TABLES AND FIGURES

TABLE 3.1 COVERAGE OF SERVICE OF PRESENT SEWERAGE SYSTEM

Districts	Total of District		Sewered Area		Sewered Population	
	Area (ha)	Population	(ha)	(%)	Nos.	(%)
Cap Manuel	402	54,321	402	100	36,938	68
Hann-Fann	1,850	370,831	1,739	94	330,208	89
Baie de Hamm	1,132	64,683	866	77	0	0
Camberene	2,409	487,536	767	32	65,264	13
Secteur Ouest	468	51,441	272	58	9,739	19
Pikine Niayes	1,576	171,167	38	2	11,809	7
Secteur Est	1,899	236,522	0	0	0	0
Villages	1,668	80,899	0	0	0	0
Mbao Gare	647	0	0	0	0	0
Total	12,051	1,517,400	4,084	34	453,958	30

Note: Refer to Table 3.1 in the Supporting Report for details.

TABLE 3.2 ESTIMATED WASTEWATER AMOUNT AND BOD LOAD (1993)

	Wastewater (m≥/day)*			BOD load (kg/day)		
Districts	Generated		Collected	Generated		Collected
	Domestic	Industrial		Domestic	Industrial	
Cap Manuel	17,702	0	10,375	2,755	0	1,938
Hann-Fann	52,480	0	39,348	18,634	0	16,719
Baie de Hamm	10,012	11,700	8,874	4,269	10,646	7,867
Camberene	39,037	1,214	5,051	23,034	1,105	3,641
Secteur Ouest	4,552	0	1,294	2,483	0	520
Pikine Niayes	14,663	0	1,268	8,046	0	556
Secteur Est	22,685	0	0	13,495	0	0
Villages	6,943	0	0	4,092	0	0
Total	168,074	12,914	66,210	76,808	11,751	31,241

* : Refer to Table 3.3 in the Supporting Report for details.

TABLE 3.3 PUMPING STATIONS (SEWERAGE)

No.	Name	Location	Type	Capacity (1/s)	Total Head(m)
1	MERMOZ	Mermoz	S	16	17
2	UNIVERSITE	Universite	D	230	12
3	SOUMBEDIOUNE	Baie Soumbedioune	D	125	14
4	MALICK SY	Angle Malick Sy	S	78	3
5	RUE 10	Rue 10	S	73	4
6	NIMZATT	Mimzatt	S	42	13
7	OUAGOUNIAYES	Ouagouniayes	S	36	13
8	ZONE INDUSTRIE	Zone Industrie	S	64	4
9	III B (GENIE RURAL)	Hann	S	34	12
10	FAYCAL	Cite Faycal	S	14	
11	UNITE 9	Parcell Assainies	S	15	18
12	UNITE 15	Parcell Assainies	S	20	22
13	UNITE 23	Parcell Assainies	S	12	16
14	UNITE 17	Parcell Assainies	S	5	5
15	UNITE 22	Parcell Assainies	S	21	6
16	UNITE 7	Parcell Assainies	S	24	15
17	UNITE 13	Parcell Assainies	S	53	18
18	DJILY MBAYE	Parcell Assainies	S	35	17
19	UNITE 2	Parcell Assainies	S	29	19
20	GUEDIAWAYE	Guediawaye	S	16	17
21	XII (DOMINIQUE)	Pikine Centre	S	35	7
22	CIMETIARA	Pikine SR12	S	120	30
23	SOTIBA	Sotiba	S	13	15
24	MARCHE AUX POISSONS	Marche aux Poissins	S	17	
25	SACRE COLUR III				

Note : Type S : Submersible
Type D : Dry Pit
Source : SONEES

TABLE 3.4 WATER TARIFFS OF SONEES

(Unit: FCFA/m3)

Structures	Sewered Area (A)	Unsewered Area (B)	(A-B)	(A-B)/B
Urban Consumers with Connections				
Social Section	113.91	113.91	0.00	0.0%
Normal Section	389.15	366.92	22.23	6.1%
Disuasive Section	446.92	421.35	25.57	6.1%
Public Stand	166.20	141.45	24.75	17.5%
Gardening Crops Growers				
1st Section	50.07	50.07	0.00	0.0%
2nd Section	70.42	70.42	0.00	0.0%
3rd Section	386.65	386.65	0.00	0.0%

Source: SONEES

TABLE 3.5 INCOME STATEMENT OF SONEES

(Unit: million FCFA)

Item	1989	1990	1991
Revenues			
Water Bill	13,137	14,077	14,305
Bill for Works			
Water Supply	332	160	182
Sanitation	2	39	12
Others	1	6	1
Provision of Various Services	110	149	259
Rent	2	3	4
Works of the Company	881	1,127	1,343
Various Revenues and Profits	97	5,124	3,069
Financial Revenues	5	25	965
Subsidy for Operation	0	0	45
Total Revenues	14,603	20,711	20,182
Costs of Operation			
Materials and Supply	4,846	5,272	5,736
Transportation Costs	98	101	136
Costs of Other Services	1,959	1,999	1,611
Various Costs and Losses	1,541	3,775	862
Personnel Costs	3,239	3,906	3,955
Taxes	249	267	443
Payment of Interest	726	1,004	2,039
Total Costs	12,658	16,324	14,782
Operating Profits	1,945	4,386	5,400
Fund for Depreciation	-2,665	-3,891	-3,895
Fund for Provision	-4,631	-4,317	-3,823
Property Disposal	2	7	-6
Refunding of Provision	4,775	3,940	2,432
Profits before Taxes	-574	125	108
Taxes	0	1	1
Net Profits	-574	124	107

Source: SONEES

TABLE 3.6 WASTEWATER DISPOSAL METHODS BY HOUSING TYPE

Type of discharge/storage of toilet

Description	Type - 1		Type - 2		Type - 3		Type - 4		Type - 5		Type - 6	
	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)
Pit without lining	0	0.0	1	4.5	2	3.6	0	0.0	0	0.0	0	0.0
Pit with lining	32	88.9	21	95.5	25	45.5	19	23.2	9	22.5	0	0.0
Penetration with Septic Tank	4	11.1	0	0.0	3	5.4	6	7.3	2	5.0	0	0.0
Sewerage system	0	0.0	0	0.0	25	45.5	57	69.5	29	72.5	6	100.0
Total	36	100.0	22	100.0	55	100.0	82	100.0	40	100.0	6	100.0

Type of toilet by Housing Types

Description	Type - 1		Type - 2		Type - 3		Type - 4		Type - 5		Type - 6	
	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)
Simple toilets*	1	2.2	0	0.0	2	3.6	0	0.0	0	0.0	0	0.0
WC (Turkish)**	34	75.7	23	95.8	41	73.1	52	63.4	22	55.0	1	16.7
WC (Western)	2	4.4	0	0.0	9	16.1	30	36.6	18	45.0	4	66.6
Public toilet	2	4.4	0	0.0	2	3.6	0	0.0	0	0.0	1	16.7
No toilet***	6	13.3	1	4.2	2	3.6	0	0.0	0	0.0	0	0.0
Total	45	100.0	24	100.0	56	100.0	82	100.0	40	100.0	6	100.0

* : Toilet with no flushing
** : Toilet with flushing
*** : People go into bushes to do

Discharge of Laundry Water

Description	Type - 1		Type - 2		Type - 3		Type - 4		Type - 5		Type - 6	
	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)
To the ground	21	50.0	9	34.6	18	30.5	12	14.5	0	0.0	0	0.0
To penetration pit	0	0.0	0	0.0	1	1.7	4	4.8	1	2.5	0	0.0
To roads	12	28.6	11	42.3	10	16.9	0	0.0	2	5.0	1	16.7
To penetration lot	0	0.0	2	7.7	1	1.7	2	2.4	1	2.5	0	0.0
To pit	9	21.4	4	15.4	5	8.5	8	9.6	5	12.5	0	0.0
To Sewerage System	0	0.0	0	0.0	24	40.7	57	68.7	31	77.5	5	83.3
Total	42	100.0	26	100.0	59	100.0	83	100.0	40	100.0	6	100.0

Discharge of Kitchen Water

Description	Type - 1		Type - 2		Type - 3		Type - 4		Type - 5		Type - 6	
	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)	Numbers	(%)
To the ground	20	47.6	9	34.6	13	26.5	8	9.6	0	0.0	0	0.0
To penetration pit	0	0.0	0	0.0	0	0.0	6	7.2	3	3.9	0	0.0
To roads	13	31.0	10	38.5	23	46.9	0	0.0	2	2.6	1	16.7
To penetration lot	0	0.0	2	7.7	2	4.1	5	6.0	1	1.3	0	0.0
To pit	9	21.4	5	19.2	4	8.2	8	9.6	3	3.9	0	0.0
To Sewerage System	0	0.0	0	0.0	7	14.3	56	67.6	67	88.3	5	83.3
Total	42	100.0	26	100.0	49	100.0	83	100.0	76	100.0	6	100.0

Type-1: Village
Type-2: Irregular spontaneous
Type-3: Regular spontaneous
Type-4: Planned
Type-5: Detached
Type-6: Flats

Data Source: Strategy Plan

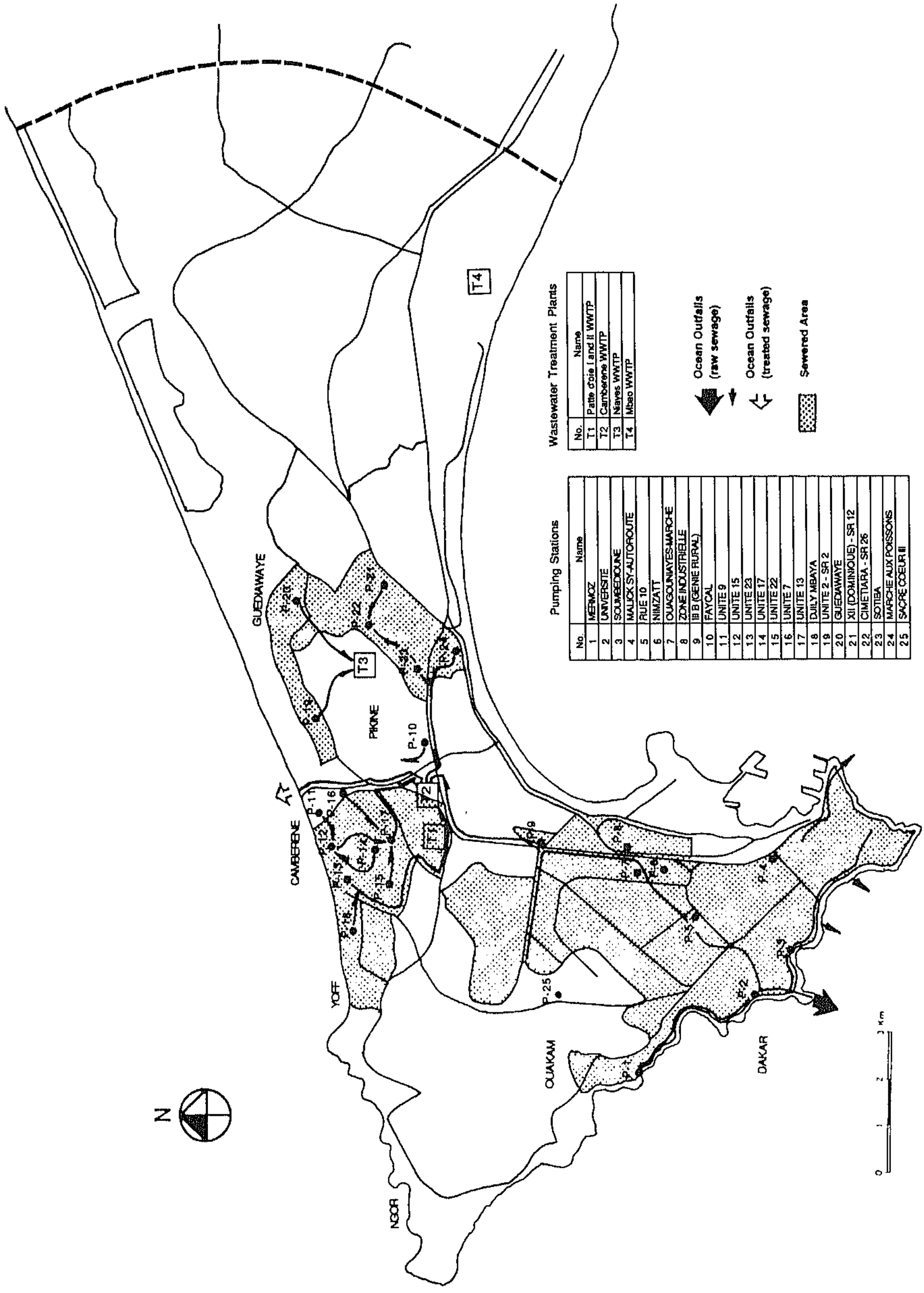

FIGURE 3.1 EXISTING SEWERAGE SYSTEM (1993)

Data Source: SONEES

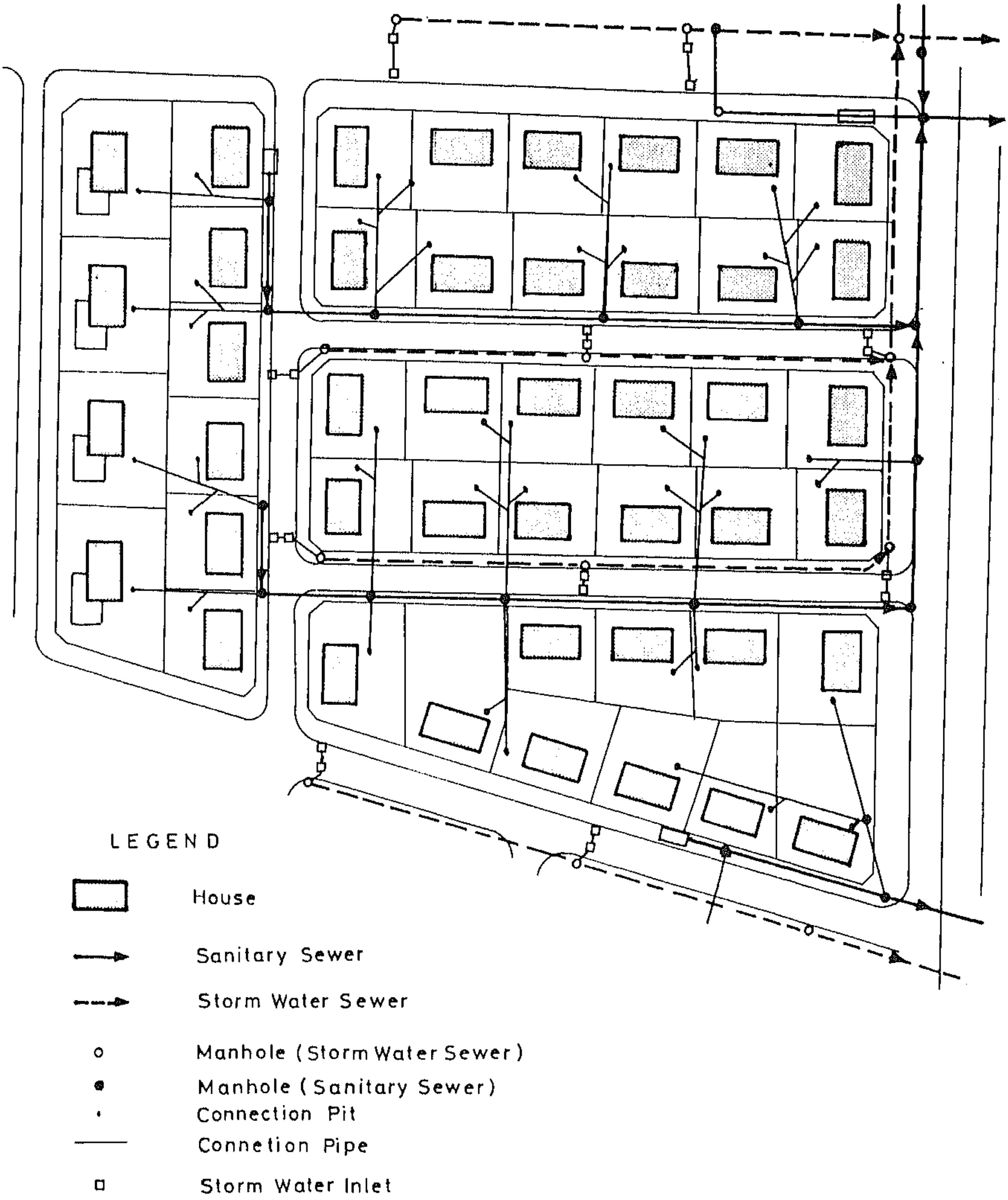

FIGURE 3.2 TYPICAL ARRANGEMENT OF SEWERS AND APPURTENANCES

Data Source: SONEES

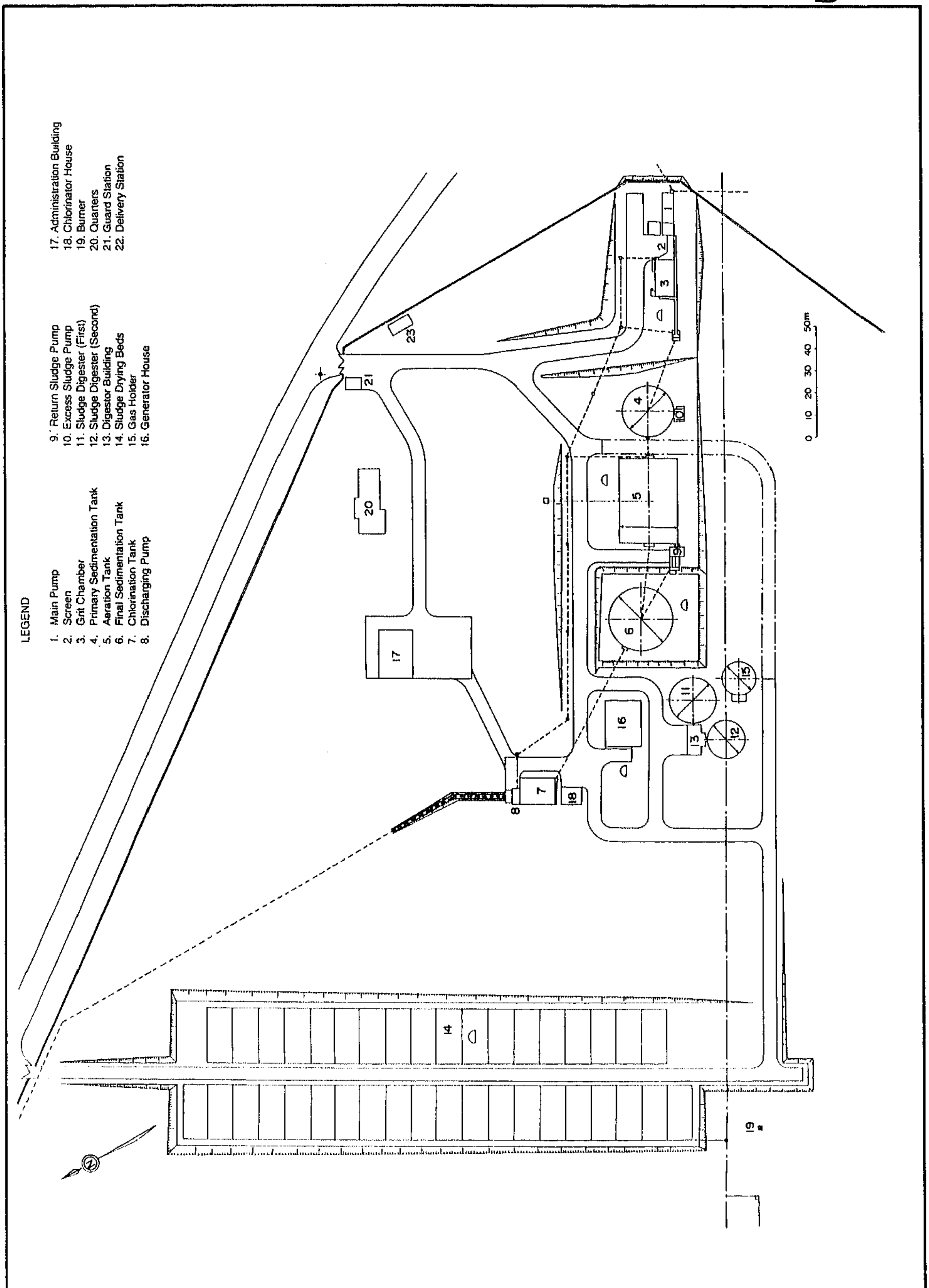

FIGURE 3.3 PLAN OF CAMBERENE WASTEWATER TREATMENT PLANT

Data Source: SONEES

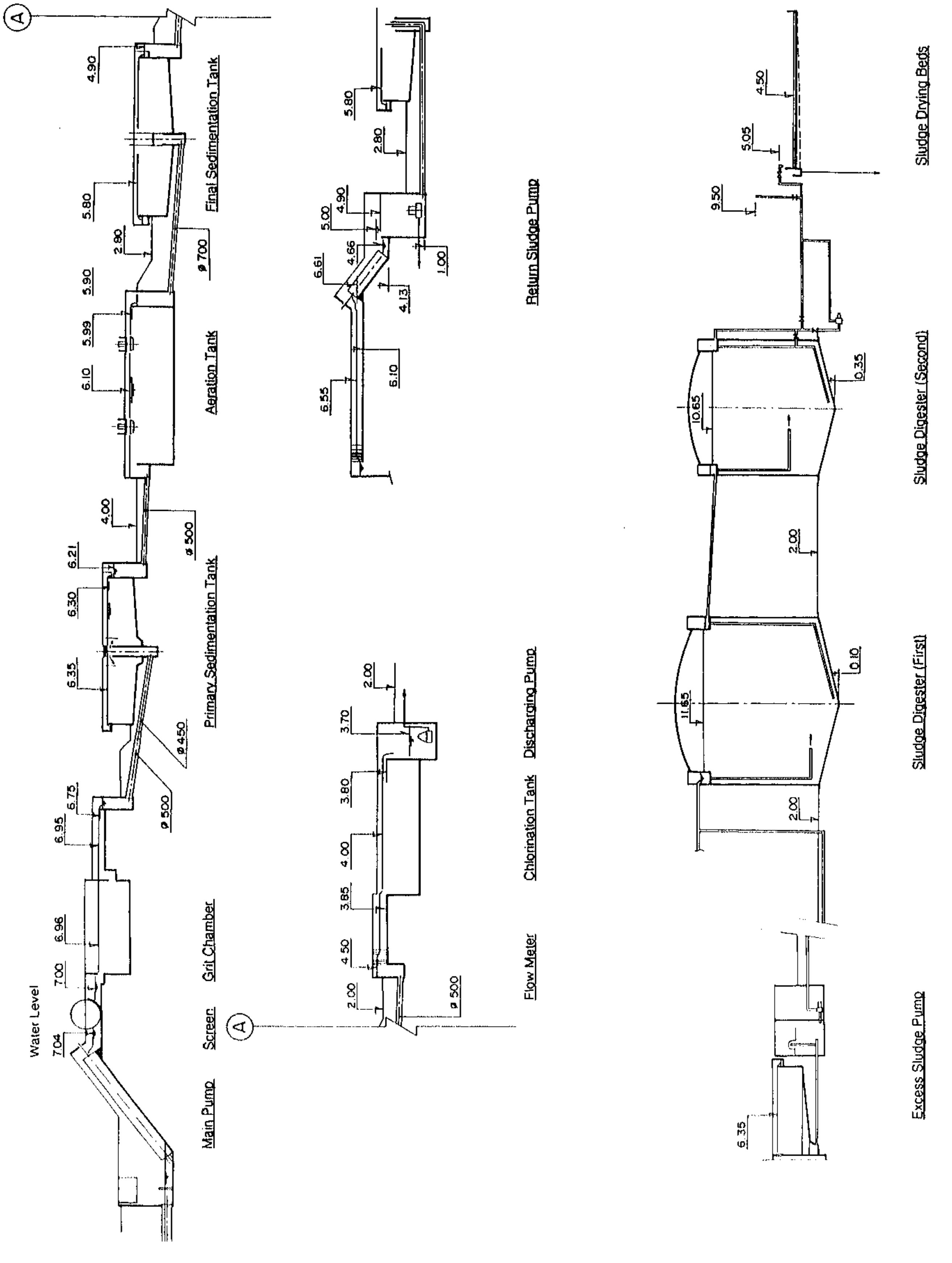

FIGURE 3.4 HYDRAULIC PROFILE OF CAMBERENE WWTP

Data Source: SONEES

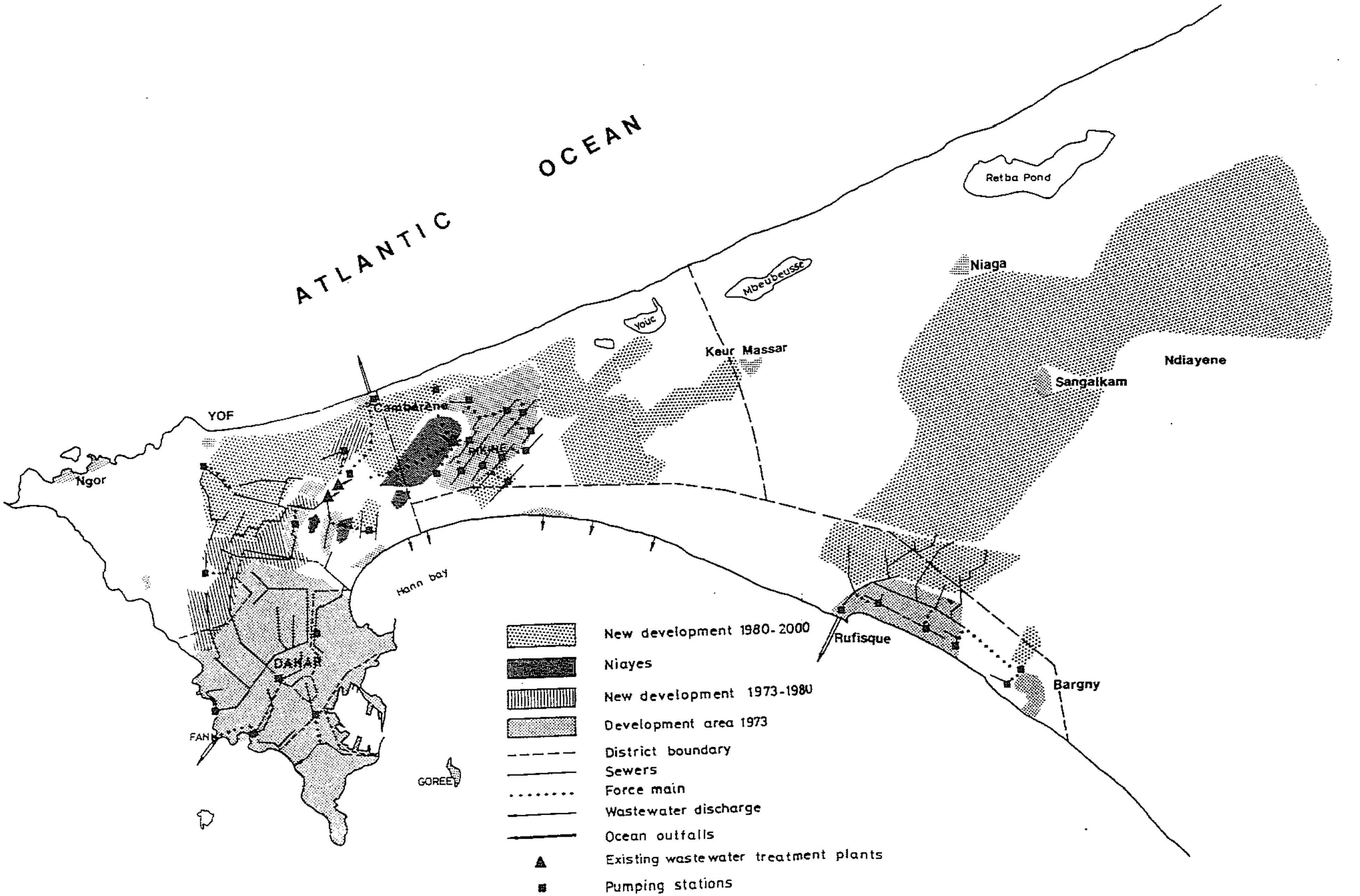

FIGURE 3.5 SEWERAGE SYSTEM PROPOSED BY WATER SUPPLY AND SEWERAGE MASTER PLAN

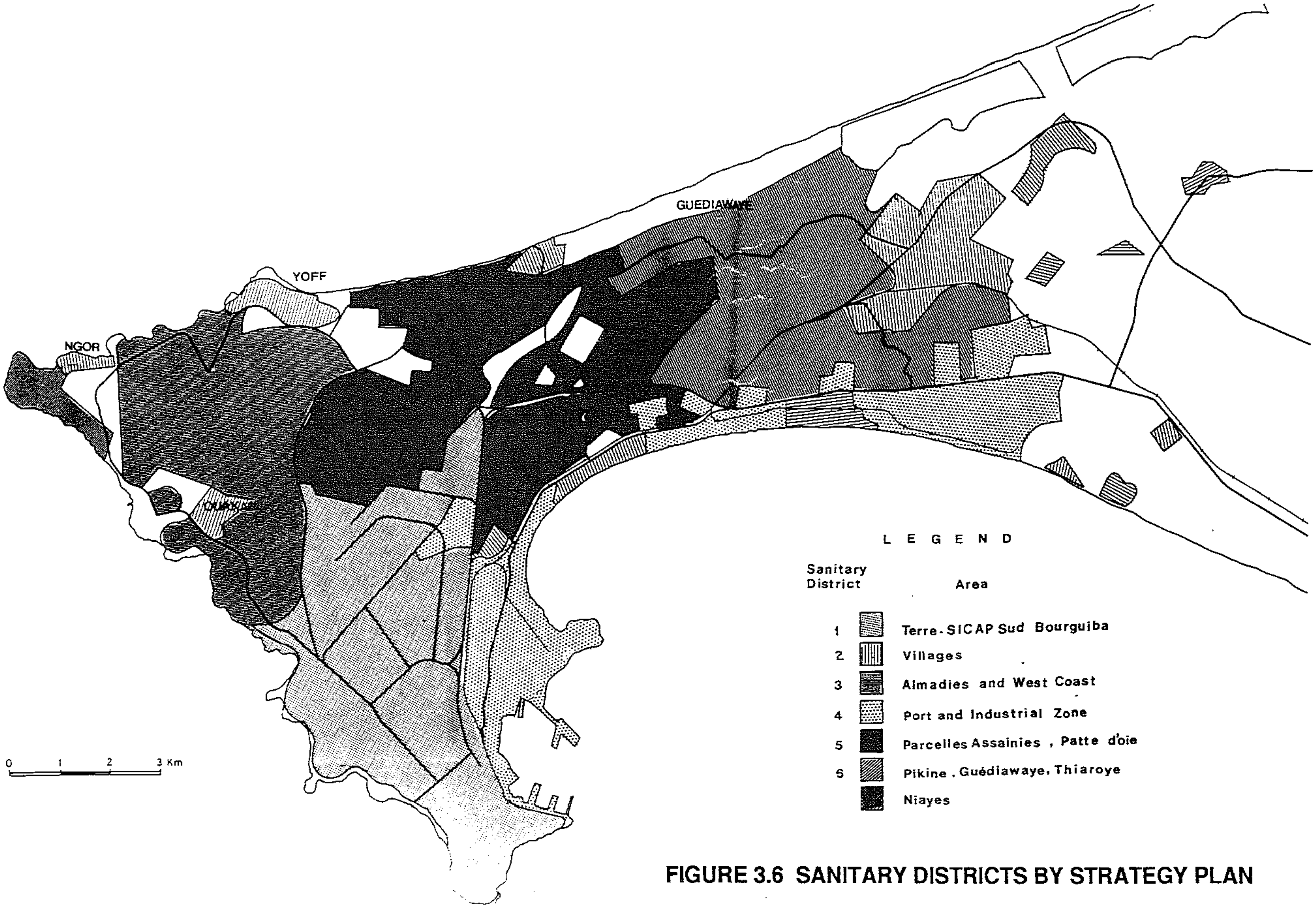

FIGURE 3.6 SANITARY DISTRICTS BY STRATEGY PLAN

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CHAPTER 4

PLANNING CONDITIONS

CHAPTER 4 PLANNING CONDITIONS

This chapter deals with the planning fundamentals for the sewerage and sanitation systems. The planning and design basis for the component facilities have been developed and various alternative plans for possible sanitary systems have been considered so that the most appropriate system plan can be worked out for the Study Area. Following a review of appropriate technologies, the best solution for each of the units has been selected.

4.1 PLANNING FRAME

4.1.1 Population and Landuse

As mentioned in chapter 3, the population projections and the future land use worked out in the Strategy Plan are the basis for the current study, as the Plan was prepared just two years ago in 1991, and the study area is identical. However, during this study, information regarding new development was obtained from various development authorities. Ten new development areas including on-going development areas were identified and development plans were collected. For these areas, population projections made by the Strategy Plan were reviewed and modifications were made, as required. The location of the ten new development areas are shown in *Figure* 4.1.

Among the ten new developments, a huge development area, the Mbao Housing Development, is located between Reboisement de Mbao and Rufisque to the north of National Highway No. 1. Because of the configuration and inclusion of the area, the boundary of the Study Area has been modified as shown in *Figure* 4.1.

With the modifications mentioned above, the population in the Study Area in 2010 has changed from 2,815,459 to 2,908,871 (3.3 % increase). The projected population in each unit in the years 2000 and 2010 is tabulated in *Table* 4.1.

4.1.2 Sewered Area and Unsewered Area

1) Criteria of Selection

The conventional sewerage system existing in the Study Area is not always the best solution to realize satisfactory sanitary conditions. Many constraints prohibit the application of the sewerage system, such as economic, financial, social, physical and other constraints.

A simplified form of the algorithm focusing on the selection of a sewerage system shown in *Figure* 4.2, which is a modification of the World Bank's algorithms, was adopted to select sewered areas. Process of the selection was as mentioned below:

- Availability of yard or house connections and water supply service level indicated by per-capita wastewater flow (lpcd) are the first and the second steps of the selection process, respectively. Inhabitants who do not have access to SONEES distribution networks and who use standpipes are left out from sewerage service.

- Population density and plot size are the next steps. They are closely related to the housing types. Perspectives worked out for each unit by the Strategy Plan are adopted in general, with a few exceptions, for the current study. A minimum population density of 50 persons/ha is adopted, taking into account the present population densities of the sewered units.

- Soil permeability is the next step. Based on the soil classifications identified by the Strategy Plan, suitability of wastewater disposal was determined.

- At the final step of the selection, cost comparison between the septic tank and the conventional sewerage systems is to be conducted. The selection of the systems will be discussed later.

- Social and environmental criteria are neglected since no such constraints were observed in the Study Area.

In addition to the above, the possibility of the small bore sewer system is determined for the areas where the water supply service level is too low for the conventional sewerage system, but whose connection to a sewer network can otherwise be readily implemented. Suitable units for the small bore sewer system will be selected after the sewerage planning area is determined.

2) Sewerage Planning Area

The sewerage planning area was determined as shown in *Figure* 4.3.

Most of the traditional villages, such as Hann Pecheurs, Thiaroye Mer, Yoff, Grand Mbao, Malika, Yeumbeul and Kamb Goundao, were shifted out because of their low water consumption, disorderly road network, or remote location. On the other hand, some of the traditional villages, such as Hann, Ouakam, and Ngor were included in the sewerage planning area because of their proximity to other sewerage planning areas or soil conditions.

Two large housing development areas, viz. Malika and Mbao, were included in the sewerage planning area, since wastewater should be treated and sewerage system is considered to be the most appropriate sanitation system for the areas. Sewerage systems for the areas can not be designed to the same detail as in case of the other planning area because of non-availability of topographic maps. The location and processes of the treatment plants are recommended and construction costs are estimated.

The industrial area along the seashore of the Hann Bay is included in the sewerage planning area. A sewerage system mainly for collection and treatment of the industrial wastewater is designed as one of the alternatives. Alternatives for industrial wastewater treatment, i.e. either by sewerage system or by individual treatment are discussed later in this report.

A total of 2,135,435 inhabitants or 73.4 % of the total population of the Study Area in 2010 will reside in the sewerage planning area.

4.1.3 Wastewater Quantities and Pollutant Loads

All the pollutant sources in the Study Area which produce wastewater have been identified and wastewater quantities and pollutant loads from such sources have been calculated as follows:

- Domestic wastewater quantities are calculated based on the population projections and unit wastewater flow rates.

- Wastewater quantities from the other sources, such as industrial, commercial, and institutional establishments are also calculated, based on the water consumption projections and wastewater characteristics.

- Wastewater quantities and pollutant loads for all units are calculated for the years 2000 and 2010, regardless of the availability of a sewerage system. Wastewater quantities and pollutant loads to be collected by the sewerage system are then worked out, taking into account the sewer connection ratios.

- Pollutant loads from non-point sources, such as storm water runoff and agricultural drainage, are not considered because of the non-availability of basic data.

1) Per-capita Water Consumption Rates

Per-capita water consumption widely varies in the Study Area, depending upon the economic status of the consumers, which is reflected in the types of houses, and more precisely in the number of water taps available in the house. Access to the SONEES water distribution networks affects the consumption rates. However, SONEES distribution networks have been extended to almost all the existing urbanized area. Every new housing development has provision for water supply system. Therefore, access to the distribution networks is not a serious problem in the Study Area.

The Strategy Plan used the figures in *Table* 4.2 for sewerage system planning. Upgrading the water supply service level by the implementation of major projects, such as the completion of the Cayor canal and relevant improvements in the distribution system, and the realization of major sewerage projects were envisaged in working out the consumption rates. Therefore, it is considered to be appropriate to use these figures for the planning of the sewerage system.

2) Commercial and Institutional Water Consumption

Per-capita water consumption rates presented in *Table 4.2* include water consumption for commercial and institutional purposes, as far as these establishments are comparatively small and included in the residential areas and not identified separately as a unit. Large scale commercial and institutional establishments, such as resort hotel complexes, military camps, the university, and schools, are identified as separate units, and their water consumptions are calculated separately on a basis of their population equivalence. Therefore, commercial and institutional water consumption is estimated either as a part of domestic water consumption or separately.

3) Industrial Water Consumption

The results of the questionnaire survey for selected factories are used to work out the industrial water consumption rate per area (ha). Among 24 factories responding to the questionnaire, both the plot area and water consumption were available for 15 factories. The average water consumption rate per plot area is calculated to be 62 m^3/ha/day. Then, the actual area occupied by factories as a percentage of the industrial area was investigated, selecting a representative fully developed industrial area along Canal IV. This percentage works out to be 58 %. Therefore, the industrial water consumption was calculated as follows.

Industrial Water Consumption: $62 \times 0.58 = 36.0$ m^3/ha/day

This unit industrial water consumption rate is used uniformly to estimate the future industrial water consumption. Industrial areas designated at present have not been fully occupied and open spaces are still available. It is assumed that the designated industrial area will be developed fully by 2010 in estimating the industrial water consumption.

4) Per Capita Pollutant Load

The current per capita pollutant load (BOD) was worked out to be 47 gpcd. For planning purposes, an increase in per capita load should be considered since the per capita load increases as per capita water consumption increases. In the Strategy Plan, a per capita BOD load of 60 gpcd was used for the estimation of the future pollutant load as well as for the design of the treatment plants. An annual average increment of 0.76 gcpd was applied based on the study of the Strategy Plan.

Other parameters, viz. SS and COD, are determined in proportion to the BOD load. The ratios obtained from the results of the water quality analysis of the raw sewage at Camberene WWTP were used. Per capita pollutant load for BOD, SS and COD is determined to be as follows.

Parameter	1993	2000	2010
BOD (gpcd)	47	52	60
SS (gpcd)	51	57	65
COD (gpcd)	89	99	114

5) Industrial Pollutant Load

It is expected that new factories will be established in the industrial area along the Hann Bay. The type of new industries cannot be known at present. However, it can be reasonably assumed that factories which consume large quantity of water and produce strong wastewater, such as organic chemical and pulp and paper factories, will not be established in the near future, and that types of new factories do not differ significantly from those that exist at present. Therefore, the average concentration figures shown below obtained from the analysis is used for all industrial wastewater.

Characteristics of Industrial Wastewater

Parameter	Concentration
BOD	910 mg/l
SS	1,010 mg/l

A slaughter house located in Pikine discharges very strong wastewater, i.e. BOD 6,000 mg/l. Pollutant load generated by the slaughter house is estimated separately using the obtained BOD concentration.

6) Projection of Wastewater Flow and Pollutant Loads

Wastewater flow projection for the entire Study Area is tabulated in *Table* 4.3. Domestic wastewater flow is estimated to increase from 160,574 m^3/day in 1993 to 484,197 m^3/day in 2010, i.e. 200 % increase. Overall per capita wastewater flow rate, which is 106 lpcd in 1993, will increase to 166 lpcd in 2010. Industrial wastewater flow will also increase from 12,912 m^3/day in 1993 to 26,810 m^3/day in 2010, i.e. 108 % increase. Total wastewater flow will increase from 173,486 m^3/day to 511,007 m^3/day.

The pollutant load in terms of BOD generated in each unit is tabulated in *Table* 4.4. The total BOD load generated will increase from 86.2 t/day in 1993 to 202.9 t/day in 2010, i.e. 135 % increase. Out of the total BOD load of 202.9 t/day, 178.5 t/day or 88 % is domestic in origin, and the remaining 24.4 t/day or 12 % is industrial in origin.

4.2 SYSTEM CONSIDERATION

4.2.1 Wastewater Flow

1) Inflow ratios

A part of the water demand is not returning to the sewerage system or other sanitary systems due to loss by evaporation to air, infiltration into the ground and draining to drainage system Therefore, in order to estimate the wastewater flow from the water consumption, a certain ratio is usually adopted. The ratios by housing types shown below, which had been used in the Strategy Plan, were used for this study:

Category	Wastewater Discharge Ratio
Housing Type 1	0.85
Housing Type 2	0.85
Housing Type 3	0.75, 0.80 or 0.85
Housing Type 4	0.75, 0.80 or 0.85
Housing Type 5	0.75 or 0.85
Housing Type 6	0.85
Industry	0.80
Port	0.80

Airport	0.25
Others	0.75 or 0.80

2) Infiltration

The groundwater elevations in the existing sewerage service areas are generally lower than the sewers, and no serious infiltration has occurred until now. However, groundwater elevations in Pikine and the Niaye areas in the Study Area are generally high. Groundwater infiltration should be taken into account in designing sewer networks for these areas.

Since no data is available in the existing sewerage system for the infiltration rates, an effort was made to work out the infiltration rate.

Based on the study results in other country and considering actual site conditions, 4.0 m^3/day/ha is used for the design of the sewers in the area where the groundwater table is shallower than 4.0 m from the surface of the ground. Areas where groundwater infiltration is considered is shown in *Figure* 4.4.

3) Peak Flow

In order to work out the peak flow based on the daily average flow, round-the-clock flow rates measured at the Camberene WWTP at two- hour intervals were examined. These are shown in *Figure* 4.5. The ratio of the peak flow to the average flow was calculated to be 1.92. Thus, the peak flow was determined to be two times the daily average flow.

4.2.2 Sewerage System - Conventional vs Small-bore

1) Conventional

The conventional gravity sewer system is one of the most reliable sewerage systems, and much experience is available in planning, design, construction, and operation and maintenance, and is the most widely applied system throughout the world, but in general, it is the most expensive among the possible alternative systems available for safe disposal of wastewater.

2) Small-bore

The small-bore sewer system, which carries settled effluent only, is one possibility for a less expensive sewerage system. The system is designed to receive only the liquid portion of household wastewater for off-site treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewers are separated from the wastewater flow in interceptor tanks installed upstream of every connection to the sewers, and the solids which accumulate in the tanks are removed periodically for safe disposal.

3) Comparison

Though detailed cost comparison between the small-bore and conventional sewers has not been made, a study undertaken by the World Bank indicates that the costs of conventional and small-bore sewerage systems planned for a 73 ha district serving a population of 39,420 were in the ratio of 1,581 to 1,013, or that the small-bore system costs roughly 60 % of the conventional system. The major costs of the conventional sewer facilities are the street laterals and manholes, which are sized to facilitate entry of solids cleaning equipment and therefore larger than peak flows would require.

Advantages and disadvantages of both systems are compared as follows:

System	Advantages	Disadvantages
Conventional	- Greatest conveniences to receive large amount of waste-water. - Lowest risks for health problem. - Few service interruption	- Expensive construction costs. - Requirements for high construction, operations and maintenance skills.
Small-bore	- Reduced water requirement - Low construction costs - Reduced treatment requirement.	- Clogging of sewers. - Removal of sludges from interceptor tanks

Given the high convenient level of the conventional sewerage system and considering the present situation of the area where the conventional sewerage system has a long history and operated by SONEES for a few decades without any serious problems, this system is the most appropriate system. However, a small-bore system may be applied to limited areas, such areas where water consumption rate is less than 50 lpcd and the sewerage system is available in the vicinity.

4.2.3 Wastewater Treatment and Disposal System

The need for appropriate treatment of wastewater is obvious to protect public health and the environment, but the degree of treatment required may vary depending on the local conditions. For wastewater treatment planning, there are essentially two major alternatives, viz. 1) discharge to the sea with a level of treatment as needed to supplement the purifying capacity of the water body (primary process), and 2) discharge to the sea or reuse of the effluent after high level of treatment (secondary process).

It is reported that the pollution of the Hann Bay has been progressing to the extent that the fish catch in the bay is affected. The cause of the pollution in the bay is obviously the industrial and domestic wastewater discharged through open channels and closed pipes along the bay.

As estimated in the previous section, the quantity of wastewater and the pollutant load will increase significantly in the future. Pollution of beaches along the west coast and the Hann Bay, and of the sea water will no doubt become serious if no treatment of wastewater is performed.

Water quality standards for the natural water body including sea water and for various effluents have yet to be established. However, these are under consideration currently by the Government of Senegal. It is anticipated that effluent standards for sewerage system will be determined, based on those obtainable by the secondary treatment processes.

Under the circumstances mentioned above, treatment of wastewater is considered indispensable for the large urban community such as Dakar, and even in case of disposal to the sea, treatment should be based on biological processes. Therefore, in the sewerage planning for the Study Area, biological secondary wastewater treatment is considered.

4.2.4 On-site System

The areas to be covered by a conventional sewerage system will be selected by considering such constraints as economic, financial, social, technical and other constraints, and some areas would remain not to be sewered. In such areas, wastewater generated in each house has to be treated or disposed individually by on-site system.

There are several types of on-site system that would be applicable to the study area. *Table* 4.5 explains on-site system classified by treatment methods and by disposal methods. Non-treatment means that system does not have any treatment process before disposal of wastewater. Most of the present on-site system in the area is considered to be of this type. In a septic tank treatment, wastewater is separated into effluent and sediment. The effluent is discharged from the tank and the sediment is stored in the tank under aerobic condition to be decomposed. Some of on-site system in the area have a septic tank. Aerobic biological treatment is a method that employs similar treatment process to that of sewage treatment in a conventional sewerage system. No on-site system with aerobic biological treatment exists in the area.

Appropriate treatment type depends on the required water quality of the treated water and type of the final disposal. If the disposal is to discharge treated water to surface water, aerobic biological treatment would be preferable so that it does not cause water pollution problems of the surface water. If infiltration is applicable, septic tank would be acceptable, because further progress of purification can be expected during the process of infiltration even though effluent of septic tank has not been treated sufficiently. In addition, even non-treatment would be acceptable in case of infiltration, if it is not in densed area.

Therefore, appropriate on-site system is selected according to the flow chart shown in *Figure* 4.6 mainly considering the above mentioned matters.

4.3 DESIGN CRITERIA

In general, except for special reasons, the sewerage facilities are planned and designed on the basis of the following design criteria.

1) Sewers

Sewers are designed based on calculation by Manning's equation against design peak flows considering following factors:

n values for Manning's equation:	0.012 to 0.015 depending on pipe materials.
Minimum size:	200 mm, but 150 mm only for house connection.
Minimum flow velocity:	0.75 m/sec for cement bonded pipe, 0.60 m/sec for clay and PVC pipes.
Maximum flow velocity:	3.0 m/sec.
Earth covering:	not less than 1 m.

2) Pumping Stations

The design of pumping stations of recent construction in the Study Area have been reviewed. The present design practice adopted by SONEES is generally satisfactory. The following is the general design criteria for pumping stations.

Design flow:	Design peak flows.

Types (in general):	Submersible type for less than 50 l/sec. Dry pit with centrifugal type for above 50 l/sec.
Drive:	Electric motor driven with emergency power supply by diesel engines.
Others:	Screening devices and wet wells.

3) Wastewater Treatment Plants (WWTPs)

Various kinds of biological secondary treatment processes have been developed and applied for wastewater treatment. Among them, three treatment processes were selected for evaluation, viz. the conventional activated sludge, oxidation ditch and the oxidation pond processes.

The conventional activated sludge process was evaluated because the existing Camberene WWTP was designed and constructed based on that process and it is the most representative secondary treatment process widely used all over the world.

Oxidation ditch process is another representative secondary process applied in many countries. This process is said to be less expensive for construction than the activated sludge process when wastewater flow is comparatively small. Operation and maintenance of the process is also easier than activated sludge process. Therefore, oxidation ditch process is applied for small capacity treatment plant.

Energy consumption of oxidation pond process is the least among all secondary treatment processes. The process utilizes solar energy alone to degrade and reduce organic compounds. The construction costs for oxidation pond system is also less than any other secondary treatment system because of the minimum mechanical and electrical equipment required, and the fact that the pond is generally constructed with earth banks. However, the most serious disadvantage of the system is its requirement of huge area. For the effective utilization of solar energy, the pond cannot be deep, e.g. shallower than 2 m for the facultative pond.

Three biological secondary processes are designed and their suitability for adoption and construction costs are compared in the later section. The design criteria for the component facilities are those generally adopted worldwide.

TABLES AND FIGURES

TABLE 4.1 POPULATION PROJECTION

(unit : person)

District	Area (ha)	1993	2000	2010
Cap Manuel	402.4	54321	79982	116640
Hann-Fann	1850.0	370831	432918	521611
Baie de Hann	1132.4	64683	76267	92815
Camberene	2408.7	487536	638879	845560
Secteur Ouest	468.0	51441	64327	82735
Pikine Niayes	1576.4	171167	216688	281715
Secteur Est	1898.7	236522	386711	565883
Villages	1668.1	80899	104951	139310
Mbao Gare	647.0	-	137600	262602
Total	12051.7	1517400	2138323	2908871

Source : Study Team

TABLE 4.2 PER-CAPITA WATER CONSUMPTION RATES FOR SEWERAGE PLANNING

(unit: lpcd)

Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
80	100	150	200	250	400

Source : Strategy Plan

TABLE 4.3 WASTEWATER FLOW (PRODUCTION)

(unit : m3/day)

District	Per-capita Water Consumption (lpcd)			Domestic Wastewater Productior			Industrial Wastewater Productior			Total Wastewater Flow (m3/d)		
	1993	2000	2010	1993	2000	2010	1993	2000	2010	1993	2000	2010
Cap Manuel	302	340	393	17,702	28,645	47,516	0	0	0	17,702	28,645	47,516
Hann-Fann	132	156	190	52,480	71,458	104,014	0	0	0	52,480	71,458	104,014
Baie de Hann	110	117	126	10,012	11,929	14,950	11,700	17,460	25,596	21,712	29,389	40,546
Camberene	78	108	148	39,037	70,356	127,327	1,214	1,784	2,624	40,251	72,140	129,951
Secteur Ouest	86	105	131	4,552	6,905	11,052	0	0	0	4,552	6,905	11,052
Pikine Niayes	86	115	157	14,663	24,876	44,230	0	0	0	14,663	24,876	44,230
Secteur Est	79	98	123	22,685	42,949	75,751	0	0	0	22,685	42,949	75,751
Villages	80	99	124	6,943	11,014	18,062	0	0	0	6,943	11,014	18,062
Mbao Gare	150	170	200	-	23,392	52,520	0	0	0	-	23,392	52,520
Total	102	129	163	168,074	291,524	495,422	12,914	19,244	28,220	180,988	310,768	523,642

Source : Study Team

TABLE 4.4 POLLUTION LOAD PRODUCED (BOD)

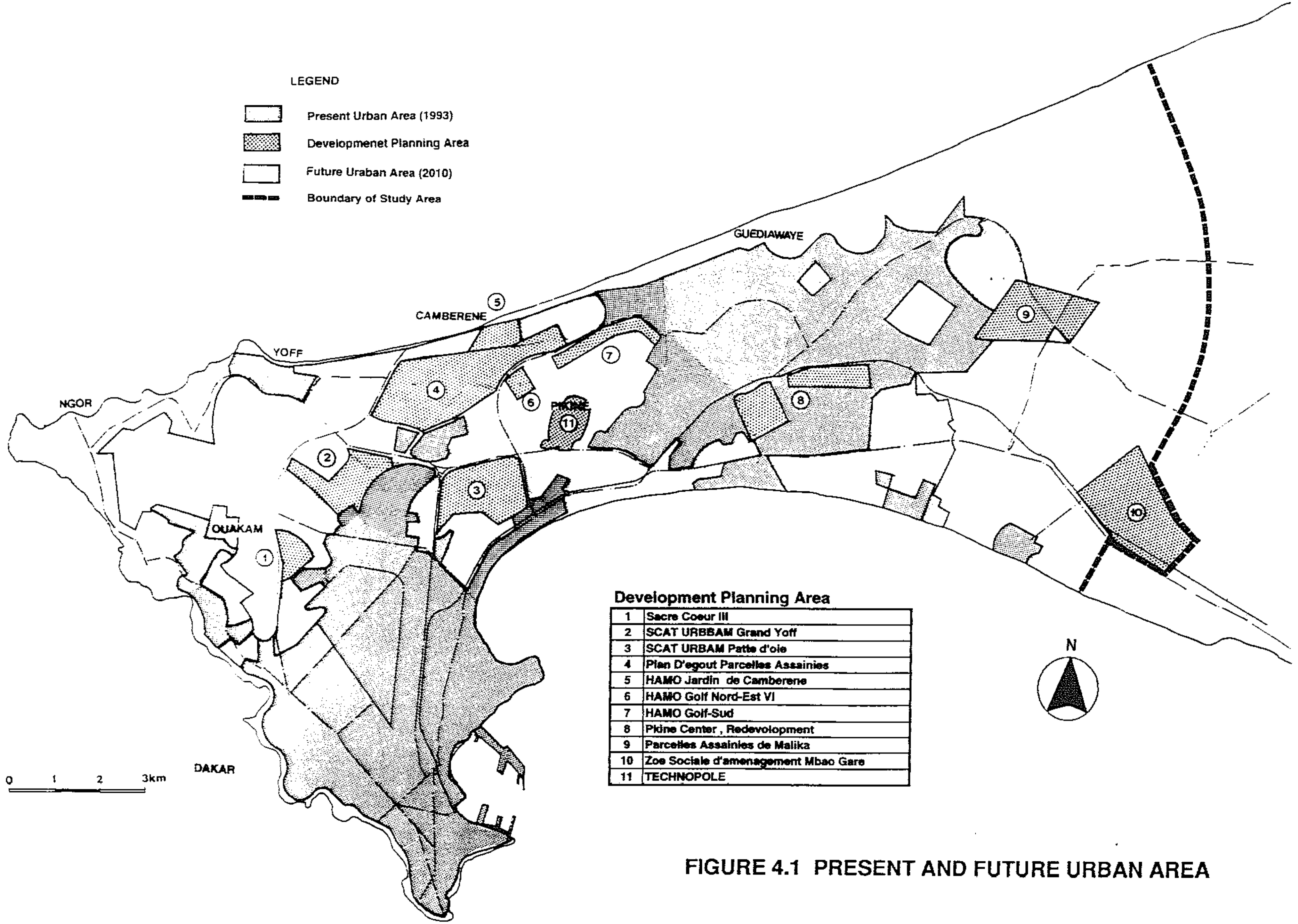
(unit :kg/day)

District	Pollution Load Production (BOD)								
	Domestic Wastewater			Industrial Wastewater			Total		
	1993	2000	2010	1993	2000	2010	1993	2000	2010
Cap Manuel	2,755	4,383	7,256	0	0	0	2,755	4,383	7,256
Hann-Fann	18,634	23,840	32,832	0	0	0	18,634	23,840	32,832
Baie de Hann	4,269	5,323	7,134	10,646	15,888	23,292	14,915	21,211	30,426
Camberene	23,034	33,540	51,261	1,105	1,624	2,388	24,139	35,164	53,649
Secteur Ouest	2,483	3,417	5,049	0	0	0	2,483	3,417	5,049
Pikine Niayes	8,046	11,267	16,902	0	0	0	8,046	11,267	16,902
Secteur Est	13,495	22,736	36,984	0	0	0	13,495	22,736	36,984
Villages	4,092	5,776	8,725	0	0	0	4,092	5,776	8,725
Mbao Gare	-	7,155	15,756	0	0	0	-	7,155	15,756
Total	76,808	117,437	181,899	11,751	17,512	25,680	88,559	134,949	207,579

Source : Study Team

TABLE 4.5 CLASSIFICATION AND CHARACTERISTICS OF ON-SITE SYSTEM

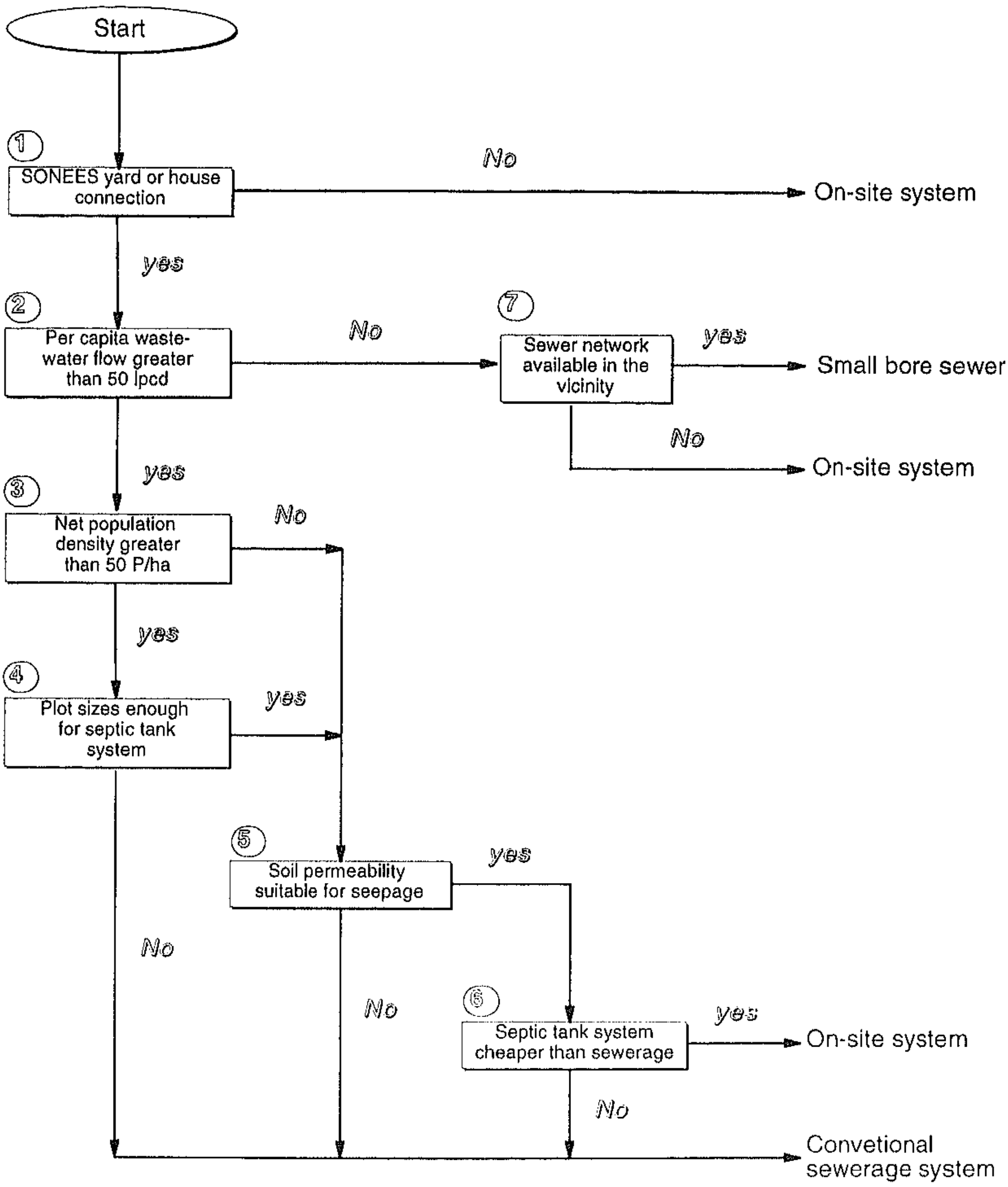
TREATMENT METHOD	WASTEWATER	DISPOSAL METHOD	POSSIBLE EFFECTS TO ENVIRONMENT
NON	TOILET WASTE	DISCHARGE	BACTERIOLOGICAL CONTAMINATION, SEVERE WATER POLLUTION
		INFILTRATION	BACTERIOLOGICAL CONTAMINATION OF GROUND WATER
		COLLECTION	DEPENDING ON TREATMENT / DISPOSAL OF COLLECTED WASTE
SEPTIC TANK	TOILET WASTE	DISCHARGE	LESS BACTERIOLOGICAL CONTAMINATION AND WATER POLLUTION
		INFILTRATION	HIGH DENSITY INFILTRATION MAY CAUSE GROUNDWATER CONTAMINATION (NITROGEN)
AEROBIC BIOLOGICAL TREATMENT (ACTIVATED SLUDGE / FILTRATION BED)	ALL WASTEWATER	DISCHARGE	EFFECTS TO ENVIRONMENT MAY BE AS SAME LEVEL AS THAT OF SEWAGE TREATMENT IN SEWERAGE SYSTEM AS LONG AS OPERATION / MAINTENANCE BEING MAINTAINED NORMAL
		INFILTRATION	POSSIBILITY OF GROUNDWATER CONTAMINATION IS ALMOST ELIMINATED EXCEPT NITROGEN CONTAMINATION



Development Planning Area

1	Sacre Coeur III
2	SCAT URBBAM Grand Yoff
3	SCAT URBAM Patte d'oie
4	Plan D'egout Parcelles Assainies
5	HAMO Jardin de Camberene
6	HAMO Golf Nord-Est VI
7	HAMO Golf-Sud
8	Pikine Center , Redevolopment
9	Parcelles Assainies de Malika
10	Zoe Sociale d'amenagement Mbao Gare
11	TECHNOPOLE

FIGURE 4.1 PRESENT AND FUTURE URBAN AREA



Note: Appropriate on-site systems are not specified

FIGURE 4.2 SELECTION OF SANITARY SYSTEMS

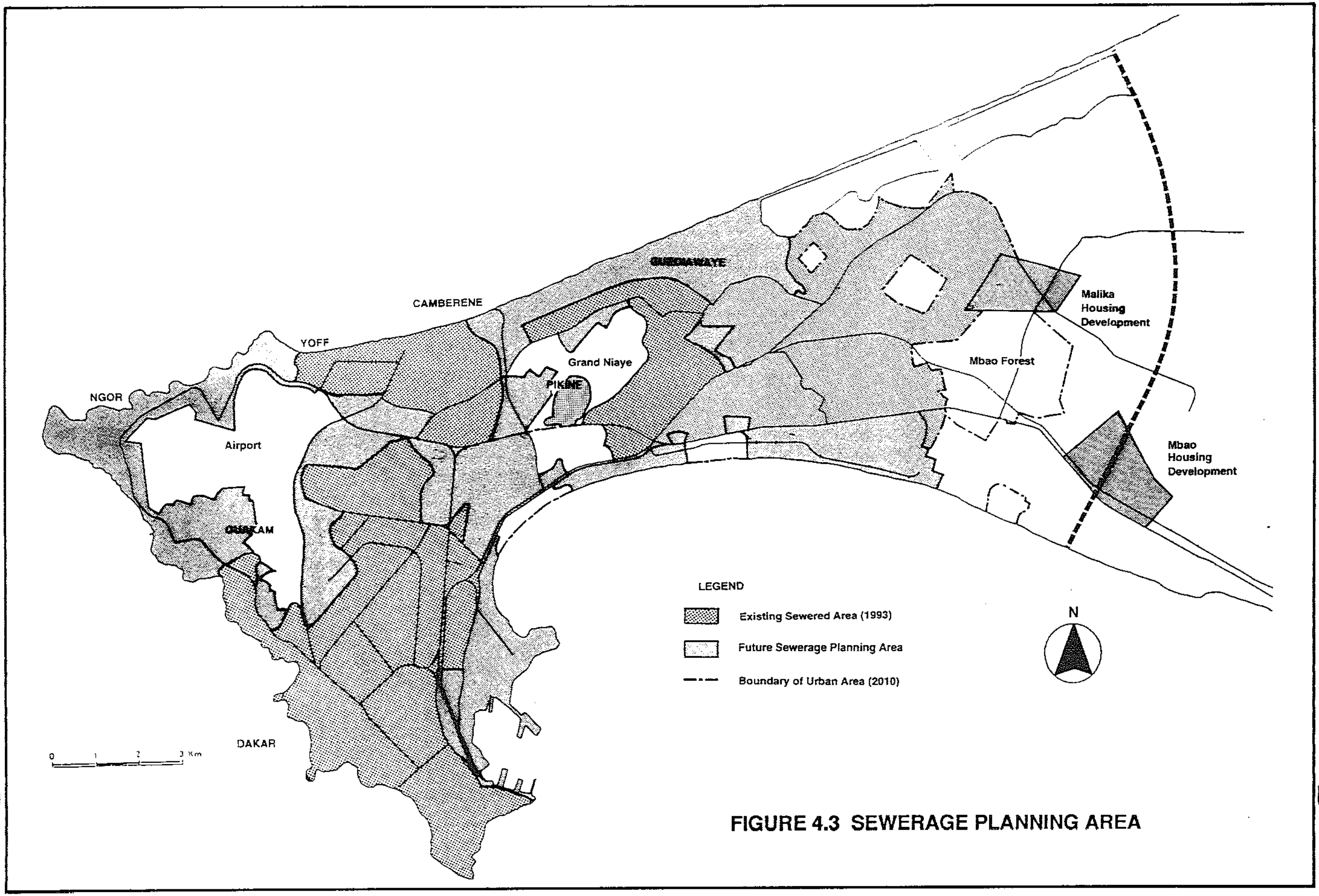
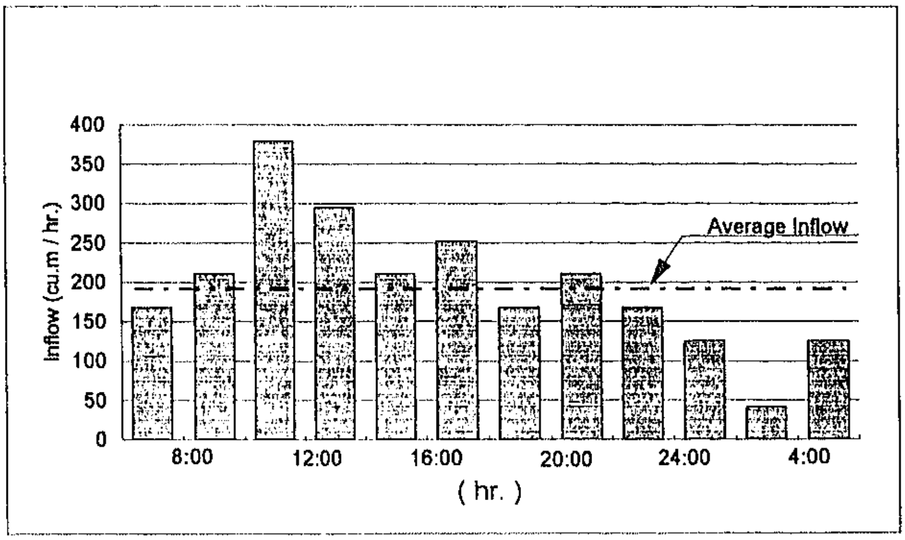


FIGURE 4.3 SEWERAGE PLANNING AREA

FIGURE 4.4 AREA FOR INCLUSION OF INFILTRATION

Data Source: Strategy Plan



Data Source: SONEES

FIGURE 4.5 FLOW RATES TO CAMBERENE WWTP

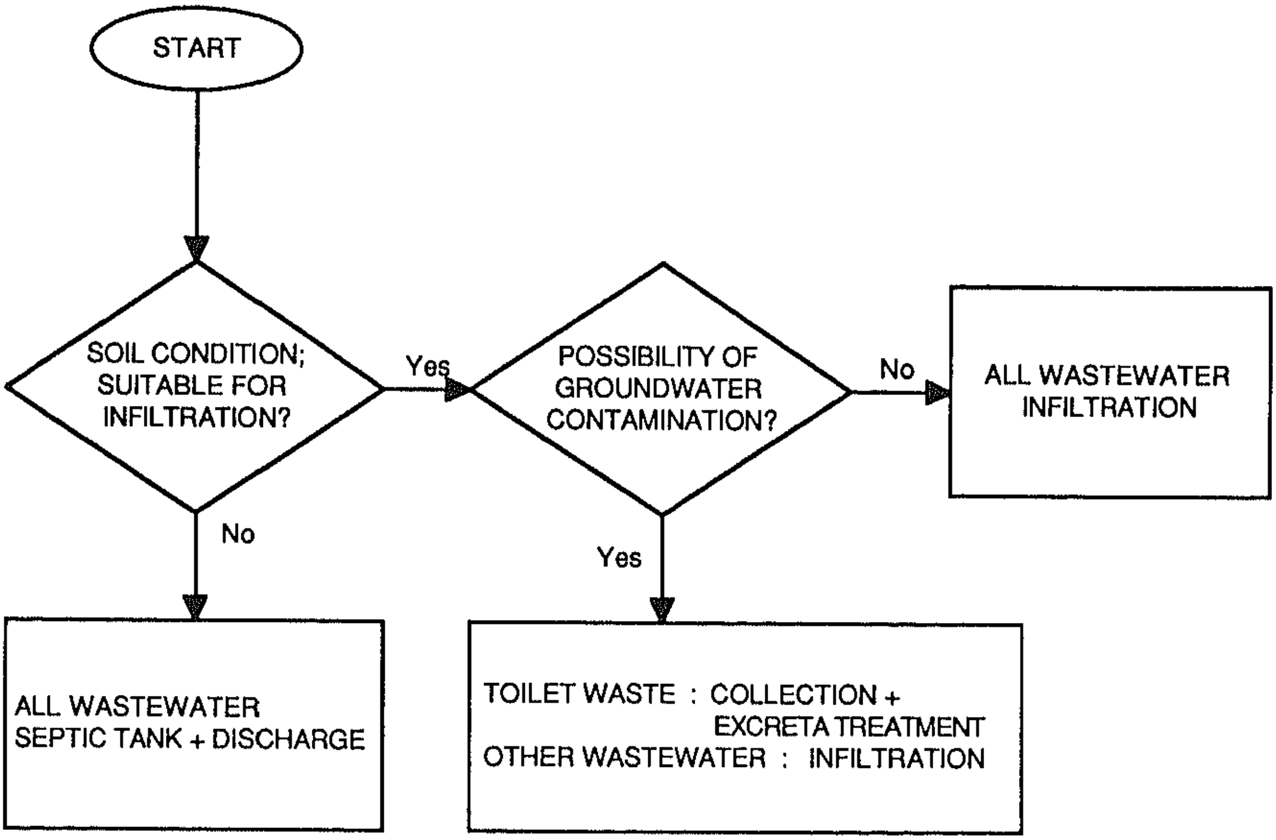


FIGURE 4.6 FLOW CHART FOR SELECTION OF ON-SITE TREATMENT

CHAPTER 5

PROPOSED WASTEWATER SYSTEM

CHAPTER 5 PROPOSED WASTEWATER SYSTEM

5.1 SEWERAGE ZONES

The Sewerage planning area determined in Chapter 4 is divided into 14 sewerage zones for system design, taking into account the topographic conditions and the existing sewerage system. *Figure 5.1* shows the sewerage zones. Units included in each sewerage zone are shown in *Table 5.1.*

Units which should be provided with small bore sewer system were identified according to the criteria mentioned in Chapter 4. These units are also shown in *Table 5.1.*

5.2 WASTEWATER FLOW AND CHARACTERISTICS FOR FACILITY DESIGN

5.2.1 Wastewater Flow

Two sets of wastewater flow were calculated for sewerage facilities design, viz. total flow and actual flow. The former is the total wastewater flow generated in each unit in 2010. The latter is the flow expected to be actually collected by the sewerage system in 2010, calculated by taking into account the connection ratios (connection ratio is the ratio of no. of houses connected to sewerage system to total no. of houses). For the design of sewer pipes including trunk sewers (diameter 300 mm or more), the complete wastewater flow is used because the useful life time of sewer pipes is, in general, much longer than the 16-year period up to 2010, and replacement or installation of new pipes to increase the capacity will require unnecessarily high cost.

On the other hand, treatment plant is usually extended by stages to meet the increasing wastewater flow. Pumping stations, at least their mechanical and electrical equipment, are also installed to keep pace with the increase of wastewater flow. Therefore, for the design of these facilities, the actual flow which is likely to flow in the sewerage system in 2010 is used.

Factors discussed in Section 4.4, such as discharge ratio and infiltration, are taken into account in calculating the wastewater flow. Two wastewater flows in sewerage zones are presented in *Tables 5.2 and 5.3.*

In 2010, a total wastewater flow of 426,449 m^3/day (daily average) will be generated in the entire sewerage planning area, out of which 335,917 m^3/day or 78.8 % of the total will be collected by the sewerage system.

5.2.2 Wastewater Characteristics

The BOD load to be collected by the sewerage system in 2010 amounts to 143,888 kg/day. Out of the total BOD load collected, 118,208 kg/day or 82.2 % is domestic in origin. Among the 14 sewerage zones, wastewater in 10 zones except for Dakar Port (No.2), Pikine Industrial (No.8) and Thiaroye Industrial (No.9), is domestic in nature. BOD load to be collected by the sewerage system in 2010 and BOD concentrations are calculated as shown in *Table 5.4.* The average BOD concentration of raw wastewater of the 10 zones is 382 mg/l.

The SS concentration of the raw wastewater was estimated based on its ratio to BOD obtained from the water quality analysis at the Camberene WWTP. Consequently, concentrations for the design of treatment plant for the 10 zones were determined as shown below.

Raw Wastewater Characteristics for Design (10 Sewerage Zones)

Parameter	Concentration (mg/l)
BOD	380
SS	410

For the three sewerage zones where industrial wastewater is dominant, BOD concentration are calculated as shown in *Table 5.5.* The average BOD and SS concentrations are calculated in the same manner as shown below.

Raw Wastewater Characteristics for Design (3 Industrial Sewerage Zones)

Parameter	Concentration (mg/l)
BOD	970
SS	1,100

5.3 CONSIDERATIONS ON SEWERAGE SYSTEMS

5.3.1 Sewer Networks

Sewer networks for each sewerage zone were investigated considering the existing sewerage system, topographic conditions and present and future developing conditions as follows:

1) Dakar Zone

This zone was already provided with sewer networks and the connection ratio of most of the units is 100 %. Therefore, the extension of the sewerage network is not necessary, except for minor extension and replacement of damaged pipes.

The most important issue for the sewer network in this zone is the capacity of the main trunk sewers. The total wastewater flow in the zone is estimated to increase from 49,461 m^3/day (daily average) in 1993 to 115,327 m^3/day in 2010 and capacities of the Hann-Fann collector was found to be insufficient to accommodate the design flow in 2010.

In order to resolve the problem, the following two alternative measures were considered:

Alternative A:	Installation of an additional collector in parallel with the existing collector
Alternative B:	Conversion of the upstream catchment area to the Camberene WWTP to keep the wastewater flow within the capacity of the existing culvert

The construction cost for Alternative B is lower than that for Alternative A. In addition, there are many advantages with Alternative B. The wastewater flow of the upstream catchment area, i.e. about 30,000 m^3/day on daily average basis, will be treated at the Camberene WWTP. Extension of the Camberene plant is likely to be realized earlier than the future treatment plant in Ouakam. Thus, this will decreases the pollutant load which will otherwise be discharged from Pointe de Fann.

Construction of a pumping station and force mains to the Camberene WWTP is much easier than that of a new collector in parallel with the existing Hann-Fann collector. In case of the new collector, installation of large pipes along the main roads in the bustling urban center will cause much more disturbance to the inhabitants as well as to traffic. Conversion of the secondary mains to the new collector will require additional costs and increase disturbances.

For the reasons mentioned above, Alternative B, i.e. conversion of the upstream catchment area of the Hann-Fann collector to the Camberene WWTP, is proposed.

2) Parcelles Assainies and Its Surroundings Zone

Most of the small units included in this sewerage zone were already provided with sewer networks and the wastewater is sent to the Camberene WWTP for treatment. Wastewater from new housing developments can be sent to the Camberene WWTP without difficulty. The main problem for the zone is low sewerage connection ratio in the large Parcelles Assainies area. Installation of sewer networks should be accelerated.

Improvements of the existing pumping stations in this area should be considered in accordance with the concept of the current sewerage planning.

In the preliminary design of the trunk sewers for the zone, two collectors separately flowing into the Camberene WWTP are proposed. One network pumping station is necessary for the west collector because of the topography of the zone.

Two new network pumping stations are proposed for the east collector.

3) Grand Yoff Zone

Small housing units recently developed in the zone have been provided with sewer networks. Two large housing units, viz. Unit 43b (SCAT-URBAM) and Unit 45 (Grand Yoff/Khar Yalla), are not sewered at present.

Provision of a sewer network in Unit 45 is considered to be difficult because of the present conditions of the houses. Special considerations are required for the design of sewer networks. Construction costs for sewer networks of Unit 45 are expected to be higher than those for other units.

4) Hann Zone

Units in this zone are generally small and residential areas have been developed with adequate road networks. Yet all residential units, except for Unit 94 (Cite Faycal), do not have sewer networks. The early provision of sewer networks is, therefore, recommended for the zone. The proximity of this zone to the Camberene WWTP is an advantage.

5) Pikine Regular and Guediawaye Zones

These are two large residential areas, and the already present large population of the areas will further increase up to 2010 and further.

A difficulty encountered in sewerage planning is the topography of the zone. The zone is located on sand dunes and depressions, both of which run in the northeast-southwest direction. Therefore, several long secondary sewers along the depressions will be required to collect wastewater. Road networks in some areas are not adequately provided.

Sewer networks in the Technopole (Unit 94b) should be designed and constructed by the development authority as one of the necessary utilities. For the sewerage planning purpose, it is assumed that the first phase of the development project will be completed by 2000 and the second phase by 2010. Wastewater flow generated in the Technopole is taken into account for the planning of main sewerage facilities, such as trunk sewers and the Camberene WWTP. However, it is likely that the completion of the first phase will come ahead of the construction of trunk sewers. In this case, a pumping station and a force main which will transfer the wastewater to the Camberene WWTP should be provided.

Wastewater generated in the Technopole is considered to be of two different kinds in nature, viz. domestic wastewater and wastewater generated from various institutions and factories. Characteristics of the latter wastewater vary significantly, like industrial wastewater, depending on the kinds of institutions and factories. The development authority should investigate the characteristics of wastewater of an institution or a factory in selecting them. Institutions or factories which may produce hazardous wastewater should not be allowed, or these can be allowed if their wastewater is treated individually by themselves to the allowable level and not to be discharged to the sewerage system.

6) Malika and Mbao Housing Development Zones

These are two large housing development areas. Housing development in a part of the Malika area has been initiated recently. Most of the development area is, however, still an open area. There is no construction of any kind in the Mbao development area, and the area is left untouched at present.

Taking into account the present conditions in the zones and future sanitary and environmental conditions of the entire Study Area, these two zones are proposed to be included in the sewerage planning area. Construction of the sewerage facilities along with the development of the area is much easier and requires less time and money.

Individual sewerage systems for the two zones and a combined system with one treatment plant can be considered which are discussed in later section.

7) Almadies Zone

The sewerage planning area surrounds the northern and western sides of the Dakar Airport. The topography of the northern part of the zone becomes lower towards the west, and that of the western part becomes lower towards the north. Therefore, wastewater in the zone is taken to the northwestern part of the zone near Ngor. In case of individual treatment, a treatment plant will be located at the side of the existing stormwater drain near Ngor. Advantages and disadvantages of the two alternatives, viz.

individual treatment and combination with the Ouakam zone will be discussed in the later section.

8) Ouakam Zone

Most of the newly developed units in the zone have been provided with sewer networks. There is one traditional village called Village de Ouakam, and one spontaneous irregular area called Quartir de Ouakam. It is difficult to construct sewer networks in these areas unless they are redeveloped. However, these areas are surrounded by already sewered areas, and construction of a small bore sewer system can be considered. Therefore, sewerage systems in the units are planned on the basis of small bore sewer system instead of the conventional sewer system.

9) Dakar Port, Pikine Industrial and Thiaroye Industrial Zones

These are port and industrial zones. The characteristics of wastewater in the zones are quite different from those of the domestic wastewater generated in the zones previously mentioned.

It is advisable to separate the wastewater of these zones from that of other zones from view points of wastewater treatment and reuse of the effluent. Industrial wastewater sometimes contains hazardous materials, such as heavy metals, which have a serious effect on the operation of the plant or can not be reduced by the conventional wastewater treatment, making the reuse of the effluent for the agricultural purposes impossible.

Individual treatment by each factory is another desirable alternative for industrial waste treatment. If industrial waste contains only inorganics or non-biodegradable organics, the wastewater should be excluded from the sewerage system which depends on the biological treatment. Otherwise, inclusion of these kinds of industrial wastewater into the sewerage system increases the construction cost needlessly.

10) Pikine Irregular

This sewerage zone consists of the units which are classified as spontaneous irregular housing type. Road networks are disorderly arranged and construction of sewer networks is very difficult at present. A sewerage system should be provided after or in keeping pace with redevelopment of the area. Therefore, main sewerage facilities, such as trunk sewers, pumping stations and a treatment plant are planned based on the redevelopment plan. A commercial and administrative center planned at the existing military camp is taken into account for the calculation of wastewater flow and facility design.

5.3.2 Wastewater Treatment Process

Three representative wastewater treatment processes selected in the previous Chapter 4 were evaluated in order to find the most suitable process for the sewerage system in the Study Area. Three processes are as follows.

(1) Conventional Activated Sludge
(2) Oxidation Ditch
(3) Oxidation Pond

Design of the wastewater treatment plants based on the three processes were carried out under the same conditions mentioned below, and construction cost functions are developed based on the actual construction costs for the Camberene WWTP. General plans of the plants were drawn to investigate land area required for each process.

Design Basis		
	Daily Average Flow:	10,000 m^3/day
Raw Sewage		
	BOD Concentration:	380 mg/l
	SS Concentration:	410 mg/l
Effluent		
	BOD Concentration:	30 mg/l (60 mg/l for oxidation pond)
	SS Concentration:	30 mg/l (60 mg/l for oxidation pond)

The general plans of the conventional activated sludge process, the oxidation ditch treatment and the oxidation pond treatment are shown in *Figures 5.2, 5.3 and 5.4* respectively. As shown in the figures, the necessary land areas including green spaces as a buffer zone to the surrounding areas are 3.91 ha, 5.13 ha and 17.82 ha, respectively.

Cost functions for the three processes were worked out by modifying those developed in Japan. The construction cost for the Camberene WWTP at 1987 price level was converted to 1993 price level and then to March 1994 price level as shown below, and used for the modification. The obtained cost functions are shown in *Figure 5.5.*

While the oxidation pond treatment is the cheapest method among the compared three, it is eliminated from the treatment to be applied in the proposed sewerage system because of its land requirement. Remaining two methods, the conventional activated sludge treatment and the oxidation ditch treatment are considered to be suitable for the sewerage planning depending on wastewater flow.

5.3.3 Possible Wastewater Treatment Plant Sites

Nine (9) possible wastewater treatment plant sites shown in *Figure 5.6* were investigated and following sites were selected as possible treatment sites:

No.	Location of the Site
1	Around the Camberene WWTP and the Patte d'Oie WWTPs
3	Around the Niaye WWTP
4	North of Pikine, near Lac Warouwaye
5	East of Malika, near Khereub Keur
6	Around the Mbao Industrial WWTP
7	South of the National Road No.1, between the Reboisement de Mbao and Rufisque
8	Ouakam, near the old aerodome
9	Ngor, near the downstream of storm water drain

Firstly, the present WWTP sites were selected since extension of a treatment plant is, in general, easier than constructing a new treatment plant at a different site. Sizable land is available at the site, and land, as needed, can be purchased easily in the vicinity of the existing WWTP. Therefore, Nos. 1, 3, and 6 were selected.

No. 8, the site in Ouakam near the old aerodome is selected as the site for treatment of the wastewater from Dakar sewerage zone, which is presently discharged to the sea from Pointe de Fann without treatment..

Nos. 4, 5 and 7 were selected as possible treatment sites for Pikine Irregular, Malika and Mbao housing development sewerage zones.

Sites No.5 and No.7 are open spaces and have convenient topographic conditions to collect wastewater from these areas. No. 7 site was selected so as not to have an adverse effect on the old village located near the Cap des Biches.

Site No. 7, near the existing industrial wastewater treatment plant was selected for a possible new industrial wastewater treatment plant for sewerage zones of Dakar Port, Pikine Industrial and Thiaroye Industrial.

Site No. 9 in Ngor was selected for a possible treatment plant for the Almadies sewerage zone.

5.4 WASTEWATER SYSTEMS FOR ENTIRE STUDY AREA

The wastewater system for the entire study area comprises of i) sewerage system for the sewered area, ii) industrial wastewater treatment system for the industrial areas and iii) the on-site treatment for the unsewered area. In addition, re-use of treated wastewater is discussed as one of the components of the wastewater system.

5.4.1 Sewerage System

The sewerage system proposed covers all of the 14 sewerage zones which have been identified as areas to be sewered according to the criteria mentioned in Chapter 4.

Seven (7) wastewater treatment plants are proposed to be constructed to treat the wastewater from 14 sewerage zones. Name of the treatment plants, which are virtually the name of the sewerage systems, and their corresponding sewerage zones are shown in *Table 5.6.*

All wastewater treatment plants are proposed to adopt biological secondary treatment processes. Five treatment plants, except Almadies WWTP, are conventional activated sludge plants. The Almadies WWTP is proposed to be an oxidation ditch plant. The design capacities of the six treatment plants are shown in *Table 5.7.*

Ocean outfalls which discharge the effluents sufficiently far from the coast are proposed for four treatment plants, viz. Ouakam, Camberene, Lac Warouwaya and Malika WWTPs.

Systems of the trunk sewers and large pumping stations attached to them to collect wastewater from corresponding sewerage zones and to send to each treatment plant were designed. Sizes and lengths of trunk sewers in each sewerage system are shown in *Table 5.8.* A total of eleven (11) large pumping stations are proposed. Design capacities of the pumping stations are shown in *Table 5.9.*

The major components of the sewerage system are shown in *Figure 5.7.*

5.4.2 Industrial Wastewater Treatment

The Mbao Industrial sewerage system, which is to treat wastewater from the industrial areas along the Hann bay, has been proposed as one of the 7 sewerage systems. In this section, another alternative for the treatment of the industrial wastewater, that is individual treatment by each factory, is investigated. Therefore, factories concerned will be able to study on two options, namely individual treatment and collective treatment when they are required to treat their wastewater before discharging.

Typical processes for each industry type are shown in ***Figure*** *5.8.* and total costs for the estimated wastewater quantity in 2010 are shown in *Table 5.10.*

As shown in a comparison of construction costs required for both alternatives below, the required cost for the individual treatment is lower than those for the collective treatment. Reasons of higher cost for the collective treatments are understood that this alternative requires i) wastewater collecting system and ii) pre-treatment in each factory that reduces concentrations of its specific pollutants.

Therefore, it is proposed to apply individual treatments for the industrial wastewater treatment in the Study Area.

COSTS COMPARISON OF INDUSTRIAL WASTEWATER TREATMENT

(FCFA million)

CENTRALIZED TREATMENT		INDIVIDUAL TREATMENT
Pre-treatment (in each factory)	Wastewater treatment plant	
9,268	18,776	
28,044		20,160

5.4.3 On-site System

On-site system that is to be used in the unsewered area was supposed to be proposed aiming the following two improvements:

- Sanitation conditions: fly control, deodorization, protection of bacteriological contamination of well water.
- Groundwater conditions: mitigation of the nitrate contamination of the groundwater.

To improve the sanitation conditions, it is necessary;

i) to cut off the air movement between the excreta storage place and the toilet compartment,
ii) to isolate the excreta storage place from the external atmosphere,
iii) to accelerate the ventilation of the toilet compartments and the excreta storage place, and

iv) to locate the excreta storage place with a certain distance (minimum 10 m) away from shallow wells.

An example of the toilet meeting the above requirements is shown in *Figure 5.9.*

To improve the groundwater condition, it was considered necessary to stop the disposal of wastewater by infiltration in the area where the groundwater would be affected by the infiltration. Therefore, the system that collects excreta by withdrawal from each house and transfers them by tankers to a treatment facility was investigated based on conditions below:

Total population in the unsewered areas in 2010:	1,222,000
Daily quantity of excreta per capita (including excreta itself, anal cleansing water and pour flush water):	5 l/day/capita
Daily excreta generation in these areas:	6,110 m^3/day

Required facilities are considered as follows:

Treatment plants:	200m^3/day x 30
Collection vehicle:	682 pumping cars (with a suction pump and 3m^3 tank), supposing one car works three times a day.

The required costs are roughly estimated at 310,000 FCFA million (price before the Devaluation) and exceed the estimated costs for a conventional sewerage system by several folds.

As such, the excreta collection system that aimed to reduce the infiltration of the wastewater in the area is judged to be not feasible from technical and financial view points. For the on-site system, therefore, it is proposed to improve toilet facilities from view point of local sanitation.

5.4.4 Re-use of Treated Water

Re-use of the treated wastewater is investigated based on the assumption that the treated water of conventional treatment without any advanced treatments is used for irrigation and watering.

1) Irrigation

Maximum potential demand of water for irrigation of the crops and not to be eaten raw in the entire study area is estimated at 20,000 m^3/day. The facility plan shown in *Figure 5.10* are proposed to transmit the treated wastewater from the Camberene treatment plant to the reservoir and to supply irrigation water to farm land around the Grand Niaye. Indicative costs for the plan is estimated at 1,372 million FCFA.

2) Watering of trees

The facility plan shown in *Figure 5.11* is proposed to provide watering of trees along roads and Mbao reforestation area. The indicative costs are estimated at 680 million FCFA.

5.4.5 Cost Estimates for Sewerage System

1) Basis for Cost Estimates

The latest information regarding the construction of similar facilities as the sewerage facilities was collected from the authorities concerned, including the Department of Hydraulics and SONEES, and utilized for the estimation. For construction costs for the facilities or methods which have not available in Dakar, standardized costs used in Japan were modified and applied.

All costs are indicated at March, 1994 price level taking price escalation effects by devaluation of FCFA of January, 1994 into account.

The project cost is composed of the following components.

Project Cost Components
1. Direct Construction Cost
2. Land Acquisition Cost
3. Engineering Cost
4. Government Administration Cost
5. Physical Contingency

(1) Direct Construction Costs

Direct construction cost was estimated for each sewerage facility as below:

Sewer Networks: Average length of sewer pipes, numbers of manholes and numbers of pumping stations per unit area were calculated based on the preliminary design for Parcelles Assainies area as follows:

Sewer:	282 m/ha for residential area and 135 m/ha for industrial area.
Manhole:	8.77 nos./ha.
Pumping stations:	0.018 nos./ha.

Applying unit costs for each component shown below, unit sewer network costs are calculated at 14,725 thousand FCFA/ha for residential areas and 7,832 thousand FCFA/ha for industrial areas.

Sewer:	40,000 FCFA/m
Manhole:	282,000 FCFA/nos.
Pumping stations:	54,000,000 FCFA/nos.

Trunk Sewers and Force Mains: Construction costs for trunk sewers (diameter 300 mm or more) and force mains were estimated based on the preliminary design. Representative unit construction costs for trunk sewers and force mains are shown in *Tables 5.11 and 5.12* respectively.

Pumping Stations: Construction costs for the major pumping stations (capacity 50 l/sec or more) were estimated based on the capacities obtained from the preliminary design and the cost function shown in *Figure 5.12.*

Treatment Plants: Construction costs for the treatment plants were estimated in the same manner as for pumping stations. The following cost functions were used:

Cost Functions for Treatment Plants

a. Conventional Activated Sludge Process: $C = 989\ Q^{0.73}$

b. Oxidation Ditch Process: $C = 912\ Q^{0.79}$

where C: Construction Cost (million FCFA)

Q: Design Flow (1,000 m^3/day)

(2) Land Acquisition Costs

Land acquisition cost was estimated based on the land areas necessary for the construction of facilities and unit land price. Sizable land areas are necessary for construction of large pumping stations and treatment plants. Unit land prices at various locations were collected from the Department of Cadastral, the Ministry of Finance.

(3) Indirect Costs

Two indirect cost components, viz. engineering cost and government administration cost, were estimated as ratios of the direct construction cost. 10 % and 1.5 % of the direct construction cost were applied for the engineering and government administration costs, respectively.

(4) Physical Contingency

The physical contingency cost was also estimated as a ratio of direct construction cost. A commonly used ratio of 10 % of the direct construction cost was applied.

(5) House Connection

Although the cost for installation of house connections is paid for by the beneficiaries and is not a part of the project cost, it was also estimated so as to get an idea of the magnitude of expenses borne by the beneficiaries.

Using a unit cost for installation of a house connection of 264,000 FCFA (1994 price level) and an average number of house connections per unit area (35 nos./ha), a unit cost per area of 9.24 million FCFA/ha was obtained.

2) Project Cost

The project cost for the seven sewerage systems is shown in *Table 5.13*, with breakdowns for component facilities. The total project cost amounts to approximately 311 billion FCFA at 1994 price level.

In addition, costs for the house connection to be borne by the beneficiaries are shown in *Table 5.14*. As shown in the table, a total of 50,744 million FCFA will be necessary to provide house connections in the entire sewerage planning area.

5.5 WASTEWATER MASTER PLAN

5.5.1 Master Plan and Long Term Plan

The sewerage system to cover the entire study area, which was discussed in section 5.4, was estimated to amount to approximately 311 billion FCFA. It was considered very difficult to complete all projects of the sewerage system by 2010 in terms of work volume and required project costs. Financial analysis revealed that 100 billion FCFA would be a realistic amount of project cost up to 2010. Therefore, the proposed sewerage system was reconsidered to make the master plan realistic and then the original sewerage system was understood as a long term sewerage plan that would be completed beyond the year 2010.

5.5.2 Selection of Master Plan Components

Projects to be included in the Master Plan were selected considering cost efficiencies, progress of development and grade of the present sewerage system:

1) Cost Efficiency

A unit direct construction cost per unit wastewater was calculated for each sewerage system as a factor that indicates the cost efficiency as follows:

Sewerage System	Ouakam	Camberene	Malika	Mbao	Almadies	Pikine Irregular
Unit Cost (1,000 FCFA/m^3/day)	624	766	899	650	3,161	867

The Almadies sewerage system gives the highest unit cost, i.e. the lowest cost efficiency, due to its small amount of wastewater generation compared to its area. The population density of the area is very low, consisting of large hotels and holiday resorts and high quality residential areas. On-site facilities (individual treatment by septic tanks) would be available in this area in terms of site availability and affordability. Therefore, this system is shifted out from the Master Plan.

2) Progress of Development Activities

No significant difference in unit cost comparison was found among sewerage systems except the Almadies sewerage system. However, three sewerage systems, namely the Malika, the Mbao and the Pikine Irregular systems, were shifted out from the Master Plan because of reasons below:

The Mbao and Malika sewerage systems are to be constructed for the new housing developments and a different financial arrangement, therefore, can be considered for these systems. Thus, construction of these systems should be implemented as a part of housing development.

The Pikine Irregular sewerage system is to be constructed in the Pikine Irregular area which is due to be redeveloped. The sewerage system can not be constructed before the area is redeveloped. While main facilities for the sewerage system have been proposed based on a conceptual developing plan to give an indicative idea for reference, it is difficult to incorporate it into the Master Plan before concrete schedules of the redevelopment are prepared.

3) Service Level of the Sewerage System

The highest cost efficiency was given to the Ouakam sewerage system in the comparison of the unit cost discussed above. This is because that the system serves the Dakar and Ouakam sewerage zones where sewer networks in most areas have already been provided. No construction cost for provision of sewer network is required. Most of the required cost comprises of the construction cost for the WWTP.

While construction of the WWTP will contribute greatly to the reduction of pollutant loads to the sea, which is presently receiving untreated wastewater discharge, it will not enhance the service level of the already sewered area in term of elimination of wastewater from the vicinity of residents. It is also an important function of sewerage system to reduce pollutant loads discharged, however, higher priority should be put on the elimination of wastewater to improve living environment. Therefore, the Ouakam sewerage system was shifted out from the Master Plan.

5.5.3 Proposed Master Plan

As mentioned above, several sewerage systems in the long term plan were shifted out from the Master Plan. As a result, the construction of the Camberene sewerage system was proposed in the Master Plan for the wastewater system. The proposed Master Plan together with priorities of its components, which will be discussed in the next section, are shown in *Figure 5.13.* Major features of the Master Plan are summarized as follows:

Components of the Project	Zones to be done
Construction of sewer networks	Parcelles Assainies, Dakar-Yoff, Hann, Guediawaye, Pikine regular
Construction of trunk sewers	Parcelles Assainies, Dakar-Yoff, Guediawaye, Pikine regular
Expansion of wastewater treatment plant	Camberene wastewater treatment plant
Improvement of collector system	Ouakam

5.5.4 Implementation Schedule

The implementation schedule for the Master Plan has been developed to be initiated in 1995 and completed by 2010. Implementation of the Master Plan depends upon the availability of funding in Senegal since it involves a heavy investment including a sizable foreign currency component.

The Camberene sewerage system covers three sewerage zones, namely Parcelles Assinies zone, Grand Yoff and Hann zone, and Guediawaye and Pikine Regular zone. Unit construction costs of each zone were compared to evaluate priority of the implementation. The priority was identified as shown below and proposed implementation schedule is shown in *Figure 5.14*.

Priority 1: Parcelles Assinies zone
Priority 2: Grand Yoff and Hann zone
Improvement of collector system in Ouakam zone
Priority 3: Guediawaye and Pikine Regular zones

5.5.5 Project Cost and Operation and Maintenance Cost by Phase

1) Project Cost

Project cost over a 16 year period from 1995 to 2010 was estimated based on the implementation schedule developed in the previous section. Indirect cost items, such as engineering service, government administration and physical contingency, are included in the project cost.

Project cost is divided into two currency portions, viz. local and foreign currency portions. Percentages of the two portions in each cost items are as follows.

Percentage of Local and Foreign Currency Portions

Cost Item	Work Item	L/C	F/C
Direct Construction	Sewer (1)	30 %	70 %
	Sewer (2)	15 %	85 %
	Pumping Station	25 %	75 %
	Treatment Plant	30 %	70 %
Land Acquisition		100 %	0 %
Engineering Service		30 %	70 %
Government Administration		100 %	0 %
Physical Contingency		100 %	0 %

Breakdowns of the project cost by year are shown in *Table 5.15*. Project cost distribution up to 2010 is shown in *Figure 5.15*.

The total project cost amounts to approximately 102,279 million FCFA at 1994 price level, of which 29,828 million FCFA or 29 % is local currency portion and 72,451 million FCFA or 71 % is foreign currency portion.

2) Operation and Maintenance Cost

Operation and maintenance cost required for all sewerage facilities to be completed by 2010 was estimated based on the extents and numbers of the facilities.

Additional annual operation and maintenance cost which is required for the operation and maintenance of the sewerage facilities proposed under the Master Plan is 392 million FCFA, and its breakdown is shown in *Table 5.16*.

5.6 FINANCIAL ANALYSIS

5.6.1 Financial Sources

The initial costs and the operation and maintenance costs for the projects proposed in the Master Plan are estimated to amount to 102,279 million FCFA and 2,350 million FCFA annually, respectively. Among the total initial costs, the foreign components are estimated at 72,451 million FCFA, accounting 70.8% of the total.

Financial analyses were carried out for the following three cases:

Cases 1:	100 % of the initial costs;	Governmental subsidy
Cases 2:	100 % of the initial costs;	Government loan
Cases 3:	70 % of the initial costs;	Government loan
	30 % of the initial costs;	Governmental subsidy

Note: In each case, the operation and maintenance costs are paid by beneficiaries.

5.6.2 Financial Analysis

Financial projections were carried out for the three cases mentioned above based on the assumption below:

Depreciation period:	50 years for civil facilities 15 years for electro-mechanical equipment
Period of projection:	30 years
Annual rate of inflation:	2%
Rate of tax on corporate income:	30%
Terms of government loan:	Annual interest rate of 5% Repayment period of 25 years Grace period of 5 years
Sewerage charge collection efficiency:	90%

Source of operation, maintenance and replacement costs:
Revenue from sewerage charge

In addition, following sewerage charge for each case is proposed considering the necessary revenue for repayment of loans and operation and maintenance costs and willingness to pay of the beneficiaries.

Proposed Average Sewerage Charges for each Case

Period	Case 1	Case 2	Case 3
up to 2000	21.01 FCFA/m^3 (6.1 % of water charge)	21.01 FCFA/m^3 (6.1 % of water charge)	21.01 FCFA/m^3 (6.1 % of water charge)
2001 to 2010	24.12 FCFA/m^3 (7 % of water charge)	48.23 FCFA/m^3 (14 % of water charge)	41.34 FCFA/m^3 (12 % of water charge)
2011 on	27.56 FCFA/m^3 (8 % of water charge)	96.46 FCFA/m^3 (28 % of water charge)	75.79 FCFA/m^3 (22 % of water charge)

Cost benefits streams for each cases were prepared as shown in *Tables 5.17 to 19* and the financial internal rate of return (FIRR) was calculated at 7.4 % for the Case 1 and 6.8 % for the Case 2. These FIRR are judged to be reasonable, exceeding interest rate of repayment (5 %).

From view points of comparison of willingness to pay (24.7 % of water charge and FIRRs calculated, any of cases is considered to be feasible. However, if possible, it is recommended to apply case 1 for implementation of the projects. Sewerage projects benefit more general public than people who are connected to system by its effects to environmental sanitation improvement. In this context, nature of sewerage projects are, some how, similar to drainage projects. Furthermore, although the proposed sewerage charge is within the people's willingness to pay surveyed, it would be still hard for beneficiaries.

5.7 INSTITUTIONAL CONSIDERATION

5.7.1 Institutional Support for Connection to Sewerage

One problem identified in the existing sewerage system was a low connection ratio to sewerage system. This is because of high initial costs (166,000 FCFA in average at the pre-devaluation level) of the connection, which is to be paid by each household. This means much of the initial capital invested in the sewerage system is being left un-utilized and will be same in the future.

To rectify this situation, it is proposed that the state institutionally make it possible for the households to pay the connection charge on installment. Examples of such installment are shown below:

Examples of Installment for Sewerage Connection

Initial cost	Period of installment	Annual interest	Monthly Repayment
165,000 FCFA	36 months	2 %	4,467 FCFA
165,000 FCFA	60 months	2 %	2,733 FCFA

5.7.2 Increasing of Sewerage Charge

The present sewerage charge is estimated to be equivalent to 6.1% of the water supply charge in average and covers operation and maintenance costs and minor replacement costs. However, this would never cover the repayment if the initial investments are provided by loans. The financial analysis for the proposed Master Plan has indicated that the plan would be financially feasible based on a certain range of increase of the sewerage charge. While magnitude of the increase depends on the cases of financial sources, increase of the sewerage charge is indispensable in implementation of the Master Plan.

5.7.3 Organizational Strengthening

Presently the Ministry of Hydraulic is responsible for planning and construction of sewerage system and SONEES is responsible for its operation and maintenance. As far as under the present situation where the sewerage system is considered to be a matter of the social sector and the state is responsible for all initial construction costs, this would work. However, once the sewerage system is treated as a income generating business like a water supply system, one organization should be responsible for all the scheme of the sewerage system as SONEES is so in the water supply sector.

Such organization could be created by either expansion of the Sanitation Service of SONEES or combination of the several organization presently related to the sewerage system. A proposed new organization is shown in *Figure 5.16.*

5.8 PROJECT EVALUATION

The proposed sewerage projects will cover an area of 3,480 ha, which is 20 % of the total study area. The proposed system will collect wastewater for a population of 1,041,328, which is 35.8 % of the total population in 2010 of the study area, and treat 97,200 m^3/day of wastewater that is equivalent to that for a population of 635,466. This will increase the sewerage coverage rate from 29.9 % to 35.8 % and the treatment rate from 4.2 % to 21.8 %.

The proposed Master Plan has following distinct objectives:

- To enable the maximum utilization of the existing capacity of the Camberene WWTP, which was constructed by a loan from the African Development Bank and only 40 % of its capacity is presently utilized.

- To expand the sewerage service area towards the Pikine area, which is being established as a new urban center.

- To balance the development of sewage collection area and sewage treatment area in Pikine area by expanding the Camberene WWTP.

Purposes of the development of a sewerage system are to collect and eliminate wastewater from areas where the wastewater is generated, to improve sanitation conditions of the areas as it was so in the initial stage of the sewerage history, and to reduce pollutants loads to the nature by treatment in order to improve the water quality, environment inside and/or surrounding areas, which is now a major concern in most of the urban areas. Thus sewerage system usually consists of a set of collection system and treatment system, resulting in high projects costs. However, if such project costs are not affordable, it is reasonable to put priority on either of two purposes namely sewage collection or sewage treatment by considering urgent requirements of the project area. In this regard, the sewage collection has been put a higher priority in the study area, which is situated in an arid zone and has few natural water surface except the surrounding sea. The initial environmental investigation conducted in this study has identified possible adverse effects to the western shoreline in limited periods of a year (June and August) by continuing untreated wastewater discharge from Fann. However, it is not judged to be so severe to require urgent improvement. Therefore, it can be justified to put a higher priority on the expansion of the sewage collection than the treatment of wastewater presently discharged to the sea.

Another big concern in this area is the pollution of the groundwater which is at present one of the major water supply sources. The proposed sewerage plan may result in the reduction of wastewater infiltration that is supposed to be a major cause of the groundwater contamination up to some extent, but the infiltration from on-site system that will remain in the un-sewered areas is estimated to be big enough to increase the contamination. The on-site treatment that eliminate the infiltration was investigated but judged to be not feasible. Therefore, the plan recommends the substitution of the present wells by a surface water source.

In terms of the financial feasibility, the proposed projects, the total costs of which is 102,279 million FCFA, is judged to be affordable by considering the people's willing to pay for sewerage service and the subsidy by the government.

5.9 RECOMMENDATION

- The Sewerage Master Plan was proposed by shifting out several project components from the Sewerage Development Plan that covered the whole study area, because of budget constraint. The proposed Sewerage Master Plan is considered to have the essential components to satisfy the minimum requirements to improve the present sewerage conditions of the area and to ensure further development following the shifted out project components. Therefore, it is recommended to implement projects according to the proposed Master Plan as early as possible. In this regard, political decision to provide special financial supports to the projects are strongly required.

- It is desired to review this master plan when the projects in the plan proceed to some extent to cope with areas not included in this master plan.

- Either by re-organization of SONEES or by creation of a new organization, one organization should take responsibilities for planning and execution of the projects, operation and maintenance of the facilities and management of organization and finance of sewerage system, as SONEES is presently doing in the water supply system. The Ministry of Hydraulics, which is presently responsible for the projects execution, should be involved in the system as an governmental authority to give approval to each activity.

- Efforts to improve present conditions existing in the Study Area, especially to increase wastewater flow to the Camberene WWTP by promoting house connections in the existing sewered areas, should be continued. Provision of installment would help these efforts.

- It is recommended that efforts to replace the existing deteriorated sewer networks in Dakar should be continued.

- Though industrial wastewater was recognized as one of major pollutant sources, sewerage system for industrial zones were shifted out from the Master Plan. It is proposed that the industrial wastewater is treated by individual treatment system to be installed in each factory Therefore, it is recommended that the government apply regulations for the wastewater discharges to encourage this direction.

- Improvement of toilet facilities of on-site system should be encouraged to mitigate the sanitary problems of the area, in particular bacteriological contamination of shallow well water.

- Substitution of Thiaroye water supply source by other water sources would be essential to avoid supplying water with high concentrations of nitrate nitrogen. In this regard, earlier implementation of the Cayor Canal project is strongly recommended.

- Reuse of raw sewage from the Niaye WWTP for agricultural purpose should be ceased as soon as possible.

- The coordination and cooperation among the Ministries and other organizations concerned are prerequisites if the sewerage construction project and operation & maintenance of the sewerage facilities are to be successfully conducted. In this connection establishment of the Coordination Committee is recommended.

TABLES AND FIGURES

TABLE 5.1 COMPONENT UNITS IN SEWERAGE ZONE

	Sewerage Zone	Units
1	Dakar	24, 25, 26, 27, 28, 29, 30, 50, 50b, 51, 51b, 52, 52b, 52t, 53, 53b, 53t, 54, 55, 55b, 56, 57, 58, 59, 59b, 60, 61, 62, 63, 63b, 65, 66, 67, 68, 69, 70, 71, 71b, 72, 73, 74, 75, 75b, 76, 77, 78
2	Parcelles Assainies and Its Surroundings	33, 34, 35, 36, 37, 38, 39b, 40, 41, (42), 98, 99, 100, 101, (102), 103, 104, 105
3	Grand Yoff	31, 32, 43, 43b, 44, 45, 46, 46b, 47, 48, 49
4	Hann	(81), 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92
5	Pikine Regular	94, 94b, 111, 112, 112b, 113, 114, 115b
6	Guediawaye	107, 108, 108b, 109, 109b, 129, 130, 130b, 131, 132, 133, 134
7	Malika Housing Dev.	142b
8	Mbao Housing Dev.	159
9	Almadies	1, 2, 3, (4), 5, 6, 7, 8
10	Ouakam	9, 10, 11, 12, 13, 14, 15, 16, (17), 18, 19, (20), 21, 22, 23
11	Dakar Port	79, 80 (part)
12	Pikine Industrial	80 (part), 115, 116, 117, 118
13	Tiaroye Industrial	80 (part), 120, 123, 153
14	Pikine Irregular	119, 121, 124, 125, 126, 127, 128, (135), (136), 137, 138, (139), 143, 144, 145, (146), 147, 148, 149

Note : Unit number in parentheses is small bore sewer system.

Source : Study Team

TABLE 5.2 WASTEWATER FLOW IN 2010 (TOTAL)

(unit : m3/day)

Sewerage Zone	Daily Average Flow	Peak Flow
1 Dakar	124,524	249,046
2 Parcelles Assainies and Its Surroundings	39,383	78,762
3 Grand Yoff	24,110	48,219
4 Hann	10,783	20,537
5 Pikine Regular	23,379	45,030
6 Guediawaye	39,098	75,590
7 Malika Housing Development	22,472	43,272
8 Mbao Housing Development	44,604	86,620
9 Almadies	12,008	24,175
10 Ouakam	9,001	17,998
11 Dakar Port	8,362	16,723
12 Pikine Indusrial	648	1,201
13 Tiaoye Industrial	4,466	8,486
14 Pikine Irregular	63,611	120,560
Total	426,449	836,219

Source : Study Team

TABLE 5.3 WASTEWATER FLOW IN 2010 (ACTUAL)

(unit : m3/day)

Sewerage Zone	Daily Average Flow	Peak Flow
1 Dakar	115,327	230,653
2 Parcelles Assainies and Its Surroundings	23,946	47,886
3 Grand Yoff	17,037	34,074
4 Hann	8,807	16,585
5 Pikine Regular	10,848	19,969
6 Guediawaye	8,890	15,173
7 Malika Housing Development	22,472	43,272
8 Mbao Housing Development	44,604	86,620
9 Almadies	4,111	8,222
10 Ouakam	5,231	10,459
11 Dakar Port	15,351	30,701
12 Pikine Indusrial	2,212	4,329
13 Tiaoye Industrial	8,791	7,108
14 Pikine Irregular	48,290	89,918
Total	335,917	644,969

Source : Study Team

TABLE 5.4 BOD CONCENTRATION OF DOMESTIC SEWAGE

Sewerage Zone	BOD Load (kg/day)	Daily Average Flow (m3/day)	BOD Concentration (mg/l)
1 Dakar	36,992	115,327	321
2 Parcelles Assainies and Its Surroundings	10,403	23,946	434
3 Grand Yoff	6,601	17,037	387
4 Hann	2,961	8,807	336
5 Pikine Regular	5,256	10,848	485
6 Guediawaye	2,643	8,890	297
7 Malika Housing Development	7,800	22,472	347
8 Mbao Houing Develoment	15,756	44,604	353
9 Almadies	1,437	4,111	350
10 Ouakam	2,182	5,231	417
14 Pikine Irregular	26,285	48,290	544
Total	118,316	309,563	382

Source : Study Team

TABLE 5.5 BOD CONCENTRATION OF INDUSTRIAL SEWAGE

Sewerage Zone	BOD Load (kg/day)	Daily Average Flow (m3/day)	BOD Concentration (mg/l)
11 Dakar Port	14,634	15,351	953
12 Pikine Industrial	2,318	2,212	1,048
13 Tiaroye Industrial	8,569	8,791	974
Total	25,521	26,354	968

Source : Study Team

TABLE 5.6 WASTEWATER TREATMENT PLANTS AND CORRESPONDING SEWERAGE ZONES

WWTP	Sewerage Zone
1. Ouakam	Dakar(part), Ouakam
2. Camberene	Dakar(part), Parcelles Assainies, Grand Yoff, Hann, Pikine Regular, Guediawaye
3. Malika	Malika Housing Development
4. Mbao	Mbao Housing Development
5. Almadies	Almadies
6. Mbao Industrial	Dakar Port, Pikine Industrial, Tiaroye Industrial
7.Lac Warouwaye	Pikine Irregular

TABLE 5.7 PROPOSED WASTEWATER TREATMENT PLANT

Sewerage System	Location	Process*	Capacity (m3/day)
Ouakam	Ouakam	AS	85,400
Camberene	Camberene	AS	100,000
Malika	Malika	AS	22,500
Mbao	Mbao	AS	44,600
Almadies	Ngor	OD	4,200
Pikine Irregular	Lac Warouwaye	AS	63,600
Industrial	Mbao	AS	26,400

Note *AS = Activated Sludge
OD = Oxidation Ditch

TABLE 5.8 PROPOSED TRUNK SEWERS AND FORCE MAINS

items		DAKAR	CAMBERENE	MALIKA	MBAO	ALMADIES	OUAKAM	INDUSTRY	P.IRREGULAR	TOTAL
Trunk Sewer	350 mm diameter		210	1,030						1,240
	400 mm diameter		940							940
	450 mm diameter		630	1,150						1,780
	500 mm diameter		60			370				430
	600 mm diameter		2,440		3,000	1,600				7,040
	700 mm diameter	1,700	4,370	1,750	2,100	1,910		1,700	570	14,100
	800 mm diameter	2,100	540			1,090		2,700	980	7,410
(Concrete Pipe)	900 mm diameter	150	3,900			50		6,100	1,040	11,240
	1000 mm diameter		0		3,200				420	3,620
	1100 mm diameter		1,000						1,630	2,630
	1200 mm diameter		490						210	700
	1350 mm diameter		2,190						400	2,590
	1500 mm diameter		2,010						1,560	3,570
	1650 mm diameter		4,520							4,520
	Total	3,950	23,300	3,930	8,300	5,020	0	10,500	6,810	61,810
Force Main	150 mm diameter		430							
	200 mm diameter		3,530							
	250 mm diameter		2,500							2,500
	300 mm diameter					680				680
	350 mm diameter		2,380							
(Ductile Iron Pipe)	500 mm diameter								40	40
	600 mm diameter								170	170
	700 mm diameter			1,300					640	1,940
	800 mm diameter	1,300								1,300
	900 mm diameter		1,100							
	1000 mm diameter	4,000								4,000
	1350 mm diameter		1,100							1,100
	Total	5,300	11,040	1,300	0	680	0	0	850	19,170

TABLE 5.9 PROPOSED PUMPING STATIONS

Sewerage System	Zone	No.	Capacity (l/s)
Ouakam	Dakar	1	2,000
		2	650
		3	133
		4	67
Camberene	Guediawaye	1	133
		2	250
	Pikine Regular	3	750
	Hann	4	417
	Pacelles Assainies	5	144
Malika	Malika	1	500
Almadies	Almadies	1	83

TABLE 5.10 CONSTRUCTION COSTS OF INDUSTRIAL WASTEWATER TREATMENT PLANT (ON SITE)

Treatment Processes	Industry Type	Industrial Wastewater Quantity in 2010 (cu.m/d)	Unit Construction Cost (million CFA/cu.m/d)	Construction Cost in 2010 (million CFA)
Biological Tr. & Sedimentation	Fishing & Canning	3,486	0.44	1,534
	Beer, Beverage, Condensed Milk, others	3,217		1,416
	sub-total	6,703		2,950
Flotation & Biological Tr.	Cooking Oil, Slaughterhouse	4,289	1.22	5,232
Coagulation & Sedimentation	Textile	9,652	0.70	6,756
	Fertilizer	2,681		1,876
	sub-total	12,333		8,632
Flotation	Fuel	2,949	0.96	2,832
	Shipbuilding	536		514
	sub-total	3,485		3,346
Total		26,810	-	20,160

TABLE 5.11 UNIT CONSTRUCTION COST FOR TRUNK SEWERS

(unit: FCFA/m)

Diameter (mm)	Earth 1.0	Covering 3.0	(m) 6.0
300	117,500	305,500	(888,300)
500	235,000	376,000	(987,000)
800	352,500	423,000	(1,217,300)
1,500	376,000	N.A.	N.A.
2,000	582,800	N.A.	N.A.
2,500	658,000	N.A.	N.A.

Note : Figures in parentheses are driving method

TABLE 5.12 UNIT CONSTRUCTION COST FOR FORCE MAINS

Diameter (mm)	300	600	800
Unit Cost (FCFA/m)	141,000	323,000	526,000

TABLE 5.13 PROJECT COST FOR SEVEN SEWERAGE SYSTEMS (1)

(unit:1,000 FCFA)

Item	DAKAR	CAMBERENE	MALIKA	MBAO	ALMADIES	OUAKAM	INDUSTRY	P.IRREGULAR	TOTAL
I. Direct Construction Cost									
1. Sewer Network	2,616,633	21,946,680	6,155,050	9,527,075	2,887,573	976,268	3,052,493	13,049,295	60,211,067
2. Trunk Sewer									
350 (Concrete Pipe)	0	31,921	338,870	0	0	0	0	0	370,791
400 (Concrete Pipe)	0	212,199	0	0	0	0	0	0	212,199
450 (Concrete Pipe)	0	151,011	405,375	0	0	0	0	0	556,386
500 (Concrete Pipe)	0	14,280	0	0	86,950	0	0	0	101,230
600 (Concrete Pipe)	0	767,781	0	1,195,680	601,600	0	0	0	2,565,061
700 (Concrete Pipe)	1,156,200	1,983,834	740,250	888,300	807,930	0	359,550	398,338	6,334,402
800 (Concrete Pipe)	937,650	759,285	0	0	1,255,135	0	1,205,550	517,953	4,675,573
900 (Concrete Pipe)	222,075	1,805,439	0	0	65,800	0	2,867,000	587,872	5,548,186
1000 (Concrete Pipe)	0	0	0	1,579,200	0	0	0	204,674	1,783,874
1100 (Concrete Pipe)	0	423,000	0	0	0	0	0	815,424	1,238,424
1200 (Concrete Pipe)	0	1,217,394	0	0	0	0	0	109,388	1,326,782
1350 (Concrete Pipe)	0	1,128,444	0	0	0	0	0	207,612	1,336,056
1500 (Concrete Pipe)	0	1,180,875	0	0	0	0	0	1,349,020	2,529,895
1650 (Concrete Pipe)	0	5,981,690	0	0	0	0	0	0	5,981,690
sub-total	2,315,925	15,657,153	1,484,495	3,663,180	2,817,415	0	4,432,100	4,190,281	34,560,549
3. Force Main									
150 (Ductile Iron Pipe)	0	18,490	0	0	0	0	0	0	18,490
200 (Ductile Iron Pipe)	0	197,680	0	0	0	0	0	0	197,680
250 (Ductile Iron Pipe)	0	167,500	0	0	0	0	0	0	167,500
300 (Ductile Iron Pipe)	0	0	0	0	95,880	0	0	0	95,880
350 (Ductile Iron Pipe)	0	418,881	0	0	0	0	0	0	418,881
500 (Ductile Iron Pipe)	0	0	0	0	0	0	0	10,415	10,415
600 (Ductile Iron Pipe)	0	0	0	0	0	0	0	54,702	54,702
700 (Ductile Iron Pipe)	0	0	458,250	0	0	0	0	241,279	699,529
800 (Ductile Iron Pipe)	534,747	0	0	0	0	0	0	0	534,747
900 (Ductile Iron Pipe)	0	618,499	0	0	0	0	0	0	618,499
1000 (Ductile Iron Pipe)	2,083,040	0	0	0	0	0	0	0	2,083,040
1350 (Ductile Iron Pipe)	0	803,100	0	0	0	0	0	0	803,100
sub-total	2,617,787	2,224,150	458,250	0	95,880	0	0	306,396	5,702,463
4.Pumping Station									
No.1	4,698,750	1,566,250	2,506,000	0	1,096,375	0	0	563,850	10,431,225
N0.2	2,819,250	2,192,750	0	0	0	0	0	2,819,250	7,831,250
No.3	1,566,250	3,132,500	0	0	0	0	0	3,759,000	8,457,750
No.4	783,125	1,879,500	0	0	0	0	0	2,192,750	4,855,375
No.5	0	256,700	0	0	0	0	0	0	256,700
No.6	0	53,900	0	0	0	0	0	0	53,900
No.7	0	53,900	0	0	0	0	0	0	53,900
Replacement	0	130,999	0	0	0	0	0	0	130,999
sub-total	9,867,375	9,266,499	2,506,000	0	1,096,375	0	0	9,334,850	32,071,099

TABLE 5.13 PROJECT COST FOR SEVEN SEWERAGE SYSTEMS (2)

(unit:1,000 FCFA)

Item	DAKAR	CAMBERENE	MALIKA	MBAO	ALMADIES	OUAKAM	INDUSTRY	P.IRREGULAR	TOTAL
5.Treatment Plant	0	26,414,080	9,592,000	15,822,400	6,100,160	38,127,443	10,776,232	15,030,400	121,862,715
6. Ocean Outfall		709,060							709,060
total	17,417,720	76,217,622	20,195,795	29,012,655	12,997,403	39,103,711	18,260,825	41,911,222	255,116,953
II. Land Acquisition and Compensation									
Pumping Station	4,500	5,450	0	0	0	0	0	0	9,950
Treatment Plant	0	820,000	54,000	51,000	16,000	100,000	51,500	60,000	1,152,500
sub-total	4,500	825,450	54,000	51,000	16,000	100,000	51,500	60,000	1,162,450
III. Engineering Service	1,741,772	7,621,762	2,019,580	2,901,266	1,299,740	3,910,371	1,826,083	4,191,122	25,511,695
IV. Government Administration	261,266	1,143,264	302,937	435,190	194,961	586,556	273,912	628,668	3,826,754
V. Physical Contingency	1,741,772	7,621,762	2,019,580	2,901,266	1,299,740	3,910,371	1,826,083	4,191,122	25,511,695
VI. Project Cost	21,167,030	93,429,861	24,591,891	35,301,376	15,807,845	47,611,009	22,238,402	50,982,135	311,129,548

TABLE 5.14 COSTS FOR HOUSE CONNECTIONS

WWTP	Sewerage Zone	Cost (million FCFA)
1. Oukam	Dakar	2,616
	Ouakam	976
	Sub-total	3,592
2. Camberene	Dakar	-
	Parcelles Assainies	2,431
	Grand Yoff	3,740
	Hann	5,601
	Pikine Regular	2,689
	Guediawaye	1,122
	Sub-total	15,583
3. Malika	Malika Housing Development	6,155
4. Mbao	Mbao Housing Development	9,527
5. Almadies	Almadies	2,888
6. Lac Warouwaye	Pikine Irregular	13,049

TABLE 5.15 PROJECT COST UP TO 2010

(Unit: 1,000 FCFA)

Cost Item		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
I. Direct Construction Cost	L/C	77,295	77,295	392,043	326,769	912,263	1,108,498	1,572,211	1,992,675	1,858,659	3,038,942	2,241,568	1,388,053	393,268	160,136	676,999	676,999	16,893,673
	F/C	180,354	180,354	2,060,861	2,231,776	3,841,680	4,809,944	6,076,924	8,459,560	7,700,133	7,694,018	6,616,602	4,570,960	3,110,516	2,742,143	3,165,029	3,165,029	66,605,883
	Total	257,649	257,649	2,452,904	2,558,545	4,753,943	5,918,442	7,649,135	10,452,235	9,558,792	10,732,960	8,858,170	5,959,013	3,503,784	2,902,279	3,842,028	3,842,028	83,499,556
II. Land Acquisition and Compensation		0	0	250	50	0	550	820,700	0	1,600	1,000	800	0	0	1,700	0	0	826,650
III. Engineering Service	L/C	69,464	69,464	116,674	116,674	155,355	186,633	242,249	242,249	242,248	211,040	195,039	156,358	147,078	147,078	103,692	103,692	2,504,987
	F/C	162,084	162,084	272,239	272,239	362,496	435,478	565,247	565,247	565,246	492,426	455,090	364,834	343,181	343,181	241,948	241,948	5,844,968
	Total	231,548	231,548	388,913	388,913	517,851	622,111	807,496	807,496	807,494	703,466	650,129	521,192	490,259	490,259	345,640	345,640	8,349,955
IV. Government Administation		3,865	3,865	36,794	38,378	71,310	88,777	114,737	156,784	143,383	160,995	132,873	89,385	52,557	43,534	57,630	57,630	1,252,497
V. Physical Contingency		25,765	25,765	245,290	255,855	475,394	591,844	764,914	1,045,224	955,880	1,073,297	885,817	595,901	350,378	290,227	384,202	384,202	8,349,955
VI.Project Cost	L/C	176,389	176,389	791,051	737,726	1,614,322	1,976,302	3,514,811	3,436,932	3,201,770	4,485,274	3,456,097	2,229,697	943,281	642,675	1,222,523	1,222,523	29,827,762
	F/C	342,438	342,438	2,333,100	2,504,015	4,204,176	5,245,422	6,642,171	9,024,807	8,265,379	8,186,444	7,071,692	4,935,794	3,453,697	3,085,324	3,406,977	3,406,977	72,450,851
	Total	518,827	518,827	3,124,151	3,241,741	5,818,498	7,221,724	10,156,982	12,461,739	11,467,149	12,671,718	10,527,789	7,165,491	4,396,978	3,727,999	4,629,500	4,629,500	102,278,613

TABLE 5.16 ANNUAL OPERATION AND MAINTENANCE COST

Item	Quantity	Unit Cost (FCFA)	Cost (million FCFA/Year)
1. Sewer Pipes	13 persons	2,160,000/person	28
2. Pumping Stations			
Electricity	33,400,000 m3	4.66/m3	156
Repairing	Construction Cost x 0.5 %		46
Personnel	12 persons	2,160,000 /person	26
Sub-total			228
3. Treatment Plant			
Electricity	36,500,000 m3	22/m3	803
Chemicals	36,500,000 m3	1.5/m3	55
Repairing	Construction Cost x 0.5%		132
Personnel	50 persons	2,160,000/person	108
Sub-total			1,098
4. Overheads	75 persons	2,160,000/person	162
Total			1,516

TABLE 5.17 COST BENEFIT STREAMS (CASE 1)

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:FCFA Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	363	417	780	599	-182
2	1996	363	512	875	599	-276
3	1997	2187	607	2793	599	-2195
4	1998	2269	701	2970	832	-2139
5	1999	4073	796	4869	1158	-3711
6	2000	5055	891	5946	1578	-4368
7	2001	7110	1194	8304	3340	-4964
8	2002	8723	1289	10012	3576	-6436
9	2003	8027	1384	9410	3812	-5599
10	2004	8870	1478	10348	4048	-6300
11	2005	7369	1573	8942	4284	-4658
12	2006	5016	1668	6684	4520	-2163
13	2007	3078	1763	4840	4757	-84
14	2008	2610	1857	4467	4993	526
15	2009	3241	1952	5193	5229	36
16	2010	3241	2047	5287	5465	178
17	2011	0	2350	2350	10020	7670
18	2012	422	2350	2772	10020	7248
19	2013	361	2350	2711	10020	7309
20	2014	437	2350	2787	10020	7232
21	2015	454	2350	2804	10020	7216
22	2016	981	2350	3331	10020	6689
23	2017	981	2350	3331	10020	6689
24	2018	981	2350	3331	10020	6689
25	2019	1685	2350	4035	10020	5984
26	2020	1403	2350	3753	10020	6266
27	2021	1215	2350	3565	10020	6454
28	2022	746	2350	3096	10020	6924
29	2023	746	2350	3096	10020	6924
30	2024	1028	2350	3378	10020	6642
31	2025	1028	2350	3378	10020	6642
32	2026	1028	2350	3378	10020	6642
33	2027	422	2350	2772	10020	7248
34	2028	361	2350	2711	10020	7309
35	2029	437	2350	2787	10020	7232
36	2030	454	2350	2804	10020	7216
37	2031	981	2350	3331	10020	6689
38	2032	981	2350	3331	10020	6689
39	2033	981	2350	3331	10020	6689
40	2034	1685	2350	4035	10020	5984

TABLE 5.18 COST BENEFIT STREAMS (CASE 2)

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:FCFA Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	519	417	936	599	-337
2	1996	519	512	1031	599	-432
3	1997	3124	607	3731	599	-3132
4	1998	3242	701	3943	832	-3111
5	1999	5819	796	6615	1158	-5456
6	2000	7222	891	8112	1578	-6535
7	2001	10157	1194	11351	3896	-7455
8	2002	12462	1289	13750	4172	-9579
9	2003	11467	1384	12851	4447	-8403
10	2004	12672	1478	14150	4723	-9427
11	2005	10528	1573	12101	4998	-7102
12	2006	7166	1668	8833	5274	-3559
13	2007	4397	1763	6160	5549	-610
14	2008	3728	1857	5585	5825	240
15	2009	4630	1952	6582	6101	-481
16	2010	4630	2047	6676	6376	-300
17	2011	0	2350	2350	12752	10402
18	2012	422	2350	2772	12752	9980
19	2013	361	2350	2711	12752	10041
20	2014	437	2350	2787	12752	9965
21	2015	454	2350	2804	12752	9949
22	2016	981	2350	3331	12752	9422
23	2017	981	2350	3331	12752	9422
24	2018	981	2350	3331	12752	9422
25	2019	1685	2350	4035	12752	8717
26	2020	1403	2350	3753	12752	8999
27	2021	1215	2350	3565	12752	9187
28	2022	746	2350	3096	12752	9657
29	2023	746	2350	3096	12752	9657
30	2024	1028	2350	3378	12752	9375
31	2025	1028	2350	3378	12752	9375
32	2026	1028	2350	3378	12752	9375
33	2027	422	2350	2772	12752	9980
34	2028	361	2350	2711	12752	10041
35	2029	437	2350	2787	12752	9965
36	2030	454	2350	2804	12752	9949
37	2031	981	2350	3331	12752	9422
38	2032	981	2350	3331	12752	9422
39	2033	981	2350	3331	12752	9422
40	2034	1685	2350	4035	12752	8717

TABLE 5.19 COST BENEFIT STREAMS (CASE 3)

CC=Capital Costs; OM=O/M Costs; CS=Costs; BF=Benefits
CF=Cash Flow (=BF - CS)

(Unit:FCFA Million)

NO.	YEAR	CC	OM	CS	BF	CF
1	1995	0	417	417	599	182
2	1996	0	512	512	599	87
3	1997	0	607	607	599	-8
4	1998	0	701	701	832	130
5	1999	0	796	796	1158	362
6	2000	0	891	891	1578	687
7	2001	0	1194	1194	1948	754
8	2002	0	1289	1289	2086	797
9	2003	0	1384	1384	2224	840
10	2004	0	1478	1478	2361	883
11	2005	0	1573	1573	2499	926
12	2006	0	1668	1668	2637	969
13	2007	0	1763	1763	2775	1012
14	2008	0	1857	1857	2912	1055
15	2009	0	1952	1952	3050	1098
16	2010	0	2047	2047	3188	1141
17	2011	0	2350	2350	3643	1293
18	2012	422	2350	2772	3643	872
19	2013	361	2350	2711	3643	933
20	2014	437	2350	2787	3643	856
21	2015	454	2350	2804	3643	840
22	2016	981	2350	3331	3643	313
23	2017	981	2350	3331	3643	313
24	2018	981	2350	3331	3643	313
25	2019	1685	2350	4035	3643	-392
26	2020	1403	2350	3753	3643	-110
27	2021	1215	2350	3565	3643	78
28	2022	746	2350	3096	3643	548
29	2023	746	2350	3096	3643	548
30	2024	1028	2350	3378	3643	266
31	2025	1028	2350	3378	3643	266
32	2026	1028	2350	3378	3643	266
33	2027	422	2350	2772	3643	872
34	2028	361	2350	2711	3643	933
35	2029	437	2350	2787	3643	856
36	2030	454	2350	2804	3643	840
37	2031	981	2350	3331	3643	313
38	2032	981	2350	3331	3643	313
39	2033	981	2350	3331	3643	313
40	2034	1685	2350	4035	3643	-392

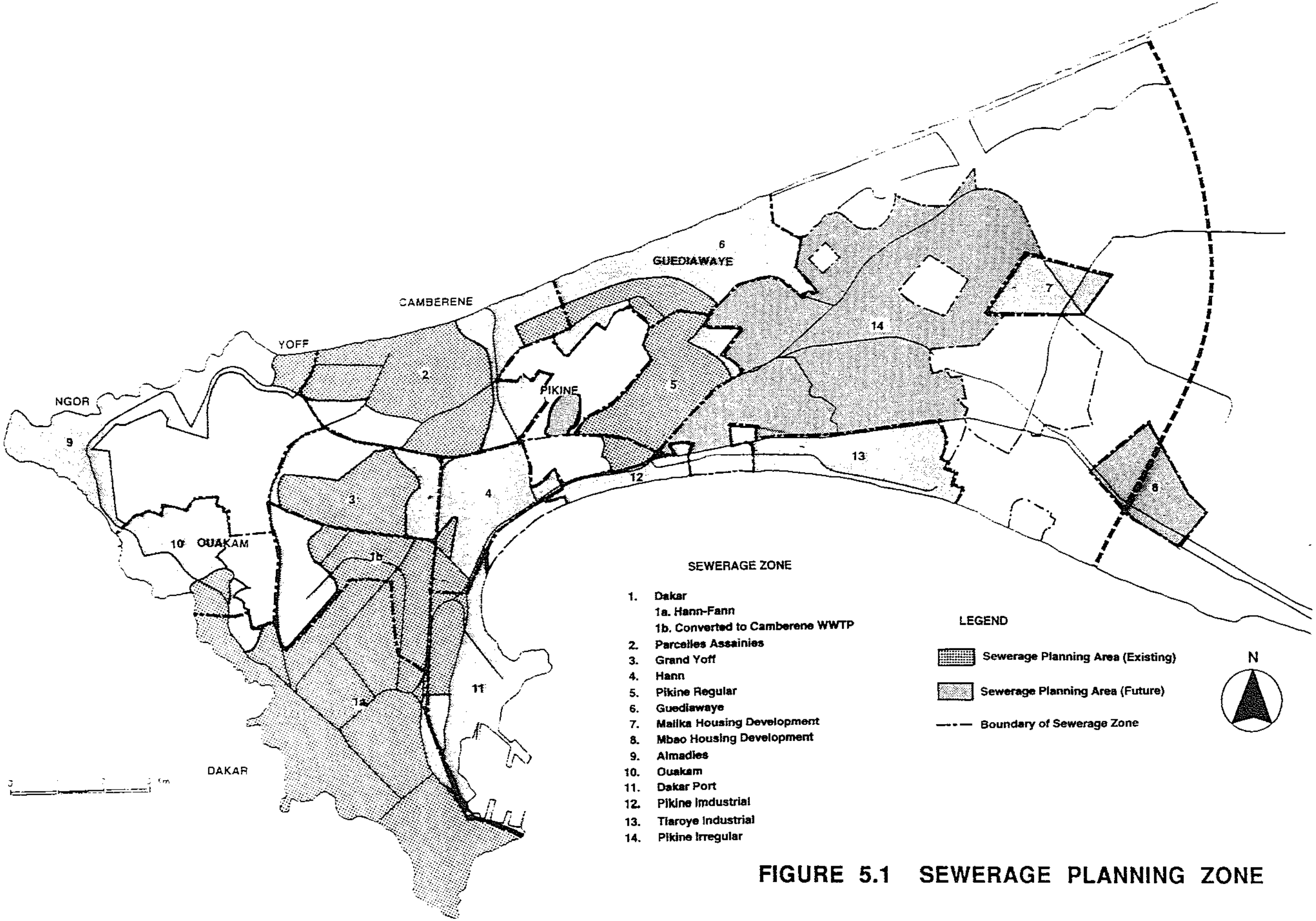


FIGURE 5.1 SEWERAGE PLANNING ZONE

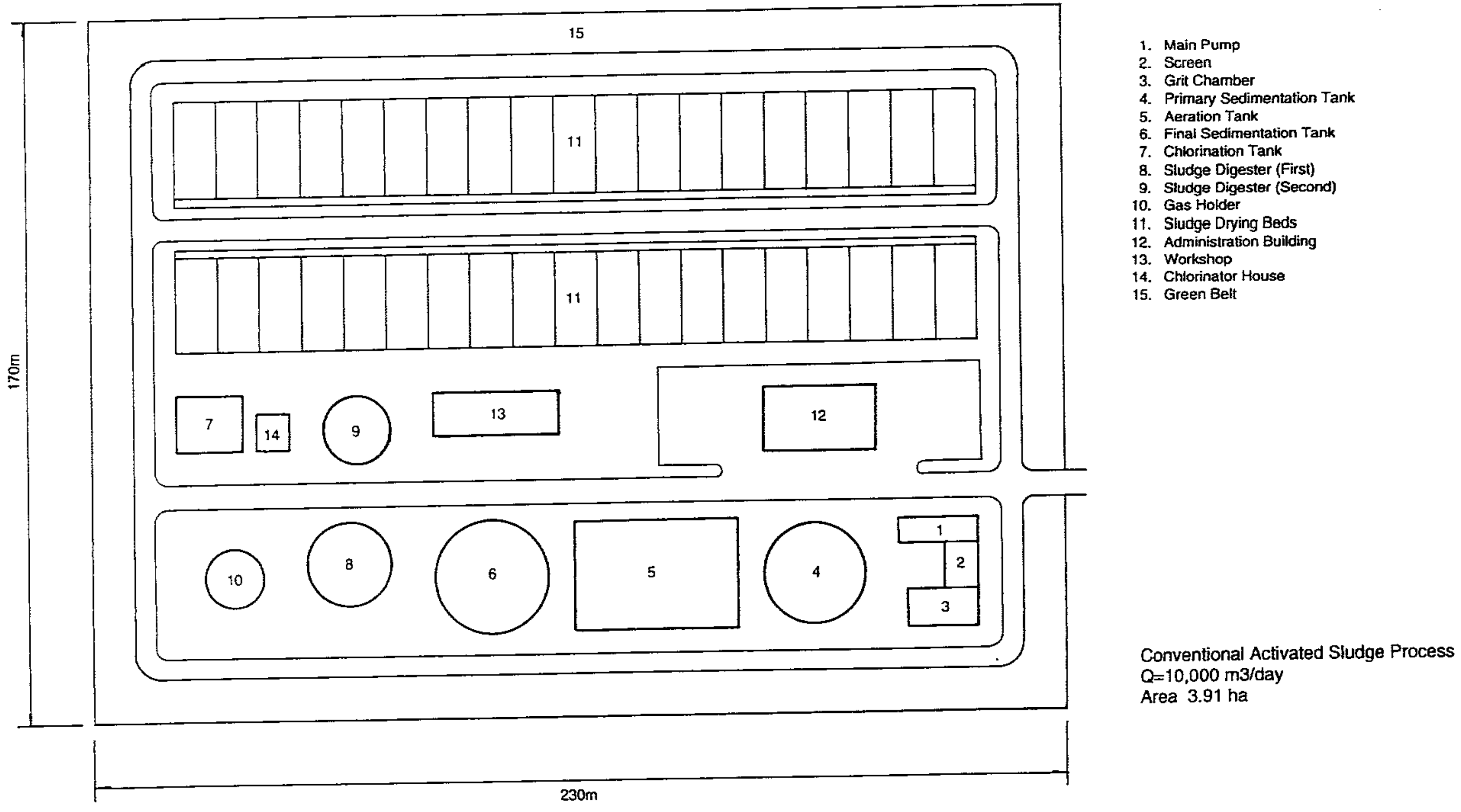
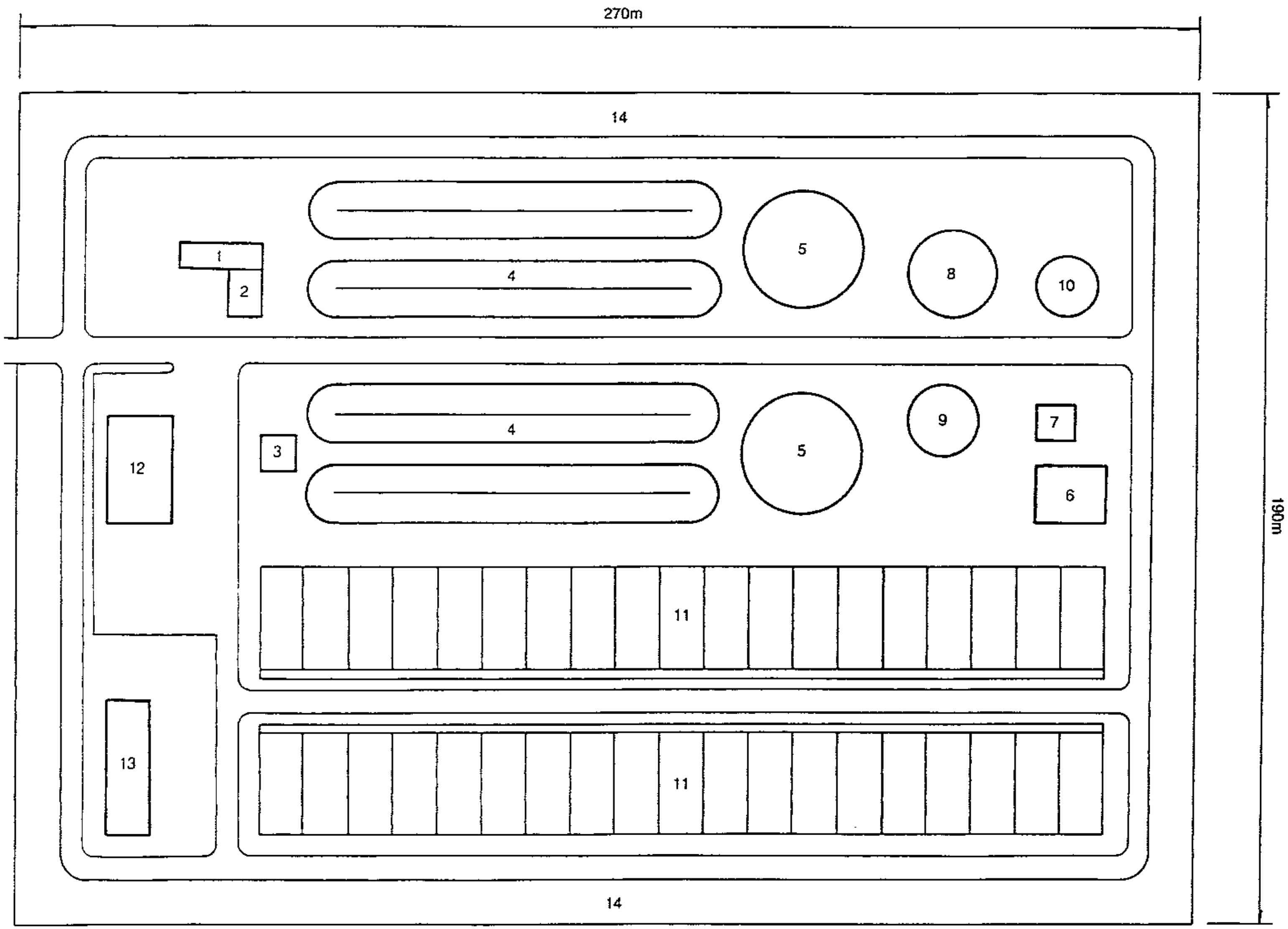


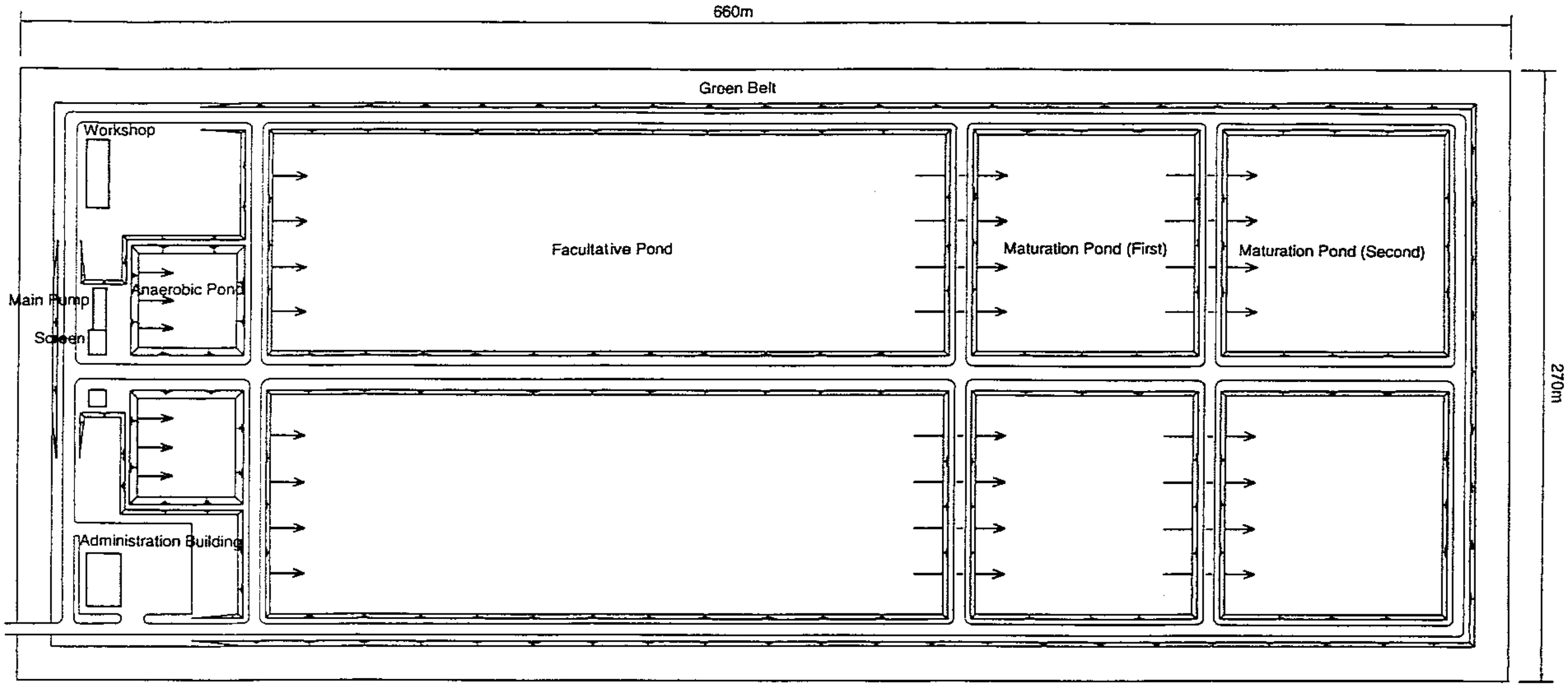
FIGURE 5.2 GENERAL PLAN OF TREATMENT PLANT (CONVENTIONAL ACTIVATED SLUDGE PROCESS)



1. Main Pump
2. Screen
3. Distribution Tank
4. Oxidation Ditch
5. Final Sedimentation Tank
6. Chlorination Tank
7. Chlorination House
8. Sludge Digester (First)
9. Sludge Digester (Second)
10. Gas Holder
11. Sludge Drying Beds
12. Administration Building
13. Workshop
14. Green Belt

Oxidation Ditch Process
Q=10,000 m3/day
Area 5.13 ha

FIGURE 5.3 GENERAL PLAN OF TREATMENT PLANT (OXIDATION DITCH)



Oxidation Pond Process
Q=10,000 m3/day
Area 17.82 ha

FIGURE 5.4 GENERAL PLAN OF TREATMENT PLANT (OXIDATION POND)

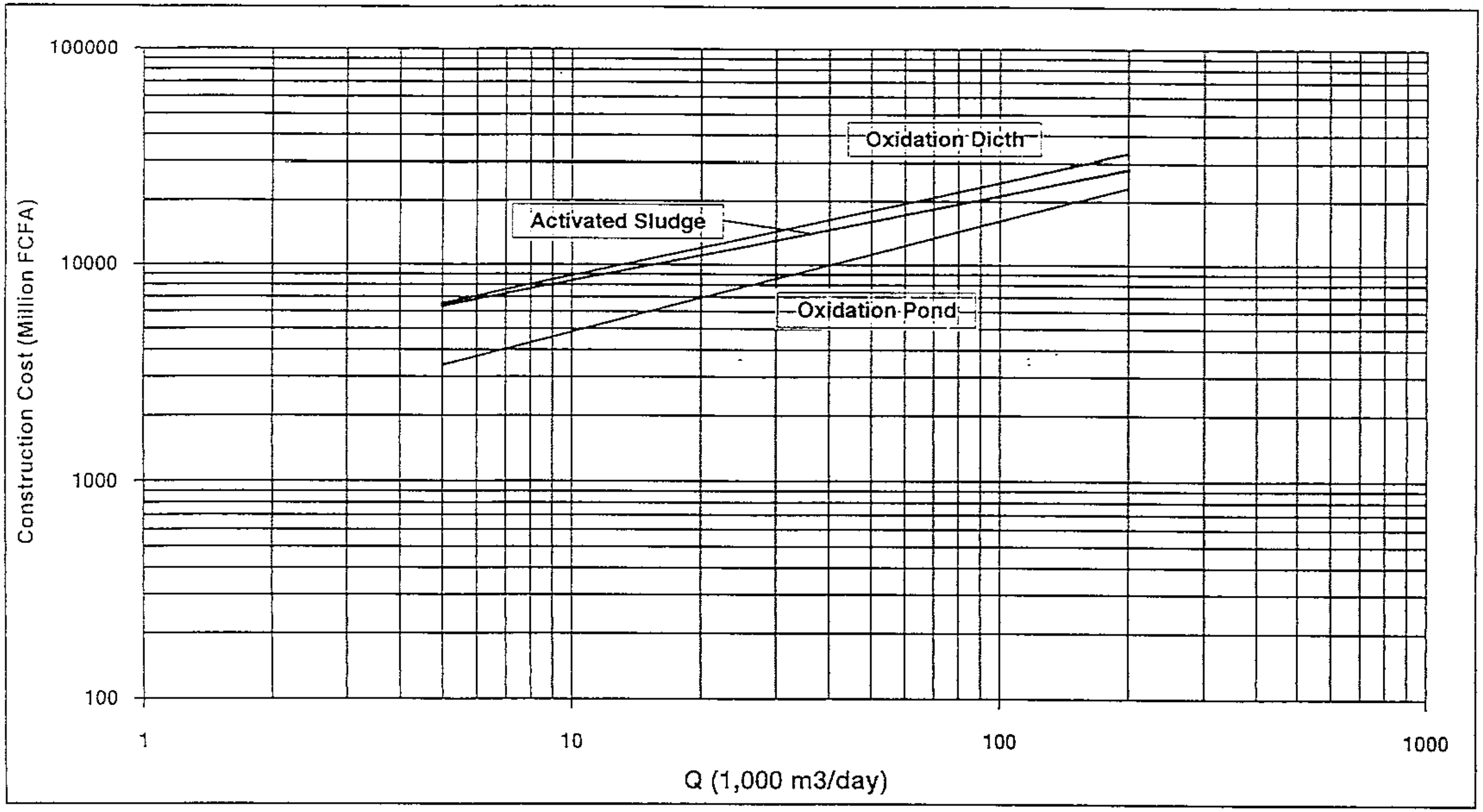


FIGURE 5.5 COST FUNCTIONS

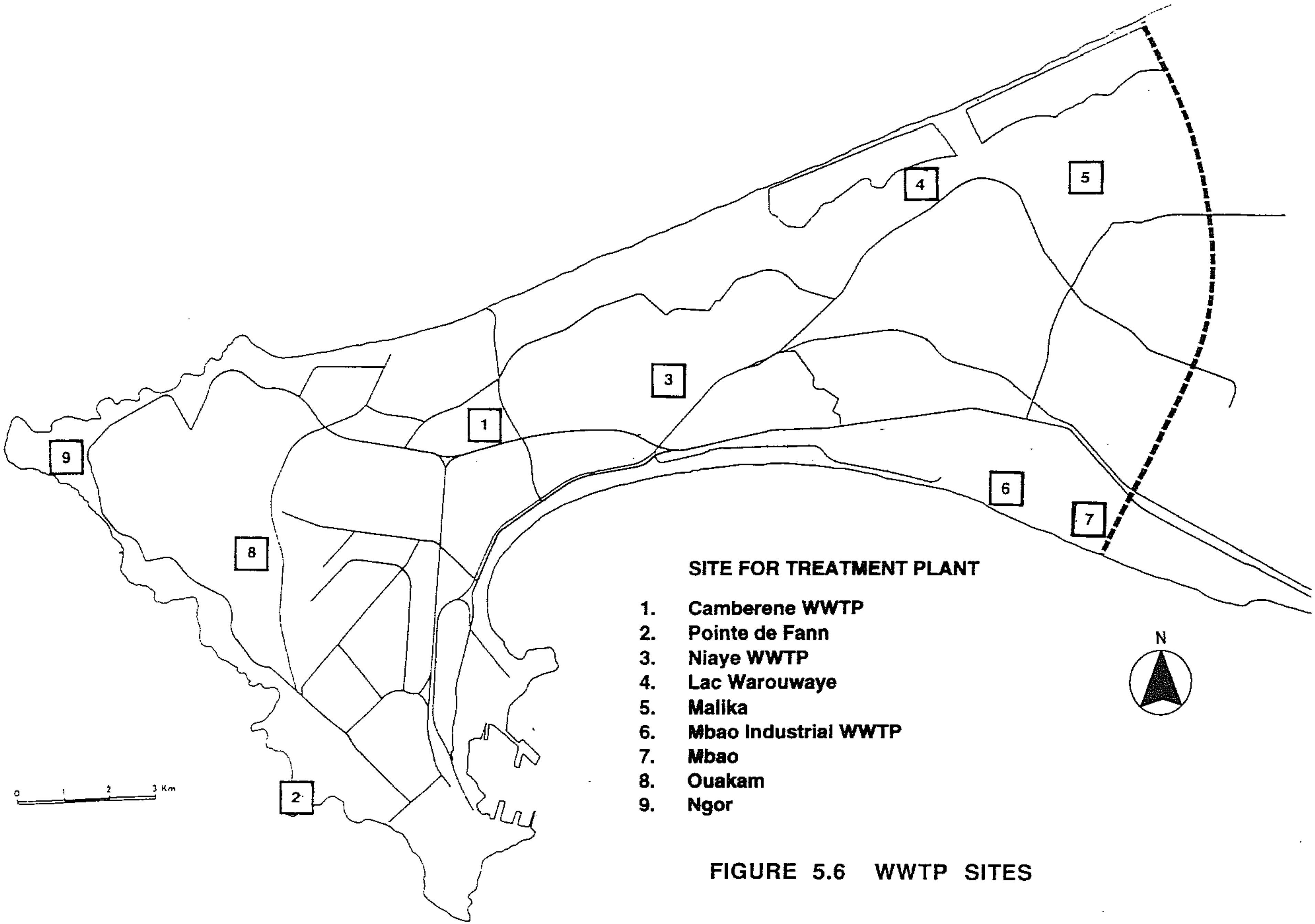


FIGURE 5.6 WWTP SITES

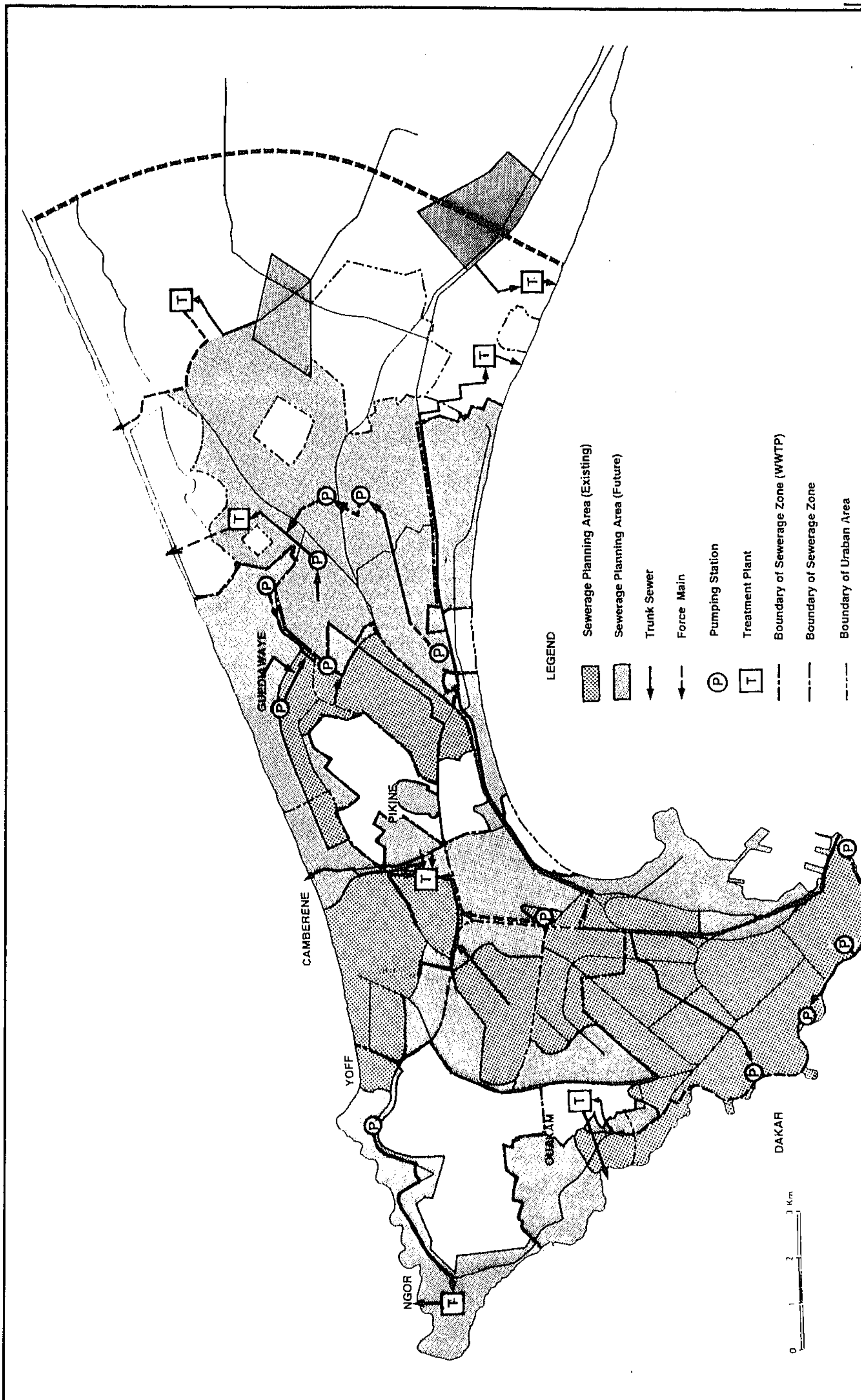
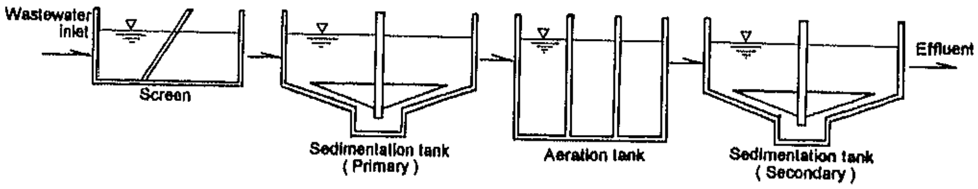
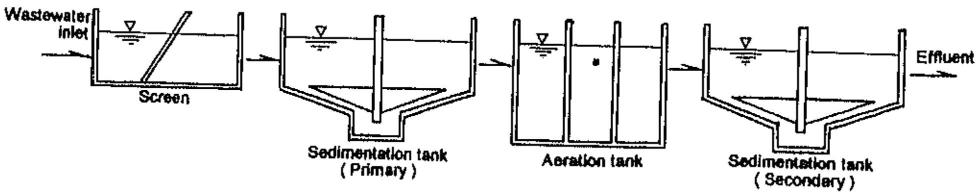


FIGURE 5.7 PROPOSED SEWERAGE SYSTEM

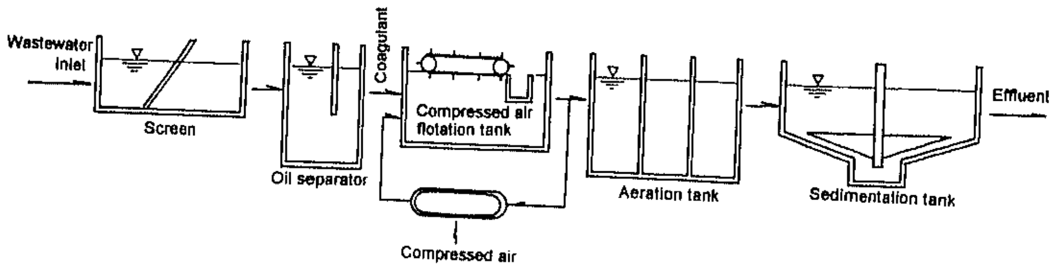
Fishing & Canning (Biological Treatment & Sedimentation)



Beer, Beverage, Condensed Milk (Biological Treatment & Sedimentation)



Cooking Oil (Flotation - Biological Treatment & Sedimentation)



Textile (Coagulation & Sedimentation)

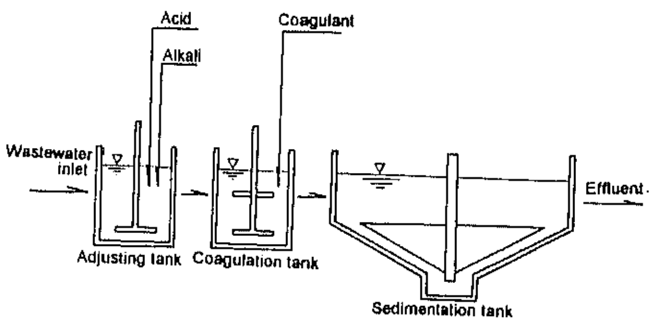
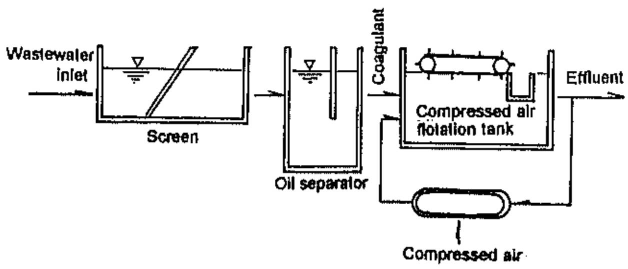
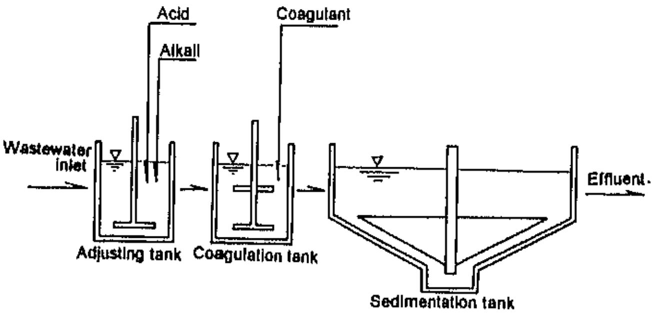


FIGURE 5.8 TYPICAL TREATMENT PROCESS FOR INDUSTRIAL WASTEWATER (1)

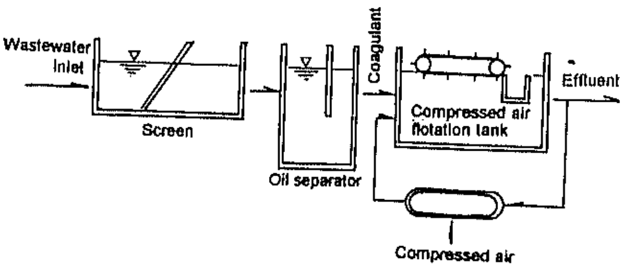
Fuel (Flotation)



Fertilizer (Coagulation & Sedimentation)



Shipbuilding (Flotation)



Slaughterhouse (Flotation - Biological Treatment & Sedimentation)

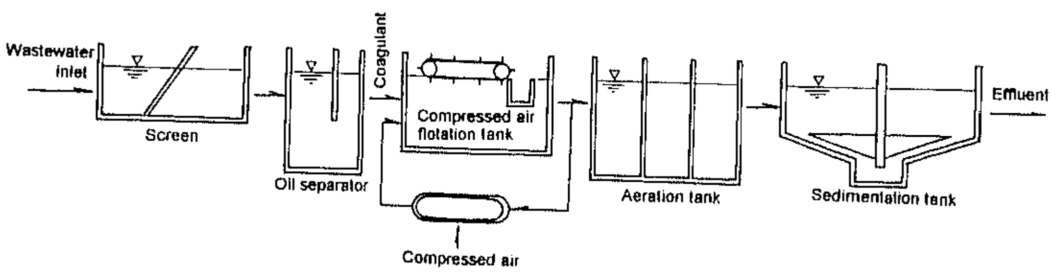


FIGURE 5.8 TYPICAL TREATMENT PROCESS FOR INDUSTRIAL WASTEWATER (2)

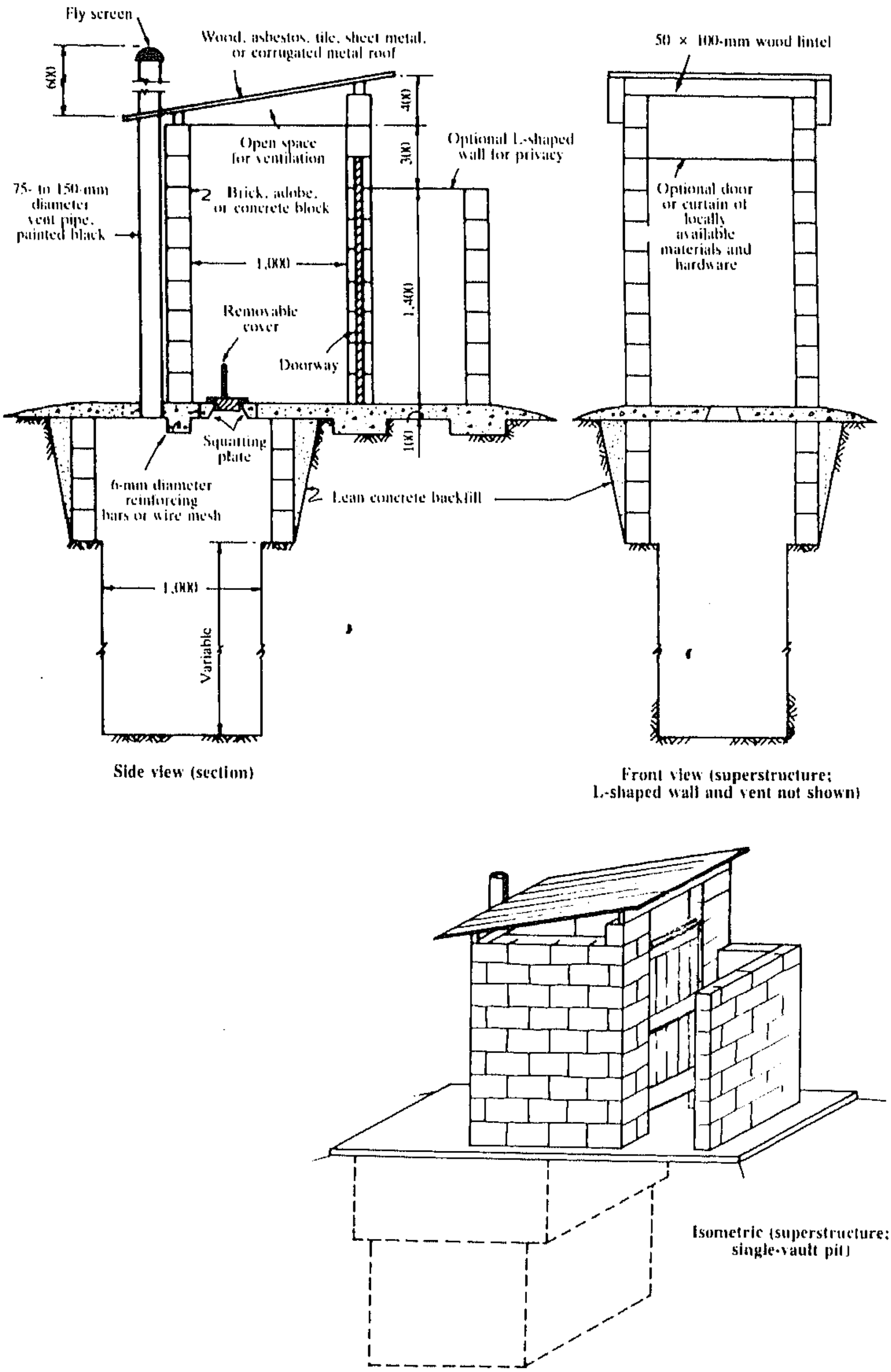


FIGURE 5.9 AN EXAMPLE OF FLY FREE, SMELL FREE TOILET

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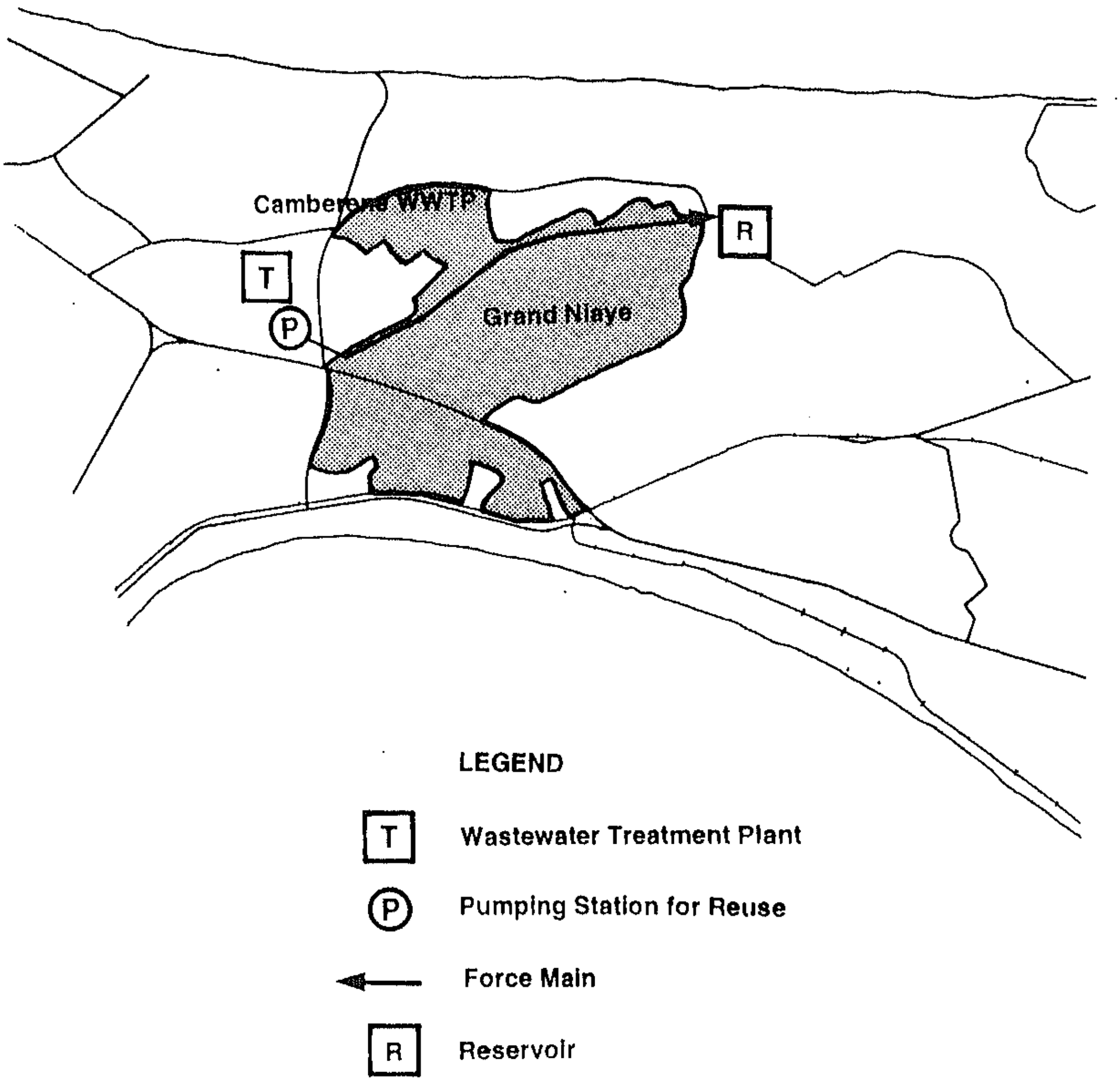

FIGURE 5.10 FACILITY PLAN OF REUSE (IRRIGATION)

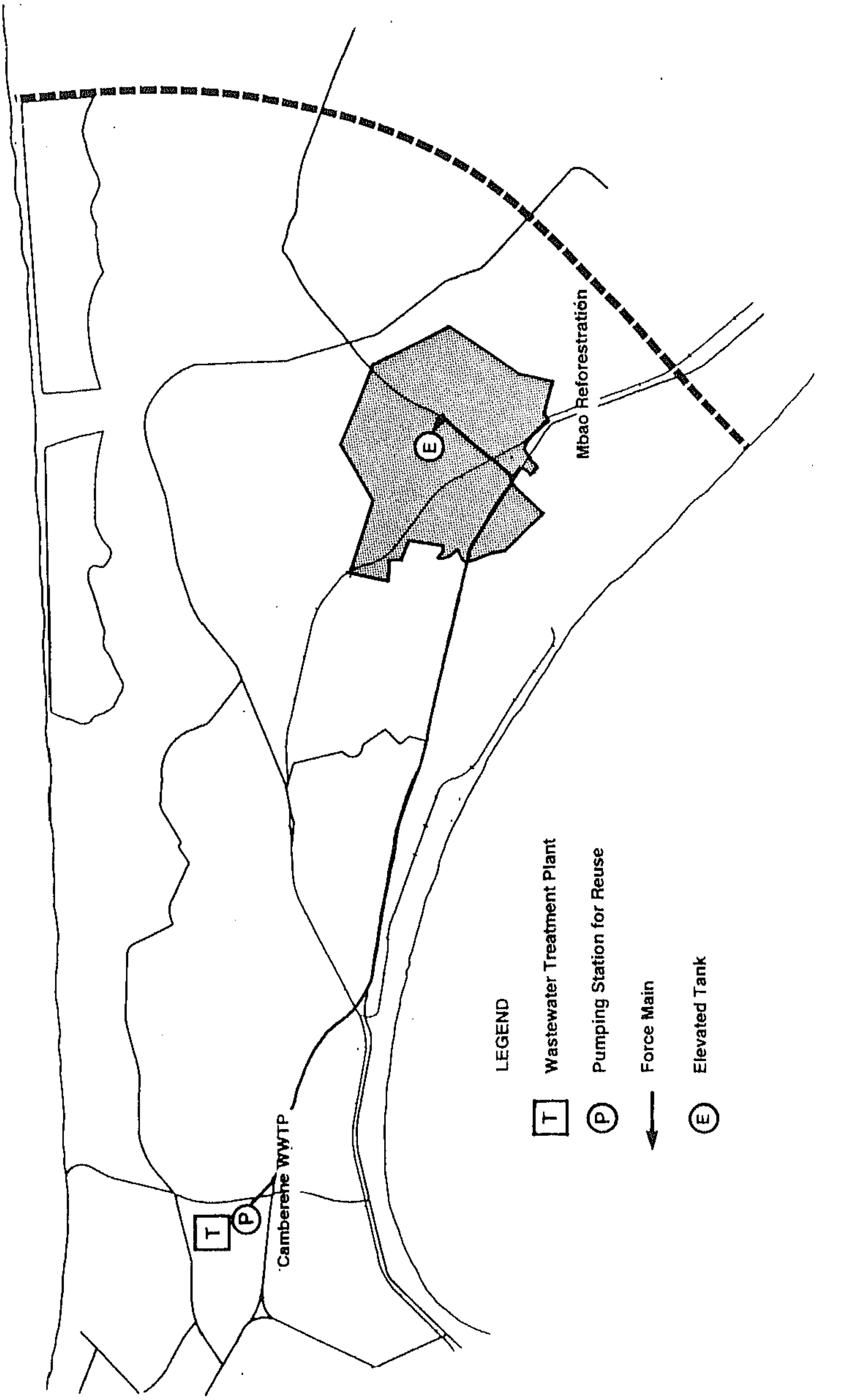

FIGURE 5.11 FACILITY PLAN OF RE USE (REFORESTATION)

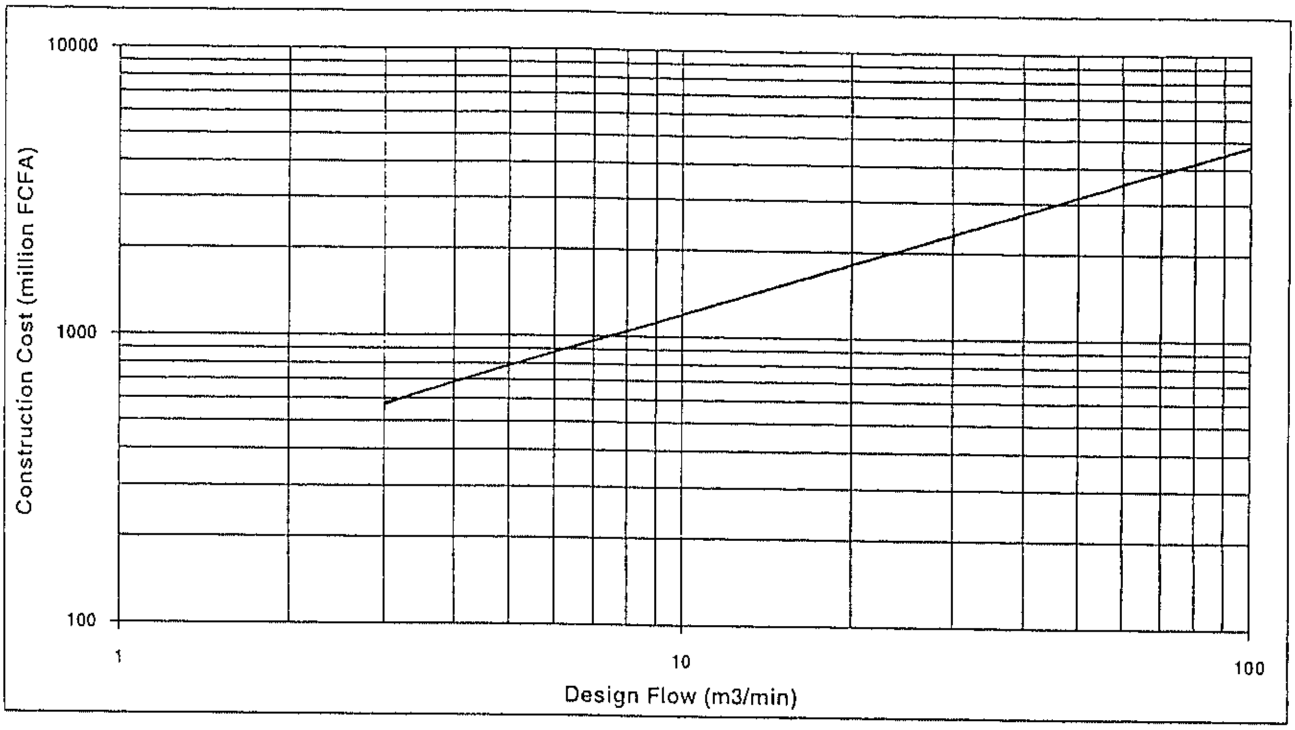

FIGURE 5.12 CONSTRUCTION COST FOR PUMPING STATION

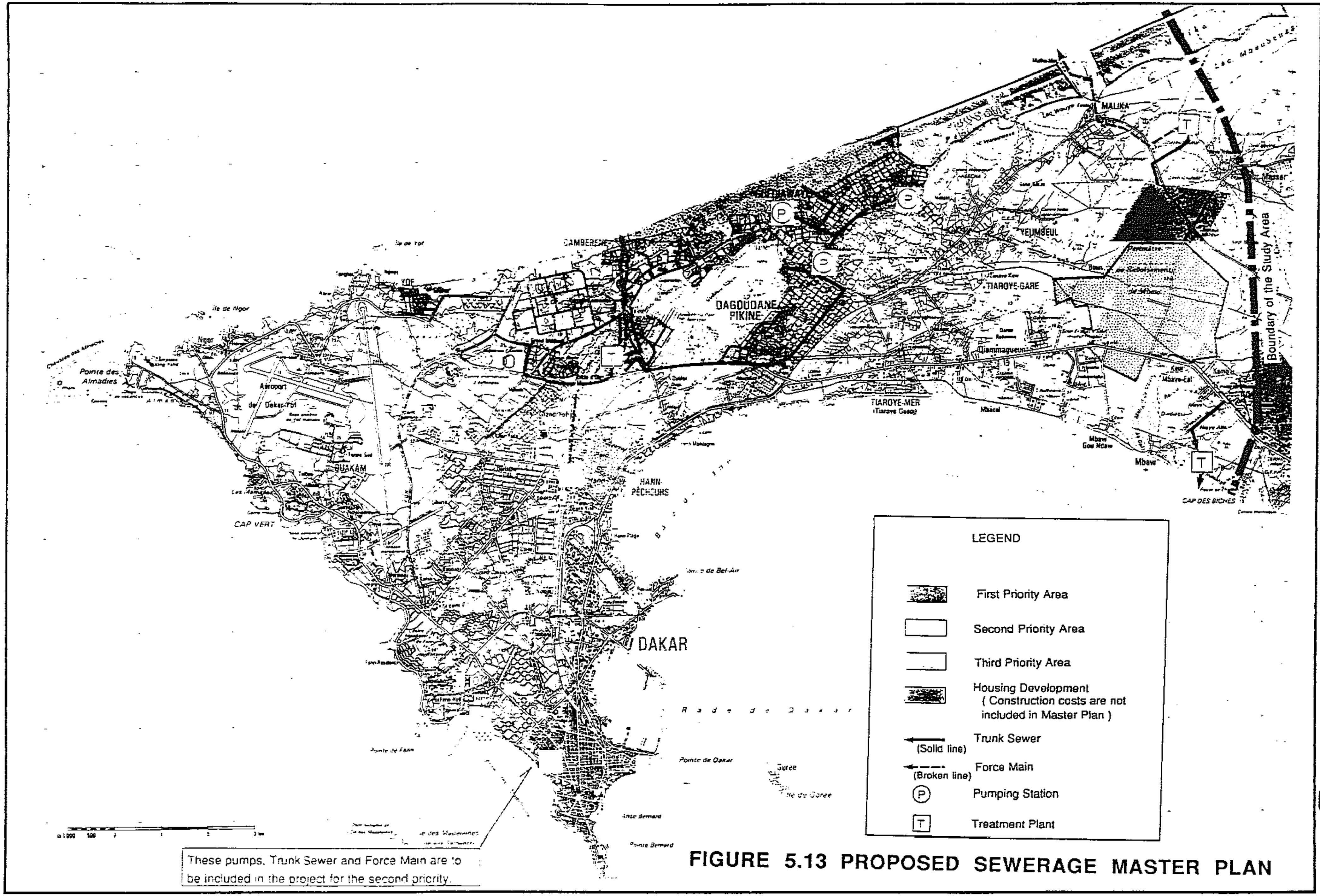

FIGURE 5.13 PROPOSED SEWERAGE MASTER PLAN

FIGURE 5.14 IMPLEMENTATION SCHEDULE

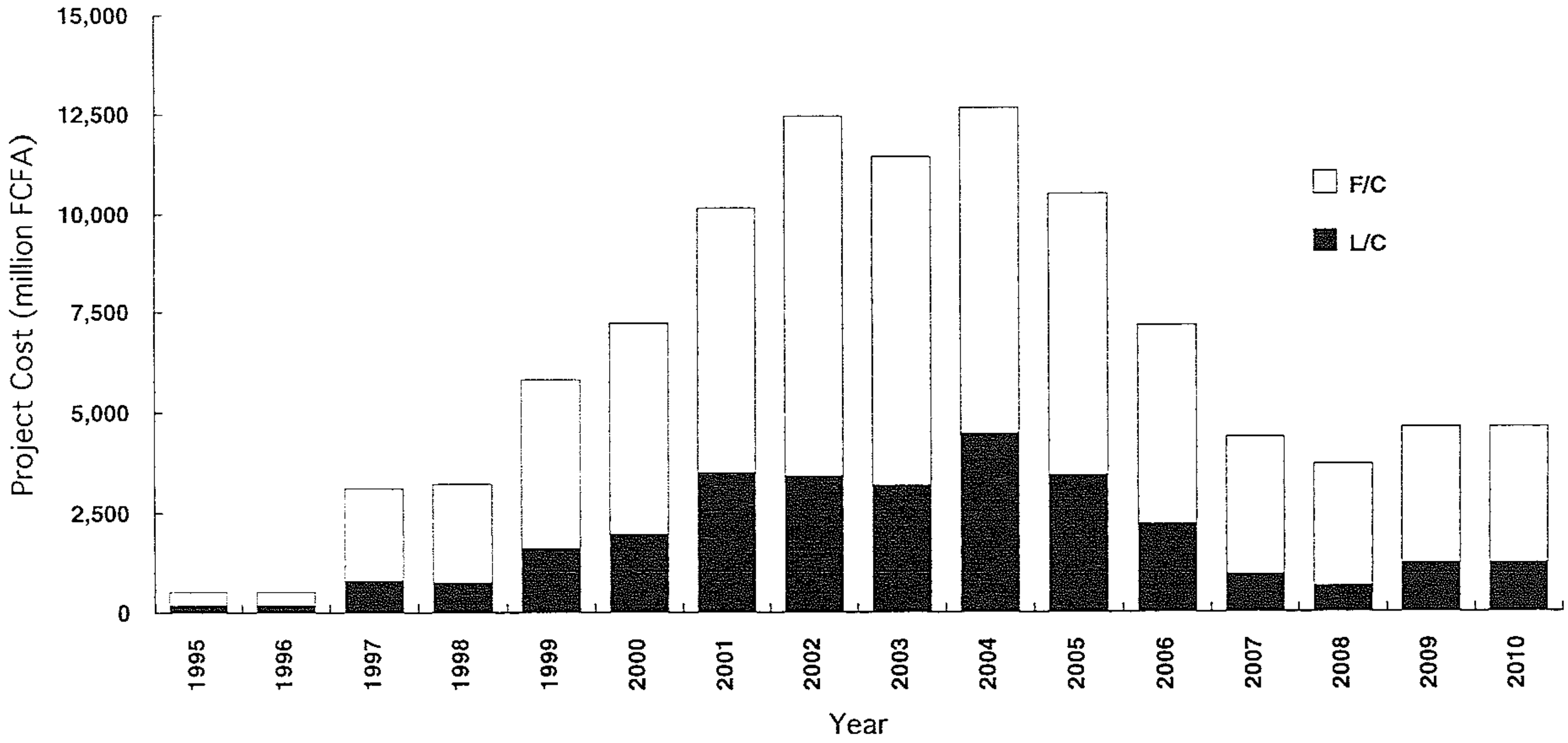

FIGURE 5.15 PROJECT COSTS UP TO 2010

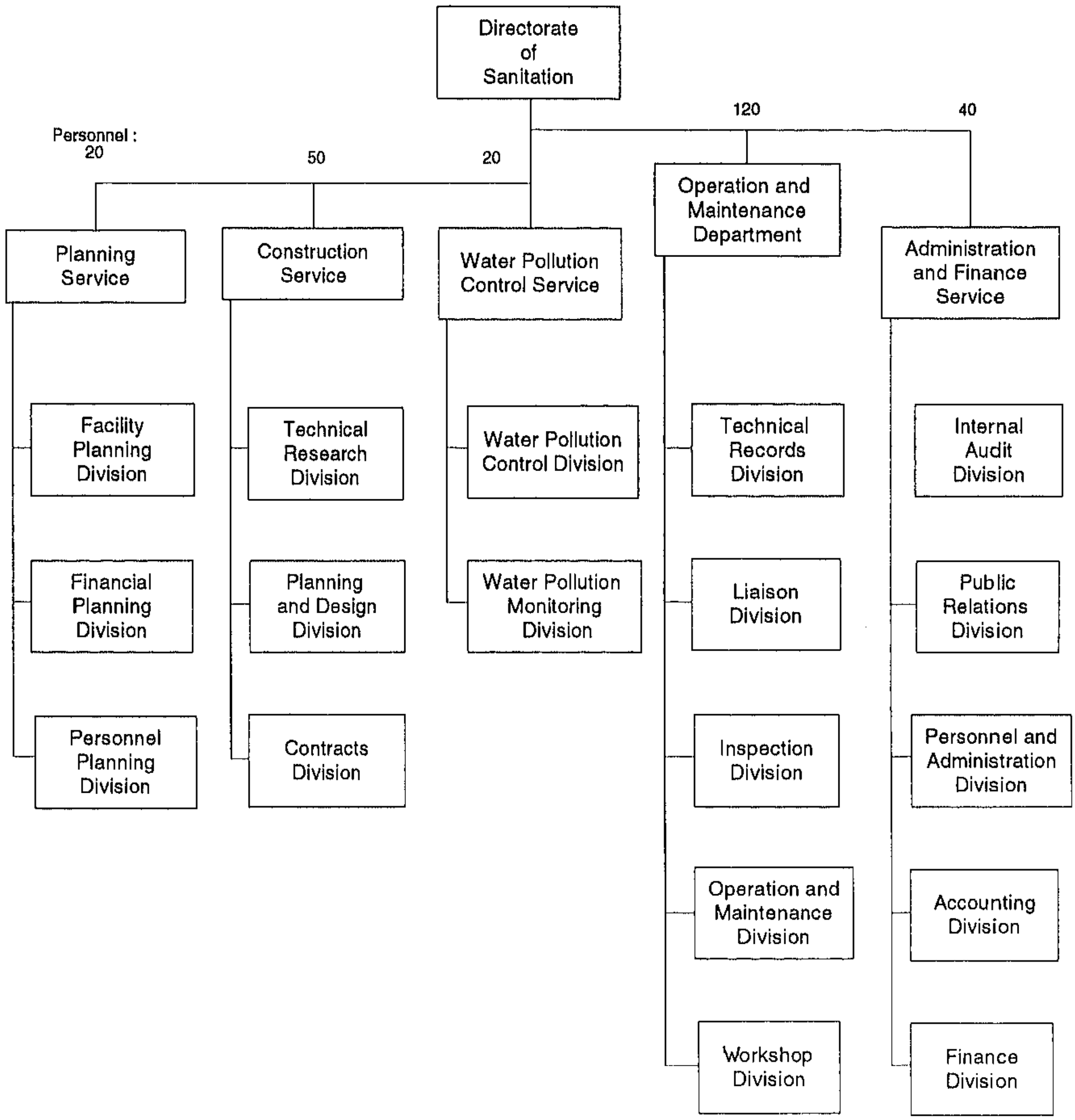

FIGURE 5.16 PROPOSED ORGANIZATIONAL STRUCTURE FOR SANITATION SECTOR FOR SONEES MODIFICATION OF NEW ORGANIZATION

CHAPTER 6

FEASIBILITY STUDY ON THE WASTEWATER PRIORITY PROJECT

CHAPTER 6 FEASIBILITY STUDY ON THE WASTEWATER PRIORITY PROJECT

6.1 PROJECT AREA

6.1.1 Feasibility Study Area

The feasibility study area for the wastewater priority project was selected under the Master Plans, and it is Parcelles Assainies and its surroundings sewerage zone which is shown in *Figure* 6.1. The study area is one of the sewerage zones of the Camberene sewerage system.

As shown in the figure, the zone is divided into 14 subzones taking into account the service areas of the existing pumping stations and development conditions.

Three areas, viz. Cemetery (Unit 39), Grand Niaye and Grand Medina (Unit 42) are excluded from the sewerage service area because the first two areas are open space and generate no wastewater and Grand Medina is a spontaneous irregular housing area where conventional sewer system can not be constructed. Nevertheless, a part of wastewater from Grand Medina is taken into account in the preliminary designing of sewerage facilities because small bore sewer system can be applied in the area in the future.

The project area for the sewerage project totals 820 ha, and areas of the subzones are as follows.

No.	Name of Subzones	Area (ha)
1	P.A. P/S Unite 2	69
2	P.A. P/S Unite 7	55
3	P.A. P/S Unite 9	19
4	P.A. P/S Unite 13	64
5	P.A. P/S Unite 17	6
6	P.A. P/S Unite 15	130
7	P.A. P/S Unite 22	19
8	P.A. P/S Unite 23	26
9	North to Stadium	57
10	Djily Mbaye P/S	46
11	Nord Foire	129
12	Stadium	92
13	Patte d'Oie	80
14	East to Patte d'Oie	28
Total		820

6.1.2 Existing Sewer Networks

At present, provision of sewer networks in subzones varies greatly. There are sewer networks in all subzones in Pacelles Assainies except North to Stadium subzone, although they are rather thinly provided and connection ratio is as low as 25 % on an average.

In Djily Mbaye subzone, all the houses are connected to the sewer networks although development is now progressing and many houses are yet to be constructed. All wastewater in this subzone is collected to the existing Djily Mbaye pumping station at the lowest point. Wastewater from undeveloped areas can naturally be collected to the pumping station by sewer networks which are to be provided by the developer.

Patte d'Oie subzone has been fully developed and sewered. There is no pumping station and all wastewater is collected by gravity sewers and connected to the main collector along the Autoroute.

There are no sewer networks in the three new development subzones, viz. Nord Foire, Stadium and East to Patte d'Oie.

6.2 SEWERAGE PLANNING

6.2.1 Basis for Sewerage Planning

Basis for the sewerage planning, such as limits of the sewerage service area, development plans, and criteria for planning and preliminary design, has been established through discussions with Senegalese counterpart staff and various agencies concerned.

It was found that sewer networks can not be planned in the three new development subzones because detailed road network plan is not available. Even the development plan for the Nord Foire subzone can not be used for the planning purpose. However, wastewater flows from the three subzones are taken into account in the preliminary design of the major sewerage facilities, such as secondary collectors and wastewater treatment plant because these should be accommodated by the proposed facilities in the future.

The sewerage facilities proposed in this chapter, therefore, have enough capacities to collect, treat and dispose all the wastewater flow envisaged in the study area in 2010.

6.2.2 Wastewater Flow

Populations and wastewater flow of the study area at present (1993) and in 2010 projected under the Master Plan are as follows.

Year:	1993	2010
Population:	159,618	260,696
Sewered Population:	51,306	167,237
Connection Ratio (%):	32.1	64.1
Wastewater Flow (m^3/day):		
Actual (Collected by sewerage):	3,169	23,946
Total (Generated):	11,360	39,383
Peak Flow (Generated):	22,720	78,762

For the design of sewer pipes and pumping stations, total wastewater flow (peak flow) which is generated in an area is used, while actual wastewater flow which is considered to be actually collected by the sewerage system in 2010 is used for treatment plant design.

Wastewater flow in 2010 presented above include the flow from the small bore sewerage systems in two neighboring areas, viz. Grand Medina and Camberene village. Although small bore sewer system is not planned in the study, wastewater flow can readily be accepted to the nearest sewer networks in the sewerage service area.

For the design of sewer pipes and pumping stations, the peak flow is used. The following unit flow is calculated to be used for this purpose.

Unit wastewater flow for sewer pipe and pumping station design:

$$78{,}762 / 820 = 96.1 \text{ (m}^3\text{/day/ha)}$$
$$\text{(0.00111 m}^3\text{/sec/ha)}$$

For the design of the wastewater treatment plant, the actual flow of the daily average basis is used. Wastewater flow in the study area will increase from 3,169 m^3/day in 1993 to 23,946 m^3/day, i.e. an increment of 20,777 m^3/day. Taking the existing design capacity of and wastewater flow to the Camberene WWTP into account, additional two process trains will be required to treat increased wastewater flow.

6.2.3 Wastewater Treatment and Disposal

Wastewater from the sewerage zone is to be treated at the Camberene WWTP. The existing facilities have been put into operation in 1989. The plant is designed as biological secondary treatment by the activated sludge process with sludge treatment by anaerobic digestion and sand drying beds. The treated effluent is disinfected by chlorination and pumped through a force main and finally discharged to the sea at Camberene village.

The same treatment and disposal system should be adopted for the proposed system from public health and environmental protection view point. Although facilities for the reuse of the treated effluent is not planned in the study, this should be considered in the future.

6.3 FACILITIES PLANNING

6.3.1 Basic Concept for Facilities Planning

The following two notions are considered as a basic concept for the sewerage facilities planning.

- Existing facilities should be utilized to the maximum extent possible
- New facilities should be the most economical ones

There exists following sewerage facilities in the zone. Although some of them cause occasional problems, they are generally functioning properly. Therefore, the existing facilities should be used as long as they do not conflict with the proposed system for the economy of the project.

Existing Sewerage Facilities

- Sewer networks in many subzones
- Nine pumping stations
- A gravity collector along the Autoroute
- Camberene WWTP including a force main and a gravity pipe for effluent discharge

6.3.2 Examination of the Existing Facilities

1) Existing Gravity Collector along the Autoroute to the Camberene WWTP

Downstream sections of the existing gravity collector along the Autoroute from the Camberene WWTP to the neighborhood of Grand Medina, the length 2,463 m, was found to have the smallest capacity of 1.072 m^3/sec in the upper most section and considered to have sufficient capacity.

2) Branch Sewers

The capacity of the existing sewer networks in the area was examined by using the unit flow rate mentioned above and some sections were found to be of short capacity. Improvement of the existing sewer pipes is, therefore, one of the important factors in the preliminary designing of the proposed system.

3) Pumping Stations

There are nine (9) pumping stations in Parcelles Assainies and a neighborhood area. Pumping stations form a network system as schematically shown in *Figure 6.2* and can be said to be a relay system. This system causes overload problem to two pumping stations. In addition, this system is regarded as wasteful system from energy consumption view point.

In addition, the capacity of most pumping stations do not match the design wastewater flow in future as shown below:

Pumping Station	A: Existing Capacity (l/s)	B: Design Flow (l/s)	B/A
P/S Unite 15	20	144	7.20
P/S Unite 17	5	6	1.20
P/S Unite 22	21	21	1.00
P/S Unite 13	53	71	1.34
P/S Unite 9	15	21	1.40
P/S Unite 7	24	61	2.54
P/S Unite 2	16	76	4.75
P/S Unite 23	12	28	2.33
P/S Djily Mbaye	35	51	1.46

Therefore, re-arrangement of pumping stations including necessary new pumping stations together with determination of the capacity to match the design flow is an important factor in the facility planning. This will be discussed as alternatives for the sewerage system in the later section.

4) Wastewater Treatment Plant

There is one process train of which capacity is 9,600 m^3/day on daily average basis with raw sewage BOD and SS concentrations of 625 mg/l and 938 mg/l respectively.

Design parameters of the main facilities for the original design (9,600 m^3/day) was compared with the current design (10,000 m^3/day) and the design parameters of these facilities for the current design were found to be still within the normal range.

Therefore, it is considered desirable that the design of the additional two process trains is the same as that of the existing facilities, taking into account advantages such as ease of operation, interchangeable spareparts and so on.

Civil structures of some facilities, including main pump house, grit chamber, and chlorination tank have been constructed to accommodate the flow from the second stage digester (additional 9,600 m^3/day). The second stage sludge digester also has enough capacity to receive digested sludge from two first stage digesters. These should be utilized with the necessary modification or provision of mechanical and electrical equipment.

5) Force Main and Gravity Pipe for Effluent Discharge

There exists a force main and a gravity pipe with diameter 600 mm from the Camberene WWTP to the ocean outfall for effluent discharge. The lengths of force main and gravity pipe are approximately 900 m and 1,800 m respectively.

The capacity of the force main has been examined. It was revealed that the force main has enough capacity for the peak flow from the two process trains, i.e. approximately 40,000 m^3/day. However, the capacity is not enough for the peak flow from the three process trains, i.e. approximately 60,000 m^3/day. Higher velocity, approximately 2.5 m/sec, results in excess pumping head. Therefore, an additional force main is needed when the third train is put into operation.

6.3.3 Proposed Sewerage System

1) Pumping Station System

To avoid the relayed transmission of the wastewater by several pumping stations and to provide for the increase of the wastewater flow in future, a new pumping station system as shown in *Figure 6.3* is proposed. In the new system all pumping stations except P/S Unite 15, pump wastewater of their own service area to trunk sewers.

In addition to the three new pumping stations proposed, at least one new pumping station will be needed in Nord Foire to connect to the new collector because of the topography. Since its location can not be determined at present, therefore, its construction is not included in construction program.