3.16 Environmental Impact by the Sewerage Projects and Recommended Countermeasures

With reference to the construction of sewerage facilities, adverse impact to nature and community was studied by stage through implementation of the project. Figure 3.16.1 illustrates a total view on the causes and impact related to major sewerage facilities.

Among potential nuisances, several factors screened are summarized in Table 3.16.1 based on the experiences in this sector. Among environmental problems mentioned above, further descriptions are made on the complains by the inhabitants in surrounding area of WWTP. A questionnaire survey conducted in Japan covering 526 WWTP nationwide revealed that major complains were offensive odor, injurious insects, effluent quality and noise problems. In consideration of potential wastewater and sludge treatment for this master planning (wastewater; SP, AL, OD, AS and sludge; dry bed, dewatering equipment), the causes and impacts, and countermeasures thereto are described as follows:

(1) Offensive Odor

Causes: Major facilities causing the problem; grit chamber, screen, primary sedimentation tank, aeration tank, sludge thickener, sludge dry bed/dewatering equipment and sludge incinerator

Countermeasures: provision of cover over the unit facility, appropriate operation of facilities and ensuring distance from residential areas as much extent as possible (more than 100 m is taken into account)

(2) Injurious insects

Causes: stagnant water exists in the WWTP

Countermeasures: Especially for the ponds with long detention time and for the facilities utilizing natural land, an adequate maintenance could minimize problems

Figure 3.16.1 Potential Impact Caused by Sewerage Projects

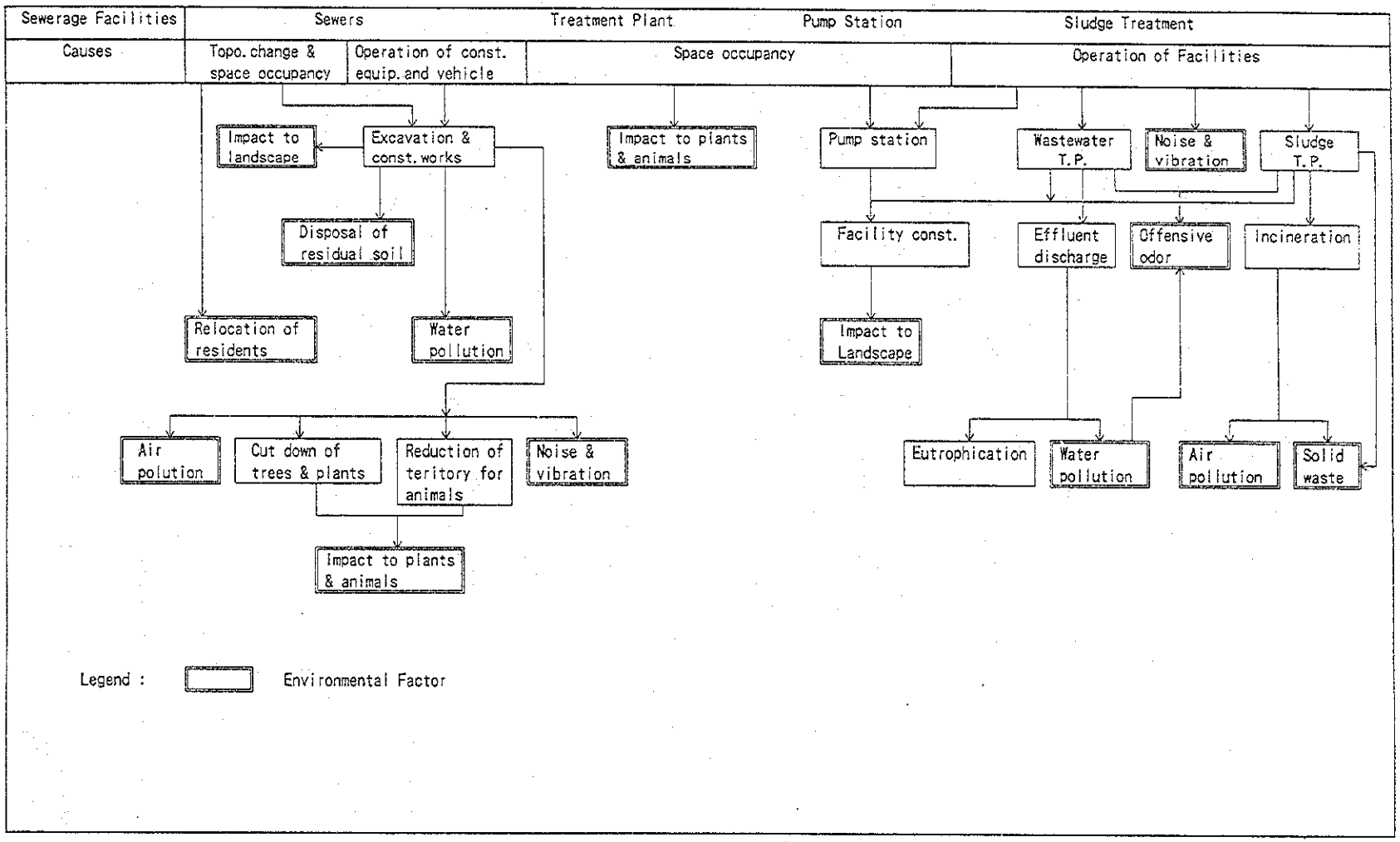


Table 3.16.1 Environmental Problems and Countermeasures

Actions Affecting Environmental Resources and Valves	Damage to Environment	Recommended Feasible Protection Measures
A.Problems Related to Siting of Facilities		
1.Interference with other utilities/ Street, traffic/blocking of access to buildings	1.Nuisances/disturbances to public	1.Alignment of sewer routes to minimize interference with other utilities
2.Nuisance hazards to neighboring areas	2.Nuisances/hazards to worker and neighbors	2.Careful planning/design/O & M and adequate buffer areas
3.Inadequate resettlement provisions	3.Social inequities	3.Adequate planning and budgeting
4.Impairment of historical/cultural movements/areas	4.Loss or impairment of these values	4.Careful planning and offsetting measures
B.Problems During Design Stage		
1.Overflow/bypassing hazards	1.Pollution and flooding	1.Proper design/O & M and operation monitoring
2.Inadequate management of industrial wastewater discharge	2.Damage to sewers/treatment plants	2.Careful planning/design and operation monitoring
3.Hazards of sulfide corrosion	3. - do -	3. - do -
4.Odors and noise from treatment process or sludge disposal operations	4.Nuisance to public	4.Site treatment works only near compatible land use Select appropriate technology Include odor control and low-noise equipment
C.Problems During Construction Stage		
1.Silt runoff from construction operations	1.Soil erosion, damage to water quality /land values	1.Proper resurfacing and construction monitoring
2.Dust/odors/fumes	2.Hazards to workers and nearby residents	2.Appropriate controls
3.Prolonged periods of sewer construction	3.Traffic congestion/blocking of access to buildings	3.Careful construction scheduling
4.Noise and vibrations	4.Hazards to workers or nearby residents	4.Appropriate controls
D.Problems During Operation Stage		
1.Hazards to health/safety of workers	1.	1.Careful O & M and operation monitoring
a) Toxic gases in sewers and hazardous materials in sewage	a) Serious/health/safety hazards	a) Careful O & M program with of emergencies
b) Communicable disease hazards	b) - do -	b) Careful O & M program and monitoring
c) Sewer trench cave-in monitoring	c) - do -	c) - do -
2.Inadequate operation stage monitoring	2.O & M likely to depreciate	2.Losses in overall system functioning
3.Overflow from sewers	3.Nuisance/public health hazard	3.Routinely, inspect sewers for illegal connections and obstructions Clean sewers as required Provide monitoring system with alarms for pump station failure Educate public to prevent disposal of solid waste in sewers

(3) Effluent quality

Causes: color of effluent, high contents of suspended solids and bubble by detergent

Countermeasures: control of industrial wastewater and detergent use

Reduction of bubble in the aeration tank would be performed by an appropriate O&M. The conditions on receiving waterways for the effluent from WWTPs in quality and quantity are summarized in Section 3.8, Chapter 2. Planned effluent quality (BOD) 20-40 mg/l is expected to be diluted with sufficient flow of receiving river/channel (ranging from 3 - more than one thousand times of effluent volume) at least to meet present water quality (1.2-35 mg/l).

3.17 Recommendations on the Sanitation Improvement in the DTCP Area

Improvement of public health and the quality of life of the rural population, within the DTCP area but out of sewerage service area, depends in part on the provision of an improved water supply and sanitation services.

Present situation and fundamental problems on sanitation related components in the rural area are summarized in Chapter 4, Part I covering water supply, refuse disposal, and nightsoil treatment/disposal. The investigation results on water supply revealed the needs of reduction in bacteria levels. Domestic vector control program initiated by the DOH, MOPH is not yet realized as of the present time. Insanitary living conditions make lower the productive potential of the people.

In this section, wastewater especially nightsoil disposal in the rural area is the main theme. Other components are discussed in the previous section with reference to the requirements of sanitation improvements for the sewerage planning areas.

In the urbanized area the standard solution for the sanitary disposal of human excreta is sewerage with flush toilet, which are designed to maximize user convenience rather than health benefits at substantial economic and

environmental costs. Some clusters with comparatively higher population density in the subject area may introduce sewerage system in the future. However, accomplishment of a significant reduction in the transmission of excreta-related diseases is a major objective in the rural area. Low-cost sanitation facilities for health benefits shall be provided for the majority of the population.

Sequential Improvement of Nightsoil Treatment

A particular series of improvement experienced in developed countries take a long time to reach to more sophisticated solutions such as conventional waterborne sewerage. Users decide the time frame over which improvements are to be made and is thus able to provide higher levels of convenience, keeping pace with increasing income.

Most appropriate technology is more time intensive than that of traditional feasibility analysis. Sanitary toilet, water sealed toilet is wide spread, which is the minimum requirement being promoted in the developing countries.

The ventilated improved pit latrine (VIP), acceptable in the rural area would be upgraded to pour flush system, which can include a low-volume cistern-flush toilet with water seal for added user convenience. The improvement is an equally high standard sanitation system as conventional sewerage. It is substantially cheaper and it can be reached by staged improvement of several different sanitation technologies.

The prevalent types of cesspool and septic tank with a standard design are referred to in Section 3.3.2. The upgrading of toilet facilities would be achieved from aforementioned VIP, a basic low-cost facility to such on-going toilet type.

Improvement of Current-Use Tank

Pour-flush latrines are obligatory for houses and buildings in Thailand. The Government has been encouraging this on-site disposal of nightsoil supported by sludge removal services. The effluent is released to a seepage pit/leaching tank. However, overflow of wastewater may be confronted, especially during rainy season under impermeable soil condition. A pollution problem to

groundwater may also occur which affects drinking water. In this connection, collection of overflow water shall be put into practice in the future in provision of appropriate overflow pipes to the septic tank. Furthermore, a periodic control to check the conditions of the septic tank shall be introduced as well as adequate desludging services.

Institutional Improvement

Incremental sanitation requires municipal activity in sanitation programs to be spread over a considerably longer time fame, since the users have the option of whether and when to proceed to the next higher level of convenience.

Community participation is different depending on respective one. Therefore, personal contacts and dialogue are important to support the activity.

The long-term objective of community participation in sanitation program is to ensure that the level of the facility matches the preference and resource constraints of users.

Institutional support by the central and local governments is needed to supply technical expertise and support services not available in the community, such as provision of revolving funds, training of officials and research and development; investigation on the efficiency of existing facilities, measures in the area with impermeable soil condition, sullage treatment, septic tank up-grading, sludge removal and disposal, etc.

User education entailing water pollution control and institutional development programs will generally form an essential part of sanitation programing.

CHAPTER 3

SEWERAGE MASTER PLAN FOR RESPECTIVE MUNICIPALITIES/AREAS

SECTION 1

CHAI NAT MUNICIPALITY

CHAPTER 3 SEWERAGE MASTER PLAN FOR RESPECTIVE MUNICIPALITIES/AREAS

SECTION 1 CHAI NAT MUNICIPALITY

1.1 Description of the Study Area

The DTCP area (about 56.5 km^2) covers present municipality area (6.06 km^2) and its surrounding Tambols; Thapra, Ban Kruai, Chai Nat, Thachai, Had Thasao and Thamakul. The subject area, about 195 km far from Bangkok, is located in the east bank area of the Chao Phraya river.

The area is affected by north-eastern monsoon with annual rainfall of 1200 mm and average temperature of 28.1 ^oC. General topography is characterized as plain plateau excepting hilly northeast area (15 m amsl) where bird gardens and recreational areas are developed. Soil bearing capacity is reported to be about 8-10 ton/m^2.

Trunk roads are constructed along main rivers both for transportation and flood protection purposes. Road conditions are comparatively good and only about 10% of existing roads need to be improved for vehicle use. A bridge is installed at the southeast of the municipality crossing the Chao Phraya river to connect with other districts and provinces. The commercial area is concentrated along National Road No. 1 across the central area from east to west. While, about half of houses/buildings exists outside of the municipality area (within the DTCP area).

The cottage industry exists in the municipality area comprising food and drinks, furniture, equipment repair shop and printing. Industrial development will be gradually proceeded, although still being conservative. A slaughterhouse is operated at Phomprasert R.D., Muang district (2 rai area and 8 m^3/d water consumption), 250 m far from the municipal boundary. There are two fresh markets; municipal market at Kong Tham road and private one at Chainarong road. Electric power supply covers most of households in the DTCP area (99.37%).

1.2 Existing Sanitation/Sewerage and Flood Protection Systems

1.2.1 Existing Sanitation Facilities

The municipal government serves for refuse collection and disposal covering about 30 percent of the population in the DTCP area (53% in the municipality area and 10% in the outside of the municipality). Generated garbage out of the service area is usually disposed of by means of burning or bury. The municipal government uses two trucks for the services to collect an amount of 80 m^3/d. Refuse disposal site (67 rai) is situated at Klao Phong, Tambol Thapha. On-site treatment and disposal of nightsoil is common either provided by septic tank or cesspool as described in Section 3, Chapter 2 (refer to standard facilities in the same section).

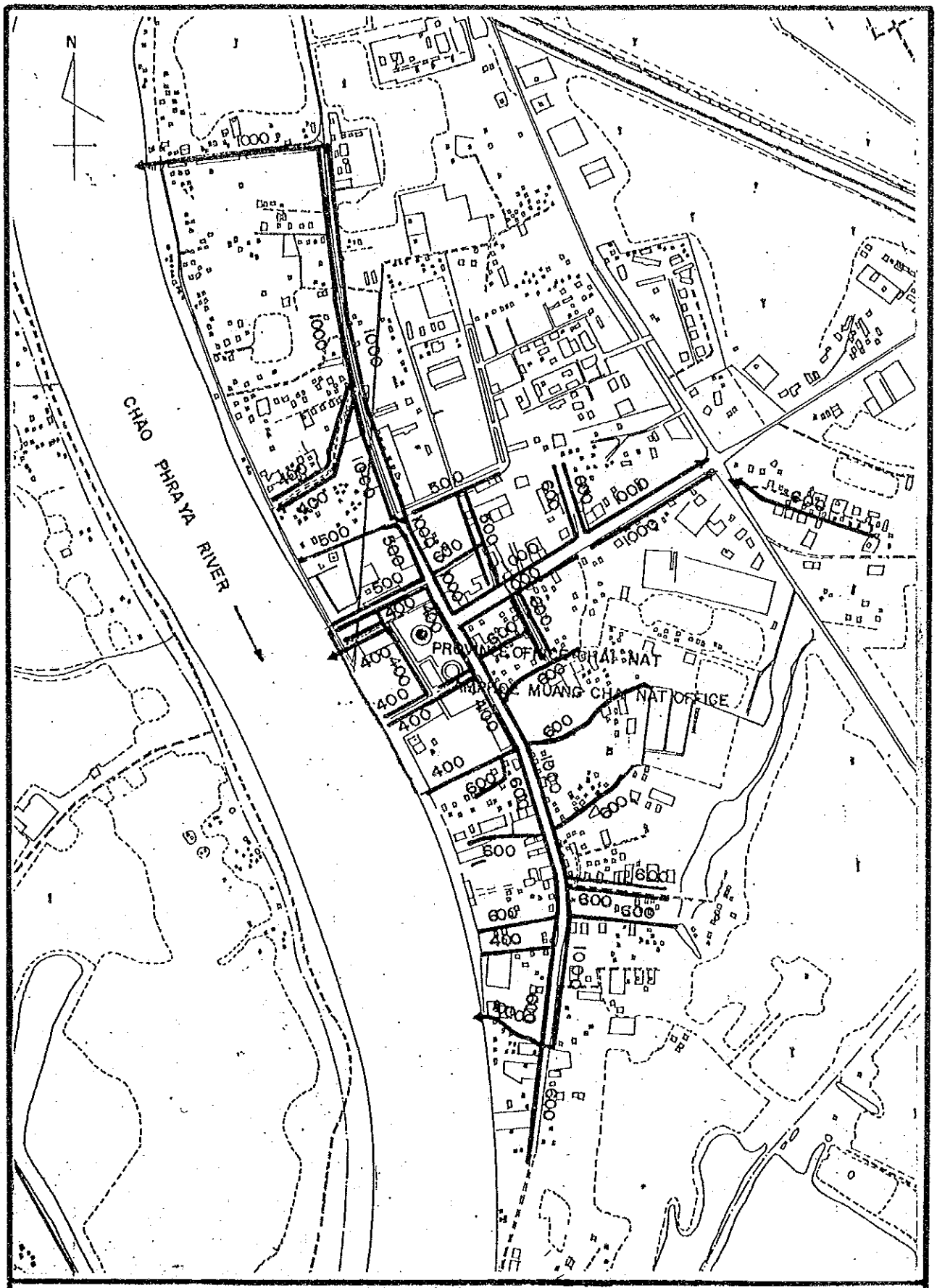
1.2.2 Existing Sewerage Facilities

Drainage facilities, working as combined sewers, are provided along major roads (about 90% of municipal road extension), which are made of reinforced concrete pipe (RC) ranging from ϕ400 mm to ϕ1,000 mm. The composition of pipes is shown in Table 1.2.1. Area coverage and configuration of the facilities are shown in Figure 1.2.1.

Table 1.2.1 Existing Drainage Facilities

Size (mm)	Length (m)	Type	Drainage Area (ha)
dia. 1,000	5,100	RC. Pipe	45.8
dia. 600	4,150	RC. Pipe	42.4
dia. 500	1,250	RC. Pipe	8.6
dia. 400	2,550	RC. Pipe	19.4
Total	13,050		116.2

There are four discharge points, details of which are shown below.



LEGEND : 600 DIAMETER (mm)
DRAINAGE PIPE ⟶ OUTFALL SCALE 1 : 12,000

FIGURE 1.2.1 EXISTING DRAINAGE SYSTEM IN CHAI NAT MUNICIPALITY

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Approximate Location	Receiving Water Body/ Discharge Point	Pump Facility
North, Chainarong road	Chao Phraya river	Pump station (movable type)
Behind the municipal hall	-do-	-do-
South, chainarong road	-do-	-do-
East, Wong Toh Road	Public land	None

A large amount of wastewater flows into the drainage channel across the center of the municipality. The channel seems to play a role as a stabilization pond and is connected to the river at the southern boundary of the municipality.

The municipality has been undertaking improvements and expansion of the drainage facilities using its own budget.

1.2.3 Flood Protection Facilities

There are lots of RID's dikes around the community area. Flood problems in the area rarely occur protected by such dikes in addition to strategically installed roads along main rivers.

1.3 Water Supply

The total of 32% of population in the DTCP area enjoy drinking water supply services by the waterworks of the PWA (60% in the municipality). People out of the service area use different water sources: rain water, well and river water.

Chao Phraya dam, a major facility to control the flow of the Chao Phraya river, is located in Chai Nat and operated by the RID mainly for irrigation use. Sub-systems constructed for irrigation purposes are as follows:

Provincial irrigation projects	:	six (6) projects for a total area of 619,815 rai
Middle size projects	:	87,902 rai
Small size projects	:	more than 22 sub-projects covering 119,580 rai

1.4 Population and Land Use

Features of houses/buildings by land use type at present are summarized as follows:

Land Use Type	Features with Approximate Percentage
Residential area (private ownership; 70%)	single story house, 75% wooden house, 75% zinc roof, 85%
Commercial area	single story building, 40% (wooden building, 35%; concrete building, 40%) two-story building, 60%
Industrial area (private ownership; 100%)	single/two story wooden building, 60%

Residential areas will be developed slowly but steadily with a plan of housing estate (370 ha), however, commercial area is expected to be developed steeply. The municipality has a plan for road extension (six roads with the width of 9-13 m). Land use at present and in the future (2011) is referred to in Section 3, Chapter 2 and Figure 1.4.1 presents the projection in the year 2011. The following are projected features of land use by sub-area.

- West bank area of Chao Phraya river:

  About half of houses were built more than 20 years ago. Houses are being constructed along the river and Highway No.3183. Moderate development as a residential area is expected.

- Center of the municipality in the east bank area of Chao Phraya river: Area expansion is expected as commercial and institutional area with high population density.

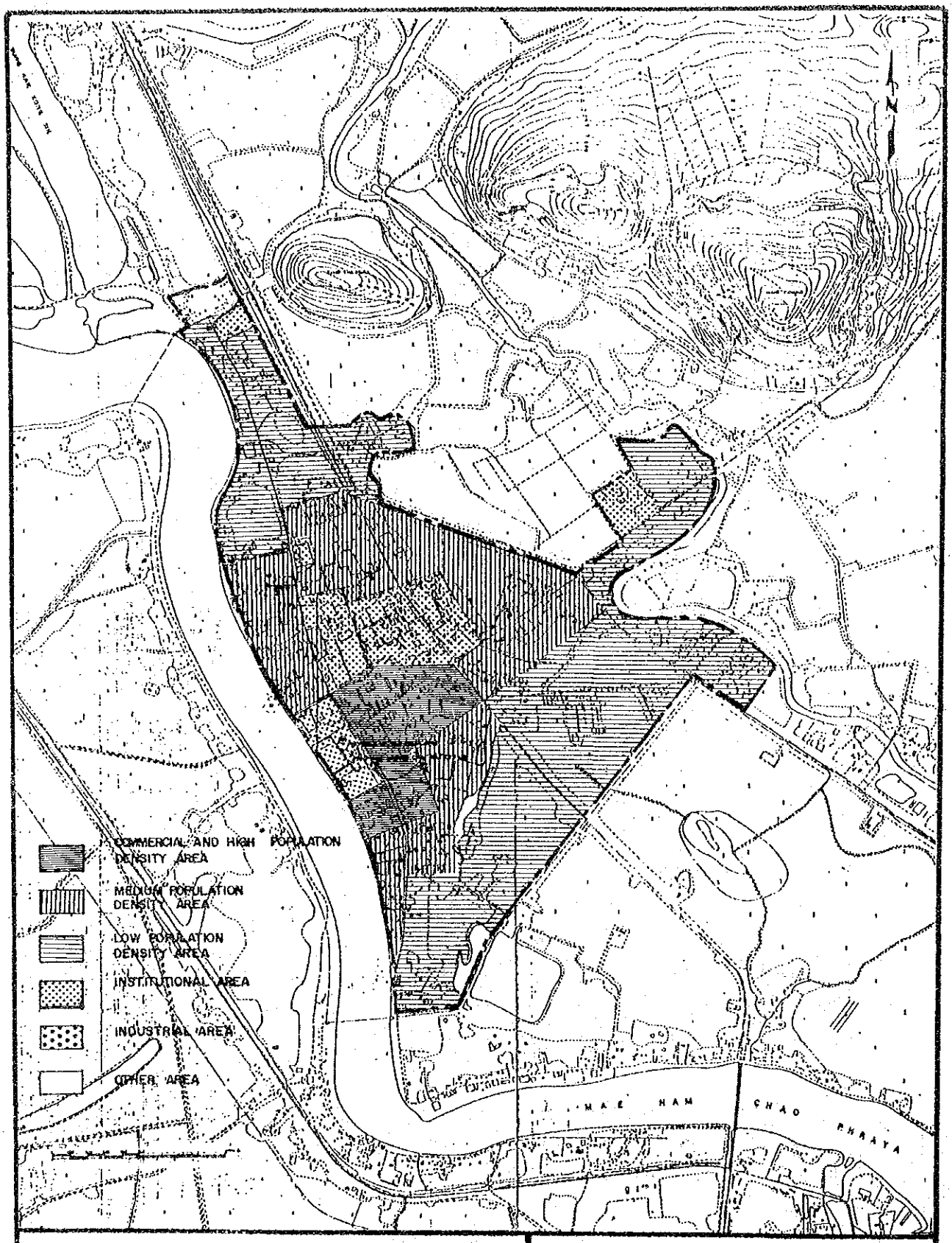


FIGURE 1.4.1 FUTURE LAND USE - YEAR 2011 (CHAI NAT)

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

- Northern portion of the municipality:

  Medium population density area with sufficient land available for further development

- Eastern portion of the municipality:

  Low population density area

- Southern portion of the municipality:

  Because of locational advantage provided with access roads for neighboring communities, development for business activities is expected.

Study area and population are as follows:

Area & Population	Present Municipality	Future Exp. Area	Sewerage M/P Area	Other Area	DTCP Area
Area (km^2)	6.06	0.84	6.90	49.59	56.49
Pop. in 1991	13,983	2,035	16,018		
Pop. in 2011	19,765	2,035	21,800		

1.5 Quality and Quantity of Wastewater

1.5.1 Unit Wastewater and Pollution Load on a Discharged Basis

(1) Domestic Wastewater

Unit quality (BOD) and quantity on the daily average basis at present and in design year are tabulated breaking down into sullage and toilet waste.

Domestic wastewater discharge is assumed at 80% of water consumption. Toilet waste is treated by septic tank with assumed treatment efficiency of 50%.

Year	Unit Wastewater (lpcd)			Unit BOD Load (gpcd)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Present	100	12	112	33.6	5.5	39.1
Design Year (2011)	136	24	160	35.1	5.5	40.6

(2) Business Wastewater

Those for business wastewater (commercial and institutional) is assumed to be 30% and 40% of domestic wastewater for the present and design year (2011), respectively.

	Unit Wastewater (lpcd)	Unit Pollution Load (BOD_5 gpcd)
Present	32	6.1
Design Year (2011)	64	7.7

1.5.2 Discharged Wastewater and BOD Load

(1) Domestic Wastewater

Wastewater quantity and BOD load on a discharged basis are estimated for the present and design year (2011) multiplying service population by unit wastewater quantity/BOD load. The following are the estimation results.

Item	Present			Design Year (2011)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Wastewater Quantity (m^3/d)	1,602	192	1,794	2,965	523	3,488
BOD Load (kg/d)	538.2	88.1	626.3	765.2	119.9	885.1

(2) Business Wastewater

Discharged wastewater quantity and BOD load are estimated in the same procedure as domestic wastewater.

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	513	1,395
BOD Load (kg/d)	97.7	167.9

(3) Total Wastewater Quantity and BOD Load

Total discharged wastewater quantity and BOD load (daily average basis) at present and in the design year (2011) for Chai Nat Sewerage Development area are figured out as shown below.

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	2,307	4,883
BOD Load (kg/d)	724.0	1,053.0

1.6 Proposed Sewerage System

1.6.1 Service Area

The service area with 690 ha is situated on the left bank area of the Chao Phraya river. Present population in the area is about 16,000 and design population is projected to be about 21,800.

The area is generally flat with a mild slope from east toward west. A single sewerage system is recommended covering the whole service area as shown in Figure 1.6.1.

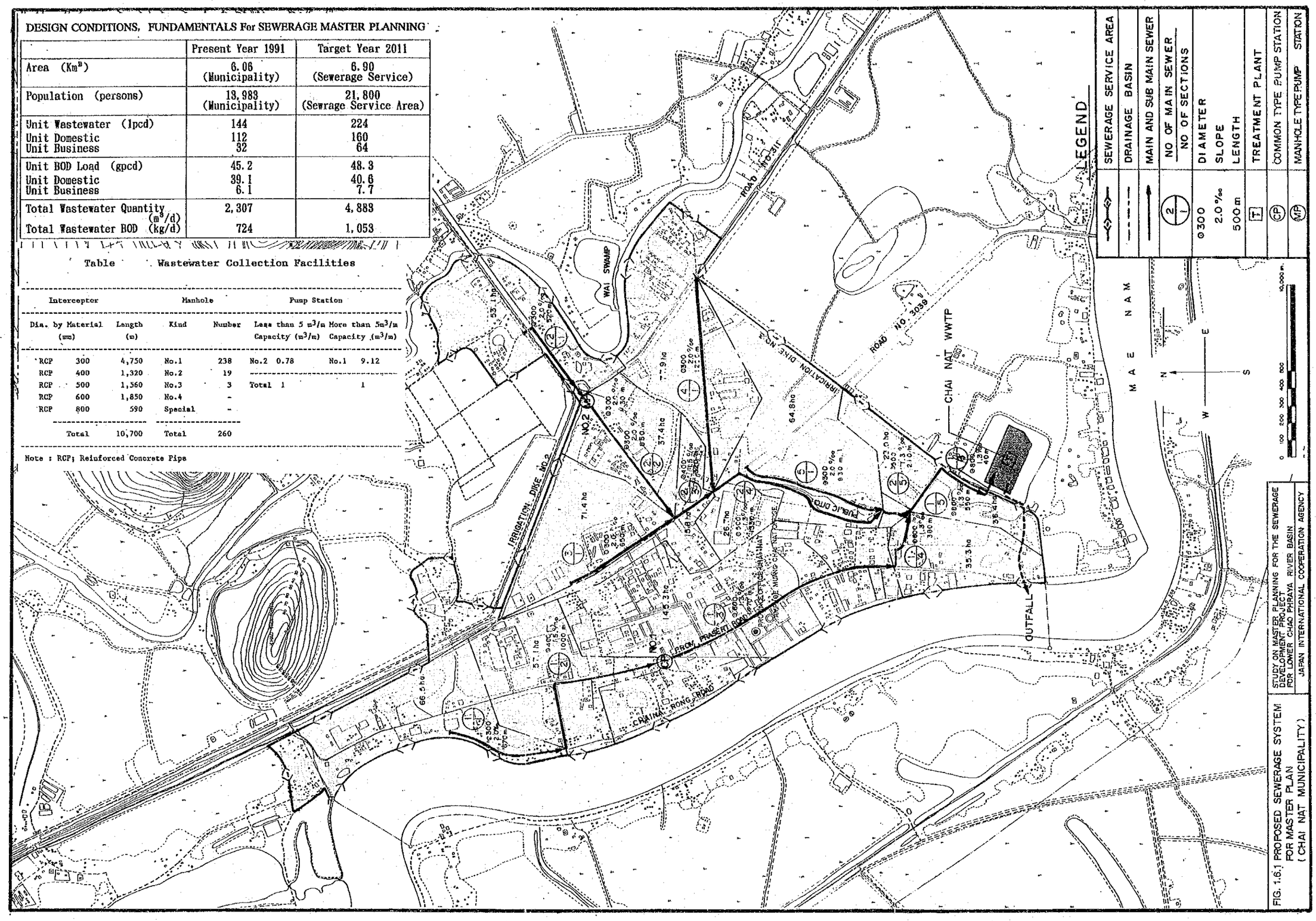
DESIGN CONDITIONS, FUNDAMENTALS For SEWERAGE MASTER PLANNING

	Present Year 1991	Target Year 2011
Area (Km^2)	6.06 (Municipality)	6.90 (Sewerage Service)
Population (persons)	13,983 (Municipality)	21,800 (Sewrage Service Area)
Unit Wastewater (lpcd)	144	224
Unit Domestic	112	160
Unit Business	32	64
Unit BOD Load (gpcd)	45.2	48.3
Unit Domestic	39.1	40.6
Unit Business	6.1	7.7
Total Wastewater Quantity (m^3/d)	2,307	4,883
Total Wastewater BOD (kg/d)	724	1,053

Table Wastewater Collection Facilities

Interceptor			Manhole		Pump Station	
Dia. by Material (mm)		Length (m)	Kind	Number	Less than 5 m^3/m Capacity (m^3/m)	More than 5m^3/m Capacity (m^3/m)
RCP	300	4,750	No.1	238	No.2 0.78	No.1 9.12
RCP	400	1,320	No.2	19		
RCP	500	1,560	No.3	3	Total 1	1
RCP	600	1,850	No.4	-		
RCP	800	590	Special	-		
	Total	10,700	Total	260		

Note : RCP; Reinforced Concrete Pipe



STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. 1.6.1 PROPOSED SEWERAGE SYSTEM FOR MASTER PLAN (CHAI NAT MUNICIPALITY)

Location of WWTP is recommended in the area near the southern boundary of the municipality, where the existing drainage is crossing and the land elevation is relatively low. Treated wastewater may be discharged into the drainage channel.

1.6.2 Wastewater Collection System

Wastewater collection system in application of the combined collection method is designed taking into account of the factors such as possibilities for construction and availability of land for sewer systems.

Distribution of population and wastewater quantity was made in use of population density assumed by land use type (refer to calculation table in Supporting Report 3.1.6).

Alignments of main interceptors and pump stations are proposed as indicated in Figure 1.6.1 and their profiles are shown in Figure 1.6.2 (refer to hydraulic calculation in Supporting Report 3.1.6). The following are brief descriptions on the sewer systems.

- Five (5) systems of interceptor mains are planned in consideration of elevation of the road along Chao Phraya river (high along urban center) and flow direction of existing drainage pipes in the central area. Sewer No.: 1/1 - 1/6, 2/1 - 2/5, 3/1, 4/1 and 5/1.

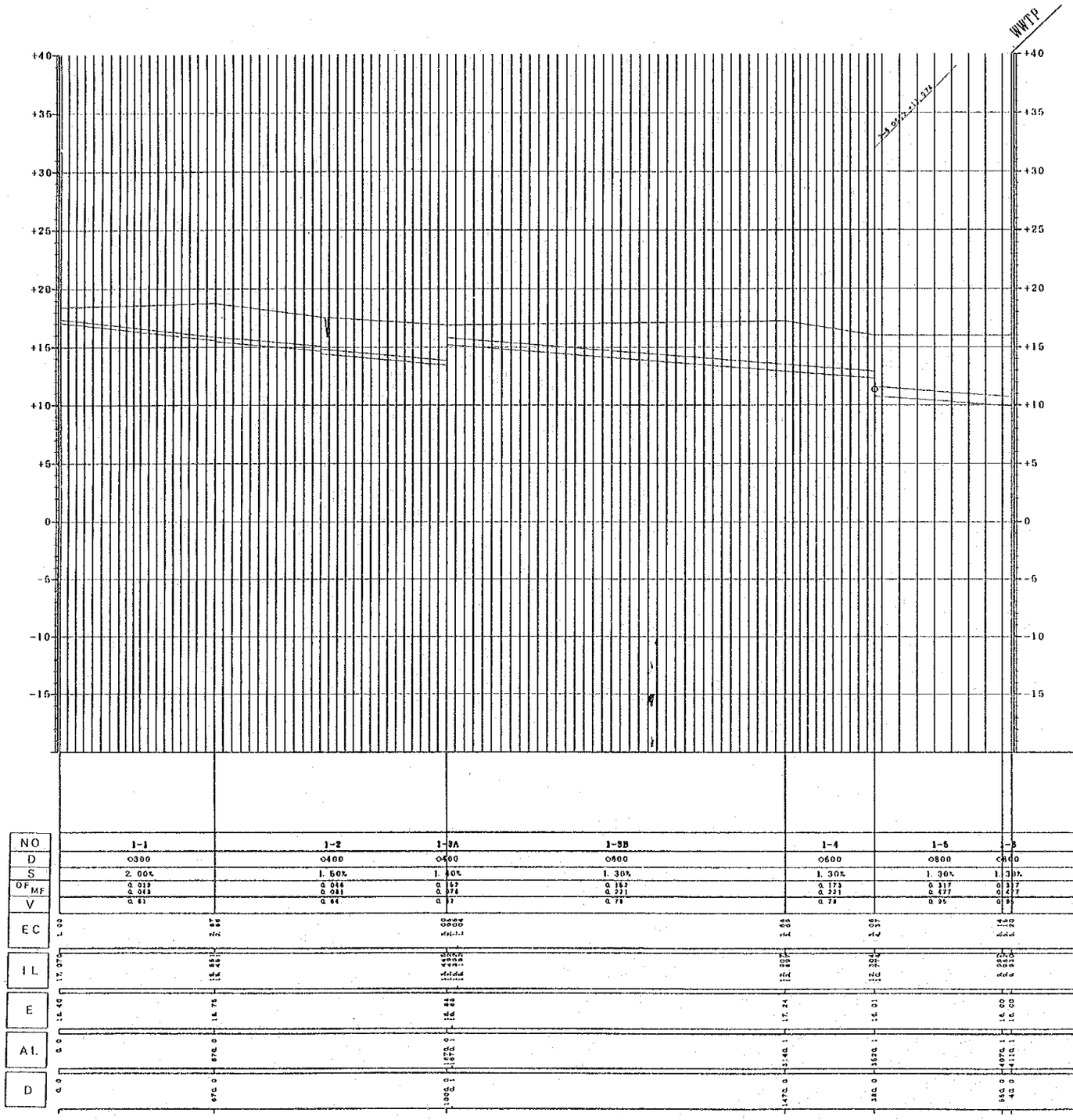
- The longest main (1/1 - 1/6) starts from northern end of the service area and is connected to the treatment plant via the center of the municipality, Prom Par Sert road.

- Interceptors 2/1 - 2/5 start about 600 m east of irrigation dike No. 2 and connect to the upstream of the 1/5 interceptor.

- 3/1 interceptor is along road No 3039 to connect to 2/3 interceptor.

- 4/1 interceptor starts from road No 311 to connect to 2/4 interceptor.

- 5/1 interceptor starts from the crossing point of road No. 3039 with a channel.



LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

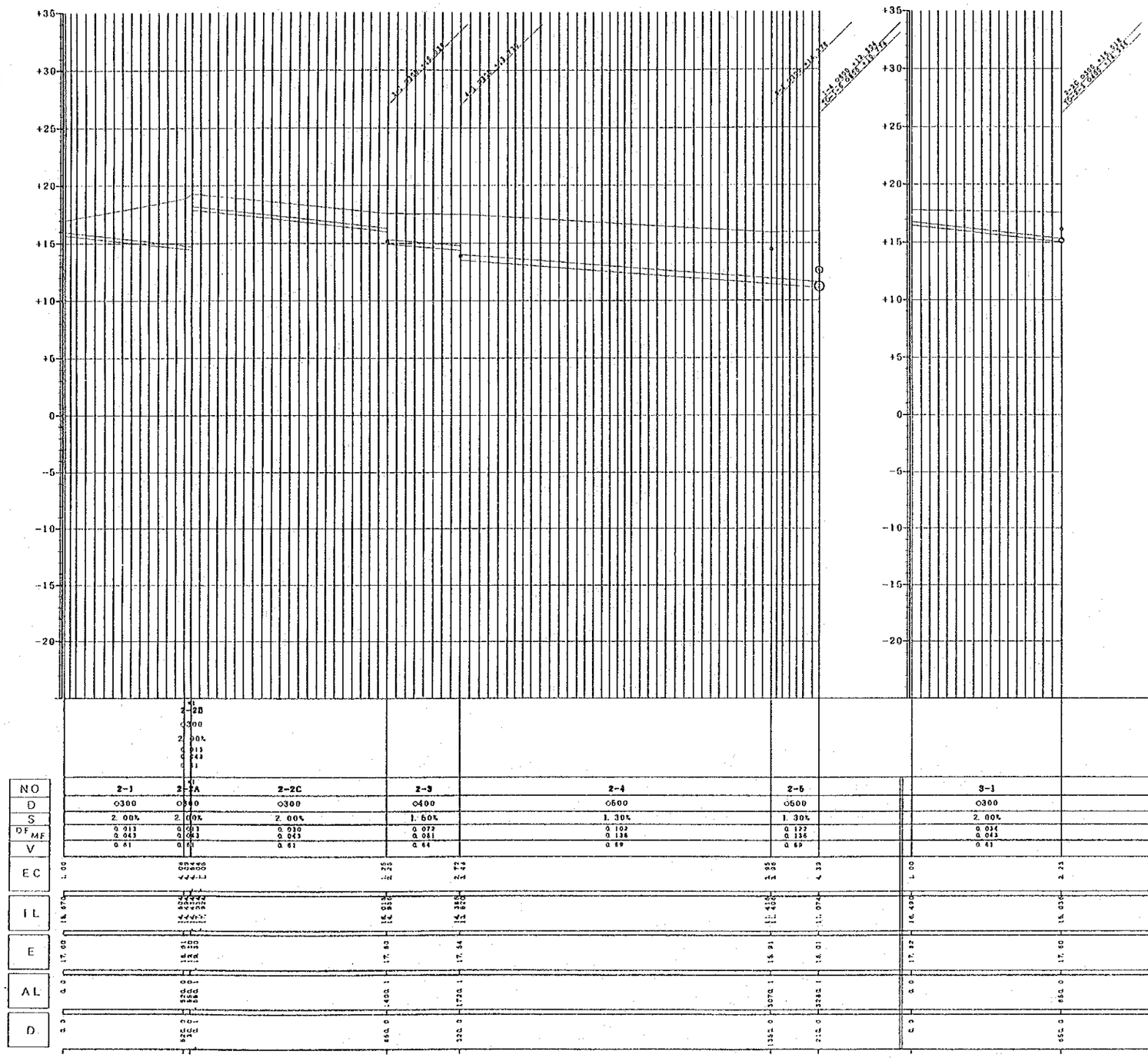
1-1	1-2	1-3A	1-3B	1-4
1-5	1-6			

FIG. 1.6.2 (1)
CHAI NAT

V 1:200
H 1:10,000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

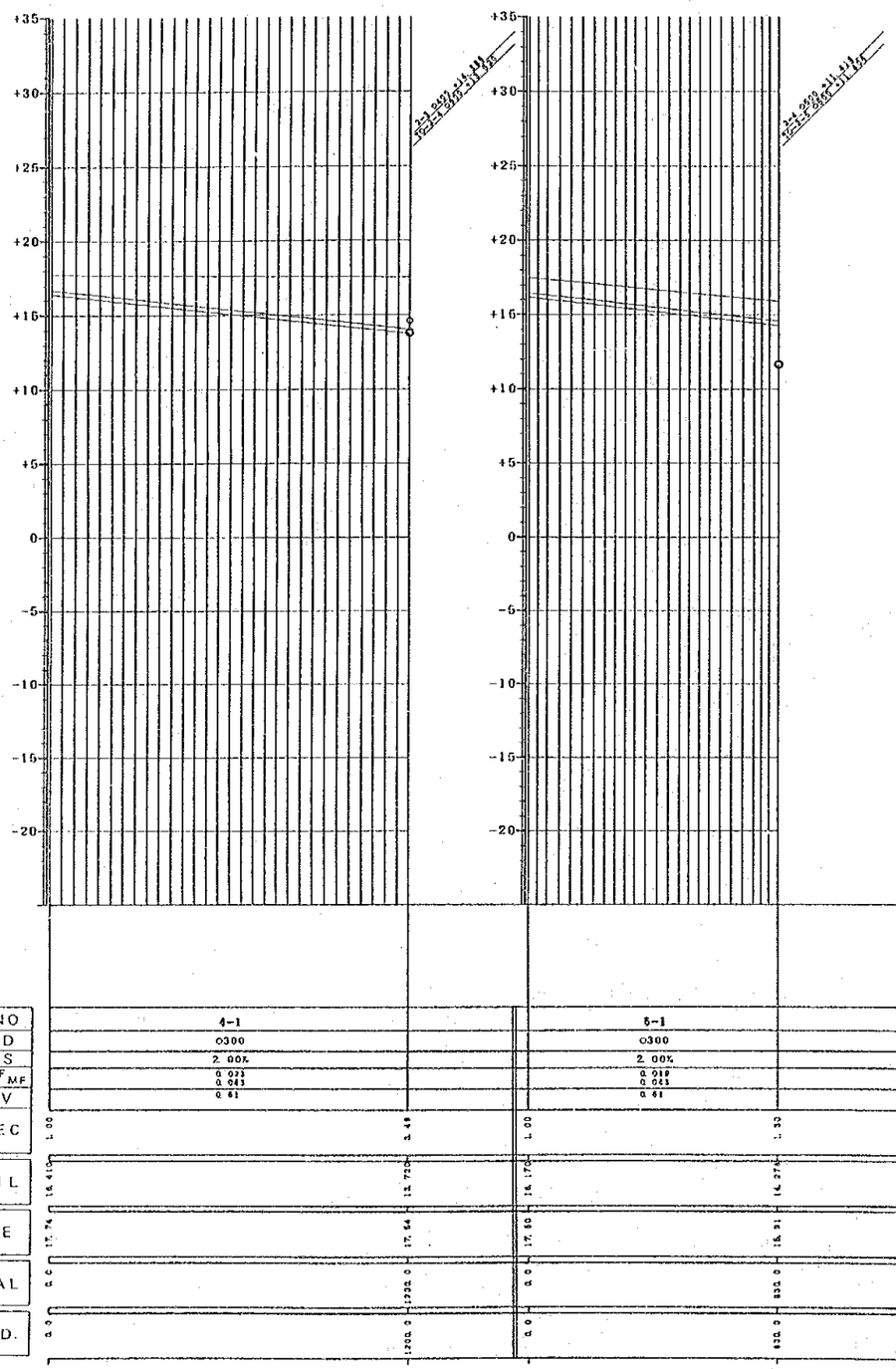
2-1	2-2A	2-2B	2-2C	2-3
2-4	2-5	3-1		

FIG. 1.6.2 (2)
CHAI NAT

V 1:200
H 1:10,000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



NO	4-1	5-1
D	Ø300	Ø300
S	2.00%	2.00%
DF	0.023	0.018
MF	0.043	0.043
V	0.61	0.61
EC	1.00 / 3.49	1.00 / 1.30
IL	14.419 / 13.730	14.170 / 14.270
E	17.74 / 17.64	17.80 / 16.91
AL	0.0 / 1230.0	0.0 / 830.0
D.	0.0 / 1230.0	0.0 / 830.0

LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

4-1	5-1			

FIG. 1.6.2 (3)
CHAI NAT

V 1:200
H 1:10,000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

- Inflow of wastewater from existing drainage pipes; Interceptors 1/2, 1/3 2/3 and 2/4.

Table 1.6.1 shows composition of collection facilities. Specifications of pump stations and siphon and river crossing are included in Supporting Report 3.A.6, 3.B.6 and 3.C.6.

Table 1.6.1 Wastewater Collection Facilities

Interceptor			Manhole		Pump Station			
Dia. by Material (mm)		Length (m)	Kind	Number	Less than 5 m^3/m Capacity (m^3/m)		More than 5m^3/m Capacity (m^3/m)	
RCP	300	4,750	No.1	238	No.2	0.78	No.1	9.12
RCP	400	1,320	No.2	19				
RCP	500	1,560	No.3	3	Total	1		1
RCP	600	1,850	No.4	-				
RCP	800	590	Special	-				
	Total	10,700	Total	260				

Note : RCP; Reinforced Concrete Pipe

1.6.3 Wastewater Treatment and Sludge Disposal System

(1) Wastewater Treatment and Disposal Method

The wastewater discharge in the sewerage development area of Chai Nat municipality is estimated to be 4,883 m^3/d in the year of 2011. Groundwater infiltration at 20% of wastewater discharge is assumed. The design wastewater to the treatment plant is estimated to be 5,900 m^3/d. The treated water quality is expected to be less than 40 mg/l as BOD.

The following three (3) treatment systems are applicable to meet the above requirements in quality and quantity.

1) Stabilization Pond
2) Aerated Lagoon
3) Oxidation Ditch

(2) Comparative Evaluation

The above three (3) treatment systems are compared in terms of required construction and O&M costs, required land area and easiness of O&M as shown below (Details are included in Supporting Report3.1.6.2).

Evaluation Item	Stabilization Pond	Aerated Lagoon	Oxidation Ditch
(1) Construction Cost (million Baht)	8.91	14.96	35.63
(2) Land Cost (million Baht)	14.25	6.75	3.75
(3) O/M Cost (million Baht/year)	0.13	0.50	3.46
(4) Required Land Area (ha)	7.6	3.6	2.0
(5) Easiness of O/M			
- Adaptability of overload	A	A	B
- Required technology level	A	A	B
- Sludge disposal	A	A	C

Note : 1) Construction cost : direct construction cost excluding land acuqisition, engineering administration costs
2) O/M cost : wages, electric charge, chemical and others
3) Adaptability of overload : A: high, B: middle, C: low
4) Required technology level : A: low, B: middle, C: high
5) Sludge disposal : A: easy, B: medium, C: hard

As evident from the above table, construction and land acquisition cost of aerated lagoon system is the most economical. While the annual operation and maintenance cost of stabilization pond system is 0.37 million Baht cheaper than that of aerated lagoon system. Then, these two (2) systems are compared by Net Present Value (NPV) of construction and land acquisition cost, and operation and maintenance for 30 years (refer to Supporint Report 3.1.6.3).

	Stabilization Pond	Aerated Lagoon
NPV	47.82 million Baht	98.15 million Baht

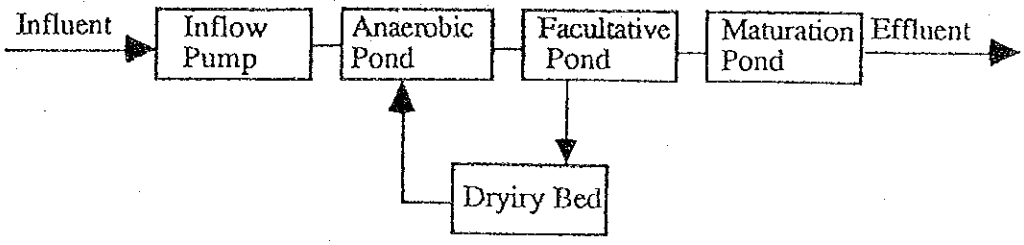
Thus, stabilization pond system is proposed for the treatment plant of Chai Nat.

(3) Plan of Treatment Plant

The proposed location of the wastewater treatment plant for Chai Nat is the

existing pond in Tambol Ban Klaui. The pond is now used as the irrigation reservoir with a total area of 15.4 ha (98 rai). The proposed treatment plant of stabilization pond with a capacity of 5,900 m^3/d requires a net space of 7.6 ha. This occupies a half of the existing pond area.

The flow sheet of stabilization pond system and the capacity dimension and other relevant details of each treatment facility is shown below.



Flow of Stabilization Pond System

Inflow Pump	:	Design capacity	:	9,200 m^3/d (dry, hourly max.)
			:	27,600 m^3/d (wet, hourly max.)
	:	Capacity	:	6.39 m^3/min. with 7.6 m hydraulic head (dry, hourly max.)
			:	19.17 m^3/min. with 7.6 m hydraulic head (wet, hourly max.)
Grit Chamber	:	Surface loading	:	1,769 m^3/m^2/d (dry weather)
			:	2,654 m^3/m^2/d (wet weather)
	:	Retention time	:	29 sec (dry), 20 sec (wet)
	:	Size : 0.8 m(W) x 6.5 m(L) x 0.6 m(D) x 2 units (1 unit for dry weather)		
	:	Constructed with R.C		
Anaerobic Pond	:	Design capacity		5,900 m^3/d (daily ave. dry)
	:	Pond capacity		29,500 m^3
	:	Pond surface area		9,600 m^2
	:	Retention time		5 days
	:	Dimension 60 m(W) x 80 m(L) x 4.0 m(D) x 2 units		
	:	Embankment protected by masonry		

During F/S stage, study on the sewage characteristics shall be further made to determine whether anaerobic pond is employed or not. Polishing pond may be added instead.

Facultative Pond	:	Pond capacity	29,500 m^3
	:	Pond surface area	16,800 m^2
	:	Retention time	5 days
	:	Dimension 70 m(W) x 120 m(L) x 2.0 m(D) x 2 units	
	:	Embankment protected by masonry	
Maturation Pond	:	Pond capacity	29,500 m^3
	:	Pond surface area	20,920 m^2
	:	Retention time	5 days
	:	Dimension 63 m(W) x 83 m(L) x 1.5 m(D) x 4 units	
	:	Embankment protected by masonry	
Drying Bed	:	Drying area	192 m^2
	:	Detention time	15 days
	:	Dimension	6 m x 8 m x 4 units

The treated water is discharged to Chao Phraya river. Layout of the treatment plant and hydraulic profile of the treatment process are shown in Figure 1.6.3, and Figure 1.6.4, respectively.

1.7 Cost Estimates

1.7.1 Construction Cost

In the previous chapter, cost functions for interceptors, pump stations (more than 5 m^3/min.) and wastewater treatment plants are developed. Land acquisition cost is also considered to come up with the total construction cost. The following are cost requirements (million Baht) for the design year 2011.

(1)	Direct Cost	
	1) Interceptor	111.7
	2) Pump station	4.7
	3) W.W.T.P.	8.91
	Total of Direct Cost	125.31
(2)	Contingency (20% of Direct Cost)	25.06

Wastewater Treatment Plant

Wastewater Treatment method	Stabilization Pond System
Plant Space Area (ha)	7.6
Treatment Capacity (m^3/d) (inclusive of G.W)	5,900
Discharge Point	Chao Phraya River

Main Facilitie's

1)	Inflow Pump	Submerged Pump
	(Dry Season)	ø200m/mx3.0m^3/minx7.6^{m}Hx2units
	(Wet Season)	ø250m/mx6.0m^3/minx7.6^{m}Hx2units
2)	Grit Chamber	Constructed with R.C. Size 0.8^{m}Wx6.5^{m}Lx0.6^{m}Dx2units (1 unit for dry weather)
3)	Anaerobic Pond	Enbankment protected by masonry Dimension 60^{m}Wx80^{m}Lx4.0^{m}Dx2units Retention Time 5 days
4)	Facultative Pond	Enbankment protected by masonry Dimension 70^{m}Wx120^{m}Lx2.0^{m}Dx2units Retention Time 5 days
5)	Maturation Pond	Constructed with R.C. Dimension 63^{m}Wx83^{m}Lx1.5^{m}Dx4units Retention Time 5 days
6)	Drying Bed	Dimension 6^{m}x8^{m}x4units Detention Time 15 days

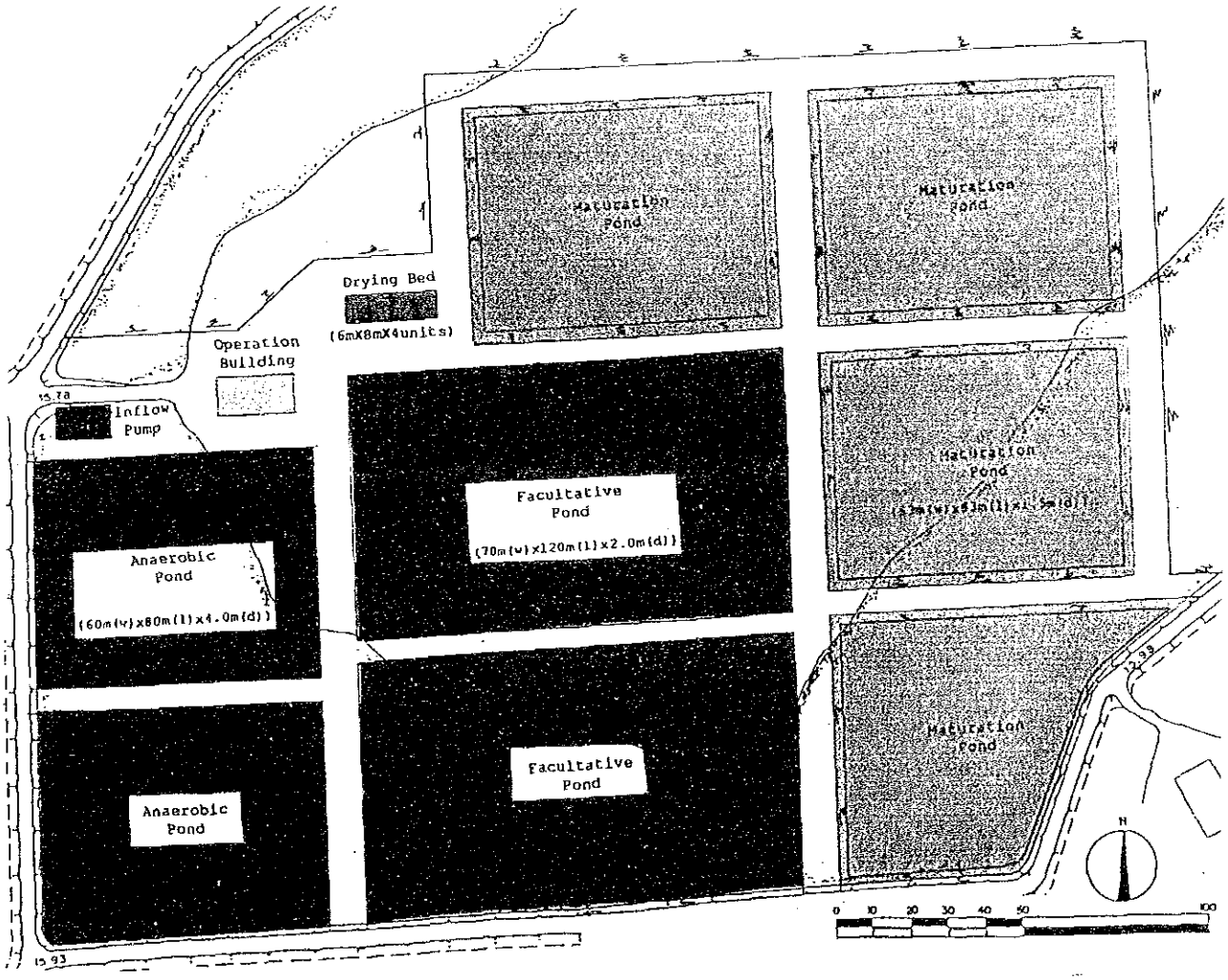


FIGURE 1.6.3 Layout of Sewage Treatment Plant (Chai Nat)

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JAPAN INTERNATIONAL COOPERATION AGENCY

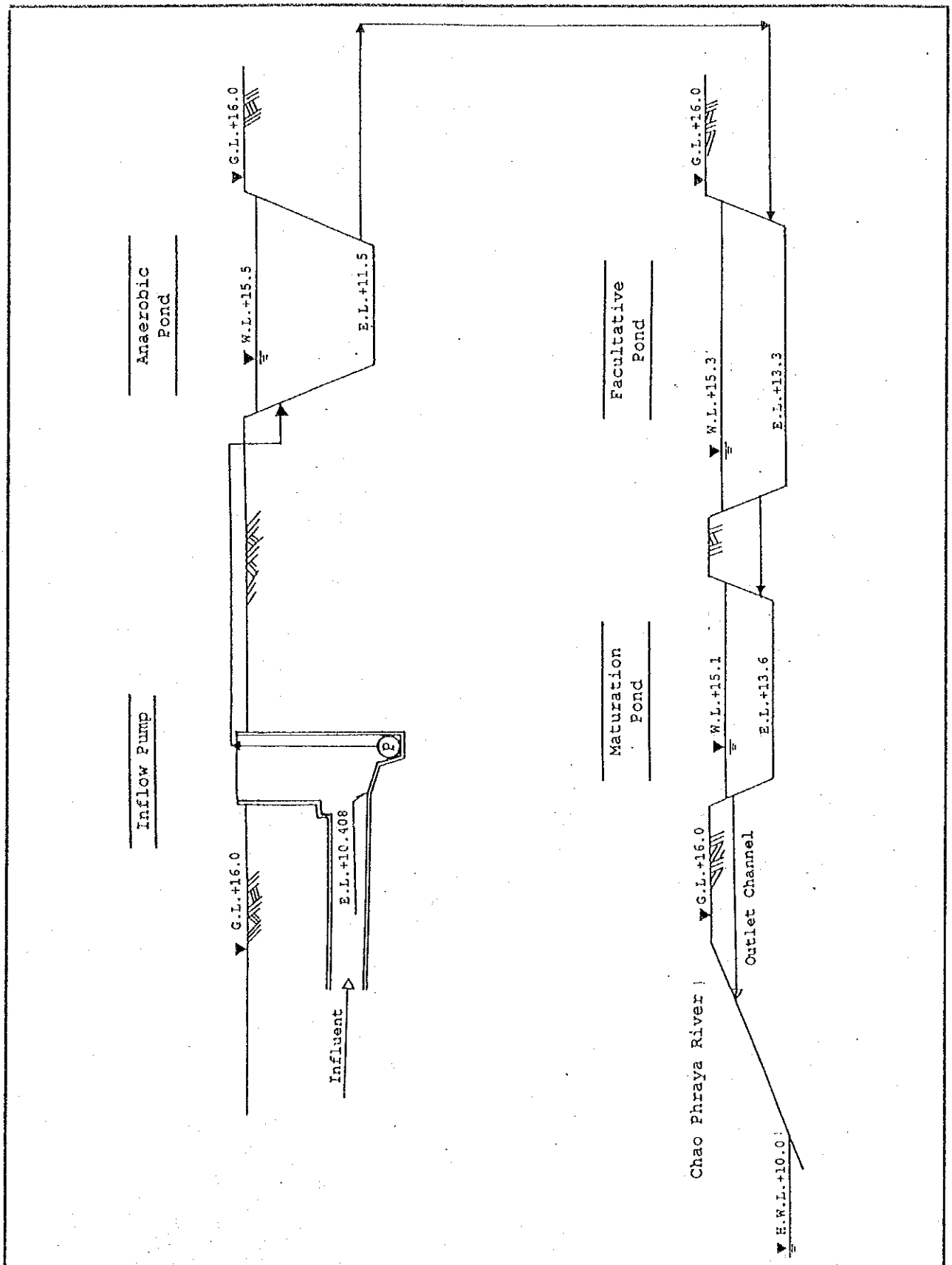


Figure 1.6.4	Hydraulic Profile of Sewage Treatment Plant (Chai Nat)	STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY

(3)	Total of Construction Cost ((1)+(2))	150.37
(4)	Engineering & Construction Supervision (17% of (3))	25.56
(5)	Land Acquisition	
	1) Pump Station	0.09
	2) W.W.T.P.	14.25
	Total of Land Acquisition	14.34
	Grand Total (Million Baht)	190.3

1.7.2 Operation and Maintenance Cost

Annual Operation and Maintenance cost (thousand Baht) is estimated using cost functions/unit cost studied in the previous chapter.

(1)	Interceptor	632
(2)	Pump Station	190
(3)	W.W.T.P.	130
	Total of O&M Cost	952

1.8 Implementation Plan

The provision of a complete sewerage system for the entire study area with its increasing population will require a great investments of capital fund as estimated in the previous section. Some areas within the study area is presently undeveloped land and environmental conditions of such areas are different from built-up areas. Although the study area needs to be sewered in early stage, the urgency of sewerage requirements is different depending on land use features of areas.

Staged construction will be advantageous to minimize the excessive initial investment and capital expenditures.

Implementation program is prepared for first 20 years, dividing into 4 stages of five year each, taking the design period up to the year 2011 into account. The assumed schedule giving priority to developed/being developed

areas is shown below.

Stage	Period	Works with Priority
1st	1991-1995	Preparatory work & design of facility
2nd	1996-2001	Construction for central area
3rd	2002-2006	Construction for northern area
4th	2007-2011	Construction for southern area

1.9 Administrative and Financial Study

1.9.1 General

As mentioned above, Thailand has a centralized political system. The central government controls local governments to details. The staffing size and assignments of local government are decided by regulations of Ministry of Interior.

There is little room for municipalities to play with their management capacities in order to improve the present conditions. the officials working in municipalities are not well aware of sewerage system, nor capable to deal with it effectively.

The sewerage system requires careful operation and maintenance. Otherwise it will fail short of successful management. Such examples can be found in many countries. Though a sewerage system has been completed, it cannot deliver expected performance due to lack of appropriate routine maintenance. Collection pipes are clogged without proper cleansing. Treatment plants can not work well without proper maintenance activities.

1.9.2 Existing Administrative System

The present administration is as follows (see Figure 1.9.1):

- Legislative body: Municipality assembly
- Executive body : Five divisions

The five divisions are doing their duties and functions:

- Administration Division
- Treasury Division
- Health Division
- Technical Division
- Education Division

There are a total of 142 officials and employees working in those divisions under the mayor and chief officer. Seventy-two (72) teachers are working for schools within the municipality.

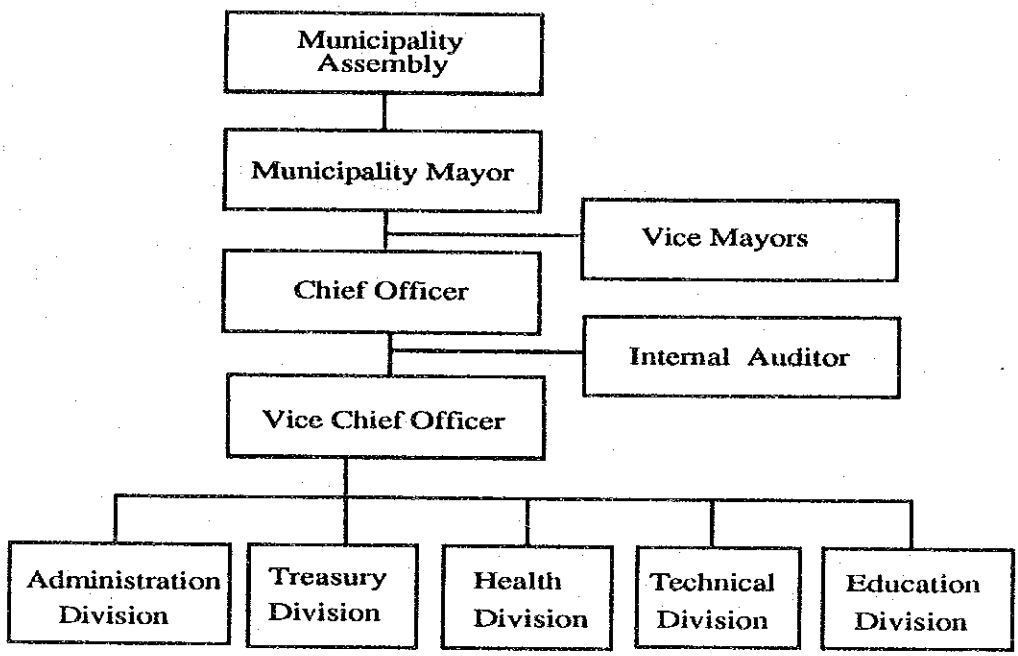


Figure 1.9.1 Administrative Structure of Municipality of Chai Nat

1.9.3 Recommendations

The duties and functions of the municipality are basically regulated by the Municipal Government Act (1953), and the room is limited to include the O&M activities for the sewerage system.

The implementation plan is explained in the previous section. Now the staffing requirement is calculated as follows:

Stage	Period	Staffing requirement
1st	1991 - 1995	4
2nd	1996 - 2001	7
3rd	2002 - 2006	13
4th	2007 - 2011	25

The proposed sewerage system is new into this municipality. Two options are possible:

- (A) to include it in the municipal organization
- (b) to create an independent organization with liaison with the municipality.

Option (A) and option (B) are shown in Figure 1.9.2 and 1.9.3 respectively.

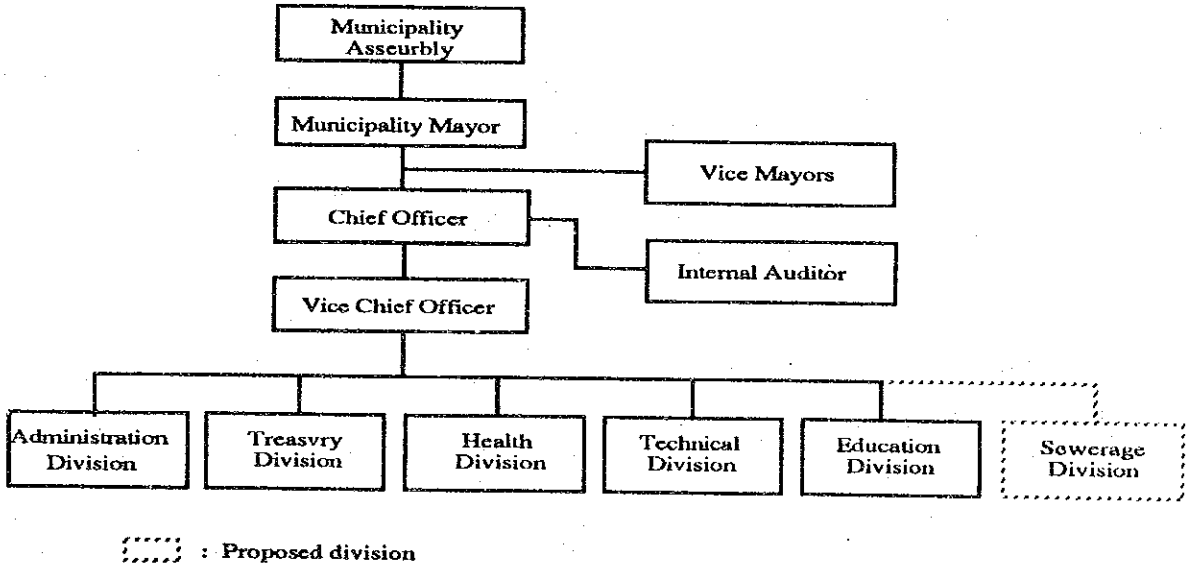


Figure 1.9.2 Option (A) for Muncipality of Chai Nat

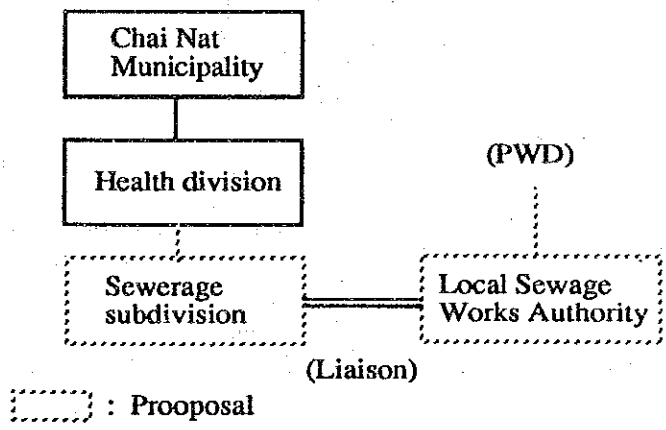


Figure 1.9.3 Option (B) for Municipality of Chai Nat

The staff number of the municipality is 72, excluding teachers. The staffing requirement is estimated at 25 in full capacity (2011). It is estimated at 7 until 2nd stage, because the treatment capacity is so small as 4,883 n^3/d in 2011.

The Study Team recommends that option (a) be implemented. But in the future the possibility of Option (b) should be open, because the nationwide organization for sewerage system will be implemented in the future.

There are two types of trainings: on job training and off job training. On job training can be given to new comers. Off job training should be better given in the central training center, because the municipality is so small and the number of operators is so small as 15.

1.9.4 Financial Considerations

The relative burden, as defined as the ratio of 25% land acquisition cost to fixed investment on land and construction, was 296%. While the amount of fixed investment varies with fiscal year, this figure of 296% was the highest among eight municipalities.

Chai Nat has not yet developed social infrastructure, compared with that of Rangsit and Bang Bua Thong. The proportion of public fixed investment to total expenditures was only 5.4% in 1991, the second smallest among eight municipalities. This appears to reflect that the greater the portion of public fixed investment, the smaller the relative burden of land acquisition cost. For example, when public fixed investment increases to, say, 40% of total expenditures, the relative burden of land acquisition cost becomes also 40%. Thus, the relative burden of 298%, while extremely high, should be interpreted in a framework not only of fixed investment but also of total expenditures.

Nevertheless, when the relative burden exceeds a certain figure, say, 10%, it will add substantial burden on local municipality. This is due to limited capability of increasing local revenues in financing a large public investment project as the sewerage project.

Chai Nat is not exception. Financing options that are available are (1)

municipality development fund, (2) environment fund, or (3) increasing local revenues.

Environmental fund is available to local agencies in the form of grant and.or loan. It is recommended that Chai Nat explore loan financing to allocate financial burden into the future, compared to raising local revenues or utilizing municipality development fund whose objectives are more general than those of environmental fund.

The average household user cost in item 4.3 of Table 1.9.1, is well below one percent of low household income in 2011 for Chai Nat. The user cost, however, could be administratively increased by two factors, one is the interest rate of the local that Chai Nat would transfer to the user, and the other, the loss of the sewerage revenue collection that could be compensated for and would be included as part of the user charge.

The household users were estimated on the basis of the project service area in 2011. The household is assumed to have 4.1 persons on the average. We have also assumed that household users as sewerage users for simplicity. The average sewerage user cost was calculated on O&M cost divided by {(0.7+0.2x1.2+0.1x2) (number of household users)}.

The average rate of non household users could be assumed to pay as high as the highest progressive rate of the household user rate structure. The progressive rate structure is 1.0 to 1.3 to 2.0 for low, medium, and high household income group respectively. A summary is shown in 4.4 of Table 1.9.1.

Finally, affordability will be considered. The affordability level is defined as the ratio of the average household user cost to low household income level of 96,571 Baht in 2011 in the Central Region. With available data on household income by Chai Nat, the figure indicated in 4.5 of Table 1.9.1, would then be updated and could also be modified with allocation of loan cost among the users.

Table 1.9.1 Selected indicators for Chai Nat

1.1	Service Pop in 2011	21,800
1.2	Household Users in 2011	5,317
2.1	Total Expenditures, 1991 (Thousand Baht)	22,111
2.2	Investment on Land & Const., 1991 (Thousand Baht)	1,211
2.3	Land Land Acquisition Cost (Thousand Baht)	3,584
2.4	Relative Burden (2.3/2.2) in %	298
2.5	Sanitation Expenditures, 1991 (Thousand Baht)	na
3.1	Total Revenues, 1991 (Thousand Baht)	24,587
3.2	Central Government Support, 1991 (Thousand Baht)	10,041
4.1	Treatment capacity (m3/d), in 2011	5,900
4.2	Unit O&M Cost of 4.1, in 2011	0.44
4.3	Household Users Cost/Year, in 2011 without loan	179
4.4	Progressive Rates: 1:1.3:2.0 in 2011	154 201 309
4.5	Loan Cost/H User/Year 50% Local, 50% Foreign Loan, 25 Years	57
4.6	Affordability (4.3 + 4.5) for Low Income Household, 96571 baht, 2011	0.25%

SECTION 2

SING BURI MUNICIPALITY

SECTION 2 SING BURI MUNICIPALITY

2.1 Description of the Study Area

The DTCP area extending about 31.33 km^2 covers the present municipality area of 9.02 km^2 and its surrounding Tambols; Bang Mal, Bang Krabue, Thonpho and Muang Moo. Sing Buri is located in the central region about 142 km north of Bangkok. The province is about 841 km^2 and is connected to five other provinces. The topography of the province is generally flat with a gentle slope from north to south and with an elevation of 2-19 m above the mean sea water level, whereas the municipality has an elevation of 10-16 m amsl. The province consists of two different areas; flood plains in most parts of the province and low terraces. Sandy soil, which is suitable for agriculture, is common in the study area. The Noi river, the Lop Buri river and some tributaries flow across the area.

The area falls in both west-eastern monsoon zone and south-eastern monsoon zone making summer and winter quite extreme with the maximum temperature of 39.9°C and the minimum temperature of 10.0°C. The average rainfall is 1,139.8 mm/year.

The study area has 5 irrigation projects serving a total area of about 80,000 ha. Its major water sources are the Chao Phraya river, the Noi river and the Lop Buri river, while the secondary water sources are Lum Maeka, Lum Karong, Cheing Rai canal and Po Chai canal. The institutional and business areas are mostly located in the west bank area of the Chao Phraya river, where car or motorbike repair shops are the major type of small industry. Commercial area is concentrated at Khun Swan, Nai Thong Men and along Promsatit road. Most of the commercial shops existing in the municipal area deal with food and beverages.

A slaughterhouse is located in Tambol Thon Po, Amphoe Muang about 2 km from the boundary of the municipality with a water consumption of 20 m^3/d. About 40-45 pigs, 1-3 cows and a buffalo are slaughtered daily there. The wastewater is discharged to the public ditch. There is no wastewater treatment plant installed in the area. Two fresh markets are available in the study area; the Tesabal 1 and Tesabal 2 with each market occupying an area of 1 rai. The electricity supply is provided by PEA. There is one office of PEA in the area and its services have reached quite a wide area not only within

the municipality but also outside of the municipality. The study area has about 2,000 telephone lines available and a limited lines for long distance call service.

There are two public hospitals of which one has a wastewater treatment plant in application of the rotating biological contactor (RBC).

2.2 Existing Sanitation/Sewerage and Flood Protection Systems

2.2.1 Existing Sanitation Facilities

The municipality operates 4 trucks, each with a capacity of 55 m^3, to collect 110 m^3 of refuse 8 times per day and dispose them at a dumping site located in the west side. It is about 4 km away from the municipality and has an area of 12 rai. At this site, landfill and partial burning are practiced.

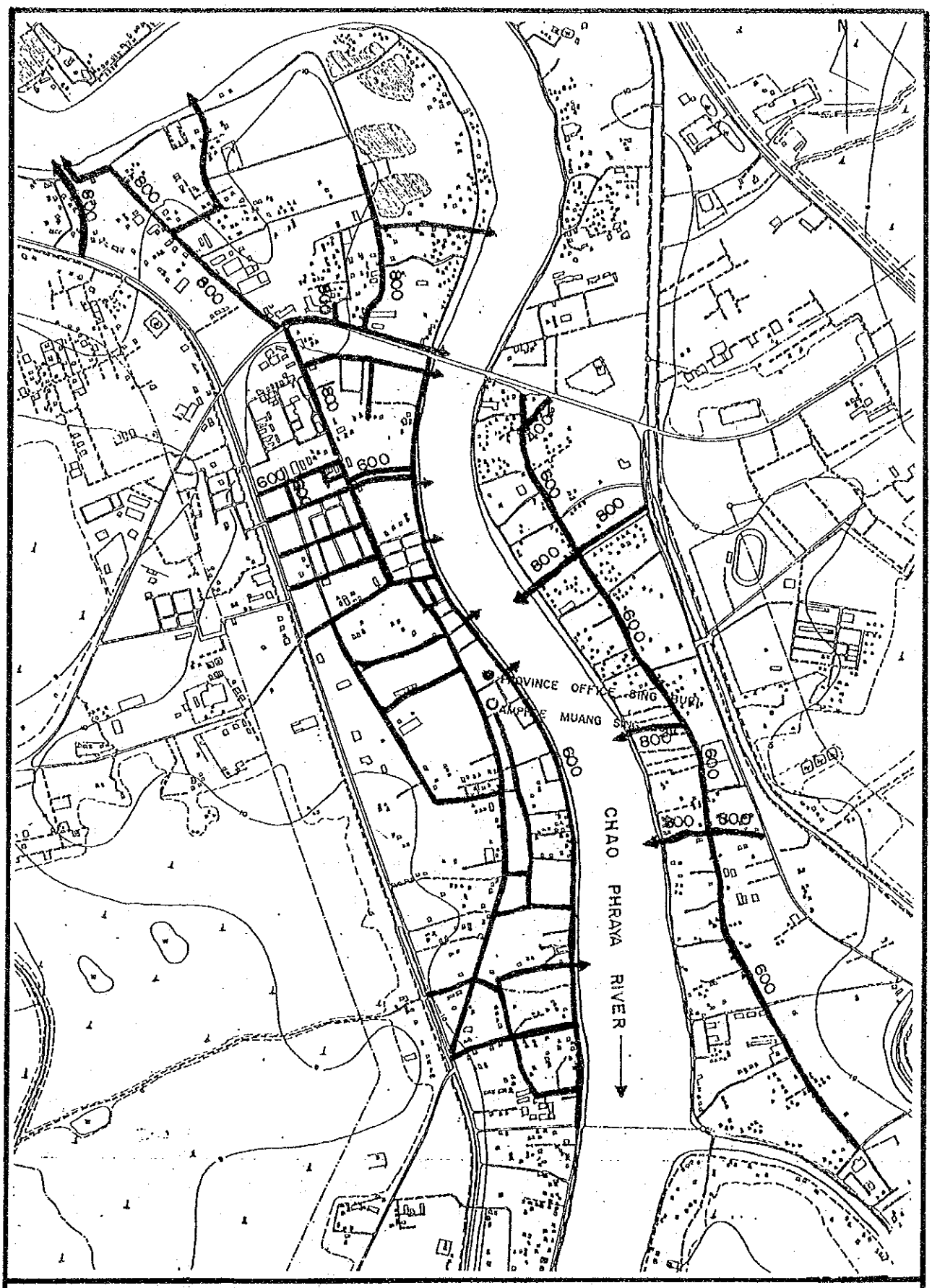
On-site treatment and disposal of nightsoil is practiced as mentioned in Section 3, Chapter 2.

2.2.2 Existing Sewerage Facilities

The study area uses three systems for drainage; discharge to natural ditch, discharge to sewers and percolation. Sewers laid on the west bank of the Chao Phraya river are too small. On the other hand, the east bank which is a residential area has no drainage system yet especially along the Sunkaraj road. It causes social and health problems. Composition of existing drainage facilities is summarized in Table 2.2.1. Area coverage and location of sewers are shown in Figure 2.2.1.

Table 2.2.1 Existing Drainage Facilities

Size (mm)	Length (m)	Type of Pipes	Drainage Area (ha)
dia. 600	12,700	RC. Pipe	121.3
dia. 800	250	RC. Pipe	1.6
dia. 400	5,200	RC. Pipe	43.6
Total	18,150		166.5



LEGEND : 600 DIAMETER (mm)
DRAINAGE PIPE ⟶ OUTFALL SCALE 1:15,000

FIGURE 2.2.1 EXISTING DRAINAGE SYSTEM IN SING BURI MUNICIPALITY

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN
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2.2.3 Flood Protection Facilities

Flooding occurs during the rainy season especially in the north area of Tambol Bangkrabue, Tambol Bang Mun and along the river bank due to the unavailability of flood protection facilities. Only in the west bank of Chao Phraya river, dikes are installed starting from Bang Rajan Bridge point through the south upto the municipality boundary. There are two pump stations for flood control with pipelines (ϕ1000 mm) along the river. However, the pumps have not been operated for more than 20 years.

2.3 Water Supply

Water is supplied by PWA to three districts; Amphoe Muang, Thachang and Bangrachan with a production capacity of 6,000 m^3/d and is ample to meet the demand. The other communities use water supply from Sanitary District and from water supply developed at about 145 schools by a Rural Health Project.

2.4 Population and Land Use

The average population density is about 10 persons/ha in the DTCP area, while it is 24 persons/ha in the municipality. The growth rate of the municipality between 1985-1990 is 2.03% per year. High population density area is extended along both sides of Nai Muang road. A common type of houses is single-story houses which are about 10-20 years old and mostly owned privately. About 95% of the land is used mainly for agriculture with rice, peanuts, fruit, vegetables and flowers as the main products.

Land use at present and in the future (2011) is referred to in Section 3, Chapter 2 and Figure 2.4.1 presents the projection in the year 2011.

Study area and population are as follows:

Area & Population	Present Municipality	Future Exp. Area	Sewerage M/P Area	Other Area	DTCP Area
Area (km^2)	9.02	2.89	11.91	19.42	31.33
Pop. in 1991	22,570	5,727	28,297		
Pop. in 2011	35,973	5,727	41,700		

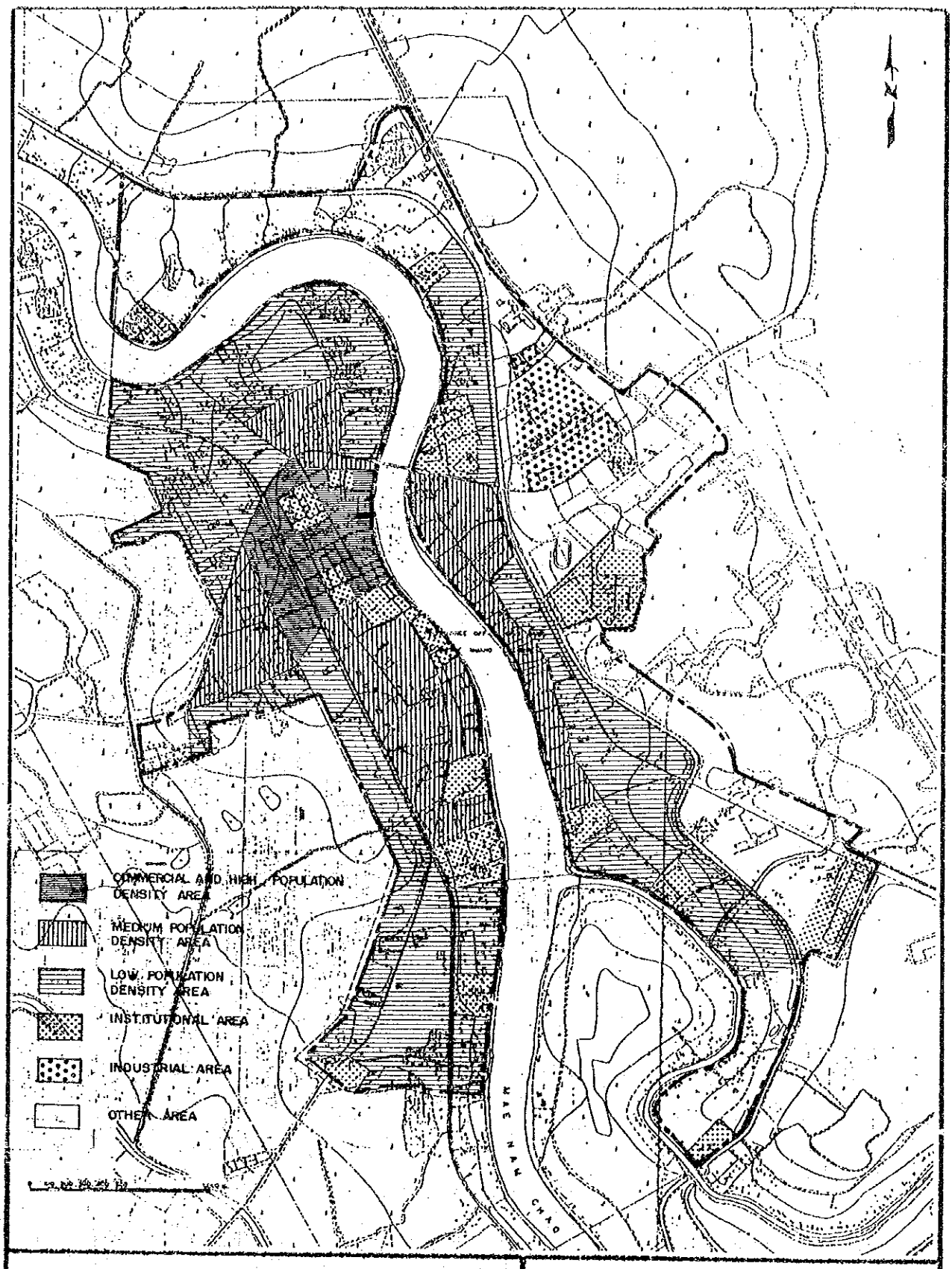

FIGURE 2.4.1 FUTURE LAND USE - YEAR 2011 (SING BURI)

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2.5 Quality and Quantity of Wastewater

2.5.1 Unit Wastewater and Pollution Load on a Discharged Basis

(1) Domestic Wastewater

Unit quality (BOD) and quantity on the daily average basis at present and in design year are tabulated breaking down into sullage and toilet waste.

Domestic wastewater discharge is assumed at 80% of water consumption. toilet waste is treated by septic tank with assumed treatment efficiency of 50%.

Year	Unit Wastewater (lpcd)			Unit BOD Load (gpcd)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Present	100	12	112	33.6	5.5	39.1
Design Year (2011)	136	24	160	35.1	5.5	40.6

(2) Business Wastewater

Those for business wastewater (commercial and institutional) is assumed to be 30% and 40% of domestic wastewater for the present and design year (2011), respectively.

	Unit Wastewater (lpcd)	Unit Pollution Load (BOD_5 gpcd)
Present	32	6.1
Design Year (2011)	64	7.7

2.5.2 Discharged Wastewater and BOD Load

(1) Domestic Wastewater

Wastewater quantity and BOD load on a Discharged basis are estimated for the present and design year (2011) multiplying service population by unit wastewater quantity/BOD load. The following are the estimation results for the two sewerage development areas as studied in Section 2.6.

Sing Buri East Sewerage Development Area

Item	Present			Design Year (2011)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Wastewater Quantity (m^3/d)	768	92	860	1,537	271	1,808
BOD Load (kg/d)	257.6	42.2	299.8	396.6	62.2	458.8

Sing Buri West Sewerage Development Area

Item	Present			Design Year (2011)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Wastewater Quantity (m^3/d)	2,067	248	2,315	4,134	730	4,864
BOD Load (kg/d)	693.1	113.5	806.6	1,067.0	167.2	1,234.2

(2) Business Wastewater

Discharged wastewater quantity and BOD load are estimated in the same procedure as domestic wastewater.

Sing Buri East Sewerage Development Area

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	246	723
BOD Load (kg/d)	46.8	87.0

Sing Buri West Sewerage Development Area

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	661	1,946
BOD Load (kg/d)	125.8	234.1

(3) Total Wastewater Quantity and BOD Load

Total discharged wastewater quantity and BOD load (daily average basis) at present and in the design year (2011) for Sing Buri East/West Sewerage Development area are figured out as shown below.

Sing Buri East Sewerage Development Area

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	1,106	2,531
BOD Load (kg/d)	346.6	545.8

Sing Buri West Sewerage Development Area

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	2,976	6,810
BOD Load (kg/d)	932.4	1,468.1

2.6 Proposed Sewerage System

2.6.1 Service Area

A total service area of 1,191 ha with a present population of about 28,300 is divided into two areas by the Chao Phraya river. Under the topographic conditions and no bridge available crossing the Chao Phraya river in the southern portion of the service area, two sewerage systems; East and West bank areas are recommended in the economical reason as shown in Figure 2.6.1.

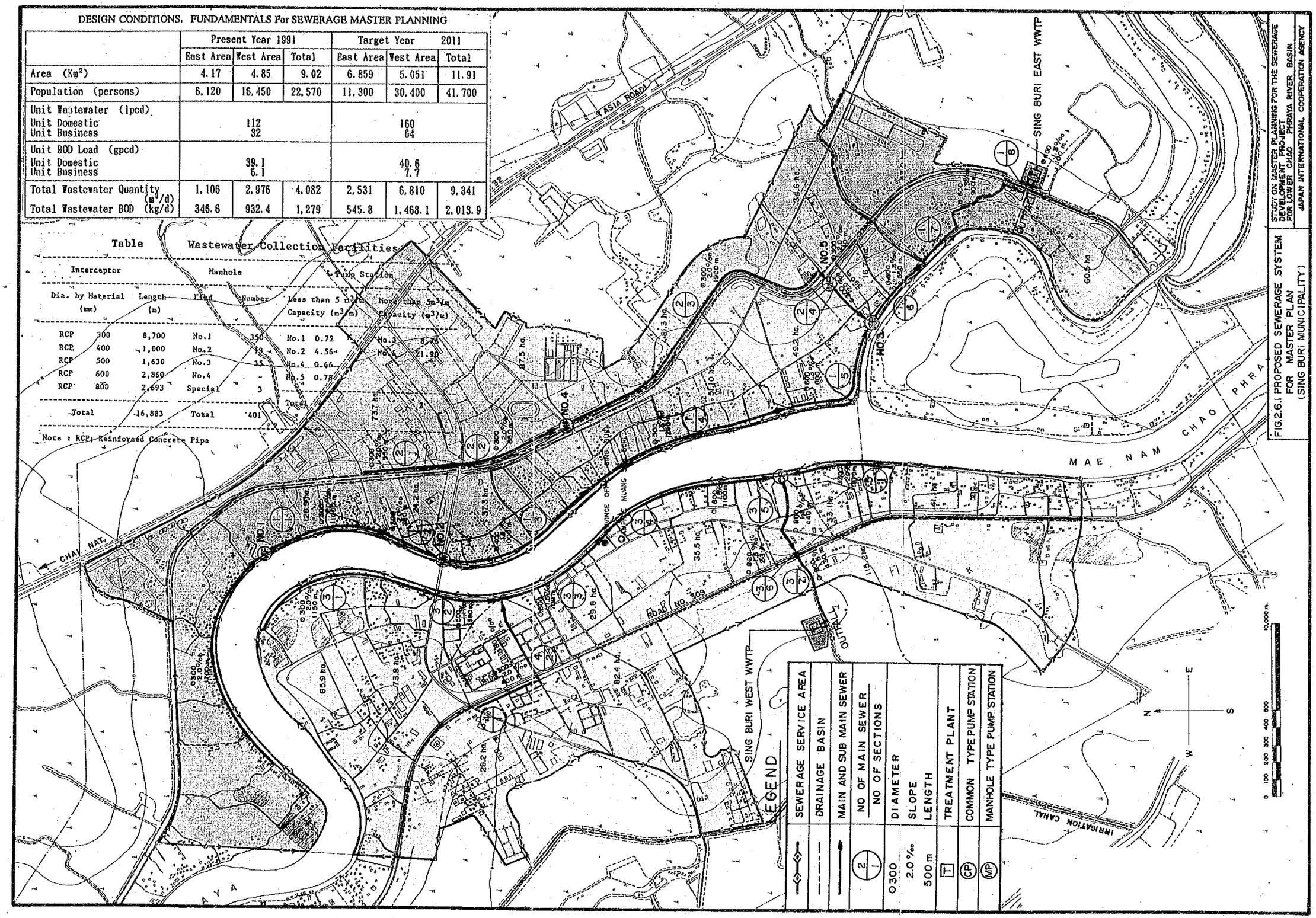
DESIGN CONDITIONS, FUNDAMENTALS For SEWERAGE MASTER PLANNING

	Present Year 1991			Target Year 2011		
	East Area	West Area	Total	East Area	West Area	Total
Area (Km^2)	4.17	4.85	9.02	6.859	5.051	11.91
Population (persons)	6,120	16,450	22,570	11,300	30,400	41,700
Unit Wastewater (lpcd)						
Unit Domestic	112			160		
Unit Business	32			64		
Unit BOD Load (gpcd)						
Unit Domestic	39.1			40.6		
Unit Business	6.1			7.7		
Total Wastewater Quantity (m^3/d)	1,106	2,976	4,082	2,531	6,810	9,341
Total Wastewater BOD (kg/d)	346.6	932.4	1,279	545.8	1,468.1	2,013.9

Table Wastewater Collection Facilities

Interceptor			Manhole & Pump Station			
Dia. by Material (mm)	Length (m)	Kind	Number	Less than 5 m^3/s Capacity (m^3/s)	More than 5 m^3/s Capacity (m^3/s)	
RCP 300	8,700	No.1	350	No.1 0.72	No.3 8.28	
RCP 400	1,000	No.2	13	No.2 4.56	No.6 21.90	
RCP 500	1,630	No.3	35	No.4 0.66		
RCP 600	2,860	No.4	-	No.5 0.78		
RCP 800	2,693	Special	3	Total		
Total	16,883	Total	401			

Note : RCP; Reinforced Concrete Pipe



STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN
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FIG.2.6.1 PROPOSED SEWERAGE SYSTEM FOR MASTER PLAN (SING BURI MUNICIPALITY)

The topography in the both area is generally flat with a mild slope from north to south along the Chao Phraya river. The east bank area is separated by the main irrigation canal flowing from north to south.

Location of WWTP by the sewerage system is recommended as follows:

East Bank Area: southern tip of the service area

West Bank Area: west side of the slaughterhouse, out of the present municipality area, but within DTCP area

2.6.2 Wastewater Collection System

Wastewater collection system employing the combined collection method is designed considering existing drainage facilities, main roads, topography and land availability for sewerage facilities.

Distribution of population and wastewater quantity was made based on population density assumed by land use type (refer to calculation table in Supporting Report 3.2.6).

Alignments of main interceptors and pump stations are proposed as shown in Figure 2.6.1. The profile of sewers is presented in Figure 2.6.2 (refer to hydraulic calculation in Supporting Report 3.2.6). The following are brief descriptions on the sewer systems.

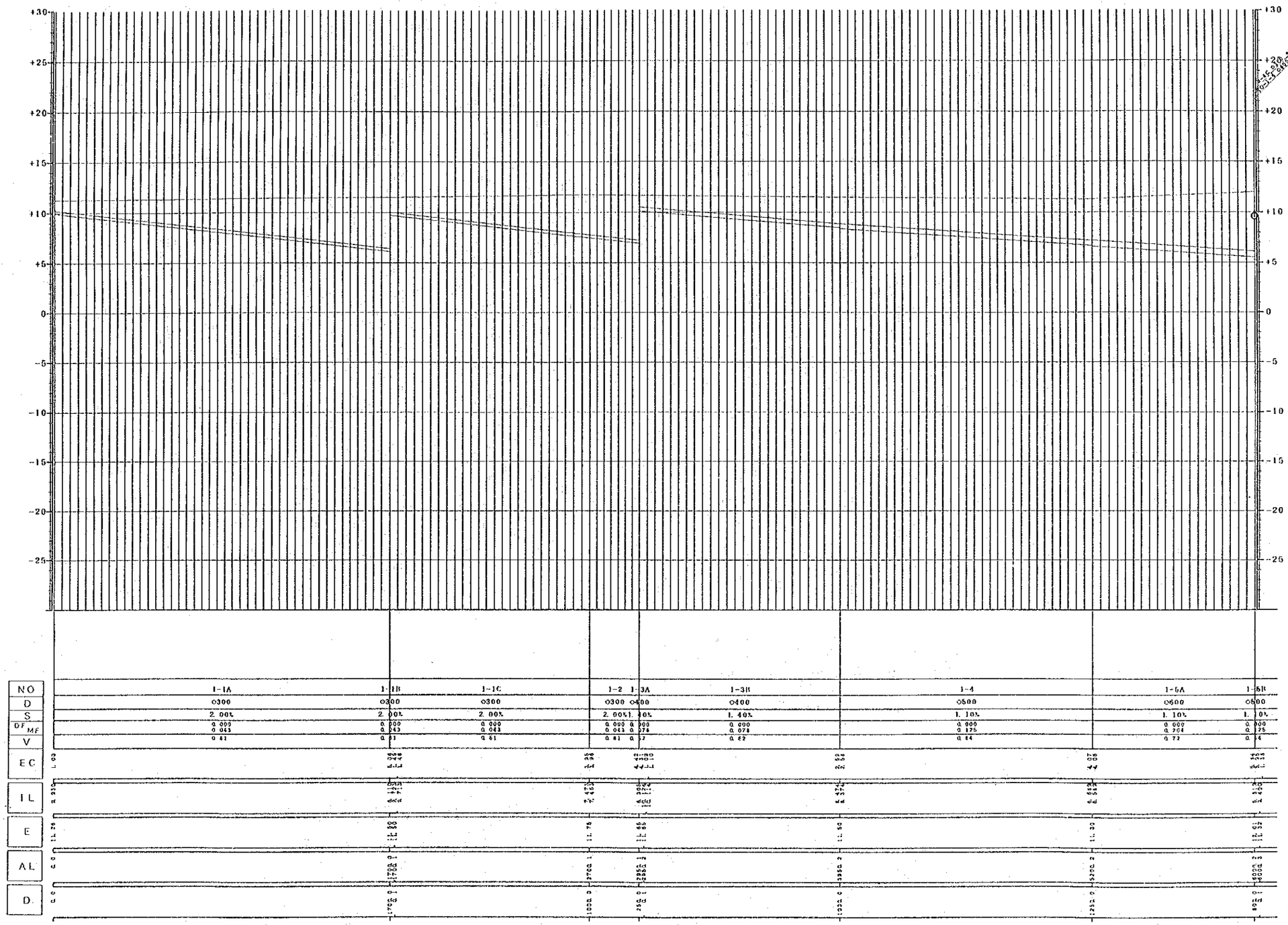
East Bank Area: 685.9 ha, population 7,700 in 1991 and 11,300 in 2011

- Two (2) major systems are planned; one is along Chao Phraya river (interceptors 1/1 - 1/7) and the other along main irrigation canal (interceptors 2/1 - 2/4).

- Service population in the sewer system, 1/2 - 2/4 is limited. Thus, this sewer system is connected to the upstream of interceptor 1/6.

West Bank Area: 505.1 ha, population 20,600 in 1991 and 30,400 in 2011

- Three (3) sewer systems are planned.



LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

1-1A	1-1B	1-1C	1-2	1-3A
1-3B	1-4	1-5A	1-5B	

FIG. 2.6.2 (1)
SING BURI - EAST (1)

V 1:200
H 1:10,000

MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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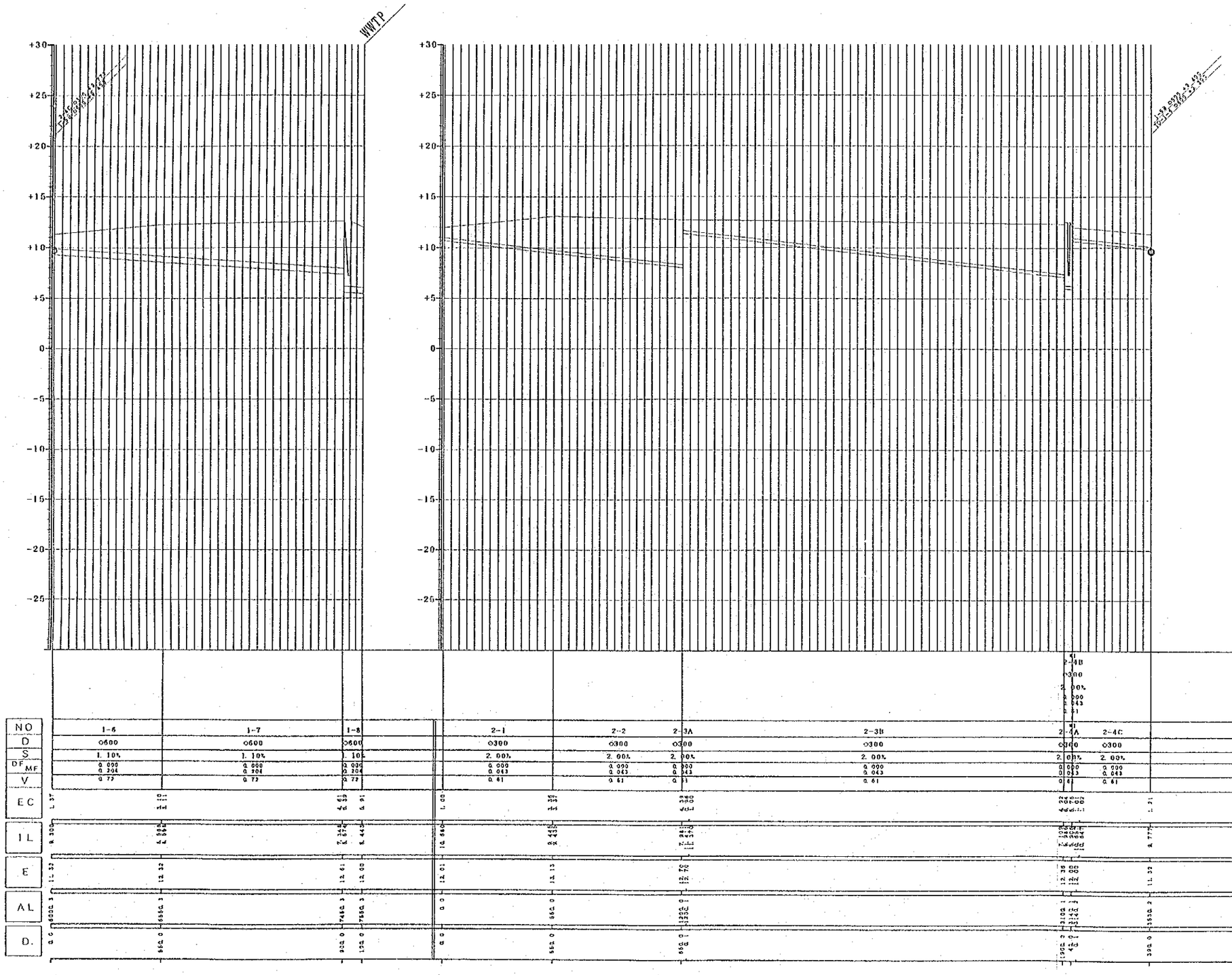


LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

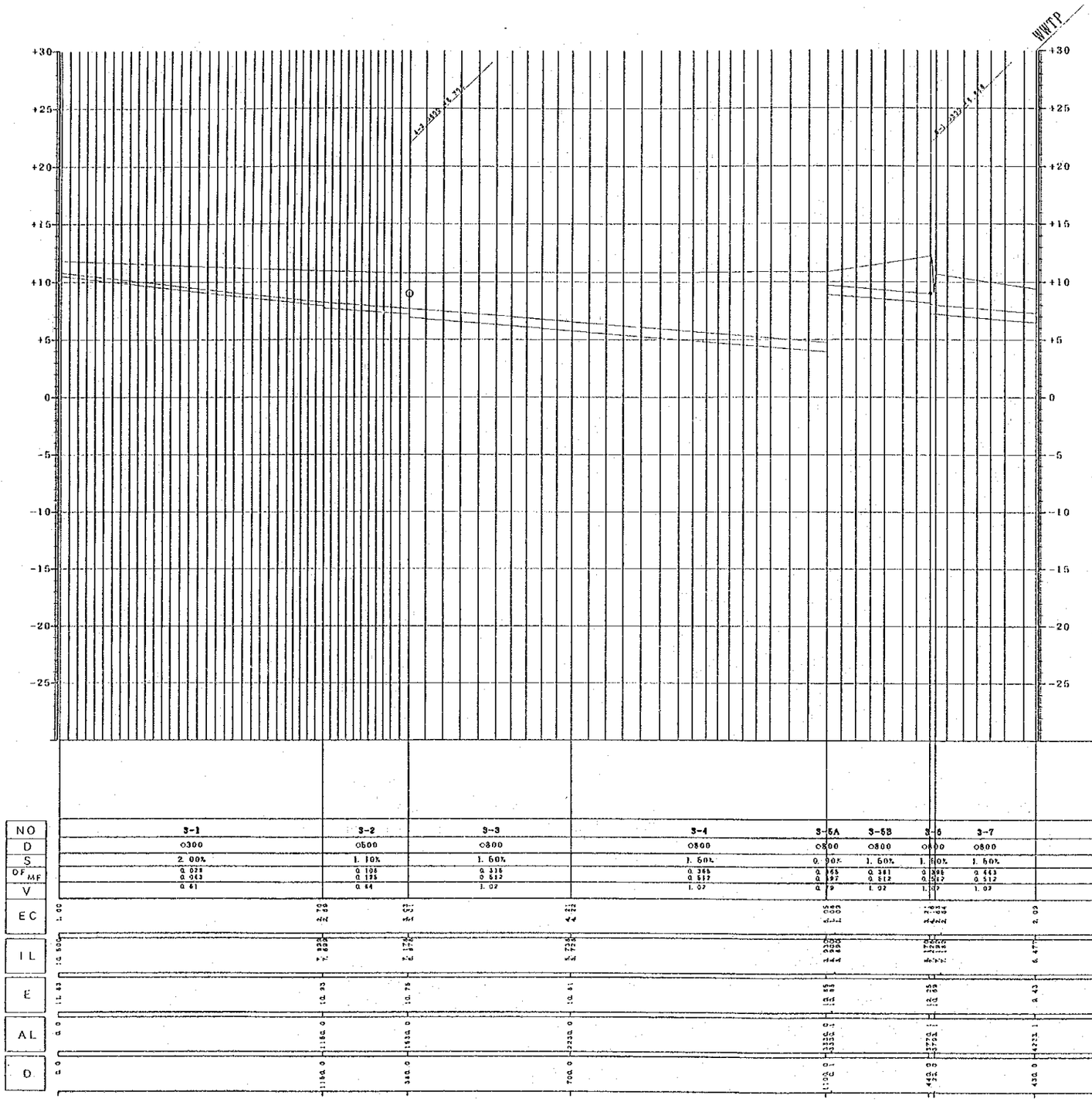
1-6	1-7	1-8	2-1	2-2
2-3A	2-3B	2-4A	2-4B	2-4C

FIG. 2.6.2 (2)
SING BURI - EAST (2)

V 1:200
H 1:10.000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

3-1	3-2	3-3	3-4	3-5A
3-5B	3-6	3-7		

FIG. 2.6.2 (3)
SING BURI - WEST (1)

V 1:200
H 1:10,000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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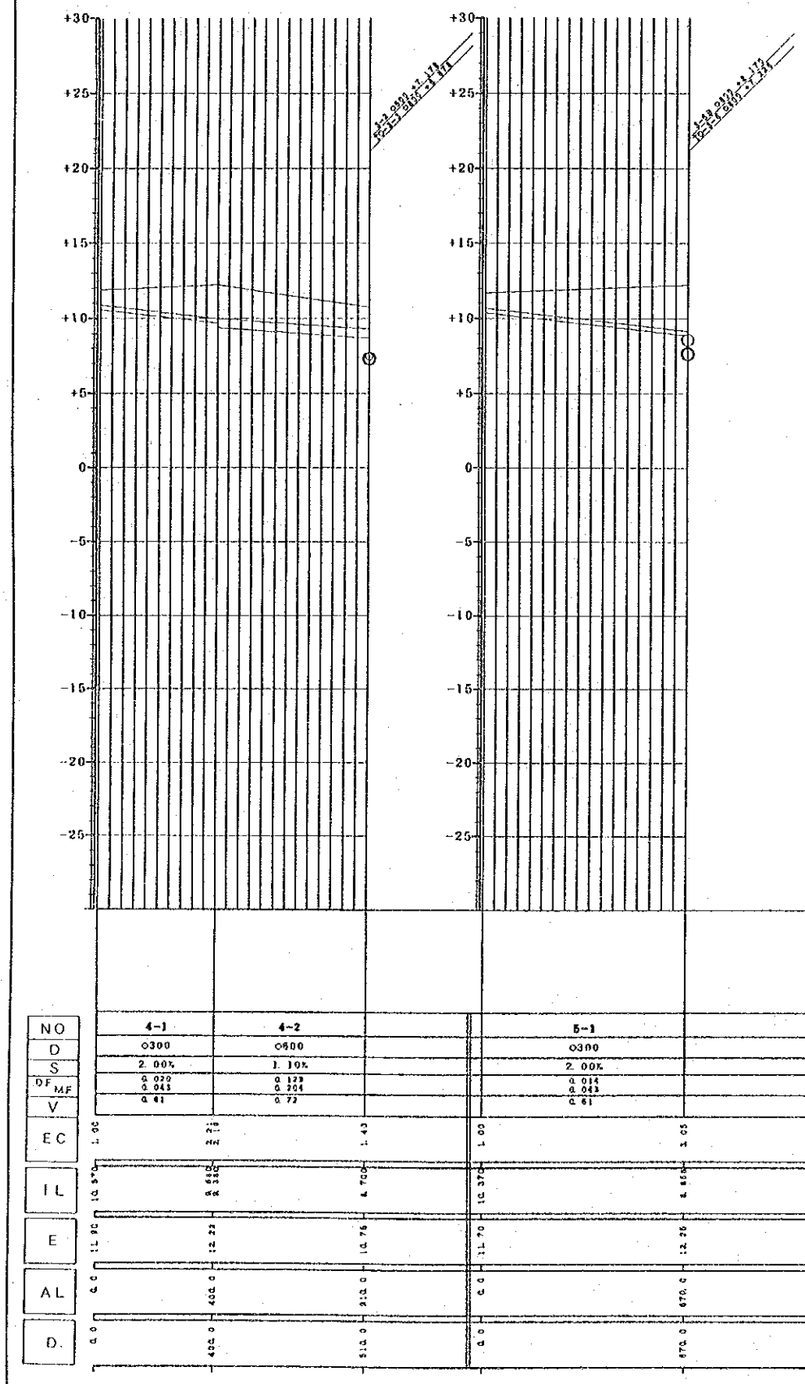

LEGEND

Item	Description
NO	NO. of Sewers
D	Diameter
S	Slope
DF MF	Design Flow Maximum Flow for Pipe
V	Velocity
EC	Earth Cover
IL	Invert Level
E	Elevation
AL	Accumulated Length
D	Distance

No. of Sewers

4-1	4-2	6-1		

FIG. 2.6.2 (4)
SING BURI - WEST (2)

V 1:200
H 1:10.000

MASTER PLANNING FOR THE SEWERAGE
DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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- The longest main is planned along the Chao Phraya river (3/1 - 3/7).

- Interceptors 4/1 - 4/2 are arranged along road No. 309 to connect to interceptor 3/3.

- Interceptor 5/1 connects to 3/5.

Table 2.6.1 summarizes planned collection facilities. Details on pump specifications and siphon are included in Supporting Report 3.A.6 - 3.C.6.

Table 2.6.1 Wastewater Collection Facilities

Interceptor			Manhole		Pump Station			
Dia. by Material (mm)		Length (m)	Kind	Number	Less than 5 m^3/m Capacity (m^3/m)		More than 5m^3/m Capacity (m^3/m)	
RCP	300	8,700	No.1	350	No.1	0.72	No.3	8.76
RCP	400	1,000	No.2	13	No.2	4.56	No.6	21.90
RCP	500	1,630	No.3	35	No.4	0.66		
RCP	600	2,860	No.4	-	No.5	0.78		
RCP	800	2,693	Special	3				
					Total	4		2
Total		16,883	Total	401				

Note : RCP; Reinforced Concrete Pipe

2.6.3 Wastewater Treatment and Sludge Disposal Method for Sing Buri East Area

(1) Wastewater Treatment and Disposal Method

The future wastewater discharge in the sewerage development area of Sing Buri East area is estimated to be 2,531 m^3/d in the year of 2011. Groundwater infiltration of 20% of wastewater discharge is assumed. The design wastewater to the treatment plant becomes to be 3,000 m^3/d. The treated water quality is expected less than 40 mg/l as BOD.

The following three (3) treatment systems are applicable to meet the above requirements in quality and quantity.

1) Stabilization Pond
2) Aerated Lagoon
3) Oxidation Ditch

(2) Comparative Evaluation

The above three (3) treatment systems are compared in terms of required construction and O&M costs, required land area and easiness of O&M as shown below (Details are reffered to in Supporting Report 3.1.6.2).

Evaluation Item	Stabilization Pond	Aerated Lagoon	Oxidation Ditch
(1) Construction Cost (million Baht)	4.53	8.34	18.72
(2) Land Cost (million Baht)	6.00	3.25	1.71
(3) O/M Cost (million Baht/year)	0.07	0.31	1.75
(4) Required Land Area (ha)	4.8	2.6	1.37
(5) Easiness of O/M			
- Adaptability of overload	A	A	B
- Required technology level	A	A	B
- Sludge disposal	A	A	C

Note: 1) Construction cost : direct construction cost excluding land acquisition, engineering and administration costs
2) O/M cost : wages, electric charge, chemical and others
3) Adaptability of overload : A: high, B: middle, C: low
4) Required technology level: A: low, B: middle, C: high
5) Sludge disposal : A: easy, B: medium, C: hard

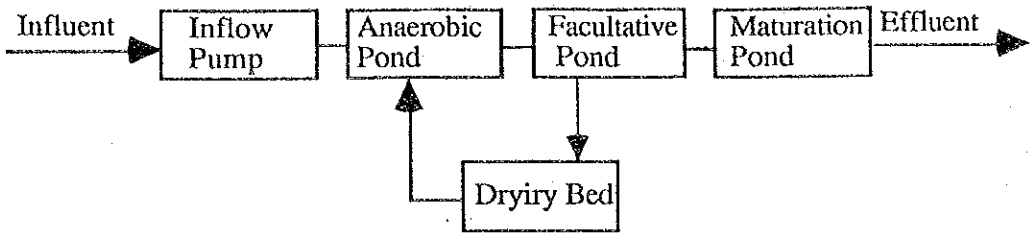
As evident from cost comparison in NVP, stabilization pond system is the most economical. Cost comparison in NVP is included in supporting Report 3.1.6.3.

(3) Plan of Treatment Plant

The proposed wastewater treatment plant of Sing Buri East is now being used for fish-culture by fishery department. The proposed treatment plant of stabilization pond with a capacity of 3,000 m^3/d requires a net space of 4.8 ha.

The flow sheet of stabilization pond system and the capacity dimension and other relevant details of each treatment facility is shown below.

Employment of anaerobic pond shall be further studied during F/S stage to consider updated information on sewage quality.



Flow of Stabilization Pond System

Inflow Pump	: Design capacity	: 4,700 m^3/d (hourly max. dry)	
		: 14,100 m^3/d (hourly max. wet)	
	: Capacity	: 3.26 m^3/min. with 8.5 m hydraulic head (hourly max. in dry)	
		: 9.79 m^3/min. with 8.5 m hydraulic head (hourly max. in wet)	
Grit Chamber	: Surface loading	: 1,567 m^3/m^2/d (dry weather)	
		: 2,350 m^3/m^2/d (wet weather)	
	: Retention time : 33 sec(dry), 22 sec (wet)		
	: Size	0.6 m(W) x 5 m(L) x 0.6 m(D) x 2 units (1 unit for dry weather)	
	: Constructed with R.C		
Anaerobic Pond	: Design capacity	3,000 m^3/d	
	: Pond capacity	15,750 m^3	
	: Pond surface area	5,400 m^2	
	: Retention time	5.25 days	
	: Dimension 45 m(W) x 60 m(L) x 4.0 m(D) x 2 units		
	: Embankment protected by masonry		
Facultative Pond	: Design capacity	3,000 m^3/d	
	: Pond capacity	15,560 m^3	
	: Pond surface area	9,000 m^2	
	: Retention time	5.19 days	
	: Dimension 50 m(W) x 90 m(L) x 2.0 m(D) x 2 units		
	: Embankment protected by masonry		

Maturation Pond	:	Design capacity 3,000 m^3/d
	:	Pond capacity 15,500 m^3
	:	Pond surface area 12,000 m^2
	:	Retention time 5.17 days
	:	Dimension 40 m(W) x 75 m(L) x 1.5 m(D) x 4 units
	:	Embankment protected by masonry
Drying Bed	:	Drying area 240 m^2
	:	Detention time 15 days
	:	Dimension 6 m x 10 m x 4 units

The treated water is discharged to irrigation canal. Layout of the treatment plant and hydraulic profile are shown in Figure 2.6.3.(1) and Figure 2.6.4.(1), respectively.

Wastewater Treatmentplant

	East T.P.	West T.P.
Wastewater Treatment method	Stabilization Pond System	Aerated Lagoon System
Plant Space Area (ha)	4.8	9.85
Treatment Capacity (m^3/d) (inclusive of C.W)	3,000	8,200
Discharge Point	Irrigation Canal	Khlong

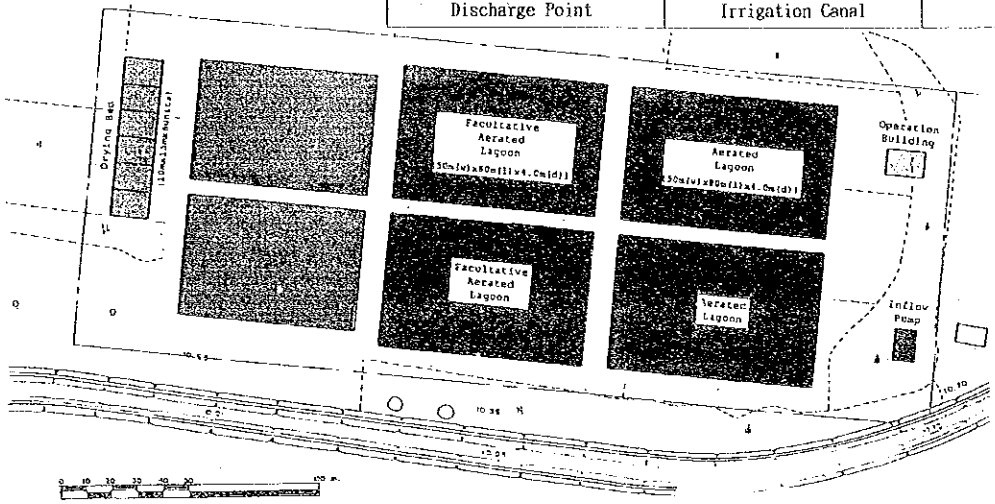


FIGURE 2.6.3 (2) Layout of Sewage Treatment Plant (Sing Buri West)

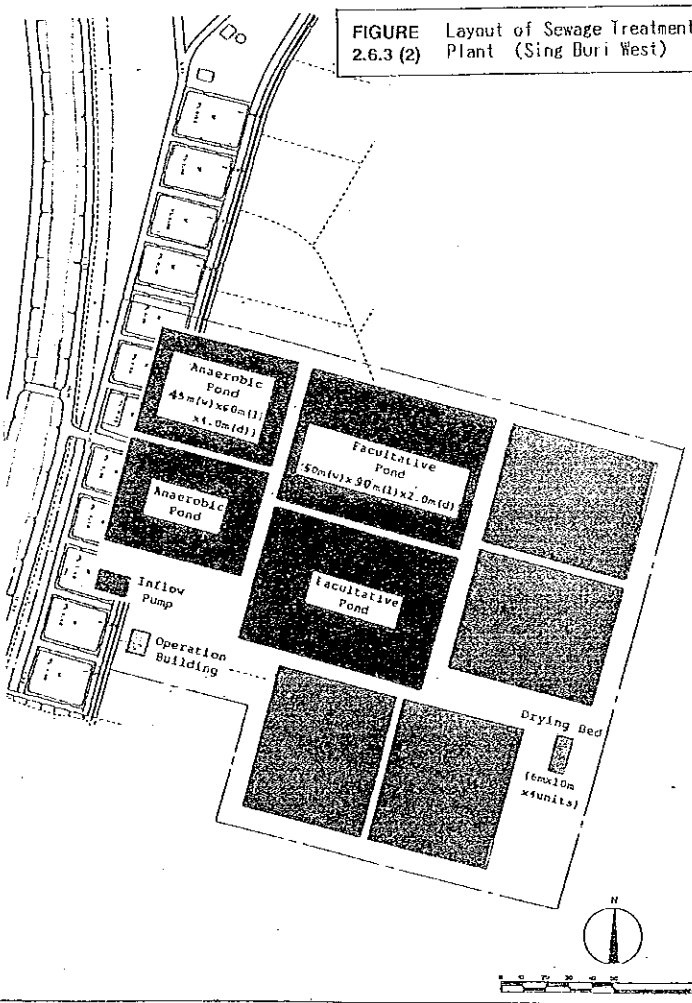


FIGURE 2.6.3 (1) Layout of Sewage Treatment Plant (Sing Buri East)

STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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Main Facilities

	West T.P.
1)Inflow Pump	Submerged Pump
(Dry Season)	ϕ200m/m×4.15m^3/min×4.8"H×2units
(Wet Season)	ϕ300m/m×8.4m^3/min×4.8"H×2units
2)Grit Chamber	Constructed with R.C.
	Size
	1.0"W×7.5"L×0.6"D×2units
	(1unit for dry weather)
3)Aerated Lagoon	Enbankment protected by masonry
	Dimension
	50"W×80"L×4.0"D×2units
	Retention Time 3 days
4)Facultative Aerated Lagoon	Enbankment protected by masonry
	Dimension
	50"W×80"L×4.0"D×2units
	Retention Time 3 days
5)Polishing Pond	Enbankment protected by masonry
	Dimension
	45"W×70"L×1.5"D×2units
	Retention Time 1 days
6)Drying Bed	Dimension
	10"×15"×6units
	Detention Time 15 days

Mai Facilities

	East T.P.
1)Inflow Pump	Submerged Pump
(Dry Season)	ϕ150m/m×1.6m^3/min×8.5"H×2units
(Wet Season)	ϕ200m/m×3.2m^3/min×8.5"H×2units
2)Grit Chamber	Constructed with R.C.
	Size
	0.6"W×5.0"L×0.6"D×2units
	(1unit for dry weather)
3)Anaerobic Pond	Enbankment protected by masonry
	Dimension
	45"W×60"L×4.0"D×2units
	Retention Time 5 days
4)Facultative Pond	Enbankment protected by masonry
	Dimension
	50"W×90"L×2.0"D×2units
	Retention Time 5 days
5)Maturation Pond	Enbankment protected by masonry
	Dimension
	40"W×75"L×1.5"D×4units
	Retention Time 5 days
6)Drying Bed	Dimension
	6"×10"×4units
	Detention Time 15 days

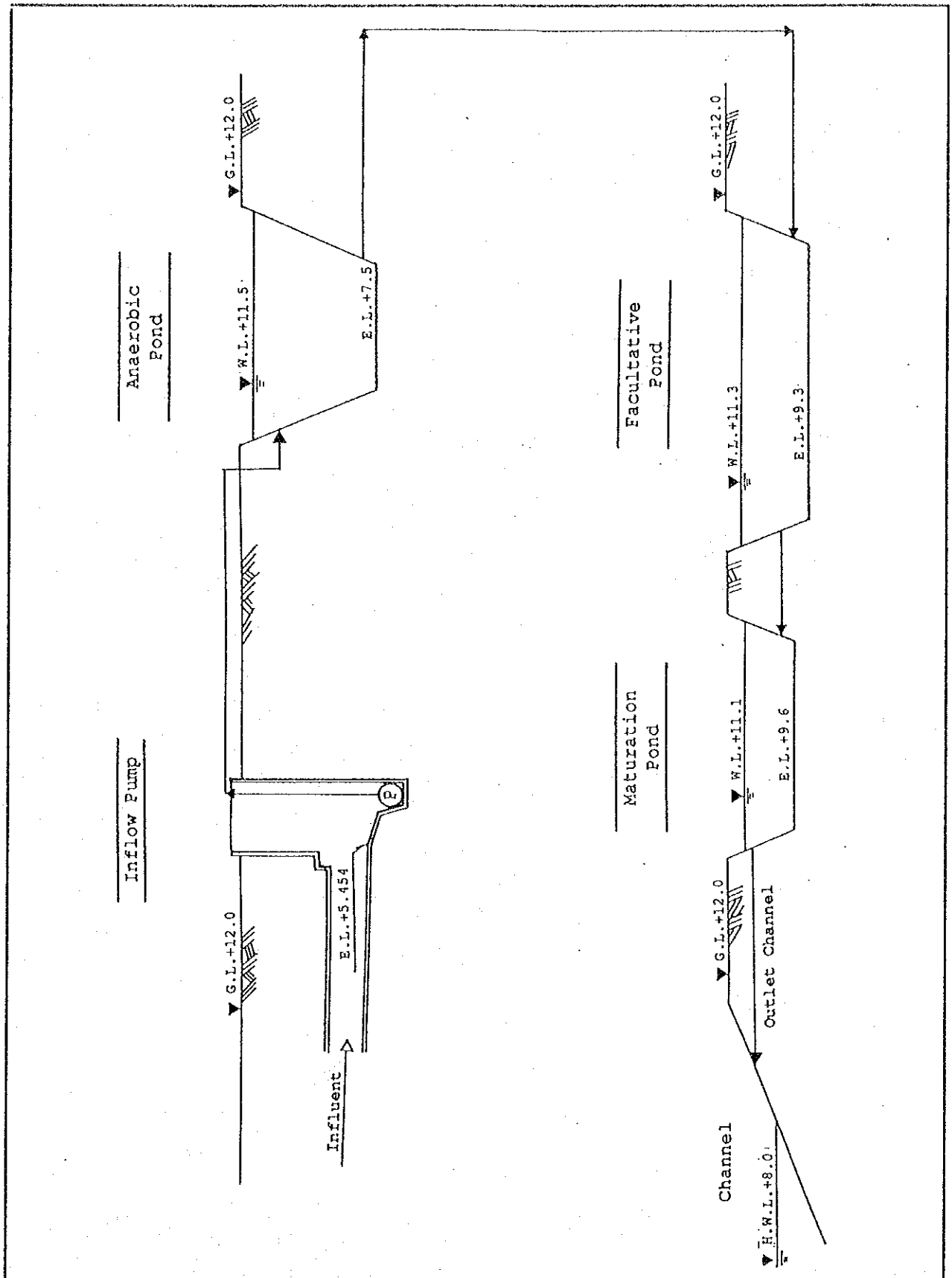

Figure 2.6.4.(1) Hydraulic Profile of Sewage Treatment Plant (Sing Buri East)

STUDY ON MASTER PLANNING FOR THE SEWERAGE DEVELOPMENT PROJECT FOR LOWER CHAO PHRAYA RIVER BASIN

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2.6.4 Wastewater Treatment and Sludge Disposal System for Sing Buri West Area

(1) Wastewater Treatment and Disposal Methods

The future wastewater discharge in the sewerage development area of Sing Buri West area is estimated to be 6,810 m^3/d in the year of 2011. Groundwater infiltration of 20% of wastewater discharge is assumed. The design wastewater to the treatment plant becomes to be 8,200 m^3/d. The treated water quality is expected less than 40 mg/l as BOD_5.

The following three (3) treatment systems are applicable to meet the above requirements in quality and quantity.

1) Stabilization Pond
2) Aerated Lagoon
3) Oxidation Ditch

(2) Comparative Evaluation

The above three (3) treatment systems are compared in terms of required construction and O&M costs, required land space and easiness of O&M as shown below (Details are included in Supporting Report 3.1.6.2).

Evaluation Item	Stabilization Pond	Aerated Lagoon	Oxidation Ditch
(1) Construction Cost (million Baht)	12.58	20.17	49.55
(2) Land Cost (million Baht)	10.47	4.99	2.39
(3) O/M Cost (million Baht/year)	0.17	0.63	4.83
(4) Required Land Area (ha)	9.85	4.70	2.25
(5) Easiness of O/M			
- Adaptability of overload	A	A	B
- Required technology level	A	A	B
- Sludge disposal	A	A	C

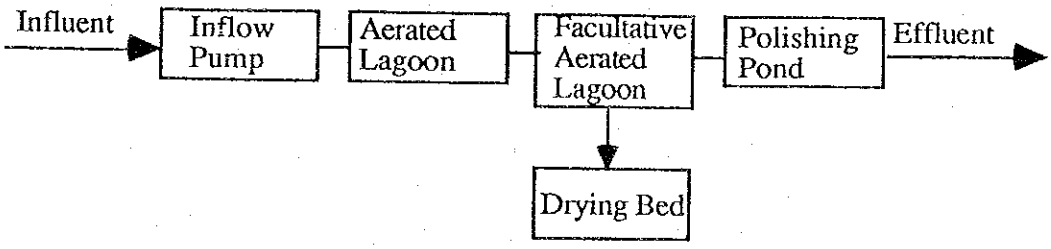
Note : 1) Construction cost : direct construction cost excluding land acquisition, engineering and administration costs
2) O/M cost : wages, electric charge, chemical and others
3) Adaptability of overload : A: high, B: middle, C: low
4) Required technology level : A: low, B: middle, C: high
5) Sludge disposal : A: easy, B: mediums, C: hard

As evident from cost comparison by NPV (refer to NPV cost in Supporting Report 3.1.6.3), stabilization pond system is the most economical. While the required land space of 9.85 ha is quite large comparing with the available land area of 4.5 ha. Thus, the secondly economical system of aerated lagoon is proposed for the treatment system of Sing Buri West.

(3) Plan of Treatment Plant

The proposed location of the wastewater treatment plant for Sing Buri West is currently used as the paddy field. The proposed treatment plant of aerated lagoon with a capacity of 8,200 m^3/d requires a net area of 4.70 ha.

The flow sheet of aerated lagoon system and the capacity dimension and other relevant details of each treatment facility is shown below.



Flow of Aerated Lagoon System

Inflow Pump	:	Design capacity	12,700 m^3/d (hourly max. dry)
			38,100 m^3/d (hourly max. wet)
	:	Capacity of	8.82m^3/min. with 4.8 m hydraulic head (hourly max. dry)
			26.46 m^3/min. with 4.8 m hydraulic head (hourly max. wet)
Grit Chamber	:	Surface loading	: 1,693 $m^3/m^2/d$ (dry weather)
			: 2,540 $m^3/m^2/d$ (wet weather)
	:	Retention time	: 31 sec (dry), 20 sec (wet)
	:	Size	: 1.0 m(W) x 7.5 m(L) x 0.6 m(D) x 2 units (1 unit for dry weather)
			: Constructed with R.C

Aerated Lagoon	:	Design capacity	8,200 m^3/d (daily ave. dry)
	:	Pond capacity	24,650 m^3
	:	Pond surface area	8,000 m^2
	:	Retention time	3.0 days
	:	Dimension	50 m(W) x 80 m(L) x 4.0 m(D) x 2 units
	:	Aerator	11 kw x 6 units/lagoon
	:	Embankment protected by masonry	
Facultative/	:	Pond capacity	24,650 m^3
Aerated Lagoon	:	Pond surface area	8,000 m^2
	:	Retention time	3.0 days
	:	Dimension	50 m(W) x 80 m(L) x 4.0 m(D) x 2 units
	:	Aerator	3.7 kw x 5 units/lagoon
	:	Embankment protected by masonry	
Polishing Pond	:	Pond capacity	8,200 m^3
	:	Pond surface area	6,300 m^2
	:	Retention time	1.0 day
	:	Dimension	45 m(W) x 70 m(L) x 1.5 m(D) x 2 units
	:	Aerator	3.7 kw x 5 units/lagoon
	:	Embankment protected by masonry	
Drying Bed	:	Required drying area	760 m^2
	:	Detention time	15 days
	:	Dimension	10 m x 15 m x 6 units (900 m^2)

The effluent is discharged to Chao Phraya river through khlong. Layout plan of the treatment plant and hydraluic profile are shown in Figure 2.6.3.(2) and Figure 2.6.4.(2), respectively.

2.7 Cost Estimates

2.7.1 Construction Cost

In the previous chapter, cost functions for interceptors, pump stations (more than 5 m^3/min.) and wastewater treatment plants are developed. Land acquisition cost is also considered to come up with the total construction cost. The following are cost requirements (million Baht) broken down into two sewerage systems for the design year 2011.

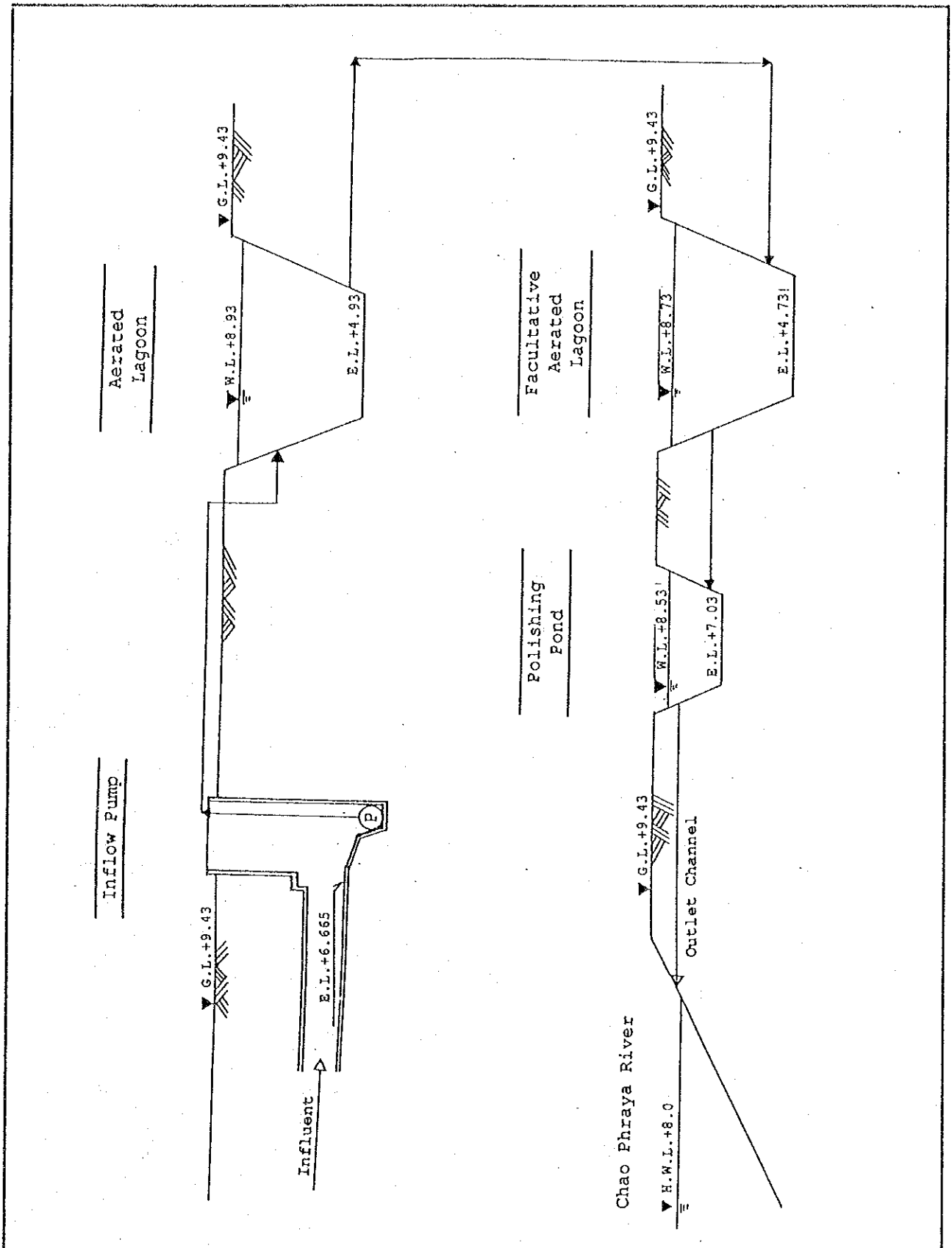


Figure 2.6.4.(2) Hydraulic Profile of Sewage Treatment Plant (Sing Buri West)

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Cost Item	Sing Buri East	Sing Buri West	Total
(1) Direct Cost			
1) Interceptor	111.2	89.5	200.7
2) Pump Station	12.1	8.9	21.0
3) W.W.T.P.	4.53	20.17	24.72
Total of Direct Cost	127.83	118.57	246.4
(2) Contingency (20% of Direct Cost)	25.6	23.7	49.3
(3) Total of Construction Cost ((1)+(2))	153.43	142.27	295.7
(4) Engineering & Construction Supervision 17% of (3)	26.1	24.2	50.3
(5) Land acquisition			
1) Pump Station	0.13	0.1	0.23
2) W.W.T.P.	6.0	4.99	10.99
Total of Land Acquisition	6.13	5.09	11.22
Grand Total (million Baht)	185.66	171.56	357.22

2.7.2 Operation and Maintenance Cost

Annual Operation and Maintenance cost (thousand Baht) is estimated in the previous chapter.

Cost Item	Sing Buri East	Sing Buri West	Total
1) Interceptor	657	483	1,140
2) Pump Station	559	411	970
3) W.W.T.P.	70	630	700
Total of O&M Cost	1,286	1,524	2,810

2.8 Implementation Plan

The provision of a complete sewerage system for the entire study area with its increasing population, will require a great investments of capital fund as estimated in the previous section. Some areas within the study area is presently undeveloped land and environmental conditions of such areas are different from built-up areas. Although the study area needs to be sewered in early stage, the urgency of sewerage requirements is different depending on the land use features of areas.

Staged construction will have advantages to minimize the excessive initial investment and capital expenditure.

Implementation program is prepared for the first 20 years, dividing into 4 stages of five year each, taking the design period up to the year 2011 into account. The schedule is assumed giving priority to developed/being developed areas.

Stage	Period	Works with Priority
1st	1991-1995	Preparatory work & design of facilities
2nd	1996-2001	Construction for central area of Sing Buri West
3rd	2002-2006	Construction for northern & southern area of Sing Buri West
4th	2007-2011	Construction for Sing Buri East area

2.9 Administrative and Financial Study

2.9.1 General

This municipality is also under strict control of ministry of Interior as other ones, and has little room and capacity of play for the newly proposed sewerage system. The duties and functions of the municipal government are decided by the Municipal Government Act (1953).

2.9.2 Existing Administration System

There are five divisions like other municipalities of this size (see Figure 2.9.1):

- Administration division
- Treasury division
- Health division
- Technical division
- Education division

The functions of each division are explained in the previous section.

The staff number of the municipality is 225 at present, excluding teachers of 125 at present. About 30% of the staff numbers are officials who have been recruited mainly by Ministry of Interior. They are appointed by DOLA. The remaining staff are employees, either permanent or temporary.

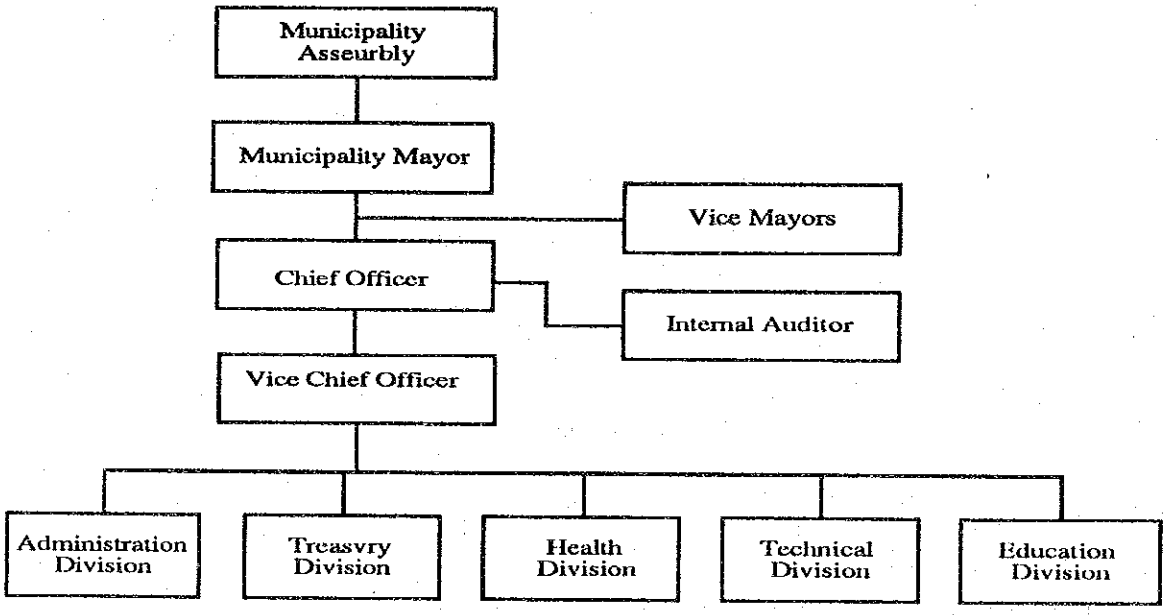


Figure 2.9.1 Administrative Structure of Municipality of Sing Buri

2.9.3 Recommendations

According to the implementation plan, the staffing requirement to treat wastewater of 9,341 m3/d in 2011 is estimated as follows:

Stage	Period	Staffing requirement
1st	1991 - 1995	7
2nd	1995 - 2001	13
3rd	2002 - 2006	25
4th	2007 - 2011	50

For administration two options are possible as follows:

- (A) to integrate it into the municipal organization (see Figure 2.9.2)
- (B) to create an independent one (see Figure 2.9.3)

The present staff of the municipality are 100, excluding teachers. The first stage of 1991 - 1995 will require only several staff for preparation of the sewerage system. Therefore Option (A) is more practical than option (B).

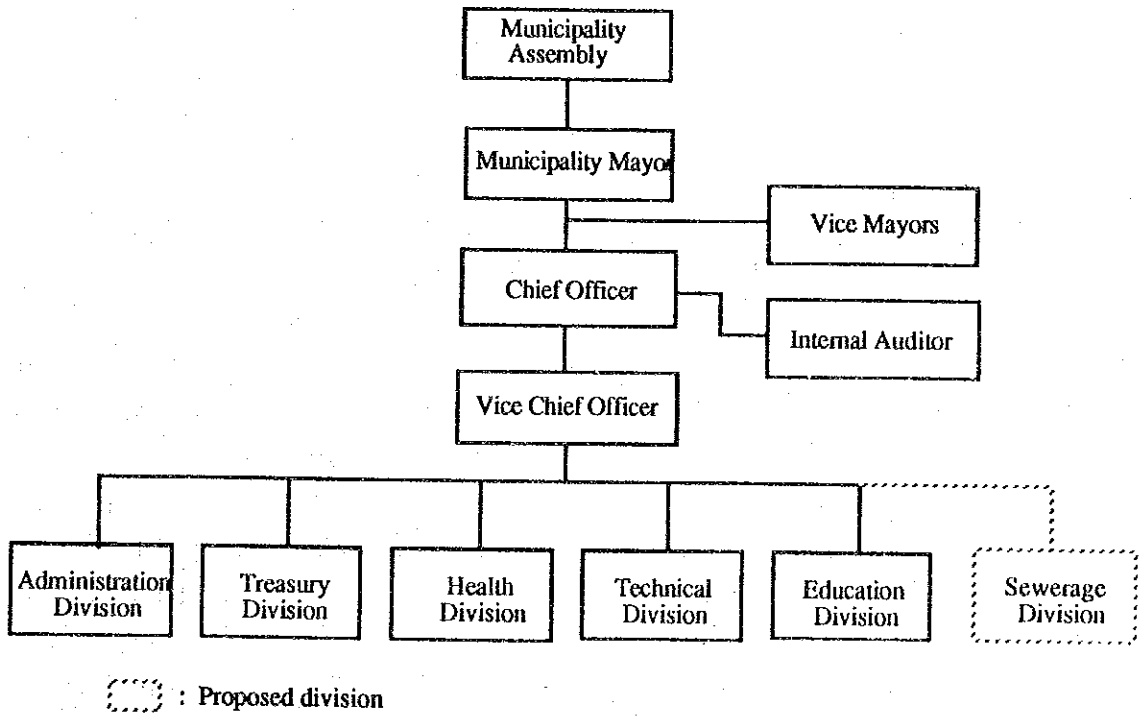


Figure 2.9.2 Option (A) for Muninipality of Sing Buri

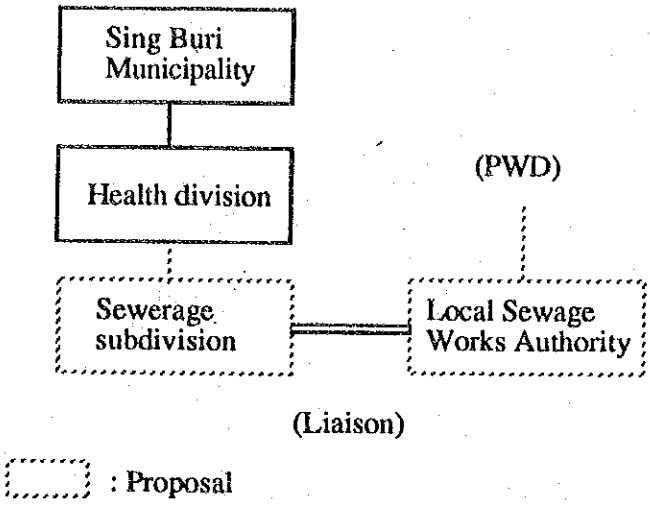


Figure 2.9.3 Option (B) for municipality of Sing Buri

However as the sewerage system develops, the staffing requirement will in increase. It is recommendable that Option (b) be considered in the future, when an independent management is needed for sewerage system.

2.9.4 Financial Considerations

The relative burden, as defined as the ratio of 25% land acquisition cost to fixed investment on land and construction, was 83%. While the amount of fixed investment varies with fiscal year, this figure of 83% was very high among eight municipalities.

Sing Buri has not yet developed social infrastructure, compared with that of Rangsit and Bang Bua Thong. The proportion of public fixed investment to total expenditures was only 13.4 % in 1991. This appears to reflect that the greater the portion of public fixed investment, the smaller the relative burden of land acquisition cost. For example, when public fixed investment increases to, say, 40% of total expenditures, the relative burden of land acquisition cost becomes also 40%. Thus, the relative burden of 83%, while very high, should be interpreted in a framework not only of fixed investment but also of total expenditures.

Nevertheless, when the relative burden exceeds a certain figure, say, 10%, it will add substantial burden on local municipality. This is due to limited capability of increasing local revenues in financing a large public

investment project as the sewerage project.

Sing Buri is no exception. Financing options that are available are (1) municipality development fund, (2) environment fund, or (3) increasing local revenues.

Environmental fund is available to local agencies in the form of grant and/or loan. It is recommended that Sing Buri explore loan financing to allocate financial burden into the future, compared to raising local revenues or utilizing municipality development fund whose objectives are more general than those of environmental fund.

The average household user cost in item 4.3 of Table 2.9.1, is well below one percent of low household income in 2011 for Sing Buri. The user cost, however, could be administratively increased by two factors, one is the interest rate of the local that Sing Buri would transfer to the user, and the other, the loss of the sewerage revenue collection that could be compensated for and would be included as part of the user charge.

The household users were estimated on the basis of the project service area in 2011. The household is assumed to have 4.1 persons on the average. We have also assumed that household users as sewerage users for simplicity. The average sewerage user cost was calculated on O&M cost divided by [(0.7+0.2x1.2+0.1x2)(number of household users)].

The average rate of non household users could be assumed to pay as high as the highest progressive rage of the household user rate structure. The progressive rate structure is 1.0 to 1.3 to 2.0 for low, medium, and high household income group respectively. A summary is shown in 4.4 of Table 2.9.1.

Finally, affordability will be considered. The affordability level is defined as the ratio of the average household user cost to low household income level of 96,571 Baht in 2011 in the Central Region. With available data on household income by Sing Buri, the figure indicated in 4.5 of Table 2.9.1 would then be updated and could also be modified with allocation of loan cost among the users.

Table 2.9.1 Selected indicators for Sing Buri

1.1	Service Pop in 2011	41,700
1.2	Household Users in 2011	10,170
2.1	Total Expenditures, 1991 (Thousand Baht)	30,303
2.2	Investment on Land & Const., 1991 (Thousand Baht)	4,067
2.3	Land Land Acquisition Cost (Thousand Baht)	3,375
2.4	Relative Burden (2.3/2.2) in %	84
2.5	Sanitation Expenditures, 1991 (Thousand Baht)	3
3.1	Total Revenues, 1991 (Thousand Baht)	23,810
3.2	Central Government Support, 1991 (Thousand Baht)	7,813
4.1	Treatment capacity (m3/d), in 2011	11,300
4.2	Unit O&M Cost of 4.1, in 2011	0.68
4.3	Household Users Cost/Year, in 2011 without loan	276
4.4	Progressive Rates: 1:1.3:2.0 in 2011	238 309 476
4.5	Loan Cost/H User/Year 50% Local, 50% Foreign Loan, 25 Years	28
4.6	Affordability (4.3 + 4.5) for Low Income Household, 96571 Baht, 2011	0.32%

SECTION 3

LOP BURI MUNICIPALITY

SECTION 3 LOP BURI MUNICIPALITY

3.1 Description of the Study Area

The DTCP area extending about 12.85 km^2 covers the present municipality area of 6.85 km^2 and its surrounding Tambols; Bangkhan Mak, Phrommas, Thahin, Thalae Choopsorn, Samyod, Thasala, Kokkoh, Patal and Pohkaoton excluding four military bases. The study area is in the central part of Thailand about 155 km north of Bangkok along Phapholyothin road. The municipality has three major areas; the old commercial area in the vicinity of railway station and Lop Buri river, the new commercial area near Sri Suriyothai Circle and the institutional area around Sodej Pra Narai Maharaj Circle.

The area is affected by west-eastern monsoon with an annual rainfall of 1,139.8 mm/year. The climate is warm and humid, with an average maximum temperature of 33.47°C, average minimum temperature of 23.52°C and average humidity of 83.42%. There are three seasons in a year with summer lasting from March to June, rainy season from July to October and winter lasting from November to February. During heavy rains, the western portion of the DTCP area experience flooding with about 35% of the DTCP area subjected to inundation. The eastern part is free of flood problems because it is elevated sloping towards the west. The main topographic characteristics are the mountainous terrain covering about 70% of the total area in the north, east and south, and the western plain occupying the remaining 30% of the area.

Lop Buri has 4 national conservation areas. However, the forest cover has been reduced to about 25,200 rai at present. On the other hand, the land suitable for rice production is 25% of the total area. The water sources for agriculture and other purposes are the Lop Buri river, the Pasak river and the Phochai river. Lop Buri is also rich in mineral resources; iron, copper, lead, lime, etc.

The study area has many tourist spots offering natural, cultural and historical attractions which are accessible from Bangkok. Road and railways are comparatively good. There are six major roads connecting to the neighboring provinces with a traffic volume of 3,000 to 5,000 vehicles/d for each road. There are a total of thirteen hotels to accommodate the tourists.

The electricity services cover all district areas. There are four telephone centers and about 6,000 telephones have been installed. According to the National Economic and Social Development Plan, Sara Buri province is the center of the Central Region, and Lop Buri is a satellite city to Sara Buri. The Narai Maharaj road is the only main road between the two cities.

The main source of living is agriculture. There are small scale factories for processing agricultural products, which handles 26% of the central region produce. Fishery and livestock are the other major sources of living. Commercial and industrial activities rank third. The cottage industries mainly comprise food products, clothing, printing, plastic and rubber and repair shops. There are 5 fresh food markets; 4 are private (Bon Muang, Tha Khun Nong, Ta Po and Talad Srakhaew) and 1 operated by the municipality, each occupying an area of about 1 rai. There is a 6 rai slaughterhouse, with a building area of 210 m^2, along Ramdeacho Rd. about 10 cows and buffaloes and 16-20 pigs are slaughtered daily. This place use water supplies and drain the wastewater to nearby canals.

3.2 Existing Sanitation and Sewerage Systems

3.2.1 Existing Sanitation Facilities

The municipality operates 7 trucks, each with a capacity of 10-15m^3, to collect 200 m^3/d of refuse and dispose them at a dumping site at Tambol Tale Chubsorn which is about 2 km from the municipality and has an area of 11.75 rai. There are about 73 workers operating the waste disposal. The disposal method is drying and burning. However dumping site is flooded almost every year.

On site treatment and disposal of nightsoil is practiced as referred to in Section 3, Chapter 2.

Water quality improvement has been carried out at Khlongs Sai Boa, Ruak, Srakaen and Bangkrabhi provided by mechanical aerator.

3.2.2 Existing Sewerage Facilities

Main drainage facilities (ϕ600, ϕ800, and ϕ1000 mm) are provided along the three major roads extended from east to west, which are finally connected to khlongs flowing from north to south. In addition, drainage pipes (ϕ600 mm - ϕ800 mm) are installed under major roads in the commercial and the high population density areas located in the western portion of the municipality. The sewage (combined system) is discharged into nearby khlongs. Composition of existing drainage facilities is summarized in Table 3.2.1. Area coverage and location of drains are shown in Figure 3.2.1.

Table 3.2.1 Existing Drainage Facilities

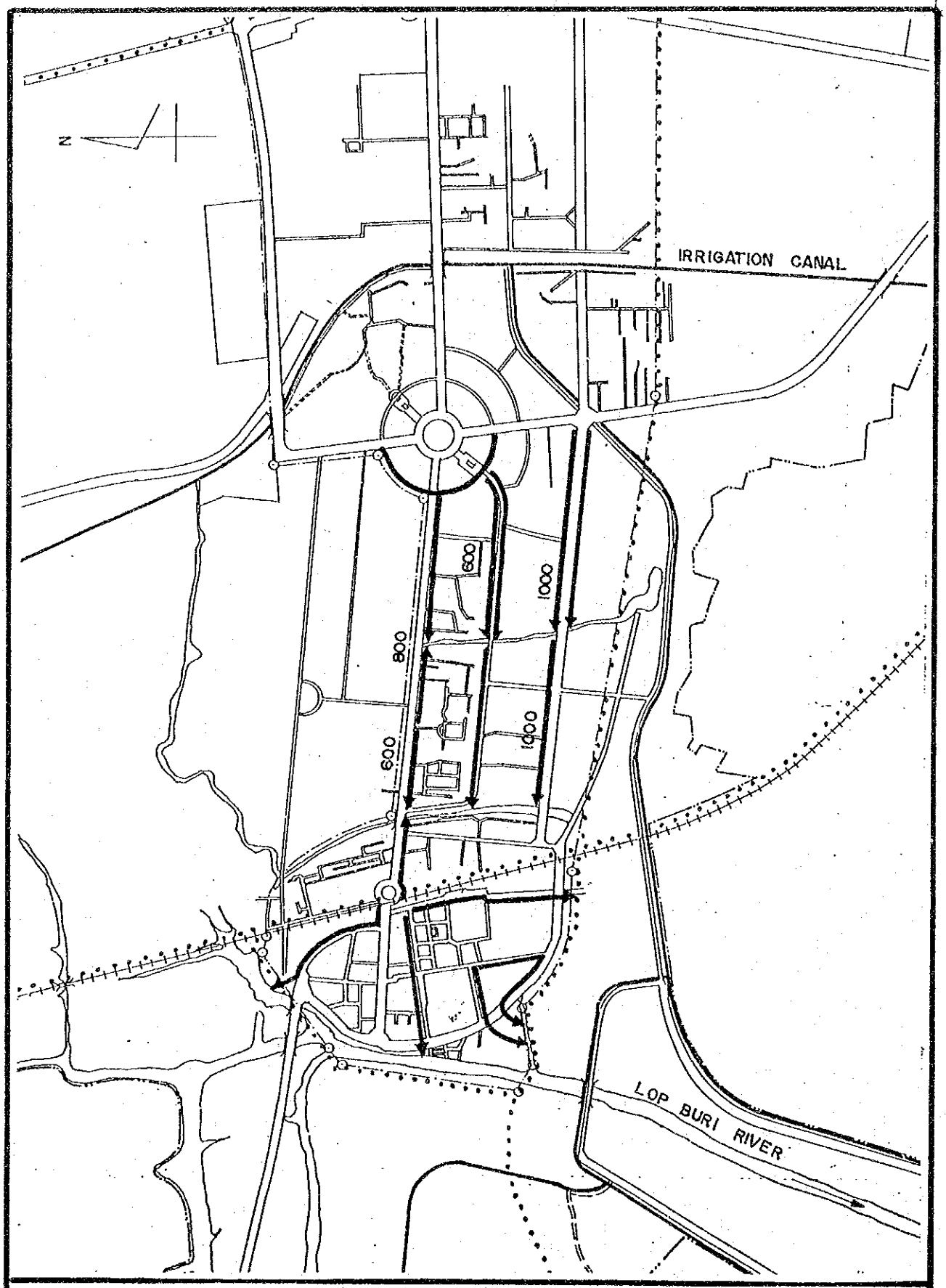
Size (mm)	Length (m)	Type	Drainage Area (ha)
dia. 1,000	2,800	RC. Pipe	39.6
dia. 800	2,400	RC. Pipe	26.5
dia. 600	5,350	RC. Pipe	69.6
Total	10,550		135.7

3.3 Water Supply

Water supply is provided by PWA, the municipality and the private sector. PWA operates three water works, Lop Buri, Piboon Songkram 1, and Piboon Songkram 2 waterworks, which covers an area of 14 rai. PWA's source is surface water from Chinat Pasak Irrigation Canal (No 7) with a production capacity of 26,000 m^3/d and a supply rate of 16,000 m^3/d.

The municipality's water supply source is 2 groundwater wells 22 m deep with a generating capacity of 1,500 m^3/d and a supply rate of 1,000 m^3/d. This waterworks covers an area of 3 rai.

People without access to these water supplies are still using water from khlongs, nearby channels and rain.



LEGEND : 600 DIAMETER (mm)
DRAINGE PIPE ⟶ OUTFALL SCALE 1 : 25,000

FIGURE 3.2.1 EXISTING DRAINAGE SYSTEM IN LOPBURI MONICIPALITY

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3.4 Population and Land Use

The average population density at present in the municipality is about 50 persons/ha which is higher than common local municipality. More than half of the municipality area is vacant land being developed as residential areas. There are some clusters out of the municipality area within the DTCP area. Land use and the percentage of types of structures within each land use category are enumerated below.

Land Use Type	Features with Approximate Percentage
Residential area (20.35%)	Single storied structures (90%)
	Wooden houses (80%)
	Over ten years old (60%)
Commercial (5.16%)	Mostly two-storied structures
Industrial (2%)	
Government office (15.38%)	Excluding military offices
Uncultivated and Agricultural land (57.11%)	

Land use at present and in the future (2011) is referred to in Section 3, Chapter 2 and Figure 3.4.1 presents the projection in the year 2011.

Study area and population are as follows:

Area & Population	Present Municipality	Future Exp. Area	Sewerage M/P Area	Other Area	DTCP Area
Area (km^2)	6.85	3.38	10.23	2.62	12.85
Pop. in 1991	36,832	11,980	48,812		
Pop. in 2011	49,320	11,980	61,300		

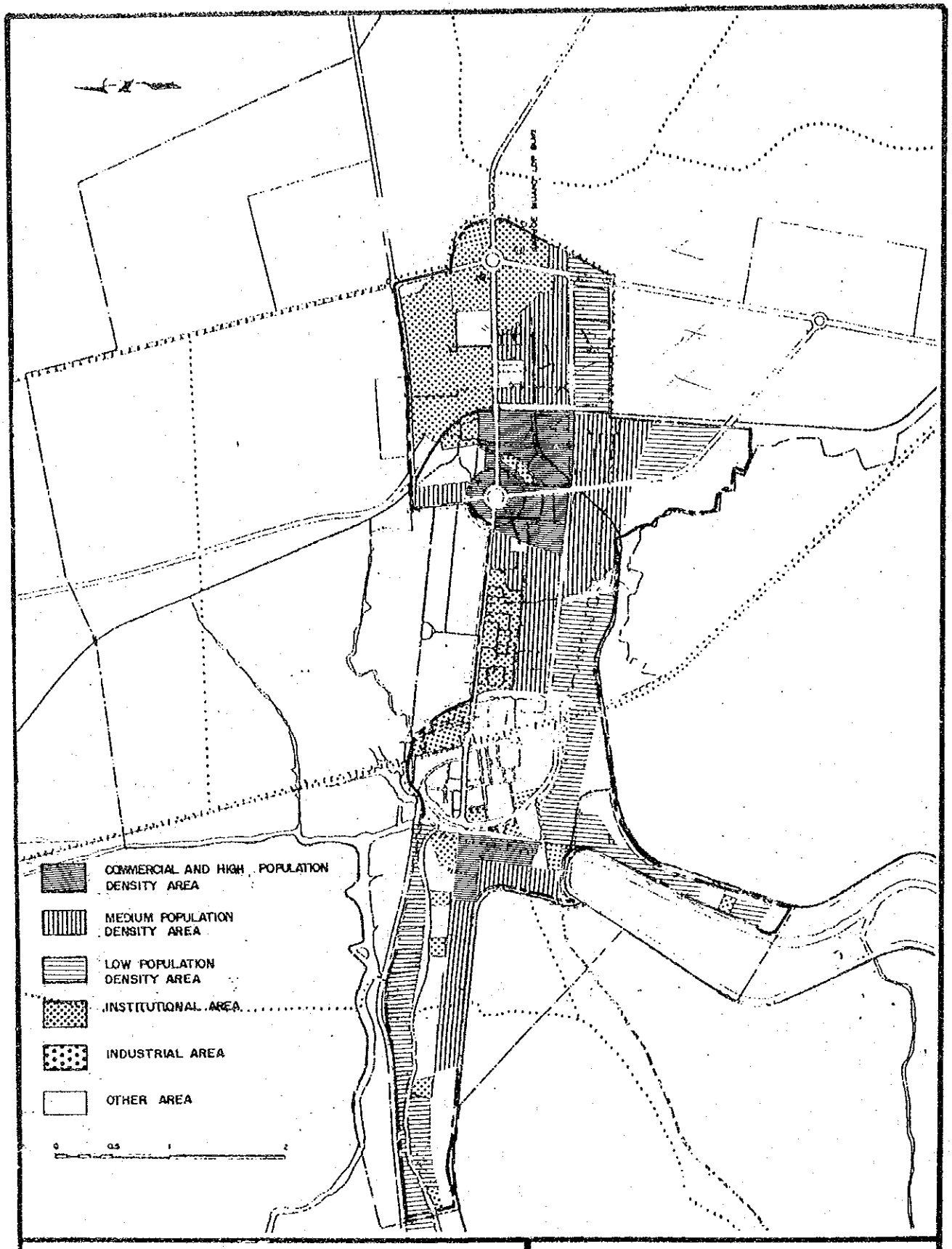

FIGURE 3.4.1 FUTURE LAND USE - YEAR 2011 (LOP BURI)

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3.5 Quality and Quantity of Wastewater

3.5.1 Unit Wastewater and Pollution Load on a Generation Basis

(1) Domestic Wastewater

Unit quality (BOD) and quantity on the daily average basis at present and in design year are tabulated breaking down into sullage and toilet waste.

Domestic wastewater discharge is assumed at 80% of water consumption. Toilet waste is treated by septic tank with assumed treatment efficiency of 50%.

Year	Unit Wastewater (lpcd)			Unit BOD Load (gpcd)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Present	100	12	112	33.6	5.5	39.1
Design Year (2011)	136	24	160	35.1	5.5	40.6

(2) Business Wastewater

Those for business wastewater (commercial and institutional) is assumed to be 30% and 40% of domestic wastewater for the present and design year (2011), respectively.

	Unit Wastewater (lpcd)	Unit Pollution Load (BOD gpcd)
Present	32	6.1
Design Year (2011)	64	7.7

3.5.2 Discharged Wastewater and BOD Load

(1) Domestic Wastewater

Wastewater quantity and BOD load based on a discharge basis are estimated for the present and design year (2011) multiplying service population by unit wastewater quantity/BOD load. The following are the estimation results.

Item	Present			Design Year (2011)		
	Sullage	Toilet Waste	Total	Sullage	Toilet Waste	Total
Wastewater Quantity (m^3/d)	4,886	586	5,472	8,337	1,471	9,808
BOD Load (kg/d)	1,640	268.5	1,908.6	2,151.6	337.2	2,488.8

(2) Business Wastewater

Discharged wastewater quantity and BOD load are estimated in the same procedure as domestic wastewater as shown below.

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	1,564	3,923
BOD Load (kg/d)	297.8	472.0

(3) Total Wastewater Quantity and BOD Load

Total discharged wastewater quantity and BOD load (daily average basis) at present and in the design year (2011) for Lop Buri Sewerage Development are figured out as shown below.

Item	Present	Design Year (2011)
Wastewater Quantity (m^3/d)	7,036	13,731
BOD Load (kg/d)	2,206.4	2,960.8