JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTERIO DEL AMBIENTE Y DE LOS RECURSOS NATURALES RENOVABLES
THE REPUBLIC OF VENEZUELA

# THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

## FINAL REPORT

## VOLUME 3

## MAIN REPORT (FEASIBILITY AND PRE-FEASIBILITY STUDY)



AUGUST 1997

CTI ENGINEERING CO., LTD.
KOKUSAI KOGYO CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTERIO DEL AMBIENTE Y DE LOS RECURSOS NATURALES RENOVABLES
THE REPUBLIC OF VENEZUELA

# THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

# FINAL REPORT

## VOLUME 3

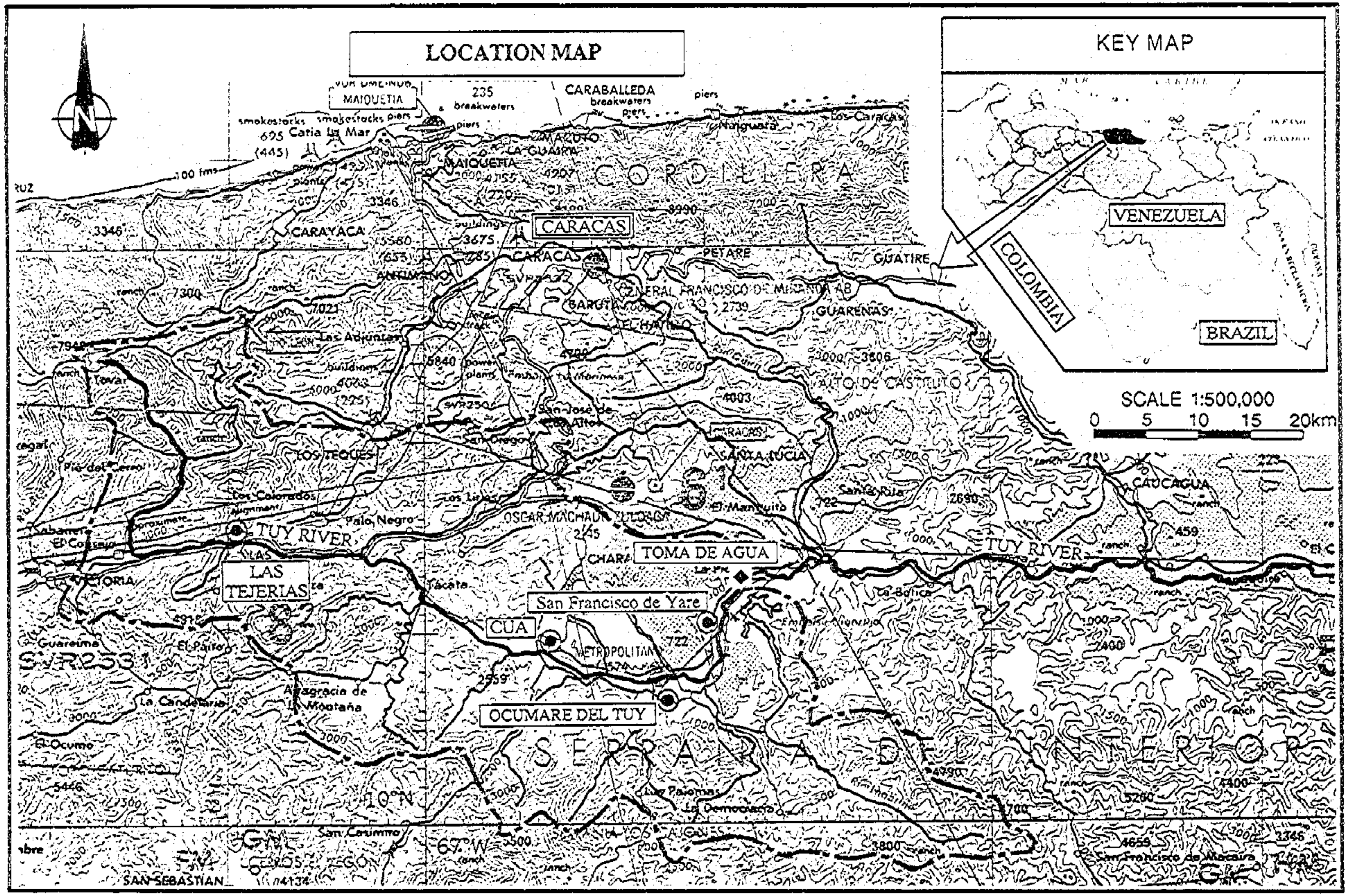
## MAIN REPORT (FEASIBILITY AND PRE-FEASIBILITY STUDY)

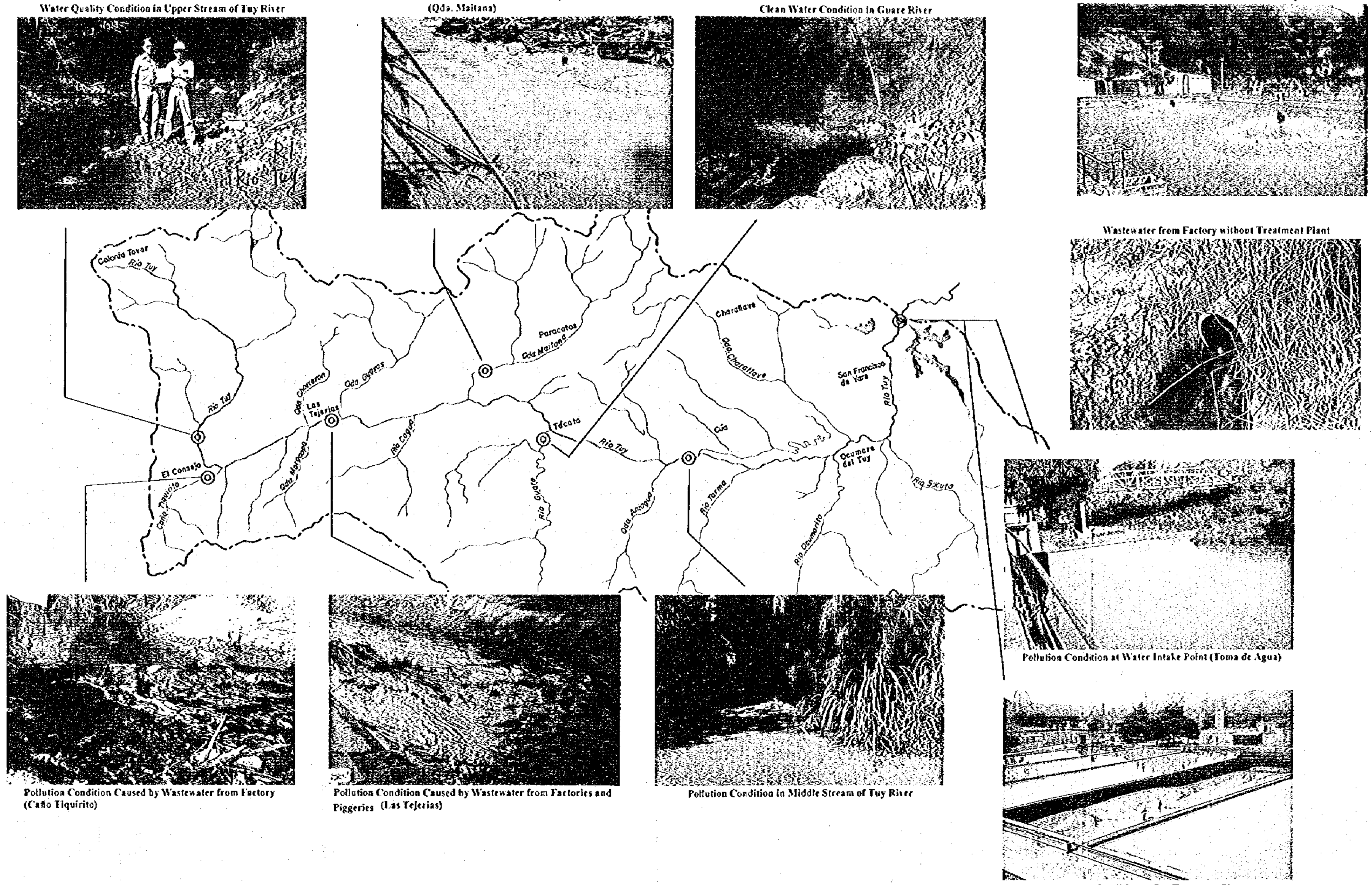
AUGUST 1997

CTI ENGINEERING CO., LTD.
KOKUSAI KOGYO CO., LTD.

**THE COST ESTIMATE IS BASED**
**ON THE PRICE LEVEL OF JULY 1996**
**AND EXPRESSED IN US DOLLARS (US$)**
**ACCORDING TO THE FOLLOWING EXCHANGE RATES:**

**US$1.00 = Bs. 470 = ¥100.20**
**(AS OF JULY 16, 1996)**


LOCATION MAP
KEY MAP
VENEZUELA
COLOMBIA
BRAZIL
SCALE 1:500,000
0 5 10 15 20km
MAIQUETIA
CARABALLEDA
Catia La Mar
CORDILLERA
CARACAS
PETARE
GUATIRE
GUARENAS
CARAYACA
LOS TEQUES
SANTA LUCIA
CAUCAGUA
TUY RIVER
TOMA DE AGUA
LAS TEJERIAS
San Francisco de Yare
CUA
OCUMARE DEL TUY
SERRANIA DEL INTERIOR
OSCAR MACHADO ZULOAGA
SAN SEBASTIAN
10°N
67°W




Water Quality Condition in Upper Stream of Tuy River

Pollution Condition Caused by Sand Quarries (Qda. Maitana)

Clean Water Condition in Guare River

Treatment Plant of Food Factory

Wastewater from Factory without Treatment Plant

Pollution Condition at Water Intake Point (Toma de Agua)

Pollution Condition at Pre-Treatment Plant

Pollution Condition Caused by Wastewater from Factory (Caño Tiquirito)

Pollution Condition Caused by Wastewater from Factories and Piggeries (Las Tejerias)

Pollution Condition in Middle Stream of Tuy River

| | |
|---|---|
| THE STUDY ON<br>THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN<br>IN THE REPUBLIC OF VENEZUELA<br>JAPAN INTERNATIONAL COOPERATION AGENCY | **POLLUTION CONDITION OF TUY RIVER** |

# PREFACE

In response to a request from the Government of the Republic of Venezuela, the Government of Japan decided to conduct the Study on the Environmental Improvement Program of the Upper and Middle Stream of the Tuy River Basin and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Venezuela a study team headed by Mr. Yoshiharu Matsumoto, CTI Engineering Co., Ltd., and composed of members from CTI Engineering Co., Ltd. and Kokusai Kogyo Co., Ltd., four times between January, 1996 and June, 1997.

The team held discussion with the officials concerned of the Government of the Republic of Venezuela, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Venezuela for the close cooperation extended to the team.

August 1997

KIMIO FUJITA
President
Japan International Cooperation Agency

August 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Sir:

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report on the Study on the Environmental Improvement Program of the Upper and Middle Stream of the Tuy River Basin, Venezuela. The report contains the advice and suggestions of authorities concerned of the Government of Japan and the Japan International Cooperation Agency (JICA), as well as the formulation of the environmental improvement program for the study area. Also included are the comments made by the authorities concerned of the Government of the Republic of Venezuela during the technical discussions on the Draft Final Report.

The Final Report presents the Master Plan of the Environmental Improvement Program of the Upper and Middle Stream of the Tuy River Basin to secure a potable water supply with acceptable water quality and to establish a sustainable pollution control system. In view of the urgency and necessity to improve the environmental condition in the study area, the priority projects were selected and technical viability and financial feasibility were identified. It is recommended that the Government of the Republic of Venezuela should promote all priority projects to the next stage of project implementation at the earliest possible time.

Finally, we wish to take this opportunity to express our sincere gratitude to the Government of Japan, particularly, JICA, the Ministry of Foreign Affairs, the Ministry of Construction and other offices concerned. We also wish to express our deep appreciation to Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR), Tuy River Basin Agency, Oficina Central de Coordinacion y Planificacion de la Presidencia de la Republica (CORDIPLAN), HIDROCAPITAL and other authorities concerned of the Government of the Republic of Venezuela for the close cooperation and assistance extended to the JICA Study Team during the Study.

Very truly yours,

YOSHIHARU MATSUMOTO
Team Leader
JICA Study Team

Encl. : a/s

# COMPOSITION OF FINAL REPORT

| | |
|---|---|
| Volume 1: | Executive Summary |
| Volume 2: | Main Report (Master Plan Study) |
| Volume 3: | Main Report (Feasibility and Pre-Feasibility Study) |
| Volume 4: | Supporting Report (I) (Sector A to E) |
| Sector A: | Water Quality Condition and Monitoring |
| Sector B: | Existing Water Supply System |
| Sector C: | Industrial and Piggery Wastewater Treatment |
| Sector D: | Sewage Treatment |
| Sector E: | Turbid Water Treatment |
| Volume 5: | Supporting Report (II) (Sector F to J) |
| Sector F: | Securement of Water Quantity |
| Sector G: | Institutional Aspect |
| Sector H: | Construction Plan and Cost Estimate |
| Sector I: | Socioeconomic Condition and Project Evaluation |
| Sector J: | Environmental Aspect |
| Volume 6: | Data Book |
| Volume 7: | Resumen (Summary in Spanish) |
| Volume 8: | Informe Principal: Estudio del Plan Maestro<br>(Main Report for Master Plan Study in Spanish) |
| Volume 9: | Informe Principal: Estudio de Factibilidad y de Pre-Factibilidad<br>(Main Report for Feasibility and Pre-Feasibility Study in Spanish) |

**THE STUDY ON**
**THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF**
**THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN**

**MAIN REPORT**

**FEASIBILITY AND PRE-FEASIBILITY STUDY**

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# ABBREVIATIONS

## 1. VENEZUELAN GOVERNMENT AGENCIES

| | | |
|---|---|---|
| MARNR | : | Ministerio del Ambiente y de los Recursos Naturales Renovables (Ministry of Environment and Natural Renewable Resources) |
| ODEPRI | : | Oficina de Desarrollo Profesional y Relaciones Internacionales |
| CORDIPLAN | : | Oficina Central de Coordination y Planificacion de la Presidencia de la Republica |
| SINAIHME | : | Database of the Office of Hydrology and Meteorology, MARNR |
| ACRT | : | Agencia de la Cuenca del Rio Tuy (Tuy River Basin Agency) |
| INOS | : | Instituto Nacional de Obras Sanitarias (National Institute of Sanitary Works) |

## 2. JAPANESE GOVERNMENT AND INTERNATIONAL ORGANIZATIONS

| | | |
|---|---|---|
| JICA | : | Japan International Cooperation Agency |
| IBRD | : | International Bank for Reconstruction and Development (World Bank) |
| UNDP | : | United Nations Development Programme |
| GTZ | : | Deutsche Gesellschaft für Technische Zusammenarbeit |

## 3. UNIT OF MEASURE

| | | | | | |
|---|---|---|---|---|---|
| *(Length)* | | | *(Weight)* | | |
| mm | : | millimeter(s) | mg | : | milligram(s) |
| cm | : | centimeter(s) | g, gr | : | gram(s) |
| m | : | meter(s) | kg | : | kilogram(s) |
| km | : | kilometer(s) | ton | : | tonne(s) |
| *(Area)* | | | *(Time)* | | |
| $mm^2$ | : | square millimeter(s) | s, sec | : | second(s) |
| $cm^2$ | : | square centimeter(s) | min | : | minute(s) |
| $m^2$ | : | square meter(s) | h (hrs) | : | hour(s) |
| $km^2$ | : | square kilometer(s) | d (dys) | : | day(s) |
| ha | : | hectare(s) | y, yr (yrs) | : | year(s) |
| *(Volume)* | | | *(Concentration)* | | |
| $cm^2$ | : | cubic centimeter(s) | mg/ℓ | : | milligram per litter |
| ℓ | : | liter(s) | | | |
| $m^3$ | : | cubic meter(s) | | | |
| mcm | : | million cubic meter | | | |

*(Speed/Velocity)*

| | | |
|---|---|---|
| cm/sec, cm/s | : | centimeter per second |
| m/sec, m/s | : | meter per second |
| km/hr, km/h | : | kilometer per hour |

*(Stress)*

| | | |
|---|---|---|
| $kg/cm^2$ | : | kilogram per square centimeter |
| $ton/m^2$ | : | ton per square meter |

*(Discharge)*

| | | |
|---|---|---|
| ℓ/sec, ℓ/s | : | liter per second |
| $m^3/sec$, $m^3/s$ | : | cubic meter per second |
| $m^3/yr$, $m^3/y$ | : | cubic meter per year |

(Note: Other combined units may be constructed similarly as above.)

*(Electrical Units)*

| | | |
|---|---|---|
| W | : | watt(s) |
| kW | : | kilowatt(s) |
| MW | : | megawatt(s) |
| kWh | : | kilowatt-hour |
| MWh | : | megawatt-hour |
| GWh | : | gigawatt-hour |
| V | : | volt(s) |
| kV | : | kilovolt(s) |

*(Water Quality Related Terms)*

| | | |
|---|---|---|
| BOD ($BOD_{5,20}$) | : | 5-day biochemical oxygen demand at 20°C |
| COD | : | Chemical oxygen demand |
| DO | : | Dissolved oxygen |
| EC | : | Electric conductivity |
| TOC | : | Total organic carbon |
| SS | : | Suspended solids |
| TN | : | Total nitrogen |
| TP | : | Total phosphorus |
| Pb | : | Plumbum (lead) |
| Cr | : | Chromium |
| Cu | : | Cuprum (copper) |
| Zn | : | Zinc |

Pollution flowrate

## 4. MONETARY TERMS

| | | |
|---|---|---|
| ¥ | : | Japanese Yen |
| US$ | : | United States Dollar |
| Bs. | : | Venezuelan Bolivare |

## 5. SPANISH TERMS

| | | |
|---|---|---|
| Municipio | : | Municipality |
| Parroquia | : | Parish |
| Qda. (Quebrada) | : | Intermittent stream |
| Ing. (Ingeniero) | : | Eng. (Engineer) |

## 6. OTHERS

| | | |
|---|---|---|
| Art. | : | Article |

# CHAPTER 1. INTRODUCTION

## 1.1 General

The catchment of the Tuy River has a total area of 8,619 $km^2$, encompassing the Caracas Metropolitan Area and the area to the south and south-east of Caracas. The Tuy flows generally in an east-west direction and Caracas is located on a northern tributary, the Guaire River. The upper and middle streams, the Study Area, play an important role as a major source of potable water supply for the people of Caracas.

Due to wastewater from factories, piggeries and urban areas in particular, the water quality of the Tuy has deteriorated to the stage where aquatic life cannot exist in some parts. In addition, the environmental condition has worsened due to sediment production resulting from human activities, including over-development, riparian sand quarrying and deforestation. Consequently, the water supply to Caracas has been adversely affected.

To counter the environmental problems facing the Tuy, the Master Plan has been formulated followed by this Feasibility Study on priority projects. Further, a Pre-Feasibility Study is carried out for water resources development.

In the Master Plan, the present and future environmental conditions have been identified based on the investigation of present conditions and the projection of future conditions. To improve the present conditions and to counter future deterioration, two targets, the short-term and the mid-term, have been set.

To achieve the targets, various physical and institutional measures have been examined and the optimum measures selected. For the formulation of the Master Plan, the measures have been arranged into short-term and mid-term depending on the priority given to each measure. The Master Plan thus formulated has been evaluated considering technical soundness and financial viability.

An outline of the Master Plan is presented in Table 1.1-1, and an implementation schedule in Fig. 1.1-1.

This report presents the Feasibility Study results of the investigation on selected priority projects for the improvement of water quality and the Pre-Feasibility Study for water resource development.

## 1.2 Project Components for Feasibility Study and Pre-feasibility Study

Project components for the Feasibility Study and the Pre-feasibility Study are summarized below.

### 1.2.1 Project Components for Feasibility Study

**Structural Measures**

(1) Water Quality Improvement

To achieve the target of water quality, the following measures are adopted:

(a) Organic Pollution

- Installation of treatment plants for existing factories which do not meet the water quality standards.
- Installation of treatment plants for newly built factories.
- Installation of sewage treatment plants for Las Tejerías and Ocumare del Tuy areas.

The installation of sewage treatment plant in Las Tejerías is necessary to improve the water quality at Boca de Cagua, while that in Ocumare del Tuy is necessary to achieve the target at Toma de Agua.

(b) Toxicant

- Installation of treatment plants for existing factories which do not meet the water quality standards.
- Installation of treatment plants for newly built factories.

(c) Turbidity

- Installation of treatment plants for existing factories which do not meet the water quality standards.
- Installation of treatment plants for newly built factories.
- Reforestation in an area of Qda. Maitana.

(2) Securement of Water Quantity

Among the project components to secure the water quantity, the following items are conducted in the feasibility study to reduce frequency of water suspension due to odor, color and turbidity:

- Installation of treatment plants for factories that discharge pollution effluent related to odor and color.
- Construction of sand settling pond at the water intake point of Toma de Agua.

**Institutional Measures**

In general, the following institutional measures are essential to achieve the objectives of the Short-Term Program:

- Provision of laws and regulations.

- Strengthening of organizational functions.
- Establishment of monitoring system and enforcement of laws and regulations.
- Establishment of environmental fund and its use to assist factories and piggeries.
- Imposition of pollution charges for factories and piggeries which do not comply with the water quality standard.
- Establishment of education program to promote public awareness.

### 1.2.2 Project Components of Pre-feasibility Study

The pre-feasibility study is conducted for the following project components to secure the water quantity of 2.0 $m^3/s$.

- Torrent diversion of Súcuta.
- Ocumarito-Lagartijo Diversion Channel.
- Ocumarito-Lagartijo Diversion Channel together with the construction of El Peñón Dam.
- Construction of Ocumarito-Tuy III pumping system.
- Construction of Guare Dam.

# CHAPTER 2. FEASIBILITY STUDY ON THE INSTALLATION OF TREATMENT PLANT FOR FACTORIES AND PIGGERIES

## 2.1 General

In the Master Plan study, an inventory of factories and piggeries was prepared based on the following information: (1) OCEI census in 1990, (2) list of factories and piggeries registered with the Tuy Agency, and (3) other information collected through field investigation. An inventory of 103 factories and 33 piggeries was finally arranged, and classified according to industry category and location. The inventory includes the number of employees (refer to Table 2.1-1).

In the feasibility study, the installation condition of a treatment plant in each factory and piggery is re-examined to identify the following points: (1) percentage of factories and piggeries with a wastewater treatment plant, (2) percentage of factories and piggeries that fulfill the water quality standard for wastewater discharged, (3) basic process of planned treatment plants, and (4) cost to install and maintain a treatment plant.

Based on the above information, the factories and piggeries are broadly classified into several groups to which similar wastewater treatment processes can be applied. For each group, the standard treatment plant that can fulfill the water quality standard, together with the necessary cost for its installation and maintenance, is examined.

Then the cost to install a wastewater treatment plant for each factory and piggery that does not satisfy the water quality standard at present is roughly estimated based on the cost of a standard treatment plant. The necessary cost to install wastewater treatment plants for factories built in the future by 2003 is also estimated. These costs are required to promote the measures for treatment of wastewater from the factories and piggeries. The costs are to be shouldered by the factory and piggery owners. The costs are also applied in the formulation of the proposed environmental fund which is to be used when factory and piggery owners face financial difficulty to install a treatment plant.

## 2.2 Installation Condition of Treatment Plant

To investigate the installation condition of a treatment plant, 38 out of 103 factories and 10 out of 13 piggeries in the inventory have been selected at random, in addition to the 27 factories and 3 piggeries investigated in the master plan study stage. As a result of the investigation for 65 factories and 13 piggeries, the following conditions are confirmed:

The installation condition of factories and piggeries is broadly divided into three cases: (1) those which satisfy the water quality standard; (2) those which do not satisfy the standard although they have installed a treatment plant; and, (3) those which have not installed a treatment plant (refer to Table 3.1-2).

The three cases are summarized as follows:

| Case | No. of Factories | Percentage (%) |
|---|---|---|
| Factories that satisfy the water quality standard | 25 | 38 |
| Factories that do not satisfy the standard although they have installed a plant | 5 | 8 |
| Factories that have not installed a plant | 35 | 54 |
| Piggeries that satisfy the water quality standard | 2 | 15 |
| Piggeries that do not satisfy the standard although they have installed a plant | 8 | 62 |
| Piggeries that have not installed a plant | 3 | 23 |

Treatment plants in factories and piggeries at present can be classified broadly according to the following processes:

(1) Biological treatment process to reduce high concentration of bio-organic substances which are easily resolved.

(2) Biological followed by physico-chemical treatment process to reduce medium concentration of bio-organic substances.

(3) Physico-chemical treatment process to reduce chemical and organic substances which are difficult to be resolved.

(4) Physico-chemical followed by biological treatment process to reduce metals and organic substances.

(5) Physico-chemical treatment process to reduce metals.

(6) Physico-chemical treatment process to reduce non-organic suspended solids (SS)

(7) Biological treatment process to reduce high concentration of bio-organic substances which are easily resolved.

In general, the above treatment processes are applied to the following categories of industries. The installation costs are also shown in the following table (see Table 2.2-2):

| Process | Category of Industries | Number of Factories and Piggeries by Category* | Installation Costs (US$ thousand ) | | |
|---|---|---|---|---|---|
| | | | Large Scale Factories | Middle Scale Factories | Small Scale Factories |
| (1) | Food Product Industries | 6 | 345 - 1,002 | 104 | 64 - 117 |
| (2) | Manufacturing of Textiles | 4 | 390 - 420 | no data | 132 - 160 |
| (3) | Chemical Industry | 6 | 267 -465 | 82 - 200 | 30 -76 |
| (4) | Tannery | 3 | no data | no data | 47 |
| (5) | Metal manufacturing | 7 | 156 | 40 - 175 | 31 - 122 |
| (6) | Sand quarries | 3 | no data | no data | 15 |
| (7) | Piggeries | 13 | no data | 1.2 - 28 | no data |

* Factories and piggeries that satisfy the water quality standard among those surveyed.

As for operation and maintenance cost, the following percentages to installation cost are obtained:

| Process | Category of Industry | O&M Cost (%) |
|---|---|---|
| (1) | Food Product Industries | 8.0 |
| (2) | Manufacturing of Textiles | 7.5 |
| (3) | Chemical Industry | 8.6 |
| (4) | Tannery | 8.5 |
| (5) | Metal Manufacturing | 7.4 |
| (6) | Sand Quarries | 7.5 |
| (7) | Piggeries | 7.5 |

## 2.3 Study on Standard Treatment Processes

Based on the above present installation condition of treatment plants, standard treatment processes for several cases were examined to estimate the cost to install a treatment plant.

<u>**Classification of Industries to Examine Standard Treatment Process**</u>

As identified through the investigation, treatment processes for the present factories and piggeries are broadly classified into seven (7) cases. In this connection, the standard treatment processes are examined.

(1) Biological treatment which applies to food product industries

Biological treatment is used to reduce the high concentration of bio-organic substances (BOD 2,000 to 4,000 mg/l), mainly produced by food factories. A typical biological treatment process is the activated sludge process with extended aeration.

The treatment plant consists of a screen tank, an aeration tank, a sedimentation tank and a chlorination tank. A primary sedimentation tank is not necessary because of few solids.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (1/7).

(2) Biological followed by Physico-chemical treatment which applies to manufacturing of textiles

This treatment is used to reduce medium concentration of bio-organic substances mainly produced by textile industries. Generally, a standard activated sludge method is adequate. Since BOD load is medium, primary sedimentation is effective. The pH is not neutral and thus, neutralization as pretreatment is required.

The treatment plant consists of a screen, and neutralization, primary sedimentation, aeration, final sedimentation and chlorination facilities.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (2/7).

(3) Physico-chemical treatment which applies to chemical industry

In the chemical industry, mainly produced are substances such as oil containing chemicals, paints and synthetic resins. Physico-chemical treatment method is appropriate for this sewage due to biodegradable organic compounds. A storage tank is effective for flow equalization and reduction of high SS, followed by flocculation.

The treatment plant consists of a screen, and storage, neutralization, flocculation, chemical conditioning and sedimentation facilities. Storage and sedimentation tanks have to enable treatment processes of long duration.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (3/7).

(4) Physico-chemical followed by biological treatment which applies to Tannery

This treatment process is used to reduce metals and organic substances which are mainly produced in the tannery industry. Treatment for both organic substances and chromium is required. Treatment is to reduce the valence of chromium from 6+ to 3+, followed by neutralization, flocculation and biological process (activated sludge method).

The treatment process consists of chemical reduction, neutralization, flocculation, and sedimentation for chromium treatment. The other combination for organic substances is for aeration, sedimentation and chlorination.

This is the generally recommended configuration for tanneries. It should be warned that local factors in sewage characteristics may modify this recommendation.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (4/7).

(5) Physico-chemical treatment process which applies to metal manufacturing

This treatment process is used to remove metals which are mainly produced from metal manufacturing industries. Flocculation treatment is appropriate for removal of such heavy metals.

The treatment process consists of storage, neutralization, flocculation, and sedimentation. Two types of sediment are collected; one is suspended type in storage tank and flocculate.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (5/7).

(6) Physico-chemical treatment process which applies to sand quarries

This treatment process is used to remove inorganic suspended solids (SS) which are mainly produced from sand quarry industries. Natural sedimentation cannot achieve the limitation of water quality standard that SS should be below 80 mg/l. Flocculate aid is applied to remove it.

The combination of treatment tanks consists of flow equalization, chemical conditioning flocculation and sedimentation.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (6/7).

(7) Biological treatment which applies to piggeries

Biological treatment is in general the same as that for food product industries. A typical biological treatment process is the activated sludge process with extended aeration.

The treatment plant consists of a screen tank, an aeration tank, a sedimentation tank and a chlorination tank. A primary sedimentation tank is not necessary because of few solids.

The standard treatment process of this type of treatment plant is shown in Table 2.3-1 (7/7).

<u>Cost Estimation for Standard Treatment Plant</u>

Based on the standard treatment process, the costs of standard treatment plants for the seven cases are estimated assuming the scale of the factories and piggeries in three cases: (1) large scale factory and piggery, (2) medium scale factory and piggery, and (3) small scale factory and piggery. The scale of factories and piggeries ias expressed by the discharge volume of factories and piggeries.

Table 2.3-2 shows the cost estimate by standard treatment processes while Fig. 2.3-1 shows the relation between cost and discharge volume of waste water according to interviews and the cost estimation for standard treatment plants. As noted from these figures, the cost of standard treatment plant approximately coincides with the average value of actual costs of treatment plants obtained from interviews.

## 2.4 Cost Estimate for Installation of Treatment Plant for Existing Factories

Based on the costs of standard treatment plants, the cost for installation of treatment plants for existing factories and piggeries can be estimated multiplying the cost of a standard treatment plant by the number of existing factories. Since factories meeting the water quality standard do not need to install a new treatment plant, the cost estimate is only for factories which do not fulfill the water quality standard.

As mentioned earlier, among the existing factories and piggeries with treatment plant, the percentages of those which do not fulfill the water quality standard are 8% and 6%, and the percentages of factories and piggeries which do not have treatment plants are 54% and 59%, respectively.

In this connection, the cost for the installation of treatment plants for existing factories and piggeries is calculated in the following manner:

- For factories with treatment plants not fulfilling the water quality standard, 50% of the standard treatment plant cost is adopted considering their scale.

- For factories with no treatment plant, 100% of the standard treatment plant cost is adopted considering their scale.

- O&M cost is calculated by multiplying the percentage of O&M cost with the installation cost.

The total costs for installation of treatment plants for existing factories and piggeries are US$ 12,449,000 and US$1,404,900, while annual O&M costs are US$1,001,824 and US$105,368. Tables 2.4-1 and 2.4-2 show the cost estimate.

## 2.5 Cost Estimate for Factories Newly Constructed until 2003

The number of factories newly constructed in the basin has been estimated in the Master Plan Study. Based on the number of factories by industrial category, the total cost and the annual O&M cost necessary for treatment plants for newly constructed factories have been estimated at US$9,965,300 and US$796,228. The cost estimates are shown in Tables 2.5-1 and 2.5-2.

## 2.6 Project Evaluation

Economic analysis has been undertaken to show indicative values of economic criteria. For details refer to Chapter 3 of Sector I in the Supporting Report.

### 2.6.1 Effect of Installation of Treatment Plant

As identified in the key issues and problems in the master plan study, the wastewater from factories and piggeries is the main cause of the Tuy river water pollution, i.e., organic pollution, toxicant and turbidity. Pollution results in unfavorable environmental conditions represented by the loss of aquatic life and the dirty brown gray colored and bad smelling water. This results in unstable water supply sources and high operation and maintenance costs. These conditions can be improved with the installation of treatment plants.

### 2.6.2 Necessary Cost

The cost estimated on the basis of the standard treatment plant is as follows:

(1) Initial Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 23,817 |

The proposed implementation period is from the middle of the year 2000 to the end of 2003. The cost is distributed in proportion to the length of time.

(2) O&M Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 1,903 |

The O&M cost is assumed to be incurred starting in 2004.

### 2.6.3 Expected Benefits

In general, some essential benefits derived from the implementation of environmental improvement projects are difficult to evaluate in monetary term. The benefits are herein presented in a descriptive manner.

**Direct Benefits**

As the direct benefits derived from the installation of treatment plants for factories and piggeries, the following items are enumerated:

- BOD of 45.3 ton/day from the area is reduced by the installation of treatment plants for factories and piggeries. This corresponds to a 43% of reduction against the total of 105.4 ton/day from the area. Thus, water quality is improved to the target of the short term program. (Refer to Fig. 2.6-1.)

- Water quality improvement brings about better environment to the Tuy River. The present dirty colored and bad smelling water will change to that with less smell and less dirty color.

- The removal of BOD and turbid substances brings about a reduction of the times of water intake suspension due to color, odor and turbidity. This also brings about reduction of operation and maintenance cost for treatment of water.

- The Tuy River water can be used as a safe water resource with less coliform and heavy metals for water supply to the Caracas Metropolitan Area.

<u>**Indirect Benefits**</u>

As the indirect benefits, the following effects are expected:

- As a result of water quality improvement, estate values along the river course will appreciate.

- Waterborne diseases will be reduced.

- The value of the Tuy River basin will appreciate as a tourism resource.

- The existence value of the Tuy River basin will appreciate.

### 2.6.4 Financial Evaluation

Financial evaluation for the installation of treatment plants for factories and piggeries is not discussed in this section but in Section 7.6.1, Establishment of Environmental Fund, for the following reason:

The installation of treatment plants in factories and piggeries will be carried out by their owners using their own funds whether they be internal or external. To successfully realize the installation, establishment of the Environmental Fund is proposed. With the Environmental Fund, it is assured that the installation of treatment plants by factory and piggery owners is financially viable. The point to be discussed is to determine whether the factory and piggery owners are capable of repaying their loan from the Environmental Fund.

# CHAPTER 3. FEASIBIITY STUDY ON CONSTRUCTION OF SAND SETTLING POND AT TOMA DE AGUA

## 3.1 General

In the Master Plan Study, the construction of a sand settling pond at Toma de Agua has been selected as the optimum measure to remove turbidity from the water. In this Feasibility Study, a more detailed study on the effectiveness as well as the design features of the sand settling pond is conducted based on the additional data obtained from the site such as sediment materials and topographic survey results.

## 3.2 Additional Turbidity Study

To confirm the effectiveness of the proposed sand settling pond, sediment properties of the Tuy River were examined in the feasibility study. Besides this, sediment depth was measured and samples were taken in the pre-treatment ponds. Other samples of turbid water of the Tuy River were collected in front of the intake and their settled solids were tested in a laboratory.

Fig. 3.2-1 shows the sediment depth and sampling points in the five pre-treatment ponds (one pond was cleaned ). The sediment in each pre-treatment pond forms a flat and plain surface for 20 m from the inlet to the outlet.

Moisture and mechanical analyses were applied to the samples. The moisture ranges from 76 to 124%, and it becomes higher toward the outlet.

Fig. 3.2-2 shows the result of the mechanical analysis. Sediment size ranges from 0.008 mm to 0.04 mm and fine particles increase toward the outlet.

To compare the grain curves of sediment of the pre-treatment pond and the suspended solids of the Tuy River, the mean grain of sediment of the pre-treatment pond was calculated along with the sediment volume, moisture ratio and grain curve of each sample. The two grain curves obviously resemble each other, as in Fig. 3.2-2.

Table 3.2-1 shows the actual cleaning time and sediment volume deposited in the pre-treatment pond in 1996. The total sediment volume was 117,000 $m^3$/year and the mean intake volume was 3.2 $m^3$/s. If the main intake volume increases to 5.6 $m^3$/s, the sediment volume will increase to 204,750 $m^3$/year assuming the turbidity does not change.

## 3.3 Particle Elimination Rate by Sand Settling Pond

For the evaluation of the sand settling pond, it is essential to confirm the particle elimination rate ($E$). The elimination rate was calculated in the following procedure.

- The trace of a falling particle is expressed in the vector of current horizontal velocity $v$ and falling velocity $w$;

- When falling velocity from an inlet to an outlet of pond is set as $w_o$, the particle of $w$ ($< w_o$) entirely settles. And, the eliminating rate $E$ of particle of $w$ ($< w_o$) is expressed as the rate of $w/w_o$;

- If the detention time $t_o$ of particle in pond is reflected as $L/v$, then the relation of inflow volume $Q$ to pond and $w$ is as expressed in the following equation:

$$w_o = \frac{h_o}{t_o} = \frac{h_o}{L/v} = \frac{Q}{LB} = \frac{Q}{A}$$

where

$L$ : Length of settling pond
$B$ : Breadth of settling pond
$h_o$ : Depth of settling pond
$A$ : Water surface area of settling pond

- The particle eliminated in the settling pond is unrelated to depth by the water surface area of settling pond. The elimination rate $E$ of particle having a falling velocity $w$ is expressed in the following equation.

$$E = \frac{h}{h_o} = \frac{wt_o}{w_o t_o} = \frac{w}{w_o} = \frac{w}{Q/A}$$

where

$t_o$ : settling time

- The falling velocity of a particle is calculated by the Stokes Formula, and Fig. 3.3-1 shows the relation between particle size and falling velocity.

$$w = \left(\frac{1}{18} \cdot \frac{\rho_s - \rho}{p w_o} \cdot g\right)^{1.0} v^{-1.0} d^2$$

where

$\rho$ : Density of water
$v$ : Coefficient of kinematics viscosity
$d$ : Diameter

## 3.4 Size of the Sand Settling Pond

The particle elimination rate $E$, whose falling velocity is $w$, is expressed in the above formula and it will be subject to the intake volume ($Q$) and water surface area ($A$) of the settling pond.

According to the recent study by Hidrocapital, it is proposed that design maximum volume at intake is 8.72 $m^3/s$ by increasing the pump capacity with 8 pumps. In the report "Incremento de la Extracción de la Toma II de San Antonio en el Rio Tuy, y

Compensación en el Embalse Quebrada Seca, Edo.Miranda", it is mentioned that the discharge volumes of dry, rainfall season and main are 2.93 $m^3$/s, 6.42 $m^3$/s and 5.61 $m^3$/s, respectively.

Then, the elimination rate $E$ is calculated for different water surface areas ($A$) of settling pond. As a result, Fig. 3.3-1 shows the elimination rate curve of each settling pond size. According to this figure, the efficiency increases in proportion to the settling pond size. However, the available space at the site is $A=5,000\ m^2$ (refer to Fig. 3.6-1). Consequently, the settling pond size is decided at 5,000 $m^2$.

## 3.5 Study on Design Features

To design the intake of the sand settling pond, it is necessary to set the maximum and normal water levels at the intake point of the sand settling pond.

The Tuy River Basin does not have a concrete plan for flood control so far. In this plan, it is proposed that the capacity of the sand settling pond is designed for the flood of 10-year return period. According to the previous study result, the flood discharge $Q$ with 10-year return period is 525.3 $m^3$/s (refer to the report of "Impacto Morfologico del Trasvase de Aguas del Lago de Valencia al Rio Tuy", López, J. L., 1992).

The maximum and normal water levels are calculated as follows:

- The water level at the intake weir, which is calculated by the overflow equation, is the starting point for the upstream.
- The water level at the intake of sand settling pond is calculated at 5 cross sections in the upstream of the actual weir by non-uniform flow equation.

The maximum and normal water levels were calculated at EL. 136.3 m and EL. 133.3 m, as in Fig. 3.5-1. Design features of the sand settling pond are shown in the table below.

| Part | Size | | Bottom | |
|---|---|---|---|---|
| | Length (m) | Width (m) | Height (EL.m) | Inclination |
| Inlet | 30 | 20 | 131.5 | 0 |
| Spreader | 25 | 20~52 | 131.5~130.5 | 1/25 |
| Settling Pond | 100 | 52 (25×2) | 129.5~129.08 | 1/240 |
| Intake | 20 | 52~20 | 129.08~129.0 | 1/240 |
| Outlet | 40 | 20~10 | 129.0~128.87 | 1/240 |
| Channel | 20 | 10 | 128.87~128.75 | 1/240 |
| Sediment Charging Volume ($m^3$) | 5,000 | | | |

## 3.6 Preliminary Design

The intake of sand settling pond is located at 650 m upstream from the actual weir of the intake. The topographic condition determines 50 m wide and 100 m long for the sand settling pond.

The pond should be deeper than 3 m so as to reduce current velocity, and sediment storage volume for 1 week ensures 1 m deep of sediment.

The bottom of the pond should incline as I = 1/240 which is needed to produce the velocity for flashing settled sediment.

Fig. 3.6-1 shows the preliminary design.

## 3.7 Operation and Maintenance

The water level of EL. 132.8 m controls the intake volume, which is as high as the existing intake weir. When the water level is lower than EL. 132.8 m, the intake valve at the pump station shall throttle to reduce the intake volume.

To clean the sand settling pond, the inlet and outlet gates shall be operated. If sediment fills the sediment storage volume, the inlet gate is closed and the outlet gate is opened to drain off the sediment. After the pond becomes empty, the inlet gate is slightly opened and sediment is flushed out. Gate operation is required approximately three times a month.

## 3.8 Construction Plan and Cost Estimate

The main items of construction works are: the sand settling pond, steel pipeline, pipeline bridge and concrete maintenance bridge.

The proposed site of the sand settling pond is located on the banks of the Tuy River and is thus prone to fluctuations of the Tuy's water level. Therefore, the construction method is an important factor that influences the cost estimate. Due to conditions of the site and factors influencing construction techniques in Venezuela (see Sector H for more detail) the preliminary design assumes that the slurry trench method is used.

It is also assumed that the sand settling pond superstructure is constructed in one dry season to reduce the problems associated with the rising of the river.

| Sand Settling Pond Implementation Schedule | | | |
|---|---|---|---|
| Activity | 1999 | 2000 | 2001 |
| Civil Works | | | |
| - Site Preparation | | | |
| - Excavation | | | |
| - Structure | | | |
| Bridges | | | |
| Pipeline Installation | | | |
| Testing & Operation | | | |
| Note: Fine line represents detailed design, tendering, and procurement stage, while thick line is for the supply/construction stage. | | | |

The cost estimate is described in more detail in Sector H of the Supporting Report. The cost estimate is mainly influenced by the cost of the construction of concrete superstructure (42% of the total cost). To reduce the influence of the fluctuating Bolivar, the costs are calculated in US dollars (US$1 = Bs 470). Since most materials for the construction can be acquired in Venezuela, the foreign component is considered negligible. The cost estimate also includes a 25% additional cost to cover physical contingencies and non-construction costs.

Sand Settling Pond Cost Estimate

| Item | Cost (US$) |
|---|---|
| Site Preparation | 9,450 |
| Excavation and Backfilling | 375,000 |
| Structure Construction | 3,275,162 |
| Bridges | 181,960 |
| Pipeline installation | 953,264 |
| Gates and Screen | 201,600 |
| Total | 6,245,545 |

Note: Cost of land is not included since the site is currently owned by Hidrocapital.

Operation and maintenance consists of the operation of the flushing gates, and manpower is calculated at $17,000 a year.

### 3.9 Project Evaluation

In this section economic and financial analyses are performed. The values and conditions which are applied or relevant to both analyses are shown below.

| | |
|---|---|
| 1. Initial Cost | US$6,245 thousand |
| 2. O & M Cost | US$17 thousand |
| 3. Implementation Period | 1999 to 2001 |
| 4. Durable Life | Electro-Mechanical Equipment: 15 years;<br>Civil Engineering Structures and Other Facilities: 40 years |

### 3.9.1 Effect of Construction of Sand Settling Pond

The main objective of the construction of a sand settling pond at Toma de Agua is to reduce the turbidity of water taken from the Tuy River for water supply. This project brings about reduction of water suspension due to high turbidity and reduction of operation and maintenance cost at the pretreatment plant.

### 3.9.2 Economic Analysis

**Estimation of Economic Cost**

(1) Initial Cost

(Unit: US$ thousand)

| Item | Financial Cost | Conversion Factor | Economic Cost |
|---|---|---|---|
| Total | 6,245 | (0.904) | 5,646 |

The cost is distributed over years according to the implementation schedule.

(2) O&M Cost

(Unit: US$ thousand)

| Item | Financial Cost | Conversion Factor | Economic Cost |
|---|---|---|---|
| Total | 17 | (0.765) | 13 |

The O&M cost is assumed to be incurred starting in 2002.

**Estimation of Economic Benefits**

The benefits pertain to the elimination of turbidity. Two kinds of benefits are expected to arise in the with project case as shown below.

(Unit: US$ thousand)

| Item | Financial Benefits | Conversion Factor | Economic Benefits |
|---|---|---|---|
| 1. Reduction of Water Intake Suspension due to Turbidity | 485 | 0.87 | 422 |
| 2. Reduction of Chemicals for Pre-treatment | 238 | 0.96 | 228 |
| 3. Elimination of Necessity for Pre-treatment Pond Cleaning by Heavy Machine | 96 | 0.83 | 80 |
| 4. Reduction of Water Intake Suspension for Sediment Disposal | 127 | 0.87 | 110 |
| Total | 946 | | 840 |

The total economic benefit of US$840 thousand will be realized annually in the with-project case.

The benefits will start to be realized in 2002.

Economic Analysis

In performing economic analysis, it is assumed that project life is 30 years after the project is implemented and also that the opportunity cost of capital is 12%.

Using the cost benefit flow shown in Table 3.3-1 of Sector I of the Supporting Report, the following economic criteria are worked out:

| NPV (US$ thousand) | B/C | EIRR |
|---|---|---|
| 279 | 1.07 | 12.9% |

As the above table shows, EIRR is 12.9%, or 0.9% higher than the opportunity cost of capital. Therefore, the project is judged to be economically feasible.

### 3.9.3 Financial Analysis

Two types of financial analyses were performed. One is affordability analysis and the other, projection of financial statements. Values and conditions used in both of them are shown below.

Beneficiary

| Ultimate Beneficiary | Direct Beneficiary |
|---|---|
| CMA Households | HIDROCAPITAL |

The direct beneficiary of the project is Hidrocapital, but the ultimate beneficiaries are the CMA (Caracas Metropolitan Area) clients of Hidrocapital. The clients are represented by households.

Financial Source, Lending Terms and Bearer of Cost

| External Source | Government Budget | Lending Terms | Bearer of Cost |
|---|---|---|---|
| 100% | - | shown below* | Beneficiary |

Note: * Annual interest rate: 6%, grace period: 3 years, repayment period: 15 years

O&M cost and repayment cost will be borne by the beneficiaries.

Financial Capacity of Beneficiaries

| Item | No. of CMA Households | Income/Household/ Month | Aggregate Household Income/Year |
|---|---|---|---|
| Estimated Value in 1997 | 843,371 | US$496 | US$5,019,744 thousand |
| Annual Growth Rate | 1.81% | 2% | 3.85% |

| Item | Income of HIDROCAPITAL |
|---|---|
| Estimated Value in 1997 | US$74,701 thousand |
| Annual Growth Rate | 2% |

## Affordability Analysis

This is an analysis to judge and determine if the beneficiaries are capable of bearing the cost of the project.

(1) Cost Bearer = CMA Households

It is revealed that over the 14 years from 2003 to 2016, CMA households will shoulder US$784 thousand on average annually.

| Monthly Payment as Percentage of CMA Household Income | Corresponding Monthly Payment per CMA Household in 1997 |
|---|---|
| 0.010% | US$0.05 or Bs.24 |

At present they pay 1.1% of their income for water. The new addition is considered not to unduly affect their budgets.

(2) Cost Bearer = HIDROCAPITAL

It is revealed that during 14 years from 2003 to 2016 HIDROCAPITAL will shoulder US$784 thousand on average annually.

| | |
|---|---|
| Annual Payment as Percentage of Income of HIDROCAPITAL | 0.82% |

In terms of the percentage of income, Hidrocapital will pay 0.820% of its income to the external agency annually. This seems to be not a heavy obligation.

## Projection of Financial Statements

Financial statements (income statement, funds statement and balance sheet) of the project were projected on condition that the financial entity be Hidrocapital and it collects sufficient funds from CMA households to make the project financially feasible.

Table 3.3-4 of Sector I of the Supporting Report shows the annual financial statements of the project for 20 years from 1999 to 2018. The tables below highlight the statements.

| Monthly Payment as Percentage of CMA Household Income | Corresponding Monthly Payment per CMA Household in 1997 |
|---|---|
| 0.0145% | US$0.072 or Bs. 34 |

| Ratio of Working Capital to Total Assets | Ratio of Revenues to Total Assets |
|---|---|
| 10.2% | 7.4% |

# CHAPTER 4. FEASIBILITY STUDY ON SEWAGE SYSTEM IN OCUMARE DEL TUY

## 4.1 General

In the Master Plan Study, the improvement of sewage system along with the construction of sewage treatment plant has been selected among the priority projects to conduct the feasibility study.

In this feasibility study, a more detailed study is conducted putting emphasis on the following points based on the additionally collected data and topographic survey results: (1) volume of sewage to be received by the sewage treatment plant; (2) design features of sewage treatment plant; (3) construction cost and preliminary design; and, (4) project evaluation.

## 4.2 Outline of Objective Area

### 4.2.1 Objective Area Covered by Sewage System

The objective area includes the urban areas of Ocumare del Tuy, Piloncito and Santa Barbara, which corresponds to the objective area of an urban development study undertaken by the Ministry of Urban Development (MINDUR). MINDUR's study also includes the centers of Súcuta and Las Yaguas located downstream of the proposed sewage treatment plant. These centers, however, are not included in the objective area of this present study. (Refer to Fig. 4.2-1.)

### 4.2.2 General Condition of the Objective Area

<u>Land Use Condition</u>

There are three main land uses of the objective area: residential, commercial and industrial. Of these the residential and commercial zones tend to be located near the center of the urban areas along the right riverbank, while the industrial zones are generally located along the left riverbank.

MINDUR's plan proposes that future residential and commercial zones be developed in both the southern and northern directions. Fig. 4.2-2 shows the future land use based on this development plan, and Table 4.2-1 shows both present and future land use. By 2010, residential and commercial areas are forecast to expand from 700 to 2,350 ha., occupying 65% of the urban area. Moreover, the industrial area will expand from 191 to 576 ha., while agricultural and forest areas will decrease from 2,600 to 500 ha.

<u>Population</u>

The 1990 population of the objective area as presented by OCEI and future populations of 2003 and 2010 as estimated in the Master Plan Study stage in this

JICA study are shown in Table 4.2-2. As noted from the table, the population of about 67,000 as of 1990 will increase to 122,000 in 2003 and 166,000 in 2010.

**Present System**

An open canal serves as the main collector covering most of the present urban area with a total length of 62.75 km. However, the present sewage network naturally receives both sewage and storm water and is damaged in several places. The existing system is not suitable and should be replaced (refer to Table 4.2-3).

Secondary collectors exist having a distribution density of between 70 m/ha and 140 m/ha. Since these sewer pipes also are damaged in several places, they cannot be used in the proposed sewerage system. Therefore, they should also be replaced.

### 4.2.3 Future Urban Development

The proposed Ocumare del Tuy sewage treatment plant is designed to treat domestic waste and industrial effluent for the target year 2003. Apart from this, it is also necessary that the sewerage system be gradually expanded to cope with future increases of pollutant load due to increases of population and industries after 2003. Therefore, the sewerage system plan for the Mid-term target year of 2010 is examined as well.

## 4.3 Basic Condition for the Establishment of Sewage System

### 4.3.1 Volume of Sewage to be Collected under the Sewage System Plan

**Objective Sewage**

The sewage to be collected by the sewage system is composed of domestic and industrial wastewater. Some infiltration from groundwater is also expected. In the case of industrial wastewater, it is assumed that the sewage system collects wastewater that complies with national water quality standards.

**Size of Objective Area**

The objective areas to be covered by the sewage system are the three urban centers mentioned above, Ocumare del Tuy, Piloncito, and Santa Barbara, covering an aggregate area of 3,636 hectares.

**Population in the Objective Area**

(1) Total Population in the Objective Area

The population in the objective area is calculated based on the percentage of households located in the urban centers to those in the whole municipality. The number of households is calculated using 1/25,000 aerial photographs and 1/5,000 topographic maps. The percentages are as follows:

| Name of Municipality | Percentage of Households (%) | Population in the Objective Area | |
|---|---|---|---|
| | | 2003 | 2010 |
| Ocumare del Tuy | 95 | 106,129 | 144,386 |
| Piloncito | 70 | 5,220 | 7,102 |
| Santa Barbara | 90 | 2,786 | 3,789 |

(2) Spatial Distribution of Population

To decide on the sewerage network, spatial distribution of the total population is determined in the following manner:

(a) Ocumare del Tuy

The population in the Ocumare del Tuy is assumed to be distributed based on the following land use of the urban area: (1) commercial area, (2) present residential area, and (3) future residential area.

The population density according to land use is calculated as follows:

- The population in the commercial area is calculated assuming the population density of 300 persons/ha for 2003 and 350 persons/ha for 2010; in accordance with MINDUR's urban development plan.
- The population in the present residential area is calculated assuming the population density of 90 persons/ha in 2003 and 120 persons/ha in 2010.
- The population in the future residential areas is calculated by deducting the population of commercial and present residential areas from the total population.

(b) Piloncito and Santa Barbara

Since land use is mainly residential in Piloncito and Santa Barbara the population is broadly distributed to the present and future residential areas. In this connection, it is assumed that in the present residential areas the current population density will remain constant and future increases of population will occur in the future residential areas.

Although there exists population in the areas having other land uses such as in industrial, forest, and agricultural areas, the population in these areas is neglected because of low density.

Table 4.3-1 shows the spatial distribution of population.

<u>**Number of Industries**</u>

The number of industries at present and future projections are as shown in Tables 2.1-1 and 2.5-1 in Chapter 2. It is assumed that all industries are located in the industrial zones and they discharge wastewater within the limits of the water quality standards; thus, the sewerage system will collect all the wastewater from industries. As for the volume of industrial wastewater, it is calculated based on the number of employees of each industry. The number of employees are shown in Table 4.3-2.

**Design Volume of Wastewater**

(1) Domestic Wastewater

The volume of domestic wastewater is calculated by the following equation:

*Design Volume of Domestic Wastewater = Wastewater Flow Rate per Capita × Population*

Herein the wastewater flow rate is defined as the unit wastewater volume discharged by one person in a day. The wastewater flow rate is decided in the following manner based on the collected data (refer to Table 4.3-3):

- The wastewater flow rate in 1995 adopts the value used in the study of "Actualization ...., in 1994" (No. C in Table 4.3-3).
- The wastewater flow rate in 2010 adops the average value of three studies (No. A, B, and C in Table 4.3-3).
- The wastewater flow rate in 2003 adopts the mean value between 1995 and 2010.

The wastewater flow rate thus obtained is shown in the following table:

| Year | Wastewater Flow Rate(l/capita/day) |
|---|---|
| 1995 | 238 |
| 2003 | 287 |
| 2010 | 330 |

The design volume of domestic wastewater (daily maximum sewage volume) is calculated by multiplying the wastewater flow rate with the population. However, to design the sewage treatment plant, it is necessary to take into account daily fluctuations of the domestic wastewater; daily mean sewage volume and hourly maximum. In general, these values are presumed based on the ratio to the daily maximum sewage volume. Since the ratio is not available in Venezuela, that applied in Japan is adopted assuming that the pattern of daily activities of Venezuelans is not substantially different from the Japanese.

The ratios of daily mean and hourly maximum to the daily maximum are 0.7 and 1.5, respectively. (Daily mean : Daily maximum : Hourly maximum = 0.7 : 1.0 : 1.5; refer to Table 4.3-4).

(2) Industrial Wastewater

Industrial wastewater is calculated in the following manner:

*Design Industrial Wastewater = No. of Employees by Industry Sector × Discharge Flow Rate per Employee*

Where, the discharge flow rate is defined as unit wastewater volume discharged from a factory per day per employee.

The discharge flow rate by industrial sectors which is applied in Venezuela is shown in Table 4.3-2.

The industrial wastewater is shown in Table 4.3-5. The ratio of daily mean and hourly maximum to the daily maximum, which is necessary for the design of a sewage treatment plant, is adopted from that commonly used in Japan:

*Daily mean : Daily maximum : Hourly maximum = 1 : 1 : 2*

(3) Groundwater

Groundwater infiltrates the sewerage system through joints and breaks. The volume of groundwater infiltration is assumed to be 15% of the domestic wastewater. The groundwater is only considered for the calculation of wastewater of hourly maximum volume, but not for daily mean and daily maximum.

(4) Total Wastewater Volume

The total wastewater volume consisting of domestic wastewater, industrial wastewater and infiltration is shown in Table 4.3-6. The daily mean value is used for the design of treatment of sludge in sewage treatment process, the daily maximum for design of treatment of wastewater, and the hourly maximum for design of sedimentation pond and pump.

### 4.3.2 Target Water Quality

**Inflow Water Quality**

(1) Water Quality of Domestic Wastewater

Inflow water quality from domestic wastewater is calculated in the following manner:

*Water Quality (mg/l) = Pollution Load (mg/day) / Wastewater Volume (l/day)*

Herein, the pollution load is calculated applying BOD in the following equation:

*BOD Pollution Load = BOD Pollution Load Flow Rate (g/cap/day) × Population*

In this equation, BOD pollution load flow rate is 54 g/person/day which was derived from previous studies.

(2) Water Quality of Industrial Wastewater

Inflow water quality from industrial wastewater is assumed to be within the water quality standard for factories: BOD < 350 (mg/l)

(3) Inflow Water Quality to Sewage Treatment Plant

Based on the total wastewater volume and BOD load from domestic and industrial wastewater, the inflow water quality at the sewage treatment plant is assumed as shown in Table 4.3-7.

Target Water Quality discharged from Sewage Treatment Plant

As shown in Table 4.3-7, the inflow water quality at the sewage treatment plant is estimated at about 150 mg/l in the year of 2010. Moreover, to achieve the water quality target by the year of 2010, it is required to reduce the BOD pollution load at Ocumare del Tuy by 90% in accordance with the results of the RIOS model water quality analysis.

Consequently, the target water quality discharged from the sewage treatment plant is set at 15 mg/l of BOD, corresponding to 10% of the inflow water BOD.

## 4.4 Planning of Sewage Treatment Plant

### 4.4.1 Planning Condition

Site of Sewage Treatment Plant

The site of sewage treatment plant is decided considering the availability of sufficient open space near Ocumare del Tuy and geographically advantageous for the collection of sewage from the basin.

Area Available for Construction of Sewage Treatment Plant

The area available for construction of the sewage treatment plant is located on a site roughly 40 hectares. Since the area is low, and inundation is possible, a flood protection dike surrounding the sewage treatment plant is proposed.

Method of Sewage Treatment

In the Master Plan Study, four alternative methods of sewage treatment were examined: (1) stabilization pond method, (2) activated sludge process method, (3) simplified activated sludge process method, and (4) the trickling filter method. Finally, the trickling filter method was selected because of the simplicity of maintenance, though this type of system requires a relatively large area.

In the feasibility study, this system's suitability is reexamined taking into account future population increases and the availability of land in the Ocumare del Tuy district for a sewage treatment plant.

The reexamination provided the following conclusions:

- Judging from future population projections for 2010, the population will be 2.5 times that of 1990. Therefore, it is desirable to apply a method which requires less space, even though the method requires more maintenance work. Thus, the activated sludge process method is proposed to be applied in the future.

- However, in the initial stages, a low maintenance method is preferable because of the inexperience in the operation and maintenance of sewage treatment plants in Venezuela. At current population levels the need for space is not so critical.

- Among low maintenance methods the trickling filter method is preferred, because of flexibility with variable pollution inflows and recovery from accidental inflow of toxicants.

As a result, it is proposed that the trickling filter method be applied from the beginning to the year 2003 and from then gradually change to the activated sludge process method to cope with the future increases in population. (Refer to Fig. 4.4-1.)

<u>Sewage Drainage System Network</u>

In this study the sewer network proposed by MINDUR is adopted with minor modifications due to the different proposed locations of the sewage treatment plants (refer to Fig. 4.4-2).

<u>Pumping Station</u>

In general, gravity collectors are preferable, but geographical restraints often prevent this from practice. In this case, it is necessary to provide a pump to collect the sewage. In the case of Ocumare del Tuy, one pumping station is necessary to collect the sewage from the areas located on the opposite side of the river. The sewage collector is proposed to be placed under the Tuy River to cross the river and the sewage is pumped up to the treatment plant.

### 4.4.2 Outline of Sewage Treatment Process

The sewage treatment process is outlined as follows (refer to Fig.4.4-3):

- Sewage collected is transported to a primary settling tank by a pump. In this settling pond, sand and silt are settled and removed as sludge together with garbage trapped by the grit chamber.

- The sludge is transported to gravity thickeners and disposed of.

- The sewage is transported to primary high rate filters and treated.

- The sewage is circulated between primary high rate filter and primary settling tank and then transported to secondary high rate filters.

- From the final settling tank, the treated sewage flows to the chlorine contact basin for chlorination.

The sewage is finally discharged to the Tuy River.

## 4.5 Preliminary Design and Cost Estimate

The sewerage system consists of the construction of the sewerage treatment plant (STP) and the sewage collectors in Ocumare del Tuy. The layout of the STP can be seen in Fig. 4.4-3.

The site is easily accessible from Ocumare del Tuy and is relatively flat. It is, however, located very near the Tuy and the lower portions sometimes flood. Also the site is heavily covered with native vegetation so this must be removed prior to undertaking any work.

Due to the condition of the soil and the fact that the structures are relatively light, no special foundation works such as piling is necessary. However, for the construction of the main pumping station it will be necessary to use some form of dewatering measures to excavate and construct the walls of the pumping station to the estimated 15 meter depth. It is assumed in the preliminary design that the slurry wall method is used.

The sewer network is very extensive. Sewers (rubber jointed) range in size from 12 to 42 inches. There is a total of 221,550 meters of sewers to be installed in Ocumare del Tuy. It is expected that the installation will be difficult due to lack of space in areas of the town.

Work on the construction of the STP is to begin in early 1998 and is expected to take three and a half years, with the commissioning of the plant in the middle of 2001.

The detailed design for the installation of the sewers is planned to commence early in 1998 and the sewer installation is expected to be completed by the end of 2003.

Ocumare del Tuy Sewerage System Implementation Schedule

| Activity | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|
| STP | | | | | | |
| Land Acquisition | | | | | | |
| Civil Works | | | | | | |
| - Site Preparation | | | | | | |
| - Earthworks | | | | | | |
| - Structures | | | | | | |
| - Yard Piping | | | | | | |
| Pumps | | | | | | |
| Process Equipment | | | | | | |
| Gas Storage Tanks | | | | | | |
| Main Pumping Station | | | | | | |
| Testing and Training | | | | | | |
| SEWER NETWORK | | | | | | |
| - Sewers in vicinity of STP | | | | | | |
| - Right Bank Sewers | | | | | | |
| - Siphon and Left Bank Sewers | | | | | | |

Note: Fine line represents the detailed design, tendering and procurement stage, while the thick line is the supply/construction stage.

The cost estimate is described in more detail in Sector H of the Supporting Report. The cost estimates are very much influenced by the cost of foreign procured equipment. Mainly this includes the cost of the process equipment and the pumps, and accounts for 43% of the cost of the STP.

The costs are estimated using data published every three months and data supplied from contractors and suppliers who have undertaken similar works. Costs are calculated in US dollars to offset the current volatility in the Bolivar (US$1 = Bs. 470).

Ocumare del Tuy Sewerage System Cost Estimate

| Item | Cost (US$) |
|---|---|
| Land Acquisition | 1,500,000 |
| Site Preparation Works | 165,535 |
| Earthworks | 230,439 |
| Roadwork | 48,862 |
| Structures | 3,032,946 |
| Yard Piping | 790,531 |
| Supply and Installation of Pumps | 1,668,310 |
| Filters | 428,132 |
| Process Equipment | 2,285,000 |
| Gas Storage | 160,000 |
| Operation and Maintenance Equipment | 305,000 |
| Pumping Station | 248,167 |
| Sub-Total | 13,578,652 |
| Sewer Network | 13,184,481 |
| Total | 26,763,133 |
| Operation and Maintenance | 341,409 |

## 4.6 Project Evaluation

In this section financial analyses are performed. However, economic analysis is not made because the benefit derived from this kind of environmental project is hard to evaluate in monetary term. The values and conditions which are applied to the analyses are shown below:

| | |
|---|---|
| Initial Cost | US$26,763 thousand |
| O&M Cost | US$341 thousand |
| Implementation Period | 1998 to 2001 for sewage treatment plant<br>1998 to 2003 for sewers |
| Durable Life | Electro-mechanical equipment: 15 years<br>Civil engineering structures and other facilities: 40 years |

### 4.6.1 Effect of Construction of Sewage System

As identified in the key issues and problems in the master plan study, the wastewater from the urban centers is one of the main causes of the Tuy river water pollution, most notably, organic pollution. River water pollution results in unfavorable environmental conditions such as loss of aquatic life, dirty brown gray colored and bad smelling water, and proliferation of coliform which is harmful to human health, especially when the water is supplied for domestic use. Pollution also results in unstable water supply as well as high operation and maintenance cost to facilities.

These conditions can be improved with the installation of treatment plants. Further, when the open sewers are replaced by closed sewers, the environment in the urban area will improve.

### 4.6.2 Necessary Cost

The cost estimated on the basis of the preliminary design is as follows:

(1) Initial Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 26,763 |

The cost is distributed over years according to the implementation schedule.

(2) O&M Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 341 |

The O&M cost will be incurred starting in 2004.

### 4.6.3 Expected Benefits

In general, some essential benefits derived from the implementation of environmental improvement projects are difficult to evaluate in monetary term. Therefore, the benefits are herein presented in a descriptive manner.

**Direct Benefits**

As direct benefits from the construction of sewage treatment plants along with the development of the drainage network, the following items are enumerated:

- BOD production load of 5.6 ton/day in total from industrial and domestic waste in the area is reduced by the installation of a sewage treatment plant in Ocumare del Tuy. This corresponds to about 25% reduction against the total effluent BOD of 22.4 ton/day of wastewater from domestic sources and factories (refer to Fig. 4.6-1). Thus, water quality is improved to the target of the short term program.

- The Tuy River water can be used as a safe water source with less coliform for water supply to the Caracas Metropolitan Area.

- Water quality improvement brings about better environment to the Tuy River. The present dirty colored and bad smelling water will change to that with less smell and less dirty color.

- The removal of BOD and turbid substances brings about a reduction of the times of water intake suspension due to color, odor and turbidity. This also brings about reduction of operation and maintenance cost for treatment of water.

**Indirect Benefits**

As indirect benefits the following effects are expected:

- As a result of water quality improvement, estate values along the river course will appreciate.

- Waterborne diseases will be reduced, especially for the population which consumes water from the wells along the Tuy River.

- The value of the Tuy River basin will appreciate as a tourism resource.

- The existence value of the Tuy River basin will appreciate.

### 4.6.4 Financial Analysis

According to the general recommendation of the World Bank, water and sewerage charges as percentage of household income should be up to 4% and 2%, respectively. In the study area, however, sewerage charge is proposed to be up to 1% of household income. It is assumed that the household's willingness to pay for sewerage charge is no more than the actual payment for water charge, which is currently on average 1%

of the household income. The percentage of initial cost to be externally borrowed and repaid by the cost-bearers is determined based on this premise.

Two types of financial analyses are performed. One is affordability analysis and the other, projection of financial statements. Values and conditions used in both of them are shown below.

**Polluters**

The polluters concerned are households, factories and piggeries in Ocumare del Tuy.

**Financial Source, Lending Terms and Bearer of Cost**

| External Source | Government Budget | Lending Terms | Bearer of Cost |
|---|---|---|---|
| 35% | 65% | shown below* | Polluters |

* Annual interest rate: 6%; grace period: 3 years; repayment period: 15 years

O&M cost and initial investment cost are to be borne by the polluters.

**Financial Capacity of Polluters**

| Item | No. of Targeted Households | Income/Household/ Month | Aggregate Household Income /Year |
|---|---|---|---|
| Estimated Value in 1997 | 18,100 | US$507 | US$110,120 thousand |
| Annual Growth Rate | 4.58% | 2% | 6.67% |

| Item | No. of Targeted Factories/Piggeries | Sales/Factory /Piggery/Year | Aggregate Sales /Year |
|---|---|---|---|
| Estimated Value in 1996 | 9 (F), 7 (P) | US$5,662T (F), US$234T (P) | US$50,958T (F), US$1,638T (P) |
| Annual Growth Rate | 6.26% (F), 0% (P) | - | 6.26% (F), 0% (P) |

It is assumed that 90% of the initial investment cost and O&M cost will be borne by households and the remaining 10% by factories and piggeries in accordance with their respective contribution rates to the pollution of sewage.

**Affordability Analysis**

This is an analysis to judge and determine if the polluters are capable of bearing the cost of the project.

It is revealed that over the 14 years from 2004 to 2017, the amount to be annually shouldered by all households will be US$1,523 thousand.

| Monthly Payment as Percentage of Household Income | Corresponding Monthly Payment per Household in 1997 |
|---|---|
| 0.69% | US$3.498 or Bs.1,644 |

In terms of the percentage of household income, each household will monthly pay 0.69% of its income as an addition to water charge. This means US$3.498 or Bs.1,644 on average in 1997.

At present they pay 1% of their income for water. The addition is considered not to unduly affect household budgets.

Likewise, over the same period the amount to be annually shouldered by all factories and piggeries will be US$169 thousand.

| Annual Payment as Percentage of Sales of a Factory/Piggery | Corresponding Annual Payment per Factory/Piggery |
|---|---|
| 0.16% | US$9,059 (F), US$374 (P) |

In terms of the percentage of sales, each factory/piggery will yearly pay 0.16% of its sales as sewerage charge. This means US$9,059 for a factory and US$374 for a piggery on average.

**Projection of Financial Statements**

Financial statements (income statement, funds statement and balance sheet) of the project are projected on condition that the financial entity is the Tuy River Basin Agency and it collects sufficient funds from households to make the project financially feasible.

Table 3.4.3 of Sector I of the Supporting Report shows the annual financial statements of the project for 20 years from 1998 to 2017. The tables below highlight the statements.

| Monthly Payment as Percentage of Household Income | Corresponding Monthly Payment per Household in 1997 |
|---|---|
| 0.90% | US$4.563 or Bs.2,145 |

| Annual Payment as Percentage of Sales of a Factory/Piggery | Corresponding Monthly Payment per Household in 1997 |
|---|---|
| 0.17% | US$9,625 (F), US$398 (P) |

| Ratio of Working Capital to Total Assets | Ratio of Revenues to Total Assets |
|---|---|
| 11.1% | 2.2% |

**Alternatives on Cost Recovery**

(1) Alternative I

Polluters, that is, households and factories/piggeries in Ocumare del Tuy bear the cost.

In this alternative 90% of the initial investment cost and O&M cost is borne by households and the remaining 10% by factories/piggeries according to their respective contribution rates to the pollution of sewage.

Four (4) representative cases are considered regarding the percentage of cost to be borne by households and factories/piggeries and the corresponding sewerage charges.

(Unit: %)

| Item | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by Households and Factories/Piggeries | 100 | 50 | **35** | 0 |
| Sharing of the O&M Cost by Households and Factories/Piggeries | 100 | 100 | **100** | 100 |
| Sewerage Charge as Percentage of Household Income | 2.07 | 1.13 | **0.90** | 0.54 |
| Sewerage Charge as Percentage of Sales of Factories/Piggeries | 0.65 | 0.27 | **0.17** | 0.03 |

As the above table shows, supposing both the initial cost and O&M cost is entirely recovered from households and factories/piggeries, households will set aside 2.07% of their income for sewerage charge, and factories/piggeries will allocate 0.65% of their sales for the same purpose.

On the other hand, supposing only the O&M cost is recovered from households and factories/piggeries, households will set aside 0.54% of their income for sewerage charge, and factories/piggeries will allocate 0.03% of their sales for the same purpose.

The bold lettered case (Case 3) is proposed by the JICA study team.

(2) Alternative II

Both polluters, that is, households and factories/piggeries in Ocumare del Tuy and beneficiaries, that is, household in CMA bear the cost.

In this alternative 90% of the initial investment cost and O&M cost is recovered from households in Ocumare del Tuy and CMA, and the remaining 10% from factories/piggeries in Ocumare del Tuy.

Four (4) representative cases are considered regarding the percentage of cost to be borne by households and factories/piggeries and the corresponding sewerage charges.

(Unit: %)

| Item | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by Households and Factories/Piggeries | 100 | 50 | 35 | 0 |
| Sharing of the O&M Cost by Households and Factories/Piggeries | 100 | 100 | 100 | 100 |
| Sewerage Charge as Percentage of Household Income | 0.058 | 0.031 | 0.024 | 0.014 |
| Sewerage Charge as Percentage of Sales of Factories/Piggeries | 0.65 | 0.27 | 0.17 | 0.03 |

As the above table shows, supposing both the investment cost and O&M cost is entirely recovered from households and factories/piggeries, households will set aside 0.058% of their income for sewerage charge, and factories/piggeries will allocate 0.65% of their sales for the same purpose.

On the other hand, supposing only the O&M cost is recovered from households and factories/piggeries, households will set aside 0.014% of their income for sewerage charge, and factories/piggeries will allocate 0.03% of their sales for the same purpose.

Supposing 35% of the initial cost and 100% of the O&M cost is recovered from households and factories/piggeries, households will set aside 0.024% of their income for sewerage charge, and factories/piggeries will allocate 0.17% of their sales for the same purpose.

(3) Alternative III

Beneficiaries, that is, households in the Caracas Metropolitan Area bear the cost.

Four (4) representative cases are considered regarding the percentage of cost to be recovered from the CMA households and the corresponding sewerage charge.

(Unit: %)

| Item | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by CMA Households | 100 | 50 | 35 | 0 |
| Sharing of the O&M Cost by CMA Households | 100 | 100 | 100 | 100 |
| Sewerage Charge as Percentage of Household Income | 0.068 | 0.036 | 0.028 | 0.016 |

As the above table shows, supposing both the initial cost and O&M cost is entirely recovered from the CMA households, they will set aside 0.068% of their income for sewerage charge.

On the other hand, supposing only the O&M cost is recovered from the CMA households, they will set aside 0.016% of their income for sewerage charge.

Supposing 35% of the initial cost and 100% of the O&M cost are recovered from the CMA households, they will set aside 0.028% of their income for sewerage charge.

**Billing and Collection of Sewerage Charge**

The Tuy River Basin Agency is supposed to manage the sewerage services including billing and collection of sewage charge. However, in view of the fact that the volume of the discharge of sewage corresponds to the consumption of water, for the sake of efficiency it is proposed that sewerage charge be added onto water charge as a fixed percentage, so that the water bill now in use is used as the water and sewerage bill, and the sewerage charge is collected together with the water charge by HIDROCAPITAL.

# CHAPTER 5. FEASIBILITY STUDY ON SEWAGE SYSTEM IN LAS TEJERÍAS

## 5.1 General

In the Master Plan Study, the improvement of sewage system along with the construction of sewage treatment plant in Las Tejerías has been selected among the priority projects to conduct the feasibility study.

In this feasibility study, a more detailed study is conducted putting emphasis on the following points based on the additionally collected data and topographic survey results: (1) volume of sewage to be received by the sewage treatment plant; (2) design features of sewage treatment plant; (3) construction cost and preliminary design; and, (4) project evaluation.

## 5.2 Outline of the Objective Area

### 5.2.1 Objective Area Covered by Sewage System

The objective area of this study is the urban area of Las Tejerías. This area is the same as the area covered by MINDUR's urban development plan as shown in Fig. 5.2-1.

### 5.2.2 General Condition of the Objective Area

<u>Land Use Condition</u>

The present land use condition of the objective area is featured as follows: (1) the core of the urban area has been developed on the left bank of the Tuy river; (2) a major highway runs parallel to the Tuy River; and, (3) since the area is located between two relatively steep slopes, the direction of development is limited. According to MINDUR's development plan, increases of future population will occur mostly in the present urban area, increasing population density, and any new outward expansion will result in the conversion of the present forest and agriculture lands. (Refer to Fig. 5.2-2.)

The composition of the present and future land use is shown in Table 5.2-1. According to the table, the residential area will increase from 190 to 280 ha, while the industrial area is forecast to remain at the current 103 hectares.

<u>Population</u>

The population of the objective area in 1990 was obtained from an OCEI report and future populations, 2003 and 2010, were estimated in the Master Plan Study stage of this JICA study. The population of the objective area is as shown in Table 5.2-2. As noted from the table, the population of about 20,000 as of 1990 will increase to 27,000 in 2003 and 31,000 in 2010.

<u>Present Sewage System</u>

The present sewage system, which covers most of the present urban area, mainly consists of open channels stretching 12.68 km. Similar to the Ocumare del Tuy, the present trunkline network naturally receives both sewage and stormwater. Since the proposed sewage system is to employ separate systems for sewage and stormwater, the present system cannot be used (refer to Table 5.2-3).

Secondary collectors exist with a density ranging from 160 to 170 meters/ha. However, these collectors are damaged in several places. The present secondary collector network, therefore, cannot be used in the proposed sewage system. In this study, the present secondary collector network is proposed to be replaced.

### 5.2.3 Consideration of Future Urban Development

The proposed Las Tejerías sewage treatment plant is designed to treat domestic waste and industrial effluent for the target year 2003. Apart from this, it is also necessary that the sewerage system be gradually expanded to cope with future increases of pollutant load due to increases of population and industries after 2003. Therefore, the sewerage system plan for the Mid-Term target year of 2010 is examined as well.

## 5.3 Basic Condition for the Establishment of Sewage System

### 5.3.1 Volume of Sewage to be Collected under the Sewage System

<u>Objective Sewage</u>

The sewage to be collected by the sewage system is composed of domestic and industrial wastewater. Also, infiltration from groundwater is expected. In the case of industrial wastewater, it is assumed that the sewage system collects wastewater that complies with the national water quality standard.

<u>Objective Area</u>

The objective area covered by the sewage system is the urban area of Las Tejerías of 495 ha.

<u>Population in the Objective Area</u>

(1) Total Population in the Objective Area

The population in the objective area is calculated based on the percentage of households located in the urban area to the whole administrative area of Las Tejerías. The number of households in the whole administrative area of Las Tejerías is calculated using 1/25,000 aerial photographs and 1/5,000 topographic maps. It is determined that the ratio of population in the urban area of Las Tejerías is 95% of the total administrative area.

(2) Spacial Distribution of Population

To decide the layout of sewage network, the spacial distribution of total population is assumed in the following manner:

- The population density in new residential areas is assumed to be 50 persons/ha in the year 2003 and 70 persons/ha in 2010.
- Future increases of population are assumed to be absorbed in the present residential area.

Table 5.3-1 shows the spacial distribution of population.

**Number of Industries**

The number of industries at present and future projections are as shown in Tables 2.1-1 and 2.5-1 in Chapter 2. It is assumed that all the industries are located in the industrial zones and discharge wastewater, within the limits of the water quality standards. Thus, the sewage system will collect all the wastewater from industries. As for the volume of industrial wastewater, it is calculated based on the number of employees of each industry. Table 5.3-2 shows the number of employees.

**Design Volume of Wastewater**

(1) Domestic Wastewater

The volume of domestic wastewater is calculated in the same way as Ocumare del Tuy, as follows:

*Design Volume of Domestic Wastewater = Wastewater Flow Rate per Capita × Population*

Herein the wastewater flow rate is defined as the unit wastewater volume discharged by one person in a day. The wastewater flow rate is decided in the following manner based on the collected data (refer to Table 5.3-3):

- The wastewater flow rate in 1995 adopts the value used in the study of "Actualization ...., in 1994" ( No. C in Table 5.3-3).
- The wastewater flow rate in 2010 adopts the average value of three studies (No. A, B, and C in Table 5.3-3).
- The wastewater flow rate in 2003 adopts the mean value between 1995 and 2010.

The wastewater flow rate thus obtained is shown in the following table:

| Year | Wastewater Flow Rate(l/person/day) |
| --- | --- |
| 1995 | 206 |
| 2003 | 256 |
| 2010 | 300 |

The design volume of domestic wastewater (daily maximum sewage volume) is calculated by multiplying the wastewater flow rate with the population. To design the sewage treatment plant, it is, however, necessary to take into account daily fluctuations of the domestic wastewater, daily mean sewage volume and hourly maximum. In general, these values are presumed based on the ratio to the daily maximum sewage volume. Since the ratio is not available in Venezuela, that applied in Japan is adopted assuming that the pattern of daily activities of Venezuelans is not substantially different from the Japanese.

The ratios of daily mean and hourly maximum to the daily maximum are 0.7 and 1.5, respectively Daily mean : Daily maximum : Hourly maximum = 0.7 : 1.0 : 1.5; refer to Table 5.3-4).

(2) Industrial Wastewater

Industrial wastewater volume is calculated in the following manner:

*Design Volume of Industrial Wastewater = No. of Employees by Industrial Sector × Discharge Flow Rate per Employee*

The discharge flow rate by industrial sector which is applied in Venezuela is shown in Table 5.3-5.

The industrial wastewater volume is shown in Table 5.3-6. The ratio of daily mean and hourly maximum to the daily maximum, which is necessary for the design of a sewage treatment plant, is adopted from that commonly used in Japan, to wit:

*Daily Mmean : Daily Maximum : Hourly Maximum = 1 : 1 : 2*

(3) Groundwater

Groundwater infiltrates sewerage systems through joints and breaks. The volume of groundwater infiltration is assumed to be 15% of the domestic wastewater. The groundwater is considered only for the calculation of wastewater of hourly maximum volume, but not for daily mean and daily maximum.

(4) Total Wastewater Volume

The total wastewater volume consisting of domestic wastewater, industrial wastewater and infiltration is shown in Table 5.3-6. The daily mean value is used for the design of treatment of sludge in the sewage treatment process, the daily maximum for design of treatment of wastewater, and the hourly maximum for design of sedimentation pond and pump.

### 5.3.2 Target Water Quality

**Inflow Water Quality**

(1) Water Quality of Domestic Wastewater

Inflow water quality of domestic wastewater is calculated in the following manner:

*Water Quality (mg/l) = Pollution Load (mg/day) / Wastewater Volume (l/day)*

Herein, the pollution load is calculated applying BOD in the following equation:

*BOD Pollution load = BOD Pollution Load Flow Rate (g/capita/day) × Population*

In this equation, BOD pollution load flow rate is 54 g/person/day which is derived from the previous studies.

(2) Water Quality of Industrial Wastewater

Inflow water quality from industrial wastewater is assumed to be within the water quality standard for factories: BOD < 350 (mg/l)

(3) Inflow Water Quality at Sewage Treatment Plant

Based on the total wastewater volume and BOD load from domestic and industrial wastewater, the inflow water quality at the sewage treatment plant is assumed as in Table 5.3-7.

**Target Water Quality Discharged from Sewage Treatment Plant**

As in Table 5.3-7, the inflow water quality at the sewage treatment plant is estimated at about 230 mg/l in the year 2010. Moreover, to achieve the water quality target by the year 2010, it is required to reduce the BOD pollution load at Las Tejerías by 90% in accordance with the results of the RIOS model water quality analysis.

Therefore, the target water quality discharged from the sewage treatment plant is set at 25 mg/l of BOD, corresponding to about 10% of the inflow water BOD.

## 5.4 Planning of Sewage Treatment Plant

### 5.4.1 Planning Conditions

**Site of Sewage Treatment Plant**

The site of sewage treatment plant is decided considering the availability of sufficient open space near Las Tejerías and geographically advantageous for the collection of sewage from the basin.

**Area Available for Construction of Sewage Treatment Plant**

A suitable area exists near the center of the town. The area has been proposed for the construction of a sewage treatment plant in previous studies. The available area measures approximately 20 hectares and is situated next to the Tuy. The area is low so a flood protection dike surrounding the site is proposed.

**Method of Sewage Treatment**

In the Master Plan Study, four alternative methods of sewage treatment were examined: (1) stabilization pond method; (2) activated sludge process method; (3) simplified activated sludge process method; and, (4) trickling filter method. The trickling filter method was finally selected because of simplicity of maintenance, though this type of system requires a relatively large area.

Similar conditions as in Ocumáre del Tuy exist in Las Tejerías; therefore, in the feasibility study, the most suitable method is reexamined considering the future population and availability of land for the sewage treatment plant.

The following conclusions are obtained:

- Similar to Ocumare del Tuy at the beginning, it is desirable to introduce a low maintenance method because of the inexperience in the operation of sewage treatment plants in Venezuela.

- Among low maintenance methods, the trickling filter method is preferred because of flexibility with variable pollution inflows and recovery from accidental inflow of toxicants.

- Judging from the increase in population to 2010 with only 14% from 2003, it is preferable to construct all the treatment facilities with the capacity of the wastewater volume at the year 2010 to avoid duplicate investment from the beginning.

Therefore, it is proposed that the trickling filter method is applied to the sewage treatment system in Las Tejerías. (Refer to Fig. 5.4-1.)

**Sewage Network**

In this study the sewer network proposed by MINDUR is adopted. (Refer to Fig. 5.4-2.)

**Pumping Station**

In general, gravity collectors are desirable. However, geographical restraints often prevent this. In this case, it is necessary to provide a pump to collect the sewage. The Las Tejerías site necessitates some form of pumping.

### 5.4.2 Outline of Sewage Treatment Process

The sewage treatment process is outlined as follows (refer to Fig. 5.4-3):

- Sewage collected is transported to a primary settling tank by a pump. In this settling pond, sand and silt are settled and removed as sludge together with garbage trapped by the grit chamber.
- The sludge is transported to gravity thickeners and disposed of.
- The sewage is transported to primary high rate filters and treated.
- The sewage is circulated between primary high rate filter and primary settling tank and then transported to secondary high rate filters.
- The treated sewage flows from the final settling tank to the chlorine contact basin for chlorination.

The sewage is finally discharged to the Tuy River.

### 5.4.3 Protection Work for Preservation of Environment

To protect the environment from deterioration, the following measures should be taken:

**Measures to Avoid Production of Flies at High Rate Filter**

In case flies break out at the high rate filter, it is necessary to pour chlorine on the filter to avoid their reproduction. For that purpose, a chlorinator is provided.

**Protection of Unfavorable Odor**

For protection from unfavorable odor, it is also necessary to pour chlorine on the spot where the odor breaks out.

## 5.5 Preliminary Design and Cost Estimate

The sewerage system consists of the construction of the sewage treatment plant (STP) and the collectors in Las Tejerías. The layout of the STP is shown in Fig. 5.4-3.

The site selected in the study is easily accessible and relatively flat. The soils are alluvial so excavation is not expected to be difficult. The site is however susceptible to flooding so works should be undertaken during the drier months of the year and a flood retaining levee should be constructed.

Due to the soil condition and the fact that the structures are relatively light, no special foundation works are required. Concrete slabs resting on a 0.5 meter layer of granular materials is sufficient.

The sewer network is extensive. Sewers range from 8 to 33 inches in diameter (rubber jointed). There are 13,800 meters of primary sewers and 47,800 meters of secondary sewers.

It is estimated that it will require two and a half years to construct the STP and three and a half years to install the sewer network.

| Las Tejerías Sewerage System Implementation Schedule | | | | | |
|---|---|---|---|---|---|
| Activity | 1999 | 2000 | 2001 | 2002 | 2003 |
| STP | | | | | |
| Civil Works | | | | | |
| - Site Preparation | | | | | |
| - Earthworks | | | | | |
| - Structures | | | | | |
| - Yard Pipine | | | | | |
| Pumps | | | | | |
| Process Equipment | | | | | |
| Gas Storage Tanks | | | | | |
| Testing and Training | | | | | |
| SEWER NETWORK | | | | | |
| - Redirect Sewers | | | | | |
| - Sewers | | | | | |
| Note: Fine line represents the detailed design, tendering and procurement stage, while the thick line is the supply/construction stage. | | | | | |

The cost estimate is described in more detail in Sector H of the Supporting Report. The cost estimates are very much influenced by the cost of foreign procured equipment. Mainly, this includes the cost of the process equipment and the pumps, and accounts for 41% percent of the cost of the STP.

The costs are estimated using data published every three months and data supplied from contractors and suppliers who have undertaken similar works. Costs are calculated in US dollars to offset the current volatility in the Bolivar. The rate used is US$1= Bs. 470.

Las Tejerías Sewerage System Cost Estimate

| Item | Cost (US$) |
|---|---|
| Land Acquisition | 1,064,000 |
| Site Preparation | 38,196 |
| Earthworks | 176,595 |
| Roadwork | 54,382 |
| Structures | 1,664,514 |
| Yard Piping | 315,653 |
| Supply and Installation of Pumps | 885,800 |
| Filters | 228,005 |
| Process Equipment | 1,379,000 |
| Gas Storage | 120,000 |
| Operation and Maintenance Equipment | 305,000 |
| Sub-Total | 7,788,930 |
| Sewer Network | 3,579,537 |
| Total | 11,368,467 |
| Operation and Maintenance | 194,373 |

## 5.6 Project Evaluation

In this section financial analyses are performed. However, the economic analysis is made to show indicative values of economic net benefits. For details refer to Chapter 3 of Sector I in the Supporting Report. The values and conditions which are applied to financial analyses are shown below:

| | |
|---|---|
| Initial Cost | US$11,368 thousand |
| O&M Cost | US$194 thousand |
| Implementation Period | 2000 to 2002 for sewage treatment plant<br>2000 to 2003 for sewers |
| Durable Life | Electro-mechanical equipment: 15 years<br>Civil engineering structures and other facilities: 40 years |

### 5.6.1 Effect of Construction of Sewage System

As identified in the key issues and problems in the master plan study, the wastewater from the urban centers is one of the main causes of the Tuy river water pollution most notably, organic pollution. River water pollution results in unfavorable environmental conditions such as loss of aquatic life, dirty brown gray colored and bad smelling water, and proliferation of coliform which is harmful to human health especially when the water is supplied for domestic use. Pollution also results in unstable water supply as well as high operation and maintenance cost to facilities.

These conditions can be improved with the installation of treatment plants. The installation of a sewage system at Las Tejerías will bring about water quality improvement especially in the upper stream. Further, when the open sewers are replaced by closed sewers, the environment in the urban area will improve.

### 5.6.2 Necessary Cost

The cost estimated on the basis of the preliminary design is as follows:

(1) Initial Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 11,368 |

The cost is distributed over years according to the implementation schedule.

(2) O&M Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 194 |

The O & M cost will be incurred starting in 2004.

### 5.6.3 Expected Benefits

In general, some essential benefits derived from the implementation of environmental improvement projects are difficult to evaluate in monetary term. Therefore, the benefits are herein presented in a descriptive manner.

Direct Benefits

As the direct benefits derived from the construction of a sewage treatment plant along with the development of the drainage network, the following items are enumerated:

- BOD production load of 3.4 ton/day at Boca de Cagua is reduced by the installation of a sewage treatment plant in Las Tejerías. This corresponds to 77% of the total effluent BOD of 4.4 ton/day by wastewater from domestic sources and factories. Thus, water quality is improved to the target of the short term program. (Refer to Fig. 2.6-1.)

- The Tuy River water can be used as a safe water source with less coliform for water supply to the Caracas Metropolitan Area.

- Water quality improvement brings about better environment to the Tuy River. The present dirty colored and bad smelling water will change to that with less smell and less dirty color.

- The removal of BOD and turbid substances brings about a reduction of the number of water intake suspension due to color, odor and turbidity. This also brings about a reduction of operation and maintenance cost for treatment of water.

Indirect Benefits

As the indirect benefits the following effects are expected:

- As a result of water quality improvement, estate values along the river course will appreciate.
- Waterborne diseases will be reduced, especially for the population which consumes water from the wells along the Tuy River.
- The value of the Tuy River basin will appreciate as a tourism resource.
- The existence value of the Tuy River basin will appreciate.

### 5.6.4 Financial Analysis

According to the general recommendation of the World Bank, water and sewerage charges as percentage of household income should be up to 4% and 2%, respectively. In the study area, however, sewerage charge is proposed to be up to 1% of household income. It is assumed that the household's willingness to pay for sewerage charge is no more than the actual payment for water charge, which is currently on average 1% of the household income. The percentage of initial cost to be externally financed and repaid by the cost-bearers is determined based on this premise.

Two types of financial analyses are performed. One is affordability analysis and the other, projection of financial statements. Values and conditions used in both of them are shown below.

**Polluters**

The polluters concerned are households, factories and piggeries in Las Tejerías.

**Financial Source, Lending Terms and Bearer of Cost**

| External Source | Government Budget | Lending Terms | Bearer of Cost |
|---|---|---|---|
| 20% | 80% | shown below* | Polluters |

* Annual interest rate: 6%; grace period: 3 years; repayment period: 15 years

O&M cost and initial investment cost will be borne by the polluters.

**Financial Capacity of Polluters**

| Item | No. of Targeted Households | Income/Household/ Month | Aggregate Household Income /Year |
|---|---|---|---|
| Estimated Value in 1997 | 5,062 | US$494 | US$30,008 thousand |
| Annual Growth Rate | 2.10% | 2% | 4.14% |

| Item | No. of Targeted Factories/Piggeries | Sales/Factory /Piggery/Year | Aggregate Sales /Year |
|---|---|---|---|
| Estimated Value in 1996 | 18 (F), 2 (P) | US$5,662T (F), US$234T (P) | US$101,916T (F), US$468T (P) |
| Annual Growth Rate | 5.57% (F), 0% (P) | - | 5.57% (F), 0% (P) |

It is assumed that 50% of the inital investment cost and O&M cost will be borne by households and the remaining 50% by factories and piggeries in accordance with their respective contribution rates to the pollution of sewage.

## Affordability Analysis

This is an analysis to judge and determine if the polluters are capable of bearing the cost of the project.

It is revealed that over the 14 years from 2004 to 2017, the amount to be shouldered by all households will beUS$347 thousand.

| Monthly Payment as Percentage of Household Income | Corresponding Monthly Payment per Household in 1997 |
|---|---|
| 0.75% | US$3,705 or Bs.1,741 |

In terms of the percentage of household income, each household will monthly pay 0.75% of its income as an addition to water charge. This means US$3.705 or Bs.1,741 on average in 1997.

At present they pay 1% of their income for water. The addition is considered not to unduly affect household budgets.

Likewise, over the same period the amount to be annually shouldered by all factories and piggeries will be US$347 thousand.

| Annual Payment as Percentage of Sales of a Factory/Piggery | Corresponding Annual Payment per Factory/Piggery |
|---|---|
| 0.18% | US$10,192 (F), US$421 (P) |

In terms of the percentage of sales, each factory/piggery will yearly pay 0.18% of its sales as sewerage charge. This means US$10,192 for a factory and US$421 for a piggery on average.

## Projection of Financial Statements

Financial statements (income statement, funds statement and balance sheet) of the project are projected on condition that the financial entity be theTuy River Basin Agency and it collects sufficient funds from households to make the project financially feasible.

Table 3.5.3 shows the annual financial statements of the project for 20 years from 2000 to 2019. The tables below highlight the statements.

| Monthly Payment as Percentage of Household Income | Corresponding Monthly Payment per Household in 1997 |
|---|---|
| 0.90% | US$4.446 or Bs.2,090 |

| Annual Payment as Percentage of Sales of a Factory/Piggery | Corresponding Monthly Payment per Factory/Piggery |
|---|---|
| 0.22% | US$12,456 (F), US$515 (P) |

| Ratio of Working Capital to Total Assets | Ratio of Revenues to Total Assets |
|---|---|
| 11.2% | 1.0% |

## Alternatives on Cost Recovery

(1) Alternative I

Polluters, that is, households and factories/piggeries in Las Tejerías bear the cost.

In this alternative 50% of the initial investment cost and O&M cost is borne by households and the remaining 50% by factories/piggeries according to their respective contribution rates to the pollution of sewage.

Four (4) representative cases are considered regarding the percentage of cost to be borne by households and factories/piggeries and the corresponding sewerage charges.

(Unit: %)

| Item | Case 1 | Case 2 | **Case 3** | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by Households and Factories/ Piggeries | 100 | 50 | **20** | 0 |
| Sharing of the O&M Cost by Households and Factories/ Piggeries | 100 | 100 | **100** | 100 |
| Sewerage Charge as Percentage of Household Income | 2.45 | 1.40 | **0.90** | 0.70 |
| Sewerage Charge as Percentage of Sales of Factories/Piggeries | 0.73 | 0.39 | **0.22** | 0.15 |

As the above table shows, supposing both the initial cost and O&M cost is entirely recovered from households and factories/piggeries, households will set aside 2.45% of their income for sewerage charge, and factories/piggeries will allocate 0.73% of their sales for the same purpose.

On the other hand, supposing only the O&M cost is recovered from households and factories/piggeries, households will set aside 0.70% of their income for sewerage charge, and factories/piggeries will allocate 0.15% of their sales for the same purpose.

The bold lettered case (Case 3) is proposed by the JICA study team.

(2) Alternative II

Both polluters, that is, households and factories/piggeries in Las Tejerías and beneficiaries, that is, households in CMA bear the cost.

In this alternative 50% of the initial investmentt and O&M cost is recovered from households in Las Tejerías and CMA, and the remaining 50% from factories/piggeries in Las Tejerías.

Four (4) representative cases are considered regarding the percentage of cost to be borne by households and factories/piggeries and the corresponding sewerage charges.

(Unit: %)

| Item | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by Households and Factories/ Piggeries | 100 | 50 | 20 | 0 |
| Sharing of the O&M Cost by Households and Factories/ Piggeries | 100 | 100 | 100 | 100 |
| Sewerage Charge as Percentage of Household Income | 0.016 | 0.008 | 0.005 | 0.004 |
| Sewerage Charge as Percentage of Sales of Factories/Piggeries | 0.73 | 0.39 | 0.22 | 0.15 |

As the above table shows, supposing both the initial cost and O&M cost is entirely recovered from households and factories/piggeries, households will set aside 0.016% of their income for sewerage charge, and factories/piggeries will allocate 0.73% of their sales for the same purpose.

On the other hand, supposing only the O&M cost is recovered from households and factories/piggeries, households will set aside 0.004% of their income for sewerage charge, and factories/piggeries will allocate 0.15% of their sales for the same purpose.

Supposing 20% of the initial cost and 100% of the O&M cost are recovered from households and factories/piggeries, households will set aside 0.005% of their income for sewerage charge, and factories/piggeries will allocate 0.22% of their sales for the same purpose.

(3) Alternative III

Beneficiaries, that is, households in the Caracas Metropolitan Area bear the cost.

Four (4) representative cases are considered regarding the percentage of cost to be recovered from the CMA households and the corresponding sewerage charge.

(Unit: %)

| Item | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sharing of the Initial Cost by CMA Households | 100 | 50 | 20 | 0 |
| Sharing of the O&M Cost by CMA Households | 100 | 100 | 100 | 100 |
| Sewerage Charge as Percentage of Household Income | 0.034 | 0.018 | 0.011 | 0.008 |

As the above table shows, supposing both the initial cost and O&M cost is entirely recovered from the CMA households, they will set aside 0.034% of their income for sewerage charge.

On the other hand, supposing only the O&M cost is recovered from the CMA households, they will set aside 0.008% of their income for sewerage charge.

Supposing 20% of the initial cost and 100% of the O&M cost is recovered from the CMA households, they will set aside 0.011% of their income for sewerage charge.

**Billing and Collection of Sewerage Charge**

The Tuy River Basin Agency is supposed to manage the sewerage services including billing and collection of sewage charge. However, in view of the fact that the volume of the discharge of sewage corresponds to the consumption of water, for the sake of efficiency it is proposed that sewerage charge be added onto water charge as a fixed percentage, so that the water bill now in use is used as the water and sewerage bill, and sewerage charge is collected together with water charge by HIDROCAPITAL.

# CHAPTER 6. FEASIBILITY STUDY ON REFORESTATION IN PRIORITY AREA

## 6.1 General

In the Master Plan Study, reforestation has been selected among the priority projects to achieve the target for the turbidity of river water of the Tuy River.

In this Feasibility Study, a more detailed study is conducted putting emphasis on the selection of reforestation site, reforestation operation and maintenance plan, preliminary design, cost estimate and project evaluation. To conduct the feasibility study, information was collected through consultation with the offices concerned in reforestation such as ACRT, SEFORVEN and CONARE.

## 6.2 Reforestation Site Selection

At present, SS is estimated at 900 mg/*l* against the water quality standard of 750 mg/*l* at the water intake point in San Antonio de Yare. This value is estimated to increase to 960 mg/*l* in 2003 due to land development. To prevent the increment of SS, the target of the short term program is set at 920 mg/l. Therefore, the increment of 40 mg/l in 2003 shall be reduced by the optimum combination of measures.

Reforestation is selected for grassland on steep sloped areas in Qda. Maitana (3,400 ha.) which is more effective to reduce sediment production according to the result of the Universal Soil Loss Equation. It is expected that 22,080 $m^3$ of suspended solids is annually reduced by the reforestation of 3,400 ha.

The reforestation areas are located in two separate blocks. Their location and area, named Qda. Santa María and Palo Negro are shown in Table 6.2-1 and Fig. 6.2-1. These two blocks are located in the protection zone of Caracas City established in 1972 by Cabinet Order. According to the order, expropriation is not necessary for the implementation of reforestation; only permission from the landowners is needed. Table 6.2-2 presents the landowners in the planting area.

## 6.3 Reforestation Operation Plan

**Planting Plan**

The planting area is mainly composed of a fire resistant belt and a reforestation area because the grassland and deforestation area in the study area incidentally burns in every dry season. From the point of fire prevention, 20 m wide forest belts on both sides of a road will act as fire breakers with fire resistant trees. The evergreen tree whose inside is wetter than the deciduous tree in dry season is appropriate as fire resistant tree. An example is shown in Fig. 6.3-1.

Reforestation has two ways: a single plantation and mixed plantation. The single plantation is generally used for forest products, while the mixed plantation is applied for an environmental improvement project. With the aim of reforestation in the Study, which is environmental improvement and erosion control, a mixed planting plan is recommended. The mixed plantation expects the following advantages:

- A mixed plantation creates a multi-layered vegetation cover which is desirable for the protection of surface soil against the impact of rain and hence erosion.
- A mixed plantation provides a wide range of resistance to insects and plant diseases in comparison to a mono-culture plantation.

**Choice of Tree Types**

For the fire resistant belt and mixed planting, the following characteristics shortlist tree types. These tree types are listed in Table 6.3-1.

- Existing types common in and around the study area with growth capability in degraded sites.
- Leguminous for nitrogen fixation to improve soil condition.
- Fast growth to form a vegetation cover for the area in the shortest possible time.
- Seedling costs more than cutting. Kinds for logging should be limited in order to reduce the total project cost.

For the fire resistant belt, Cuji, evergreen and medium fire resistant tree, is chosen and will be planted at a distance of 3 m × 3 m (1,110 trees/ha) according to tree size.

For the mixed plantation, Gliriscidia sp and Bauhinia, larger than other trees, are selected from the list. The mixing rate of two trees is one to one. A planting distance of 2.5 m × 3 m (1,334 trees/ha) will be applied to the mixed planting.

The target reforestation area and the required number of seedlings are shown in Table 6.2-1.

**Compartmentalization**

The necessary reforestation sites are located in five separate blocks whose area is from 639 ha to 2,675 ha. A plantation area is divided into compartments from 100 to 300 ha for a better plan implementation and management considering human working capacity and natural features.

The compartment of Qda. Santa Maria No. 2 is subdivided into sub-compartments of approx. 200 ha that will function as units with existing access roads and natural features such as streams and ridges forming their boundaries. An example of a suitable area for reforestation divided into compartments is shown in Fig. 6.3-2.

**Nursery Plan**

There is the existing idle nursery station of MARNR of 0.28 ha located in Qda. La Virgen in the north area of Los Teques. This nursery with seeding facilities will be used for the implementation, although the capacity of this nursery is insufficient and the topographic condition does not allow extension of the area. Therefore, a new nursery is an alternative for mainly potted seedling. The new nursery will be built in a suitable location near the project area (refer to Section 6.5).

**Planting Season**

The planting season depends on soil moisture, which is critical to rooting. Thus, the period from May (beginning of the rainy season) to the end of September is preferable.

## 6.4 Maintenance and Protection Plan

This includes activities such as replanting, fertilizer application and weeding.

**Replanting**

To realize the target to reduce surface erosion, replanting is needed when seedling is withered at a certain level. When mortality rate of planted seedlings is more than 10% which is generally applied in the reforestation plan, replanting will be carried out two to three months after planting using the same types.

**Fertilizer Application**

To accelerate the growth of plants which is mainly affected by pH, ion and organic matters, neutralization of acidic soil by lime and both chemical and organic fertilizers will be applied. To know the need of neutralization and fertilizers, soil pH test, measurement of electric conductivity and soil observation were conducted in the planting area. A pH value between 6 and 7 has been recorded for the whole planting area, which means that soil is slightly acidic and does not need lime neutralization.

The electric conductivity test shows dissolution of ion in soil and the need for fertilizer. The measured values are between 0.2 and 1.3 ms/cm. Such value means soils need fertilizers. Ten (10) grams of NPK fertilizer will be applied.

According to the field observation, the soil of planting area is sandy and does not contain any organic matter. Therefore, 50 grams of organic fertilizers will be enough.

Fertilizer application will firstly be during tree planting. Fertilizer is mixed with topsoil and put at the bottom of planting hole before planting. If tree grows weak and slowly, the second fertilizer will be applied after the first weeding.

**Weeding**

To promote the expected growth of seedlings, it is necessary to weed unwanted grass which hinders the growth of seedling between planted trees. For that purpose, weeding should be preferably two months after planting before applying fertilizer. An area up to 1.0 m wide around tree trunk shall be cleared.

Grazing and Fire Prevention

Cattle grazing is common in the Project Area and this may damage plantations. To protect plantations, a fence is effective but its price is not economical in the area. Therefore, it is recommended to promote public education on the reforestation and cooperation to keep their cattle out of plantations.

In the study area, bush fire is hazardous to reforestation. Local cooperation near plantations is essential. Like grazing, public education and advertisements can be more favored for the prevention of forest fires.

## 6.5 Preliminary Design of Facilities

Nursery

Based on the standards in Venezuela, pots of which size is generally 15 cm in length and 10 cm in width will be used. Access path will be 0.6 m wide and road width will be 4 m. The nursery area for the reforestation period of 5 years which will require 460,700 seedlings/year is calculated as follows:

One 15 cm long and 10 cm wide pot when filled with soil will have a filled area of 78.5 $cm^2$. Thus, 127 pots/$m^2$ of pot bed can be accommodated. Seedlings or pots amounting to 460,700 will be required and 467,000/127 = 3,630 $m^2$ will be for pot bed. A seedbed area 20% of pot bed area which is 1,280 $m^2$, is considered. Therefore, pot bed and seedbed areas will be 4,360 $m^2$. An additional 20% of the bed area will be set aside as a reserve. Hence, the total bed area or productive area will be 5,230 $m^2$.

Non-productive areas such as access path, road between beds, soil mixing and compost shed, fence and windbreak, working shed, tool shed, etc., will be roughly twice of the productive area. Therefore, the total area of the nursery will be 15,690 $m^2$ or approximately 1.57 ha for the 5 years.

MARNR has a nursery of 0.28 ha in Los Teques. Therefore, a new nursery of 1.3 ha has to be constructed. A nursery site is chosen at adjacent land to the proposed wastewater treatment plant at Las Tejerías, considering the following points:

- Accessibility for easy mobilization of equipment and manpower;
- Topographic requirement which should be flat and spacious;
- Availability of irrigation water, especially during dry season;
- Climatic adaptability to the reforestation area;

Forest Road

The existing road in the reforestation area will be used as much as possible as forest road. New forest road will be constructed until where the forest distance to reforestation site is 1 km.

The forest road plan is the first activity that will be carried out before actual planting starts. In the Project Area it is estimated that the construction of 1 km of forest road could take some 5 weeks for the section of more than 8% of gradient and some 3 weeks for the flat section.

Forest roads will be constructed to provide suitable access to the areas required for the reforestation and to facilitate operation and maintenance. Planned forest roads will be connected with existing secondary and main roads as shown in Fig. 6.3-1. Table 6.2-1 shows the total road length in the planned reforestation areas. When needed, work roads will be extended from planned forest roads to each work unit.

Forest road and access road construction will be implemented in accordance with following specifications:

| | |
|---|---|
| Road bed width | 6.00 meters |
| Carriage-way width | 3.00 meters |
| Thickness of pavement | 0.2 meter |
| Pavement material | graveled |
| Slope of pavement | 6% |
| Shoulder width | 1.5 meters (ea.) |
| Slope of shoulder | 6% |
| Longitudinal slope | 8% up to 12% |
| Maximum radius of curvature | 30 meters |

**Planting Plan**

This includes staking, digging of holes and out-planting. Staking should be carried out to indicate digging points. It will be conducted after the spacing is decided. A planting hole of 30 cm × 30 cm × 30 cm will be dug. Holes smaller than this size may hamper root development. About 20 to 25 cm height of healthy seedlings with a vigorous growth and 30 cm of tree cuttings will be planted along contour lines.

Planting period is scheduled to be 5 years starting from 1999. In order to follow this schedule, 9 teams are required to accomplish the planting for 1,170 ha/year, and each should be composed of 23 persons to cover 1 ha/day. Table 3.5.4 is the planting schedule.

## 6.6 Cost Estimate

The cost estimate includes the cost of the 1.3 hectare nursery and the reforestation activities at Quebrada Santa Maria and Palo Negra. For a more detailed cost data, see Sector H, Section 3.6.

The nursery is to be situated on the same site as the Las Tejerías sewage treatment plant so the cost of land is included in its cost estimate. The cost estimate for the nursery includes the cost of the irrigation system, planting beds, vinyl houses, and related civil works, while the cost estimate for the reforestation activities includes the cost of constructing forest roads, and seeding and planting of the various varieties of trees.

| Activity | Cost (US$) |
|---|---|
| New nursery in Las Tejerías | 190,268 |
| Reforestation of Qda. Santa Maria | 2,431,348 |
| Reforestation of Qda. Palo Negra | 725,103 |
| Total | 3,346,719 |

## 6.7 Project Evaluation

In this section financial analysis is performed. However, economic analysis has been undertaken to show indicative values of economic net benefits. For details refer to Chapter 3 of Sector I in the Supporting Report. The values and conditions which are applied to the financial analysis are shown under:

| | |
|---|---|
| Initial Cost | US$3,347 thousand |
| O&M Cost | Virtually not necessary |
| Implementation Period | 1998 for the nursery<br>1999 to 2003 for the reforestation operations |
| Durable Life | Electro-mechanical equipment: 15 years<br>Civil engineering structures and other facilities: 40 years |

### 6.7.1 Effect of Reforestation

As identified in the key issues and problems in the master plan study, soil erosion from the basin is one of the main causes of the Tuy river water pollution, most notably, turbidity. Pollution results in unfavourable environmental conditions represented by the dirty brown colored water. This results in unstable water supply sources and high operation and maintenance costs.

These conditions can be improved with reforestation. Besides, the reforestation brings about several positive effects in the preservation of better environment providing the space for ecology.

### 6.7.2 Necessary Cost

The cost estimated on the basis of the preliminary design is as follows:

(1) Initial Cost

(Unit: US$ thousand)

| Item | Financial Cost |
|---|---|
| Total | 3,347 |

The cost is distributed over years according to the implementation schedule.

(2) O&M Cost

Due to the nature of the O&M costs for the nursery and the reforestation works, they are included in the initial cost.

### 6.7.3 Expected Benefits

In general, some essential benefits derived from the implementation of environmental improvement projects are difficult to evaluate in monetary term. The benefits are herein presented in a descriptive manner.

<u>**Direct Benefits**</u>

As the direct benefits derived from reforestation, the following items are enumerated:

- The turbidity at Toma de Agua is reduced from 960 mg/l to 935 mg/l by reforestation. Thus, turbidity is improved so as to reach the target of the short-term program.
- Water quality improvement brings about better environment to the Tuy River. The present dirty brown colored water will change to that with less dirty color.
- The removal of turbid substances brings about a reduction of the times of water intake suspension due to turbidity. This also brings about reduction of operation and maintenance cost for treatment of water.

<u>**Indirect Benefits**</u>

As the indirect benefits, the following effectiveness are expected:

- As a result of water quality improvement, estate values along the river course will appreciate.
- The value of the Tuy River basin will appreciate as a tourism resource.
- The existence value of the Tuy River basin will appreciate.
- Reforestation will provide a better environment for ecological equilibrium.

### 6.7.4 Financial Analysis

Affordability analysis is performed to judge and determine if the responsible organizations will be capable of bearing the cost of the project.

<u>**Responsible Organizations**</u>

The responsible organizations are the MARNR, Aragua State and Miranda State. These government organizations are responsible for the preservation of the natural environment and the reduction of turbidity of the Tuy River in the upper and middle basin. Reforestation is one of the most far-reaching and effective means to that end.

Therefore, it is considered to be appropriate that they bear the repayment cost of the project.

**Financial Source, Lending Terms and Bearer of Cost**

| External Source | Government Budget | Lending Terms | Bearer of Cost |
|---|---|---|---|
| 100% | - | shown below* | Responsible Organizations |

* Annual interest rate: 6%; grace period: 3 years; repayment period: 15 years

**Financial Capacity of Responsible Organizations**

| Item | MARNR | Miranda State | Aragua State | Total |
|---|---|---|---|---|
| Annual Budget (US$ thousand) in 1996 | 210,000 | 133,300 | 143,500 | 486,800 |

The combined financial capacity of the responsible organizations works out to US$486,800 thousand in 1996. This is estimated to grow at the average annual rate of 4%.

It is revealed that over the 14 years from 2004 to 2017, the organizations will annually shoulder US$383 thousand.

| Percentage of Annual Budget to be Allocated by the Organizations | Corresponding Budget Allocations in 1996 |
|---|---|
| 0.048% | US$234 thousand |

In terms of the percentage of annual budget to be allocated by the organizations, they will annually pay 0.048% of their budgets. This corresponds to US$234 thousand in 1996. This appears to be not a heavy load.

Project evaluation is as follows:

| | |
|---|---|
| Initial Cost | US$3,347 thousand |
| O&M Cost | Virtually not necessary |
| Implementation Period | 1998 for the nursery<br>1999 to 2003 for the reforestation operations |
| Durable Life | Electro-Mechanical Equipment: 15 years<br>Civil Engineering Structures and Other Facilities: 40 years |