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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE GENERAL DIRECTION OF CONSTRUCTION AND HYDRAULIC OPERATION (DGCOH)
GENERAL SECRETARIAT OF WORKS
THE FEDERAL DISTRICT OF MEXICO

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

MAIN REPORT

DECEMBER 1994

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

JICA THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO MAIN REPORT DECEMBER 1994

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In this report, project cost is estimated at May 1994 price and at an exchange rate of
1 US$ = ¥ 105.0 = N$ 3.20

PREFACE

In response to a request from the Government of the United Mexican States, the Government of Japan decided to conduct the Feasibility study on Wastewater Treatment in the Federal District of Mexico and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Mexico a study team headed by Mr. Masami Kondo, Pacific Consultants International (PCI), two times between February 1994 and November 1994.

The team held discussions with the officials concerned of the Government of Mexico, 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 United Mexican States for their close cooperation extended to the team.

December 1994

Kimio Fujita
President
Japan International Cooperation Agency

THE FEASIBILITY STUDY
ON
WASTEWATER TREATMENT
IN
THE FEDERAL DISTRICT OF MEXICO

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO". This report has been prepared by the Study Team in accordance with the contract signed on 16 February 1994 and 19 October 1994 between the Japan International Cooperation Agency and Pacific Consultants International.

The report examines the existing conditions of wastewater disposal and treatment in D.F. Mexico and Mexico State and presents the results of a feasibility study on wastewater treatment plant at Texcoco which was proposed by the Master Plan conducted by Mexican side.

The report consists of the Executive Summary, Main Report, and Supporting Study Report. The Summary Summarizes the results of all studies. The Main Report elaborates the background conditions of study area, selection of optimum wastewater treatment plant, basic design of urgent stage treatment plant and economical and financial evaluations. Recommendations for the effective implementation of the project are also described. The Supporting Study Report includes data and technical details. In addition, a Data Book has been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs. Ministry of Construction, and Embassy of Japan in Mexico, and also to officials and individuals of the Government of the United Mexican States for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the socio-economic development and the improvement of health and hygiene in D.F. Mexico and Mexico State.

Yours faithfully,

M. Kondo

Masami KONDO
Team Leader

MAIN REPORT

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ABBREVIATION

BOD	Biochemical Oxygen Demand
CEAS	State Committee of Water Supply and Sanitation
CNA	National Water Commission
COD	Chemical Oxygen Demand
DF	District Federal
DGCOH	The General Direction of Construction and Hydraulic Operation
DO	Dissolved Oxygen
GDP	Gross Domestic Product
JDM	Japanese Design Manual on Wastewater Treatment
JICA	Japan International Cooperation Agency
M/E	Mechanical and Electrical Works
MLSS	Mixed Liquor Suspended Solids
MPN	Most Probable Number
O/M	Operation and Maintenance
SARH	Ministry of Agriculture and Hydraulic Resources
SEDESOL	Ministry for Social Development
SRT	Sludge Retention Time
SS	Suspended Solids
TC	Total Coliforms
TSS	Total Suspended Solids
W/E	Wastewater Engineering (Metclf/Eddy)
WEF	WEF Manual of Practice No.8 & ASCE Manual and Report on Engineering Practice No. 76

CHAPTER 1

CHAPTER 1 INTRODUCTION

1. Background of the Study

The Metropolitan Area of Mexico City (AMCM), located in the Mexico Valley, with an altitude of about 2,240 m, consists of entire Federal District of Mexico (D.F. Mexico) and 17 municipalities of Mexico State. AMCM has been rapidly developed as the political and economical center of the United Mexican States. The Population has increased from 14.2 million in 1980 to 16.7 million in 1993, and is expected to grow further to 21.35 million in 2000.

More than 80 % of the existing population in D.F. Mexico and Mexico State of AMCM is covered by the existing sewerage system. The existing rivers are being used as a part of drainage system for both wastewater and storm water.

However, only a small proportion of collected sewage is treated for reuse purpose. Consequently a large proportion of collected wastewater is being discharged without any treatment to the Tula river through Gran Canal and Emisor Central. Tula river containing untreated wastewater, is being used for irrigating about 125,000 ha of area as shown in Fig 1.1. The untreated wastewater has caused very serious environmental impact in the downstream area. The rivers and irrigation canals in the area are visibly polluted; black in color and emanate offensive odor. The situation has led to the outbreak of water-borne diseases. Average annual incidence rate of water borne and water related diseases per 100,000 population in the untreated wastewater irrigated area is found to be more than 50 times higher than that in the treated wastewater irrigated area. Consequently in the Tula irrigation area, administrative restriction on cropping practice has been introduced by CNA. In other words crops that could be produced are restricted to those that are not traditionally consumed raw and are feed for livestock/animal husbandry.

It can be summarized that the discharged untreated wastewater has resulted in the deterioration of the environmental conditions in the downstream areas and has also adversely affected the inhabitants.

In December 1992, the Government of Mexico stipulated the "National Water Law" (Ley de Aguas Nacionales) to improve the water quality of the public water bodies. According to the law, within six (6) years all wastewater should be treated before discharging to public water bodies.

In response to the stipulation of the law, DGCOH made a master plan for wastewater treatment systems covering the urbanized area of both D.F. Mexico and Mexico State "Plan Maestro de Tratamiento y Reuso del Districto Federal 1993" (hereinafter referred to

as "the Master Plan)" and proposed that wastewater treatment plants with a total capacity of 83 m^3/sec are required to treat all discharged wastewater of Mexico valley. And a wastewater treatment plant with a capacity of 35 m^3/sec is proposed at Texcoco lake (hereinafter referred to as "Texcoco wastewater treatment plant").

Under these circumstances, the Government of Japan conducted the project formation study in February 1993. Based on the study, the Government of United Mexican States requested to the Government of Japan to conduct a Feasibility Study for the proposed wastewater treatment plant at Texcoco. In response to the request, Japan International Cooperation Agency (JICA) dispatched a preparatory study team to Mexico in October, 1993 and the scope of work for the Study was signed on October 6, 1993.

With Master Plan study as a basis, the feasibility study of Texcoco wastewater treatment plant has been conducted. The Feasibility Study has been classified into two (2) stages;

- Final Project with a target year of 2015

- Urgent Project with a target year of 1997

In the Final Project, the proposed optimum wastewater treatment system should have enough capacity to treat the wastewater discharged in the year 2015 and treated wastewater quality should meet the proposed design effluent quality necessary for the improvement of environmental conditions of downstream areas and necessary for satisfying irrigation water requirements.

In the Urgent Project stage, the wastewater treatment system is proposed to mitigate the existing deteriorated water environment. The target year of Urgent Project is chosen to be 1997 so as to satisfy the condition of treating wastewater within six (6) years, as laid in National Water Law (1992). The treatment system for the Urgent Project should be in conformity with the optimum treatment system for the year 2015.

2. Objectives of the Study

The objectives of the Study are :

1. To conduct a feasibility study on wastewater treatment plant for the Final Project

2. To conduct preliminary design on wastewater and sludge treatment plant for the Urgent Project

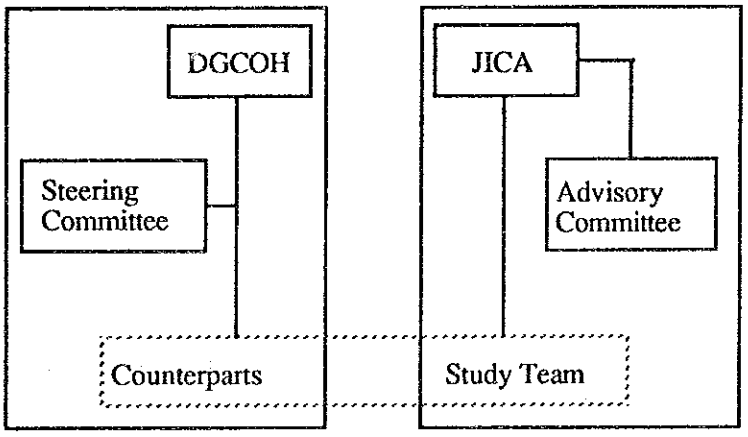
3. To make recommendations on advanced technologies of
   - Efficient reuse of sludge

- Wastewater treatment process
- Reuse of treated wastewater

3. Implementation of the Study

General Direction of Construction and Hydraulic Operation (DGCOH) of the Federal District of Mexico (D.F. Mexico) was assigned as the counterpart executing agency of the Government of the United Mexican States, while the Japan International Cooperation Agency (JICA), an official agency responsible for the implementation of the technical cooperation program of the Government of Japan, was the executing agency from Japanese side.

The Study was carried out by the Japanese consultant team contracted with JICA and Mexican counterpart staff. The operation of the study was monitored by Steering Committee, organized by DGCOH. The overall concept of the organizational structure is shown below.



The whole study was conducted from February to November in 1994. The members involved in the study are listed below.

(1) JICA Study Team

<u>Team Leader</u>

Mr. Masami Kondo (PCI)

<u>Members</u>

Mr. Kiyoshi Nakahara (PCI)

Mr. Michiharu Jonan (PCI)

Mr. Nobuyuki Gonohe	(PCI)
Mr. Takaaki Katsuki	(PCI)
Dr. Sanjay Arora	(PCI)
Mr. Naomichi Ishibashi	(PEI)
Dr. Somasundaram Jayamohan	(PCI)

(2) JICA Advisory Committee

Chairman

Mr. Kazuo Takeishi	Ministry of Construction

Member

Mr. Kenji Yamashita	Nagoya Municipality

(3) Steering Committee of Mexico

Chairman

Ing. Oscar Hernandez Lopez	Technical Director, DGCOH

Members

Ing. Juan Carlos Guasch y Saunders	Sub-Director of Programming, DGCOH
Ing. Antonio Cappella Vizcaino	Adviser to Director General, CNA
Ing. Francisco Rafael Mortera Aguirre	Operation Director, Mexico State
Ing. Enrique Perez San German	Manager of Study and Project Office, Mexico State

(4) Counterparts

Chairman

Ing. Oscar Hernandez Lopez	Technical Director, DGCOH

Members

Ing. Juan Carlos Guasch y Saunders	Sub-Director of Programming, DGCOH

Ing. Miguel Angel Cortes	Chief, Master Plan Department, DGCOH
Ing. Octavio Lopez Maya	Chief, Drainage Project Department, DGCOH
Ing. Gregorio Martinez Ramirez	Chief, Development Sub-Direction DGCOH
Ing. Rolando Rodriguez Sobreyra	Chief, District Hydraulic Plan Department, DGCOH
Ing. Juan A. Rosales Guzman	Sub-Director, Financial Resources DGCOH
Ing. Virginia Juarez Cordova	Chief, Treatment Plants, DGCOH
Ing. Rafael Ibarra Pescador	Chief, Office of Hydraulic Structure, DGCOH

4. Composition of Report

This Feasibility Study Report consists of five (5) components: Summary Report, Main Report, Supporting Report, Drawing and Data Book.

The Main Report presents the major outcome of the feasibility study on the wastewater treatment plant at Texcoco. The Main Report consists of Nine (9) Chapters. Introduction is illustrated in Chapter 1. The existing conditions are basically summarized from Chapter 2 to Chapter 4. Wastewater Treatment System is proposed, designed and evaluated from Chapter 5 to Chapter 9.

The Main report is summarized in the Summary Report, backed up by the Supporting Report which deals every section in detail. Data Book contains the related calculations and relevant drawings.

These reports are listed below.

(1) Main Report
(2) Supporting Report
(3) Drawing
(4) Data Book
(5) Executive Summary

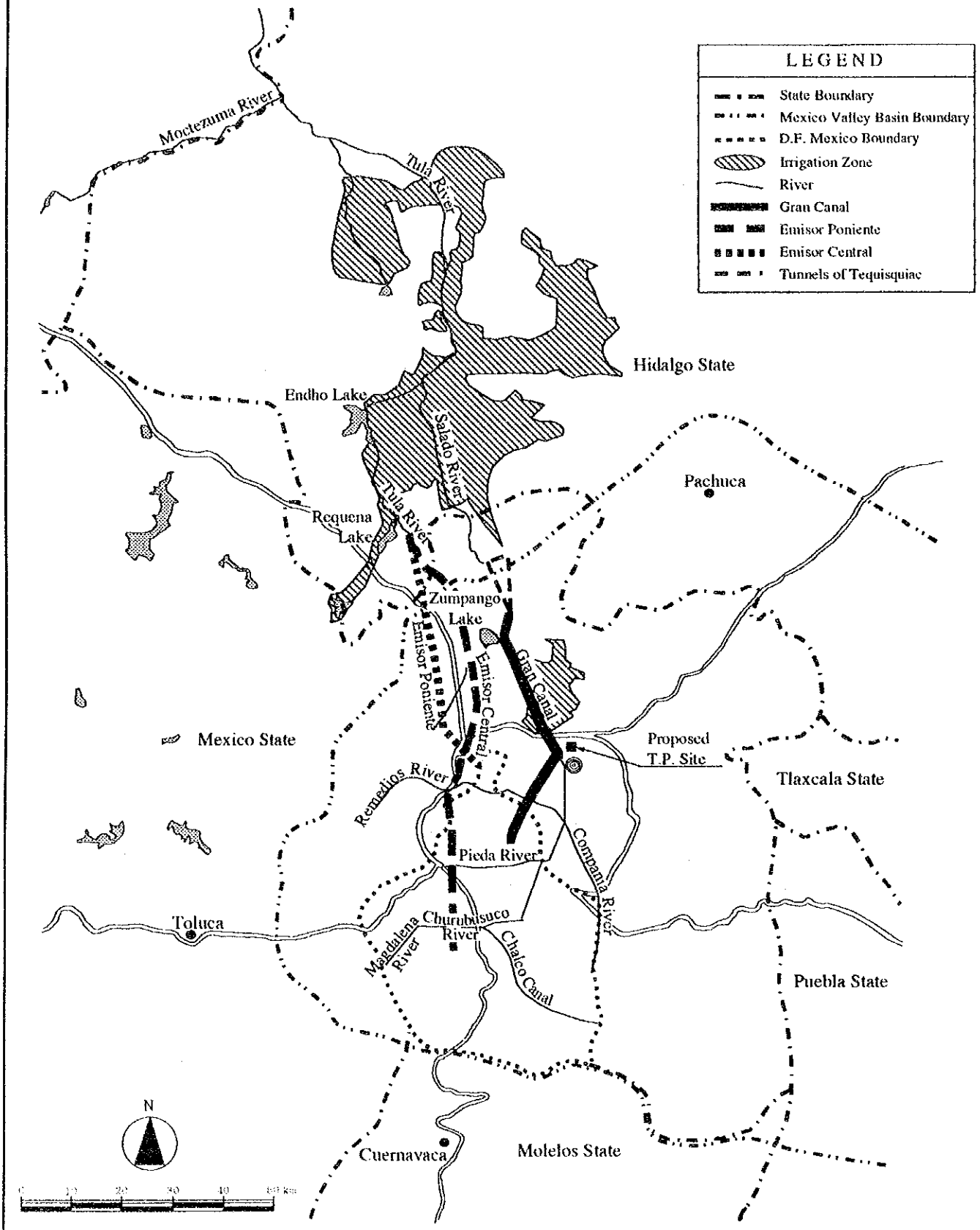


Fig. 1.1 Major irrigation Areas of Untreated Wastewater in the Mexico and Hidalgo States

CHAPTER 2

CHAPTER 2 CHARACTERISTICS OF STUDY AREA

1. Study Area

1.1 Population and Land Use

The Study Area covering a drainage area of the Gran Canal of approximately 2,740 km^2 consists of all the 16 Districts of D.F. Mexico and 15 Municipalities of the Mexico State. In this report, "Mexico State" should be considered as "Mexico State belonging to the Study area", unless mentioned otherwise.

The administrative boundaries of Districts and Municipalities are shown in Fig. 2.1.

The existing total population of the Study Area in 1993 is estimated to be 13,426,700, out of which 8,662,600 (64.5 %) population is in the D.F. Mexico and 4,764,100 (35.5 %) population in the Mexico state.

The data related to future population till the year 2000 is available for the D.F. Mexico and the Mexico State. Following the same trend of population, JICA study team has predicted the future population, in the D.F. Mexico and Mexico State for the year 2015. Future population, in the years of 1997 and 2015, of the Study Area is projected to be 14,890,100 and 20,335,600 respectively.

Future population of D.F. Mexico and Mexico State in the year 1997 and 2015 are shown below.

	1997	2015
D.F. Mexico	9,277,200	12,774,800
Mexico State	5,612,900	7,560,800
Total	14,890,100	20,335,600

The regional distribution of the population density in 1993, 1997 and 2015 is shown in Fig. 2.2.

Existing land use of both D.F. Mexico and Mexico State in the Study Area are estimated as follows.

Land Use	D.F. Mexico (km^2)		Mexico State (km^2)		Total (km^2)	
Residential Use	386.3	(28.8 %)	688.7	(49.3 %)	1,075.0	(39.2 %)
Commercial Use	92.0	(6.8%)	52.8	(3.7 %)	144.8	(5.3 %)
Institutional Use	64.3	(4.8%)	76.8	(5.5 %)	141.1	(5.2 %)
Industrial Use	31.8	(2.4%)	78.0	(5.6 %)	109.8	(4.0 %)
Other Use	767.7	(57.2%)	501.4	(35.9 %)	1,269.1	(46.3 %)
Total	1,342.1	(100%)	1,397.7	(100 %)	2,739.8	(100 %)

1.2 Economy

The existing (1990) and future (2015) gross regional domestic product (GRDP) and per capita GRDP of the Study Area in D.F. Mexico and Mexico State are estimated at 1993 prices and are shown below.

Area	Item	1990	2015
D.F. Mexico	GRDP (N$ million)	293,170	781,543
	Per Capita GRDP (N$)	35,597	61,178
Mexico State	GRDP (N$ million)	57,034	171,412
	Per Capita GRDP (N$)	12,749	22,671
Total	GRDP (N$ million)	350,204	952,955
	Per Capita GRDP (N$)	27,555	46,861

The aspects related to economy of the Study Area are further elaborated in Appendix A.

1.3 Natural Climate

Average annual rainfall of the Study Area is estimated to be 720.4 mm of which more than 80 % concentrates in the four (4) rainy months from June to September.

Monthly average air temperature ranges from 12.9°C in December to 19.3°C in May with an annual average of 15.0°C.

The Study Area has altitude of more than 2,200 m and is closed in the south, west and east sides by mountains with an altitude of more than 3,000 m. The land of the central area gently declines toward north.

Recently, the land subsidence has been observed in the central to the north eastern part of the Study Area, ranging from 20 cm to 250 cm for the last 10 years (ref. Fig. 2.3). The main reason of land subsidence is the excess groundwater withdrawal.

2. Water Supply of the Study Area

2.1 Water Resources of the Study Area

The Study Area is located in the Valley of Mexico which is facing the shortage of water resources. Based on the annual report on water for D.F. Mexico "Agua 2000 Estrategia para la Ciudad de Mexico (Agua 2000)", existing and future available capacity of water sources for the Study Area is estimated as follows.

(Unit : m^3/sec)

Year	D.F. Mexico	Mexico State	Total
1993	35.3	16.59	51.89
1997	36.3	16.45	52.75
2000	36.3	14.82	51.12

2.2 Existing Water Supply

The existing population of D.F. Mexico of 8.66 million is fully covered by the existing pipe distribution water supply system. And 95 % of existing population in Mexico State of 4.53 million is covered by the pipe distribution water supply system. Hence existing unit per capita water supply of D.F. Mexico and Mexico State are estimated to be 352.1 lpcd and 300.9 lpcd respectively.

At the existing conditions, water leakage is found to be 30 % in D.F. Mexico and 35 % in Mexico State, of the total water supply. With due consideration of existing water leakage, existing unit per capita water consumption of both D.F. Mexico and Mexico State are estimated to be 246.5 lpcd and 195.6 lpcd respectively.

Existing water consumption in the Study Area are estimated by multiplying existing unit per capita water consumption with the population served. Estimated water consumption in D.F. Mexico and Mexico State are shown below:

D.F. Mexico	24.71 m^3/sec
Mexico State	10.79 m^3/sec
Total	35.5 m^3/sec

2.3 Future Water Supply

Future population in the Study Area of D.F. Mexico and Mexico State is expected to be fully covered by the piped water supply system. And water leakage conditions of both D.F. Mexico and Mexico State are assumed to slightly improve

to 28 % and 30 % respectively by the year 1997 and these conditions are expected to continue in the future.

Unit per capita water consumption of D.F. Mexico and Mexico State for the year 1997 and 2000 are estimated as follows:

(Unit : lpcd)

	1997	2000
D.F. Mexico	243.4	230.5
Mexico State	177.2	152.0

Unit per capita water consumption in 2015 of both D.F. Mexico and Mexico State are assumed same as those in the year 2000 with the following considerations:

- Unit per capita water consumption of Yr 2000 are considered to be the minimum requirment which maintains the living standards of Mexico city.

- Program on the efficient use of the water (PUEDA) will be implemented (ref Appendix E for further details).

Future water consumption in the Study Area is estimated by multiplying per capita water consumption with population served. Future water consumption in 1997, 2000 and 2015 is shown below.

(m^3/sec)

	D.F. Mexico	Mexico State	Total
1997	26.14	11.51	37.65
2000	26.14	10.38	36.52
2015	34.08	13.30	47.38

3. Water Environment

3.1 River Network

The Study Area has two (2) types of rivers; Natural rivers and Canals for drainage. The major natural rivers are La Piedad, Churbusco, Remedios, Consulado, Magdalena, San Buenaventura, Compania and National canal of Chalco. The major canals for drainage are Gran Canal, Emisor Central and Emisor Poniente.

The network of above rivers and canals is shown in Fig. 2.4.

3.2 River Water Quality

Water quality of all natural rivers and drainage canals, except Magdalena river and Tarango river, has been aggravated due to the municipal wastewater discharged to rivers and canals.

Water quality of major rivers and drainage canals in the Study Area have been periodically observed by Central Laboratory of DGCOH. Water quality of rivers and canals, in terms of BOD_5, SS and total coliforms are as follows:

	BOD_5 (mg/l)	SS (mg/l)	Total Coliform (No/100 ml)
Natural Rivers	100 ~250	50 ~ 400	2.0E+07 ~ 5.0E+07
Drainage Canals	159 ~ 230	110 ~ 500	2.0E+07 ~ 4.0E+08

3.3 River Uses

Most of the existing rivers are being used as a part of drainage system for both wastewater and storm water. Discharged wastewater of the Study Area is carried towards Tula irrigation area through the natural rivers and drainage canals. Some portion of the natural rivers has already been converted into box culverts to mitigate the offensive odor emanation. Only Magdalena river is being used for water source of potable water supply.

In dry season wastewater discharged in the Study Area is carried by Gran Canal only whereas in rainy season wastewater is divided to Emisor Central and Gran Canal through discharge gates.

3.4 Groundwater Quality and Use

Groundwater is the major source of water supply and 847 wells exist in the Study Area. And very few wells are being used for irrigation and industrial uses. Depth of wells varies from 50 m to 400 m. No organic pollution was observed. The major problem in groundwater quality is due to Fe and Mn ions.

3.5 Water Borne Disease

Generated wastewater in the Study Area is being used for irrigation at Tula irrigation area without any treatment and has deteriorated environmental conditions of Tula irrigation area. It has led to breakout of water borne diseases in that area. Cases of water borne diseases in Tula irrigation area are compared with that of D.F. Mexico and Mexico State. In D.F. Mexico irrigation with

untreated wastewater is not practiced in any District, whereas in Mexico State untreated wastewater is being used for irrigation purpose in only one municipality of Tecamac and in Tula irrigation area untreated wastewater is being used extensively. The incidence of water borne diseases per 100,000 population in above three (3) areas is summarized below.

	No. of cases / 100,000 population
D.F. Mexico	106
Mexico State	2,795
Tula Area, Hidalgo State	5,696

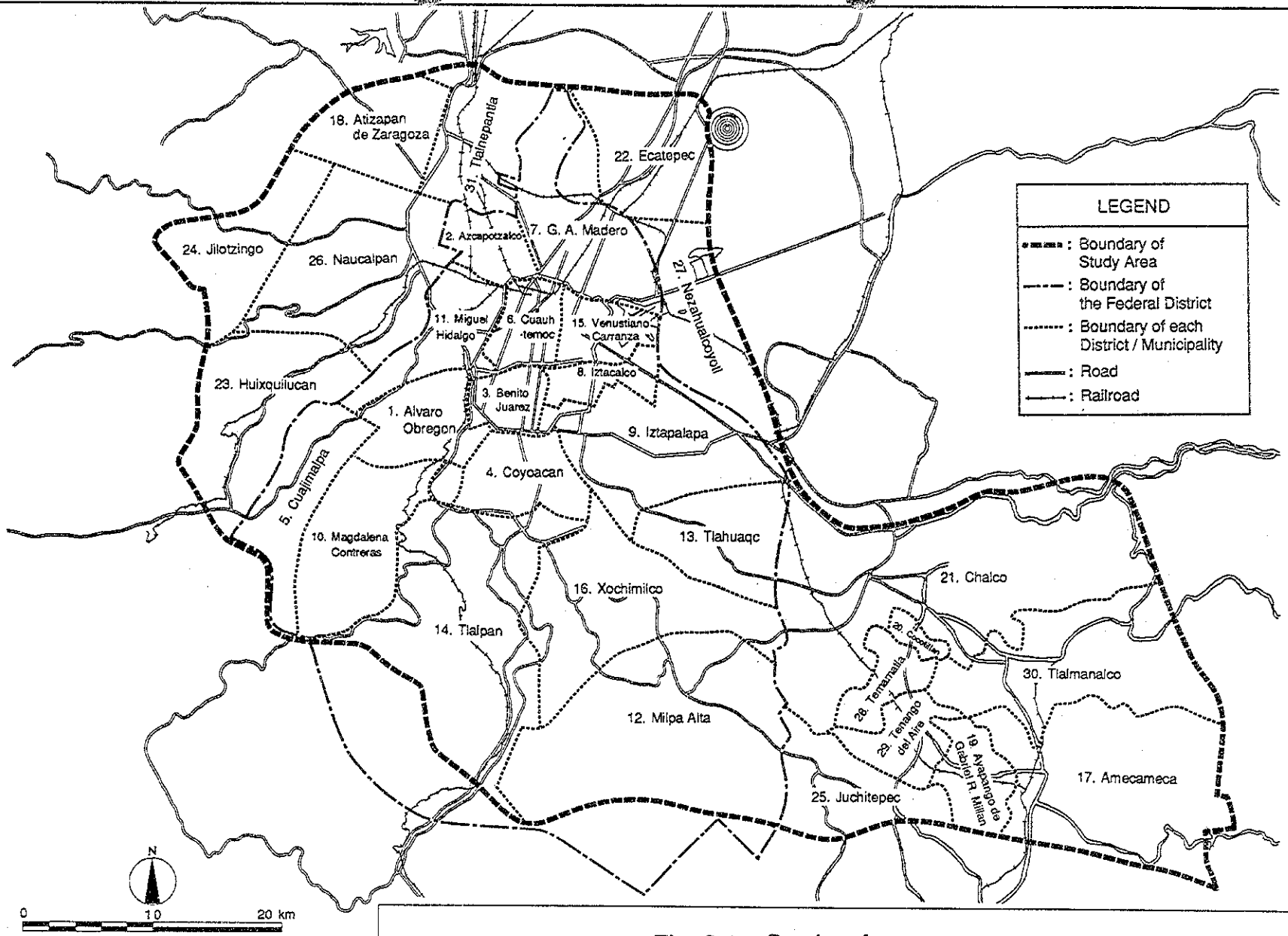


Fig. 2.1 Study Area

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

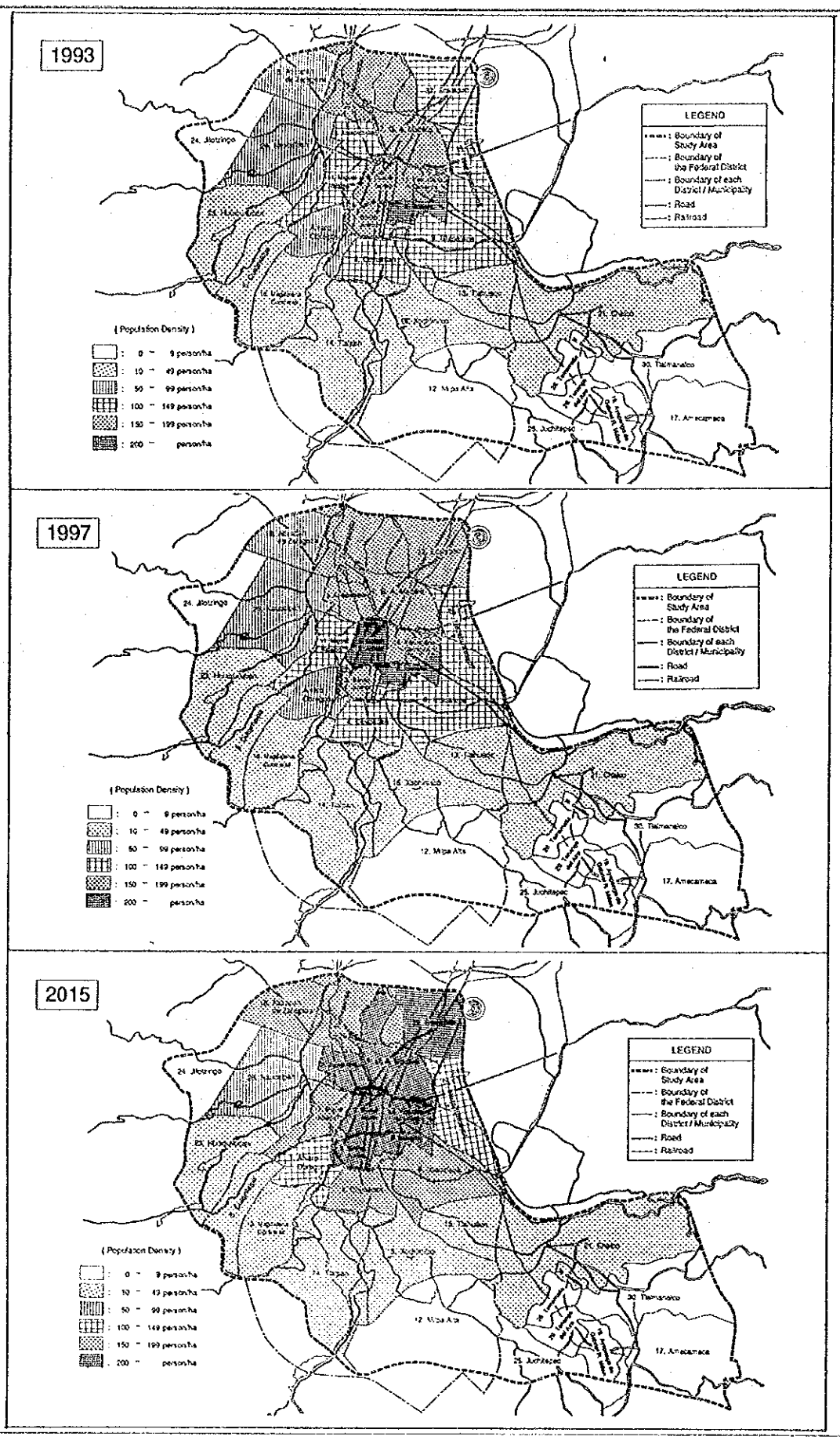


Fig. 2.2 Regional Distribution of Population Density in 1993, 1997 and 2015

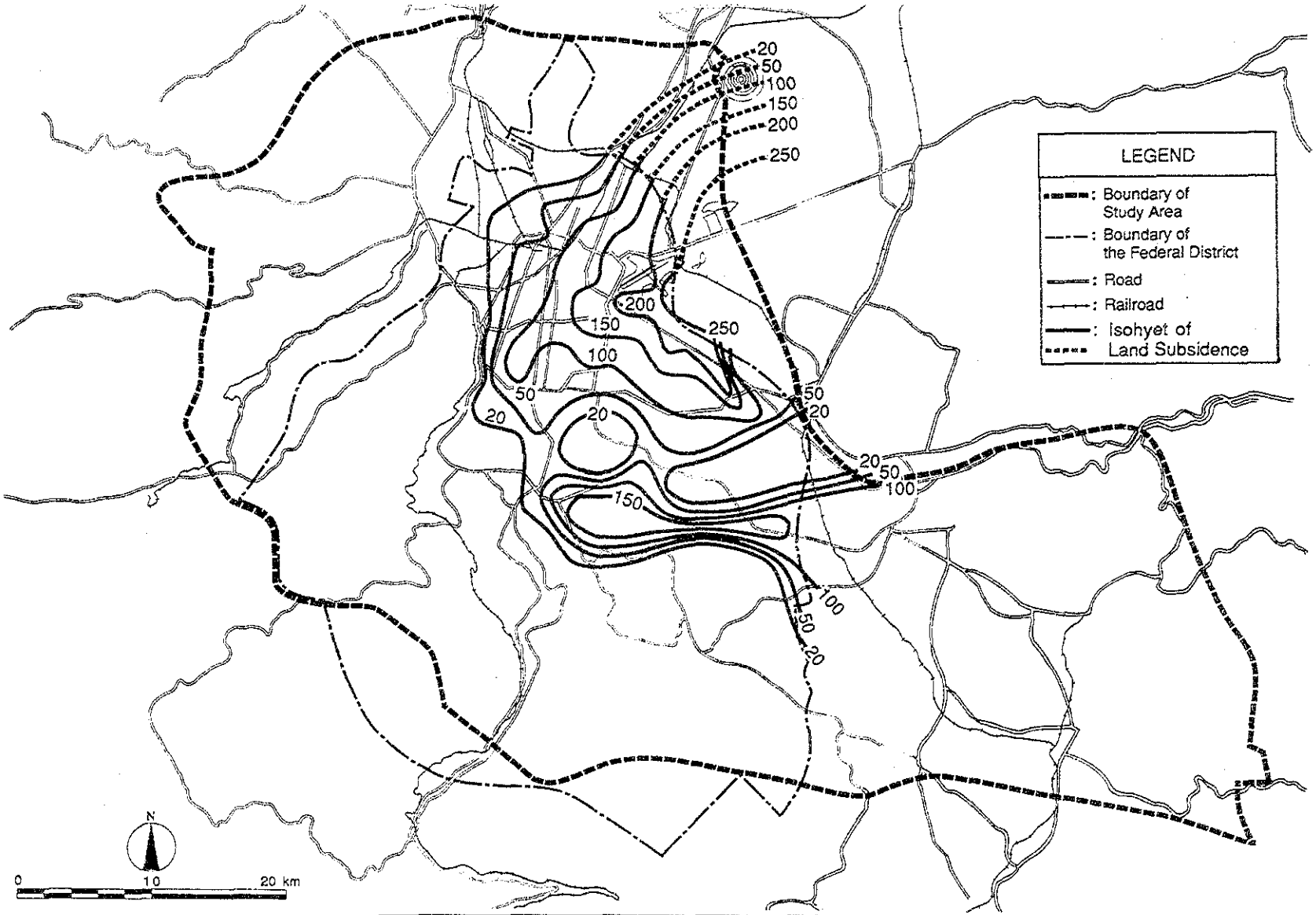


Fig. 2.3 Land Subsidence for the Last 10 Years (1983 to 1992) in Study Area

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

JICA

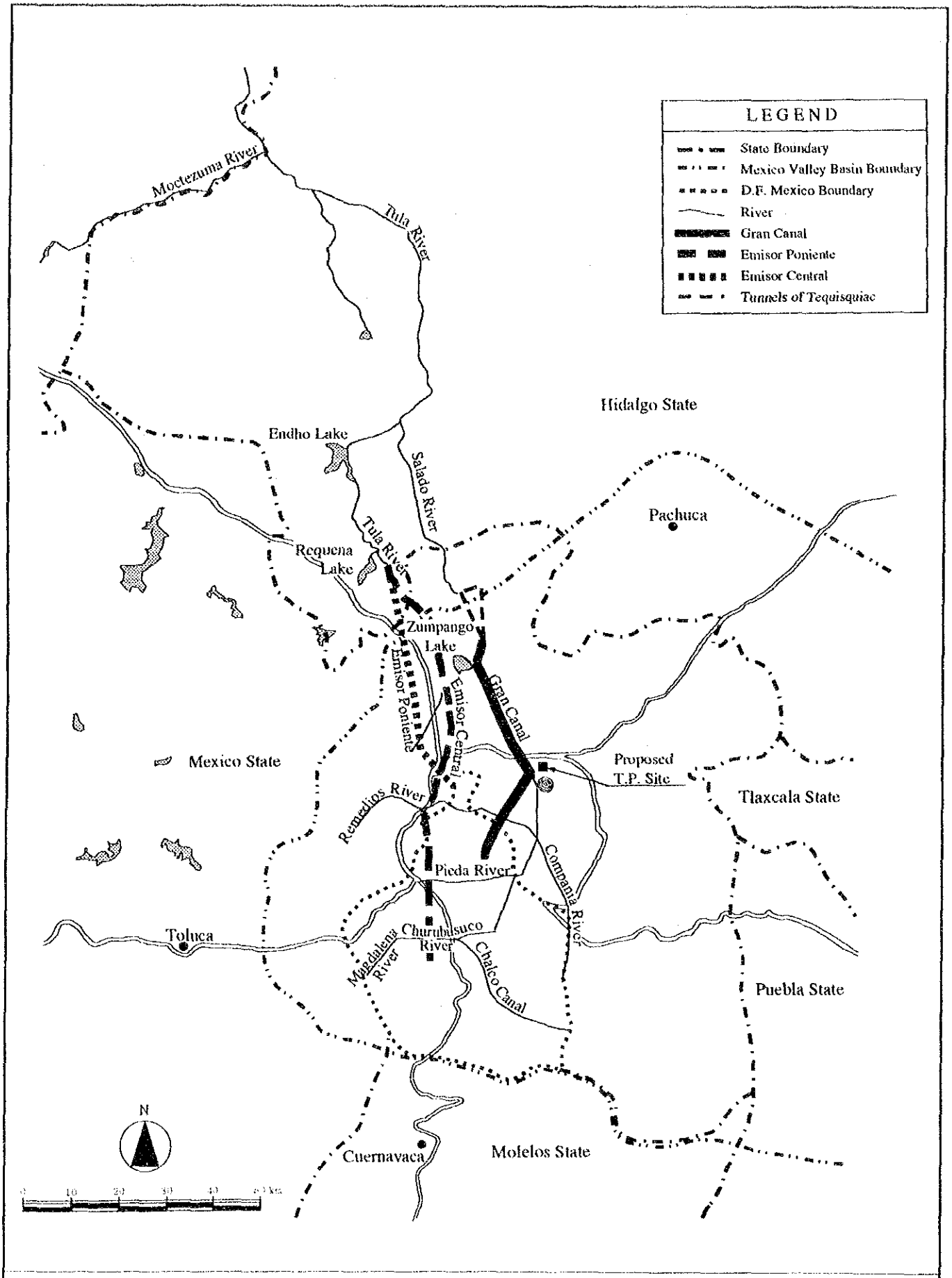


Fig. 2.4 Networks of Rivers and Canals

CHAPTER 3

CHAPTER 3 SEWERAGE SYSTEM

1. Service Area and Service Population

1.1 D.F. Mexico

About 71 % of the total administrative area of D.F. Mexico i.e., 956.11 km^2 is covered by the existing sewerage system. Existing sewerage service area is shown in Fig. 3.1.

Among 16 districts located in the Study Area, the eight (8) districts which are located in the central area of D.F. Mexico, are entirely covered by existing sewerage system, while areal sewerage service ratio, for the districts located at the fringes of D.F. Mexico, ranges from 20 % to 60 %.

Existing sewerage system covers about 94 % of the total population of 8.66 million in the Study Area of D.F. Mexico. The entire population in the above mentioned eight (8) districts with 100 % of areal service ratio is covered by the existing sewerage system. The lowest population service ratio of 30 % is observed in Milpa Alta District which is located at the southern fringe of the Study Area.

Existing sewerage service area and population for each district is shown in Table 3.1 and Fig. 3.2.

JICA Study Team has assumed the future sewerage service population ratio to estimate the wastewater discharge volume in future. The assumed sewerage service population ratio is mentioned below:

Year	Service Population Ratio
1997	98 %
2015	100 %

1.2 Mexico State

About 42 % of the Study Area of Mexico State i.e. 584.26 km^2 is covered by the existing sewerage system. Existing service area of each municipality is shown in Table 3.1. Areal service ratio varies from 15 % to 95 % depending on the location and land use conditions in the municipality.

Population service ratio in the municipalities ranges from 15 % to 95 % with an average of 85 %. Percentage of existing sewerage service population for the each municipality is shown in Fig. 3.2.

Future sewerage population service ratio in the year 1997 and 2015 are assumed as follows:

Year	Service Population Ratio
1997	95 %
2015	100 %

2. Discharged Wastewater

2.1 Quantity of Wastewater

Wastewater generation is assumed to be the same amount of water consumption, which has been previously estimated in Chapter 2. Hence existing wastewater generation in the study area is estimated to be 35.5 m^3/sec and the total wastewater generation for the Urgent Project (Yr. 1997) and the Final Project (Yr. 2015) is estimated to be 37.65 m^3/sec and 47.38 m^3/sec respectively.

The quantity of total discharged wastewater is estimated by multiplying wastewater generation with the sewerage service population ratio. Existing and future wastewater discharge quantity in the Study Area of D.F. Mexico and Mexico State are described below.

	D.F. Mexico (m^3/sec)	Mexico State (m^3/sec)	Total (m^3/sec)
Existing	23.23	9.17	32.40
Future (1997)	25.62	10.93	36.55
Future (2015)	34.08	13.30	47.38

2.2 Quality of Discharged Wastewater

No data regarding unit pollution load generation in D.F. Mexico and Mexico State is available. JICA Study Team has estimated the existing unit pollution load discharge based on the wastewater characteristics of Gran Canal.

Water quality data of Gran Canal at the station of San Cristobal, which is located near the proposed treatment site is available for five (5) years from 1989 to 1993. Annual average BOD_5 of 215 mg/l and SS of 230 mg/l are defined as the existing water quality of Gran Canal.

As described in the previous section existing discharged wastewater is 32.4 m^3/sec and distribution in D.F. Mexico and Mexico State is shown below.

D.F. Mexico	:	23.23 m^3/sec
Mexico State	:	9.17 m^3/sec
Total	:	32.40 m^3/sec

Existing treatment plants in the Study Area are treating wastewater of 2.97 m^3/sec. About 0.67 m^3/sec treated water is reused for industrial purpose and is discharged again to the sewerage system, however 2.30 m^3/sec of treated water is reused for irrigation purpose and is not discharged to the Gran Canal. Hence the wastewater of 30.10 m^3/sec is discharged to the Gran Canal.

With due consideration to the operating conditions of existing wastewater treatment plants, according to which treated sludge is discharged to the sewer again, BOD_5 and SS of municipal wastewater are calculated as 206 mg/l and 213 mg/l respectively.

And estimated unit per capita pollution load of BOD_5 and SS in D.F. Mexico and Mexico State are shown below.

	BOD_5	SS
D.F. Mexico	50.8 gpcd	52.5 gpcd
Mexico State	40.3 gpcd	41.7 gpcd

Quality of discharged wastewater is estimated by dividing unit per capita pollution load by unit per capita water consumption. JICA Study Team has assumed that the existing unit per capita pollution load, in terms of BOD_5 and SS, is not changed in future. Existing and future discharged wastewater quality of the Study Area in terms of BOD_5 and SS is summarized below.

	BOD_5 (mg/l)	SS (mg/l)
Existing	206	213
Future (1997)	214	221
Future (2015)	233	241

3. Sewer Networks

3.1 Sewer Networks in D.F. Mexico

The existing sewer network system consists of following six (6) components:

- Secondary Sewer
- Main Sewer

- Intermediate Level Sewer
- Deep Level Sewer
- Drainage Pumping Station
- Drainage Pumping Station at Road Intersection

Secondary sewer of 11,226.4 km with a pipe diameter ranging from 300 mm to 450 mm exists in the Study Area of D.F. Mexico. Secondary sewer length per unit administrative area of District ranges from 1.15 km/km^2 to 49.81 km/km^2 with an average of 8.37 km/km^2. The most densely laid secondary sewer area is found to be in Benito Juarez district and the lowest is observed in Cuajimalpa district. The length of secondary sewer of each district is shown in Table 3.2.

Main sewers of 1,408.4 km with a pipe diameter ranging from 610 mm to 4,000 mm are found to be existing in the year 1991. Length of main sewer in each district is shown in Table 3.2.

Intermediate level sewer is laid at the depth of 8-10 meters below ground surface. Length of Iztapalapa intermediate level sewer is 5.29 km and Obrero Mundial intermediate sewer 0.71 km. Diameter of both Iztapalapa and Obrero Mundial intermediate sewers is 3.1 m.

Deep level sewer is constructed at a depth greater than 20 meters below ground surface. Deep level sewer has been constructed since 1975 and still now some are under construction. There are six (6) deep level sewers with a total length of 121.1 km in D.F. Mexico.

Length, diameter and laying depth of Intermediate level sewer and Deep level sewer are shown in Table 3.3 and their location are shown in Fig. 3.3.

Planned Intermediate level sewer and deep level sewer for the future are being constructed as per schedule, however main and secondary sewers are constructed depending on the availability of budget and the urgency.

About 70 drainage pumping stations with a capacity ranging from 0.10 m^3/sec to 49.60 m^3/sec are existing in the Study Area of D.F. Mexico.

For draining storm water on the roads and the footways, 91 pumping stations exist in the Study Area. The capacity ranges from 0.01 m^3/sec to 0.84 m^3/sec.

3.2 Sewer Networks in Mexico State

The sewer network system in Mexico State consists of following three (3) components:

- Secondary Sewer
- Main Sewer
- Drainage Pumping Station

Secondary sewer of about 4,170 km with a pipe diameter ranging from 300 mm to 450 mm exist in the Study Area. Secondary sewer length per unit administrative area of Municipality ranges from 0 km/km^2 to 23.11 km/km^2 with an average of 2.98 km/km^2. The most densely laid secondary sewer area is found to be in Ecatepec municipality and the lowest is observed in Jilotzingo municipality. The length of secondary sewer in each municipality is shown in Table 3.2.

Main sewers of 762.3 km with a pipe diameter ranging from 610 mm to 4,000 mm are found to exist in the year 1991. Length of main sewer in each district is shown in Table 3.2.

Total 100 drainage pumping stations exist in the Study Area in 1993 with a design capacity ranging from 0.02 m^3/sec to 7.00 m^3/sec.

4. Wastewater Treatment Plant

4.1 Wastewater Treatment Plant in D.F. Mexico

All existing 21 wastewater treatment plants in D.F. Mexico have been constructed to create the new water resources from treated water. These treatment plants treat only 11.6 % of the total average discharged wastewater of 23.23 m^3/sec. in the Study Area. The total design capacity of existing 21 treatment plants is 5.860 m^3/sec, however the average operating capacity in the year 1992 is found to be 2.697 m^3/sec, which is about 46 % of the total design capacity. Existing treatment plants are very small and design capacity ranges from 0.0075 m^3/sec to 4.0 m^3/sec. Details of existing 21 treatment plants are described in Table 3.4.

Conventional activated sludge process is used for all 21 existing treatment plants. Only three (3) treatment plants, i.e., Rosario in Azcapotzalco district, Iztacalco in Iztacalco district and San Luis Tlaxialtemalco in Xochimilco district are equipped with tertiary treatment process of sand filter and/or activated carbon filtraton. Seventeen (17) treatment plants have been constructed before 1981 and do not

possess sludge treatment facilities, and produced sludge has been discharged to sewer system without any treatment. Remaining 4 treatment plants are equipped with sludge treatment process of anaerobic digestion with drying bed or mechanical dewatering and aerobic digestion with thickener and drying bed. However, due to operational problems and unavailability of equipment for repairing, the sludge from these treatment plants is also being discharged to sewer system without any treatment.

4.2 Wastewater Treatment Plant in Mexico State

There are eight (8) wastewater treatment plants existing in the Study Area of Mexico State. All were constructed to reuse the treated water for irrigation and industrial purpose.

Total design capacity of existing eight (8) treatment plants is 0.855 m^3/sec with an operation capacity of 0.375 m^3/sec which is about 45 % of the design capacity. All existing treatment plants have small design capacity ranging from 0.005 m^3/sec to 0.40 m^3/sec. The produced sludge from these treatment plants is discharged directly to the sewer system with no treatment.

5. Treated Wastewater Quality and Reuse

The reuse of treated water is mainly practiced within the D.F. area, though there are some in the state of Mexico area as well. The treated water is conveyed, mostly through pressure pipe system, for various reuses in D.F. area with the major reuse being irrigation of green areas and parks including ecological replenishment of lakes, ponds and canals (83 %) followed by cooling water for industry (10 %), agricultural irrigation (5 %) and non potable commercial use (2 %). The existing and future pipe distribution system of reuse water in D.F. is shown in Fig. 3.4.

As treated water is used for irrigation hence no cropping restriction is implemented and variety of agricultural crops including cauliflower, cabbage and artichoke are being cultivated. The agriculture area are located in the districts of Milpa Alta, Tlahuac and Xochimilco located along the south eastern fringes of the D.F. area.

Besides conventional reuses, non conventional reuses such as groundwater recharge is also being practiced on experimental basis. Advanced wastewater treatment is done before injecting treated water for groundwater recharging. In

Tlahuac, at Santa Catarina, groundwater recharging is being done on experimental basis.

5.1 Monitoring of Water Quality of Treated Water

The water quality of treated water being used for conventional uses is monitored semimonthly by the Central Laboratory. About 78 monitoring station are located at various types of reuse areas in D.F. 45 monitoring station are in lake and canals, 16 in green areas and parks, 9 in industrial cooling, 6 in agricultural irrigation and 1 each in recreational facility and public washing facility. The water quality parameters measured cover the typical physical, chemical and biological parameters. Most of the parameters conform to the standard requirements, only coliforms were found to exceed the prescribed maximum limit.

The water quality of treated water for non conventional uses such as groundwater recharging is being monitored weekly by Central Laboratory. Besides influent and effluent, water quality is monitored at the end of each intermediate process. The measured parameters include major physical, chemical and biological parameters. Most of the parameters except oil and grease are found to be in conformity with the prescribed standards. Hence more efficient oil removal process at the groundwater injection site must be installed.

5.2 Future Reuse

Treatment and Reuse Master Plan (1990) envisages on a short term basis in the near future, expansion of treated wastewater reuse for agricultural irrigation and industry because for these reuses secondary wastewater treatment would be adequate. On a long term basis, more non conventional reuse of treated water has been emphasized. The two important non conventional reuses considered are; Groundwater recharge and non potable domestic reuse. These non conventional reuse could mitigate the problem of over exploitation of groundwater and land subsidence. However these reuses require tertiary treatment of wastewater.

5.3 Water Quality Standards of Reuse

The water quality standards on National basis as well as on D.F. basis, regarding the quality of wastewater to be reused have been established. These regulations are listed below.

(1) Regulations for water reuse in Federal District (Reglamento para el Reuso del Agua en el Distrito Federal 1987). This law prescribes limits of various parameters based on the type of reuse.

(2) Mexican Official Standard Nom-CCA-032-ECOL/1993. This law dictates the maximum limit of pollutants for irrigation waters.

(3) Mexican Official Standard Nom-CCA-033-ECOL/1993. This law dictates the maximum limit of bacteriological parameters for irrigation waters to be used for irrigation of vegetables and fruits. This law specifies the minimum interval between last irrigation and harvest and type of crops permitted, depending on the type of irrigation and the level of treatment.

More detailed discription of these standards is given in Appendix C, Section 6.

6. Reuse of Sludge

At present only four (4) existing treatment plants have sludge processing facilities, however due to operational problems, these facilities are not in operation and sludge is being discharged to sewerage system.

In future with the installation of sludge processing facilities in the new treatment plants, the quantity of sludge production would increase and appropriate reuse alternatives for sludge would become an important consideration.

7. Design Conditions and Criteria of Existing Treatment Plant

Any design criteria for wastewater treatment plant were not established. All existing treatment plants were designed based on the design standards of EPA and/or WEF, and also the reference book published by Metcalf & Eddy.

The design capacity of each existing treatment plant has been decided based on the requirements of reuse conditions.

Details of design criteria of Cerro de la Estrella which has the largest design capacity of 4.0 m^3/sec. are summarized in Table 3.5.

8. Operation and Maintenance

Existing wastewater treatment system in the Study Area of D.F. Mexico is managed by DGCOH. All existing 16 wastewater treatment plants and 70 drainage pumping stations are operated and managed by the staffs of Operation and Maintenance section of DGCOH.

Annual expenditure of N$ 18.482 million for the operation and maintenance of wastewater treatment system in the year of 1993 has been reported. The breakdown of the expenditure is as follows:

- Personal expenditure : N$ 10.681 million
- Fuel and power cost : N$ 2.580 million
- Chemical cost : N$ 0.320 million
- Repairing cost : N$ 2.645 million
- Other cost : N$ 2.256 million

Operation and maintenance cost per unit treated wastewater is evaluated for Cerro de la Estrella treatment plant as described below.

Monthly operation and maintenance cost of Cerro de la Estrella treatment plant is found to be 1.159 million in the year 1992. The breakdown is as follows:

- Personal expenditure : N$ 0.173 million
- Fuel and power cost : N$ 0.285 million
- Chemical cost : N$ 0.060 million
- Repairing cost : N$ 0.632 million
- Other cost : N$ 0.009 million

Equipment installed at the existing treatment plant are mainly imported ones and that could be the reason of the higher repairing cost.

The unit operation and maintenance cost of Cerro de la Estrella Treatment Plant is found to be N$ 0.317/ m^3 of average treated wastewater. The operation and maintenance cost for sludge treatment have not been included in this O/M cost.

9. Organization

9.1 Organization

The organization directly concerned to sanitation in the Study Area are DGCOH in D.F. Mexico, CEAS, i.e. State Commission of Water Supply and Sanitation in Mexico State and CNA, i.e. National Water Commission at the national level.

DGCOH and CEAS are responsible for the planning, construction and operation and management of water supply and sanitation facilities in their respective jurisdictions. CNA is responsible for the establishment of national plan on hydraulics, sanitation and river management.

DGCOH has total work force of 12,935 in 1993, of which managers, technicians, workers and clerks accounted for 0.5 %, 9.4 %, 80.7 % and 9.4 % respectively.

DGCOH has the annual budget of N$ 1,222 million or 7.5 % of the total budget of DDF in 1994.

The total work force of CEAS is found to be 1,573 in 1993, of which managers, technicians and workers, and clerks accounted for 3.0 %, 68.3 % and 28.7 % respectively.

The annual budget of the Government of Mexico State for the fiscal year 1994 is N$ 3,211 million, of which N$ 288 million or 9.0 % is allocated to CEAS.

CNA is a national organization under the Ministry of Agriculture and Hydraulic Resources which was established in January, 1989 as an organization carrying the mission to resolve or manage the various conflicts arising in connection with the distribution, exploitation and use of water.

9.2 Water Tariffs

The water tariffs of DDF and Mexico State are basically composed of the one for the clients with water meters and the other for the clients without water meters. These are further divided into two (2) categories; for domestic users and for non domestic users.

Unit water charge for the clients with water meter in both D.F. Mexico and Mexico State vary depending upon bimonthly water consumption as shown below.

(Unit: N$/m^3)

D.F. Mexico	Domestic	0 ~3.8
	Non-Domestic	1.4~6.7
Mexico State	Domestic	0.45~2.46 0.56~3.08
	Non-Domestic	1.01~5.15 1.23~6.38

Note: Municipalities of Mexico State are classified into two (2) groups based on their general economic level.

Domestic clients without meters in D.F. Mexico pay fixed bimonthly charges, whose amount varies depending on the assessed type of areas and the assessed value of buildings from zero to N$ 401.45. Non-domestic clients without meters pay fixed bimonthly charges of N$ 100.35 to N$ 799,623.90 based on the diameter of the tap.

In Mexico State, domestic clients without meters pay fixed bimonthly charges of N$ 38.30 to N$ 860.94 depending on the group they belong, the income class they belong and the diameter of the tap they use. Non-domestic clients without meters in Mexico State pay fixed bimonthly charges of N$ 89.49 to N$ 16,653.17 depending on the group they belong and the diameter of the tap they use.

Table 3.1 Existing Sewerage Service Area and Population by District / Municipality in Study Area

No.	Name of District / Municipality	Total Area (km^2)	Existing (1993) Population	Service Area Area (km2)	Service Area (%)	Service Population Population	Service Population (%)
District in Federal District			1)		3)		3)
1.	Alvaro Obregon	94.50	690,100	94.50	100%	690,100	100%
2.	Azcapotzalco	33.50	493,000	33.50	100%	493,000	100%
3.	Benito Juarez	26.60	426,100	26.60	100%	426,100	100%
4.	Coyoacan	54.40	666,700	54.40	100%	666,700	100%
5.	Cuajimalpa	80.90	127,300	40.45	50%	89,100	70%
6.	Cuauhtemoc	32.44	625,700	32.44	100%	625,700	100%
7.	G. A. Madero	87.00	1,326,100	82.65	95%	1,326,100	100%
8.	Iztacalco	22.90	467,000	22.90	100%	467,000	100%
9.	Iztapalapa	117.50	1,567,900	99.88	85%	1,364,100	87%
10.	Magdalena Contreras	68.00	204,200	40.80	60%	153,200	75%
11.	Miguel Hidalgo	42.50	430,900	42.50	100%	430,900	100%
12.	Milpa Alta	222.16	67,000	44.43	20%	20,100	30%
13.	Tlahuaqc	93.00	221,300	83.70	90%	199,200	90%
14.	Tlalpan	212.23	515,500	127.34	60%	386,600	75%
15.	Venustiano Carranza	32.42	547,200	32.42	100%	547,200	100%
16.	Xochimilco	122.00	286,600	97.60	80%	243,600	85%
	Total of District	1,342.05	8,662,600	956.11	71%	8,128,700	94%
Municipality in Mexico State			2)		3)		3)
17.	Amecameca	181.20	38,100	27.18	15%	5,700	15%
18.	Atizapan de Zaragoza	48.13	330,700	38.50	80%	281,100	85%
19.	Ayapango de Gabriel R. Millan	42.50	4,400	6.38	15%	700	15%
20.	Cocotitlan	40.00	8,500	6.00	15%	1,300	15%
21.	Chalco	203.75	296,800	30.56	15%	59,400	20%
22.	Ecatepec	69.69	1,022,300	55.75	80%	920,100	90%
23.	Huixquilucan	122.50	138,400	73.50	60%	83,000	60%
24.	Jilotzingo	85.00	5,100	25.50	30%	1,500	30%
25.	Juchitepec	40.94	4,200	6.14	15%	800	20%
26.	Naucalpan	158.13	825,200	142.32	90%	742,700	90%
27.	Nezahualcoyotl	93.13	1,317,800	88.47	95%	1,251,900	95%
28.	Temamatla	56.88	5,600	8.53	15%	800	15%
29.	Tenango del Aire	90.31	6,500	13.55	15%	1,300	20%
30.	Tlalmanalco	119.06	23,200	17.86	15%	3,500	15%
31.	Tlalnepantla	46.34	737,300	44.02	95%	700,400	95%
	Total of Municipality	1,397.56	4,764,100	584.26	42%	4,054,200	85%
	Total of Study Area	2,739.61	13,426,700	1,540.37	56%	12,182,900	91%

Source : 1) DGCOH
2) Comissión Estatal de Agua y Saneamiento (CEAS)
3) JICA

Table 3.2 (1) Length of Main and Secondary Sewers of Each District in D.F. Mexico

Name of District	Area (km2)	Sewer Length (km)		Sewer Length per Unit Area (km/km2)	
		Main	Secondary	Main	Secondary
Alvaro Obregon	94.50	58.3	1,508.3	0.62	15.96
Azcapotzalco	33.50	85.3	401.4	2.55	11.98
Benito Juarez	26.60	84.2	1,325.0	3.17	49.81
Coyoacan	54.40	103.0	729.0	1.89	13.40
Cuajimalpa	80.90	2.6	92.8	0.03	1.15
Cuauhtemoc	32.44	87.5	487.8	2.70	15.04
G.A.Madero	87.00	205.0	1,682.0	2.36	19.33
Iztacalco	22.90	39.7	491.0	1.73	21.44
Iztapalapa	117.50	255.0	1,118.0	2.17	9.51
Magdalena Contreras	68.00	19.3	218.0	0.28	3.21
Miguel Hidalgo	42.50	162.0	1,173.0	3.81	27.60
Milpa Alta	222.16	27.9	433.0	0.13	1.95
Tlahuac	93.00	70.0	185.0	0.75	1.99
Tlalpan	212.23	57.2	459.0	0.27	2.16
Venustiano Carranza	32.42	95.0	700.0	2.93	21.59
Xochimilco	122.00	56.4	223.1	0.46	1.83
Total	1,342.05	1,408.4	11,226.4	1.05	8.37

Table 3.2 (2) Length of Main and Secondary Sewers of Each Municipality in Mexico State

Name of District	Area (km2)	Sewer Length (km)		Sewer Length per Unit Area (km/km2)	
		Main	Secondary	Main	Secondary
Amecameca	181.20	3.80	42.3	0.02	0.23
Atizapan de Zaragoza	48.13	50.70	396.2	1.05	8.23
Ayapango de Gabriel R. Millan	42.50	2.80	4.4	0.07	0.10
Cocotitlan	40.00	0.90	11.0	0.02	0.28
Chalco	203.75	8.40	66.2	0.04	0.32
Ecatepec	69.69	136.50	1,610.8	1.96	23.11
Huixquilucan	122.50	93.90	149.7	0.77	1.22
Jilotzingo	85.00	0.50		0.01	
Juchitepec	40.94	2.70	30.8	0.07	0.75
Naucalpan	158.13	183.50	682.7	1.16	4.32
Nezahualcoyotl	93.13	200.60	686.3	2.15	7.37
Temamatla	56.88	6.00	4.0	0.11	0.07
Tenango del Aire	90.31	2.40	17.4	0.03	0.19
Tlalmanalco	119.06	3.30	32.8	0.03	0.28
Tlalnepantla	46.34	66.30	435.0	1.43	9.39
Total	1,397.56	762.3	4,169.6	0.55	2.98

Table 3.3 Deep and Intermediate Level Sewer

(1) Intermediate Level Sewer

Sewer	Length (km)	Diameter (m)	Capacity (m^3 /s)	Depth (m)	
				Min.	Max.
Collector Iztapalapa Intermediate	5.29	3.1	20	11.5	15.5
Collector Obrero Mundial Intermediate	0.71	3.1	20	10	16
Total	6.00				

Note : 1994

(2) Deep Level Sewer

Sewer	Length (Km)	Diameter (m)	Capacity (m^3 /s)	Depth (m)	
				Min.	Max.
Collector del Poniente Deep	16.5	4.0	25	12	18
Collector Centro - Poniente Deep	16.5	4.0	40	22	51
Collector Centro Deep	16.1	5.0	90	22	41
Collector Oriente Deep	18.6	5.0	85	37	55
Emisor Central	49.7	6.5	220	48	217
Collector Centro - Centro Deep	3.7	5.0	90	25	26
Total	121.1				

Note : 1994

Table 3.4 Existing and Planned Wastewater Treatment Plant in D.F. Mexico

(1) Existing Wastewater Treatment Plant

No.	Name	Location (District)	Wastewater (m^3/sec)		Construction Year	Area of Treatment Plant (m^2)	Treatment Process	Water Quality (Upper: Planned / Lower: Operated)				Purpose of Reuse
			Planned	Operated				SS (mg/l)		BOD (mg/l)		
								Influent	Effluent	Influent	Effluent	
1	Chapultepec	Miguel Hidalgo	0.160	0.106	1956	22,900	(1) (2)	208.3 242.6	8.0 11.0	203.3 206.2	6.0 4.8	(1) (3)
2	Coyoacàn	Coyoacàn	0.400	0.336	1959	39,600	(1) (2)	91.0 132.0	12.0 28.6	117.7 171.0	6.3 7.4	(1) (3)
3	Ciudad Deportiva	Iztacalco	0.230	0.080	1958	12,000	(1) (2)	126.5 350.6	--- 10.3	290.5 297.4	--- 2.7	(1) (4)
4	San Juan de Aragòn	Gustavo A. Madero	0.500	0.364	1964	30,200	(1) (2)	144.6 219.6	94.0 19.8	215.5 220.0	10.0 7.8	(1) (3)
5	Tlatelolco	Cuauhtemoc	0.020	0.014	1965	2,300	(1) (2)	297.8 388.0	9.5 5.3	138.5 115.8	4.4 5.5	(1)
6	Cerro de la Estrella	Iztapalapa	4.000	1.409	1971	108,200	(1) (2)	73.0 123.2	20.0 23.8	112.5 155.2	3.0 8.2	(2) (4)
7	Bosques de las Lomas	Miguel Hidalgo	0.055	0.027	1973	2,400	(1) (2)	175.3 228.6	26.5 10.6	145.6 174.2	4.3 6.0	(1)
8	Acueducto de Guadalupe	Gustavo A. Madero	0.080	0.057	1975	15,600	(1) (4)	352.5 408.6	10.0 4.0	296.0 324.2	3.5 5.6	(1)
9	El Rosario	Azcapotzalco	0.025	0.022	1981	3,900	(1) (2) (6)	219.0 421.0	23.8 5.6	294.3 294.0	1.8 1.9	(1)
10	Reclusorio Sur	Xochimilco	0.030	0.013	1981	2,300	(1) (2)	69.3 129.0	12.5 6.7	62.3 108.3	4.5 2.7	(1) (3)
11	Colegio Militar	Tlalpan	0.020	0.018	1980	7,600	(1) (3)	320.0 254.5	--- 17.5	537.0 363.0	--- 10.5	(1)
12	Iztacalco	Iztacalco	0.015	0.010	1971	1,800	(1) (2) (7)	292.0 174.4	7.5 8.3	305.0 267.0	1.3 4.4	(1)
13	San Luis Tlaxialtemalco	Xochimilco	0.150	0.110	1989	29,500	(1) (5) (6)	303.0 184.8	5.0 5.6	183.7 183.5	3.7 4.2	(1) (3) (5)
14	San Miguel Xicalco	Tlalpan	0.0075	0.005	1993	2,200	(1) (5)	-	-	-	-	(1)
15	Parres	Tlalpan	0.0075	0.0075	1993	600	(1) (5)	-	-	-	-	(1)
16	Abasolo	Tlalpan	0.0150	0.0150	1993	1,200	(1) (5)	-	-	-	-	(1)
17	La Lupita	Tlalpan	0.0150	0.0150	_	_	_	_	_	_	_	_
18	San Nicolas Tetelco	Tlalpan	0.0150	0.0150	_	_	_	_	_	_	_	_
19	CD. Universitaria	Coyoacan	0.0600	0.0270	_	_	(1) (2)	_	_	_	_	(1)
20	Pemex Picacho	Tlalpan	0.0250	0.0200	1984	_	(1) (2)	_	_	_	_	(1)
21	Campo Militar	Miguel Hidalgo	0.0300	0.0260	1994	_	(1) (2)	_	_	_	_	(1)
TOTAL			5.860	2.697								

Note: Treatment Process

(1) Conventional Activated Sludge Process

(2) Sludge : Drain

(3) Sludge : Aerobic Digestion and Drying Bed

(4) Sudge : Anaerobic Digestion and Drying Bed or Centrifuge

(5) Sludge : Aerobic Digestion, Concentration and Drying Bed

(6) Tertiary Treatment : Filtration

(7) Tertiary Treatment : Sand Filter Tower and Activate Carbon Filter Tower

Purpose of Reuse

(1) Irrigation of Green Field

(2) Irrigation of Crops

(3) Recriation of Pond or Canal

(4) Industrial Use

(5) Ground Water Recharge

Table 3.5 Design Criteria of Cerro de la Estrella

Facility	Design Criteria
Primary Sedimentation Tank	
Surface Loading	48 $m^3/m^2/day$
Effective Depth	2.6 m
Retention Time	1.3 hrs.
Aeration Tank	
F/M ratio	0.4 kg BOD_5/kg VSS day
MLSS Concentration	1,670 mg/l
Aeration Time	4.8 hrs
Return Sludge Ratio	25 %
Return Sludge Concentration	8,000 mg/l
Effective Depth	5.0 m
Secondary Sedimentation Tank	
Surface loading	36 $m^3/m^2/day$
Effective Depth	3.3 m
Retention Time	2.2 hrs.

Fig. 3.1 Existing Sewerage Service Area and Collection System

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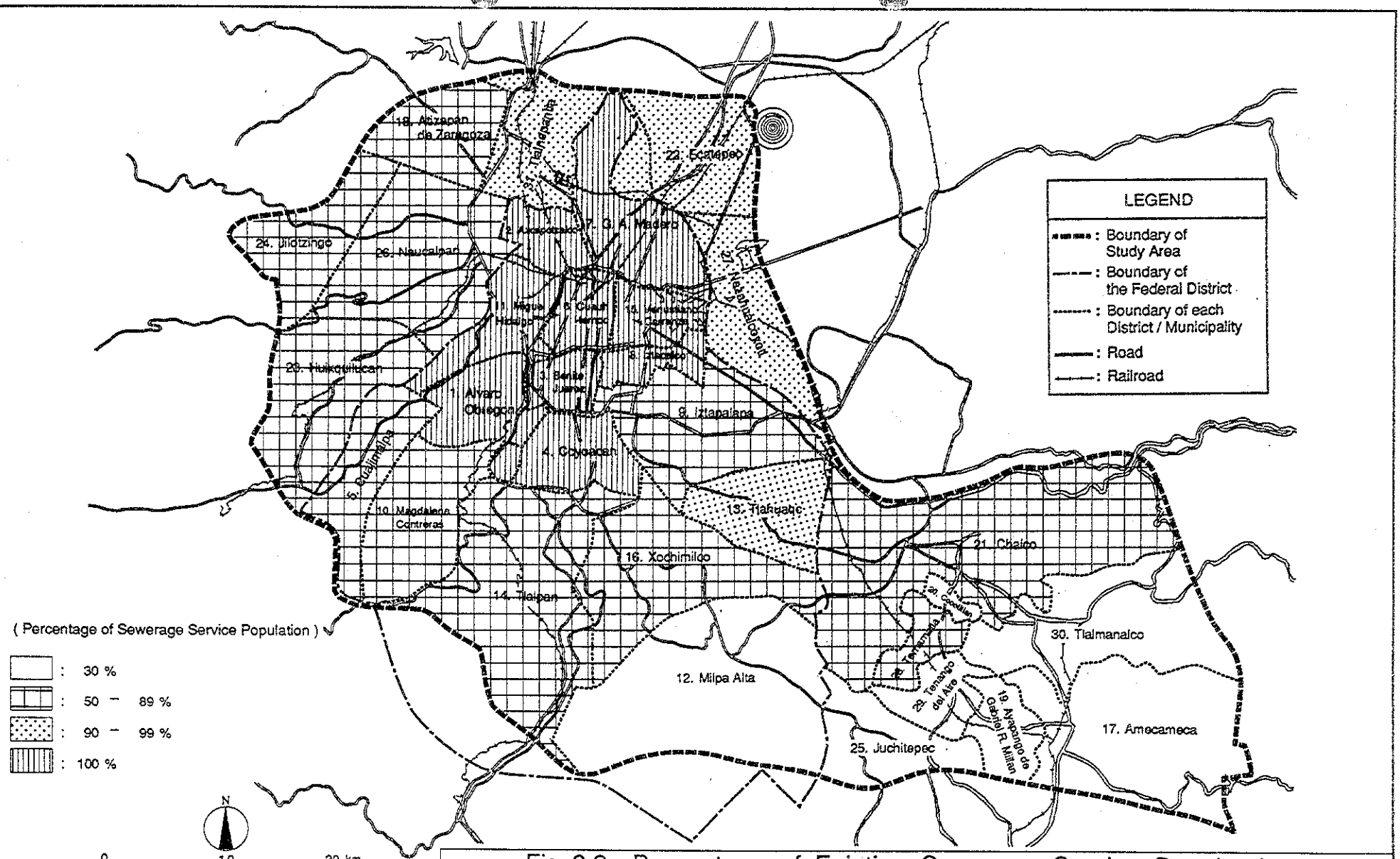

Fig. 3.2 Percentage of Existing Sewerage Service Populaation by District / Municipality (1993)

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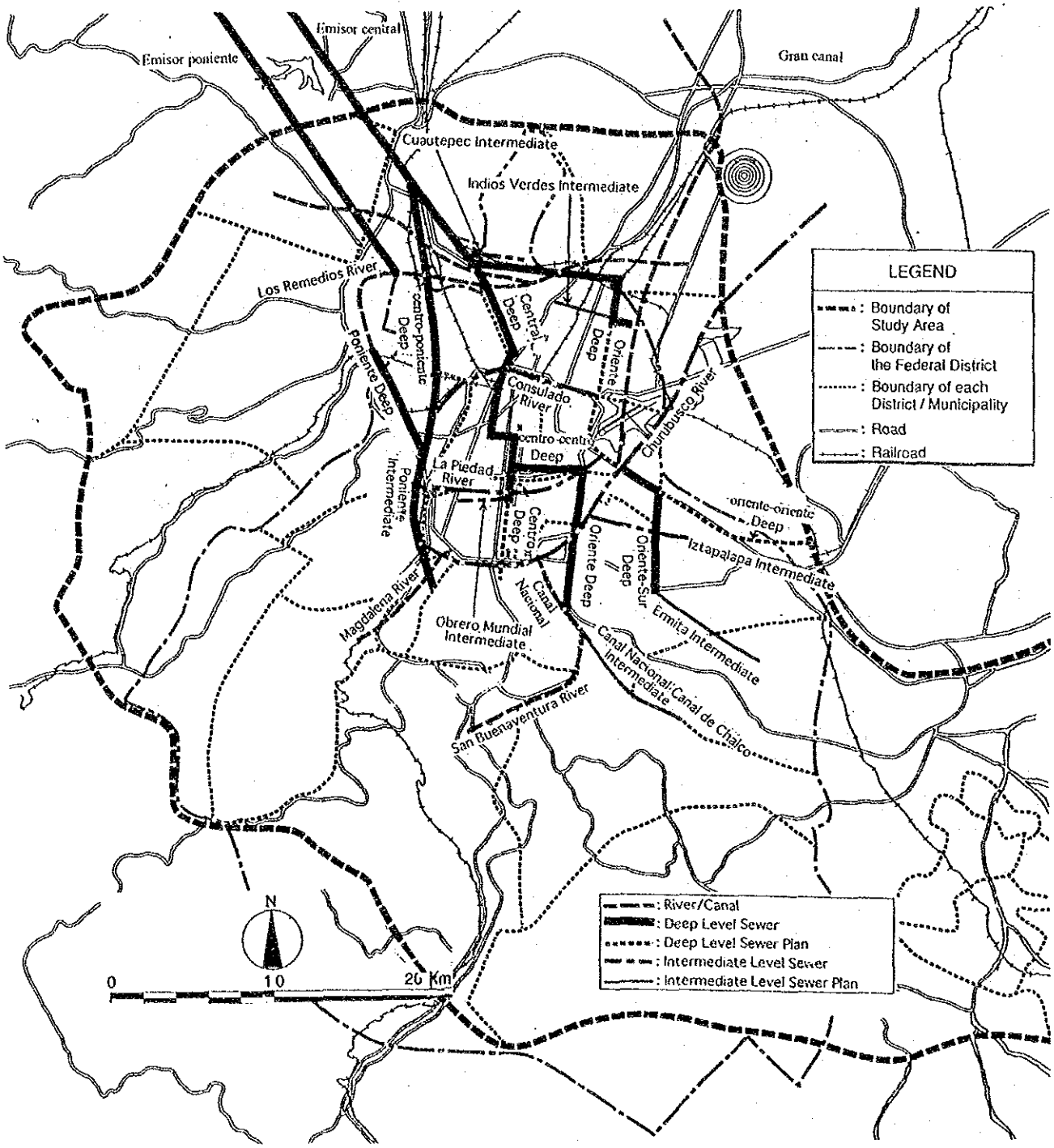

Fig. 3.3 Location of Intermediate and Deep Level Sewer in D.F.

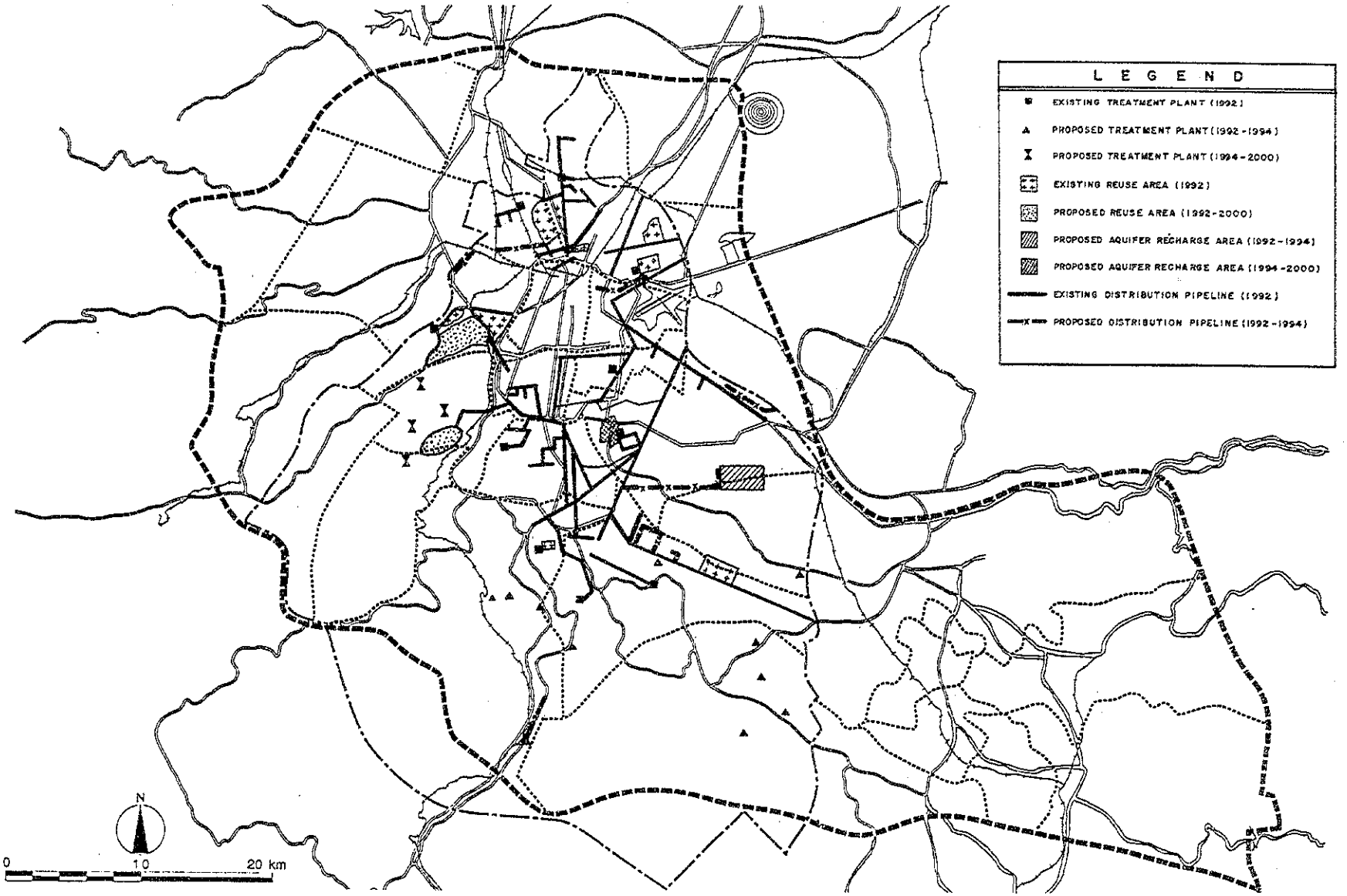

Fig. 3.4 Existing and Proposed Pressure Pipe System of Reuse Water in D.F.

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CHAPTER 4

CHAPTER 4 STUDY OF RELEVANT REPORTS

1. Wastewater Disposal for the Valley of Mexico (The Master Plan, 1993)

This Master Plan study was conducted by National Water Commission (CNA) in 1993. The report elaborate existing sanitary and environmental conditions and proposed the solutions for improving the existing sanitary environments in the downstream irrigation area.

The existing drainage system is a combined system which drains about 1.6 billion m^3 per annum of wastewater as well as storm water generated in the Mexico valley. Out of which 1.2 billion m^3 corresponds to wastewater.

Among annual discharged wastewater of 1.6 billion m^3, 0.15 billion m^3 is reused in the urbanized area, 0.1 billion m^3 is used for recreational purpose at Texcoco lake and the remaining 1.35 billion m^3 is carried by the three (3) main conduits; Gran Canal, Emisor Central and Emisor Poniente towards the Tula area. This 1.35 billion m^3 of discharge is being used for irrigation without any treatment covering about 90,000 ha in Chicomautla, Zumpango and Tula areas.

The discharge has typical characteristics of sewage with SS varying from 200 mg/l to 500 mg/l, BOD of 150 mg/l to 300 mg/l and Coliforms about 3.0 E + 08 No/100 ml.

Existing irrigation area is functioning as secondary wastewater treatment, and the water discharged to the rivers from the irrigation areas has reasonably good quality with BOD less than 10 mg/l and DO of 5 mg/l. However Coliforms are still high of the order of 1.0 E+07 No/100 ml in the irrigated water. Consequently the inhabitants of the irrigation area suffer from parasitic infections with the indexes between 6 to 22 times greater than in other areas. The high contraction ratio of helminths in this area could also affect the hygiene in the urbanized area of D.F. Mexico.

The report concluded that wastewater treatment plants with a total capacity of 83 m^3/sec are required to treat all discharged wastewater of Mexico valley. And from the above mentioned environmental conditions of the irrigation areas, the main objectives of wastewater treatment plants are to remove Coliform and Helminth eggs. And a wastewater treatment plant with a capacity of 35 m^3/sec is proposed at the north of Texcoco Lake.

The report indicated the comparative study on eight (8) alternatives of wastewater treatment process and proposed the primary sedimentation with coagulation, an advanced primary treatment process, for the wastewater treatment plant at the north of Texcoco Lake. The proposed treatment process is shown in Fig. 4.1. Lime stabilization process has been proposed for sludge stabilization and stabilized sludge is dried utilizing the existing drying beds which were utilized by the former soda factory.

The construction cost of proposed advanced primary treatment system with a capacity of 35 m^3/sec is estimated to be N$ 350 million at the price of 1993. Annual operation and maintenance cost is estimated to be N$ 143.49 million.

2. Treatment and Reuse Master Plan (1990)

The study conducted by DGCOH is revision of the Treatment and reuse Master plan study conducted in 1982 and explore possible reuse options.

Deficit in the water supply-demand balance and over exploitation of aquifers necessitate the treated water reuse. Various possible options of treated water reuse include irrigation, industrial purpose, lake recharging and groundwater recharging.

The condition of existing nine (9) treatment plants (Acueducto de Guadalupe, Azcapotzalco, Chapultepec, Cerro de la Estrella, Bosques de las Lomas, Ciudad Deportiva, Coyoacan, San Juan de Aragon and Tlatelolco) in terms of operation efficiency and effluent quality is examined. Low operation efficiency varying from 10-30 % was observed. Most of the plants do not pass the quality criteria for green area watering, lake filling and steam production, but for cooling only Coyoacan and Tlateloco do not pass the quality criteria.

Various causes of poor operation efficiency and poor effluent quality have been found out and following measures have been proposed:

- intense maintenance of sedimentation tanks to rectify the differential settlement
- complete substitution of the obsolete electromechanical equipment
- providing adequate mixing in the aeration tanks
- providing adequate disinfection facility
- providing proper laboratory facilities
- providing sludge treatment facilities

In the report five (5) alternatives of treatment and reuse system have been projected to mitigate the water shortage problem. The first two elaborate what will happen if treated water quantity and quality are not improved and remaining three include the proposed improvement in quantity and quality. Alternative 5 which emphasize on increasing the treated water reuse for non conventional reuses has been proposed. The strategy to be adopted in the proposed alternative is described below:

- The treated water supply should be increased to fulfill the demand and quality should be according to the potential use.
- To enlarge the treated water contribution to the conventional uses so as to satisfy 100 % demand.
- Pilot test related to aquifer recharging should be carried out.
- Provide treated water for non drinking domestic uses.

To achieve the objectives of treatment and reuse master plan development various policies have been formed as described in Table 4.1. Table 4.2 shows the short term, medium term and long term goals defined in the development plan. To achieve these goals following programs have been structured:

- Infrastructure development program
- Operation and maintenance program
- Quality control program
- Diversification of treated water reuse program
- Technology development program
- Support programs
- To increase the reuse of treated water for irrigation and industrial purpose as these uses do not require quality similar to drinking water
- To improve the quality of treated water so that it can be used for recharging groundwater and for domestic purposes
- Optimize usage of water quantitatively and qualitatively
- To reduce over exploitation of the aquifers
- To substitute the drinking water with treated water as far as possible

Table 4.1 Policies of Reuse Master Plan Development Program

- To fully utilize the existing infrastructure available for the production and distribution of the treated water
- To carry out proper maintenance of the existing wastewater treatment plants
- To impulse the capacity of the personnel in charge of the wastewater treatment
- To increase the usage of treated water to conventional uses through efficient supplying patterns
- To develop research program so as to increase the non conventional uses
- To study administrative options which favors the elimination of subsidies and enable the establishment of concession schemes of the wastewater treatment system
- To implement effectively the legislation related to industrial effluent discharge to sewerage system

Table 4.2 Goals Defined in the Development Plan

(Short Term)

- construction of 67 km of treated water pipeline
- construction of four pumping stations for treated water each of 150 l/s
- construction of treatment plants
    * in Milpa Alta directorate
    * in Tlahuac directorate
    * third module of San Juan de Aragon (500 l/s)
    * third and forth module of San Luis Tlaxialtemalco (75 l/s each)
- Rehabilitation of the treatment facilities and optimization of its quality
    * Addition of foaming, coagulation-flocculation filtration processes to the Cerro de la Estrella, Azcapotzalco and Coyoacan plants.
    * Installation of foaming, coagulation-flocculation filtration and activated carbon adsorption processes to the San juan de Aragon and Ciudad Deportiva
    * Addition of foaming and filtration processes to the Acueducto de Guadalupe, Tlatelolco and Chapultepec
- conduct theoretical-practical courses for operators of treatment plants
- complete the development of operation handbooks
- study soil behavior during groundwater recharging by injection method
- provide sufficient laboratory facilities at the treatment plants
- strengthen the central laboratory to improve the reliability level required for reusing treated water specially for groundwater recharging and domestic purpose
- utilize water from the Santa Ursura spring in Coyoacan.

(Medium Term)

- construction of 80 km of treated water lines, including the proposed interconnections
- Construction of six (6) pumping station for treated water each of 150 l/s
- construction of 4 and 5 module of San Luis Tlaxialtemalco plant
- rehabilitation of the facilities to operate treatment plants at nominal capacity
- groundwater recharging with treated water as per DGCOH plan
- construction of storage tanks close to treatment plants, with the total capacity of 318000 m^3 to regulate during 12 hrs, the treated water flow and thus optimize distribution.

(Long Term)

- lower down the drinking water consumption by 30 %, substituting it by treated water
- establish administration and operation to commercialize the treated water
- Establish fee system for the drinking water based on the real value of the resource, hence making it attractive due to low cost.

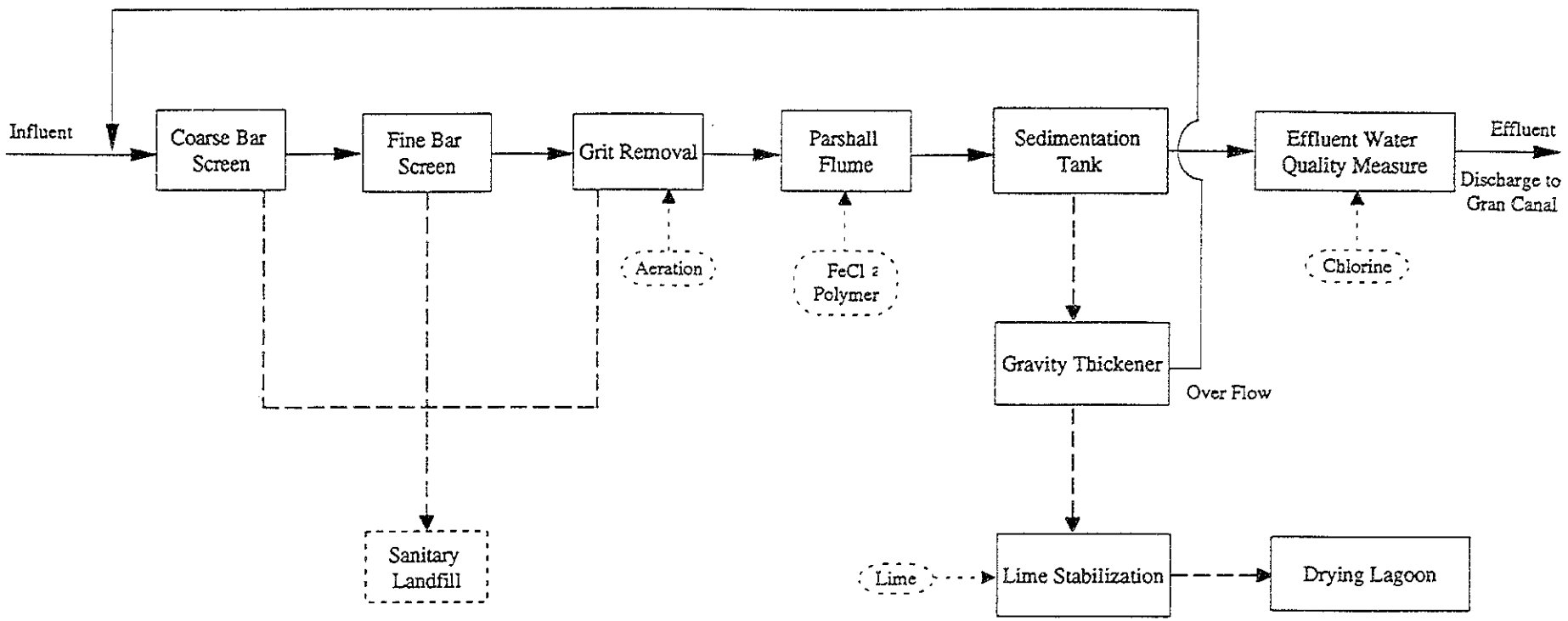

Fig. 4.1 Flow Diagram of Advanced Primary Treatment of Master Plan

THE FEASIBILITY STUDY ON WASTEWATER TREATMENT IN THE FEDERAL DISTRICT OF MEXICO

CHAPTER 5

CHAPTER 5 WASTEWATER AND SLUDGE TREATMENT PLANT FOR THE FINAL PROJECT

1. Treatment Plant Site

1.1 Location

The wastewater treatment plant site in the Texcoco area has been selected in the Master Plan. Reconnaissance survey of the selected site has been conducted by JICA Study Team. The proposed wastewater treatment plant is located in the Texcoco area, Ecatepec municipality in the Mexico State (Refer to Fig. 5.1). More precisely, the treatment plant site is at a point in the Texcoco area where Gran Canal changes its direction from north east to north west.

1.2 Land Use of the Treatment Plant Site

The proposed treatment plant site is in the north of Texcoco which was known as Texcoco lake in the Pre Hispanic period. Lately, this place was used as soda producing factory. The factory has been closed since end of 1993 and the land is now under the jurisdiction of the National Water Commission (CNA), the Government of Mexico.

The land is almost flat except some stock residue of soda producing factory. The total area available is about 8,000 ha. The required area for the treatment plant in the year 2015 is about 192 ha.

1.3 Land Elevation

The existing ground elevation of the former soda producing factory is located at the altitude from 2,234 to 2,236 meter. The land is almost flat except the stock yard of residue of the soda product which is about 10 meter high with an area of 17.9 ha.

The river bed elevation of Gran Canal at the proposed discharging point is about 2,226 meter, which is about 9 meter lower than the existing ground elevation of the proposed treatment plant site.

1.4 Soil Condition

The area is reclaimed area of Texcoco Lake. Hence as could be expected the top surface layer of proposed treatment plant site is rather soft. Based on the soil data of previous survey and the survey conducted by JICA Study Team, the base layer of the soil is found at a depth of more than 55 meters from ground surface. The

shallower layers consist of clay and sand layers alternatively. The characteristics of the shallow clay and sand layers are described below.

Layer	Depth (m)	Nature of soil	SPT (N value)
(1)	0.0~G.L -9.0 m	Very soft clay	0 ~ 3
(2)	GL-9.0~-12.0 m	Silty sand	10
(3)	GL-12.0~16.0 m	Soft clay	0 ~ 5
(4)	GL-16.0~19.0 m	Silty sand	10 ~ 50
(5)	GL-19.0~28.0 m	Clay and sand	0 ~ 20
(6)	GL-28.0~37.0 m	Silty sand	30 ~ 50
(7)	GL-37.0~55.0 m	Soft clay and silty sand	10 ~ 50 *

Note: SPT with * is assumed from the data, which was conducted at the end of 1993.

Among these seven (7) layers, consolidation settlements are expected to occur at the clay layers of (1), (3), (5) and (7). Ultimate consolidation settlements in the clay layer (1) is 1.5 m, layer (3) is 1.0 m and layer (5) is 0.2 m. Consolidation settlement in the layer (7) is assumed to be 1.5 cm per annum on the basis of soil data of previous survey.

The silty sand layer found at the depth of 28.0 m to 37.0 m from the ground surface, with the SPT value of 30-50 is proposed to be the foundation layer of the proposed treatment facilities.

2. Formulation of Design Conditions

2.1 Wastewater Discharge to the Treatment Plant

The wastewater to be treated is basically carried by Gran Canal. However due to land subsidence problem, which is the severe most at the intersection point of Los Remedios river and La Compania river along the Gran Canal, the pumping of wastewater is necessary. The drainage pumping station will be constructed at the intersection point and wastewater will be continuously conveyed by pressure pumping main.

2.2 Wastewater Quantity

The total discharged wastewater quantity in the study area of D.F. and Mexico state for the Year 1997 and 2015 are estimated to be 36.55 m^3/sec and 47.38 m^3/sec respectively. However due to shortage of water sources, a small portion of wastewater is proposed to be treated in small treatment plants and reused for irrigation and industrial purpose. The amount of treated water being

reused for industrial purpose will be discharged again to the sewerage system, however treated water being reused for irrigation purpose will not return to the sewerage system.

The expected wastewater quantity for the Texcoco treatment plant is calculated by subtracting the quantity to be reused for irrigation purpose from the total discharged wastewater quantity.

(1) Total Discharged Wastewater Quantity

(Unit : m^3/sec)

Year	D.F. Mexico	Mexico State	Total
1997	25.62	10.93	36.55
2015	34.08	13.30	47.38

(2) Wastewater to be Reused for the Irrigation Purpose

(Unit : m^3/sec)

Year	D.F. Mexico	Mexico State	Total
1997	2.20	1.10	3.30
2015	4.40	2.60	7.00

(3) Expected Wastewater Quantity for the Texcoco Treatment Plant

(Unit : m^3/sec)

Year	D.F. Mexico	Mexico State	Total
1997	23.42	9.83	33.25
2015	29.68	10.70	40.38

The design wastewater flow of the treatment plant in the year 1997 for the Urgent Project and in the year 2015 for the Final Project are determined based on the drainage capacity of Gran Canal and the capacity of the influent drainage pumping station, planned to be constructed at the intersection of the Los Remedios river and La Compania river. Hence hourly peak flow is controlled and is not much different from the daily average flow.

Design wastewater flow of Urgent and Final Project is estimated as shown below.

Design Wastewater Flow	Urgent Project (Yr.1997)	Final Project (Yr. 2015)
Daily Average & Hourly Peak Flow	35.0 m^3/sec	40.0 m^3/sec

2.3 Wastewater Quality

The municipal wastewater quality has been determined based on the characteristics of wastewater being generated in the study area as discussed in Chapter 3. The municipal wastewater quality in terms of BOD_5 and SS in the year 1997 and 2015 are shown below.

	1997	2015
BOD_5 (mg/l)	214	233
SS (mg/l)	221	241

The influent wastewater quality in terms of BOD_5 and SS for the Texcoco treatment plant is estimated with due consideration to the condition that sludge is discharged back into the sewerage system from the small wastewater treatment plants, being operated for achieving reusable treated water.

The influent wastewater quality of the treatment plant for the Urgent Project and Final Project are established as follows.

	1997	2015
BOD_5	220 mg/l	245 mg/l
SS	235 mg/l	260 mg/l
Coliforms (MPN/100 ml)	10^7	10^7

For designing suitable treatment process, further wastewater characteristics in terms of SS and BOD were examined. One (1) set of data for San Cristobal and Lopez portillo for the dry and rainy season is illustrated below.

Sampling Point	Dry Season			Rainy Season		
	SS (mg/l)	BOD (mg/l)		SS (mg/l)	BOD (mg/l)	
		Soluble	Particulate		Soluble	Particulate
San Cristobal	230	169	66	-	-	-
Lopez Portillo	235	182	69	266	108	78

The data from the sampling stations San Cristobal and Lopez Portillo (near the proposed treatment plant) shows that in dry season soluble BOD constitutes about 70 % and particulate BOD constitutes only 30 %. And in Rainy season soluble BOD constitutes about 60 %.

2.4 Design Effluent Quality

The treated wastewater is intended to be reused for irrigation purpose in the Tula irrigation area. The quality of treated wastewater to be reused for irrigation purpose is governed by Mexican Official Standards Nom-CCA-032-ECOL/1993 and Nom-CCA-033-ECOL/1993, as discussed in Appendix 3, section 6. For the Urgent Project treated water is proposed as Type III water.

The effluent wastewater quality of the treatment plant for the Urgent Project in the year 1997 are established as follows:

Parameter	Concentration
BOD_5	120 mg/l
SS	120 mg/l
Coliforms (MPN/100 ml)	< 100,000

The effluent quality standards for the water bodies to be reused for irrigation purpose have been proposed by the study team (ref. Appendix 3, section 7). The proposed standards have been developed based on the treated water quality standards, required for the crops to be eaten raw, as prescribed in the existing standard "Regulations for water reuse in Federal District (Reglamento para el Reuso del Agua en el Distrito Federal 1987) (ref. Appendix 3, section 6). Based on these proposed standards, design effluent quality of the treatment plant for the Final Project has been established which is shown below.

Parameter	Concentration
BOD_5	20 mg/l
SS	30 mg/l
Coliforms (MPN/100 ml)	< 1,000

2.5 Treated Wastewater Discharge

The treated wastewater will be discharged by channel, crossing the Av Central road, into Gran Canal between the railway crossing and confluence point of Gran Canal and Canal of Sales. The treated water will be finally carried to the Tula irrigation area.

3. Alternative Study for Wastewater and Sludge Treatment

3.1 General

The various possible alternatives of wastewater treatment system have been studied with the following basic considerations:

(1) Proposed treatment system for the year 2015 should have enough capacity to treat wastewater and treated wastewater quality should meet the proposed design effluent quality.

(2) A portion of the proposed optimum wastewater treatment system with or without some modification should be selected as the Urgent treatment system. The selected treatment system for the Urgent Project should be in conformity with the treatment system for the year 2015.

(3) Soluble BOD constitutes 60-70 % of total BOD and only 20 % BOD removal efficiency was achieved by primary sedimentation at Termoelectrica Valle de Mexico treatment plant. Hence biological treatment process is required to achieve design effluent quality in both Final Project (Yr. 2015) and Urgent Project (Yr.1997).

(4) The treatment process with high treatment efficiency per unit treatment space is required because of the large amount of wastewater (3.0 million m^3/day) to be treated.

3.2 Alternatives of Wastewater and Sludge Treatment Process for the Year 2015

In the Master Plan conducted by CNA and DGCOH, eight (8) alternatives were compared as the Urgent wastewater treatment system. And the advanced primary treatment system (primary sedimentation with coagulation) was selected as the optimum Urgent treatment system.

JICA Study Team has reviewed eight (8) alternatives proposed by the Master Plan to check their applicability for the Final Project in the Year 2015. The alternatives have been evaluated based on the following criteria:

- required treatment space
- required construction cost
- required operation cost
- required skilled personnel for operation
- quantity of sludge generated

From the comparative evaluation, JICA study team found conventional activated sludge process suitable for alternative study. The other two alternatives being selected for alternative study are activated sludge with chemical coagulation and dual process (biofilter followed by conventional activated sludge). These three (3) alternatives are shown in Fig. 5.2.

The above mentioned three (3) alternatives are compared based on the following criteria to select the optimum system:

- Required technology level of operation and facility management
- Required costs of construction and operation and maintenance
- Required land space

Selection of sludge treatment system should go hand in hand with the selection of liquid treatment system. Various possible alternatives at each step of sludge treatment process are technically evaluated. Based on the technical evaluation, following alternative process at each step of sludge treatment has been considered for the study.

Thickening Process
- Separate thickening
- Combined thickening

Stabilization Process
- Anaerobic digestion
- Aerobic digestion

Dewatering process
- Belt filter press
- Drying bed
- Drying lagoon

Disposal process
- Land disposal
- Sanitary Landfill

These alternatives have been financially evaluated and appropriate sludge treatment system for Alternative I, Alternative II and Alternative III have been selected and is shown below.

Sludge treatment system for Alternative I of liquid treatment system consists of Separate thickening, Anaerobic digestion, Belt filter press and land disposal.

For Alternative II, chemically precipitated sludge is produced in the primary sedimentation tank. Hence anaerobic digestion and aerobic digestion as sludge stabilization process is not recommended. Recommended sludge treatment process for Alternative II consists of Combined thickening, Belt filter press and Sanitary Landfill.

Sludge treatment process for Alternative III consists of Gravity thickening for primary and biofilter sludge, Centrifugal thickening for activated sludge, Anaerobic digestion, Belt filter press and Land disposal.

The wastewater and sludge treatment system for each alternative is described in Fig. 5.2.

3.3 Financial Evaluation for the Selection of Optimum Wastewater and Sludge Treatment System for the Year 2015

The above mentioned three (3) integrated wastewater and sludge treatment systems are compared in terms of required construction and O/M costs.

Total direct construction and annual O/M costs of each alternative for the integrated wastewater and sludge treatment system have been compared. For comparison, construction costs for the items such as administrative building, access roads, etc., which are common in all the three (3) alternatives, have been neglected. Similarly O/M costs for items such as personal expenditure, repairing cost etc., which are common or negligibly different, have been ignored. The comparison of construction and O/M cost is shown below.

(Unit : N$ million)

Alternative	Construction Cost	Annual O/M Cost
I	2,644.6	127.8
II	2,574.3	304.7
III	3,095.2	117.2

Alternative II has the lowest direct construction cost of N$ 2,574.3 million whereas Alternative III has the lowest annual O/M cost of N$ 117.2 million.

Construction and O/M costs of these three (3) alternatives for the project life time are compared, in terms of present values, estimated based on the following assumptions.

- Discount rate is 10% per annum (it was so assumed in consideration of the opportunity cost of capital in today's Mexico)

- O/M period (effective project life time) is up to 30 years after the completion of the construction of the treatment plant

The comparison of the three (3) alternatives in terms of construction and O/M costs (in terms of present value) are shown below.

(Unit : N$ million)

Alternative	Construction Cost	O/M Cost	Total Cost
I	2,702	1,206	3,908
II	2,638	2,869	5,507
III	3,119	1,105	4,224

It is evident from the above comparative table that **Alternative I** is the most economical alternative and hence is selected as the Optimum Wastewater and Sludge Treatment system for the Final Project (Yr. 2015).

4. Proposed Wastewater and Sludge Treatment System

4.1 Wastewater Treatment System

Conventional activated sludge system consists of (1) receiving tank, (2) distribution tank, (3) primary sedimentation tank, (4) aeration tank and (5) secondary sedimentation tank. The effluent is disinfected to kill pathogens. The layout and hydraulic profile of the treatment plant is shown in Fig. 5.3 and 5.4, respectively.

Total capacity of the treatment plant is 40 m^3/sec. The whole treatment system has been divided into eight (8) units, each having capacity of 5 m^3/sec. The stepwise construction of the system is recommended.

(1) Receiving Tank

Receiving tank should have the function to equally distribute wastewater to the eight (8) treatment units. The tank is divided into two (2) compartments by the center wall for maintenance purpose.

Hydraulic retention time of 1.5 minutes is considered for designing the receiving tank . The total capacity of tank is 3628 m^3. The tank is 31.6 m long and 21.5 m wide, with an effective water depth of 5.34 m

(2) Distribution Tank

The total wastewater discharge of 40 m^3/sec. is equally distributed to each unit of treatment system by the distribution tank. Each unit of treatment system has one distribution tank. The flow is controlled by weir provided in the distribution tank.

Hydraulic retention time of 1.5 minutes is considered for designing distribution tank also. The total capacity of each distribution tank is 450 m^3. The distribution tank is also divided into two (2) compartments to facilitate proper maintenance. The tank is 11.2 m long and 11.2 m wide, with an effective water depth of 3.59 m.

(3) Primary Sedimentation Tank

The width of primary sedimentation tank is decided based on the capacity of sludge collector. The tank is 10 m wide and 39 m long with an effective water depth of 3 m. Required number of tanks for one (1) unit are 32.

Hydraulic retention time of primary sedimentation tank is 2.1 hours with an overflow rate of 34.6 $m^3/m^2/d$.

Chain flight type sludge collector (2 in number) each with a capacity of 2.2 kW is installed in each tank. Cross collector (1 in number) with a capacity of 1.5 KW is installed for each two (2) tanks. Sludge pump with a capacity of 7.5 kW is installed for each two (2) tanks.

(4) Aeration Tank

Aeration tank is 10.3 m wide and 89 m long with an effective water depth of 6 m. The required number of tank for one (1) unit are 32.

Hydraulic retention time is 9.5 hours and sludge recirculation ratio is 35 %.

Diffused type aeration is installed in the aeration tank. The blower, with a capacity of 900 kW is installed for each eight (8) aeration tanks.

(5) Secondary Sedimentation Tank

The tank is 10 m wide and 54 m long with an effective water depth of 3.5 m. Required number of tanks for one (1) unit are 32.

Hydraulic retention time is 3.36 hours with an overflow rate of 25 $m^3/m^2/d$.

Chain flight type sludge collector with a capacity of 2.2 kW is installed in each tank. Sludge pump (required to pump sludge to the centrifugal unit) with a capacity of 11 kW is installed for each two (2) tanks and 24 sludge return pumps with a capacity of 30 kW are installed for each unit.

(6) Disinfection

Chlorine gas is employed for disinfection. The chlorine contact time of 15 minutes is proposed before discharging Gran Canal. Contact tank is planned to be constructed besides the No. 2 wastewater treatment plant site. The contact tank is designed of 10 m width and 4 m effective depth. The tank is divided indo 12 compartments by baffles and total length of flow is 780 m. The contact tank has a capacity of 31,200 m^3 with a contact time of 13 minutes for the final project stage. Subsequently discharge channel of 250 m long functions a part of contact tank with a contact time of 2 minutes.

4.2 Sludge Treatment

Sludge treatment system consists of:

- Separate thickening (primary sludge to be thickened by gravity thickener and secondary sludge to be thickened by Centrifugal thickener)
- Anaerobic digester
- Belt filter press

The treated sludge has to be Land disposed.

The whole sludge treatment system is divided into four (4) units and each unit treat sludge discharged from two (2) units of wastewater treatment plants.

Structure design of sludge treatment system is conducted based on the solid balance as shown in Fig. 5.5.

(1) Gravity Thickener

The total amount of primary sludge of 4,020 m^3/day, having solid content of 3.0 % from two (2) units of wastewater treatment plant is concentrated by Gravity thickener.

Gravity thickener of 4 tanks with 19 m diameter and 4 m depth are required for each sludge treatment unit. Hydraulic retention time is 1.1 days with a solid loading of 106.9 kg/m^2/d.

(2) Centrifugal Thickener

The total amount of activated sludge of 19,340 m^3/day, having solid content of 0.8 % is concentrated by Centrifugal thickener.

Centrifugal thickener of 6 sets with a capacity of 170 m^3/hr are required for one unit. Centrifugal thickeners are installed in the solid processing building.

(3) Anaerobic Digester

Anaerobic digester stabilizes primary sludge of 1,600 m^3/day with a solid content of 6.0 % and activated sludge of 2,320 m^3/day with a solid concentrate of 6.0 % obtained from thickening unit.

Anaerobic digester of 12 tanks with 26 m diameter and 12.5 m depth are required for each unit. Retention time of anaerobic digester is 20.3 days. In anaerobic digester, 33 % of solids are removed as digester gas.

Blower with a capacity of 45 kW is installed to agitate sludge for each tank of anaerobic digester.

(4) Belt Filter Press

The most commonly used mechanical dewatering process i.e., belt filter press is employed for this project. Belt filter press dewaters digested sludge of 2,220 m^3/d with a solid content of 6.0 %. Polymer of 668 kg/d is added as a coagulant.

Belt filter press of 20 sets with 3 m belt width are installed for each unit in the sludge dewatering house.

Dewatered sludge of 540 m^3/d with a solid content of 22 % is produced.

(5) Land Disposal

About 540 m^3/d (120.54 t/d) of dewatered sludge is obtained from one unit, hence amount of sludge to be disposed annually from the whole sludge treatment system is 175,988 tons. For the dedicated land disposal site, 370

tons/ha of annual application rate is recommended. Hence about 500 ha of area for land disposal is required.

4.3 Layout and Hydraulic Profile

Design ground elevation of the proposed treatment plant site is decided at the altitude of 2,235 meter as an average of the existing ground elevation.

Layout of the integrated wastewater and sludge treatment plant is proposed with due consideration to the following aspects.

- To minimize the length of influent and effluent pipes
- To avoid the crossing of influent and effluent pipes
- To preserve the existing buildings and structures of former soda producing factory

The layout is shown in Fig. 5.3 and layout of one unit of proposed treatment plant for the Final Project is shown in Fig 5.6.

The hydraulic profiles of the liquid treatment plant for the year 2015 is shown in Fig. 5.4.

4.4 Estimated Cost

4.4.1 Project Cost

The total project cost of the Final Project consists of direct construction cost, land compensation cost, administration cost, engineering cost and physical contingency. Physical Contingency is assumed to be 10 % of the direct construction cost. The total project cost of the Final Project is estimated to be N$ 4,212.9 million at 1994 price. Its breakdown by cost item is shown below.

		(Unit : N$ million)
(A) Direct Construction Cost		3,578.8
1) Wastewater Treatment		2,250.2
(1)	Receiving Tank	5.8
(2)	Connecting Pipe	82.3
(3)	Distribution Tank	4.0
(4)	Primary Sedimentation Tank	433.9
(5)	Aeration Tank	747.2
(6)	Blower	172.8
(7)	Secondary Sedimentation Tank	579.2
(8)	Disinfection	20.9
(9)	Discharge Channel	22.2
(10)	Cost of using treated water within treatment plant	39.2
(11)	Electrical Works	142.7
2) Sludge Treatment		1,016.7
(1)	Gravity & Centrifugal Thickener	151.2
(2)	Anaerobic Digester	336.0
(3)	Belt Filter Press	125.6
(4)	Gas generator	262.8
(5)	Electrical Works	141.1
3) Building Construction		220.3
4) Other Works		91.6
(B) Land Compensation Cost		115.1
(C) Administration Cost		35.8
(D) Engineering Cost		125.3
(E) Physical Contingency		357.9
	Total	4,212.9

Breakdown of the project cost is shown in Table 5.1.

4.4.2 Operation and Maintenance Cost

Total annual O/M cost of wastewater treatment plant with a complete capacity of 40 m^3/sec. is estimated to be N$ 200.4 million at 1994 price. Its breakdown is shown below.

	(Unit : N$ million)
(1) Personal Expenditure	14.3
(2) Electrical Charge	52.6
(3) Chemical Cost	40.0
(4) Sludge Disposal Cost	26.4
(5) Repairing Cost	67.1
Total	200.4

5. Selection of Urgent Project (Year 1997)

Based on the wastewater characteristics of the Gran Canal and design effluent quality required in terms of BOD_5 and SS, biological treatment system is necessary to achieve required effluent quality. However at the Urgent project stage, conventional activated sludge process is not required because of low standard of design effluent quality of 120 mg/l of BOD and 120 mg/l of SS. Modified activated sludge process comprising of aeration tank and secondary sedimentation tank (without primary sedimentation tank) is proposed for the Urgent Project.

At the Urgent Project stage, two (2) units of the Final Project (8 units) comprising of aeration tank and secondary sedimentation tank [without primary sedimentation tank] will be constructed. As a result, the two (2) units (each treating 17.5 m^3/sec) will be operated as modified activated sludge system at the Urgent Project stage and will be operated as conventional activated sludge system at the Final Project stage (each unit treating 5 m^3/sec.).

Sludge treatment system consisting of centrifugal thickening, anaerobic digestion and belt filter press is proposed for treating activated sludge being produced in the Urgent Project stage.

Table 5.1 Break-down of Direct Construction Cost for the Final Project

(Unit = N$ million)

Description	Civil / Architecture			Mechanical / Electrical			Total
	Quantity	Unit Cost	Const. Cost	Quantity	Unit Cost	Const. Cost	
1) Wastewater Treatment							
(1) Receiving Tank	1 ls.	-	3.2	1 ls.	-	2.6	5.8
(2) Connecting Pipe	9,960 m	0.00826	82.3	-	-	-	82.3
(3) Distribution Tank	8 unit	0.5	4.0	-	-	-	4.0
(4) Influent Channel	8 unit	1.31	10.5	-	-	-	10.5
(6) Primary Sedimentation Tank	8 unit	32.1	256.8	8 unit	20.83	166.6	423.4
(7) Aeration Tank	8 unit	67.1	536.8	8 unit	26.3	210.4	747.2
(8) Blower	-	-	-	32 set	5.4	172.8	172.8
(9) Secondary Sedimentation Tank	8 unit	43.9	351.2	8 unit	28.5	228.0	579.2
(10) Disinfection Tank	1 ls.	-	11.9	8 unit	1.13	9.0	20.9
(11) Discharge Channel	1 ls.	-	22.2	-	-	-	22.2
(12) Treated Water Reuse	-	-	-	8 unit	4.9	39.2	39.2
Sub-Total			1,278.9			828.6	2,107.5
(11) Electrical Work	-	-	-	1 ls.	-	142.7	142.7
Sub-Total of 1) Wastewater Treatment			1,278.9			971.3	2,250.2
2) Sludge Treatment							
(1) Sidestream Reservoir	4 tank	1.7	6.8	4 tank	2.3	9.2	16.0
(2) Gravity Thickener	8 unit	3.4	27.2	8 unit	1.8	14.4	41.6
(3) Centrifugal Thickener	-	-	-	24 set	3.9	93.6	93.6
(4) Anaerobic Digester	48 tank	5.7	273.6	48 tank	1.3	62.4	336.0
(5) Mechanical Dewatering (Belt Filter Press)	-	-	-	80 set	1.57	125.6	125.6
(6) Gas Holder	16 tank	0.12	2.0	16 tank	10.1	161.6	163.6
(7) Gas Generator	-	-	-	16 set	6.2	99.2	99.2
Sub-Total			309.6			566.0	875.6
(8) Electrical Work	-	-	-	1 ls.	-	141.1	141.1
Sub-Total of 2) Sludge Treatment			309.6			707.1	1,016.7
3) Building Construction							
(1) Blower House	8 house	5.85	46.8	-	-	-	46.8
(2) Centrifugal Thickener House	4 house	17.2	68.8	-	-	-	68.8
(3) Anaerobic Digester (Electrical Room)	4 house	1.2	4.8	-	-	-	4.8
(4) Mechanical Dewatering House (Belt Filter Press)	4 house	15.28	61.1	-	-	-	61.1
(5) Co-Generator House	4 house	1.6	6.4	-	-	-	6.4
(6) Control Building	1 house	7.2	7.2	-	-	-	7.2
(7) Sub-Control Building	7 house	3.6	25.2	-	-	-	25.2
Sub-Total of 3) Building Construction			220.3			-	220.3
4) Other Works							
(1) Preparatory Work	1 ls.	-	14.2	-	-	-	14.2
(2) Main Earth Work	1 ls.	-	39.0	-	-	-	39.0
(3) Site Preparation	1 ls.	-	38.4	-	-	-	38.4
Sub-Total of 4) Other Works			91.6			-	91.6
Grand Total			1,900.4			1,678.4	3,578.8

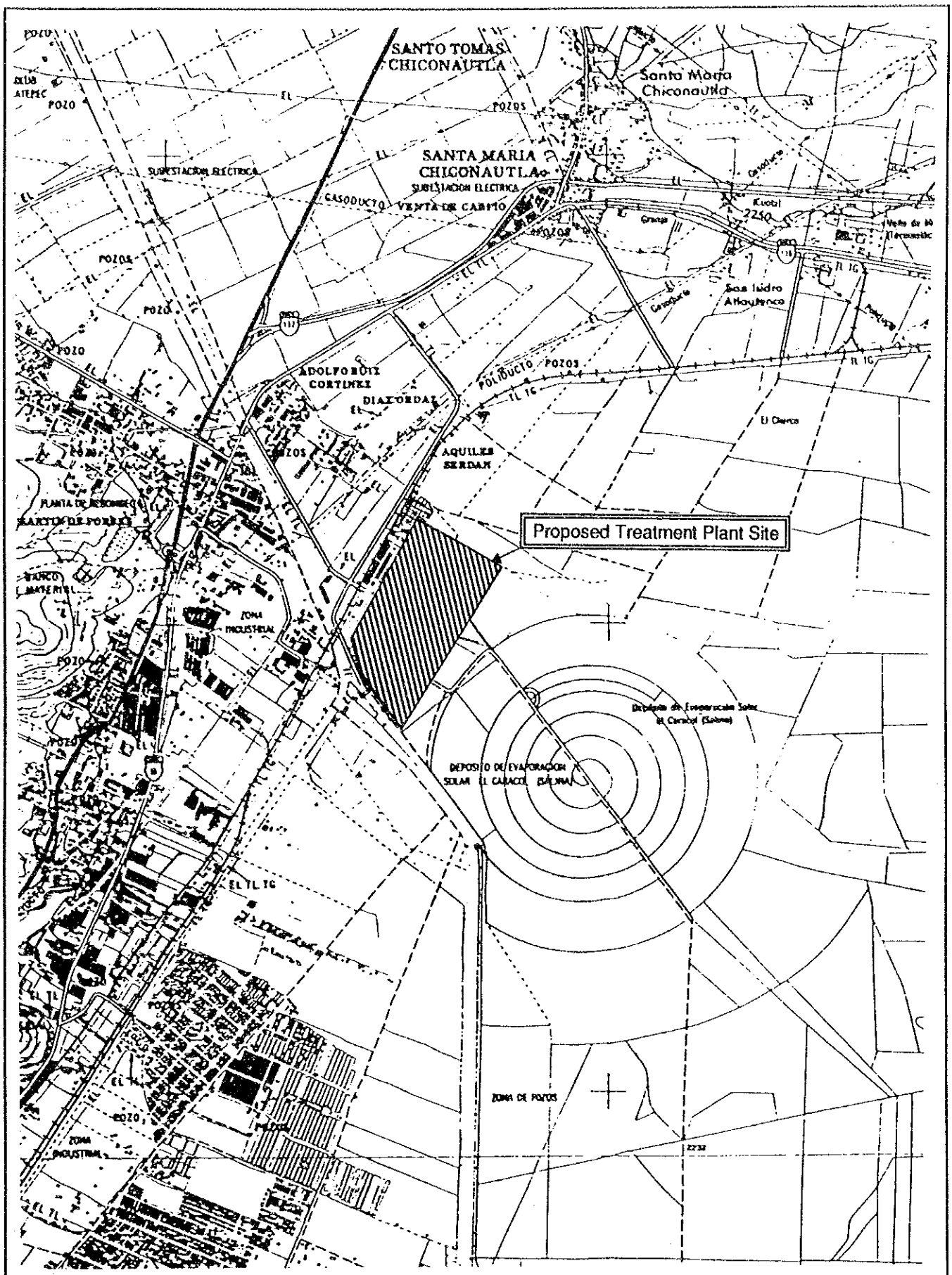

Fig. 5.1 Location of The Proposed Treatment Plant Site

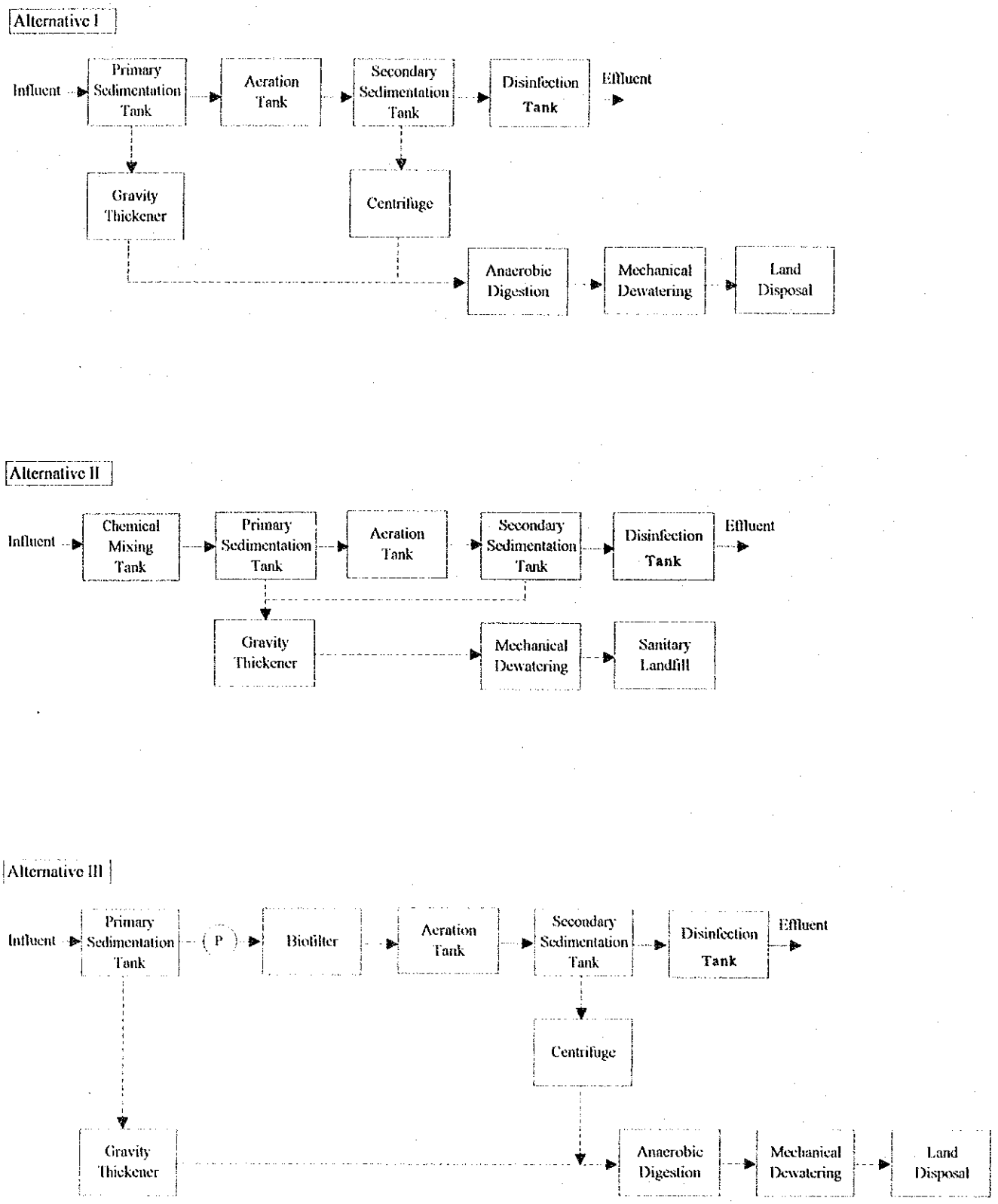

Fig. 5.2 Flow of Treatment System for Three (3) Alternatives

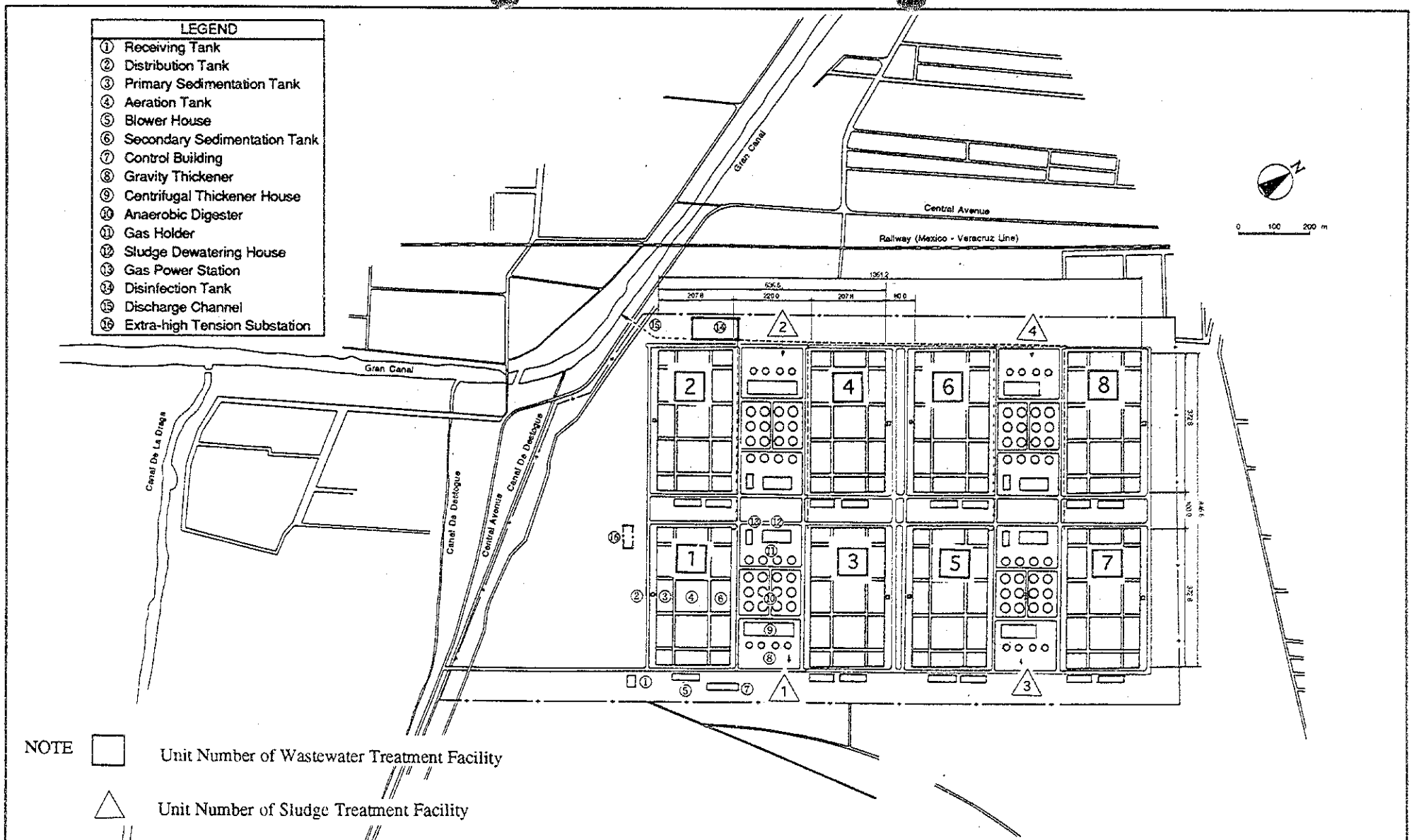

Fig. 5.3 General Layout of the Treatment Plant for the Final Project

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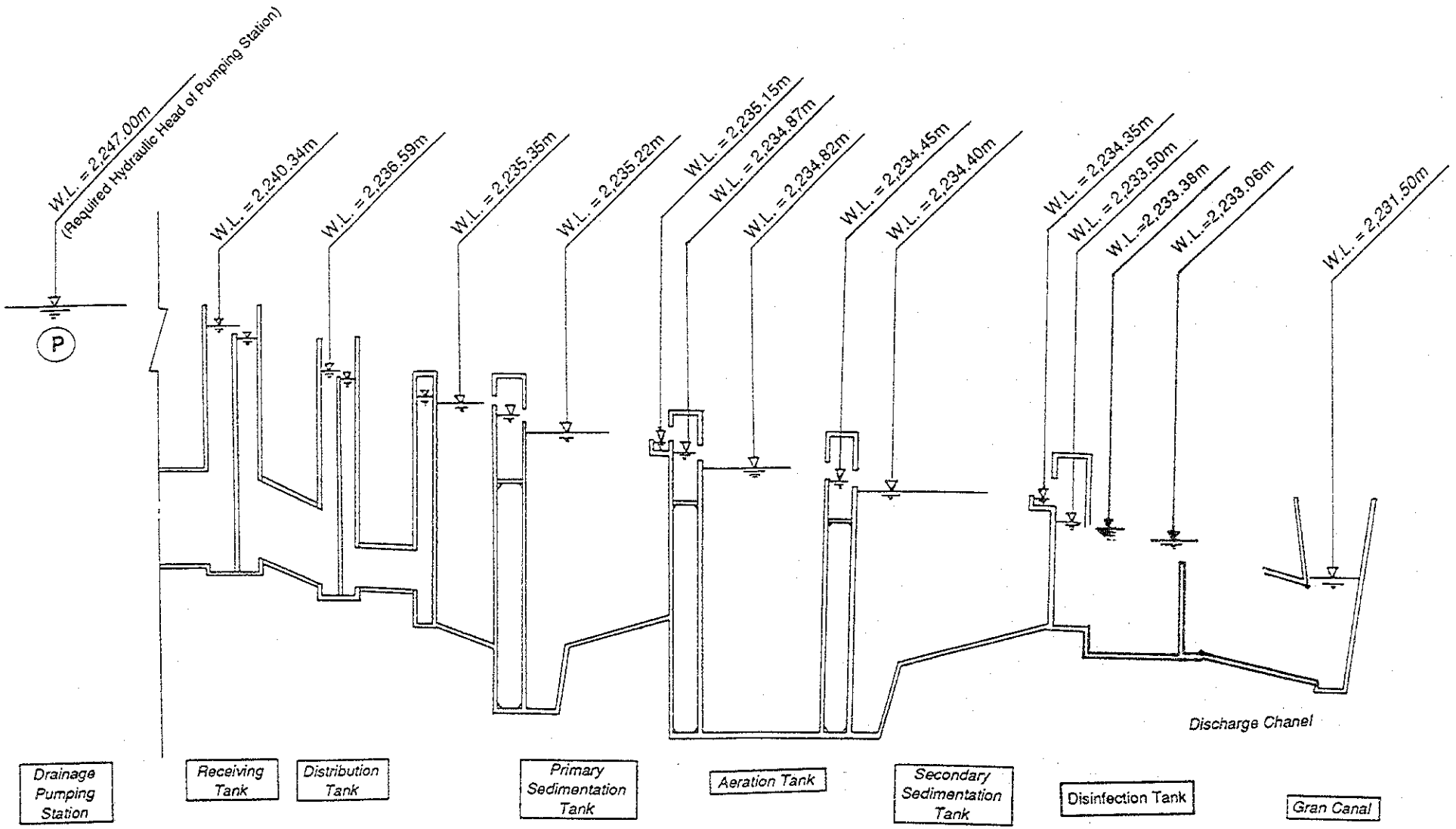

Fig. 5.4 Hydraulic Profile of the Treatment Plant for the Final Project

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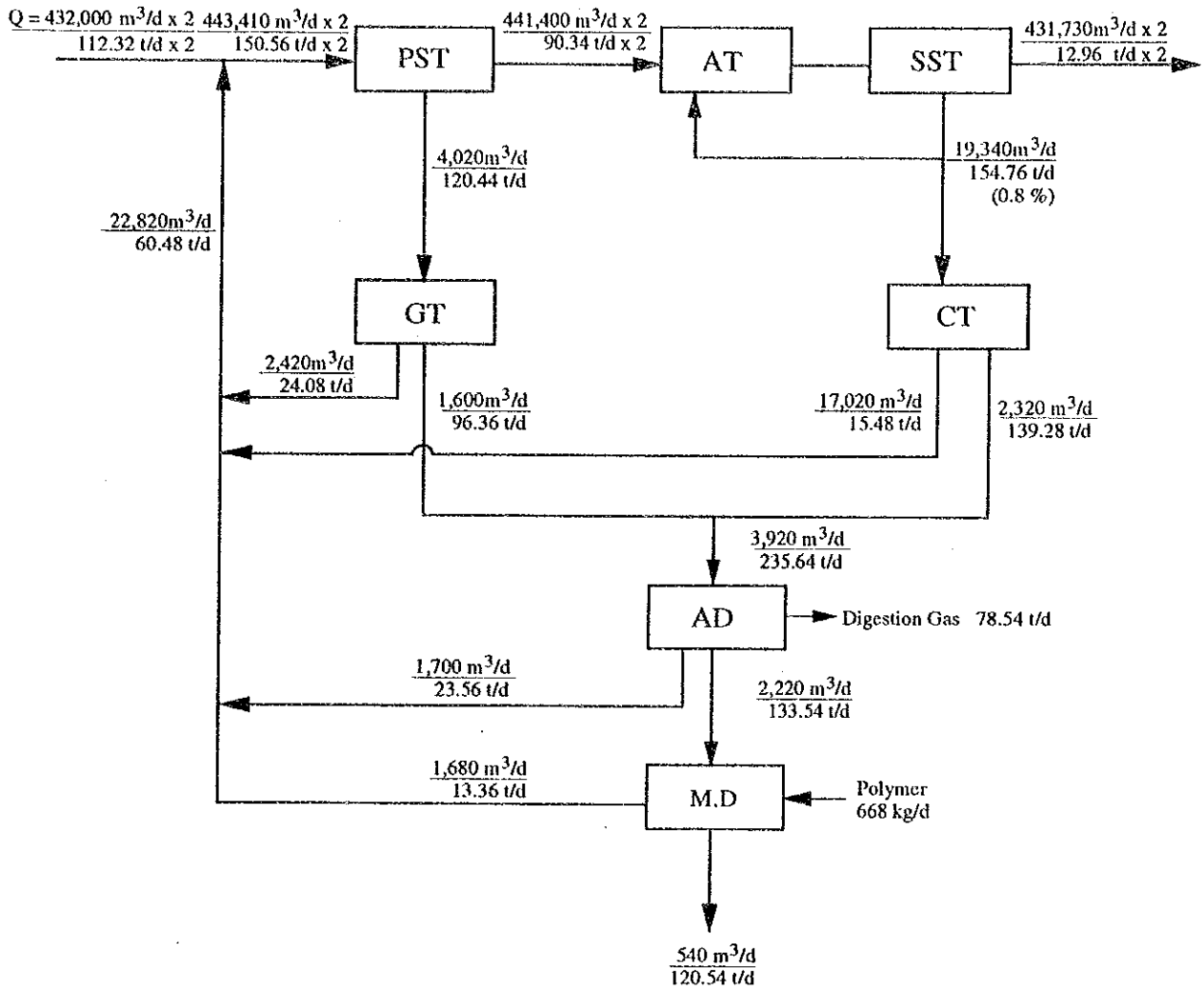

Note : 0,000 ----- Quantity of WW/sludge
00.00 ----- Dry Solid

GT : Gravity Thickening
CT : Centrifugal Thickening
AD : Anaerobic Digester
MD : Mechanical Dewatering by Belt Filter Press

Fig. 5.5 Solid Balance of Each Unit for the Final Project

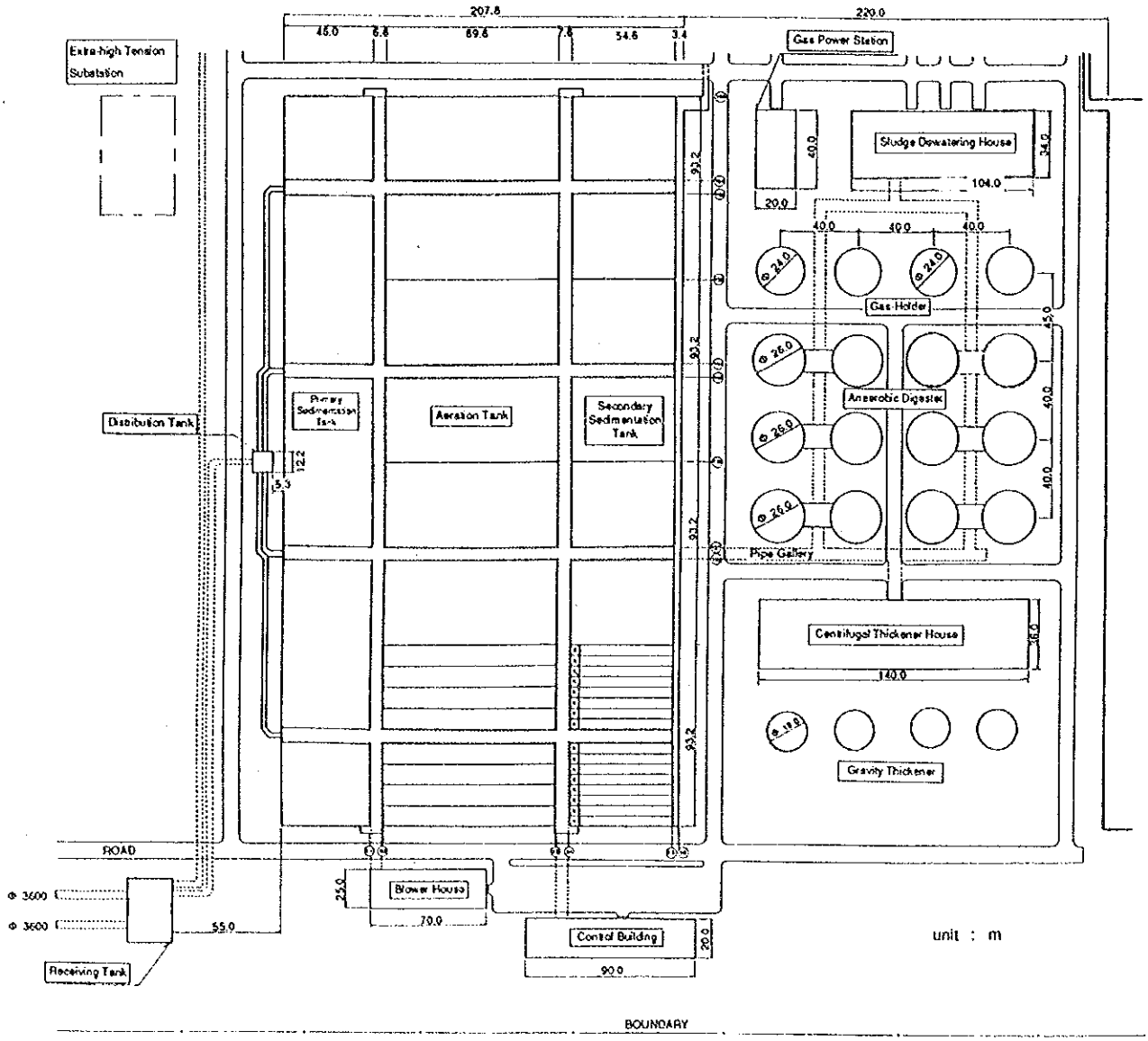

Fig. 5.6 Layout of One Unit of Proposed Treatment Plant for the Final Project

CHAPTER 6

CHAPTER 6 DESIGN OF WASTEWATER AND SLUDGE TREATMENT SYSTEM FOR URGENT PROJECT

1. General

Basic design of wastewater and sludge treatment plant for the Urgent Project with a capacity of 35 m^3/sec. has been conducted. Two (2) units of wastewater treatment system have been proposed. Each unit having capacity of 17.5 m^3/sec. consists of aeration tank and secondary sedimentation tank. Wastewater treatment system is designed to function as the modified activated sludge process at the Urgent Project stage. Two (2) units of sludge treatment system consisting of centrifugal thickener, anaerobic digestion tank and belt filter press are designed. Layout of whole wastewater and sludge treatment system and layout of one unit, for the Urgent Project, are shown in Fig. 6.1 and Fig. 6.2 respectively. Hydraulic profile of the proposed system for the Urgent Project is shown in Fig. 6.3. Details of each facility is shown in the attached " Drawings".

Design influent and effluent wastewater quality of the Urgent Project are shown below.

Water Quality	Influent	Effluent
BOD_5	220 mg/l	120 mg/l
SS	235 mg/l	120 mg/l
Coliforms (MPN/100ml)	10^7	<100,000

2. Wastewater Treatment Facilities

2.1 Receiving Tank

Two (2) influent pipes, each having diameter of 3.6 m, are designed to carry wastewater from the influent pumping station to the receiving tank.

Only about 10 % of treatment capacity is supposed to be augmented from Urgent Project stage to Final Project stage, hence the structure of receiving tank for the complete treatment system till Final Project is proposed to be constructed at the Urgent Project stage itself.

Proposed elevation of the crest of overflow weir is 2,239.40 meter. Width of overflow weir is proposed to be 3.0 m. Required water depth of the overflow weir to discharge wastewater of 35 m^3/sec is calculated to be 2.16 m. Hence the water level of receiving tank at the Urgent Project stage is required to be at the

level of + 2,241.56 meter. Hydraulic retention time of 1.8 minutes (1.5 minutes for Final Project) is achieved with an effective depth of 6.56 m. Detailed hydraulic calculations are described in Data Book.

Manually operated sluice gate with a diameter of 2.8 m is installed in each unit of the Urgent Project stage.

2.2 Connection Pipe

Connection pipe of 2.8 m diameter, between receiving tank and distribution tank is designed for each unit of the Urgent Project. Connection pipes of 2.0 m diameter is designed for each of the remaining six (6) units of treatment plant, to be constructed at the Final Project stage. These diameters are decided to make the hydraulic loss same in both urgent and final stages. At the Urgent Project stage, six (6) units of 2.0 meter diameter connection pipe with blind flange are also installed at the piercing part of concrete wall.

2.3 Distribution Tank

Distribution tank distributes wastewater of 17.5 m^3/sec to four (4) sub-units of treatment plant by rectangular weirs with each width of 2.5 m. The crest elevation of rectangular weir is proposed at the level of 2,236.17 m. Required overflow depth of weir is 1.196 m to distribute wastewater of 4.375 m^3/sec. in each sub-unit of treatment plant. Hydraulic retention time of distribution tank is estimated to be 0.5 minutes.

Wastewater of 17.5 m^3/sec is distributed to four (4) sub-units of treatment plant by open channel with a width and depth of 2.5 m and 1.5 m respectively.

2.4 Aeration Tank

Aeration tank is designed as a conventional aeration tank for the Final Project. Aeration tank is 89.0 m long and 10.3 m wide. Number of tank for one (1) unit are 32.

At the Urgent Project stage, two (2) units of aeration tank are required to treat wastewater of 35 m^3/sec. For the Urgent Project stage, two (2) units of aeration tank for the Final Project are designed as modified activated sludge process.

The design criteria for modified activated sludge process and design values in Urgent Project are shown below.