To assess the effects of the proposed sewerage system on the water quality of the Chao Phya River, a pollution analysis of the river was made using new Chao Phya River model developed by the Study Team as shown in Appendix J of this Report.

The estimated water quality in the Chao Phya River is shown in Figure 11.1. This indicates that anaerobic condition may extend in the reaches of the river if no water pollution control measure is provided on either domestic or industrial wastewater discharge estimated by the year 2543 (2000), and that, if the proposed sewerage system and industrial wastewater control are completed, water pollution of the Chao Phya River may mostly be eliminated.

The oxygen sag curve of Case 2 in Figure 11.1 indicates that the water pollution of the river may be remarkably mitigated by the effects of industrial wastes control and Zone 2 sewerage system (see Figure 11.1). In this case, the effluent quality from the wastewater treatment facility is assumed to be of 60 mg/l in BOD. If the wastewater collected from Zone 2 is discharged without treatment, the lower reaches of the river may become anaerobic condition and nuisance condition may appear in the area.

As mentioned in Appendix J, further detail study is required because the field data of the Chao Phya River, especially, on the loadings of pollutional matter are not completely reliable for input data. However, the comparison of the estimated water quality implies that the wastewater management is required for water quality control of the Chao Phya River, and that the intercepted and collected wastewater cannot help but to be treated before discharge to prevent increasing nuisance condition in the receiving water, and that the required effluent quality of 60 mg/l in BOD is reasonable for the initial stage of the sewerage system construction.

11.2 Selection of Wastewater Treatment Process

Among a number of wastewater treatment processes, taking into account the present conditions in Bangkok, following processes which will be applicable to the wastewater treatment are selected for comparative study.

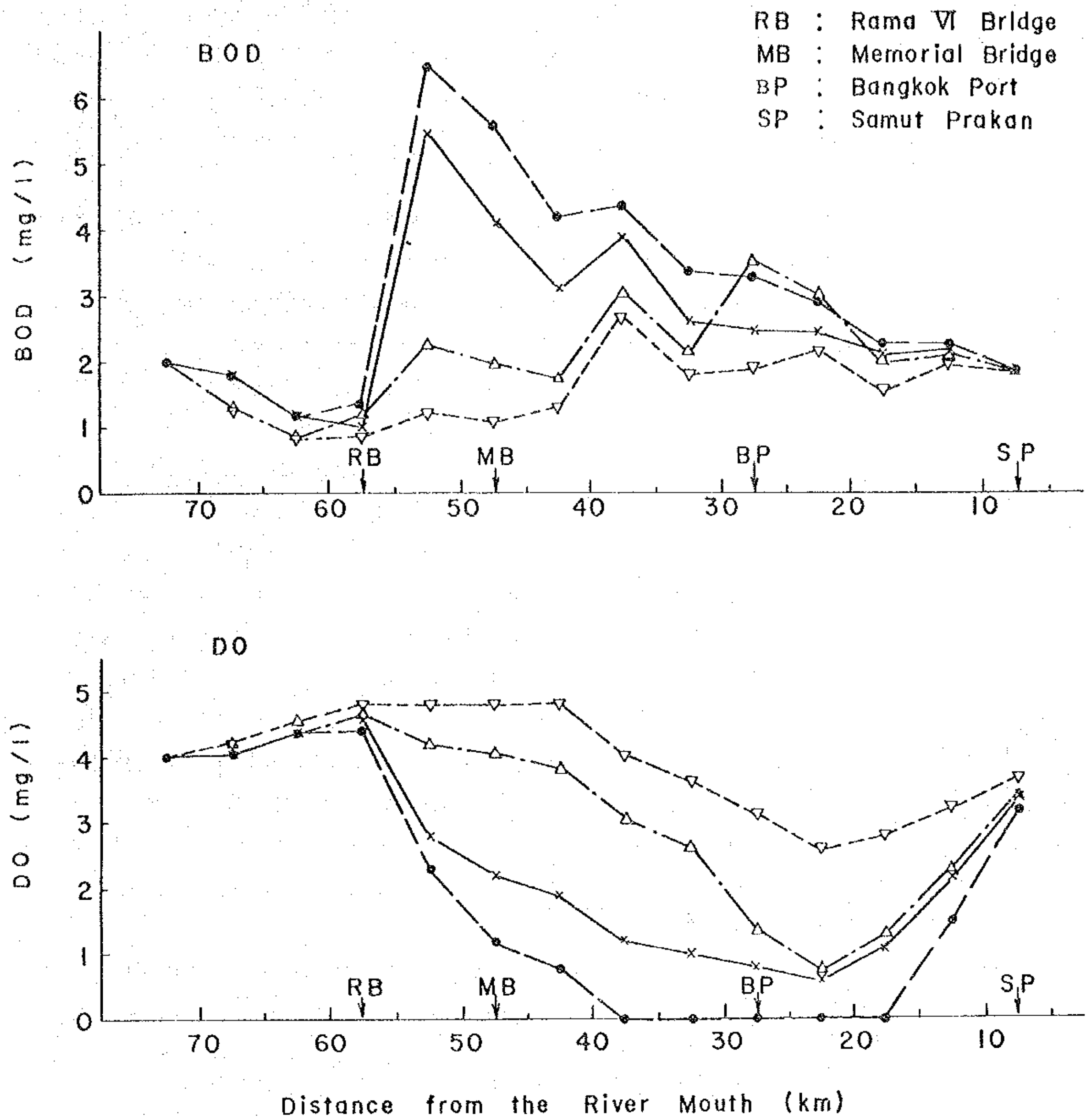

Figure II.1 Estimated Water Quality in Chao Phya River

(1) Stabilization Pond Process

(2) Aerated Lagoon Process

(3) Oxidation Ditch Process

(4) Conventional Activated Sludge Process

(5) Modified Aeration Process 1/

Although trickling filter and rotating bio-disc processes may be necessary to be discussed in this study too, it is difficult to convert trickling filter process to another process for higher quality effluent to be required in the future, and design and operation manuals of rotating bio-disc process has not been evidently established. Therefore, both of them are excluded from this study.

There are a lot of modifications of activated sludge process. Among them, modified aeration process is selected, because it will be easily converted to conventional activated sludge process to meet anticipated requirement of higher quality effluent in the future and cost saving can be expected in the initial stage of construction.

Where sufficient space for treatment facility is available at reasonable price, stabilization pond and aerated lagoon processes have advantages, because they are easy in operation and maintenance and save the construction and operation and maintenance costs.

General description, design criteria recommended taking account of hot climate conditions, and typical layout of each treatment process are as follows.

11.2.1 Stabilization Pond Process

Stabilization pond process has been successfully used in many countries, which is sometimes referred as "oxidation pond" or "lagoon". They have con-

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1/ A modification of the activated sludge process in which a shortened period of aeration.

siderable advantages particularly as regards to the costs and maintenance requirements and the removal of faecal bacteria. They are the most economical process of wastewater treatment in hot climates where sufficient land is available in reasonable cost and where the temperature is most favourable for their operation.

On the basis of operational condition, the stabilization ponds are classified into three types, namely, aerobic, faculatative and anaerobic pond. Among them, since aerobic type requires large land area and anaerobic type emits bad odor, facultative pond described below will be the most appropriate type in the Study Area.

(a) Facultative Pond

Facultative pond is the system in which the upper layers of the pond are aerobic and the bottom layers are either devoid of dissolved oxygen or are anaerobic. At present most of the existing waste stabilization pond installations are of the facultative type. The facultative pond is oxygenated principally by the photosynthetic activity of algae under the influence of solar radiation, although, in the larger ponds, surface aeration by the wind action contributes significantly to the total oxygen supply. The dissolved oxygen concentration is greater during daylight period than at night. The measurement of oxidation-reduction potential will show the tendency towards either aerobic or anaerobic conditions. For the function of facultative pond, temperature is very important factor because it affects the rate of biochemical degradation. Variations of temperature influence the biological, physical, and chemical process in the pond.

The most important factors on stabilization pond design are areal load of BOD and depth of the pond. On the basis of the experience of treatment facility operation, 300 kg.BOD/day/ha of surface area and 1.5 m of pond depth is proposed for this study. This corresponds to 10 days of mean detention time.

(b) Maturation Pond

The main function of maturation pond which is provided as a second stage to facultative pond is the destruction of faecal bacteria and viruses. The principal factor for the design of the maturation pond is detention time. The detention time in the maturation pond is determined primarily by the degree of bacteria reduction required. In design of maturation pond the reduction of faecal coliform in a pond has been found to follow first order kinetics. The appropriate equation is as follows:

$$Ne = \frac{Ni}{1 + K_{b(t)}T}$$

$$K_{b(t)} = 2.6\ (1.19)^{t-20}$$

where Ne : effluent coliform, cells/ml

Ni : influent coliform, cells/ml

$K_{b(t)}$: dieoff coefficient of coliform at t°C, 1/day

T : detention time, days

From the above mentioned equation, the estimated number of effluent coliform from facultative pond (Ne) is 4,500/ml, assuming.

$Ni = 4 \times 10^5$/ml,

$K_{b(27)} = 8.8\ d^{-1}$, and

T = 10 days

This value (Ne=4,500/ml) is unsatisfied on sanitary aspect, so that the facultative pond should be followed by a maturation pond (detention time is 3 days) for further reduction of coliforms.

This is

$$Ne = \frac{4 \times 10^5}{(1+8.8x10)(1+8.8x3)} = 164/ml$$

This can be satisfied for environmental protection from coliform contamination by treatment facility effluent.

The design criteria for stabilization pond process are summarized in Table 11.1 A typical layout of stabilization pond process is shown in Figure 11.2.

Table 11.1 Design Criteria for Stabilization Pond Process

Unit Process	Item	Design Criteria
Facultative Pond	BOD Loading	300 Kg.BOD/day/ha
	Pond Depth	1.5 m
	Detention Time	10 days
Maturation Pond	Pond Depth	1.5 m
	Detention Time	3 days

11.2.2 Aerated Lagoon Process

The aerated lagoon is an activated sludge unit operated without sludge return. This is historically developed from stabilization pond.

The main difference between stabilization pond process and this process is aeration system. In this process, commonly, floating aerator for surface aeration is used to supply the necessary oxygen and for mixing lagoon contents.

In common with all activated sludge systems, aerated lagoon is not particularly effective in removing faecal coliforms and suspended solids. Faecal coliform reduction is only 90 - 95 percent and further treatment, with maturation pond may, therefore, be necessary.

For the design of aerated lagoon in this study, design criteria are proposed as shown in Table 11.2. A typical layout of aerated lagoon process is shown in Figure 11.3.

Table 11.2 Design Criteria for Aerated Lagoon Process

Unit Process	Item	Design Criteria
Aerated Lagoon	Lagoon Depth	3.0 m
	Detention Time	4 days
Maturation Pond	Pond Depth	1.5 m
	Detention Time	3 days

11.2.3 Oxidation Ditch Process

The oxidation ditch is a modification of the activated sludge process, generally followed by sedimentation basin except for small size plant. The oxidation ditch is a long continuous channel usually oval in plan and 1.0 - 1.5 m deep. The ditch liquor is aerated by one or more brush or rotors placed across the channel.

At present, there are a few oxidation ditches in Bangkok.

A design of oxidation ditch is purely empirical at the present time. According to Mara (1978)[1/], the depth is in the range of 1 - 2 m and the volume is dependent on the detention time which in turn is based on the sludge loading factor which is the weight of BOD applied to the ditch liquor suspended solids per day.

The sludge loading factor is given by following equation.

$$r = \frac{Li}{St}$$

where r = sludge loading factor, 1/day

Li = influent BOD, mg/l

S = ditch liquor suspended solids, mg/l

t = detention time, days

1/ Mara, D.D. "Sewage Treatment in Hot Climates" New York: John Wiley & Sons, Ltd., 1978

Then, ditch volume is estimated as follows;

$$V = \frac{LiQ}{Sr}$$

where V = ditch volume, m^3

Q = flow rate, m^3/day

The design value of this study are taken as $r = 0.1\ d^{-1}$, S = 4,000 mg/l, t = 0.5 days, and depth is assumed at 1.5 m. The recommended design criteria for oxidation ditch process are as shown in Table 11.3. A typical layout of oxidation ditch process is shown in Figure 11.4

Table 11.3 Design Criteria for Oxidation Ditch Process

Unit Process	Item	Design Criteria
Oxidation Ditch	BOD-SS Loading	0.1 Kg.BOD/kg.SS/day
	MLSS	4,000 mg/l
	Detention Time	0.5 days
	Depth	1.5 m
Sedimentation Tank	Overflow Rate	30 m^3/day/m^2
	Detention Time	2.0 hr
Chlorination tank	Detention Time	15 min
Drying Bed	Required Area	0.03 m^2/cap

11.2.4 Conventional Activated Sludge Process

Activated sludge is defined as "Sludge floc produced in a raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen, and accumulated in sufficient concentration by returning floc previously formed."

The conventional activated sludge process is defined as "A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation, and wasted or returned to the process as needed. The treated wastewater overflows the weir of the settling tank in which separation from the sludge takes place."

The basic activated sludge system consists of a series of interrelated components.

These components include the followings:

i) A single or multiple aeration tank designed for staged or completely mixed flow; each tank with sufficient size to provide hydraulic detention time of as little as 0.5 hr to as much as 24 hr.

ii) An aerator of supplying air or oxygen containing gases into the mixed liquor which consists of raw wastewater and activated sludge.

iii) A sedimentation tank for separation of liquid and sludge.

iv) A device of collecting and recycling the sludge (activated sludge) to the aeration tank.

v) A device of removing or wasting excess sludge from the system.

The conventional activated sludge process is capable of producing somewhat higher degree of treatment, 90 to 95 percent BOD reduction, and producing a clearer effluent than most other biological oxidation processes.

Conventional activated sludge process is usually of relatively high capital cost as can be seen in the later section in which various processes are compared. In addition the running cost is high as shown in Figure 11.9. This process also requires constant and skilled supervision which is not readily available in Thailand at present. Further, some units of this process require mechanical equipment and spares which are not yet manufactured in Thailand. This process, however, requires relatively smaller areas of land than areas for other treatment methods (see Table 11.6).

The recommended design criteria for conventional activated sludge process are presented in Table 11.4. A typical layout of conventional activated sludge process is shown in Figure 11.5.

Table 11.4 Design Criteria for Conventional Activated Sludge Process

Unit Process	Item	Design Criteria
Primary Sedimentation Tank	Overflow Rate	40 m3/day/m^2
	Detention Time	1.5 hr
Aeration Tank	BOD-SS Loading	0.50 Kg.BOD/Kg.SS/day
	MLSS	2,000 mg/l
	Aeration Time	4.0 hr
	Return Sludge Ratio	25 percent
Final Sedimentation Tank	Overflow Rate	30 m^3/day/m^2
	Detention Time	2.0 hr
Chlorination Tank	Detention Time	15 min
Thickening Tank	Sludge Loading	60 Kg/day/m^2
	Detention Time	12 hr
Digestion Tank	Detention Time	30 days
Drying Bed	Detantion Time	10 days
	Sludge Depth	20 cm

11.2.5 Modified Aeration Process

The flow diagram for modified aeration process is identical with that of the conventional activated sludge process. The difference in the systems is that modified aeration uses shorter aeration times, usually 1.5 to 3 hr and a high food-to-microorganism ratio. The MLSS concentration is relatively low, whereas the organic loading is high. The resultant BOD removal is about 75 percent; thus the process is not suitable where a high-quality effluent is desired. On the other hand, the process has the advantage as follows:

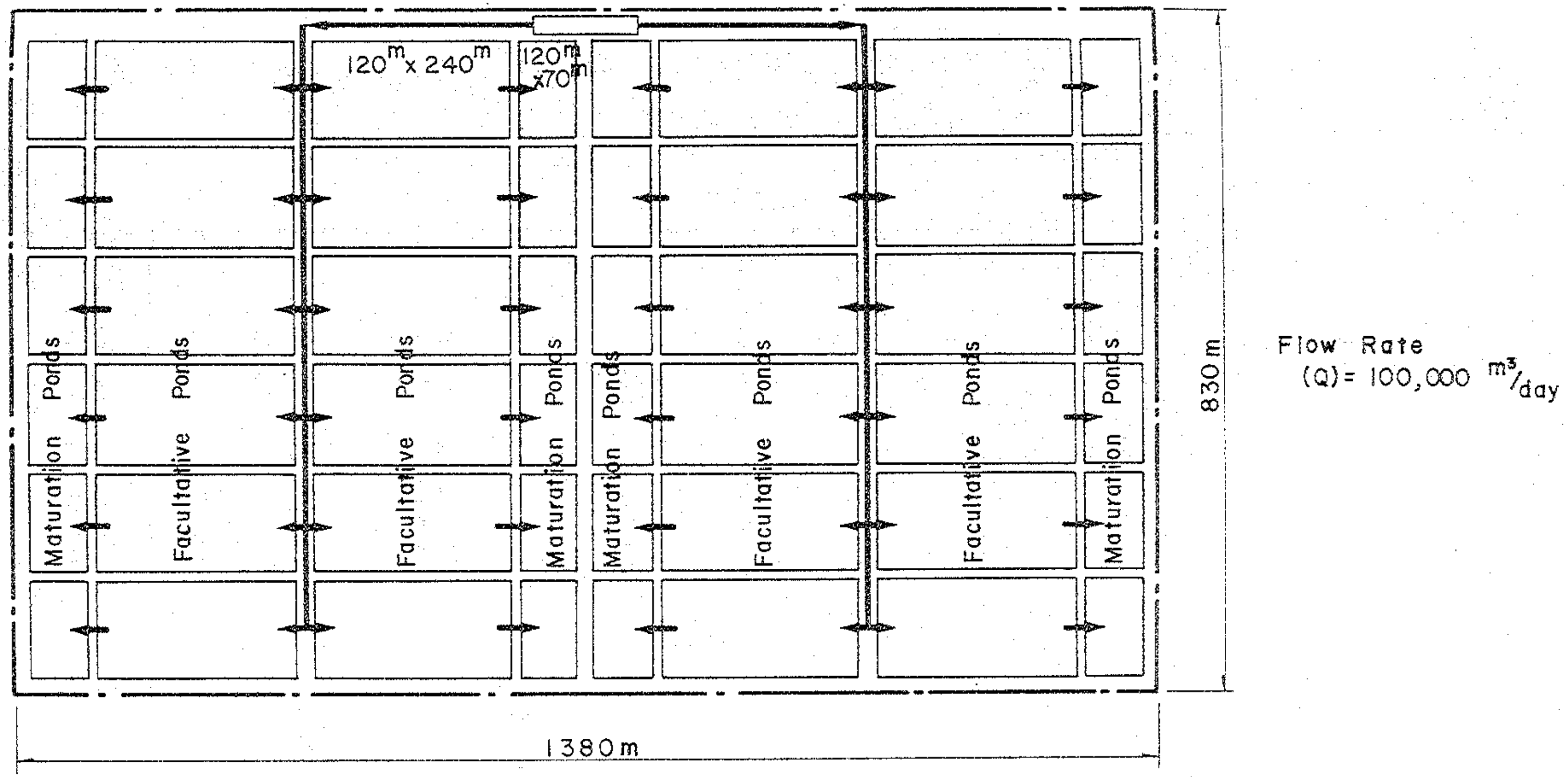
1. Site area required is smaller than other activated sludge processes.
2. Capital construction cost and operation cost are relatively inexpensive.
3. When a high-quality effluent is desired, this process can easily be converted into conventional activated process.

In view of above mentioned the modified aeration process is superior to other processes, where available land is limited.

The recommended design criteria for modified aeration process are described in Table 11.5. A typical layout of modified aeration process is shown in Figure 11.6.

Table 11.5 Design Criteria for Modified Aeration Process

Unit Process	Item	Design Criteria
Primary Sedimentation Tank	Overflow Rate Detention Time	40 $m^3/day/m^2$ 1.5 hr
Aeration Tank	BOD-SS Loading MLSS Aeration Time Return Sludge Ratio	3.5 Kg.BOD/Kg.SS/day 800 mg/l 1.5 hr 10 percent
Final Sedimentation Tank	Overflow Rate Detention Time	30 $m^3/day/m^2$ 2.0 hr
Chlorination Tank	Detention Time	15 min
Thickening Tank	Sludge Loading Detention Time	60 $Kg/day/m^2$ 12 hr
Digestion Tank	Detention Time	30 days



Scale = 1:800

Figure II·2 Typical Layout of Stabilization Pond Process

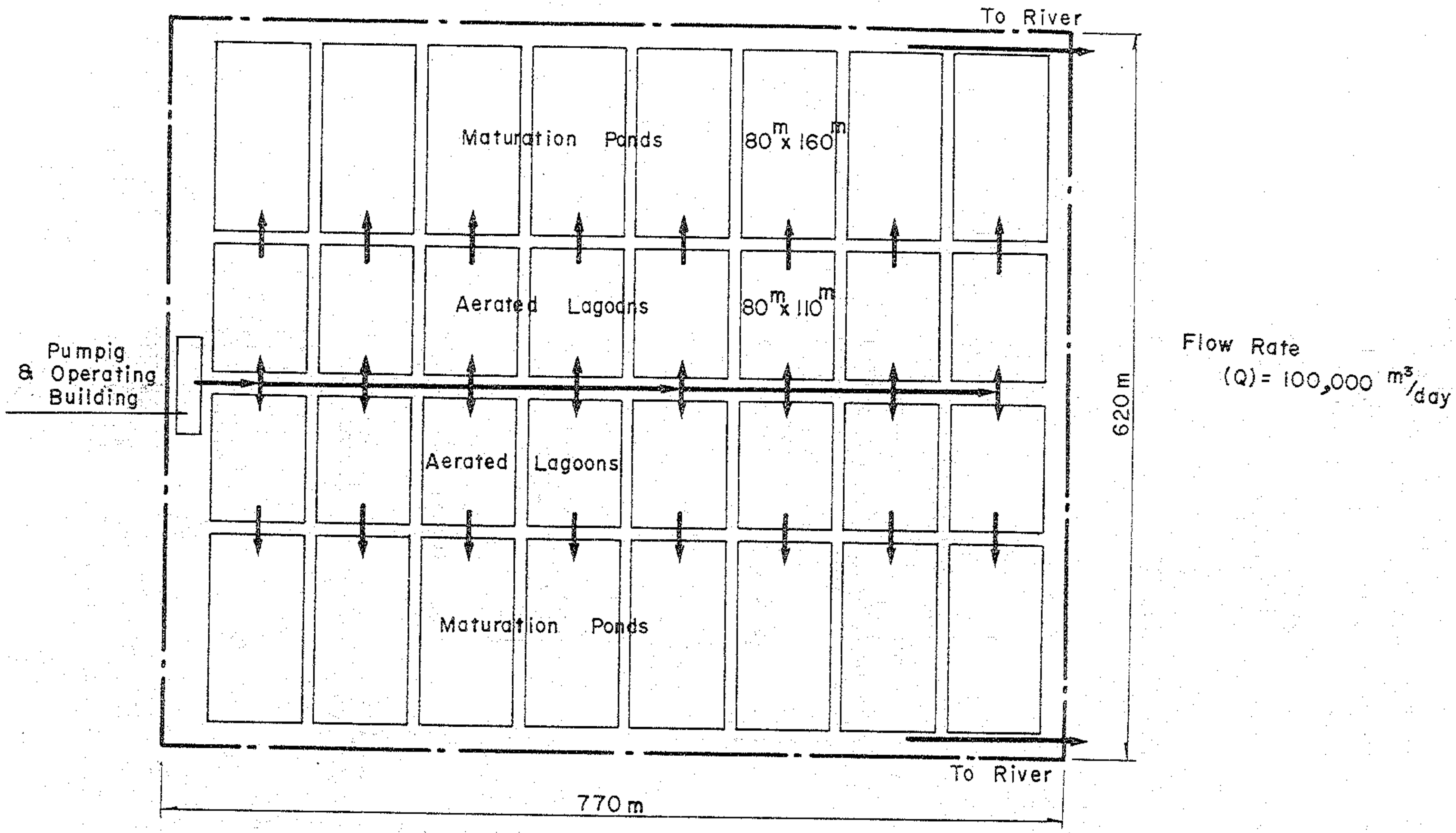
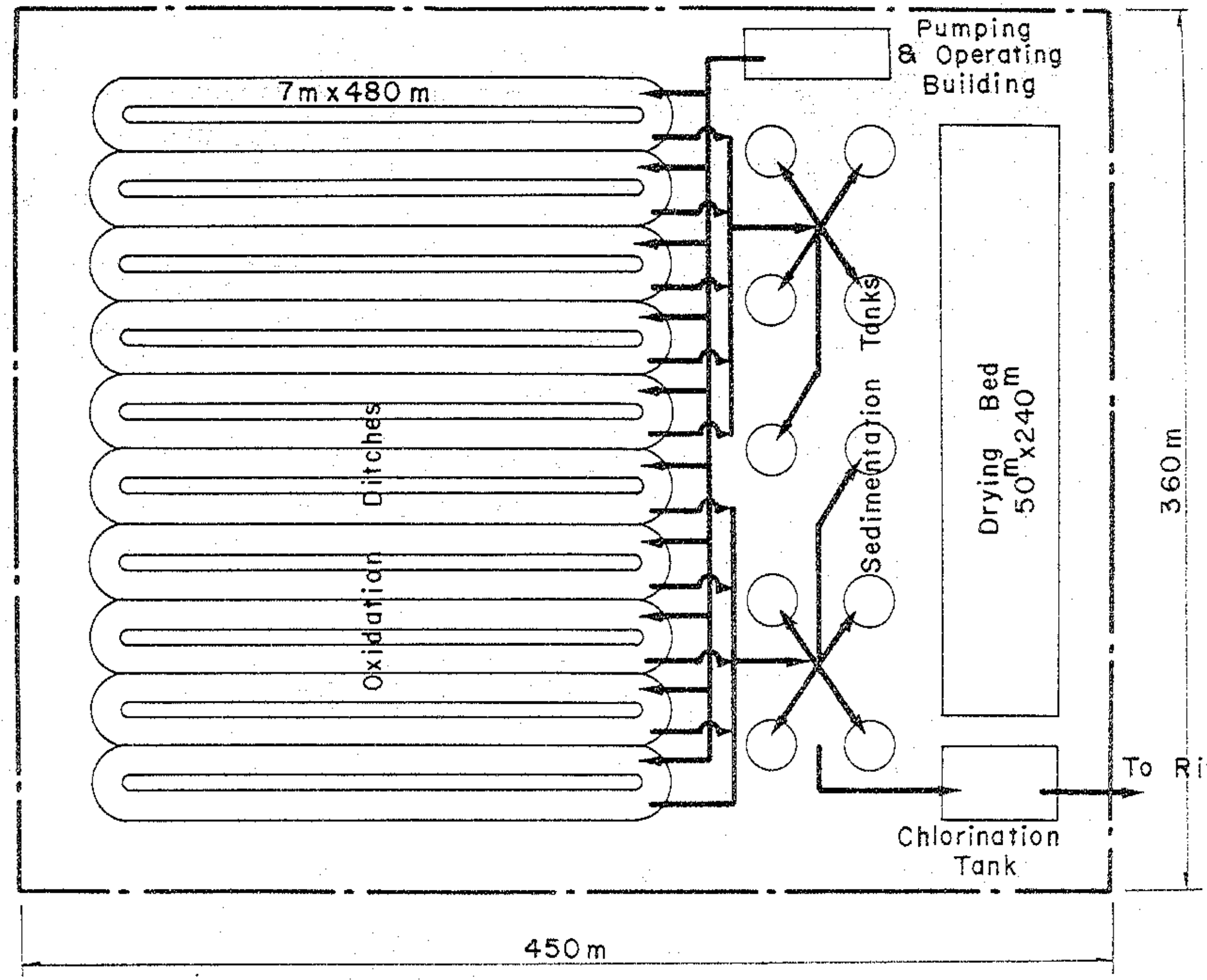


Figure II·3 Typical Layout of Aerated Lagoon Process



Flow Rate
(Q)= 100,000 m^3/day

Scale = 1:300

Figure II·4 Typical Layont of Oxidation Ditch Process

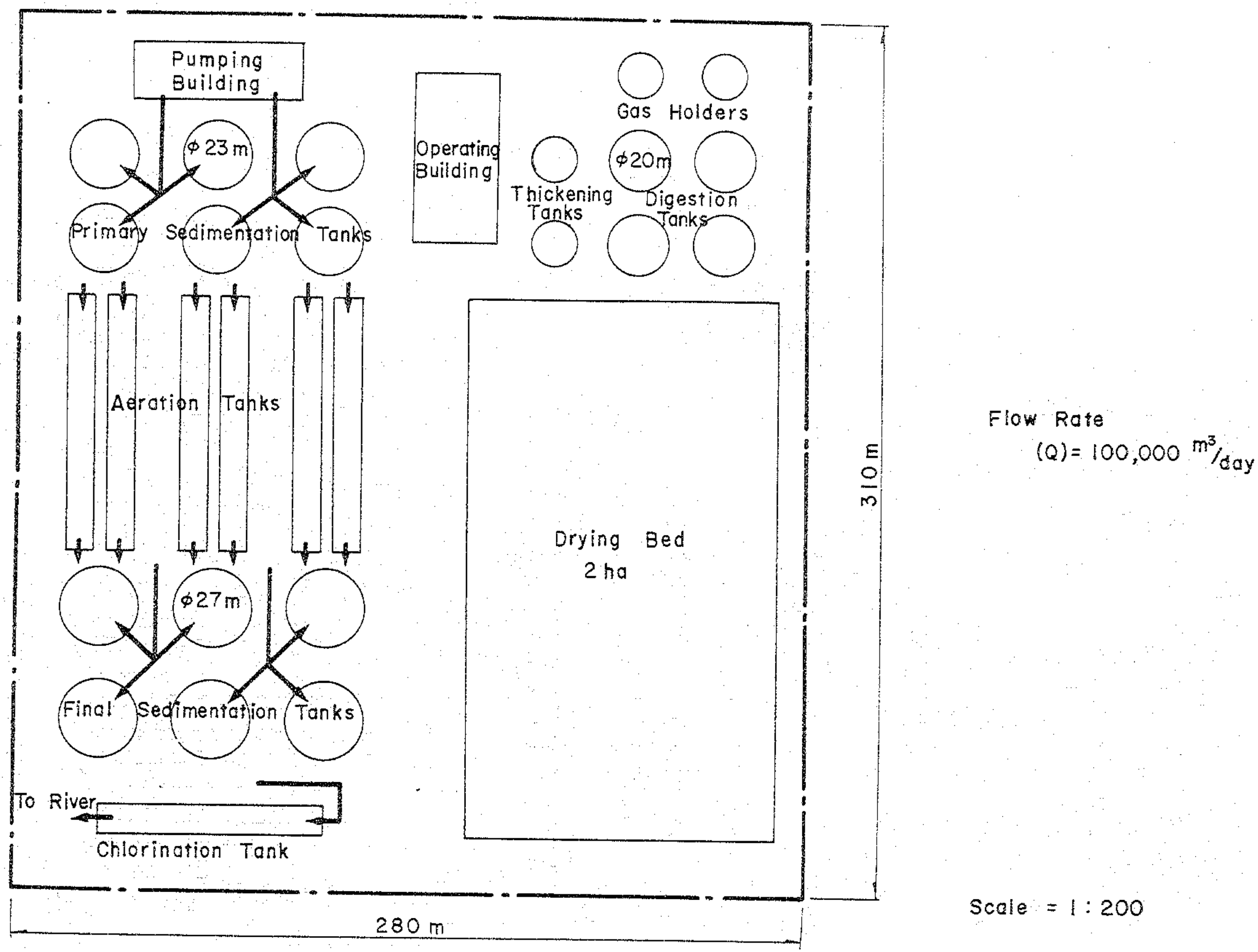


Figure II·5 Typical Layout of Conventional Activated Sludge Process

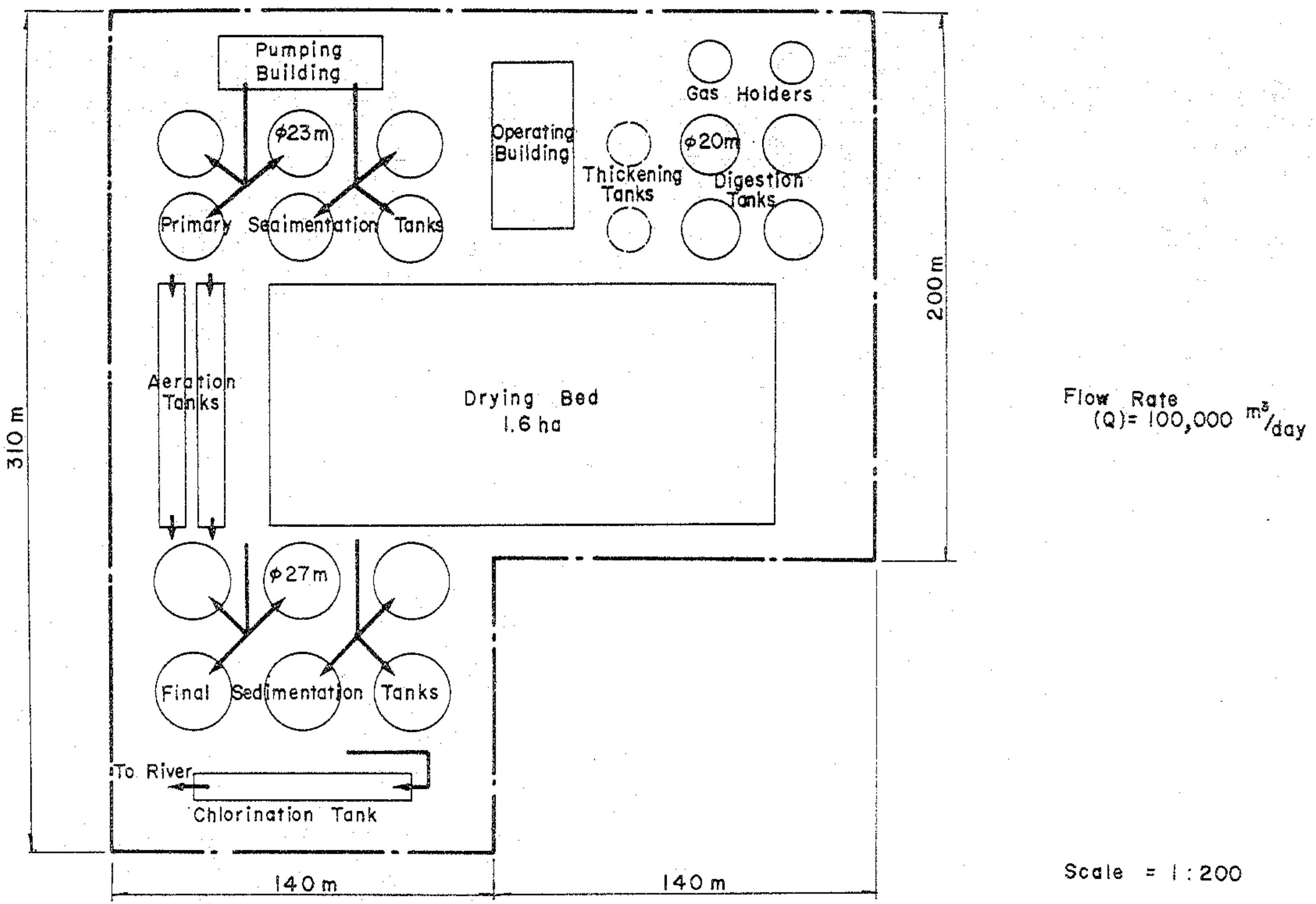


Figure II·6 Typical Layout of Modified Aeration Process

11.3 Comparison of Different Types of Wastewater Treatment Process

In selecting the most suitable wastewater treatment process in the Study Area, the cost of the land, capital construction cost, operation and maintenance cost, and operating problems are important factors.

In order to make comparative study on the wastewater treatment processes described in Section 11.2 above, i.e. stabilization pond, aerated lagoon, oxidation ditch, conventional activated sludge, and modified aeration, cost estimation was made for each treatment type of daily flow of 50,000, 100,000 and 500,000 m^3/day.

The contents of each type of treatment for comparison are described below:

i) Stabilization pond process shall consist of the facultative pond and maturation pond in series.

ii) Aerated lagoon process shall consist of the aerated lagoon and maturation pond in series.

iii) Oxidation ditch process shall consist of oxidation ditch, sedimentation tank, and sludge drying bed.

iv) Conventional activated sludge process shall consist of primary sedimentation tank, aeration tank, final sedimentation tank, sludge thickening tank, digestion tank, and sludge drying bed.

v) Modified aeration process shall consist of primary sedimention tank, aeration tank, final sedimentation tank, sludge digestion tank and drying bed.

The wastewater quality of each treatment is estimated with the influent BOD of 200 mg/l and the expected BOD removal rate is 75 percent for

i) stabilization pond process
ii) aerated lagoon process
v) modified aeration process

and 90 percent for
iii) oxidation ditch process
iv) conventional activated sludge process.

11.3.1 Land Requirements

On the basis of layout plan of five different treatment process, required site areas are obtained as shown in Table 11.6 and Figure 11.7 (refer to Appendix D in detail). In this study, it is estimated that each treatment plant site would be surrounded by a 10 m wide strip of land for odor screening, part of which would be used for access to the ponds or lagoons, while the remainder would be planted with shrubs and trees to landscape the area and to afford a degree of visual screening.

Table 11.6 Site Area Required for Treatment Processes

(Unit: ha)

Treatment Process	Flow Rate (m^3/day)		
	50,000	100,000	500,000
o Stabilization Pond	60.72	114.54	545.10
o Aerated Lagoon	26.04	47.74	226.92
o Oxidation Ditch	9.45	16.20	59.40
o Conventional Activated Sludge	5.58	8.68	32.86
o Modified Aeration	4.59	7.14	26.08

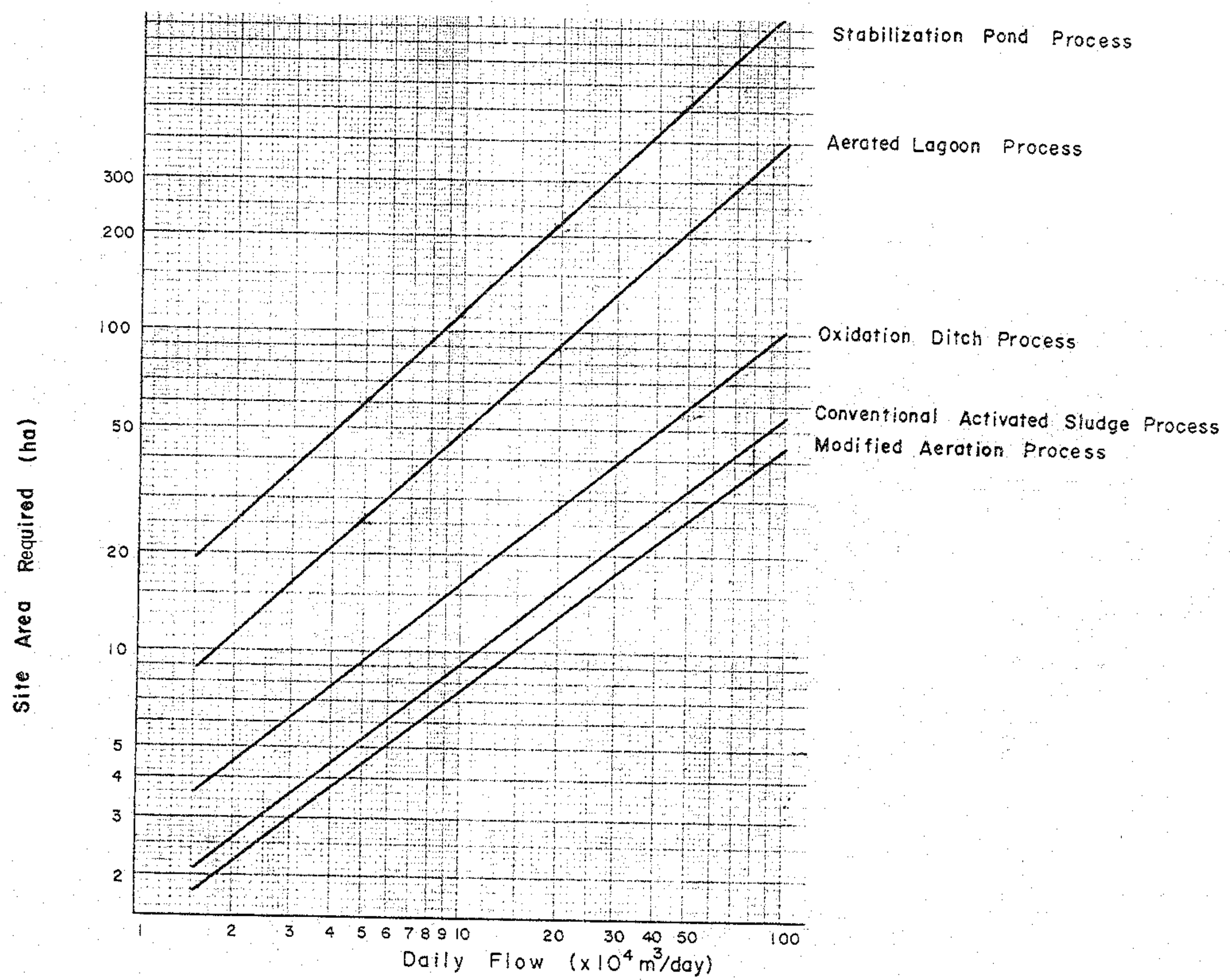


Figure II- 7 Site Area Required for Treatment Processes

11.3.2 Construction Cost Estimates for Alternative Treatment Processes

The capital construction costs of the five wastewater treatment processes are shown in Table 11.7 (refer to Appendix E in detail). In each case the costs include for ponds, tanks, mechanical and electrical equipment; inlet and outlet works, screens and flumes; drainage of the site; fencing, site roads and embankments; and works office and stores. For activated sludge processes the costs also include for thickening tanks, digestion tanks, and sludge drying beds which occupy about 30 percent of the area of site required. The curves of the construction costs for alternative treatment processes are shown in Figure 11.8.

The construction cost per cubic meter per day for stabilization pond is substantially lower than for the other treatment methods, although the stabilization pond requires much more land than other processes. However, where no large area for treatment facility site is available, aerated lagoon is more preferable than stabilization pond, because of the lower capital cost.

Table 11.7 Construction Costs for Alternative Treatment Processes

(Unit: 1,000 baht)

Treatment System	Flow Rate (m^3/day)			Cost Function
	50,000	100,000	500,000	
o Stabilization Pond	48,744	76,783	290,183	$C=9.751xQ^{0.784}$
o Aerated Lagoon	53,475	82,092	308,966	$C=11.980xQ^{0.773}$
o Oxidation Ditch	90,268	166,952	744,536	$C=4.318xQ^{0.919}$
o Conventional Activated Sludge	235,834	405,106	1,345,855	$C=67.634xQ^{0.755}$
o Modified Aeration	163,885	301,841	1,018,279	$C=33.861xQ^{0.787}$

Note: C: Construction cost in thousands baht

Q: Daily average wastewater flow in m^3/day

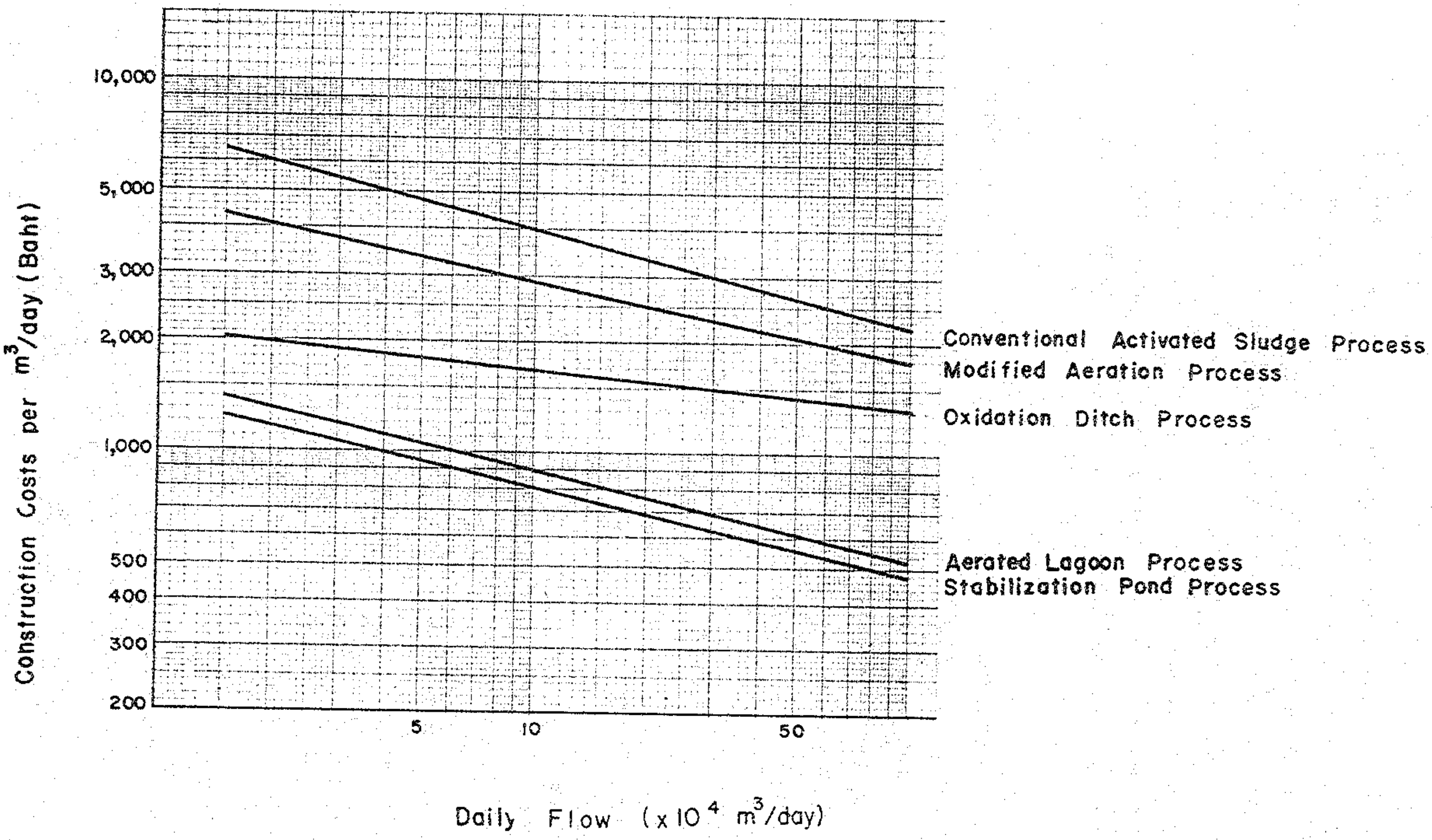


Figure II-8 Construction Cost Curves for Alternative Treatment Processes

11.3.3 Operation and Maintenance Costs

The annual operation and maintenance costs of the five treatment processes are shown in Table 11.9. These costs include for electricity, salaries, repairs to civil, mechanical and electrical works, and sludge disposal. In developing the annual operation and maintenance costs for treatment work followings are assumed:

(a) Daily average number of operator (including labour) is as follows:

Table 11.8 Number of Operator for Alternative Treatment Processes

(persons)

Treatment Process	Flow Rate (m^3/day)		
	50,000	100,000	500,000
o Stabilization Pond	3	5	10
o Aerated Lagoon	3	5	10
o Oxidation Ditch	8	10	15
o Conventional Activated Sludge	20	30	50
o Modified Aeration	18	27	45

(b) Average salary of operator is 40,000 baht/year.

(c) Electricity is 1.5 baht/kW.hr.

(d) Repairs and replacement of parts are estimated at one percent of capital construction cost of civil works and two percent of mechanical and electrical works.

Figure 11.9 shows curves of the annual operation and maintenance costs per cubic meter per day for five treatment processes. Details of this study are shown in Appendix E.

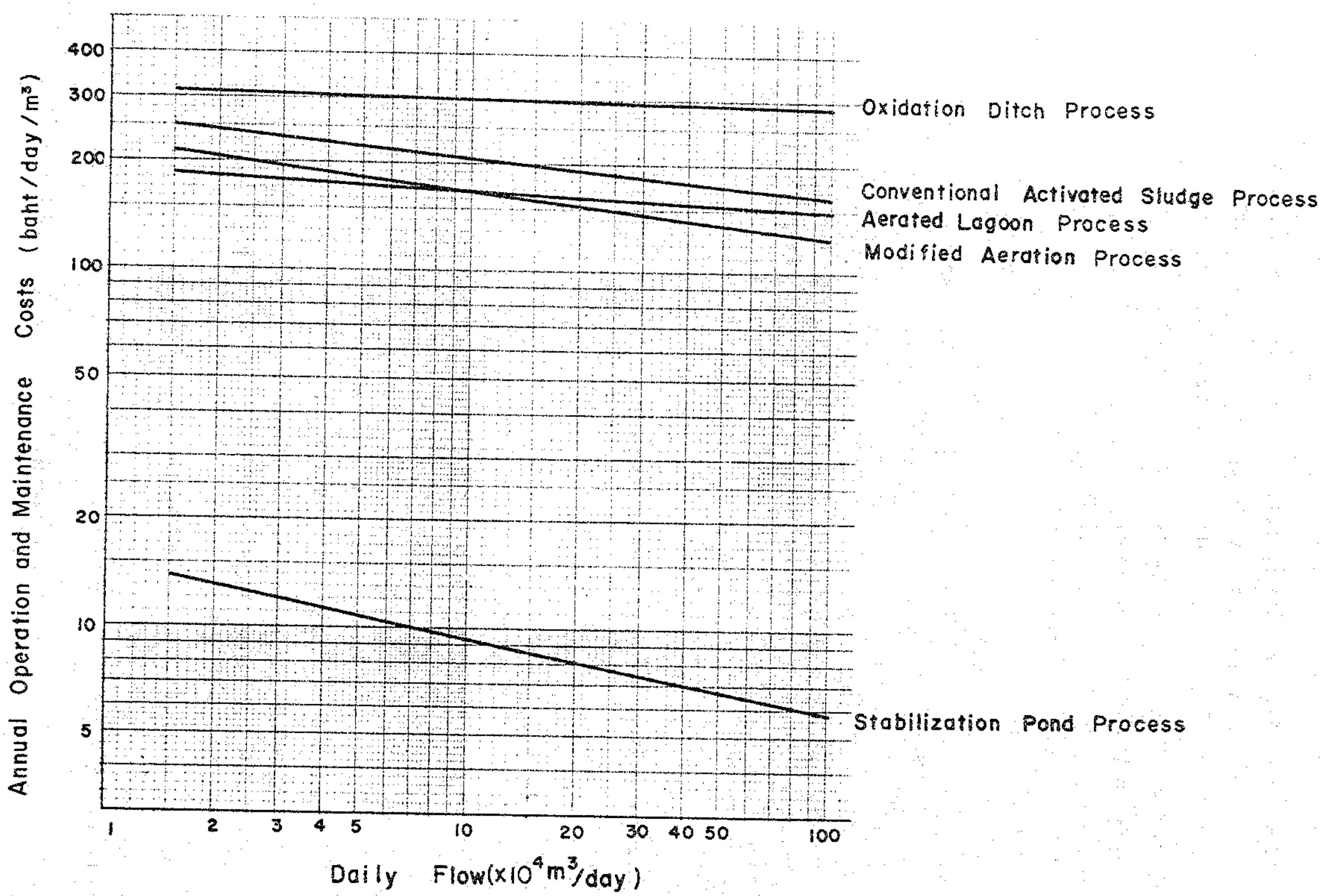


Figure II·9 Annual Operation and Maintenance Cost Curves for Alternative Treatment Process

The operation and maintenance costs of stabilization pond is the most inexpensive because little machinery and power are required, and the cost of labour is essentially for supervising the site and keeping it tidy.

Table 11.9 Annual Operation and Maintenance Cost for Alternative Treatment Processes

(1,000 baht)

Treatment Process	Flow Rate (m^3/day)			Cost Function
	50,000	100,000	500,000	
o Stabilization Pond	607	968	3,302	$C=0.198xQ^{0.740}$
o Aerated Lagoon	8,709	17,036	75,400	$C=0.355xQ^{0.935}$
o Oxidation Ditch	15,072	29,652	145,367	$C=0.354xQ^{0.985}$
o Conventional Activated Sludge	11,440	21,297	91,282	$C=0.657xQ^{0.902}$
o Modified Aeration	8,895	16,983	72,662	$C=0.471xQ^{0.911}$

Note: C: O & M Cost (1,000 baht/year)
Q: Daily average wastewater flow (m^3/day)

11.3.4 Proposed Treatment Process

The purpose of this study is to judge suitable treatment process without particular reference to local requirement in the Study Area. As described in previous section, land requirement, capital construction costs, and operation and maintenance costs vary widely with the treatment process. It appears that the land cost is the significant factor among others for selecting proper alternative in the Study Area.

A selection among five treatment processes is based on a comparison of annual costs, i.e., interest of capital construction costs and land acquisition costs, depreciation, operation and maintenance costs. Cost estimates are prepared for each type of work to treat wastewater flow with rate from 10,000 to 1,000,000 m^3/day. Figures 11.10 through 11.12 show curves of the total annual costs for five treatment processes at unit land cost of 100, 500 and 1,000 baht/m^2 (refer to Appendix F in detail).

These indicate that stabilization pond is more economical than the other processes of treatment at land value of about 100 baht/m^2. Further, at land value of about 500 baht/m^2 and wastewater flow of less than approximately 150,000 m^3/day, aerated lagoon is economical process. On the condition with land value of about 500 baht/m^2 and wastewater flow of 150,000 m^3/day and above, modified aeration process is more economical, because of the lower land acquisition cost. On the condition with land value of about 1,000 baht/m^2, modified aeration is the most economical.

It is concluded that where available land is enough and where this can be acquired at less than 500 baht/m^2, aerated lagoon is preferable. Where the land required can be acquired at about 1,000 baht/m^2, modified aeration process is preferable. Where there is insufficient land for the sitting of aerated lagoon, modified aeration is recommendable.

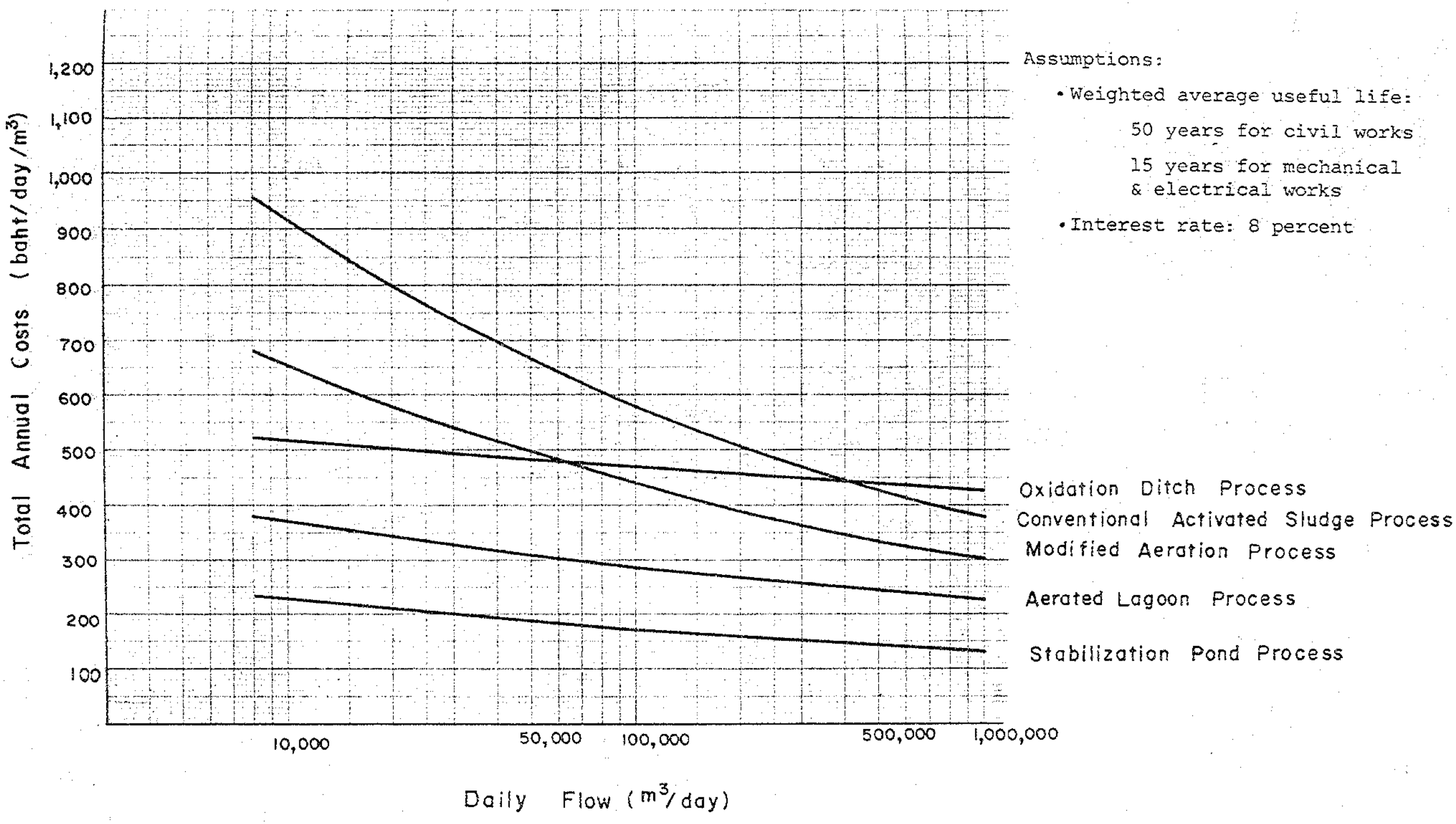


Figure II·10 Total Annual Costs by Treatment Process at Land Value 100 Baht/m^2

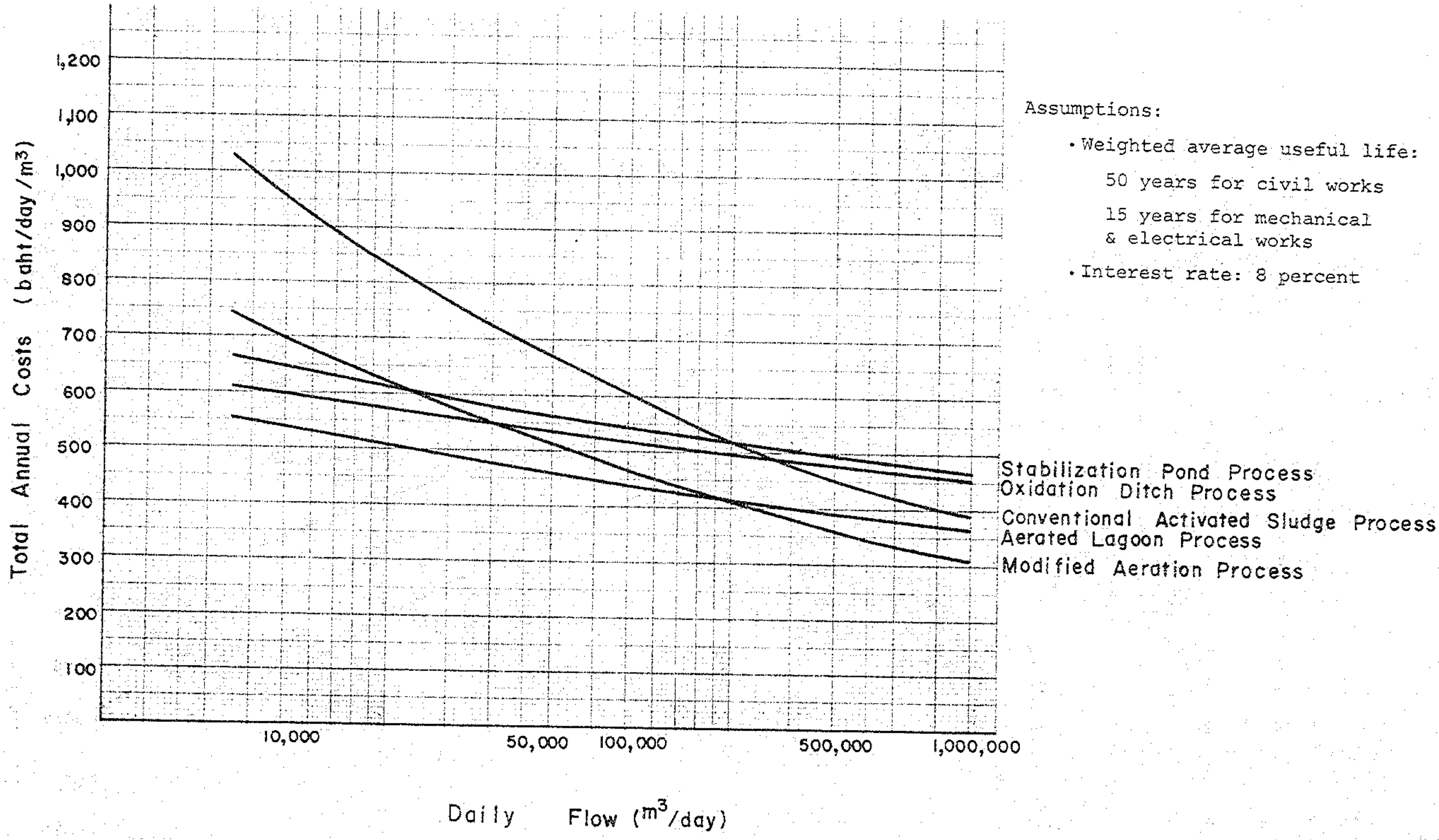


Figure II·11 Total Annual Costs by Treatment Process at Land Value 500 Baht/m^2

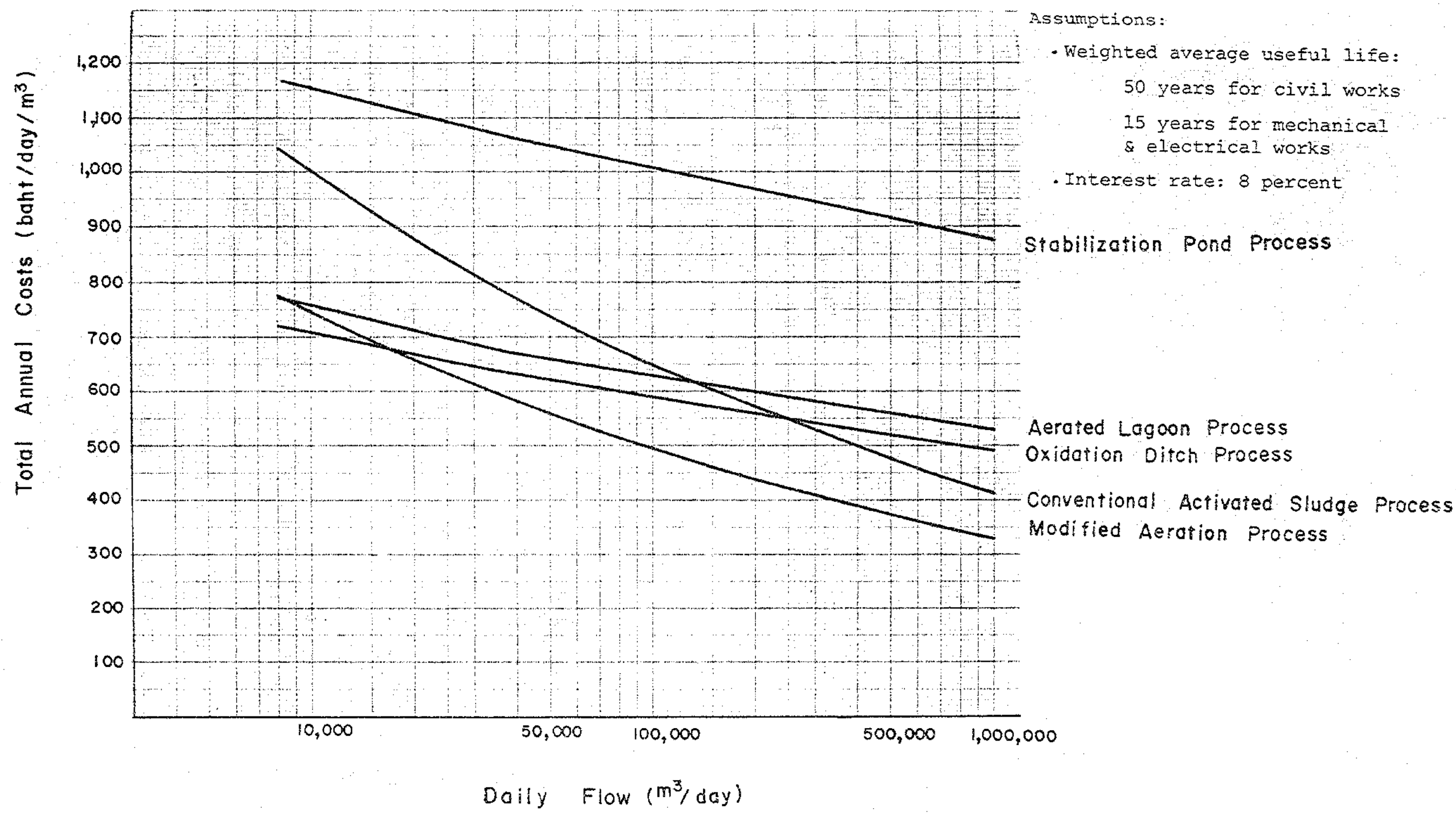


Figure II·12 Total Annual Costs by Treatment Process at Land Value 1,000 Baht/m^2

11.4 Sludge Treatment and Disposal

In this section sludge treatment and disposal methods are studied for each treatment process described previously. In all wastewater treatment processes, sludge is produced to be disposed of in a safety manner. The sludge is objectionable matters which may cause health hazard and odor nuisance. Proper sludge disposal facilities must be provided to forestall these objectionable conditions.

In the wastewater treatment facilities discussed in this chapter, the following types of sludge can be anticipated.

(a) Screenings

Materials, such as rags, paper, tree limbs and other trash which are too large to pass through a 20-mm bar opening, is removed mechanically and/or manually from wastewater flow. The material can be disposed of safely in a sanitary landfill with municipal refuse.

(b) Grit

Grit is normally classified as inorganic materials such as sand and gravel that will readily settle. The grit can be hauled to a sanitary land fill.

(c) Scum and Grease

Scum and grease are solids that will rise to the surface of the basins when the flow is quiescent. Normally, they are skimmed and removed from the surface of primary settling basins, and also grease removal basins may be provided if large quantity of grease is anticipated. This material can be hauled to a sanitary landfill or pumped into sludge digesters.

(d) Wastewater Sludge

Characteristics of wastewater sludge varies with the character of the wastewater and varies according to wastewater treatment process concerned.

Also, sludge treatment process varies with the type, size and location of the wastewater treatment facility. Sludge production and its treatment process for each wastewater treatment process is studied as follows:

i) Stabilization Pond Process and Aerated Lagoon Process

Since a long detention time is inherent in the design concept of the stabilization pond and/or aerated lagoon process, nearly all organic matter is destroyed. There will be a gradual buildup of inorganic and low organic solids on the bottom of the pond. The rate of sludge accumulation is approximately 0.03 - 0.04 m^3/year/cap and desludging is required when the pond is half-full of sludge.1/ This occurs every n years where n is given by;

$$\frac{\frac{1}{2}(\text{Pond volume, } m^3)}{(\text{Sludge accumulation rate, } m^3/\text{year/cap}) \times (\text{Population})}$$

For instance, in case of flow rate with 100,000 m^3/day, a pond may require draining and dredging every 20 year for aerated lagoon and every 40 year for stabilization pond.

ii) Oxidation Ditch Process

Since oxidation ditch process is supposed to be long time aeration, sludge generation will be small quantity as compared with conventional activated sludge and modified aeration process, furthermore characteristics of sludge is relatively stable. In hot climate area, it is economical that sludge drying beds are used to dewater the sludge because of low construction cost and easy operation. As according to actual results in Bangkok, sludge is placed on the beds in about 20 cm layer and detention time is 10 days.

It is proposed that after drying, the sludge is removed and disposed of in landfill, or ground for use as fertilizer.

1/ Ref: Mara, D.D. "Sewage Treatment in Hot Climates", New York: John Wiley & Sons, Ltd., 1978

iii) Conventional Activated Sludge Process and Modified Aeration Process

Sludge from conventional activated sludge and/or Modified aeration process is of large quantity, i.e. 1 to 2 percent of wastewater flow, and unstable as they are undigested. To select economical and practical processes for treatment and disposal of the sludge, following alternatives are considered;

<u>Alternative I:</u> Sludge from each wastewater treatment facility is barged and treated in anaerobic lagooning.

The anaerobic lagoon is essentially an open disgester. For small plants and where large areas are available, sludge lagooning offer an economical solution to sludge disposal. Lagoon is usually approximately 2 m in depth and have good drainage. This is usually best accomplished by constructing the lagoons with the bottom of the lagoon at natural ground level. Preferably, sludge lagoon should not be built with bottom below ground water level. For instances, area required for wastewater flow with 500,000 m^3/day and 100,000 m^3/day are about 170 ha and 35 ha respectively. In the study area, above porous soil and large site is not available, and besides ground water table is very high. Anaerobic lagoons, furthermore, emit offensive odor.

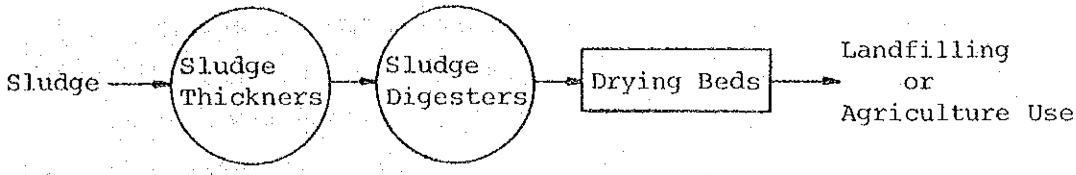
Also barging sludge through klongs in the Study Area will cause following problems.

(1) Since some of klongs run dry at low tide, water level must be controlled all the year round to enable navigation.

(2) Some klongs must be repaired and dredged and navigation gates must be placed to navigate sludge barge, and

(3) Harbor must be constructed at each treatment site to load and unload sludge of barge.

Alternative II: Sludge is pumped from all treatment facilities to sludge treatment site. A transported sludge is treated by following process:



Among various sludge handling processes, it is recommended that the sludge removed from the primary and secondary sedimentation tanks be gravity thickened. Gravity sludge thickening provides the following advantages:

(1) It reduces water content and contributes reduction of digester volume.
(2) It uniforms sludge quantity and quality.
(3) It generally reduces treatment facility costs due to savings in physical facility size, labor, and power.

After thickening, sludge is digested by unheated anaerobic manner with following advantages:

(1) It reduces sludge volume.
(2) It can be safe and sanitary.
(3) Excess methane gas can be used for power, if it is required.

The centralized sludge treatment provides the following advantages:

(1) Since sludge treatment facility will be constructed in less populated suburban area, it can reduce odor nuisance to surrounding residents.
(2) Construction costs for centralized sludge treatment facility are cheapter than the individual case.
(3) Required sludge treatment facility site area is less than total site areas of individual case.

On the other hand, since a distance of force main sewer will be significant, construction, operation and maintenance costs will be expensive. For instance, electricity fee for wastewater sludge volume with 5,000 m^3/day and maintenance costs for force main of length of 10 km is about 2.4 million baht/year. Furthermore transporting sludge by pumping is troublesome technically.

Alternative III: Sludge is treated with the same process as proposed in Alternative II but in the individual wastewater treatment site.

Initial investment and operation cost of this alternative is lower than previous alternatives because of no transportation system. Therefore, if the area required for the process is available, this alternative is considered suitable in the Study Area.

As apparent from description of above three Alternatives, Alternative I and II have considerable disadvantages in the practicability and Alternative III is considered the most adequate approach for the disposal of the sludge.

After drying, such sludge is recommended to be disposed of to the specific places for the landfilling or the agricultural use. Since the sludge will increase yearly, it is important to secure the sufficient spaces for dumping and landfill of the sludge. In selecting the site for sludge disposal, a consideration must be given to the probable nuisance and health hazards. As the sludge is useful as fertilizer, it is preferable to develop the marketing and look into further the technology development.

Wastewater gas contains CH_4 about 60 to 70 percent of total gas volume, CO_2 about 30 to 40 percent, and small amounts of N_2, H_2, and other gases. Byproduction of gas is one of the best advantage of digestion because it can be used as fuel. Therefore, when large amount of wastewater gas can be available from digestion in the future, particular consideration should be given to the utilization of such gas as fuel for the internal combustion engines for pumps, operating blowers and other purpose as generating of electricity.

CHAPTER 12

PROPOSED SEWERAGE SYSTEM

The Study Area is characterized by occupants of millions of population, mixture of highly developed and developing areas, varied land use patterns, heavy traffic of cars throughout urbanized area, and variety of utility services, etc. The sewerage system to be proposed should well cope with variety of existing facilities and services as well as the environmental and socio-economical requirements to be emerged along with evolution of the Metropolis.

The functions of the sewerage system are to collect, treat, and dispose of wastewater in the most economical manner as required. Facilities to effectuate the best sewerage function consist of sewers, pumping stations and treatment facilities. These facilities to be proposed are selected among several alternatives, taking into account the topographical conditions, population density and characteristics of wastewater flow, etc.

12.1 Zoning

12.1.1 Sewerage Zone

The Study Area has total area of 37,000 hectares, but excluding water surface of the Chao Phya River, the area for sewerage planning purpose is 36,100 hectares.

The physical characteristics of the Study Area are: (1) populated built-up areas concentrated centrally, (2) areas surrounding central area, to be developed in the future, and (3) mostly flat ground surface.

Initially, two alternative sewerage systems are considered. One is a centralized sewerage system covering the whole Study Area with a single treatment facilities, and the other system is with multiple treatment facilities.

If a centralized sewerage system is proposed in the Study Area with a large flat ground surface as described above, large-sized and deep trunk sewers are required to convey centralized large amount of wastewater by gravity flow from individual house all the way to the treatment facilities, causing high initial investment as well as difficulties in implementing construction program particularly in the populated built-up areas.

Under the circumstance, it is considered practical that the Study Area be properly divided into several sewerage zones to be dealt with separately, rather than planning centralized area-wide system to cover whole Area.

Accordingly, the Study Area is initially divided into two areas largely as the central area and the surrounding area, with due consideration on built-up area, future development area and high priority area for flood protection.

The central area is densely populated urbanized area of about 9,700 hectares and the center of commercial and administrative activity in Bangkok. The flood protection and drainage project for the area of about 8,300 hectares in the central area is presently under consideration by BMA.

The surrounding areas are still remained to be developed in the future.

(a) Zoning for the central area

In the central area, the available land areas for treatment facilities are limited to the places such as pond of Makkasan, pond of Tobacco-Monopoly and the mouth of Klong Chong Nonsi.

From above condition, alternative sewerage systems are considered for this area, and then construction cost, operation and maintenance cost and minimum requirement of implementation for each alternative are compared.

As a result of comparative study, the central area except for the demonstration project area is divided into 3 zones as Zone 1, Zone 2 and Zone 3. In the demonstration project area of 200 ha a sewerage system planning has already been initiated separately by BMA. Therefore, this area is separated from the present Master Plan called Zone 4. (Refer to Appendix A of Volume IV)

(b) Zoning for the surrounding area

It is considered practical that the surrounding area also be properly divided into zones. The advantages of divisioned independent system in each sewerage zone would be:

(i) The design of sewer facilities can be adapted to the characteristics of each area.

(ii) The implementation program can be adjusted flexibly to the degree of requirement and availability of financial resources in the future.

(iii) In the areas anticipated to be developed in the future more flexible systems can be designed to cope with future modification by development.

The surrounding area is divided for implementation purpose into 6 zones as shown in Table 12.1 and Figure 12.1, with due consideration of the followings:

(i) Population density by area
(ii) Condition of built-up area
(iii) Land use situation
(iv) Chao Phya River, klongs, railways and roads
(v) Topography
(vi) Master plan of flood protection and drainage system

In addition to the above, the appropriate scale of sewerage zone is recommended ranging 3,000 to 10,000 hectares from the model study. (Refer to Appendix A of Volume IV)

Sewerage zones and areas are shown in Table 12.1 and Figure 12.1.

12.1.2 Description of Sewerage Zone

Location and present situation of each zone are described as the followings:

(1) Zone 1

This zone lies in the central part of the Study Area with a total area of 3,400 hectares, surrounded by the Chao Phya River in the west, by the Klong Bang Sue in the north, by the proposed ring road in the east and by the Klong Phadung Krung Kasem, the Klong Ma Ha Nak and the Klong Saen Saep in the south.

The west part of this area consists of mainly the public, green and institutional area and the east part is mainly developed for housing area.

(2) Zone 2

This zone lies also in the central part of the Study Area with a total area of 3,600 hectares, surrounded by the Klong Lord in the west, by the Klong Phadung Krung Kasem, the Klong Ma Ha Nak and the Klong Saen Saep in the north, by the Phrakhanong-Lat Prao Road in the east and by the Eastern Railway Line and the Sathorn Nua Road in the south.

This area is the most densely populated urbanized area, consisting mainly of the commercial, institutional, and residential area.

(3) Zone 3

This zone lies the south of the Study Area with a total area of 2,500 hectares, surrounded by the Chao Phya River, the Sathorn Nua Road and the Chua Phleeng Road.

This area is developed for commercial and residential area.

(4) Zone 4

This zone lies to the west of Zone 2 with a total area of 200 hectares, surrounded by the Chao Phya River and the Klong Lord.

This area is the demonstration project area of BMA as mentioned in previous paragraph.

This area mostly consists of the public area. There are many noted places for historical and cultural monuments such as Grand Palace, National Museum, Wat Phrakeo and Wat Pho, etc.

(5) Zone 5

This zone lies the north of the Study Area with a total area of 3,100 hectares, surrounded by the Chao Phya River in the west, by boundary of BMA in the north, by the Phahon Yothin Road in the east and by the Klong Bang Sue in the south.

This area consists mainly of the residential and the green area, and is mainly developed along the roads such as the Phahon Yothin Road, and the Pracha Chuen Road.

(6) Zone 6

This zone lies to the east of Zone 5 with a total area of 2,600 hectares, surrounded by the Phahon Yothin Road in the west and by the Klong Bang Sue in the south.

The west part of this area is mainly developed for housing area.

(7) Zone 7

This zone lies the east of the Study Area with a total area of 6,400 hectares, surrounded by the Klong Bang Sue in the north, by the boundary of the Study Area in the east, by the Klong Saen Saep and the Klong Sam Sen in the south and by the proposed ring road in the west.

This area is mainly developed for the residential area, along the Rat Prao Road and the Ramkamheng Road.

(8) Zone 8

This zone lies the east of the Study Area with a total area of 4,200 hectares, surrounded by the Klong Sam Sen in the north, by the boundary of the Study Area in the east, by near the Klong Phrakhanong in the south, and by the Phrakhanong-Lat Prao Road in the west.

This area is still undeveloped.

(9) Zone 9

This zone lies the south of the Study Area with a total area of 4,600 hectares, surrounded by the Chao Phya River in the west, by near the Klong Phrakhanong in the north and by the boundary of the Master Plan Area in the east and south.

This area is developed along the Chao Phya River and the Sukhumvit Road, and consists mainly of the industrial and residential area.

(10) Zone 10

This zone lies the west of the Study Area with a total area of 5,500 hectares, surrounded by the Chao Phya River and klongs.

This area consists mainly of the residential and green area. Thonburi district and the area of along main roads are mostly developed.

Table 12.1 Sewerage Zone and Area

Name of Zone	Area (ha)	Remarks
Zone 1	3,400	The Central Area
Zone 2	3,600	"
Zone 3	2,500	"
Zone 4	200	Demonstration Project Area by BMA
Zone 5	3,100	
Zone 6	2,600	
Zone 7	6,400	
Zone 8	4,200	
Zone 9	4,600	
Zone 10	5,500	
Sub-Total	36,100	Sewerage Planning Area
Water Course	900	Chao Phya River Surface in the Study Area
Total	37,000	Study Area

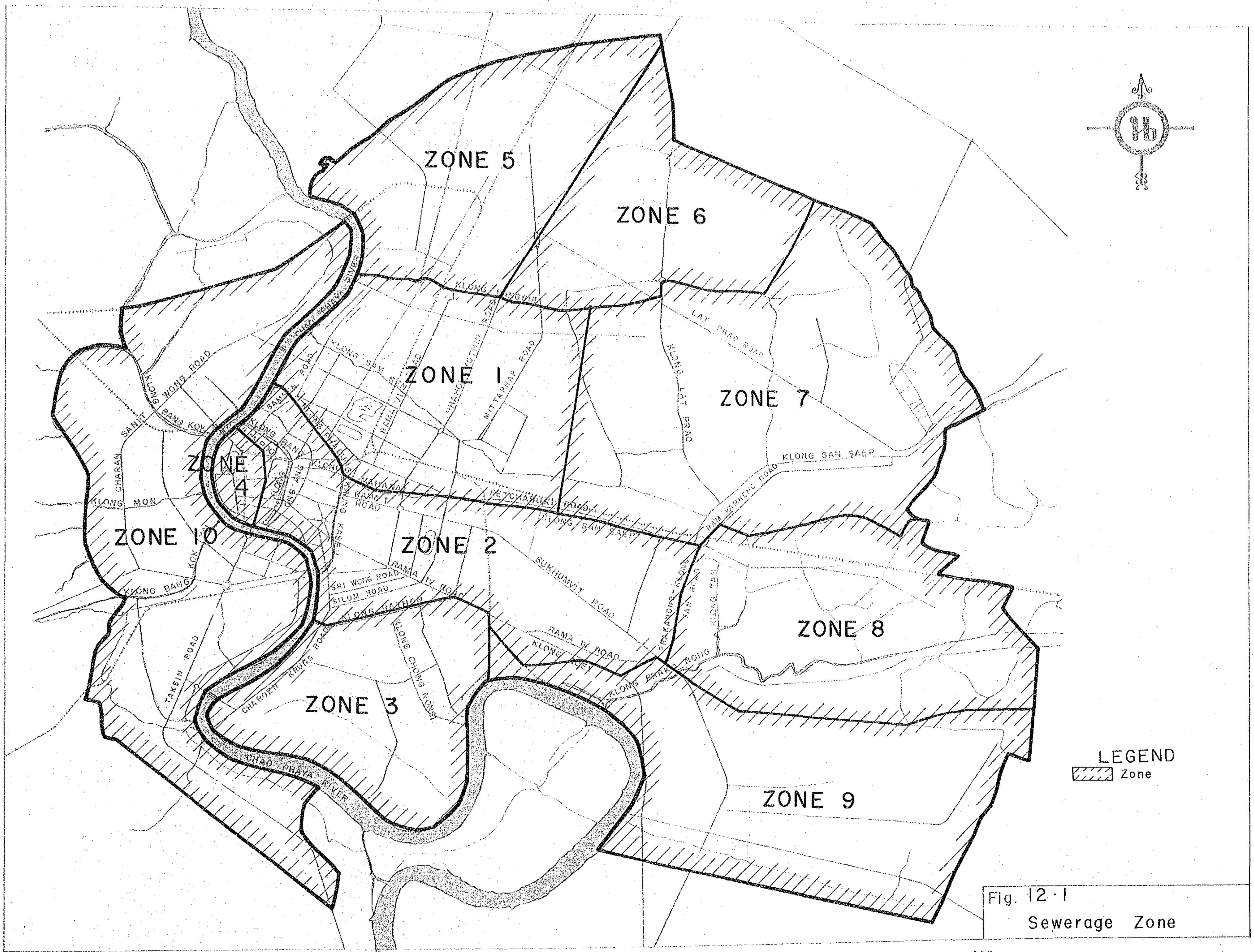


Fig. 12·1 Sewerage Zone

12.1.3 Population Distribution by Zone

Population of each zone is estimated based on the population distributed in districts of each zone. (Refer to Chapter 7).

Table 12.2 shows the area of districts comprised in zone. Population of district by zone in 2522(1979) and 2543(2000) are shown in Tables 12.3 and 12.4.

The estimated population in the year 2522(1979) and 2543(2000) together with the population density by zone are tabulated in Table 12.5.

Table 12.2 Area of District by Zone

Unit: hectare

District \ Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Total
Phra Nakhon		276		200							476
Pomprap Sattru Pai		248									248
Pathumwan		790									790
Sampanthawong		122									122
BangRak		385									385
Yan Nawa		12	2,500								2,512
Dusit	1,000				1,347						2,347
Phaya Thai	1,686										1,686
Huai Kwang	714					120	1,568				2,402
Phra Khanong		1,767						4,130	4,600		10,497
Bang Khen					1,753	1,467					3,220
Bang Kapi						1,013	4,832	70			5,915
Thon Buri										826	826
Klong San										523	523
Bangkok Noi										2,257	2,257
Bangkok Yai										605	605
Bangkhun Thian										385	385
Rat Burana										904	904
Total	3,400	3,600	2,500	200	3,100	2,600	6,400	4,200	4,600	5,500	36,100

Table 12.3 Population of District by Zone in 2522 (1979)

Unit: hectare

District \ Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Total
Phra Nakhon		98,200		26,700							124,900
Pomprap Sattru Pai		194,300									194,300
Pathumwan		233,000									233,000
Sampanthawong		78,200									78,200
BangRak		126,500									126,500
Yan Nawa		1,800	373,400								375,200
Dusit	241,900				220,300						462,200
Phaya Thai	514,200										514,200
Huai Kwang	58,000					9,700	127,400				195,100
Phra Khanong		75,400						176,300	196,300		448,000
Bang Khen					80,900	67,700					148,600
Bang Kapi						25,000	119,100	1,700			145,800
Thon Buri										256,700	256,700
Klong San										140,900	140,900
Bangkok Noi										378,800	378,800
Bangkok Yai										100,000	100,000
Bangkhun Thian										8,200	8,200
Rat Burana										35,300	35,300
Total	814,100	807,400	373,400	26,700	301,200	102,400	246,500	178,000	196,300	919,900	3,965,900

Table 12.4 Population of District by Zone in 2543 (2000)

Unit: hectare

Zone / District	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Total
Phra Nakhon		85,000		23,000							108,000
Pomprap Sattru Pai		161,000									161,000
Pathumwan		233,000									233,000
Sampanthawong		67,000									67,000
BangRak		134,000									134,000
Yan Nawa		2,400	499,600								502,000
Dusit	286,000				300,000						586,000
Phaya Thai	590,000										590,000
Huai Kwang	142,700					24,000	313,300				480,000
Phra Khanong		141,400						330,500	368,100		840,000
Bang Khen					157,300	131,700					289,000
Bang Kapi						89,900	428,900	6,200			525,000
Thon Buri										289,000	289,000
Klong San										104,000	104,000
Bangkok Noi										456,000	456,000
Bangkok Yai										121,000	121,000
Bangkhun Thian										34,000	34,000
Rat Burana										81,000	81,000
Total	1,018,000	823,800	499,600	23,000	457,300	245,600	742,200	336,700	368,100	1,085,000	5,600,000

Table 12.5 Population and Population Density by Zone

Name of Zone	Area (ha)	Population (persons)		Population Density (persons/ha)		Remarks
		in 2522	in 2543	in 2522	in 2543	
Zone 1	3,400	814,100	1,018,700	239	300	
Zone 2	3,600	807,400	823,800	224	229	
Zone 3	2,500	373,400	499,600	149	200	
Zone 4	200	26,700	23,000	134	115	Demonstration Project Area
Zone 5	3,100	301,200	457,300	97	148	
Zone 6	2,600	102,400	245,600	39	94	
Zone 7	6,400	246,500	742,200	39	116	
Zone 8	4,200	178,000	336,700	42	80	
Zone 9	4,600	196,300	368,100	43	80	
Zone 10	5,500	919,900	1,085,000	167	197	
Total	36,100	3,965,900	5,600,000			

12.1.4 Wastewater Quantity and Quality

Table 12.7 provides estimated wastewater quantities (volume) generated from zones on daily average flow basis for the year 2543(2000). Furthermore the same table indicates estimated wastewater qualities (strength) as to BOD for the year 2543(2000). These quantities and qualities will be used for preliminary designing of treatment facilities.

Table 12.6 shows estimated wastewater quantities and qualities for the year 2543(2000). (Refer to Chapter 8).

Table 12.6 Estimated Wastewater Quantities and Qualities in 2543(2000)

Wastewater	Quantity	Quality (BOD)	Remarks
Domestic	201 l/day/cap	260 mg/l	for the population of 5,600,000 persons
Commercial	116 m^3/day/ha	260 mg/l	for the area of 2,180 hectares
Extraneous	7.6 m^3/day/ha	-	for the area of 36,100 hectares

Table 12.7 Wastewater Quantities and Qualities by Zone in 2543 (2000)

Name of Zone	Area (ha)	Population (persons)	Wastewater Flow				BOD		Remarks
			Domestic (m^3/d)	Commercial (ha, m^3/d)	Extraneous (m^3/d)	Total (m^3/d)	Load (1,000 kg/d)	Concentration (mg/l)	
Zone 1	3,400	1,018,700	204,800	380 44,100	25,800	274,700	64.7	240	
Zone 2	3,600	823,800	165,600	1,570 182,100	27,400	375,100	90.4	240	
Zone 3	2,500	499,600	100,400		19,000	119,400	26.1	220	
Zone 4	200	23,000	4,600	75 8,700	1,500	14,800	3.2	220	Demonstration Project Area
Zone 5	3,100	457,300	91,900		23,600	115,500	23.9	210	
Zone 6	2,600	245,600	49,400		19,800	69,200	12.8	190	
Zone 7	6,400	742,200	149,200		48,600	197,800	38.8	200	
Zone 8	4,200	336,700	67,700	5 600	31,900	100,200	17.8	180	
Zone 9	4,600	368,100	74,000	5 600	35,000	109,600	19.4	180	
Zone 10	5,500	1,085,000	218,100	145 16,800	41,800	276,700	61.1	220	
Total	36,100	5,600,000	1,125,700	2,180 252,900	274,400	1,653,000	358.2		

12.2 Proposed Location of Sewerage Facilities

Sewerage facilities in each zone should be properly located for the effective use of each facility such as sewers, pumping stations and treatment facilities, taking account of the factors such as possibilities for construction and availability of lands for the above facilities.

12.2.1 Treatment Facilities

Sewerage layout plan has been with due emphasis to minimize the overall cost, inclusive both for construction and operation and maintenance. Since the Study Area is almost flat, it is the most economical way to distribute the treatment facilities near the central portion of each zone. However, the selection of treatment facilities site is usually influenced by the ability of the land.

Availability of land for treatment facilities sites is investigated through ground reconnaissance. Consequently, location and land available for treatment facilities of each zone are selected as shown in Table 12.8 and Figure 12.2. Every site located near klongs or the Chao Phya River is selected because of the convenience for effluent discharge.

12.2.2 Trunk Sewers and Pumping Stations

Trunk sewer routes and pumping stations are proposed as indicated in Figure 12.3 on the basis of;

(1) Topographical condition,
(2) Minimum number of pumping stations and availability of land for pumping stations,
(3) Availability of land for trunk sewers and
(4) Traffic condition.

Table 12.8 Proposed Treatment Facilities Site

Name of Zone	Location of Treatment Facilities
Zone 1	The pond of Makassan
Zone 2	The pond of Tobacco-Monopoly
Zone 3	The mouth of Klong Chong Nonsi
Zone 4	-
Zone 5	The land along Klong Bang Khen
Zone 6	The land along Klong Lat Prao
Zone 7	The land near the Klong Chan Housing Scheme
Zone 8	The land along Klong Prakanong
Zone 9	The land along Klong Khled
Zone 10	Tha land along Klong Chak Phra

Note: Zone 4 is Demonstration Project Area

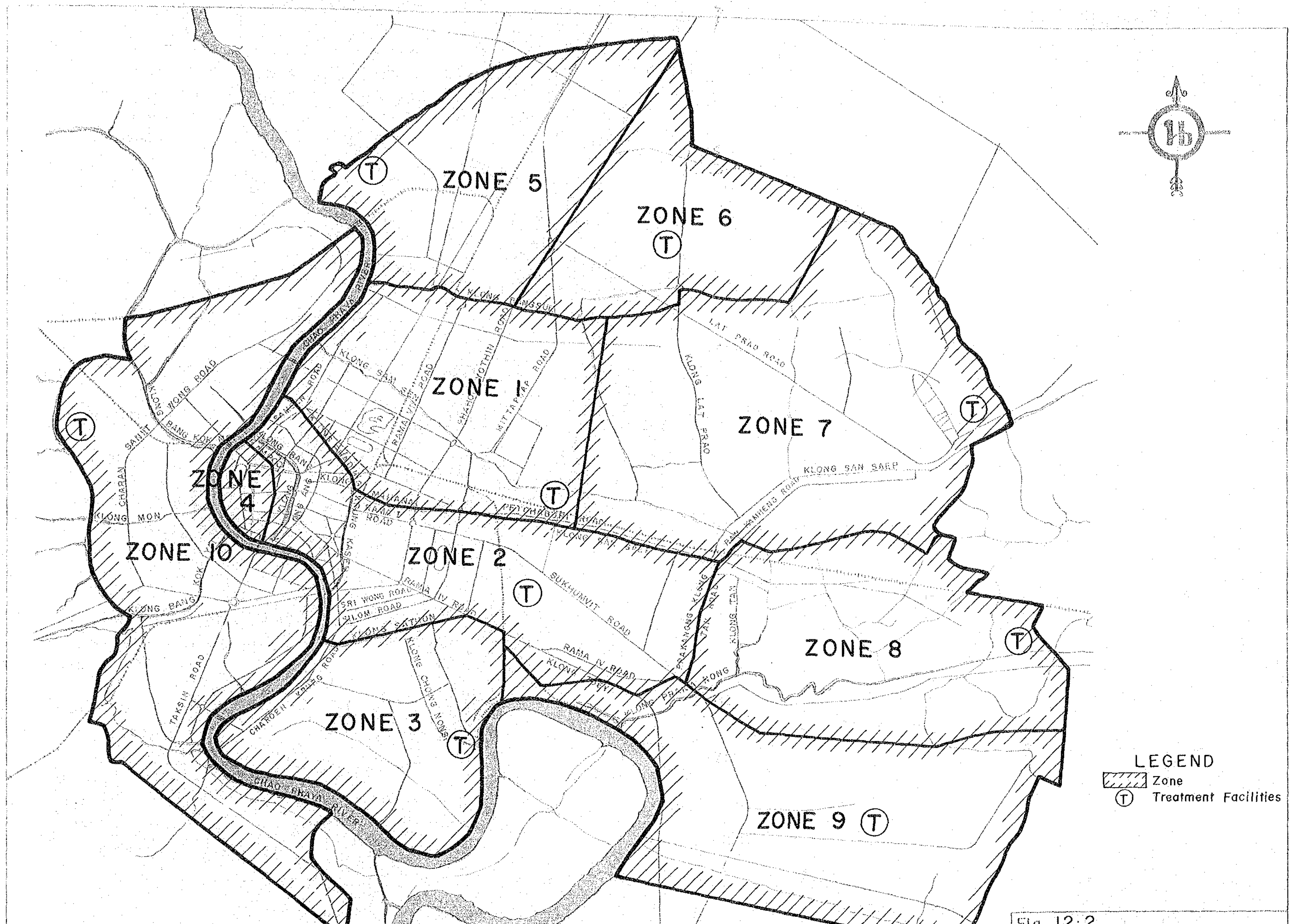


Fig. 12.2 Sewerage Zone and Location of Treatment Facilities

It is normally the basic engineering requirement to minimize the number of pumping stations with proper selection of trunk sewer routes. When sewer invert depth becomes more than about 7 m, a pumping station will be necessary to avoid further extra cost for laying sewers more deeply.

12.3 Proposed Treatment Process

Treatment process is recommended taking followings into consideration;

(a) Local conditions such as meteorology, possibility of land acquisition and availability of skilled operators,
(b) Degree of effluent quality,
(c) Capital construction cost and annual operation and maintenance costs, and
(d) Engineering characteristic.

On the basis of above consideration, it is assumed that, where land is available at less than 500 baht/m^2, aerated lagoon or stabilization pond is preferable. Where available land is more than 1,000 baht/m^2, modified aeration is advisable. And further, where there is insufficient land for the sitting of stabilization pond and/or aerated lagoon, modified aeration is recommendable. (Refer to Chapter 11).

At present in zones 1, 2, 3 and 4, the available land space is not sufficient for stabilization pond and/or aerated lagoon. Therefore, modified aeration is proposed in these zones.

For surrounding zones such as zones 5, 6, 7, 8, 9 and 10, since the land value of proposed treatment facilities site is about 500 baht/m^2 and the available land space is sufficient, aerated lagoon process is proposed. If the use of such extensive land for aerated lagoon process is not eventually effectuated by various reasons, the process may be modified easily to another one which requires less land space than aerated lagoon and can meet higher degree of effluent quality to be possibly required in the future.

Proposed treatment process and required site area of each zone are shown in Table 12.9.

Table 12.9 Proposed Treatment Process and Required Site Area of Each Zone

Name of Zone	Daily Average Flow (m^3/d)	Proposed Treatment Process	Required Land Area (ha)	Required Land Area by Alternative Process			Remarks
				S.P.	A.L.	M.A.	
Zone 1	274,700	M.A.	20	306	128	20	available land is 20 ha
Zone 2	375,100	M.A.	25	412	171	25	25 ha
Zone 3	119,400	M.A.	11	138	58	11	50 ha
Zone 4	14,800	-	-	19	8	2	Demonstration Project area
Zone 5	115,500	A.L.	56	134	56	9	
Zone 6	69,200	A.L.	35	82	35	6	
Zone 7	197,800	A.L.	94	224	94	13	
Zone 8	100,200	A.L.	49	117	49	8	
Zone 9	109,600	A.L.	54	127	54	8	
Zone 10	276,700	A.L.	129	308	129	16	

Note: M.A. is modified aeration process.
A.L. is aerated lagoon process.
S.P. is stabilization pond process.

12.4 Proposed Collection System

For the Study Area, it is recommended that the sewerage system be basically a separate system, but in answer to immediate needs, existing public drains be used as temporary combined sewers in the central area, until such time when financing of a complete separate is possible. (Refer to Chapter 10).

Therefore, the separate system is adopted for whole Study Area, but in answer to immediate needs, temporary combined system is adopted for a part of Zone 2.

The area in which temporary combined system is proposed is west part of Zone 2. This area is 1,700 hectares, consisting of densely populated commercial area in urbanized central area. There are many underground structures in this area such as public drains, water supply pipes and electric cables, etc. At present, the drains are furnished in whole area and the storm-water are discharged into the Klong Ong Ang, the Klong Bang Lam Phu, the Klong Ma Ha Nak and the Chao Phya River through the main sewer of the Rama IV Project.

Under the existing conditions mentioned above, although the area may require sewerage systems as soon as possible, it is hardly possible to construct wastewater sewers because it involves many problems for construction and needs of exorbitant capital costs. Therefore, in this area, for short term plan, combined sewerage system is adopted temporarily.

On the basis of previous studies in this Chapter and other Chapters concerned, proposed layout plan for sewerage facilities including trunk sewers, pumping stations and treatment facilities are made and are shown in Table 12.10 and Figure 12.3.

Table 12.10 Proposed Sewerage Facilities

Name of Zone	Sewer						Pumping Station			Treatment Facility		
	Trunk		Branch and Lateral		House Connection		Name of Station	Peak Flow (m^3/sec)	Required Land Area (m^2)	Average Daily Flow (m^3)	Treat-ment Process	Required Land Area (ha)
	Diameter (mm)	Length (m)	Diameter (mm)	Length (m)	Diameter (mm)	Length (m)						
Zone 1	1,000-2,700	17,200	200-900	815,800	150	2,778,000	P1-1 P1-2 P1-3 P1-4	1.335 0.701 0.175 0.271	950 450 260 300	274,700	M.A.	20
Zone 2	400-3,000	21,930	200-900	454,500	150	1,185,000	P2-1 P2-2 P2-3 P2-4 P2-5	0.243 0.199 0.436 2.722 0.030	290 270 370 1,300 130	375,100	M.A.	25
Zone 3	1,000-2,100	7,600	200-900	604,900	150	1,362,000	P3-1 P3-2	0.109 0.201	210 270	119,400	M.A.	11
Zone 4	Demonstration Project Area									14,800	-	-
Zone 5	1,000-2,000	7,400	200-900	752,100	150	1,247,999	P5-1	0.629	420	115,500	A.L.	56
Zone 6	1,000-1,650	3,700	200-900	633,300	150	671,000	P6-1 P6-2 P6-3	0.124 0.164 0.244	220 250 290	69,200	A.L.	35
Zone 7	1,000-2,400	24,200	200-900	1,543,800	150	2,024,000	P7-1 P7-2 P7-3 P7-4	0.303 0.946 0.644 0.244	320 500 430 300	197,800	A.L.	94
Zone 8	1,000-1,900	9,800	200-900	1,019,200	150	918,000	P8-1 P8-2	0.298 0.379	320 350	100,200	A.L.	49
Zone 9	1,000-1,900	10,700	200-900	1,116,300	150	1,004,000	P9-1 P9-2	0.501 0.389	390 350	109,600	A.L.	54
Zone 10	1,000-2,700	24,700	200-900	1,322,800	150	2,960,000	P10-1	0.920	490	276,700	A.L.	129

Note: M.A. is modified aeration process.
A.L. is aerated lagoon process.

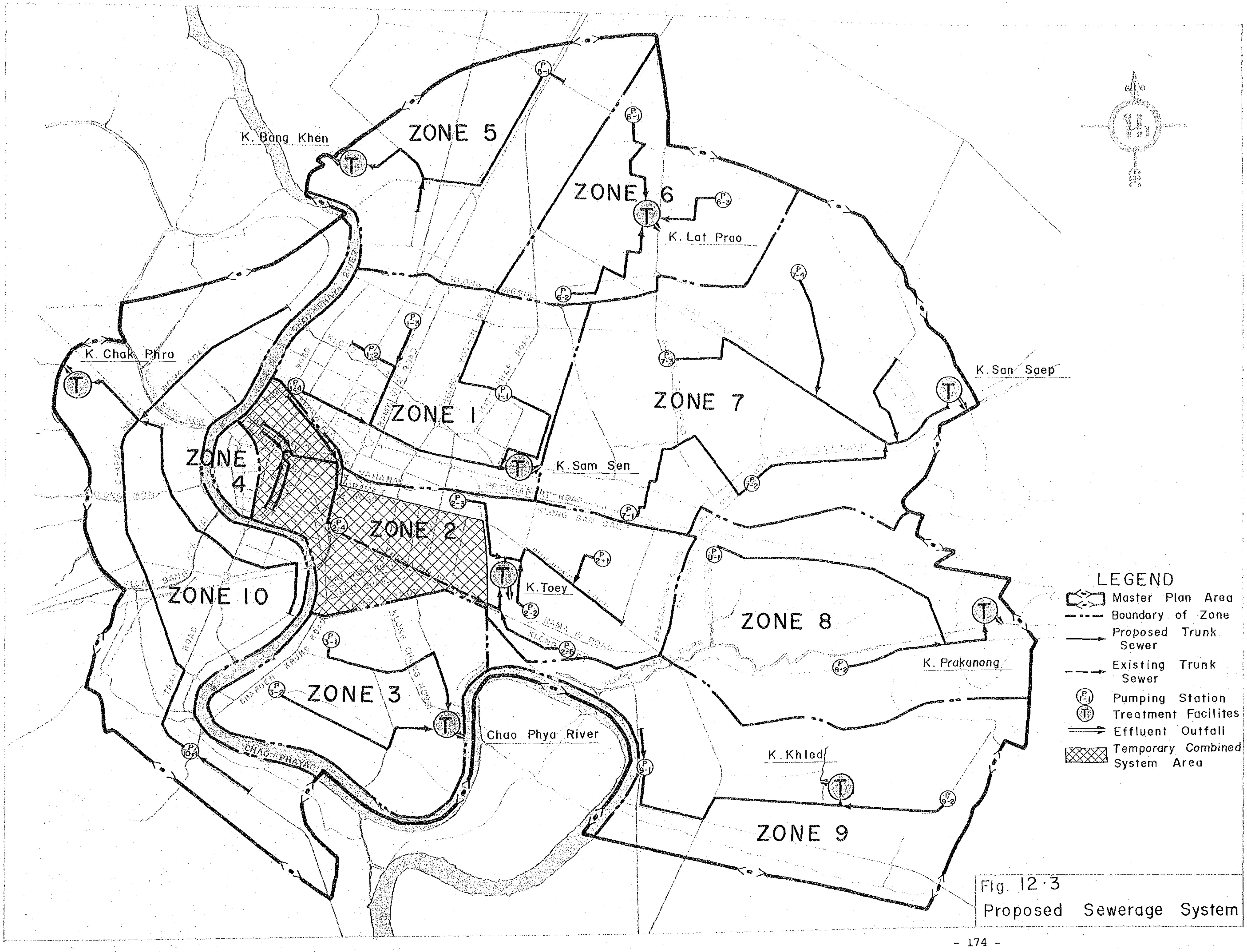


Fig. 12·3
Proposed Sewerage System

CHAPTER 13

CONSTRUCTION MATERIALS AND METHODS

13.1 Special Construction Problems and Conditions

(a) Climate

As far as climatic conditions described in Chapter 2, no special problems for sewerage construction is foreseen. Concrete can be placed the year round with attention only to the features of high evaporation rates and high temperature particulary in the dry season. During the rainy season rain can be expected on almost a daily basis, 16 to 22 days monthly from May through October. Construction can be proceeded all the year round with proper dewatering procedures.

(b) Ground Water Level

The presence of ground water will be an important factor to affect sewer construction procedures because it spoils the soil stability in excavations either and dewatering is required by open or tunnelling method. The ground water level in Bangkok varies from about 36 m in the wet season to about 35 m in the dry season above mean sea level of 35.02 m. It is obvious that water will be present in even quite a shallow trench less than 1 m depth. In all tunnel construction, compressed air and/or chemicals will be required to control ground water infiltration.

(c) Soil Condition

The Study Area consists of alluvial flood plain, formed over the years by the deposition of silt carried down by the river. The recent boring records are shown on Figures 13.1, 13.2 and 13.3.

The zone of excavation for the proposed sewerage facilities extends from the existing ground surface to a depth of approximately 10 m below ground surface. Within this range of depth, subsoil consists of soft or very soft compressible gray clay normally consolidated.

Fig. 13.1
Location of Borings

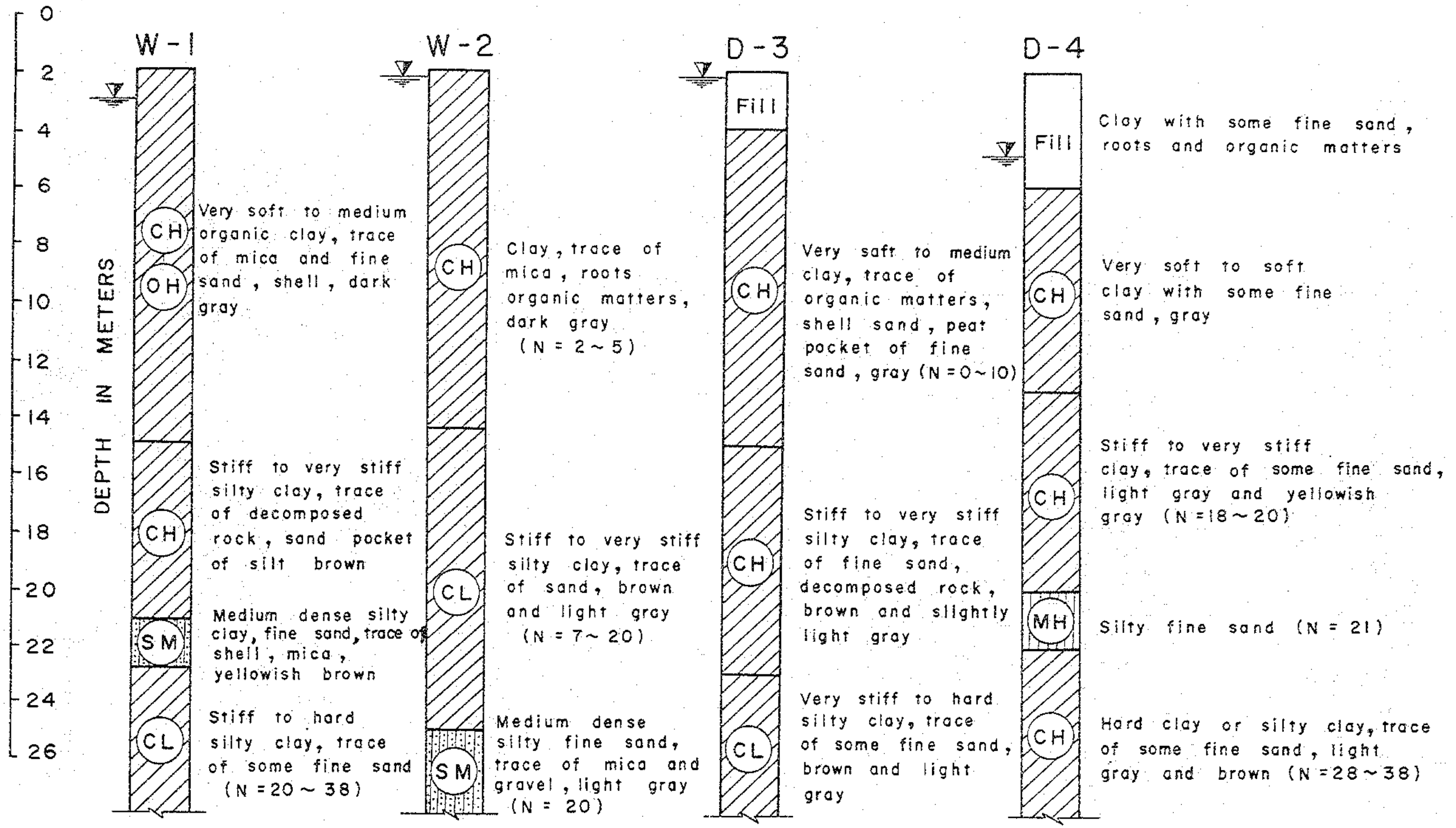


Figure 13-2 Soil Boring Logs

NOTES: W-1 Wet Season Boring
D-3 Dry Season Boring

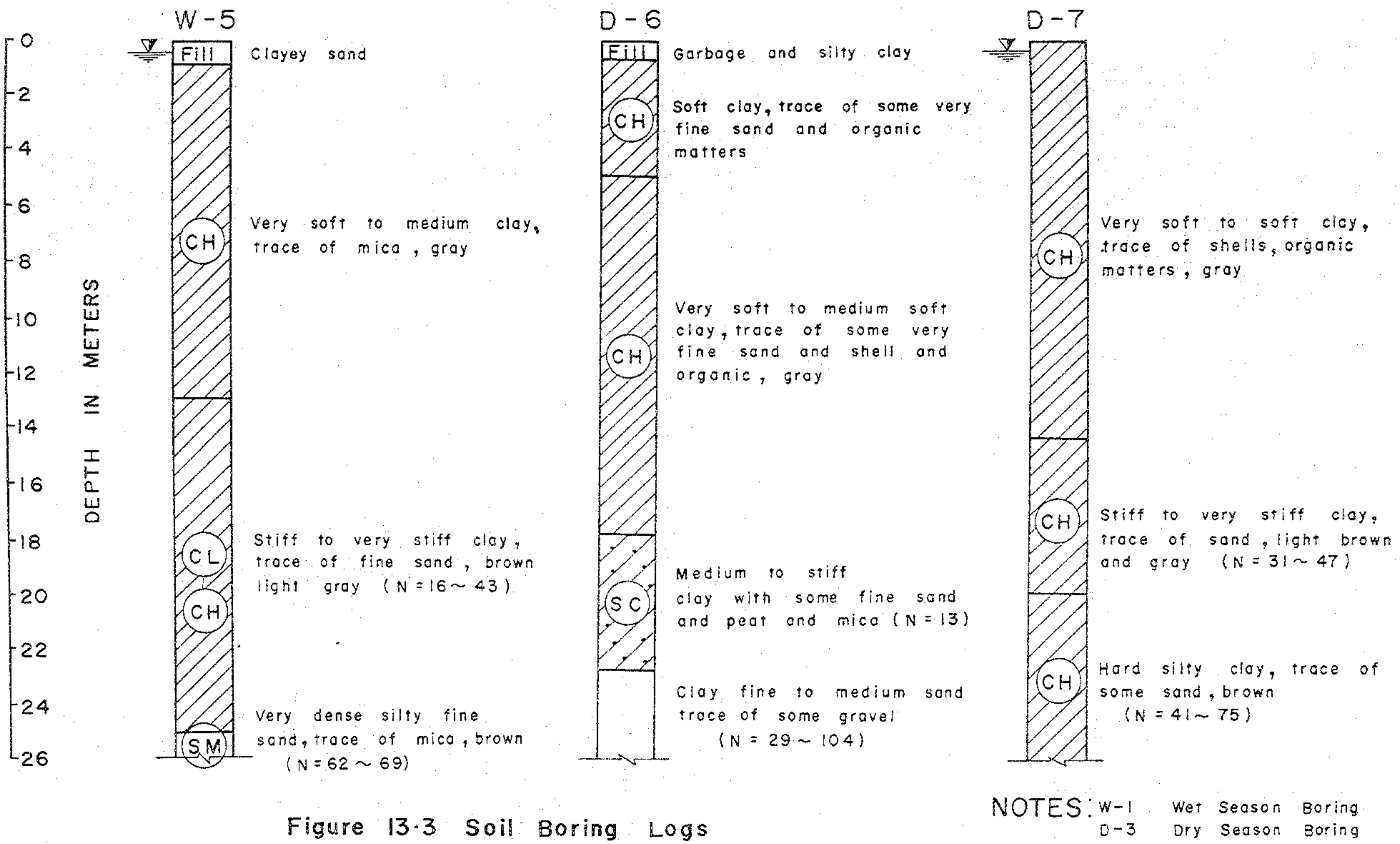


Figure 13-3 Soil Boring Logs

(d) Traffic

The traffic condition in Bangkok, especially in urbanized area, is not necessarily favourable and likely to be worsen, because of high commercial activities with high population density. For instances, Petchaburi, Rama I, Sukumvit, Rama IV, Paya Thai and Din Daeng - Asoka, have heavy traffic all the day. Along these roads, office buildings, markets and shops are located, and specific attention should be paid not to disturb their daily commercial activities in the course of sewer construction. Therefore, if sewers are proposed along these roads, tunnelling and/or other specialized construction methods should be considered to minimize the problem. Prior to design and construction, the traffic condition of each road should be surveyed carefully.

(e) Contractors, Labor, and equipment

At the present time, major construction works in Thailand are accomplished by joint-venture of local and foreign contractors. There are several Thai contractors, who have sufficient experiences for major works such as tunnels, pumping station and treatment facilities construction. Therefore, the required civil works can be performed by local contractors under cooperation with foreign contractors.

Both skilled and unskilled labors are available for works on construction projects in Bangkok.

All construction equipments may be available in Thailand except tunnel construction equipment and accessories which will be imported.

13.2 Construction Materials

(a) Availability

Presently most of the construction materials are manufactured in Thailand and are available in adequate quantities and quality.

Concrete aggregates are sufficiently available. Coarse aggregate is obtained by rock crushing works in the mountainous regions to the north, northeast, and south of Bangkok. Sand is customarily obtained from the north where it is dredged from the rivers and transported by barge downstream to meet the demands in the Bangkok. Cement is produced locally in adequate quantity. Cement is made in three types; standard portland cement, high-early strength cement (quick setting) and a high silica cement. Steel reinforcing bars are manufactured in a steel mill approximately 105 km north of Bangkok.

There are no facilities for the production of pumps, large valves, and other mechanical or electrical equipment. Practically everything of this nature is imported at present. Common building materials such as wood, timber, bricks roofing and floor tiles are readily available from the local market.

Reinforced concrete pipe is manufactured locally in a good quality and adequate quantities. Pipe is being manufactured in a wide range of sizes and in classes II, III, and IV (Americal Society for Testing Materials) from 300 mm to 1,500 mm in diameter. After this, the factory may be able to produce pipes of large size easily to meet future requirement.

Asbestos cement pipe is manufactured in a modern plant located along the Chao Phya River a short distance north of Bangkok. The pipe meets all of the standard of the American Water Works Association (AWWA). Pipe is manufactured in standard sizes up to 500 mm diameter in pressure classes for water pipe.

Plastic pipe (PVC) is manufactured in Thailand from raw materials from Japan. Pipe is produced in sizes up to 200 mm diameter.

Vitrified clay pipe (VC) is not currently manufactured in Thailand despite the apparent large supply of suitable clays available for its manufacture. One manufacturer has experimented successfully with the local clays to determine its suitability for the manufacture of vitrified clay pipe, and consideration is being given to the full scale production of VC pipe, complete with pre-moulded joints suitable for sewer construction. Should an adequate market develop it is possible that an adequate supply of vitrified clay pipe in the standard sizes would become available from local manufactures.

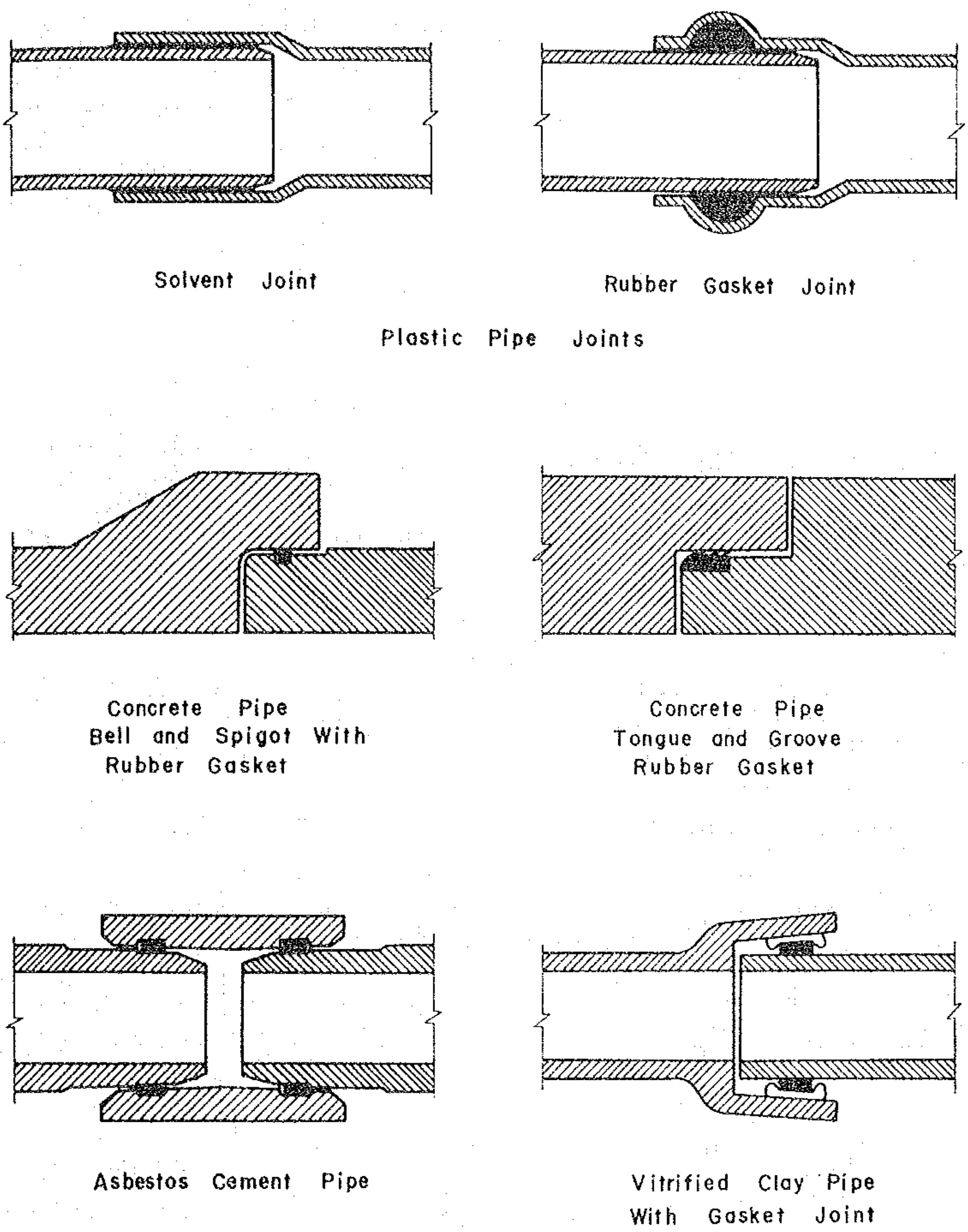


Figure 13.4 Pipe Joints

(b) Selection of Sewer Materials

Pipes for the sanitary sewer system must have tight joints to limit infiltration. (Refer to Figure 13.4)

In addition, hydrogen sulfide gas generated by septic wastewater will form sulfuric acid which will attack concrete surface not submerged.

For ventilation reasons and to avoid sulfide gas generation, it is undesirable for sanitary sewers to flow full or nearly full. However, from economical reasons, to avoid excessive investment, instead of keeping inside of pipes free from sulfide generation, anti-sulfide corrosion pipes such as vitrified clay pipes, plastic pipes and lined or coated concrete pipes should be used.

13.3 Tunnel vs. Open Trench Excavation

Due to the traffic condition stated earlier, tunnelling is very useful for sewer construction in congested traffic areas. As opposed to tunnelling, open trench excavation method which usually requires sheeting and bracing, backfilling, dewatering of both ground and rainwater and traffic blockage is used. Insofar as the latter is applied, an excavation trench width for a 2.6 m pipe in diameter will be at least 4 m at the top, which will completely block street and will permit only one-way traffic. The result of an analysis of sewer construction method either by tunnelling or deep open cuts indicates that, where pipe depth is approximately 7 m and over, tunnel method is more economical than open trench excavation method.

Trench excavated to a depth greater than 5 m will require steel sheeting against the high lateral soil pressures and will require sharp cost increase in accordance with depth of trench. (See Figure 14.1) Also, as trench is deepened, the excavated material will increase, and additional disruption to traffic will be arisen. During the course of sewer construction, the open trench excavation method will have the following disadvantages over tunnelling:

1. Where existing drain and water pipes conflict with proposed sewer, additional works or relocation of them will be required to keep their condition in order.

2. Special traffic control of inconvenience, such as detouring, one-way traffic, etc., will be needed.

3. The noise of driving sheet piling will cause an annoyance to adjacent residents.

4. Retail business and market activities will be disrupted, with attendant loss of revenue.

Where disadvantages as described above are evident tunnel method should be adopted.

13.4 Deep Foundation Structures

The main pumping station will require a foundation extending approximately 10 m below existing ground surface. This construction poses particular problems because of the high ground water table and the type of soil at the site. The normal method of excavation, using sheet piling, is doubtful for application for deep foundation, even with a series of well points or pumps for drain. There are several other methods by which this excavation can be handled.

One system is caisson construction, shown schematically on Figure 13.5. In this system, a cutting edge is cast; excavation initialed in the center, and the structure is permitted to sink under controlled conditions. Additional concrete lifts are then placed, and excavation continued until final grade is reached. At the time the heavy concrete base is placed and the structure made watertight. After that point, the internal structure may be completed. Also, controlled sinking of a structure in the soils present would be difficult, and would require a number of skilled workmen.

Another useful system for placing foundations in soil of this type is by freezing the ground where the excavation is to take place. Freezing is accomplished by installing pipes in the soil around the perimater of the area to be excavated, and circulating a brine solution through the pipes. After freezing, excavation can proceed by using normal excavation procedures. Exterior walls would be constructed from the top down, in sections as excavation proceeds. Freezing must be maintained until the exterior walls are completed, and the structural integrity of structure is attained. It has the advantages of permitting common construction procedures to be used after freezing has been accomplished and allows a structural configuration more efficient for equipment layout.

Chemical stabilization, using chemical grouting, is also acceptable. At present, however, this system, is relatively expensive.

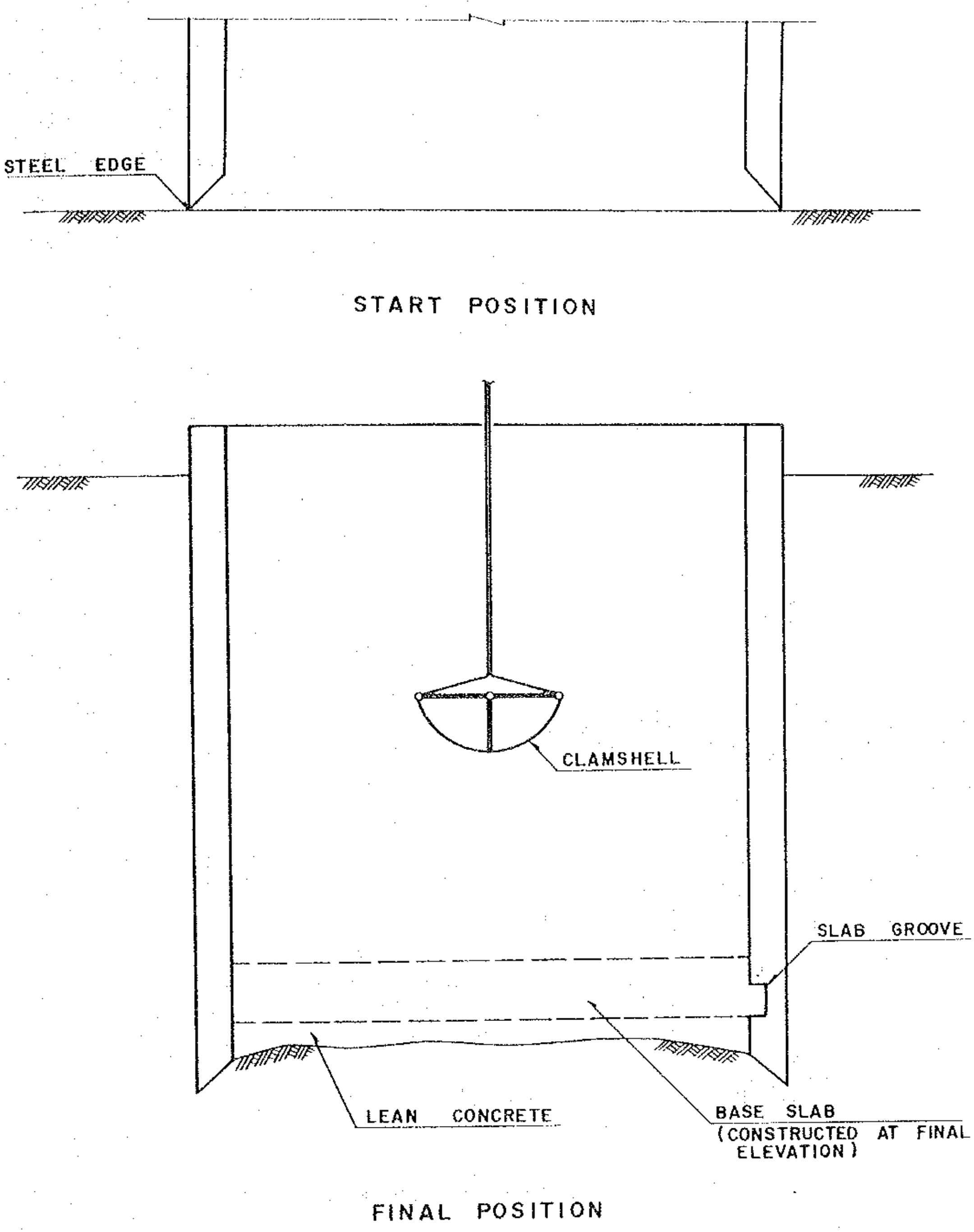


Figure 13.5 Open Caisson Type Construction

CHAPTER 14

COST ESTIMATION

14.1 Basis of Construction Cost Estimates

Construction costs for the Master Plan implementation is estimated based on all assumed expenditures related to construction. These expenditures are largely divided into direct cost and indirect costs. In this study, preliminary designs have been made to assume required amounts of materials and works and then these have been multiplied by appropriate unit prices to obtain the total costs of project components.

In estimating the construction costs of the facilities, unit costs for domestic items such as labor, materials, power, equipment and transportation, and items to be imported such as materials and equipment, are collected through agencies concerned.

Laborers required for the sewerage constructions range from common worker to skilled operators for heavy equipment. The current, 2523 (1980, official costs for various types of labor in the Bangkok are from 54 baht to 216 baht per day as given in Table 14.1.

Table 14.1 Labor Costs at the End of 2523 (1980) Price Level

Type of Laborer	baht/day
Common Worker	54
Concrete Mixer Operator	72
Steel Worker	86
Carpenter	100
Bricklayer	100
Plumber	132
Bulldozer Operator	216
Mobile Crane Operator	216
Power Shovel Operator	216
Foreman	180

Data Source: Bureau of Drainage and Sewerage, BMA

Generally, for construction of structures including pumping stations and treatment facilities, most of the materials required are available, except for mechanical and electrical equipments which have be imported.

Reinforcing bars, timber, sand and gravel for concrete products, reinforced concrete pipes (less than 1,500 mm in diameter) are available in the Bangkok. The unit official price of these basic materials are given in the Tables 14.2, 14.3 and 14.4.

Table 14.2 Price of Basic Materials at the End of 2523 (1980) Price Level

Item	Unit	Price (Baht)
Cement	ton	1,080
Sand	m^3	135
Gravel (0- 80 mm)	m^3	144
Crashed Stone (0- 80 mm)	m^3	144
Wood (150mm x 150mm x 6m)	m^3	1,300
Timber	m^3	6,356
Steel	ton	9,500
Round Bar	ton	7,605
Deformed Bar (D 16mm- D 25mm)	ton	7,889
Selected Soil	m^3	90
Petrol	l	10
Heavy Oil	l	25

Data Source: Bureau of Drainage and Sewerage, BMA

Table 14.3 Price of Sewers at the End of 2523 (1980) Price Level

Pipe		Unit	Price (Baht)
Asbestors Cement Pipe (mm in dia.)			
Ø	150	m	37
Ø	200	m	39
Plastic Pipe (mm in dia.)			
Ø	150	m	222
Reinforced Concrete Pipe (mm in dia.)			
Ø	300	m	104
Ø	400	m	135
Ø	500	m	183
Ø	600	m	221
Ø	800	m	405
Ø	1,000	m	544
Ø	1,200	m	675
Ø	1,500	m	990
Cast Iron Pipe (mm in dia.)			
Ø	150	m	166
Ø	200	m	257
Ø	250	m	329
Ø	300	m	392

Data Source: Bureau of Drainage and Sewerage, BMA

Table 14.4 Unit Costs for Construction (including labor and materials) at the End of 2523 (1980) Price Level

Item	Description	Unit	Cost (Baht)
Concrete Works	mix. 1:2:4	m^3	1,305
	mix. 1:3:6	m^3	1,224
Reinforced Concrete Works		m^3	1,885
Mortar Works	mix. 1:2	m^2	117
	mix. 1:3	m^2	108
Excavation (by machine)		m^3	18
Backfilling		m^3	99
Compaction		m^3	180
Form Works		m^2	225
Dewatering		d	135
Restoration of Paving (t = 0.10 m)		m^2	225
Masonry Works		m^2	90
Turfing		m^2	5
Sheeting by Timber	(Depth* 1.0-2.0 m)	m	225
	(Depth 2.0-3.0 m)	m	270
	(Depth 3.0-4.0 m)	m	405
	(Depth 4.0-5.0 m)	m	450
Steel Sheet-Pile Works	(Depth 4.0-5.0 m)	m	3,500
	(Depth 5.0-6.0 m)	m	4,500
	(Depth 6.0-7.0 m)	m	5,200
	(Depth 7.0-8.0 m)	m	6,500

Data Source: Bureau of Drainage and Sewerage, BMA

* Depth is excavation depth.

14.1.1 Sewers

In order to estimate the cost of construction of sewers recommended in the Master Plan it is necessary to estimate unit costs for sewer facilities which include all of materials, labor and other related costs. In many instances it is possible to estimate from known costs for previous construction of similar nature. In other instances, particularly in estimating costs for the work without having precedent, it is necessary to assume a method of construction based upon well conceived preliminary designs and elaborate assumption for unexpected conditions which might be encountered during the construction.

Except for tunnels, most of the sewers will be constructed at a depth of less than 6 m. The depth will vary depending on location, with the larger sizes usually being constructed at the greater depths. Excavation shall generally be made by trench method with sheetings depending upon soil conditions and depth to be excavated. In estimating the cost of sheeting and bracing, it has been assumed that about 90 percent of the wood poles and wood bracing may be recovered and re-used and that 95 percent of the steel sheeting and bracing may be re-used.

The estimated cost of sewer constructions of various sizes at various depths are shown on Figure 14.1. These unit costs are used in estimating all of the open cut sewers proposed in this Master Plan Report. Costs allowances have been made for the installation of manholes at the curves of sewers and for miscellaneous structures and the replacement of pavements. The allowance is also necessary for the additional costs of constructing conduits in congested streets, and for construction contingencies.

The estimated cost of construction of tunnel is based on empirical costs in Water Supply Phase II Project of MWWA. (Refer to Chapter 5) The cost curve is shown in Figure 14.2. It is somewhat expensive, because shield machines and associated equipments have to be imported.

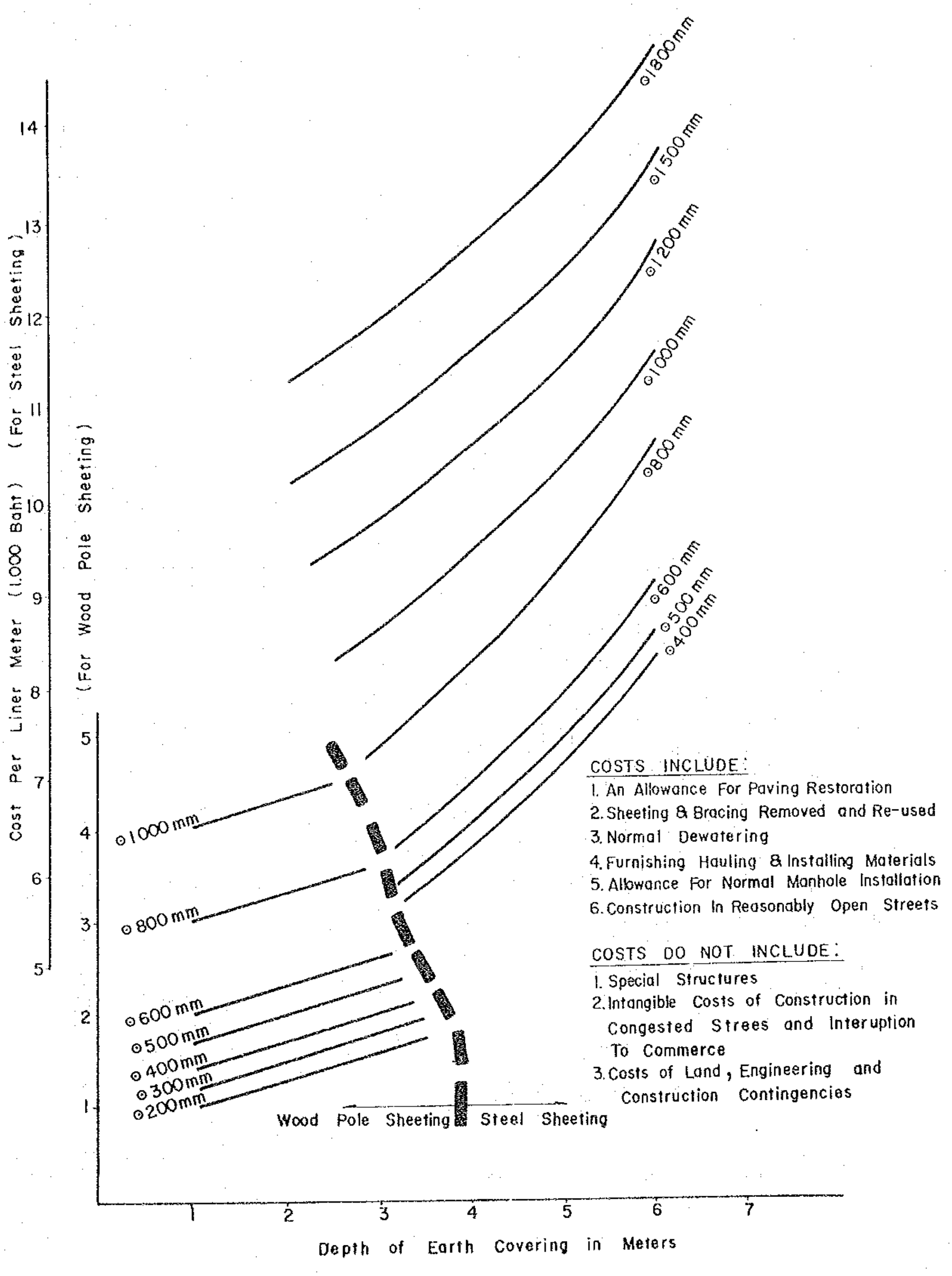
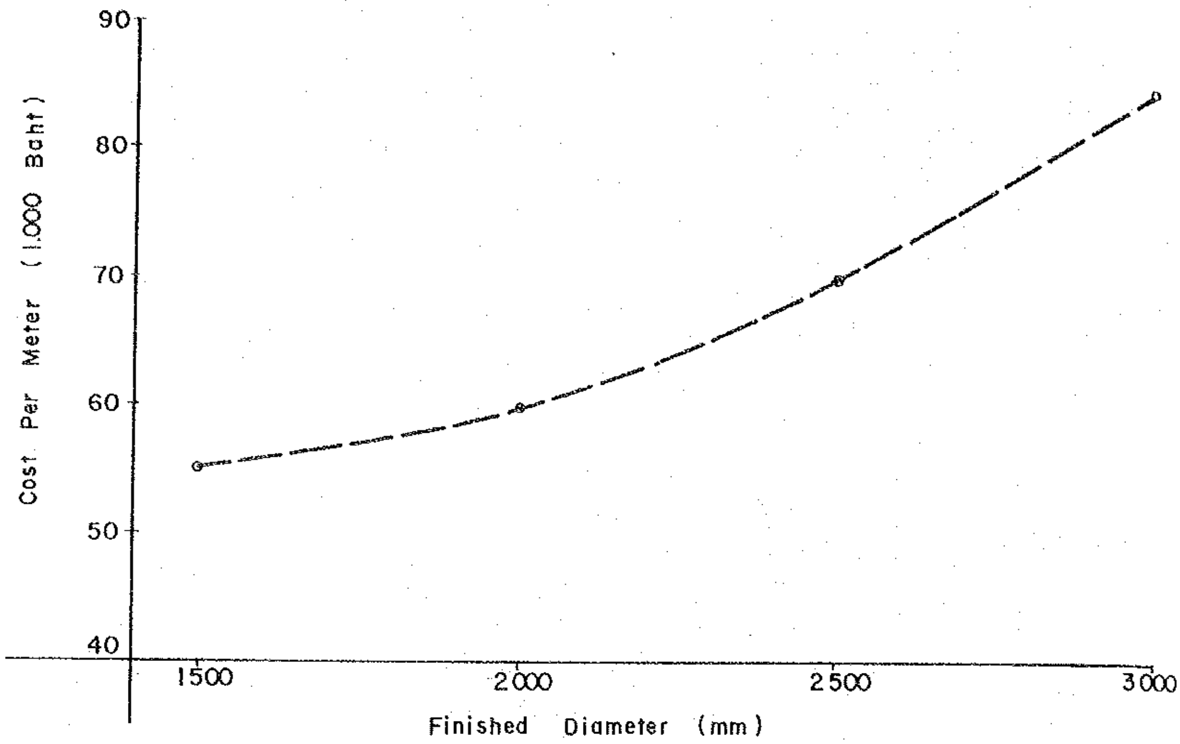


Figure 14.1 Estimated Costs of Construction of Sewers



COSTS INCLUDE :

1. Furnishing Hauling & Installing Materials
2. Allowance for Constructing Shaft

COSTS DO NOT INCLUDE :

1. Intangible Costs of Construction in Congested Streets and Interuption to Commerce
2. Costs of Land , Engineering and Construction Contingencies

Figure 14.2 Costs of Contruction of Tunnel (Shield)

14.1.2 Pumping Stations

Pumping stations are required at most of the treatment facilities sites and other locations where the costs for installation of pumps are considered less than the costs for laying sewers at unreasonable depth.

To estimate construction costs for the various types of pumping station, the cost curves are prepared as shown in Figure 14.3. In developing the cost curves, construction cost is calculated based on the rectangular type for small capacity stations with peak flow rate of less than 1.0 m^3/sec and the circular type for large capacity stations with peak flow rate of 1.0 m^3/sec and above (see Figures 9.3 and 9.4). Data for the required mechanical and electrical equipments were obtained from various manufacturers in Japan. Based upon soils investigations, piling foundations have been found to be necessary for each station and the costs of piling have been included in the estimates.

14.2 Land Costs

Land values in Bangkok are generally high but widely variant. For instance, official price for land located adjacent to major roads is about 11,000 baht per 4 m^2 while interior portions with poor access in the same area is about 30 percent of the cost of above land on front streets. The data for official price has been obtained from the Department of Land, Ministry of Interior. In the Study Area, the land value is varying from 400 to 45,000 baht per 4 m^2. (Refer to Appendix E in detail)

14.3 Foreign Exchange Component of Construction Costs

In computing the estimated value of the foreign exchange component of the costs of construction it is assumed that all equipment such as pumps, motors, diesel engines, electrical equipment, large gate and valves, and

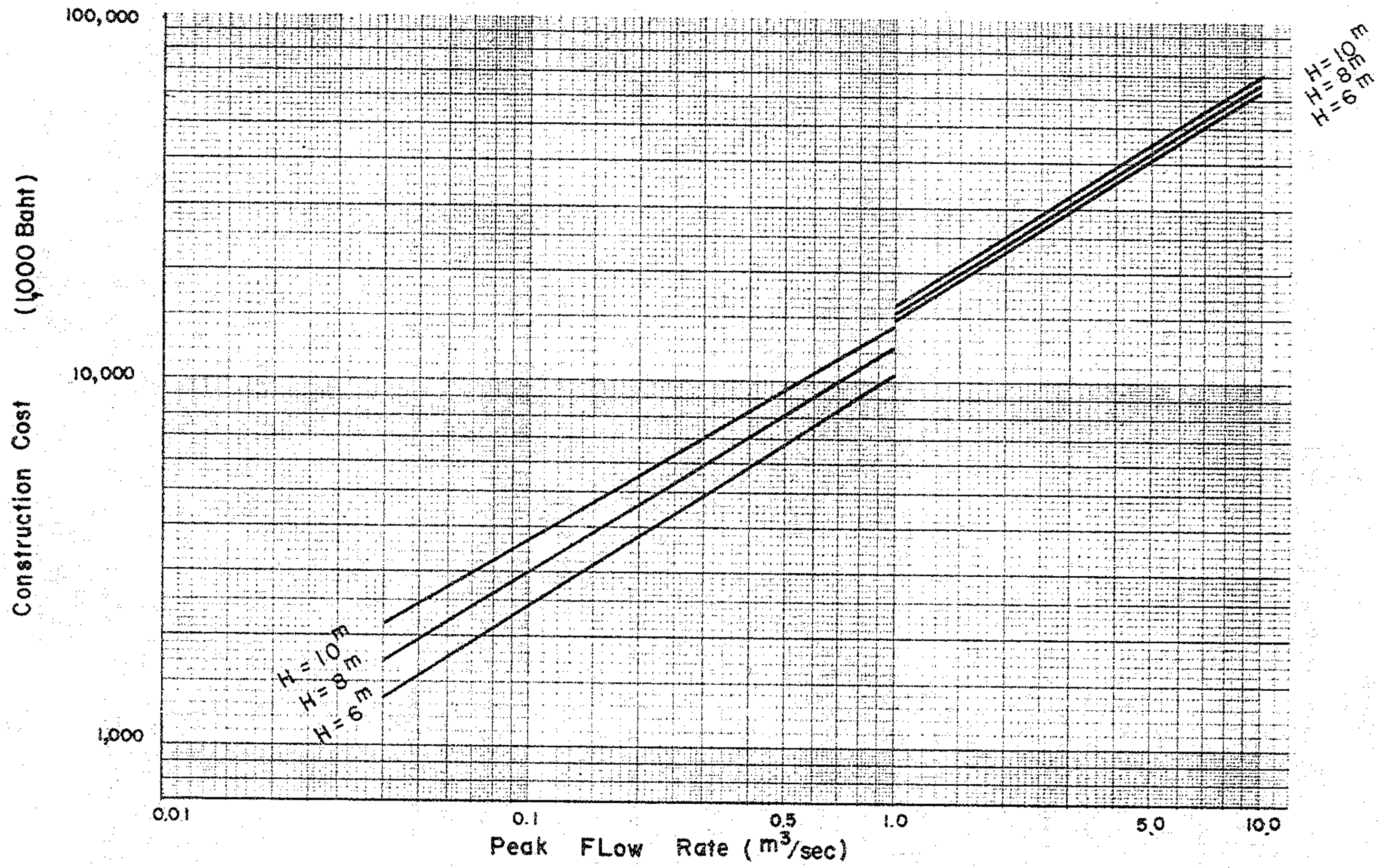


Figure 14-3 Construction Cost for Pumping Stations

all miscellaneous equipments not manufactured in Thailand would be imported from foreign sources. It is further assumed that materials such as structural steel, reinforcing steel, steel sheet piling, cast iron pipe and raw materials for the local manufacture of plastic pipe or jointing would also be imported. It is assumed that all of the pipes required for the project will be available from local manufacturers.

For the Study Area, the values of all equipments and materials to be imported are estimated on the basis of preliminary quotations issued from equipment manufacturers and suppliers of the various equipments materials for construction. Furthermore, in the case of the construction of some of the more complicated works such as the pumping stations, tunnels (shield) and treatment facility, it is assumed that the work would be done by foreign contractors who would require partly foreign currency payment. The amount of foreign currency portion required for such complicated civil works is generally equivalent to approximately 15 percent of total costs for civil works.

14.4 Basis of Operation and Maintenance Costs

The operation and maintenance for sewers, pumping stations and treatment facilities would be under the responsibility of BDS, BMA. The BDS under the approval of BMA would finance annual expenditures required for operation and maintenance of the facilities. For estimation of the costs, comparable information obtained from cities with same features such as Osaka and Tokyo in Japan have been reviewed, and the results are used as the basis for reasonable cost estimations. In this section, basis for operation and maintenance costs of sewers and pumping stations are described, and reference to treatment facilities is made in Chapter 11.

14.4.1 Sewers

Small sewers of 150 mm in diameter is cleaned either by rodding equipment or hydraulically-propelled tool. For sewers 200 mm in diameter or larger, power driven bucket machine is used

The assumptions made for the estimation of the overall operation and maintenance costs are as follows:

(a) Frequency of cleaning for public sewer (trunk sewer and branch and lateral sewer) is once in every 4 years.

(b) Frequency of cleaning for house connections is once in every 10 years.

(c) Capability to clean by one team for public sewers is 200 m/day.

(d) Capability to clean by one team for house connection with average length of 15 m is 2.5 hours per connection.

(e) Useful life of cleaning equipment is 10 years.

(f) Team member for public sewers is 6 persons.

(g) Team member for house connection is 3 persons.

(h) Costs per annum for spare parts, repairing, overhauling of equipment are equivalent to 5 percent of equipment cost.

(i) Annual rehabilitation cost of sewers is 0.5 percent of construction cost.

(j) Working days and hours;

Working days are 250 days/year
Working hours are 6 hours/day

(k) Labor cost is 54 baht/day.

(l) Price of power driven bucket machine and rodding equipment to clean sewers is 2.2 and 0.8 million baht/set respectively.

Based on assumptions above, operation and maintenance costs per meter run of sewer per year except administrative expenses are estimated to be 10 baht (public sewer) and 4 baht (house connection).

14.4.2 Pumping Stations

Operation and maintenance costs for pumping stations are derived from the 2523 (1980)-year labor and material costs in the Study Area, including power, fuel, lubrication, screenings removal and disposal, and major repairing of equipment. The annual costs curves are shown in Figure 14.4. (Refer to Appendix E in detail) Annual cost for repairing of civil works and buildings is assumed to be one percent per annum of the construction cost and two percent per annum for electrical and mechanical works. Power costs are estimated at 1.5 baht/kWh.

14.5 Cost of Proposed Sewerage System

In the previous section unit costs are developed in order to determine the costs of construction, operation and maintenance for the proposed sewerage facilities. The costs of sewers, house connections, pumping stations, treatment facilities, land acquisition, including allowances are presented below in order to indicate the magnitude of the total amount.

In estimating the costs, it is assumed that while sewers (i.e. branch, lateral and trunk sewers), pumping stations, treatment facilities and land acquisition will be provided by the Government contribution, house connection will be provided by the private contribution

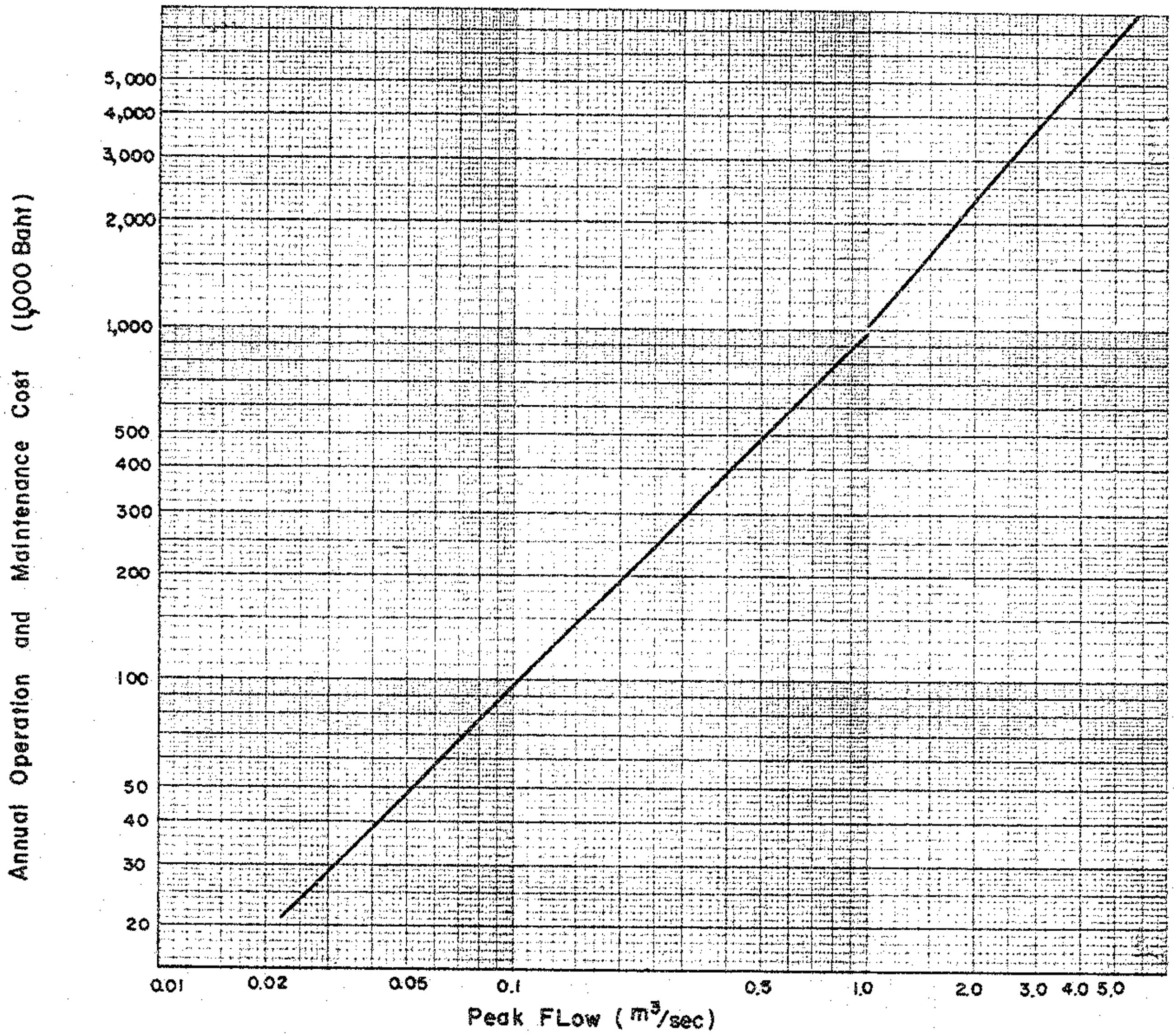


Figure 14-4 Annual Operation and Maintenance Cost of Pumping Stations

The total capital cost of facilities required for whole study area (except demonstration project area) is summarized in Table 14.5.

Table 14.5 Total Capital Cost of the Proposed Sewerage System in the whole Study Area at the End of 2523 (1980) Price Level

Million Baht

Facilities	Estimated Capital Cost	Percent of Total
o Sewers	13,701.0	37
o House Connection	9,409.0	26
o Pumping Stations	188.3	1
o Treatment Facilities	2,796.7	8
o Land Acquisition	2,226.5	6
o Engineering Fee and Contingency	8,349.6	23
Total	36,671.1	100

Details of these cost estimates are indicated in Tables 14.6 and 14.7.

Table 14.6 Estimated Cost of the Proposed Sewerage System (Government Portion)

Unit: Million Baht, at the End of 2523 (1980) Price Level

	Public Sewers	Pumping Stations	Treatment Facilities	Land Acquisition	Engineering Fee and Contingency	Total
Zone 1	1,585.0	38.3	689.9	50.6	740.2	3,104.0
Zone 2	999.0	48.3	877.4	191.3	616.0	2,732.0
Zone 3	934.0	7.8	363.2	33.2	417.6	1,755.8
Zone 4*	-	-	-	-	-	-
Zone 5	1,149.0	9.3	125.1	280.1	410.7	1,974.2
Zone 6	919.0	12.7	85.8	131.5	325.6	1,474.6
Zone 7	2,548.0	32.5	185.3	470.7	885.0	4,121.5
Zone 8	1,534.0	12.7	112.1	368.0	530.8	2,557.6
Zone 9	1,676.0	15.0	119.8	216.7	579.5	2,607.0
Zone 10	2,357.0	11.7	238.1	484.4	834.2	3,925.4
Total	13,701.0	188.3	2,796.7	2,226.5	5,339.6	24,252.1

Note: *Demonstration Project Area

Table 14.7 Estimated Cost of House Connection (Private Portion)

Unit: Million Baht, at the End of 2523 (1980) Price Level

	House Connection	Engineering Fee and Contingency	Total
Zone 1	1,945.0	622.0	2,567.0
Zone 2	333.0	106.0	439.0
Zone 3	953.0	305.0	1,258.0
Zone 4*	-	-	-
Zone 5	873.0	280.0	1,153.0
Zone 6	470.0	150.0	620.0
Zone 7	1,417.0	453.0	1,870.0
Zone 8	643.0	206.0	849.0
Zone 9	703.0	225.0	928.0
Zone 10	2,072.0	663.0	2,735.0
Total	9,409.0	3,010.0	12,419.0

Note: * Demonstration Project Area

CHAPTER 15

IMPLEMENTATION PROGRAM

The provision of a complete sewerage system for the entire Study Area with its large and expanding population, will require a great investments of capital fund as estimated in Table 14.5. The plan is designed to serve future generations as well as the present inhabitants of the Study Area. Much of the area within the Study Area is presently undeveloped land, however, and environmental conditions of such area are different far from built-up area. Although there is a pressing need for the construction of sewerage facilities throughout the inhabited area, the urgency of such sewerage requirement is different depending on the characteristics of areas. Much of construction works can be postponed to a future date until the need and urgency become more evident.

According to the above mentioned reasons, it is necessary to establish the required facilities in stages based on the urgency of need and effectiveness to be derived. Staged construction will have advantage to minimize the excessive initial investment and capital expenses distributing such capital over an extend period of years.

Therefore, in this Chapter, the study for order of priority of sewerage zones is made, taking into account the various important elements which affect sanitary conditions in the study area, applying a reasonable rating procedure. After then, staging for construction is carried out for high priority zones selected in previous study, with due consideration on technical and financial aspects.

Implementation Program is prepared for first 20 years, dividing into 4 stages of 5 years each, taking the design period of the year 2543 (2000) into account. Assuming that sewerage construction will start in 2526 (1983), staged periods are proposed as followings

1st Stage	2526 (1983) - 2530 (1987)
2nd Stage	2531 (1988) - 2535 (1992)
3rd Stage	2536 (1993) - 2540 (1997)
4th Stage	2541 (1998) - 2545 (2002)

15.1 Rating to Decide the Implementation Priority

The major factors affecting the order of priority for sewerage zones are selected to applied for in Bangkok, are as followings.

(a) Water pollution on klongs

One of the main purposes for construction of sewerage facilities is improvement of environmental conditions. Water quality of klong is applicable parameter to indicate the degree of environmental deterioration and therefore the needs for improvements.

(b) Waste load generation

The waste load excluding human excreta generated from the housing and commercial areas is generally discharged into drains and klongs without any treatment. It is, therefore, necessary to quantify the waste load in each of the sewerage zone to determine the urgency of need for sewerage facilities.

(c) Population density

The number of persons who will be benefited by the system is one of the most important factors. It is particularly significant to provide sewerage facilities in high population density area in order to gain the maximum benefit extended to the maximum population with the minimum expenditure thus making the benefit-cost ratio higher.

(d) Flood problems and drainage facilities

In order to operate the sewerage system effectively, it is desirable that flood protection facilities are completely installed.

Although the authority has undertaken improvement works for the existing klongs and drains, flooding has occurred frequently and caused substantial damage in the built-up area. Sewerage facilities, therefore, should be constructed in with the progress of drainage construction program.

Based on above factors, which are closely related to sanitary conditions, evaluation points have been given according to their importance. The following rating points are representing total points of each point distributed in 10 zones.

(a) Water pollution on klongs .... 300 points
(b) Waste load generation .... 300 points
(c) Population density .... 200 points
(d) Flood problems and drainage facilities .... 100 points

Further consideration on these factors and distribution of points to each zone are discussed followings

(a) Water pollution on klongs

As the most important factor, the extent of water pollution on klongs is assigned the highest points of total 300. The distribution of points are performed as shown in Table 15.1, based on the discussion made in Chapter 6 which describes existing polluted conditions of klong's water. From this description it is evident that Zone 2 and Zone 4 are under the worst condition followed by Zone 1.

Table 15.1 Distributed Points for Water Pollution on Klongs by Zone

Zone	Distributed Points
1	50
2	60
3	20
4	60
5	20
6	20
7	20
8	20
9	10
10	20
Total	300

(b) Waste load generation

Waste load generation is evaluated by waste load ratio to area both for present and future. Estimated waste load ratio in the year 2523(1980) and 2543(2000), and assigned total points of 300 distributed are presented in Table 15.2.

Table 15.2 Evaluation for Waste Load Generation by Zone

Zone	Waste load (kg/day/ha)		Distributed Points
	2523(1980)	2543(2000)	
1	14.3	19.0	50
2	21.3	25.1	60
3	7.3	10.4	30
4	15.4	17.3	50
5	4.8	7.7	30
6	2.0	4.9	10
7	2.0	6.1	20
8	2.1	4.2	10
9	2.2	4.2	10
10	8.7	11.1	30
	Total		300

(c) Population Density

Population density by sewerage zone both for present and future ranges approximately from 40 to 300 persons per hectare. Population density and distributed total points of 200 are shown in Table 15.3.

Table 15.3 Evaluation for Population Density by Sewerage Zone

Zone	Population Density (persons/ha)		Distributed Points
	2523(1980)	2543(2000)	
1	242	300	40
2	225	229	30
3	152	200	25
4	133	115	20
5	100	148	20
6	42	95	10
7	42	116	10
8	44	80	10
9	44	80	10
10	169	177	25
	Total		200

(d) Flood problems and drainage facilities

During the course of field survey in 2523 (1980), when the heavy rain which had not occurred last 5 years coincided with high tide and condition was the worst in last 37 years, every zones suffered serious flooding in the Study Area.

Based on the situation mentioned above and taking into account the order of priority for construction of flood protection and drainage project now being undertaken by BMA, the total points of 100 are distributed as shown in following Table 15.4.

Table 15.4 Evaluation of Flood Problems and Drainage Facilities

Zone	Distributed Points
1	20
2	20
3	20
4	40
5	0
6	0
7	0
8	0
9	0
10	0
Total	100

All evaluation points for 4 major items are summarized in Table 15.5.

Table 15.5 Overall Distributed Points by Zone

Zone	Water Pollution on Klongs	Waste Load Generation	Population Density	Flood Problems and Drainage Facilities	Total Distributed Points	Order of Priority
1	50	50	40	20	160	3
2	60	60	30	20	170	1
3	20	30	25	20	95	4
4	60	50	20	40	170	1
5	20	30	20	0	70	6
6	20	10	10	0	40	9
7	20	20	10	0	50	7
8	20	10	10	0	40	9
9	10	10	10	0	30	10
10	20	30	25	0	75	5
Total	300	300	200	100	900	-