CHAPTER 4
EXISTING SEWERAGE SYSTEM

4.1 GENERAL

The original Santiago sewerage system started its construction in the 1970's and has gradually been extended toward the peripheral districts. In 1976, CORAASAN developed a sewerage master plan for the year 2000 to cover the City urban districts of 3,300 hectares, with an estimated 568,000 service population.

The plan established an urban development plan that classifies the whole sewer service area into six land use patterns, i) residential, ii) commercial/residential, iii) light industries, iv) heavy industries, v) institutional/municipal, and vi) green/park zones.

In the1970s and thereafter, sewers, pumping stations and new WWTPs have been added to the sewerage system basically in accordance with the original master plan proposal, which recommended that one centralized WWTP in Rafey be constructed to treat all the wastewater from the whole sewer service districts.

In 1976, one train of the conventional activated sludge treatment facilities was constructed with a nominal treatment capacity of 900 L/s. Then, two small-scale WWTPs at El Emerujo and La Loteria were built in the early 1980s, and further four more WWTPs were added from 1994 to 1997 to meet the ever-increasing demands for wastewater treatment.

4.2 SEWERS AND PUMPING STATIONS

4.2.1 PRESENT SEWER SERVICE AREA/DISTRICTS

The present sewered area in Santiago City accounts for about 90 percent in the central urban districts, which can be briefly divided into four major sewer districts, namely i) Rafey, ii) Cienfuegos, iii) Los Salados, and iv) Emburjo. In addition, there are four small-scale sewer districts in the eastern zone of Santiago City to discharge the wastewaters to three independent WWTPs, i.e. La Loteria, P.U.C.M.M. and Thomen.

These small sewer service areas would either be integrated to the Rafey Sewer District or led to a new WWTP at the right bank of the Yaque del Norte River, west of Los Jazmines, and may be abandoned in the future when these districts are connected to the improved sewerage system.

4.2.2 WASTEWATER COLLECTION SYSTEMS

(1) Santiago City

The Santiago's separate sewer system collects the domestic, commercial, institutional and industrial wastewaters in the same conduits, and to some extent unintended surface stormwater inflows. The City sewer networks already serve a substantial portion of the central urban districts, and the remainder discharge the wastewaters either directly or through septic tanks into nearby watercourse or ground.

According to the CORAASAN's estimate, the present sewers collect about 90 percent of the total wastewater production of 4,149.75 L/s or 358,538.5 m^3/day (75 percent of the water supply rate by CORAASAN's assumption) through branch and lateral, sub-main, and main sewers of about 840 km long. The existing sewer pipes made either of plain concrete, reinforced concrete, PE or PVC, range from 200 mm to 1,750 mm in diameter. The existing sewer size and length in Santiago City are shown in the following table:

Existing Sewer Length by Size

Pipe Size	Pipe Length (m)
8" (203.2 mm)	781,700
12" (304.8 mm)	24,100
15" (381 mm)	9,100
21" (533.4 mm)	12,000
24" (609.6 mm)	5,500
30" (762 mm)	1,400
36" (91.44 mm)	250
42" (1,066.7 mm)	200
48" (1,219.2 mm)	4,300
60" (1,524 mm)	250
70" (1,750 mm)	1,200
Total	840,000 m

Source: CORAASAN

Because of the moderately inclined ground surface prevalent throughout the sewered areas, most of the sewers can flow the wastewater by gravity all the way through the WWTPs or outfalls except at some limited low-lying districts. The main collector sewers are generally laid along the river courses to collect the wastewaters from housing, commercial and industrial districts generally located at the higher ground.

The existing main/collector sewers ranging from 12" (300 mm) to 70"(1,750 mm) convey the wastewater by gravity, crossing the Yaque del Norte River through inverted siphons at two locations near Nibaje and C.E. Malagon. The inverted siphons, with parallel river-crossing pipes of 48"(121 mm) and 30"(760 mm) in diameter, have bypass structure that often overflows the wastewater to the river when the wastewater inflow surpassed the flow capacities.

Although no wastewater pumping station was planned under the original sewerage master plan, there now exist two pumping stations (E-B No.1 and No.2) at the right bank of the River. These were constructed to lift the wastewaters coming from the newly developed housing complexes located along the Avenida Yapur Dumit. As the pumping equipment of these stations is either out of order or obsolete, most of the inflowing wastewaters are discharged directly to the River.

A sewerage improvement plan is now underway by CORAASAN to connect the sewer systems in URB area, Fernando Valerio, to the City sewerage system. The sewers in the area may be connected to a new WWTP in the Zona Sur District to be located at the right bank of the Yaque del Norte River near Los Jazmines.

Although the sewers were planned to separate the stormwater, the stormwater runoffs inflow to the sewer system at many locations through roof or garden drains connected to the sewers or broken sewers and manholes. At present, the exact infiltration and inflow (I/I) rate to the sewers has not been confirmed yet, but such rate is likely to be high particularly during wet seasons.

(2) Tamboril City

The Tamboril's sewer system is a separate one, comprising sewers mostly of 200 mm in diameter. The City has a conventional activated sludge WWTP located about 300 m at the south of Carretera and Canca, to which all the wastewater is transported by gravity.

The City's main collector sewer, laid at the southern peripheral of the City and along Carretera a Canca, intercepts the wastewater collected through branch and lateral sewers and transmits to the WWTP. The treated wastewater effluent is finally disposed of to the nearby stream. Currently, the sewerage system serves the population of 10,450 within the sewered district.

(3) Licey City

Licey City has at present a population of about 8,500 within its urban district. The City is now expanding toward the west along the Carretera Duarte. The City has at present no sanitary sewer system but only storm drainage system. The area is relatively flat and gradually declines toward a nearby river.

The City has a development plan to build a housing complex at the south of the present urban districts down to Uveral area: however, no definite plan for such a development has been established yet, and the magnitude of scale and land-use plan for such development are not available yet.

Due to the topographic conditions of the area, a WWTP may be located at the southern edge of the urban built-up district. The selected new WWTP construction site is at the southwest of the City close to the new International Airport that is expected to complete in 2001.

4.2.3 PHYSICAL CONDITIONS OF SEWERS

Since its implementation, the Santiago sewer networks have gradually been extended. Sewers constructed in the 1970s are now almost 30 years old. Consequently, some portions are obsolete or physically damaged. Manholes and other appurtenances of the sewerage system are also damaged, and at many locations manhole covers are missing.

Sewer pipe materials are of concrete, reinforced concrete, Rib Loc, Polyethylene, some of the pipes with rubber joint sockets, which were selected by pipe sizes or site conditions. For small pipes such as house connection, PVC is also used. Standard pipe materials by size are as summarized below:

Sewer Pipe Materials by Size

Pipe Diameter (inch)	Pipe Materials
8	Concrete
12	Concrete
15	Concrete
18	Concrete
21	Concrete
24	Concrete
24	Polyethylene
37	Rib Loc 5T
42	Polyethylene
43	Rib Loc 6T
48	Polyethylene
48	Reinforced concrete with rubber joints

Source: CORAASAN

Although CORAASAN has conducted inspections on the existing sewers to identify the physical conditions of sewers and appurtenances, the complete data on the physical conditions of the system are yet to be finalized. Although a comprehensive survey on the entire existing sewers is out of the present scope of work, field observations and hearing from CORAASAN officials during the Study indicate that many of the old pipes need rehabilitations.

Sewer pipe cleaning and maintenance works are mostly carried out by means of manually operated sewer rodding equipment for small sewers, but for large sewers a truck-mounted high pressure water jet machine with vacuum suction is being used, but sewer inspection equipment such as CCTV monitoring unit has not been used yet.

4.2.4 INFILTRATION AND INFLOW (I/I)

Due to the deficit of house connection pipes, through defective joints of sewer pipes, and broken or cracked pipes and manholes, certain amount of the unwanted water infiltrates or inflows into sewers. At many locations, sewers receive stormwater runoff during rains, and function as a combined sewer system. In certain districts, much portion of surface stormwater runoff is discharged into the public sewers through drainpipes or street gutters.

Although no comprehensive field survey has been conducted yet on the extent of the actual infiltration and inflow (I/I) rates, CORAASAN has a view that I/I rates are generally low except at limited low-lying areas where groundwater elevations are high or stormwater drains are connected to the sewers. An I/I study may be conducted to identify the actual conditions and to find out appropriate ways to reduce I/I rates so as to save energy costs particularly after the time when the existing WWTPs are expanded and the new WWTPs start their operation.

4.2.5 HYDRAULIC CAPACITY OF MAIN SEWERS

The hydraulic capacities of the main sewers, where new sewers are to be connected, are checked based on the present domestic wastewater, industrial wastewater, and I/I rates to the collection system. The new sewerage system in the Districts of Arroyo Hondo, Pekin, Camboya, Cristo Rey, etc., which are currently disposing of the wastewater to the nearby watercourses, are studied to determine whether these are to be connected to the existing main collectors, or to a new WWTP. A preliminary review result indicates that most of the existing main collector sewers have sufficient hydraulic capacities to transport the additional wastewater inflows to the Rafey WWTP.

It should be noted, however, that significant quantities of stormwater runoffs inflow to the sewers at many locations during heavy rainfalls, particularly at low-lying areas. In some areas wastewater seeps out on the streets because of the insufficient hydraulic capacity of sewer pipes or defective manholes.

4.2.6 WASTEWATER PUMPING STATIONS

The existing pumping stations are generally provided with influent gates, manually cleaned course bar screens and wet-well, with a grit removal facility. The inflowing wastewater enters an inflowing channel, and after screening inflows to the wet-well. Manually removed screenings are brought to a storage pit or taken away for disposal.

The entire facilities, excluding the screens and grit chambers, are housed to protect the mechanical equipment. The pumping station structures are made of reinforced concrete, but at some portions concrete surface is eroded and peeled off, and the reinforcing steel bars are exposed, due mainly to inferior concrete quality.

The existing three wastewater pumping stations are not functioning satisfactorily and apparently need rehabilitation or replacement. Because of the recent housing development in the areas and the consequent increased wastewater inflows, the pumping capacities of E-B No.1 and No.2 stations appear to be not sufficient to handle the inflowing wastewater.

These pumping stations serve Pekin, Conani URB Fernando Valerio Crist Rey, Abajo, and Urbanizacion Thomen areas, and are to discharge the wastewater to the main sewers of 21” (533.4 mm) laid along the Av. Mirador del Yaque. The pumping equipment of the station E-B Cerro has been out of order and the capacity is not sufficient to handle all the inflows. This condition cause occasional spills of the wastewater or often bypassed directly into the nearby waterways. The electrical and control equipment are mostly in bad shape too.

A study is now underway on diverting these inflowing sewer pipes toward the new WWTP

(Zona Sur) and finally abandoning of these pumping stations. Other pumping stations may need an immediate improvement of equipment, if these are to be further used. Present conditions of the pumping stations are summarized in the following table:

Features of Existing Wastewater Pumping Stations

No.	Pumping station	No. of pumps (units)	Type of pumps	Pump discharge x TDH	Influent pipe diameter	Operating conditions
1	No.1 Abitacional av. Yapur dumit	2	Submersible	0.43m^3/min. x 10.7 m	8"(200mm)	Needs rehab. or abandoned.
2	No.2 Abitacional av. Yapur dumit	3	Submersible	0.66m^3/min. x 35.2 m	21"(533mm)	Needs rehab. or abandoned.
3	Otra Banda	4	Submersible	0.43m^3/min. x 10.7 m	8"(200mm)	Needs rehab.
4	Gerro Alto	2	Submersible	NA	NA	Needs rehab.

Sources: CORAASAN, all conditions are as of April 2001.

4.2.7 INDUSTRIAL WASTEWATER DISCHARGE TO PUBLIC SEWERS

Some of the industries are currently discharging the wastewaters directly into the public waterways without pretreatment. The factory scales range from small to medium, producing wastewaters with different qualities. The wastewaters containing some toxic substances such as tannery wastes are required appropriate pretreatments by the water quality regulations before discharge to the public watercourses.

The industrial wastewaters containing hazardous or toxic substances that may be impeding to WWTPs' function shall not be allowed to the sewerage system. Only the selected wastewaters that will not give significant impacts to the WWTPs' functions will be accepted. The possibility of further introduction of industrial wastewater to the public sewers are considered, provided that the stringent wastewater quality monitoring and enforcement by the relevant industrial wastewater prior to the discharge to the public sewers (more details are discussed in Chapter 5 "Current Industrial Wastewater Management").

4.3 WASTEWATER TREATMENT PLANTS

4.3.1 EXISTING WWTPS

Presently, a total of nine small- and large-scale WWTPs exist within the sewer service area either being operated or abandoned. The existing WWTPs are of the activated sludge treatment process except old and small scale WWTPs of primary treatment process. Major features of the existing WWTPs are as summarized in the following table:

Major Features of Existing WWTPs

WWTP	Treatment Process	Year of Construction	Design Capacity (L/s)	Operational Conditions
1. Rafey	CAS	1976	900	Operated and maintained
2. Cienfuegos	CAS	1994	175	Operation suspended
3. Los Salados	CAS	1995	175	Operation suspended
4. Tamboril	CAS	1997	175	Operated
5. El Embrujo (new)	CAS	1996	80	Not operational
El Embrujo (old)	CAS	Early 1980s	80	Operated
6. La Loteria	Aeration /Imhoff Tanks	- " -	40	Operated
7. Thomen	Imhoff Tanks	NA	20	Operated
8. P.U.C.M.M.	Primary settling/ oxidation pond	NA	NA	Operated

Source: CORAASAN and the Study Team (as of August 2001).
Note: CAS =Conventional Activated sludge Process

The planned total treatment capacity of the seven WWTPs (El Rosal and P.U.C.M.M. not included) is 1,585 L/s or 136,944 m^3/d. It assumes that the average daily wastewater production

rate of 4,150 L/s accounts for about 75 percent of the total water supply production of 5,533 L/s. The overall treatment capacity is about 38 per cent of the estimated total wastewater production.

4.3.2 RAFEY WWTP

(1) General

The Rafey WWTP has the largest treatment capacity among the existing WWTPs of the Santiago sewerage system, serving the major central districts of Santiago City. The initial master plan proposed that by 2000 four trains of the conventional activated sludge facilities be constructed.

In 1976, under the first phase sewerage project, one train of the liquid treatment facilities with a nominal treatment capacity of 25,920 m^3/day was constructed. The excess sludge from the final sedimentation tanks is aerated at the stabilization tank and sent to the sludge drying beds for drying.

The wastewater inflows to the plant through a 70" (1,750mm) diameter main sewer that collects the wastewater from the central part of the City, but the excess amount of the wastewater is bypassed directly to the Yaque del Norte River through the bypass pipeline of 1,750 mm diameter ahead of the Rafey WWTP. The existing major treatment facilities are shown in the following table:

Major Facilities of Rafey WWTP

Facility	Nr. of units	Size, Type and Specifications
Inflow pumps	2	Screw pumps, 1,200 mm diameter x 30 kW motor.
Screening chamber	1	Rectangular, 19.0 m (L) x 3.4 m (W)x 1.05 (D) at the entrance.
Aerated grit chambers	1	Rectangular, 35.7 m (L) x 5.0 m(W) x 6.15 m (D)
Primary settling tanks	1	Circular, 45.0 m diameter x center depth 3.38 m, side depth 1.72 m.
Aeration tank	1	Rectangular, 54.0m (L) x 36.0 m (W) x 4.6 m (D) with 0.9 m free board
Return sludge pumps	2	Screw pumps, 1,000 mm diameter x 11 kW 1,750 r.p.m.
Sludge stabilization tank	1	Rectangular, 54.0 m (L) x 18.0 m (W) x 4.6 m (D) with 0.9 m free board
Final settling tanks	2	Circular, 45.0m diameter x 4.63 (D) x 2.08 m at side depth
Chlorination tank	1	Rectangular, 29.12 m (L) x 12.15 m (W) x 2.4 m (D)
Sludge thickener	1	Circular, 14.0 m diameter x center depth 4.07 m, side depth 3.5 m
Sludge drying sand beds	1	Rectangular, 171.3 m (W) x 41.6 m (L), separated into 40 bed units.
Outfall conduit	1	Square open conduit 2.0 m x 2.0 m.

Source: Detailed design drawings of the Rafey WWTP facilities, CORAASAN.
Note: All the dimensions are of the effective sizes, excluding those of walls and hoppers.

(2) Present Conditions

The Rafey WWTP operation has been occasionally suspended because of frequent power outages and defective equipment. Some of the electrical and mechanical equipment have been worn out and obsolete. Civil structures are generally in working conditions.

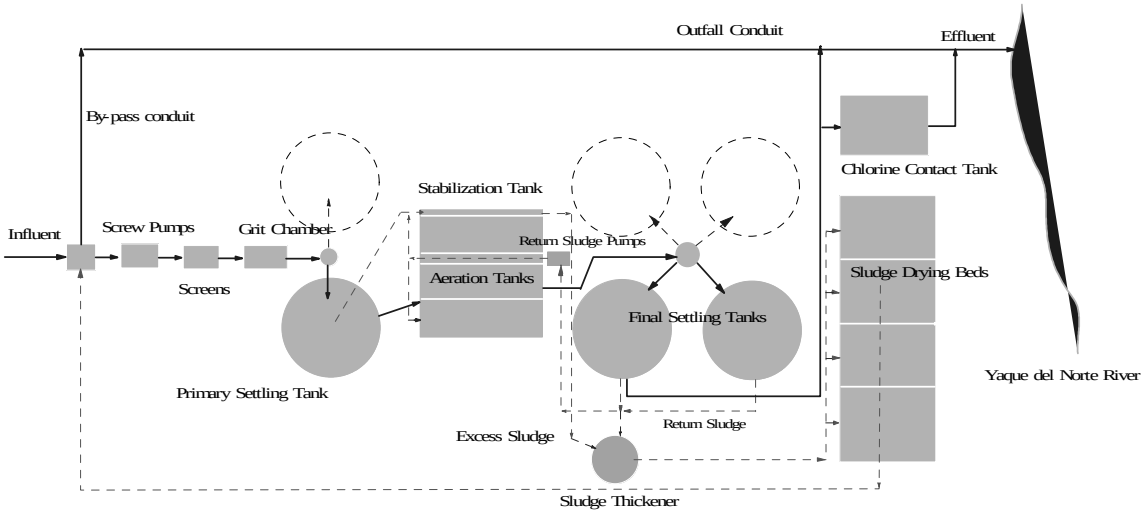
The originally planned total treatment capacity is 900 L/sec or 77,760 m^3/day comprising four parallel trains of facility. The existing one train consists of one each of primary settling tank and aeration tank, and two final sedimentation tanks, has a treatment capacity of 300 L/sec or 25,920 m^3/day, according to the CORAASAN's estimate.

(3) Treatment Process

The schematic of the existing activated sludge treatment process is shown in the following:

The inflowing wastewater through the main sewer of 1,750 mm in diameter first enters the inlet chamber and pumped up to the grit chamber by screw pumps. After floatable is removed by bar screens, the wastewater inflows to the aerated grit chamber, then flows down to the primary settling tank.

SCHEMATIC OF RAFEY WASTEWATER TREATMENT PLANT PROCESS



The circular center feed primary settling tank is expected to remove approximately 40 to 50 percent of the suspended solids (SS). The sludge solid is withdrawn from time to time and transported toward sludge stabilization tank or through the sludge thickener to the sludge drying beds.

The supernatant from the primary settling tank is aerated with the return activated sludge by mechanical surface aerators. The mixed liquor is allowed to settle to the bottom of the final settling tanks. Generally, about 25 to 30 percent of the activated sludge is recycled to the aeration tank from the final settling tanks.

The final stage of treatment takes place in the chlorine contact tanks, where the wastewater is to be mixed with liquid chlorine to kill any remaining bacteria. The treated wastewater effluent flows down by gravity through the outfall conduit, and then it is finally discharged to the Yaque del Norted River.

The separated filtrate wastewater from the sand beds is returned to the head works. The dried sludge is loaded on to trucks and transported to the municipal solid disposal sites.

(4) Present Working Conditions of Major Facilities

Present working conditions of the existing WWTP major component facilities are summarized in the following:

- A rectangular shape reinforced concrete confluent chamber with sluice gates and by-pass conduit, which receives the wastewater through the incoming sewer of 1,750 mm in diameter. This chamber structure has been in working order;
- Two units of the screw pumps of 1,200 mm in diameter, driven by a 30 kW x 1,750/40 rpm motor, lift the incoming wastewater to the screening chamber, where the floatable materials are removed manually and mechanically cleaned bar screens with 50 mm and 25 mm bar spacing respectively. One pump is recently repaired and as of August 2001 two pumps are in working condition;
- One unit of rectangular aerated grit chamber with grit removal equipment. The sand deposit in the grit hoper is removed through the airlift, and the removed grit and sand is led to the grit storage bin for dewatering and final disposal. The grit collector equipment and airlift compressors need repair to make the facility serviceable;
- One unit of the circular center feed primary settling tank of 45.00 m in diameter having a 2,736 m^3 hydraulic capacity. The sludge settled out on the tank bottom is collected to

the center hopper with a rotary bridge supported scraper. The settled sludge is either pumped out of the tank to the sludge stabilization tank for aeration or withdrawn directly to the sand beds. Lighter materials floating on the tank surface are also removed with scum removers attached to the bridge scrapers. The sludge collector is operational;

- A unit of rectangular aeration tank with a total hydraulic capacity of 8,942 m3 is aerated with six surface aerator units each operated with 55kW motor. An approximate average tank aeration time is eight hours for the nominal plant treatment capacity (25,920m^3/day) with an average return sludge ratio of 20 to 50 percent to the inflow rate. Aerators are being operated in general but some maintenance work is needed;
- A unit of rectangular sludge stabilization tank of a half size of the aeration tank unit (using a portion of the future aeration tank) attached to the aeration tank aerates the raw primary sludge from the primary settling tank. After the aeration the sludge is withdrawn to the sand beds. Three units of 55 kW aerators are operational;
- A splitter chamber to distribute the mixed liquor equally to the final settling tanks, generally functioning;
- Two units of the final settling tanks, each having a 6,617m^3 hydraulic capacity. The settled sludge is collected with a bridge supported sludge scraper to the sludge hopper and led to the return sludge screw pump chamber to control the activated sludge volume in the aeration tank. The activated sludge is transported to the aeration tank through a gravity sludge conduit after being lifted with the screw pumps;
- Two units of screw pump of 1,000 mm diameter driven by 11 kW motor transport the return sludge from the final settling tanks to the aeration tank inlet. Also, two units of 11 kW centrifugal pumps transport the primary sludge to the stabilization tank, but one of which needs repair;
- A gravity sludge thickener with a mechanical thickening equipment with a drive motor of 1.5 kW is operational;
- Sludge drying beds of 171.3 m by 41.6 m in size, comprising 40 units of separated sand bed with concrete foundation, each provided with an inlet control valve and drain pipelines. These are functional, but may need some cleaning and maintenance works;
- One reinforce concrete contact tank to disinfect the effluent before final discharge to the River. So far no chlorine dosing has been practiced;
- A gravity effluent outfall of square open conduit of 2.0 m x 2.0 m discharges both the plant effluent and bypass to the Yaque del Norte River;
- Although the wastewater flow rates have been measured by a rectangular weir with a float level meter at the end of the grit chamber, the measurement of a long width weir (5 m) is unlikely to indicate accurate effluent flow rates. There is no mean to quantify the bypassed wastewater flows;
- The excess sludge is withdrawn from the final settling tanks and after being aerated in the stabilization tank sent to the sand drying beds and dried over 4 to 5 days under normal weather. The dried sludge cake is manually scraped and transported by trucks for disposal to the municipality's solid disposal site;
- The power generator has been out of order and there is no means for emergency power supply to operate the facility during extended power outages. Power failures, which sometimes last over several hours, might have caused operational problems particularly in aeration tanks; and
- The control panel has already been abandoned due mainly to physical failures. The switchboard has already been out of use and cables are directly connected to each of the equipment.

Although some operational problems exist, the plant is as a whole relatively well maintained and operated producing seemingly good effluent.

(5) Need for Rehabilitation of Facilities

Because until 2015 there would be a little possibility that a large-scale sewer extension scheme comes up in the Rafey Sewer District, it is only prudent to consider that the present capacity of the plant facilities be increased up to the expected maximum incoming hydraulic and pollutant loads. The effort is to be concentrated therefore to rehabilitation or repair of the presently mal-functioning or broken equipment and structures.

(6) Rehabilitation and Upgrading of Existing Facilities

The major O/M problems in the Rafey WWTP have been due to the difficulty with the supply of spare parts and repair works, in addition to the frequent power outages. Certain equipment are either worn out or obsolete, hence need to be replaced or repaired.

Major defective plant facilities, materials and equipment that need immediate improvement measures are listed in the following table:

Conditions of Major Equipment

Facility	Nr. of units	Size, Type and Specifications	Present Conditions
A) Pumps			
Pump No.1	1	30 kW x 1,750 rpm, 40 rpm	Operational
Pump No.2	1	30 kW x 1,750 rpm, 40rpm	Operational
B) Mechanical Screens			
Screen No.1	1	1.5kW	Operational
Screen No.2	1	1.5kW	Operational
C) Grit Chambers			
Compressor No.1	1	7.5 kW	Not operational, needs repair
Compressor No.2	1	18.5 kW	Not operational, needs repair
Compressor No.3	1	18.5 kW	Not operational, needs repair
Grit Remover	1	1.5kW	Not operational, needs repair
Grit Remover	1	1.5kW	Not operational, needs repair
D) Primary Settling Tank			
Bridge drive motor	1	1.5kW x 1,100 rpm	Operational
Primary sludge motor	1	76 kW	Operational
Sludge motor No.1	1	2kW	Operational
Sludge motor No.2	1	2kW	Operational
E) Aeration Equipment			
Turbine No.1	1	55 kW x 1,700/56 rpm	Operational
Turbine No.2	1	55 kW x 1,700/56 rpm	Operational
Turbine No.3	1	55 kW x 1,700/56 rpm	Operational
Turbine No.4	1	55 kW x 1,700/56 rpm	Operational
Turbine No.5	1	55 kW x 1,700/56 rpm	Operational
Turbine No.6	1	55 kW x 1,700/56 rpm	Not Operational
F) Sludge Stabilization			
Turbine No.1	1	55 kW x 1,700/56 rpm	Operational
Turbine No.2	1	55 kW x 1,700/56 rpm	Operational
Turbine No.3	1	55 kW x 1,700/56 rpm	Operational
G) Return Sludge Pumps			
Pump No.1	1	11kW x 1,750/40 rpm	Not operational, needs repair
Pump No.2	1	11kW x 1,750/40 rpm	Operational
H) Sludge Recirculation Pumps			
Pump motor	1	2kW	Operational
Pump motor	1	2kW	Operational
I) Final Settling Tanks			
Drive motor A	1	1.5kW x 1,100 rpm	Operational
Drive motor B	1	1.5kW x 1,100 rpm	Operational
Drive mechanism			Operational
J) Sludge Thickener			
Drive motor	1	1.5kW	Operational
Drive mechanism			Operational
K) Filtrate Pumps		4 kW	Not provided
L) Chlorinator		4 kW	Not provided, needs to install
M) Emergency Power Supply			
Emergency generator	1		Out of order. Needs new generator
N) Substation			
Distribution panel	1	1,800 kW, 440 – 480V	Operational
Distribution panel	1	150kW, 127 – 220V	Operational
O)Control Panel			Out of order. Needs new one.

Source: CORAASAN and inspected by the Study Team (as of August 2001)

4.3.3 EMBRUJO, CIENFUEGOS, LOS SALADOS AND TAMBORIL WWTPS

(1) Present Conditions

The present conditions of the major component facilities and equipment of these WWTPs have been assessed to verify whether or not they are to be rehabilitated or replaced. As these WWTPs have almost the same configuration and capacity, their hydraulic capacities and treatment ca-

pacities of the waste loads are reviewed in principle based on the same criteria. Each plant has further been checked as to whether the present plant capacity is sufficient to treat the wastewater inflow rates expected in the year 2015.

The Cienfuegos, Los Salados and Tamboril WWTPs have almost the same configurations and hydraulic capacity, whereas the Embrujo WWTP has a little larger treatment capacity than other WWTPs.

Presently, these WWTPs have not been fully operated, as they were originally intended, because of the defective and obsolete electrical and mechanical equipment. These conditions have further been worsened by the frequent power failures and deficient in power generators at Los Salados and Embrujo WWTPs.

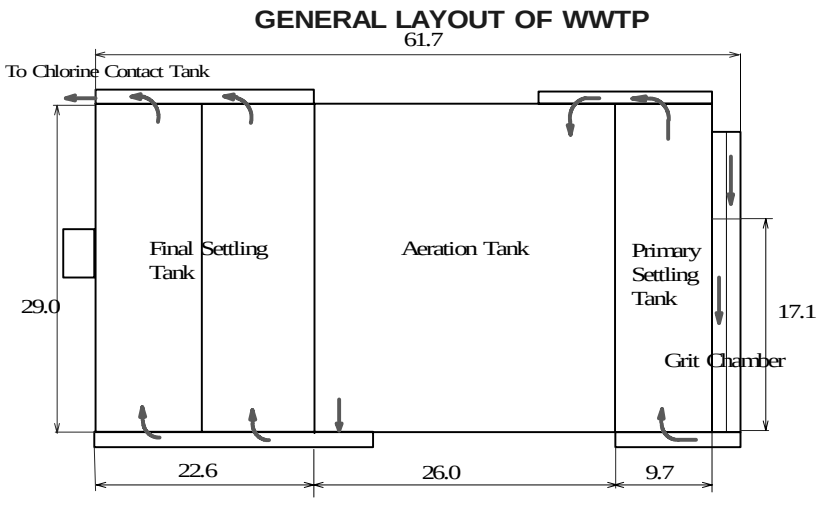
Tamboril and El Embrujo (old) WWTPs are currently (as of August 2001) in operational condition, while the Cienfuegos and Los Salados WWTPs have not been in working condition due to occasional power outages and defective equipment. The Embrujo (new) WWTP has only concrete structures but no electrical and mechanical equipment have so far been installed. Other small-scale WWTPs, such as La Loteria, Thomen and P.U.C.M.M., are being continuously operated although certain rehabilitation and proper O/M procedures are required.

Because the four activated sludge WWTPs had been constructed during the 90's, the civil structures are generally in working condition although some improvement may be necessary, although many of the electrical/mechanical equipment need either rehabilitation or replacement. These WWTPs have more or less the same common problems.

Major common operational problem is that the sludge collection and withdrawal in settling tanks is quite difficult because neither sludge collector nor hopper is provided. Also, the insufficient surface aerator capacities cause the same problem as in Tamboril WWTP. These defects are to be checked and appropriate remedial measures be considered.

(2) Plant Configuration

These four WWTPs consist of preliminary, primary and secondary treatment process. The excess sludge is to be dried on the sand drying beds. A schematic of general configuration of the WWTPs (dimensions shown are those for plants other than Embrujo) is shown in the following:



The numbers, sizes of the major component facilities of the WWTPs are shown below:

Component Facilities of Cienfuegos, Los Salados and Tamboril WWTPs

Facility	Nr. Of units	Size, Type and Specifications
Grit chamber	1	Rectangular, 17.0m(L) x 1.1m(W) x 3.5m(H)
Primary settling tank	1	Rectangular, 29.0m x 9.7m(W) x 3.5m(H)
Aeration tank	1	Rectangular, 28.4m(L) x 25.4m(W) x 3.45m(H)
Final settling tanks	2	Rectangular, 2 units x 29.0m(L) x 11.3m(W) x 3.5m(H)
Sludge drying sand bed	1	Rectangular, sizes different by WWTP
Chlorine contact tank	1	Rectangular, with baffles. 20m(L) x 4.0m (W)x 1.0m(D)
Outfall sewer	1	Circular concrete sewer

Source: CORAASAN

Component Facilities of Embrujo WWTP

Facility	Nr. Of units	Size, Type and Specifications
Grit chamber	1	Rectangular, 20.88m(L) x 2.8m(W) x 1.42m(H)
Primary settling tank	1	Rectangular, 30.3m x 11.54m(W) x 3.5m(H)
Aeration tank	1	Rectangular, 28.4m(L) x 25.4m(W) x 3.5m(H)
Final settling tanks	2	Rectangular, 2 units x 30.3m(L) x 13.54m(W) x 3.5m(H)
Sludge drying sand bed	1	Rectangular, 4 units x 14.23m x 10.22m
Chlorine contact tank	1	Rectangular, with baffles.
Outfall sewer	1	Circular concrete sewer

Source: CORAASAN

(3) Treatment Processes

The influent wastewater enters either by gravity or through a pumping station to the grit chamber. Floatable materials in the wastewater are removed by manual bar screens. The wastewater, after passing through the grit chamber, further flows down to the primary settling tank. The tank has no sludge collection equipment, but sludge is withdrawn to the sludge drying sand beds by gravity through the sludge pipes of 100 mm in diameter laid at the bottom of the tank.

The primary tank supernatant overflows the weir and inflows to the aeration tank, where it is aerated with the return activated sludge by four units of the mechanical aerators over several hours. Each of the aerators is driven by a motor of 5hp ~ 7.5 hp.

Two units of separated final clarifier in rectangular shape, receive the mixed liquor from the aeration tank, and separate the sludge on the bottom. Most of the settled activated sludge is returned to the aeration tank by sludge pumps.

The final tank supernatant will be led to the chlorine contact tank with baffles, where the wastewater is to be mixed with liquid chlorine to remove any remaining bacteria. The treated wastewater effluent flows down by gravity through the outfall conduit to the nearby waterways.

The separated filtrate wastewater from the sand beds is returned to the head works. The dried sludge is loaded on to trucks and transported to the municipal solid disposal sites.

(4) Operational Conditions

1) General

The common operation and maintenance problems all of these WWTPs are facing may be summarized as follows:

- Certain aerators need to be repaired;
- Parshall flumes do not function and actual influent quantities have not been measured;
- Air supplying capacity of the surface aerators appears not sufficient to supply the required air to the aeration tanks (with 5 hp motor, shallow submersing depth of 25 cm, and insufficient air supply capacity), that dictates the need for rehabilitation;
- Because of the sedimentation tank without sludge collectors, settled sludge and floating solids removal is evidently not easy. An appropriate type of sludge collector shall be installed to effectively and efficiently collect the sludge;
- The tank bottom depressions (sludge hoppers) located in the center of the basin is shallow and small to store the settled sludge and to handle the return and excess sludge properly. Appropriate type of sludge hoppers shall be built in the tank with sufficient sludge holding capacity;
- All the sedimentation tank overflow weirs are too short. Need much longer weirs;
- The sludge is dried on the sand drying beds, but as the sludge withdraw system does not function well, only the limited amount of sludge could be dried;
- An emergency power generator shall be provided where there is no such provision, which is capable of supplying at least the minimum power requirements to maintain the plant function, but preferable to have 100 % power requirements in case of extended power outages are expected; and
- Each of the plants has its own O/M problems, and defective facilities and equipment need either to be rehabilitated or replaced.

2) Embrujo WWTP

The old Emerujo WWTP was built in the early 1980's with a nominal treatment capacity of 80 L/sec. Currently, the new WWTP has not been operated and only old plant has been operated. Because of the condition, the current inflow rate appears to be far less than the design flow rate (may be at around a half of the design capacity as plant staff explained), though the actual inflow rates over an extended period are yet to be measured.

The new Embrujo plant was constructed in 1996, using the same design concepts, criteria and dimensions as those of Cienfuegos, Los Salados and Tamboril WWTPs. The plant consists of a primary settling tank, aeration tank and final settling tank, which are constructed in common rectangular-shape concrete structures. The effluent is disinfected in the chlorine contact tanks and disposed of to the nearby river. The aerator in the old plant facility was rehabilitated and the facility is normally being operated.

The plant structures were already completed, however, no equipment has so far been installed yet, and hence, the new facilities remain unused. The new system has the same problems as those in other two WWTPs, and requires major rehabilitation or renovation. The conditions of the major equipment are summarized below:

Conditions of Major Equipment of Embrujo WWTP

Facility	Nr. of Units	Size, Type and Specifications	Present Conditions
A) Aerators			
Turbine No.1	1	25 hp x 1,745 rpm	Operational, needs repair
Turbine No.2	1	25 hp x 1,745 rpm	Not operational, needs repair.
Turbine No.3	1	25 hp x 1,745 rpm	Operational, needs repair
Turbine No.4	1	25 hp x 1,745 rpm	Operational
C) Circulation Pump			
Pump No.1	1	20 hp x 1,745 rpm	Operational
D) Emergency Power Supply			
Emergency generator	1	125 kW	Operational
E) Substation			
Transformer	31	100 kW	Operational

Source: CORAASAN

3) Los Salados WWTP

Currently the WWTP has not been operated (as of August 2001). All the tanks were unfilled and aerators are laid on the empty tank bottom. The plant operation has been suspended due to mechanical failures since December 2000, and since then no wastewater has been treated. Because of the elevated plant site ground, all the influent wastewater is to be pumped up to the primary settling tank, but all the wastewater is currently being bypassed to the nearby river ahead of pumping station. The conditions dictate the urgent need for rehabilitation of pumps and other WWTP equipment. The present conditions of major mechanical and electrical equipment of the WWTP are summarized in the following:

Conditions of Major Equipment of Los Salados WWTP

Facility	Nr. of Units	Size, Type and Specifications	Present Conditions
) Pumps			
Pump No.1	1	75 hp x 1,775 rpm	Operational, may need rehabilitation
Pump No.2	1	100 hp x 1,775 rpm	Not operational, may need repair.
Pump No.3	1	75 hp x 1,775 rpm	Operational, may need repair
B) Aeration Equipment			
Aerator No.1	1	7.5 hp x 1,745 rpm	Operational, but insufficient capacity
Aerator No.2	1	7.5 hp x 1,745 rpm	Operational, but insufficient capacity
Aerator No.3	1	7.5 hp x 1,745 rpm	Operational, but insufficient capacity
Aerator No.4	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
Aerator No.5	1	7.5hp x 1,745 rpm	Not operational, insufficient capacity
Aerator No.6	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
C) Recirculation Pump			
Pump No.1	1	20 hp x 1,745 rpm	Operational
Pump No.2	1	20 hp x 1,745 rpm	Not operational
D) Emergency Power Supply			
Emergency generator	1	125 kW	Operational
E) Substation			
Transformer	31	100 kW	Operational

Source: CORAASAN

4) Cienfuegos WWTP

The Cienfuegos plant has occasionally bypassed all the influent to the nearby waterway ahead of the preliminary facility. The operation of influent pumps were frequently suspended and liquid treatment works became out of operation. The present conditions of the plant's electrical/

mechanical equipment are as follows:

Conditions of Major Equipment in Cienfuegos WWTPs

Facility	Nr. of Units	Size, Type and Specifications	Present Conditions
A) Pumps			
Pump No.1	1	30 hp	Operational, may need rehabilitation
Pump No.2	1	30 hp	Not operational, may need repair.
Pump No.3	1	75 hp	Operational, may need repair
Pump for gate control	1	0.7 hp x 1745 rpm	Operational
B) Aeration Equipment			
Aerator No.1	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
Aerator No.2	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
Aerator No.3	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
Aerator No.4	1	7.5 hp x 1,745 rpm	Not operational, insufficient capacity
C) Recirculation Pump			
Pump No.1	1	20 hp x 1,745 rpm	Operational
Pump No.2	1	20 hp x 1,745 rpm	Not operational
D) Emergency Power Supply			
Emergency generator	1	75 kW	Operational, insufficient capacity
E) Substation			
Transformer	1	100 kW	Operational

Source: CORAASAN

5) Tamboril WWTP

This WWTP, constructed in 1997, has been receiving about 40 percent of the design capacity or 6,912 m^3/d according to CORAASAN's estimate. The wastewater treatment facility comprises a rectangular concrete tank that is separated into three zones; primary settling tank, aeration tank and final settling tank from upstream to downstream. At present, the plant is being operated relatively well with less problems than other WWTPs. The outline and present operating conditions of major equipment of the plant are as summarized in the following table:

Conditions of Major Equipment of Tamboril WWTP

Facility	Nr. of Units	Size, Type and Specifications	Present Conditions
A) Aeration Equipment			
Aerator No.1	1	5 hp x 1,765 rpm	Operational, insufficient capacity
Aerator No.2	1	5 hp x 1,765 rpm	Operational, insufficient capacity
Aerator No.3	1	5 hp x 1,765 rpm	Operational, insufficient capacity
Aerator No.4	1	5 hp x 1,765 rpm	Operational, insufficient capacity
Aerator No.4	1	5 hp x 1,765 rpm	Not operational
Aerator No.4	1	5 hp x 1,765 rpm	Not operational
B) Circulation Pumps			
Pump No.1	1	20 hp x 1,765 rpm	Operational
Pump No.2	1	20 hp x 1,765 rpm	Operational
C) Emerge. Power Supply			
Power generator	1	125 kW	Operational
E) Substation			
Transformer	1	50 kW	Operational

Source: CORAASAN

4.3.4 LA LOTERIA, TOHMEN, AND PUCMM WWTPS

La Loteria plant has an aeration tank ahead of an Imhoff tank, which aerates the influent wastewater ahead of the Imhoff tank, whereas the Thomen has only an Imhoff tank. The PUCMM

plant that receives the wastewater mainly from the university consists of a circular primary settling tank and a rectangular oxidation pond. All of these WWTPs withdraw their sludge to the sand drying beds.

These plants are generally in operational conditions although some rehabilitation and proper operation may be required. These WWTPs require no power for wastewater treatment except for the aerator in La Loteria plant. The present hydraulic conditions of these WWTPs are summarized in the following:

Physical Considerations of Loteria, Tohmen and PUCMM WWTPs

WWTP	Design Capacity (L/d)	Design Capacity (m^3/d)	Actual capacity (L/d)	Actual Treatment (m^3/d)	Percentage (%)
PUCMM	NA	NA	NA	NA	-
La Loteria	40	3,456	40	3,456	100
Thomen	40	3,456	20	1,728	50

Source: CORAASAN

4.4 EVALUATION OF EXISTING WWTPS

4.4.1 REVIEW CRITERIA

The hydraulic and pollutant loads on the component facilities are evaluated in light of design criteria as shown in the table below.

Design Criteria for the Conventional Activated Sludge Process

Items	Standard Values
1. Grit Chamber (Aerated chamber)	
Hydraulic retention time	3 minutes
Rate of aeration	1.5 liters/sec/m or more
2. Primary Settling Tank	
Overflow rate	35～70 m^3/m^2/day
Hydraulic retention time	1.5 hours
Effective depth	2.5～4.0 m
Weir overflow rate	250 m^3/m/day or less
Free board	50 cm or more
3. Reactors	
MLSS concentrations	1,500 ~2,000 mg/l
Minimum dissolved oxygen in mixed liquor	2.0 mg/l (mechanical aerator)
Air requirements	100 m^3/kg of BOD_5
Oxygen demands	1.2 kgO_2 /kg of max BOD_5
BOD to SS loads	0.2 ~ 0.4 kg BOD/ kg SS・day
Water depth of reactor	4 ~ 6 m (Tank width is one to twice of depth)
Shape of reactor	Generally rectangular
H.R.T. (hydraulic retention time)	6 ~ 8 hours
A.S.R.T.(activated sludge retention time)	4 ~ 6 days
Return sludge Ratios	15 to 75 percent to inflow
4. Final Settling Tanks	
Overflow rate	20～30 m^3/m^2/day
Hydraulic retention time	3～4 hours
Effective depth	2.5 m～4.0 m
Weir overflow rate	150 m^3/m/day or less
Free board	50 cm or more
5. Aerobic Sludge Digestion	
Hydraulic detention time	20 days (minimum 15 days)
Percentage of cell tissue oxidized	40 percent
Oxygen requirement	2kgO_2/kg of destroyed cell tissue
Required power of mechanical mixers	18 to 35 hp/1,000 m^3 of tank volume
6. Chlorine Contact Tank	
Contact time	15 minutes or longer

4.4.2 ASSESSMENT OF COMPONENT FACILITIES

(1) Rafey WWTP

Each of the component facilities has been checked on its hydraulic and pollutant loads and capacity to verify the plant's overall treatment capacity in light of the design criteria.

It should be noted that the most critical component facility to keep an appropriate operation in an activated sludge treatment plant is the aeration tank. Because of this, the function of the aeration tank is the governing factor to determine the overall maximum treatment capacity of the existing system.

The evaluation results indicate that it is reasonable to assume that the existing Rafey WWTP could safely treat a maximum of 35,800 m^3/day wastewater inflow if the system is properly operated and maintained.

1) Preliminary Facilities

- Screw pump units may have a maximum capacity of 10 to 12 m^3/min, which is more than the expected maximum hourly wastewater inflow rate in the future;
- The present grit chamber has a hydraulic capacity of 1,098 m^3, which could retain the maximum daily flow for over approximately 3 minutes; and
- Conduits and other auxiliary facilities have also enough capacity of handling the expected maximum hourly flow rate.

2) Primary Treatment Facilities

- The primary clarifier surface area has 1,591 m^2. During the maximum daily flow rate at a surface overflow rate of 23 m^3/m^2/day, the primary clarifier can handle the expected wastewater of 35,800 m^3/day; with the hydraulic detention time of 1.9 hours; and
- Weir overflow rate of 261 m^3/m/day at the maximum daily flow rate appears to be reasonable.

3) Aeration Tank

- As the primary tank removes about 30 percent and 50 percent of the influent BOD and SS, respectively. The aeration tank capacity is 8,942m^3 and a MLSS concentration is 1,600 mg/L, BOD load to SS will be 0.1 kg BOD/ kg SS・day;
- The hydraulic detention time will be about 6 hours at the inflow rate of 35,800 m^3/day; and
- Under the average daily wastewater flow rate, SRT is 2.5 days.

4) Final Settling Tanks and Chlorine Contact Tank

- The two final settling tanks have a total surface area of 3,181 m^2. When a maximum surface overflow rate of 30 m^3/m^2/day (at the maximum daily flow) is considered, the two clarifiers can handle the wastewater of 35,000 m^3/day;
- The hydraulic detention time of a clarifier is 9.1 hours;
- Chlorine contact time at the maximum flow rate will be 35 minutes.

5) Sludge Handling Facility

- The present sand beds of 7,126 m^2 surface area could handle the daily sludge production of 425 m^3 (solids content of 1 %) or 4,250 kg dry solids; and
- After the new sludge dewatering equipment is applied for the aerobically digested sludge in the Second Stage Program or later, parts of the bed area can be converted as the sludge storage yards.

More details of the evaluation of the Rafey WWTP are discussed in Appendix-9.1, "Rafey Wastewater Treatment Plant," Volume III- Supporting Report.

(2) Embrujo, Cienfuegos, Los Salados and Tamboril WWTPs

The nominal plant capacity of 15,120 m^3/day that was originally set are checked in view of the present conditions and actual capacity be identified. Major component facilities of the four WWTPs have been reviewed in light of the general criteria widely used elsewhere under similar conditions. The analyses on the WWTPs have led to the following conclusions:

- The governing factor to determine the plants' actual treatment capability is the aeration tank capacity. Other facilities, such as settling tanks, have sufficient hydraulic capacities against the maximum allowable wastewater flow rate applied for the aeration tank;
- The review results have indicated that the present plants' nominal treatment capacity of 15,200 m^3/day seem to be rather conservative side to handle the estimated future wastewater inflows;
- The Cienfuegos, Los Salados and Tamboril plants' facilities could safely treat a wastewater quantity of 10,000 m^3/day while the Embrujo could safely treat up to 11,000 m^3/day, provided that all the necessary improvement of the facilities and proper O/M are undertaken.
- Because of the sedimentation tanks without sludge collectors, no efficient removal of settled sludge and floating solids is quite likely. All the sedimentation tanks should have sludge collector equipment with sludge hoppers;
- The hoppers shall be sufficiently deep and large to store the settled sludge and to handle the return and excess sludge properly. The hopper shape and size are to be so determined that increase the sludge holding capacity if it is structurally appropriate to do so;
- The excess sludge is to be dried on the sand drying beds. Where sludge beds are not appropriately provided, these are also to be constructed in the First Stage Program; and
- An emergency power generator is to be provided in each WWTP with sufficient output to operate the minimum equipment required during the power failure. The power generator is to be capable of supplying 100 % power requirements in case of extended power outages.

Details of the evaluation are presented in Appendix-9.3 "Cienfuegos and Los Salados Wastewater Treatment Plants," Volume III- Supporting Report.