社会開発調査部報告書

No. 52

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

SUMMARY

DECEMBER 1994

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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

SUMMARY

DECEMBER 1994

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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,

Masami KONDO
Team Leader

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

ABSTRACT

(1) Target Year

Urgent Project : 1997

Final Project : 2015

(2) Service Population

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

(3) Capacity of Treatment Plant

Urgent Project : 35 m^3/sec.

Final Project : 40 m^3/sec.

The required area for the treatment plant, for the Final Project, is about 192 ha.

(4) Wastewater Quality

	Influent Wastewater	Effluent Wastewater
Urgent Project :		
BOD_5	220 mg/ℓ	120 mg/ℓ
SS	235 mg/ℓ	120 mg/ℓ
Coliforms	10^7 MPN/100mℓ	10^5 MPN/100mℓ
Final Project :		
BOD_5	245 mg/ℓ	20 mg/ℓ
SS	260 mg/ℓ	30 mg/ℓ
Coliforms	10^7 MPN/100 mℓ	<1,000 MPN/100 mℓ

(5) Proposed Wastewater Treatment Plant

At the Final Project stage, conventional activated sludge system consisting of primary sedimentation tank, aeration tank and secondary sedimentation tank is proposed as an optimum wastewater treatment system. Proposed sludge

treatment system for the Final Project consists of separate thickening (gravity thickening and centrifugal thickening), anaerobic digester, belt filter press and land disposal. Proposed wastewater treatment system for the Final Project is divided into eight (8) units, each having capacity of 5 m^3/sec. The whole sludge treatment system is divided into four (4) units and each unit treats sludge discharged from two (2) units of wastewater treatment plant.

For the Urgent Project, a portion of the selected optimum treatment system with some modification is selected as the treatment system for the Urgent Project.

Two (2) units of the Final Project (8 units) comprising of aeration tank and secondary 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.

Two (2) units of sludge treatment system consisting of centrifugal thickener, anaerobic digester, belt filter press and land disposal is proposed for treating activated sludge, being produced in the Urgent Project stage.

(6) Project Cost and O/M Cost

(A) Project Cost (N$ million)

	Urgent Project	Final Project	Total
Direct Construction Cost	1,115.4	2,463.4	3,578.8
Land Compensation	115.1	0	115.1
Administration Cost	11.1	24.7	35.8
Engineering Cost	39.0	86.3	125.3
Physical Contingency	111.5	246.4	357.9
Total	1,392.1	2,820.8	4,212.9

(B) Annual O/M Cost

Urgent Project : N$ 83.7 million / annum

Final Project : N$ 200.4 million / annum

The adopted currency exchange rate : US$ 1 = N$ 3.2 = ¥ 105

(7) Proposed Sewerage Service Charge

The proposed sewerage service charge is estimated under the conditions that initial cost, O/M cost, repayment cost and replacement cost will be fully recovered by the revenue of sewerage charge.

The ultimate sewerage service charge per unit m^3 of sewage after the completion of the Final Project at 2016 in both D.F. Mexico and Mexico State are proposed to be N$ 0.605/m^3 and N$ 0.600/m^3 respectively. They are 48% of what beneficiaries are willing to pay.

The provisional sewerage charges from 1998, the year immediately following the completion of the Urgent Project up to 2015 when the Final Project will be completed in both D.F. Mexico and Mexico State are proposed to be N$ 0.378/m^3 and N$ 0.375/m^3 respectively.

(8) Financial Evaluation

The financial rate of return (FIRR) of the project consisting of the Urgent Project and the Final Project is estimated to be 13.3 % under the following conditions.

(i) Initial cost, O/M cost, repayment cost and replacement cost will be fully recovered by the revenue of sewerage charge.

(ii) Sewerage service population ratio, in the year 1997, is assumed to be 98 % and 95 % for D.F. Mexico and Mexico State respectively. The ratio is assumed to be 100 % in D.F. Mexico and Mexico State for the year 2015.

(iii) Bill collection efficiency is assumed to be 85 %.

(iv) External Agency A provide the loan for 100% of the initial costs under the following conditions:

Annual interest rate : 5.25 %
Repayment Period : 15 Years (maximum)
Grace Period : Construction period

SUMMARY REPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

1. Background of the Study

The Metropolitan Area of Mexico City (AMCM), located in the Mexico Valley, with an altitute 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 rivers through Gran Canal and Emisor Central. The discharged untreated wastewater has resulted in the deterioration of the environmental conditions in the downstream areas. 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 and has 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 the Federal District of Mexico and the Mexico State "Plan Maestro de Tratamiento y Reuso del Districto Federal 1993" (hereinafter referred to as "the Master Plan)" and proposed a wastewater treatment plant at Texcoco to improve the quality of river water which is being used for irrigation at the lower river basin.

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 is classified into two (2) stages; Final Project with a target year of 2015 and 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 area 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.

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

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

(1) JICA Study Team

Team Leader

Mr. Masami Kondo	(PCI)

Members

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

3. Wastewater Generation

The Study Area is located in the valley of Mexico which is facing the shortage of water resources. Hence unit per capita water consumption is repressed and decreasing in the future.

Existing and future wastewater generation in D.F. Mexico and Mexico State is assumed to be the same amount of water consumption. Existing and future water consumption has been estimated by multiplying unit per capita water consumption with the service population.

Existing and Future wastewater generation in D.F. Mexico and Mexico state is summarized below.

(Unit : m^3/sec.)

Year	D.F. Mexico	Mexico State	Total
1993	24.71	10.79	35.50
1997	26.14	11.51	37.65
2015	34.08	13.30	47.38

Unit per capita pollution load generation in terms of BOD and SS are estimated based on the wastewater characteristics of Gran Canal. Estimated unit per capita pollution load 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

Future unit per capita pollution load generation of D.F. Mexico and Mexico State are assumed to be the same as those of existing ones.

4. Water Environment

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. Existing water quality of rivers and canals in the Study Area, in terms of BOD_5, SS and total coliforms, are as follows.

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

Generated wastewater in the Study Area without any treatment is being used for irrigation at Tula irrigation area 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

5. Sewerage System

Sewerage system covers about 94% of the existing population of D.F. Mexico and about 85% of Mexico State. And future sewerage covering ratio of population in both D.F. Mexico and Mexico State are assumed, as shown below.

Year	Service Population Ratio	
	D.F. Mexico	Mexico State
1997	98%	95%
2015	100%	100%

Existing sewer networks in D.F. Mexico and Mexico State are shown below.

	D.F. Mexico	Mexico State
Secondary Sewer (Ø300~Ø450)	11,226.4 km	4,170 km
Main Sewer (Ø610 ~ Ø4,000)	1,408.4 km	762.3 km
Intermediate Level Sewer (Laying depth of 8 ~ 10 m)	5.29 km	-
Deep Level Sewer (Laying depth of greater than 20 m)	121.1 km	-
Drainage Pumping Station	70 stations	100 stations

Existing sewer length per unit area of one (1) km^2 in both D.F. Mexico and Mexico State are 9.51 km/km^2 and 3.53 km/km^2 respectively.

All existing 21 wastewater treatment plants in D.F. Mexico and eight (8) plants in Mexico State have been constructed to create the new water resources from treated water. The total design capacity of existing 21 treatment plants in D.F. Mexico 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 only 10.9% of the total average generated wastewater of 24.71 m^3/sec. in D.F. Total design capacity of existing eight (8) treatment plants in Mexico State is 0.855 m^3/sec with an operation capacity of 0.375 m^3/sec which is about 3.5% of the total generated wastewater of 10.79 m^3/sec.

All existing wastewater treatment plants adopts conventional activated sludge process for liquid treatment. Only four (4) existing treatment plants in D.F. Mexico constructed after 1982 are equipped with sludge treatment process. 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.

Annual expenditure of N$ 18.482 million for the operation and maintenance of wastewater treatment system in D.F. Mexico in the year 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

On the basis of monthly data of operation and maintenance cost of the Cerro de la Estrella treatment plant in 1992, the unit operation and maintenance cost is found to be N$ 0.317 /m^3 of average treated wastewater of 1.409 m^3/sec.

6. The Master Plan

The Master Plan study was conducted by the National Water Commission (CNA) in 1993. The report proposed to construct wastewater treatment plants with a total capacity of 83 m^3/sec for improving the existing sanitary environments in the downstream irrigation area.

Treatment plant with a capacity of 35 m^3/sec was proposed at the north of Texcoco Lake by the Master Plan. 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 major purpose of this treatment plant is to remove the coliforms and helminth eggs from the irrigation water.

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 O/M cost is estimated to be N$ 143.49 million.

7. Wastewater and Sludge Treatment Plant for the Final Project

7.1 Treatment Plant Site

The proposed treatment plant site is located in the Texcoco area, Ecatepec municipality in the Mexico State (Refer to Fig.2). The area is reclaimed area of Texcoco lake and the top surface layer is rather soft with the SPT value of 0 ~ 3. The silty sand layer found at the depth of 28 m to 37 m from the ground surface, with the SPT value of 30 - 50, is proposed to be the foundation layer of the proposed treatment facilities.

7.2 Wastewater Quantity and Quality

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. Design wastewater flow of Urgent and Final Projects is estimated to be 35 m^3/sec and 40 m^3/sec respectively.

The design 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 existing small treatment plants, being operated for achieving reusable treated water.

The design influent wastewater quality of the treatment plant for Urgent and Final Projects is as follows.

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

Further more wastewater characteristics shows that soluble BOD constitutes 70% and 60% of the total BOD in dry and rainy season respectively. These soluble BOD constitution ratio is rather high comparing with other municipal wastewater which has general range of 30 - 40%.

The treated wastewater is intended to be reused for irrigation purpose in the Tula irrigation area. The quality of treated wastewater is governed by Mexican Official Standards. The design effluent wastewater quality of the treatment plant for Urgent and Final Projects is described below.

Year	1997	2015
BOD_5 (mg/l)	120	20
SS (mg/l)	120	30
Coliforms(MPN/100ml)	<100,000	<1,000

7.3 Proposed Wastewater and Sludge Treatment Plant

The various possible alternatives of the integrated wastewater and sludge treatment system have been studied with the following basic considerations.

(1) 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.

(2) 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).

(3) The treatment process with high treatment efficiency per unit treatment space is required because of the large amount of wastewater (3.5 million m^3/day) to be treated.

Based on the technical and financial evaluation, following wastewater and sludge treatment system is proposed for the Final Project. The required area for the treatment plant is about 192 ha.

Wastewater Treatment System

Conventional activated sludge system consisting of primary sedimentation tank, aeration tank and secondary sedimentation tank is selected as the optimum wastewater treatment system for the Final Project. The layout and hydraulic profiles of the treatment plant is shown in Fig. 3 and Fig. 4.

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

Sludge Treatment System

The proposed 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 treats sludge discharged from two (2) units of wastewater treatment plant.

Structural design of sludge treatment system is conducted based on the solid balance as shown in Fig. 5.

7.4 Estimated Project Cost and O/M Cost

Project cost of the Final Project is estimated to be N$ 4,212.9 million at 1994 price. Annual O/M cost is estimated at N$ 200.4 million at 1994 price. Breakdown of the project cost and O/M cost of the Final Project are shown in Table 1.

8. Design of Wastewater and Sludge Treatment System for the Urgent Project

8.1 General

A portion of the selected optimum treatment system for the Final Project with some modification is proposed as the treatment system for the Urgent Project.

Based on the wastewater characteristics of the Gran Canal with high soluble BOD constitution, biological treatment process is necessary to achieve required effluent quality. 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.).

Two (2) units of sludge treatment system consisting of centrifugal thickener, anaerobic digester and belt filter press is proposed for treating activated sludge, being produced in the Urgent Project stage. Layout and hydraulic profile of wastewater and sludge treatment system for the Urgent Project are shown in Fig. 6 and Fig. 7 respectively. Details of each facility is shown in the attached " Drawings".

8.2 Proposed Treatment Facilities

Required treatment facilities for the Urgent Project are initially designed under the conditions of Final Project. And the facilities are verified under the conditions of Urgent Project.

General layout and hydraulic profile of the proposed treatment plant for the Urgent Project is shown in Fig. 6 and Fig. 7. And layout of one (1) unit of wastewater and sludge treatment plant is shown in Fig. 8.

Specification and actual design load of each facility under the Urgent Project stage are shown in Table 2.

At the treatment plant, electrical power is generated using the digestion gas produced in the anaerobic digester. At the Urgent Project stage, electrical power of 4,500 kw/d is produced from one (1) unit of sludge treatment plant. It saves about 35% of the total electrical expenditure.

Pile foundation with diameters of Ø600 and Ø800 are adopted for supporting the treatment facilities.

8.3 Estimated Cost and Implementation Program

Project cost of the Urgent Project is estimated to be N$ 1,392.1 million at 1994 price. Annual O/M cost of the Urgent Project is estimated to be N$ 83.7 million at 1994 price. Breakdown of the project cost and O/M cost are shown in Table 3.

9. Implementation Program

Implementation of the project will be divided into four (4) stages. At the first stage, Urgent Project will be implemented from 1995 to 1997. The detailed design of the Urgent Project will be completed in 1995 and the construction works will be conducted in the year 1996 and 1997. The remaining works will be divided into three (3) stages. In the second stage, detailed design of the remaining facility will be conducted in the year 2007 and subsequently construction works will be implemented from the year 2008 to 2015.

The inflow pumping station, which will convey wastewater to Texcoco treatment plant is designed by the Mexican side. And it is necessary to construct pumping station simultaneously with Texcoco treatment plant.

10. Evaluation of the Project

10.1 Economical Evaluation

(1) Reduction of Water-borne Diseases

The annual incidence of water-borne and water related diseases, in the irrigation area which uses untreated wastewater for irrigation, is 31,214 cases more than that of irrigation area which uses treated water for irrigation. An average medical cost of water-borne and water related

diseases are N$ 74.3 per case. Consequently an average annual medical expenditure of water-borne and water related diseases is estimated to be N$ 2.3 million.

The proposed Texcoco wastewater treatment project will greatly contribute to reduction of water-borne diseases and water related diseases and related economical cost.

(2) Increase of Agricultural Products

The annual incremental amount of agricultural income in the untreated wastewater irrigation area, after completion of the project, is expected to be N$ 60.0 million.

(3) Justification of the Project

The inital costs of Urgent and Final Projects are estimated to be N$ 1,392.1 million and N$ 2,820.8 million respectively, summing up to N$ 4,212.9 million. Annual operation and maintenance cost of Urgent and Final Projects are estimated to be N$ 83.7 million and N$ 200.4 million respectively.

The economical benefits, in terms of reduction in medical cost of waterborne diseases and increase in agricultural income, can neither cover the inital cost nor the annual O/M cost. It is obvious that the benefits are limited because polluters and beneficiaries are not one and the same, and the number of beneficiaries are very small compared with that of polluters. A long term viewpoint is required to discuss the justification of the project. The project must be viewed in the context of the national environmental protection policy.

10.2 Financial and Institutional Aspects

(1) Water Charge in the Study Area

Existing average unit water charge in the Study Area of D.F. Mexico and Mexico State are N$ 1.056 and N$ 1.142 respectively.

Supposing that the collection efficiency of water bills will be 85% in both D.F. Mexico and Mexico State and also the O/M cost in Mexico State will go up by 50% in future, the price of water per m^3 fully covering the O/M costs will be N$ 1.837 in D.F.Mexico and N$ 1.310 in Mexico State.

(2) People's Willingness to Pay

The average willingness to pay for water supply and sewerage service of both D.F.Mexico and Mexico State are as follows:

	Water Supply	Sewerage Service
D.F. Mexico	N$ 1.890 /m^3	N$ 1.260 /m^3
Mexico State	N$ 1.874 /m^3	N$ 1.249 /m^3

The average willingness to pay for water supply in both D.F. Mexico and Mexico State are greater than the required water charge for covering the O/M cost.

The total willingness to pay for water supply and sewerage service as percentage of household income in D.F. Mexico and Mexico State are estimated to be 1.35% and 2.02% respectively.

(3) Proposed Sewerage Charge

The proposed sewerage service charge is estimated under the conditions that initial cost, O/M cost, repayment cost and replacement cost will be fully recovered by the revenue of sewerage charge.

The ultimate sewerage service charge per unit m^3 of sewage after the completion of the Final Project at 2016 in both D.F. Mexico and Mexico State are proposed to be N$ 0.605/m^3 and N$ 0.600/m^3 respectively. They are 48% of what beneficiaries are willing to pay.

The provisional sewerage charges from 1998, the year immediately following the completion of the Urgent Project up to 2015 when the Final Project will be completed in both D.F. Mexico and Mexico State are proposed to be N$ 0.378/m^3 and N$ 0.375/m^3 respectively.

The proposed combined water supply and sewerage service charge per unit m^3 in both D.F.Mexico and Mexico State are as follows.

(Unit : N$/$m^3$)

	From 1998 to 2015	From 2016 ~
D.F. Mexico	2.215	2.442
Mexico State	1.685	1.910

(4) Financial Analysis

It is proposed that :

(i) Initial cost, O/M cost, repayment cost and replacement cost will be fully recovered by the revenue of sewerage charge.

(ii) Sewerage service population ratio, in the year 1997, is assumed to be 98 % and 95 % for D.F. Mexico and Mexico State respectively. The ratio is assumed to be 100 % in D.F. Mexico and Mexico State for the year 2015.

(iii) Bill collection efficiency is assumed to be 85 %.

(iv) External Agency A provide the loan for 100% of the initial costs under the following conditions:

Annual interest rate	:	5.25 %
Repayment Period	:	15 Years (maximum)
Grace Period	:	Construction period

For the above financial conditions, the financial internal rate of return (FIRR) of the project is estimated to be 13.3% which is greater than the annual interest rate of the loan plus the commission charge of BANOBRAS, and hence the proposed plan is financially feasible.

Supposing the Urgent Project is itself the final project, the financial analysis of the Urgent Project was also conducted for the Proposed Plan. The afore-mentioned financial source and preconditions/assumptions regarding the recovery of costs, depreciation period, period of projection, rate of tax on corporate income and collection efficiency of bills apply to the Urgent Project.

The proposed sewerage service charge per cubic meter of sewage will be N$ 0.265 in the Federal District and N$ 0.262 in the Mexico State.

FIRR was calculated to be 10.6 %. It is greater than the annual interest rate plus the BANOBRAS commission charge.

(5) Institutional Aspect

Strict financial management should be implemented by the water organizations to achieve the objective of self financing. Institutional and

organizational strengthening is necessary to effectuate the realization of strict financial management.

JICA Study Team proposes to establish an independent sewerage organization in the course of time with the target year set at 2015. The self financing system is required for strengthening the independent sewerage organization.

Following countermeasures are proposed to establish self financing system:

- Raising of water tariffs and water bill collection efficiency
- Introduction of sewerage service charge
- Real implementation and expansion of water meter system
- Reduction of leakage

11. Recommendations

(1) An immediate implementation of the Urgent Project is necessary for both improvement of the overall sanitary environment at the downstream irrigation areas and increasing agricultural product.

The inflow pumping station, which will convey wastewater to Texcoco treatment plant, should also be constructed simultaneously with Texcoco treatment plant.

Hence, it is recommended to commence the necessary financial procurement at the earliest.

(2) The importance of wastewater treatment as a protective measure for the spreading of parasitic diseases can not be ignored. However social education program to prevent human exposure and to reduce parasitic infections is also necessary. Major aspects to be included in the program are listed below.

- Importance of using appropriate footwear and gloves by field workers
- Properly cooking vegetables, meat and boiling milk
- Providing immunization against Typhoid, Hepatitis A etc.
- Providing facilities for Diarrhea diseases
- Emphasizing importance of personal and food hygiene
- Providing health education to mothers and also children in the schools
- Providing immunization facilities for the children in the schools

(3) This report elaborates feasibility study stage of the project. In detailed design stage, especially following studies should be conducted in more detail.

- Designing layout of wastewater and sludge treatment plant with due consideration to the actual implementation program
- Estimation of solid content of activated and thickened sludge by pilot test
- Designing size of aeration tank and return sludge feeding system
- Detailed analysis of soil characteristics and detailed sesign of foundation structure

Table 1 Breakdown of Project and O/M Costs for the Final Project

Project Cost	(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	115.1
(C) Administration Cost	35.8
(D) Engineering Cost	125.3
(E) Physical Contingency	357.9
Total	4,212.9

O/M Cost	(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

Table 2 Specification and Actual Design Load of Each Facilities under the Urgent Project

1. Wastewater Treatment Facilities		
1.1 Receiving Tank		
1) Dimension	:	21.5 m (W) x 31.6 m (L) x 5.34 m (D)
2) Number	:	1 tank
3) Hydraulic Retention Time	:	1.8 min.
1.2 Connection Pipe		
1) Diameter & Length	:	ø2,800 mm x 290 m (L) for Unit 1
	:	ø2,800 mm x 750 m (L) for Unit 2
1.3 Distribution Tank		
1) Dimension	:	11.2 m (L) x 11.2 m (W) x 3.59 m (D)
2) Number of Tank for 1 Unit	:	1 tank
2) Hydraulic Retention Time	:	0.5 min.
1.4 Aeration Tank		
1) Dimension	:	89.0 m (L) x 10.3 m (W) x 6.0 m (D)
2) Number of Tank for 1 Unit	:	32 tanks
3) FM Ratio	:	3.23
4) BOD Volumetric Load	:	1.95 BOD kg/m3•d
5) Retention Time	:	2.7 hr.
6) MLSS	:	805 mg/l
7) Return Sludge Solid Concentration	:	6,500 mg/l
8) Return Sludge Ratio	:	10 %
1.5 Secondary Sedimentation Tank		
1) Dimension	:	54.0 m (L) x 10.0 m (W) x 3.5 m (D)
2) Number	:	32 tanks
3) Surface Loading	:	87.5 m3/m2•d
4) Solid Loading		79.1 kg/m2•d
5) Weir Loading	:	190 m3/m•d
6) Length of Trough per 1 Basin	:	125 m
1.6 Disinfection		
1) Chorine Dosage (Chlorine Gas)	:	2.0 mg/l
2) Contact Time	:	17 min.
2. Sludge Treatment Facilities		
2.1 Centrifugal Thickener		
1) Capacity	:	170 m3/hr.
2) Number of Thickener for 1 Unit	:	11 sets
3) Operation Hour per Day	:	24 hr.
4) Operation Efficiency	:	80 %
5) Thickened Sludge Concentration	:	6.0 %
2.2 Anaerobic Digester		
1) Dimension	:	ø26.0 m x 12.5 m (D)
2) Number of Tank for 1 Unit	:	10 tanks
3) Retention Time	:	19.3 days
4) Ratio of Sludge-digestion Gas	:	33 %
2.3 Belt Filter Press		
1) Belt Width	:	3 m
2) Dry Polymer	:	0.5 g/kg dry solids
4) Capacity	:	250 m3/hr.
5) Number of Set for 1 Unit	:	16 sets
6) Operation Hour per Day	:	12 hr.
7) Operation Efficiency	:	80 %

Table 3 Breakdown of Project and O/M Costs for the Urgent Project

Project Cost	(Unit : N$ million)
(A) Direct Construction Cost	1,115.4
1) Wastewater Treatment	503.4
(1) Receiving Tank	15.0
(2) Distribution Tank	5.2
(3) Aeration Tank	262.4
(4) Secondary Sedimentation Tank	144.8
(5) Disinfection	14.9
(6) Discharge Channel	11.1
(7) Equipment for reclaimed Wastewater	9.8
(8) Electrical Works	40.2
2) Sludge Treatment	481.9
(1) Centrifugal Thickener	93.8
(2) Anaerobic Digester	140.0
(3) Belt Filter Press	50.2
(4) Gas Generation System	131.4
(5) Electrical Works	66.5
3) Building Construction	95.2
4) Other Works	34.9
(B) Land Compensation	115.1
(C) Administration Cost	11.1
(D) Engineering Cost	39.0
(E) Physical Contingency	111.5
Total	1,392.1

O/M Cost	(Unit : N$ million)
(1) Personal Expenditure	3.9
(2) Electrical Charge	21.4
(3) Chemical Cost	16.6
(4) Sludge Disposal Cost	11.7
(5) Repairing Cost	30.1
Total	83.7

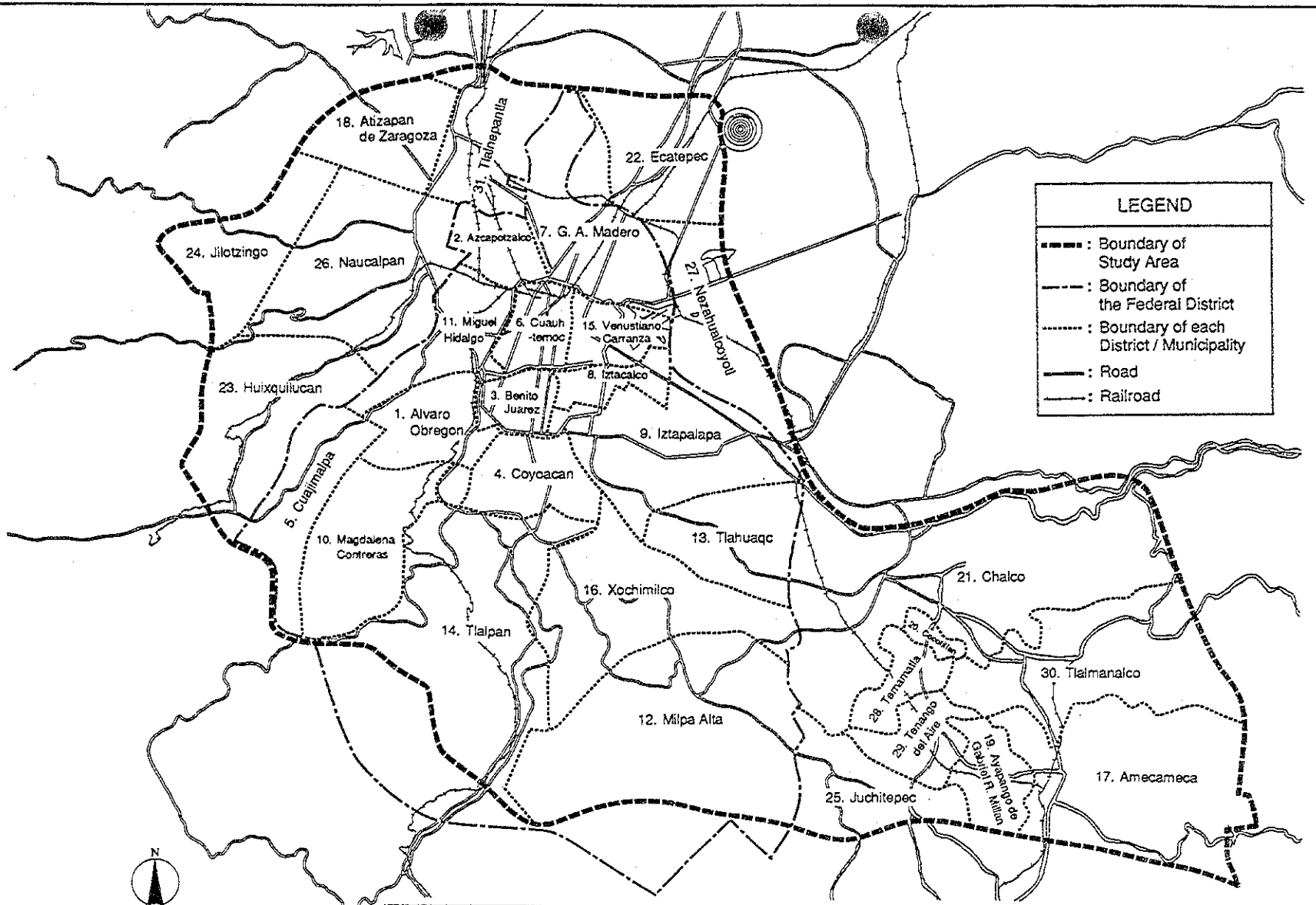


Fig. 1 Study Area

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

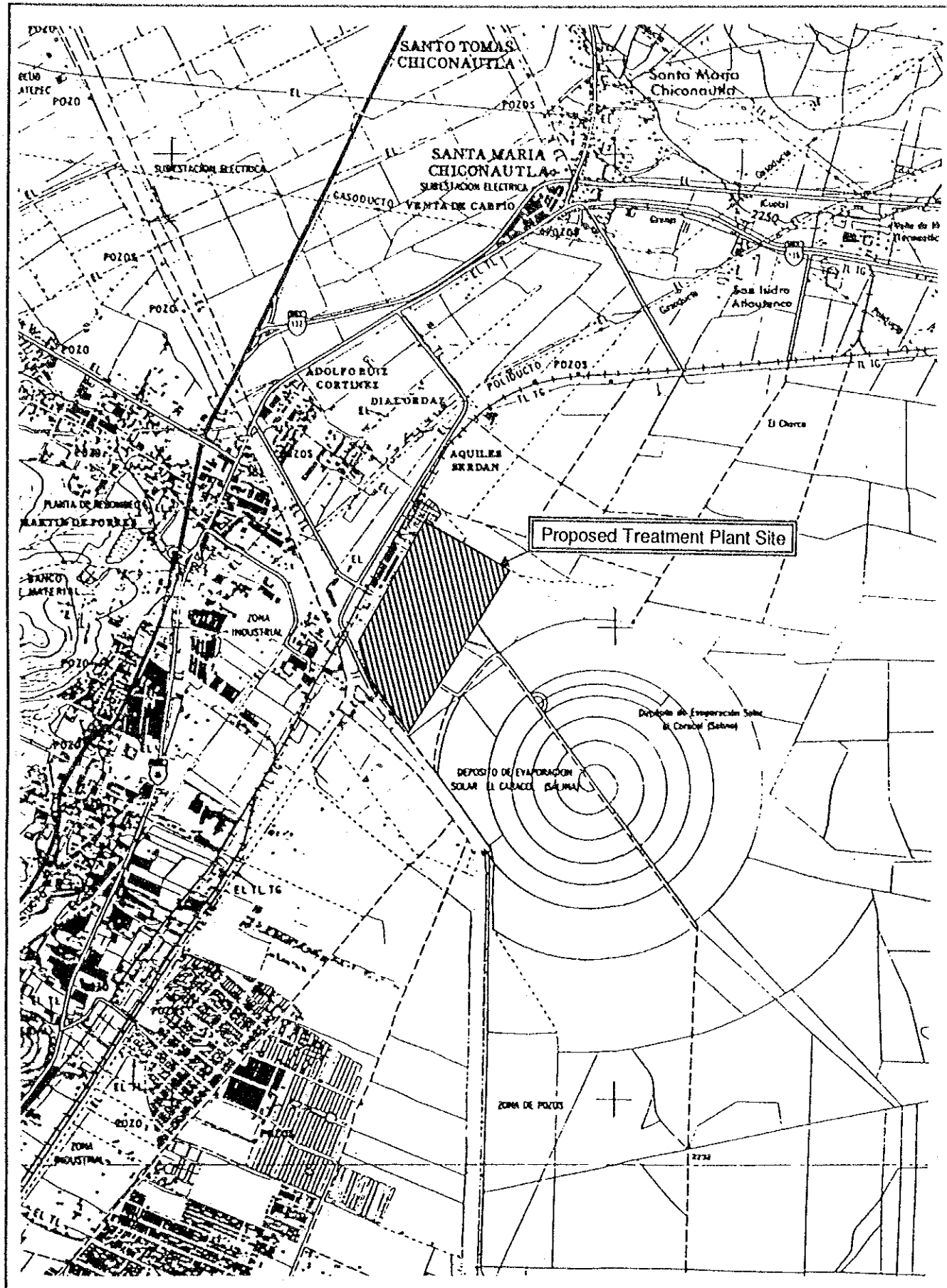


Fig. 2 Location of The Proposed Treatment Plant Site

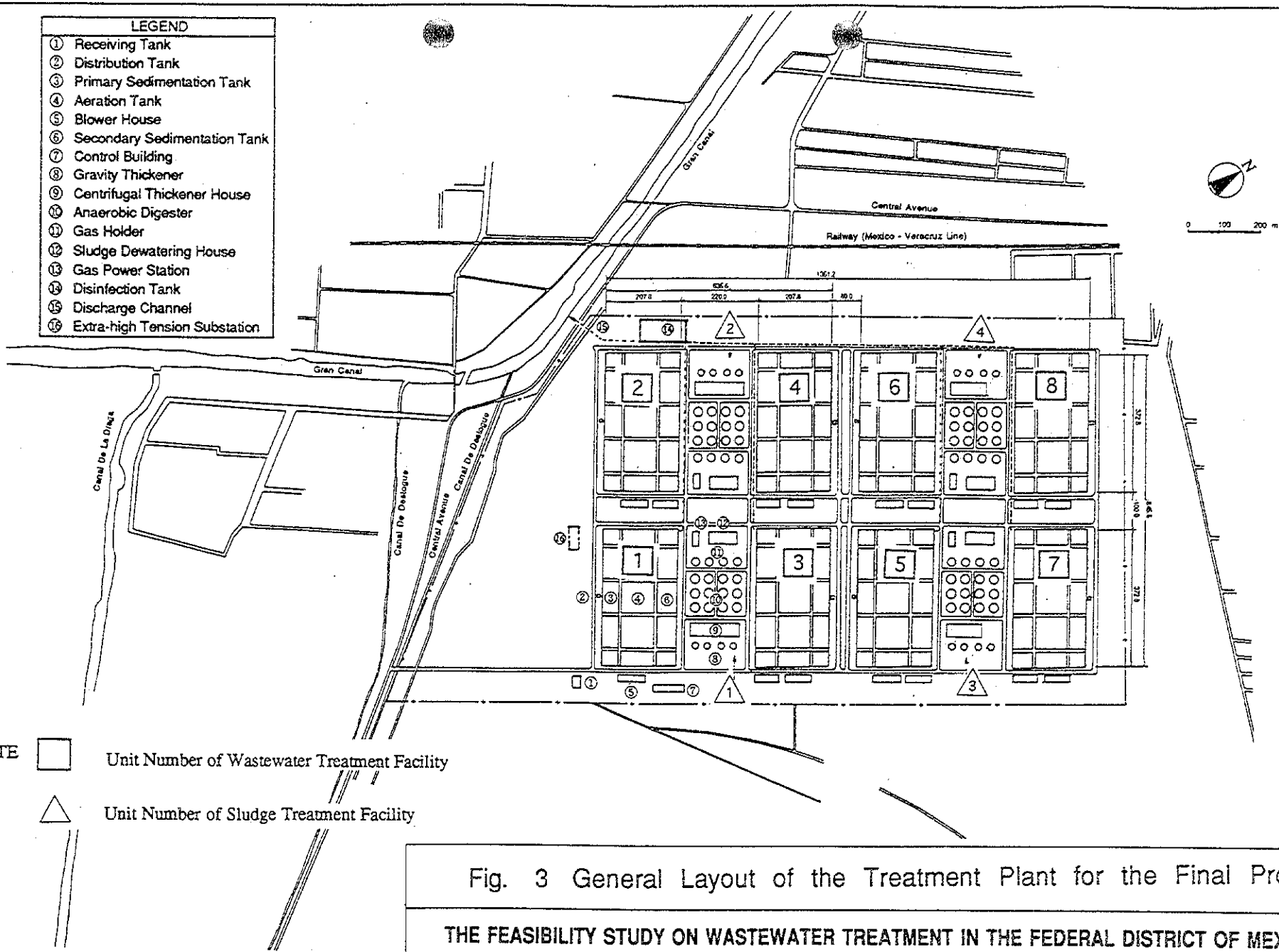


Fig. 3 General Layout of the Treatment Plant for the Final Project

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

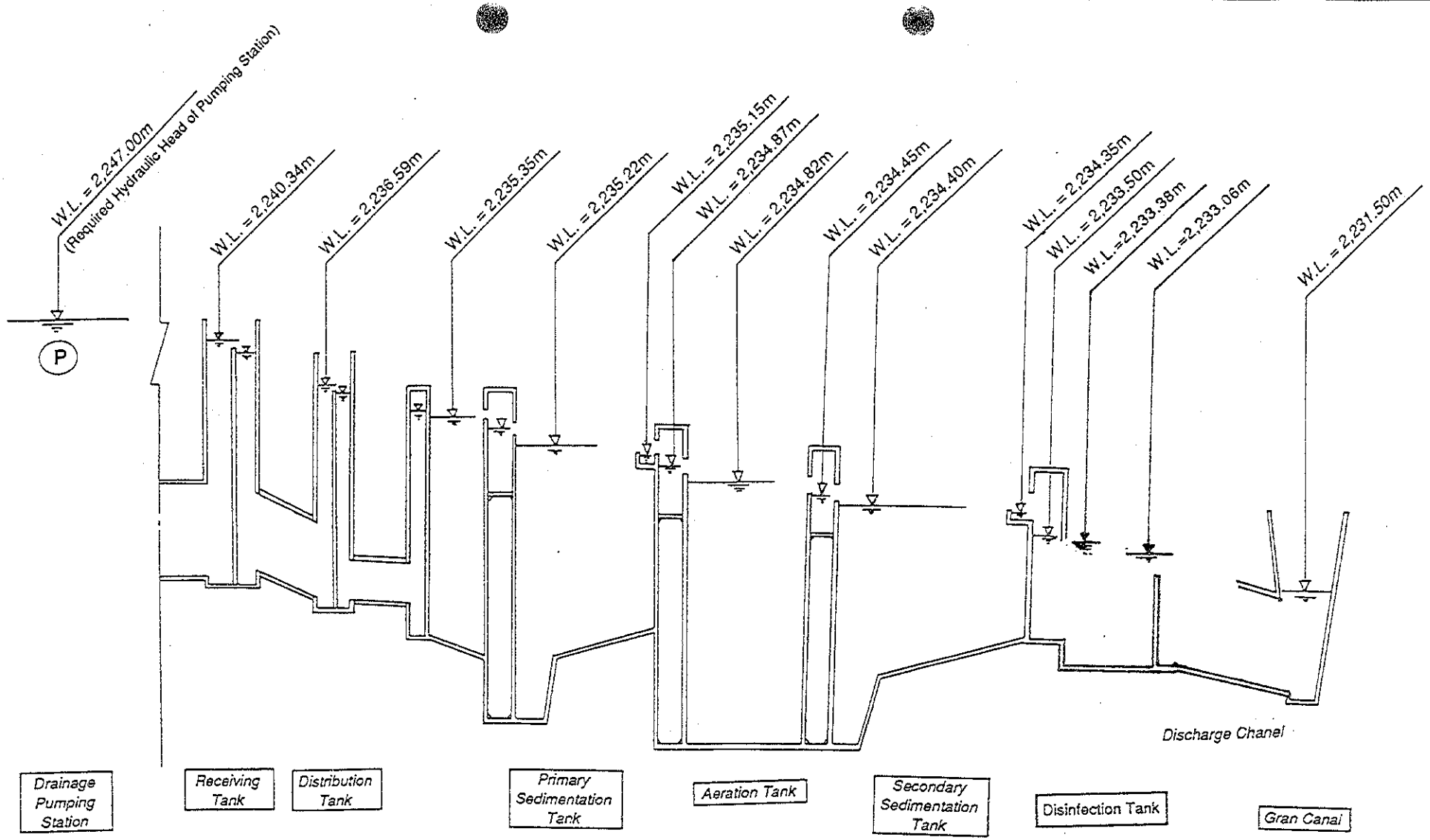
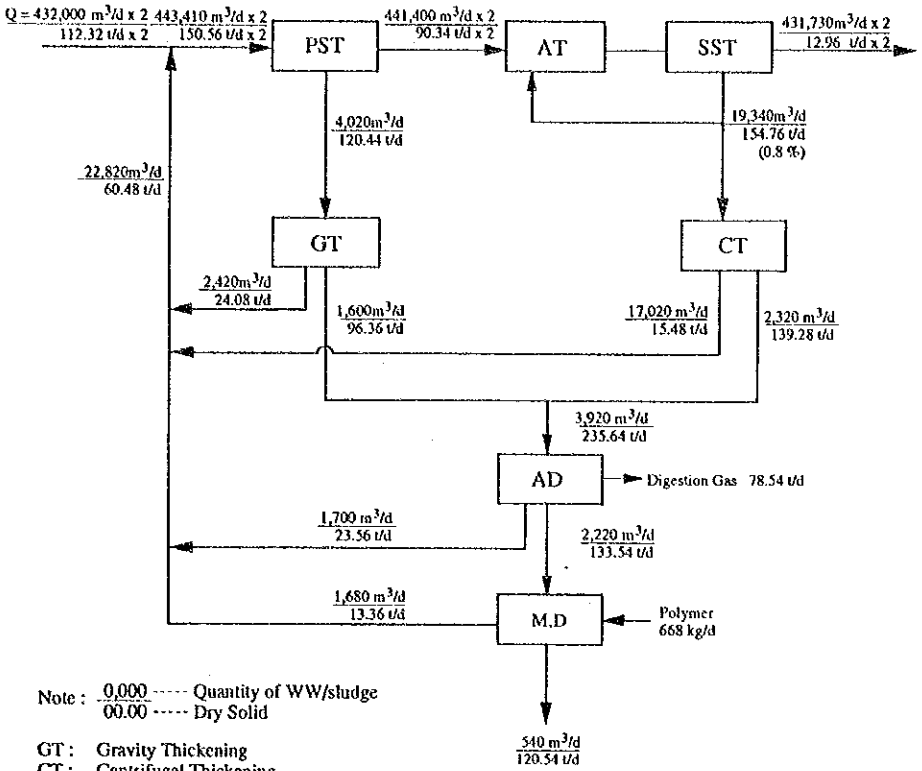


Fig. 4 Hydraulic Profile of the Treatment Plant for the Final Project

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

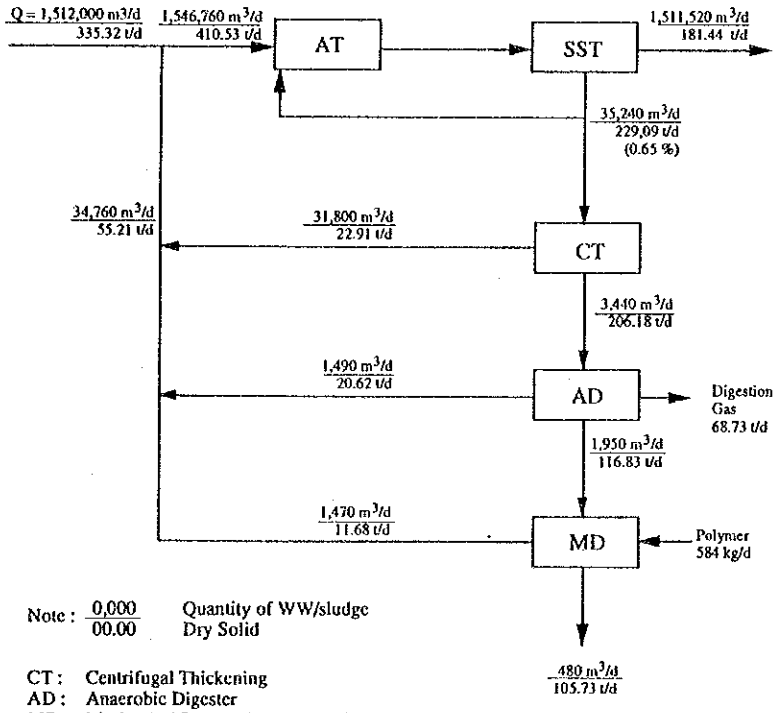
Final Project



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

Urgent Project



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

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

Fig. 5 Solid Balance of the Treatment Plant for the Final and Urgent Projects

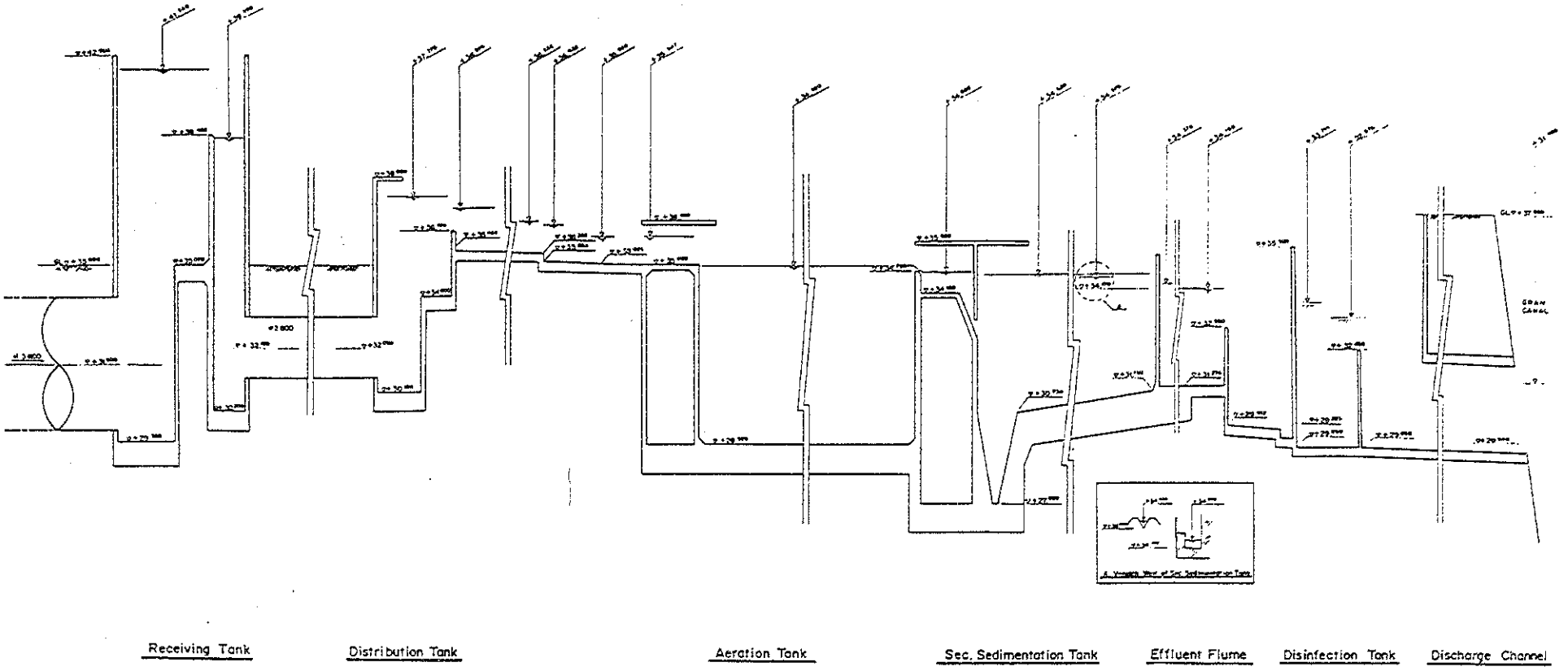


Fig. 6 Hydraulic Profile of the Proposed System for the Urgent Project

JICA

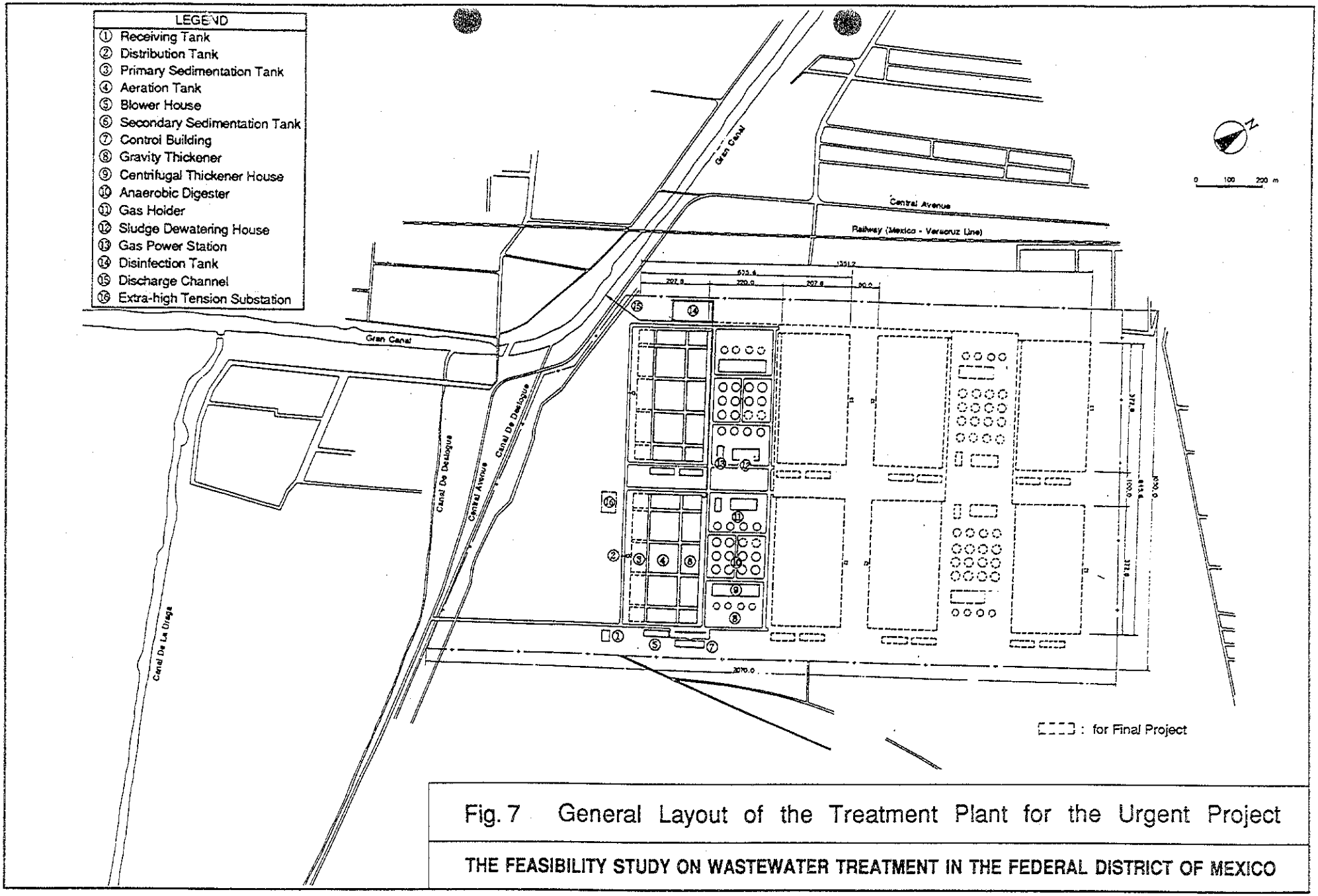


Fig. 7 General Layout of the Treatment Plant for the Urgent Project

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

JICA

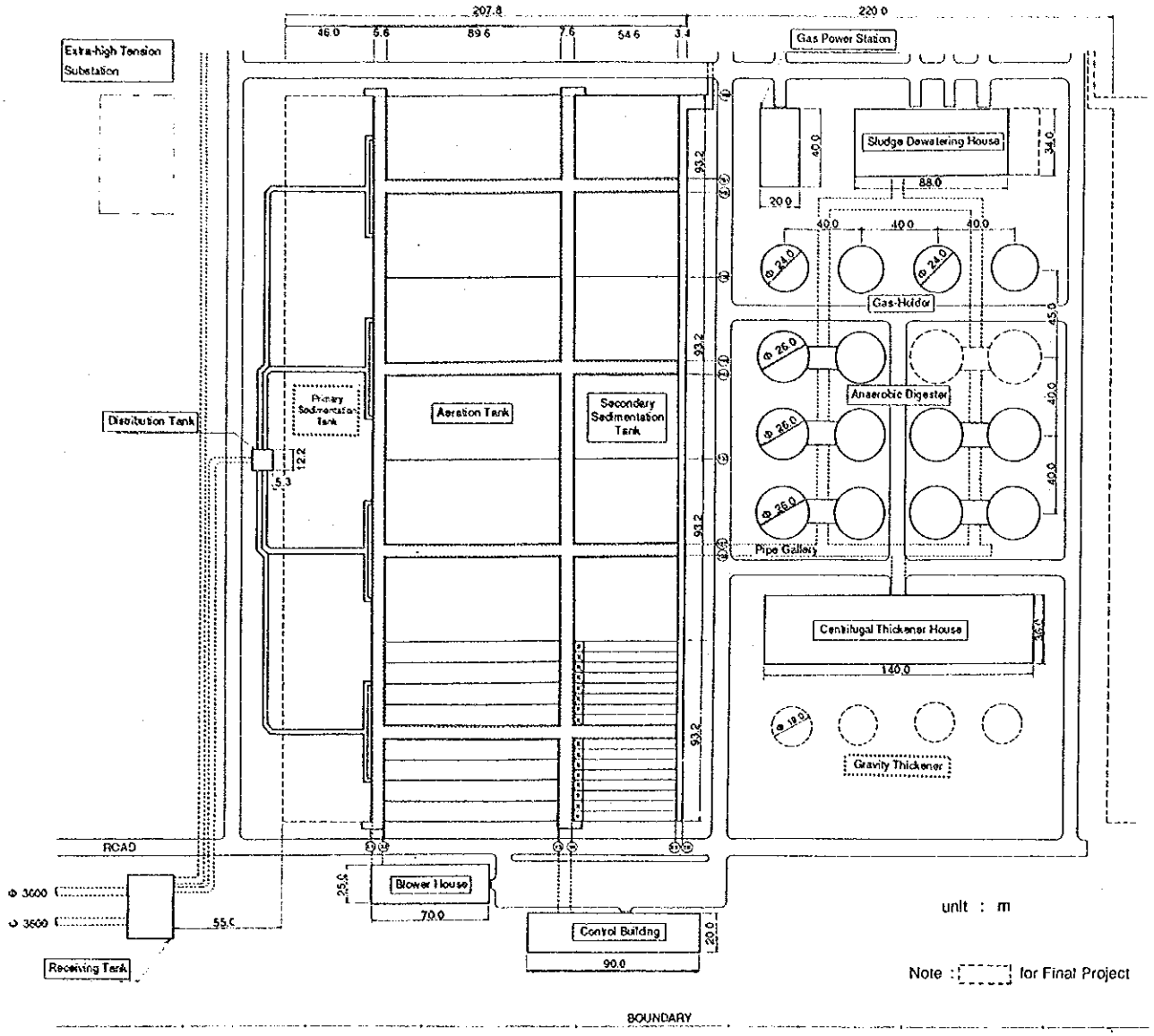


Fig. 8 Layout of One (1) Unit of the Wastewater and Sludge Treatment Plant for the Urgent Project