development plans and revised edition of the Feasibility Study of Bangkok Sewerage System Project, 1982, by JICA, commenced the planning for establishment of wastewater disposal facilities. Since commissioning of the first scheme, the Si Phraya interceptor sewer and wastewater treatment plant in 1994, nine more wastewater schemes are now under construction (six schemes) or planned (three schemes).

However, with the completion of these schemes and their subsequent operation, large amounts of sewage sludge will be generated and plans are now required for its disposal.

As a result of rapid urbanization and development of industry in the metropolitan region of Bangkok there is an increasing demand for water. Due to the severe draught period in 1993, the Metropolitan Waterworks Authority (MWA) was obliged to cut water intake by 25 percent, so saving water and finding of new water resources is therefore required.

Thus, arrangements for the efficient disposal of sewage sludge and reuse of reclaimed wastewater are urgently required to meet the needs of waste disposal and improvement of urban environment, and as a counter-measure to the water shortage. In order to achieve these targets, the Government of the Kingdom of Thailand requested the Government of Japan to conduct a study of these issues. Consequently, the JICA Study Team was formed to carry out the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok.

1.3 Objectives of the Study

BMA has undertaken an explicit program for water quality conservation of Chao Phraya river and adjacent khlong in compliance with the National Plan. As a part of wastewater management in the Bangkok metropolitan area, BMA is now planning and implementing nine wastewater collection and treatment systems. The sludge that will be generated from these system requires proper treatment and disposal. Hence, the objectives of this Study focusing on the development of wastewater sector in Bangkok are:

1) To formulate a master plan for the year 2020 for effective sewage sludge treatment/disposal for BMA area,
2) To determine a viable reclaimed wastewater reuse plan for BMA area and
3) To transfer technical knowledge to the Thai counterpart personnel during the course of the Study.

1.4 The Study Area

The Study Area covers all of BMA area (1,569 km^2) controlled by the BMA. The area currently consists of 50 districts.

1.5 Organization of the Study

1.5.1 Japanese Organization

The Japanese organization consists of the Study Team under JICA direction and the Advisory Committee set up at the JICA headquarters.

Study Team

Mr. Keisuke Okazaki	Team Leader
Mr. Keith Hitchcock	Sewage Treatment Planner
Mr. Tadashi Shoji	Sludge Treatment Disposal/Environment Expert
Mr. Toshiki Naka	Reclaimed Wastewater Reuse Planner
Mr. John A. L. Chettoe	Organization/Institution Expert
Mr. Toru Ishibashi	Economic/Financial Expert
Mr. Tsutomu Yamamoto	Facility Designer/Cost Estimator
Mr. Shigenobu Hibino	Coordinator

JICA Advisory Committee

Mr. Haruki Takahashi	Chairman
Mr. Tsuyoshi Yanagi	Member

1.5.2 Thai Organization

Steering Committee

1.	Deputy Bangkok Governor	Advisor of the committee
2.	Ms. Hansa Sanguannoi Assistant Secretary to Bangkok Governor	Advisor of the committee
3.	Mr. Sutat Weesakul Chairman Board Committee of Flood Protection and Management	Advisor of the committee
4.	General Director of the Department of Drainage and Sewerage	President of the committee
5.	Deputy of General Director of the Department of Drainage and Sewerage	Committee member
6.	Expertise of Sewerage System	Committee member
7.	Director of the Department of Public Cleansing	Committee member
8.	Representative of the Department of Policy and Planning of BMA	Committee member
9.	Ms. Preeda Parkpian Environmental Engineering Program, Asian Institute of Technology	Committee member
10.	Ms. Orawan Sirirapiriya Chulalongkorn University	Committee member

11.	Mr. Suwit Chumnumsiriwat Sanitary Engineering Program Faculty of Public Health Mahidol University	Committee member
12.	Mr. Chart Chiemchaisri Environmental Engineering Program Faculty of Engineering Kasetsart University	Committee member
13.	Representative of Office of Environmental Policy and Planning Ministry of Science Technology and Environment	Committee member
14.	Representative of Department of Agricultural Promotion Ministry of Agricultural and Co-operatives	Committee member
15.	Representative of Department of Public Works Ministry of Interior	Committee member
16.	Representative of Wastewater Management Authority	Committee member
17.	Director of Water Quality Management Division Department of Drainage and Sewerage	Committee member and Secretary
18.	Chief of Technical Sub-Division Water Quality Management Division	Committee member and Secretary

Counterparts

Ms. Apinan Jaruchaiyakul	Chief of Technical Sub-division, DDS, BMA
Mrs. Suthimol Kessomboon	Sanitary Engineer DDS, BMA
Ms. Ubolwan Boontavee	Scientist, DDS, BMA
Ms. Chantana Rirattanapong	Scientist, DDS, BMA
Ms. Sermsook Pakkattang	Sanitary Scientist, DDS, BMA
Ms. Prayoon Chanya	Sanitary Scientist, DDS, BMA
Mr. Kitchapat Yinhirum	Civil Engineer
Mr. Prasith Inthachom	Civil Engineer
Mr. Suwapan Chiemrungsi	Civil Engineer
Mr. Kosit Srijaeng	Scientist

CHPATER 2 GENERAL CONDITIONS OF THE STUDY AREA

2.1 Natural Conditions

2.1.1 Topography

Bangkok is situated on the flat deltaic plain of the Chao Phraya River, part of the Lower Central Plain of Thailand. General ground levels in the city are 1 – 2 m above Mean Sea Level (MSL), although there are low spots within the Study Area almost down to MSL.

The city and its environs have been subject to land subsidence due to groundwater abstraction from deep aquifers and the resultant compression of intermediate clay layers, but subsidence is now being by brought under control by restricting groundwater abstraction.

2.1.2 Meteorology

Bangkok experiences a tropical humid climate influenced by the southwest and northeast monsoons. The climatic conditions are summarized below based on thirty year records from the Department of Meteorology, Bangkok.

There are three seasons:

i) Hot Season from February to April with maximum air temperatures of about 35° C,
ii) Wet Season from May to October caused by the southwest monsoon,
iii) Cool Season from November to January with a mean temperature of 21°C caused by northeast monsoon.

The average monthly temperature ranges from 25.6 to 29.7°C. Relative humidity is high between 71 % in January and 82 % in September and an average of 77 %. Total annual evaporation is almost 1,800 mm. Average wind velocities are in the range 2.0 - 4.8 knots, although much higher velocities occur during storms and typhoons.

2.1.3 Hydrology

Monthly rainfall varies from 9.1 mm in January to 344.2 mm in September. Total annual mean rainfall of 1,496 mm occurs during an average of 125 rainy days each year. Storms are usually intense but occur over limited areas moving across the city. Hyetographs used by BMA Department of Drainage and Sewerage (DDS) indicate hourly rainfall intensities of up to;

i) 61 mm/h for a 2 year storm,
ii) 87 mm/h for a 10 year storm,
iii) 150 mm/h for a 100 year storm.

These storms cause frequent short term flooding in low lying areas in many parts of the city as discussed in Section 2.1.5.

2.1.4 Geology and Hydrogeology

The soil conditions found in the Bangkok area are the result of long term sedimentation of material transported southwards by the Chao Phraya River. Many areas of Bangkok have a layer of imported fill to raise the land above flood level.

Bangkok soils have been classified into four general groups above the first sand layer:

i) Top soil of dark gray clay varying from 0.5 m to 3 m in thickness.
ii) Compressible soft and very soft clays from 3 m to 8 m thickness with an unconfined compressive strength less than 10 t/m^2 overlying medium strength clays. Their combined thickness varies up to a maximum of 16 m.
iii) Stiff and very stiff clays lie beneath typically from below 14 m depth but the interface wih the medium clays is generally not well defined. Compressive strengths are is in the range 10 - 40 t/m^2.
iv) Hard clays of a different colour lie below in thicknesses of between is 2 m and 6 m and have an unconfined compressive strength in excess of 40 t/m^2.
v) The first sand layer lies beneath the clays at depths of between 21 m and 24 m.

Groundwater in the BMA area and surrounding region originates in the central plain and flows through clay and rock layers before being stored in the underlying granular deposits. The Department of Minerals has carried out drillings to depths of 650 m, revealing eight aquifer layers before bedrock is encountered at depths of between 50 m and 550 m.

Excessive abstraction of groundwater up until the 1980s resulted in subsidence due to consolidation of the intervening clay layers. Saline intrusion into the higher aquifers resulted in their abandonment and exploitation of lower aquifers. Legislation restricted abstraction from the mid-1980s reducing the rate of subsidence.

A geological section through the Chao Phraya plain is shown in Figure 2.1.4.1

2.1.5 Drainage and Canal System

(1) Flood Control

Because of the low lying flat topography, many areas of BMA are liable to flooding. Subsidence caused by groundwater abstraction together with the continuous development of the city has exacerbated the problem. Drainage arrangements are therefore critical to life in the city.

As development has taken place, ditches have been replaced by concrete pipes and culverts laid in the roads which receive storm water from roadside gullies as well as other storm water and wastewater. These drain to extensive system of canals (khlongs) which have traditionally been a feature of Bangkok and have served for transport routes as well as land drainage.

Flood control systems have been developed over the years, defining flood protection zones by raised roads and dikes and installing flood gates and pumping stations to control levels in the khlongs. BMA now operate a sophisticated control system to regulate the system to minimize flooding in the city.

Storm water drainage is now designed on rainfall hyetographs adopting storm return periods of five years for the main drains and two years for subsidiary drains. Appropriate run-off coefficients are adopted to suit different land use. However, it is acknowledged that many of the older drains provide a lesser degree of flood protection.

The flat topography close to sea level results in low flows in the khlongs and much of the drainage system is unable to drain freely. Many of the drains remain full or surcharged and severe silting often takes place. This reduces their capacity for storm water removal, increasing the likelihood and extent of flooding. It also makes them less suitable for conveying wastewater efficiently, and wastewater often remains stagnant and putrefies in the drains releasing unpleasant sewer gas.

(2) Khlong Water Improvements

Due to the very limited wastewater services, the khlongs have become heavily polluted. A khlong water improvement project was initiated by JICA in 1990 and completed in 1996. The project comprises facilities to re-circulate cleaner water to the khlongs and to oxygenate the khlong water with aerators. These facilities are listed in Tables 2.1.5.1 and 2.1.5.2 and their locations are shown in Figure 2.1.5.1.

During the dry season from December to April, river water is pumped from the Chao Phraya River to the khlongs and polluted khlong water is pumped back to the river at an average of 2,083 m^3/min from Phra Khanong Pumping Station. The system includes gates on the khlongs which are needed to prevent salt water entering the khlongs at high tide, but despite this, some khlongs have become saline.

Several aeration systems have been installed in the khlongs and there is also a boat-mounted mobile aerator. There are also three aerated lagoons systems to treat khlong water: the Makkason Pond is to improve Khlong Sam Sen, the Rama IX Pond to improve Khlong Lat Phrao, and the Buddamonthon Sai 2 Pond to improve the Khlong Bang Jak. These are listed in Table 3.1.1.3 in the following Chapter and the main features of two of the ponds inspected are included in Data Book C.

The improvements to the khlong water are indicated in Table 2.1.5.3 in the four systems shown on Figure 2.1.5.1.

i) Considerable improvement was achieved in System 1 except for the Khlong Sam Sen and Khlong Huay Kwuang.
ii) Little improvement has occurred in System 2.
iii) Small improvements were acheived in Systems 3 and 4.

Pollution was especially poor in 1993 due to the shortage of rain.

2.2 Socioeconomic Conditions

2.2.1 Population and Population Forecasts

(1) Records of Current Population

Recent population statistics have been collected by the Study Team from the Ministry of Interior as shown in Table 2.2.1.1. These figures do not account for temporary residents or migrants and this has been investigated by NESDB who estimate the current (1999) population to be 7.5 million.

Table 2.2.1.1 Recent Population Statistics for BMA Area

Record	Year	Population
Census	1990	5,882,411
Registered Population	1990	5,546,937
	1991	5,620,591
	1992	5,362,141
	1993	5,572,712
	1994	5,584,226
	1995	5,570,743
	1996	5,584,963
	1997	5,604,772

(2) Population Forecasts

Inquiries were made concerning the best available population statistics and forecasts. The Bangkok Metropolitan Administration (BMA) City Planning Department has no recent data or forecasts although a demographic study is in progress. The Study Team reviewed the information included in past studies and a comparison of various population records and projections is shown in Figure 2.2.1.1

Population forecasts in the following studies were reviewed:

i) A Feasibility Study on BMA Wastewater User Charge, 1998,
ii) NESDB 1995 and 1983 population projections,
iii) The Pollution Control Department (PCD) Bangkok Metropolitan Region (BMR) Wastewater Master Plan, 1993, and
iv) The Master Plan for Water Supply and Distribution of Metropolitan Bangkok, 1990.

The 1998 BMA Wastewater User Charge Study included population forecasts based on an analysis of the population records and took account of past studies of population growth. Forecasts were made to 2017. Forecasts were made for the 36 districts and converted to the 50 new districts using subdistrict data, although the district boundaries were not finalized at that time. Adjustments were made to forecasts in each district from the average growth for the whole BMA area to allow for the potential for further development. Three zones were considered: an inner city zone, two intermediate zones east and west, and two outer zones beyond.

Population forecasts for the BMA area were developed by NESDB in 1985 and 1995 but only forecast to 2010. The 1995 projection shown in Table 2.2.1.2 identified some 1.5 million unregistered persons and took account of birth and death rates, life expectancy, population migration, and the effects of AIDS from a 1993 survey. This was used in national development policy and was adopted by GOT agencies including BMA at that time.

In the 1993 PCD BMA Wastewater Management Master Plan, the existing population and growth rates were based on the average of the different census data and registered population records. Forecasts were made to 2020 for each of the 36 districts at that time. Adjustments were made to the forecasts in each district from the average growth for the whole of the BMA area to allow for the potential for further development in each district based on current population densities.

The 1990 Water Supply Master Plan also made a compromise between the census and registered population data in predicting current population and future growth. Forecasts were made for the 24 districts that BMA had at that time up to 2017.

The Wastewater User Charge study, the 1993 Wastewater Management Master Plan, and the MWA Water Supply Master Plan investigated past records and were based on population statistics at a district level; the Wastewater User Charge study also made use of subdistrict level data. All drew from population records over the preceding years and were researched in detail, and the two later studies made appropriate assumptions concerning migration and growth in different parts of the BMA area related to development potential. However, the forecasts differ significantly. For the BMA area as a whole the difference in 2020 is 13 % and as much as 36 % for some districts. Differences in forecasts in 2000 also vary considerably indicating differences in interpretation of the records. However, since the Wastewater User Charge study is based on later records and had the benefit of the earlier studies including the NESDB forecasts, it is considered to be the best available guide to future populations. BMA now use the Wastewater User Charge study for their population forecasting purposes and it is adopted for use in this Study.

The User Charge study gives population forecasts in each of the 50 proposed new district areas. Population forecasts from the User Charge study have been extrapolated from 2017 to 2020 to meet the planning horizon of this Study and these are shown in Table 2.2.1.3. The population forecast for the BMA area in 2020 is 11.9 million. Forecast population densities in each of the districts in 2020 are shown in Figure 2.2.1.2. Some changes to district boundaries have occurred since the User Charge study was prepared. However, these are mostly small and population densities are generally used in the analysis of proposed service area populations so they are not significant for this Study.

2.2.2 City Planning and Land Use

The BMA City Planning Office prepares Land Use Plans with a 20 year planning horizon and revise these every 5 years. These are incorporated into the 5 year National Socioeconomic Development Plans and so become government policy. The current plan is included in the 8th National Plan (1997-2002) and draws from a number of studies including the Massachusetts Institute of Technology Bangkok Plan (1995-2005). The current Land Use Master Plan is shown in Figure 2.2.2.1.

A key feature of the Land Use Plan is the environmental protection zone east of the King's Dike to the east of the city where development will be restricted, though satellite development is forecast to take place beyond this at Nong Jok and in the south of Lat Krabang near to the planned second airport. Rapid development is also expected to take place along the main roads to the west and southwest of the city. In the east, a number of key developments are being established at strategic road junctions in the suburban area before reaching the King's Dike.

2.2.3 Water Supply and Consumption

(1) Current Water Abstraction and Treatment

The water supply of Bangkok City was initiated in 1914 supplying 400 households in the central part of the city. In 1967, the Metropolitan Water Works Authority (MWA) was established under the Ministry of Interior to provide water to the metropolitan area.

The main water resource is the Chao Phra River. The main water treatment plant at Bang Khen has a capacity of 3,200,000 m^3/d and draws water from an intake at Sam Lae in Pathum Thani Province 96 km upstream of the estuary which is delivered through an 18 km canal. The Sam Sen treatment plant with a capacity of 700,000 m^3/d and the Thonburi treatment plant with a capacity of 170,000 m^3/d also draw water from the Chao Phra River. The fourth treatment plant constructed in 1966 at Maha Sawat abstracts water from the Tha Chin River and has a capacity of 400,000 m^3/d. Groundwater abstraction is currently 140,000 m^3/d but this is being phased out as it is causing ground subsidence as described in Section 2.1.1. Total MWA supply capacity is currently 4,668,000 m^3/d.

(2) Development Plans

Water demand is forecast to increase to 8,200,000 m^3/d in 2017 according to the 1990 Master Plan for Water Supply and Distribution of Metropolitan Bangkok. This is to be provided by development of the Maha Sawat plant to a capacity of 4,000,000 m^3/d. The scheme includes a dam on the Tha Chin River at Vajiralongkorn and a 70 km canal to deliver raw water to the plant. Groundwater abstraction is to be maintained as an emergency resource.

Table 2.2.3.1 lists the present and planned future capacities of these plants.

(3) Water Distribution

MWA serves most of the urban areas of the city and is extending its service area to all urban development within the BMA area and into Samut Prakan. Their 1997 annual report indicates that their service provides 1,342,000 customers with 945,000 million m^{3} of water each year over an area of 1,100 km^2 from the four water treatment plants. In 1997 the number of customers and water supplies were increasing at 4 % each year and the service area extending at a rate of 13 % pa. The growth of MWA services is shown in Figure 2.2.3.1.

2.2.4 Solid Waste Disposal

(1) Collection

Solid waste collection and disposal services are provided by BMA Department of Public Cleansing (DPC) and district offices. Detailed records of these services are available and the main features are given in Table 2.2.4.1. Apart from solid waste collection and disposal, DPC also collects and incinerates infectious wastes from hospitals. About half of the solid waste collected is organic.

Table 2.2.4.1 Solid Waste Collection Services: 1996/7

Properties with collection service	634,532 (37 % of total in BMA area)
Average daily collection	8,314.25 m³/d
Infectious waste collection from hospitals	8,040.09 kg/d
Manpower (BMA & Districts)	13,116
Collection vehicles (BMA & Districts)	
Collection trucks etc	2,031 (1 - 5 t capacity)
Road sweep. & wash., & tree cutting	160
Boats	55
Transfer stations	
Number	3
Location	Nong Khaem On-Nut Tharaeng

Over the past ten years the amount of solid waste collected has doubled and this is expected to double again over the next fourteen years.

(2) Disposal

At On-Nut, part of the waste is segregated and the organic material composted. The plant is owned by BMA but managed by a contractor who sells the product.

The remainder of the solid waste is disposed in two sanitary landfills by contractors. The contractors collect solid waste from the transfer stations and are responsible for acquiring the landfill site as well as landfill operations. Information on the landfills is included in summarized in Table 2.2.4.2 and reports on site inspections included in Data Book B.

Table 2.2.4.2 Solid Waste Disposal: 1999

Method	Compost and Sale	Sanitary Landfill			
Location	On-Nut	Kampangsaen	Lad Krabang	Samuk Prakarn	Bang Khun Thien
Area	n/a	160 ha	35 ha	c 30 ha	35 km^2
Status	Operational	Operational	Operational	Preparation	Planned
Daily Quantity	1,000 m^3/d	4,000 t/d	3,500 t/d	3,500 t/d	not determined
Total Capacity	n/a	40 million t	6 million t	6 million t	140 million m^3
Remaining Capacity	n/a	38 million t	Little	6 million t	
Remaining Life	n/a	> 30 years	< 1 year	c 5 years	>> 30 years
Condition	Satisfactory	Good	Poor		
Impact on Environment	Little	Little	Damaging		

The two current landfills are sealed with clay and have leachate abstraction and treatment systems but no gas management.

i) The landfill at Kampangsaen is well managed with regular soil covering. There are few residents in the vicinity and the landfill causes little inconvenience.

ii) The Lad Krebang site is poorly operated and causes offensive odors to nearby residents.

The contractor for the Lad Krebang landfill is currently preparing a new landfill site in Samuk Prakarn but few details are available. The development of an extensive landfill at Bang Khun Thien on land owned by BMA is being investigated. However, this area is not ideal, as it is swampy and currently used for prawn farming.

No consideration has been given to using wastewater or night soil sludges as a cover material.

Despite current sanitary landfill disposal plans, DDS is considering alternative disposal options but proposing that prospective contractors tender for solid waste disposal term contracts selecting their own disposal methods. This is likely to result in sanitary landfill as this is expected to be the least cost option.

2.2.5 Public Health

Poor sanitary conditions prevail in many parts of Bangkok and BMA's current program of wastewater schemes should result in significant improvements.

Records of some water-related diseases generally associated with sanitary conditions in the Annual Epidemiological Surveillance Report of the Epidemiological subdivision, Disease Control Division, Department of Health, BMA are listed in Table 2.2.5.1. These, however, will not represent the true extent of water-related diseases as most cases will not be recorded.

Table 2.2.5.1 Reported Cases of Some Water Related Diseases

Intestinal Tract Diseases	1993		1994		1995		1996		1997	
	C	D	C	D	C	D	C	D	C	D
1. Acute Diarrhea	44,749	-	44,492	10	39,307	5	39,313	-	46,169	-
2. Food Poisoning	2,178	-	1,924	-	1,300	-	1,523	-	2,054	-
3. Dysentery - Total	1,170	-	930	-	613	-	676	-	599	-
- Bacillary	194	-	128	-	112	-	138	-	67	-
- Amoebic	49	-	26	-	26	-	36	-	33	-
- Unspecified	927	-	776	-	475	-	502	-	499	-
4. Enteric Fever - Total	217	-	147	-	143	-	807	-	218	-
- Typhoid	62	-	65	-	60	-	244	-	105	-
- Paratyphoid	4	-	9	-	18	-	445	-	54	-
- Unspecified	151	-	73	-	67	-	118	-	59	-

Note: C = Cases,
D = Deaths

2.2.6 Economic Development Plan and Index

(1) The 8th National Economic and Social Development Plan

The 8th National Economic and Social Development Plan for the five year period 1997-2001 emphasizes shifting the development paradigm from a segmented approach to holistic people-centered development, with the goal of achieving a sustainable development pattern, for which investment promotion in the rehabilitation and protection of urban, regional and rural environments is listed in the major targets of the plan.

With regard to environmental management, the plan stresses to ensure that water quality does not fall below 1996 standards in rivers, seas, coastal areas and all natural water resources, with particular emphasis on the lower Chao Phraya River and others. Furthermore, it encourages long-term investment in comprehensive wastewater treatment in regional economic centers including Bangkok Metropolitan region (BMR) and other regional centers.

As the development guideline to improve environmental management in terms of water quality, it is proposed to collect fee for raw water from industrial and agricultural producers and from domestic consumers, for which the pricing structure should be adjusted to properly reflect the actual costs of procurement, production, distribution and wastewater treatment.

Along this national environmental development strategy, the Central Government has been assisting BMA by providing financial support in the field of wastewater treatment by constructing wastewater treatment plants in the BMR.

(2) The BMA Development Plan

In the 5th Bangkok Metropolitan Development Plan for 1997 to 2001, deterioration of environmental conditions is listed as one of the most significant problems of Bangkok metropolis and, therefore, the plan clearly describes that the construction of unfinished wastewater treatment plants continue so as to enable them to operate in their full capacity. In addition, the plan mentions that three new wastewater treatment plants are to be constructed.

The wastewater related projects listed in the sub-work plan are (1) construction of the fifth (Phrakanong and Khlong Toey), sixth (Thonburi) and seventh (Nong Bon) phase of the common wastewater treatment system, (2) consecutive constructions of ongoing plants including Yannawa, Nong Khaem, Pasicharoen, and Tatburana, and (3) improvement of small-scale treatment plants from NHA.

(3) Current Economic Conditions in the Country

The economic crisis in Thailand started on July 2, 1997 after the Thai Government decided to introduce a floating Thai Baht, after which the Thai Baht sharply depreciated from 25.79 to 56 Baht/US$ in January 1998. Shortly after the economic crisis, the Government agreed to follow the IMF Guidelines to obtain its loan to reform the Thai economy with significant government budget cuts, an increase of VAT from 7 % to 10 %, and an order to close 42 finance companies.

During this period, the real GDP annual growth rate has become negative and is estimated to be –0.4 % and –7.0 % in 1997 and 1998, respectively. However, due to Government efforts and political stability, the Thai economy has been recovering gradually, showing positive fundamental economic indicators, e.g., (1) the acceptable annual inflation rate is 5.6 % in 1997 and is estimated 9.2 % in 1998, which is less than the expected rate, (2) the exchange rate has become stable at around 36 Baht/US$, (3) the trade balance has been in surplus by a sharp increase in exports, i.e., 28.0 % and 57.5 % in 1997 and in 1998(up to July).

Although other economic indicators, such as private investment, production, consumption, and unemployment, show that the Thai economy is still in recession, it is certain that the Thai economy is actually recovering.

2.2.7 Financial and Economic Conditions in the Area of Environmental Preservation

(1) National Level

The environment related budget has rapidly increased in the last two decades in Thailand. The wastewater related budget had the largest share, i.e., 88.35 % of the total execution budget in 1993, according to the report titled "A Feasibility Study of BMA Wastewater User Charge, May 1998". These environmental preservation activities have been managed and implemented by various ministries, among which major players are Ministry of Science, Technology, and Environment (MOSTE), Ministry of Industries (MOI), and Ministry of Interior. The Ministry of Interior is responsible for managing environmental preservation activities at the provincial level including BMA.

During the high growth period, namely, 1992 to 1997, the overall national budget had increased by an average annual growth rate of 11.9 %, while the total environment development budget of all relevant ministries had increased by 19.9 % per annum and the environment related BMA budget had increased by 29.4 % per annum, as shown in Table 2.2.7.1. This clearly indicates that the Central Government has been paying more attention to environmental preservation, especially for BMA area which has been suffering more from environmental deterioration by its rapid urbanization and industrialization.

Due to the economic crisis, however, the overall national budget has dropped by 16.2 % in the 1998 Thai Fiscal Year (TFY) and the total environmental development budget and the BMA's environment budget have decreased more sharply by 50.3 % and 69.5 %, respectively. This is reasonably considered as the exceptional budget allocation in a case of emergency by the Thai economic crisis.

Table 2.2.7.2 shows the detailed Central Government budget structure in the field of environment in the 1997 TFY, from which the followings are observed;

i) MOSTE, Ministry of Interior (exclude BMA), and BMA have the major budget holders from the Central Government with shares of 38.57 %, 26.49 %, and 26.32 %, respectively, followed by Ministry of Industry with 5.46 %.

ii) Administrative and managerial budget has 6.91 % share, all of which belongs to MOSTE. These activities include policy making, database development, network development, public participation, which implies that MOSTE is expected to function as a headquarter of the national environmental development activities.

iii) Environmental project implementation budget has 82.04 % share and all BMA budget come from this portion, which include Ratanakosin Wastewater Treatment Plant (WWTP), Din Daeng (Stage 1) WWTP, dredging canal project, Yannawa WWTP, Nong Khaem garbage disposal project, Nong Khaem-Pasicharoen-Ratburana WWTP, and Chatuchak (Stage 4) WWTP.

iv) Research and planning portion has 8.74 % share, mainly used by MOSTE. This is a budget mainly to identify measurements in protecting environmental deterioration.

v) It seems that a large part of the budget is used for water quality management, compared to air, industrial toxins, and noise.

(2) BMA

1) Overall

Major findings of the BMA financial data shown in Table 2.2.7.3, are as follows:

i) The total expenditure of BMA has been constantly growing at the rate of 16.9 % per annum for the last five years at current prices. Since the general consumer price index for the period ranges from 5.1 % to 5.9 % per annum, the actual annual growth of the BMA expenditure is 11.4 % on average, which is quite high.

ii) The BMA financial balance has been continuously in surplus for the last five years and the remaining budget has been reserved and accumulated as the BMA fund for emergency use. (Note that the 1998 budget appears negative in the table, only because the amount of special revenue from the Central Government has not been fixed yet.)

iii) The debt-service ratio of the BMA is currently zero, since all current and ongoing projects of wastewater treatment plants have been financed for 60 % by the Central Government and for 40 % by the BMA. This proportion might be changed for the future BMA projects.

iv) The expenditure for drainage and wastewater treatment has been one of the highest growing activities for the last five years, which implies that an important priority for the BMA is to improve drainage and wastewater treatment.

v) All these observations clearly indicate that, from a financial viewpoint, the BMA is capable enough and needs to implement and manage the project on sewage sludge treatment/disposal and reclaimed wastewater reuse

2) Department of Drainage and Sewerage (DDS)

Major findings of the financial data of DDS shown in Table 2.2.7.4 and Table 2.2.7.5 are given as follows:

i) The budget for wastewater management has a large share of the DDS budget since 1996, i.e., 62 % in 1996 and 39 % in 1997, because construction of the large scale wastewater treatment plants started, which include Din Daeng, Yannawa and Nong Khaem and Ratburana.

ii) Salary budget is reasonably low at the level of 9.5 % (9.49 %=7.79 %+1.70 % and 9.44 %=7.59 %+1.85 % in 1996 and 1997, respectively). In order to cope with human resource demand to operate the forth coming five wastewater treatment plants, however, the long term human resource development plan and its financial arrangement will become necessary very soon, unless they are completely privatized.

iii) Expenditure of overtime and small equipment has remained at the level of around 6 %, which implies that the operation and maintenance activity may not have significant constraints, at least that affect the budget.

3) Department of Public Cleansing (DPC)

Major findings from Table 2.2.7.6 and Table 2.2.7.7, the financial data of DDS, are given as follows;

i) The budget of public cleansing has been also growing at the rate of 15.4 % per annum for the last five years, reflecting the growing environmental awareness.

ii) The labor cost is relatively low, ranging between 15 % to 20 % (19.88 %=18.30 %+1.58 % and 14.73 %=12.47 %+2.26 % in 1996 and 1997, respectively) and the expenditure of overtime and small equipment has maintained at the level of around 10 % (12.49 % and 9.03 % in 1996 and 1997, respectively).

iii) In order to improve efficiency and to reduce the DPC's work load, dumping and treatment plant operations have been privatized under the DPC management.

4) Revenue Structure

Major findings from Table 2.2.7.8, Detailed BMA Revenue Structure, are given as follows;

i) The overall revenue is divided into 2 parts, i.e., BMA revenue and Commercial revenue. The former has 98.69 %, while the latter has only 1.31 % in the 1997 TFY.

ii) The BMA revenue consists of Permanent revenue and Special revenue which the Central Government supplies. The former has 85.79 % and the latter has 12.89 % in the 1997 TFY.

iii) The Permanent revenue consists of (1) tax, (2) Fee/Service/Fine/License, (3) Revenue from property, (4) Revenue from public utility and commerce and (5) Miscellaneous. Tax and Revenue from property contribute by 77.72 % and 5.45 % in the 1997 TFY, respectively.

iv) Major Tax items are (1) Value added and special tax (40.00 %), (2) Car and vehicles tax and fee (15.51 %) and (2) Property and land tax (14.96 %) in the 1997 TFY.

v) Major item of Revenue from property is Bank interest (5.32 %) from the accumulated BMA Fund.

Some revenue items related to the Study are: (% in the total BMA revenue)

• Garbage collections fee	60.00 Mil. B.	0.21 %
• Waste collections fee	23.80 Mil. B.	0.08 %
• Cleansing service	2.40 Mil. B.	0.01 %
• Checking water quality	0.05 Mil. B	0.00 %

These observations indicates:

- The BMA revenue heavily depends on tax relevant items which are steady income sources,
- The BMA revenue from services and activities is very limited, and
- The accumulated BMA fund seems to make a quite significant contribution to its financial structure.

Note that it appears the total revenue of the 1998 TFY decreased, which is because Special revenue has not been decided yet for the year.

2.2.8 Administrative Boundaries

The BMA area is divided into districts and subdistricts. The districts are being re-arranged from 36 to 50. Some changes to district boundaries have occurred since the User Charge study was prepared but these are mostly small. The current district boundaries are shown in Figure 2.2.8.1.

CHAPTER 3 EXISTING SEWERAGE SYSTEM IN BANGKOK

3.1 Existing and Ongoing Wastewater Treatment Systems and Facilities in BMA

3.1.1 Public Wastewater Services Program

(1) Major Wastewater Schemes

1) Current BMA Wastewater Services Program

In the early 1990s, BMA embarked on a major program of wastewater sewerage and wastewater treatment schemes to improve water quality in the khlongs and in the Chao Phraya River. The initial project in Si Phraya became operational in 1994 and currently six more schemes are being implemented. These are all expected to be completed by 2003 and will provide services over a total area of 192 km^2 for an initial population of 2.2 million and 3.4 million when the later phases of treatment are constructed. The location of these schemes is indicated in Figure 3.1.1.1, the main features of these services included in Table 3.1.1.1, and further details included in Data Book A

2) Si Phraya Interceptor Sewer and WWTP

The Si Phraya Wastewater Scheme serves a population of 120,000 in an area of 2.7 km^2 in the older part of the city. It includes a 2.3 km interceptor sewer laid beneath khlong Phadung Krung Kasem and direct connections from the drainage system. After preliminary treatment, biological treatment can be provided on three floors for flows up to 30,000 m^3/d within a completely housed building using the activated sludge contact stabilization process. The treated effluent is chlorinated before discharge to the khlong shortly up-stream of the Chao Phraya River. Sludge is de-watered to a cake by belt presses and transported for disposal and use in Queen Sirikit Park, a public park in the city. The plant also includes a rapid gravity sand filter for further treatment of effluent to be used for road washing.

The WWTP produces an excellent quality effluent considerably superior to the khlong water, but the organic loading on the plant is much smaller than planned as the BOD of the influent is low, average 61 mg/l. Records of the plant performance are included in Data Book M. Possible reasons for the low BOD concentration are discussed in Sections 4.1.2 and 6.1.1.

The khlong will not be much improved until the Din Daeng and Ratanakosin schemes are complete as the khlongs are interconnected. Furthermore, treatment at Si Phraya WWTP does not much benefit the khlong as the outfall is close to the Chao Phraya river and the benefits to the Chao Phraya River are less important.

3) Wastewater Schemes under Construction

a) Flows and Loads

In the later schemes (Nong Khaem, Ratburana, and Chatuchak), wastewater flows are based on populations derived from project feasibility studies and a per capita flow of 376 l/c/d. This is based on water consumption forecasts by the Metropolitan Waterworks Authority (MWA) and assumes 256 l/c/d for domestic consumption and 120 l/c/d for all other use. Wastewater flows for the Din Daeng scheme were derived directly from water demand forecasts. Wastewater loads for all of the larger schemes are derived from an assumed BOD load concentrations listed in Table 3.1.1.2.

Table 3.1.1.2 Specified Wastewater Quality and Treated Effluent Quality Requirements for BMA Wastewater Schemes

Parameter	Wastewater Influent Quality Assumed for Design		Treated Effluent Quality
	Phase 1 (mg/l)	Phase 2 (mg/l)	(mg/l)
BOD	150	200	20
Suspended Solids	150	200	30
N (total)	30	35	10
N (NH_3)	-	-	5
P	8	10	2
DO	-	-	5

b) Sewerage Systems

The new schemes all adopt the interceptor sewerage system in which wastewater carried by the combined drains is intercepted before discharge to the khlongs and diverted to new interceptor sewers. The interceptor or diversion chambers are hydraulically designed to accept 5 x Dry Weather Flow (DWF) into the interceptor sewers and to allow excess flows to pass to the khlongs.

The large capacity drains laid to flat gradients are sized to carry storm water and are not ideal in conveying wastewater in dry weather. In particular, waste solids are deposited in the drains which putrefy and cause hydrogen sulfide gas release through the un-sealed manholes. However, all properties are required to have septic tanks installed to accept toilet wastes or other forms of wastewater treatment at source, and this should limit deposits of fecal matter in the drainage system. Proper operation of the septic tanks and regular cleaning of the drains is an important requirement of the interceptor sewerage system, and these should be improved for the new wastewater schemes to be fully effective.

The interceptor sewers in the BMA schemes are designed to carry 5 x DWF. However, the hydraulic control systems cannot limit diverted flows precisely and this specified requirement is interpreted differently in the various schemes. In the Yannawa scheme, overflows to the khlong commence when the diverted flow to the Interceptor sewer is 5 x DWF and larger flows are diverted to the interceptor sewer as storm flows increase. In the Nong Khaem and Ratburana schemes, overflows to the khlong commence when less than 5 x DWF is diverted to the Interceptor sewer but are designed to rise to 5 x DWF under full storm flow conditions.

c) Wastewater Treatment Plants

The Wastewater Treatment Plants (Central WWTPs) are designed to give preliminary treatment (screening and grit removal) to 5 x DWF, and full treatment to 1.5 x DWF in the initial phase and to 2.5 x DWF in future phases. Wastewater quality is assumed for design purposes as set out in Table 3.1.1.2. Full treatment comprises biological treatment and the later schemes also require nutrient removal to effluent quality standards, and these are also set out in Table 3.1.1.2. The need for nutrient removal is to avoid eutrophication in the khlongs.

Various forms of the activated sludge treatment process are adopted. These include two-stage activated sludge at Ratanakosin where nutrient removal is not required, and conventional activated sludge at Din Daeng, the sequential batch reactor process at Yannawa and the vertical loop reactor system at Nong Khaem and Ratburana which require nitrogen and phosphorous removal. The sequential batch reactor process at Yannawa is modified to remove nutrients biologically but the Din Daeng, Nong Khaem and Ratburana WWTPs require chemical treatment for phorous removal. Biological phosphorous removal processes are more complicated and require careful control and skilled operator staff. Chemical treatment is simpler but requires the addition of chemicals which add to the plant operating costs.

All these Central WWTPs except that at Nong Khaem are multi-story plants with treatment processes on several floors. The Nong Khaem plant has a conventional open layout. The Central WWTPs at Ratanakosin and Yannawa are to have full air management and odor control systems but those at Din Daeng and Ratburana have air management and odor control only for the inlet pumping and preliminary treatment processes.

The Yannawa Central WWTP, like that at Si Phraya, is located on the bank of the Chao Phraya River and treatment therefore will not benefit the khlongs but improve river quality.

d) Sludge Treatment and Disposal

Sludge is required to be pressed to a cake of at least 20 % dry solids (DS) and thickeners and belt presses are to be used for this purpose at all plants with polymer (artificial poly-electrolyte) pre-conditioning. Lime is added as powder to the sludge cake to control odor rather than as a means of sludge stabilization. Sludge cakes from Ratanakosin, Din Daeng and Chatuchak are to be trucked from the Central WWTP sites but arrangements for subsequent disposal are not yet made. Sludge cakes from Yannawa and Ratburana are to be trucked to Nong Khaem to be re-liquefied and anaerobically digested together with locally produced liquid sludge. Digested sludges are to be subsequently de-watered to a 20 % DS sludge cake for disposal off the WWTP site yet to be arranged. The Chatuchak Central WWTP is also to include sludge digestion plant.

The use of lime to control odor will need to be restricted if it is not to impair subsequent digestion processes.

e) Night Soil Treatment

The Central WWTPs at Yannawa and Ratburana will accept a total of 1,400 m^3/d of night soil and this is screened and added to the sludge streams for thickening and de-watering.

f) Implementation Program

The Ratanakosin and Din Daeng schemes are delayed due to contractual difficulties but it is expected that the Ratanakosin scheme will nevertheless be completed in 1999. Completion of the Din Daeng scheme, which is now 86 % complete, remains uncertain. The Yannawa scheme is also scheduled for completion in 1999 and the Nong Khaem and Ratburana schemes in 2001. A contract for the Chatuchak scheme is planned to be let early in 1999 and programmed for completion in 2003.

These anticipated completions are indicated in Table 3.1.1.1 and in Data Book A.

(2) Community Wastewater Schemes

Fourteen Community WWTPs were constructed for the National Housing Authority (NHA) and all but one have now been taken over by BMA. The main features of these are given in Table 3.1.1.3 and those inspected are reported in Data Book C and their locations shown in Figure 3.1.1.2.

These generally serve populations of between 1,000 and 20,000 with treatment provided by conventional or extended aeration activated sludge plants or aerated lagoons. Some are served by separate sewerage and others treat effluent from NHA septic tanks. Many are in poor condition but BMA plan to renovate these. Although BMA are currently studying the cost-effectiveness of these plants they have no plans to extend them or construct further Community WWTPs. The present total serviced population of these plants of 133,000 is expected to remain constant.

BMA have also taken over three aerated lagoon plants for improving khlong water quality.

(3) Further Major Wastewater Schemes Planned

1) Khlong Toey and Thonburi Schemes

a) Current Plans

A pre-investment study has been undertaken for these schemes complete with preliminary engineering. This Special Assistance for Project Formation (SAPROF) study was undertaken for the Overseas Economic Cooperation Fund of Japan (OECF) in 1998 with a view to bi-lateral funding for these schemes. Both projects are listed in Section 3.3.1 of the Bangkok Metropolitan Development Plan (1997 - 2001). Information on these planned schemes is included in Data Book A and the service areas and proposed Central WWTP sites shown on Figure 3.1.1.1.

Both schemes are based on the 1993 Pollution Control Department (PCD) Bangkok Metropolitan Region (BMR) Wastewater Management Master Plan proposals as regards service areas and populations. They adopt the design criteria regarding per capita flows, the type of sewerage system, peak flow factors, sewage quality and treated effluent and sludge quality requirements of the current BMA schemes described above.

Both schemes are large, serving ultimate populations of 694,000 and 1,381,000 respectively as determined by SAPROF Study. Neither scheme provides for night soil treatment or sludge digestion.

A feasibility study is planned for the Khlong Toey Scheme funded by USAID and this is likely to take place in 2000.

b) Proposed Plans

It is proposed to divide the schemes into smaller packages for populations of between 200,000 and 500,000 for more convenient management, to allow incremental development, and to limit the lengths of trunk sewers especially in the Thonburi scheme.

The earlier Khlong Toey scheme is divided in two, West and East, by Khlong Phra Khanong. The WWTP for Khlong Toey West is as previously proposed in the port area and a new site is proposed for Khlong Toey East south of the Bang Na expressway. However, the feasibility study will consider the whole of the earlier scheme area. A key factor will be whether a second WWTP site could be acquired for the Khlong Toey East area.

The earlier Thonburi scheme is divided into three, North, Central, and South by the major khlongs, Bangkok Noi and Bangkok Yai, and Central WWTPs are proposed in each proposed service area at newly proposed sites.

These revised schemes proposals are described in Sections 6.1.3 and 6.1.4.

2) The Nong Bon Scheme

This scheme is also included in the Bangkok Metropolitan Development Plan (1997 - 2001) but it has not been studied. In the evaluation of priority requirements for wastewater services included in Section 6.1.2, Nong Bon is not identified as a priority area despite the likelihood of development as a result of the planned second Bangkok Airport in Samut Prakan Province close by.

3.1.2 Wastewater Treatment System of Private Sectors

(1) Septic Tanks

All private properties are required to have some form of wastewater treatment. Small private houses are required to have septic tanks to accept toilet wastes and these generally have outlets to the drains or khlongs. Other domestic wastewaters pass directly to the drains. Septic tank effluents cannot generally be disposed of by leaching into the soil because of the high groundwater and impermeable clay soils. Typical septic tank arrangements are shown in Figure 3.1.2.1.

Building regulations concerning the installation of septic tanks are understood to be well enforced through the district offices. However, there is no regulation concerning the removal of septage or night soil, and night soil is only removed on request of the property owner. Furthermore night soil collection services are limited as described in Section 3.2.2 and night soil collection services are limited. If night soil is not regularly removed, the septic tank will become ineffective.

(2) Private Wastewater Treatment Plants

1) Regulation and Enforcement

Larger properties and housing estates are required to provide WWTPs to treat wastewaters to prescribed quality standards set out in the Building Effluent Standards in the Laws and Standards on Pollution Control in Thailand, PCD, MOSTE, 4th edition, 1997 included in Data Book F. These require wastewaters to be treated to standards of between 50:50 BOD: SS (mg/l of BOD and suspended solids) and 20:30 BOD:SS depending on the size of the premises. Biological treatment will be necessary to achieve all these standards. Only small restaurants and shops are permitted to discharge less treated wastes.

Five such plants were inspected and found to be operating satisfactorily but it is understood that some WWTPs are constructed and not properly utilized.

2) Treatment Facilities

A variety of treatment processes are used in these plants. Of those inspected, they included various types of activated sludge plant and anaerobic filters. Sludges may be tankered out in liquid form, de-watered to cakes and trucked out, or sun dried on the site. Details of the WWTPs inspected are included in Data Book D and summarized in Table 3.1.2.1.

(3) Industrial Wastewater Disposal

1) Regulation and Enforcement

The current industrial wastewater regulations as set out in the Laws and Standards on Pollution Control included in Data Book F require that most industries treat their wastewaters to a standard of 20 mg BOD /l.

However some industries (animal processing and food products, starch, textiles, tanning, paper and pulp, chemicals, pharmaceuticals and frozen foods) are permitted to produce an inferior quality effluent to a standard of 60 mg/l, and it is likely that at least half the wastewater producing industries in Bangkok are in this category.

The Department of Industrial Works in the MOI is responsible for regulating and enforcing treated industrial wastewater quality. Under the Environmental Quality Act, 1992, failure to comply with these effluent standards may result in fines of four times the cost of treatment together with environmental damages costs and costs of damage to public wastewater services. However, the Department's records imply that enforcement is inadequate and this might be expected from an institution whose main task must be to support and promote industrial development.

2) Treatment Facilities

Serviced industrial estates are being developed complete with wastewater collection and treatment facilities. The present industrial estate in Lat Krebang has a 16,000 m^3/d capacity WWTP and together with those being developed in Bang Chan, Minburi will provide for 221 factories. Four other industrial estates are being planned in the BMA region: a large one in the Ratburana and proposed Thonburi South wastewater scheme areas, another large one in the proposed City South West scheme area and two small ones in the proposed City South West and Nong Bon scheme areas. However the majority of industries will remain outside the industrial estates and although several of the larger industries are proud to claim good environmental credentials (compliance to ISO 9001), many of the medium and smaller enterprises may provide little treatment. The Singha Beer WWTP was inspected and found to be satisfactory. Details are also provided in Data Book D and summarized in Table 3.1.2.1.

3.2 Existing Night Soil Treatment Systems

3.2.1 General

Collected night soil means the septage, which is taken out from the receiving or treatment tanks for night soil, like septic tanks, leaching, cesspools, etc. It includes sludge from private WWTPs in large hotels, apartment blocks and office buildings. The effluent water from septic tanks and the likes is normally led to drain ultimately joins nearby watercourses. Due to the absence of sufficient infrastructure for collection and treatment of septage, the sludge often overflows to water bodies and sometimes is disposed off illegally.

The responsibility for the collection of night soil lies with the Department of Public Cleansing (DPC). The district offices are in charge of looking after the collection needs of the individual houses, but for the collection from large buildings (i.e. hotels, apartments, condominium, etc.) and government institutions are controlled directly by the DPC. The fee for desludging of on-site night soil treatment tanks is Baht 50 per m^3 of collected night soil.

The normal desludging frequency for a septic tank, leaching pit, etc. varies from once a year to three years. Collection services are only provided when the owner makes a request or there are complaints of nuisance caused by overflowing on-site treatment tanks.

3.2.2 Night Soil Collection Service

Table 3.2.2.1 presents the vehicles employed for night soil collection in BMA in the districts and in the DPC. Each vehicle is manned with one driver and two laborers.

Table 3.2.2.1 Night Soil Collection Vehicles in BMA at Present

Capacity	BMA District Offices	BMA DPC	Total
2 m^3	134	18	152
5 m^3	9	5	14
7 m^3	23	0	23
12 m^3	89	16	105
Total	255	39	294

Source: Compiled by JICA Study Team, based on the data given by DPC.

Night soil service areas in BMA are separated into two zones: Nong Khaem and On-Nut. The Nong Khaem service area is located in the western part of BMA area, covering a land area of 693.9 km^2 and a population of some 5.5 million, as shown in Table 3.2.2.2. Meanwhile, the On-Nut service area is located in the eastern part, covering a land area of 286.4 km^2 and population of some 2.3 million

Table 3.2.2.2 Outline of Current Night Soil Service Area

Items \ Service area		Nong Khaem	On-Nut	BMA total
Land area	(km^2)	693.9	286.4	980.3
Living population	(x 1,000)	5,461	2,264	7,725
Collected night soil[1)]	(m^3/d)	732	286	1,018
Collection ratio based on collected quantity	(%)	13.4	12.7	13.2
Treated night soil	(m^3/d)	450 (400 to 500)	200	650
Actual collection ratio based on treated quantity	(%)	8.2	8.8	8.4

Note: 1) The quantity was calculated based on 1.0 l/c/d of night soil generation rate.

Based on the tariff collection records, the total collected night soil in the whole of BMA area is calculated as 1,018 m^3/d, resulting in 13 % of the collection ratio on the population base, as shown in Table 3.2.2.3. On the other hand, the quantities of actually treated at NSTPs are 450 m^3/d (400 to 500 m^3/d) and 200 m^3/d at Nong Khaem and On-Nut, respectively. Accordingly, the actual collection ratio of night soil is regarded to remain at 8.4 % on the whole. While the whereabouts of collected night soil other than treated one is unknown, some of them might be illegally disposed off to some watercourses.

3.2.3 Night Soil Treatment

At present, the night soil treatment plants (NSTP) are working at Nong Khaem and On-Nut. The Nong Khaem NSTP, as shown in Figure 3.2.3.1, is presently operated by the subcontractor of DPC. This is about eight years old and has facilities for primary, secondary and tertiary treatment. Some 150 m^3/d of leachate from the adjacent landfill site for municipal solid waste mixed in and treated with night soil. The On-Nut NSTP, shown in Figure 3.2.3.2, is operated by BMA staff. The treatment process is similar to that at Nong Khaem, except there is no denitrification stage.

The maximum design capacity of each of the NSTPs is 600 m^3/d. However, these are not being operated at their full capacity. Apart from the shortage of the vehicles for night soil collection, one of reasons is that the treatment plants have suffered from problems with mechanical components, resulting in only limited capacity. At the present, the Nong Khaem NSTP receives about 400 to 500 m^3/d of night soil, whereas only some 200 m^3/d arrives at the On-Nut NSTP.

Besides the Nong Khaem and the On-Nut NSTP, other night soil treatment schemes are ongoing along with the Central WWTP construction projects at

Yannawa and Ratburana. In either Central WWTPs, collected night soil will be treated together with sewage sludge, after screened and stored in tank. The night soil treatment capacity at the Yannawa and the Ratburana Central WWTP are planned as 1,000 m³/d and 400 m³/d, respectively.

3.3 Existing Sludge Treatment/Disposal Systems

3.3.1 Current Sludge Generation and Treatment/Disposal

(1) Sludge Generation and Treatment

At the moment, only the Si Phraya Central WWTP is working in BMA area as the central wastewater treatment system. Community wastewater treatment systems, like the Huay Kwuang Cmmunity WWTP, are under operation at 14 places in BMA. Besides these, the night soil treatment plant is also in existence at Nong Khaem and On-Nut. As shown in Table 3.3.1.1, the quantities of sludge generated from all those sources are estimated at 17.9 t DS/d.

Table 3.3.1.1 Present Sludge Generation in BMA Area

Items / Sludge generation source	Dry sludge quantity (t/d)	Wet sludge quantity (m³/d)	Moisture content (average base) (%)
Si Phraya Central WWTP	0.3	1.8	85
Community WWTPs[1]	7.6	51	85 (assumed)
Nong Khaem NSTP	6.5	26	75
On-Nut NSTP	3.5 (3 to 4)	17.5	80
Total	17.9	96.3	-

Source: Compiled by JICA Study Team.
Note: 1) Final Report of Master Plan Study on Treatment and Disposal of Domestic Sewage Sludge including Night Soil and Oil and Grease Residues for Bangkok Metropolitan, AIT (1995)

Almost all of sludge mentioned above is discharged as sludge cakes after dewatered by dehydrators. Among all sludge treatment systems, only the Huay Kwuang Community WWTP is equipped with digester to stabilise sludge but digestion gas is simply burn out without being utilised as recovered energy.

(2) Current Ultimate Disposal

Sludge cakes from the Si Phraya Central WWTP and the Huay Kwuang Community WWTP are used for sludge fertilizer or soil conditioner in nearby parks, after mixed with ash, coconut husk, or soil.

Sludge cake from the On-Nut NSTP is also used in city parks. Most of sludge cakes from the Nong Khaem NSTP are disposed of in a nearby dumping site, except for a small part being utilized for agricultural land.

3.3.2 Ongoing Sludge Treatment/Disposal Schemes

Respective Central WWTPs under ongoing status, i.e.: Ratanakosin, Din Daeng, Yannawa, Nong Khaem, Ratburana, and Chatuchak, have been planned to construct sludge treatment facilities in each site. Except that the Chatuchak WWTP is under consideration for sludge digestion, all other WWTPs have been planned to construct sludge thickening and dewatering without employing sludge digestion.

The sludge treatment facilities of the Central WWTPs in Yannawa and Ratburana are planned to receive night soil and to treat it with mixing sewage sludge. The quantities of night soil received in the Central WWTPs in Yannawa and Ratburana are specified as 1,000 m^3/d and 400 m^3/d, respectively.

The Nong Khaem Sludge Treatment Center (STC) is also ongoing. This is designed collectively to treat sludge generated from the above Central WWTPs with the maximum capacity of 120 t DS/d. As for the sludge transportation to the Nong Khaem STC, the truck transportation after dehydration in respective sites has been scheduled. The sludge transported to Nong Khaem is supposed to be treated by digestion and dehydration, after dissolution with clean water. While ultimate sludge disposal after treatment is not clarified, landfill disposal and agricultural use appears to be aimed. This scheme has been delayed due to contractual problems but it is reported to inaugurate the operation in 2001. The Nong Khaem STC is further detailed in the subsection 7.3.4.

3.3.3 Previous Sludge Treatment/Disposal Studies

The DDS of BMA engaged the Asian Institute of Technology (AIT) to undertake the study for the treatment and disposal on sludge generated from wastewater systems and night soil treatment systems in BMA, namely:

- Master Plan on Treatment and Disposal of Domestic Sewage Sludge including Night Soil and Oil and Grease Residues for Bangkok Metropolitan (1995), and
- Feasibility Study on Agricultural Use and Land Application of Sewage and Night Soil for Bangkok Metropolitan (1998).

The former Master Plan recommended two main treatment and disposal options:

- *First Priority* : Mono-incineration at a central sludge processing facility after dewatering at the Central WWTPs, and

- *Second Priority* : Agricultural uses after dewatering at the Central WWTPs, or composting of sludge at a central processing facility after dewatering at the Central WWTPs and using the sludge product for agricultural use or land reclamation.

The later Feasibility Study was concerned with the agricultural use of wastewater and night soil sludge. This concluded that the potential for sludge utilization on agricultural land exceeded anticipated sludge production. The section 7.2.4 in this Report has quoted the results of this Feasibility Study, in detail.

3.4 Existing Wastewater Characteristics

3.4.1 Existing Wastewater Quality from WWTPs

Table 3.4.1.1 summarizes the results of wastewater analyses both from treatment plants and from samples from the drains.

(1) Si Phraya and Huay Kwuang Wastewater Treatment Plants

Good wastewater quality and flow records are available from these WWTPs and are included in Data Book M and summarized in Table 3.4.1.1. These give monthly averages of weekly samples and so do not indicate the full variability of wastewater quality.

The incoming sewage to Si Phraya Central WWTP averages 61 mg/l and values between 37 and 89 mg/l. This low strength does not account for the pollution loads produced within the service area as identified in Section 4.1.1. This is explained by BOD losses in the combined drainage system due to dilution and biological de-composition and is discussed and accounted for in Section 6.1.1. The flow to Si Phraya WWTP is often limited by the operating capacity of the pumping equipment.

The wastewater inflow to Huay Kwuang Community WWTP is more typical of urban wastewaters in major cities around the world. Incoming wastewaters average 246 mg/l and values between 160 and 400 mg/l. The Huay Kwuang WWTP service area has a predominantly separate sewerage system where there is little opportunity for dilution and biological de-composition so that little BOD reduction would be expected.

(2) Other Wastewater Treatment Plant Records

Limited records of wastewater quality and quantity are available from the other BMA Community WWTPs. Information from the other five WWTPs visited is included in Data Book M and the limited wastewater quality data is also included in Table 3.4.1.1. These indicate typical strength wastewaters similar to that at Huay Kwuang WWTP.

No records were available of the performance of private WWTPs.

3.4.2 Previous Wastewater Quality in the Drainage System

(1) Wastewater Quality Investigation by Yannawa Wastewater Project Contractor

The contractor for the Yannawa Wastewater project sampled wastewaters twice at four locations in the scheme area in April 1995. These analyses are presented in Data Book J and summarized in Table 3.4.1.1 and indicate an average BOD in the scheme area of 69 mg/l with values ranging between 26 and 214 mg/l. These demonstrate the generally low strength and high variability of the wastewater.

(2) Wastewater Quality Investigation by JICA Expert

A JICA expert to BMA investigated wastewater quality at two locations in the drainage system in Lumphini in 1998. These analyses are presented in Data Book K and summarized in Table 3.4.1.1. At one location the BOD was found to average 225 mg/l with a maximum of 300 mg/l. At the other the average BOD was 45 mg/l. The average of all these analyses of 135 mg/l is included in Table 3.4.1.1. These results indicate the large variability in wastewater quality.