SUPPORTING REPORT B

SEWAGE TREATMENT FACILITY PLAN

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1. EXISTING SITUATION OF SEWERAGE AND SANITARY FACILITIES

1.1 Introduction

The construction of sewerage facilities in the RMR was started at the old center of Recife in the beginning of the 1900s. Most of current sewerage facilities were constructed between the 1950s and the 1980s and managed by COMPESA since the beginning of the 1980s, along with the inauguration of the national sewerage and sanitation policy in Brazil.

Although the State Government and the municipal governments had prepared a number of sewerage development plans up to now, large-scale investments have not been made in the RMR since the middle of 1980s, except for a limited number of small-scale systems. Thus, most populations are forced to rely on individual and precarious sanitary facilities at present. The findings on the current status of sewerage facilities and sanitation in the RMR are described below.

1.2 Present Sewerage Facilities

Sewerage facilities are defined as an integrated system, which are equipped with sewers and treatment plants. The present situation on sewerage facilities has been learnt as follows:

1.2.1 Four Major Systems

The sewerage system in RMR features an extremely dispersed or decentralized allocation of small service areas with a small treatment plant.

In terms of sewage collection type, the sewerage systems in the RMR were originally designed as completely separated systems so as to collect only wastewater excluding rainwater. Wastewater, however, diverts into the rainwater networks in many places, in reality, because a large portion of pump stations and sewage pipes are broken due to mainly aging.

COMPESA manages almost all of the existing sewerage system in the RMR, dividing them into four major systems: the Janga System, the Peixinhos System, the Cabanga System and the Southern System. Besides these, other small systems are managed by COMPESA as well.

Each four (4) major systems is comprised of numbers of sewerage units. These are the principal ones in the RMR in terms of sewage treatment capacity and are totaled as follows:

- Serviced population: 933,000 people including the converted population equivalent to the sewage from the business and institutional,
- Treatment station: 44 places with total capacity 223,000 m^3/day,
- Sewage networks: 900 km, and
- Pumping stations: 96 places with relay pumps of 167 sets.

Fig. B.1-1 and Fig. B.1-2 shows the locations of existing sewerage systems.

(1) Janga system

The Janga System serves the areas with some 23 housing estate in Olinda and districts in the Municipality of Paulista, Igarassu and Abreu e Lima located to the north of Refice. The areas covered belong to the northern part of the Beberibe River Basin and other small basins of coastal rivers.

This system serves a total some 266,000 people with total seven sewage treatment stations whose total treatment capacity reaches near 55,000 m^3/day, as shown below. Of seven treatment stations, the Janga Treatment Station (ETEJ-01) located in Eng. Maranguape is the largest capacity of some 34,000 m^3/day, accounting for 62 % of the total capacity in the entire System.

General Characteristics of Janga System

ID No.	Location		Treatment Process	Capacity (m^3/day)	Served Population (person)
	Municipalities	Site			
ETEJ-01	Paulista	Janga	Oxidation Ditch	34,214	175,152
ETEJ-02	Paulista	Arthur Lundgren	Aerated Lagoon	6,750	30,900
ETEJ-03	Abreu Lima	Caetes III	Aerated Lagoon	8,900	26,530
ETEJ-04	Paulista	Jardim Paulista	Aerated Lagoon	3,085	20,850
ETEJ-05	Igarassu	Igarassu	Stabilization Pond	270	1,035
ETEJ-06	Paulista	Mutirao	Stabilization Pond	1,700	11,250
ETEJ-07	Abreu e Lima	Abreu e Lima	Imhoff Tank	unknown	unknown
Total				54,919	265,717

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

Note: The served population in the table includes the converted people number equivalent to the sewage from businesses and institutions.

The Janga Treatment Station, which is the latest large-scale one in the RMR, was built in 1981. The incoming sewage is purified into the secondary water level with over 90 % of BOD removal in the principle of oxidation ditch process. Discharged sewage is led into the Timbo River through the dual embedded pipes. The disinfection of treated water is not incorporated into the treatment system. Most of sludge generated in sewage treatment is disposed of within the treatment site after dried naturally in drying beds. A small portion of sludge is used for gardening on a private basis.

The main figures of the Janga Treatment Station are delineated as follows:

- Grit chamber:	2 units, rectangular type 7.25 m wide x 7.25 m long Accessories: Parshall flume
- Oxidation ditch:	2 units, horserace track type, 37 m wide x 97 m long x 4.5 m-Water Depth Accessories: Aerator, 125 HP x 6 units
- Sedimentation tank:	2 units, circular type 38 m dia. x 2.9 m deep Accessories: Sludge return pump, 10 HP x 2 units
- Other facilities:	Treated water discharge well, 1 unit Sludge storage pond, 2 units Sewage inlet box, 1 unit

Other treatment stations besides the Janga Station rely on an aerated lagoon and primitive purification methods like a septic tank and a facultative pond. Of these, the Arthur Lundgren Station (ETEJ-02) and the Mutirao Station (ETEJ-06) are out of service due to aging, at present.

The total pipe length of existing sewers is some 440 km with the diameters between 50 mm and 700 mm, as shown below. The sewers, theoretically, collect only wastewater, designed as a separated system from the rainwater drainage. However, some sewers receive the intrusion of rainwater through broken pipelines. Meanwhile, due to imperfect house connections, a significant amount of wastewater flows into rainwater channels.

In the Janga System, there are 50 sets of relay pumps in total, as shown in the table below. This large number of pump units is explained by relatively shallow sewers, which are mostly less than 3 or 3.5 m of earth covering. Of all pump stations in the System, as many as 46 % units are not functioning due to breakdowns and/or aging. Thus, wastewater is diverted into rivers and channels in many places, without being connected to treatment stations.

Extension of Existing Sewers in Janga System

Pipe Diameter (mm)	Pipe Length (m)	Pipe Diameter (mm)	Pipe Length (m)
50	27,158	300	1,110
75	7,815	400	1,470
100	3,082	500	1,121
150	58,660	600	257
200	5,159	700	739
250	2,114	Not Identified	331,843
Total Length (km)		441	

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

Existing Pumping Station in Janga System

Diameter of Delivery Pipe (mm)	Quantities of Pumps (set)	
	Total	Broken
100	4	1
150	4	3
200	6	3
250	8	5
300	3	2
400	3	1
450	3	0
500	3	1
700	4	2
Not Identified	12	5
Total (unit)	50	23

Sources: Compiled based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

(2) Peixinhos system

The Peixinhos System serves the districts in the Municipality of Olinda and Recife. These served areas belong to the basins of the Beberibe River and the Capibaribe River.

This system covers total 330,000 people and accommodates total nine sewage treatment stations with a total treatment capacity of near 38,000 m³/day, as shown in the table below. Of nine treatment stations, the Peixinhos Treatment Station (ETEJ-01) has the largest capacity of some 36,000 m³/day, accounting for 95 % of the total capacity.

The Peixinhos Treatment Station, which is the oldest one in the RMR, was built in 1967. It employs the low-grade secondary water level with about 70 % BOD removal in the principle of aerobic biological filtration process and then discharges treated sewage into the Beberibe River. The disinfection for treated water is not incorporated into the treatment system.

General Characteristics of Peixinhos System

ID No.	Location		Treatment Process	Capacity (m^3/day)	Served Population (person)
	Municipalities	Site			
ETEX-01	Olinda	Peixinhos	Biological Filtration	36,000	314,500
ETEX-02	Recife	Macaxeira –Buriti Village	Septic Tank + Anaerobic Filter	272	2,500
ETEX-03	Recife	Macaxeira – Buriti Village	Septic Tank + Anaerobic Filter	389	1,500
ETEX-04	Recife	Macaxeira – Buriti Village	Septic Tank + Anaerobic Filter	200	2,000
ETEX-05	Recife	Macaxeira – Buriti Village	Septic Tank + Anaerobic Filter	389	1,500
ETEX-06	Recife	Canaa Community	RAFA	346	5,000
ETEX-07	Olinda	Passarinho Housing Estate (1)	Septic Tank + Filter	314	1,900
ETEX-08	Olinda	Passarinho Housing Estate (2)	Septic Tank + Filter	238	1,385
ETEX-09	Refice	Esperanca Village	Septic Tank + Filter	unknown	unknown
Total				38,148	330,285

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

Note: The served population in the table includes the converted people number equivalent to the sewage from businesses and institutions.

While the Station is equipped with sludge digestion facilities, these are not operated long time without any particular reason. Sludge generated in sewage treatment is disposed in the site of the Janga Treatment Station, after being dried naturally in drying beds and transported. A small portion of sludge is used for gardening on the private basis.

The main figures of the Peixinhos Station are described as follows:

- Bar screens: 2 units, screen opening 25 mm,
- Grit chambers: 2 units, rectangular type, 6.5 m dia.. x 0.6 m-Water Depth,
- Primary sedimentation tank: 2 units, rectangular type, 27 m dia. x 2.7 m deep,
- Bio-Filters: 2 units, cylindrical type, 39 m dia. x 2.0 m high,
- Secondary sedimentation tank: 2 units, cylindrical type, 27 m dia. x 3.3 m high,
- Sludge digester: 2 units, cylindrical type, 15.1 m dia. x 6.9 m high,

- Sludge drying bed: 25 units, rectangular type,
9.0 m wide x 22 m long.

Other treatment stations besides the Peixinhos Station rely on primitive methods such as a septic tank. The RAFA process is applied to the Canaa Community Treatment Station.
The total length of sewers is some 185 km with diameters between 100 mm and 600 mm, as shown below.

Extension of Existing Sewers in Peixinhos System

Pipe Diameter (mm)	Pipe Length (m)	Pipe Diameter (mm)	Pipe Length (m)
100	82	400	9,686
150	33,495	500	825
200	45,427	600	6,132
250	16,116	Not Identified	66,749
300	6,944		
Total Length (km)		185	

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

In the Peixinhos System, there are 43 relay pumps in total as shown below. Of all pump stations in the system, as many as 47 % units are forced to interrupt the operation due to breakdowns and aging.

Existing Pumping Station in Peixinhos System

Diameter of Delivery Pipe (mm)	Quantities of Pumps (set)	
	Total	Broken
100	2	0
150	8	4
200	2	2
250	2	1
400	19	8
450	0	2
500	3	0
Not Identified	7	3
Total (unit)	43	20

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

(3) Cabanga system

The Cabanga System occupies the central zone of the RMR where is located in the basins of the Capibaribe River and Tejipio River. The System serves districts in the Municipality of Recife: Santo Antonio, Recife, Sao Jose, Boa Vista, Madalena, Torre, Santo Amaro, Afogados and Boa Viagem.

The Cabanga System covers total about 233,000 people and is constituted by total 11 sewage treatment stations with a total treatment capacity of near 107,000 m^3/day, as shown below. Of 11 treatment stations, the Cabanga Treatment Station (ETEC-01) has the largest capacity of some 80,000 m^3/day, accounting for 75 % of the total capacity in the entire system.

General Characteristics of Cabanga System

ID No.	Location		Treatment Process	Capacity (m^3/day)	Served Population (person)
	Municipalities	Site			
ETEC-01	Recife	Cabanga	Primary Sedimentation	80,000	130,000
ETEC-02	Jaboatao	Jardim Piedade	Aerated Lagoon	1,625	7,402
ETEC-03	Jaboatao	Barra de Jangada	Oxidization Ditch	1,833	8,000
ETEC-04	Jaboatao	Marcos Freire housing estate	Aerated Lagoon	5,846	23,360
ETEC-05	Jaboatao	Muribeca housing estate	Imhoff Tank	1,439	8,000
ETEC-06	Recife	Varzea- Caxanga III	Activated Sludge - prolonged Aeration	247	720
ETEC-07	Recife	Villa Roda de Fogo	Septic Tank + Filter	4,752	18,234
ETEC-08	Refice	Villa Iputinga	RAFA	4,416	18,000
ETEC-09	Jaboatao	Praia Grande Estate	RAFA + Lagoon	3,142	9,040
ETEC-10	Recife	Mangeira	RAFA + Lagoon	3,732	8,500
ETEC-11	Recife	Villa Arraes	RAFA + Lagoon	404	1,780
Total				107,436	233,036

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

Note: The served population in the table includes the converted people number equivalent to the sewage from businesses and institutions.

The Cabanga Treatment Station was built in the 1920s and supplemented in 1972. It has only a primary sedimentation, whose BOD removal ratio is only 40 % more or less, and treated sewage is discharged into the Tejipio River. The disinfection for treated water is not incorporated into the treatment system. As of today, the operation of the entire Cabanga Treatment Station is stopped due to the break down of intake pumps. Therefore, incoming sewage is simply discharged into river without any kind of purification at present.

While the Station is equipped with sludge digestion facilities, these are not operated without any particular reason. Sludge generated in sewage treatment is disposed of at the site of Janga Treatment Station, after being dried naturally in drying beds and transported.
The main figures of the Cabanga Station are delineated as follows:

- Bar screens: 2 units, automatic screen
  1.2 m wide, opening 25 mm
- Influent pumps: 5 units, vertically centrifugal type
  0.44 m3/min x 13 m-Head x 75 HP
- Grit chambers: 2 units, rectangular type,
  8.75 m wide x 8.75 m long x 0.7 m deep
  Accessories: grit pumps
- Primary sedimentation tank: 4 units, circular type,
  26 m dia. x 1.7 m deep
- Sludge digester: 2 units, cylindrical type
  25 m dia. x 8.2 m high,
  Accessories: sludge pumps
- Gas holder: 1 unit, cylindrical water seal type
  10 m dia. x 5 m high (floating tank)
  Accessories: waste gas burner

The combination of RAFA and lagoon is used in four treatment stations in the Cabanga System. Other treatment stations rely on aerobic biological systems such as aerated lagoons and an oxidation ditches.

The total length of existing networks for sewage collection and transportation is around 135 km, as shown below. The diameters of these sewage pipes range between 150 mm and 800 mm.

Extension of Existing Sewers in Cabanga System

Pipe Diameter (mm)	Pipe Length (m)	Pipe Diameter (mm)	Pipe Length (m)
150	34,138	500	596
200	33,334	600	1,559
250	10,672	700	2,844
300	4,672	800	465
400	6,713	Not Identified	39,971
Total Length (km)		135	

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

In the Cabanga System, there are 51 relay pumps in total as shown below. Of all pump stations in the System, as many as 32 % units are not functioning. The diameter of delivery pipes ranges from 100 mm to 600 mm.

Existing Pumping Station in Cabanga System

Diameter of Delivery Pipe (mm)	Quantities of Pumps (set)	
	Total	Broken
100	4	0
150	8	1
250	4	2
300	6	5
350	14	2
400	6	3
600	3	1
Not Identified	6	2
Total (unit)	51	16

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

(4) Southern system

The Southern System is located in the basins of the Tejipio River, the Jaboatao River and the Ipojuca River in the southern zone of the RMR. The System serves some districts in the Municipality of Recife and housing estates in the Municipality of Camaragibe, Sao Lourence da Mata, Jaboatao dos Guraràrapes, Moreno and Cabo de Santo Agostinho.

The Southern System covers a population of 104,000 people and has a total treatment capacity of near 27,000 m^3/day in 17 treatment stations, as shown below. Of these stations, the largest is the sewage treatment station in Curado IV housing estate (ETES-02) with the capacity of some 7,000 m^3/day, which carries out secondary treatment in aerated lagoon. The Ignes Andreaza Station (ETES-01) is equipped with an extended aeration process, which can treat to a secondary water level. However it works precariously due to the breakdown of equipment.

RAFAs are applied to two treatment stations in two treatment stations of the Southern System. Other treatment stations rely on aerobic biological method like aerated lagoon and oxidation ditch. Septic tanks and stabilization ponds are applied, also.
The total pipe length of existing networks of sewage collection and reaches some 141 km, as shown below. The diameters of these sewage pipes range between 200 mm and 400 mm.

Present General Characteristics of Southern System

ID No.	Location		Treatment Process	Capacity (m^3/day)	Served Population (person)
	Municipalities	Site			
ETES-01	Recife	Ignes Andreaza Housing Estate	Extended Aeration	2,217	12,320
ETES-02	Jaboatao	Curado IV	Aerated Lagoon	7,021	33,170
ETES-03	Cabo	Pirapama Housing Estate	Aerated Lagoon	3,060	17,000
ETES-04	Sao Lourenco	Capibaribe Park	Aerated Lagoon	2,735	15,200
ETES-05	Recife	UR-II – Ibura	Stabilization Pond	unknown	unknown
ETES-06	Jaboatao	Curado II	Aerated Lagoon	unknown	unknown
ETES-07	Jaboatao	Curado I	Stabilization Pond	unknown	unknown
ETES-08	Jaboatao	Vila Rica	Aerated Lagoon	1,427	9,440
ETES-09	Recife	Vinicius de Moraes Housing Estate	Imhoff Tank	unknown	unknown
ETES-10	Recife	Felipe Camarao Housing Estate	Aerated Lagoon	300	3,040
ETES-11	Jaboatao	Lagoa Encantada	Aerated Lagoon	607	4,050
ETES-12	Camaragibe	Vale das Pedreiras	Oxidization Ditch	889	2,820
ETES-13	Moreno	Vila Liberdade	Stabilization Pond	1,728	1,000
ETES-14	Recife	Jardim Sao Paulo-	Imhoff Tank	unknown	unknown
ETES-15	Jaboatao	Fiber Industry Complex	Stabilization Pond	976	416
ETES-16	Recife	Villa dos Milagres	RAFA + Lagoon	890	4,965
ETES-17	Recife	Milagres Community	RAFA + Lagoon	4,965	917
Total				26,815	104,338

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

Extension of Existing Sewerage Networks in Southern System

Pipe Diameter (mm)	Pipe Length (m)	Pipe Diameter (mm)	Pipe Length (m)
200	1,013	400	228
250	3,201	Not Identified	107,891
300	388	Total length (km)	141

Source: Updated based on "Diagnosis of the Sewerage Systems Operated by COMPESA in the RMR" (1995).

In the Southern System, there are 23 relay pumps in total as shown below. The large number of pump units is explained by relatively shallow sewers, which are mostly less than 3 or 3.5 m of earth covering. Of all pump stations in the System, as many as 30 % units are forced to interrupt the operation due to break downs and/or aging. Thus, wastewater is discharged into rivers and channels in many places.

Existing Pumping Station in Southern System

Diameter of Delivery Pipe (mm)	Quantities of Pumps (set)	
	Total	Broken
100	1	0
150	3	1
200	8	1
250	6	3
400	3	0
Not Identified	2	2
Total (unit)	23	7

Source: Updated based on "Diagnosis of the Sewerage Systems

1.2.2 Other Sewerage Systems

In the RMR, there are sewerage systems other than the four (4) major sewerage systems. Though most of these are managed by COMPESA, they are managed, separately from four major systems mentioned before. These systems serve mainly specific areas such as public condominium or housing estates. In most cases, both collection pipes and treatment plants were constructed at the same time that the estates were developed.

These systems are being operated in 31 places serving around 106,000 people, as shown in Table B.1-1. Although various kinds of treatment systems are used to treat wastewater, most of them use a simple septic tank. They include a number of small capacity systems established by municipalities.

1.3 Sanitation Facilities in Poverty Areas

People living in poverty areas, who occupy significant portion of the whole population in the RMR, are suffering from worsened sanitation conditions and, at the same time, are considered one of major sources causing the deterioration of water environment.

Only 7 % of the population in poverty areas are served by sewerage. On the other hand, in the areas not covered by sewerage, only half of the households in poverty areas are equipped with a individual septic tank. The rest relies on a pit latrine and people of 2 % do not have even their own toilets. In such conditions, substandard hygiene often causes water-born diseases. Together, untreated excrement/gray water is the major causes for surface water as well as ground water pollution.

In the RMR, the condominial type sewerage system, rather than the conventional-type one is regarded as one of the viable solutions for the improving sanitary condition in poverty areas.

The condominial type system is characterized as follows:

- Sewage pipes are embedded at a shallow depth (less than 0.9 m earth covering) in the backyard or front yard of individual plots (in some cases, in sidewalks) and are connected to a short and shallow house connection (less than 0.7 m earth covering) at the nearest location,

- In some cases, a small-scale and simple sewage treatment plant to deal with a small service area is equipped with and, in other cases, collected sewage simply is led to conventional type sewerage or directly discharged into watercourses, and

- To efficiently and economically implement projects, strong users' participation are requested in each stages of the planning, implementation and operation and maintenance.

As seen from the above, the condominial type sewerage is aimed to provide economical solution for the improvement of sanitation, with the participation of users and/or communities. The RMR has developed the condominial-type system, which serves some 120,000 people in 54 poverty areas, as shown in Table B.1-2.

1.4 Individual Sanitation Facilities

For small building for businesses and institutions, and individual houses, which are not served by a sewerage system, a septic tank is installed in accordance with building regulations and codes. A gravel filter in some cases is attached to a septic tank. Treated water from a septic tank is discharged into watercourses or infiltrated into the ground through a leaching pit.

In such individual treatment systems, the sludge from septic tanks is causing a serious problem. Although periodical sludge removal is crucial to properly operate, the system for sludge removal and disposal is rudimentary in the RMR. Besides, the administrative management and responsibility for the handling of such sludge is not defined clearly.

Nowadays, there are about several private companies that work for sludge removal. Their numbers are still limited and the treatment facilities for removed and collected sludge have been not established yet. Even if sludge is removed from septic tanks, most of it is simply dumped into sewage manholes, or, in some cases, into swamps, vacant lots, etc. This deficient system of sludge disposal causes malfunctions of septic tanks, and results in the serious deterioration of the water environment in the RMR.

1.5 Industrial Wastewater Treatment Facilities

In the RMR, industrial wastewater generated from manufacturing factories is handled separately from domestic sewage in line with the policy of COMPESA. Respective factories are mandated to be provided with proper treatment facilities by their own responsibilities. Accordingly, sewerage systems in the RMR do not receive industrial wastewater, except for a negligible small-discharge from industries located in urban areas.

The discharge of industrial wastewater is supervised by the CPRH. The effluent limit of it is impartially specified as less than 60 mg/l of BOD. At present, the CPRH authorizes total 38 factories with BOD loading of around 310 ton/day in total in the RMR, as shown below.

Industrial Wastewater from Industries Authorized by CPRH in RMR

River Basins	Number of Factories	Generated BOD Loading (ton/day)	Discharged BOD Loading (ton/day)
Beberibe	5	3.36	0.5
Capibaribe	8	3.42	1.8
Jaboatao	10	21.4	7.4
Ipojuca	4	30.6	2.1
Pirapama	11	252.7	95.8
Total RMR	38	311.5	107.6

Source: Compiled based on the data provided by CPRH in 1999.

Most of factories are equipped with treatment systems in their own properties and they discharge the BOD loading of 110 ton/day altogether (equivalent to 65 % removal) into public watercourses after the treatment. However, some of theses factories are discharging polluted wastewater into nearby watercourses without proper treatment.

1.6 Ongoing Projects in Sewerage

Total eight (8) projects managed by COMPESA with a total investment amount of some R$ 40 million are enumerated as projects for implementation, as shown below. Most of these are under the basic planning or design stage.

In addition to the projects implemented by COMPESA, municipalities in the RMR are inaugurating sewerage projects by themselves. Their total investment amount is some R$ 1.5 million. Table B.1-3 shows those identified at the present.

Besides the projects mentioned above, the development project in the Beberibe River Basin has been inaugurated with the aid of the World Bank, just in recent. This project is mainly aimed at the infrastructure improvement in poverty areas, including the rehabilitation and expansion of the Peixihnos Sewerage Systems.

Ongoing Projects being Implemented by COMPESA

Municipalities	Projects		Effluents Destination	Served Population	Cost Estimate (1000 R$)
	Title	Phase			
Recife	Sewerage System of Arruda and Mangabeira (PROEST-1)	Basic design	ETE Peixinhos	36,422	8,605
Olinda-Sede	Collecting network of Olinda coast area	Basic design	ETE Janga	61,740	24,300
Moreno	Villa Massaranduba	Basic design	ETE to be construct	1,380	216
	Center	Basic design	ETE to be construct	38,254	6,378
Total					39,499

Source: COMPESA

1.7 Identified Issues in Existing Sewerage and Sanitary Facilities

Based on the findings on the present situation of sewerage and sanitary facilities, the following issues have been identified:

(1) Shortage of financial investment in sewerage development:

Although a relatively small-scale sewerage project has been undertaken in a certain extent, the investment amount to the sewerage management has been very limited since the 1980s. As a result, the present provision of sewerage facilities is very modest as a basic social-economic infrastructure and the water environment in the urban area has been worsened to the significant level by the increasing urban population and their social-economic activities. Much more investment in the extension and rehabilitation of sewerage is called to mitigate the current situation.

(2) Precarious practice in operation and maintenance:

Due to the breakdown of sewers, and pump and treatment stations, significant parts of collected sewage are discharged into watercourses without treatment. Many parts of sewerage facilities need proper and urgent rehabilitation works. Together, the ledger documents of facilities to support the operation and maintenance are incomplete. More investment to financial and human resources are called to deal with such substandard operation and maintenance practice.

(3) Sludge removal, treatment and disposal:

Almost third quarters of urban population in the RMR rely on septic tanks to dispose their daily wastewater. Because proper sludge removal and treatment system is not established, most of them fall in ill function and the effluent is one of major causes for the pollution of surface water and groundwater. Thus, the adequate establishment of measures to remove, treat and dispose sludge discharged from on-site treatments is an urgent need. In the similar connection, the disposal and/or utilization of excess biological sludge and other kind sludge generated from sewage treatment require the establishment of proper measures.

(4) Condominial type sewerage system:

The condominial-type sewerage system, which possibly can provide less-expensive sanitary facilities to people living in poverty areas, has been already deployed in the RMR. While this system is one of effective and efficient solutions to improve sanitary conditions, especially in poverty areas, the problems in community involvement and participation interrupt the sewerage extension in many cases. From this connection, adequate and initiative and strengthened intervention of the responsible authority should be studied to establish a condominial sewerage scheme.

(5) Application of the RAFA process in sewage treatment:

In Brazil, the RAFA process has become the major sewage treatment process since last decade, accounting for more than 200 installations in this country. The RMR also has applied seven RAFA processes, whose development were supported by the technical aids of the State University, and this are proposed as the main process of treatment station by PQA. The RAFA process is regarded in Brazil as the promising process, which is easy-manageable and less-expensive one. Meanwhile, the application of the RAFA process in sewage treatment can be rarely seen in the world, except for the ones in specific industrial wastewater. Thus, the adaptability of this process will be verified precisely in this Study from the technical and economical points of view.

2. DEVELOPMENT PLAN OF SEWERAGE FACILITIES

2.1 Development Scheme of Sewerage Facilities

2.1.1 General

The sewerage facility plan proposed here is a structural measure to attain the goals of the sewerage improvement toward 2020. As mentioned in the previous section, a total of 55 sewerage systems were selected for the sewerage improvement and specific planning conditions for them were proposed, also.

As sewage collection type, a completely separate sewerage is adopted, following existing sewerage systems in the RMR.

A number of sewerage facilities comprising sewage collection facilities and sewage treatment facilities (STF) are existing in the RMR. To implement economically the sewerage improvement, it is essential that existing facilities be used as much as possible, after proper rehabilitation. Accordingly, the proposed plan of sewerage facility are comprised of the following schemes:

- Development of new facilities: To increase the hydraulic capacity of sewers and treatment facilities and the performance capacity of water quality, by means of new installation or additional installation of necessary facilities,
- Rehabilitation of existing facilities: To restore the original functions and capacities of existing facilities, by means of the replacement of equipment, the supplement provisions of necessary components, etc.

Based on the surveyed data on existing sewerage, the development schemes to be entailed on respective 55 systems are shown in Table B.2-1. In 55 sewerage system, the development by new installation works will take place in 19 sewage collection facilities and in 39 STFs. In the rest of sewerage systems, different kinds of additional installation will take place along with necessary rehabilitation.

2.1.2 Basic Planning Conditions

The basic planning conditions applied for the entire RMR are presented as follows:

(1) Sewage collection method

Completely separate sewerage system will be applied. Accordingly, only wastewater from toilet, kitchen, etc. excluding stormwater is handled by the sewerage facilities.

(2) **Sewerage area in the entire RMR**

Sewerage area in 2020:	29,960 ha
Existing sewerage area at the present:	8,520 ha
Total sewerage area to be developed up to 2020:	21,440 ha

(3) **Sewage flow in 2020 in the entire RMR**

Daily average flow:	531,000 m^3/day
Daily maximum flow:	612,000 m^3/day
Hourly maximum flow:	853,000 m^3/day

(4) **Influent sewage quality:**

BOD:	340 mg/l on the average of the RMR
SS :	370 m/l on the average of the RMR

(5) **Removal rate of pollutants:**

BOD:	Over 90 %
SS :	Over 90 %

(6) **Sludge treatment:**

The sludge to be generated from sewage treatment will be dewatered into cake-shape in STFs, by using a mechanical dehydrator or a natural drying bed.

The specific planning conditions for respective sewerage systems are shown in Table B.2-2.

2.2 Development of Sewage Collection Facilities

2.2.1 General

The sewers to collect and transport sewage are comprised of collectors, branch sewers, trunk sewers and pressure sewers. In this Study, these are defined as follows:

(1) **Condominial collectors:**

This is the sewer to collect sewage in condominial type sewerage for poverty areas, embedded mainly in the backyard or front yard of individual house plots.

(2) **Conventional collectors:**

This is the sewer to collect sewage in conventional type sewerage for ordinary areas, embedded mainly along sidewalks

(3) **Branch sewers:**

This is the sewer to transport sewage from collectors into trunk sewers.

(4) **Trunk sewers:**

This is to collect sewage from branch sewers and transport sewage generated in the UEs (the abbreviation of Sewerage Unit in Portuguese) at the upstream. Sewage in trunk sewers flows by gravity.

(5) **Pressure sewers:**

This is to transport sewage from trunk sewers to a downstream UE or a sewage treatment station. Sewage in pressure sewers flows by pumping up.

Fig. B.2-1 shows the conceptual layout of sewers and other related facilities in sewerage systems. Sewerage areas are usually comprised of several UEs, which are the minimum units of sewage discharge. When sewage cannot be conveyed from one UE to another by gravity, pump stations are introduced.

2.2.2 Planning Criteria

This development of sewage collection facilities was planned applying the following criteria:

(1) **Size of sewers:**

Nominal diameter (ND) of sewers was designed by using the velocity of 0.6 to 3.0 m/sec including 50 to 100 % allowance of sectional area. Minimal diameter is defined as ND 150 mm.

In this Study, the diameter of collectors and branch sewers are assumed as follows, based on the review of previous projects in the RMR:

- Condominial collectors: ND 150 to 200 mm
- Sidewalk collector: ND 150 to 200 mm
- Branch sewers: ND 200 to 300 mm

(2) Earth covering:

The following earth coverings are tentatively assumed:

- Condominial collectors:	Average 0.9 m
- Conventional collectors :	Average 1.5 m
- Branch sewers:	1.5 to 3.0 m (representatively 2.0 m)
- Trunk sewers:	3.0 to 6.0 m (representatively 3.0 m)
- Pressure sewers:	1.0 to 1.5 m (representatively 1.2 m)

As mentioned above, the depth of sewers were assumed to be relatively shallow, following the prevalent practice in the RMR.

(3) Material of pipes:

As a result of the survey on the availability of piping material and prevalent practice in Brazil, the following materials are used:

- ND 150 to 300 mm:	Polyvinylchloride pipe (VP)
- ND 350 to 1000 mm:	Ductile cast iron pipe (DIP)

(4) Sewer length:

In this Study, the lengths of collectors and branch sewers are calculated by the expedient method using the following pipe densities:

Condominial collectors:	Pipe density 120 m/ha
Conventional collectors:	Pipe density 180 m/ha
Branch sewers:	100 m/ha

The lengths of trunk and pressure sewers were calculated by assuming the piping route on the map of 1/10000 scale, referring the results of the PQA. The length of trunk sewers was deducted from the length of branch sewers that are calculated by the pipe density.

The location of pump stations was determined on the map of 1/10,000 scale, reviewing the results of the PQA. The set numbers of pumps are three including one-set standby and its shaft powers are computed assuming 20 m of pump head.

2.2.3 Proposed Plan of Sewage Collection Facilities

Based on the above-mentioned criteria, the development plans of 55 systems were formulated. Of these, the results of overall layout for seven (7) candidate priority systems selected in the Master Plan are shown in Fig. B.2-2 to Fig. B.2-8.

As a result, the total length of sewers to be expanded toward 2020 is about 5,900 km and the total shaft power of pump stations is some 9,700 CV. These are summarized in the following table and are detailed in Table B.2-3:

Summary of Development Works of Sewage Collection Facilities

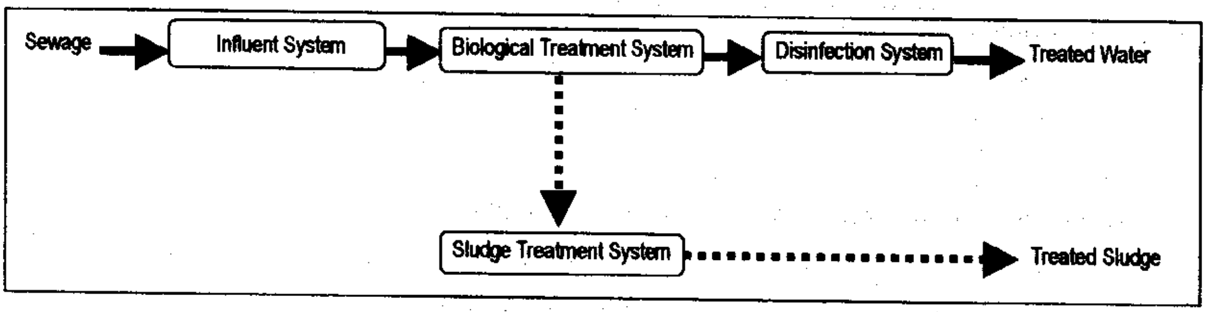
Items			Units	Quantities
Sewers	Condominial collectors	Pipe length	(km)	530
	Conventional collectors	Pipe length	(km)	3,077
	Branch sewers	Pipe length	(km)	2,063
	Trunk sewers	Pipe length	(km)	133
	Pressure sewers	Pipe length	(km)	65
	Total	Max. diameter	(mm)	ND 1000
		Pipe length	(km)	5,868
Pumping station		Total set number	(set)	441
		Total power	(CV)	9,748

2.3 Development of Sewage Treatment Facilities

2.3.1 Examination on Sewage Treatment Process

In general, sewage treatment facilities are composed of an influent system, a biological treatment system, a disinfection system and a sludge treatment system as shown below:

General Flow Diagram of Sewage Treatment



The influent system aims to remove coarse substances contained in sewage. It includes lift pumps for incoming sewage, if sewage comes by gravity flow. A bar screen, a lifting pump, a grit chamber and related equipment make up the influent system, also.

Various processes are available for a biological treatment system, a disinfection system and a sludge treatment system. To select optimum ones applicable for the RMR, the following examinations were undertaken:

(1) Biological treatment system

The biological treatment system plays a major role in sewage treatment facilities to remove pollutants such as BOD and SS from sewage. Different kinds of treatment processes are applied for the sewage treatment in the RMR, as shown in the following table.

Process Applied in Existing Treatment Facilities in RMR

No.	Treatment Processes	Number of Treatment Stations	Remarks
1	Septic Tank	11	Including the types with and withou filters, and imhoff tank type.
2	Primary Sedimentation	1	
3	Bio-Filter (Trickling Filter)	1	High-rate type
4	Extended Aeration or Oxidation Ditch	5	
5	Conventional Activated Sludge	0	
6	Stabilization Pond (Lagoon)	6	Including oxidation pond type
7	Aerated Lagoon	11	
8	RAFA	6	Including RAFA attached to a stabilization pond
Total		41	

Source: Compiled based on "Report of Pumping Station and Sewage Treatment Station in RMR" issued by COMPESA (1999).

Note: Of a total of 44 sewerage stations in major systems, the process applied in three systems is not known.

The lagoon process including aerated lagoon and stabilization pond process predominates in the RMR, except for septic tanks. The conventional activated sludge process, which is most prevalent in the world, does not exist in the RMR. Based on the survey results, a salient tendency in the RMR is the use of the RAFA process.

RAFA (Retor Anaerobico de Flux Ascendente in Portuguese), which is called UASB (Upflow Anaerobic Sludge Blanket) in English, is a process in which organic substances in sewage are removed by anaerobic granular-shaped organisms, while wastewater flows upward through a sludge layer bed. While this process has not often been applied in sewage around the world, it has been used in many places in Brazil, especially in the State of Parana, as shown in Table B.2-4. Relative high temperature of sewage and accumulated experience in aerobic technology appears to be the main cause for this proliferation. As a result, RAFA has been seen as the most promising process for sewage treatment, ever since a previous sewerage development study[1] recommended it several decades ago.

[1]: The Program for Urban Restoration in Tejipio River Basin (PROST-1)

In this Study, the following process options were compared from the technical and economical point of view:

(1) **Activated sludge process:**

Sewage is purified in a relatively short time by the activity of suspended biomass in an aeration tank. This process is regarded as a standard and conventional one in sewage treatment and is employed most widely throughout the world.

(2) **Oxidation ditch process:**

Sewage is treated in a running track-shaped reactor by suspended biomass. This requires a relatively long time to complete purification. Outlying areas rather than densely populated urban areas tend to adopt this process, because of the necessity of wide open space.

(3) **Aerated lagoon:**

In this process, the purification takes place in a lagoon whose normal capacity is a four to seven day. A mechanical aerator is installed to supply oxygen to biomass. A relatively wide space is required to adopt this process.

(4) **Bio-filtration process:**

In this process, the biomass growing on the surface of gravel acts to remove pollutants in sewage. Sewage is sprayed from the top of filters and dripped between gravel. A sedimentation tank necessarily accompanies this process.

(5) **"RAFA + lagoon" process:**

The BOD removal rate of the RAFA process by itself is limited to 70 to 80 %. Its combination with aerobic treatment can be expected to increase the removal rate to around 90 %. Usually, lagoons accompanies RAFA reactors as a post treatment.

(6) **"RAFA + bio-filtration" process:**

In this process, bio-filters follows RAFA reactors for the same reason as the "RAFA + lagoon" process. This can greatly save the required land space. Over 90 % BOD removal may be expected in this process.

Table B.2-5 compares these optional processes. Among them, the aerated lagoon process and the bio-filtration process alone cannot be adopted due to the inferior BOD removal rate (less than 90 %). Other processes are examined comparatively by using the weighted evaluation method, which allocates the following weighted points: i) 5 for construction cost, ii) 3 for energy consumption, iii) 3 for sludge generation rate, iv) 5 for ease of operation and maintenance, and v) 5 for required land space. The results are shown in table below:

Evaluation of Biological Treatment Processes

Comparison Items		Weighting	Optional Processes			
			Activated Sludge	Oxidation Ditch	RAFA + Lagoon	RAFA + Bio-Filtration
Construction Cost	Basic score	5	1	1	5	3
	Weighted score		5	5	25	15
Energy Consumption	Basic score	3	1	1	5	3
	Weighted score		3	3	15	9
Sludge Generation Rate	Basic score	3	1	3	5	5
	Weighted score		3	9	15	15
Easiness of O and M	Basic score	5	1	3	5	3
	Weighted score		5	15	25	15
Required Land Space	Basic score	5	5	3	1	5
	Weighted score		25	15	5	25
Total Score			41	47	85	79

Note: The basic scores stand for: 5 - "excellent", 3 - "medium" and 1 - "inferior".

As evident from this comparison, the RAFA process combined with lagoon or bio-filtration process represents significant advantage. This result is attributed to the fact that:

- The RAFA process is of anaerobic treatment that needs no energy to decompose organics,
- The BOD space loading rate of the RAFA process is extremely high (some 1.5 kg-BOD/m^3/day) as compared to other processes, and
- The sludge generation rate in the RAFA process is very low.

Based on these results, the following criteria for process selection were induced, placing the RAFA process at the highest priority:

- Where there is no space limitation at the treatment station, the applicable one is:
  "RAFA + lagoon" process,
- Where there is space limitation at the treatment station, the applicable one is:
  "RAFA + bio-filtration (including sedimentation)" process.

A typical configuration of RAFA reactor is shown in Fig. B.2-9. Fig. B.2-10 shows a typical application for the combined process with RAFA reactors.

Although the combined RAFA process is considered promising as mentioned above, special attention and appropriate measures should be taken in terms of the generation of offensive odor, especially in densely populated areas.

(2) Sludge treatment system

At present, all the existing sewage treatment stations in the RMR rely on sludge drying beds to treat the sludge generated. Given the climatic conditions in the region, the natural sludge drying process is considered the most economical way. This practice, however, should be reassessed on the occasion of sewerage expansion.

The characteristics of the sludge drying process are evaluated as follows:

- It requires a large land space due to a low rate of drying, and
- It might generate an offensive odor.

Based on the above, the following criteria for the selection of a sludge treatment system are proposed:

- A mechanical dehydration should be introduced in the sewage treatment stations that are limited in space, or that are sited in densely populated areas,
- A natural drying bed may continue to be applied in the sewage treatment stations that are not constrained by lack of space, if there is no concern about the surrounding environment.

At present, the unit processes of sludge dehydration being used widely are belt press filters, pressure filters, centrifugal separators, and vacuum filters in many countries.

2.3.2 Basic Development Scheme

For 55 sewerage systems for the Master Plan Study, the development works for sewage influent systems, biological treatment systems, disinfection systems and sludge treatment systems were examined. In sewerage systems in which existing facilities are not available, the whole treatment station will be newly installed, based on the examination results of optimum processes mentioned in the previous section.

In case the existing facilities are available at present, disinfection systems will be added in all the systems, because all of them are not provided at present. The capacities of both sewage influent systems and sludge treatment systems will be increased by the additional installation, if their capacities are not enough for the given conditions in 2020.

As for biological treatment systems, of all the existing sewage treatment facilities, some can continue to be used after the expansion by additional installation, and others are abolished and replaced by facilities installed newly. In this judgement, the following criteria were referred:

(1) The existing facilities, which consist of an oxidation ditch, an extended aeration tank or the "RAFA reactor + lagoon" process, will continue to be used as a rule, since their water quality performance is regarded to meet the given requirement in 2020. If their hydraulic capacities are less than the given condition in 2020, another series of treatment facilities employing the "RAFA + lagoon" or the bio-filtration process will be installed additionally,

(2) The existing facilities consisting of septic tanks are abolished and replaced by new facilities using the "RAFA + lagoon or bio-filtration" process, because they do not satisfy the water quality performance in 2020,

(3) The existing facilities, which consist of bio-filters, aerated lagoons, stabilization ponds and RAFA reactors only, will be altered into the "RAFA + lagoon" or the "RAFA + bio-filtration" process. As a rule, aerated lagoons and stabilization ponds will continue to be used as the post treatment of the RAFA, after necessary rehabilitation.

2.3.3 Proposed Plan of STFs

Of the existing treatment stations, the sewage treatment facilities at total 24 locations will be modified into new processes or continue to be used as it is. Modification methods to be applied for respective treatment facilities are shown in Table B.2-6.

Table B.2-7 enumerates specific development plans of all 55 systems, including component unit processes to be applied.

As a rule, all respective sewerage systems are equipped with their one STF. In the Cordeiro, Prazeres and Curcurana System, however, the following special schemes were undertaken, considering effective uses of treatment facilities exiting in respective sewerage areas:

(1) Cordeiro System:

Apart from the main system, the existing Villa Iputinga System (ETEC-08) will be used as another system. To do so, the treatment station of ETEC-08 will be altered from the existing RAFA process alone to the "RAFA + lagoon" process.

(2) Prazeres System:

The Prazeres System has the existing Jardim Piedade System (ETEC-02) employing aerated lagoon process. ETEC-02 will be used as another system separately from the main system, after being altered to the "RAFA + lagoon" process.

(3) Curcurana System:

The Curcurana System has the existing Barra de Jangada System (ETEC-03) and the Praia Grande System (ETEC-09), which employ the oxidation ditch and the "RAFA + lagoon" process, respectively. Both ETEC-03 and ETEC-09 will be used as other systems separately from the main system, after being rehabilitated.

The locations of 55 STFs were predetermined in the PQA. These locations were endorsed in this Study, based on the following criteria:

1) The existing sites continues to be used, unless there are particular reasons,

2) The new sites have been selected, considering:

- Accessibility to the watercourses for treated sewage,
- Topographic conditions to collect and transfer sewage easily,
- Allowable land space,
- Land use situation of the surroundings, and
- Accessibility to sites from main roads.

2.3.4 Specific Development Works of Three Major STFs

The STFs for three major systems, Janga, Peixinhos and Cabanga System, will be altered to the systems to be equipped with their one STF. Their STFs will be developed as follows:

(1) Janga System: (as shown in Fig. B.2-11 and Fig. B.2-14)

The existing STF of the Janga System is of oxidation ditch process. The sewerage flow in 2020 will be increased to 59,900 m^3/day (daily average) from the present 34,200 m^3/day (daily average). The present BOD removal rate is almost 90 %, satisfying the given requirement in 2020.

The existing series will continue to be used as it is. For the incremental flow in 2020, the new series consisting of RAFA reactors and lagoons will be installed adjacent to existing ones, along with a grit chamber and a disinfection tank. This scheme is justified by the abundant land space in the existing site.

The disinfection system and sludge treatment system will be newly installed for the existing facilities as well as newly installed STF.

(2) Peixinhos System: (as shown in Fig. B.2-12 and Fig. B.2-15)

The existing STF for the Peixinhos System is comprised of primary sedimentation tanks, bio-filters and secondary sedimentation tanks. The sewage flow in 2020 will be increased to 57,300 m^3/day (daily average) from the present 36,000 m^3/day (daily average). The present BOD removal remains 70 % to 80 % according to operation records.

To upgrade its BOD removal performance and hydraulic capacity, RAFA reactors, additional bio-filters and additional secondary sedimentation tanks will be installed. The existing primary sedimentation tanks will be abolished. A disinfection tank will be added, also.

As the sludge treatment system, a sludge thickener and sludge dehydrators will be newly constructed. Existing sludge digesters, a gasholder and a bio-gas burner will continue to be used after being rehabilitated. Existing sludge drying beds will be abolished after the completion of the new sludge treatment system.

(3) Cabanga System: (as shown in Fig. B.2-13 and Fig. B.2-16)

The sewage treatment of the Cabanga System relies on only primary sedimentation at present. The sewage flow in 2020 will be reduced into 55,300 m^3/day (daily average) from the existing 80,000 m^3/day (daily average). The present BOD removal rate remains only 40 % or so, according to the COMPESA's reports.

To upgrade its performance, RAFA reactors, bio-filters and sedimentation tanks will be added. A disinfection tank will be also installed newly.

In the sludge treatment system, a sludge thickener and sludge dehydrators will be newly installed. Existing sludge digesters, a gas holder and a bio-gas burner will continue to be used after being rehabilitated.

Existing primary sedimentation tanks and sludge drying beds will be abolished to provide the installation space for RAFA reactors, bio-filters, sedimentation tanks and other ancillary equipment.

2.4 Rehabilitation of Existing Facilities

2.4.1 Sewage Collection Facilities

Sewage collection facilities consist of sewers and pump stations.
Total 96 pump stations are working at present in four (4) major sewerage system, equipped with total 167 sets of different-type pumps. The site investigation and the data prepared by COMPESA have revealed that almost all pumps have been damaged in certain levels. As a results, a significant portion of collected sewage are discharged into the nearby water courses without treatment.

The situation on damaged equipment may be described typically as follows:

(1) Several sets of total pumps are missing and only foundations are left,

(2) Drive motors for pumps are missing,

(3) Some pumps are left without working due to no replacement of consumable parts, and

(4) Most of electrical panel and water level instrument for pumps are imperfect.

As a result of the site survey and the review of the data prepared by COMPESA, the rehabilitation items entailed on 55 systems are summarized in Table B.2-8. Ranging from the supplement of new pumps to the replacement of component parts, the rehabilitation works will include the necessary measures for respective pump stations in line with their present situation.

The sewers are classified into sewage collectors, branch sewers, trunk sewers and pressure sewers. Of the total near 30,000 ha sewerage area in 2020, the area of 8,500 ha is provided with sewer networks at present. These sewers are calling for urgent rehabilitation, because they have also broken at many points, mainly due to aging. Besides, the silting in pipes is found to be serious, resulting into the lowering flow capacity.

Based on the data prepared by COMPESA and the site investigation, the quantities of repair and cleaning works for the existing sewage collection facilities are estimated. They contain the necessary rehabilitation works such as the supplement of pipelines, the repair of pipe connections, the inspection of silting, the cleanings, etc.

2.4.2 Sewage Treatment Facilities

The rehabilitation works is aimed to recover the original functions and capacities of existing facilities.

A total of 44 STFs are working in four major sewerage systems at present. Of these, 24 stations are planned to be used in 55 systems proposed in the Master Plan. Their treatment capacities are some 210,000 m^3/day in total. Most of these need the rehabilitation, partly or totally, to meet the original functions and the capacities.

Most of existing treatment stations are suffering from different damage at present, being forced partial or complete stoppage of the operation. Through the site investigation, the following typical damages have been identified:

(1) Of sewage lifting pumps in STF, some are not working, because drive motors have been missing or broken,

(2) Most screens and grit chambers are not working due to no periodical cleaning,

(3) Most sewage inflow measurement equipment are missing,

(4) Almost one third of aerators are not working due to broken motors and mechanical parts,

(5) Some of sludge collectors for sedimentation tanks are not working due to mechanical failures, and

(6) Many parts of pipes, especially for sludge transport, are clogging or rusted and valves are broken.

Taking the above situation into account, necessary rehabilitation works for existing treatment facilities are listed up in Table B.2-8.

3. DESIGN CONDITIONS FOR FEASIBILITY STUDY

3.1 General

The development plan of sewage treatment facilities (hereinafter called "STF") for the following seven (7) priority systems was elaborated in this Feasibility Study. The preliminary designs for the facilities installed newly as well as the rehabilitation planning for the facilities exiting at present have been prepared.

- Conceicao System,
- Janga System,
- Cabanga System,
- Boa Viagem System,
- Cordeiro System,
- Prazeres System, and
- Curcurana System.

In the Janga STF and the Cabanga STF, old treatment facilities are existing at the present. Of the existing equipment, some will be utilized as a part of treatment facilities, to economize the development of sewage treatment facilities. Meanwhile, the other STFs will be constructed as totally new projects.

3.2 Sewage Flow

Basically, the sewage flows (daily maximum, daily average and hourly maximum) in 2020 of the systems, as shown in the following table, were adopted in the preliminary design. In the Janga STF, however, the design flow was calculated by deducting that of the existing facilities, since almost all of them are used separately from the newly installed facilities.

Meanwhile, in the Cabanga STF, the sewage flows in 2020 were used for the preliminary design. This is because parts of existing facilities are used in combination with newly installed facilities.

Design Sewage Flow

Design sewage flows	Units	Sewage Treatment Facilities (STFs)						
		Conceicao	Janga	Cabanga	Boa Viagem	Cordeiro	Prazeres	Curcurana
Sewage Flow in 2020								
Daily maximum flow	(m^3/d)	14,900	73,585	66,374	31,337	22,245	38,219	28,762
Daily average flow	(m^3/d)	13,135	64,464	57,381	27,087	19,308	32,677	24,795
Hourly maximum flow	(m^3/d)	20,508	102,382	93,791	44,408	31,091	53,937	40,638
Capacity of Existing Treatment Facilities								
Daily maximum flow	(m^3/d)	-	39,200	80,000	-	-	-	-
Daily average flow	(m^3/d)	-	34,341	69,161	-	-	-	-
Hourly maximum flow	(m^3/d)	-	54,541	113,045	-	-	-	-
Sewage Flows for Expansion or New Installation								
Daily maximum flow	(m^3/d)	14,900	34,385	66,374	31,337	22,245	38,219	28,762
Daily average flow	(m^3/d)	13,135	30,123	57,381	27,087	19,308	32,677	24,795
Hourly maximum flow	(m^3/d)	20,508	47,841	93,791	44,408	31,091	53,937	40,638

3.3 Water Quality

The BOD and SS of inflow sewage for the STFs are based on the results of the sewerage planning study shown in the following table.

The treated water quality in terms of BOD and SS is defined as the removal rate of 90 % for all STFs, in compliance with the instruction of No. 2002 issued by the CPRH.

Besides, the temperature of 28 ℃ of inflow sewage was applied in the preliminary design.

Water Quality of Inflow Sewage and Treated Sewage

Design parameters	Units	Sewage Treatment Facilities (STF)						
		Conceicao	Janga	Cabanga	Boa Viagem	Cordeiro	Prazeres	Curcurana
Inflow Sewage Quality								
BOD	(mg/l)	257	271	304	315	305	386	327
SS (Suspended Solids)	(mg/l)	285	301	338	350	339	429	363
Treated Sewage Quality								
Removal rate	(%)	90	90	90	90	90	90	90
BOD	(mg/l)	26	27	30	32	31	39	33
SS (Suspended Solids)	(mg/l)	29	30	34	35	34	43	36

3.4 Construction Sites

While the sites of seven (7) STFs were basically predetermined in the PQA, some locations of them were changed, because of future land use plans. The respective municipalities have already agreed to the sites as being for the construction of the sewage treatment station, which are shown in Fig. B.3-1.

These construction sites are deemed to be appropriate for the construction of STFs for the following reasons:

- There is enough land space to accommodate planned treatment facilities,
- No obstacle to the conveyance of collected sewage to the treatment station,
- Compatible with the land use plan established by municipalities for the internal and surrounding areas,
- Located at places where watercourses can be used for the discharge of treated sewage,
- No existence of potential environmental hazards caused by the construction and operation of treatment facilities, and
- Presence of appropriate physical conditions for construction works and operation, such as access roads, electricity, water supply, etc.

The JICA Study Team undertook a series of topographic and soil condition surveys for the respective STF sites in the Feasibility Study.

Information on the current situation of the STF sites is given in the section 6 Of this Chapter.

4. SELECTION OF TREATMENT PROCESSES

4.1 General

The STFs comprise:

- Biological treatment system,
- Disinfection system, and
- Sludge treatment system.

The processes of the STFs to be applied have to meet regional requirements and characteristics of the RMR. They were selected as follows:

4.2 Biological Treatment System

(1) Background

In the phase of the Master Plan Study, six (6) kinds of biological processes were compared from the viewpoint of the applicability to regional requirements in the RMR. These were activated sludge, oxidation ditch, aerated lagoon and bio-filtration for aerobic treatment, and the "RAFA + lagoon" and the "RAFA + bio-filtration" for combined anaerobic treatment. Of these, the Master Plan Study selected combined anaerobic treatment such as the "RAFA + lagoon" and the "RAFA + bio-filtration" processes as promising ones for the RMR.
Moreover, in the light of the attributes of these processes, the following criteria were established in the Master Plan Study:

- When there is no limitation in the land space of the treatment station, the "RAFA + lagoon" process is the most suitable, and
- When there is a certain limitation in the land space of the treatment station, the "RAFA + bio-filtration" process is the most suitable.

Based on these results, the lagoon treatment process was studied in more detail as the post-treatment of RAFA.

In general, lagoon treatment includes various types, such as an aerated lagoon, an "aerated lagoon + polishing pond", a facultative lagoon, an anaerobic lagoon, etc. Of these, an "aerated lagoon + polishing pond" and a facultative lagoon were evaluated from the technical and economical viewpoints, since they potentially meet the requirements of this Study.

(2) "Aerated lagoon + polishing pond" process

An aerated lagoon is equipped with aerators to supply oxygen necessary for bio-degradation. In the combined anaerobic process, sewage pre-treated by RAFA reactors undergoes secondary treatment in aerated lagoons and is finally clarified in polishing ponds. Following RAFA reactors with its BOD removal rate of 75 %, an overall rate of 90 % (design value in this Study) can be achieved by the combination of an aerated lagoon and a polishing pond.

(3) Facultative lagoon process

A facultative lagoon is the treatment process in which the necessary oxygen for bio-degradation is supplied by algae growing on the water surface and by natural wind. Therefore, this is considered to be a nearly natural purification process.

In the RMR, this treatment has been applied to the Mangueira Treatment Plant with the facultative lagoon of 3-day hydraulic retention time. Table B.4-1 and Fig. B.4-1 shows the results of water quality analysis of it over the duration of some 36 months operation.

Base on these operation data, the RAFA reactor indicated satisfied BOD removal rate higher than 75 %. Significant BOD removal was, however, not found in the facultative lagoon, resulting in far less than 90 % rate of overall BOD removal. This is explained by:

- A facultative lagoon with some 3-day hydraulic retention time is not a process that can achieve significant BOD removal. In other words, enormous volume (to be ambitious, one to three-week retention time) may be required to get higher removal,
- Under the sewage characteristics and climatic conditions in the RMR, algae proliferate in the lagoon at a large scale is unavoidable and may cause the increase of BOD in some cases.

Consequently, it has been concluded that, in practical, the overall BOD removal rate of 90 % is impossible in the combined anaerobic treatment using facultative lagoons.

(4) Selection criteria of biological system

From the above, the "aerated lagoon + polishing pond" treatment was selected as the most feasible system as the post-treatment of RAFA in a combined anaerobic system.
Thus, the following criteria are applicable to the selection of a biological treatment system, incorporating the results of the Master Plan Study on this matter:

- When there is no limitation in the land space of the treatment station, the "RAFA + aerated lagoon + polishing pond" process is the most suitable, and
- When there is a certain limitation in the land space of the treatment station, the "RAFA + bio-filtration" process is the most suitable.

The characteristics of respective biological treatment processes examined in the Study are compared in Table B.4-2.

4.3 Disinfection System

To reduce coliform group bacteria in treated sewage, different disinfection processes such as chlorine, ultra-violet light, ozone process are generally used. Their process principles are delineated below:

1) Chlorine process:

Chlorine (chlorine gas in most case) is injected into treated sewage in a tank with some 15 minutes of detention time. Treated sewage is disinfected by the function of active chlorine. This is most widely applied in many countries.

2) Ultra violet light process:

Ultra violet light generated in a special lamp, which is submerged in treated sewage, is irradiated to treated water. Ultra violet light can reduce coliform bacteria in treated sewage.

3) Ozone process:

Ozone gas produced by an ozone generator is injected into treated sewage in an ozone contactor. Coliform bacteria in treated sewage is reduced by the function of active oxygen. The characteristics of respective processes are compared in the following table.

Comparison of Disinfection Processes

No.	Items	Disinfection Processes		
		Chlorine Gas	Ultra Violet Light	Ozone Gas
1	Construction cost	Low	Medium	Extremely high
2	O and M Cost	Low	Medium	High
3	Generation of byproducts	Organic chlorine compounds are generated possibly.	Nothing	Hydroperoxide compounds are generated possibly.
4	Influence to the environment	Remaining chlorine and byproducts may influence to aquatic lives.	Nothing	Excessive remaining ozone may influence to aquatic lives.
5	Experience of installation	Countless (used conventionally in developed countries)	More than a thousand stations in U.S. Canada, Europa and Japan.	A limited number

Source: Compiled by JICA Study Team.

From this comparison, it is obvious that chlorine process is the most advantageous in terms of the economic efficiency in both initial cost and operation and maintenance cost. However, the influence of residual chlorine and generated chlorine compounds to aquatic lives has been proved through recent studies. This is why many developed countries are substituting ultra violet light process for chlorine process.

While a specific policy of disinfection method has not been established in the RMR yet, the CPRH suggested that ultra violet light disinfection be desirable to protect mangroves growing in riversides. Considering that all of seven (7) STFs discharge treated water into rivers, whose shores have mangroves, it is suggested that ultra violet light process be applied in the RMR to protect the environment.

4.4 Sludge Treatment System

(1) General criteria

At present, all the existing sewage treatment stations in the RMR rely on sludge drying beds to treat sludge. Given the climatic conditions in the region, natural sludge drying process is considered to be the most economical method. However, it requires a large area of land due to the low-rate of drying and might generate an offensive odor.

Based on the above, the following general criteria for the selection of the sludge treatment system are proposed:

- Mechanical dehydration shall be introduced at the STFs that are constrained in the land area, or that are sited in densely populated areas, and

- Natural drying bed shall continue to be used at the STFs that have large areas where odor ill not cause concerns in the surrounding environment.

(2) Selection of mechanical dehydration process

The unit processes of sludge dehydration being used widely are the types of belt press filter, pressure filter, centrifuge separator, and vacuum filter. Their salient features are described below:

1) Belt press filter:

A belt-press filter is equipped with a number of rolls and sludge is pressurized and filtrated by filter cloths while running between the rolls. This usually comprises the section of gravity separation, pressure dehydration and compression dehydration. The filter cloths are washed continuously to prevent from clogging. Usually, organic coagulant is applied to this filter.

2) Pressure filter:

A pressure filter is equipped with a large number of filtration chambers constructed by filtration cloths. Sludge is filtrated in the chamber by pump pressure and then compressed through diaphragms by hydraulic and/or pneumatic pressure. The operation, which is full computerized normally, is proceeded by automatically sequential-batch system. Usually, inorganic coagulant is applied to this filter.

3) Centrifuge separator:

This is the method to dewater sludge by using centrifugal force with 1,500 to 3,000 times gravity. Sludge solids are separated in a bowl rotating at a high-speed and are discharged into the outside by a screw. The edge of screw may cause abrasion depending on the sludge properties and proper mitigation measure for noise is needed, also.

4) Vacuum filter:

This type is to make the inside of a drum covered by filter cloth vacuum and to absorb and dehydrate sludge on the surface of filter cloth. The drum is partitioned into the three zones: adsorption, dehydration and exfoliation zone. The vacuum pressure is kept to some 600 mmHg at the adsorption zone and about 300 mmHg at the dehydration zone. Inorganic coagulant aided by lime is usually applied to sludge in this filter.

Using the weighted evaluation method, these unit processes of sludge dehydration were compared. The weighing points allocated are: i) 5 for dehydration performance, ii) 5 for easiness of operation and maintenance, iii) 5 for cost performance, and iv) 3 for space requirement.

Evaluation of Sludge Dehydration Processes

Comparison Items		Weighing	Optional Processes			
			Belt-press	Pressure	Centrifuge	Vacuum
General performance	Basic Score	5	5	5	3	1
	Weighted Score		25	25	15	5
Easiness of O & M	Basic Score	5	5	1	3	1
	Weighted Score		25	5	15	5
Cost performance	Basic Score	5	5	1	5	3
	Weighted Score		25	5	25	15
Space requirement	Basic Score	3	5	3	5	1
	Weighted Score		15	9	15	3
Total Scores			90	44	70	28

Note: The basic score stand for: 5 to "excellent", 3 to "medium" and 1 to "inferior".

As understood from this, it is obvious that the belt-press filter is the most suitable in the RMR.

4.5 Overall Treatment Processes Applied for Priority Systems

Based on the above-mentioned examination and criteria, the results of applicable process selection for respective STFs are enumerated in Table B.4-3.

In terms of biological system, the Cabanga STF and the Cordeiro STF shall apply the "RAFA + bio-filtration" process due to the limitation of available land area. Meanwhile, the "RAFA + aerated lagoon + polishing pond" process shall be applicable for other STFs, which have enough land space.

As for sludge treatment systems, mechanical dehydration shall be employed in the Cabanga STF, the Boa Viagem STF and the Cordeiro STF, since they are located in densely populated urban areas. Other STFs shall use natural drying process.

5. DESIGN CRITERIA APPLIED FOR PRIORITY SYSTEMS

5.1 General

The preliminary design has been carried out in accordance with the "Guidance on Sewerage Facilities Planning and Design" (issued by the Japan Sewage Works Association). The ABNT standards and norms relevant to sewerage facility design were also incorporated, when they were considered appropriate and suitable for this Study.

5.2 Basic Design Criteria

In the preliminary design of the STFs, the following were adopted:

(1) Layout plan of STFs

The layout plans of the STFs were formulated in accordance with the following basic criteria:

- The facilities were located to allow enough space for routine and periodical operation /maintenance and overhauls, and
- The plans and vertical sections were designed so that water in main lines flows by gravity as a rule.

(2) Utility and auxiliary facilities

STFs shall be provided with a source of electricity to allow continuous operation. Alternative power facilities for emergency shall not be incorporated in the STF, as the STF can cope with potential power stoppages in the RMR.

Supervisory boards shall be installed in the control room of administration buildings. The supervision and monitoring of the operating status of not only STFs but also pump stations in the respective sewerage areas shall take place at these boards, collectively.

Adequate sanitation facilities (water supply and toilets) shall be provided in administration buildings.

The STFs shall be equipped with laboratory facilities necessary for daily and periodical measurements/analyses of water and sludge quality.

(3) Site preparation and access roads

The ground surfaces of STF sites shall be leveled off by grading or reclamation at the elevation required to protect against submersion of sites and to allow for the discharge of treated sewage into receiving water bodies by gravity.

Access roads of at least six (6) meters in width from major roads to STF sites shall be provided, if they are not available at present

(4) Measures to deal with environmental problems

The following preventive and preservation measures shall be incorporated to avoid environmental problems arising from the construction works and operation of the STFs:

- Green zones (10 m in width at least, as a rule) shall be laid around the periphery of STF sites to mitigate offensive odor and noise, and to avoid damage to the surrounding landscape,
- To prevent the emission of offensive odor, influent systems consisting of grit chambers, bar screens and influent pumps, and dehydrators shall be accommodated inside the building and a simple deodorizer shall treat exhausted air,
- Emitted gas from RAFA reactors, which contains offensive odor constituents, shall be diffused from a centralized stack into the air,
- The installation of STFs shall take place, avoiding mangrove areas contained in the land proposed by the Counterpart.

5.3 Design Criteria for Facilities

Component facilities in STFs shall be designed based on the following criteria, in compliance with the aforementioned applicable standards/norms and special conditions in this Study.

The process calculation results in the preliminary design are shown in the APPENDICES.

(1) Grit chamber

Type:	Rectangular type
Design base flow:	Hourly maximum flow
Water surface loading rate:	Max. 1,300 m^3/m^2/day
Hydraulic Retention Time:	40 sec.

Grit chambers are designed to remove grit particles with larger than 0.15 mm in diameter.

(2) **Influent pump**

Type:	Vertically mixed flow or centrifugal type
Design base flow:	Hourly maximum flow
Suction side velocity:	Less than 2 m/sec

(3) **RAFA reactor**

Type:	Rectangular type
Design base flow:	Daily maximum flow
BOD removal rate:	75 %
Hydraulic detention time:	7 hours
Water depth of reactor:	5.0 - 6.0 m

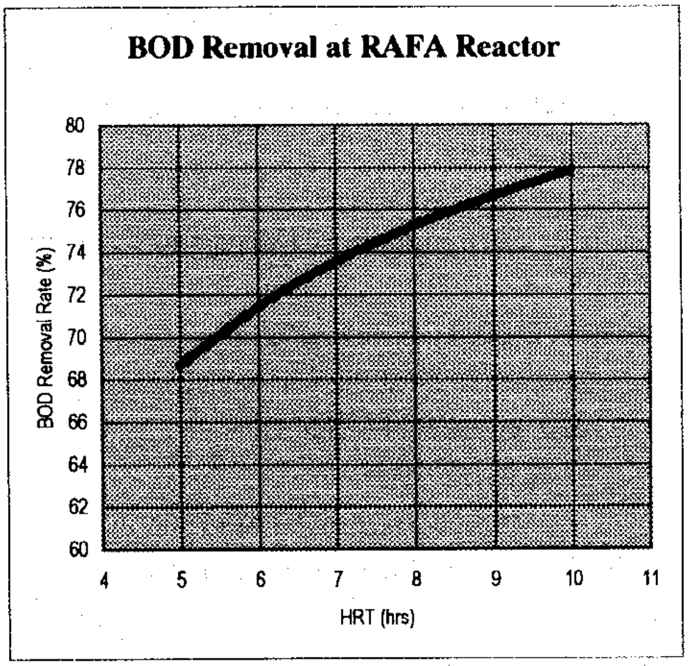
The required HRT of RAFA reactors is justified below.

It has been known that the BOD removal rate in an RAFA reactor is highly influenced by the water temperature. Based on the operation data, which were obtained from actual reactors in Colombia, Brazil, etc., the BOD removal rate is shown in the following figure in the relation with the HRT under the temperature of between 20 and 25 ℃ (average 23 ℃) and is expressed in the following equation[1]:

$E_{23} = 100\,(1 - 0.70\,\theta^{-0.50})$

Where, E_{23} : BOD removal rate at 23℃ (%)

θ : HRT (hours)



[1] : "Wastewater Treatment by Anaerobic Process" issued by PROSAB.

In this Study, the following expedient formula was employed to correct the influence of temperature:

$E_t = 100 (1 - 0.70 \theta^{-0.50}) \times 1.012^{(t-23)}$ .... (1)

Where, E_t : BOD removal rate at t ℃ (%)

Applying 28 ℃ of the design temperature, the formula (1) gives 78.1 % of BOD removal rate to the HRT of 7.0 hours. This result coincides with the performance results of the Mangueira treatment plant. Consequently, 75 % of BOD removal was applied for this Study.

The standard configuration of a RAFA reactor to be used is shown in Fig. B.5-1.

(4) Aerated lagoon

Type:	Rectangular type with aeration
Design base flow:	Daily maximum flow
BOD removal rate:	60 % (after being clarified at polishing ponds)
Hydraulic detention time:	1.0 day
Water depth of lagoon:	3.8 m

The required HRT of an aerated lagoon is justified below.

Assuming the BOD removal rate in a RAFA Reactor and an aerated lagoon to be η_1 and η_2, respectively, the overall BOD removal rate of a STF (η_0, %) may be expressed by:

$\eta_0 = \eta_1 + (100 - \eta_1)(\eta_2/100)$ (%)

Under the conditions that η_0, η_1 are 90 % and 75 %, respectively, the required η_2 may be calculated as:

$\eta_2 = 100 (\eta_0 - \eta_1)/(100 - \eta_1)$

$= 100 (90 - 75)/(100 - 75)$

$= 60$ (%)

The filtered effluent BOD (F_e, mg/l) of the aerated lagoon may be expressed by:

$F_e = L_i (1 - \eta_2/100)$ (mg/l)

Where, L_i: Influent BOD of aerated lagoon (mg/l)

Assuming the influent BOD of an aerated lagoon, namely the effluent BOD of a RAFA reactor to be 90 mg/l as a representative figure,

$F_e = 90 (1 - 60/100) = 36$ (mg/l)

Applying a first-order removal reaction to the BOD reduction in an aerated lagoon, the effluent BOD of an aerated lagoon (F_e) may be calculated by[1]:

$F_e = L_i / (+ k X t)$ (mg/l) (1)

Where k: First-order removal rate constant (day^{-1})

[1] : "Sewage Treatment in Hot Climates" by D. Mara (1975)

X: Cell concentration (mg/l)

t: Hydraulic retention time (HRT) (mg/l)

Assuming the "k_{20}" at 20 °C to be 0.07 of empirical figure, the "k_{28}" at 28 °C may be calculated as follows:

$k_{28} = k_{20} (1.05)^{T-20}$

$= 0.07 (1.05)^{28-20}$

$= 0.0887$ (day^{-1})

The equation (1) may be transformed as follows:

$t = (Li - F_e)/F_e\, k\, X$

Assuming "X" to be 35 mg/l as a representative value,

$t = (90 - 36) / (36 \times 0.0887 \times 35)$

$= 0.48$ (day)

As understood from the above, the BOD removal rate (filtered BOD base) in an aerated lagoon may reach 60 % within the HRT of some 0.5 day.

Based on literatures and experience in wastewater treatment, it has been known that the whole lagoon system consisting of an aerated lagoon and a polishing pond requires two (2) to three (3) days at least to keep the coagulation of cell secured. Therefore, the HRT was designed as 1.0 and 1.5 days in an aerated lagoon and a polishing pond, respectively.

(5) Polishing pond

Type:	Rectangular type without aeration
Design base flow:	Daily maximum flow
Functions:	Settling of solids
Hydraulic detention time:	1.5 day
Water depth of lagoon:	3.6 m

(6) Bio-filter

Type:	Circular and high-rate type
Design base flow:	Daily maximum flow
BOD removal rate:	60 %
BOD loading rate:	Max. 0.75 kg-BOD/m^3/day
Depth of filter media:	2.0 m

Circulation rate of treated water: 2.0 to the influent sewage flow

Regarding the process design of a bio-filter, reliable and practical procedures that were based on the theory of biological reaction have not been established. In this Study, the above-mentioned criteria were adopted based on performance data in actual treatment plant working in Japan and other countries. It is considered that the applied BOD loading rate is enough light to prevent the emission of offensive odor and the generation of flies.

The standard configuration of the bio-filter is shown in Fig. B.5-2.

(7) **Sedimentation tank**

Type:	Circular or rectangular type
Design base flow:	Daily maximum flow
Water surface loading rate:	Max. 24 m^3/m^2/day

The standard configurations of the sedimentation tanks are shown in Fig. B.5-3 and Fig. B.5-4.

(8) **Disinfection tank**

Type:	Rectangular type with UV light disinfection unit
Design base flow:	Daily maximum flow

(9) **Sludge thickener**

Type:	Rectangular and gravity type
Design base flow:	Daily average flow
Sludge content:	Inlet 1.0 % and outlet 3.5 %
Solid surface loading rate:	Max. 60 kg-DS/m^2/day

(10) **Sludge dehydrator**

Type:	Belt-press type
Design base flow:	Daily average flow
Operation hour:	8 hours per day
Water content of sludge:	Inlet 96.5 % and outlet 80 %
Filtration rate:	Max. 130 kg-DS/m/hour

(11) **Sludge drying bed**

Type:	Natural drying bed type with roof
Design base flow:	Daily average flow
Water content of sludge:	Inlet 99 % and outlet about 50 to 60 %
Drying rate:	1.3 kg-DS/m^2/day

6. PRELIMINARY DESIGN OF PRIORITY SYSTEMS

6.1 General

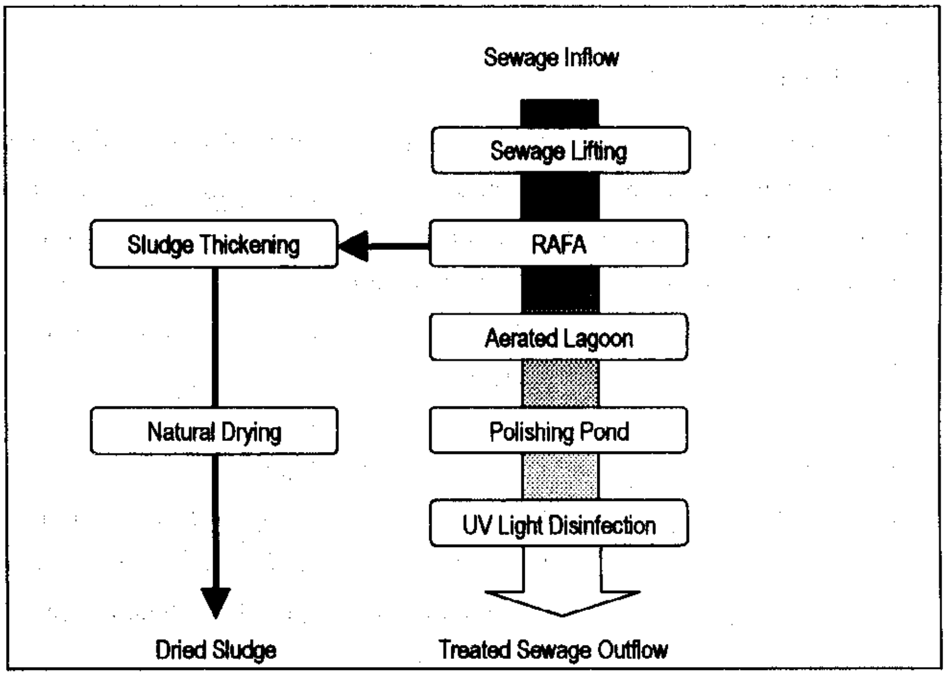
Based on the design conditions, the selection of treatment processes and the design criteria mentioned before, the preliminary design of the seven (7) priority STFs was carried out. The Bill of Quantities for respective STFs formulated based on the preliminary design are shown in the APPENDICES.

6.2 Conceicao STF

(1) General

The Conceicao STF consists of the following steps: the "RAFA + aerated lagoon + polishing pond" for the biological treatment system and the "natural drying" for the sludge treatment system, as shown below.

Treatment Flow of Conceicao STF



Treated sewage shall be discharged by gravity into the Timbo River through embedded discharge pipes. The sludge generated from the treatment facilities shall be disposed of at landfill sites, transported after being dried naturally at the STF site.

The flow diagram, the hydraulic profile and the layout plan of the STF shown in Fig. B.6-1, Fig. B.6-2 and Fig. B.6-3, respectively are the results of preliminary design.

(2) Construction site

The site is situated at the locally determined coordinates, 2.97E / 91.29N, in the Municipality of Paulista and lies near lagoons in the estuary of the Timbo River and its tributaries. The land of 8.2 ha shall used as the treatment station. At present, the land belongs to a private enterprise, which has a cement factory nearby.

At the moment, the land is vacant with bushes and trees. A beverage factory is in operation next to the site to the south and residential houses are sited to the east.

The present ground surface at the site is inclined from the north to the south with the level between 20 m and 2 m (+ MSL). The STF shall be constructed on a plot at a level of 4.5 m (+ MSL), prepared by grading and reclamation to prevent the site from submersion and to discharge treated sewage by gravity.

(3) Major facilities and structural works

1) Influent system

(a) Grit chamber

The grit chambers are designed to remove coarse substances like sand by gravity separation and equipped with motor-driven bucket conveyers to remove settling materials on the bottom of the chamber. They are mainly constructed of reinforced concrete and have the following specifications:

Type:	Rectangular concrete tank with bucket conveyers,
Quantities:	2 units,
Dimensions:	2.0 m wide x 5.0 m long x 0.5 m deep/water per unit,
Water surface:	10 m2 x 2 units = Total 20 m2,
Appurtenances:	Inflow gates, coarse bar screens (manually operated), fine bar screens (motor-driven), grit hoisting crane, and biological-film type deodorization equipment with exhaust fan.

(b) Influent pump

The influent pumps are designed to lift up incoming sewage to the subsequent system. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically mixed flow pump,
Quantities:	3 units including one standby,

Capacity:	7.2 m^3/min x 300 mm-ND x 16 m-Head x 40 CV per unit,
Appurtenances:	Inflow sewage flow meter, maintenance crane and influent well.

2) **Biological treatment system**

(a) RAFA reactor

The RAFA reactors are designed to decompose organic pollutants in sewage by anaerobic biological degradation. They are mainly constructed of reinforced concrete and equipped with gas-liquid-solid separators inside, which are comprised of inflow pipes, baffle plates, outflow troughs, etc. Their main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	4 trains x 9 units = Total 36 units,
Dimensions:	5.0 m wide x 5.0 m long x 6.0 m deep per unit,
Volume:	Effective 125 m^3 x 36 units = Total 4,500 m^3,
Appurtenances:	RAFA distribution box, distribution trough, lagoon distribution box, exhaust stacks, sludge sump and sludge draw-off pumps.

(b) Aerated lagoon

The aerated lagoons are designed to remove organic pollutants remaining in the outflow from the RAFA reactors by aerobic biological purification. They are formed by earthen embankments with partial concrete revetment and equipped with submersible aerators. Main specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	2 units,
Dimensions:	32 m wide x 100 m long x 4.3 m deep per unit,
Volume:	Effective 7,695 m^3 x 2 units = Total 14,900 m^3,
Appurtenances:	Submersible aerators (3.7 kw x 6 units).

(c) Polishing pond

The polishing ponds are designed to settle suspended solids in the outflow from aerated lagoons by gravity separation and also to digest anaerobically a part of accumulating sludge. Earthen embankments with partial concrete revetment constitute their main portions. Their specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	2 units,
Dimensions:	32 m wide x 152 m long x 4.3 m deep per unit,
Volume:	Effective 11,246 m^3 x 2 units = Total 22,492 m^3.

3) **Disinfection system**

The disinfection system is designed to reduce pathogens and parasites in biologically treated sewage so as to meet the discharge standard for total coliforms. The system consists of a disinfection tank and an ultra-violet (UV) light disinfection unit, as shown below:

Type:	Rectangular concrete tank,
Quantities:	1 unit,
Dimensions:	3.0 m wide x 6.0 m long x 2.5 m deep per unit,
Volume:	Effective 45 m^3
Appurtenances:	UV light disinfection unit.

4) **Treated sewage discharge system**

Finally treated sewage is discharged into the Timbo River through the following embedded pipes and the outfall:

Design water level:	1.36 m (+ MSL),
Pipe:	ND 800 mm x 2,900 m long,
Material:	Reinforced concrete.

5) **Sludge treatment system**

(a) Sludge thickener

The sludge thickener is designed to thicken the sludge generated from the biological treatment system and homogenize it. Its main portion is constructed of reinforced concrete and a motor-driven sludge collector is attached inside. Its specifications are as follows:

Type:	Cylindrical concrete tank,
Quantities:	1 unit,
Dimensions:	4.5 m dia. x 5.0 m deep,
Volume:	Effective 63 m^3
Appurtenances:	Sludge collector.

(b) Sludge drying bed

The sludge drying beds are designed to naturally dry the sludge generated from the biological treatment system. Their main portions are constructed of reinforced concrete and their specifications are as follows:

Type: Rectangular concrete tank,
Quantities: 6 units,
Dimensions: 10 m wide x 15 m long x 1.0 m deep,
Volume: Effective 900 m^2,
Dehydrated sludge quantity: 2.1 ton-Wet (60 % moisture),

6) Electrical and control system

All equipment in the sewage treatment station as well as all pumps in the pump stations of the Conceicao Sewerage System shall be collectively supervised from the integrated supervisory board. This shall be installed in the control room of the administration building.

7) Buildings and civil works

The following building construction and civil works shall be carried out:

(a) Buildings

Influent pump room: 10 m wide x 10 m long,
Disinfection room: 7 m wide x 12 m long,
Electrical room: 7 m wide x 10 m long,
Administration building: 25 m wide x 40 m long (one storey)

The administration building shall accommodate rooms such as: control room, administration room, electrical room, laboratory, staff room, workshop, storage, resting room with toilets and conference room.

(b) Civil works

Civil works shall include miscellaneous structures in the station yard, such as: guard fence and gates, landscaping, parking lots, rainwater drainage, etc.

6.3 Janga STF

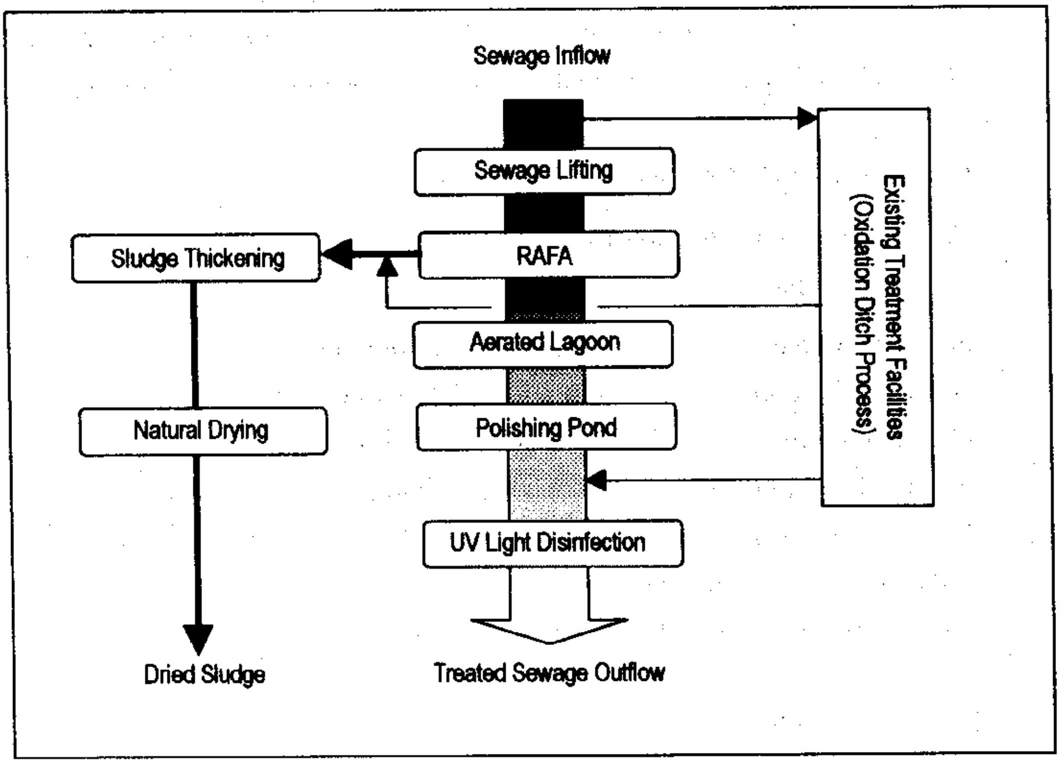
(1) General

The Janga STF shall be equipped with dual treatment trains. One comprises the existing treatment facilities consisting of oxidation ditches and other related equipment, which are used after the necessary rehabilitation. The other is a newly installed treatment facilities consisting of the following steps: the "RAFA + aerated lagoon + polishing pond" for the biological treatment system and the "natural drying" for the sludge treatment system, as shown below.

The treated sewage and the sludge from the existing facilities will be handled by the newly installed facilities after being mixed together as shown in the following figure.

Treated sewage shall be discharged by gravity into the Timbo River through embedded discharge pipes. This discharge pipe will be newly installed, replacing the existing one. The sludge generated from the treatment facilities shall be disposed of at landfill sites, transported after being dried naturally at the STF.

Treatment Flow of Janga STF



The flow diagram, the hydraulic profile and the layout plan of the facilities shown in Fig. B.6-4, Fig. B.6-5 and Fig. B.6-6, respectively are the results of preliminary design.

(2) Construction site

The site is located at the existing treatment station situated at the locally determined coordinates, 2.96E / 91.22N, in the Municipality of Paulista and lies near the upper reach of the Timbo River and its tributaries. The land belongs to COMPESA.

New series of treatment facilities will be constructed next to the existing ones and certain component facilities will be placed in the area of the existing facilities. The land of 12.3 ha excluding the area occupied by the existing facilities shall be used for the treatment station.

The present ground at the site is inclined from north to south with levels between 25 m and 5 m (+ MSL). It is currently vacant with bushes and trees, and a certain portion of the scheduled area has already been leveled. The STF shall be constructed at ground levels of 8.0 m, 11.0 m, 13.0 m and 16.0 m (+ MSL), which are prepared by grading and reclamation.

(3) Major facilities and structural works

1) Influent system

(a) Grit chamber

The grit chambers are designed to remove coarse substances like sand by gravity separation and equipped with motor-driven bucket conveyers to remove settling materials on the bottom of the chamber. They are mainly constructed of reinforced concrete and have the following specifications:

Type:	Rectangular concrete tank with bucket conveyers,
Quantities:	3 units,
Dimensions:	2.0 m wide x 7.0 m long x 0.8 m deep/water per unit
Water surface:	14 m^2 x 3 units = Total 32 m^2,
Appurtenances:	Sewage distribution well, inflow gates, coarse bar screens (manually operated), fine bar screens (motor-driven), grit hoisting crane and biological-film type deodorization equipment with exhaust fan.

(b) Influent pump

The influent pumps are designed to lift up incoming sewage to the subsequent system. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically mixed flow flow,
Quantities:	4 units including one standby,
Capacity:	11.5 m^3/min x 350 mm-ND x 13 m-Head x 50 CV per unit,
Appurtenances:	Inflow sewage flow meter, maintenance crane and influent well.

2) Biological treatment system

(a) RAFA reactor

The RAFA reactors are designed to decompose organic pollutants in sewage by anaerobic biological degradation. They are mainly constructed of reinforced concrete and equipped with gas-liquid-solid separators inside, which are comprised of inflow pipes, baffle plates, outflow troughs, etc. Their main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	4 trains x 21 units = Total 84 units,
Dimensions:	5.0 m wide x 5.0 m long x 6.0 m deep per unit,
Volume:	Effective 125 m^3 x 84 units = Total 10,500 m^3,
Appurtenances:	RAFA distribution box, distribution trough, lagoon distribution box, exhaust stacks, sludge sumps, anaerobic sludge draw-off pumps.

(b) Aerated lagoon

The aerated lagoons are designed to remove organic pollutants remaining in the outflow from the RAFA reactors by aerobic biological purification. They are formed by earthen embankments with partial concrete revetment and equipped with submersible aerators. Main specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	4 units,
Dimensions:	50 m wide x 66 m long x 4.3 m deep per unit,
Volume:	Effective 8,659 m^3 x 4 units = Total 34,636 m^3,
Appurtenances:	Submersible aerators (3.7 kw x 16 units).

(c) Polishing pond

The polishing ponds are designed to settle suspended solids in the outflow from aerated lagoons by gravity separation and also to digest anaerobically a part of accumulating sludge. Earthen embankments with partial concrete revetment constitute their main portions. Their specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	4 units,
Dimensions:	50 m wide x 100 m long x 4.3 m deep per unit,
Volume:	Effective 12,960 m^3 x 4 units = Total 51,840 m^3.

3) **Disinfection system**

The disinfection system is designed to reduce pathogens and parasites in biologically treated sewage so as to meet the discharge standard for total coliforms. The system consists of a disinfection tank and an ultra-violet (UV) light disinfection unit, as shown below:

Type:	Rectangular concrete tank,
Quantities:	1 unit,
Dimensions:	4.0 m wide x 10 m long x 2.5 m deep per unit,
Volume:	Effective 88 m^3
Appurtenances:	UV light disinfection unit.

4) **Treated sewage discharge system**

Finally treated sewage is discharged into the Timbo River through the embedded pipes and the outfall. The existing discharged pipes (ND 800 mm x 2 sets) will be demolished, since they are old and broken partially. Instead, the following additional pipe will be installed.

Design water level:	1.36 m (+ MSL),
Pipe:	ND 1200 mm x 2,300 m long,
Material:	Reinforced concrete.

5) **Sludge treatment system**

(a) Sludge thickener

The sludge thickener is designed to thicken the sludge generated from the biological treatment system and homogenize it. Its main portion is constructed of reinforced concrete and a motor-driven sludge collector is attached inside. Its specifications are as follows:

Type:	Cylindrical Concrete tank,
Quantities:	1 unit,
Dimensions:	15 m dia. x 5.0 m deep,
Volume:	Effective 706 m^3,
Appurtenances:	Sludge collector.

(b) Sludge drying bed

The sludge drying beds are designed to naturally dry the sludge generated from the biological treatment system. Their main portions are constructed of reinforced concrete and their specifications are as follows:

Type:	Rectangular concrete tank,

Quantities: 56 units,
Dimensions: 10 m wide x 15 m long x 1.0 m deep,
Volume: Effective 8,400 m^2,
Dehydrated sludge quantity: 24.6 ton-Wet (60 % moisture),
Appurtenances: Filtered water return pumps.

6) **Electrical and control system**

All equipment in the sewage treatment station as well as all pumps in the pump stations of the Conceicao Sewerage System shall be collectively supervised from the integrated supervisory board. This shall be installed in the control room of the administration building.

7) **Buildings and civil works**

The following building construction and civil works shall be carried out:

(a) Buildings

Influent pump room: 10 m wide x 18 m long,
Disinfection room: 10 m wide x 15 m long,
Electrical room: 10 m wide x 15 m long,
Administration building: 20 m wide x 27.5 m long (two-storey)

The administration building shall accommodate rooms such as: control room, administration room, electrical room, laboratory, staff room, workshop, storage, resting room with toilet and conference room.

(b) Civil works

Civil works shall include miscellaneous structures in the station yard, such as: guard fence and gates, landscaping, parking lots, rainwater drainage, etc.

6.4 Cabanga STF

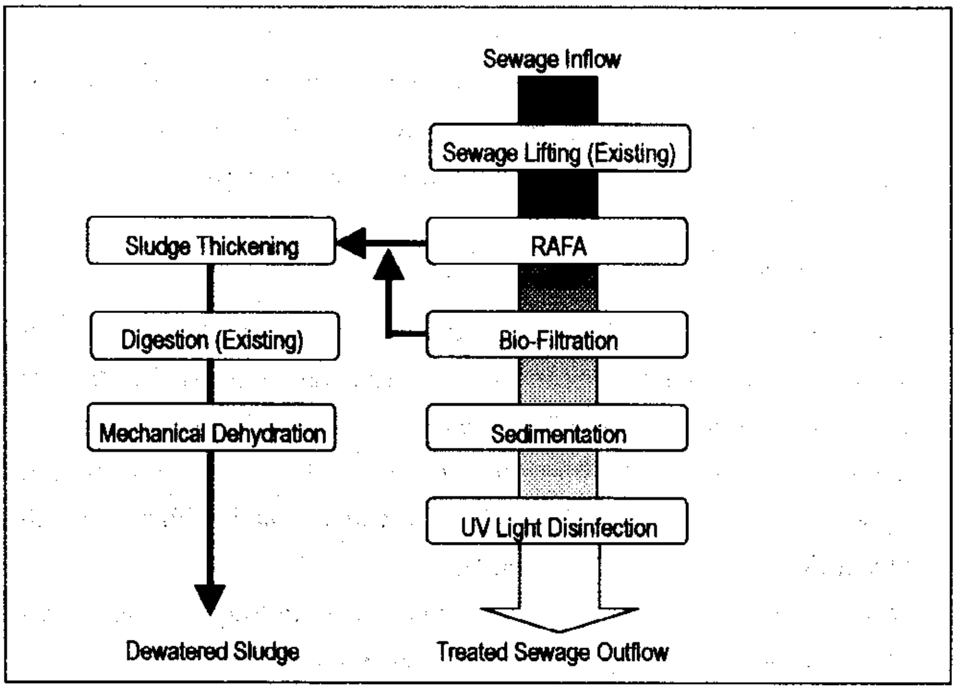
(1) General

The Cabanga STF consists of the following steps: the "RAFA + bio-filtration" for the biological treatment system and the "digestion + mechanical dehydration" for the sludge treatment system. Of the existing facilities, influent pumps, grit chambers, sludge digesters and gasholder shall be used after rehabilitation and integrated in the newly installed facilities, as shown below.

Treated sewage shall be discharged by gravity into the Pina Bay through embedded discharge pipes. The sludge generated from the treatment facilities shall be disposed of at landfill sites, after being dehydrated mechanically at the STF site and transported.

The flow diagram, the hydraulic profile and the layout plan of the facilities shown in Fig. B.6-7, Fig. B.6-8 and Fig. B.6-9, respectively are the results of preliminary design.

Treatment Flow of Cabanga STF



(2) Construction site

The facilities will be constructed in the existing treatment station at the locally determined coordinates, 2.91E / 91.07N, in the Municipality of Recife. It is close to the Governador Agamenon Maglhnaes Bridge and belongs to COMPESA.

The ground at the site is almost flat with levels of around 2.5 to 3.0 m (+ MSL) and the STF shall be constructed on the plot at a level of 3.0 m (+ MSL).

The total area of the Station is 3.8 ha without any expansion area outside. The STF shall be constructed in the space, which is used as a football ground and others. The areas for parts of old existing facilities to be demolished will be used also.

(3) Major facilities and structural works

1) Influent system

(a) Influent pump

The influent pumps, which are existing now, were designed to lift up incoming sewage to the subsequent system and include one standby unit. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically centrifugal pump,
Quantities:	5 units including one standby,
Capacity:	26.4 m^3/min x 75 HP per unit,
Appurtenances:	Influent well, fine bar screens (motor-driven) and influent trough, biological-film type deodorization equipment with exhaust fan.

(b) Grit chamber

The grit chambers, which are existing now, were designed to remove coarse substances like sand by gravity separation and equipped with motor-driven grit collectors to remove settling materials on the bottom of chambers. Main portions of them are constructed of reinforced concrete and have the following specifications:

Type:	Rectangular concrete tank with rotary collector,
Quantities:	2 units,
Dimensions:	8.75 m wide x 8.75 m long x 0.6 m deep/water per unit,
Water surface:	76 m^2 x 2 units = Total 152 m^2.

(c) Transfer pump

The transfer pumps are designed to transfer sewage treated by the grit chambers to the RAFA reactors and include one standby unit. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically mixed flow and axial flow pump,
Quantities:	5 units including one standby,
Capacity:	16.5 m^3/min x 450 mm ND x 10 m-Head x 50 CV per unit,
Appurtenances:	Transfer tank.

2) Biological treatment system

(a) RAFA reactor

The RAFA reactors are designed to decompose organic pollutants in sewage by anaerobic biological degradation. They are mainly constructed of reinforced concrete and equipped with gas-liquid-solid separators inside, which are comprised of inflow pipes, baffle plates, outflow troughs, etc. Their main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	8 trains x 17 units = Total 136 units,
Dimensions:	5.0 m wide x 5.0 m long x 7.0 m deep per unit,
Volume:	Effective 150 m^3 x 136 units = Total 20,400 m^3,
Appurtenances:	RAFA distribution box, B/F distribution box, distribution trough, exhaust stacks, sludge sumps and RAFA sludge draw-off pumps.

(b) Bio-filter

The bio-filters are intended to remove organic pollutants remaining in the outflow from RAFA reactors by aerobic biological purification. They are mainly constructed of reinforced concrete. Gravel as the media to be attached by the biological film is packed inside. Main specifications are as follows:

Type:	Cylindrical concrete tank,
Quantities:	3 units,
Dimensions:	39 m dia. x 2.5 m deep per unit,
Horizontal area:	Effective 1,194 m^2 x 3 units = Total 3,582 m^2,
Appurtenances:	Rotary spray units.

(c) Recirculation pump

The recirculation pumps are intended to return treated sewage to the bio-filters and to spray water, so that water drops uniformly onto the gravel surface. Their maximum discharge is designed to be twice the daily maximum sewage flow. Main specifications are as follows:

Type:	Vertically mixed flow and axial flow pump,
Quantities:	7 units including one standby,
Capacity:	16.0 m^3/min x 450 mm-ND x 8 m-Head x 40 CV per unit,
Appurtenances:	Recirculation well.

(d) Sedimentation tank

The sedimentation tanks are designed to settle suspended solids in the outflow from bio-filters by gravity. They are mainly constructed of reinforced concrete and are equipped with a chain conveyer to collect sludge from the bottom. Main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	4 units,
Dimensions:	12 m wide (4 m x 3 channels) x 60 m long x 3.8 m deep per unit,
Horizontal area:	Effective 720 m^2 x 4 units = Total 2,880 m^2.

3) Disinfection system

A disinfection system is designed to reduce pathogens and parasites in biologically treated sewage so as to meet the discharge standard for total coliforms. The system consists of a disinfection tank and an ultra-violet (UV) light disinfection unit, as shown below:

Type:	Rectangular concrete tank,
Quantities:	1 unit,
Dimensions:	5.0 m wide x 12 m long x 2.5 m deep per unit,
Volume:	Effective 150 m^3
Appurtenances:	UV light disinfection unit.

4) Treated sewage discharge system

Finally treated sewage is discharged into the Pina Bay through the following embedded pipes and the outfall:

Design water level:	1.36 m (+ MSL),
Pipe:	ND 1000 mm x 50 m long x two (2) sets,
Material:	Reinforced concrete.

5) Sludge treatment system

(a) Sludge thickener

The sludge thickener is designed to thicken the sludge generated from the biological treatment system and homogenize it. Its main portion is constructed of reinforced concrete and a motor-driven sludge collector is attached inside. Its specifications are as follows:

Type:	Cylindrical concrete tank,
Quantities:	1 unit,

Dimensions:	13 m dia. x 5.0 m deep,
Volume:	Effective 530 m^3
Appurtenances:	Sludge collector.

(b) Sludge digester

The sludge digesters, which already exist, are intended to anaerobically decompose easily degraded components of the sludge generated from the biological treatment system. They are mainly constructed of reinforced concrete and their specifications are as follows:

Type:	Cylindrical concrete tank,
Quantities:	2 units,
Dimensions:	25 m diameter x 8.2 m deep,
Volume:	Effective 4,115 m^3 x 2 units = Total 8,230 m^3,
Appurtenances:	Sludge recirculation pumps, digested sludge pumps.

(c) Gas holder

The gas holder, which already exists, is designed to store bio-gas generated from the sludge digester. It is mainly constructed of reinforced concrete and its specifications are as follows:

Type:	Cylindrical concrete tank (floating roof type),
Quantities:	1 unit,
Dimensions:	10 m diameter x 5.0 m deep,
Volume:	Effective 780 m^3,
Appurtenances:	Bio-gas burner.

(d) Dehydrator

The dehydrators are designed to dewater the sludge generated from the biological treatment system and their specifications are as follows:

Type:	Filter belt-press type,
Quantities:	2 units,
Dimensions:	2.5 m wide (belt),
Dehydrated sludge quantity:	22.4 ton-Wet (80 % moisture),
Appurtenances:	Polymer coagulant injection unit, biological-film type deodorization equipment with exhaust fan.

6) Electrical and control system

All equipment in the sewage treatment station as well as all pumps in the pump stations of the Conceicao Sewerage System shall be supervised from the integrated supervisory board. This shall be installed in the new administration room.

7) Buildings and civil works

The following building construction and civil works shall be carried out:

(a) Buildings

Transfer pump room:	7 m wide x 10 m long,
Recirculation pump room:	10 m wide x 25 m long,
Disinfection room:	10 m wide x 15 m long,
Electrical room:	10 m wide x 15 m long,
Administration building:	18 m wide x 25 m long (three-storey)

The administration building shall accommodate rooms such as: control room, administration room, dehydration room, chemical room, sludge cake room, electrical room, laboratory, staff room, workshop, storage, resting room with toilet and conference room.

(b) Civil works

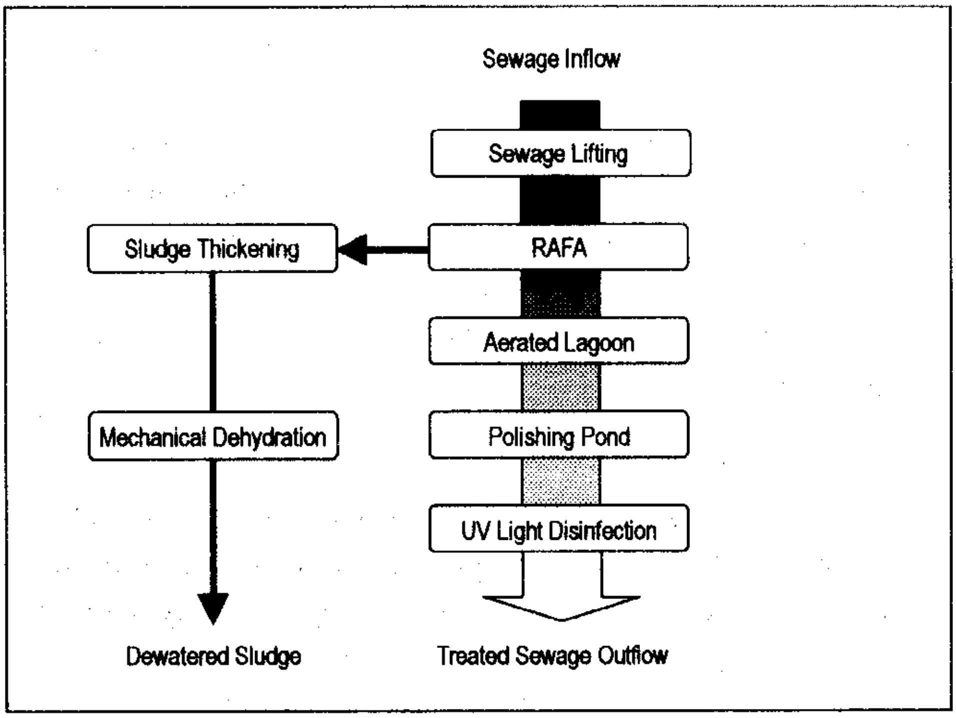
Civil works shall include miscellaneous structures in the station yard, such as: guard fence and gates, landscaping, parking lots, rainwater drainage, etc.

6.5 Boa Viagem STF

(1) General

The Boa Viagem STF consists of the following steps: the "RAFA + aerated lagoon + polishing pond" for the biological treatment system and the "natural drying" for the sludge treatment system, as shown below.

Treatment Flow of Boa Viagem STF



Treated sewage shall be discharged by gravity into the Jordao River through embedded discharge pipes. The generated sludge from the treatment facilities shall be disposed of at a landfill site, after being dehydrated mechanically at the STF site and transported.

The flow diagram, the hydraulic profile and the layout plan of the facilities shown in Fig. B.6-10, Fig. B.6-11 and Fig. B.6-12, respectively are the results of preliminary design.

(2) Construction site

The site is located at the locally determined coordinates, 2.89E / 91.03N, in the Municipality of Recife. The site with an area of 8.7 ha lies between the Jordao River and a railway, and the land belongs to several private citizens.

At present, the land has many high-trees and is being used sporadically as a park. The site faces factories to the south and residential zones to the west beyond the railway. Although a road from the south is the only access way to the site, this is being occupied by illegal settlement. It is requested that these illegal houses are moved to ensure the free flow of traffic for the construction and the operation.

The land with an area of 8.7 ha shall be used as the STF site. The ground at the site is undulated between 2 m and 4 m (+ MSL). The Station will be constructed on the plot at a level of 4.0 m (+ MSL), which is to be prepared by reclamation and grading.

As a result of the environmental survey in this Study, a mangrove area of some 0.7 ha was identified at the riverside to the east of the land proposed by the Counterpart. Therefore, the utilization of this area as the construction site of the STF was avoided.

(3) Major facilities and structural works

1) Influent system

(a) Grit chamber

The grit chambers are designed to remove coarse substances like sand by gravity separation and equipped with motor-driven bucket conveyers to remove settling materials on the bottom of the chamber. They are mainly constructed of reinforced concrete and have the following specifications:

Type:	Rectangular concrete tank with bucket conveyers,
Quantities:	3 units,
Dimensions:	2.0 m wide x 7.0 m long x 0.8 m deep/water per unit
Water surface:	14 m^2 x 3 units = Total 42 m^2,
Appurtenances:	Inflow gates, coarse bar screens (manually operated), fine bar screens (motor-driven), grit hoisting crane and biological-film type deodorization equipment with exhaust fan..

(b) Influent pump

The influent pumps are designed to lift up incoming sewage to the subsequent system. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically mixed flow pump,
Quantities:	4 units including one standby,
Capacity:	11.0 m^3/min x 350 mm-ND x 16 m-Head x 60 CV per unit,
Appurtenances:	Inflow sewage flow meter, maintenance crane and influent well.

2) **Biological treatment system**

(a) RAFA reactor

The RAFA reactors are designed to decompose organic pollutants in sewage by anaerobic biological degradation. They are mainly constructed of reinforced concrete and equipped with gas-liquid-solid separators inside, which are comprised of inflow pipes, baffle plates, outflow troughs, etc. Their main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	4 trains x 20 units = Total 80 units,
Dimensions:	5.0 m wide x 5.0 m long x 6.0 m deep per unit,
Volume:	Effective 125 m^3 x 80 units = Total 10,000 m^3,
Appurtenances:	RAFA distribution box, distribution trough, lagoon distribution box, exhaust stacks, anaerobic sludge draw-off pumps.

(b) Aerated lagoon

The aerated lagoons are designed to remove organic pollutants remaining in the outflow from the RAFA reactors by aerobic biological purification. They are formed by earthen embankments with partial concrete revetment and equipped with submersible aerators. Main specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	3 units,
Dimensions:	49 m wide x 86 m long x 4.3 m deep per unit,
Volume:	Effective 11,439 m^3 x 3 units = Total 34,317 m^3,
Appurtenances:	Submersible aerators (3.7 kw x 15 units).

(c) Polishing pond

The polishing ponds are designed to settle suspended solids in the outflow from aerated lagoons by gravity separation and also to digest anaerobically a part of accumulating sludge. Earthen embankments with partial concrete revetment constitute their main portions. Their specifications are as follows:

Type:	Rectangular earth pond,
Quantities:	3 units,
Dimensions:	49 m wide x 125 m long x 4.3 m deep per unit,
Volume:	Effective 16,146 m^3 x 3 units = Total 48,438 m^3,

3) **Disinfection system**

The disinfection system is designed to reduce pathogens and parasites in biologically treated sewage so as to meet the discharge standard for total coliforms. The system consists of a disinfection tank and an ultra-violet (UV) light disinfection unit, as shown below:

Type:	Rectangular concrete tank,
Quantities:	1 unit,
Dimensions:	3.0 m wide x 10 m long x 2.5 m deep per unit,
Volume:	Effective 75 m^3
Appurtenances:	UV light disinfection unit.

4) **Treated sewage discharge system**

Finally treated sewage is discharged into the Jordao River through the following embedded pipes and the outfall:

Design water level:	1.36 m (+ MSL),
Pipe:	ND 800 mm x 95 m long,
Material:	Reinforced concrete.

5) **Sludge treatment system**

(a) Sludge thickener

The sludge thickener is designed to thicken the sludge generated from the biological treatment system and homogenize it. Its main portion is constructed of reinforced concrete and a motor-driven sludge collector is attached inside. Its specifications are as follows:

Type:	Cylindrical Concrete tank,
Quantities:	1 unit,
Dimensions:	7.5 m dia. x 5.0 m deep,
Volume:	Effective 176 m^3
Appurtenances:	Sludge collector, thickened sludge pump.

(b) Dehydrator

The dehydrators are designed to dewater the sludge generated from the biological treatment system and their specifications are as follows:

Type:	Filter belt-press type,
Quantities:	2 units,
Dimensions:	1.5 m wide (belt),
Dehydrated sludge quantity:	11.9 ton-Wet (80 % moisture),

Appurtenances:	Polymer coagulant injection unit, biological-film type deodorization equipment with exhaust fan.

6) **Electrical and control system**

All equipment in the sewage treatment station as well as all pumps in the pump stations of the Conceicao Sewerage System will be supervised from the integrated supervisory board. This shall be installed in the administration room.

7) **Buildings and civil works**

The following building construction and civil works shall be carried out:

(a) Buildings

Influent pump room:	8 m wide x 15 m long,
Disinfection room:	10 m wide x 12 m long,
Electrical room:	10 m wide x 12 m long,
Administration building:	20 m wide x 25 m long (two-storey)

The administration building shall accommodate rooms such as: control room, administration room, dehydration room, chemical room, sludge cake room, electrical room, laboratory, staff room, workshop, storage, resting room with toilet and conference room.

(b) Civil works

Civil works shall include miscellaneous structures in the station yard, such as: guard fence and gates, landscaping, parking lots, rainwater drainage, etc.

6.6 Cordeiro STF

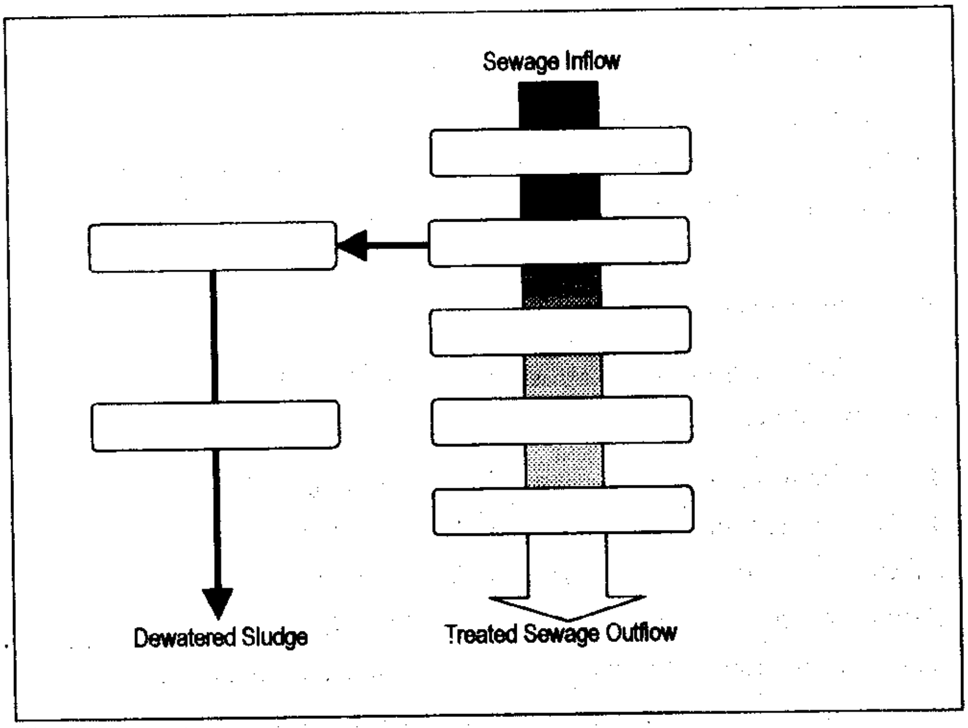
(1) General

The Cordeiro STF consists of the following steps: the "RAFA + bio-filtration + sedimentation" for the biological treatment system and the "sludge thickening + mechanical dehydration" for the sludge treatment system, as shown below.

Treated sewage shall be discharged by gravity into the Capibaribe River through embedded discharge pipes. The generated sludge from the treatment facilities shall be disposed of at landfill sites, after being dehydrated mechanically at the STF site and transported.

The flow diagram, the hydraulic profile and the layout plan of the facilities shown in Fig. B.6-13, Fig. B.6-14 and Fig. B.6-15, respectively are the results of preliminary design.

Treatment Flow of Cordeiro Sewage STF



(2) Construction site

The site is situated at the locally determined coordinates, 2.87E / 91.11N, in the Municipality of Recife. The site lies alongside the Capibaribe River. The available land area is of 4.0 ha and it belongs to the state of Pernanbuco.

At present, the land is almost vacant with bushes and several abolished buildings. The site faces residential zones to the south and a new road is being planned just outside the site.

The ground at the site is undulated between 2 m and 4 m (+ MSL). The Station will be constructed on the plot at a level of 4.0 m (+ MSL), which is to be prepared by reclamation and grading.

(3) Major facilities and structural works

1) Influent system

(a) Grit chamber

The grit chambers are designed to remove coarse substances like sand by gravity separation and equipped with motor-driven bucket conveyers to remove settling materials on the bottom of the chamber. They are mainly constructed of reinforced concrete and have the following specifications:

Type:	Rectangular concrete tank with bucket conveyers,
Quantities:	2 units,
Dimensions:	2.0 m wide x 6.0 m long x 0.8 m deep/water per unit
Water surface:	12 m^2 x 2 units = Total 24 m^2,
Appurtenances:	Inflow gates, coarse bar screens (manually operated), fine bar screens (motor-driven), grit hoisting crane and biological-film type deodorization equipment.

(b) Influent pump

The influent pumps are designed to lift up incoming sewage to the subsequent system. They are automatically operated with a water level meter. Their specifications are as follows:

Type:	Vertically mixed flow pump,
Quantities:	3 units including one standby,
Capacity:	11.0 m^3/min x 350 mm-ND x 16 m-Head x 60 CV per unit,
Appurtenances:	Inflow sewage flow meter, maintenance crane and influent well.

2) Biological treatment system

(a) RAFA reactor

The RAFA reactors are designed to decompose organic pollutants in sewage by anaerobic biological degradation. They are mainly constructed of reinforced concrete and equipped with gas-liquid-solid separators inside, which are comprised of inflow pipes, baffle plates, outflow troughs, etc. Their main specifications are as follows:

Type:	Rectangular concrete tank,
Quantities:	4 trains x 13 units = Total 52 units,
Dimensions:	5.0 m wide x 5.0 m long x 6.0 m deep per unit,
Volume:	Effective 125 m^3 x 52 units = Total 6,500 m^3,
Appurtenances:	RAFA distribution box, distribution trough, lagoon distribution box, exhaust stacks, anaerobic sludge draw-off pumps.

(b) Bio-filter

The bio-filters are intended to remove organic pollutants remaining in the outflow from RAFA reactors by aerobic biological purification. They are mainly constructed of reinforced concrete. Gravel as the media to be attached by the biological film is packed inside. Main specifications are as follows:

Type:	Cylindrical Concrete tank,
Quantities:	2 units,
Dimensions:	27.0 m dia. x 2.5 m deep per unit,
Horizontal area:	Effective 572 m^2 x 2 units = Total 1,144 m^2,
Appurtenances:	Rotary spray units.

(c) Recirculation pump

The recirculation pumps are intended to return treated sewage to the bio-filters and to spray water, so that water drops uniformly onto the gravel surface. Their maximum discharge is designed to be twice the daily maximum sewage flow. Main specifications are as follows:

Type:	Vertically mixed flow pump,
Quantities:	3 units including one standby,
Capacity:	16.0 m^3/min x 450 mm-ND x 8 m-Head x 40 CV per unit,
Appurtenances:	Recirculation well.

(d) Sedimentation tank

The sedimentation tanks are designed to settle suspended solids in the outflow from bio-filters by gravity. They are mainly constructed of reinforced concrete and are equipped with a chain conveyer to collect sludge from the bottom. Main specifications are as follows:

Type:	Circular concrete tank,
Quantities:	2 units,
Dimensions:	25 m dia. x 3.5 m deep per unit,
Horizontal are:	Effective 491 m^2 x 2 units = Total 982 m^2.

3) **Disinfection system**

The disinfection system is designed to reduce pathogens and parasites in biologically treated sewage so as to meet the discharge standard for total coliforms. The system consists of a disinfection tank and an ultra-violet (UV) light disinfection unit, as shown below:

Type:	Rectangular concrete tank,
Quantities:	1 unit,
Dimensions:	3.0 m wide x 8.0 m long x 2.5 m deep per unit,
Volume:	Effective 60 m^3
Appurtenances:	UV light disinfection unit.

4) **Treated sewage discharge system**

Finally treated sewage is discharged into the Capibaribe River through the following embedded pipes and the outfall:

Design water level:	2.76 m (+ MSL),
Pipe:	ND 800 mm x 50 m long,
Material:	Reinforced concrete.

5) **Sludge treatment system**

(a) Sludge thickener

The sludge thickener is designed to thicken the sludge generated from the biological treatment system and homogenize it. Its main portion is constructed of reinforced concrete and a motor-driven sludge collector is attached inside. Its specifications are as follows:

Type:	Cylindrical concrete tank,
Quantities:	1 unit,
Dimensions:	8.0 m dia. x 5.0 m deep,
Volume:	Effective 201 m^3
Appurtenances:	Sludge collector.

(b) Dehydrator

The dehydrators are designed to dewater the sludge generated from the biological treatment system and their specifications are as follows:

Type:	Filter belt-press type,
Quantities:	2 units,
Dimensions:	1.5 m wide (belt),
Dehydrated sludge quantity:	11.6 ton-Wet (80 % moisture),
Appurtenances:	Polymer coagulant injection unit, deodorization equipment with exhaust fan.