CHAPTER 12
STUDIES ON IMPROVEMENT AND DEVELOPMENT OF SEWERAGE SYSTEM

12.1 GENERAL

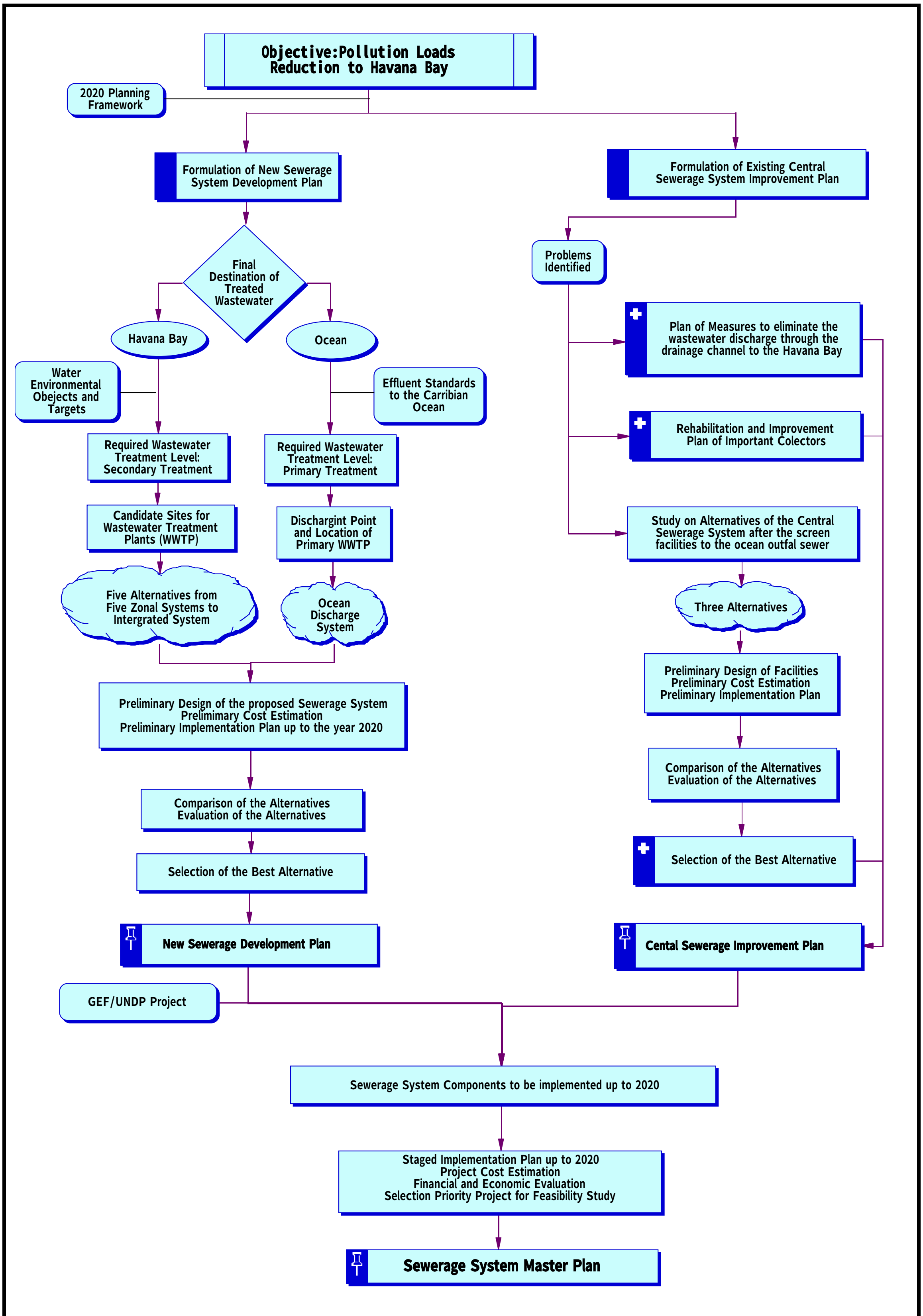
The major objective of the improvement and development of the sewerage system in the Study is aimed to contribute to a water quality improvement in the Havana Bay. The construction of sewerage facilities generally demands huge capital investment and long time. To seek high effects on the improvement of water quality by the least cost solution, a series of study have been conducted. Figure 12.1 shows a procedure to formulate the Sewerage System Master Plan (up to the year 2020) for the Havana Bay, but this chapter only describes the existing Central sewerage system improvement plan, the new sewerage development plan, and the selection of sewerage system components to be implemented up to the target year of 2020. The proposed implementation programs for the selected sewerage system components will be further studied to examine the technical, financial, economical, environmental and social aspects to formulate an appropriate sewerage master plan for the Havana Bay.

Different approaches have been used to formulate the improvement plan of the existing sewerage system and the development plan of a new sewerage system.

For the improvement plan of the existing sewerage system, the present problems are analyzed at first to identify the reasons and to prepare appropriate solutions. Engineering studies have been conducted to prepare the Central Sewerage Improvement Plan, comprising following plans:

- Plan of measures to eliminate the wastewater discharge through the drainage channel to the Havana Bay.
- Rehabilitation and improvement plan of important Colectors.
- Alternative Study on the Central sewerage system after the screen facilities to the ocean outfall sewer to select the best alternative.

For the development plan of new sewerage system, an alternative study has been conducted to select the best alternative for the most effective and efficient new sewerage system in terms of pollution loads reduction and costs. Based on the final destination of the treated wastewater discharge, five alternatives are prepared for the discharge to the Havana Bay, which are comprising from the five zonal sewerage systems to the integrated (one) sewerage system and one alternative are prepared for the ocean discharge.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.1 Flowchart of formulating Sewerage System Master Plan
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12.2 IMPROVEMENT OF THE EXISTING SEWERAGE SYSTEM

12.2.1 GENERAL

(1) Problems and Improvement Measures

Table below summarizes problems encountered in the existing sewerage system and improvement measures to solve the problems.

Table 12.1 Problems and Improvement Measures

System Component	Problems	Improvement Measures
1. Sewers and Colectors	The existing sewers and Colectors are very old, some parts of the pipe alignment and the internal structure are deteriorated. Capacity of some parts of the existing Colectors would be inadeauate for future wastewater flow. Cross connection problems between sanitary sewers and drainage pipes or conduits causes the direct wastewater discharge to the Havana bay.	Rehabilitation and replacement of the existing sewers will be necessary to maintain the function and extend their life. To solve the inadequate capacity of existing sewers and Colectors, new ones shall be installed to replace or add. Detail surveys are necessary to identify the locations and the physical conditions of the cross connections to prepare measures to solve the cross connection problems. Solution measures for the cross connection may be installation of a new sewer pipe to connect the sewer to the sewer main nearby with plugging the cross connection pipe and installation of the additional sewer main to increase an inadequate capacity of the existing sewer main.
2. Screen	Two number of screen equipment are out of order. They cause accumulation of sand and screens at the bottom of siphon and may cause clogging of cleaning pipe without proper maintenance.	1) To replace the two screen equipment. 2) To operate the pump for cleaning the siphon continuously, instead of the currently practiced intermittent operation.
3. Siphon	Inflow of sea water to the siphon may cause shorten operational life of pump equipment due to corrosion by sea water and increase O/M cost due to pumping sea water flowed into.	1) A detailed survey is required to identify the physical conditions of inner wall of siphon and the inflow of sea water. 2) Based on the results of survey, appropriate rehabilitation measures shall be studied and selected, including a study the necessity to install an additional siphon.

Source: JICA Study Team

Table 12.1 Problems and Improvement Measures (Continued)

System Component	Problems	Improvement Measures
4. Casablanca Pumping Station	1) Special attention on O/M is needed to maintain the existing pump equipment in good conditions. 2) Spare parts are not available in ordinary market, because the used spare parts are custom-made. 3) The limited capacity of wet well requires continuous and accurate water level measurements, but the existing sound wave type equipment cannot measure the water level properly, thus the pump equipment is operated manually by operators' visual observation. 4) No practice of continuous measurement of pumped wastewater volume to provide little information on Operation and Maintenance of wastewater collection system.	1) To install a new type pump equipment. 2) To install a new wastewater level measurement device. 3) To install a new wastewater volume measurement device.
5. Transmission Tunnel	Cracks in the inner wall were identified in the previous survey. The cracks may be made in the process of worn-out phenomena.	1) When the tunnel is used in gravity flow conditions, simple and partial rehabilitation works only are required. 2) When the tunnel is used in pressured flow conditions, a complete rehabilitation work is required: insert steel pipe or inner wall lining with reinforced plastics and mortar injection. 3) In case of the complete rehabilitation works required, it is impossible to pump the wastewater during the period of rehabilitation work. To avoid this situation, construction of new transmission tunnel will be required.
6. Outfall Sewer	It is required an improvement in the water quality of discharged wastewater.	1) To execute the improvement plan of outfall sewer. 2) A proposed improvement plan of existing wastewater collection system will increase pollution loads such as BOD and SS contents.

Source: JICA Study Team

(2) Design Conditions

1) Design Flows

Table 12.2 summarizes a planning basis for the existing sewerage system to evaluate the current capacity and to prepare a improvement plan for the future.

The design flows are calculated by the sewer service population, the future per capita wastewater generation, the individual wastewater generation from large water consumers, and the inflow/infiltration of groundwater as described in the Chapter 11.

2) Design Influent Quality

Based on the average daily flow and the assumptions on pollution load described section 11.4.5, each parameter of the design influent quality is estimated as shown in Table 12.2.

3) Design Effluent Quality

Design Effluent Quality: The design effluent quality is estimated based on the treatment level to satisfy the effluent standards for the receiving water body as shown below.

Effluent Quality Standards: The wastewater would be discharged to Playa del Chivo, the following effluent standards will be applied.

- Total suspended solids - 150 mg/L
- BOD_5 - 150 mg/L
- pH - 5 –10 pH units
- Fats, oil and grease - 50 mg/L
- Floatables - not visible

Treatment Efficiency: To satisfy the effluent standards, a primary wastewater treatment process will be applied and each treatment efficiency on major quality parameters can be set as follows:

- BOD and SS: 30–50 % removal
- T-N and T-P: 10-20% removal

Table 12.2 Design Bases for the Existing Central Sewerage System (Target year 2020)

Item	Existing Central Sewerage System
1. Service Population	**587,000** (*427,900) (**159,100)
2. Planning Area (ha)	**2,988.9** (*2,222) (**766.9)
3. Wastewater Generation (m^3/d)	**207,300** **(*148,200)**
3.1 Domestic (m^3/d)	98,617 (*71,888)
3.2 Non-domestic, small scale sources (m^3/d)	90,398 (*65,897)
3.3 Non-domestic, large scale sources (m^3/d)	18,214 (*10,377)
3.4 Total (m^3/d)	207,229 (*148,162)
4. Design Flows	
4.1 Infiltration/Inflow (m^3/d)	23,340
4.2 Average Daily Flow (m^3/d)	230,569 **= 230,600**
4.3 Maximum Daily (m^3/d)	**272,000**
4.4 Maximum Hourly (m^3/d)	**329,500**
5. Design Wastewater Quality	
5.1 Influent Quality	
BOD (mg/L)	190
SS (mg/L)	190
T-N (mg/L	28
T-P (mg/L)	2.6
5.2 Effluent Quality	
With Primary Treatment	
BOD (mg/L) <30–50 % removal>	120
SS (mg/L) <40–60 % removal>	120
T-N (mg/L) <10-20% removal>	24
T-P (mg/L) <10-20% removal)	2.2

Note) *: within the Havana Bay Basin, **: from the out of the Havana Bay Basin

12.2.2 CROSS CONNECTION PROBLEMS AND SOLUTION MEASURES

(1) Further Field Surveys

As described in the section 5.2.3, the initial cross connection survey by use of dye colored water had been conducted for the pilot areas related to the drainage channels of San Nicolas, Arroyo Matadero and Agua Dulce, but found very limited cases of cross connections between house connection to nearby drains, only three connections out of 217 samples surveyed. The additional survey identified a cross connection between sewer main and drainage channel. These results suggested that house connections were connected properly to lateral sewers or street sewers but some sewer mains would be connected to drainage pipes/conduits when the capacity of sewer did not have enough capacity.

Without any measures taken to solve the cross connection problem, it would be difficult for the Central sewerage system rehabilitated to reduce the pollution loads efficiently because some parts of the wastewater would be still being discharged to the Havana Bay through the existing drainage channels.

In the next section, measures for rehabilitation and improvement of the Central sewerage system will be studied and proposed, these measures are planed and designed based on an assumption that the cross connection problem would be solved before their commissioning.

A further cross connection field survey has been conducted on four of the locations previously identified by the INRH to understand the detail situations of the cross connections in the area related to the Dren Matadero.

(2) Solution Measures Needed

Out of the four locations it was possible to identify the origin or source of cross connection at three locations. Figures 12.2 to 12.4 show the survey results of the locations where origin or source was identified.

To eliminate the cross connections in these three locations following measures are required.

- A cross connection is from a housing apartment block at Avenida Colon y Bellavista and only some part of the grey water is discharged as exhibited in Figure 12.2. This cross connection can be eliminated easily by connecting to the nearest sewer main.
- Figure 12.3 shows a cross connection between a sewer manhole to a nearby drain manhole at Tulipan y Estancia. Reason for the cross connection could be either inadequate capacity of the nearest sewer or due to simple mistake. Elimination of this will require an investigation of existing capacity and elevation of sewer main.
- Figure 12.4 exhibits a cross connection due to inadequate capacity of sewer at Ermita y San Pedro. In this case, it will be necessary to construct new sewers to increase the capacity of sewer.

In addition to the above findings, it was also found that the siphon structured Colectors crossing over the nearby storm-water channel had overflow structures to divert the wastewater to the drainage channel when it reached over the capacity of Colector.

The above survey results recommend that a long-term detailed survey would be required to identify the exact locations and reasons of the cross connections and to prepare appropriate and cost-effective solution measures for different cases of cross connections.

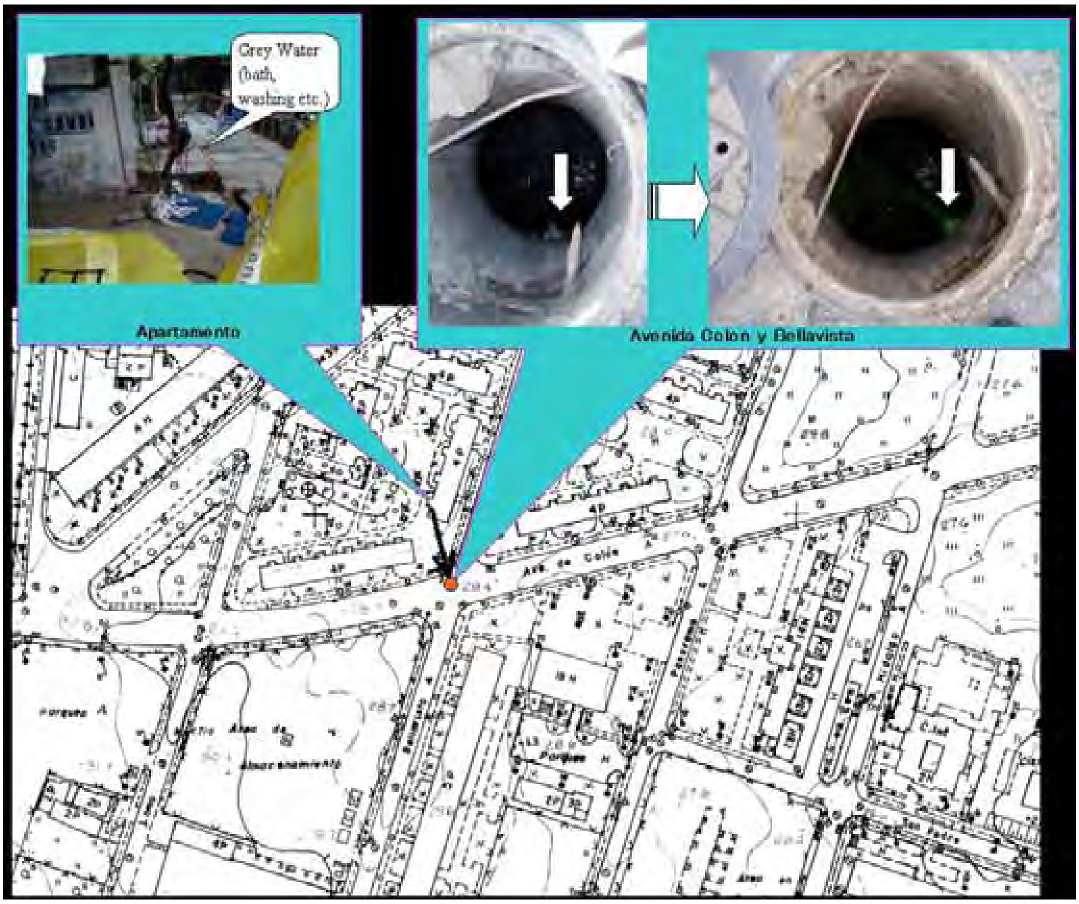

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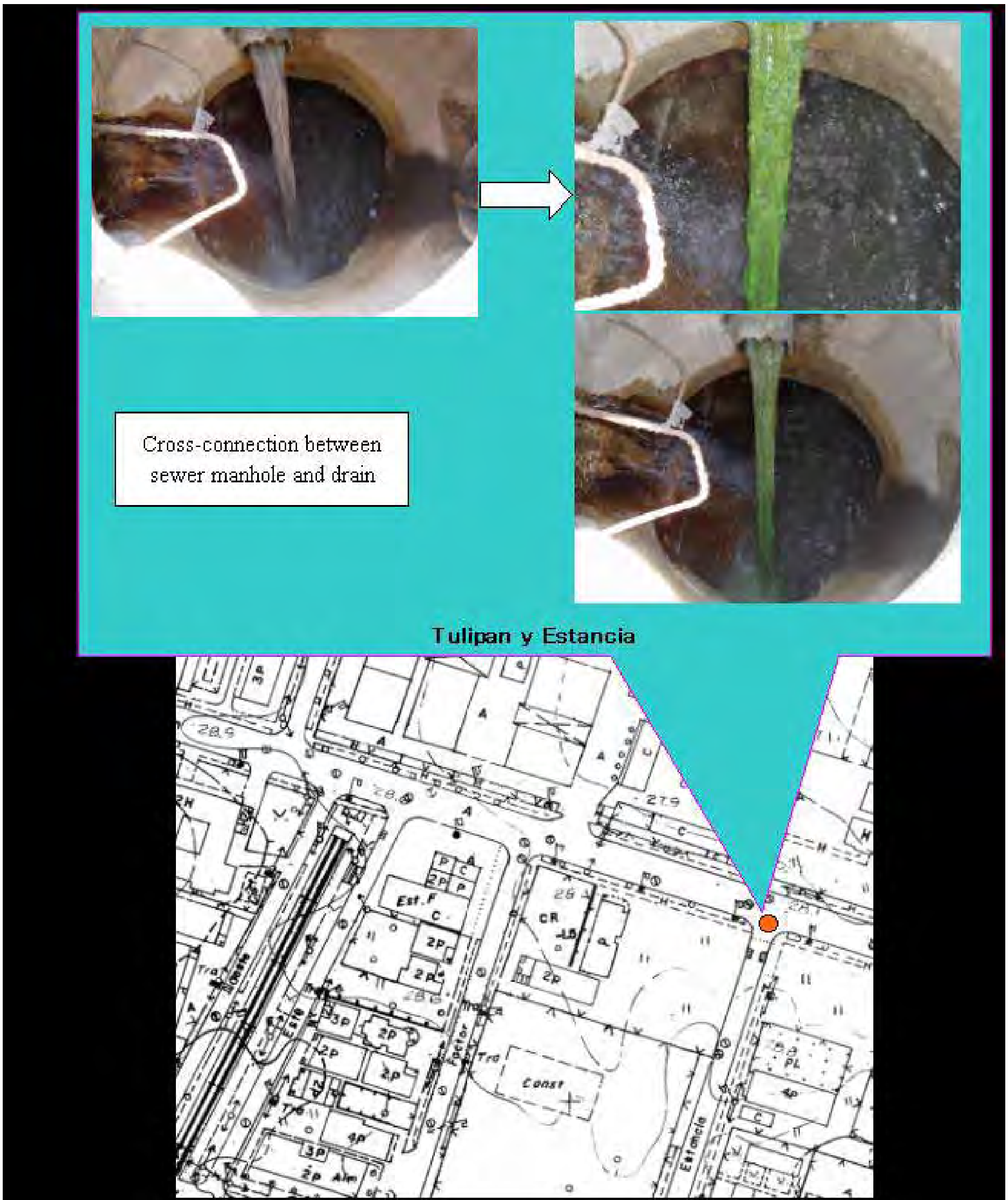
Figure 12.2 Cross connection of Sewer Manhole of Housing Apartment to the nearby Drain



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.3 Cross connection of Sewer Manhole to Drain due to Inadequate Sewer Capacity or Mistake
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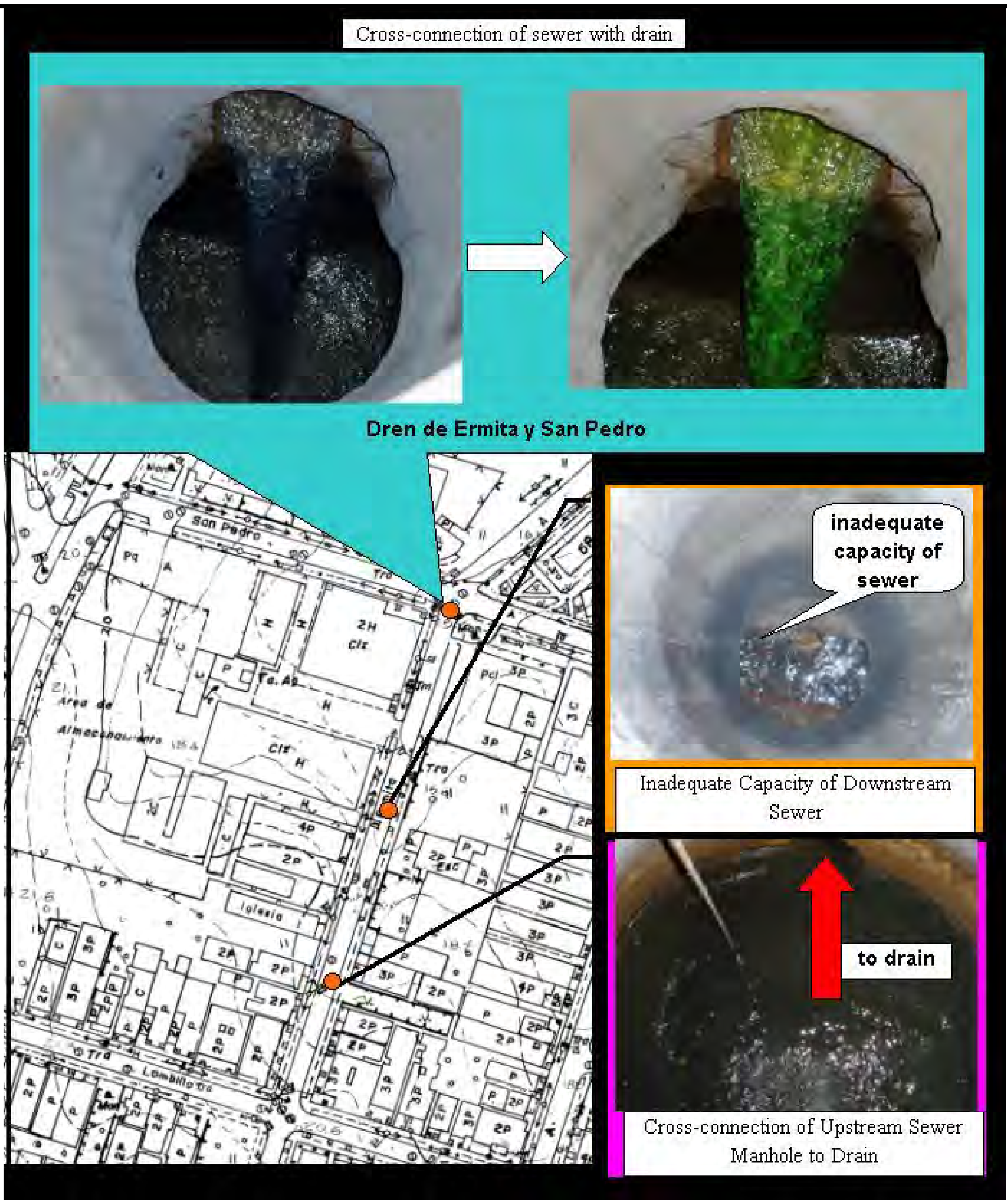

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.4 Cross connection of Sewer Manhole to Drain due to Inadequate Sewer Capacity
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12.2.3 REHABILITATION AND IMPROVEMENT OF THE COLECTORS

(1) Methodology

The capacity of the existing Colectors of Centro Habana, Cerro, Sur 1, Sur 2, Sur 3 and Sur located as shown Figure 12.5, is estimated and compared against the design flows in the year 2020 to determine whether augmenting the capacity with new Colector is required or not. New Colector system is planned for the additional capacity required.

The current capacity is estimated based on the available information of the Colectors: shape and diameter, slope, invert level, and length. The roughness coefficient in the Manning formula, n-value of 0.016 is used.

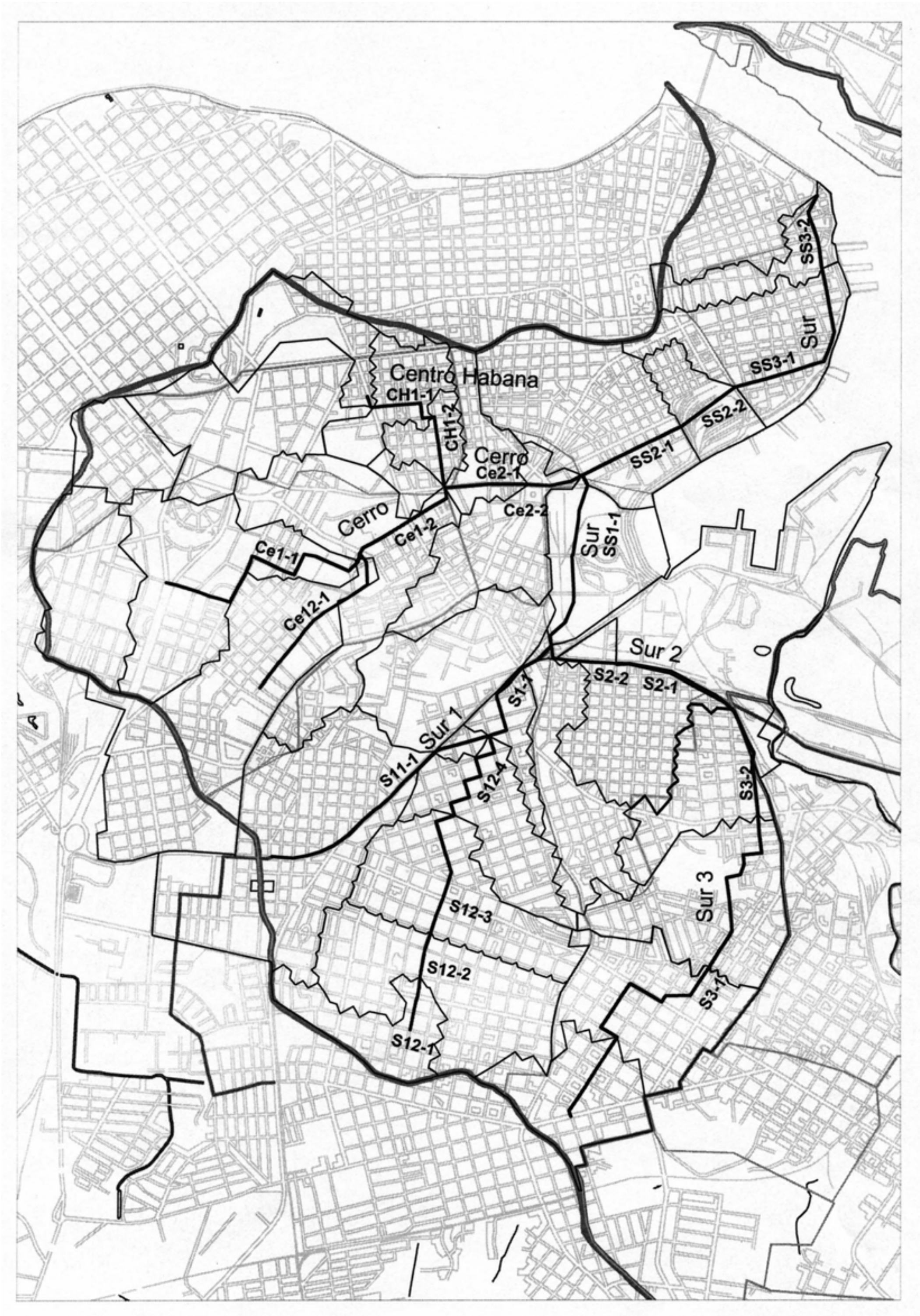
(2) Capacity of the existing Colectors

The table below summarizes the Colectors having lower capacity than the design flows. The detailed results of examination on the current capacity of the existing Colectors shall be referred to the Appendix-10 of the Supporting Report, Volume III. Since the existing Colectors were designed and installed based on the surface slope generally, some parts of the Colector listed in the table below could keep the enough capacity under the hydraulic gradient conditions. Therefore, it is recommended that the listed Colectors should be surveyed in detail to find any problems caused by an inadequate capacity or physical conditions and to identify appropriate rehabilitation or improvement measures.

Table 12.3 Colectors Recommended For Further Study

Colector	Diameter (mm)	Length (m)	Remarks
Cerro	675	294	
	1200	285	
	1350	380	
Centro Habana	450	314	
	675	250	
	750	115	
Sur-1	900	210	
Sur-2	750	518	
	900	391	
Sur-3	350	229	
	400	703	
	750	783	
Sur	1500	380	
	1950	602	
	2100	849	

Source: JICA Study Team



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.5 Central System – Sewer Sub-districts
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(3) Colector Sur and Colector Sur 2

1) General

Figure 12.5 shows Colector Sur 3 joins into Colector Sur 2 and Colector Sur 2, Sur 1, Centro Habana, and Cerro, join into Colecto Sur finally to convey the wastewater to the screen facilities at Caballeria. The Colector Sur and Sur 2 are important main facilities for the Central sewerage system, but these Colectors have used more than 90 years and do not have enough capacity for the future wastewater flows. Therefore, rehabilitation and improvement of these Colectors are indispensable for the Central sewerage system.

2) Design Conditions

The capacity of Colectors after rehabilitation is calculated based on the following assumptions:

- Reducing the diameter

  After the rehabilitation works, it is assumed that the diameter of Colector will be reduced to 90% of the original diameter.

- Decreasing the roughness coefficient of n-value

  The roughness coefficient, n-value of 0.013 is applied, taking into account of a critical case of using mortar lining pipes.

Other design conditions are referred to the section 11.6.1.

3) Design Capacity of Rehabilitated Colectors

The present capacity of Colector Sur and Colector Sur 2 is estimated as shown in Table 12.4. The table also shows the capacity of Colector Sur after rehabilitation.

Since the estimated capacity of Colector Sur 2 is too small to convey the future wastewater flows, it is proposed that an additional new Colector, namely Colector A shown in Figure 12.6, will be constructed to convey the wastewater and the existing Colector Sur 2 will be used as a street sewer or sub-main sewer. The design flow for the design of

The table shows that the capacities of Colector Sur after rehabilitation are beyond the design flows but the design allowance specified in Table 11.13 are not satisfied. The insufficient capacity will be covered by the proposed new Colecor in the following section, which could make possible to rehabilitate the Colector Sur and improve the reliability of Colector Sur. The table also shows that the design capacity and sufficient allowance when the proposed new Colector system is applied.

Table 12.4 Capacity of the Colector Sur and Sur 2

Colector	Sub-colector	Design Flow (2020)	Dia.	Hydraulic Gradient	System Capacity*	System Capacity after rehabilitation	Design Capacity with Allowance
		(L/s)	(mm)	(1/1000)	(L/s)	(L/s)	(L/s)
Sur	SS1-1	1,504	1,350	1.0	1,820	1,689 (12%)	1,059 (59%)
	SS2-1	2,506	1,750	0.8	3,255	3,007 (20%)	2,100 (43%)
	SS2-2	2,567	1,750	0.8	3,255	3,007 (17%)	2,162 (39%)
	SS3-1	2,686	1,900	0.8	3,983	3,742 (39%)	2,284 (64%)
	SS3-2	2,733	1,900	0.8	3,983	3,742 (37%)	2,332 (60%)
Sur 2	S2-1	613	750		175 (349)	with new Colector Sur A	
	S2-2	676	900		286 (573)	with new Colector Sur A	
	S21-1	734				no rehabilitation	

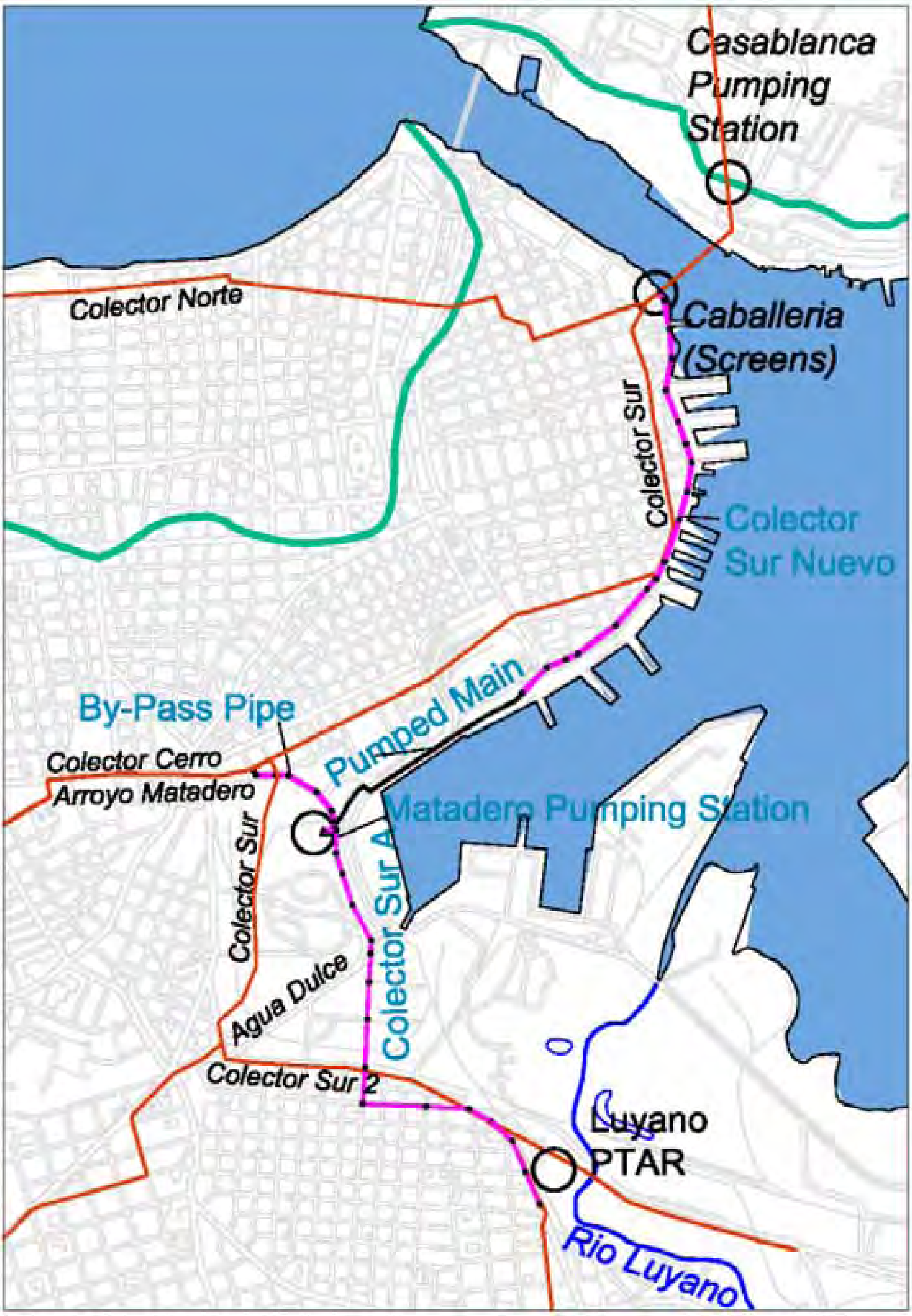
Note: * estimated full flow capacity with n=0.016 and with average hydraulic gradient
Source: JICA Study Team

4) Proposed System for rehabilitation of the Colector Sur

The following new Colector system is proposed as shown in Figure 12.6 to rehabilitate the Colector Sur and to improve the reliability of the Central System:

- Colector Sur A
- Matadero Pumping Station
- Pumped Main
- Colector Sur Nuevo

The design of these sewerage facilities will be described in detail in the section 12.3.3. Because the design also takes into account of the wastewater during rehabilitation of Colector Sur and the wastewater generated from the area of left bank of Rio Luyanó.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.6 Proposed Colector System for improve the Central Sewerage System
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12.2.4 ALTERNATIVE STUDY ON THE EXISTING SEWERAGE SYSTEM

(1) General

A preliminary study on the screen facilities, Casabalanca pumping station, the transmission tunnel and the outfall sewer had been conducted by Cuban instituitions. Therefore, the improvement plan related to the sewerage system components after the screen facilities will be prepared through an alternative study based on review of the preliminary study to select the best alternative.

(2) Alternatives

Three alternatives are prepared to improve the sewerage facilities except the Colector Sur. A description of each alternative is provided below and illustrated in Figure 12.7 and Figure 12.8.

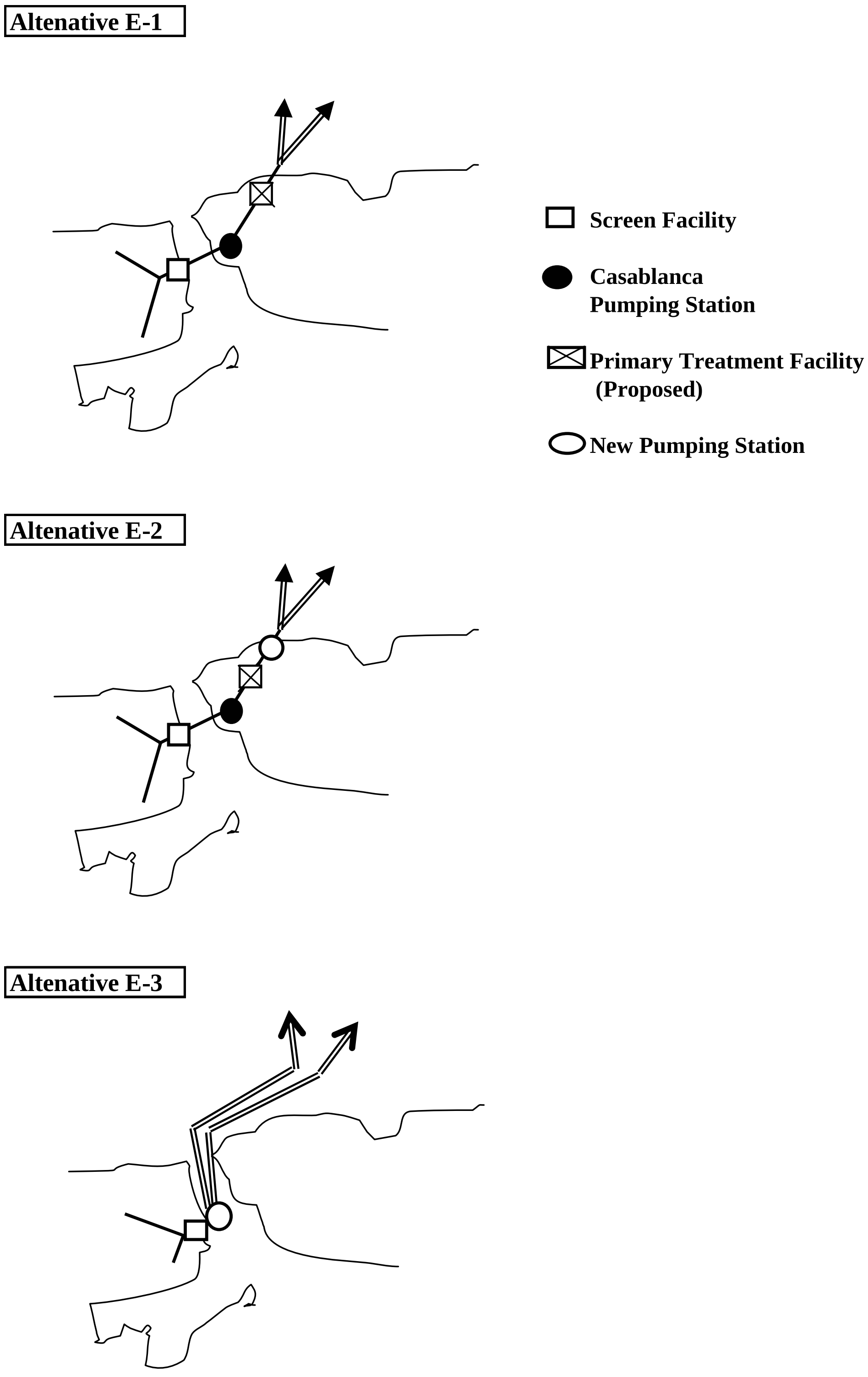
Alternative E-1: Rehabilitation work of Casablanca Pumping Station, installation of pump equipment to cover higher pumping head of about 15 to 20m from the current 8m, rehabilitation work of screen facilities, replacement of the outfall sewer, and construction of preliminary wastewater treatment facilities in Chivo area.

When the outfall sewer at Playa del Chivo is replaced with new one, about 8m higher pumping head is required for the pumps to be installed at Casablanca Pumping Station. In addition, in this case the transmission tunnel will be operated under pressured flow condition, a complete repair work of transmission tunnel from the Casablanca pumping station to the outfall sewer is required against the pressured flow condition.

Alternative E-2: Rehabilitation of Casablanca Pumping Station with installation of pump equipment having pumping head of 8 m, construction of Re-pumping Station, a partial and easy repair work of transmission tunnel, rehabilitation work of screen facilities, replacement of the outfall sewer, and construction of preliminary wastewater treatment facilities in Chivo area.

The differences between alternative 1 and 2 are repair work required for the existing transmission tunnel. In this case, additional pumping equipment is proposed to install after the transmission tunnel, a simple or easy repair work is required because the tunnel will be operated under gravity flow conditions as same as the present condition.

Alternative E-3: Construction of a new pumping station near the existing screen at Caballero and construction of outfall facilities through the bay to discharge at Playa del Chivo.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.7 Alternatives for Improvement of Existing Central Sewerage System
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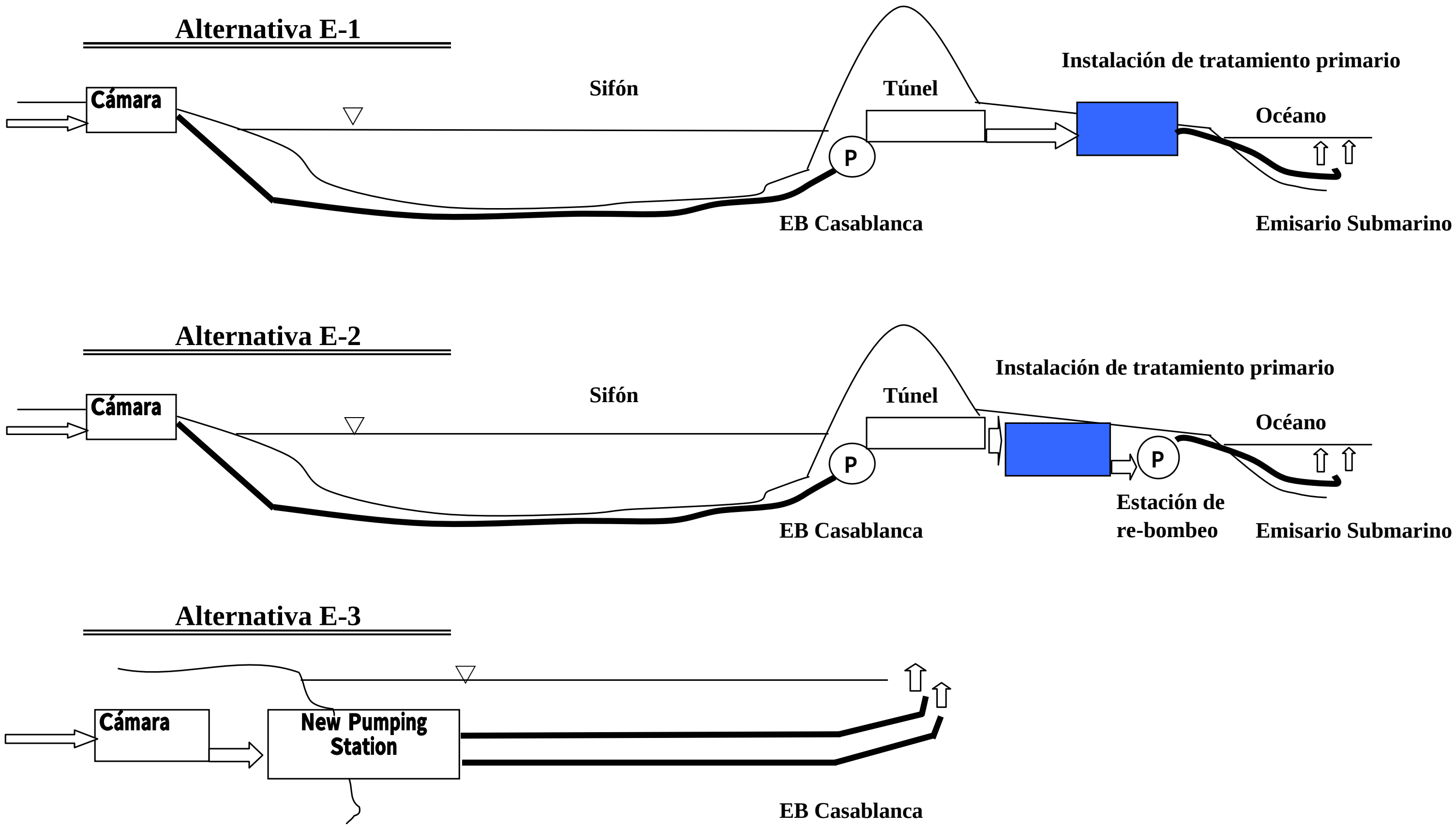


Figure 12.8 Profile of three alternatives for improvement of the existing wastewater conveyance system

(3) Phased Rehabilitation Plan for Each Alternative

Take into consideration of importance and emergency, a phased rehabilitation plan of components for each alternative is prepared and summarized in Table 12.5.

Table 12.5 Rehabilitation Plan for each Alternative on Central System Improvement

Period	Proposed Rehabilitation Works	Alternative E-1 (Casablanca P/S)	Alternative E-2 (Casablanca P/S + Re P/S)	Alternative E-3 (New P/S)
0 ~ 5 Years	1. Rehabilitation of existing P/S	Replace existing pumps with new ones, but the technical specification will not be changed: Q=1.75 m^3/s, H= 8 m	Same as it is proposed for alternative E-1	Same as it is proposed for alternative E-1
	2. Rehabilitation of existing screens	1) Replacement of 2 broken screens 2) Replacement of 3 screens in future	Same as it is proposed for alternative E-1	Same as it is proposed for alternative E-1
5 ~ 10 Years	3. Reconstruction of outfall sewer	1) Replacement of pumps with higher pumping head: about H=15 m required. 2) Reconstruction of the outfall sewer L=300+140=440m x 2 outfall sewers, including Diffuser of 140m in length.	1) Construction of a Re P/S is required. Q=1.75 m3/s, H=5m, 4 units (1stand-by) 2) Reconstruction of the outfall sewer	1) Construction of new pumping station near the siphon. Q=1.321 m3/s, H=20.7m, 325kw, 5units (1 stand-by) 2)Construction of new outfall sewers from the screen facilities to the discharging point (Chivo), L=3100+140=3,240m x 2 outfall sewers
	4. Rehabilitation of transmission tunnel	Complete rehabilitation works will be required against the pressured flow conditions	Rehabilitation works will not be required under gravity-flow conditions	1) Abandon of the tunnel and outfall sewer. 2) Abandon the existing P/S or use as a sewerage museum
	5. Reconstruction of siphon	Based on a detailed survey on the physical conditions of siphon, reconstruction of a new siphon will be considered.	Same as it is proposed for alternative 1	The existing siphon can be used as a storage facility if no sea water inflow is confirmed through the detailed survey.
10 ~ 20 Years	6. Construction of Primary treatment facility	Replacement of pumps to meet higher pumping head of about 20 m will be required.	Construction of primary treatment facility between the tunnel and Re P/S will not require the pump specifications of Re P/S.	

(4) Comparison of Alternatives

To compare each alternative, following parameters are taken into consideration and their preliminary comparison on each alternative are also summarized in Table 12.6:

- Land acquisition
- Application of local construction capacity
- Pollution load reduction to Greater Caribbean Sea
- Effect during construction
- Construction cost or main facilities (only for comparison based on preliminary cost estimation)
- O/M cost (only for comparison of preliminary power cost based on the pumping head required)

Table 12.6 Comparison of Alternatives for Central Sewerage System Improvement (1/2)

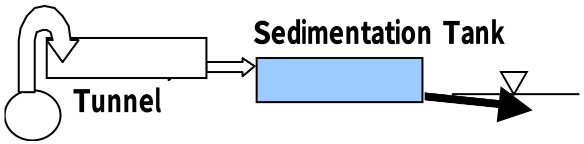
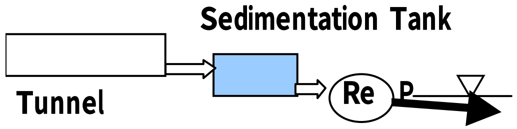
Item	Alternative E-1 Casablanca P	Alternative E-2 Casablanca P + Re P	Alternative E-3 New Pumping Station
1. Sequence of rehabilitation	1. Rehabilitation of existing Casablanca Pumping Station (within 5 years) 2. Construction of outfall sewer, repair work required to strengthen the inner wall of tunnel (within 5 to 10 years) 3. Construction of primary treatment facility(sedimentation tank), and extension work to increase capacity of Casablanca Pumping Station (within 10 to 20 years) 	1. Rehabilitation of existing Casablanca Pumping Station (within 5 years) 2. Construction of outfall, construction of pumping station (Re P), with minor repair work of tunnel where necessary for gravity flow (within 5 to 10 years) 3. Construction of primary treatment facility if necessary (within 10 to 20 years) 	1. Rehabilitation of existing Casablanca Pumping Station (within 5 years) 2. Construction of outfall for the new pumping station (within 10 to 15 years)
2. Land acquisition	- Except for primary treatment facility, others are existing facilities - Possible to locate sedimentation facilities in the coastal area	- Sedimentation tank and new pumping station is necessary - Possible to locate sedimentation facilities in the coastal area following the tunnel	- Difficult to obtain land for pumping station near existing screen facilities
3. Applicability of Local Construction Capacity	Construction technology of Cuba is applicable except for strengthening work of whole of tunnel	Construction technology of Cuba is applicable to whole of the works	Construction technology of Cuba is applicable to whole of the works
4. Pollution load reduction to Greater Caribbean Sea	Removal rate BOD_5 and SS - 40 to 50%	Removal rate BOD_5 and SS - 40 to 50%	Removal rate BOD_5 and SS - 0%

Table 12.6 Comparison of Alternatives for Central Sewerage System Improvement (2/2)

Item	Alternative E-1 Casablanca P	Alternative E-2 Casablanca P + Re P	Alternative E-3 New Pumping Station
5. Effect during construction		4.	
1) within the existing facility	Initially - rehabilitate 2 screens Future - rehabilitate 3 screens	Initially - rehabilitate 2 screens Future - rehabilitate 3 screens	Initially - rehabilitate 2 screens Future - rehabilitate 3 screens
2) outside the existing facility	To the access road	Investigation (to decide whether a new tunnel is required)	Possible use as a wet well for new pumping station if infiltration is smaller
3) in the bay	Due to wastewater discharge to bay during construction	---------------------	Due to outfall construction to shipping movement or vice versa
6. Construction cost of main facilities	- Outfall construction - Tunnel (complete repair works to strengthen the inner wall against pressured flow conditions) - Primary Treatment Facility - Rehabilitation of Casablanca Pumping station 130%	- Outfall construction - Tunnel (minor repair) - Primary Treatment Facility - Rehabilitation of Casablanca Pumping station 100%	New pumping station and outfall construction - 400%
7. O/M Cost (Preliminary Cost comparison based on pumping required)	Total pumping head required: H=20 m, (120%)	Total pumping head required: H=17 m, (100%)	Total pumping head required: H=21 m, (120%)

Source: JICA Study Team

(5) Selection of Alternative

1) Selection Criteria

To select the best alternative, the following criteria are taken into consideration:

- Discharge to bay during construction
- Effect during construction
- Complexity of construction (applicability of Cuban construction capacity)
- Applicability of phased construction (suitable for financing constraints)
- Land requirement
- Construction cost
- O/M cost
- Use of existing system
- Pollution load reduction to Greater Caribbean Sea

2) Evaluation of Each Alternative

Evaluation of each alterative is presented in Table 12.7 using a preliminary ranking: ◎ – Very Good, ○ – Good, △ – Fair and X – Poor.

To select the best alternative, phased construction shall be applicable to have high potential for realization of each alternative, taken into consideration the following view points.

- Shall be within the construction capacity of Cuba to reduce construction cost.
- Land acquirement (availability) shall be easier as it is a pre-condition for construction.
- Pollution load to bay shall be minimal during construction.
- Pollution load to Greater Caribbean Sea shall be minimal.
- Construction and operation cost shall be minimal.

3) Selection of Best Alternative

Based on the above, alternative to which phased construction is applicable and lower cost alternative to which obtaining financing is preferable. As the results of evaluation of each alternative, Alternative E-2 is selected because this alternative is advantageous for realization considering phased construction.

Table 12.7 Evaluation of Alternative Systems for Existing Central Sewerage System Improvement (1/3)

Item	Alternative E-1 Casablanca P	Alternative E-2 Casablanca P + Re P	Alternative E-3 New Pumping Station
1 Discharge to bay during construction	About three months during strengthening of tunnel X	No discharge to bay ◎	Short period during switching from existing pump to new pump ○
2 Effect during construction	- Strengthening of tunnel within the facility boundary - Construction of sedimentation tank outside the facility boundary - Modifying pumping facilities during phased construction will be necessary △	Major part of construction is rehabilitation of the existing system and construction of sedimentation tank and pumping station (Re P) outside the existing facility boundary will affect traffic ○	Traffic congestion due to construction of pumping station adjacent to major road. Since outfall construction affect shipping traffic, restriction on construction will be made. X
3 Complexity of construction (applicability of Cuban construction capacity)	Except strengthening of tunnel which require foreign technology, local capacity is adequate for the rest. ○	Local capacity is adequate for the whole construction. ◎	Local capacity is adequate for pumping station construction below ground water level as well as laying outfall pipes. ◎
4 Applicability of phased construction (suitable for financing constraints)	Strengthening of tunnel and outfall construction are necessary during a single phase. Further, rehabilitation of pumps is also necessary in the same phase. All of the three above will be necessary at the same phase. ○	Compared with Alternative 1 which is applicable for phased construction, absence of strengthening of tunnel makes this alternative attractive for phased construction. ◎	Necessary to construct the whole system at once. Requires large capital and obtaining finance will be difficult. X

Note : ◎ – Very Good, ○ – Good, △ – Fair and X - Poor

Table 12.7 Evaluation of Alternative Systems for Existing Central Sewerage System Improvement (2/3)

Item	Alternative E-1 **Casablanca P**	Alternative E-2 **Casablanca P + Re P**	Alternative E-3 **New Pumping Station**
5 Land Requirement	Land for sedimentation facility is necessary ○	Land for sedimentation facility and pumping station (Re P) is necessary ○	Land for pumping station near existing screens is difficult. **X**
6 Construction Cost	Construction cost of outfall, tunnel strengthening and pump rehabilitation will be necessary in a single phase. ○	In the phased construction, outfall and pumping station (Re P) construction (cost) will be together. Construction of other facilities can be carried out individually. ○	Large-scale construction cost is necessary. **X**
7 O/M Cost	- single pumping station ○	- two pumping stations but with lower maintenance cost. ◎	Power cost for pumping will be the major portion of O/M cost ○
8 Use of existing system	Fully utilized ◎	Fully utilized ◎	Almost all facility will be abandoned **X**
9 Pollution load reduction to Greater Caribbean Sea	Primary treatment ◎	Primary treatment ◎	No treatment **X**

Note : ◎ – **Very Good**, ○ – **Good**, △ – **Fair and X - Poor**

Table 12.7 Evaluation of Alternative Systems for Existing Central Sewerage System Improvement (3/3)

Item	Alternative E-1 Casablanca P	Alternative E-2 Casablanca P + Re P	Alternative E-3 New Pumping Station
10 Overall evaluation	- Phased construction shall be applicable to have high potential for realization. - Shall be within the construction capacity of Cuba to reduce construction cost. - Land acquirement (availability) shall be easier as it is a pre-condition for construction. - Pollution load to bay shall be minimal during construction. - Pollution load to Greater Caribbean Sea shall be minimal. - Construction and operation cost shall be minimal. Based on the above, alternative to which phased construction is applicable and lower cost alternative to which obtaining financing is preferable.		
	○ Single pumping station compared to Alternative 2 which is advantageous in terms of O/M cost.	◎ Phased construction and lower construction and operation cost of this alternative is advantageous for realization	X If large-scale financing possible, this is an attractive alternative.

Note : ◎ – **Very Good,** ○ – **Good,** △ – **Fair and** X - **Poor**

12.2.5 PROPOSED IMPROVEMENT PLAN OF EXISTING CENTRAL SYSTEM

In summary, the proposed improvement plan of the existing sewerage facilities is presented in the table below.

Table 12.8 Proposed Improvement Plan of the Existing Central Sewerage System

Item	Proposed Plan	Remarks
1. Target Population (year 2020)	Total Service Population: 587,000 Within Havana Bay Area: 427,900 From Out of the Bay Area: 159,100	
2. Sewerage Service Area	Total Area: 2,989 ha Within（2,222 ha）, From Outside(767 ha)	
3. Wastewater Production （year 2020）	207,229 m^3/day （148,162 m^3/day）	(figure)：within Havana Bay Area
Domestic Wastewater	98,617 m^3/day（71,888 m^3/day）	
Other wastewater（Small consumers）	90,398 m^3/day（65,897 m^3/day）	
Other wastewater（Large consumers）	18,214 m^3/day（10,377 m^3/day）	
4. Design Flows		
Average Daily Flow	230,600 m^3/day	
Maximum Daily Flow	272,000 m^3/day	
Maximum Hourly Flow	329,500 m^3/day	
5. Projected Wastewater Influent Quality to the Primary Wastewater Treatment Plant	BOD: 190 mg/L, SS: 190 mg/L T-N: 28 mg/L, T-P: 2.6 mg/L	

6. Effluent Wastewater Quality Standards	BOD: 150 mg/L, TSS: 150 mg/L	The Greater Caribbean
7. Improvement Plan of the Existing Central System		
7.1 Detailed Surveys on cross connections to prepare appropriate solution measures.	To conduct Detailed Surveys for identifying the cross connections and preparing solution measures to eliminate the direct wastewater discharge through the Dren Matadero and the Dren Agua Dulce to Havana Bay at Atares.	
7.2 Rehabilitation of the inadequate capacity of Colectors	The inadequate capacity of the existing Colectors in the Centro Habana, Cerro, Sur 1, Sur 2 and Sur 3 will be added or replaced with new Colectors.	
7.3 Rehabilitation of Colector Sur and Construction of the proposed Colector system	Rehabiltation of Colector Sur (Dia.: 1500 to 2100mm, CP, Length: 2.78km) and Construction of the proposed Colector system: pumped main (Dia.: 1,350mm, CP, Length 1,020m), Colector Sur Nuevo (Dia. 1500mm, CP, Length: 1,830m), and interconnection pipe (Dia.:1,030/1200mm, HDPE, to 1500mm, CP, Length: 500m) Construction of the proposed Colector Sur A (Open Cut, Dia.1500mm, CP, Length: 580m, and Tunnelling, Dia.1500mm, CP, Length:1070m) Construction of the proposed Matadero pumping station, Q=20 m^3/min, H=12 m, 3 units including one standby. During the rehabilitation of Colector Sur, additional Q=40 m^3/min, H=12 m, 2 units will be installed.	CP: Centrifugal reinforced concrete pipe. HDPE: High density polyethylene pipe. HDPE shows inner/ outer diameter.
7.4 Rehabilitation of Screen Facilities and Detailed Survey of Siphon Structure	To rehabilitate the screen facilities (2 units) at Caballeria, and to conduct detailed surveys on physical conditions of siphon structures to prepare rehabilitation plans.	
7.5 Rehabilitation of Casablanca Pumping Station	To replace the pump equipment (Q=1.75 m^3/s, H=8 m), 4 units including one unit standby.	The existing pumping equipment is Q=2.6 m^3/s, H=8 m, 3 units including one standby.
7.6 Rehabilitation of transmission tunnel and construction of pumping station to discharge the wastewater to the ocean by installation of new ocean outfall sewer	To discharge the wastewater by new ocean outfall sewer with minor repairs of the transmission tunnel, a pumping station, Q=1.75 m^3/s, H=5 m, 4 units including one standby, shall be constructed after the tunnel to mitigate the water head loss. The wastewater can be transmitted gravity flow in the tunnel, thus a simple repair work such as inner lining can be applicable.	
7.7 Wastewater Primary Treatment and Sludge Treatment Facilities	To meet the greater Caribbean wastewater effluent standards, a construction of wastewater primary treatment and sludge treatment facilities may be necessary in the future. A general layout plan of the treatment facilities is prepared.	The necessity of construction of treatment facilities shall be decided based on wastewater quality monitoring study prior to the execution of the plan.
7.8 Installation of Ocean Outfall Sewers	To install an ocean outfall sewers 300m in length including two diffuser pipes of 140m long.	

Source: JICA Study Team

12.3 DEVELOPMENT PLAN OF NEW SEWRAGE SYSTEM

12.3.1 GENERAL

It is ideal for constructing all sewerage systems needed by the target year of 2020 to achieve the future water quality goals set for the Havana Bay. However, because the development of new sewerage system demands huge investment of time and money, only some parts of sewerage development plans could be developed up to the target year. Thus, a sewerage system development plan bringing significant effects or substantial benefits with minimum investment would be highly appreciated. In this Study, the main objective of the sewerage system development is to reduce pollution loads discharging into the Havana Bay, the sewerage system development plan which could reduce pollution loads significantly but with the least cost solution would be requested.

In the following section, for the areas where are unsewered at present but appropriate to collect the wastewater generated by a sewerage system, several sewerage plans are prepared and studied comparatively to formulate an appropriate sewerage development plan to satisfy the objective of sewerage system development.

12.3.2 ALTERNATIVE STUDY ON NEW SEWERAGE SYSTEM

(1) Alternatives

To prepare alternatives for a new sewerage system, two final destinations for the treated wastewater are taken into account, one is the Havana Bay and another is the Greater Caribbean Ocean. Depending on the destinations, the following six alternatives are prepared for a new sewerage development.

1) Havana Bay

The following five alternatives are proposed to study. Each sewer district in all the alternatives has a wastewater treatment plant (WWTP) equipped with a biological secondary process.

Alternative N-1 (Five Zonal systems): Five small sewer districts are set as shown in the Figure 12.9. This alternative is the basic form, other alternatives are formulated to combine some sewer districts.The boundary of the each zone is determined such that a gravity sewer system can be applied. The five zones are named, 1) Luyanó Abajo sewer district, 2) Luyanó Arriba sewer district, 3) Martín Pérez Abajo sewer district, 4) Martín Pérez Arriba sewer district and 5) Tadeo sewer district. Each zone has a wastewater treatment plant (WWTP). Therefore, in this alternative five WWTPs would be developed.

Alternative N-2 (Four Zonal systems): This is a modified alternative N-1, in which the Luyanó Abajo sewer district and the Martín Pérez Abajo sewer district are combined to form a Luyanó-Martin Pérez Abajo sewer district. Other four each zone is the same as that in the alternative N-1. Figure 12.10 shows the four zonal systems.

Alternative N-3 (Three Zonal systems): This is the case that each sewer district is set for a river basin each. Therefore, this alternative is composed of three sewer districts, namely, 1) Luyanó sewer district, 2) Martín Pérez sewer district, and 3) Tadeo sewer district. Figure 12.10 shows the three zonal systems.

Alternative N-4 (Two Zonal systems): This is a modified alternative N-2, in which the Tadeo sewer district is combined with the Martín Pérez sewer district. Figure 12.10 shows the two zonal systems.

Alternative N-5 (Integrated system): All of five sewer districts are integrated into one sewer district. Figure 12.10 shows the integrated system.

2) Greater Caribbean Ocean (Discharge to Playa del Chivo)

One alternative is set for the ocean discharge.

Alternative N-6 (Ocean discharge system): All wastewater would convey and finally discharge to the ocean after a primary wastewater treatment to comply the effluents standards.

Figure 12.11 show the alternative of ocean outfall.

(2) Design Bases

1) Design Flows

Table 12.10 summarizes a planning basis for each sewer district, such as the sewer service population, the planning sewerage planning area, the wastewater generation, and design flows.

The design flows are calculated by the sewer service population, the future per capita wastewater generation, the individual wastewater generation from large water consumers, inflow/infiltration groundwater as described in the Chapter 11.

2) Design Influent Quality

Based on the average daily flow and the assumptions on pollution load described section 11.4.5, a design influent quality is estimated for each sewer district. Table 12.9 summarizes the design influent quality calculated.

3) Design Effluent Quality

Treatment Efficiency: A discharged pollution load after treatment at a wastewater treatment plant are set based on the following design wastewater treatment efficiencies.

Table 12.9 Treatment Efficiency

Parameter	Primary Treatment	Secondary Treatment* (overall)
BOD_5	30 – 50 %	85 – 95 %
SS	40 – 60 %	85 – 95 %
T-N	10 – 20 %	10 – 20 %
T-P	10 – 20 %	10 – 20 %

* - conventional activated sludge process

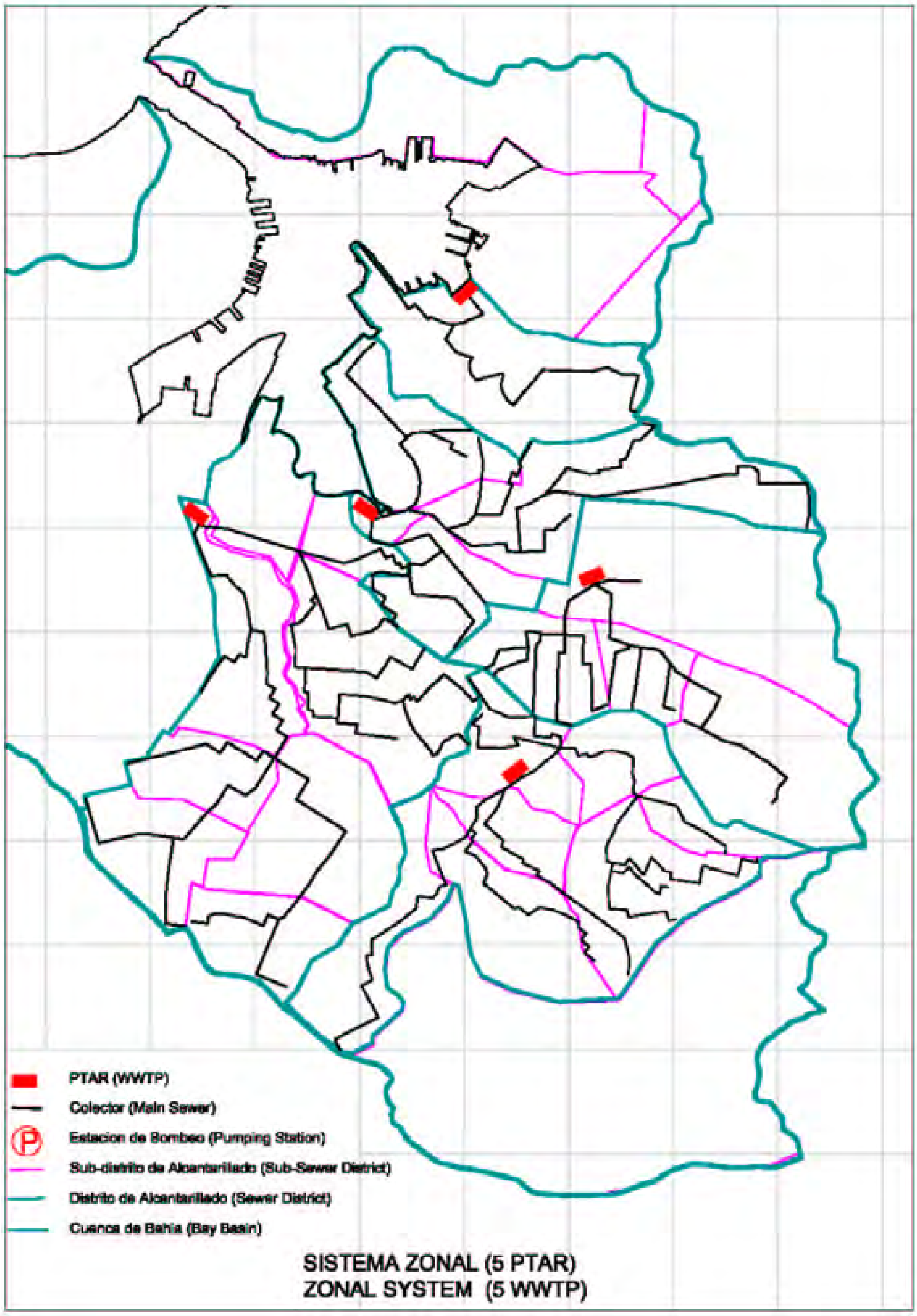
Design Effluent Quality: The design effluent quality for each sewerage scheme is summarized in Table 12.10.

(3) Alternatives of Treated Wastewater Discharge to Havana Bay

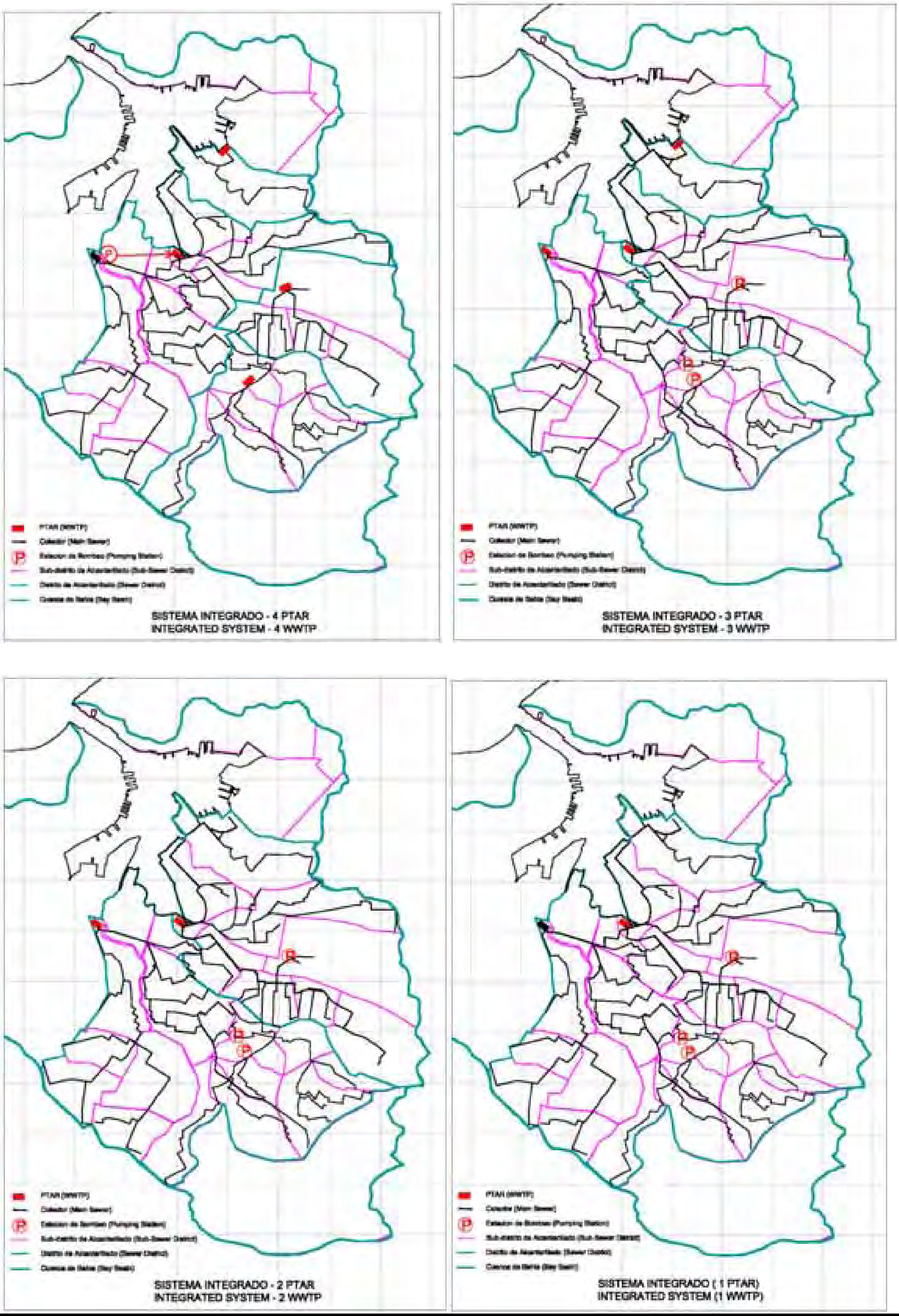
The sewerage components for the proposed five alternatives are described more in detail in the following sections, providing a preliminary evaluation of each alternative. An implementation plan for the respective alternative is also prepared under the same magnitude of construction cost of sewerage system up to the year 2020 to select the best alternative as the new sewerage development.

1) Main Features of Each Alternative

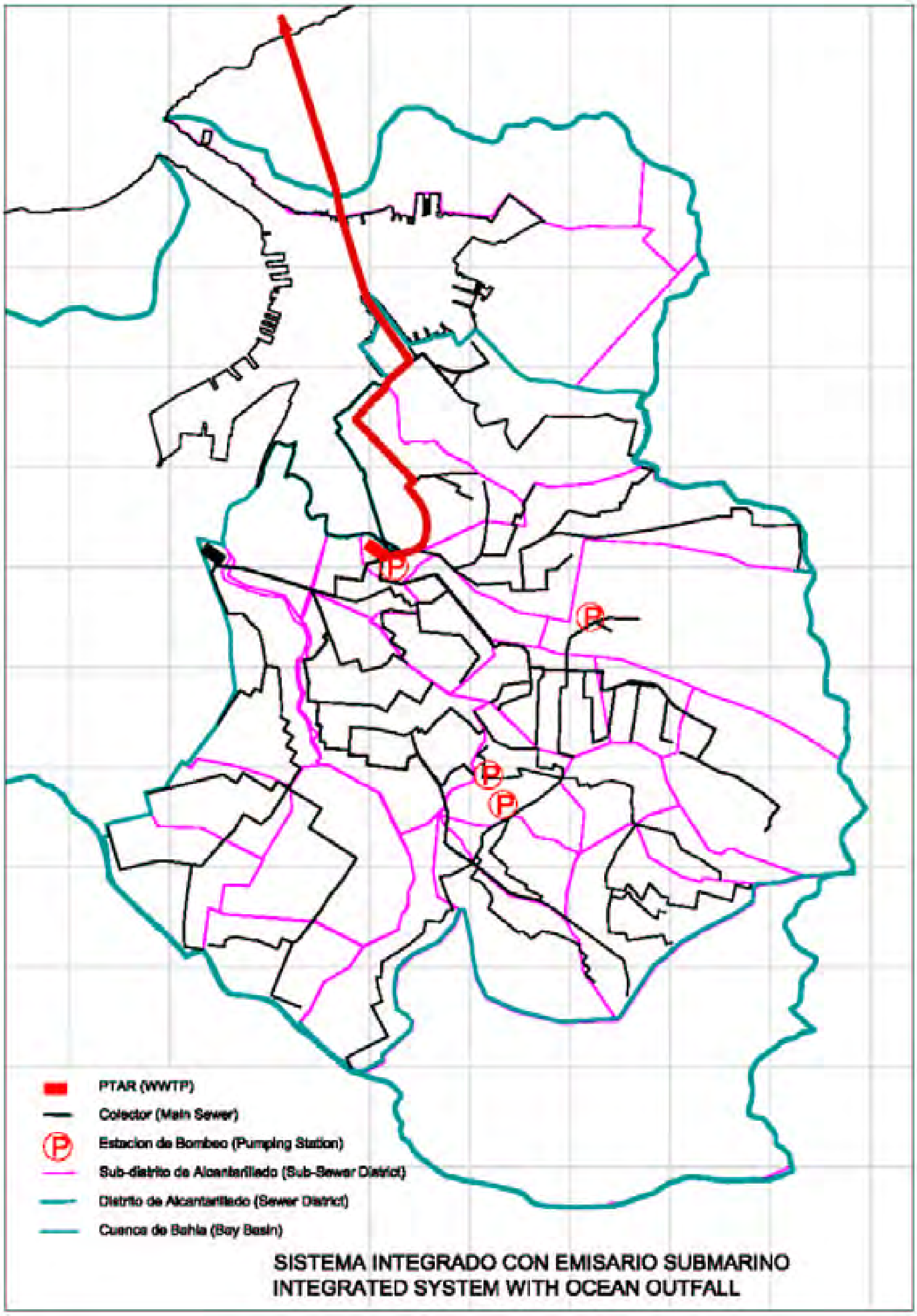
Table 12.11 summarizes the main features of each alternative: Sewer main designs, a requirement of pumping stations, land area requirements for the proposed WWTP, direct construction cost, O/M cost, and combined costs of construction and O/M. Table 12.16 shows a summary of sewer mains required for the respective alternative.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.9 Alternative N-1 for new sewerage scheme: Five Zonal Sewerage System
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.10 Alternative N-2 to N-5 for new sewerage scheme: Four Zonal System to Integrated System
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.11 Alternative N-6 for new sewerage scheme: Ocean Discharge Sewerage System
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 12.10 Design Bases for the New Alternative Sewerage Systems (Target year 2020)

Item	Alternative N-1 (Five Zonal Systems)				
	Luyanó Abajo (Zone 1)	**Luyanó Arriba** (Zone 2)	**Martin Pérez Abajo** (Zone 4)	**Martin Pérez Arriba** (Zone 3)	**Tadeo** (Zone 5)
1. Service Population	**128,000**	**61,800**	**35,600**	**51,900**	**20,400**
2. Planning Area (ha)	**1,082.4**	**766.6**	**545.3**	**770.8**	**278.2**
3. Wastewater Generation (m^3/d)	**43,600**	**20,100**	**12,800**	**23,200**	**9,000**
3.1 Domestic (m^3/d)	21,503	10,382	5,981	8,719	3,427
3.2 Non-domestic, small scale sources (m^3/d)	19,712	9,518	5,482	7,993	3,142
3.3 Non-domestic, large scale sources (m^3/d)	2,393	213	1,311	6,500	2,375
3.4 Total (m^3/d)	43,608	20,113	12,774	23,212	8,944
4. Design Flows					
4.1 Infiltration/Inflow (m^3/d)	2,560	1,236	712	1,038	408
4.2 Average Daily Flow (m^3/d)	46,168 **= 46,200**	21,349 **= 21,400**	13,486 **= 13,500**	24,250 **= 24,300**	9,352 **= 9,400**
4.3 Maximum Daily (m^3/d)	**54,900**	**25,400**	**16,100**	**28,900**	**11,200**
4.4 Maximum Hourly (m^3/d)	**85,200**	**45,000**	**30,900**	**50,300**	**22,900**
5. Design Wastewater Quality					
5.1 Influent Quality					
BOD (mg/L)	**200**	**200**	**200**	**210**	**210**
SS (mg/L)	**200**	**200**	**200**	**210**	**210**
T-N (mg/L)	**30**	**30**	**30**	**32**	**32**
T-P (mg/L)	**7.7**	**7.7**	**7.7**	**8.0**	**7.9**
5.2 Effluent Quality (Secondary Treatment)					
BOD (mg/L) <85-95% removal>	**20**	**20**	**20**	**21**	**21**
SS (mg/L) <85-95% removal>	**20**	**20**	**20**	**21**	**21**
T-N (mg/L) <10-20% removal>	**26**	**26**	**26**	**27**	**27**
T-P (mg/L) <10-20% removal>	**6.5**	**6.5**	**6.5**	**6.8**	**6.8**

Table 12.10 (Continued) Design Bases for the New Alternative Sewerage Systems (Target year 2020)

Item	Alternative N-2 (Four Zonal Systems)				Alternative N-3 (Three Zonal Systems)		
	Luyanó-Martin Pérez Abajo (Zone 1+4)	**Luyanó Arriba** (Zone 2)	**Martin Pérez Arriba** (Zone 3)	**Tadeo** (Zone 5)	**Luyanó** (Zone 1 + 2)	**Martin Pérez** (Zone 3+4)	**Tadeo** (Zone 5)
1. Service Population	**163,600**	**61,800**	**51,900**	**20,400**	**189,800**	**87,500**	**20,400**
2. Planning Area (ha)	**1,627.7**	**766.6**	**770.8**	**278.2**	**1,849.0**	**1,316.1**	**278.2**
3. Wastewater Generation (m^3/d)	**56,400**	**20,100**	**23,200**	**9,000**	**63,700**	**36,000**	**9,000**
3.1 Domestic (m^3/d)	27,484	10,382	8,719	3,427	31,885	14,700	3,427
3.2 Non-domestic, small scale sources (m^3/d)	25,194	9,518	7,993	3,142	29,230	13,475	3,142
3.3 Non-domestic, large scale sources (m^3/d)	3,704	213	6,500	2,375	2,606	7,811	2,375
3.4 Total (m^3/d)	56,382	20,113	23,212	8,944	63,721	35,986	8,944
4. Design Flows							
4.1 Infiltration/Inflow (m^3/d)	3,272	1,236	1,038	408	3,796	1,750	408
4.2 Average Daily Flow (m^3/d)	59,654 **= 59,700**	21,349 **= 21,400**	24,250 **= 24,300**	9,352 **= 9,400**	67,517 **= 67,600**	37,736 **= 37,800**	9,352 **= 9,400**
4.3 Maximum Daily (m^3/d)	**71,000**	**25,400**	**28,900**	**11,200**	**80,300**	**45,000**	**11,200**
4.4 Maximum Hourly (m^3/d)	**116,100**	**45,000**	**50,300**	**22,900**	**130,200**	**81,200**	**22,900**
5. Design Wastewater Quality							
5.1 Influent Quality							
BOD (mg/L)	**200**	**200**	**210**	**210**	**200**		**210**
SS (mg/L)	**200**	**200**	**210**	**210**	**200**		**210**
T-N (mg/L)	**30**	**30**	**32**	**32**	**30**		**32**
T-P (mg/L)	**7.7**	**7.7**	**8.0**	**7.9**	**7.7**		**7.9**
5.2 Effluent Quality (Secondary Treatment)							
BOD (mg/L) <85-95% removal>	**20**	**20**	**21**	**21**	**20**		**21**
SS (mg/L) <85-95% removal>	**20**	**20**	**21**	**21**	**20**		**21**
T-N (mg/L) <10-20% removal>	**26**	**26**	**27**	**27**	**26**		**27**
T-P (mg/L) <10-20% removal>	**6.5**	**6.5**	**6.8**	**6.8**	**6.5**		**6.8**

Table 12.10 (Continued) Design Bases for the New Alternative Sewerage System (Target year 2020)

Item	**Alternative N-4 (Two Zonal Systems)**		**Alternative N-5**	**Alternative N-6**
	Luyanó (Zone 1 + 2)	**Martin Pérez-Tadeo** (Zone 3+4+5)	**Integrated System**	**Ocean Discharge System**
1. Service Population	**189,800**	**107,900**	**297,700**	**297,700**
2. Planning Area (ha)	**1,849.0**	**1,594.3**	**3443.3**	**3443.3**
3. Wastewater Generation (m^3/d)	**63,700**	**45,000**	**108,700**	**108,700**
3.1 Domestic (m^3/d)	31,885	18,127	50,000	50,000
3.2 Non-domestic, small scale sources (m^3/d)	29,230	16,617	45,900	45,900
3.3 Non-domestic, large scale sources (m^3/d)	2,606	10,186	12,800	12,800
3.4 Total (m^3/d)	63,721	44,930	108,700	108,700
4. Design Flows				
4.1 Infiltration/Inflow (m^3/d)	3,796	2,158	5,960	5,960
4.2 Average Daily Flow (m^3/d)	67,517 **= 67,600**	47,088 **=47,100**	**114,600**	**114,600**
4.3 Maximum Daily (m^3/d)	**80,300**	**56,200**	**136,400**	**136,400**
4.4 Maximum Hourly (m^3/d)	**130,200**	**104,100**	**182,700**	**182,700**
5. Design Wastewater Quality				
5.1 Influent Quality				
BOD (mg/L)	**200**		**200**	**200**
SS (mg/L)	**200**		**200**	**200**
T-N (mg/L)	**30**		**31**	**31**
T-P (mg/L)	**7.7**		**7.8**	**7.8**
5.2 Effluent Quality				
BOD (mg/L)	**20**		**20**	**120**
SS (mg/L)	**20**		**20**	**100**
T-N (mg/L)	**26**		**27**	**27**
T-P (mg/L)	**6.5**		**6.6**	**6.6**

Table 12.11 also presents an implementation plan for the respective alternative, which has been prepared under the same magnitude of construction cost for the sewerage system:

Alternative N-1-IPP2020: Two sewer districts of the Martín Peréz Abajo sewer district and Tadeo sewer district are selected as the sewer districts to be implemented up to the year 2020 among the five zonal sewerage system. Major reasons of selecting the two sewer districts are that these two districts have never been involved in any sewerage implementation plans or on-going projects. While parts of the sewered area in the Luyanó river basin would be implemented by the on-going GEF/UNDP projects. An objective of the development of Tadeo sewer district is to improve the living and sanitary conditions and to show an appeal to the factories discharging insufficiently treated industrial wastewater. Figure 12.12 presents the areas to be covered by this alternative.

Alternative N-2-IPP2020: Area from the low to middle reaches of the Luyanó-Martín Peréz Abajo sewer district is selected to be implemented up to the year 2020. The major reason of the selection is that the pollution generation is the highest among the sewer districts thus the pollution load reduction would be expected high. Figure 12.13 shows the area to be covered by this alternative.

Alternative N-3-IPP2020: Tadeo sewer district and area of the low to middle reaches of the Martín Peréz Abajo sewer district are selected as the sewer districts to be implemented up to the year 2020. Reasons are the same as those of alternative N-1-IPP2020. Figure 12.14 shows the area to be covered by this alternative.

Alternative N-4-IPP2020: The basic approach for selection of the area to be implemented up to the year 2020 is the same as that of alternative N-3-IPP2020. However, since the Tadeo area is involved in the Martin Perez Abajo sewer district, the construction cost of Tadeo WWTP would be used for construction of Colector, pumping station, and for primary sewers, in other words the sewer service area would be larger than that of alternative N-3-IPP2020. Figure 12.15 shows the area to be covered by this alternative.

Alternative N-5-IPP2020: Area from the low to middle reaches of both the Luyanó river basin and the Martín Peréz river basin is selected to be implemented up to the year 2020. In this alternative, the area of the Martín Peréz river basin is prior to the area of the Luyanó river basin due to the same reason mentioned in the alternative N1-1-IPP2020. Figure 12.16 shows the area to be covered by this alternative.

Table 12.11 Features of the Alternatives of wastewater discharge to the Havana Bay

Item	Alternatives of treated wastewater discharge to the Havana Bay					Remarks
	Alternative N-1	Alternative N-2	Alternative N-3	Alternative N-4	Alternative N-5	
1. Wastewater collection system						
1.1 Sewer main	Dia. 200 to 1,350mm Length 76.7 km	Dia. 200 to 900mm Length 77.3 km	Dia. 200 to 1,350mm Length 79.1 km	Dia. 200 to 1,350mm Length 79.4 km	Dia. 200 to 900mm Length 77.3 km	Refer to the detailed information in Table 12.16.
1.2 Pumping station	None	One (1) pumping station	Two (2) pumping stations	Two (2) pumping stations	Two (2) pumping stations	
2. Area required for wastewater treatment plant						
	Luyanó Abajo: 1.4 ha (CAS +MSD)	Luyanó-Martín Pérez Abajo: ha	Luyanó: 4.8 ha (CAS+MSD) 6.7 ha (CAS+SDB)	Luyanó: 4.8 ha (CAS+MSD) 6.7 ha (CAS+SDB)		CAS: Conventional Activated Sludge Process
	Luyanó Arriba: 1.4 ha (CAS+MSD)	Luyanó Arriba: 1.4 ha (CAS+MSD)				MSD: Mechanical Sludge Dewatering
	Martín Pérez Abajo: 1.0 ha (CAS+MSD)		Martín Pérez: 5.7 ha (CAS+MSD) 9.3 ha (CAS+SDB)	Martín Pérez-Tadeo: 6.0 ha (CAS+MSD) 10.5 ha (CAS+SDB)	Martín Pérez: 10.0 ha (CAS+MSD) 17.6 ha (CAS+SDB)	SDB: Sludge Drying Bed
	Martín Pérez Arriba: 4.5 ha (CAS+SDB)	Martín Pérez Arriba: 4.5 ha (CAS+SDB)				
	Tadeo: 1.35 ha (CAS+70%MSD+30%SDB)	Tadeo: 1.35 ha (CAS+70%MSD+30%SDB)	Tadeo: 1.35 ha (CAS+70%MSD+30%SDB)			
3. Direct Construction Cost (x 1000 US$)						
3.1 Sewer main						
by Open cut method	137,090	137,412	139,958	140,114	140,895	
by Pipe jacking or tunneling construction method	0	0	0	3,738	4,988	
sub-total	137,090	137,412	139,958	143,852	145,883	
3.2 Pumping Station	0	6,503	12,385	12,385	12,385	
3.3 Sewer main and pumping station	137,090	143,915	152,343	156,237	158,268	
3.4 Wastewater Treatment Facilities						
CAS+MSD	207,168	191,814	187,400	173,648	143,351	
CAS+SDB	160,086	145,326	139,541	129,338	106,772	
3.5 Total direct construction cost						
CAS+MSD	344,258	335,729	339,743	329,885	301,619	
CAS+SDB	297,176	289,241	291,884	285,575	265,040	

Source: JICA Study Team

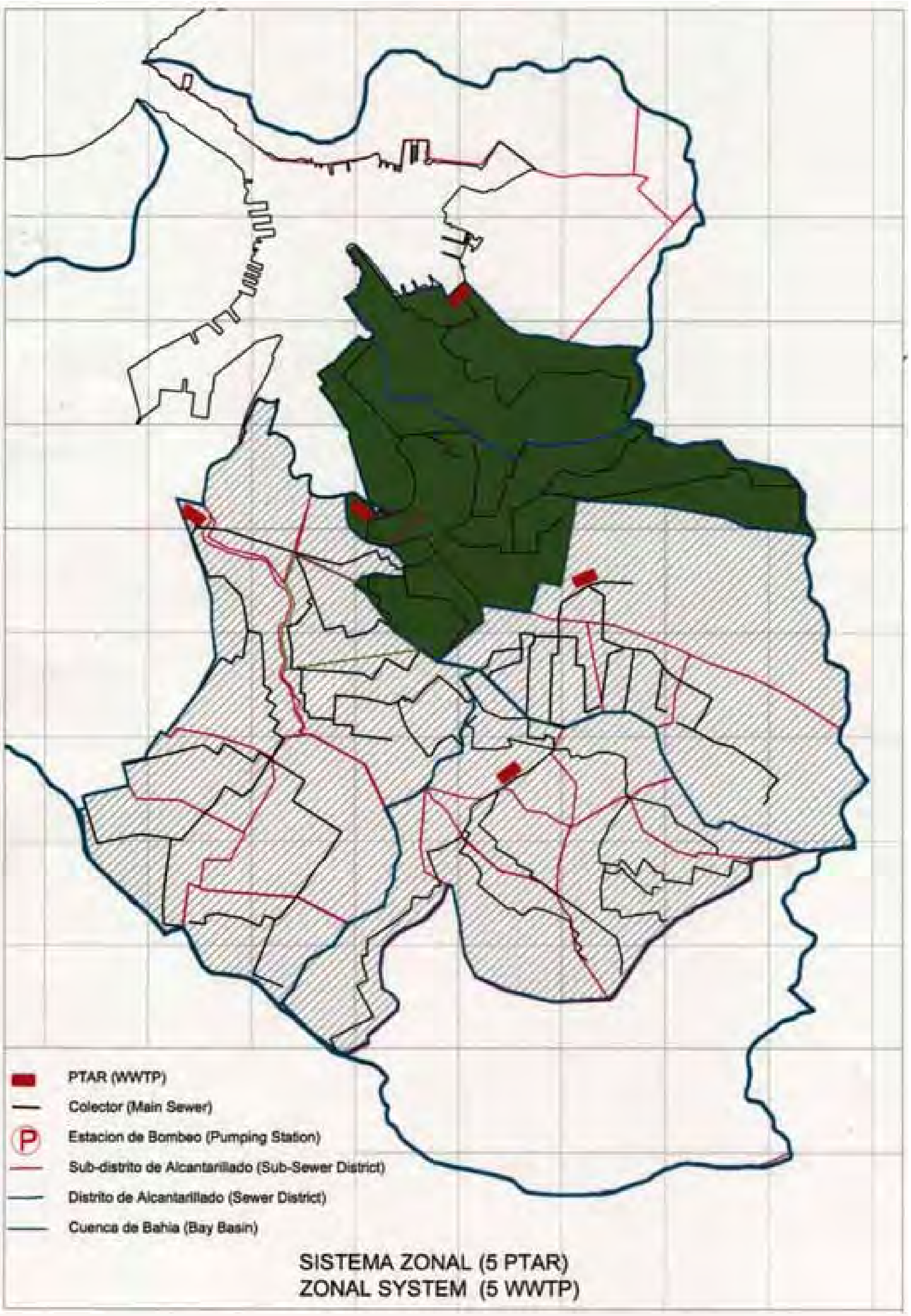
Table 12.11 (continued) Features of the Alternatives of wastewater discharge to the Havana Bay

Item	Alternatives of treated wastewater discharge to the Havana Bay					Remarks
	Alternative N-1	Alternative N-2	Alternative N-3	Alternative N-4	Alternative N-5	
4. O/M cost (x1000 US$)						
4.1 CAS+MSD						
1) Annual O/M cost	2,631	2,827	3,254	3,036	2,481	
2) 20 years O/M cost	52,620	56,534	65,080	60,720	49,620	
3) 30 years O/M cost	78,930	84,801	97,620	91,080	74,430	
4.2 CAS+SDB						
1) Annual O/M cost	---	2,330	2,598	2,380	1,826	
2) 20 years O/M cost	---	46,591	51,960	47,600	36,520	
3) 30 years O/M cost	---	69,887	77,940	71,400	54,780	
5. Direct Construction Cost + O/M cost (x 1000 US$)						
5.1 CAS+MSD						
1) 20 years O/M cost	396,878	392,263	404,823	390,605	351,239	
2) 30 years O/M cost	423,188	420,530	437,363	420,965	376,049	
5.2 CAS+SDB						
1) 20 years O/M cost		335,832	343,844	333,175	301,560	
2) 30 years O/M cost		359,128	369,824	356,975	319,820	
6. An implementation plan up to the year 2020	Figure 12.12 shows a sewer service area for the proposed implementation plan.	Refer to Figure 12.13	Refer to Figure 12.14	Refer to Figure 12.15	Refer to Figure 12.16	Total direct construction cost of about US$ 124,170,000 is assumed for an implantation plan up to the 2020.
6.1 Sewer service area (ha)	823.5	745.0	708.5	814.4	414.7	
6.2 Sewer service population	56,000	93,700	61,000	71,900	40,000	
6.3 Design flows (m^3/d)						
1) Average daily flow	23,000					
2) Maximum daily flow	27,300					
6.4 Pollution loads estimated (1000kgBOD/d)						
1) Influent	4.6	6.7	4.9	5.7	3.1	
2) Effluent (Discharged)	0.5	0.7	0.5	0.6	0.3	
3) Reduction	4.1	6.0	4.4	5.1	2.8	

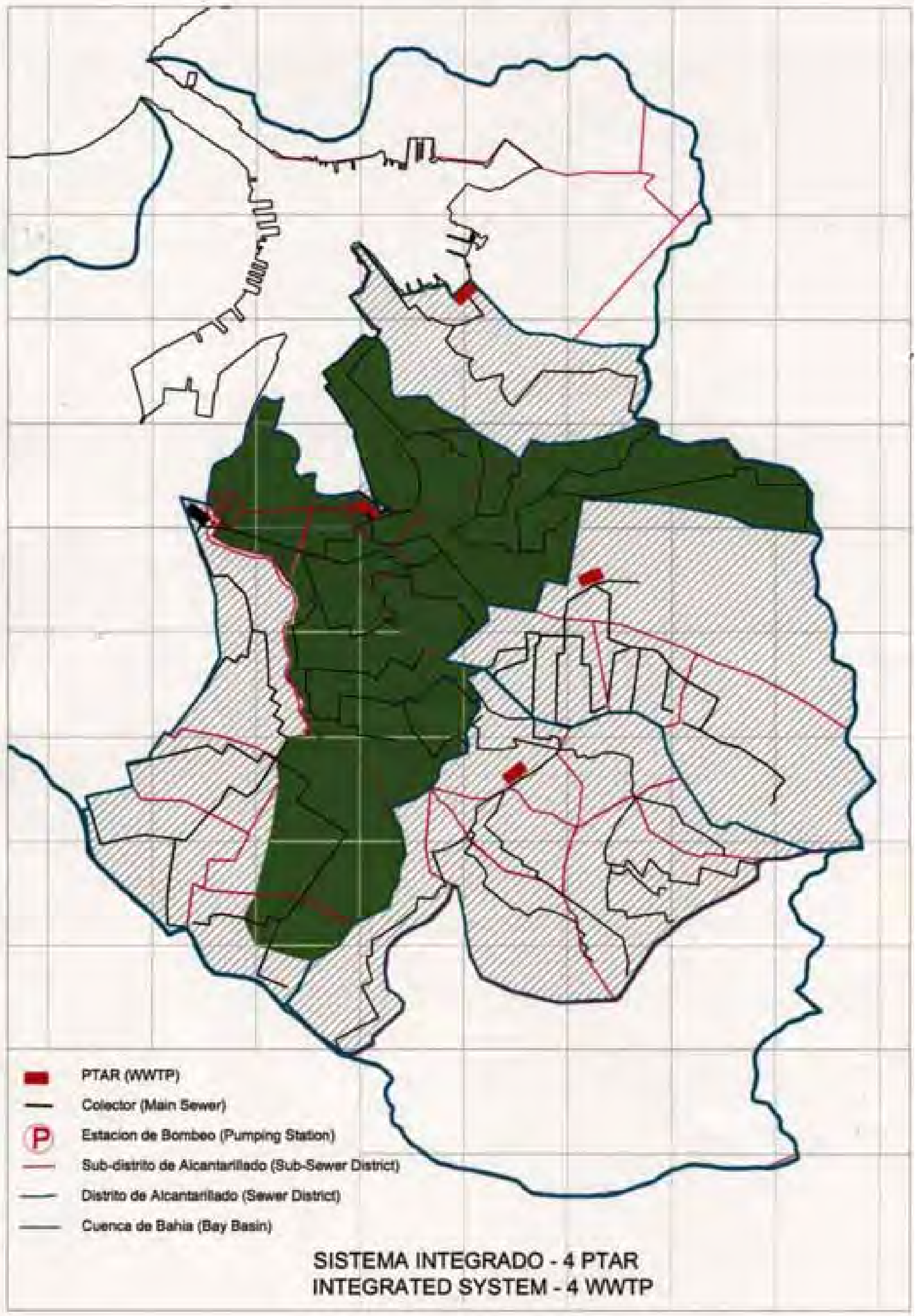
Table 12.12 Sewer Main for Each Sewer District in the Alternatives

Diameter	Length of Sewer Main designed									
	Alternative N-1 (Five zones)						Alt N-2	Alt N-3	Alt N-4	Alt N-5
	Luyanó Arriba	Luyanó Abajo	Martín Pérez Arriba	Martín Pérez Abajo	Tadeo	Sub-total	Four zones	Three zones	Two zones	Integrated
200 mm	4,400	6,740	4,120	2,690	720	18,670	18,660	17,580	17,740	17,580
300 mm	6,570	4,860	2,130	9,720	1,270	24,550	24,500	24,530	25,200	24,120
350 mm	3,310	2,690	-	470	-	6,470	6,010	6,300	6,460	6,110
450 mm	-	-	70	-	230	300	500	290	290	290
525 mm	2,030	2,670	-	4,240	-	8,940	8,930	8,220	9,200	7,130
600 mm	2,850	1,480	1,900	360	1,040	7,630	8,430	7,000	8,030	6,630
750 mm	50	2,820	780	70	1,210	4,930	4,920	4,580	3,720	7,370
825 mm	-		1,990	-	80	2,070	2,070	1,010	2,070	1,010
900 mm	-	1,730	-	-	490	2,220	3,330	3,230	3,050	3,100
1050 mm	-	1,000	-	-	-	1,000	-	6,170	3,540	5,880
1200 mm	-	-	-	-	-	-	-	90	90	1,400
1350 mm	-	70	-	-	-	70	-	90	-	140
Total	19,210	24,060	10,990	17,550	5,040	76,850	77,350	79,090	79,390	80,760

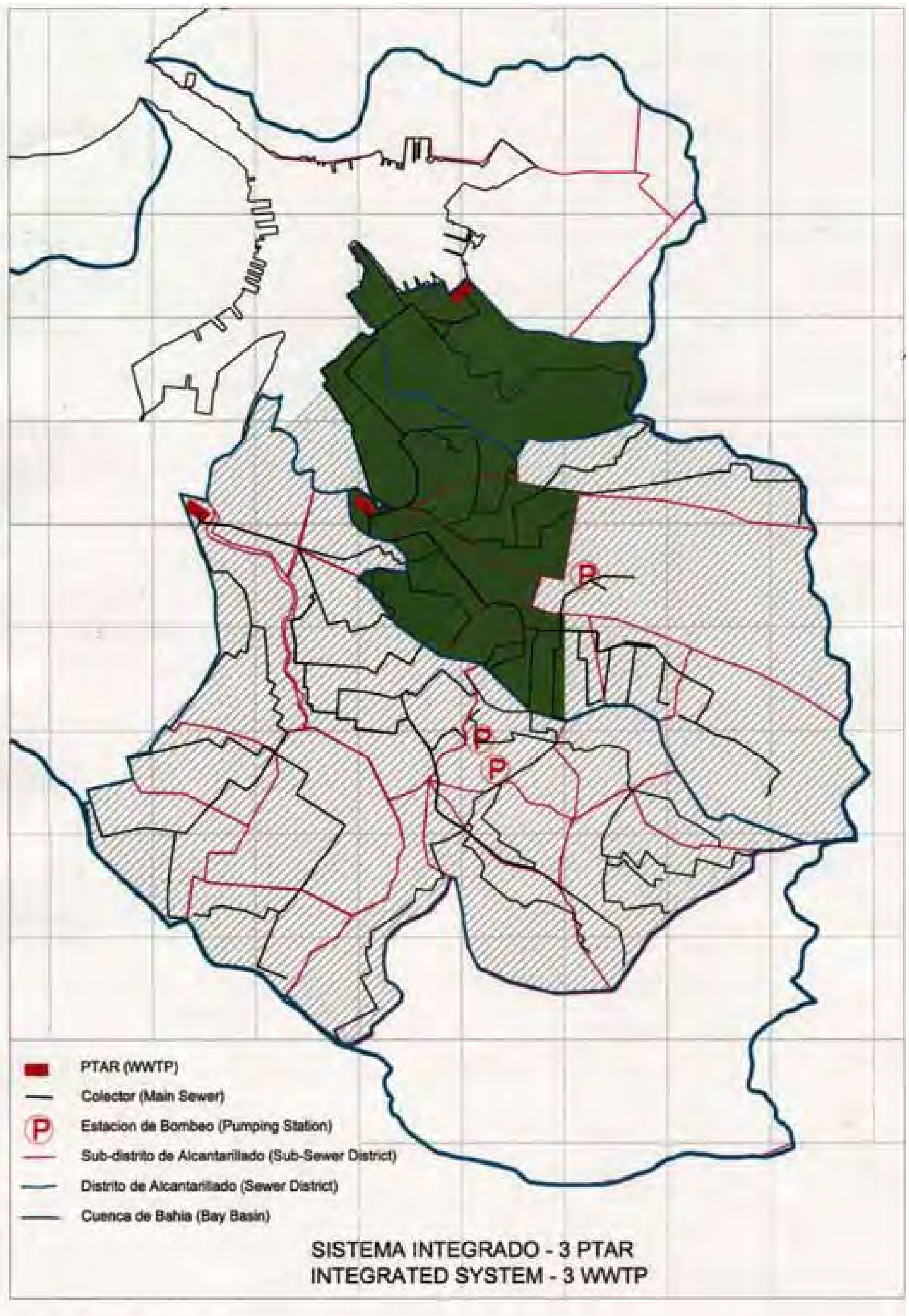
Note: Each figure is rounded up by 10m each (Based on Digital Map with scale of 1/50,000)



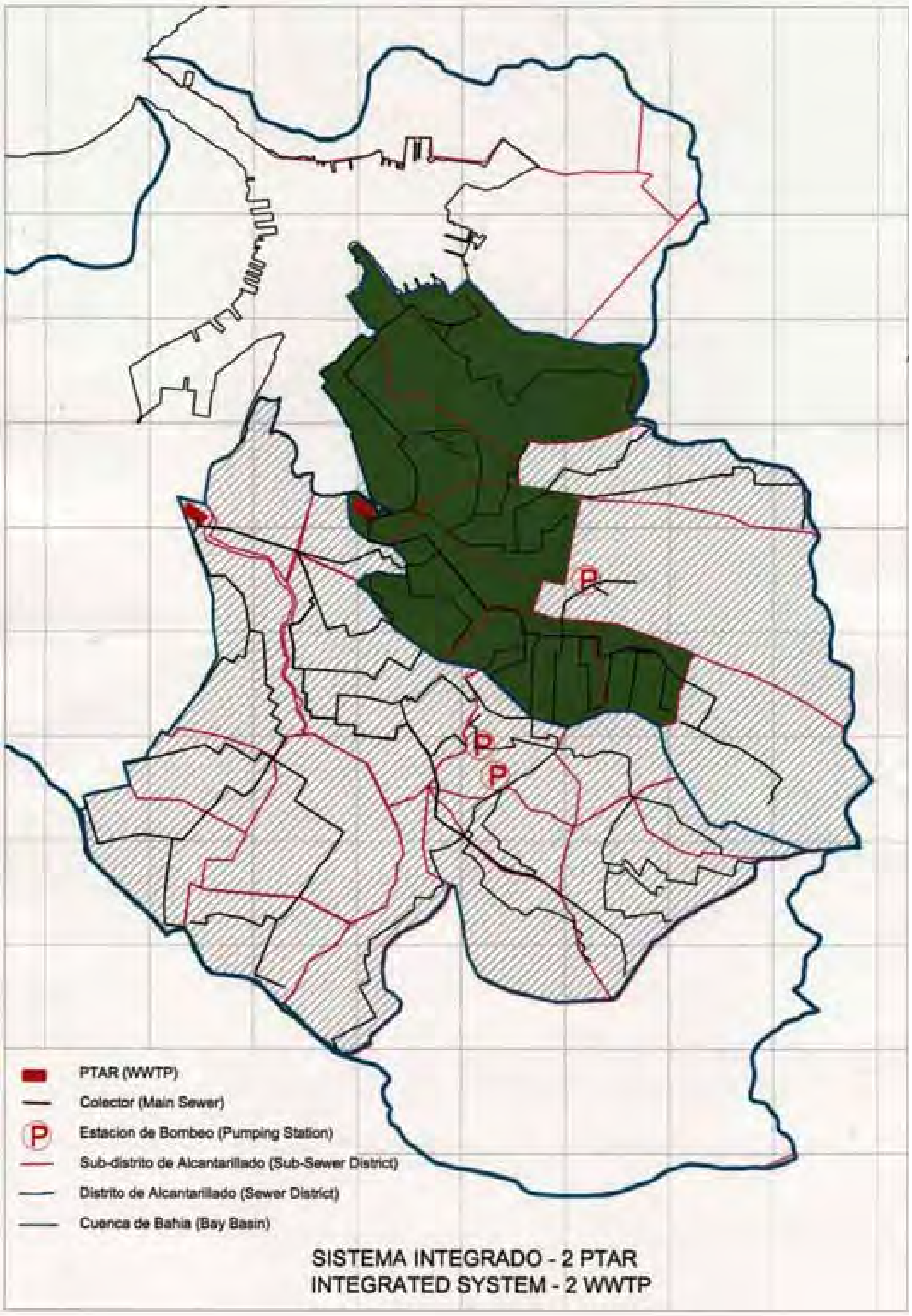
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.12 Alternative N-1 IPP2020 Possible sewer service area to be covered up to 2020
JAPAN INTERNATIONAL COOPERATION AGENCY	



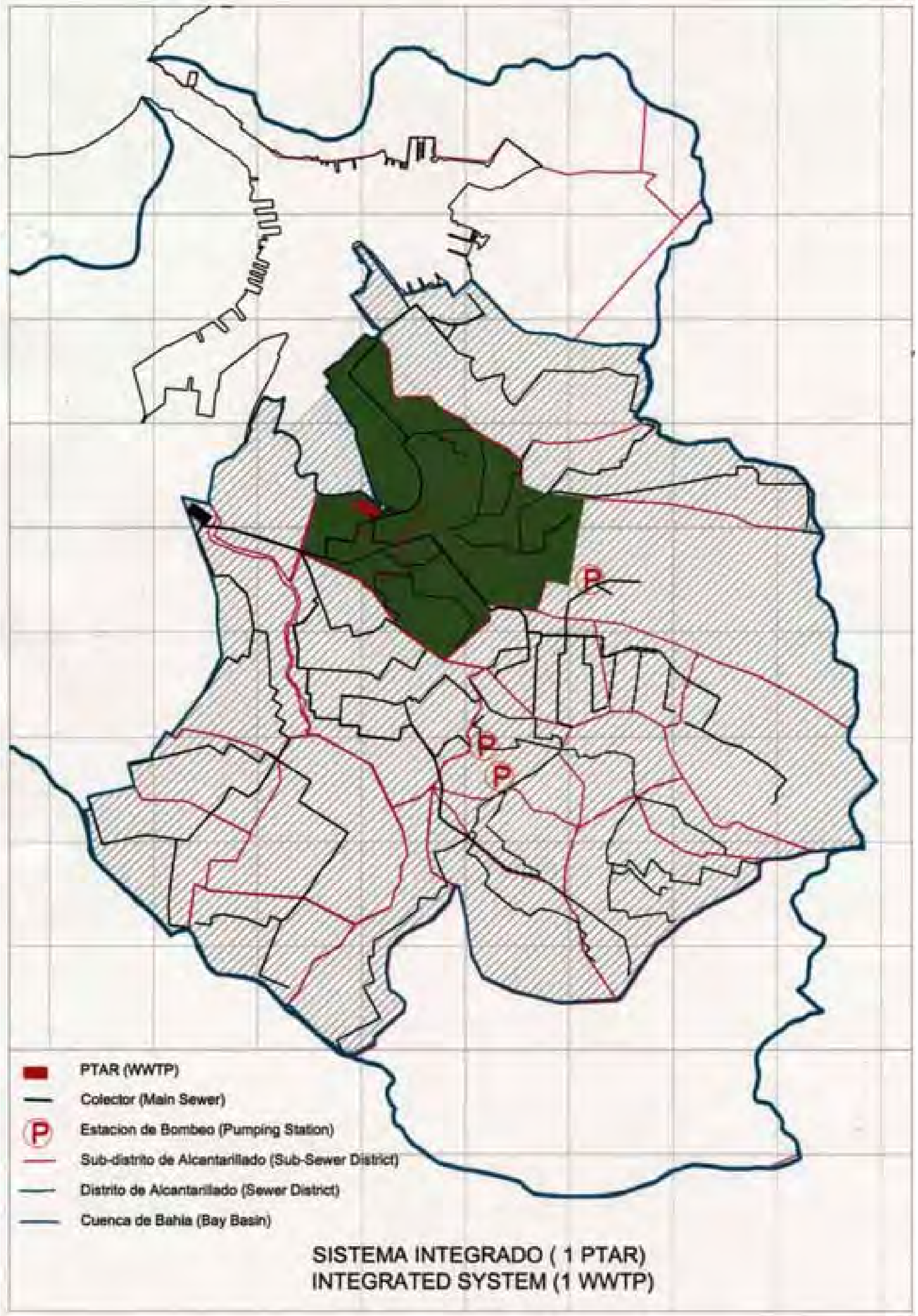
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.13 Alternative N-2 IPP2020 Possible sewer service area to be covered up to 2020
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.14 Alternative N-3 IPP2020 Possible sewer service area to be covered up to 2020
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.15 Alternative N-4 IPP2020 Possible sewer service area to be covered up to 2020
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.16 Alternative N-5 IPP2020 Possible sewer service area to be covered up to 2020
JAPAN INTERNATIONAL COOPERATION AGENCY	

2) Comparison of the Alternatives

Each alternative is compared and summarized in Table 12.13 and 12.14, taken into consideration of the following parameters:

- Construction cost
- Operation and maintenance cost
- Availability of construction site for wastewater treatment plant
- Applicability of the wastewater treatment process for nutrients removal in the future
- Adaptability in case of power failure and malfunction
- Expected project effects
- Easiness to realization of the project and problems to be solved
- Appeal to the public

3) Selection of the Best Alternative

Base on the results of comparison, the Alternative N-2 (four zonal sewerage systems) was selected as the best alternative among the five alternatives.

The main reasons are:

- Highest the pollution load reduction among the alternative considering the implementation up to the year 2020.
- The most densely populated area is proposed to cover by the sewerage system implementation plan, thus the number of direct beneficiaries receive sewer service is the maximum among the alternative.

Table 12.13 Comparison of Overall Sewerage Plan for Each Alternative of Treated Wastewater Discharge to Havana Bay

Item	Alternatives of treated wastewater discharge to the Havana Bay					Remarks
	Alternative N-1	Alternative N-2	Alternative N-3	Alternative N-4	Alternative N-5	
1. Construction cost						
1) Over all system	Op-1 : 100% Op-2 : 100%	Op-1 : 98% Op-2 :97%	Op-1 : 99% Op-2 : 98%	Op-1 : 96% Op-2 : 96%	Op-1 : 88% Op-2 : 89%	
2) Sewer + Pumping station	100 %	10 5%	111%	114%	115	
3) WWTP	Op-1 : 100% Op-2 : 100%	Op-1 : 93% Op-2 : 91%	Op-1 : 90% Op-2 : 87%	Op-1 : 84% Op-2 : 81%	Op-1 : 69% Op-2 : 67%	
4) Rating	△	△	△	○	◎	
2. Per capita direct construction Cost	Op-1: 1,339 US$/person Op-2: 1,156 US$/person	Op-1: 1,306 US$/person Op-2: 1,125 US$/person	Op-1: 1,322 US$/person Op-2: 1,322 US$/person	Op-1: 1,283 US$/person Op-2: 1,111 US$/person	Op-1: 1,173 US$/person Op-2: 1,031 US$/person	Planned sewer service population is assumed 257,070(=297,700-40,630) GEF/UNDP project would cover 40,630.
Rating	△	△	△	△	○	
3. Annual O/M cost						
1) O/M cost for Op-1	2,631,000 US$ (100%)	2,827,000 US$ (107%)	3,254,000 US$ (124%)	3,036,000 US$ (115%)	2,481,000 US$ (94%)	
2) Per capita O/M cost for Op-1	10.2 US$/person	11.0 US$/person	12.7 US$/person	11.8 US$/person	9.7 US$/person	
3) O/M cost for Op-2	-	2,330,000 US$	2,598,000 US$	2,380,000 US$	1,826,000 US$	
4) Per capita O/M cost for Op-2	-	9.1 US$/person	10.1 US$/person	9.3 US$/person	7.1 US$/person	
5) Rating	△	○	△	△	◎	
4. Availability of construction site for wastewater treatment plant	The sites were selected and studied for the WWTPs in a future sewerage development plan prepared based on the results of GEF/UNDP Study by INRH and GTE. The sites availabilities are confirmed by the urban planning department of the Havana city. A procedure, called “Micro Localization” should be obtained for facility siting, based on a result of environmental impact assessment (EIA) for a proposed project.	An availability of three sites selected for the construction of WWTPs is confirmed by the urban planning department of the Havana city. However, a site of the WWTP of Luyanó-Martín Pérez sewer district, which is located near the river mouth of Rio Martín Peréz, is difficult to obtain. Because the area is planned to use a part of container yard. Big efforts and arrangements would be required to change the future land use plan among the concerned agencies.	An availability of the WWTP site for Tadeo sewer district is confirmed by the urban planning department of the Havana city. However, the WWTP candidate site for the Luyanó sewer district is difficult to obtain.	Since a larger area is required for the WWTP site of the Luyanó sewer district, additional arrangements would be required to obtain the area enough to construct the facility. The WWTP candidate site for Martín Pérez sewer district is difficult to obtain at present.	A vacant area near the river mouth of Rio Martín Pérez is selected for a candidate site for the proposed WWTP. However, the site is planned to use a part of a container yard in the future. At present it is very difficult to obtain the candidate site for constructing the proposed WWTP. Big efforts would be required to change the future land use plan and to obtain the largest area among the alternatives.	
Rating	◎	△	△	△	X	
5. Applicability of the wastewater treatment process for nutrients removal in the future	It would be difficult to improve the facility within the limited land space available. Additional land area would be required to make renovations.	The situation is the same as that of the Alternative N-1. Additional land area would be required to make renovations.	The situation is the same as that of the Alternative N-2.	If connection pipes were installed between two treatment plants, a discharge of the treated wastewater to the ocean would be possible.	The situation is the same as that of the Alternative N-1. In stead of an introduction of an advanced wastewater treatment process, a discharge of the treated wastewater to the ocean would be possible.	
Rating	△	△	○	○	○	

Table 12.13 (Continued) Comparison of Overall Sewerage Plan for Each Alternative of Treated Wastewater Discharge to Havana Bay

	Alternatives of treated wastewater discharge to the Havana Bay					Remarks
	Alternative N-1	**Alternative N-2**	**Alternative N-3**	**Alternative N-4**	**Alternative N-5**	
6. Adaptability in case of power failure and sewerage system malfunction	Since the WWTPs are decentralized and located in the middle stream reaches of the rivers and at waterfront of the bay, simultaneous malfunctions at all WWTP would not be occurred.	To mitigate the adverse effects of power failure, the cost of introduction of generators to all wastewater treatment plants would be higher than those other cases.	Since three WWTPs would be located at the waterfront of the bay, simultaneous malfunctions at the WWTPs could not occur. But such risks would be higher than those of Alternative N-1 and N-2.	If one of two WWTPs stopped operation due to a malfunction or a power failure, untreated or insufficient treated wastewater would be discharged to the bay and would give adverse impacts to the bay water environment.	If the WWTP stopped operation, a large volume of untreated or insufficiently treated wastewater would be discharged to the bay and would give adverse impacts to the water environment. A power generator should be installed to minimize the adverse impacts.	
Rating	○	○	△	△	X	

Source: JICA Study Team

Note: Op-1 (Conventional Activated Sludge Process + Mechanical Sludge Dewatering equipment)
Op-2 (Conventional Activated Sludge Process + Sludge Drying Bed)

Table 12.14 Comparison of an Implementation Plan up to the year 2020 set for Each Alternative of Treated Wastewater Discharge to Havana Bay

Item	Alternatives of treated wastewater discharge to the Havana Bay					Remarks
	Alternative N-1-IPP2020	Alternative N-2-IPP2020	Alternative N-3-IPP2020	Alternative N-4-IPP2020	Alternative N-5-IPP2020	
1. Expected Project Effects						
1) Number of Beneficiaries	56,000	93,700	61,000	71,900	40,000	
2) Pollution loads reduction (1,000kgBOD/day)	4.1	6.0	4.4	5.1	2.8	
	○	◎	○	◎	△	
2. Easiness to realization of the project and problems to be solved	The sites are possible to obtain for constructing the proposed WWTPs. The small zonal sewerage systems have some advantages that the implementation can be done in order of importance and emergency by zones. Small sewerage schemes may be easier to find a donor or a financial source.	To obtain the WWTP site of Luyanó-Martín Pérez sewer district, which is located near the river mouth of Rio Martín Peréz, is a key issue to implement this alternative. However, it is difficult to obtain the site at present, because the area is planned to use a part of container yard. To obtain the site for the proposed WWTP, big efforts and arrangements would be required to change the future land use plan among the concerned agencies.	To obtain the two sites at the river mouths of Rio Luyanó and Rio Martín Pérez is a key issue to implement this alternative.	The situation is the same as that of alternative N-3. Since a larger area at the river mouth of Rio Martín Pérez is required, to obtain the site becomes more difficult than that of alternative N-3-IPP2020.	To obtain the largest area at the river mouth of Rio Martín Pérez is a key issue to implement this alternative. The possibility of obtaining the site is the same as that of Alternative N-2-IPP2020.	
	◎	○	○	○	△	
3. Appeal to the public	Since each zonal sewerage system collects the wastewater and treats it at a nearby WWTP, the direct beneficiaries such as residents would easily recognize that their own sewerage system would play an important role to improve their living and sanitary conditions and to improve the water environment nearby such as a water course or a river.	Because the most densely populated area is proposed to cover by the sewerage system implementation plan, the number of direct beneficiaries receiving sewer service is the maximum among the alternatives. Indirect beneficiaries also understand that the proposed plan is the most effective plan to reduce the pollutant loads to the bay.	Since two WWTPs are proposed to construct at the waterfront of the Bay, the beneficiaries could understand that the sewerage system would play a very important role to improve the water quality of the Bay. A public relation would be important to understand the sewerage system.	The residents of Tadeo area would recognize the effects of sewer, but a public relation would be important to understand that the wastewater generated in their area would be treated at the WWTP of Rio Martín Peréz.	Since main components of the proposed sewerage system should be implemented in the earliest stage, the investment for sewer networks is the minimum among the alternatives. The smallest service area development is not attractive to the direct beneficiaries. The location of WWTP is most far from the sewer service area that provides a minimum opportunity to understand the presence and the role of wastewater treatment plant to the beneficiaries.	
	◎	◎	○	○	△	

Source: JICA Study Team

(4) Alternative of Ocean Discharge (Alternative N-6)

1) General

It was examined for this alternative to be executed through a preparation of an implementation plan up to the year 2020.

A primary wastewater treatment plant will be constructed under this alternative. The primary treatment is planned before conveying the wastewater through the Bay taking into considerations of the following points:

- The design of trunk sewers such as transmission tunnel and outfall sewer is based on the design flows of year 2020. Therefore, during an initial implementation stage such as the first stage project, an actual wastewater flow and velocity are low. These may cause an easy settlement of pollutants in those sewers and corrosion of sewers. To prevent these problems, the wastewater would be treated before conveying through the Bay.

- In an emergency case such as a breakdown of pumping equipment, the wastewater should be discharged to the Bay but could reduce the pollution loads by the primary treatment.

The location of the wastewater treatment plant is set near the river mouth of Rio Martín Pérez.

2) Applicability of the Alternative N-6

Table 12.15 summarizes a preliminary construction cost estimate for all the sewerage system and the sewerage system required for the first stage project.

The total construction cost for the alternative N-6 is cheapest compared with that for the alternative N-1 through N-5, mainly because the cost required for the primary treatment in case of Alternative N-6 is much smaller than that for the secondary treatment process of the other alternatives.

Since the construction of outfall sewer system is required from the initial stage of the implementation of this alternative, the construction cost of outfall sewer system of US$ 55,814,000 which is about 20% of the overall construction cost of US$ 272,271,000 for all the sewerage system should be included in the first stage project.

The construction cost under the first stage project would be larger than the cost of US$ 85,857,000, which excluded the construction cost of wastewater collection system. When one third of the cost for the wastewater collection system is applied to the first stage project, the construction cost for the first stage project would be 138,613,000, about 50% of the total cost. The high construction cost required for the first stage project suggests that this alternative could be difficult to apply.

Table 12.15 A Preliminary Capital Cost Estimate for the Alternative N-6

Item	Design Features	Cost Estimate (x1000 US$)	Remarks
1. All the system			
1.1 Wastewater collection system		**158,268**	
1) Sewer main (open cut methods)	Dia. 200 to 1,350mm	140,895	
2) Sewer main (tunneling methods)	Dia. 750 to 1,350mm	4,988	
3) Pumping station		12,385	
1.2 Wastewater treatment plant (Primary treatment)	119,100 m^3/d (24 sedimentation tanks)	**58,189**	
1.3 Outfall sewer system		**55,814**	
1) Pressure pumping station	124 m^3/min	5,914	
2) Pressured sewer main	Dia. 1,500mm, L=4,050m	30,375	
3) Bay crossing sewer main	Dia. 1,500mm, L=920m	7,820	
4) Transmission tunnel	Dia. 1,500mm, L=1,770m	7,965	
5) Ocean outfall sewer	Dia. 1,500mm, L=300m	2,550	
6) Ocean distribution pipe	Dia. 1,500mm, L=140m	1,190	
1.4 Total cost for all the system		**272,271**	
2. First Stage Project			
2.1 Wastewater collection system		not be estimated	
2.2 Wastewater treatment plant	19,850 m^3/d (4 sedimentation tanks)	**54,369**	4tanks out of 24 tanks
2.3 Outfall sewer system		**54,369**	
1) Pressure pumping station	13.8 m^3/min	4,469	2 no. pumps out of 7 no.
2) Pressured sewer main	Dia. 1,500mm, L=4,050m	30,375	
3) Bay crossing sewer main	Dia. 1,500mm, L=920m	7,820	
4) Transmission tunnel	Dia. 1,500mm, L=1,770m	7,965	
5) Ocean outfall sewer	Dia. 1,500mm, L=300m	2,550	
6) Ocean distribution pipe	Dia. 1,500mm, L=140m	1,190	
2.4 Total Cost for the First Stage Project excluding the cost for wastewater collection system		**85,857**	

Source: JICA Study Team

(5) Results of the Alternative Studies on the New Sewerage System

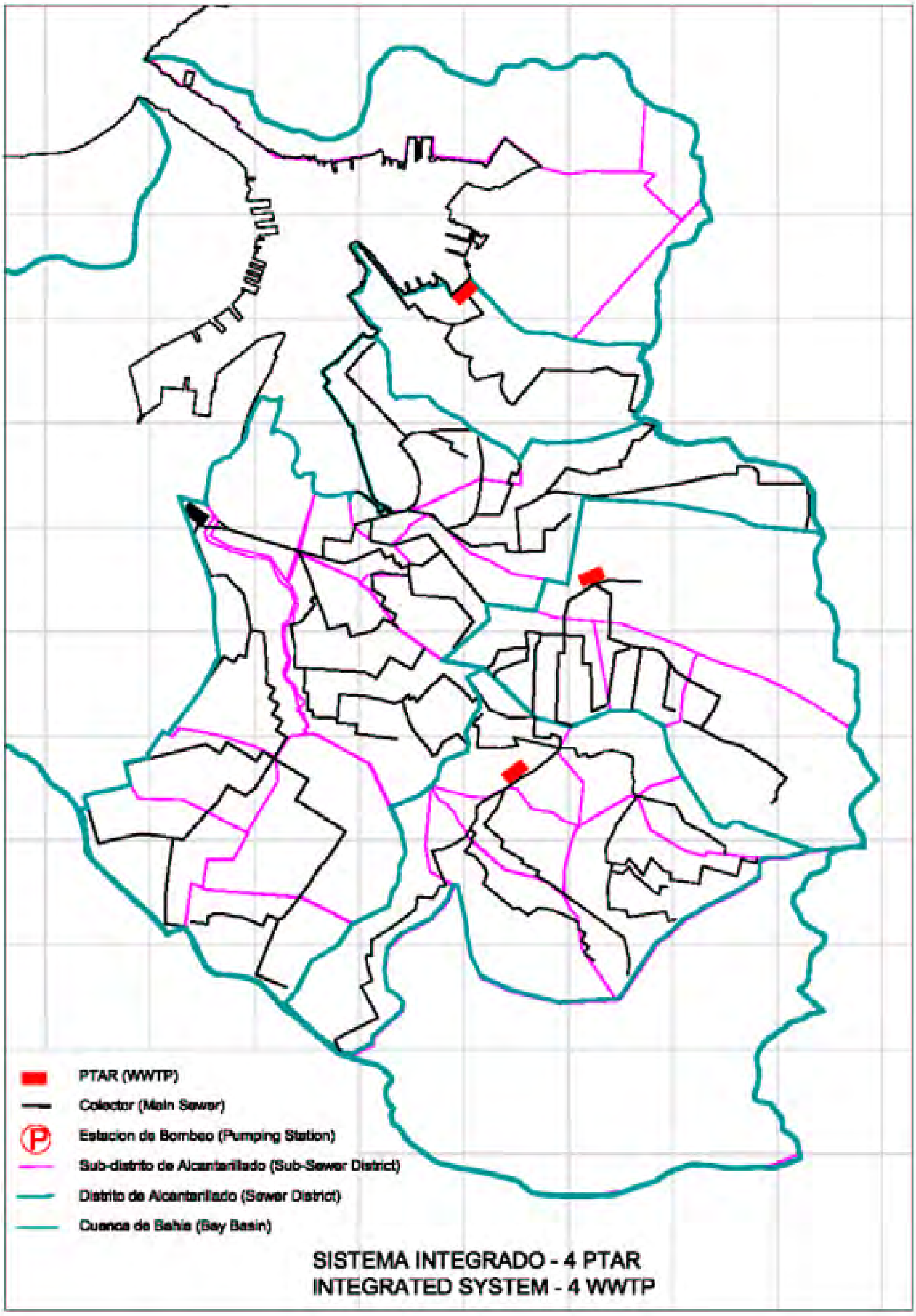
Above discussion on the study on six (6) alternatives derives following conclusions and recommendations:

- The Alternative N-2, comprising four zonal sewerage systems, is selected as the new sewerage plan for the Havana Bay basin.
- It has been demonstrated that Alternative N-2 would reduce the pollution loads to the Havana Bay most efficiently, because the possible areas to be developed by 2020 are densely populated and cover the area where many factories exist.

- The current limited availability of land areas for the construction of WWTPs selected the conventional activated sludge (CAS) process as a wastewater treatment process and also selected mechanical sludge dewatering facilities except the Guanabacoa WWTP. However, if larger land areas were available for the proposed WWTPs in the future, more appropriate wastewater and sludge treatment processes such as a conventional trickling filter process and sludge drying beds would be applicable to save the costs for construction and for operation and maintenance. When the four zonal sewerage plan is needed to revise for expansion of the sewer service, acquisition of larger land area for each WWTP would be highly recommended to be able to apply the appropriate wastewater and sludge treatment processes in operation and maintenance.

- The proposed site for WWTP of the Luyanó-Martín Pérez Abajo sewer district in the alternative study is very difficult to obtain because it is planned to use as a container stock yard. In stead of the site, GTE and INRH proposed that the site of WWTP for GEF/UNDP on-going project could be expanded to construct the Luyanó-Martín Pérez Abajo sewer district.

- The general plan of four zonal systems is presented in Figure 12.17. The design works of the proposed sewerage facilities for each sewer district are presented in Appendix-10 and Appendix-11 of the Supporting Report, Volume III of this report.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.17 Selected Sewerage Plan – Four Zonal Sewerage System
JAPAN INTERNATIONAL COOPERATION AGENCY	

12.3.3 DEVELOPMENT PLAN OF NEW SEWERAGE SYSTEM UP TO THE YEAR 2020

(1) Issues of further studies

1) General

To adopt the selected new sewerage plan for the Luyanó-Martín Pérez Abajo sewer district as the new sewerage development plan up to the year 2020, the following issues were identified and to be studied further:

- A study on possibility of Cuban proposal to divert the wastewater from part of the Luyanó sewer district to the Central sewerage system for final disposal to ocean through the Casablanca pumping station.
- Coordination is required to employ the design philosophy for both the new wastewater treatment plant (WWTP) proposed by JICA Study and to be constructed by the GEF/UNDP Project.

2) Review of Proposal by Aguas de La Habana for Luyanó Area for Integration into the new sewerage development plan up to the year 2020

- There existed a proposal by Aguas de La Habana (Figure 12.18) to collect wastewater from areas in the left bank of Rio Luyanó basin which was not planned to be covered by the GEF/UNDP Project and to pump to Colector Sur (Figure 12.18) for ultimate disposal to Playa del Chivo.
- Figure 12.19 shows the area proposed by Aguas de La Habana (hereafter Proposed Area) in relation to the sewer districts in the new four zonal sewerage systems. Table 12.16 summarizes the areal distribution of Proposed Area across the sewer districts.
- In Table 12.16, area which falls within Luyanó Arriba Sewer District will be treated at La Cumbre WWTP and that area which falls within Fosa area will be treated by septic tanks. Area which falls within Luyanó-Martín Pérez Abajo Sewer District is considered to be collected by the left bank Colector up to the Luyanó WWTP.

Table 12.16 Relationship of Proposed Area with Sewer Districts of New Four Zonal Sewerage Systems

	Sewer District	Area	Remarks
Proposed Area 1 (447 ha)	Existing (S3)	241 ha (13 ha)*	Wastewater collection by Sur 3 for disposal to Playa del Chivo
	Luyanó-Martín Pérez Abajo	193 ha	Wastewater collection by left bank Colector of Luyanó-Martín Pérez Abajo Sewer District. Treatment either at Luyanó WWTP or to existing system
Proposed Area 2 (730 ha)	Luyanó-Martín Pérez Abajo	444 ha	
	Luyanó Arriba	131 ha	To be treated at La Cumbre WWTP
	Fosa	155 ha	Treated by septic tanks

Note: * - outside the bay basin
Source : JICA Study Team

- The capacity of Colectors in Central System has been examined, based on diameter and elevations, against the required capacity for the design flow conditions without inflow from Orengo Colector and with elimination of cross connections. Selection of Colectors for rehabilitation is based on not only on the capacity but also on the physical condition of sewer. The results are presented in the section 12.2.3.
- Due to the crossing of Colector Sur 2 – Sur across Dren Agua Dulce and Dren Arroyo Matadero, the interconnections gravity flow of Sur 3 and Sur 2 to Colector Sur is not possible and pumping will be required. In this respect, pumping of wastewater must be

considered together with pumping of wastewater from Colector Sur3 and Colector Sur 2 to Colector Sur.

3) Wastewater Treatment Plant of GEF/UNDP Project

Based on the "Project Document of the Government of Cuba, CUB/99/G31"[1], the wastewater treatment plant uses an activated sludge process, designed to remove suspended solids, organic matter and nutrients. The plan will be based on the following design criteria: Organic matter in terms of BOD_5 concentration <20mg/L, Suspended Solids (SS) concentration <30mg/L, Total Nitrogen (T-N) removal rate >70% and Total Phosphorus (T-P) removal rate >56%. The wastewater treatment facilities proposed in the document are composed of the following elements:

- Preliminary treatment facilities consisting of a bar screen, grit and grease removal, and if necessary, an influent pumping station.
- Primary sedimentation tanks
- Biological treatment unit consisting of alternating anaerobic/anoxic/aerobic zones for optimized nutrient removal, equipped with biological selector zones.
- Final sedimentation tanks
- Sludge return system to maintain a high mixed liquor suspended solids (MLSS)
- Vertical flow filters for effluent polishing

INRH asked two Cuban design institutions, Investigaciones y Proyectos Hidráulics Villa Clara and Investigaciones y Proyectos Hidráulics Habana, to prepare the design works for the wastewater treatment plant of GEF/UNDP under the following revised design conditions:

- Design capacity of 200 L/s for the GEF/UNDP project with the total capacity of 600 L/s.
- Design influent quality: BOD_5 (250mg/L), TSS(270mg/L), T-N(50mg/L), T-P(10mg/L), COD (625mg/L), NH4-N (20mg/L), Oil and grease (20mg/L), Temperature (24 degree-C), pH(6.5-8.0)
- Design treated wastewater quality: BOD_5 (<30 mg/L), SS(<40mg/L), T-N(<15mg/L), T-P(<2mg/L), COD (<80mg/L), Oil and grease (<10mg/L), pH(6.5-8.0)
- Facilities of GEF/UNDP project will be located within the area of 1.08 ha in the northern part of the proposed site.

Two different wastewater treatment processes have been proposed: one is a conventional activated sludge process and the other is a kind of modifed Ludzack-Ettinger process for nitrogen removal with coagulant addition to remove phosphorus.

The proposed conventional activated process has an endless circular aeration tank having hydraulic retention time (HRT) of 6 hours, which could control dissolved oxygen level to formulate aerobic/anaerobic/anoxic conditions for removing nitrogen and phosphorus. To save the energy required to maintain the process, an energy recovery process using an anaerobic digestion is also proposed.

[1] UNDP Project Documentation of the Government of Cuba, CUB/99/G31, Demonstration of Innovative Approaches to the Rehabilitation of Heavily Contaminated Bays in the Wider Caribbean, Global Environmental Facility, Havana, April 2002

The other process is called an extended aeration process by Cubans but a kind of modifed Ludzack-Ettinger process. It consists of preliminary treatment facilities, anoxic tanks followed by aerobic tanks (HRT 16 hours) for nitrogen removal and coagulant additions prior to final sedimentation tanks for removing phosphorus.

(2) Proposed Solutions for the Issues

The followings are the solutions for the issues through engineering studies and discussions with Cubans.

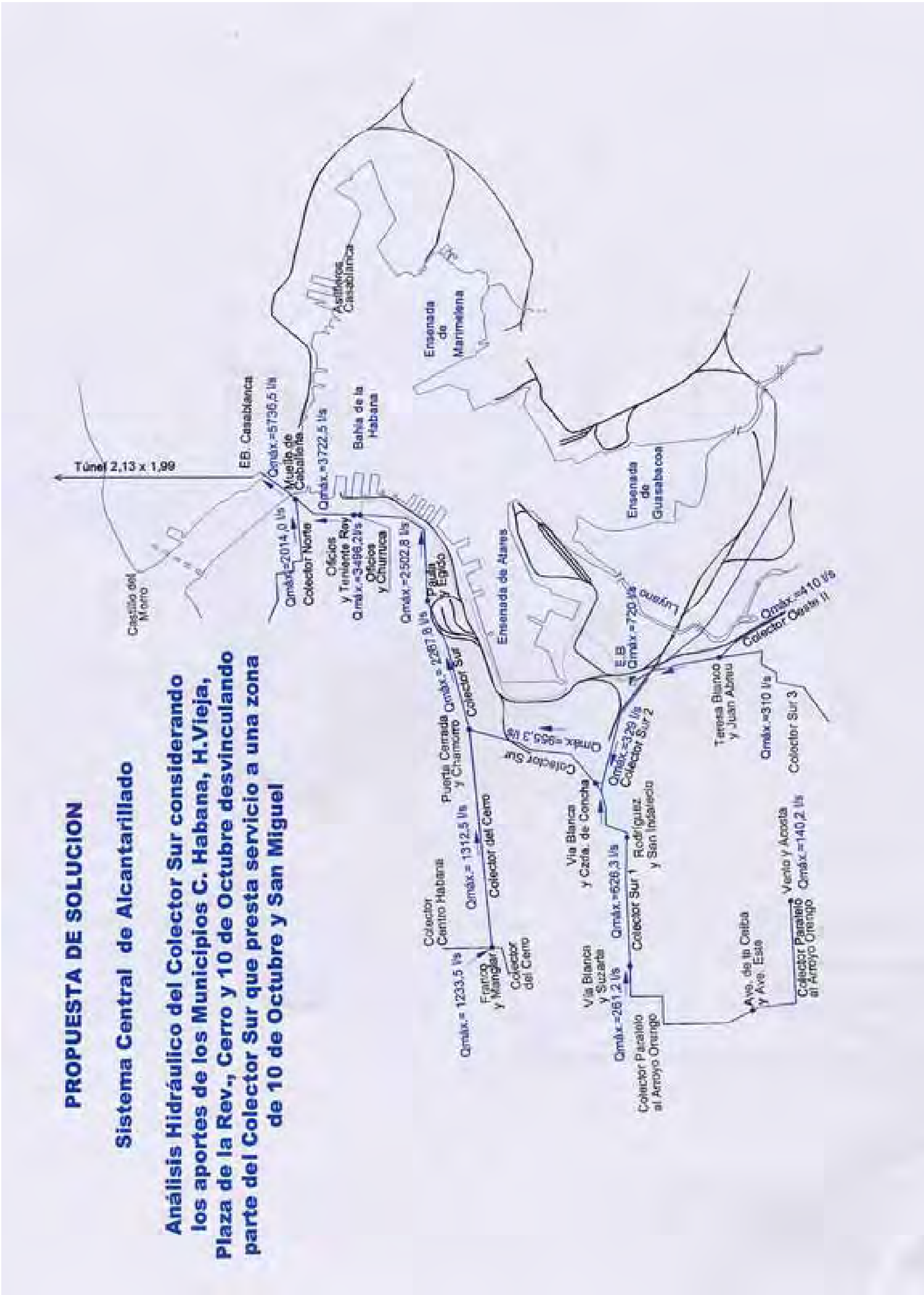
1) Luyanó Left Bank Area

- Wastewater generated in the Luyanó Left Bank Area, the Area "A", will be treated at the Luyanó Wastewater Treatment Plant in principle for the new sewerage development plan up to the year 2020. Figure 12.20 shows the planning and design figures for Colectors and Luyanó WWTP in the Luyano-Martín Pérez Abajo Sewer District.
- However, a measure that the wastewater generated in the Luyanó Left Bank Area will be discharged to the ocean through the existing Central sewerage system, with a primary treatment if necessary, is also proposed as the alternative measure against the measure of treatment at the proposed WWTP.
- Two cases for the alternative management of wastewater generated in the Luyanó Left Bank Area are prepared as shown in Figure 12.21: Case 1 (Ocean Disposal through Central system, a combination of installation of a by-pass sewer of Colector Sur2, construction of a pumping station with a gravity sewer, and the gravity sewer will be connected to the by-pass sewer of Colector Sur) and Case 2 (Ocean Disposal through Central system proposed by Aguas de La Habana). The WWTP would treat the wastewater until the alternative would be realized as illustrated in Case 3 in Figure 12.21.
- Table 12.17 summarizes a comparison of these two cases on costs, pre-conditions for implementation and time-horizon for implementation. The Case 1 is recommended due to the following advantages: only one pumping station is required, the system will make functions as a by-pass system of the existing Colector Sur, contributing to the higher reliability.
- However, it is noted that the alternative measure of ocean disposal could not be implemented without solution of cross connection problems between sanitary sewer and drainage pipe/channel. Therefore, it is recommended that a possibility of implementation of the ocean disposal alternative would be examined at the design stage for the second stage project to confirm that the cross connection problems could solved successfully by the implementation of the first stage projects.

2) Wastewater Treatment Plant

The followings are the case in which all wastewater generated in the Luyanó-Martín Pérez Abajo Sewer District will be treated at the Luyanó WWTP.

- The wastewater treatment process constructed under the GEF/UNDP Project is required to meet high nutrient removal rates, thus an advanced treatment process will be selected. However, the treatment facilities to be expanded under the Sewerage Master Plan in the JICA Study are given to the first priority to remove the organic matters, in other words, a secondary process will be applied for the expanded treatment facilities. Therefore, we propose that wastewater treatment facilities except preliminary treatment facilities such as screen and grit chamber will be constructed separately due to the different wastewater treatment levels.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.18 Schematic Diagram of Aguas de La Habana Proposal
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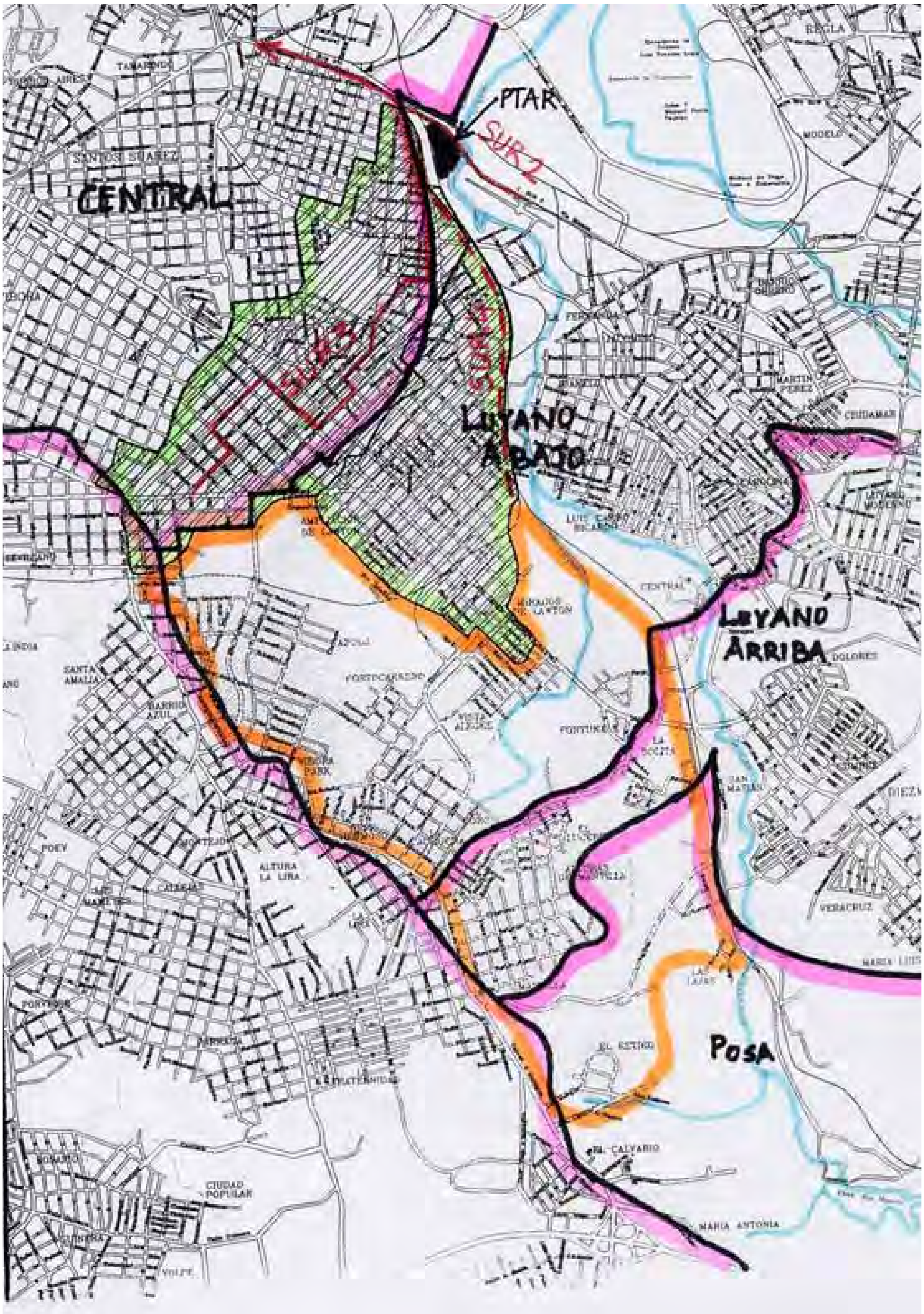

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.19 Relationship of Proposed Area with Sewer Districts of Four Zonal Sewerage Systems
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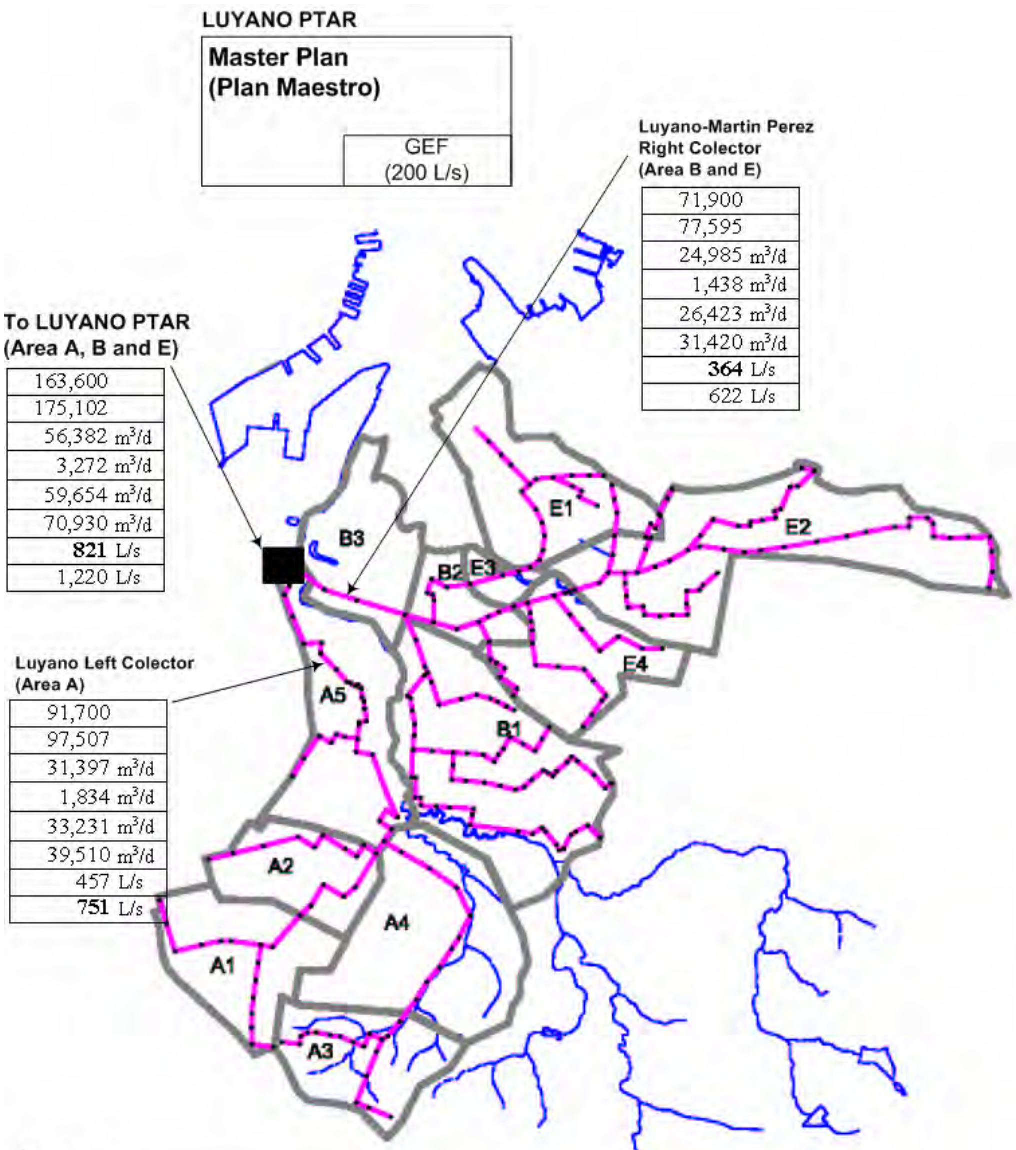
- As a biological secondary wastewater treatment process, a conventional activated sludge process is proposed for the expanded treatment facilities, considering construction site conditions. For a treatment of sludge generated in the wastewater treatment, a series of process consisting of gravity thickening, anaerobic digestion of closed type but without heating system, and mechanical dewatering is proposed. The sludge will be disposed off at a site of sanitary landfill.
- The capacity of the expanded facilities at Luyanó WWTP is 621 L/s (=821-200=621) or 53,700m^3/d, excluded the design flow of 200 L/s for GEF/UNDP project.
- An expansion plan of treatment capacity at Luyanó WWTP is proposed as shown in Figure 12.21 The treatment facility will be constructed in three stages, the capacity of the treatment facility is 207 L/s (=621/3) each in the each implementation stage. The first stage project will only cover the initial treatment facility components having capacity of 207 L/s or 17,900 m^3/d and becomes the total capacity of 407 L/s or 35,200 m^3/d.
- Figure 12.23 shows design service population and flows of each sub sewer area where the wastewater will be collected and treated at the WWTP.
- It is proposed that the following common facilities will be constructed by the GEF/UNDP Project: preliminary treatment facilities of pumping stations, screen, grit chamber and buildings of administration office and of operator house.

The followings are the case of WWDP development plan if the ocean disposal alternative of the Luyanó Left Bank Area could be implemented.

- Expansion of the treatment capacities at the second stage would be cancelled as illustrated in Figure 12.22. Instead of the treatment facilities, necessary wastewater transmission facilities such as Colector A to convey the wastewater collected at the Luyanó Left Bank area to the rehabilitated and improved Central System for ocean disposal.
- The treatment capacity of 407 L/s or 35,200 m^3/d after the first stage project could receive and treat the wastewater generated in the expanded area without any expansion in the treatment capacity. Figure 12.22 illustrates this situation as shown in the left-bottom figure in case of Feasibility Study for 2nd stage project.
- When the ocean disposal alternative would be implemented after the second stage project, it is recommended that the proposed four zonal sewerage system plan should be reviewed and revised including an evaluation of the improvement effects on bay water quality by the implemented projects. The revision of the sewerage plan would include a study that the Luyanó Arriba Sewer District could be unified with the Luyanó-Martín Pérez Abayo Sewer District to treat all wastewater at the Luyanó WWTP.



Legend

1	Population	P
2	Equivalent Population	Pe
3	Overall Wastewater flow	Qw
4	Infiltration	Qi
5	Average Daily Wastewater Flow	Qave
6-1	Maximum Daily Wastewater Flow	Qdaymax
6-2	Maximum Daily Wastewater Flow	Qdaymax
7	Maximum Hourly Wastewater Flow	Qhourmax

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 12.20
Planning and Design Figures for Colectors and Luyanó WWTP in Luyanó-Martín Pérez Abajo Sewer District

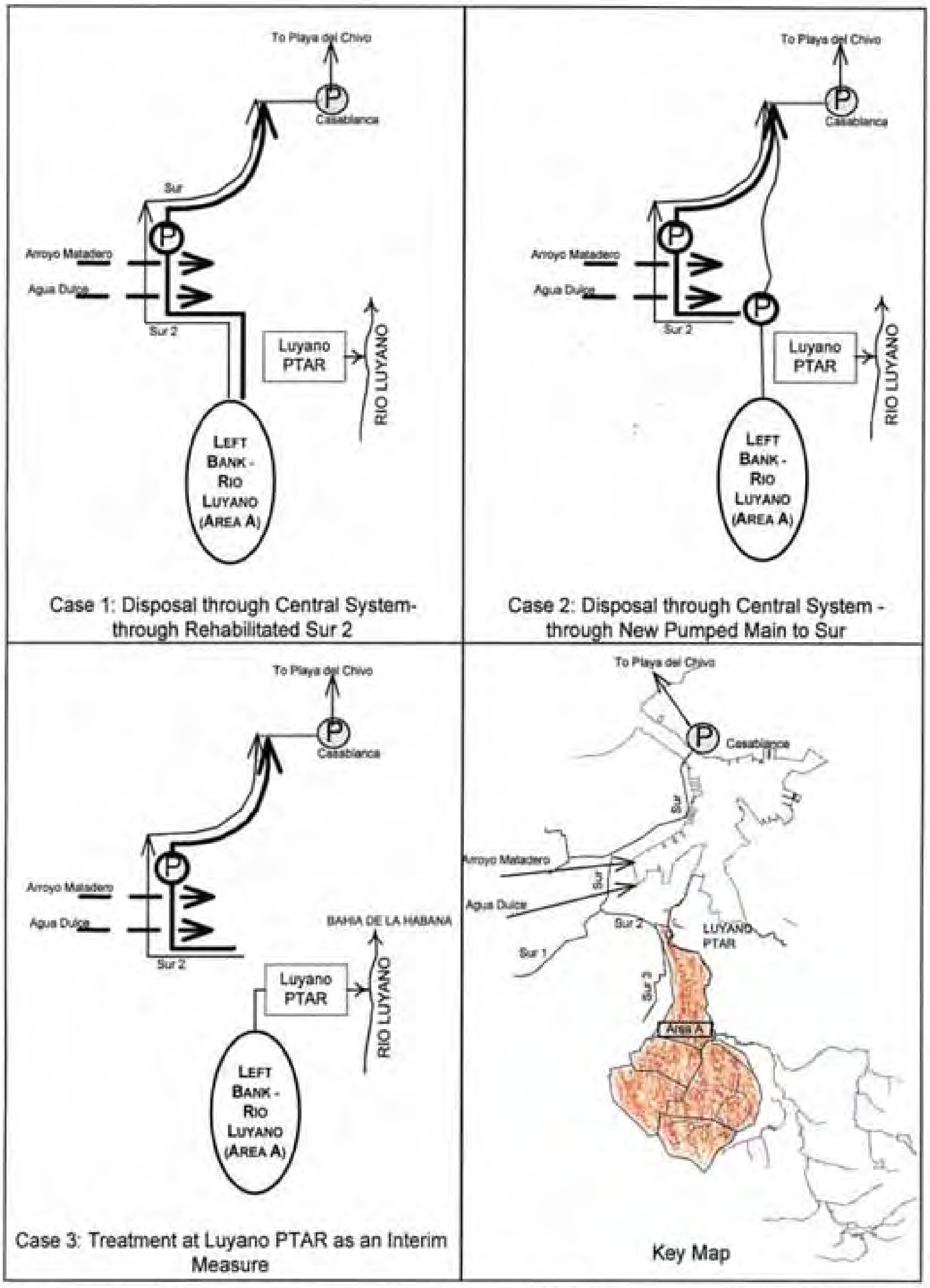

Figure Schematic Diagram of Alternatives for Wastewater Disposal from the Left Bank of Rio Luyano

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.21 Schematic Diagram of Alternative for Wastewater Disposal from the Luyanó Left Bank Area
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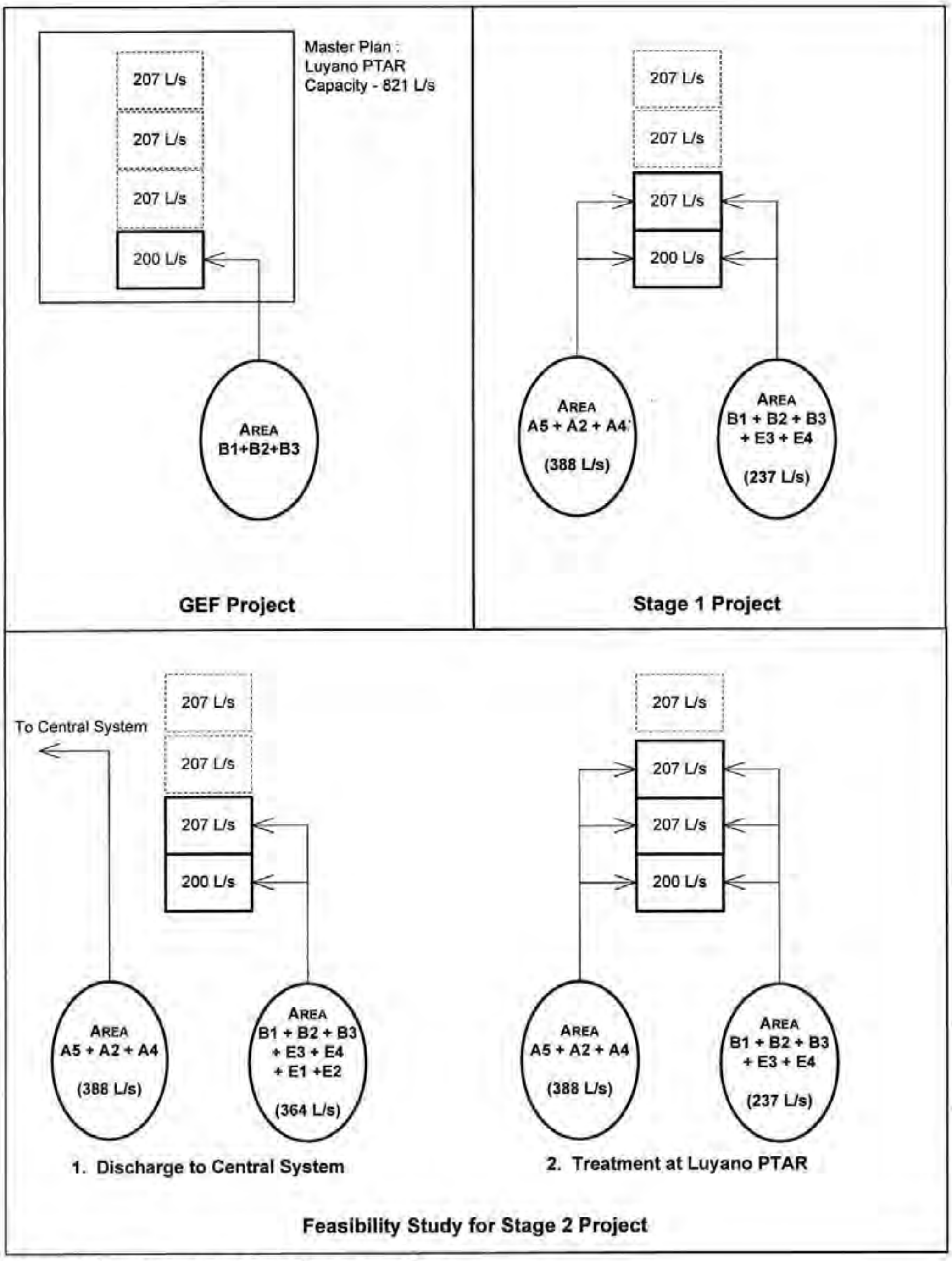
Table 12.17 Comparison of Alternatives for Disposal of Wastewater Generated from the Left Bank of Rio Luyanó

Item	Case 1 : Disposal through Central System – through Rehabilitated Colector Sur 2 and Sur	Case 2 : Disposal through Central System – through New Pumped Main to Sur
1. Main Components	① Construction of Left-bank Colector up to Sur 2 ② Rehabilitation of Sur 2 and Sur to the capacity required for flow from Sur 3 and Area A ③ Construction of Pumping station following the crossing at Matadero ④ Rehabilitation of Casa Blanca Pumping Station	① Construction of Left-bank Colector to New Pumping Station ② Construction of new Pumping Station ③ Construction of pumped main to Sur
2. Comparison		
2.1 Capital cost (excluding the common facility)	① Additional cost for rehabilitation of Sur 2 due to flow from Area A ② Additional cost for rehabilitation of Sur due to flow from Area A ③ Additional cost for Installed Capacity of Pumping Station at Matadero ④ Additional cost for Installed Capacity of Blanca Pumping Station	① Cost of gravity main to New Pumping Station (that part beyond Luyano PTAR or Sur 2) - L= 850 m, d=1200 mm Concrete ② Cost of new Pumping Station Qhourmax=751 L/s, H=9 m ③ Cost of pumped main to Sur L= 3,300 m, d=1030 mm HDPE
2.2 O/M Cost	① Additional O/M cost at Matadero Pumping Station ② Additional O/M cost at Casablanca Pumping Station	① O/M cost at New Pumping Station ② Additional O/M cost at Casablanca Pumping Station
3. Pre-conditions for Implementation	① Rehabilitation of Casablanca Pumping Station ② Rehabilitation of Siphon (if necessary) ③ Rehabilitation of Sur and Sur 2 ④ Elimination of cross connections	① Rehabilitation of Casablanca Pumping Station ② Rehabilitation of Siphon (if necessary) ③ Rehabilitation of Sur
4. Time-horizon for implementation	After year 2015	After 2010



Note: All flows shown in L/s are daily maximum flows.

Figure Staged Implementation (Draft) of Luyano PTAR

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.22 Schematic Staged Capacity Development Plan of the Luyanó WWTP
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THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

Figure 12.23
Design Figures of Sub-sewer Area

1. LUYANO-MARTIN PEREZ-ABAJO DISTRITO DE ALCANTARILLADO

Legend

1	Population	P
2	Equi-Population	Pe
3	Overall Wastewater flow	Qw
4	Infiltration	Qi
5	Average Daily Wastewater Flow	Qave
6-1	Maximum Daily Wastewater Flow	Qdaymax
6-2	Maximum Daily Wastewater Flow	Qdaymax
7	Maximum Hourly Wastewater Flow	Qhourmax

LUYANO PTAR

CLE **Luyano Abajo-Left Collector**

CLD **Luyano-Martin Perez Abajo-Left Colector**

Rio Luyano

Rio Martin Perez

A5

1	P	32,900	
2	Pe	36,881	
3	Qw	11,876	m3/d
4	Qi	658	m3/d
5	Qave	12,534	m3/d
6-1	Qdaymax	14,909	m3/d
6-2	Qdaymax	**173**	L/s
7	Qhourmax	336	L/s

A5	173 L/s
A5+0.5*A4+0.5*A2	280 L/s
A5+A4+A2	388 L/s
A5+A4+A2+A1	437 L/s
A5+A4+A2+A1+A3	457 L/s

B3

1	P	9,600	
2	Pe	9,600	
3	Qw	3,091	m3/d
4	Qi	192	m3/d
5	Qave	3,283	m3/d
6-1	Qdaymax	3,901	m3/d
6-2	Qdaymax	**45**	L/s
7	Qhourmax	109	L/s

B1+B3	154 L/s
B1+B3+B2	178 L/s
B1+B3+B2+E3+E4	237 L/s
B1+B3+B2+E3+E4+0.5*E1+0.5*E2	300 L/s
B1+B3+B2+E3+E4	364 L/s

A2

1	P	18,500	
2	Pe	562	
3	Qw	6,299	m3/d
4	Qi	370	m3/d
5	Qave	6,669	m3/d
6-1	Qdaymax	7,929	m3/d
6-2	Qdaymax	**92**	L/s
7	Qhourmax	292	L/s

A4

1	P	26,300	
2	Pe	26,300	
3	Qw	8,468	m3/d
4	Qi	526	m3/d
5	Qave	8,994	m3/d
6-1	Qdaymax	10,688	m3/d
6-2	Qdaymax	**124**	L/s
7	Qhourmax	254	L/s

B2

1	P	4,400	
2	Pe	5,086	
3	Qw	1,638	m3/d
4	Qi	88	m3/d
5	Qave	1,726	m3/d
6-1	Qdaymax	2,054	m3/d
6-2	Qdaymax	**24**	L/s
7	Qhourmax	62	L/s

E3

1	P	1,800	
2	Pe	1,800	
3	Qw	579	m3/d
4	Qi	36	m3/d
5	Qave	615	m3/d
6-1	Qdaymax	731	m3/d
6-2	Qdaymax	**9**	L/s
7	Qhourmax	25	L/s

E1

1	P	13,10
2	Pe	16,14
3	Qw	5,19
4	Qi	26
5	Qave	5,45
6-1	Qdaymax	6,49
6-2	Qdaymax	**7**
7	Qhourmax	16

A1

1	P	9,600	
2	Pe	10,364	
3	Qw	3,337	m3/d
4	Qi	192	m3/d
5	Qave	3,529	m3/d
6-1	Qdaymax	4,196	m3/d
6-2	Qdaymax	**49**	L/s
7	Qhourmax	116	L/s

A3

1	P	4,400	
2	Pe	4,400	
3	Qw	1,417	m3/d
4	Qi	88	m3/d
5	Qave	1,505	m3/d
6-1	Qdaymax	1,788	m3/d
6-2	Qdaymax	**21**	L/s
7	Qhourmax	55	L/s

B1

1	P	22,300	
2	Pe	23,238	
3	Qw	7,482	m3/d
4	Qi	446	m3/d
5	Qave	7,928	m3/d
6-1	Qdaymax	9,424	m3/d
6-2	Qdaymax	**109**	L/s
7	Qhourmax	229	L/s

E4

1	P	9,700	
2	Pe	10,731	
3	Qw	3,456	m3/d
4	Qi	194	m3/d
5	Qave	3,650	m3/d
6-1	Qdaymax	4,341	m3/d
6-2	Qdaymax	**50**	L/s
7	Qhourmax	119	L/s

E2

1	P	11,00
2	Pe	11,00
3	Qw	3,54
4	Qi	22
5	Qave	3,76
6-1	Qdaymax	4,47
6-2	Qdaymax	**5**
7	Qhourmax	12

(3) Development Plan of New Sewerage System up to the Year 2020

Table 12.18 presents the new sewerage development plan up to year 2020. It is proposed that all the wastewater generated in the Luyanó-Martín Pérez Abajo sewer district will be treated at the Luyanó WWTP in principle. The sewerage systems planned to develop up to the year 2020 are described in detail in the section of 13.2.2.

Table 12.18 Outline of New Sewerage Development Plan up to the year 2020

Item	Luyanó-Martín Pérez Abajo Sewer District	Proposed Total with GEF/UNDP
1. Sewer Service Population	138,300	163,600
2. Sewerage Service Area	1,054 ha	1,300 ha
3. Wastewater Generation as of year 2020	47,940 m^3/d	56,400 m^3/d
Domestic	23,240 m^3/d	27,485 m^3/d
Non-domestic (small consumers)	21,300 m^3/d	25,194 m^3/d
Non-domestic (large consumer)	3,400 m^3/d	3,704 m^3/d
4. Wastewater Collection System		
4.1 Sewer Networks	*Dia.: 216/250 mm, HDPE, Length: 212 km (Luyanó-Martín Pérez Right Colector: 105 km long, Luyanó Left Colector: 107 km long)	
4.2 Sewer Main (Colector)	Luyanó-Martín Pérez Right Colector: Open Cut Method: Dia.: 216/250mm to 1030/1200mm, HDPE, Length: 13.0 km, Tunneling Method: Tunnel Dia. 1500mm, Length: 5.4 km. Inserted Inner Pipe Dia. 216/250 mm to 1030/1200mm, HDPE.	
	Luyanó Left Colector: Open Cut Method: Dia. 216/250mm to 1030/1200mm, HDPE, Length:13.0 km, Tunneling Method: Tunnel Dia. 1500mm, CP, Length: 1.3 km, Inserted Inner Pipe Dia. 535/630 mm to 1030/1200mm, HDPE	
5. Wastewater Treatment Plant	Luyanó WWTP	
5.1 Design Capacity	53,700 m^3/d (621 L/s)	71,000 m^3/d (821 L/s)
5.2 Wastewater Treatment Level and Process	Secondary Treatment Level, Conventional Activated Process; Preliminary Treatment + Primary Sedimentation + Aeration + Final Sedimentation + Sludge Return	
5.2 Sludge Treatment and Disposal	Sludge thickener + Anaerobic Digestion + Mechanical Dewatering +Disposal (Sanitary Landfill)	

Note: *The HDPE (High density polyethylene pipe) shows both inner and outer diameter.
Source: JICA Study Team

(4) Alternative of Wastewater Ocean Disposal for the Area of Luyanó Left Colector

1) General

When the cross connection problems in drainage area of Dren Arroyo Matadero are solved by the measures of the first stage project, the alternative of ocean disposal could be possible to implement in the second stage project, i.e. the wastewater generated from the left bank of Rio Luyanó would be conveyed by the proposed new Colector system for the Colector Sur through the Casablanca pumping station to the ocean.

When this alternative is applied, the expansion of treatment facilities will not be required after the second stage as illustrated in Figure 12.22.

The proposed Colector systems required for rehabilitation and improvement of Colector Sur have enough capacity as presented and explained in the following.

2) Design of Proposed Colector Systems for Colector Sur

Table 12.19 shows the outline of required Colector systems for rehabilitation and improvement of Colector Sur.

Table 12.19 Required Colector System for the Alternative

Item	After Rehabilitation	During Rehabilitation
1) Inflow pipe	Colector Sur A	By-Pass Pipe
Design Inflow - Maximum Hourly	1,271 L/s 76.26 m^3/min	2.283 L/s 137.00 m^3/min
Inflow Pipe and material	1500 mm concrete	1500 mm concrete
Invert Level	-5.55 m	-5.55 m
2) Pumps		
- pump type	Submersible Sewage Pump	Submersible Sewage Pump
- capacity and number of pumps	ø 400 mm x 20 m^3/min x 2 pumps (without stand-by) ø 600 mm x 40 m^3/min x 2 pumps (two duty one stand-by)	ø 400 mm x 20 m^3/min x 3 pumps ø 600 mm x 40 m^3/min x 2 pumps (without stand-by)
- pump head	12 m	12 m
- total capacity	80 m^3/min	140 m^3/min
- remarks		Out of 5 pumps two are large bore with ø 600 mm
3) Pumped Main		
- Diameter and material	ø 1350 mm ductile iron	ø 1350 mm ductile iron
- average velocity during peak flow	0.89 m/s	1.59 m/s
- Length	1,020 m	1,020 m
4) Sur Nuevo		
- Diameter and material	ø 1500 mm concrete	ø 1500 mm concrete
- Length	1,830 m	1,830 m

Source: JICA Study Team

The table also shows that the systems have enough capacity to convey the wastewater under the conditions of after rehabilitation, which is collected by Colector Sur 3, Colector S2-1 and S2-2 and Luyanó Left Colector through Colector Sur A, new Colector.

Colector A: This Colector is required to convey the wastewater generated from the area “A” of the left bank of Rio Luyanó as well as the area being covered by the Colector Sur 3 and Sub-colector S2-1 and S2-2. Figure 12.24 and 12.25 shows the route and the longitudinal section of Colector A.

Matadero Pumping Station: This pumping station need to be planned for two very important functions as follows.

During Rehabilitation : To by-pass wastewater from Colector Cerro and Colector Sur (Part 1[2]) to Colector Sur Nuevo to facilitate survey and rehabilitation works in Colector Sur (Part 2[3])

After Rehabilitation : To pump wastewater collected from Colector Sur 3, Sub-colector S2-1 and S2-2, and Luyanó Left Colector.

Large submergible sewage pumps as specified in the above table will be used to cope with the higher flow during rehabilitation but without stand-by pumps considering the temporary nature of their use during rehabilitation.

Wastewater flow through the pumping station will as follows:

Inflow ➔ Coarse Screen ➔ Gravity type Grit Removal Tank ➔ Fine Screen ➔ Inflow Gate ➔ Submersible Sewage Pump ➔ Pumped Main ➔ Sur Nuevo

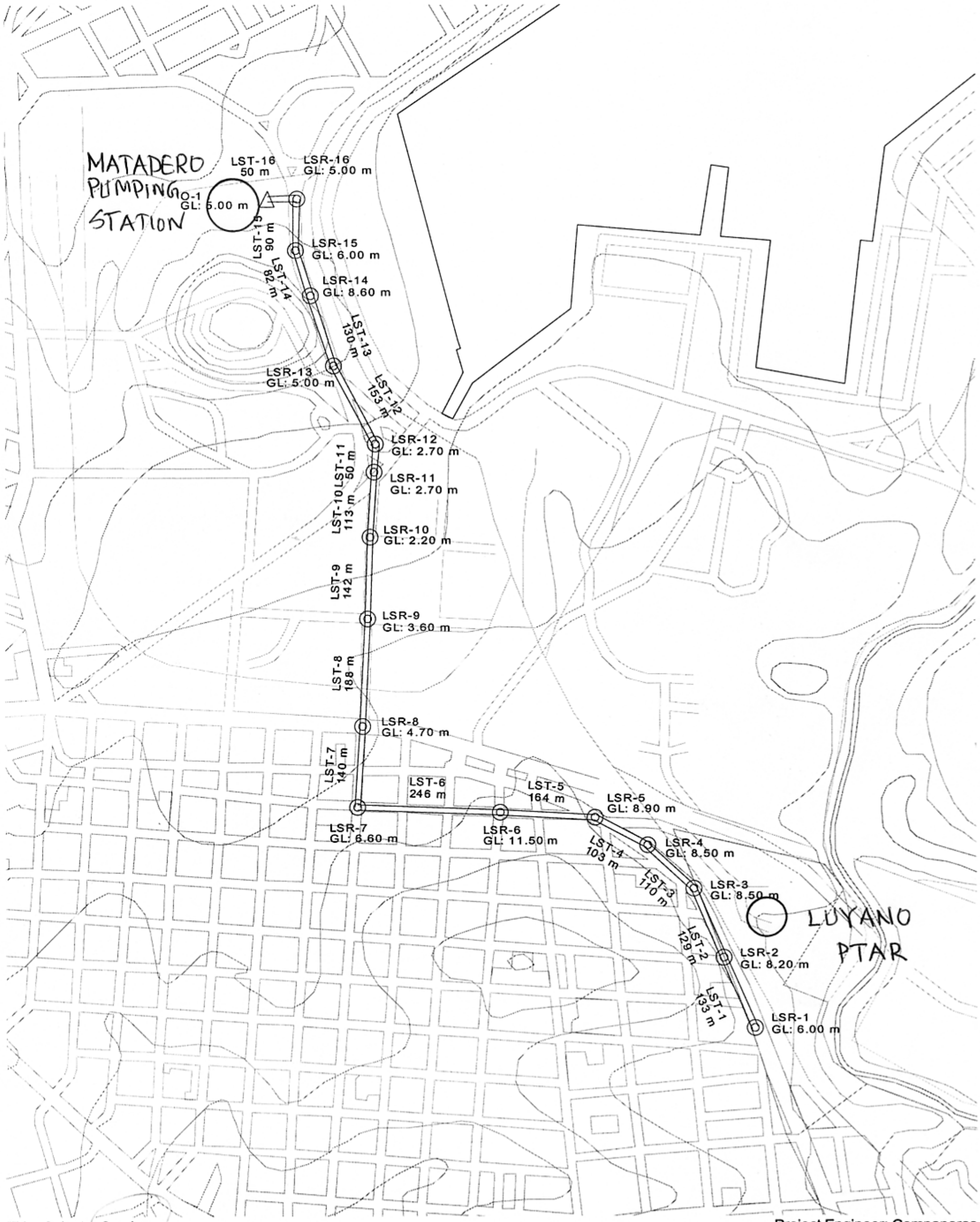
Total area required for the pumping station is approximately 46 m x 36 m (0.17 ha). Consultations were made with DPPF (Provincial Physical Planning Department) regarding the site for Matadero Pumping Station. Location for the Matadero Pumping Station is selected to a vacant land belonging to FAR (*Fuerzas Armada de Revolucionaria*) as shown in Figure 12.26.

Pumped Main and Colector Sur Nuevo: The pumped main of ductile iron pipe having 1,350mm in diameter and 1,020m in length is designed to convey the wastewater flow of 2,283 L/s during rehabilitation of Colector Sur. Under the same conditions, Colector Nuevo is designed to have concrete pipes of 1500mm in diameter, 1,830 m in length and 0.1% (1/1000) in gradient. The capacity of Colector having 2,235 L/s doest have any allowance for the design flows during rehabilitation of Colector Sur but have enough allowance for the flows after the rehabilitation work.

Interconnection Pipe for Colector Cerro and Colector Sur: During the rehabilitation work of Colector Sur, interconnection pipe are needed for the Colector Cerro and the Colector Sur to convey the wastewater to the proposed Matadero Pumping Station. The necessary interconnection pipes are 500 m in total length: dia.1030mm of 100m long and dia.1500mm of 400m long.

[2] Colector Sur (Part 1) is that part up to the confluence with Colector Cerro (dia. 1500 mm).
[3] Colector Sur (Part 2) is from the confluence with Colector Cerro to Cabelleria (dia 1950 mm & 2100 mm).

Scenario: Base



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Page 1 of 1

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 12.24 Route of Colector Sur A
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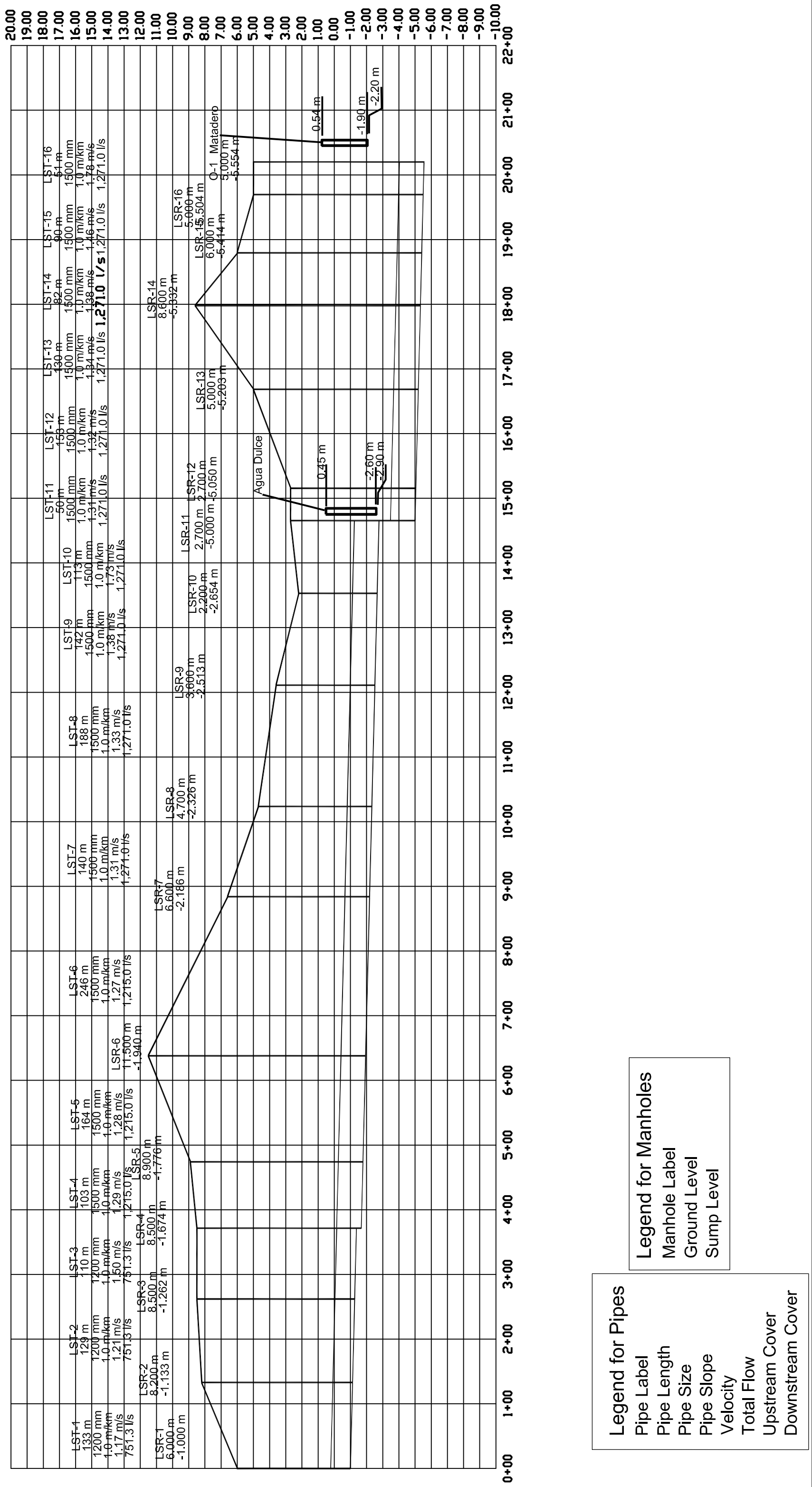

THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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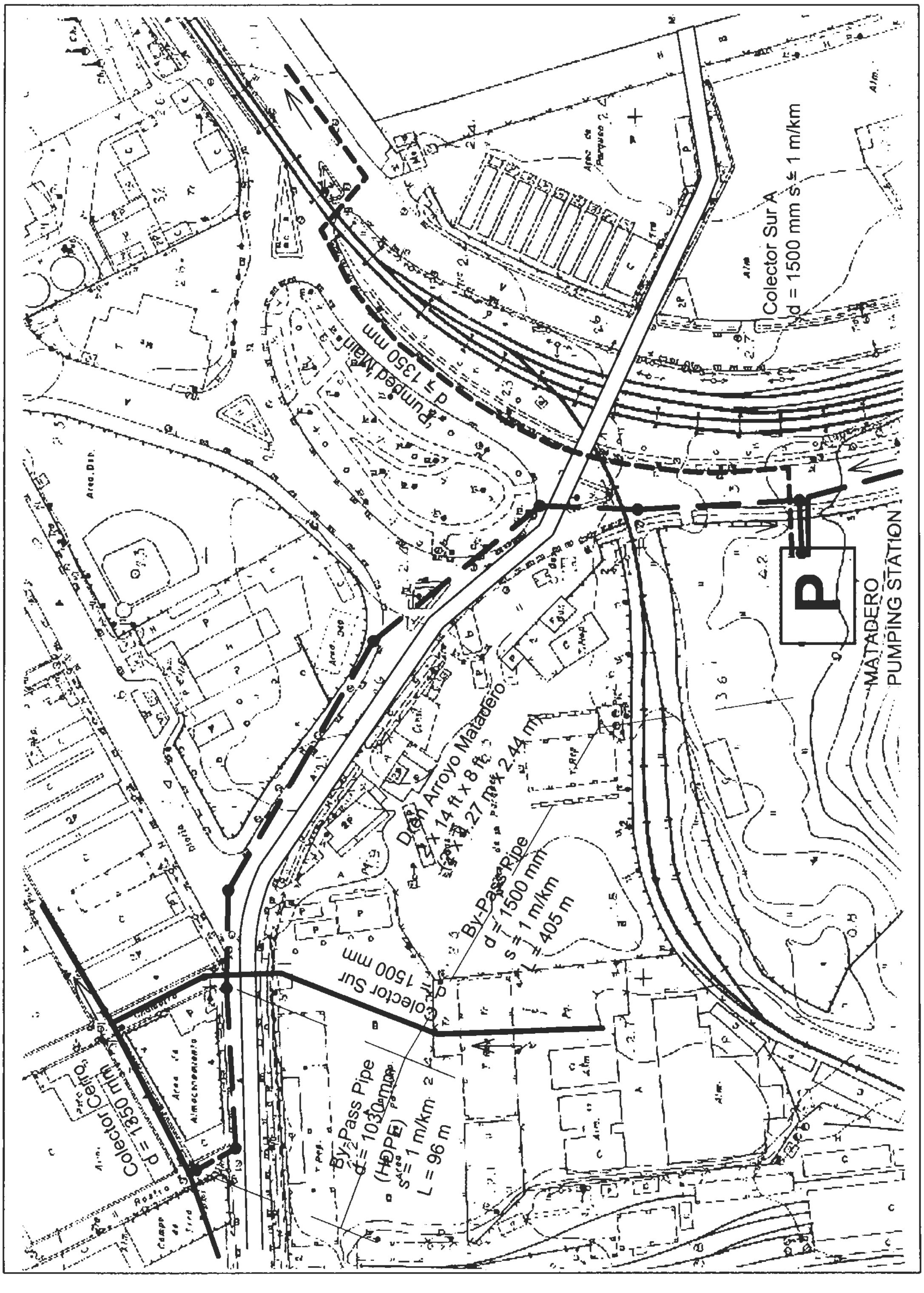
Figure 12.25
Longitudinal Section of Colector Sur A



THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 12.26
Matadero Pumping Station - Location Map

CHAPTER 13
SEWERAGE SYSTEM MASTER PLAN

13.1 GENERAL

The sewerage system components to be improved and developed up to the target year of 2020 are expected to have the following effects:

1) To contribute to the water quality improvement of the most deteriorated areas in the bay.

- To solve the cross connection problems and to convey the wastewater through rehabilitated and improved existing sewerage system to eliminate the wastewater discharge to Atares where is the most deteriorated area in the bay. Arroyo Matadero and Agua Dulce constitute the major portion of the load discharged to Atares area.

2) To reduce the pollutant loads effectively and efficiently by developing new sewerage system

- Through the alternative study on the new sewerage system development, the Luyanó-Martín Pérez Abajo sewer district is selected to be developed up to the target year of 2020. The new sewer district is expected the highest pollutant loads reduction by providing a secondary wastewater treatment plant, because the service area covers the most densely populated area in the unsewered area in the bay basin.

3) To increase the reliability of the existing system which would otherwise adversely affect the environment of the bay.

- Rehabilitation of the screen equipment at Caballeria and of the pump equipment of the Casablanca pumping station.
- Rehabilitation and improvement of the Colector Sur, which is the most important Colector to convey the wastewater generated in the existing sewer area.

This chapter presents a summary of the proposed sewerage system components to be implemented up to the target year 2020, a preliminary operation and maintenance plan for the proposed sewerage system, a staged implementation program, a proposal for necessary institutional strengthening, projects cost estimation based on the proposed implementation program, project effects on the water quality improvement in the Havana bay, a study on financing capacity for the projects, financial and economic evaluations for the proposed sewerage system master plan, selection of the priority projects for feasibility study, and the initial environmental examination of the proposed sewerage system master plan.

13.2 PROPOSED SEWERAGE SYSTEM

13.2.1 PROPOSED EXISTING SEWERAGE SYSTEM IMPROVEMENT

The rehabilitation and improvement of the Central sewerage system has been studied in section 12.2. The proposed improvement plan of the existing Central sewerage system is summarized in Table 13.1. The general map is shown in Figure 13.1.

(1) Sewers

The following components will be included: the rehabilitation of the Colector Sur, the replacement of inadequate existing sewer mains, and the new construction of pumped main and Colector Sur Nuevo from the proposed Matadero pumping station and the screen facilities at Caballeria, the simple repair works of the transmission tunnel from Casablanca to Playa del Chivo, and the replacement of outfall sewer to the ocean.

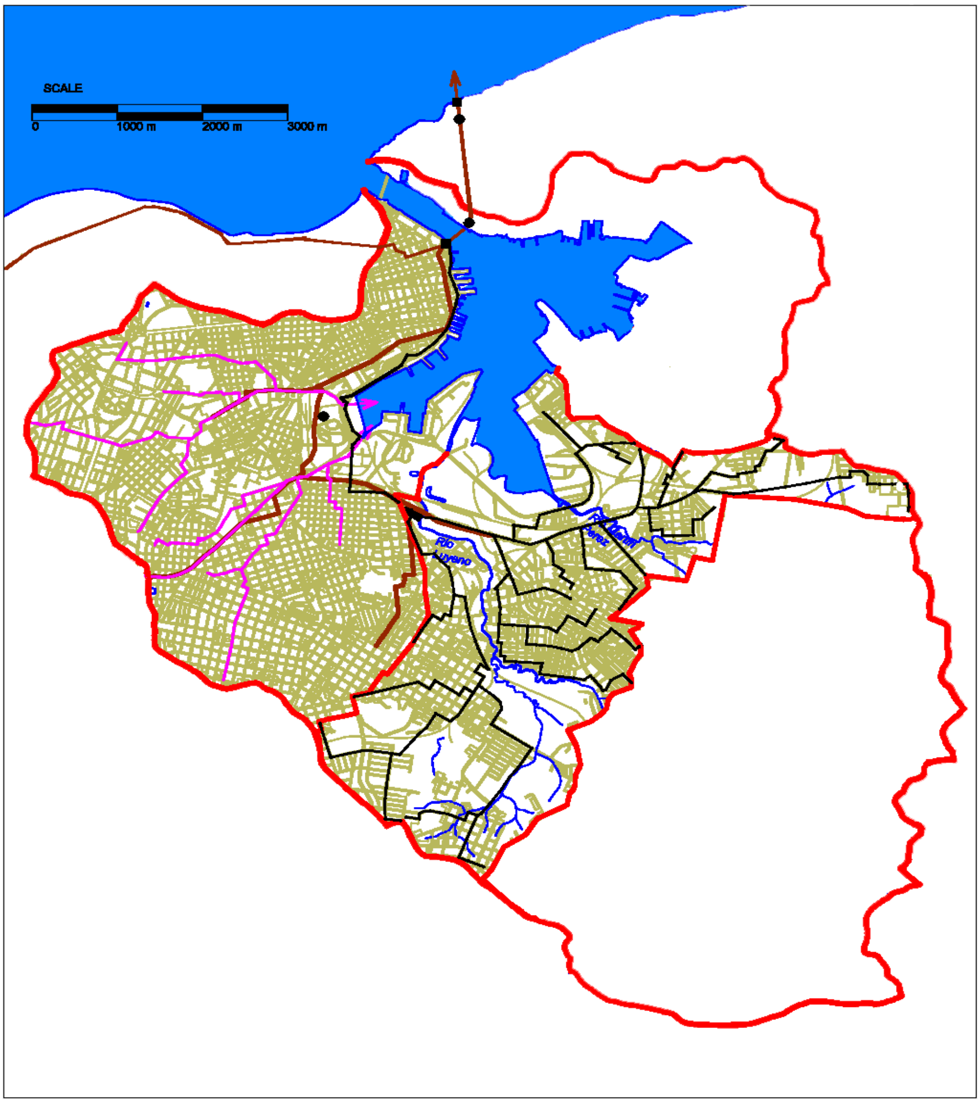
(2) Pumping Stations and related facilities

The pump equipment of the Casablanca pumping station and the screen equipment at Caballeria will be replaced with new equipment. The proposed Matadero pumping station and Re-pumping station will be constructed.

Table 13.1 Improvement Plan of the Central Sewerage System

Item	Proposed Plan	Remarks
1. Detailed Surveys on cross connections to prepare appropriate solution measures.	To conduct Detailed Surveys for identifying the cross connections and preparing solution measures to eliminate the direct wastewater discharge through the Dren Matadero and the Dren Agua Dulce to Havana Bay at Atares.	
2. Rehabilitation of the inadequate capacity of Colectors	The inadequate capacity of the existing Colectors in the Centro Habana, Cerro, Sur 1, Sur 2 and Sur 3 will be added or replaced with new Colectors.	
3. Rehabilitation of Colector Sur and Construction of the proposed Colector system	Rehabiltation of Colector Sur (Dia.: 1500 to 2100mm, CP, Length: 2.78km) and Construction of the proposed Colector system: pumped main (Dia.: 1,350mm, CP, Length 1,020m), Colector Sur Nuevo (Dia. 1500mm, CP, Length: 1,830m), and interconnection pipe (Dia.:1,030/1200)mm, HDPE, to 1500mm, CP, Length: 500m) Construction of the proposed Colector Sur A (Open Cut, Dia.1500mm, CP, Length: 580m, and Tunnelling, Dia.1500mm, CP, Length:1070m) Construction of the proposed Matadero pumping station, Q=20 m^3/min, H=12 m, 3 units including one standby. During the rehabilitation of Colector Sur, additional Q=40 m^3/min, H=12 m, 2 units will be installed.	CP: Centrifugal reinforced concrete pipe. HDPE: High density polyethylene pipe. HDPE shows inner/outer diameter.
4. Rehabilitation of Screen Facilities and Detailed Survey of Siphon Structure	To rehabilitate the screen facilities (2 units) at Caballeria, and to conduct detailed surveys on physical conditions of siphon structures to prepare rehabilitation plans.	
5. Rehabilitation of Casablanca Pumping Station	To replace the pump equipment (Q=1.75 m^3/s, H=8 m), 4 units including one unit standby.	
6. Rehabilitation of transmission tunnel and construction of pumping station to discharge the wastewater to the ocean by installation of new ocean outfall sewer	To discharge the wastewater by new ocean outfall sewer with simple repairs of the transmission tunnel, a pumping station, Q=1.75 m^3/s, H=5 m, 4 units including one standby, shall be constructed after the tunnel to mitigate the water head loss. The wastewater can be transmitted gravity flow in the tunnel, thus a simple repair work such as inner lining can be applicable.	
7. Installation of Ocean Outfall Sewers	To install an ocean outfall sewers 300m in length including two diffuser pipes of 140m long.	

Source: JICA Study Team



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 13.1 Sewerage System Master Plan-General Map
JAPAN INTERNATIONAL COOPERATION AGENCY	

13.2.2 PROPOSED NEW SEWERAGE SYSTEM DEVELOPMENT

Figure 13.1 also shows the general map of the proposed new sewerage system development up to the year 2020 in which the Luyanó-Martín Peréz Abajo sewer district is developed up to the year 2020.

(1) Sewers

Lateral sewer required to formulate sewer networks are designed based on the sewer service area, taken into consideration of the land use and availability of existing sewer networks. The following design criteria are set to estimate the sewer networks requirement:

- 100 m/ha (Area where factories and container yards exist and existing sewer networks are available, called Existing Area in the table below)
- 250 m/ha (Residential and commercial area where no sewer networks exist, called New Area)

Table below summarizes the sewer networks requirement.

13.2 Sewer Networks for the Luyanó-Martín Pérez Abajo Sewer District

Related Colector	Serwer Service Area (ha)		Length of New Sewer Networks (m)		
	Existing Area	New Area	Existing Area	New Area	Total
Luyanó-Martin Perez Right	208.3	336.6	20,830	84,150	104,980
Luyanó Left	134.5	374.2	13,450	93,550	107,000
Total	342.8	710.8	34,280	177,700	211,980

Source: JICA Study Team

Table 13.3 shows required Colectors for the development of the Luyanó-Martín Pérez Abajo Sewer District up to 2020, considering construction method. Pumping station in the collector will not be required in the preliminary design.

Table 13.3 Colectors Required in the Luyanó-Martín Pérez Abajo Sewer District

	Pipe	Pipe Dia.		Luyanó-Martín Pérez Colector	Luyanó Left Colector	Total
		Outer	Inner	Length:m	Length:m	Length:m
Open Cut		φ250	φ216	5,000	3,660	8,660
		φ315	φ271	1,980	760	2,740
		φ400	φ343	3,670	1,720	5,390
		φ500	φ427	640	670	1,310
		φ630	φ535	720	560	1,280
		φ800	φ678	970	2,250	3,220
		φ1,000	φ851	0	120	120
		φ1,200	φ1,030	0	2,410	2,410
		Above Main Total		12,980	12,150	25,130
Tunnelling	Insert Pipe	Tunnel Inner Dia.	Insert Pipe Inner Dia.	Length:m	Length:m	Length:m
	Plastic	1,500	φ216	530	0	530
			φ271	0	0	0
			φ343	990	0	990
			φ427	0	0	0
			φ535	0	350	350
			φ678	2,550	330	2,880
			φ851	250	0	250
			φ1,030	1,070	570	1,640
		Above total		5,390	1,250	6,640
	Total by Tunneling Method			5,390	1,250	6,640
Total				18,370	13,400	31,770

Source: JICA Study Team

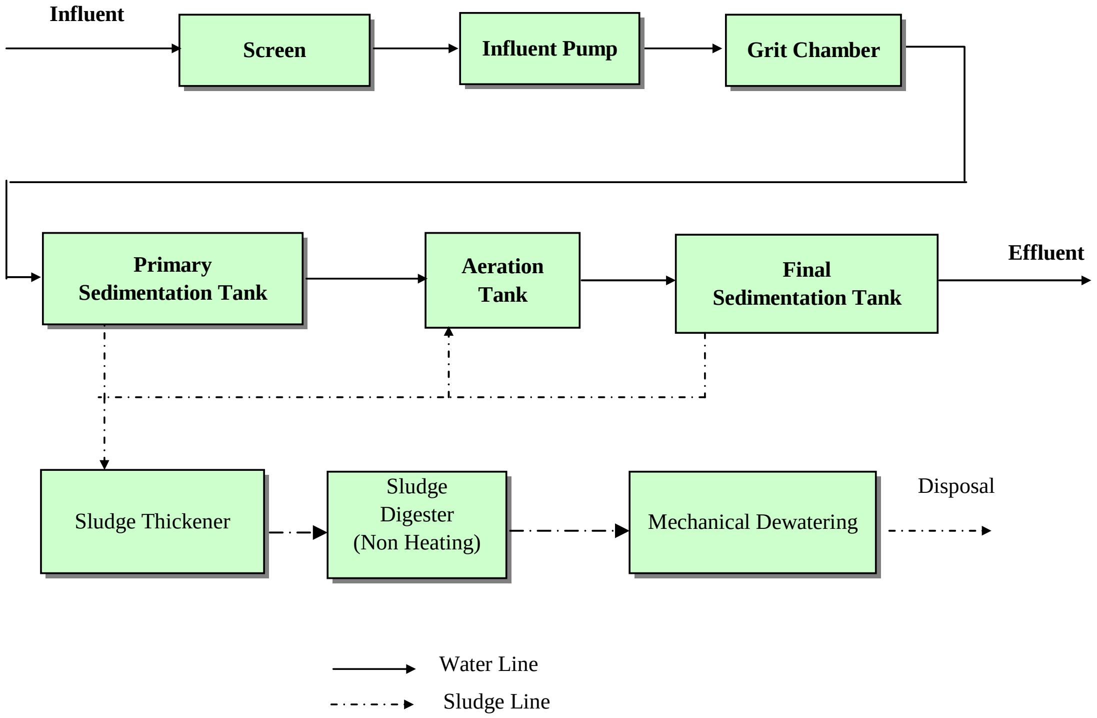
(2) Wastewater Treatment Plant

Table 13.4 shows major facilities to be constructed at the Luyanó Wastewater Treatment Plant. The flow sheet of the wastewater and sludge treatment is illustrated in Figure 13.2.

Table 13.4 Major WWTP Facilities to be Constructed by the Sewerage MP

Facility	Facility Type	Quality	Size, Capacity, SPECS	Remarks
1. Preliminary Facility				
	1.1 Screening chamber	3 units		one unit for GEF
	1) Coarse screen	3 units	Rectangular tank, mLx1.2mW, with manual screen equipment.	/UNDP project
	2) Fine screen	3 units	Rectangular tank, mLx1.2mW, with mechanical screen equipment.	
	1.2 Grit chamber	3 units	Rectangular tank, 10mLx1.5mWx0.7mH, with mechanical grit collector.	
	1.3 Influent pumps			
	1) Submergible pumps	GEF	300mm dia., 9.5 m^3/min	
	2) Submergible pumps	3 units, inc. 1standby	450mm dia., 19.0 m^3/min	
	1.4 Flow measurement	GEF	Parshall flume, 3ft	
2. Primary sedimentation tank	Rectangular tank	6 units	17.8mLx10.0mWx3.0mH, with a chain-and-flight type sludge collector	Surface loading: 50 m^3/m^2/d
3. Aeration tank	Rectangular tank	12 units	47.0mLx5.0mWx5.0mH	BOD-SS Loading: 0.35kgBOD/kgSS/day
	Blower	4 units, inc. 1 standby	300/200mm x 62 m^3/min	
4. Final sedimentation tank	Rectangular tank	6 units	35.5mLx10.0mWx3.0mH, with a chain-and-flight type sludge collector	Surface loading: 25 m^3/m^2/d
5. Return sludge pumps	Screw pumps	6 units	3.1 m^3/min	Average Return ratio of 25%
6. Sludge thickener	Circular type	1 units	12.0mDia.x3.0mH, with mechanical sludge collector	Floor loading: 60kg/m^2/day
7. Sludge digester	Circular radial flow type	3 units	17.8mDia.x8.9mH, without heating system	Retention time: 20days
8. Mechanical dewatering	Belt filter press	4 units	Filter width: 3m	Filter loading rate: 110kg/m/hour

Source: JICA Study Team



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 13.2 Flow Sheet of the Proposed Treatment Facilities of Luyanó WWTP
JAPAN INTERNATIONAL COOPERATION AGENCY	

13.3 OPERATION AND MAINTENANCE PLAN

13.3.1 FACILITIES REQUIRED O/M

The main infrastructure components of both the existing and the proposed new systems are:

- Main and sub-main sewers;
- Branch and lateral sanitary sewers;
- Pumping stations; and
- Wastewater treatment plant.

13.3.2 OPERATION AND MAINTENANCE TASKS

Operation and maintenance (O&M) of the wastewater system means respectively a) operating the system according to designed and documented procedures and standards and b) making sure that the system is kept in good operating condition. Facilities must be adequately maintained, so that the system can efficiently and safely accomplish its intended functions of collecting and conveying wastewater to the treatment plant, treating the wastewater, and disposing of treated wastewater and sludge to the environment.

There are two classes of maintenance: preventive and corrective. Preventive maintenance involves initial inspection of the collection and treatment system and analysis of existing data to identify trouble areas. This provides guidance in developing the type, degree, and frequency of planned preventive maintenance required.

Corrective maintenance means emergency or unplanned maintenance. This can deal with the collapse of an existing sewer; stoppage due to solid waste, roots or grease; or excessive inflow or infiltration. These conditions require immediate action to correct the problem. The objectives are to improve service, reduce emergency occurrences, and to minimize the cost of the preventive maintenance program.

(1) Sewers

A year-round pipeline maintenance program should be developed with the emphasis on preventive maintenance. Under the program, sewers, including maintenance manholes, pumping stations, and special structures, should be regularly inspected and, if necessary, repaired. Locations known to give trouble should be checked at more frequent intervals. Pipeline maintenance crews should clean and maintain large sewer lines, chemically treat sewers for root control, and perform insect and rodent abatement work. At present most sewer maintenance is unplanned, but is estimated to be more frequent than a planned preventive schedule because of continual abuse of the sewerage system by most of the public.

The design of the new sewers should ensure that aerobic conditions are maintained within larger main sewers and appropriate ventilation provided throughout the sewerage system. In order to achieve this general requirement a number of principal ventilating factors will need to be taken into consideration including wind, rise and fall of wastewater in the sewers, respiration of the wastewater, and an understanding of the ventilation ducts in the sewer system.

Cleaning and flushing to remove blockages or build up of deposition of grit and wastewater debris will be required from time to time. As they are a major asset, regular inspection of sewers must be carried out. The risk of structural deterioration should be assessed in relation to ground conditions, the quality of the constructed sewer, and the nature and characteristics of the wastewater. This assessment will provide a base to judge inspection frequencies throughout the overall length of the sewers and the items to be observed and recorded when inspections take place. Inspection of the interceptors should be carried out with the aim to detect trends of deterioration as well as obvious defects that might be observed during an inspection.

It is difficult to recommend a frequency for inspection of the main sewers without appreciating the potential risks more clearly. However, assuming a long asset life, minimum inspection frequencies may be as follows:

1) General walk through the man-entry main sewers once every year.
2) Of the non man-entry sewers a visual inspection of the sewer from the manholes should also be carried out once every year; and
3) Detailed inspection of selected sections once every five years.

Manhole covers should be checked for soundness and security and greased if necessary each time a manhole is lifted. Metalwork such as ladders, step irons, handrails and safety chains should be inspected for soundness and security. The general conditions of the manhole shaft, landings and benching should be inspected for defects. The manholes should be inspected at least once a year until a pattern of recorded information is built up when the frequency can be reviewed.

(2) Pumping Stations

The security of power supply to pumping stations is critical, while electrical, mechanical and instrumentation equipment plus structural and building components require regular inspection and maintenance. As there are many items of equipment to be inspected, all of which are important, a detailed planned maintenance program should be prepared and mounted on display within the control panels of any small local district stations and within the superstructure of the larger pumping stations. The key points from electrical and mechanical manuals should be identified before the station is commissioned.

For removing blockages, grit and sediment, high pressure water jetting and/or vacuum systems can be utilized from fixed or mounted plant to extract the material from the station wet well.

In pumping stations, screens, wetwells and grit chambers will be the major sources of odors. Wastewater screenings should be kept in closed containers until they are transported to a landfill for burial or dewatered and incinerated. These precautions can prevent the release of odors from sulfur- and nitrogen-bearing organic compounds such as mercaptans, and indoles and skatoles, respectively.

Wetwells frequently contain or receive septic wastewater. In addition to hydrogen sulfide being released, odors evolve from grease deposits on walls and the liquid surface. The walls should be cleaned and the scum removed and placed in covered containers to be disposed of along the screenings. Wetwells should be flushed at least weekly to prevent deposition of solids that may become anaerobic and produce odorous gases.

In larger pumping stations, grit chambers will be equipped ahead of pumps. They may be cleaned manually or mechanically. Grit washing may be necessary to produce grit that is sufficiently free of organic materials so that odors are minimized both in plant and at the final grit disposal site. It is important to clean units promptly when they are removed from service so that wastewater and solids do not become septic and generate odors.

(3) Wastewater Treatment Plants

To help prevent and control airborne pollutants and thereby reduce odor, the following general measures should be considered in the detailed design and operation and maintenance stages:

- Regular and careful cleaning, including frequent removal of slime, scum, screenings and grit accumulations and regular inspection and maintenance of all plant structures.
- Maintaining adequate levels of dissolved oxygen by aeration.
- Preventing sludge accumulation or aging by maintaining frequent solids withdrawals, adequate mixing in tanks, sufficient velocity of flow, or placing smooth transitions in structures to eliminate "dead" pockets.
- Placing potentially odorous units such as sludge dewatering equipment, sludge holding tanks, etc., in structures with forced ventilation; placing a forced ventilation over the odorous unit.
- Preventing overloading by recirculating, equalizing flow, or providing overflow units.

13.4 STAGED IMPLEMENTATION PROGRAM

13.4.1 GENERAL IMPLEMENTATION SCHEDULE

A staged construction of the proposed sewerage system components will spread capital expenditures over an extended period of years. An entire 15-year sewerage implementation program is proposed for realization of the proposed sewerage plan up to the year 2020 as shown in Figure 13.3. The implementation program will be divided into three consecutive construction stages, starting at the earliest in 2006 and ending in 2020.

13.4.2 STAGED SEWERAGE SYSTEM COMPONENT

The sewerage system components to be constructed in each stage are in the followings:

(1) First Stage

1-1) Execution of necessary measures to solve the cross connections in the area related to the Dren Matadero.

1-2) Rehabilitation of the screen facilities at Caballeria.

1-3) Rehabilitation of Casablanca pumping station.

1-4) New construction of the proposed Matadero pumping station.

1-5) New installation of the interconnection pipe between the Colector Cerro and the Matadero pumping station.

1-6) New installation of the pumped main and the Colector Sur Nuevo between the proposed Matadero pumping station to the screen facilities at Caballeria.

1-7) New installation of the proposed Luyanó-Martín Pérez Right Colector.

1-8) New installation of the proposed Luyanó Left Colector.

1-9) New construction of biological secondary wastewater treatment facilities at the same site of GEF/UNDP WWTP (Treatment Capacity of 207 L/s), namely Luyanó WWTP. The total treatment capacity becomes 407 L/s or 35,200 m^3/d.

1-10) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo Sewer District.

1-11) Detailed survey and design work to solve the cross connection problems in the area related to the Dren Matadero.

1-12) Survey on physical conditions of the siphon.

(2) Second Stage

2-1) Execution of necessary measures to solve the cross connections in the area related to the Dren Agua Dulce.

2-2) Rehabilitation of the Colector Sur.

2-3) Construction of the proposed Colector Sur A.

2-4) Construction of the proposed re-pumping station for the Central sewerage system

2-5) Repair works of the transmission tunnel.

2-6) Replacement of the outfall sewer.

2-7) Extension of the Luyanó-Martín Pérez Right Colector.

2-8) Extension of the Luyanó Left Colector.

2-9) Expansion of the biological secondary wastewater treatment facilities at the Luyanó WWTP. The expansion in treatment capacity is 207 L/s, thus the total treatment capacity becomes 614 L/s or 53,100 m^3/d.

2-10) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo sewer districts.

2-11) Detailed survey and design work to solve the cross connection problems in the area related to the area of the Dren Agua Dulce.

(3) Third Stage

3-1) Execution of necessary measures to solve the cross connections in the area related to the Dren Agua Dulce.

3-2) Extension of the Luyanó-Martín Pérez Right Colector.

3-3) Extension of the Luyanó Left Colector.

3-4) Expansion of the biological secondary wastewater treatment facilities at the Luyanó WWTP. The expansion in treatment capacity is 207 L/s, thus the total treatment capacity becomes 821 L/s or 71,000 m^3/d.

3-5) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo sewer district.

13.4.3 PROPOSED IMPLEMENTATION SCHEDULE FOR EACH STAGE PROJECT

The implementation schedule for each stage project is summarized in Figure 13.4 to Figure 13.6.

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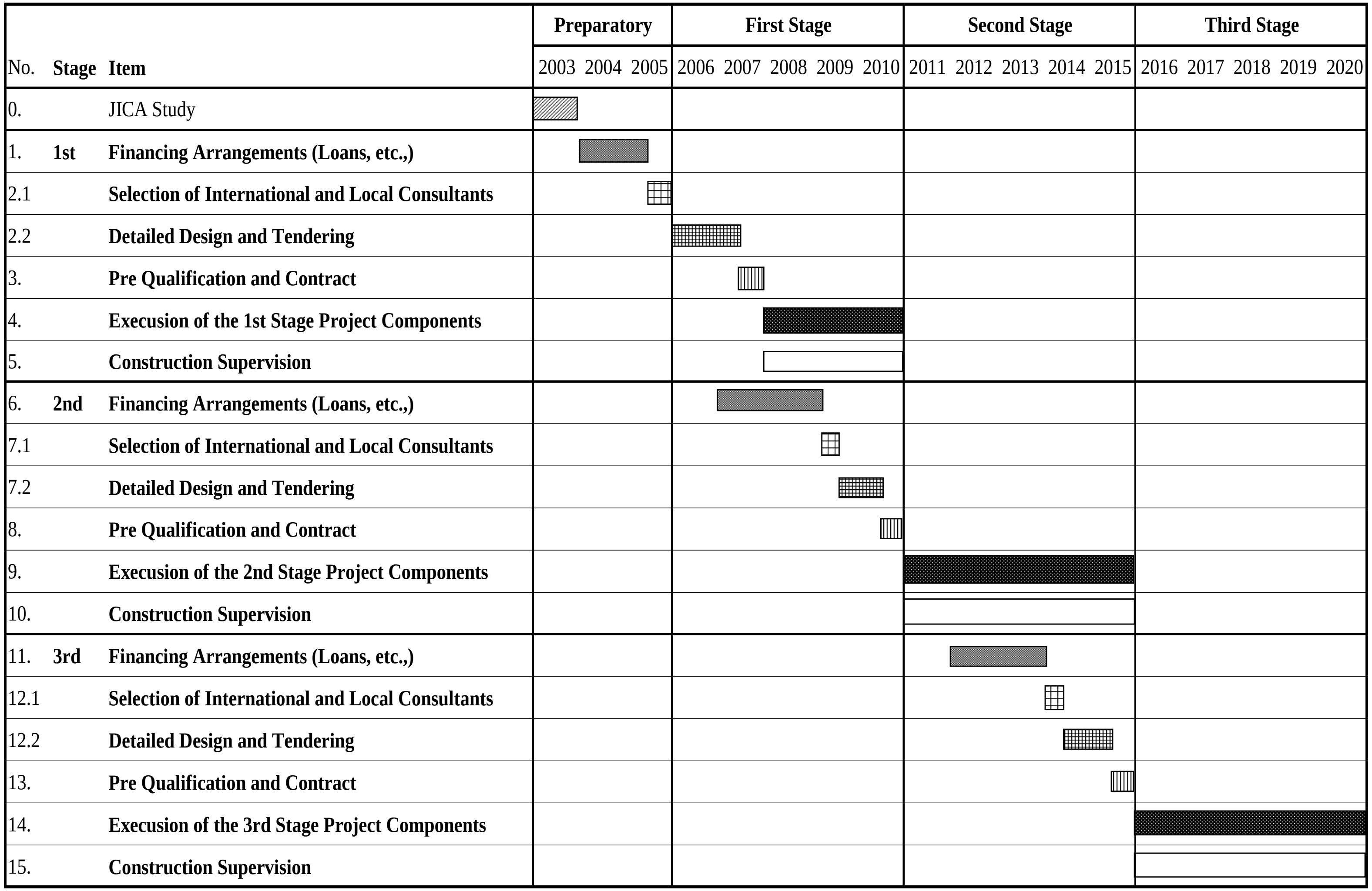

Figure 13.3
General Implementation Schedule

No.	Stage	Item	Preparatory 2003	2004	2005	First Stage 2006	2007	2008	2009	2010
0.		JICA Study								
1.	**1st**	**Financing Arrangements (Loans, etc.,)**								
2.1		**Selection of International and Local Consultants**								
2.2		**Detailed Design and Tendering**								
3.		**Pre Qualification and Contract**								
4.		**Execusion of the 1st Stage Project components**								
		1) Execusion of necessary measures to solve the cross connections in the area related to the Dren Matadero.								
		2) Rehabiliation of the screen facilities at Caballeria.								
		3) Rehabiliation of Casablanca pumping station.								
		4) New construction of the proposed Matadero pumping station.								
		5) New installation of the interconnection pipe between the Colector Cerro and the Matadero pumping station.								
		6) New installation of the pumped main and the Colector Sur Nuevo between the Matadero pumping station and the screen facilities at Caballeria.								
		7) New installation of the proposed Luyanó-Martín Pérez Right Colector								
		8) New installation of the proposed Luyanó Left Colector								
		9) New construction of biological secondary wastewater treatment facilities at the Luyanó WWTP, having the treament capacity of 207 L/s, the total treatement capacity becomes 407 L/s or 35,200 m^3/d.								
		10) New installation of sewer networks and house connections in Luyanó-Martín Pérez sewer district								
		11) Detailed survey and design work to solve the cross connections in the area related to the Dren Matadero.								
		12) Survey on physical conditions of the Siphon								
5.		**Construction Supervision**								

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Figure 13.4
Proposed Implementation Schedule for First Stage Project

No.	Stage	Item	First Stage					Second Stage				
			2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
6.	**2nd**	**Financing Arrangements (Loans, etc.,)**										
7.1		**Selection of International and Local Consultants**										
7.2		**Detailed Design and Tendering**										
8.		**Pre Qualification and Contract**										
9.		**Execusion of the 2nd Stage Project Components**										
		1) Execusion of necessary measures to solve the cross connections in the area related to the Dren Agua Dulce.										
		2) Rehabilitation of the Colector Sur.										
		3) Construction of the proposed Colector Sur A										
		4) Construction of the proposed Re-pumping Station for the Central sewerage system.										
		5) Repair works of the transmission tunnel.										
		6) Replacement of th outfall sewer.										
		7) Extension of the Luyanó-Martín Pérez Right Colector.										
		8) Extension of the Luyanó Left Colector.										
		9) Expansion of the biological secondary wastewater treatment facilities at the Luyanó WWTP. The expasion of the treatment capacity is 207 L/s, thus the total treatment capacity becomes 614 L/s or 53,100 m^3/d.										
		10) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo sewer district.										
		11) Detailed survey and design Work to solve the cross connections in the area related to the Dren Agua Dulce.										
10.		**Construction Supervision**										

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Figure 13.5
Proposed Implementation
Schedule for Second stage Project

No.	Stage	Item	Second Stage 2011	2012	2013	2014	2015	Third Stage 2016	2017	2018	2019	2020
11.	**3rd**	**Financing Arrangements (Loans, etc.,)**										
12.1		**Selection of International and Local Consultants**										
12.2		**Detailed Design and Tendering**										
13.		**Pre Qualification and Contract**										
14.		**Execusion of the 3rd Stage Project components**										
		1) Execusion of necessary measures to solve the cross connections in the area related to the Dren Agua Dulce.										
		2) Extension of the Luyanó-Martín Pérez Right Colector										
		3) Extension of the Luyanó Left Colector										
		4) Expansion of the biological secondary wastewater treatment facilities at the Luyanó WWTP. The expasion of the treatment capacity is 207 L/s, thus the total treatment capacity becomes 821 L/s or 71,000 m^3/d.										
		5) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo Sewer District										
15.		**Construction Supervision**										

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THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

Figure 13.6 Proposed Implementation Schedule for Third Stage Project

13.5 INSTITUTIONAL STRENGTHENING

13.5.1 GENERAL

(1) INRH

The governmental agency responsible for the water and sewerage sector, INRH, was first created in 1962 by the Revolutionary Government as an organization with the responsibility of carrying out the government's policy on the use of water resources in terms of the economic and social development of the Revolution.

There were some institutional changes in 1969 and 1977, and then in 1989, by Ordinance 114, INRH was confirmed as the leading institution of the central government to direct, execute and control the application of government's policy related to the hydraulic resources of Cuba. INRH is a viable institution and does not require any strengthening.

The link between INRH and the water and sewerage corporations is clear and direct in that INRH controls these enterprises through its managerial system as shown in Figure 7.4. In all cases INRH, on behalf of government, is the owner of assets, with the enterprises being responsible for operation and maintenance. Close liaison is maintained with the water and sewerage enterprises through the provincial delegations. Hence, in the case of Ciudad de la Habana, liaison is through DPRH/Havana city.

(2) Water and Sewerage Corporations

Aqueducto del Este is a wholly Cuban enterprise and enjoys the full support of INRH. Aguas de la Habana is a mixed enterprise with a strong partnership between INRH and Aguas de Barcelona, the latter being responsible for the management, operation and maintenance under a concession agreement. Since it is likely that the service area of Aguas de la Habana will be extended to include Acueducto del Este in the near future, the institutional situation with the water and sewerage corporation, Aguas de la Habana, under a long term concession agreement does not give rise to any institutional concerns.

(3) CITMA

CITMA is the governmental agency in charge of environmental policy and management. Unlike INRH, CITMA does not have any significant income other than the monetary appropriations through government. Regarding marine waters and resources, environmental matters are also the responsibility of other ministries and institutions as shown in Figure 3.10, the ministries being MINAG (mangrove areas), MIP (marine ecosystem) and MINTRANS (port activities).

In addition, the Environmental Law (No. 81) also requires CITMA to combine its activities with the Ministries of Tourism, Economy and Planning, INRH, among others, and the government agencies of the Popular Power.

In the Focus Group discussions in November 2002, the pollution problems of the bay noted by the participants included lack of environmental information and education, lack of finance, absence of a centralized port authority, lack of laws and decrees and enforcement of the law, and lack of representatives of the environment within industries. At the environmental education workshop held in February 2003, some of these points were raised again.

It would seem therefore that due to the complexity of cooperation and liaison with many other government entities there is a need to look closer at the financing and institutional system of CITMA during the feasibility stage. There may be a need for strengthening the administrative and executive capacity of CITMA.

In addition, the purpose of Law No. 81 is to establish the legal principles to govern environmental policy and the basic legal requirements to regulate environmental management. Whilst it is acknowledged that decrees and regulations have subsequently been issued, more laws and regulations in the environmental sector are required to strengthen the basic law and to ensure enforcement, bearing in mind the economic constraints particularly as regards industry.

(4) MINTRANS & GTE

With regard to the operation of Havana Bay, MINTRANS plays a significant role, and the State Working Group (GTE) has the role of strengthening state inspection activities for the security, functioning and cleaning up of the Bay. As shown in section 7.2.2 of this report, GTE, CIMAB, CITMA, CENHICA and EAH are all involved in water quality and contamination of the Bay and its feeder rivers. As suggested in section 10.4 of this report, it is recommended that GTE receive sufficient funding to take responsibility for an integrated water quality data base.

It is further recommended that GTE coordinate the environmental functions of MINAG, MINSAP and MIP within the Bay, to strengthen its position as the leading group responsible for the environment of the Bay. However, such strengthening does not provide the whole solution as there is still the important issue of the industries on the perimeter of the Bay that continue to discharge pollutants directly into the Bay.

At the Focus Group discussions, the session on planning for problem solving, cited MINBAS as the sector that should in charge of hydrocarbon pollution, yet MINBAS does not appear to be within the institutional framework regarding pollution of the bay. The point was also made that there is no centralized port authority which would be able to draw together all of the stakeholders of the bay.

It is suggested that GTE plays a greater role in the control of this pollution, in addition to monitoring the water quality. It is recognized that much of the pollution problem is a function of economic constraints rather than a lack of will to enforce the law. GTE's financing and institutional structure should be further discussed and investigated during the feasibility stage.

13.5.2 SEWERAGE SYSTEM OPERATION & MAINTENANCE STAFF

(1) General

On the safe assumption that the service area of Aguas de la Habana will be extended to include the area currently under the jurisdiction of Acueducto del Este prior to the commencement of any works under this project, the institution responsible for all operation and maintenance will be Aguas de la Habana.

The mixed enterprise Aguas de la Habana is about three years into its twenty five year concession agreement with Aguas de Barcelona, and has already achieved major improvements in the management of operations and the rehabilitation of the assets. As is the case in most enterprises with participation of the private sector, the initial thrust was to examine and restructure the organization where necessary and to agree new labor conditions and contracts with the employees. In addition the administrative, accounting and communication systems were upgraded using the Aguas de Barcelona corporate applications package.

Operations have been considerably improved with the new communications system and levels of service have been increased, including response time to complaints, continuity of piped water supply and level of chlorination. Improvements will continue, particularly to achieve the target of a 24 hour piped water supply to all customers.

Aguas de Barcelona has a 5 year investment program of US$ 18.7 million and as an example of the achievements of the new entity, in 2001 and 2002, a total of 150km of the water distribution network was rehabilitated representing a little under 10% of the total network requiring rehabilitation. The main areas were Centro Habana, Habana Vieja and Playa. The population benefiting from this work totaled almost 330,000.

Much has been achieved in the first few years of the concession, but it is recognized that there is still much more to do to all of the systems which are old and have been in operation for many years. Rehabilitation works has concentrated mainly on the water supply rather than on the sewerage system for which rehabilitation and extensions are proposed in this study.

All of the personnel detailed in the following sections (2), (3) and (4) are to be stationed at the actual site of the works.

(2) Treatment Plants

The following table shows the new personnel required for the proposed treatment plant:

Table 13.5 New Treatment Plant Personnel

Description	**Stage I No. of Staff**	**Stage II No. of Staff**	**Stage III No. of Staff**
Luyano PTR Main (WWTP)			
Manager	1	1	1
Section Chief – Management	0	0	0
Section Chief – Treatment	1	1	1
Section Chief – Operations	1	1	1
Section Chief – Water Quality	1	1	1
Engineer – Treatment	2	2	2
Engineer – Water Quality	3	3	3
Administrator – Management	1	1	1
Operators – Treatment	2	2	2
Operators – General	9	12	12
Drivers	2	2	2
Workers	4	4	4
Totals	**27**	**30**	**30**

Under the institutional arrangement of the concession, INRH will become the owner of the assets on behalf of the state, and Aguas de la Habana will operate and maintain them. Whilst the new Luyano treatment plant using the activated sludge system will require training of the staff there would be little need for any institutional strengthening. The Management & Training Section of the Human Resources Department should be able to cope with staff training for the additional works.

On the job training will form part of the construction contract, and Aguas de Barcelona, through its management contract within the concession agreement can provide any further specialized training requirements. Aguas de la Habana already operates such plants in Varadero, where it was shown that the Cuban staff has the education level to readily absorb new technology.

(3) Pumping Stations

The following table shows the personnel required for the existing (to be rehabilitated) and proposed pumping stations:

Table 13.6 Pumping Station Personnel

Description	Stage I No. of Staff	Stage II No. of Staff	Stage III No. of Staff
Matadero Pumping station			
Manager	0	0	0
Section Chief – Management	1	1	1
Section Chief – Operations	1	1	1
Engineer	0	0	0
Administrator – Management	1	1	1
Operators – Pumping Plant	8	8	8
Drivers	1	1	1
Workers	2	2	2
Total for Matadero P S	**14**	**14**	**14**
Casablanca Pumping station			
Manager	1	1	1
Section Chief – Management	0	0	0
Section Chief – Operations	1	1	1
Engineer	0	0	0
Administrator – Management	1	1	1
Operators – Pumping Plant	12	12	12
Drivers	1	1	1
Workers	6	6	6
Total for Casablanca P S	**22**	**22**	**22**
Re-Pumping Station			
Manager		0	0
Section Chief – Management		0	0
Section Chief – Operations		1	1
Engineer		0	0
Administrator – Management		1	1
Operators – Pumping Plant		6	6
Drivers		1	1
Workers		3	3
Total for Re – P S	**0**	**12**	**12**

For Matadero and the re-pumping station the usual on the job training will apply at the end of the construction contract, and additional expertise is available from within Aguas de la Habana.

Casablanca is an existing pumping station and there will be no problem in retraining the staff on the new pumping plant. This will be done through on the job training as part of the contract.

(4) Sewers and Drainage

Operation and maintenance of improvements to the central system will be absorbed into the current Sewerage and Drainage Division of Aguas de la Habana. As and when the service area is extended to cover the eastern area, a new division may be set up based on personnel of the Sewerage and Drainage Unit currently under Acueducto del Este. This would then become the Eastern Sewerage and Drainage Base under Aguas de la Habana. None of this work would impact on the institutional system or require any significant staff training.

13.5.3 OTHER HUMAN RESOURCES DEVELOPMENT PLANS

(1) Headquarter of Executing Agency

As already stated, it is likely that the mixed enterprise Aguas de la Habana will expand and take over the service area of Acueducto del Este in the near future and certainly well before the proposed commencement of this project. Aguas de la Habana will therefore be the executing agency, under the jurisdiction of INRH.

Aguas de la Habana has a Human Resources Department with a section devoted to Management and Training. The need for a Human Resources Development program to manage the proposed project can be provided through this department. Since management and training forms part of the concession agreement there would not be any problem for the executing agency to draw up a human resources development plan.

A significant part of the overall scheme is the projects comprising construction of sewer networks and house connections commencing in the Luyanó-Martín Pérez Abajo sewer district.

The headquarters departments required for the new sewer district development are as follows:

a) Management and Services Department

For the new sewer district development, more management and services personnel will be required. A decision on as to whether a new department will be formed or the personnel absorbed into the existing institutional framework may be made by the executing agency (see figure 7.5). Nonetheless, the number of extra personnel is calculated to be 26 initially, rising to 31, and 32 for the subsequent stages in the following divisions:

Director General	1
General Management	5
Accounting	4
Billing Management (Collection)	9
Personnel	3
Property Affairs	3
Information Management	3
Vehicle Management	4

The implementing agency would have no problem in making the necessary institutional changes for this headquarters requirement.

b) Construction Department

This new headquarters department is required for the self projects comprising construction of sewer networks and house connections in the eastern area. Since there is little or no expertise in the type of work outside of the water and sewerage corporations, it may be assumed that Aguas de la Habana will establish a new department for the construction of the sewer network. For the house connections, it should be possible to include community mobilization for unskilled labor works from houses to the branch sewers. This would be a new concept to the current management of Aguas de la Habana but should not pose any institutional problems as successful community involvement in Cuba has been achieved many times in the past.

Construction of the sewer network and installation of house connections is a continuous process throughout all three stages and the personnel required from the beginning totals 31 in the following divisions:

Head of Department	1
General Management	6
Planning Division	4
Design Division	6
Construction division	7
House connection Engineering	7

This new department would come under the overall control of the Construction Division of the existing Technical Department.

c) Operation and Maintenance Department

As the new works come into operation during the staged construction the need for operation and maintenance staff will increase. The number of personnel is calculated to be 20 initially, rising to 25 at the end of the 3rd Stage. The following divisions would be required:

Head of Department	1
General Management	6
Sewer Maintenance	4
Wastewater Treatment Plant	4
Water Quality Monitoring	3
House Connection Services	7

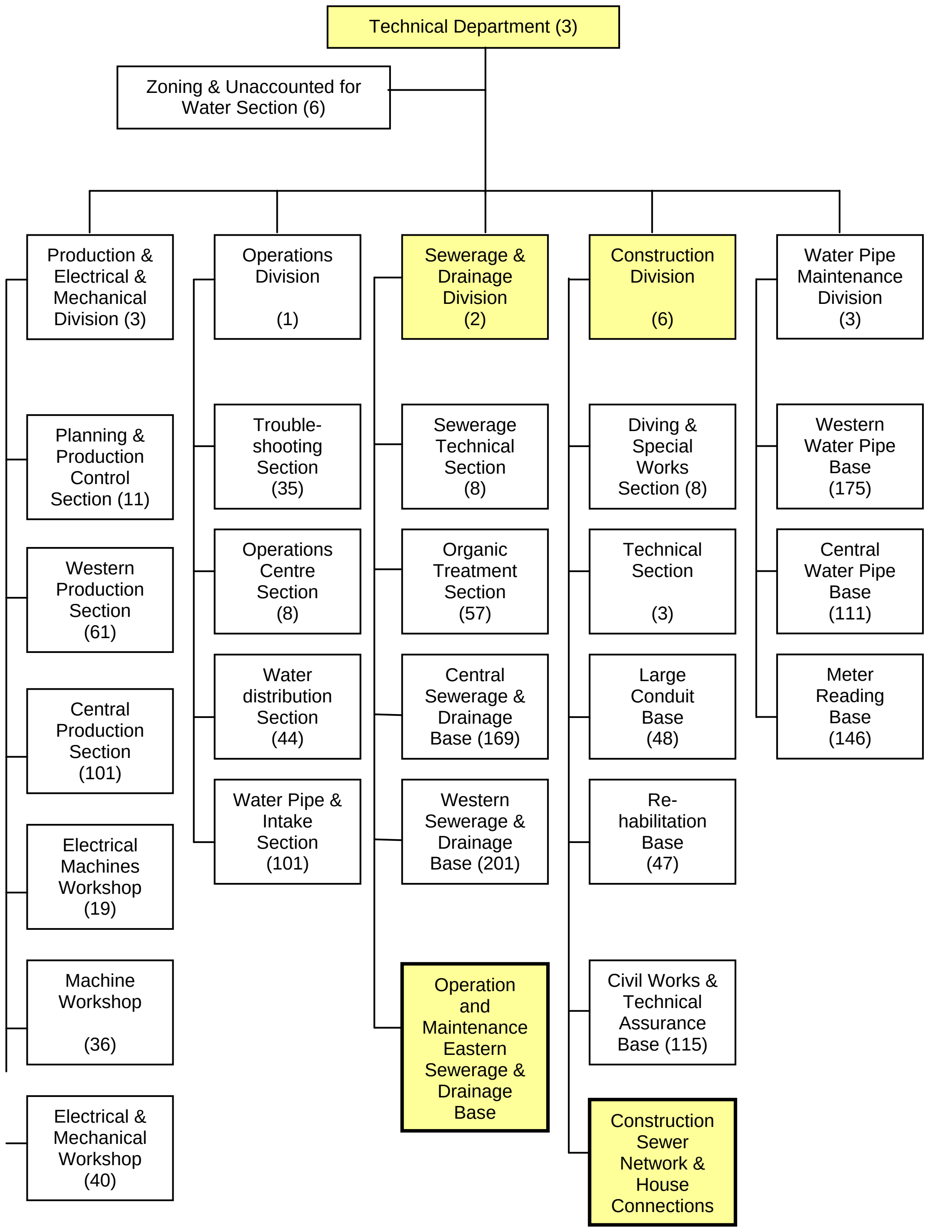
This new department would come under the overall control of the Sewerage and Drainage Division of the existing Technical Department.

d) Sewer Maintenance Branch Offices

There will be a need for two branch offices in the eastern area to maintain close contact with the works and the customers. The number of personnel is calculated to be 24 initially, rising to 48 at the end of the 3rd Stage. The following personnel would be required:

Managers	2
Engineers	8
Administrators	2
Drivers	12
Workers	24

Figure 13.7 shows how the new departments could integrated with the present organization.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 13.7 Organization Chart for additions to the Technical Department of Aguas de la Habana
JAPAN INTERNATIONAL COOPERATION AGENCY	

(2) INRH

Regarding Human Resources Development (HRD), the governmental agency responsible for the Water Supply and Sanitation Sector, INRH has two Centers for Professional Upgrading and Training; the Faustino Perez Hernandez Center in Villa Clara, and the Maximo Gomez Baez Center in Granma. The mission of these centers is to qualify and upgrade both technical and professional staff for all of the entities under the control of INRH, and to prepare executives as well as providing training for young professionals.

In the unlikely event that Aguas de la Habana does not take over the service area currently operated and maintained by Acueducto del Este, INRH has the institutional structure to contribute to human resources development should this be necessary.

(3) Water Quality Monitoring

Water quality monitoring is covered in section 10.4 of this report and it is clear from this section that the current human resources available are more than adequate with a high level of technical competence. Hence, there is no need for any development plans for water quality monitoring.

13.6 CAPITAL INVESTMENT

13.6.1 GENERAL

Capital investment is estimated in accordance with project components and implementation plan of the Sewerage Master Plan for the year 2020: "Project System Components" and "Staged Implementation Programs". The capital investment is estimated based on two cases of project components in order to compare their costs and find the realistic scale of the project from the view point of capital investment.

The Capital investment comprises following compositions and each cost item is estimated.

1) Direct Construction Cost
2) Land Acquisition and Compensation
3) Administrative Expense
4) Engineering Services
5) Physical Contingency

13.6.2 BASIS OF COST ESTIMATE

The capital investment is estimated based on the following conditions.

1) Price Level

The price level of the capital investment is as of 2003.

2) Foreign and Local Currency Portion

The capital investment includes Foreign Currency (F.C.) portion and Local Currency (L.C.) portion. The allocation of F.C. and L.C. is determined applying assumed percentages for each work. Foreign currency is estimated in terms of US Dollar and local currency is estimated in Pesos.

13.6.3 DIRECT CONSTRUCTION COST

(1) Sewers

The construction cost of sewers is estimated based on the capital cost estimate, multiplying the quantity by the unit price:

- Calculate the quantity of the sewer pipes and the civil works required.
- Estimate the unit price based on the Cuban cost estimation system, called “PRECONS” and other examples of practices in the Central American countries and Japan. The unit price also includes cost for common temporary woks, site expenses and overhead expenses.

1) Pipe materials

The designed pipe materials are high density polyethylene for pipes having the inner diameter of 1030mm or less in principle, centrifugal reinforced concrete for the pipes having diameter larger than 1030mm, and ductile iron pipes for pressured or pumped main. These pipes are mainly imported from other countries. The cost of high density polyethylene is based on the Cuban information, but other cost is based on the cost in Japan considering reducing factors such as importing those products from the neighboring countries.

2) Civil work

Pipe installation methods are open cut method and tunneling method. The soil conditions are assumed that clay exists 3m deep from the earth surface and soft rock exists deeper than 3m.

The costs for the following major civil work are estimated: remove pavement, excavation, sheathing, soil moving, dumping waste soil, and backfilling.

(2) Pumping Station and Wastewater Treatment Plant

Four kinds of construction work such as civil work, architectural work, mechanical work and electrical work are estimated separately as follows.

1) Civil wok

The cost is estimated based on the capital cost estimate, multiplying the quantity by the unit price:

- Calculate the quantity of the civil works required.
- Estimate the unit price based on the Cuban cost estimation system, called “PRECONS” and other examples of practices in the Central American countries and Japan. The unit price also includes cost for common temporary woks, site expenses and overhead expenses.

2) Architectural work

The cost is also estimated based on the capital cost estimate:

- Calculate the quantity of the architectural works expressed in vacant volume of m^3.
- Estimate the unit price based actual costs in Cuba and other conditions such as requirements to possess adequate structural strength and high durability.

3) Mechanical and electrical work

The mechanical and electrical equipment required is not available in Cuba in principle therefore, imported from other countries. Therefore, the cost is estimated based on the actual cost in Japan but reduced the costs considering some local costs for equipment installation work, piping work, and wiring work.

13.6.4 INDIRECT CONSTRUCTION COST

1) Land Acquisition and Compensation

The cost for land acquisition and compensation will not be required for the construction of the proposed Luyanó WWTP, Matadero pumping station, Re-pumping station at Playa del Chivo because the proposed sites are belong to the central government.

2) Administrative Expenses

The cost for administrative expenses required by Cuban executing agency, relative government bodies and related agencies for the implementation of the project is estimated at 3 % of the local portion of direct construction cost.

3) Engineering Services

The cost of engineering services is estimated separately for the rehabilitation and improvement works and for the new construction works. This service includes detailed surveys on cross connections, physical conditions of the siphon, and brief training program for operators for new WWTP as well as basic design, detail design, preparation of tender documents and construction supervision.

The cost of engineering services for the rehabilitation and improvement works of Central sewerage system is estimated at 12 % of the total direct construction cost and that for the new works is estimated at 10 % of the total direct construction cost.

4) Physical Contingency

The physical contingency is estimated at 10 % of the total direct construction cost.

13.6.5 CAPITAL INVESTMENT

Table 13.7 shows the total cost required to implement the proposed sewerage system component.

Table 13.8 to 13.10 summarizes the required cost to implement the component for each stage.

Table 13.11 and 13.12 summarizes the detailed capital investment for the improvement of the Central sewerage system and the development of the Luyanó-Martín Pérez Abajo sewer district.

Table 13.7 Total Capital Investment Cost Required to Implement the Proposed Sewerage Master Plan

Unit: FC (x 1,000 US$) and LC (x 1,000 Pesos)

No.	Item	Existing Sewer District Central System		New Sewer District Luyanó-Martín Pérez Abajo		Required Projet Cost Total	
		FC	LC	FC	LC	FC	LC
1.	**Sewers**	19,525	12,367	60,010	40,006	79,535	52,373
2.	**Pumping System**	7,881	4,117	0	0	7,881	4,117
3.	**WWTP**	0	0	20,816	9,711	20,816	9,711
	Total Direct Cost	27,406	16,484	80,826	49,717	108,232	66,201
1.	**Land Acquisition and Compensation**	0	0	0	0	0	0
2.	**Administrative Expenses**	0	495	0	1,491	0	1,986
3.	**Engineering Services**	3,018	1,830	8,083	4,972	11,101	6,802
4.	**Physical Contingency**	2,741	1,648	8,083	4,972	10,824	6,620
	Total Indirect Cost	5,759	3,973	16,166	11,435	21,925	15,408
	Total Capital Cost at 2003 Price	33,165	20,457	96,992	61,152	130,157	81,609

Source : JICA Study Team

Table 13.8 Total Capital Investment Cost for the First Stage Project

Unit: FC (x 1,000 US$) and LC (x 1,000 Pesos)

No.	Item	Existing Sewer District Central System		New Sewer District Luyanó-Martín Pérez Abajo		First Stage Project Total	
		FC	LC	FC	LC	FC	LC
1.	**Sewers**	6,619	4,411	23,964	15,976	30,583	20,387
2.	**Pumping System**	5,669	2,935	0	0	5,669	2,935
3.	**WWTP**	0	0	6,891	3,273	6,891	3,273
	Total Direct Cost	12,288	7,346	30,855	19,249	43,143	26,595
1.	**Land Acquisition and Compensation**	0	0	0	0	0	0
2.	**Administrative Expenses**	0	220	0	577	0	797
3.	**Engineering Services**	1,352	810	3,086	1,925	4,438	2,735
4.	**Physical Contingency**	1,229	735	3,086	1,925	4,315	2,660
	Total Indirect Cost	2,581	1,765	6,172	4,427	8,753	6,192
	Total Capital Cost at 2003 Price	14,869	9,111	37,027	23,676	51,896	32,787

Table 13.9 Total Capital Investment Cost for the Second Stage Project

Unit: FC (x 1,000 US$) and LC (x 1,000 Pesos)

No.	Item	Existing Sewer District Central System		New Sewer District Luyanó-Martín Pérez Abajo		Second Stage Project Total	
		FC	LC	FC	LC	FC	LC
1.	**Sewers**	9,480	5,672	14,765	9,843	24,245	15,515
2.	**Pumping System**	2,212	1,182	0	0	2,212	1,182
3.	**WWTP**	0	0	7,709	3,614	7,709	3,614
	Total Direct Cost	11,692	6,854	22,474	13,457	34,166	20,311
1.	**Land Acquisition and Compensation**	0	0	0	0	0	0
2.	**Administrative Expenses**	0	206	0	404	0	610
3.	**Engineering Services**	1,255	746	2,247	1,346	3,502	2,092
4.	**Physical Contingency**	1,169	685	2,247	1,346	3,416	2,031
	Total Indirect Cost	2,424	1,637	4,494	3,096	6,918	4,733
	Total Capital Cost at 2003 Price	14,116	8,491	26,968	16,553	41,084	25,044

Table 13.10 Total Capital Investment Cost for the Third Stage Project

Unit: FC (x 1,000 US$) and LC (x 1,000 Pesos)

No.	Item	Existing Sewer District Central System		New Sewer District Luyanó-Martín Pérez Abajo		Third Stage Project Total	
		FC	LC	FC	LC	FC	LC
1.	**Sewers**	3,426	2,284	21,281	14,187	24,707	16,471
2.	**Pumping System**	0	0	0	0	0	0
3.	**WWTP**	0	0	6,216	2,824	6,216	2,824
	Total Direct Cost	3,426	2,284	27,497	17,011	30,923	19,295
1.	**Land Acquisition and Compensation**	0	0	0	0	0	0
2.	**Administrative Expenses**	0	69	0	510	0	579
3.	**Engineering Services**	411	274	2,750	1,701	3,161	1,975
4.	**Physical Contingency**	343	228	2,750	1,701	3,093	1,929
	Total Indirect Cost	754	571	5,500	3,912	6,254	4,483
	Total Capital Cost at 2003 Price	4,180	2,855	32,997	20,923	37,177	23,778

Table 13.11 Capital investment for the Central System Improvement

Unit: FC (x 1,000 US$) and LC (x 1,000 Pe

No.	Component	Project Cost		First Stage		Second Stage		Third Stage	
		FC	LC	FC	LC	FC	LC	FC	LC
1.1	New Installation of Pumped Main, Colector Sur Nuevo, and Interconnection Pipe	3,139	2,091	3,139	2,091	0	0	0	0
1.2	Solution Measures of the Cross connections	7,237	4,824	3,480	2,320	1,357	904	2,400	1,600
1.3	Rehabilitation of the Colector Sur	1,956	1,304	0	0	1,956	1,304	0	0
1.4	New Construction of Colector Sur A	3,271	2,181	0	0	3,271	2,181	0	0
1.5	Replacement of Inadequate Colectors	1,848	1,232	0	0	822	548	1,026	684
1.6	Repair of the Transmission Tunnel	174	260	0	0	174	260	0	0
1.7	Replacement of the Ocean Outfall Sewer	1,900	475	0	0	1,900	475	0	0
1.	Sub-total of the Sewers	19,525	12,367	6,619	4,411	9,480	5,672	3,426	2,284
2.1	Rehabilitation of the Screen Facilities	190	87	190	87	0	0	0	0
2.2	New Construction of Matadero Pumping Station	2,971	1,490	2,971	1,490	0	0	0	0
2.3	Rehabilitation of the Casablanca Pumping Station	2,508	1,358	2,508	1,358	0	0	0	0
2.4	New construction of the Re-pumping Station	2,212	1,182	0	0	2,212	1,182	0	0
2.	Sub-total of the Pumping Station	7,881	4,117	5,669	2,935	2,212	1,182	0	0
	Total Direct Cost	27,406	16,484	12,288	7,346	11,692	6,854	3,426	2,284
1.	Land Acquisition and Compensation	0	0	0	0	0	0	0	0
2.	Administrative Expenses	0	495	0	220	0	206	0	69
3.	Engineering Services	3,018	1,830	1,352	810	1,255	746	411	274
4.	Physical Contingency	2,741	1,648	1,229	735	1,169	685	343	228
	Total Indirect Cost	5,759	3,973	2,581	1,765	2,424	1,637	754	571
	Total Capital Cost at 2003 Price	33,165	20,457	14,869	9,111	14,116	8,491	4,180	2,855

Source: JICA Study Team

Table 13.12 Capital investment for the New Sewerage System Development

Unit: FC (x 1,000 US$) and LC (x 1,000 Pesos

No.	Component	Project Cost		First Stage		Second Stage		Third Stage	
		FC	LC	FC	LC	FC	LC	FC	LC
1.1	**Luyanó-Martín Pérez Right Colector and sewer networks**	35,303	23,535	19,234	12,822	7,554	5,036	8,515	5,677
1.2	**Luyanó Left Colectors and sewer networks**	24,707	16,471	4,730	3,154	7,211	4,807	12,766	8,510
1.	**Sub-total of the Sewers**	60,010	40,006	23,964	15,976	14,765	9,843	21,281	14,187
2.	**WWTP**	20,816	9,711	6,891	3,273	7,709	3,614	6,216	2,824
	Total Direct Cost	80,826	49,717	30,855	19,249	22,474	13,457	27,497	17,011
1.	**Land Acquisition and Compensation**	0	0	0	0	0	0	0	0
2.	**Administrative Expenses**	0	1,491	0	577	0	404	0	510
3.	**Engineering Services**	8,083	4,972	3,086	1,925	2,247	1,346	2,750	1,701
4.	**Physical Contingency**	8,083	4,972	3,086	1,925	2,247	1,346	2,750	1,701
	Total Indirect Cost	16,166	11,435	6,172	4,427	4,494	3,096	5,500	3,912
	Total Capital Cost at 2003 Price	96,992	61,152	37,027	23,676	26,968	16,553	32,997	20,923

Source: JICA Study Team

13.6.6 OPERATIONAL AND MAINTENANCE COST

The O/M cost comprises following compositions and each cost item is estimated.

1) Personnel Cost
2) Power Cost
3) Chemical Cost

The O/M cost required to operate the proposed sewerage system components is summarized in Table 13.13.

(1) Personnel Cost

Personnel cost is estimated in terms of local currency of Cuban Pesos. The unit cost is based on the actual cost required for each classified personnel. The personnel cost is estimated for the proposed personnel necessary to construct and operate and maintain the proposed sewerage facilities. The number and classification of the proposed personnel were described in the section of 13.5.2 and 13.5.3. The calculation sheet is given in the appendix 12.

(2) Power Cost

Power cost is estimated in terms of local currency of Cuban Pesos. Power cost is estimated for the existing Casablanca pumping station, the Matadero pumping station and the Re-pumping station at Chivo, and the Luyanó WWTPs. The required power cost depends on the wastewater volume pumped which is estimated based on the assumption of sewerage coverage. The detailed cost information is referred to the appendix 12.

(3) Chemical Cost

Chemical cost is estimated based on volume of chemicals required for de-watering of sludge produced in WWTP by mechanical dewatering facilities. Since the chemicals will be imported the chemical cost is estimated in terms of foreign currency of US Dollars. The cost estimation is given in the appendix 12.

Table 13.13 Annual Operation and Maintenance Cost for the proposed sewerage system components of the Sewerage MP

Year	Annual Personnel Cost (x 1,000 Pesos)							Annual Power Cost (x 1,000 Pesos)						Chemical	O/M Cost Total	
	Head Quarter	Improvements of the Central system				Luyanó WWTP	Total	Improvements of the Central system				Luyanó WWTP	Total	Cost (x 1,000 USD)	Posos	USD
		Matadero PS	Casablanca PS	Chivo Re-PS	Sub-total			Madero PS	Casablanca PS	Chivo Re-PS	Sub-total			Luyanó WWTP	x 1,000	x 1,000
2011	540	73	107	0	180	145	865	53	180	0	233	44	277	17	1,142	17
2012	540	73	107	0	180	145	865	53	180	0	233	51	284	33	1,149	33
2013	540	73	107	0	180	145	865	138	180	0	318	56	374	46	1,239	46
2014	540	73	107	0	180	145	865	138	180	0	318	59	377	54	1,242	54
2015	540	73	107	0	180	145	865	138	180	0	318	63	381	62	1,246	62
2016	657	73	107	57	237	162	1,056	53	184	118	355	101	456	83	1,512	83
2017	657	73	107	57	237	162	1,056	53	184	118	355	111	466	104	1,522	104
2018	657	73	107	57	237	162	1,056	53	184	118	355	119	474	121	1,530	121
2019	657	73	107	57	237	162	1,056	53	184	118	355	124	479	133	1,535	133
2020	657	73	107	57	237	162	1,056	53	184	118	355	130	485	146	1,541	146
2021	692	73	107	57	237	162	1,091	53	187	119	359	164	523	166	1,614	166
2022	692	73	107	57	237	162	1,091	53	187	119	359	175	534	187	1,625	187
2023	692	73	107	57	237	162	1,091	53	187	119	359	184	543	204	1,634	204
2024	692	73	107	57	237	162	1,091	53	187	119	359	190	549	216	1,640	216
2025	692	73	107	57	237	162	1,091	53	187	119	359	197	556	229	1,647	229
2026	692	73	107	57	237	162	1,091	53	187	119	359	199	558	233	1,649	233
2027	692	73	107	57	237	162	1,091	53	187	119	359	201	560	237	1,651	237
2028	692	73	107	57	237	162	1,091	53	187	119	359	204	563	241	1,654	241
2029	692	73	107	57	237	162	1,091	53	187	119	359	206	565	245	1,656	245
2030	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249
2031	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249
2032	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249
2033	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249
2034	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249
2035	692	73	107	57	237	162	1,091	53	187	119	359	208	567	249	1,658	249

Source:JICA Study Team

13.7 PROJECT EFFECTS ON WATER QUALITY IMPROVEMENT

13.7.1 POLLUTION LOAD REDUCTION

Implementation of the Projects proposed in the M/P will cover Central System and part of the New Sewerage System i.e. Luyanó-Martin Perez Abajo Sewer District with secondary treatment. Table 13.14 shows the estimated pollution load reduction with the implementation of M/P in the New Sewerage System and its comparison to the potential pollution load reduction if secondary sewage treatment is implemented in all sewer districts in the New Sewerage System.

M/P for the New Sewerage System covers approximately 51% of all the load generated in the New Sewerage System and the reduction in the M/P is also approximately 51% of the potential reduction in all Sewer Districts when Sewerage System is implemented in all districts which includes the reduction by on-going GEF/UNDP Project. Excluding the reduction by GEF/UNDP Project, the reduction by projects under the M/P is 39% of the potential reduction.

Table 13.14 Pollution Load Reduction with the M/P of New Sewerage Development

Item	Load			
	BOD_5	T-N	T-P	SS
New Sewerage System-All Sewer Districts				
Estimated load generation, kg/d	22,794	3,481	892	22,794
Estimated load reduction (A), kg/d	20,515	522	134	20,515
New Sewerage System-M/P Area				
Estimated load generation, kg/d	11,723	1,779	460	11,723
Estimated load reduction by GEF/UNDP (B), kg/d	2,546	64	17	2,546
Estimated load reduction by M/P (C), kg/d	8,005	203	52	8,005
Total estimated load reduction by GEF and M/P, kg/d	10,551	267	69	10,551
C/A	39%	39%	39%	39%
(B+C)/A	51%	51%	51%	51%

In the Central System, implementation of the M/P will ensure that 100% of pollution load generated will be diverted to Playa del Chivo. Table 13.15 shows the pollution load generated in the Central System and that being discharged through the drains due to cross-connections based on measured load.

Table 13.15 Pollution Load Reduction with the M/P of Central Sewerage Improvement

Item	Load			
	BOD_5	T-N	T-P	SS
Central Sewerage System				
Estimated load generation, kg/d	31,733	4,721	1,225	31,733
Estimated load reduction based on generation	100%	100%	100%	100%
Load reduction based on measured load through drains due to cross-connections*	17,032	1,284	2,303	7,244

* - Total of that discharged through drains Matadero, Agua Dulce and San Nicholas and It should be noted that the existing Central System covers areas outside the bay basin. Wastewater generated in the areas outside bay basin will be discontinued.

13.7.2 WATER QUALITY IMPROVEMENT

Tables 13.16 and 13.17 show the results of estimate for wastewater discharge to the Bay for existing conditions (measured) and that with the implementation of M/P based on the assumption described in Section 11.6.

Table 13.16 Case 1- Existing Conditions (year 2002)

Sewer District	Source (River System)	Flow	BOD_5	T-N	T-P	SS
		m^3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	114,826	9,784	1,627	732	3,875
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	62,122	1,518	245	55	1066
Martin Pérez-arriba						
Tadeo	Tadeo	8,517	1,812	104	46	98
Existing (Central)						
San Nicholas	San Nicholas	8,554	1,320	145	79	352
Matadero	Matadero	77,760	8,942	610	1,053	3,650
Agua Dulce	Agua Dulce	43,200	6,770	529	1,171	3,242
Refinery		*6,406*	*21,723*	*54*	*1*	
Total		321,385	51,869	3,314	3,137	12,283

Table 13.17 Case M/P

Sewer District	Source (River System)	Flow	BOD_5	T-N	T-P	SS
		m^3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	167,122	5,840	2,191	562	6,873
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	70,842	5,143	942	204	7,892
Martin Pérez-arriba						
Tadeo	Tadeo	10,635	1,934	307	76	1,945
Existing (Central)						
San Nicholas	San Nicholas					
Matadero	Matadero					
Agua Dulce	Agua Dulce					
Refinery		*6,406*	*21,723*	*54*	*1*	
Total		255,005	34,640	3,494	842	16,710

Water quality simulation results show that with the implementation of M/P, DO levels in Atares will improve to Class F (minimum 2 mg/L) from the existing level below Class F. This will be the first step in improving the water quality of the bay towards the water quality goal of 3 mg/L of DO when secondary treatment is provided (Case 4) to all the wastewater generated in the New Sewerage System area for which results of simulation results are as shown in Figure 11.1 through Figure 11.5. Complete results are described in Appendix 7 Development of Water Quality Simulation Model for Havana Bay.

13.8 FINANCING CAPACITY

13.8.1 PAYERS OF THE PROJECT

Two principles can be used in determining who should pay the cost of a project. They are the polluter pays principle and the beneficiary pays principle. Suppose that a mining company operates at the upstream of a river, discharging toxic materials into the river. And there are residents at the downstream who drinking the river water. A machine to remove the toxic substances from the river water will be obviously necessitated. In the project to install such a machine, the polluter is defined as the mining company. And the beneficiary is the people at the downstream. The polluter pays principle requires the mining company to bear the cost of installing, operating, and maintaining the machine, whereas under the beneficiary pays principle the residents have to bear those costs.

In a sewerage project to remedy the contamination of the Havana Bay, there exist various polluters and beneficiaries. In many cases, polluters also have an aspect of beneficiary. Major parties concerned in a possible sewerage project are identified and their characteristics are summarized in Table 13.18.

(1) Central Government

The central government is a polluter as well as a beneficiary. Various governmental offices in the study area are discharging wastewater into sewer, which is finally discharged into the bay with or without proper treatment. If a sewerage project materializes, the central government will benefit from the project. Because the demands created by the project and the resultant cleaner environment of the bay will affect positively activities of relevant industries, by which the central government can expect more tax revenues from and less subsidy expenditure to those industries. Possible reduction of morbidity of environment related diseases in the bay area will also lead to less medical expenditure by the government.

(2) Provincial Government of the City of Havana

The provincial government of the City of Havana is an administrative body that is positioned under the Central Government and has administrative power in the study area. It is also considered as polluter as well as beneficiary.

(3) Municipal Government

The administrative body under the provincial government of the City of Havana is municipal governments. There are 10 municipalities in the study area, namely La Habana Vieja, Regla, La Habana del Este, Plaza de la Revolución, Centro Habana, Guanabacoa, San Miguel del Padrón, Diez de Octubre, Cerro, and Arroyo Naranjo. Those municipal governments are also polluters as well as beneficiaries.

(4) Household

Households in the study area are obviously polluters even though most of them are connected to sewer or using septic tanks. Like the government offices, wastewater of the households is finally discharged into the bay with or without proper treatment. The people currently enjoy various activities in the bay area such as stroll, fishing, swimming, jogging, eating, and shopping. They are beneficiaries of the project since cleaner environment of the bay will attach more amenities to those activities.

Households outside the study area but inside the service areas of the three water companies cannot be regarded as polluter of the bay although their wastewater is polluting directly or indirectly other areas. They are however beneficiaries of a possible sewerage project since the environment of cleaner Havana Bay is accessible to everyone.

Table 13.18 Analysis of Polluters and Beneficiaries

STAKEHOLDER	*POLLUTER ASPECT*	*BENEFICIARY ASPECT*
Central government (including INRH)	Government offices discharge wastewater	If the Havana Bay becomes cleaner, various demands will be generated and the related industries will benefit from it. The government can expect more tax revenues and less subsidy expenditure. The reduction of morbidity of environment related diseases in the bay area will lead to less medical expenditure.
The City of Havana government	Ditto	Ditto
10 Municipalities in the study area	Ditto	Ditto
3 water companies in the study area	They themselves are not polluting the Havana bay although some discharges of wastewater from their facilities exist.	They may save some O/M costs that could be spent without the project. If the Havana Bay becomes cleaner, various demands will be generated and more water will be sold.
Households in the study area	They discharge wastewater	They can enjoy more leisure in the bay area.
Households outside the study area but inside the service areas of the 3 water companies	Their wastewater is not supposed to pollute the Havana Bay. However a part of the wastewater in fact infiltrates into the sewer in the study area and discharges into the bay.	Ditto
Industries in the study area	They discharge wastewater	If the Havana Bay becomes cleaner, various demands will be generated and the related industries will benefit from it.
Industries outside the study area but inside the service areas of the 3 water companies	Their wastewater is not supposed to pollute the Havana Bay. However a part of the wastewater in fact infiltrates into the sewer in the study area and discharges into the bay.	Ditto
Vessels	Ballast water, bilge water and waste oil are discharged by commercial vessels. But a sewerage project cannot resolve this type of pollution. Discharge of wastewater from small boats is negligible.	Cargo ships will have no or negligible benefit from the project. Tourist ships may benefit from the cleaned bay. Small boats can enjoy the cleaner environment of the bay.
Tourists who visit the City of Havana	Hotels and restaurants where tourists use can be considered as polluters.	They can enjoy tourism in the cleaner bay and the surrounding areas.

(5) Industry

Industries in the study area are polluters because their wastewater is finally discharged into the bay with or without proper treatment. They are beneficiaries of the project. This is because if the Havana Bay becomes cleaner, various demands will be generated and the related industries will benefit from it.

Industries outside the study area but inside the service areas of the three water companies are not polluter in a sense that their wastewater is not discharged into the bay. They will however, benefit from a sewerage project since the possibly boosted demands by the project will increase the production or service provision of relevant industries.

(6) Water company

Currently the Study Area can be subdivided into service areas of three water companies, namely the Aguas de La Habana (Havana Water) the Acueducto del Este (East Water) and the Acueducto Sur (South Water). They themselves are not polluting the Havana bay except discharging wastewater of their facilities. But they can be considered responsible for properly treating wastewater discharged from their customers who use their water. In this sense the water companies are regarded as polluters. They will be beneficiaries of the project as well because they may save some operation and maintenance costs of the currently running facilities as a result of implementation of the project. They can also expect more water sales if the bay becomes cleaner and various demands are generated.

(7) Vessel

Commercial vessels are polluting the bay by discharging wastewater such as ballast water and bilge water. This contamination however cannot be reduced by a sewerage project. Therefore ships cannot be regarded as polluter in this case. Commercial ships do not directly benefit from the environment of cleaner bay. Tourism related ships however, may benefit more directly from the improved environment of the bay.

Smaller ships used for leisure activity such as yacht and cruiser also discharge wastewater, but the volume is negligible. Also this type of pollution cannot be remedied by a sewerage project. They can benefit however, more directly from the improved bay environment by a sewerage project. The number of leisure ships will increase in future if a bay area development plan including construction of a yacht harbor materializes.

(8) Tourist

The Havana Bay and the surrounding areas provide various tourist attractions. The improvement of the bay environment is naturally favorable to tourism promotion. Therefore tourists who visit the bay and the surrounding areas are obvious beneficiaries of a sewerage project. Those tourists generate wastewater during their staying in the City of Havana. However in this case the polluters are hotels or restaurants where the services are consumed. Tourists who do not visit the City of Havana and the bay area are logically irrelevant to a sewerage project in this area.

13.8.2 ABILITY TO PAY

The ability of potential payers to pay for the benefits of a sewerage project is a measure to gauge the feasibility of the financial sustainability of the project.

(1) Government

The ability of government to pay for a sewerage project could be estimated by the size of current expenditures. Apart from the revenue and expenditure data presented in Chapter 8, the information on capital investment in environmental protection is available. The capital investment classified by investment area is shown in Table 13.19. The capital investment classified by industry type is summarized in Table 13.20.

Table 13.19 Capital Investment in Environmental Protection (Classified by Investment Sector)

(Thousand pesos at current prices)

	2000	% of GDP	2001	% of GDP
Water	91,000	(0.33%)	109,600	(0.38%)
Land	14,700	(0.05%)	21,800	(0.08%)
Atmosphere	56,200	(0.20%)	32,600	(0.11%)
Forestal waste	12,500	(0.04%)	16,600	(0.06%)
Solid waste	5,500	(0.02%)	6,600	(0.02%)
Others	16,600	(0.06%)	21,100	(0.07%)
Total Cuba	196,500	(0.71%)	208,300	(0.72%)

Source: Calculated from data of National Statistics Office, *Annual Statistics of Cuba 2001*

Table 13.20 Capital Investment in Environmental Protection (Classified by Industry Type)

(Thousand pesos at current prices)

	2000	% of industry GDP	2001	% of industry GDP
Agriculture, hunting, silviculture and fishing	13,587	(0.7%)	19,967	(1.0%)
Exploitation of mines and quarries	7,290	(1.7%)	5,075	(1.1%)
Manufacturing industry	18,043	(0.4%)	25,966	(0.5%)
Provision of electricity, gas and water	125,294	(20.9%)	104,157	(16.8%)
Construction	4	(0.0%)	170	(0.0%)
Commerce, hotels and restaurants	72	(0.0%)	200	(0.0%)
Transport, storage and communications	7,912	(0.3%)	34,671	(1.2%)
Financial intermediation	22,522	(1.1%)	15,542	(0.7%)
Communal, social, and personal services	1,776	(0.0%)	2,553	(0.0%)
Total Cuba	196,500	(0.7%)	208,300	(0.7%)

Source: Calculated from data of National Statistics Office, *Annual Statistics of Cuba 2001*

The water sector that includes sewerage, receives more capital investment. The investment amount was 91 million pesos in 2000 and 110 million pesos in 2001. These amounts are about a half of the total invest amount of each year. In terms of industry type, the provider of electricity, gas and water is by far the biggest investor. The investment by this industry amounted to 125 million pesos in 2000 and 104 million pesos in 2001. The size of the investments is more noteworthy when they are compared with industry GDP. They account for respectively 20.9 percent of the year 2000's and 16.8 percent of the year 2001. Most of those investments are considered to be in the nature of public works. It can be said that as the tendency of last two years, the Cuban Government has been annually spending about 100 million pesos for capital investment in the water and sewerage related area.

(2) Households

In case of households, their ability to pay can be measured by the ratio of the possible service charge to their total income. If the ratio is smaller, the potential ability to pay is greater and maximum limit of the rates commonly employed for sewerage charge in developing countries is approximately 2 percent, if proposed charge is lower than 2 percent of total household income, the owners of such household are considered capable of paying the proposed charge.

A series of informal interviews with local residents was conducted by the study team. The objective was to gauge the ability to pay of potential contributors of the sewerage project. The average household income and expenses were summarized in Table 13.21. The prices of daily necessities were also surveyed and the finding is shown in Table 13.22.

Table 13.21 Average Household Income and Spending

Income *	(peso)	Spending	(peso)
From husband		Purchase of food and other necessaries by ration book	50
Monthly salary	250	Rent	13
Bonus	100	Electricity	30
From wife		Telephone	20
Monthly salary	250	Gas	7
Bonus	100	Water & sewerage	5
From retired person		Transportation	30
Pesion (120 peso / old person)	60	Food	300
Total	760	Toileteries	60
		Cloths	60
		Recreation	60
		Medicine	60
		Others	65
		Total	760

* The Study Team estimates that the average household size is 4 people composed of a husband, a wife, 1.5 children, and 0.5 old person.
Source: Estimated by the Study Team

Table 13.22 Basic Prices in the City of Havana

(Havana City, Oct. 2002)

Item	Price		(price in US$ *)
Water bill	1.0	peso/ person/ month	0.04
Sewerage surcharge	0.3	peso/ person/ month	0.01
Public telephone	0.05	peso/ 3 minutes	0.00
Bus	0.4	peso/ ride	0.02
Taxi (share-ride type)	1.0	peso/ ride	0.04
News paper	0.2	peso/ copy	0.01
Rice (free market)	10.0	peso/ kg	0.38
Bean (free market)	10.0	peso/ kg	0.38
Bread	10.0	peso/ pound	0.38
Cola	9.0	peso/ can	0.35
Local tobacco (mild)	9.0	peso/ box	0.35

*US$1 is convertible to 26 pesos which is the legal but unofficial rate only used for personal transaction.
Source: Survey by the Study Team

The average size of a household is estimated to be 4 people composed of a husband, a wife, 1.5 children, and 0.5 elderly person. The monthly income and the spending of the average household are estimated to be 760 pesos.

It should be noted that the water and the sewerage prices are inexpensive compared with foods and nonessential grocery items. For example, a can of local cola sells at 9 pesos, which is about a double of monthly water bill of an average household. Even in comparison with the electricity bill, the water bill averagely costs merely one sixth.

In case of households, their ability to pay can be measured by the ratio of the possible service charge to their total income. If the ratio is smaller, the potential ability to pay is greater and maximum limit of the rates commonly employed for sewerage charge in developing countries is approximately 2 percent, if proposed charge is lower than 2 percent of total household income, the owners of such household are considered capable of paying the proposed charge.

The water and sewerage charge combined is estimated to be 5 pesos. The 5 pesos comprise 3.85 pesos of water charge and 1.15 pesos of sewerage charge since the sewerage surcharge is 30 percent of a water charge. The 1.15 pesos account for 0.15 percent of 760 pesos. A 2 percent of 760 pesos is 15.2 pesos, which is about 14 pesos higher than the current charge. In conclusion, the ability of households to pay more for sewerage charge would be considerable.

(3) Industry

There are 16,600 entities in the City of Havana, including state, non-state, industry, and commerce. Various industries and factories exist in the study area and they are discharging wastewaters into the bay. The industrial wastewater survey of 10 factories in the study area was conducted by the study team in 2002. Those factories were selected because (1) their pollution loads are larger, (2) they are representative factories in local industry, (3) their effluents contain heavy metals, and (4) sampling and flow-rate measurement are feasible. An attempt was made to collect financial data of those 10 factories and evaluate the ability of those companies to contribute for a sewerage project. Not all of the factory or company data are available. Table 13.23 shows the data obtained.

Table 13.23 Commercial Size of Major Factories in Study Area

(Thousand pesos)

Company	Item	1999	2000	2001
Ñico Lopez	Sales	170,444	346,822	416,961
(Oil refinery, 1326 employees)	Profit before tax	2,319	337	33,937
PRODAL	Sales	15,239	23,517	25,510
(Food, 926 employees)	Profit before tax	0	61	201
INDAL	Sales	7,455	11,185	10,089
(Fish processing, 300 employees)	Profit before tax	1,124	84	43
Alberto Alvarez	Sales	17,030	9,887	n.a.
(Food oil processing, 180 employees)	Profit before tax	91	0	n.a.
Debon Suchel	Sales	21,967	n.a.	10,481
(Detergent production, 270 employees)	Profit before tax	713	n.a.	-1,291
Jaiper Suchel	Sales	21,592	20,680	21,503
(Detergent production, 600 employees)	Profit before tax	605	443	2,074
Total	Sales	253,728	412,092	484,544
	Profit before tax	4,852	926	34,964

Source: Havana City Territorial Office of Statistics

Ñico Lopez is by far the biggest and dwarfs other five companies. Although the generalization is difficult, it can be said that most of those companies seems to be financially capable of defraying additional cost of wastewater treatment. Incidentally entities who are located and own port facilities along the bay coast line have been paying wharf charge since 1999 in accordance with the length of the coast line they occupy. In 2002, 38 entities paid the pierage of US$1,182,693 and Ps986,546 in total. This means that one company paid US$2,593 and

Ps2,163 monthly on average.

(4) Water Company

Currently the facilities for water supply and sewerage operated by the water companies are owned by INRH. New construction works are financed by INRH and rehabilitation works are mainly responsibility of the water companies. Operation and maintenance costs are naturally borne by the water companies.

(5) Vessels

In 2001, the number of vessels that entered into the bay and paid to shipping charges was 1,152 of which 298 were small boats. The shipping charges include the bay entrance charge, the anchorage charge, and the mooring charge, and the pier facility charge. The total of those charges collected in 2001 was US$ 1,334,012 and peso 965,187. As already evaluated, despite their status as polluter, vessels are not regarded as payer in a sewerage project. This is because their pollution to the bay cannot be solved by a sewerage project. However the vessels can be regarded as potential contributor to another type of pollution reduction project whose target pollutant is related to vessels.

(6) Tourists

The ability of foreign tourists to pay any goods and services in Cuba can be estimated by referring to actual spending data. The relevant price and tourism data are summarized in Table 13.24.

Table 13.24 Tourism Price Data

- Number of tourists who visited Cuba in 2002: 1.686 million
- Number of tourists who visited the City of Havana in 2002: 0.959 million
- Average staying period in the City of Havana: 6.5 days
- Average spending: US$975/person
- Tourist entry visa: US$20/person
- Airport tax at exit: US$20/person
- Admission fee of museum: US$3 to 10/person
- Popular Cuban show charge: US$60 to 85/person
- Regular meal at a tourist restaurant: US$10 to 20/person
- Cuban cigar: US$3 to 20/piece
- Souvenir T-shirt: US$7 to 20/piece

Sources: The City of Havana Government, National Statistics Office, The City of Havana Territorial Office of Statistics, Estimation by Study Team

Generally tourists are indifferent to additional contribution of a few dollars since they usually spend for various goods and services in Cuba, some of which are listed in Table 13.24. However, if the levying of charge was direct and straightforward, some tourists might feel uncomfortable to pay the specific charge. There is no generally accepted standard of a tourist's appropriate contribution for a sewerage project. However US$2 would be considered a safe estimation as it is merely 0.2 percent of the average tourist spending and lower than any of museum entrance fee.

13.8.3 EXTERNAL FINANCE

Cuba's external debt has stabilized at around US$11 billion during 1997-2001, as shown in Table 13.25.

Cuba has no access to the World Bank, the International Monetary Fund or the Inter-American Development Bank. The main sources of multilateral assistance are the European community and UN agencies such as the World Food Programme, UNDP, and UNICEF. The debt service ratios of Cuba are estimated at around 20 percent during 1998-2001.

Table 13.25 Hard-Currency External Debts of Cuba

(million pesos)

	1997	1998	1999	2000	2001
Official bilateral	5,853	6,248	5,737	5,669	5,727
Intergovernmental	1,512	1,601	1,640	1,837	1,836
Development assistance loan	209	220	204	254	352
Export credit with government guarantee	4,132	4,426	3,893	3,578	3,539
Official multilateral	521	575	17	17	17
Financial institutions	2,577	2,687	3,456	3,270	3,103
Bank loans and deposit	2,297	2,573	3,187	2,942	2,833
Medium and long term	1,116	1,362	1,909	1,701	1,598
Short term deposit	1,181	1,211	1,278	1,241	1,235
Import credits	280	113	269	327	271
Supplier credits	1,169	1,673	1,845	1,985	2,026
Other credits	26	27	23	21	20
Total	10,146	11,209	11,078	10,961	10,893

Source: "Annual Statistics of Cuba 2001", National Statistics Office

From 1997 through 2001, Cuba received only below US$100 million a year in development assistance, as shown in Table 13.26. Cuba's main sources of development assistance are Europe Union and United Nations. Among bilateral assistance disbursed in 2001, Canada and Holland stand out although the aid amounts were just over US$10 million. In terms of area that the development assistance is directed, technical cooperation occupied the biggest part in 2000 and 2001, accounting for 56 percent and 59 percent respectively (Table 13.27).

Taking the circumstances above analyzed into account, it would seem difficult for a single country or organization alone to finance a costly large-scale sewerage project at a stretch. If the sewerage project was split into several portions or the implementation was phased, the actual annual disbursement would be smaller, which would make donors or financial institutions easier to finance the project.

Table 13.26 Donors of Development Assistance to Cuba

(US$ 000)

	1997	1998	1999	2000	2001
Multilateral	31,941	26,033	31,236	28,904	46,995
European Union	14,498	15,073	17,822	17,003	28,737
United Nations	17,249	10,843	12,554	10,998	17,685
Other multilaterals	194	117	860	903	574
Bilateral	25,080	32,097	20,396	19,600	47,570
Canada	6,519	9,962	6,059	8,627	13,049
Holland	1,087	-	-	-	12,450
Italy	6,260	518	2,399	1,865	7,052
Norway	-	1,024	296	-	3,100
Spain	7,776	8,317	8,182	4,694	2,565
Germany	1,082	625	-	677	2,528
Japan	-	9,054	199	79	1,695
Sweden	1,224	1,244	1,495	-64	1,686
Belgium	-	-	-	-	1,414
United Kingdom	722	281	-	-	1,000
France	-	814	1,735	3,642	509
Swiss	234	173	18	10	499
Colombia	-	-	-	-	23
Ukraine	-	-	-	70	-
Austria	176	85	13	-	-
NGOs	9,587	15,418	5,280	7,357	2,069
Total	66,608	73,548	56,912	55,861	96,634

Source: Calculated from data of "Report on Development Cooperation to Cuba 2001", UNDP

Table 13.27 Type of Development Assistance to Cuba

(US$ 000)

	1997	1998	1999	2000	2001
Technical cooperation	27,002	22,173	25,288	31,137	56,750
Food aid	9,703	6,798	3,397	3,192	15,528
Emergency aid	29,383	40,696	25,961	20,154	11,139
Investment project	-	-	981	225	10,151
Investment related technical cooperation	325	900	1,285	1,103	2,648
Total	66,413	70,567	56,912	55,811	96,216

Source: Calculated from data of "Report on Development Cooperation to Cuba 2001", UNDP

Taking the circumstances above analyzed into account, it would seem difficult for a single country or organization alone to finance a costly large-scale sewerage project at a stretch. If the sewerage project was split into several portions or the implementation was phased, the actual annual disbursement would be smaller, which would make donors or financial institutions easier to finance the project.

Table 13.28 shows prevailing lending rates during the first half of the year 2003 that were applied to loans extended by multilateral lending agencies.

Table 13.28 Referential Lending Rate of Multilateral Lending Agencies

Lender	Loan type	Currency	Term (year)	Grace period (year)	Lending rate	Effective period
IDB	Soft loan	US$	40	10	1% in grace 2% thereafter	*
	Ordinary	US$	25	5	5.80%	First semester 2003
		Euro	25	5	5.59%	
		Yen	25	5	1.70%	
JBIC	Special	Yen	40	12	0.75%	From April 2003
	General	Yen	30	10	1.50%	
World Bank	Ordinary	US$	12	3	7.15%	First semester 2003
		Euro	12	3	5.67%	
		Yen	12	3	1.07%	

* One of IDB soft loans was provided in March 2003 under the conditions presented here.
Source: IDB website (www.iadb.org), JBIC website (www.jbic.go.jp), World Bank website (www.worldbank.org)

13.8.4 COMMUNITY MOBILIZATION

The Cuban society has a background in community mobilization. For example, in the wake of the devastation of Hurricane Michelle of November 2001, community efforts supported by state resources were being devoted to construction work to repair damaged houses and rebuild destroyed houses.

Another example is the campaign to eradicate and outbreak of dengue fever, which has involved the participation of local residents in 2001. As the result of the campaign, garbage and areas that used to collect stagnant water were cleared up and the environment of the City of Havana showed noticeable improvements.

Under the current political system ruled by the Partido Comunista de Cuba (PCC, the Cuban Communist Party), there exist various organizations that are authorized by PCC and can mobilize local residents at the grass-roots level.

The Comité de Defensa de la Revolución (CDR, the Defense Committee of the Revolution) has a characteristic of a neighborhood committee. The memberships amount to nearly 8 million in the whole country. CDRs organize and are involved in a wide range of activities such as rationing, repair of houses, cultures, sports, leisure, blood donation, food rationing, and house repair.

The Federación de Mujeres Cubanas (FMC, the Cuban Women's Federation) is another example of such a colossal organization. The number of members is nearly 4 million nationwide. Major focuses of activities are the female participation in the society and the status improvement of women.

Other influential organizations include for example, the Central de Trabajadores de Cuba (CTC, the trade unions federation), the Unión de Jóvenes Comunistas (UJC, the Communist Youth Union), the Federación Estudiantíl Universitaria (FEU, the Federation of University Students), the Federación Estudiantíl de Enseñanza Media (FEEM, the Secondary School Children Federation) and the Organización de Pioneros José Martí (OPJM, the Primary School Children Federation).

It would be the Consejos Populares (the People's Councils) that could coordinate various mobilization activities performed by the above-mentioned organizations. The Consejos Populares are the bottom tier of local governments. The Study Area includes 10 municipalities under which there are 72 Consejos Populares.

As various community mobilizations have been organized in Cuba, some form of community mobilization would be applicable to a sewerage project. At the end of year 2001 the sewer connection rate is 69 percent in the service area of Aguas de La Habana (Havana Water), and 6 percent in the area of Acueducto del Este (East Water). When the sewerage project materializes, it will require quite a few connection works from houses to branch sewers. That connection work is likely to exceed the water companies' capacity of labor force. In that case, unskilled labor works such as excavation and pipe laying would be possible areas to which community mobilization could be applied. However there will be still needs for the project constructor to provide communities with the rest of input to complete the work such as supervision, topographic survey, design, materials and machinery.

13.9 FINANCIAL AND ECONOMIC EVALUATIONS

13.9.1 FINANCIAL EVALUATION

(1) Methodology

The financial viability of a capital investment project is analyzed on the basis of discounted cash flow method that is essentially aiming to clarify whether the anticipated net cash flows (cash inflows or project benefits less cash outflows or project costs) from the project are reasonably attractive for the investor to risk his funds. The discounted cash flow method includes the following three indicators, which are prevailingly used by financial analysts and investors.

1) Net present value (NPV)

In the net present value (NPV) computation, the basic decision rule is that project is acceptable if the present value of the net cash flows equals or exceeds zero. In order to use this rule, one must estimate the applied discount rate, the economic life, the amount of cash inflow in each year, and the amount of cash outflow in each year.

2) Benefit cost ratio (B/C)

Same as NPV, the benefit cost ratio (B/C) computation requires to estimate, discount rate, economic life, cash inflow, and cash outflow. A project is acceptable if the present value of the cash inflows divided by the present value of cash outflows equals or exceeds one.

3) Financial internal rate of return (FIRR)

The financial internal rate of return (FIRR) computation finds the rate of return that equates the present value of net cash flows to zero. Therefore, once the FIRR is computed, the following inequalities do always hold good.

B/C $\geqq$1 and NPV $\geqq$0, if the discount rate $\leqq$ FIRR
B/C $<$ 1 and NPV $<$ 0, if the discount rate $>$ FIRR

The FIRR on total project cost can be calculated by viewing the investment as if it was all financed by equity, thus the earning power of total investment regardless of debt and/or equity financing can be obtained.

Among the above three, FIRR is the most popular indicator due mainly to needlessness of establishing discount rate and easiness in comparing with interest rates and earnings rates with which every decision maker is familiar. In the evaluation of the master plan project however, the three indicators are computed in order to analyze the financial viability from the widest scope.

(2) Basic Conditions

In estimating financial costs and benefits of the project, the following conditions and assumptions are applied.

1) Implementation agency

There are two types of implementation agency, which are constructor and operator. In the existing organizational and legal framework of Cuba, most likely scenario is that DPRH (Provincial Delegation of the National Institute of Water Resources in the City of Havana) will assume the constructor role, while Aguas de La Habana (Havana Water) will be the operator. Aguas de La Habana will represent the other water companies that operate in the City of Havana, which is based on a future merger possibility of the water companies in the city. The financing source for DPRH to construct or rehabilitate the facilities will be INRH (National Institute of Water Resources) or the central government. As the ownership of the facilities belongs to DPRH, Aguas de La Habana will pay the rent to DPRH. The financing source for Aguas de La Habana to pay the facility rent and the O/M costs will be the user charges.

In the financial analysis, DPRH and Aguas de La Habana will be imaginarily consolidated to form a singly entity that specializes in the proposed project only. As a result, the facility rent payment by Aguas de La Habana and its receipt by DPRH will be offset.

2) Project costs

The project costs consist of capital investments and O/M costs. The capital investments are the initial constructions which are planned to take three years in each of three stages. The O/M costs include only expenses required for rehabilitated or newly constructed facilities by the master plan project.

3) Project benefits

Main benefits of the project are revenues from sewerage users in served area and contributions from tourists who visit the City of Havana. Their ability to pay for sewerage services are taken into consideration. The benefits are determined as the difference between the with-project and the without-project situations. Neither Aguas de La Habana nor DPRH has a function of collecting contributions from tourists. It is assumed that the central government will collect the contributions through for example, hotels and guesthouses in the City where foreign tourists will stay. The collected charges will be transferred to the project implementation agencies.

Another project benefit can expect from the reduction of O/M cost of the existing sanitation system by the implementation of the master plan project. This benefit however can be regarded minimal therefore neglected. This is because firstly the sanitation systems of Aguas de La Habana (Havana water) are found mostly in the western part of the City of Havana, or outside the project area, which means that the system replacement and resultant cost saving is irrelevant to the project. Acueducto del Este (East water) did not disclose precise sanitation expenses, however the expense for cleaning of septic tanks in the year 2001 was as little as Ps15,800. Although data on other allocable costs to sanitation such as salary and energy were not available, they were seemingly between Ps100,000 and 300,000. As only a part of those costs can be reduced by the project, the magnitude of saving effect is considered insignificant in comparison with other benefits.

4) Exchange rate

The official exchange rate of Cuban peso maintains at parity with the US dollar, while the unofficial rate which is used for domestic personal transactions only, has been changing on the non-regular basis. Table 13.29 shows the change in exchange rates since 1997. The unofficial rate has been gradually depreciating during the period shown. At the end of August 2003, the rate was Peso26:US$1. The unofficial exchange rate has little impact on trade. Only household demands for imported consumer goods are marginally affected. The peso depreciation in the last few years can be interpreted as a result of lack of foreign currency caused by poor export performance, a contraction in tourism, and decreases of remittances.

Table 13.29 Changes in Peso/US$ Exchange Rate

(Peso:US$; annual averages)

Year	1996	1997	1998	1999	2000	2001	2002	2003 [b]
Official rate	1	1	1	1	1	1	1	1
Unofficial rate [a]	19.2	22.8	22.3	20.7	21.5	23.3	26.0	26.0

[a] A legal but unofficial exchange rate available only domestically, for personal transactions.
[b] Data up to September

The costs of the sewerage master plan project consist of two components in terms of the currency that is used for payment. Those currencies are Cuban peso and US dollar. Likewise the project benefits of the master plan can be also considered combination of Cuban peso and US dollar, reflecting two types of beneficiaries depending on their payment vehicle. Both in financial and economic analysis of the project, certain exchange rate should be applied if the project is viewed in one lump.

In fact, the practice of combining the two currency portions in analyzing the financial viability of a joint venture project is not always the case in Cuba. The two currency portions are separately analyzed or if it should be combined, the exchange rate of Ps1:US$1 is employed.

Under this dual currency system and uncertainty as to applying a single exchange rate to financial computations, it was decided that in the analysis of the sewerage master plan project, four types of currency mix were employed. The first was computation of Cuban peso portion only; the second was US$ portion only; the third was a combination of Cuban peso and US$ at the exchange rate of Ps1:US$1; and the forth was a combination at the Ps26:US$1.

5) Project life

Annual depreciation rates defined by the Ministry of Finance and Prices are 3% for building and constructions, 6% for machinery, 10% for furniture, 15% for office equipment and computer, and 20% for vehicle. Considering the approximate component mix of the project, the project life of was determined as 30 years after completion of the construction works of the second stage.

6) Discount rate

Discount rate is in other words, the opportunity cost of capital. Prevailing lending rates provided by multilateral lending agencies (Table 13.28) can be referential for US$ portion. For peso portion, the 36-month peso deposit rate (8 percent in September 2003) can be referential. Considering those referential rates, the discount rate used in US$ portion and peso portion were determined at a 6 percent and an 8 percent respectively.

7) Served population

In terms of served population or domestic contributors to the project, all the present sewerage customers of Aguas de La Habana (Havana Water) are considered as beneficiary in the central system. They pay their bills in peso. It is assumed that because of practicality in collection system, all of the domestic customers are charged as contributor to the project, an equal sewerage rate, whether they live within or outside the Havana bay basin. Thus, the number of sewer users under the existing sewerage system is assumed at 860,000 in 2004. This number is assumed to be gradually increasing to 1,000,000 under both the with-project and the without-project situations. For the newly served zones, domestic customers only include those who will be newly served.

8) Sewerage rate for domestic customers

The sewerage rate was averagely 5 peso per person per year in 2002. A tariff increase of Aguas de La Habana was likely to be effective in 2003, which would lift the average rate by about 20 percent. Hence it has been assumed that the average rate in 2004 is 6 peso annually per person. Although the timing of next tariff increase and the increase rate are uncertain, it is assumed that the rate will become 12 peso in 2006. This tariff hike is assumed to take place under both the with-project and the without-project situations. The next tariff increase is assumed to be in 2011 when the facilities of the first stage will start its operation. Then the tariff will be 36 peso annually per person. It is assumed that the tariff increase in 2011 will be caused by implementation of the project therefore effective only under the with-project situation.

9) State entities and institutional customers

State entities and institutional customers are non domestic customers who pay the bills in peso. Those customers at Aguas de La Habana totaled 10,581 at the end of 2002. In the same way as domestic customers, those customers can be regarded as beneficiaries of the central system. Based on this, the number of institutional customers in 2004 who pay their sewerage bills in peso is assumed at 11,000. This number is set stable until the ending year of the project under the without-project situations. The number of institutional customers to be served by the new system is assumed at one institutional customer per 39 residents. This ratio is derived from the served population of Aguas de La Habana in 2002, which is 13:1 with respect to the number of institutional customers. Because of the less concentration of institutional customers within the area, the ratio of institutional customers applied in the new service area is three times sparse the ratio found in the existing service area of Aguas de La Habana.

10) Sewerage rate for state entities and institutional customers

The sewerage rate was averagely 150 peso annually per customer in 2002. A tariff increase for Aguas de La Habana was likely to be effective in 2003, which would lift the average rate by about 20 percent. Hence it has been assumed that the average rate in 2004 is 180 peso per customer per year. Although the timing of next tariff increase and the increase rate are uncertain, it is assumed that the rate will become 360 peso in 2006. This tariff hike is assumed to take place under both the with-project and the without-project situations. The next tariff increase is assumed to be in 2011 when the facilities of the first stage will start its operation. Then the tariff will become 900 peso per customer. It is assumed that the tariff increase in 2011 will be caused by implementation of the project therefore effective only under the with-project situation.

11) Hard currency earners

The number of hard currency earning customers of Aguas de La Habana was 3,659 in the year 2001 and 4,473 in 2002. They pay their bills in US dollar and are regarded as beneficiaries of the central system in the same way as domestic and institutional customers. Based on this, the number of hard currency earners in 2004 was assumed at 4,500. Following the recent tendency, this number is expected to be moderately increasing until 2030 under both the with-project and the without-project situations. It is assumed that no hard currency earners exist in the newly served areas, applying a conservatism policy.

12) Sewerage rate for hard currency earners

The annual sewerage rate was averagely US$246 in 2001 and US$194 in 2002. A tariff increase for Aguas de La Habana was likely to be effective in 2003, which would lift the average rate by about 20 percent. Hence it was assumed that the average rate in 2004 is US$270 per customer per year. Although the timing of next tariff increase and the increase rate are uncertain, it is assumed that the rate will become US$365 in 2006, which is 1.35 times the previous one. This tariff hike is assumed to take place under both the with-project and the without-project situations. The next tariff increase is assumed to be in 2011 when the facilities of the first stage will start its operation. Then the tariff will be US$495 per customer, which will be 35 percent higher than the previous one. It is assumed that the tariff increase in 2011 will be caused by implementation of the project therefore effective only under the with-project situation.

13) Foreign tourists

The number of tourists who visited the City of Havana in 2002 was 0.959 million. There was a drop in 2002 due to the negative impact on global tourism caused by the September 11 attacks. The assumption made in the financial evaluation is 1.3 million tourists in 2011 when the facilities of the first stage will start the operation. The change in the number of tourist is presented in Table 13.30 below. As a result of execution of the project, it is assumed that a contribution of US$2 per tourist is levied on stay in the City of Havana, starting in 2011. The levied contribution through tax offices will be transferred to the implementation agency to be earmarked for the loan repayment and the O/M costs. The US$2 is a 0.2 percent of the average tourist spending and lower than any of museum entrance fee. The US$2 is recommendable since this rate is considered a safe level that the tourists do not feel reluctant to contribute.

Table 13.30 Change in the Number of Tourists Visiting the City of Havana

(000 persons)

	1997	1998	1999	2000	2001	2002	2011*
Tourists to the City of Havana	649	781	867	951	980	959	1,300
Tourists to Cuba	1,170	1,416	1,603	1,774	1,775	1,686	2,363
Weight of the City of Havana	55%	55%	54%	54%	55%	57%	55%

Source: The City of Havana Territorial Office of Statistics
* Estimate by the study team

(3) Evaluation of Financial Viability

Based on the conditions previously explained, the FIRRs are computed at -0.1 percent in the US$ portion, 45.1 percent in the peso portion, 21.0 percent in the US$/peso combined portion at the 1:1 exchange rate, and 1.8 percent in the US$/peso combined portion at the 1:26 exchange rate. The project cash flows and results of other financial indicators are presented in Table 13.31. Other tables that contain relevant computations are presented in Appendix 13.

The project in fact, consists integrally not piecemeal, of the US$ and peso portions. If the exchange rate of Ps26:US$1 that is actually used in personal transactions is taken under the conservatism policy, the FIRR results in a 1.8 percent. The 1.8 percent implies that the project is intrinsically self-supporting. In other words, the revenue from customers and the contribution from tourists are sufficient enough to pay for the construction cost and the O/M cost. This can be true however, on the condition that the project is financed by a concessionary loan or a soft loan whose interest rate does not surpass the 1.8 percent.

Table 13.31 Master Plan Project Cash Flow at Financial Value

Yr. no.	Year	Cost: Capital expenditure ($000)	Cost: Capital expenditure (Ps000)	Cost: Operating expend. ($000)	Cost: Operating expend. (Ps000)	Benefit: Foreign currency ($000)	Benefit: Corpo-ration (Ps000)	Benefit: Domestic user (Ps000)	Benefit: Tourist contribut. ($000)	Net Benefit: US$ ($000)	Net Benefit: Peso (Ps000)	Net Benefit: $ + Peso Ps1:$1 (Ps000)	Net Benefit: $ + Peso Ps26:$1 (Ps000)
1	2004												
2	2005												
3	2006	1,553	684							-1,553	-684	-2,237	-41,070
4	2007	1,553	684							-1,553	-684	-2,237	-41,070
5	2008	14,610	9,612							-14,610	-9,612	-24,222	-389,467
6	2009	17,251	10,861							-17,251	-10,861	-28,112	-459,376
7	2010	18,680	11,992							-18,680	-11,992	-30,672	-497,661
8	2011	5,278	3,616	17	1,142	813	6,203	21,890	2,600	-1,883	23,335	21,452	-25,618
9	2012	5,277	3,616	33	1,149	845	6,466	22,420	2,600	-1,865	24,120	22,255	-24,377
10	2013	7,059	4,672	46	1,239	878	6,663	22,848	2,600	-3,628	23,599	19,971	-70,724
11	2014	14,055	7,513	54	1,242	910	6,794	23,172	2,600	-10,599	21,212	10,613	-254,351
12	2015	9,246	5,569	62	1,246	943	6,926	23,498	2,600	-5,765	23,608	17,843	-126,283
13	2016	5,752	3,938	83	1,512	975	7,172	24,002	2,600	-2,260	25,724	23,464	-33,038
14	2017	5,751	3,938	104	1,522	1,008	7,420	24,508	2,600	-2,248	26,467	24,219	-31,971
15	2018	6,519	4,193	121	1,530	1,040	7,621	24,942	2,600	-3,000	26,840	23,840	-51,162
16	2019	8,743	5,263	133	1,535	1,073	7,777	25,306	2,600	-5,204	26,285	21,081	-109,009
17	2020	8,831	5,458	146	1,541	1,105	7,934	25,670	2,600	-5,272	26,604	21,332	-110,470
18	2021			166	1,614	1,138	8,173	26,164	2,600	3,572	32,723	36,294	125,582
19	2022			187	1,625	1,170	8,413	26,657	2,600	3,583	33,446	37,029	126,604
20	2023			204	1,634	1,203	8,604	27,075	2,600	3,599	34,045	37,644	127,606
21	2024			216	1,640	1,235	8,746	27,418	2,600	3,619	34,524	38,143	128,618
22	2025			229	1,647	1,268	8,889	27,760	2,600	3,639	35,002	38,641	129,603
23	2026			233	1,649	1,300	8,938	27,956	2,600	3,667	35,245	38,912	130,587
24	2027			237	1,651	1,333	8,987	28,152	2,600	3,696	35,487	39,183	131,570
25	2028			241	1,654	1,365	9,035	28,347	2,600	3,724	35,728	39,452	132,552
26	2029			245	1,656	1,398	9,084	28,543	2,600	3,753	35,971	39,723	133,536
27	2030			249	1,658	1,430	9,131	28,739	2,600	3,781	36,212	39,993	134,518
28	2031			249	1,658	1,430	9,131	28,859	2,600	3,781	36,332	40,113	134,638
29	2032			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
30	2033			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
31	2034			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
32	2035			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
33	2036			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
34	2037			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
35	2038			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
36	2039			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
37	2040			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
38	2041			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
39	2042			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
40	2043			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
41	2044			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
42	2045			249	1,658	1,430	9,131	28,979	2,600	3,781	36,452	40,233	134,758
	Total	130,158	81,611	6,741	54,956	43,875	295,945	949,629	91,000	-2,024	1,109,007	1,106,983	1,056,383

Results:

Case I	US$ portion	FIRR: -0.1%	B/C: 0.5	NPV($): -40,511	(Discount rate: 6%)
Case II	Peso portion	FIRR: 45.1%	B/C: 4.5	NPV(P): 176,239	(Discount rate: 8%)
Case III	US$+peso (Ps1:$1)	FIRR: 21.0%	B/C: 2.1	NPV(P): 135,728	
Case IV	US$+peso (Ps26:$1)	FIRR: 1.8%	B/C: 0.6	NPV(P): -877,044	

(4) Sensitivity Analysis

In computing the financial indicators, some parameters may have a greater influence on the final result than others. It is useful to locate the parameters that have an important influence on the final results by sensitivity analysis so that they can be subjected to special attention of decision makers. Sensitivity analysis tests the robustness of the project when changes are effected to the key project parameters. In analyzing the master plan project, the construction cost and the revenue are selected as key parameter. The results are shown in Table 13.32. The FIRR is slightly more sensitive to changes in construction cost than revenue. A decrease of 20 percent in construction cost improves the base FIRR by 1.7 points, while an increase of the same percentage reduces the base FIRR by 1.3 points and maintains the FIRR still positive. An increase of 20 percent in revenue improves the base FIRR by 1.5 points, while a decrease of the same percentage reduces the base FIRR by 1.6 points and maintains the FIRR still positive.

Table 13.32 Financial Sensitivity Analysis of Master Plan Project

	US$	Peso	US$+Peso (Ps1:US$1)	US$+Peso (Ps26:US$1)
Base case	-0.1%	45.1%	21.0%	1.8%
Construction cost increases by 20%	-1.2%	38.9%	17.4%	0.5%
Construction cost decreases by 20%	1.4%	53.5%	26.2%	3.5%
Revenue decreases by 20%	-1.6%	37.2%	16.4%	0.2%
Revenue increases by 20%	1.2%	52.2%	25.3%	3.3%

13.9.2 ECONOMIC EVALUATION

(1) Methodology

The discounted cash flow method, the same methodology as used in the financial evaluation was applied. Three indicators were similarly computed, which were the net present value (NPV), benefit cost ratio (B/C), and economic internal rate of return (EIRR). They are described in Section 13.9.1.

(2) Economic Cost Valuation

In estimating the economic cost, some items of the financial costs are omitted or adjusted. This is to reflect costs from the viewpoint of the economy as a whole rather than from the viewpoint of an individual entity. For example, since taxes, duties and subsidies incorporated in market prices of goods and services are simple transfers from one party to others in a same economy, they are excluded in economic costs. To remove those market distortions contained in financial prices of goods and services and to arrive at the economic prices, a set of conversion factors is used, which are explained subsequently.

1) Material and equipment in foreign currency

Materials and equipment quoted in foreign currency unit are traded items. In economic valuation, the value of a traded good is shown in the price at a country's border (border price)[1]. The values stated here are nets of transactional costs (e.g., internal transport, dealer margin), however they include duties.

[1] The influence of US trade sanctions is worth mentioning. As Cuba's importation from the US has been restricted since 1960, necessary goods and services domestically not producible have to be imported from other countries, whereby transportation costs to Cuba is naturally higher. According to the estimate of Cuban government, the trade sanctions cost Cuba additional US$403.5 million in 2002. The resultant loss in the last four decades is estimated at US$72 billion.

The average import duty levied on goods imported from most of western European and Latin American countries is 11 percent. Thus financial prices of materials and equipment in foreign currency unit were converted into economic prices by the following conversion factor (CF):

CF = 1/(1+0.11) = 0.9

2) Transactional cost in foreign currency

Transactional cost includes internal transportation, bank charge, insurance, and indirect cost that are necessary for the construction to take place at the project site. As the sewerage project is actually implemented somewhere in Cuba, not literally at the border, transactional costs should not be omitted in economic valuation. Also included here is the physical contingency. The physical contingency is an amount included in the price of a good or service to allow for physically adverse conditions that will add to base cost. The physical contingency should not be omitted either.

The transactional costs are nontradeable by nature. They are quoted however, in foreign currency because under the Cuban cost formula, transactional costs with regard to traded goods denominated in foreign currency are also quoted in foreign currency, using the official exchange rate of Ps1:US$1.

In using the foreign currency unit in economic valuation for nontradeable goods and services, the official exchange rate needs to be adjusted on the basis of existing trade distortions. Trade distortions are caused by trade policies such as import duties, quantitative restrictions, export subsidies, export taxes. The standard conversion factor (SCF) is used to remove the trade distortion effect under the system using the official exchange rate. The SCF is the ratio of the economic values of all goods and services in an economy at the border to their domestic market values. The SCF is defined as follows:

$$SCF = \frac{M + X}{(M + t_m - s_m) + (X - t_x + s_x)}$$

Where:
M & X are total imports and exports, respectively, in a particular year at world prices and converted into local currency at the official exchange rate.
t_m & t_x are the tax collected to M and X, respectively.
s_m & t_x are the subsidy paid to M and X, respectively.

In the year 2001 of Cuba, the relevant parameters were:
M = 5103.3 million pesos
X = 4232.0 million pesos
t_m = 381 million pesos
$t_x = s_m = t_x = 0$

$$\text{Hence, SCF} = \frac{5103.3 + 4232}{(5103.3 + 381 - 0) + (4232 - 0 + 0)}$$

$$= 0.96$$

Financial prices of transactional costs denominated in foreign currency unit are therefore converted into economic prices by 0.96.

3) Dealer margin

According to the Cuban cost formula and an opinion of Cuban specialist, the financial value in relation with procurement of tradeable material and equipment in foreign currency averagely includes the dealer margin of 20 percent. The dealer margin is regarded as a rent which distorts economic values. Thus, that was omitted when converting a financial value into its economic value.

4) Material and equipment in local currency

Materials and equipment quoted in local currency unit are items that are produced in Cuba and also tradeable. In economic valuation, the value of a tradeable good is expressed in the border price. The adjustment to correct trade distortion effect is required here. The trade distortions in relation with the official exchange rate are same as what are explained in the part of transactional cost denominated in foreign currency. Financial prices of materials and equipment are also adjustable in a similar way as explained in the SCF. The shadow exchange rate factor (SERF) is applied to this end. The difference is that the SERF is the reciprocal value of the SCF. Hence, financial prices here were converted into economic prices by the following conversion factor (CF):

CF = SERF = 1/SCF = 1/0.96 =1.04

5) Labor

For labor that is scarce, the shadow wage rate is likely to be equal to or greater than the market wage rate. For labor that is not scarce, the shadow wage rate is likely to be less than the market wage rate. Labor costs quoted here mainly represent unskilled labor which is usually abundant in Latin-American countries. The official unemployment rate of Cuba fell to 3.3 percent in 2002 from 4.1 percent in 2001. Even considering the existence of unregistered unemployment especially among young people, this figure is considerably low. The standard wage rate factor (SWRF) is used to convert the financial price of labor into its economic price. Taking into the Cuban situation, the SWRF for labor that is used in local currency portion is set at 0.8.

6) Transactional cost in local currency

Transactional costs include internal transportation, bank charge, insurance, and indirect cost that are necessary for the construction to take place at the project site. Thus, transactional costs should not be omitted in economic valuation. Transactional costs are nontradeable by nature. Thus when they are quoted in local currency unit, no adjustment is necessary to remove the trade distortion effect.

7) Land

There is no land acquisition and compensation cost. However from the viewpoint of economic valuation, any land diverted to the project is necessarily taken away from some other use. If an active land market exists and the market is regarded sufficiently representative of alternative use values for the land purchased specifically for project use, the land may be valuated using the price paid. If the land is rented, then the rental value should be considered in the project analysis.

In Cuba however, the market for land is inexistent or imperfectly existent, and the market price is difficult to estimate. In this case, the economic value of the land can be measured in its alternative use. Considering the present usage of the lands and their vicinities, urban agriculture is regarded an economically reasonable and feasible use. Table 13.33 below shows selected agricultural products that can be cultivated on the sites.

Table 13.33 Cultivable Crops in the Project Sites

Crop	Market price (peso/lb)	Yield (ton/ha)	Value added* (peso/ha)
Potatoes	2.29	7.54	15,226
Banana	1.97	8.71	15,131
Other vegetables	3.33	13.32	39,114
Maize	2.77	2.33	5,691
Bean	7.53	0.96	6,375
Citric fruits	1.76	14.76	22,908
Other fruits	3.86	7.96	27,095

Source: Computed by the study team from data of “Statistics yearbook of Cuba 2001”, National Statistics Office, and “Statistics yearbook of the City of Havana 2002”, The City of Havana Territorial Office of Statistics.
*Value added is the production value (=market value) minus the production cost. The production cost (including land reclamation cost) is estimated at 60% of the market value.

It is noted that the agriculture can annually generate between Ps5,691 and 39,114 at a hectare of the project site. Considering the urban agriculture tendency where vegetables and fruits are favored for their market accessibility and profitability, it is assumed that Ps20,000 is a reasonable added value that can be realized from a hectare of land. This foregone Ps20,000 in exchange for undertaking the project is considered the rent of the land. We suppose that the rents covering the project period are defrayed in a lump sum when the land tenure starts. The opportunity cost of capital, or discount rate is set at 10 percent, which is generally applicable in economic valuation. The project life of master plan is determined as 30 years after completion of the construction works of the second stage, which falls on 2045. For example, the tenure of the Luyanó WWTP starts in 2008 and lasts until the end of project life. Hence, *Px* or its land value in the year 2008 is computed as follows:

$$Px = \sum_{n=0}^{37} \frac{20{,}000}{(1+0.1)^n} = 214{,}118 \text{ (Ps/ha)}$$

Likewise, the values of lands required for the master plan project are computed and presented in Table 13.34.

Table 13.34 Economic Values of Land

	Area required for project (ha)	Cultivable area [b] (ha)	Tenure	Unit value (Ps/ha)	Value of land [c] (Ps)
Luyanó WWTP	3.0 [a]	2.1	38 years (2008-2045)	214,118	449,648
Matadero Pumping Station	0.2	0.1	38 years (2008-2045)	214,118	21,412
Chivo Repumping Station	0.2	0.0	35 years (2011-2045)	159,408	0
Total	4.4	2.4			471,060

Source: The study team
[a] Out of the WWTP site of 5.0ha, the GEF project will use 2.0ha, which is subtracted here.
[b] Estimated by the study team
[c] Price when the land tenure starts on the basis of the cultivable area

8) Administrative expenses

Administrative expenses are costs required by the executing agency, relevant government bodies and agencies for the project implementation. Administrative expenses should not be omitted in economic valuation. Administrative expenses are assumed as half traded (conversion factor 1.04, same as material and equipment in local currency) and half non-traded (conversion factor 1). Thus the financial cost is converted to economic cost by 1.02 (50% x 1.04 + 50% x 1).

9) Engineering services in foreign currency

Engineering services in foreign currency are provided by foreign experts and the fee is quoted at an internationally competitive price. This is considered the same as a tradeable material in foreign currency that does not include the effect of duty. Hence, there is no need for adjustment.

10) Engineering services in local currency

This comprises mainly qualified or skilled local workers. Since these workers are scarce in Cuba, the standard wage rate factor (SWRF) of 1.0 was applied to convert the financial price of labor into its economic price. As the result, no adjustment is made.

11) Physical contingency in foreign currency

Physical contingency is an amount included in a project account to allow for physically adverse conditions, and should not be omitted in economic valuation. Physical contingency is related with both tradeable and nontradeable items. Same as the aforementioned transactional costs in foreign currency, the standard conversion factor (SCF) is applied to remove the trade distortion effect, if a physical contingency denominated in foreign currency corresponds to nontradeable cost items. On the other hand if a physical contingency denominated in foreign currency corresponds to tradeable cost items, there is no need for adjustment in conversion from financial value into economic valuation. Physical contingency in foreign currency is assumed as half tradeable (conversion factor 1) and half nontradeable (SCF 0.96). Thus the financial cost is converted to economic cost by 0.98 (50% x 1 + 50% x 0.96).

12) Physical contingency in local currency

If a physical contingency in local currency corresponds to tradeable goods and services, it contains the trade distortion effect, hence the SERF (=1.04) is applied. If it corresponds to nontradeable goods and services, no adjustment is necessary. In economic valuation of this project, the SERF was applied to both cases. Physical contingency in local currency is assumed as half tradeable and half nontradeable. Thus the financial cost is converted to economic cost by 1.02 (50% x 1.04 + 50% x 1).

13) Personnel cost in O/M

Staffs to be employed additionally at the new or rehabilitated facility comprise skilled and unskilled labors. The standard wage rate factor (SWRF) applied to skilled labor and unskilled labor are estimated at 1.0 and 0.8 respectively. Personnel composition has been assumed as 30 percent skilled labors and 70 percent unskilled labors. Thus the financial cost is converted to economic cost by 0.86 (30% x 1 + 70% x 0.8).

14) Electricity cost in O/M

The electricity cost usually comprises traded components such as oil and machinery, and non-traded components such as labor and overhead. As the electricity cost component information is not available, conversion of each financial cost into economic values cannot be done. Another conversion factor exists to remove price distortion due to subsidy. Like the water tariff, the electricity tariff in Cuba has dual currency system. Some customers who can earn foreign currency are charged US$ rate, while others are charged peso rate. Aguas de La Habana (Havana Water) has been approved a preferential treatment whereby the peso rate is charged during the concession period. This preferential treatment is considered as subsidy from the government and assumed to last until the end of the project period. The cost data of electricity was not available however, we guessed that due to the effect of electricity tariff control by the government, the economic cost of electricity is higher than its financial cost. Hence, the conversion factor was assumed to be 2.0, which means that the economic cost is twice as high as its financial cost.

15) Chemical cost in O/M

The same rule is applied as material and equipment quoted in foreign currency unit. Hence, financial prices of chemical cost are converted into economic prices by the conversion factor of 0.9.

16) Discount rate

Opportunity cost of capital represents the permissible economic rate of return, or discount rate for development projects. In general, 10 percent is applied as the opportunity cost of capital for assessing the economic viability.

(3) Economic Benefit Valuation

1) Inhabitant analysis

The willingness to pay (WTP) is the maximum amount that consumers as beneficiary are prepared to pay for a good or service. This is considered as the benefit that the consumers can enjoy in using the good or service.

An inhabitant survey is a standard measure to clarify the WTP. The questionnaire generally used in the survey contains queries as to general consciousness of environmental protection, water usage and spending, present situation of sanitary and sewerage service, needs for improvement of sanitary and sewerage system, actual expenditures incurred for the sewage disposal, hygienic level of life, and morbidity record.

It was not possible for the study team to conduct a detailed inhabitant survey due to procedural problems. Instead a simple analysis was performed with the sample size of 102. The samples covered the ten municipalities in the study area. Two types of questionnaire were prepared. The first type of questionnaire included the household size, sewage disposal method, and the WTP for environmental improvement of the bay. The other type was asking the household size, sewage disposal method, and the willingness to accept (WTA) for environmental deterioration of the bay.

Theoretically the WTA would be the most appropriate measure for losers from a resource allocation decision, and WTP the proper measure for gainers from that same reallocation. A difficulty exists when it is not clear whether the respondent is a loser or gainer. In fact inhabitants in the Havana Bay basin have the two sides. To avoid confusion by asking respondents the two sidedness question, either one of WTA or WTP question was posed. The result of the analysis is summarized in Table 13.35.

The mean household size of these 102 samples was 3.9. The connection rate to sewer was 86 percent. The mean WTP of the 52 samples was 2 peso. The mean WTA of the 50 samples was 20. This notable gap between the mean WTP and the mean WTA could be explained by a customary behavior of the households in the City of Havana. The majority of households are charged a monthly flat water and sewerage rate of Ps1.3 per household member. This Ps1.3 is in fact comprised of water rate (Ps1) and sewerage rate (Ps0.3). This is generally perceived as a set of charge paid to a water company. The household data (Table 13.21) indicates that an average household of four family members paid Ps5 for water and sewerage services a month, while their total monthly income is Ps760. The water and sewerage expense accounts for 0.7 percent of the household income, which is considered a low level in comparison with many developing countries. This low rate has been made possible because the Cuban government controls the utility prices to consumers. Also there are government subsidies and financings to the utilities. As a result the water and sewerage rates to general public are maintained relatively low. Under the circumstances, when asked a WTP question, the respondents who take this low rate for granted, would unsurprisingly undervalue the WTP.

Table 13.35 Results of Inhabitant Survey

Item	Willingness to pay	Willingness to accept	Total
Number of samples	52	50	102
Mean household size (person)	3.8	4.0	3.9
Connection to sewer			
Sewer	86%	86%	86%
Septic tank	8%	12%	10%
Direct discharge to river	6%	2%	4%
Mean willingness value (Ps/month)	2 [a]	20 [b]	11
Standard deviation (Ps/month)	2	34	25
Minimum (Ps/month)	0	0	0
Maximum (Ps/month)	10	100	100
Median (Ps/month)	1	0	1
Mode (Ps/month)	1	0	0

Source: Study team

[a] Applying the Student's distribution, the mean WTP of the population lies between 1.4 and 2.6 peso at 95% confidence level.

[b] Applying the Student's distribution, the mean WTA of the population lies between 10.4 and 29.6 peso at 95% confidence level.

To the contrary, some respondents overvalue the compensation amount when they are asked a WTA question. In fact, Cuban people rarely receive monetary compensation or indemnification for damages, therefore when asked WTA, respondents tend to find themselves perplexed. A benchmark with which respondents could associate their WTA would be fines for infraction. For example, violations of traffic regulations such as illegal parking and speeding usually cost violators Ps50 or less. It is only recently that acts in contravention of environmental regulations have begun being fined. The Decree 272 of the Executive Committee of the Council of Ministers was enacted in February 2001, which stipulates that natural or juridical persons who dispose waste shall be fined. For example, a citizen who disposes of debris outside authorized dump sites is fined Ps200 to 250. If it is an entity, the fine is Ps600. Throwing garbage away on the street is Ps50 and dumping of commercial waste is Ps200. In 2001, 52,320 citizens and 4,008 entities were fined in contravention of those hygiene rules.

Taking the above situation into account, the Ps11 or the mean value of the WTP and the WTA of the 102 samples was taken as the WTP for the purpose of economic benefit valuation.

2) Benefit of inhabitants

The priority group to which the project will bring its economic benefit is inhabitants. In fact, there are two types of inhabitants, which are “direct” and “indirect” inhabitants. The “direct” inhabitants include those who reside in the area covered by the master plan project. The project will improve the sewerage system itself which is directly connected or connectible to their houses. Therefore these dwellers can be classified as “direct” inhabitants. The “indirect” inhabitants include those who live outside the project area. Hence, the sewerage or sanitation systems they are currently using are technically irrelevant to the project, but they can enjoy the improved environment of the Havana bay as a result of the project.

The most direct and perceivable benefit of the project for inhabitants emerges for example, when a new sewer connection reaches houses of those who have been using septic tanks. For those who have been already connected to sewer, an improvement of a downstream facility such as construction of a new WWTP is hardly perceivable.

In fact, the master plan project is formulated to decrease the pollutants loads discharging into he Havana bay and to improve the water environment in the bay. The social survey to ask the WTP and WTA also focuses in this aspect. Therefore not only the “direct” inhabitants but also “indirect” inhabitants should be categorized as beneficiary because they can equally enjoy the better environment. A problem here is to what extent those “indirect” inhabitants should be included when the bay in the capital city is accessible to many of the Cuban nation. A reasonable threshold of the inhabitant beneficiary is the provincial border of the City of Havana. In this economic analysis, those who live in the City of Havana are regarded as inhabitant beneficiary.

As shown in Table 11.2 of Part-I, the population of the City of Havana Province was projected to be slightly decreasing toward the year 2020. In 2010 for example, there will be 2,151,562. In 2011, the population will decrease to 2,148,399, which is considered 537,100 households, taking 4 as an average household size. The WTP per household deduced from the social survey is Ps11 per month. Hence, the aggregate benefit of inhabitants can be expressed as multiplication of the number of households and the WTP. For example, the aggregate benefit of the year 2011 is computed as follows:

$$
\begin{aligned}
B_{(2011)} &= N_{(2011)} \times W_{(2011)} \\
&= 537{,}100 \times (11 \times 12) \\
&= 70{,}897{,}200
\end{aligned}
$$

Where
$B_{(2011)}$: Aggregate benefit in the year 2011
$N_{(2011)}$: Number of household in the year 2011
$W_{(2011)}$: Willingness to pay per household in the year 2011

The aggregate benefits of the other years have been computed in the same way

3) Benefit of industries

Industries hereof include all Cuban entities except inhabitants. Commercial users, industrial users, institutional users, state entities, and joint ventures of Cuban and foreign capitals fall under this category. Those entities as well as domestic users are considered to have the WTP. The rationale that explains the WTP of inhabitants is also applicable to the WTP of industries and institutions. The sewerage charges that the industries pay to the water companies is in part, manifestation of the WTP. All the industries located in the master plan project area are somewhat polluters of the environment of the Havana bay. Some of those industries are direct beneficiaries of the improved sewerage system if their economic activities are favourably affected by the improved bay environment. Tourism is a typical example of the direct beneficiary from the improved environment. Many other industries can also enjoy the ripple effect of the economic boost. The geographical boundary to which the economic effect can reach is estimated to be the City of Havana limit the same as the case of benefit of inhabitant.

An industry survey is practical measure to clarify the WTP. Questions asked in the survey usually include sales of entity, water and sewerage charges the entity pays, and the willingness to pay for a sewerage project as percentage of sales sewerage charge. However, as it was not possible for the study team to conduct an industrial survey due to institutional reasons, an empirical estimation was employed.

An experience suggests that the WTP, or the maximum amount that industries are prepared to pay for an additional sewerage project tends to be at the level of sewerage charge that the industries are presently paying. The sewerage charges are estimated based on latest available revenue data of the four water companies that provide water and sewerage (including sanitation) services in the City of Havana. In 2002 Aguas de La Habana had the water revenue of Ps34.611 million and the sewerage revenue of Ps6.646 million, with the exchange rate of Ps1:US$26. The other three companies altogether (Acueducto del Este, Acueducto Sur, and Acueducto de Cotorro) estimatedly had the water revenue of Ps22 million and the sewerage revenue of Ps0.1 million. In total, Ps56.611 million were water revenue and Ps6.746 million were sewerage revenues. Those revenues are accounting summation of foreign currency (US$) portion and Cuban peso portion, using the exchange rate of Ps1:US$1. Furthermore the revenues were assumed to be comprised of 40 percent from domestic users and 60 percent from industry users. Domestic users were mostly payers in Cuban peso, while one third of industry users were payers in foreign currency, and two thirds in Cuban peso. These relationships can be represented in the following equations:

$T = R_d + R_f + R_l$
$R_d = T \times 0.4$
$R_f = T \times 0.6 \times 1/3$
$R_l = T \times 0.6 \times 2/3$

Where
T : total sewerage revenue charged in the City of Havana
R_d : sewerage revenue from domestic users who pay in peso.
R_f : sewerage revenue from industrial users who pay in US$
R_l : sewerage revenue from industrial users who pay in peso

By substituting 6.746 million peso for T, and applying the exchange rate of US$1:Ps1, the solution is:

R_d = Ps2,698,400
R_f = US$1,349,200
R_l = Ps2,698,400

The production of the City of Havana in 2002 was Ps5,821 million. Hence, it can be said that the industry in the City of Havana paid a 0.023 percent of its production as sewerage charge (1.3492/5821=0.023%) in US$ and 0.046 percent as sewerage charge in peso (2.6984/5821=0.046%). These percentages can be taken as the WTP of industry. Furthermore, the real growth rate of the production of the City of Havana is assumed to be 2 percent through the end of the project period.

4) Benefit of tourists

The weight of the City of Havana in Cuban tourism is considerably high. The number of tourists who visited the City of Havana was 0.98 million in 2001, which accounted for 55 percent of total visitors to Cuba. Benefit of tourists for having an improved bay environment is obvious because the touristic importance of the City of Havana and its Old Havana district cannot be dissociated from its bay and port. Founded on its present site in the sixteenth century, Havana prospered mainly due to Havana Bay, which was a natural port of call for ships sailing to and from the New World. Damage caused by environmental deterioration of the bay will be costly, affecting negatively to the tourism income of the City of Havana.

To conduct a questionnaire survey or a series of interviews is a direct measure to fathom the WTP of tourists the same as in the cases of inhabitant survey and industrial survey. However institutional difficulties existed in organizing such a survey with the sufficiently large number of samples. Instead the study team conducted informal street interviews with foreign tourists. The findings were presented in Section 13.8.2 (6). The estimated ability to pay of tourists is used as a proxy of the WTP, which is US$2 per tourist who visits the City of Havana. The US$2 accounts for 0.2 percent of the tourist's average spending of in Cuba, which is US$975. Using the same projection as the financial analysis, fore example, the aggregate WTP of tourists in 2011 will be US$2.6 million (=US$2 x 1,300,000).

(4) Evaluation of Economic Viability

Based on the conditions previously explained, the EIRRs are computed at 3.4 percent in the US$ portion, 96.7 percent in the peso portion, 54.6 percent in the US$/peso combined portion at the 1:1 exchange rate, and 7.6 percent in the US$/peso combined portion at the 1:26 exchange rate. The project cash flows and results of other financial indicators are presented in Table 13.36. Other tables that contain relevant computations are presented in Appendix 13.

The EIRR result of 7.6 percent for US$/peso combined portion at the exchange rate of 1:26, is inferior to the discount rate of 10 percent. This means that the master plan project might not be viable form the economic viewpoints. However a sewerage project like the master plan project in general usually does not have a high EIRR. Furthermore the master plan project would rather be considered in the light of fulfilling basic human needs regarding environmental conditions. In this context the master plan project would be recommendable.

Tables 13.36 Master Plan Project Cash Flow at Economic Value

Yr. no.	Year	Cost: Capital expenditure ($000)	Cost: Capital expenditure (Ps000)	Cost: Operating expend. ($000)	Cost: Operating expend. (Ps000)	Benefit: Foreign currency ($000)	Benefit: Corpo-ration (Ps000)	Benefit: Domestic user (Ps000)	Benefit: Tourist contribut. ($000)	Net Benefit: US$ ($000)	Net Benefit: Peso (Ps000)	Net Benefit: $ + Peso Ps1:$1 (Ps000)	Net Benefit: $ + Peso Ps26:$1 (Ps000)
1	2004												
2	2005												
3	2006	1,264	559							-1,264	-559	-1,823	-33,417
4	2007	1,264	559							-1,264	-559	-1,823	-33,417
5	2008	11,886	8,336							-11,886	-8,336	-20,222	-317,385
6	2009	13,981	8,845							-13,981	-8,845	-22,826	-372,348
7	2010	15,143	9,771							-15,143	-9,771	-24,914	-403,502
8	2011	3,968	2,671	15	1,298	1,600	3,200	70,897	2,600	217	70,128	70,345	75,760
9	2012	3,967	2,671	30	1,312	1,632	3,264	70,793	2,600	235	70,074	70,309	76,182
10	2013	5,307	3,451	41	1,492	1,665	3,329	70,688	2,600	-1,084	69,075	67,991	40,896
11	2014	10,566	5,549	49	1,498	1,698	3,396	70,584	2,600	-6,317	66,933	60,616	-97,299
12	2015	6,951	4,113	56	1,506	1,732	3,464	70,480	2,600	-2,675	68,324	65,650	-1,214
13	2016	4,324	2,909	75	1,820	1,767	3,533	70,311	2,600	-32	69,115	69,083	68,271
14	2017	4,324	2,909	94	1,840	1,802	3,604	70,143	2,600	-15	68,998	68,982	68,600
15	2018	4,901	3,097	109	1,856	1,838	3,676	69,975	2,600	-572	68,697	68,125	53,827
16	2019	6,573	3,888	120	1,866	1,875	3,749	69,807	2,600	-2,218	67,802	65,584	10,136
17	2020	6,639	4,032	131	1,878	1,912	3,824	69,638	2,600	-2,258	67,553	65,295	8,837
18	2021			149	1,984	1,950	3,901	69,638	2,600	4,401	71,555	75,956	185,982
19	2022			168	2,006	1,989	3,979	69,638	2,600	4,421	71,611	76,032	186,560
20	2023			184	2,024	2,029	4,058	69,638	2,600	4,446	71,673	76,118	187,259
21	2024			194	2,036	2,070	4,140	69,638	2,600	4,475	71,742	76,217	188,102
22	2025			206	2,050	2,111	4,222	69,638	2,600	4,505	71,811	76,316	188,943
23	2026			210	2,054	2,153	4,307	69,638	2,600	4,544	71,891	76,435	190,028
24	2027			213	2,058	2,196	4,393	69,638	2,600	4,583	71,973	76,556	191,136
25	2028			217	2,064	2,240	4,481	69,638	2,600	4,624	72,055	76,679	192,267
26	2029			221	2,068	2,285	4,570	69,638	2,600	4,665	72,141	76,805	193,424
27	2030			224	2,072	2,331	4,662	69,638	2,600	4,707	72,228	76,935	194,606
28	2031			224	2,072	2,378	4,755	69,638	2,600	4,753	72,321	77,075	195,911
29	2032			224	2,072	2,425	4,850	69,638	2,600	4,801	72,416	77,217	197,243
30	2033			224	2,072	2,474	4,947	69,638	2,600	4,850	72,513	77,363	198,601
31	2034			224	2,072	2,523	5,046	69,638	2,600	4,899	72,612	77,511	199,986
32	2035			224	2,072	2,574	5,147	69,638	2,600	4,949	72,713	77,663	201,399
33	2036			224	2,072	2,625	5,250	69,638	2,600	5,001	72,816	77,817	202,840
34	2037			224	2,072	2,678	5,355	69,638	2,600	5,053	72,921	77,975	204,310
35	2038			224	2,072	2,731	5,462	69,638	2,600	5,107	73,028	78,135	205,809
36	2039			224	2,072	2,786	5,571	69,638	2,600	5,162	73,138	78,299	207,339
37	2040			224	2,072	2,841	5,683	69,638	2,600	5,217	73,249	78,466	208,899
38	2041			224	2,072	2,898	5,796	69,638	2,600	5,274	73,363	78,637	210,490
39	2042			224	2,072	2,956	5,912	69,638	2,600	5,332	73,479	78,811	212,113
40	2043			224	2,072	3,015	6,031	69,638	2,600	5,391	73,597	78,988	213,768
41	2044			224	2,072	3,076	6,151	69,638	2,600	5,452	73,717	79,169	215,457
42	2045			224	2,072	3,137	6,274	69,638	2,600	5,513	73,840	79,353	217,179
	Total	101,058	63,362	6,067	67,869	79,992	159,985	2,444,278	91,000	63,867	2,473,032	2,536,899	4,133,577

Results:

Case I	US$ portion	EIRR: 3.4%	B/C: 0.5	NPV($): -20,821	(Discount rate: 10%)
Case II	Peso portion	EIRR: 96.7%	B/C: 10.3	NPV(P): 330,635	(Discount rate: 10%)
Case III	US$+peso (Ps1:$1)	EIRR: 54.6%	B/C: 4.9	NPV(P): 309,814	
Case IV	US$+peso (Ps26:$1)	EIRR: 7.6%	B/C: 0.8	NPV(P): -210,707	

(5) Sensitivity Analysis

Sensitivity analysis was performed same as done in financial evaluation. The results are presented in Table 13.37. The benchmark EIRRs would be those computed for a sum of the US$ and the peso portions at the exchange rate of Ps26:US$1. The EIRR is slightly more sensitive to changes in revenue than construction cost. A decrease of 20 percent in construction cost improves the base EIRR by 2.6 points, while an increase of the same percentage reduces the base EIRR by 1.9 points. An increase of 20 percent in revenue improves the base EIRR by 3.1 points, while a decrease of the same percentage reduces the base EIRR by 3.0 points.

Table 13.37 Economic Sensitivity Analysis of Master Plan Project

	US$	Peso	US$+Peso (Ps1:US$1)	US$+Peso (Ps26:US$1)
Base case	3.4%	96.7%	54.6%	7.6%
Construction cost increases by 20%	2.0%	87.1%	47.6%	5.7%
Construction cost decreases by 20%	5.3%	109.1%	63.9%	10.2%
Revenue decreases by 20%	0.9%	84.8%	45.7%	4.6%
Revenue increases by 20%	5.9%	107.0%	62.5%	10.7%

(6) Other Economic Benefits

A sewerage project can expectedly bring various types of benefits, some of which are perceived by inhabitants as a contributing factor to their WTP, but some are not perceived as such. Health and sanitation improvement is relatively easy to be perceived. A sewerage project naturally contributes to a reduction of morbidity and mortality that water born diseases have. Savings of medical cost and income forgone by patients while they are in bed are considered as a benefit.

A WWTP produces various by-products during the treatment process although their marketability in Cuba is not proven. Drying bed sludge has a variety of uses. Firstly it can be an ingredient of compost that is used for agricultural purpose. Dried sludge is also usable as a raw material or an auxiliary fuel in cement production. Aquaculture would use diet of fish which could contain sludge of high organic component. Digested sludge can be also sprayed as fertilizer in silviculture.

The above mentioned benefits however, are mostly unquantifiable in nature, or there is still a lack of reasonable amount of information that can be used in economic quantification. Thus in-depth quantification of those economic benefits can not be done. Instead, a simplified valuation for health benefit from having less incidence of acute diarrhea is attempted subsequently.

Morbidity data of diseases related to the development of water supply and sewerage system are shown in Section 2.2.3 (Tables 2.12 and 2.13 and Figure 2.2). The data support a common sense that the more exposed to environmental contamination, the higher morbidity. In the City of Havana the incidence of acute diarrhea has been around 250,000 per year, which means that over 11 out of 100 inhabitants complain of acute diarrhea annually.

The causal relationship between the project and the incidence of acute diarrhea should exist but the degree of relationship cannot be exactly proven at the present stage. As free medical care is universally provided in Cuba, the price that Cuban inhabitants actually pay at the doctors for the treatment of acute diarrhea is nil. Although they have to pay for prescribed medicines at pharmacies, the price of antidiarrheal agents is considered averagely Ps10 per person per cure. It is estimated that acute diarrhea causes a wage earner a two-day off from the work. The average monthly wage and the labor market participation rate of patients are estimated Ps359 and 42 percent respectively. Those data lead to the lost wage of Ps10 per patient. Combining this with medical cost, the total cost paid by a patient of is Ps20. It should be noted that the Ps20 is the cost incurred by a Cuban average patient. If a patient is non-Cuban, the price is different. Table 13.38 comparatively shows the two cases, one for Cubans and the other for foreigners. The difference between the two costs represents various economic distortions such as government subsidy to health system, wage control, foreign exchange control, and intermediary margin.

In roughly estimating the economic benefit of the project, it is assumed that if a 10 percent of the acute diarrhea is attributable to poor excreta disposal and if this can be eliminated by the project, then the reduction of the incidence would be 25,000 per year. By multiplying this by the cost incurred by a Cuban patient, the economic benefit results in Ps500,000 annually. If the foreigner price is applied, the economic benefit turns out to be US$3 million per year.

Table 13.38 Loss Caused by Contraction of Diarrhea

	Cuban local patient	Foreigner
①Medical examination	Nil	US$30
②Medicine	Ps10	US$10
③Average monthly wage	Ps 359 (a)	US$3,000
④Lost working day	2 days	2 days
⑤Labor market participation	42% (b)	40%
⑥Lost wage (③÷30×④×⑤)	Ps10	US$80
⑦Total cost (①+②+⑥)	Ps20	US$120

(a) “Economic report 2001”, Ministry of Economy and Planning.
(b) Computed from Data of “Statistics Yearbook of the City of Havana 2002”, The City of Havana Territorial Office of Statistics.
Other data are estimated by the study team.

13.10 PRIORITY PROJECTS FOR FEASIBILITY STUDY

13.10.1 SELECTION CRITERIA

The sewerage system components to be implemented up to the year 2020 (Sewerage Master Plan) have been selected from the required sewerage components considering the followings:

- Contribution to water quality improvement in Havana Bay especially to the most deteriorated area of Atares in the bay.
- Contribution to improve the system reliability to protect wastewater direct discharge to the bay.
- Contribution to reduction in the pollution loads effectively and efficiently.

13.10.2 SELECTION OF PRIORITY PROJECTS FOR FEASIBILITY STUDY

As for the Priority Project for Feasibility Study, the system components under the First Stage Program in the section 13.4.2 are selected. The followings are sewerage component facilities included in the Priority Project.

1) Execution of necessary measures to solve the cross connections in the area related to the Dren Arroyo Matadero.
2) Rehabilitation of the screen facilities at Caballeria.
3) Rehabilitation of Casablanca pumping station.
4) New construction of the Matadero pumping station.
5) New installation of the interconnection pipe between the Colector Cerro and the Matadero pumping station.
6) New installation of the pumped main and the Colector Sur Nuevo between the Matadero pumping station to the screen facilities at Caballeria.
7) New installation of the Luyanó-Martín Pérez Righ Colector in Luyanó-Martín Pérez Abajo sewer district.
8) New installation of the Luyanó Left Colector in Luyanó-Martín Pérez Abajo sewer district.
9) New construction of biological secondary wastewater treatment facilities at the same site of GEF-UNDP WWTP (treatment capacity of 207 L/s or 17,900 m^3/d), namely Luyanó WWTP. The total treatment capacity becomes 407 L/s or 35,200 m^3/d.
10) New installation of sewer networks and house connections in Luyanó-Martín Pérez Abajo sewer district.

And the following surveys and design work are also included:

11) Detailed survey and design work to solve the cross connection problems in the area related to the Dren Matadero.
12) Survey on physical conditions of the siphon.

Under the Priority Project (the First Stage Program proposed), the following project effects will be expected:

- Execution of solution measures to the cross connections in the area related to the Dren Arroyo Matadero, construction of Matadero pumping station, installation of pumped main and Colector Sur Nuevo will contribute the water environment improvement at Atares, where the water is heavily polluted by the direct wastewater discharge through the Dren Arroyo Matadero.

- Improvements in reliability of the most important components of the Central sewerage system will contribute to protect wastewater direct discharge between the Dren Matadero and the Casablanca pumping station. Since the Central system has been used more than 90 years, rehabilitation work is urgently required, especially for the Casablanca pumping station and the screen facilities at Caballeria.
- Construction of new sewerage system in Luyanó-Martín Pérez sewer district will contribute the pollution load reduction to the bay effectively and efficiently.

13.11 INITIAL ENVIRONMENTAL EXAMINATION (IEE) OF THE SEWERAGE SYSTEM MASTER PLAN

13.11.1 GENERAL

(1) Legislation

Legal requirements governing the process of environmental impact assessment is stipulated in "*Reglamento del Proceso de Evaluación de Impacto Ambiental" (Resolución No. 77/99)* of 1999. Works related to Colectors and pipes for urban wastewater effluents is designated as an activity or work which requires an environmental license for operation. Process of obtaining an environmental license comprises:

① Application for an Environmental License

② Environmental Impact Assessment, in case where it is deemed to be necessary by CITMA and its submittal to CITMA

③ The Evaluation by CITMA

④ Award or reject an Environmental License

An Environmental License thus granted will expire if the work or activity does not commence within the first year of its award. In the exceptional case that delay is due to lack of financing validity of the License could be extendable for another year.

Further, environmental impact assessment study is required to be carried out by the accredited Cuban institutions.

An important aspect in obtaining an environmental license is "Micro Localizacion" or facility siting for which case approval of the Institute of Physical Planning is required and the approval constitutes as part of the requirement for application of an environmental license.

(2) IEE and Environmental Impact Assessment (EIA)

In this Study which involves facility planning of sewerage system and improvement to drainage system, an initial environmental examination (IEE) of the Master Plan and environmental impact assessment (EIA) of the proposed priority project will be carried out, which is a requirement of JICA. Carrying out IEE and EIA in this stage will facilitate obtaining financing for the projects and finally to obtain environmental license according to the Cuban legislation prior to operation.

13.11.2 INITIAL ENVIRONMENTAL EXAMINATION

IEE on the facility siting and on the identification of positive/negative impacts is described in the following.

(1) Location of Facilities

1) WWTP

In the Sewerage Master Plan, one sewer district namely, Luyano-Martin Perez Sewer District is included and the location of WWTP is adjacent to the site selected for the on-going GEF/UNDP Project. This site was selected in consultation with DPPFA and other related Cuban organizations following consideration of land availability, future plans of highway access to port facilities, other infrastructure development plans namely electricity distribution facilities etc. The selected site satisfy most of the environmental considerations. However, it will not be possible to layout all the treatment facilities at least 100 m away from the nearest households even though best effort is made to keep facilities which could be possible source of nuisance i. e. screen, grit chamber etc.

Alternatively, provision of a green-belt and strict observation of good housekeeping procedures during the operation and maintenance will minimize the impact.

Among the alternative sites considered, the selected site is considered to be the most appropriate given the limitations in available sites.

For other WWTPs not included in the Sewerage Master Plan, their location and pertinent environmental conditions are described in Appendix-14 Environmental Impact Assessment Survey.

2) Pumping Station

There are two pumping stations to be constructed namely, Matadero Pumping Station and Re-Pumping Station following the tunnel to Playa del Chivo. Replacement and improvement work within the Casablanca Pumping Station is also proposed. Location of Matadero Pumping Station was also selected in consultation with DPPFA among the three locations all of which are closer to the selected site. Location of Re-pumping Station will be at the end of the tunnel from Casablanca Pumping Station. The site for Re-pumping Station and the primary treatment facility discussed in the following Sub-section 3) Other Facilities required to be located at the end of the tunnel. While it is agreed that these two facilities need to be located at the end of the tunnel, specific details of the site and that of the facilities need to be studied prior to their implementation in the Second Stage as these two facilities need to be within the protected zone for scenery.

3) Other Facilities

Rehabilitation of existing screens at Caballeria is proposed as a Priority Project. Construction of a primary treatment facility is also proposed as water quality of wastewater from existing system is expected to exceed the discharge quality standards due to elimination of cross-connections. Location of which is as discussed in the preceding Sub-section 2) Pumping Station.

4) Colectors

Construction of Colectors and construction of pipes to relieve interconnection of existing Colectors to drains are included in the Master Plan. Following Colectors are proposed for construction. They are,

- Colector Sur Nuevo
- Sur Nuevo Pumped Main (between Matadero Pumping Station and Colector Sur

Nuevo)

- By-Pass Pipe for Colector Cerro and Colector Sur
- Colector Sur A
- Luyano Left Colector
- Luyano-Martin Perez Right Colector

Location and route of pipes to relieve illegal connections will be identified through further surveys during implementation and their environmental impact need to be assessed on an individual basis.

(2) Positive Impacts

Major positive impacts of the proposed Master Plan for improvement of sewerage and drainage are as follows:

1) Improvement of water environment of Havana Bay due to reduction of pollutant load discharged through drains, rivers and industries
2) Improvement of living environment in the sewer districts

Main indirect benefits are to tourism and social welfare.

(3) Negative Impacts

Major negative impacts of the proposed Master Plan for improvement of sewerage and drainage are as follows:

1) Generation of odor and its impact to the surrounding environment of Luyano WWTP and Matadero Pumping Station.
2) Generation of wastewater sludge and its disposal
3) In the short-term to medium-term, continued discharge of pollution load to Carribean Sea discharged from the Central system where primary treatment is proposed in the long-term
4) Traffic congestion, noise and dust pollution during construction of facilities mainly Colectors and pipes to relieve illegal connections

(4) Assessment of Impacts

Positive impacts of the proposed Master Plan far outweigh the negative impacts and the consequences of not implementing the Master Plan will have grave impact to the national economy due to increased pollution of the bay. However, assessment of the negative impacts to mitigate their effects to the environment need to carried out in the EIA Study for the Priority Projects.

Negative impacts to be studied are as follows:

<u>Luyanó Wastewater Treatment Plant</u>

- Land acquisition / relocation
- Visual impact to the surroundings
- Treated effluent disposal to Rio Luyanó

- Odour generation
- Fly/vector generation
- Noise and vibration
- Sludge generation and its disposal or possible reuse
- Flooding
- Construction noise, vibration and dust generation

Matadero Pumping Station, Casablanca Pumping Station and Screen at Cabelleria

- Land acquisition (for Matadero Pumping Station)
- Visual impact to the surroundings
- Cultural heritage sites
- Odour generation
- Screenings disposal
- Fly / vector generation
- Traffic congestion
- Construction noise, vibration and dust generation

Colectors

- Land acquisition / relocation / right of way
- Effect to cultural heritage sites during construction
- Erosion control during construction
- Excess soil disposal
- Land subsidence and groundwater control during construction
- Traffic congestion during construction
- Construction noise, vibration and dust generation

CHAPTER 14
CONCLUSIONS AND RECOMMENDATIONS

14.1 CONCLUSIONS

This Study has prepared the improvement plan of existing sewerage system and the development plans of new sewerage systems, and formulated the implement plan up to 2020 as a Sewerage System Master Plan. It also has proposed consecutive three stage implementation program with preliminary financial and economic evaluations and finally identified the Priority Projects for Feasibility Study.

The Sewerage System Master Plan is prepared to seek water environment improvement of the Havana Bay through the improvement for existing sewerage system and the development of new sewerage system toward the target year of 2020.

The proposed Priority Projects will be studied more detail in the subsequent Feasibility Study phase. The study includes preliminary engineering design, system O/M plan, financial plan, cost estimation, EIA, evaluation of Project, and implementation plan.

14.2 RECOMMENDATIONS

14.2.1 IMPROVEMENT OF THE EXISTING SEWERAGE SYSTEM

The improvement of the Central sewerage system will contribute continuously to protect the direct discharge of the wastewater to the Havana bay. However, success of the improvement plan depends on how much the cross connection problems could be solved, which cause the wastewater discharge to the bay through the drainage system of the Dren Matadero and the Dren Agua Dulce.

The construction of the primary wastewater treatment plant at Playa del Chivo is not proposed in the Sewerage Master Plan, taking into consideration of uncertainty of the necessity of wastewater treatment to meet the effluent standards up to 2020, the current limited land availability to apply the easy sludge treatment process. But the primary wastewater treatment facilities with appropriate sludge treatment process will be required inevitably to meet the effluent standards. Therefore, it is recommended that the Cuban authorities would obtain a large enough land area to construct the primary treatment facilities with appropriate sludge treatment methods with provision of revising the regulations or removing control by the regulation related to the land use for construction site.

14.2.2 DEVELOPMENT OF THE NEW SEWERAGE SYSTEM

For the new sewerage scheme, the six alternatives had been proposed and studied to select the four zonal sewerage system, considering the expected effects to improve the water quality in the Havana bay and the maximum increase in the sewer service population up to 2020. Among the four sewer districts, only Luyanó-Martín Pérez Abajo sewer district will be implemented up to 2020. Other three sewer districts of Luyanó Arriba sewer district, Martín Pérez Arriba sewer district and Tadeo sewer district are expected to implement as soon as possible after the execution of the proposed Master Plan.

As discussed in chapter 12, the land areas available for construction of the proposed WWTPs are key issues to select the most appropriate sewerage development plan and to choose the appropriate wastewater and sludge treatment processes such as trickling filter and OD processes and sludge drying beds which are easy to operate and cheaper in capital and O/M costs. The limited land area available for construction of the Luyanó WWTP should apply the conventional activated sludge process with mechanical dewatering facilities, which requires very high technology to operate and high costs in construction and operation and maintenance.

For realizing the remaining three sewer districts after the execution of the Master Plan, it is highly recommended to devote considerable efforts to obtain the land area enough to construct the appropriate wastewater and sludge treatment processes at the wastewater treatment plant sites.

As the alternative of the expansion plan of Luyanó WWTP under the second stage project in the Master Plan, the Luyanó Left Colector is proposed to connect to the Colector system comprising Matadero pumping station, pumped main and Colector Sur Nuevo with provision of Colector A to discharge the wastewater to the Caribbean ocean. But to realize this alternative, it is required that the cross connection problems in the area related to the Dren Matadero should be solved completely.

When the alternative of Ocean disposal for area of Luyanó Left Colector is realized, the capacity development of the Luyanó WWTP up to 2020 is required only 207L/s or 17,900m^3/d out of 621L/s or 53,700m^3/d. In such case, it is recommended that the sewerage system development plan should be revised, taken into consideration of a combined plan of Luyanó Arriba sewer district and the Luyanó-Martín Pérez Abajo sewer district.

14.2.3 BAY WATER ENVIRONMENT

(1) Water Quality Monitoring

Monitoring the water quality and pollutant loads related to the Havana bay basin is very important: 1) to understand the environmental conditions, 2) to provide data and information for improvement of the future water quality projection using simulation model, 3) to confirm the effects of projects related to reduce pollutant loads discharged to the bay, and 4) to assess when the primary treatment plant for the Central Sewerage System will be required to meet the effluent quality standards.

Main issues on monitoring are 1) to establish a unified and periodic water quality monitoring system, 2) to establish a database related to the overall water environment in the Havana Bay basin, 3) to establish the rules, limitations and procedures for sharing the data and information among the concerned authorities and opening to the public, and 4) to provide the budget for establishing and maintaining the recommended monitoring system.

(2) Improvement of the Water Quality Simulation Model

Reliability of bay water quality simulation model depends on: 1) the monitored pollutant load inflow data to the bay, and 2) on the bay water environment data since these data is used to describe the behavior of bay water environment in the simulation model. As the number of sets of existing data is very limited, it is very important to refine the model by acquiring further sets of data with improved monitoring.

Behavior of bay water system to external perturbations (i.e. pollution load reduction) is yet to be verified due to limitation of available sets of data. Monitoring data on the behavior of bay water environment with the implementation of Priority Projects will provide useful information to refine the model and to verify its predictions especially related to any trend of eutrophication in the future.

Improvement of the water quality simulation model will also play an important role during the revision of Master Plan when the feasibility of the discharge of wastewater from Luyanó Left Bank Area A to Central System is examined in the future.

(3) Water Environment Objectives

Water quality standards for the bay is in the draft preparation stage and need to be finalized to set a legal basis for improvement of the bay. It will create a common understanding among the various stakeholders related to bay environment protection. Water quality standards need to be set based on the future water uses of the bay. Water quality goals set in this study need to be reviewed through further discussion among various stakeholders. This discussion will be facilitated by this Sewerage Master Plan, in which the role and contribution of the sewerage and drainage sector to the improvement of bay water environment have been made clear together with required cost and time. Role of environmental education was also included in this Master Plan. Role and contribution of other sectors for example industrial sector, port and shipping sector etc. and measures such as dredging of sediments need to be explored in the review of water quality goals together with their cost and time implications.

14.2.4 OTHER RECOMMENDATIONS

In order to seek the early realization of the Master Plan, close cooperation and coordination are deemed indispensable not only between INRH and GTE, but also among INRH, GTE, CITMA, the Havana City and the relevant authorities concerned.

As urbanization is dynamic and has been exploring toward the outskirt of Havana City, a periodical review and update of the Master Plan is indispensable. INRH shall closely cooperative with physical planning of the Havana City to reflect the latest urban development of the staged sewerage improvement plan. To achieve such a plan properly, continuous data collection within INRH and from the authorities concerned shall be programmed and carried out.

Through the formulation work of sewerage plans in the Study, the land availability for the WWTP was very limited due to the existing land use plan or regulations on land use or environmental consideration. It was also explained and presented that the sophisticated wastewater and sludge treatment processes but require very high running costs should be applied when the land for WWTP is very limited, on the contrary, when the large area is obtained for the WWTP the simple treatment process but possible to operate easily and with very low running costs. In this respect, it is advised that INRH, GTE, and other related authorities would make continuous efforts to obtain the appropriate and larger land area for the WWTPs and to revise the existing land use plans and regulations if necessary.