BANGKOK METROPOLITAN ADMINISTRATION (BMA)

PREPARATORY SURVEY FOR BANGKOK WASTEWATER TREATMENT PROJECT IN THAILAND

FINAL REPORT (II) FEASIBILITY STUDY VOL. 1 SUMMARY

JULY 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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1. WORK SCHEDULE AND IMPLEMENTATION OF PHASE 2 WORK

1.1 Work Schedule for the Entire Survey and Objectives of Phase 2 Work

The Preparatory Survey for Bangkok Wastewater Treatment Project was conducted dividing the whole period (approx. 15 months) into two phases, i.e. phase 1 (6 months) and phase 2 (9 months). The Survey flowchart is as shown in Figure 1.1.

The objective of the phase 2 work is feasibility study for the priority project selected under phase 1 work. The phase 2 work was carried out from September, 2010 to April, 2011.

"Interim Report (I)" in Figure 2.1 was changed to "Final Report (I)", "Final Report" was changed to "Final Report (II)". Date of EIA Stakeholder Meeting (I) was changed from November 2010 to February 2011, and Report Meeting (2) was cancelled.

1.2 Project Area of the Phase 2 Work

Phase 2 work was carried out for Nong Bon treatment area in BMA.

1.3 Implementing Organizations in Thailand

The implementing organization for the Survey is the Department of Drainage and Sewerage (hereafter refer to as "DDS") of BMA. Water Quality Management Office of DDS is the counterpart organization for the Survey.

1.4 Basic Policies for the Survey

The Survey work was conducted based on the basic policies described in Inception Report (2).

1.5 Survey Organization

Consultant Survey Team is composed of 4 persons from Tokyo Engineering Consultants Co., Ltd., and 3 persons from Nippon Koei Co., Ltd. The Survey Team which carried out phase 1 work continued to carry out phase 2 work.

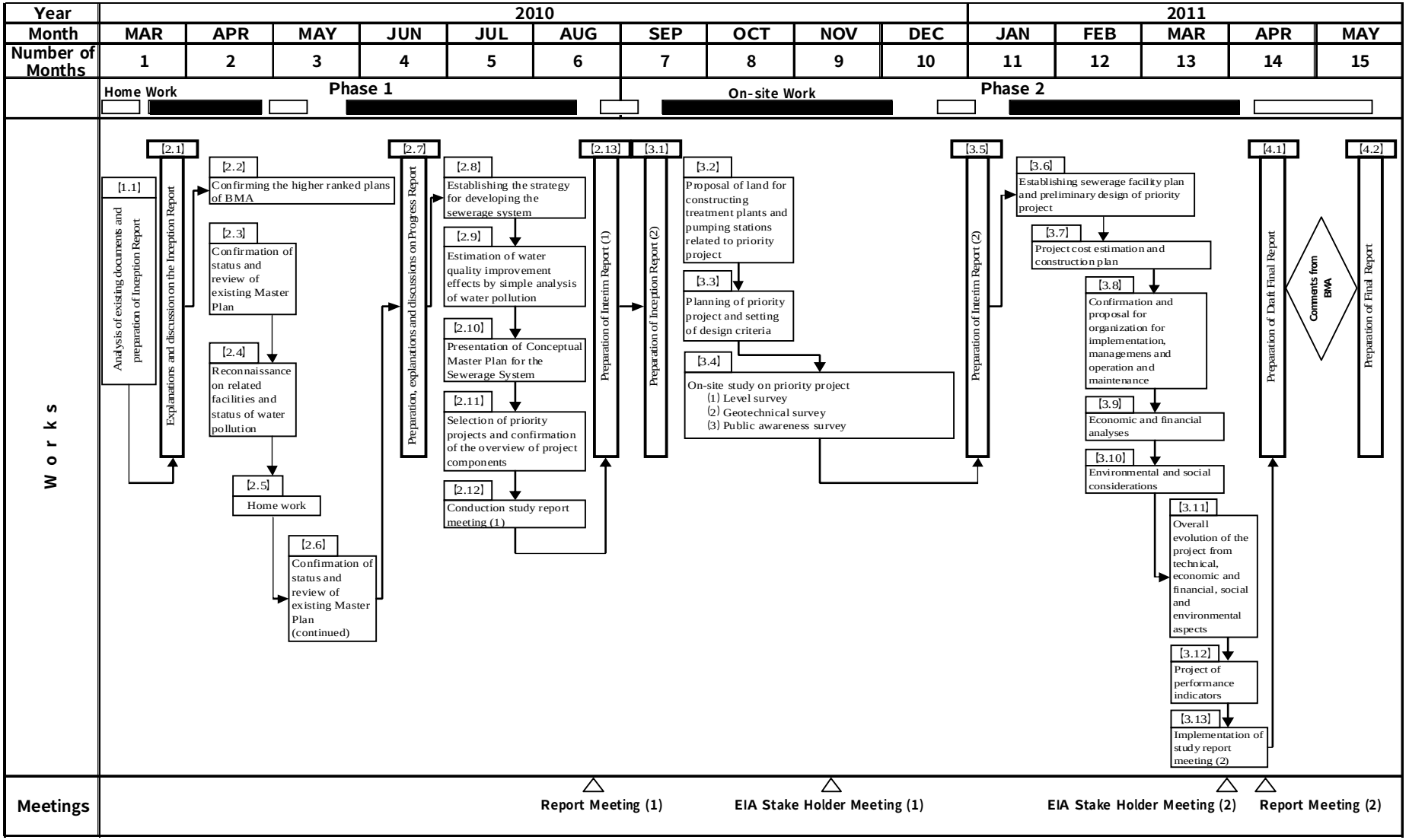


Figure 1.1 Flowchart of the Survey

2. OUTLINE OF NONG BON TREATMENT AREA

2.1 Outlines of the Treatment Area

Nong Bon treatment area is bordered with the motor way and airport link to the new airport and Pattaya on the north, with densely inhabited Klong Toei treatment area where sewerage system is to be developed on the west, and with Samut Prakan Province on the east and south.

In the city planning land use in Nong Bon treatment area is categorized as medium-density residential and commercial areas in south-western part and low-density residential areas in the remaining parts. Airport link has been put in operation in the northern part of the area, and an elevated railway is planned on the Srinakharin road in the western part. These two transportation systems are located in low-density residential areas. Population growth and development pressure are envisaged in future because the area is located in between developed urbanized area in the west (Klong Toei treatment area) and Suvarnabhumi airport in the east.

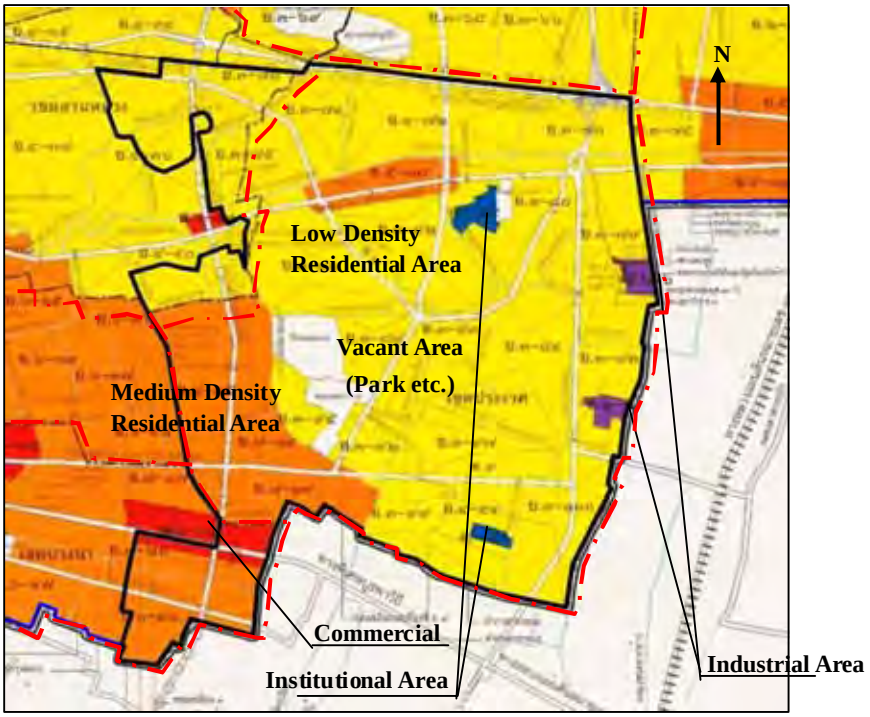
2.2 Target Year, Planning Area, Wastewater Collection System, and Reuse of Treated Wastewater and Sludge

(1) Target Year

The target year of M/P for Bangkok Wastewater Treatment Project is set at 2040, and its aim is to treat 80% of all wastewater generated in BMA by that time. The target year of the priority project, Nong Bon Wastewater Treatment Project is set at 2020. However, for design of interceptors which is difficult to expand its capacity by stages, wastewater flow in 2040 is used. On the other hand, for design of mechanical and electrical equipment of the WWTP which can be expanded easily by stages, wastewater flow in 2020 is used.

(2) Planning Area

Nong Bon treatment area was determined in updated M/P, is composed of tree districts, i.e. Bang Na, Prawet and Suan Luang Districts, and totals 6,385 ha. The treatment area is composed of residential, commercial, institutional and industrial land use areas according to land use plan 2020 prepared by City Planning Department of BMA. Figure 2.1 shows land use areas in the treatment area, and Table 2.1 shows area of each land use area.



Source: JST

Figure 2.1 Land Use Plan in Nong Bon Treatment Area

Table 2.1 Area of Land Use Category in Nong Bon Treatment Area

(ha)

Low Density Residential	Medium Density Residential	Commercial	Industrial	Institutional	Vacant, Park etc.	Road, Klong	Total
4,671	1,207	87	35	55	205	125	6,385

Source: JST

(3) Wastewater Collection System

Combined system (interceptor sewerage system) is adopted to utilize effectively the existing drainage system.

(4) Reuse of Treated Wastewater and Sludge

Treated wastewater is effectively used for sprinkling trees and for beautification of scenery in BMA. Reuse of treated effluent from Nong Bon WWTP for these purposes in adjacent Rama IX Park is to be considered.

Whole sludge produced in all WWTPs in BMA is to be treated at Nong Khaem WWTP. Reuse

of sludge by composting and generation of electricity by digestion gas have been experimented. Sludge produced at Nong Bon WWTP is also planned to transfer to Nong Khaem WWTP.

2.3 Design Frame

(1) Design Population

Design population of Nong Bon treatment area is shown in Table 2.2. Two of three districts which formulate Nong Bon treatment area, viz. Prawet and Suan Luang show population increase.

Table 2.2. Design Population of Nong Bon Treatment Area

(person)

District	2020	2030	2040
Bang Na	27,432	27,432	27,432
Prawet	191,670	203,770	216,470
Suan Luang	19,762	20,371	20,981
Total	238,863	251,574	264,883

Source: JST

(2) Design Wastewater Flow

Design wastewater flow in Nong Bon treatment area is as shown in Table 2.3.

Table 2.3 Design Wastewater Flow in Nong Bon Treatment Area

	Population (person)	Unit Water Supply (lpcd)			Water Supply (m^3/day)	Return Ratio (%)	Wastewater Generated (m^3/day)
		Residential	Non-residential	Total			
2020	238,863	186	279	465	111,071	80	88,857
2030	251,754	197	296	493	124,026	80	99,221
2040	264,883	200	300	500	132,442	80	105,953

	Wastewater Generated (m^3/day)	Sewer Coverage Ratio (%)	Wastewater Collected (m^3/day)	Infiltration Ratio (%)	Infiltration (m^3/day)	Design Wastewater Flow (m^3/day)
2020	88,857	70	62,200	40	24,880	87,080
2030	99,221	80	79,377	40	31,751	111,128
2040	105,953	90	95,358	40	38,143	133,501

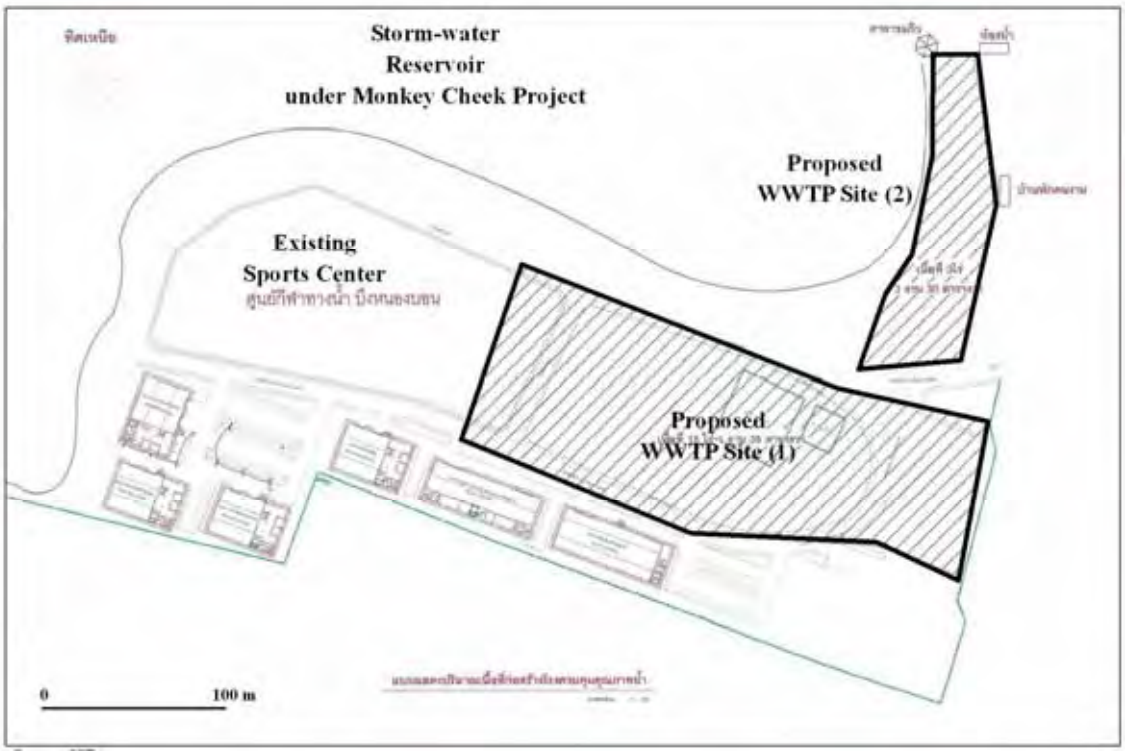
Source: JST

2.4 Site for Construction of WWT

Outline of the site for Nong Bon WWTP is shown in Figure 2.2.

Site for construction of WWTP is located in the neighborhood of Rama IX Park and in the site of storm water reservoir constructed under Monkey Cheek Project which is administrated by DDS. Water sports center which is managed by Culture, Sports and Tourism Department of BMA was constructed and a part of the reservoir is opened to the public. Construction of an administration building of DDS (Mechanical Division and Drainage Control Structures System Division) and workshops has been started in a part of DDS administration site.

Only a remaining part of the site, with an area of approximately 3.5 ha (out of which 1.1 ha can be used for above ground facilities) can be used for construction of WWTP. This area is very narrow for the WWTP with design capacity of 135,000 m^3/day. Compact type treatment facilities are to be adopted, and efficient use of underground and above ground is required. According to the results of geological survey, there exists a layer with N value more than 40 at 30 m depth and bearing layer with N value more than 50 appears at 40 m depth.



Source: JST

Figure 2.2 Proposed Site of Nong Bon WWTP

3. PRELIMINARY DESIGN OF INTERCEPTOR

3.1 Design of Interceptors

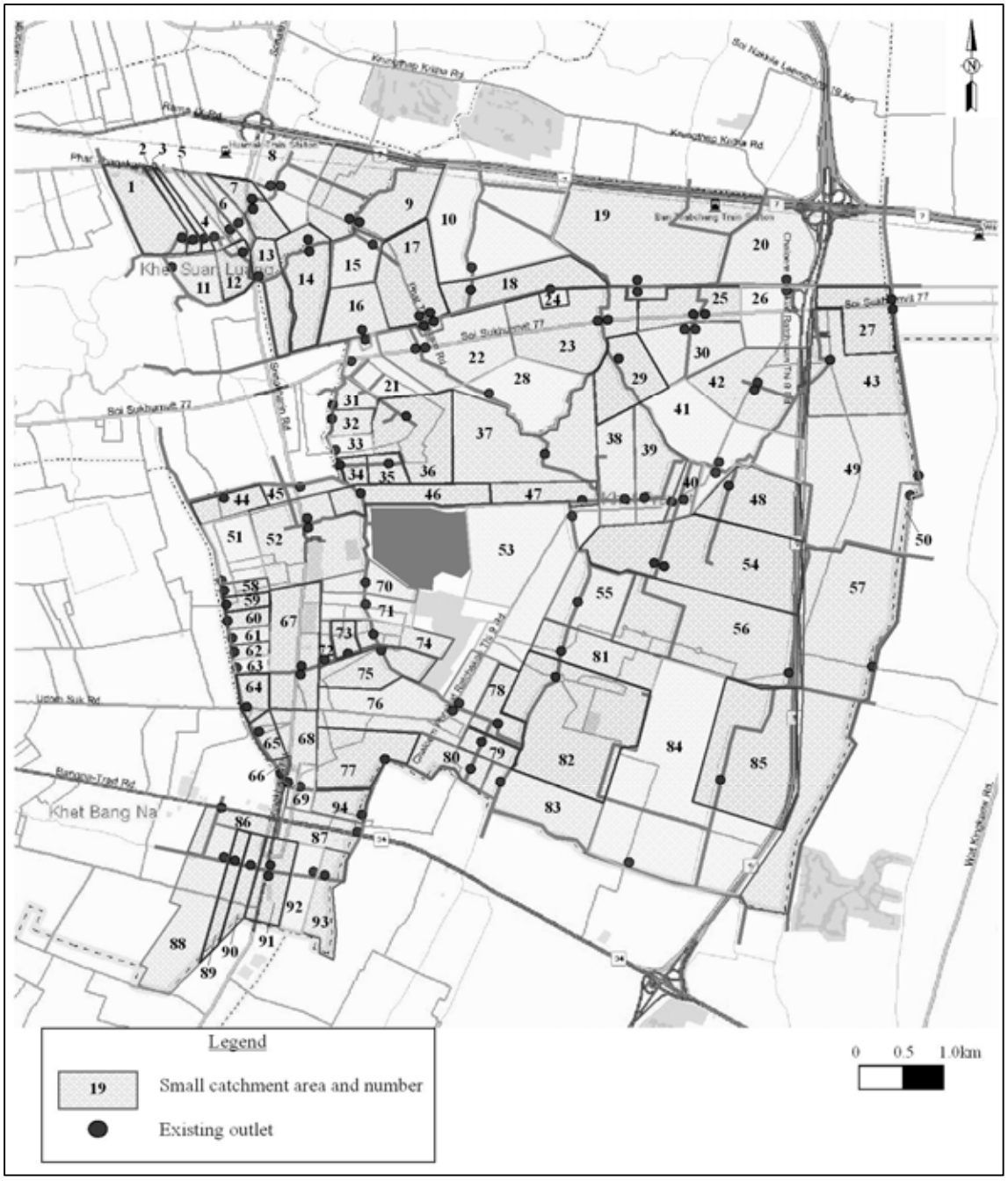
3.1.1 Design Wastewater Flow

(1) Division of Catchment Areas by Existing Outlets

Interceptor chambers are to be constructed before outlets to intercept wastewater not to be discharged to klongs (interceptor sewerage system). The treatment area can be divided into small 94 catchment areas by each of these outlets or a group of outlets which are located at both sides of the road or klong or closely each other as shown in Figure 3.1. A total of wastewater generated in these 94 small catchment areas is design wastewater in Nong Bon treatment area.

(2) Wastewater by Small Catchment Areas

Design population and design wastewater flow is presented in the former Section 2.3 Design Frame. Design wastewater flows by small catchment areas are estimated based on the design frame.



Source: JST

Figure 3.1 Catchment Areas of the Existing Outlets

3.1.2 Basic Items

(1) Intercepting Rate

Intercepting rate for interceptor chamber is set at 5DWF and intercepting rates for design of interceptors are set at 2 to 5DWF.

(2) Structure of Interceptor Chamber

Appropriate weir levels and diameters of orifices should be designed taking into account wastewater inflow and water level in klong. Orifice should be provided as required. A flap gate should be provided to prevent back flow from klong. Level of weir should be designed higher than high water level in klong, if possible.

(3) Reduction of Number of Interceptor Chamber

The method to reduce interceptor chamber is that a few of interceptor chambers closely located are integrated into one chamber and close all the outlets of the remaining chambers. However, since the existing drain pipes and outlets are under the responsibility of PWD, consultation and coordination with PWD would be required to apply this method.

(4) Laying of Interceptors (Under Klong or Road)

Interceptors are to be raid under roads or klongs. There are merits and demerits in both cases. Most suitable places should be selected.

(5) Pipe Laying Method

Intereptors become very deep in Nong Bon treatment area wether there are raid under roads or klongs because most of the interceptors cross klongs. Therefore, for construction of interceptors, open cut method is not suitable.

Generally, construction cost of pipe jacking method is less expensive than that of shield method if diameter is less than 2,000 mm. Pipe jacking method can be applied if the length of work is less than approximately 1,000 m. Interceptors in Nong Bon treatment area satisfy these conditions, therefore, pipe jacking method is applied for construction of interceptors.

(6) Pumping Stations

Rely pumping station is necessary at the most downstream of interceptors. However the site is very close to the WWTP site. Therefoere, rely pumping station is not planed and wastewater is pumped by pumps installed in WWTP.

(7) Wastewater Collection Method for Direct Discharge to Klong

Combined system (interceptor sewerage system) is adopted in Nong Bon treatment area as well

as in the other treatment areas in BMA. An interceptor chamber is constructed at upstream of outlet to intercept wastewater to interceptor. Construction of an interceptor chamber is difficult at the point where wastewater is discharged from a house to klong directly.

It is proposed that a method to collect wastewater by exposed pipes installed along a klong and intercepted at downstream be adopted, which is often seen in the mountainous areas in Japan.

3.2 Routing of Interceptors

3.2.1 Route Selection

The following prerequisite conditions are established for selecting interceptor routes.

1) All of the existing outlets are intercepted.
2) Interceptors are laid under klongs or roads.
3) Outlets are connected to WWTP by shortest possible routes since the topography of the treatment area is almost flat.
4) Collected wastewater is conveyed to the construction site for WWTP in neigbohood of Rama IX park.

Finally, wastewater is planned to flow into WWTP by two lines in order to reduce diameter of the interceptor resuling in reduction of construction cost. The most suitable route was selected and proposed as shown in Figure 3.2.

- Total length of interceptors: 64.3 km
- Average depth of interceptors: 10.3 m
- Depth of interceptors at WWTP: GL -20 to -21 m

Source: JST

Figure 3.2 Route of Interceptors

3.2.2 Summary of Interceptors

Sizes, lengths and other conditions of interceptors and vertical shafts for construction are summarized in Table 3.1.

Table 3.1 Summary of Interceptors

Interceptor			Vertical Shaft			
Diameter (mm)	Length (m)		Number		Average depth (m)	
	Under road	Under klong	Under road	Under klong	Under road	Under klong
300	480	0	4	0	6.9	-
450	0	1,455	0	11	-	7.8
600	4,970	24,900	36	172	7.5	8.1
800	4,025	9,720	27	50	14.9	10.0
1,000	4,270	755	22	5	11.7	13.3
1,200	1,595	4,125	11	23	16.7	14.8
1,500	4,970	2,645	21	19	19.0	15.6
2,000	385	0	3	0	20.6	-
Total	20,665	43,600	124	280	-	-

Source: JST

3.3 Issues and Technical Countermeasures in Future

As described in Conceptual Master Plan Report, there are many issues regarding the interceptor sewerage system. These issues should be resolved on medium- and long-term basis after implementation of the proposed project including construction of WWTP, interceptors and interceptor chambers under this F/S.

3.3.1 Prevention of Back Flow from Klong

Provision of a flap gate is planned in an interceptor chamber to prevent back flow as can be seen in other treatment areas. When flap gate is not completely closed by clogging of garbage, it can not prevent back flow from klong. Therefore the following short-term and medium- and long-term countermeasures are required.

- Periodical cleaning of interceptor chamber is to be carried out as short-term countermeasures.
- Convert the treatment area to pump drainage area and close all outlets of interceptor chamber as medium- and long-term countermeasure.

3.3.2 Enhancement of Connection of Uncollected Wastewater to Interceptor

It is very important to collect uncollected wastewater to realize water quality improvement in

public water bodies. To realize complete (100 %) collection of wastewater in future, compulsory connection to sewerage system in a treatment area by regulations and subsidy from district office or BMA for the cost of house connection should be considered.

The above enhancement of connection should be conducted by PWD with cooperation with DDS, the former department is currently responsible for connection between houses and drain pipes.

3.3.3 Strengthening of Operation and Maintenance of the Existing Drainage Pipes

The existing drainage pipes are under responsibility of PWD or district office, and DDS is responsible for construction and operation and maintenance of interceptor chambers and interceptors. Issues about operation and maintenance of the existing drainage pipes became clear through data collection and site visits for this F/S, which are shown in Table 3.2.

Table 3.2 Issues and Countermeasures about the Existing Drainage Pipes

Category	Issues	Countermeasures
Management of information about pipes	Data about the drainage pipes are required for this F/S, but necessary data are not available because construction was very old. District office was forced to prepare these data. Sewerage inventory which is common in many countries including Japan is not prepared. Management of information is dependent on certain engineers' memory.	Sewerage inventory is to be prepared as quickly as possible, although time and cost are necessary. Electronic inventory which links to map information was introduced in large cities in Japan. This is useful tool for efficient management of information about sewerage system in Bangkok.
Grasp of internal conditions of pipes	Cleaning of drainage pipes is conducted. However current status of deterioration of pipes is yet to be grasped.	There is a possibility of accident caused by road subsidence because of damage of aged or deteriorated pipes. These accidents can be avoided by countermeasures in advance if the status of the pipes is grasped. Monitoring by TV camera should be carried out according to plan.
Flow capacity of pipes	Flow capacities of the existing pipes are not known, although interceptors are designed to flow 5 DWF to WWTP. There is a possibility of spilling of storm water runoff before interceptor chamber even if interceptors are installed correctly.	Investigate all existing drainage pipes of its catchment, calculate storm water runoff and evaluate their capacities. If capacity is not enough, replacement or construction of new pipes should be carried out.

Source: JST

4. PRELIMINARY DESIGN OF NONG BON WWTP

4.1 Basis for Planning

4.1.1 Outline of Nong Bon WWTP

Outline of Nong Bon WWTP which have been selected for the Priority Project are summarized in Table 4.1.

Table 4.1 Outlines of Nong Bon WWTP

Item	Value / Remark
Treatment capacity	135,000 m^3/day for MP targeting 2040
WWTP proposed site	Beside storm water reservoir under Monkey Cheek Project next to Rama IX Park (Area 3.5ha, out of which 1.1 ha can be used for above ground facilities)

Source: JST

4.1.2 Design Wastewater Characteristics

Design wastewater characteristics for Nong Bon WWTP and effluent standards are summarized in Table 4.2.

Table 4.2 Design Water Quality

Parameters	Influent characteristic		Effluent Standards
	2040(M/P)	2020(F/S)	
pH			5.5 – 9
Biochemical oxygen demand (BOD)	150 mg/l	100 mg/l	20 mg/l
Suspended solids (SS)	150 mg/l	100 mg/l	30 mg/l
Total nitrogen (T-N)	30 mg/l	20 mg/l	10 mg/l
Nitrogen (Ammonia)	-	-	5 mg/l
Total phosphorus (T-P)	8 mg/l	6 mg/l	2 mg/l
Dissolved oxygen (DO)	-	-	5 mg/l
Fat, oil and grease	-	-	5 mg/l

Source: JST

4.1.3 Projected Dry Weather Flow and Design Capacity of WWTP

Dry weather wastewater inflow to WWTP from 2020 until 2040 which is the target year of the Mater Plan is shown in Table 4.3.

Table 4.3 Projected Dry Weather Flow

Year	2020	2030	2040
Daily average flow	87,100 m^3/day	111,100 m^3/day	133,600 m^3/day
Hourly maximum flow	174,200 m^3/day	222,200 m^3/day	267,200 m^3/day

Source: JST

Wastewater treatment facilities of the ultimate stage are planned to be composed of three trains of wastewater treatment facilities each having treatment capacity of 45,000 m^3/day considering projected flows and adequate design capacity.

Civil and architecture works of all three trains will be implemented under the Priority Project since staged development is rather uneconomical. On the other hand, mechanical and electrical works of two trains will be implemented under the Priority Project to meet required capacity for target year of the Priority Project to reduce initial investment since phased installation of equipment is possible.

The staged development plan and design capacity of Nong Bon WWTP together with projected inflow is presented in Table 4.4.

Table 4.4 Design Capacity of WWTP

Year	Civil and Architecture	Mechanical and Electrical	Design capacity of WWTP
Start – 2021	3 trains	2 trains	90,000 m^3/day
2022 – 2031	3 trains	2 + (1/2) trains	112,500 m^3/day
2032 – 2040	3 trains	3 trains	135,000 m^3/day

Source: JST

4.1.4 Design Concepts and Requirements

Design concepts and requirements applied for designing of Nong Bon WWTP are summarized below.

1) The capacity of treatment facilities is designed on the basis of daily average flow and at the same time hydraulic capacity of treatment facilities is designed to accommodate hourly maximum flow.
2) Nong Bon WWTP receives five times design flow in rainy day. Daily average dry weather flow (DWF) i.e. design flow is purified by the secondary treatment consisting of biological processes while two times design flow is discharged after the primary treatment consisting of removal of garbage and grit which are included in

wastewater. Inflow exceeding three times design flow is directly discharged without any treatment.

3) Treatment processes which ensure removal of nitrogen and phosphorus are required to satisfy effluent standard.
4) Treatment processes are required to be flexible with fluctuation of pollution loading since expected pollution loading in the beginning of operation is considerably lower comparing to the design pollution loading.
5) Sludge generated from wastewater treatment facilities is dewatered at the site and transferred to Nongkaem WWTP, which is the centralized sludge treatment plant for sludge from all WWTPs in BMA.
6) Consideration of landscape and pollution control against adverse impacts such as odor, noise and vibration is required taking into account the neighboring environment and designated land use of surrounding area.

4.2 Selection of Wastewater Treatment Process

4.2.1 Comparison of Alternatives

Four treatment processes which satisfy site condition and requirements were selected as alternatives for Nong Bon WWTP. These are recycled nitrification and denitirification process (RNDP), sequencing batch reactor (SBR), membrane biofilter (MBR), and carrier added activated sludge process (CAASP).

As the result of comparison, carrier added activated sludge process (CAASP) is recommended due to the following advantages.

1) Stable performance of purification of organic substances and nitrification is expected owing to nitrifying bacteria and microbe contained in carriers
2) Basically O&M technology is the same as those of RNDP and BMA is well accustomed to process technology.
3) CAASP has high flexibility on rainy day since carriers are retained in aeration tanks and keep microbe for purification.
4) Amount of carrier is adjusted according to pollution loading of influent at the start of operation and can be added in the future to increase to design capacity.
5) CAASP is the most economical in terms of Net Present Value since it requires the lowest investment cost and O&M cost.

4.3 Facilities Planning

4.3.1 Concepts for Facilities Planning

Concepts for facilities planning of the WWTP are summarized below.

1) Consideration of life cycle cost including initial investment, costs for operation & maintenance and replacement
2) Stable and easy operation by introducing necessary backup and automation by SCADA system and instrument
3) Total energy saving by introducing highly efficient technology, optimizing operation and minimizing hydraulic loss
4) Reduction of initial investment by applying phased installation according to increase of influent flow and pollution loading
5) Consideration of environmental and social impacts

4.3.2 Design Wasewater Flow

Design wastewater flow to each process is summarized in Table 4.5.

Table 4.5 Design Flow

Design flow	Explanation
Influent to WWTP	The maximum influent, which flows to WWTP on the peak, is five times design flow.
Primary treatment	Three times design flow flows to the primary treatment facilities which are comprised of grit chambers and fine screens.
Secondary treatment	Design flow flows to secondary treatment facilities which are comprised of biological treatment i.e. aeration tanks and settling tanks.
Wet weather activated sludge process	Two times design flow i.e. the remainder of primary effluent has two options i.e. discharging to receiving water body after the primary treatment and treating by wet weather activated sludge process. In case of wet weather activated sludge process, two times design flow flows into the later stage of aeration tanks.
Direct discharge	Two times design flow i.e. exceeding three times design flow for the primary treatment is directly discharged to the receiving water body after pumping up by lift pumps.

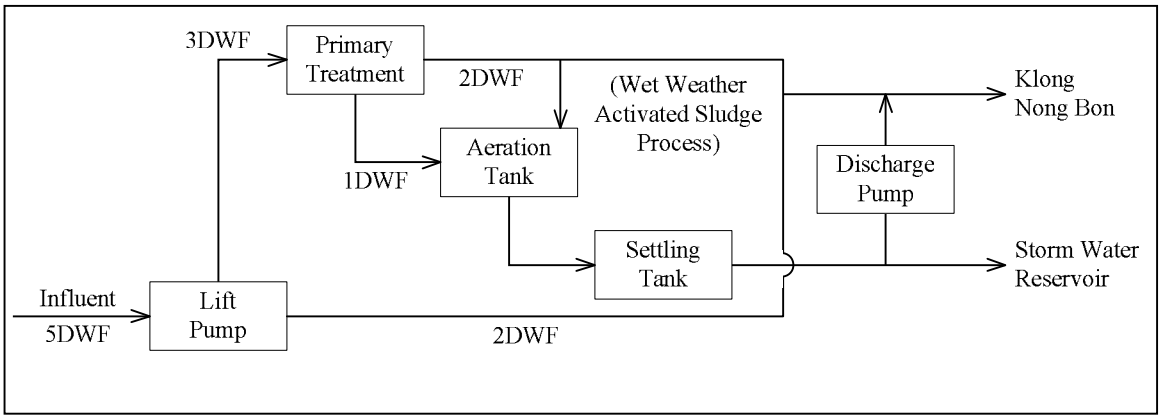
Source: JST

4.3.3 Receiving Water Body

More than one receiving water bodies are to be secured to select suitable one in operating WWTP. Klong Nong Bon, Nong Bon storm water reservoir and Nong Bon drainage tunnel can be a receiving water body. A part of treated wastewater is planned to be reused for beautification purpose in adjacent Rama IX park.

Schematic flow showing design flows of treatment facilities and receiving water bodies

depending on of effluent characteristics is shown in Figure 4.1.

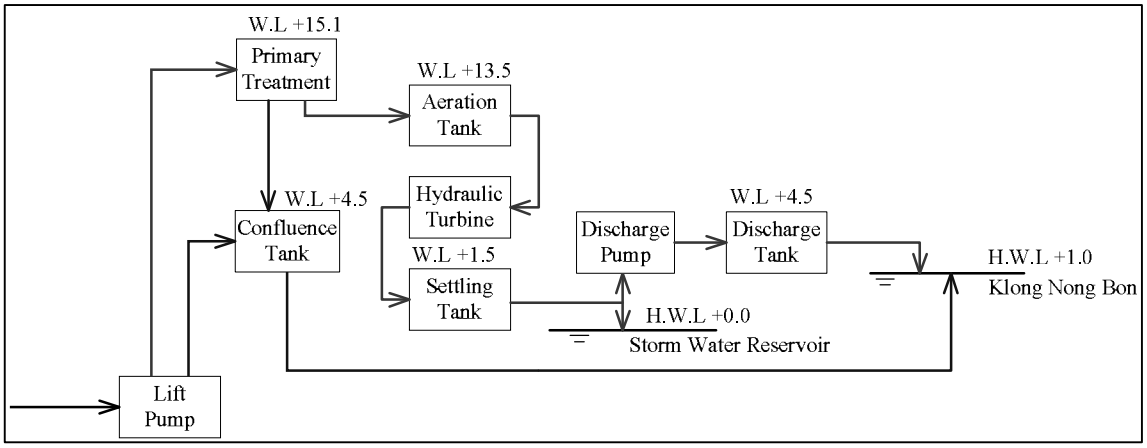


Source: JST

Figure 4.1 Design Flow and Receiving Water Body

4.3.4 Hydraulic Profile Planning

Hydraulic profile planning in dry and wet wether is shown in Figure 4.2.



Source: JST

Figure 4.2 Hydraulic Profile Planning

4.3.5 Selection of Sludge Treatment Process

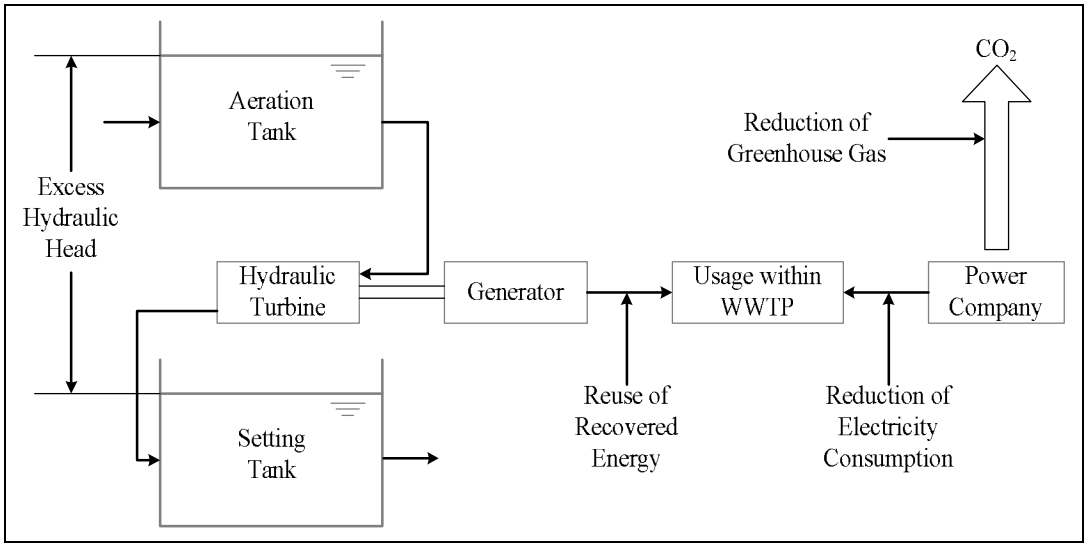
Sludge generated at Nong Bon WWTP is planned to be transferred to Nong Khaem WWTP same as sludges generated at other WWTPs. Type of the dewatering equipment is selected taking into account dewatering efficiency, economy and ease of operation and maintenance. Three types of equipment, i.e. belt press, centrifugal and screw press are compared and belt press dewatering machine is recommended for the following advantages.

1) Characteristics of dewatered sludge generated in BMA are proved to be stable and DDS staff is well accustomed to operation and maintenance due to wide adaption in existing BMA WWTPs.
2) It is the most economical in terms of net present value.

4.3.6 Countermeasure for Climate Change

BMA enhances the reduction of CO_2 emission in order to prevent global warming. Hence, in this preliminary design, energy recovery by hydraulic turbines to utilize head loss between aeration tanks and settling tanks are considered because these tanks are vertically arranged.

The systematic flow of energy recovery and reduction of greenhouse gas with hydraulic turbines is shown in Figure 4.3. The generators convert excess hydraulic energy recovered by the hydraulic turbines to electricity. Generated electricity is planned to be used by equipment installed in WWTP. At the same time, energy recovery results in reduction of emission of carbon dioxide i.e. greenhouse gas by reducing total electricity consumption supplied from the power company to WWTP.

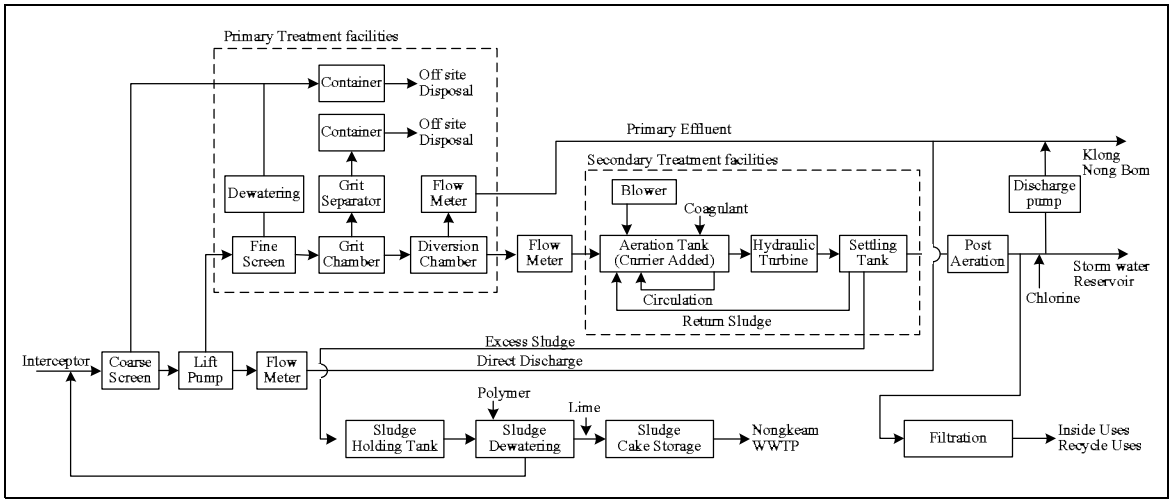


Source: JST

Figure 4.3 Schematic Flow of Energy Recovery and Reduction of GHG

4.3.7 Process of Nong Bon WWTP

The schematic flow of treatment process considering the results of facilities planning shown in Figure 4.4 is recommended for Nong Bon WWTP.



Source: JST

Figure 4.4 Schematic Flow of Process

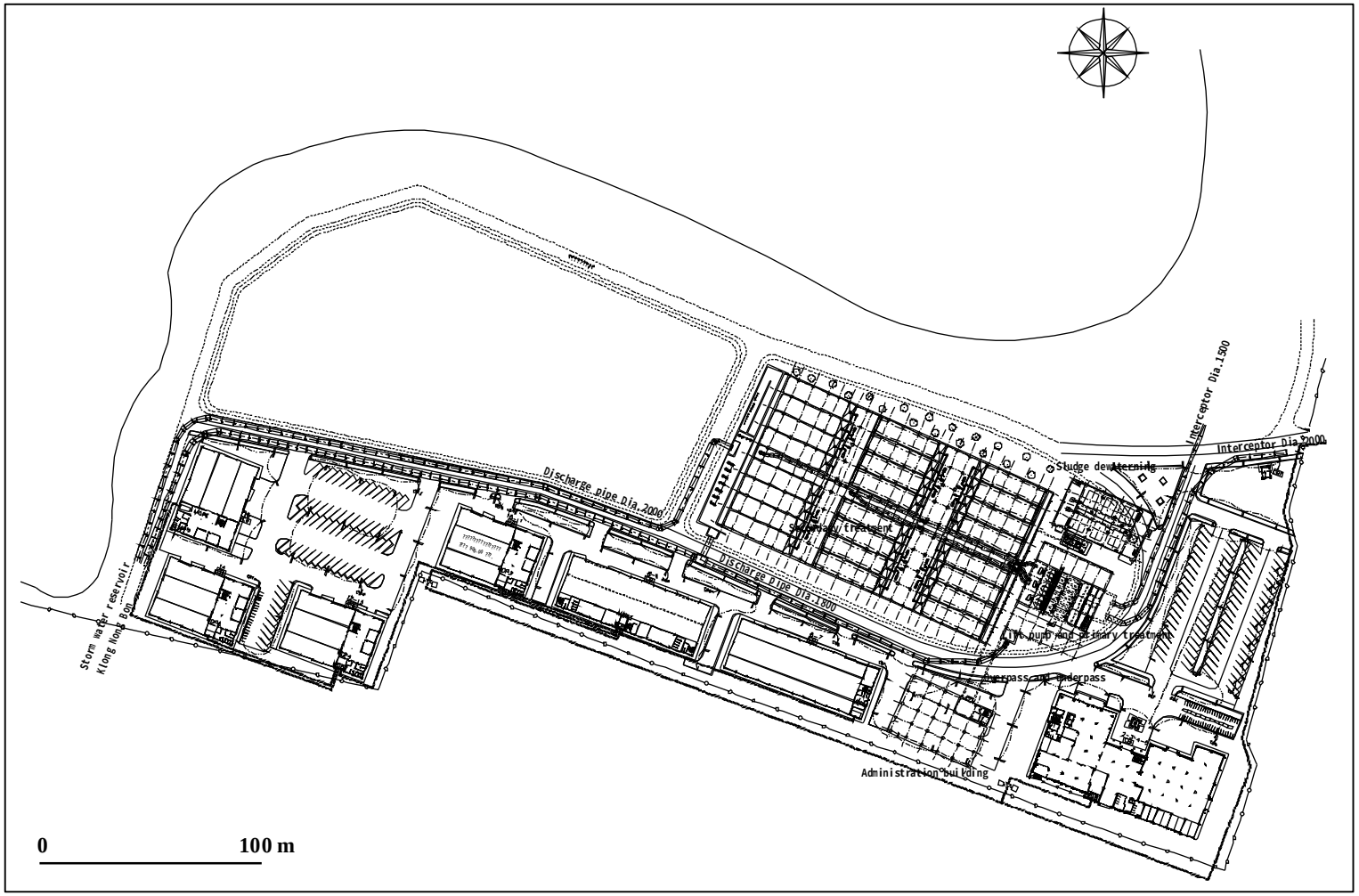
4.3.8 Outlines of Facilities Planning

Dimensions of main facilities and specifications of equipment are calculated according to design criteria and summarized in Table 4.6. The general layout of proposed facilities, the hydraulics profile and the flow diagram are shown in Figures 4.5 and 4.6.

Table 4.6 Outline of Facilities Planning

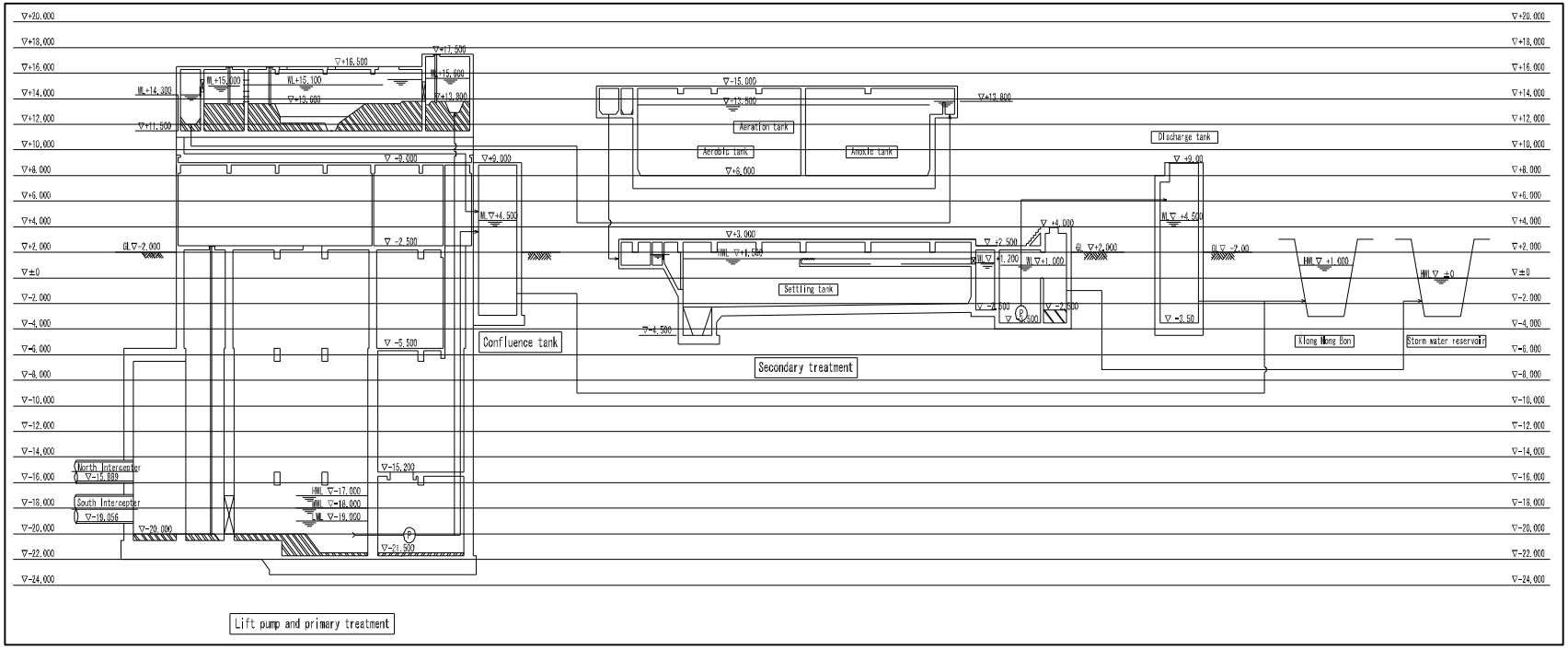
No	Facilities / Dimension / Specification	Number for M/P	Number for F/S
1.	Lift pump facilities		
1-1	Coarse screen (Channel width: 2.5m)	3 nos.	2 nos.
1-2	Large lift pump (94m3/min × 38m × 800kW)	3 nos. (1 standby)	2 nos. (1 standby)
1-3	Small lift pump (32m3/min × 38m × 280kW)	3 nos.	3 nos.
1-4	Direct discharge pump (94m3/min × 25m × 540kW)	3 nos. (1 standby)	3 nos. (1 standby)
2.	Grit chamber facilities		
2-1	Grit chamber (2.0mW × 9.5mL)	6 channels	4 channels
2-2	Fine screen (Channel width: 1.4m)	9 nos.	6 nos.
2-3	Grit dewatering (7.5m3/hour)	2 nos	2 nos
2-4	Screening dewatering (3.0m3/hour)	2 nos	2 nos
3.	Aeration tank facilities		
3-1	Anoxic tank (15.0mW × 13.0mL × 5.5mD)	12 tanks	8 tanks
3-2	Aerobic tank (15.0mW × 17.0mL × 5.5mD)	12 tanks	8 tanks
3-3	Air blower (160m3/min × 6500mmAq × 260kW)	9 nos. (3 standby)	6 nos. (2 standby)
3-4	Circulation pump (air lift pump)	12 nos.	8 nos.
3-5	Return sludge pump (8m3/min × 17m × 45kW)	12 nos.	8 nos.
4.	Settling tank facilities		
4-1	Settling tank (5.0mW × 30.0mL × 4.0mD)	24 tanks	16 tanks
4-2	Sludge collector (two tanks driven type)	12 nos.	8 nos.
5.	Effluent and recycle facilities		
5-1	Discharge pump (47m3/min × 8m × 110kW)	7 nos. (1 standby)	5 nos. (1 standby)
5-2	Disc filter (filtration area: 12m2)	3 nos.	2 nos.
6.	Sludge dewatering facilities		
6-1	Belt press dewatering machine (Width:3.0m)	6 nos. (1 standby)	3 nos. (1 standby)
6-2	Sludge cake storage (40m3)	2 nos.	1 nos.
7.	Power facilities		
7-1	Emergency generator (2,500kVA)	3 nos.	2 nos.
7-2	Hydraulic turbine generator (20kW)	6 nos.	4 nos.
8.	Deodorization facilities		
8-1	Biological deodorization equipment (240m3/min)	1 no.	1 no.
8-2	Biological deodorization equipment (760m3/min)	1 no.	1 no.
8-3	Biological deodorization equipment (380m3/min)	1 no.	0 no.

Source: JST



Source: JST

Figure 4.5 General Layout of Nong Bon WWTP



Source: JST

Figure 4.6 Hydraulic Profile of Nong Bon WWTP

5. COST ESTIMATION AND IMPLEMENTATION SCHEDULE

5.1 Project Cost

5.1.1 Condition of Cost Estimation

The project cost is estimated based on the conditions stated below.

1) The project cost comprises construction cost, administration cost, engineering cost, contingency (physical and price escalation), interest during construction, commitment charge and relevant tax.
2) The project cost is composed of the local currency potion (L.C.) and foreign currency portion (F.C.).
3) Administration cost is assumed to be 2.0 % of the construction cost.
4) Engineering cost is assumed to be 10.0 % of the construction cost.
5) Physical contingency is considered as 10.0 % of total of construction cost, administration cost, and engineering cost.
6) Price escalation of 3.3 % per annum for the local currency portion and 2.4 % per annum for the foreign currency portion are applied and price contingency is estimated based on implementation schedule shown in Table 5.3.
7) The base period of cost estimation is October in 2010 and the exchange rate considered is 1 Baht = 2.76 Yen, 1 USD=83.63 Yen.
8) The cost for land acquisition is not considered since the land required for this Project belongs to DDS i.e. the responsible agency.
9) Interest during construction is estimated taking into consideration that Project cost is financed by JICA ODA loan. (Loan condition: Preferential terms / Standard, Interest rate=0.65%, Repayment period=40year, Grace period=10year)
10) Commitment charge, which is 0.1 % of loan outstanding from signing of Loan Agreement, is estimated in order to enhance the implementation of project.
11) Custom rate is 5 % for imported goods procured for environmental project taking custom tariff of Thailand into account. Tax rate is 7 % including sales taxes and other relevant taxes.

5.1.2 Estimated Project Cost

Cost estimation for priority project has been carried out considering factors mentioned above and is shown in Table 5.1. The estimated project cost for Priority Project is 7,835 million Baht (JPY 21.6 billion) including taxes and 7,198 million Baht (JPY 19.9 billion) excluding taxes.

Table 5.1 Estimated Project Cost

No	Items	L.C. (1,000 Baht)	F.C. (1,000 Baht)	Total (1,000 Baht)
1.	Construction Cost			
A	Wastewater treatment plant			
A-1	Lift pump facilities	155,811	294,995	450,806
A-2	Grit chamber facilities	52,109	123,513	175,622
A-3	Aeration tank facilities	215,634	480,650	696,284
A-4	Settling tank facilities	287,992	167,506	455,498
A-5	Effluent and recycle facilities	113,862	73,907	187,769
A-6	Sludge dewatering facilities	96,858	111,363	208,221
A-7	Administration building	177,909	11,697	189,606
A-8	Power facilities	20,257	173,179	193,436
	Sub-total of A	1,120,432	1,436,810	2,557,242
B	Interceptor			
B-1	Pipe jacking	1,609,424	0	1,609,424
B-2	Pipe jacking shaft	721,165	0	721,165
B-3	Interceptor chamber	137,000	0	137,000
	Sub-total of B	2,467,589	0	2,467,589
	Sub-total of 1	**3,588,021**	**1,436,810**	**5,024,831**
2.	Administration Cost	100,497	0	100,497
3.	Engineering Cost	358,802	143,681	502,483
4.	Physical Contingency	404,732	158,049	562,781
5.	Price Contingency	696,347	195,584	891,931
6.	Interest during construction	63,587	23,393	86,980
7.	Commitment charge	20,320	7,683	28,003
8.	Tax and Duty	366,261	270,787	637,048
	Sub-total of (2-8)	**2,010,546**	**799,177**	**2,809,723**
	Total including Tax and Duty	**5,598,567**	**2,235,987**	**7,834,554**
	Total excluding Tax and Duty	**5,232,306**	**1,965,200**	**7,197,506**

Source: JST

5.1.3 Estimated Operation and Maintenance Cost

The operation and maintenance cost required for operating facilities for priority project is estimated and summarized in Table 5.2. The operation and maintenance cost comprises expenses on salary, electricity, maintenance, transport cost of sludge cake, consumable, and others. Annual operation and maintenance cost is estimated to be 112.1 million Baht/year (309 million Yen/year).

Table 5.2 Estimated Operation and Maintenance Cost

No	Items	Total (Million Baht/year)
1.	Salary	14.8
2.	Electricity	51.5
3.	Maintenance	20.0
4.	Transport cost of sludge cake	4.8
5.	Consumable	13.8
6.	Interceptor	4.0
7.	Others	3.1
Total		112.1

Source: JST

5.2 Implementation Schedule and Disbursement Schedule

5.2.1 Implementation Schedule

Implementation schedule is prepared based on the requirements of JICA Procurement Guidelines.

Implementation schedule starting from signing of Loan Agreement has been developed as shown in Table 5.3 taking into account necessary steps. Implementation of the project has been estimated to extend over 72 months (6 years) in total.

Table 5.3 Implementation Schedule

	Period	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Signing of LA	-	▼							
Selection of Consultant	12month	■	■						
Detailed Design	12month		■	■					
Tender Evaluation	12month			■	■				
Consultant Supervision	36month				■	■	■		
Selection of Contractor	12month			■	■				
Construction Works	36month				■	■	■		
Commissioning	24month							■	■

Source: JST

Duration necessary for selection of the consultant and the contractor has been decided considering the JICA's standard procedures and shown in Table 5.4 and Table 5.5, respectively.

Table 5.4 Detailed Implementation Schedule of Selection of Consultant

Month	1	2	3	4	5	6	7	8	9	10	11	12
Preparation of shortlist and RFP												
Approval of RFP by GOT												
Concurrence to RFP by JICA												
Issuing RFP to consultant												
Evaluation of proposals												
Approval of evaluation by GOT												
Concurrence to evaluation by JICA												
Contact negotiation with candidate												
Approval of contract by GOT												
Concurrence to contract by JICA												
Contract award												

Source: JST

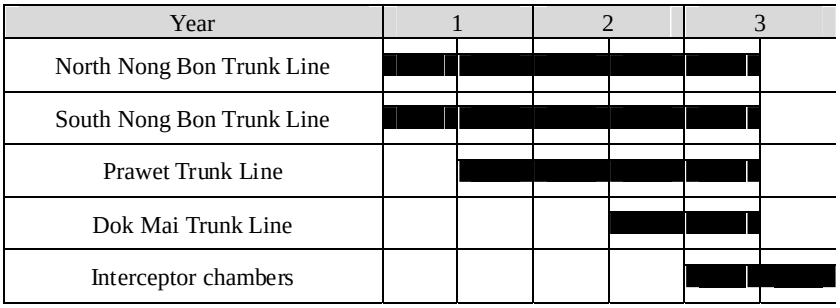
Table 5.5 Detailed Implementation Schedule of Selection of Contractor

Month	1	2	3	4	5	6	7	8	9	10	11	12
Preparation of tender document												
Concurrence to TD by JICA												
Prequalification of tenderers												
Concurrence to PQ by JICA												
Tender period												
Evaluation of tender												
Concurrence to evaluation by JICA												
Contract negotiation with candidate												
Concurrence to contract by JICA												
Contract award												

Source: JST

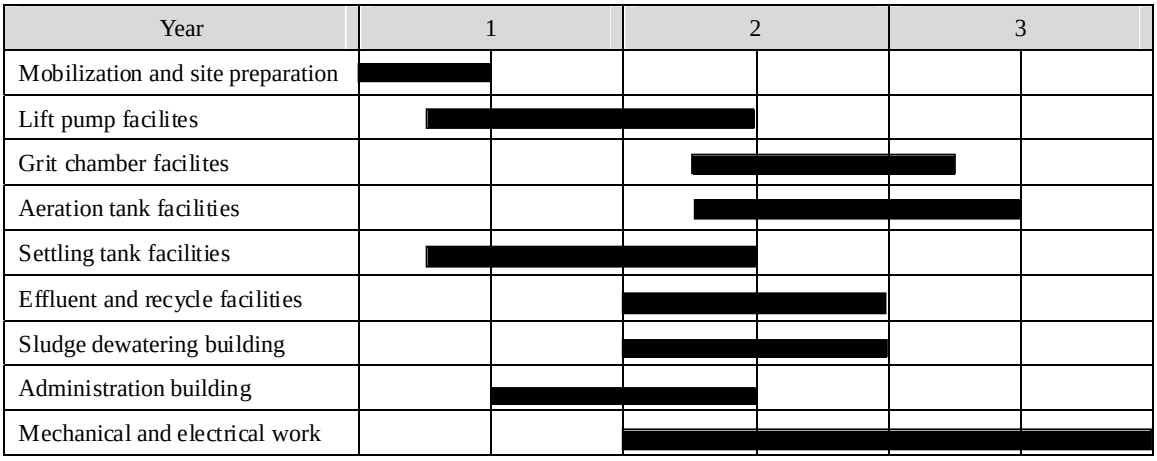
Approximately 36 months are required for construction of interceptors and WWTP as shown in Table 5.6 and 5.7.

Table 5.6 Detailed Implementation Schedule of Construction Works for Interceptors (4 Trunk Lines at once)



Source: JST

Table 5.7 Detailed Implementation Schedule of Construction Works for WWTP



Source: JST

5.2.2 Disbursement Schedule

The disbursement schedule based on the implementation schedule has been prepared as shown in Table 5.8.

Table 5.8 Disbursement Schedule

(Million Baht)

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Total
Direct construction cost	L.C	0	0	0	1,196.0	1,196.0	1,196.0	0	0	3,588.0
	F.C	0	0	0	478.9	478.9	478.9	0	0	1,436.8
	Total	0	0	0	1,674.9	1,674.9	1,674.9	0	0	5,024.8
Indirect construction cost	L.C	26.7	117.1	120.2	542.0	581.8	622.7	0	0	2,010.5
	F.C	2.1	37.5	38.3	230.6	240.4	250.3	0	0	799.2
	Total	28.8	154.7	158.5	772.6	822.2	873.0	0	0	2,809.7
Total	L.C	26.7	117.1	120.2	1,738.0	1,777.8	1,818.7	0	0	5,598.6
	F.C	2.1	37.5	38.3	709.5	719.3	729.2	0	0	2,236.0
	Total	28.8	154.7	158.5	2,447.6	2,497.1	2,548.0	0	0	7,834.6

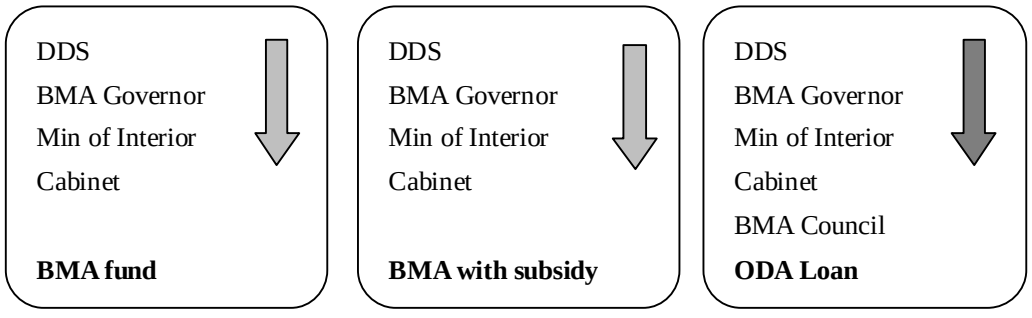
Source: JST

5.3 Management and Institutional Issues

5.3.1 Implementation Management

(1) Project Approval Process

After the approval of this JICA F/S for the proposed Nong Bon sewerage system, first by DDS / BMA and later by National Economic and Social Development Board (NESDB) under the Office of the Prime Minister, funding needs to be arranged for the implementation. Depending on the funding source, the Project approval process differs slightly. Three alternative funding sources can be considered, full BMA financing, BMA financing with central government subsidy and ODA loan financing. The approval processes for each of the alternatives are shown below.



Source: JST, based on discussion with Finance Dept of BMA

Figure 5.1 Project Approval Flow

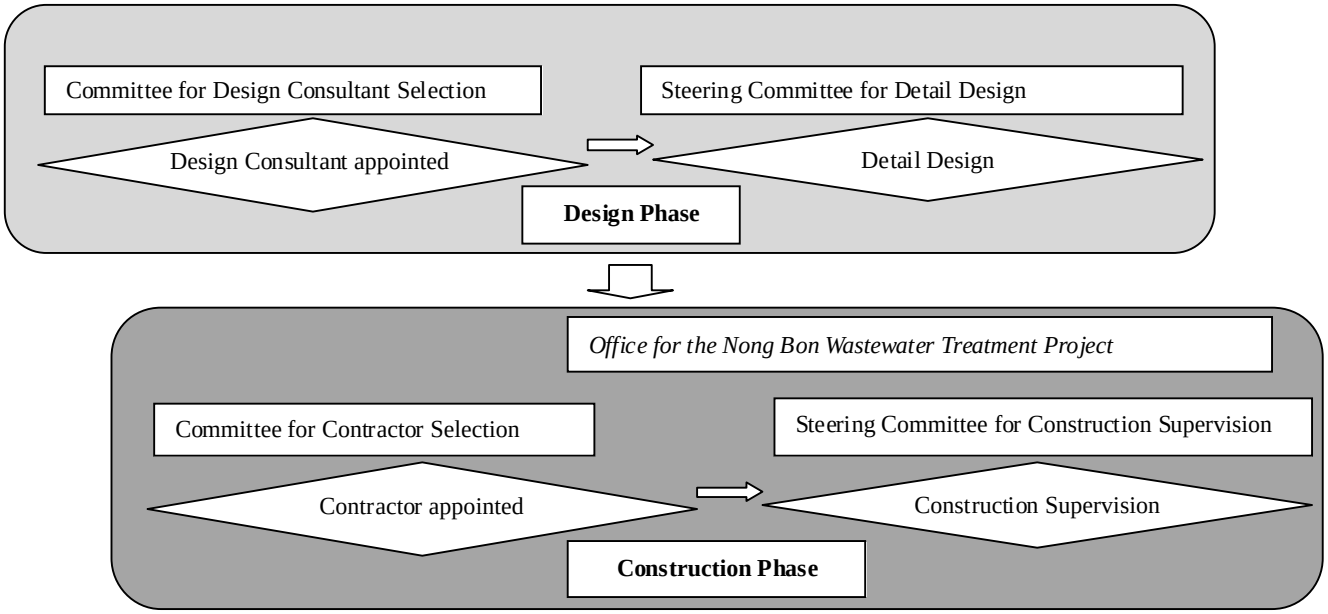
Current regulation says that for any project with a total cost of more than THB 1,000 million must need approval from the Cabinet, so approval from Cabinet is required even in case of sole BMA funding. For the ODA loan financing, an extra step is required, which is the approval from

the BMA Council.

(2) Implementation Organization and Flow

DDS has implemented 7 WWTPs and related sewerage facilities. In addition, 4 WWTPs are in preparation (one under construction and three at planning stage). DDS is judged to have enough capability to implement Nong Bon Wastewater Treatment Project taking into account the facts mentioned above.

Procesures and administration for implementation of the project are shown in Figure 5.2. It is expected that the Office for the Nong Bon Wastewater Treatment Project will be established before commencement of the project.



Source: JST, based on discussion with DDS, BMA.

Figure 5.2 Process Flow of Project Implementation

(3) Implementation Capacity and its Improvement

DDS posseses enogh capability to implement the project. Hoever, DDS has no experience to handle loan from bylateral or multilateral agencies. Strengthening of competence to handle external funds is recommended.

The following steps are recommended for the implementation capacity building.

Table 5.9 Requirement for Implementation Capacity Development

Needs	Required Action
ODA loan management	- Study JICA guideline of borrowing, - Discuss with JICA official, and - Request for short term JICA expert to explain and train DDS on ODA loan Management
Execution management	- Increase the man power of the "Office for the Implementation" - Include experts in the fields of financial/economic, environmental, institutional, and social issues

Source: JST

5.3.2 Operation Management

(1) Operation Organization

The operations of the treatment plants and sewerage systems are the responsibility of the 'Operations Sections' of WQMO under DDS. Out of current 7 WWTPs, operations of 5 plants are outsourced to private entities through management contract. The first 2 plants are operated directly by DDS. Apart from these, it is now a general policy of DDS to outsource the operation of all WWTPs. As a result, it is expected that similar approach will be followed for the proposed Nong Bon Wastewater Treatment Project.

(2) Up-gradation of Operation Contract

Current contract document is well written and convieniently protects the interest of BMA. However, up-gradiation of the contract is recommended for more efficient operation.

(3) Performance Indicator

Sewerage service provided by BMA has been improved. Introduction of PIs is recommended for further improvement. PIs should be introduced to not only DDS but to operation contractors.

(4) Capacity Development through Training Program

The O&M works are quite important for the proper functioning of the treatment equipments and machinery. Though it is expected that the operation of the proposed WWTP will be outsourced, WQMO of DDS needs competent staffs to understand the detail task regime so that they can easily detect any non compliance of the contract. This is important for project sustainability. Although WQMO of DDS already acquired high qualification by managing 5 operators over the years, proper training is also equally important to ensure maintaining and improving the skill

level. In fact, two types of human resources should be developed, officials at the managerial level in charge of policy, management information system, contract management and asset management; and officials at the operation level.

5.4 Technical Assistance

5.4.1 Training

As mentioned above, two types of human resources should be developed, officials at the managerial level and officials at the operation level.

(1) Necessary Training

Staff training and capacity development systems need improvement in order to enable the staffs to perform effectively during both implementation and operation phases. Two types of human resources should be developed; namely, for officials at the managerial level and for core members of operating staffs.

For human resources development program, particular attention should be paid for the following new technologies proposed in this F/S.

- Improvement of interceptor sewerage system (pump drainage area)
- New treatment technologies applied to narrow site area (carrier added activated sludge, membrane bioreactor etc.)
- Pollutant load reduction technologies in wet weather (wet weather activated sludge process)
- Energy recovering technologies (hydro power generation, biogas power generation)

Trainer should be, i) consultant for preparation and conducting training program at detailed design stage, ii) contractor, for training during and after construction, and iii) external organizations (e.g. JICA) for training for entire project period.

5.4.2 Program for Improvement of Management of Sewerage Works

Interceptor sewerage system in BMA is considered to be provisional system to conventional sewerage system. In order to improve service level of the sewerage system, various measures which are proposed in the M/P should be taken on a long term basis. In this regard, improvement projects mentioned elsewhere in the Main Report and M/P Report are summarized as shown below.

i) Improvement of interceptor sewerage system (Sections 3.7.1 and 3.7.2)

ii) Inventory investigation of existing drain pipes (Section 3.7.3)

iii) Institutionalize exceptional service area where installation of septic tank is exempted (Appendix 11)

iv) Introduction of PIs (Section 5.4.2)

v) Stipulation of sewerage ordinance (M/P)

6. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

6.1 Environmental and Social Considerations Study

(1) Objectives of Environmental and Social Considerations Study

The purpose of the environmental and social considerations study is to ensure that proposed project components are environmentally and socially sound and sustainable and that the environmental consequences of the project are recognized at early stage and taken into account in the project design.

(2) Necessity of Environmental and Social Considerations and EIA Report for This Project

Basic policy for environmental and social considerations for this project is described below.

i) Projects for which environmental and social impact assessment is required to be implemented and approved are determined by Environmental Quality Promotion and Prevention Act, 1992. According to provisions of this Act, environmental and social impact assessment is not required for wastewater project.

ii) The following serious impacts are not envisaged at planning, construction and operation stages.
   - Significant impacts such as involuntary resettlement of residents and adverse impacts on employment, household economy, or regional economy, are not caused for land acquisition of WWTP and interceptors construction under roads/klongs..
   - WWTP and its ancillary works do not become sources of adverse impacts on health and safety.
   - This project does not adversely impact on natural environment which is difficult to restore.
   - This project does not influence any cultural heritage and natural reserves.

iii) Consequently, Survey Team will assist DDS to carry out investigation of initial environmental assessment based on JICA Guidelines (JICA Guidelines for Environmental and Social Considerations) to minimize and mitigate potential impacts.

iv) Environmental and social considerations in this Survey includes examination of project alternatives, estimation and evaluation of impacts, recommendation of mitigation measures and preparation of monitoring plan based on data collection, site visits and stakeholder meetings (held twice in February and March, 2011).

6.2 Identification of Negative Impacts due to Implementation of the Project, Consideration of Mitigation Measures and Monitoring Plan

(1) Identification of Negative Impacts due to Implementation of the Project

Impacts caused by the implementation of the Nong Bon wastewater project have been identified. Outlines, evaluation and their durations are described in Table 6.1.

Table 6.1 Foreseeable Adverse Impacts

Environmental Elements			Grade	Reason
Social Environment	5	Existing social infrastructures and services	B	Construction Stage 1) During construction of interceptors, closing of roads (one side traffic), or use of detour may be necessary resulting in traffic congestion and inconvenience of access to public facilities 2) Traffic congestion may occur due to carrying in and out of construction materials and wastes
	11	Health and sanitation	B	Construction Stage Negative impacts due to generation of the particulates and noise by vehicles at construction stage are envisaged, which will affect health and sanitation of residents living near access road.
			D	Operation Stage Improvement of water quality in klongs by intercepting wastewater discharge is expected. There is no elements to worsen health and sanitation.
	12	Infectious diseases such as HIV/AIDS	C	Construction Stage Possibility of occurrence of infectious diseases such as HIV/AIDS due to lodging of construction workers and contact to women is envisaged. However, it is difficult to assess the impacts at present. (At present employment of foreign workers is not considered.)
	13	Hazards and security risks	C	Construction Stage Possibility of deterioration of security due to occurrence of crimes caused by lodging of construction workers is envisaged. However, the actual impacts are not clear as the above.
	14	Accidents (Traffic accidents etc.)	B	Construction Stage Possibility of traffic accidents will increase as traffic of vehicles will increase due to construction. Special attention should be paid if schools and hospitals are located along interceptor routes. However, it is not clear at present.
Natural Environment	18	Flow and hydrological features	D	Water intake from river or klong is not planned.
			C	Operation Stage Flow capacity of the klong should be taken into account since treated effluent is discharged to the klong.
Pollution	24	Air pollution	B	Construction Stage Emission of particulates is envisaged from construction machines and vehicles during construction although its duration is short.
			D	Operation Stage Emission of exhausted gas is envisaged during power failure, but duration is very limited.

Environmental Elements			Grade	Reason
Pollution	25	Water pollution	C	Operation Stage Significant positive impact, i.e. improvement of water quality in klongs is expected by reducing pollutant loads by wastewater treatment. There is no negative impact on water environment. However, in some small klongs flow will be reduced to almost zero because wastewater is intercepted. Effect of intercepting wastewater does not result in improvement of water quality. In dry season, original flow in the klong become minimal, and water pollution and emission of offensive odor may occur due to small portion of wastewater which can not be intercepted. Water pollution due to CSO in rainy weather is considered not to be sever because of dilution by storm water
	26	Soil pollution	C	Operation Stage Sludge generated at WWTP is planned to be utilize after composting as manure or soil conditioner. Monitoring of wastewater should be conducted properly since wastewater may contain heavy metals. Selection of reuse purpose, e.g. reuse for agricultural purposes as compost and reuse for greenery should be determined based on the results of the monitoring.
	29	Noise and vibration	B D	Construction Stage Generation of noise and vibration from construction machinery and vehicles is envisaged. Operation Stage All of the sources of noise and vibration at operation stage is designed to be housed in buildings, and there is no effect outside of WWTP.
	31	Offensive odor	B	Operation Stage Sources of offensive odor are sludge treatment facility and aeration tank although odor level from it is low. Countermeasures for odor are necessary.

Note: Grade is classified as follows

A: Significant effect is envisaged.
B: Some impact is envisaged.
C: Impact is not quite sure (examination is necessary).
D: No impact is envisaged.

Source: JST

(2) Consideration of Mitigation Measures

Mitigation measures against adverse effects of the project during construction stage and operation stage are shown in Table 6.2 and Table 6.3 respectively.

Table 6.2 Mitigation Measures during Construction Stage of the Project Facilities

Item	Effects	Measures
<Existing social infrastructures and social services>	・Obstruction to traffic during construction of interceptors and obstruction to access to public institutions ・Possible adverse effects such as air pollution (particulates), noise and vibration due to transportation of construction materials and wastes	• Publication of construction contents and its schedule • Agreement and observation regarding construction contents, operation and working hours of vehicles for transportation of materials • Arrangement of staff for traffic control • Attentive operation and speed restrictions of construction vehicles • Instructions to drivers operators and workers about traffic manners by contractor • Water sprinkling at roads to prevent dust • Provision of cover on the bed of lorry to prevent scattering • Arrangement of information desk and deployment of a responsible person to receive complaints from residents living in the neighborhood of construction site (quick response to complaints)
＜Health and hygiene＞	Same as above, air pollution and noise to the residents living in the neighborhood of the construction site	Same as above
<Accidents (traffic accidents)>	・Risks of occurrence of traffic accident increase due to increase of traffic of vehicles related to construction ・Reduction of road width due to construction of interceptors, particular attention should be paid for vulnerable institutions such as schools and hospitals	Same as above
＜Air pollution ＞	・Generation of particulates due to transportation of materials and construction activities ・Exhausted gases from construction vehicles and machines	• Attentive operation of construction vehicles and machined, and speed restrictions • Preventive maintenance of construction vehicles and machines • Positive use of construction machines with countermeasures against exhausted gases • Arrangement of an information desk and deployment of a responsible person to receive complaints from residents, and monitoring of number and contents of complaints
<Noise and vibration>	Noise and vibration due to construction vehicles and machines	• Attentive operation of construction vehicles and machined, and speed restrictions • Preventive maintenance of construction vehicles and machines • Positive use of low noise and low vibration construction machines • Arrangement of an information desk and deployment of

Item	Effects	Measures
		a responsible person to receive complaints from residents, and monitoring of number and contents of complaints • Monitoring of noise and vibration based on information given by the residents
＜Infectious diseases , such as HIV/AIDS＞	Possibility of occurrence of infectious diseases by persons relating to construction	• Education and enhancement of awareness to persons relating to construction (employee) by construction management company
＜Hazard (Risk) ＞	Industrial accidents due to construction work Possibility of deterioration in terms of safety such as climes caused by persons relating to construction	• Safety education to persons relating to construction, and provision of safety measures • Observation of laws relating to labor environment • Education to persons relating to construction (employee) by construction management company

Source: JST

Table 6.3 Mitigation Measures during Operation Stage

Item	Effects	Measures
<Flow status, hydrological characteristics>	Effect on flow capacity of receiving klong	• Facility planning for WWTP confirmed that the klong has enough flow capacity. However, monitoring of water level in klong is to be conducted.
<Water pollution>	Flow in the klong will be reduced due to intercepting of wastewater, and possibility of uncertainty of water quality improvement–	• Monitoring of water quality in nearby klongs • Introduce purification water or treated effluent from WWTP (reuse as purification water) to klongs of which water quality will be worsened due to decrease of flow in dry season.
<Soil contamination>	Possibility of soil contamination by reuse of sludge generated from WWTP	• Monitoring of manure and soil conditioner made of sludge compost to confirm their safety
<Noise and vibration.>	Effect on neighborhood of WWTP	• Blowers and pumps which are considered to be source of noise should be installed in buildings to mitigate effects on outside of the building and surroundings outside of the site • Periodical monitoring at outside of the building and at boundary of the WWTP site
<Offensive odor>	Emission of offensive odor from sludge treatment facilities and sludge storing facilities. Emission of offensive odor from wastewater treatment facilities	• Sludge treatment and transfer facilities should be confined in buildings, and deodorization should be provided not to emit odor to outside of WWTP directly– • Monitoring of odor

Source: JST

(3) Monitoring Program

Monitoring programs for construction and operation stages are described below.

Table 6.4 Monitoring Program at Construction Stage

Subject	Monitoring place	Item
Complaints and demands from residents	– Access road and neighborhood of construction site	Contents of demands and complaints and their numbers
Noise	– Access road – WWTP – Interceptors	Noise (monitoring by simple monitoring device)
Particulates	– Access road and neighborhood of construction site	Total Suspended Particulates (TSP)
Air quality	– Access road WWTP	CO, Ozone, SO_2, NO_2, , TSP, PM_{10}, $PM_{2.5}$

Source: JST

Table 6.5 Monitoring Program at Operation Stage

Subject	Monitoring place	Monitoring parameters
Water pollution	Surrounding klongs	Water temperature, pH, Color, BOD(COD), DO, SS, Nitrogen, Phosphorus, E-coli Water level in klong
Water pollution	Wastewater inflow Wastewater inflow (by interceptor routes)	pH, BOD, SS, Oil and grease, T-P, T-N, NH_4-N As, Cd, Hg, Ni, Cr, Pb
Water pollution	Treated effluent	pH, BOD, SS, Oil and grease, T-P, T-N, NH_4-N, DO
Noise	Boundary of WWTP site	Level of noise
Odor Sewage sludge	Boundary of WWTP site Sludge treatment facilities	Concentration of odor As, Cd, Hg, Ni, Cr, Pb, and other health parameters

Source: JST

(4) Conclusions

Environmental items which require particular attention, in other words items which may cause significant impacts or which can not be recovered easily are following five items. It is judged that there is no adverse effects on these items due to the implementation of the project.

Table 6.6 Environmental Items Which Require Particular Attention

Environmental items	Adverse effects
Involuntary resettlement of residents	Construction site of WWTP is DDS's property, acquisition of new land is unnecessary. Involuntary resettlement of residents does not occur.
Local economy such as employment and livelihood etc.	There is no loss of livelihood nor loss of property due to construction and operation of the project.
Occurrence of secondary contamination (environmental contamination caused by heavy metals and hazardous materials contained in wastewater)	Contamination by heavy metals or hazardous materials is not recognized in klongs in the project area. However, monitoring of wastewater and sludge should be carried out to ascertain these heavy metals and hazardous materials are not discharged.
Disappearance of and damage to cultural properties and heritage	There is no structures relating to cultural properties and heritage at the construction site for WWTP
Effect of natural reservation areas	There is no natural reservation areas in the project area. Nearest internationally designated area is located at a distance of 30 km.

Source: JST

In conclusion, it is judged that there is no significant adverse effect due to the implementation of the project. However, some environmental items (minor adverse effects) require attention at both construction stage and operation stage. Mitigation measures and monitoring of these environmental items are required. On the other hand, it is expected that implementation of the project will contribute to improvement of water environment and prevention of water pollution in klongs by collecting and treating of wastewater in Nong Bon treatment area.

6.3 Public Awareness Survey

6.3.1 Outline of the Survey

Public awareness survey was conducted to grasp awareness of residents living in the priority project area regarding sewerage system, water environment of klongs and health facilities. The survey was conducted as interview survey (interview to individual residents with questionnaire prepared beforehand). Local consultants were assigned to carry out interviews which were conducted during November and December, 2010. Main contents of the questionnaire are as follows.

i) Status of water supply and electricity supply in household
ii) Status of wastewater facilities in household
iii) Peoples awareness of sewerage system and water environment of klong
iv) Willingness to pay for sewerage services

The main interviewees are residents (350 samples), and additional interviews were conducted for non-residential entities (hotels, hospitals, fruits and vegetable markets, schools and factories, total 50 samples) with similar questionnaire.

6.3.2 Summary

The facts revealed from the residents awareness survey are summarized below.

- Role of the sewerage system is not sufficiently understood by residents in the Nong Bon project area. Opportunities to access to information about sewerage system (its role and effects) should be provided through mass media and schools.
- Water environment in klongs (odor, color of water, and garbage) is sufficiently recognized by the residents. Demand for improvement of water environment is thought to be strong.
- It is highly evaluated that residents recognize that main source of pollution is domestic wastewater. However, it should be noticed that pollutant load generated from sullage is larger than that generated from human excreta. Thus the fact that sewerage system is required to reduce pollutant load generated from sullage should be understood by residents.
- Residents' distaste for reuse of treated wastewater is thought not to be strong. However information about actual cases of reuse is not provided to the residents. Information about methods of reuse and effects due to effluent reuse should be provided as soon as possible to obtain their consent.
- Information on willingness to pay for sewerage service was obtained although its rate is not so high (73 Baht/household/month). This figure is approximately 1/7 water charge. It is necessary to enhance residents' awareness, and to increase willingness to pay by providing information on sewerage system (role and effects).

6.4 Stakeholder Meeting

Stakeholder meetings regarding Nong Bon Wastewater Treatment Project were held on 17th February, and 29th March, 2011. Aims of the meetings are to explain to the stakeholders including representatives of the communities about outlines of the project, environmental adverse impacts due to the implementation of the project, and mitigation measures for these impacts, and to hear comments from them to reflect these comments in implementation of the project. Simultaneously, it is also important to enhance residents' understanding about the project and to seek cooperation from them.

No opposition opinion against wastewater project was presented at both meetings. Residents' understanding about role and effects of sewerage system was obtained through site visit to Din Daeng WWTP. It became clear that every participant wishes early implementation of wastewater project.

However, DDS made promises at the meetings to pay sufficient attention for traffic disturbances

and transportation and fishery in klongs in construction of interceptors at detailed design stage. In detailed design of interceptors, location of vertical shafts should be determined with close consultation with residents and authorities concerned.

Questions regarding wastewater tariff were expressed. DDS should provide information about role and effects of sewerage system and strive to enhance understanding of residents for “appropriate cost for wastewater services”.

7. ECONOMIC AND FINANCIAL ANALYSIS

7.1 Evaluation of Wastewater Tariff

7.1.1 Plan of BMA's Wastewater Tariff Collection

BMA has been processing legal procedures to start the wastewater tariff collection for long time. In 2004, BMA obtained approval of "BMA Ordinance: Collection of Wastewater Tariff, 2004" from BMA Council and Minister of Interior.

The tariff is charged to the users in the area where the treatment is conducted, and the revenue amount is used to cover the O&M cost of WWTP. The tariff rate is set at 2.0 Baht/m^3 for residential and public buildings, 4.0 Baht/m^3 for large scale commercial facilities, and 4.0-8.0 Baht/m^3 for factories. For the residential users, the transition measures are considered to start the tariff rate at 1.0 Baht/m^3, and gradually increase it up to 2.0 Baht/m^3 later.

The tariff evaluation study was conducted by local consultant company in 2010 as ordered by BMA, and the report presents the prediction of revenue amount in the planned seven treatment area. In conclusion, total charged water consumption becomes 216 million m^3, and the total revenue becomes 495 million Baht. Out of the total revenue, the revenue from residential category accounts for 19.5 %, and the one of the commercial building account for the majority of 51 %. (Tariff rate of 2.0 Baht/m^3 is applied to the residence category, excluding households whose water consumption is less than 10 m^3/month)

Actual O&M cost of 7 WWTPs is 445.4 million Baht (including O&M for interceptors), and the above predicted revenue amount is more than this O&M cost. Hence, the principle of the treatment tariff to cover the O&M cost can be satisfied. In contrast, for the comparison, the average tariff rate for full cost recovery is calculated at 13.18 Baht/m^3 by referring average budget of DDS (3,084 million Baht) in 2007-2011, divided by the predicted charged water amount (234million m^3). Comparing the tariff of 13.18 Baht/m^3 for full cost recovery, and planned average tariff rate of 2.29 Baht/m^3, it covers only 17 %.

7.1.2 Willingness to Pay (WTP) and Affordability to Pay (ATP) for Wastewater Tariff

For evaluating the designed tariff amount with the user's opinion and affordability, willingness to pay (WTP) and affordability to pay (ATP) is calculated.

(1) Willingness to Pay (WTP)

The result of past four survey of WTP in BMA area is summarized in the Table 7.1, and the survey detail is explained in the latter part.

The sample number and methodology varies for each survey, and the WTP result varies from 39.2 to 100.8 Baht/ month-household. The result of the social survey conducted under this JICA Study became 73.3 Baht/month-household. This data matched to the past survey result, and is considered to be reliable.

Table 7.1 Past Survey Result of WTP

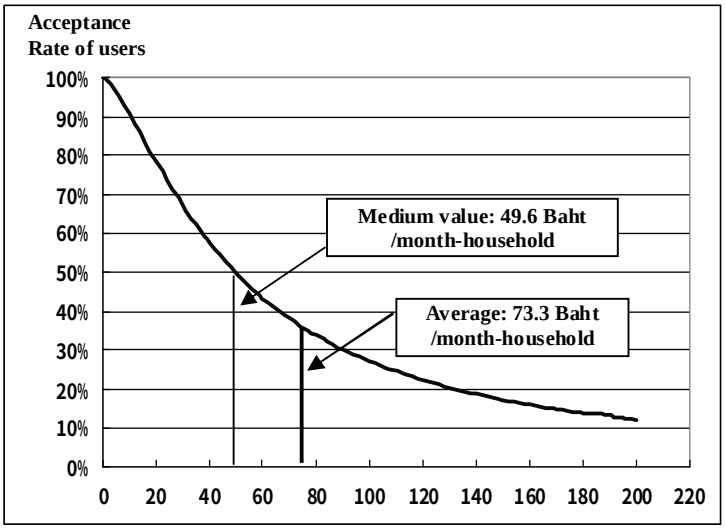
Survey Name (year)	Methodology	Question Method	Monthly WTP
JICA Study (2010)	Nong Bon area, 350 samples	CVM method	73.3 Baht/month-household
BMA Study (2010)	7 treatment areas, 2300 samples	Three answer choice	41.4 Baht/month-household
BMA Study (2006)	Bang Sue area, 326 samples	Free Answer	39.2 Baht/month-household
IDRC and others Study (1999)	6 treatment area, 1100 samples	CVM method	100.8 Baht/month-household

Source: JST

Social Survey Result of the JICA Study Team

In this study, the interview survey was conducted to 350 samples. The average of WTP becomes 73.3 Baht/month-household, and the medium value becomes 49.6 Baht/month-household.

Five difference questionnaire sheets are prepared for the survey, and the one of the five kinds is selected randomly for each interviewee, to avoid the bias of first indicated tariff amount. For calculating the WTP from survey result, approximated curve is calculated using logit linear method.



※Approximated curb made by Logit Linear method
Source: Study Team

Figure 7.1 Average and Medium Value of WTP Survey (Baht/month-household)

(2) Affordability to Pay (ATP)

Several international donor agencies recommend the affordability to pay (ATP) for wastewater tariff. As referring to the Guideline of JICA (JICA methodology of economic analysis for master plan survey -wastewater category), IBRD set it at 1.0 % of disposable income, and PAHO (Pan American Health Organization) set it at 1.5 % of total household income.

In this study, as the conservative view, the ATP is set at 1.0 % of total income of users. From the social survey result, the average household income is figured out to be 33,428 Baht/month. Hence, the ATP is calculated to be 334 Baht/month-household.

(3) Evaluation of User's Affordability

As mentioned before, the average water consumption of residence is 47.1 m^3/month-household refer to the report of tariff study in 2010. So, the average tariff amount becomes 94.2 Baht/month-household as applying the tariff rate of 2.0 Baht/m^3 for residential users. Comparing the WTP at 73.3 Baht/month-household taken from the social survey result, these amount stays at the similar level, so it is considered that users are willing to pay the tariff. Whereas, comparing the ATP at 334 Baht/month-household with average tariff amount (94.2 Baht/month-household), the average tariff amount becomes only 28 % of the ATP. Hence, it is concluded that users have the sufficient capacity to pay the planned tariff amount.

Table 7.2 Summary of WTP and ATP of Residential User

Item	Data Source	Monthly Tariff
Predicted average tariff amount	Calculated by average water consumption	94.2 Baht/month-household
Willingness to Pay (WTP)	Social Survey Result (WTP)	73.3 Baht/ month-household
Affordability to Pay (ATP)	Social Survey Result (Average income × 1.0%)	334 Baht/ month-household

Source: JST

7.2 Economic Analysis

7.2.1 Basic Assumptions

In this Section, the economic analysis is conducted to evaluate the economic viability of the project. The normal cost benefit analysis method is applied for the analysis by assuming the conditions of "With Project" and "Without Project". The result of analysis is evaluated as using indicators of the Economic Internal Rate of Return (EIRR), Net Present Value (NPV), and Benefit/Cost Ratio (B/C). Economic analysis was conducted based on the following conditions.

(1) The evaluation period is set for 36 years which includes 6 years of preparation/construction period during 2012 - 2017, and 30 years after starting the Nong Bon WWTP operation during 2018 - 2047.

(2) The cost of initial construction and O&M is estimated based on the price at October 2010 excluding any tax. Physical contingency is included in the estimated cost, and the price contingency is excluded from the estimate. The conversion factor is applied to the local cost obtained financial cost to convert to the economic cost.

7.2.2 Economic Cost

The initial investment cost and O&M cost of "With Project" are indicated below. The initial investment cost and O&M cost is not counted “Without Project”.

(1) Initial Investment Cost

The disbursement schedule of initial investment cost is shown in the table below. Two alternatives of different interceptor constructing phases are mentioned. Only the alternative case of single construction phase (base case) is used for the analysis as the result of economic analysis does not differ significantly between both cases.

Table 7.3 Disbursement Schedule of Initial Investment Cost (Financial Cost)

(Million Baht)

	2012	2013	2014	2015	2016	2017	Total
Local Currency	24.4	103.5	103.3	1,446.2	1,435.1	1,423.5	4,536.0
Foreign Currency	2.0	33.7	33.6	571.1	566.8	562.4	1,769.6
Total	26.4	137.2	136.9	2,017.3	2,001.9	1,985.9	6,305.6

Source: JST

Table 7.4 Disbursement Schedule of Initial Investment Cost (Economic Cost)

(Million Baht)

	CF	2012	2013	2014	2015	2016	2017	Total
Local Currency	0.92	22.4	95.2	95.0	1,330.5	1,320.3	1,309.6	4,536.0
Foreign Currency	1.00	2.0	33.7	33.6	571.1	566.8	562.4	1,769.6
Total		24.4	128.9	128.6	1,901.6	1,887.1	1,872.0	5,942.6

Note: CF: Conversion Factor
Source: JST

The Standard Conversion Factor of 0.92, which is presented by the report published by World Bank, is applied to obtain the economic cost. The reference report is “Sadiq Ahmed; Shadow Prices for Economics Appraisal of Project :An Application to Thailand, World Bank Staff Working Paper, Number 609.”

The extension cost, replacement cost and residual value are calculated based on the assumptions below;

- The replacement of equipment facility (1,249.9 million Baht) out of initial investment cost is executed in 15 years.
- The extension construction of WWTP of 22,500m^3/day which costs 539.8 million Baht is executed in 2021, and 2031 respectively to meet the inflow amount. The whole mentioned construction cost is considered as the equipment cost and the replacement (100% of cost) is executed in 15 years.
- The residual value of facilities is put at the final year as the benefit. The life time of concrete facility and building (which is considered as the whole facility except for equipment) is set at 50 years, and that of equipment is set at 15 years.

(2) Operation and Maintenance (O&M) Cost

The O&M cost is calculated as 112.1 million Baht for 90,000 m^3/day (32,850,000 m^3/year) capacity. As using these figures, the average O&M unit cost (Baht/m^3) is set at 3.41 Baht/m^3, and multiplying this average cost with the annual treatment amount to have the annual O&M cost at Nong Bon WWTP. The planned treatment amount of each year is calculated. The O&M cost after 2041 becomes constant as the treatment amount reaches to the maximum capacity of 135,000 m^3/day at that time.

7.2.3 Economic Benefits

The potential economic benefits procured by the project execution are summarized below;

a) Improvement of living welfare
b) Land price escalation around klong
c) Cost reduction by reusing the treated water

(1) Improvement of Living Welfare

The benefit amount is calculated multiplying the number of household and Willingness to Pay (WTP, Baht/month-household) for the benefit. Moreover, the Affordability to Pay (ATP) is also applied for the calculation, as the WTP for sewerage project tends to be lower owing to the difficulty of user's imagination about the benefit.

(2) Land Price Escalation around Klong

The expert of the study team evaluated the land value by local survey and interview with local property agencies. By the local survey, the odd smell is felt at the site approximately 30 m from

the klong, depending on the wind direction and environment. Hence, the area within 30 m from the klong side is considered as the beneficial area of land price escalation.

Table 7.5 Klong Distance and Beneficial Area

Kind	Klong Length	Width of Beneficial Area	Beneficial Area
Both side	72.4 km	60 m	4,344,000 m^2
One side (treatment area border)	27.2 km	30 m	816,000 m^2
Total			5,160,000 m^2

Source: JST

The land price information which Treasury Department published for the property tax collection is used. The land price at project area varies from 2,500 Baht/m^2 to 10,500 Baht/m^2. In general, it is said that the mentioned land price is 20 or 30 % lower than the real commercial price. Considering these data and the information from the local property agencies, the average land price besides the klong is defined at 5,000 Baht/m^2.

In the calculation, the land price increases 5 % from 2020 (third year after WWTP operation) to 2022 for continuous three years. Furthermore, after the year 2023, the annual revenue rate made from property value (land price) is set at 10 %, and the additional increase of 15 % of the said revenue is considered as the influence by the project execution. Thus, based on the original land price, the annual revenue rate at 1.5 % is considered as the incremental benefit from the project execution each year.

Benefit = "Beneficial area (m^2)" × "Average land price (Baht/m^2)"
× "Escalation rate or annual revenue rate (%)"

(3) Cost Reduction by Reusing the Treated Water

At present, BMA intends to increase the reuse rate of treated wastewater, which is used mainly for planting and scenery use in park and public area. The average reuse rate during 2008 - 2010 is 3.69% from major 7 WWTP in treatment amount. The value of treated wastewater reused is considered as the benefit, as considering the reduction of water consumption.

Benefit = "Treatment amount at Nong Bon WWTP (m^3/year)" × "Reuse rate (%)"
× "Water value (Baht/m^3)"

Regarding to the future prediction, BMA plans to increase the reuse rate up to 5 % until 2012, and 10 % in the long term future plan. Following to the BMA's planning period of every 5 years, the reuse rate is predicted at 7 % during 2013 – 2017, and 10 % after 2018. The unit value of

treated water is set at 6.2 Baht/m^3 which corresponds to the half price of average water tariff in 2009 (Annual report of MWA, 2009).

7.2.4 Result of Economic Analysis and Sensibility Analysis

The result of economic analysis is indicated as below.

Table 7.6 Result of Economic Analysis

	EIRR	NPV (D.R.=10.0%)	B/C
Case1: using WTP	4.0%	-1,900 million Baht	0.64
Case2: using ATP	7.2%	-972 million Baht	0.82

Source: JST

The EIRR became lower than 10.0 % in both cases of applying WTP and ATP for environmental improvement benefit. Hence, the project is considered to be not viable in economic view; however, considering the following factors, it is important to execute the project for the society.

Result of Sensitivity Analysis

The sensitivity analysis is executed in case of the 10% benefit reduction, 10% cost increase, and both cases occurs at the same time. The result of every cases are summarized in the below table.

Table 7.7 Summary of Sensibility Analysis

	Condition	EIRR	NPV (D.R.=10.0%)	B/C
Case1 (using WTP)	A: Base case	4.0%	-1,900 million Baht	0.64
	B: Benefit－10%	2.8%	-2,240 million Baht	0.58
	C: Cost＋10%	2.9%	-2,430 million Baht	0.58
	D: Benefit－10%, Cost＋10%	1.7%	-2,769 million Baht	0.52
Case2 (using ATP)	A: Base case	7.2%	- 972 million Baht	0.82
	B: Benefit－10%	5.8%	- 1,404million Baht	0.73
	C: Cost＋10%	5.9%	- 1,502 million Baht	0.74
	D: Benefit－10%, Cost＋10%	4.7%	- 1,934 million Baht	0.67

Source: JST

The 10% benefit reduction and 10% cost increase affect the similar impact on the EIRR and NPV. In conclusion, to maintain the benefit higher, the education activity should be done sufficiently as mentioned before. For avoiding the cost increase, prudent budget/schedule control and cost economization during operation period is expected.

7.3 Financial Analysis

In this Section, the financial analysis is conducted to evaluate the financial viability of the project. The future revenue and expenditure is predicted for both "With Project" and "Without Project", and the difference between these situations are analyzed as using Financial Rate of Return (FIRR) and Net Present Value (NPV).

7.3.1 Basic Assumptions

Financial analysis was conducted based on the same conditions for economic analysis. However, the 3.13 % of FIRR is used as the criteria for judging the financial viability of the Project. The figure is obtained by excluding "CPI rate of 2.72 % in 2010" form the "average rate of minimum interest rate of commercial banks in 2010 at 5.94 %". (Source: Bank of Thailand)

7.3.2 Financial Cost

Initial investment cost and O&M cost of "With Project" are shown in the following table. Initial cost and O&M cost of "Without Project" is not counted.

(1) Initial Investment Cost

The disbursement schedule of initial investment cost for base case is shown in the Table7.8. Depending on the governmental subsidy amount and the usage of Japanese ODA loan, five alternative cases are made as indicated in the Table 7.9.

Table 7.8 Disbursement Schedule of Initial Investment Cost (Financial Cost)

(Million Baht)

	2012	2013	2014	2015	2016	2017	Total
Local Currency	24.4	103.5	103.3	1,446.2	1,435.1	1,423.5	4,536.0
Foreign Currency	2.0	33.7	33.6	571.1	566.8	562.4	1,769.6
Total	26.4	137.2	136.9	2,017.3	2,001.9	1,985.9	6,305.6

Source: JST

Table 7.9 Alternative Cases of Initial Investment Cost

Cost Alternatives	Initial Investment Cost (2015-17)		
	BMA budget	Government Subsidy	JICA ODA loan repayment (*)
Alternative 1 : Full Cost Recovery	100%	0%	-
Alternative 2 : 40% Subsidy	60%	40%	-
Alternative 3 : 60% Subsidy	40%	60%	-
Alternative 4 : Only O&M Cost	0%	100%	-
Alternative 5 : Full Cost Recovery using ODA loan	15%	-	85%

* The condition of JICA ODA loan; Repayment period : 40 years, Grace period : 10 years, Interest rate : 0.65%, The repayment of the final year is set for 5years amount as the evaluation period is set at 36 years.
*The above condition is only applied to the initial construction cost, and the costs of capacity extension, replacement, and residual value become the same for all alternatives.
Source: JST

The extension cost, replacement cost and residual value are calculated following to the assumptions below;

- The replacement of equipment facility (1,249.9 million Baht) out of initial investment cost is executed in 15 years.
- The extension construction of WWTP of 22,500 m^3/day which costs at 539.8 million Baht is executed in 2021, and 2031 respectively to meet the increase of inflow. The whole mentioned construction cost is considered as the equipment cost, and the replacement (100 % of cost) is executed 15 years later.
- The residual value of facilities is put at the final year as the benefit. The life period of concrete facility and building (the whole facility cost except for equipment cost) is set at 50 years, and that of equipment is set at 15 years.

(2) Operation and Maintenance (O&M) Cost

The same as the O&M cost prediction in economic analysis chapter, the average treatment cost of 3.41Baht/m^3 is used for the calculation.

7.3.3 Revenue Prediction

Projection of revenue water was conducted based on the data obtained from MWA. The average tariff is obtained by using the average tariff of both household category (2.00 Baht/m^3) and commercial category (2.37 Baht/m^3), referring to the consultant report in 2010. The average tariff of whole Nong Bon area becomes 2.22 Baht/m^3 as considering the category composition.

Three alternatives are made for revenue prediction. The starting year of the tariff charge is set at the year 2012 in the existing treatment areas for all alternatives. As BMA decided to change the tariff rate every five years in the master plan, the simulation is made based on this condition. The tariff increase rates are set at 10, 20 and 30% every five years in alternatives 1 to 3. In the

real monetary term, the tariff should be adjusted regarding to the inflation rate, additional to the mentioned prediction.

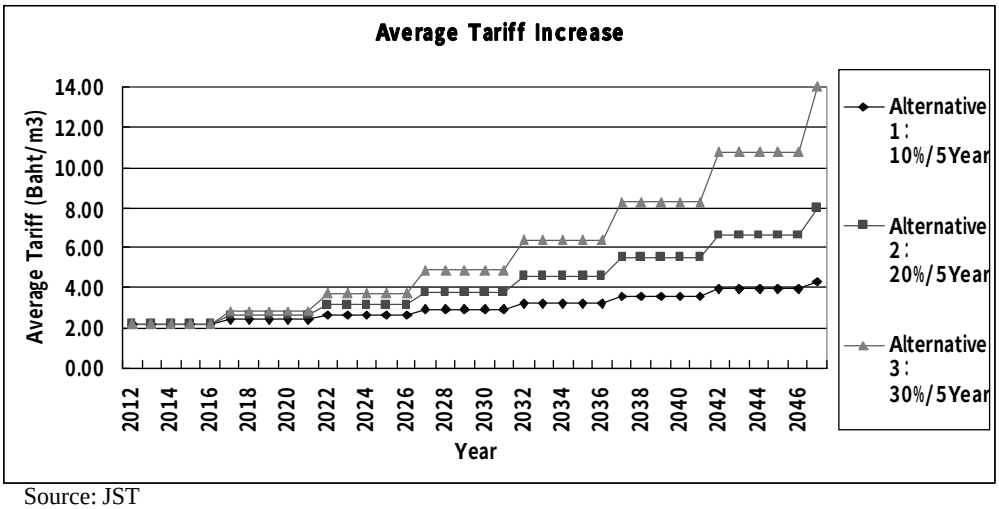
Even more, the tariff collection charge will be paid to MWA from BMA. Hence, the rate of 3.5 Baht/month (42 Baht/year, 10Baht only for the beginning month) for 70,000 users in 2012 is excluded from the above revenue amount. The user number will increase by 0.5 % per annum according to increase of water supply

Table 7.10 Revenue Prediction Alternatives

	Tariff Start Year	Tariff Increase Rate of Every 5 years
Alternative 1: 10% / 5 years	Year 2012	10%
Alternative 2: 20% / 5 years		20%
Alternative 3: 30% / 5 years		30%

* Influence of price inflation is excluded form the analysis
Source: JST

The average tariff level and predicted revenue of whole alternatives are indicated in the following figures.



Source: JST

Figure 7.2 Predicted Average Tariff Rate of All Alternatives (Baht/m^3)

7.3.4 Result of Financial Analysis

As analyzing the "5 cost alternatives"×"3 revenue alternatives", the result of each alternative cases are shown below as using FIRR and NPV of discount rate of 0 % and 3.13 %.

Table 7.11 Result of Financial Analysis

FIRR			Revenue		
			Alternative1	Alternative2	Alternative3
			10%/5years	20%/5years	30%/5years
Cost	Alternative1	BMA 100%, Subsidy 0%	-5.7%	-3.8%	-1.7%
	Alternative2	BMA 60%, Subsidy 40%	-4.8%	-2.6%	-0.3%
	Alternative3	BMA 40%, Subsidy 60%	-4.2%	-1.8%	0.8%
	Alternative4	BMA 0%, Subsidy 100%	-2.1%	1.6%	5.9%
	Alternative5	BMA15%, ODA Loan 85%	-17.7%	-11.7%	-5.5%

NPV (D.R.=0%)			Revenue		
			Alternative1	Alternative2	Alternative3
			10%/5years	20%/5years	30%/5years
Cost	Alternative1	BMA 100%, Subsidy 0%	-7,675.7	-5,743.5	-3,002.2
	Alternative2	BMA 60%, Subsidy 40%	-5,027.7	-3,095.5	-354.2
	Alternative3	BMA 40%, Subsidy 60%	-3,703.8	-771.6	969.7
	Alternative4	BMA 0%, Subsidy 100%	-1,055.8	876.4	3,617.7
	Alternative5	BMA15%, ODA Loan 85%	-8,494.5	-6,56.3	-3,821.0

NPV (D.R.=3.13%)			Revenue		
			Alternative1	Alternative2	Alternative3
			10%/5years	20%/5years	30%/5years
Cost	Alternative1	BMA 100%, Subsidy 0%	-7,125.3	-6,247.5	-5,033.4
	Alternative2	BMA 60%, Subsidy 40%	-4,783.4	-3,905.6	-2,691.5
	Alternative3	BMA 40%, Subsidy 60%	-3,612.6	-2,734.8	-1,520.7
	Alternative4	BMA 0%, Subsidy 100%	-1,270.7	-392.9	821.2
	Alternative5	BMA15%, ODA Loan 85%	-5,182.2	-4,304.4	-3,090.3

Source: JST

FIRR value becomes positive under the condition of receiving 60 % of government subsidy (cost alternative 3) if the tariff rate is increased 30 % every five years (revenue alternative 3). Also under the condition that 100 % of initial cost is covered by government subsidy (cost alternative 4), FIRR becomes positive by revenue alternative 2 (20 % increase / 5 years), and exceeds the criteria figure of 3.13 % by revenue alternative 3 (30 % increase / 5 years). Only in this best case, the financial viability is guaranteed as the FIRR exceeds the criteria of 3.13 %.

In contrast, for the full recovery cases (both cost alternative 1 and 5), the NPV does not become positive even the tariff increase rate is as high as 30 % per 5 years. It means the achievement of full cost recovery is quite difficult if the present planned tariff rate is applied at the beginning of the tariff collection. By realistic way, the wastewater charge should be started as soon as possible, and the tariff should be increased 10–20 % every 5 years for achieving the stable wastewater service. In this condition, the revenue can cover approximately half of the whole operating expenditure (including O&M cost and investment cost).

As considering the previously mentioned situation about the charge collection in Thailand, starting the wastewater tariff collection itself is difficult. There will be a possibility of social opposition by users if BMA intends to increase the tariff rate drastically at the every tariff adjustment time. Hence, BMA needs to prepare the best mitigation way to alleviate their protest, such as executing the education/enlightenment activity about wastewater treatment, and increase the user's satisfaction by service improvement.

8. OVERALL EVALUATION AND RECOMMENDATIONS

Nong Bon treatment area has been selected as project area of the priority project under Preparatory Survey for Bangkok Wastewater Treatment Project, and feasibility study has been conducted. In this Chapter, the priority project is evaluated from various aspects such as technical, economic and financial, socio-environmental and institutional aspects.

8.1 Evaluation from Various Aspects

(1) Evaluation from Technical Aspect

Sewerage system proposed in the study is to intercept wastewater flowing in the existing drainage pipes which is currently discharged to klongs. This system is called as "Thai combined sewerage system". Approximately 80 % of the wastewater generated in the area can be collected based on the result of analysis of actual inflow to the existing WWTPs.

There is no particular problem about construction of interceptors and interceptor chambers since the same method and structure of the existing facilities (construction of interceptors under roads and klong by pipe jacking method) are adopted.

Compact type WWTP is proposed because of the limited land area for the construction of WWTP with large design capacity. Carrier added activated sludge process (CAAS) is proposed as most suitable process to satisfy the requirements. This process is quite popular in Japan, but quite new in Thailand. Therefore, a technical seminar was held to enhance knowledge of counterpart personnel. Various treatment technologies including those for nutrient removal (N and P) have been adopted in BMA. CAAS process is basically modification of conventional activated sludge process, and with provision of adequate information and training, it is possible for DDS to construct and operate WWTP.

On the other hand, there are various problems in Thai combined sewerage system (low concentrations of inflow, reduction of outlets of drainage system, introduction of pumping drainage area, collection of wastewater currently discharged to klongs). For the development of sewerage system in BMA, these problems should be resolved.

(2) Evaluation from Economic and Financial Aspect

As a result of economic analysis, EIRR figures become positive at 4.0 % and 7.2 % for two cases of benefit, i.e. benefits based on willingness to pay (WTP) and affordability to pay (ATP). These two figures are lower than 10 % which is the threshold to evaluate a project as socio-economically viable. However, it is difficult to quantify benefits due to implementation of sewerage project. It is feasible to implement the project taking into account unquantified

benefits and necessity as social infrastructure.

As a result of financial analysis, positive FIRR figures are obtained in cases government subsidy 60 to 100 % and wastewater tariff is increased by 20 to 30 % every 5 years, which assure financial feasibility of the project. However, in any cases to realize full cost recovery, no positive NPV was obtained. It means that if collection of wastewater charge is started with planned tariff structure, it is very difficult to realize full cost recovery.

In conclusion, it is considered realistic for stable and sustainable wastewater services by BMA that wastewater charge should be collected as soon as possible and should be increased by 10 to 20 % every 5 years to cover approximately half of the operation and maintenance cost including depreciation of initial cost.

However, currently in Thailand sewerage service charge is collected in a few areas. Therefore it is difficult to start collection in BMA. Also it might be difficult for BMA to continually increase the tariff even if collection of charges is started as project is implemented smoothly.

(3) Evaluation from Socio-Environmental Aspect

It is determined that any negative impacts for which particular attention should be paid, such as involuntary resettlement of residents, local economy such as employment and livelihood etc., occurrence of secondary contamination, disappearance of and damage to cultural properties and heritage and effect of natural reservation areas do not occur due to implementation of the project. In conclusion, although there is no significant impact due to the implementation of the project, some adverse impacts (slight negative impacts) are envisaged at construction and operation stages, for which mitigation measures and monitoring plan are necessary.

On the other hand, this project contributes to improve water environment and water quality in klongs by collecting and treating wastewater, resulting in enhancement of living conditions of residents and development of social infrastructures.

(4) Evaluation from Institutional Aspect

DDS has experience of implementing of large sewerage projects in the past, and manages 5 WWTPs through management contracts. Therefore DDS has enough capability to implement and manage the project.

However, if external loan is required for the implementation of the project, management capability of DDS to handle external fund should be strengthened. Also, suitable training should be provided to staff of DDS to maintain and enhance their technical competence as operation and maintenance of the WWTP will be outsourced.

At present, responsibilities of sewerage services are fragmented into a few agencies in BMA, e.g. construction and operation and maintenance of interceptors and WWTPs by DDS, and existing drainage pipes and house connections by PWD or district office. These fragmented responsibilities should be brought into one agency, i.e. DDS for more efficient achievement of aims, enhancement of functions and proper management of the system. Sewerage ordinance should be stipulated in this regard.

With the measures mentioned above, DDS is strengthened, competence of its staff and DDS management capability are further enhanced.

8.2 Overall Evaluation and Recommendations

(1) Overall Evaluation

It is judged that the project is feasible from various aspects as mentioned above. Water environment and living conditions in Nong Bon treatment area will be improved and residents will receive benefits due to the implementation of the project.

(2) Performance Indicators for Effects of the Project

The following PIs are recommended to be introduced for evaluation of wastewater services.

Operation

- Ratio of marginal wastewater treatment capacity
- Ratio of actual characteristics against design characteristics (BOD)
- Compliance with discharge standard (BOD)
- Compliance with targeted water quality standard for water body (BOD)
- Ratio of treated wastewater reuse

Management

- Ratio of revenue water: Total revenue water/Total wastewater treated
- Unit wastewater unit O&M cost (O&M): Wastewater unit O&M cost(O&M)/Total accounted for water
- Cost covering ratio (O&M): Service charge revenue/Wastewater unit O&M cost x 100

(3) Recommendations

The following recommendations are made based on the evaluation mentioned above.

1) The project should be implemented as soon as possible since the project area will be developed as good residential areas and improvement of water environment and

living conditions are required.

2) Issues related to Thai combined sewerage system should be dealt with for more efficient and effective implementation of the project.
3) Sewerage service charge should be collected to realize stable and sound management of the sewerage system. Activities to enhance public awareness for current water pollution and improvement measures should be undertaken to obtain residents' understanding.
4) Investigation of the existing drainage pipes should be conducted with cooperation with agencies concerned, with the aim to bring fragmented responsibilities of sewerage system into one agency. In addition sewerage ordinance should be stipulated.
5) Strengthening of project implementing agency and capacity building program for the staff of the agency should be conducted for smooth implementation of the project.

Finally, the following soft components which are necessary for implementation of the project are recommended.

Training

1) Training on improvement measures for combined sewerage system and on pollution load reduction technologies in wet weather
2) New treatment technology which can be applied to compact facilities and energy recovery technology at WWTP
3) Training and capacity building program for staff for construction management, management of external fund and management of sewerage system

Management Improvement Program

1) Improvement of interceptor sewerage system
2) Inventory investigation of existing drain pipes
3) Institutional set up for exceptional area where provision of septic tank is exempted
4) Introduction of PIs
5) Stipulation of sewerage ordinance