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

SUPPORTING REPORT

DECEMBER 1994

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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

SUPPORTING REPORT

TABLE OF CONTENTS

APPENDIX D SEWERAGE SYSTEM

APPENDIX E STUDY OF RELEVANT REPORTS

APPENDIX F WASTEWATER AND SLUDGE TREATMENT PLANT FOR THE FINAL PROJECT

APPENDIX G DESIGN OF WASTEWATER AND SLUDGE TREATMENT SYSTEM FOR URGENT PROJECT

APPENDIX H IMPLEMENTATION PROGRAM

APPENDIX I EVALUATION OF PROJECT

APPENDIX J SUPPLEMENTARY REPORT

SUPPORTING REPORT

LIST OF TABLES

SUPPORTING REPORT

LIST OF FIGURES

APPENDIX I EVALUATION OF PROJECT

APPENDIX J SUPPLEMENTARY REPORT

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 (Metcalf/Eddy)
WEF	WEF Manual of Practice No.8 & ASCE Manual and Report on Engineering Practice No. 76

APPENDIX A

APPENDIX A STUDY AREA

1. Administrative Area

The Study Area of approximately 2,740 km^2 covers a drainage area of the Gran Canal. The Study Area consists of all the 16 Districts of Federal District of Mexico (D.F.) and 15 Municipalities of Mexico state. The location of the Study Area and the boundary of District and Municipality are shown in Fig. A.1.

Some portions of the two (2) Districts of Milpa Alta and Tlalpan in D.F. Mexico and the five (5) Municipalities of Amecameca, Ecatepec, Jilotzingo, Juchitepec, Tlalmanalco in the Mexico State are not included in the Study Area because they are located out of the boundary of the drainage area of the Gran Canal.

The seven (7) municipalities of the Mexico state covered in the study area are included in the boundary of Metropolitan Area of Mexico city (AMCM) and remaining eight (8) municipalities are located outside AMCM as shown in Fig. A.2.

2. Population

Existing Population

According to the information obtained from the General Direction of Construction and Hydraulic Operation (DGCOH) and the State Committee of Water supply and Sanitation (CEAS), the existing total population of the Study Area in the year 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 average population density of the Study Area in 1993 is 50 person/ha. The average population density of the D.F. Mexico and the Mexico State are 65 person/ha and 35 person/ha, respectively.

The population density in the Districts of the D.F. Mexico ranges from 4 person/ha in Milta Alta to 204 person/ha in Iztacalco. The three (3) Districts of Benito Juarez, Cuauhtemoc and Venustitano Carranza neighboring Iztacalco and District G.A. Madero have more than 150 person/ha. While, the six (6) Districts of Cuajimalpa, Magdalena Contreas, Milta Alta, Tlahuaqc, Tlalpan and Xochimilco located in the south have less than 50 person/ha.

The population density in the Municipalities of the Mexico State ranges from 1 person/ha in Jilotzingo, Temamatla and Tenango del Aire to 160 person/ha in Tlalnepantla. The two (2) Municipalities of Ecatepec and Nezahualcoyotl located in the north of the D.F. Mexico have more than 100 person/ha. While, the eight (8) Municipalities of Amecameca, Ayapango de Gabriel R. Millan, Cocotiltan, Juchitepec, Temamatla, Tenango del Aire, Tlalmanalco located in the south east and Jilotzingo located in the north east have less than 10 person/ha.

The existing population and population density in the District/Municipality are shown in Table A.1. The regional distribution of the existing population density in the District/Municipality is shown in Fig. A.3.

Future Population

The future land use plan in the year 1997 and 2015 for the District/Municipality has not been prepared. However, the future population of District/Municipality has been projected by the DGCOH and 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. The estimated future population is shown below ;

	1993	1997	2000	2015*
D.F. Mexico	8,662,600	9,277,200	9,776,600	12,774,800
Mexico State	4,764,100	5,612,900	5,898,600	7,560,800
Total	13,426,700	14,890,100	15,675,200	20,335,600

Note : JICA estimation

Assuming that the trend of population in the district of D.F. Mexico and in the municipality of Mexico State will also be same.

The future population and population density in the District/Municipality are shown in Table A.1. The regional distribution of the future population density by District/Municipality for the year 1997 and 2015 is shown in Fig. A.4 and A.5 respectively.

The average population density of the Study Area in 2015 is 75 person/ha. The average population density of the D.F. Mexico and the Mexico State in 2015 are 96 person/ha and 55 person/ha, respectively.

The population density in the Districts of the D.F. Mexico in 2015 ranges from 5 person/ha in Milta Alta to 301 person/ha in Iztacalco. The population density of the Districts, except the six (6) Districts of Cuajimalpa, Magdalena Contreas, Milta Alta, Tlahuaqc, Tlalpan and Xochimilco, portions of which are protected as "the ecological preservation area", will be more than 100 person/ha.

The population density in the Municipalities of the Mexico State in 2015 ranges from 1 person/ha in Tenango del Aire to 310 person/ha in Ecatepec. The population density in the two (2) Municipalities of Atizapan de Zaragoza and Tlalnepantla located in the north of the D.F. Mexico will be more than 150 person/ha.

3. Land Use

The existing land use map and data for the D.F. Mexico were prepared by "Direccion General de Reordenacion y Protection Ecologia" in 1987.

In these maps and statistical data, land use of the D.F. Mexico is classified into five (5) categories: (1) residential use, (2) commercial use, (3) Institutional use, (4) industrial use and (5) other uses.

The other uses is allocated the biggest share of 57.21%, the second biggest share is that of residential use which is 28.78%, the existing residential use shares 28.78%. The shares of commercial, institutional and industrial use are 6.85%, 4.79% and 2.37%, respectively.

The existing land use patterns in 1987 for the Districts are shown in Table A.2.

The main futures of the existing land use in the D.F. Mexico are summarized below.

(1) Residential area is concentrated in the central part of the D.F. Mexico. The share of residential use in District Benito Juarez, Coyoacan, G. A Madero, Iztacalco and Iztapalapa is higher than 50% as shown in Fig. A.6.

(2) The share of commercial use in District Cuauhtemoc is higher than 50% as shown in Fig. A.6.

(3) Other area including "the ecological conservation area" is concentrated in the southern part of the D.F. Mexico. The share of other uses in Districts of Cuajimalpa, Magdalena Contreas, Milta Alta, Tlahuaqc, Tlalpan and

Xochimilco is higher than 50% as shown in Fig. A.6. In those Districts the share of "the ecological conservation area" in other uses is more than 70%.

The existing land use map and data for the Mexico State were prepared by "Secretariat of Urban Development and Public Works, the Mexico State (Secretaría de Desarrollo Urbano y Obras Públicas, Eatado de México)" in 1990. The JICA Study Team summarized and classified these data into five (5) categories same as the land use of the D.F. Mexico as shown in Table A.2.

The residential uses is allocated the biggest share of 49.28%, the second biggest share is that of the other use which is 35.88%. The shares of commercial, institutional and industrial use are 3.78%, 5.49% and 5.58%.

Residential areas are concentrated in the north of the D.F. Mexico. The share of residential use in four (4) Municipalities of Atizapan de Zaragoza, Ecatepec, Naucalpan and Amecameca is higher than 50% as shown in Fig. A.6.

No future land use plan is available for the Study Area.

4. Land Subsidence

Recently, the land subsidence problems have occurred in the central to the north eastern part of the Study Area because of excessive withdrawal of groundwater. The land subsidence observations have been conducted by DGCOH for the last 10 years.

According to the results of the observations, the isohyet of land subsidence is shown in Fig. A.7. The solid lines are made based on the observation data by DGCOH in D.F. Mexico and the dotted lines are made by JICA Study Team based on the following study and observations ; "Estudio Geotecnico en Posibles Stitos de Ubicacion de Obras Hydraulicas en Los Afluentes de Dranaje en La Parte Norte del Ex-lago de Texcoco" conducted by CNA in 1994 and the observations of land subsidence along the Gran Canal and Dren General del Valle by DGCOH.

Land subsidence of the Study Area ranges from 20 cm to 250 cm for the last 10 years (2 ~ 25 cm/year) and declines from the central to the north east. In District Venustiano Carranza and Municipality Nezahualcoyotl, the land subside up to a depth of 20 cm/year to 25 cm/year.

The District Venustiano Carranza, in which the Gran Canal starts, the depth of land subsidence becomes shallower toward downstream along the Gran Canal.

The depths of subsidence at the starting point of the Gran Canal and around the ex-soda plant site are about 20 cm/year and 5 cm/year, respectively (See, Fig. A.8). And the biggest land subsidence along the Gran Canal is 24 cm/year which is found at connection with Remedios River.

5. Economy

The economy of the United States of Mexico underwent disturbances in a greater part of the 1980's due to drastic declines of oil prices, political factors and others. As a consequence, it can be said that the decade was economically hard to the Mexican people.

The GDP of Mexico in 1990 is calculated to be N$ 1,066,051 million at 1993 prices, while the population of the country in the same year was 81,140,922. It means that the per capita GDP was N$ 13,138 or US$ 4,106 at the exchange rate of N$ 3.2 to the US. dollar.

On the other hand, the national GDP in 1980 works out to be N$ 903,090 million at 1993 prices. In other words, the national economy grew at the average annual rate of 1.67% during the 1980's. Demographically, the nation was composed of 66,846,833 people in 1980, growing at the average annual rate of 1.96% during that decade.

It is to be noted that the demographical growth slightly overtook the economic growth from 1980 to 1990. As a consequence, the per capita GDP of the country in 1980, which is calculated to be N$ 13,510 or US$ 4,222 slightly declined a decade after.

From the latter part of 1980's up to the present the economy of the country is growing smoothly at the average annual rate of about 3%.

Turning to the economy of the Study Area, the relevant data are available only up to 1980. Therefore, it is not sure about the economic trends in the Study Area from 1980 onward. However, it can be assumed that the general economic climate of the Study Area goes hand in hand with that of the country in light of the fact that the Study Area constitutes the politico-economic center of the country, having occupied 29.30% of the national GDP in 1980.

Supposing the above assumption holds true, it can be said that the economic situation of the Study Area may not be very much different between now and

1980. That is to say, what the economy of the Study Area in 1980 tells may be useful and worthwhile in estimating the existing economy of that area.

The Study Area is composed of the D.F. Mexico and a part of the Mexico State. The GDP of the D.F. Mexico in 1980 is calculated at N$ 217,389 million at 1993 prices. From 1970 to 1975 it grew at the average annual rate of 5.9% and from 1975 to 1980 its average annual growth rate was 7.9%.

The shares of the primary, secondary and tertiary industry in GDP in the district were 0.3%, 33.8% and 65.9% respectively in 1980. It is to be noted that the proportion of the primary industry is negligible and at the same time the proportion of the tertiary industry is marked reflecting the highly urban nature of the district. Furthermore, it can be said that the proportion of the secondary industry is comparatively big when one considers that the D.F. Mexico is the political and administrative center of the country.

Sub-sector wise, "Industry, Manufacturing" tops with 27.0%, followed by "Community, Social and Personal Services" with 26.0% and "Commerce, Restaurants and Hotels" with 25.7%.

The population of the D.F. Mexico was 8,831,079 in 1980. The per capita GDP of the district in the same year is, therefore, calculated at N$ 24,616 or US$ 7,693. It is by 82.2% higher than the national average in the same year.

The GDP of the Mexico State belonging to the Study Area is assumed to be 50% of that of the whole state based on the population ratio. It is calculated at N$ 47,249 million in 1980 at 1993 prices. From 1970 to 1975 it grew at the average annual rate of 10.8% and from 1975 to 1980 its average annual growth rate was 10.2%.

The shares of the primary, secondary and tertiary industry in GDP in the area were 4.8%, 47.8% and 47.4% respectively in 1980. It is to be noted that the proportion of the secondary industry is the biggest slightly surpassing that of the tertiary industry. It can be no exaggeration to say that the Mexico State is an industrial state.

Sub-sector wise, "Industry, Manufacturing" tops with 38.1%, followed by "Commerce, Restaurants and Hotels" with 23.7% and "Community, Social and Personal Services" with 12.0%.

The population of the Mexico State belonging to the Study Area was 3,782,168 in 1980. The per capita GDP of the district in the same year is, therefore, calculated at N$ 12,493 or US$ 3,904. It is about 7.5% lower than the national average in the same year.

Demographically, the shares of the D.F. Mexico and the Mexico State in the Study Area are calculated at 70.0% and 30.0% respectively in 1980, while economically, they are calculated at 82.1% and 17.9% respectively in the same year.

The GDP of the Study Area as a whole sums up to N$ 264,638 million for 1980, whereas the population of the area adds up to 12,613,247 for the same year. It follows from the above that the per capita GDP of the Study Area was on average N$ 20,981 or US$ 6,557 in 1980. It is about 55.4% greater than the national average in the same year (Refer to Table A.3).

6. Climate, Topography and Geology

The Study Area is located in the southern part of the Valley of Mexico situated in lat. 19°24" N. and long. 99°12" W.

Climate

The climate of the Valley of Mexico is the Temperate one due to the high altitude of about 2,200 m and characterized by two (2) seasons ;

Rainy season	:	June	~	September
Dry season	:	October	~	May

Monthly average air temperature of the Study Area ranges from 12.9°C in December to 19.3°C in May with an annual average of 15.0°C (See, Fig. A.8). The fluctuation of air temperature in a day is wide due to the high altitude.

Average annual rainfall of the Study Area in the last twelve (12) years (1982 - 1993) is to be 720.4 mm of which more than 80% concentrates in the four (4) rainy months from June to September.

Monthly average rainfall of the Study Area is shown in Fig. A.9.

Topography

The altitude of the Valley is more than 2,200 m and closed in the south, west and east side by mountains with an altitude of more than 3,000 m. The land of the central area gently declines toward north (See, Fig. A.10).

The maximum area of the six (6) Districts in D.F. Mexico of Avaro Obergon, Cuajimalpa, Magdalena Contreas, Milta Alta, Tlalpan and Xochimilco and the nine (9) Municipalities in the Mexico States of Amecameca, Ayapango de Gabriel R.Millan, Cocotiltan, Chalco, Temamatla, Tenango del Arire, Juchitepec and Tlalmanaco is shared by the mountainous area.

Geology

According to the geological survey undertaken by F. Mooser, the Study Area is covered by four (4) stratigraphies of Alluvial Deposits, Volcanic Basaltic Series, Tarango Formation and Andesite (See, Fig. A.11).

The low-lying part of the Study Area is covered by the Quaternary Alluvial Deposits. The volcanic Basaltic Series blocked the Valley of Mexico at the south. The Tarango Formation and the Andesite lie in the highland parts of the east and west of the Valley.

Table A.1 Area and Population by District / Municipality in Study Area

No.	Name of District / Municipality	Area (km 2)	Existing (1993) Population	Existing (1993) Population Density (person/ha)	Urgent (1997) Population	Urgent (1997) Population Density (person/ha)	Future (2015) Population	Future (2015) Population Density (person/ha)
District in Federal District			1)		1)		3)	
1.	Alvaro Obregon	94.50	690,100	74	739,100	79	1,017,800	108
2.	Azcapotzalco	33.50	493,000	148	527,900	158	727,000	218
3.	Benito Juarez	26.60	426,100	161	456,300	172	628,300	237
4.	Coyoacan	54.40	666,700	123	713,900	132	983,100	181
5.	Cuajimalpa	80.90	127,300	16	136,400	17	187,800	24
6.	Cuauhtemoc	32.44	625,700	193	670,100	207	922,700	285
7.	G. A. Madero	87.00	1,326,100	153	1,420,100	164	1,955,600	225
8.	Iztacalco	22.90	467,000	204	500,100	219	688,700	301
9.	Iztapalapa	117.50	1,567,900	134	1,679,300	143	2,312,200	197
10.	Magdalena Contreras	68.00	204,200	31	218,700	33	301,100	45
11.	Miguel Hidalgo	42.50	430,900	102	461,500	109	635,500	150
12.	Milpa Alta	222.16	67,000	4	71,800	4	98,800	5
13.	Tlahuaqc	93.00	221,300	24	236,900	26	326,300	36
14.	Tlalpan	212.23	515,500	25	552,100	27	760,300	36
15.	Venustiano Carranza	32.42	547,200	169	586,000	181	806,900	249
16.	Xochimilco	122.00	286,600	24	307,000	26	422,700	35
	Total of District	1,342.05	8,662,600	65	9,277,200	70	12,774,800	96
Municipality in Mexico State			3)		3)		2)	
17.	Amecameca	181.20	38,100	3	48,400	3	53,600	3
18.	Atizapan de Zaragoza	48.13	330,700	69	475,300	99	783,600	163
19.	Ayapango de Gabriel R. Millan	42.50	4,400	2	5,700	2	7,000	2
20.	Cocotitlan	40.00	8,500	3	10,800	3	11,000	3
21.	Chalco	203.75	296,800	15	467,000	23	850,400	42
22.	Ecatepec	69.69	1,022,300	147	1,376,200	198	2,157,400	310
23.	Huixquilucan	122.50	138,400	12	207,100	17	426,000	35
24.	Jilotzingo	85.00	5,100	1	6,400	1	9,300	2
25.	Juchitepec	40.94	4,200	2	4,900	2	5,800	2
26.	Naucalpan	158.13	825,200	53	872,500	56	1,001,400	64
27.	Nezahualcoyotl	93.13	1,317,800	142	1,322,300	142	1,362,000	147
28.	Temamatla	56.88	5,600	1	7,200	2	9,900	2
29.	Tenango del Aire	90.31	6,500	1	8,300	1	8,800	1
30.	Tlalmanalco	119.06	23,200	2	35,100	3	23,900	3
31.	Tlalnepantla	46.34	737,300	160	765,700	166	850,700	184
	Total of Municipality	1,397.56	4,764,100	35	5,612,900	41	7,560,800	55
	Total of Study Area	2,739.61	13,426,700	50	14,890,100	55	20,335,600	75

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

Table A.2 Existing Land Use by District/Municipality in Study Area

No.	Name of District	Residential	Commercial	Institutional	Industrial	Others	Total (km2)
District in Federal District							
1.	Alvaro Obregon	44.717	3.317	9.384	3.572	33.510	94.50
		47.32%	3.51%	9.93%	3.78%	35.46%	100.00%
2.	Azcapotzalco	16.315	3.082	4.858	8.275	0.970	33.50
		48.70%	9.20%	14.50%	24.70%	2.90%	100.00%
3.	Benito Juarez	18.886	2.820	3.352	0.479	1.063	26.60
		71.00%	10.60%	12.60%	1.80%	4.00%	100.00%
4.	Coyoacan	32.096	0.544	1.632	1.632	18.496	54.40
		59.00%	1.00%	3.00%	3.00%	34.00%	100.00%
5.	Cuajimalpa	5.178	7.038	1.537	0.000	67.147	80.90
		6.40%	8.70%	1.90%	0.00%	83.00%	100.00%
6.	Cuauhtemoc	7.043	19.454	3.779	1.246	0.918	32.44
		21.71%	59.97%	11.65%	3.84%	2.83%	100.00%
7.	G. A. Madero	45.649	8.204	6.560	4.080	22.507	87.00
		52.47%	9.43%	7.54%	4.69%	25.87%	100.00%
8.	Iztacalco	13.740	1.832	4.122	2.519	0.687	22.90
		60.00%	8.00%	18.00%	11.00%	3.00%	100.00%
9.	Iztapalapa	63.568	18.213	7.520	4.935	23.264	117.50
		54.10%	15.50%	6.40%	4.20%	19.80%	100.00%
10.	Magdalena Contreras	23.310	2.870	0.000	0.000	41.820	68.00
		34.28%	4.22%	0.00%	0.00%	61.50%	100.00%
11.	Miguel Hidalgo	21.186	3.222	5.657	3.392	9.043	42.50
		49.85%	7.58%	13.31%	7.98%	21.28%	100.00%
12.	Milpa Alta	8.430	2.922	1.124	0.000	209.684	222.16
		3.00%	1.04%	0.40%	0.00%	95.56%	100.00%
13.	Tlahuaqc	14.638	3.274	0.586	0.000	74.502	93.00
		15.74%	3.52%	0.63%	0.00%	80.11%	100.00%
14.	Tlalpan	38.376	5.616	4.368	0.000	163.870	212.23
		12.30%	1.80%	1.40%	0.00%	84.50%	100.00%
15.	Venustiano Carranza	13.941	6.484	9.564	0.648	1.783	32.42
		43.00%	20.00%	29.50%	2.00%	5.50%	100.00%
16.	Xochimilco	19.215	3.062	0.244	1.061	98.418	122.00
		15.75%	2.51%	0.20%	0.87%	80.67%	100.00%
	Total of District	386.288	91.954	64.287	31.839	767.682	1,342.05
		28.78%	6.85%	4.79%	2.37%	57.21%	
Municipality in Mexico State							
17.	Amecameca	114.66	2.57	17.13	19.94	26.90	181.20
		63.28%	1.42%	9.45%	11.00%	14.85%	100.00%
18.	Atizapan de Zaragoza	32.38	1.06	1.95	0.9	11.84	48.13
		59.88%	2.20%	4.05%	1.87%	32.00%	100.00%
19.	Ayapango de Gabriel R. Millan	18.31	1.22	2.83	2.37	17.77	42.50
		43.08%	2.87%	6.66%	5.58%	41.81%	100.00%
20.	Cocotitlan	22.55	0.86	3.46	0.52	12.61	40.00
		23.10%	2.15%	8.65%	1.30%	64.80%	100.00%
21.	Chalco	74.06	6.84	11.67	7.68	103.5	203.75
		36.35%	3.36%	5.73%	3.77%	50.80%	100.00%
22.	Ecatepec	36.55	3.39	4.36	8.57	16.82	69.69
		52.45%	4.86%	6.26%	12.30%	24.14%	100.00%
23.	Huixquilucan	36.61	6.99	3.92	2.87	72.11	122.50
		29.89%	5.71%	3.20%	2.34%	58.87%	100.00%
24.	Jilotzingo	56.6	0.93	2.74	0.79	23.94	85.00
		30.41%	1.09%	3.22%	0.93%	64.35%	100.00%
25.	Juchitepec	16.26	1.27	2.54	1.91	18.96	40.94
		39.72%	3.10%	6.20%	4.67%	46.31%	100.00%
26.	Naucalpan	104.23	10.15	3.77	2.44	37.54	158.13
		65.91%	6.42%	2.38%	1.54%	23.74%	100.00%
27.	Nezahualcoyotl	28.16	6.44	1.11	10.02	47.4	93.13
		30.24%	6.92%	1.19%	10.76%	50.90%	100.00%
28.	Temamatla	26.37	1.57	4.09	1.44	23.41	56.88
		46.36%	2.76%	7.19%	2.53%	41.16%	100.00%
29.	Tenango del Aire	40.43	2.48	6.22	5.44	35.74	90.31
		29.54%	2.75%	6.89%	6.02%	54.80%	100.00%
30.	Tlalmanalco	59.31	2.84	9.04	8.79	39.08	119.06
		35.48%	2.39%	7.59%	7.38%	47.16%	100.00%
31.	Tlalnepantla	22.21	4.15	1.95	4.27	13.76	46.34
		47.9%	9.0%	4.2%	9.2%	29.7%	100.00%
	Total of Municipality	688.69	52.76	76.78	77.95	501.38	1,397.56
		49.28%	3.78%	5.49%	5.58%	35.88%	
	Total of Study Area	1074.978	144.714	141.067	109.789	1269.062	2,739.610
		39.24%	5.28%	5.15%	4.01%	46.32%	

Source : DEPARTMENTO DEL DISTRIO FEDERAL
DIRECCION GENERAL DE REORDENACION URBANA Y PROTECCION ENCOLOGIA

Table A.3 Economy of the Study Area

1. Federal District

(Unit: N$ million at 1993 prices)

Activities	1970	1975	1980
Gross Domestic Product	111,702 (100.0%)	148,488 (100.0%)	217,389 (100.0%)
1. Farming, Forestry and Fishing	302 (0.2%)	483 (0.3%)	534 (0.3%)
2. Mining	368 (0.3%)	565 (0.4%)	1,510 (0.7%)
3. Industry, Manufacturing	30,905 (27.7%)	39,521 (26.6%)	58,617 (27.0%)
4. Construction	5,300 (4.7%)	6,424 (4.3%)	11,933 (5.5%)
5. Electricity	859 (0.8%)	955 (0.6%)	1,263 (0.6%)
6. Commerce, Restaurants and Hotels	34,959 (31.3%)	42,466 (28.6%)	55,786 (25.7%)
7. Transport, Warehousing and Communications	6,408 (5.7%)	10,487 (7.1%)	17,295 (8.0%)
8. Financial Services, Insurance and Real Estate	9,487 (8.3%)	11,021 (7.5%)	13,998 (6.2%)
9. Community, Social and Personal Services	23,482 (21.0%)	36,566 (24.6%)	56,453 (26.0%)

Sources : Anuario Estadistico del Distrito Federal, 1984 and JICA

2. State of Mexico

(Unit: N$ million at 1993 prices)

Activities	1970	1975	1980
Gross Domestic Product	17,465 (100.0%)	29,111 (100.0%)	47,249 (100.0%)
1. Farming, Forestry and Fishing	1,076 (6.2%)	1,590 (5.5%)	2,256 (4.8%)
2. Mining	69 (0.4%)	127 (0.4%)	208 (0.4%)
3. Industry, Manufacturing	8,404 (48.1%)	11,509 (39.5%)	17,983 (38.1%)
4. Construction	1,130 (6.5%)	2,555 (8.8%)	3,932 (8.3%)
5. Electricity	173 (1.0%)	349 (1.2%)	485 (1.0%)
6. Commerce, Restaurants and Hotels	2,843 (16.3%)	6,026 (20.7%)	11,197 (23.7%)
7. Transport, Warehousing and Communications	773 (4.4%)	1,504 (5.2%)	2,662 (5.6%)
8. Financial Services, Insurance and Real Estate	1,514 (8.6%)	2,147 (7.3%)	2,881 (6.1%)
9. Community, Social and Personal Services	1,483 (8.5%)	3,304 (11.4%)	5,645 (12.0%)

Note: GDP of the study area is assumed to be 50% of that of the entire area.
Sources: Anuario Estadistico del Distrito Federal, 1984 and JICA

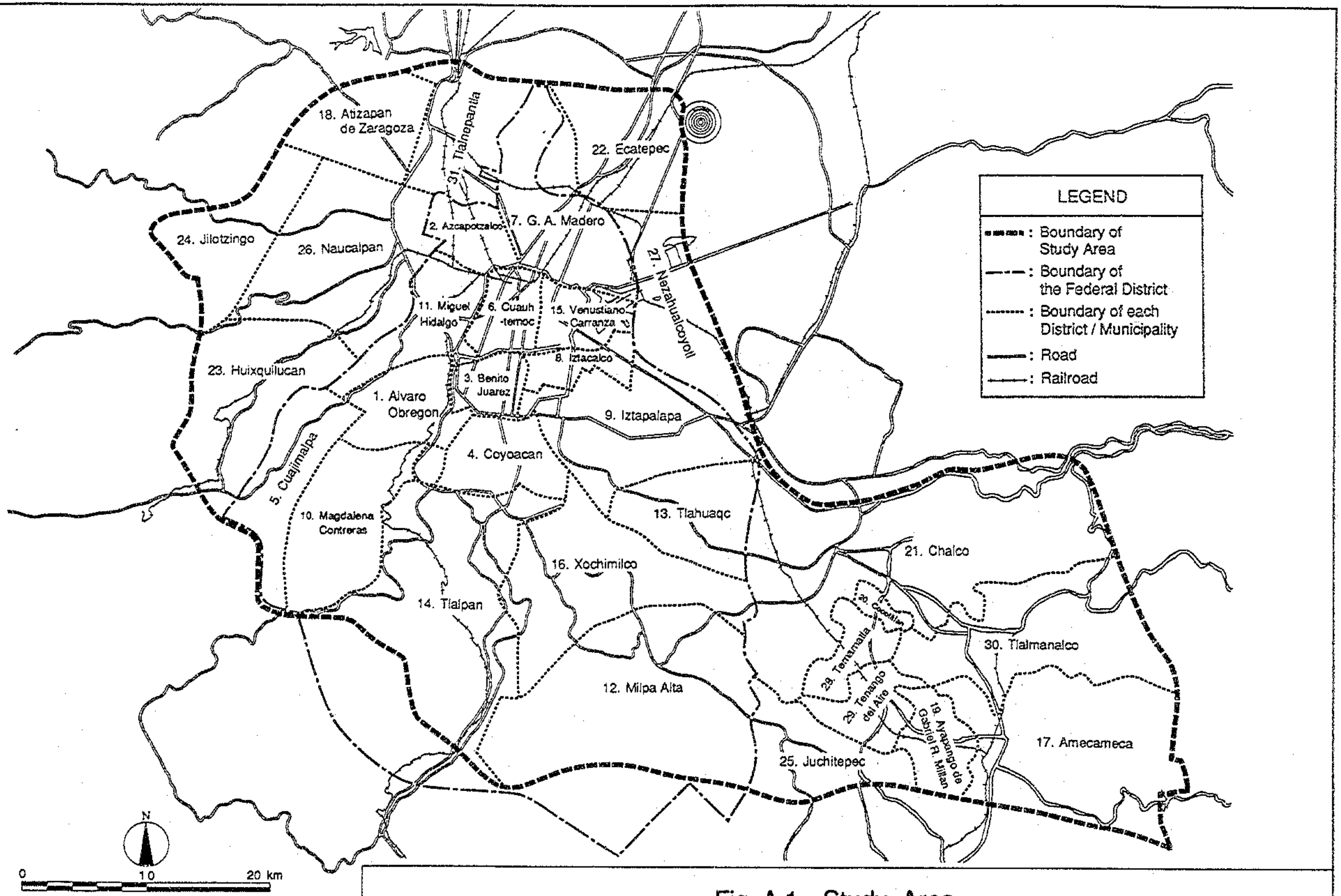


Fig. A.1 Study Area

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

JICA

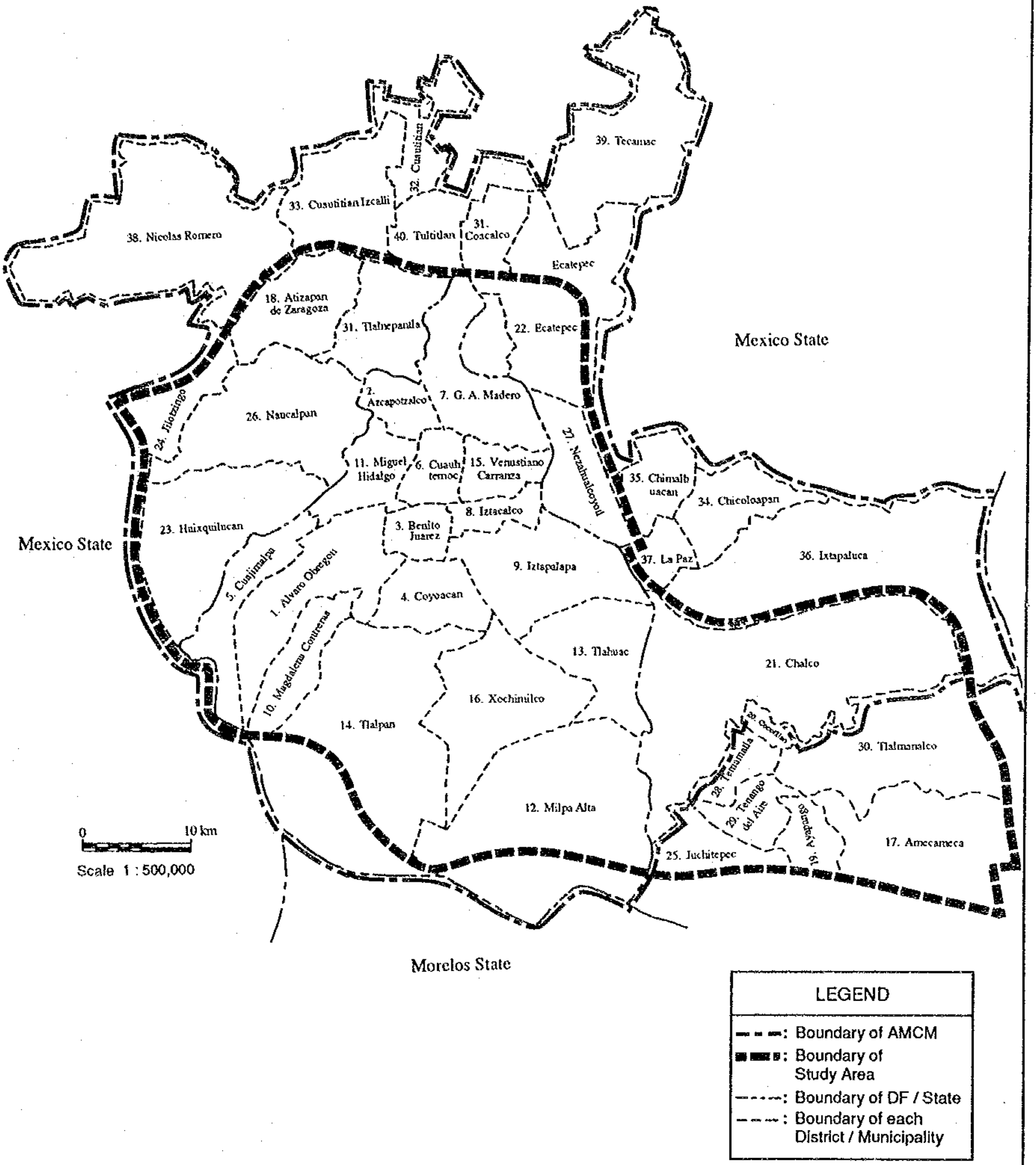


Fig. A.2 Metropolitan Area of Mexico City (AMCM)

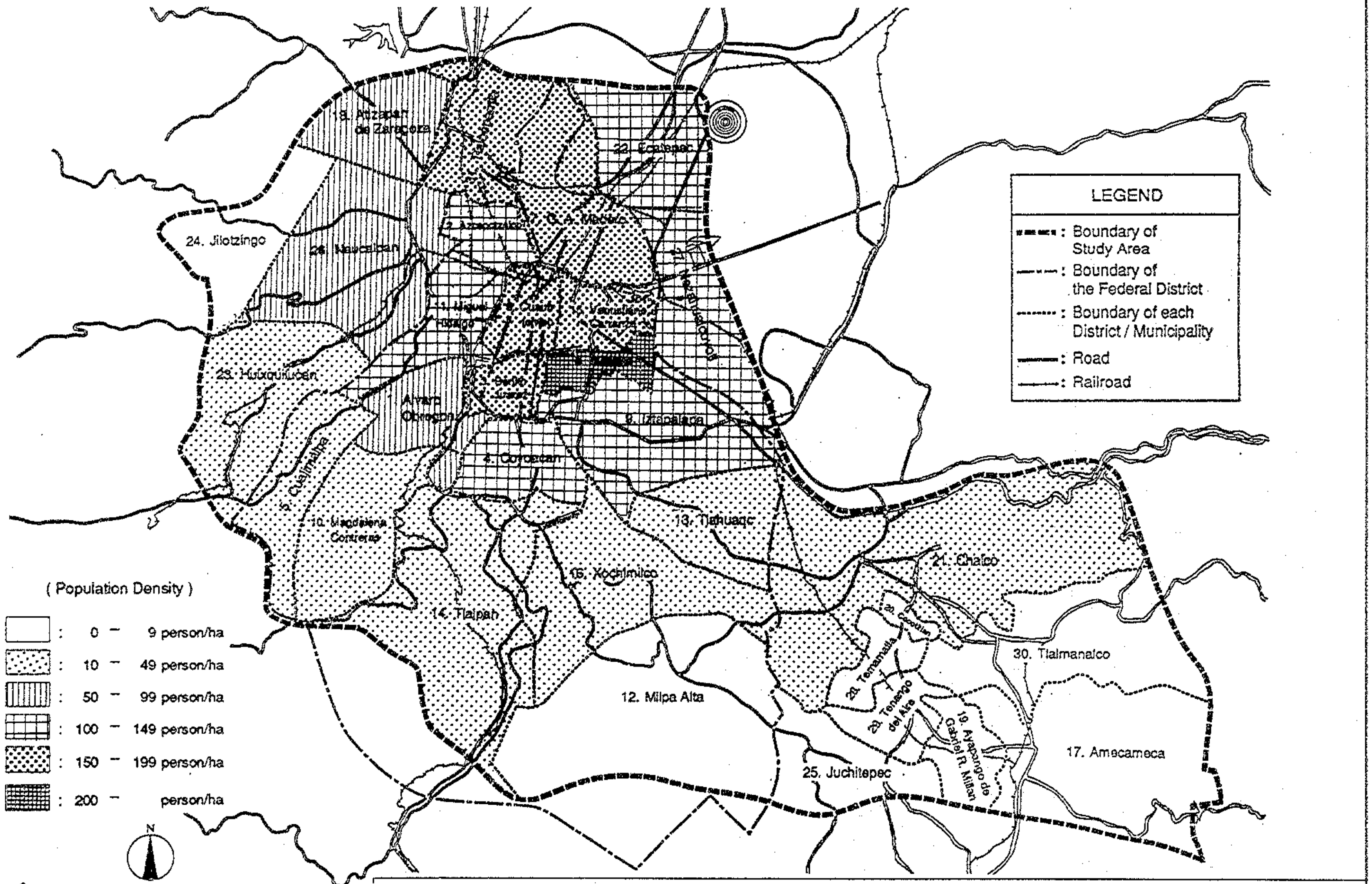


Fig. A.3 Existing Population Density by District / Municipality (1993)

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

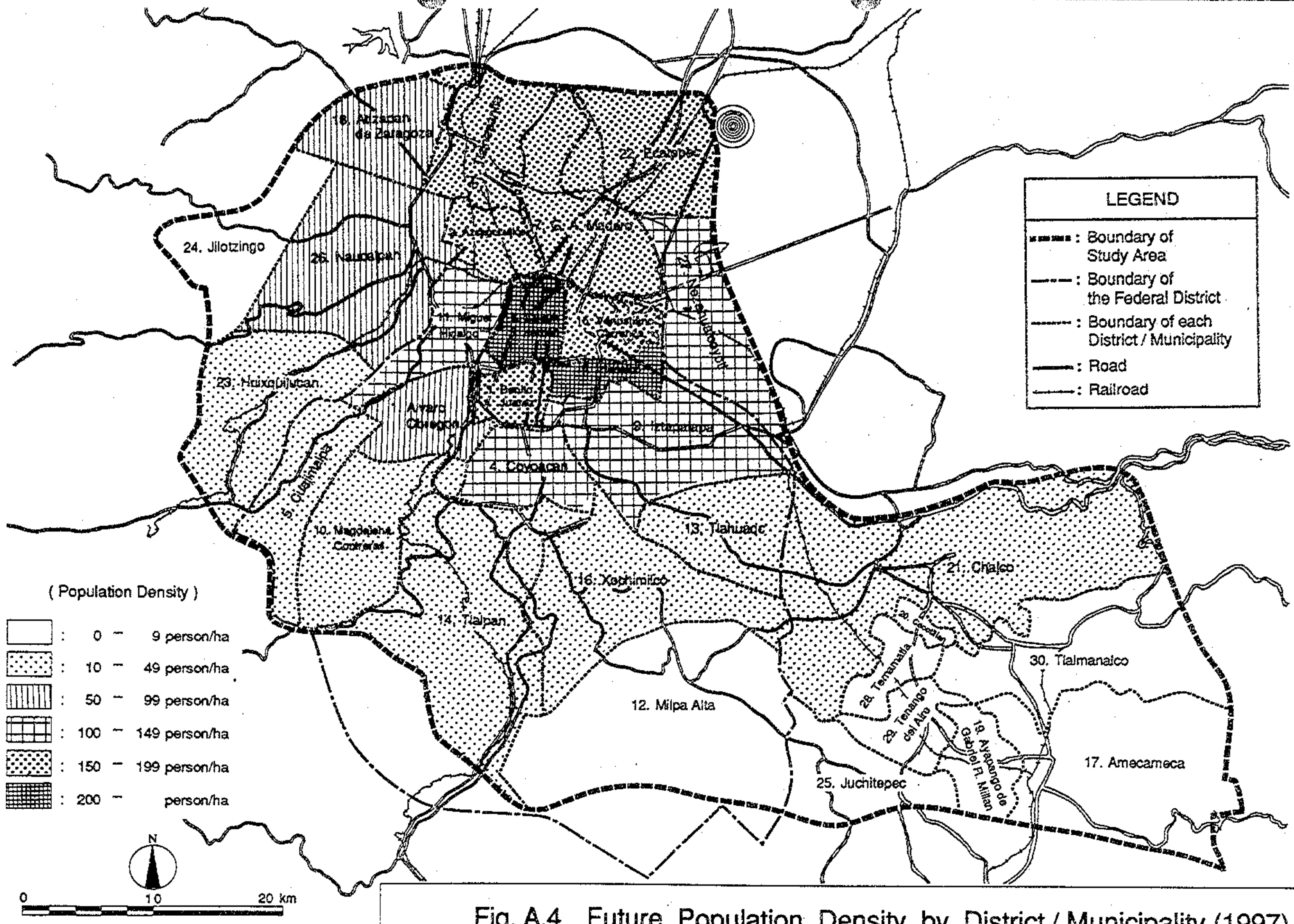


Fig. A.4 Future Population Density by District / Municipality (1997)

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

JICA

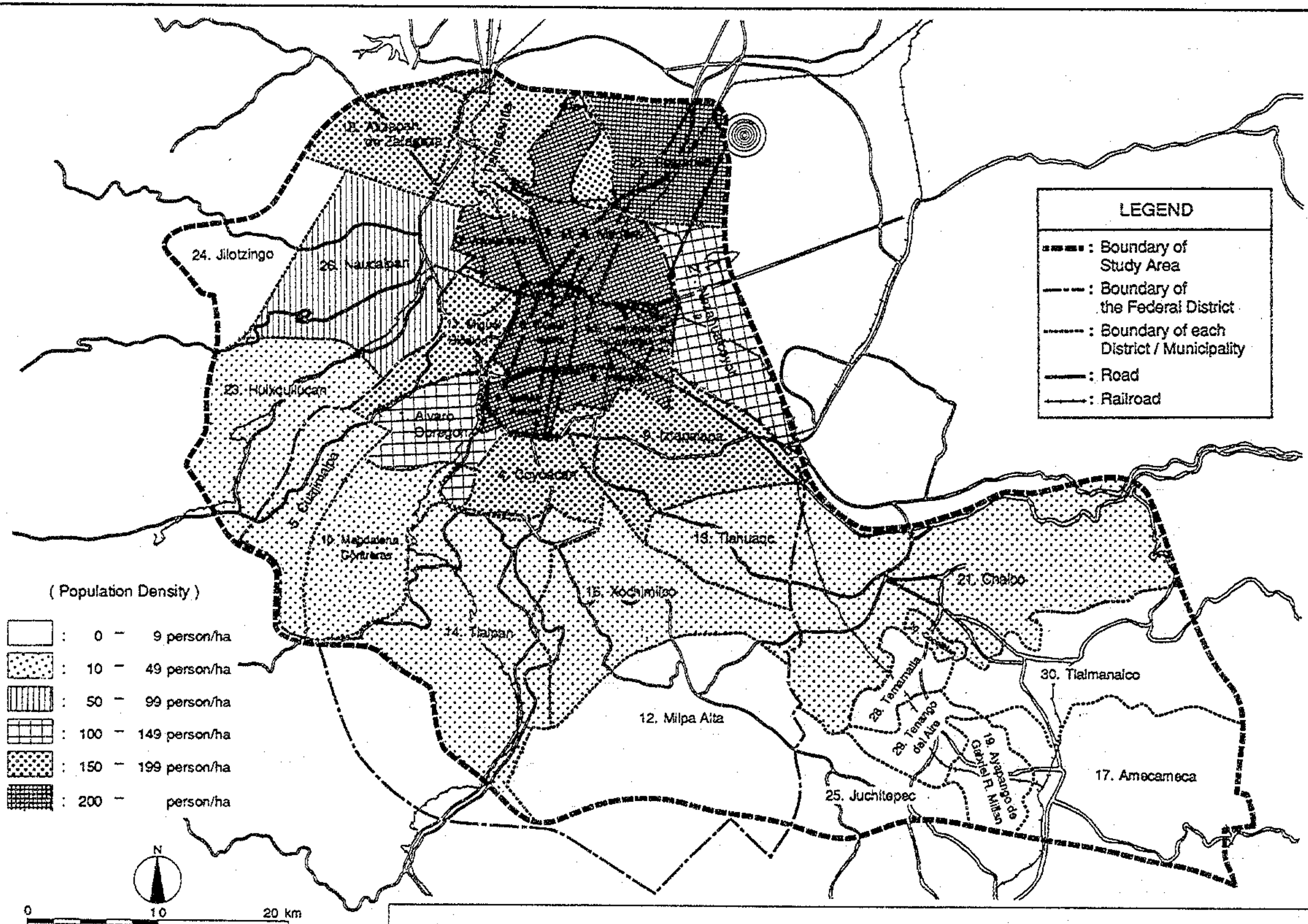


Fig. A.5 Future Population Density by District / Municipality (2015)

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

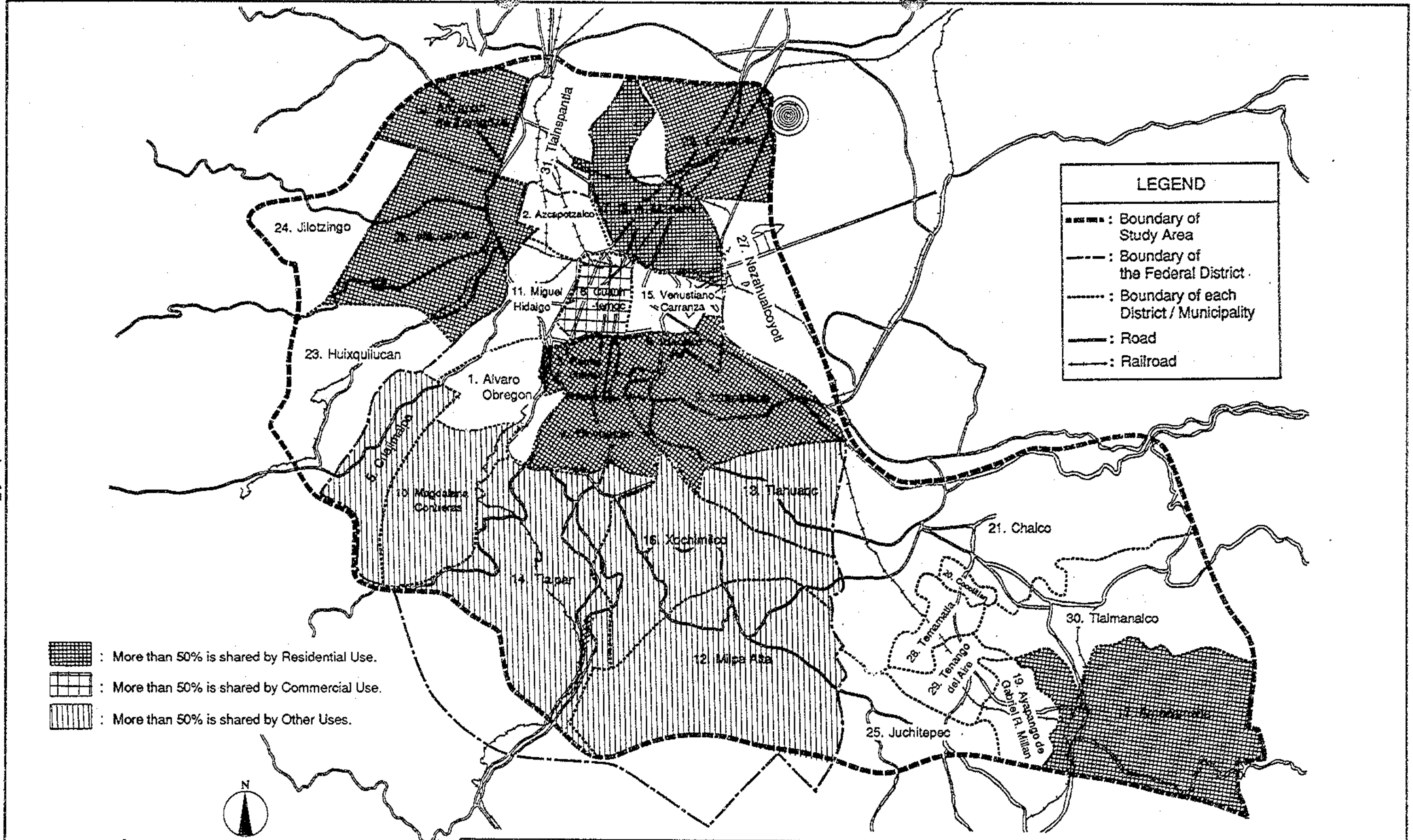


Fig. A.6 Share of Existing Land Use by District / Municipality in the DF Mexico

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

JICA

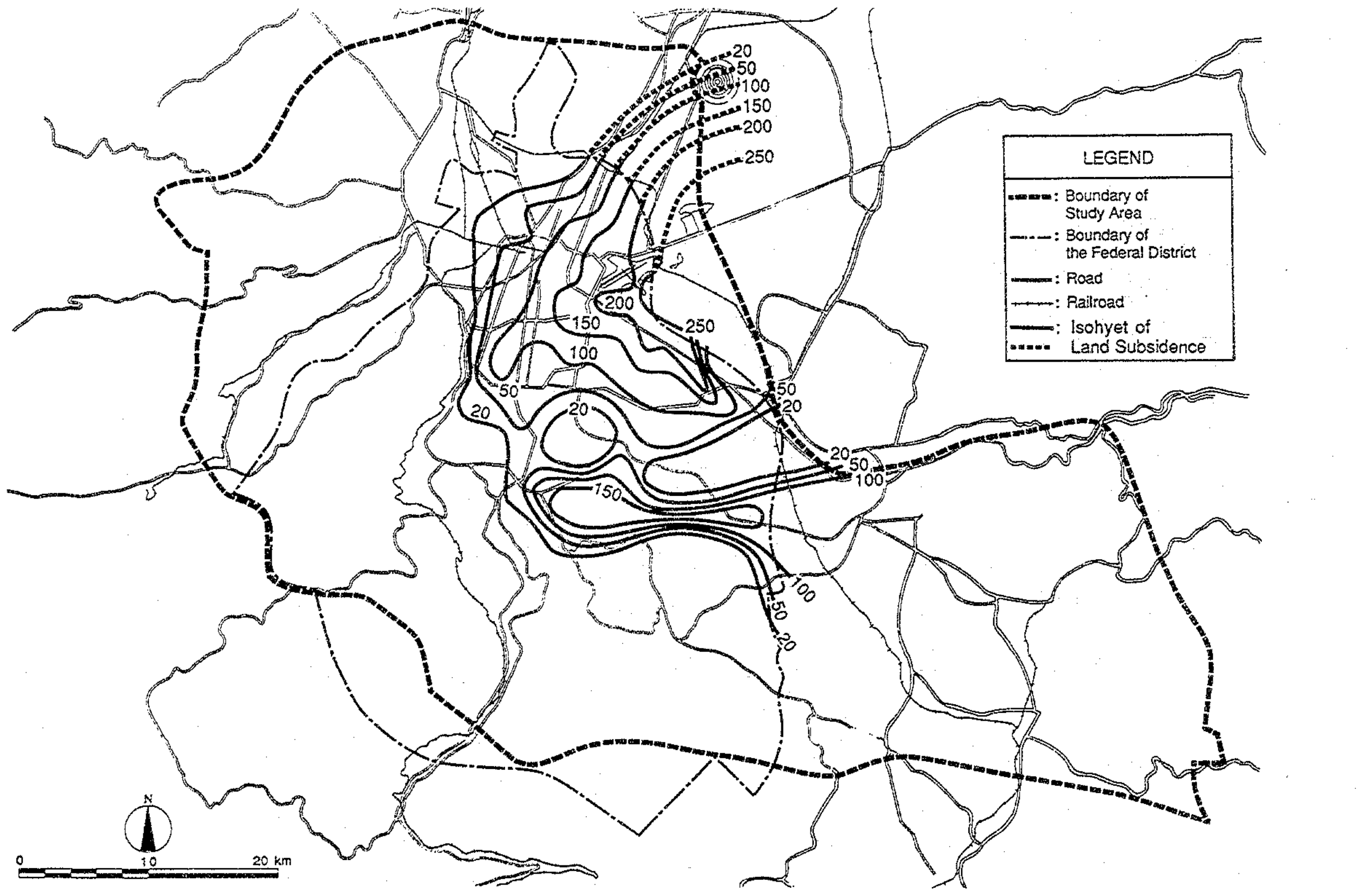


Fig. A.7 Land Subsidence for the Last 10 Years (1983 to 1992) in Study Area

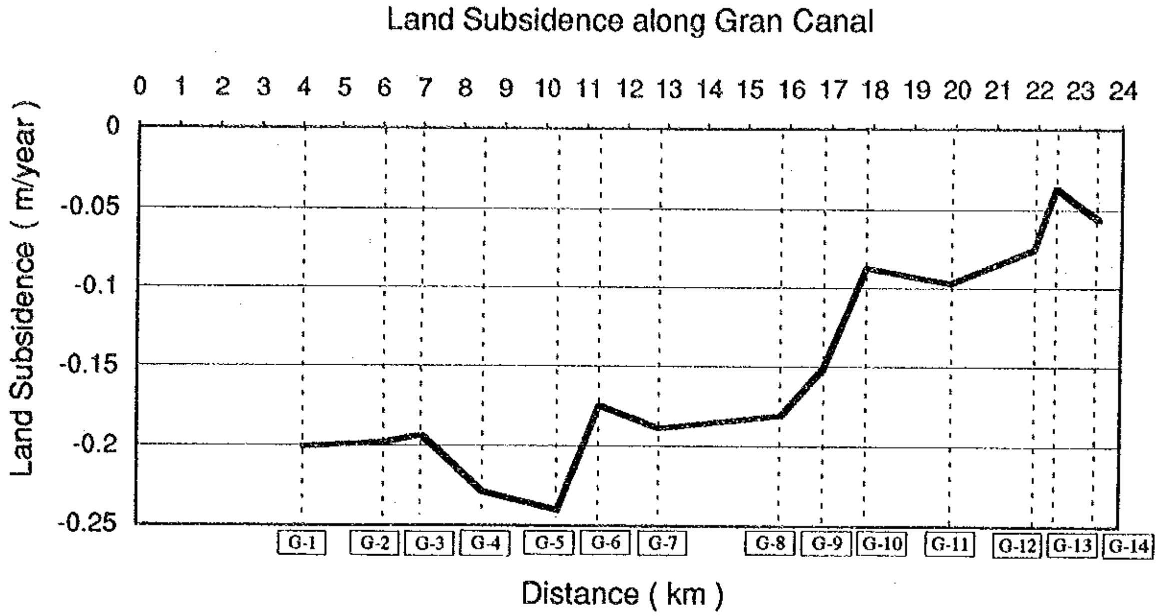
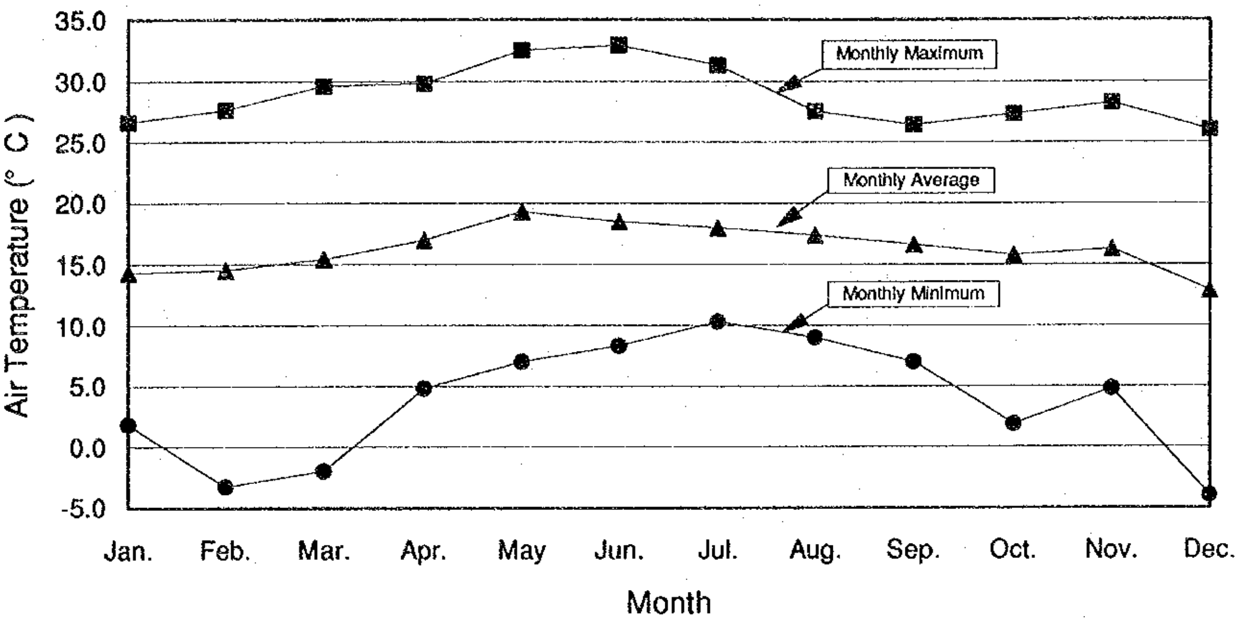


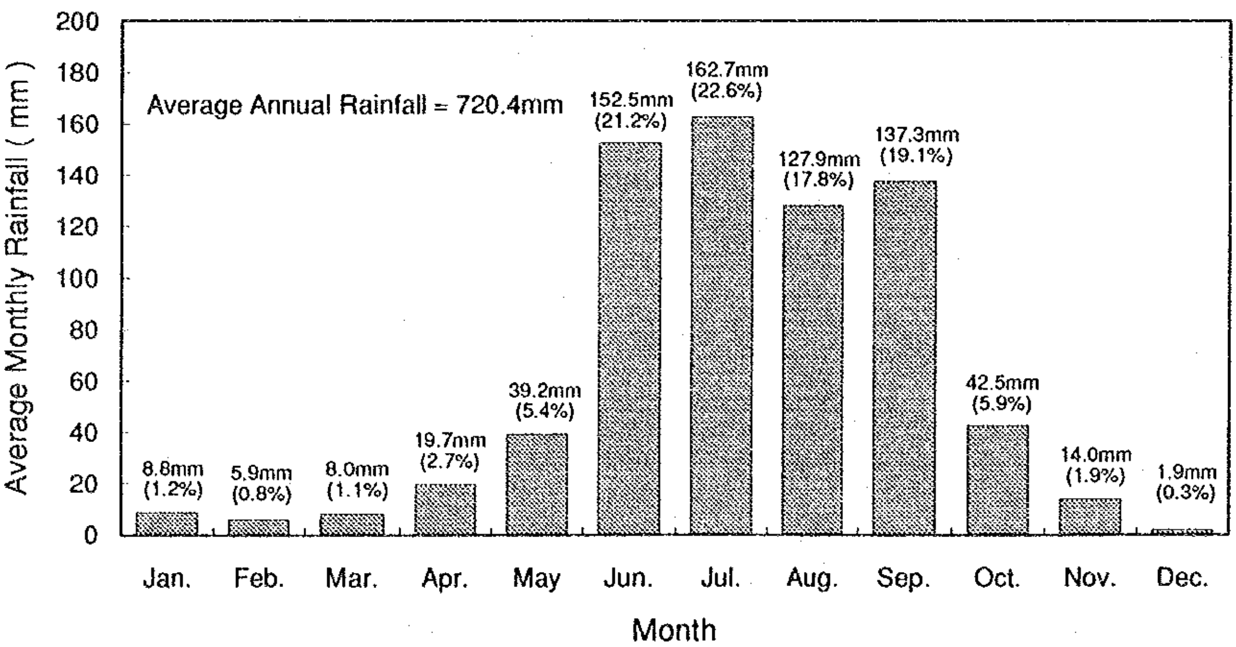
Fig. A.8 Land Subsidence along Gran Canal for the Last 5 Years (1985 to 1990)

Monthly Average Air Temperature in 1989



Source : Comision Nacional del Agua (CNA)

Average Monthly Rainfall from 1982 to 1993



Source : Subdireccion de Informatica, DGCOH

Fig. A.9 Monthly Average Air Temperature and Average Monthly Rainfall

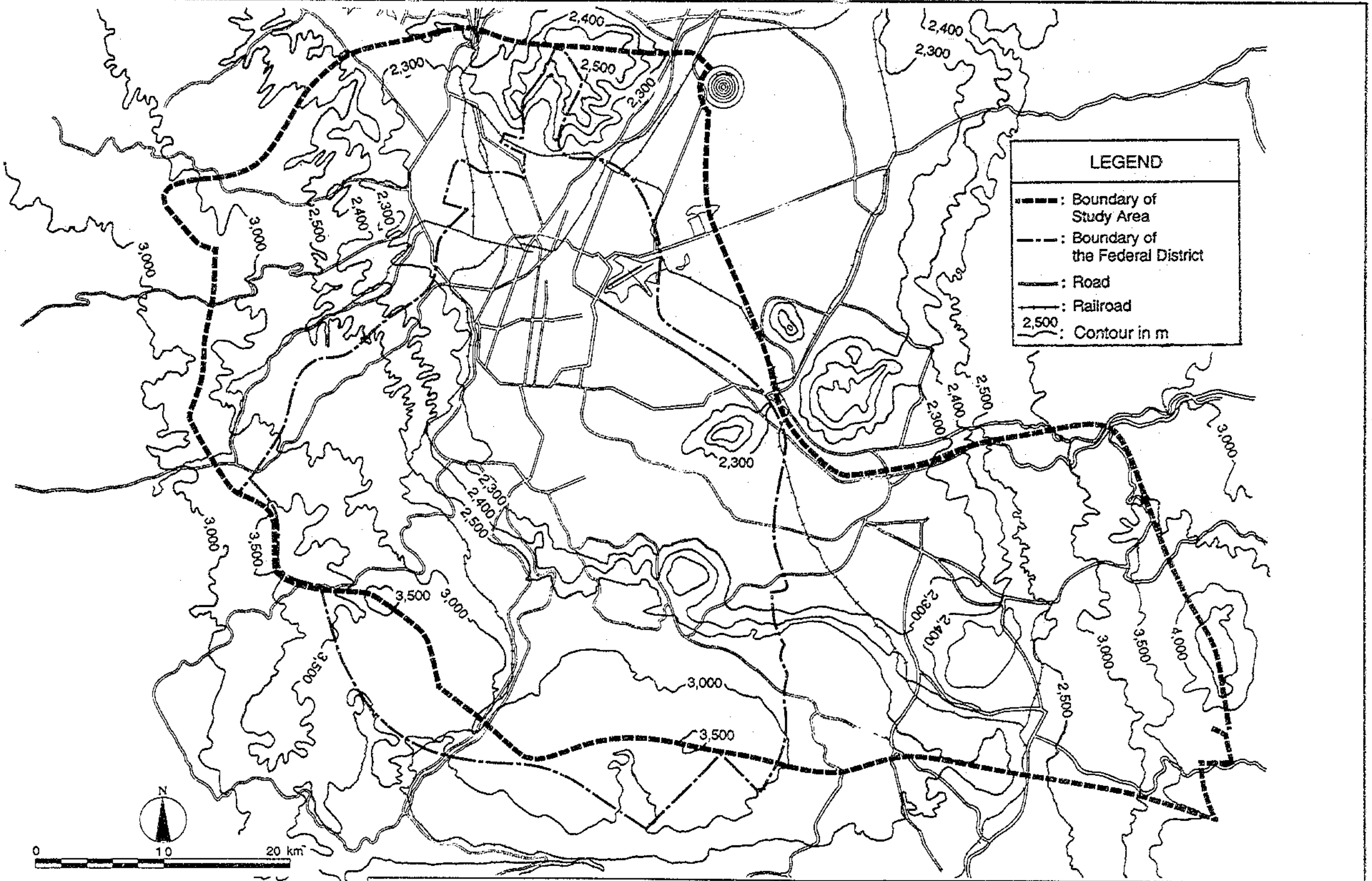
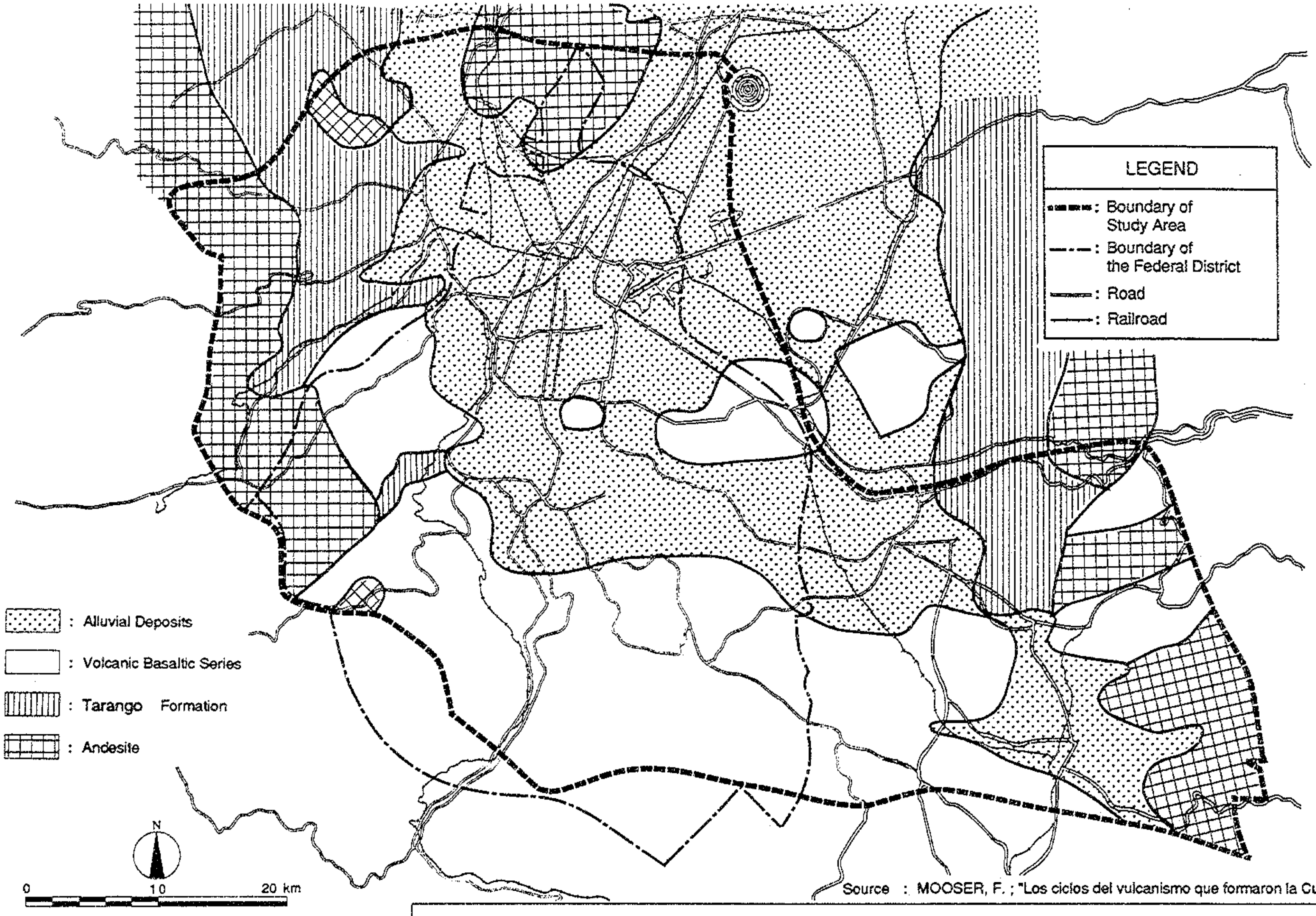


Fig. A.10 Topographic Map of Study Area

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



Source : MOOSER, F. ; "Los ciclos del vulcanismo que formaron la Cuena de Mexico"

Fig. A.11 Geological Map of Study Area

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

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APPENDIX B

APPENDIX B WASTEWATER GENERATION

1. Water Consumption

1.1 Water Resources

1.1.1 Water Resources of the AMCM Area

Metropolitan Area of Mexico City (AMCM) consists of entire D.F. Mexico and 17 municipalities of Mexico state. Seven (7) municipalities are same as that of study area (ref Appendix A, section 1). Existing water sources in AMCM are classified into three (3) categories; groundwater of Mexico Valley and Lerma Valley, spring water of Magdalena and river water of Cutzamala (refer Fig B.1)

Based on the annual report of water for D.F. Mexico "Agua 2000 Estrategia para la Ciudad de Mexico (Agua 2000)", existing total capacity of water sources of Metropolitan Area of Mexico City (AMCM) is estimated to be 59.0 m^3/sec and the quantity of each water source is as follows:

(unit : m^3/sec)

Water Source	D.F. Mexico	Mexico State	Total
Groundwater of Mexico valley	21.7	19.0	40.7
Groundwater of Lerma Valley	4.9	1.0	5.9
Spring water of Magdalena	1.1	0.5	1.6
River water of Cutzamala	7.6	3.2	10.8
Total	35.3	23.7	59.0

AMCM consists of entire D.F. Mexico and 17 municipalities of Mexico State. Existing and future population in the year of 1993 and 2000 in 17 municipalities of Mexico State is estimated to be 8.0 million and 11.57 million.

The annual report of Agua 2000 has proposed the future development plan of each water source till 2000, which is shown in Table B.1. Based on the annual report of Agua 2000, the capacity of Cutzamala water source will be increased by 8.0 m^3/sec in 1994 and 6.0 m^3/sec in 1998. Hence in Yr. 2000, the capacity of Cutzamala water source will be increased to 24.8 m^3/sec. However the amount being withdrawn from groundwater in the D.F. will be reduced by

7 m^3/sec in 1994 and further 6 m^3/sec in 1998. While Mexico State plans to increase groundwater withdrawal of 1.0 m^3/sec in Mexico Valley from 1994. Hence in Yr. 2000, the capacity of groundwater source in Mexico Valley will be reduced to 28.7 m^3/sec.

From the above discussions, the total capacity of available water sources for AMCM in the year 1994 is found to be 61.0 m^3/sec. AMCM consists of D.F. and 17 municipalities of Mexico state. Table B.1 shows that water supply available in D.F. is 36.3 m^3/sec in the year 1997 and 2010 and water supply available in Mexico state is 24.7 m^3/sec in the year 1997 and 2010.

1.1.2 Water Resources of the Study Area

The municipalities of Mexico state included in AMCM and study area are not the same. As mentioned in the Appendix A, section 1, seven (7) municipalities of the Mexico state covered in the study area are included in the boundary of AMCM. The remaining eight (8) municipalities of Mexico state covered in the study area are located outside AMCM. These eight (8) municipalities are listed below.

Amecameca, Ayapango de gabriel R.Millan, Cocotitlan, Jilotzingo, Juchitepec, Temamatla, Tenango del Aire and Tlamanalco

Total existing (Yr. 1993) and future estimated (Yr. 2015) population in these eight (8) municipalities is 95,600 and 129,300 respectively. The existing and future estimated population of these eight (8) municipalities are rather small compared to the population in other municipalities of the Study Area. The population, of these eight (8) municipalities, is about 2.0% and 1.7%, of the total population of the Study Area in Mexico State, in the year 1993 and 2015 respectively. Hence the effect of the population of the above mentioned eight (8) municipalities on the water sources of AMCM is negligible.

Thus for studying the available water resources in this project, population of these eight (8) municipalities is included in AMCM.

Existing and future estimated population of the Mexico state, in the Study Area and in AMCM is compared, as shown below.

Year	Population (million)		Ratio
	(A) Study Area	(B) AMCM	(A) / (B) (%)
1993	4.76	8.00	59.5
1997	5.61	9.92	56.6
2000	5.90	11.57	51.0

The ratio of population in the Study Area to that of AMCM is decreasing from 59.5% in 1993 to 51.0% in 2000. In other words the trend is of increasing proportion of population in the ten (10) municipalities of AMCM which are not included in the study area.

The existing water supply provided in the study area of Mexico state is 16.59 m^3/sec which amount to 70% of the total capacity (23.7 m^3/sec) of the available water sources in Mexico state in AMCM. Now assuming that in future, for allotting the proportion of water supply to the study area of Mexico state, the trend of population decrease will be followed. The expected available capacity of water sources, in the study area of Mexico state, for the year 1997 and 2000, is described below.

Year	Available Water Source in Mexico state (AMCM) (m^3/sec)	Ratio of Study Area to AMCM (%)		Water Supply in Mexico state (Study area) (m^3/sec)
		Population	Water Supply	
1993	23.7	59.5	70.0	16.59
1997	24.7	56.6	66.6	16.45
2000	24.7	51.0	60	14.82

Hence total available capacity of water sources in the Mexico state of study area is estimated to be 16.45 m^3/sec and 14.82 m^3/sec for the year 1997 and 2000 respectively. And total available water sources in D.F. is estimated to be 36.3 m^3/sec for the year 1997 and 2000.

1.2 Existing Water Supply

1.2.1 D.F. Mexico

The water supply in D.F. Mexico is being provided by DGCOH through pipe distribution system. This pipe distribution system covers the entire area of D.F., i.e., 1,342 km^2, having population of 8.66 million (Year 1993). In other words, the area belonging to D.F. in the study area is fully covered by pipe distribution system.

The total amount of water supply being distributed in D.F. in the year 1993 is found to be 35.30 m^3/sec. Hence unit per capita water supply in the year 1993 is calculated as 352.1 lpcd. The proportion of water supply, being used for domestic use, commercial and institutional use, industrial use and water leakage, are summarized below.

Water Use	Water Supply (m^3/sec)	Proportion of Water Use (%)
Domestic	16.88	47.8
Commercial & Institutional	4.05	11.5
Industrial	3.78	10.7
Water Leakage	10.59	30.0
Total	35.30	100.0

1.2.2 Mexico State

In the Mexico state, water supply through pipe distribution system is being provided by four (4) organizations namely; CNA (National Water Commission), CEAS (State Committee of Water Supply and Sanitation), Municipality and Private Sector. As mentioned earlier, study area consists of fifteen (15) municipalities of Mexico state. The amount of water supplied, in the year 1993, by the above mentioned four (4) organizations, in these fifteen (15) municipalities of Mexico state, is described in Table B.2.

In the municipality of Cocotitlan, Jilotzingo and Temamatla, the water supply is provided by municipality only. The water supply in the remaining 12 municipalities is provided by CNA, CEAS and municipality itself. In four (4) municipalities of Atizapan de Zaragoza, Ecatepec, Naucalpan and Tlalnepantla, private companies have their own well to get water for their own purposes.

The proportion of water supply by these four (4) organizations is described below:

CNA	:	41.9 %
CEAS	:	20 .0 %
Municipality	:	29.7 %
Private	:	8.4 %

The 15 municipalities are not fully covered by the pipe distribution system. The service ratio and service population covered by the pipe distribution system along with water supply quantity and unit per capita water supply, for each municipality in the study area, are described below.

Municipality	Population in 1993	Service Ratio (%)	Service Population	Water Supply (m^3/sec)	Unit per capita water supply (lpcd)
Amecameca	38,100	90	34,290	0.071	178.9
Atizapan de Zaragoza	330,700	96	317,472	1.493	406.3
Ayapango de Gabriel R.millan	4,400	90	3,960	0.017	370.9
Cocotitlan	8,500	90	7,650	0.022	248.5
Chalco	296,800	95	281,960	0.611	187.2
Ecatepec	1,022,300	89	909,847	3.848	365.4
Huixquilucan	138,400	89	123,176	0.657	460.8
Jichitepec	5,100	90	4,590	0.021	395.3
Juchitepec	4,200	90	3,780	0.017	388.6
Naucalpan	825,200	98	808,696	3.439	367.4
Nezahualcoyotl	1,317,800	97	1,278,266	3.284	222.0
Temamatla	5,600	90	5,040	0.020	342.9
Tenango del Aire	6,500	90	5,850	0.036	531.7
Tlalmanalco	23,200	90	20,880	0.071	293.8
Tlalnepantla	737,300	98	722,554	2.983	356.7
Total	4,764,100	95	4,528,011	16.590	316.6

The unit per capita water supply ranges from 178.9 lpcd (Amecameca municipality) to 531.7 lpcd (Tenango del Aire municipality), with an average of 316.6 lpcd.

The population of 236,089 which is not covered by pipe distribution system, gets water supply through water truck. Hence effectively the total water supply of 16.59 m^3/sec is being distributed in the population of 4,764,100. Thus average unit per capita water supply in the Study Area of Mexico State is calculated as 300.9 lpcd.

1.3 Future Water Supply

From the discussions of foregone sections, the total available water supply, in the study area for D.F. and Mexico State, in the year 1993, 1997 and 2000, is summarized below.

Year	Available Water Supply (m^3/sec)	
	D.F.	Mexico State (Study area)
1993	35.3*	16.59
1997	36.3*	16.45
2000	36.3*	14.82

* Ref. Table B.1

The population in the year 1997 and 2000 for D.F. and Mexico state (study area) is summarized below.

Year	Population	
	D.F.	Mexico State (Study area)
1993	8,662,600	4,764,100
1997	9,277,200	5,612,900
2000	9,776,600	5,898,600

Taking into account the forecasted population for the year 1997 and 2000 in D.F. and Mexico State (study area), the unit per capita water supply in D.F. Mexico and Mexico State (study area) are estimated as follows.

(Unit : lpcd)

	1993	1997	2000
D.F. Mexico	352.1	338.1	320.1
Mexico State	300.9	253.2	217.1

Unit per capita water consumption is estimated by subtracting the amount of water leakage from the unit per capita water supply.

At the existing conditions, water leakage is found to be 30% in D.F. (ref. Appendix B, section 1.2.1) and 35% in Mexico state, of the total water supply. However JICA Study Team has assumed that existing water leakage condition will improve in future. The percentage (%) of leakage amount to total water supply amount in future is assumed as shown below.

(Unit : %)

	1993	1997	2000
D.F. Mexico	30	28	28
Mexico State	35	30	30

Then existing and future unit per capita water consumption are estimated as follows.

(Unit : lpcd)

	1993	1997	2000
D.F. Mexico	246.5	243.4	230.5
Mexico State	195.6	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.

Future water consumption in both D.F. Mexico and Mexico State are estimated by multiplying per capita unit water consumption with population served. Future water consumption in 1997, 2000 and 2015 are shown below.

(Unit : m^3/sec)

	D.F. Mexico	Mexico State	Total
1993	24.71	10.79	35.50
1997	26.14	11.51	37.65
2000	26.14	10.38	36.52
2015	34.08	13.30	47.38

2. Wastewater Generation

2.1 Quantity of Wastewater

Wastewater generation is assumed to be the same amount of water consumption. Hence 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 breakdown is shown below.

(Unit : m^3/sec)

	D.F. Mexico	Mexico State	Total
1993	24.71	10.78	35.50
1997	26.14	11.51	37.65
2015	34.08	13.30	47.38

2.2 Quality of 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 characteristics of Gran Canal (ref. Appendix C).

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. Seasonal average of BOD_5 and SS, for five (5) years are shown below.

Year	BOD_5 (mg/l)		SS (mg/l)	
	Dry Season	Rainy Season	Dry Season	Rainy Season
1989	194	160	169	178
1990	223	252	181	290
1991	241	212	190	238
1992	235	199	239	196
1993	233	178	196	408
Average	225	200	195	262

Not much fluctuation of water quality, in terms of BOD_5 and SS, in dry and rainy seasons, has been observed. Average BOD5 in dry season is about 12.5% higher than that of rainy season. And average SS in rainy season is about 34.4% higher than that of dry season. These fluctuations do not much affect the designing of wastewater treatment plant.

Annual average BOD_5 and SS of Gran Canal at the station of San Cristobal are defined as existing water quality of Gran Canal. The figures are as follows.

BOD_5	:	215 mg/l
SS	:	230 mg/l

In this study, pollution loads of commercial and institutional, and industry are considered to be included in domestic pollution load as unit per capita pollution load.

To estimate unit pollution load, the quantity of wastewater discharged to Gran Canal is estimated.

Wastewater Generation : (Ref. Appendix B, section 2.1)

D.F.	:	24.71 m^3/sec
Mexico state	:	10.79 m^3/sec

Existing sewerage service population ratio : (ref. Appendix D, section 1.1.1 and 1.1.2)

D.F.	:	94 %
Mexico state	:	85 %

Discharged wastewater

D.F. Mexico	:	24.71 m^3/sec x 94 % =	23.23 m^3/sec
Mexico State	:	10.79 m^3/sec x 85 % =	9.17 m^3/sec
Total	:		32.40 m^3/sec

At present about 2.97 m^3/sec of wastewater is being treated by existing treatment plants. About 2.30 m^3/sec of treated water is being reused for irrigation purpose and 0.67 m^3/sec is being reused for industrial purpose. Reused wastewater of 0.67 m^3/sec for industrial purpose is discharged again to sewerage system, i.e., to Gran Canal with same quality of other municipal wastewater. However treated water being reused for irrigation purpose is not returning to the sewerage system.

Hence total discharged quantity of wastewater to Gran Canal is calculated as follows:

$$32.40 - 2.30 = 30.10 \text{ m}^3\text{/sec}$$

Besides municipal wastewater, Gran Canal receives sludge from the existing wastewater treatment plants. Hence existing treatment plants are one of the pollution load generation sources.

From the material balance of BOD_5 for Cerro de la Estrella, it has been found that BOD_5 of sludge is 45% of the influent BOD_5 and SS of sludge are 80% of the influent SS.

BOD_5 of the municipal wastewater (BOD) is calculated as follows:

$$30.10 \times BOD + 2.97 \times 45\,\% \times BOD = 30.10 \times 215$$

Hence BOD_5 = 206 mg/l

Similarly SS in the municipal wastewater are estimated as 213 mg/l.

As described in Appendix B, section 1.3 unit per capita water consumption (unit per capita wastewater generation) for D.F. and Mexico State are 246.5 lpcd and 195.6 lpcd respectively.

Hence 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 g/cd	52.5 g/cd
Mexico State	40.3 g/cd	41.7 g/cd

Table B.1 Future Development Plan of Water Sources in AMCM as Reported in Agua 2000

(Unit : m^3 /s)

Water Source		1993	1994	1995	1996	1997	1998	1999	2000
Groundwater in Mexico Valley	D.F.	21.7	14.7	14.7	14.7	14.7	8.7	8.7	8.7
	Mexico State	19.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Sub-total	40.7	34.7	34.7	34.7	34.7	28.7	28.7	28.7
Goundwater in Lerma Valley	D.F.	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	Mexico State	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Sub-total	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Spring in Magdalena	D.F.	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	Mexico State	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Sub-total	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
River in Cutzamala (GAVM)	D.F.	7.6	15.6	15.6	15.6	15.6	21.6	21.6	21.6
	Mexico State	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	Sub-total	10.8	18.8	18.8	18.8	18.8	24.8	24.8	24.8
Total	D.F.	35.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
	Mexico State	23.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
	Total	59.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

Source : Agua 2000 Estrategia para la Ciudad de México (Agua 2000), D.F. México

Table B.2 The Amount of Water Supplied by Different Organizations in Mexico State

Municipality	CNA	State	Municipality	Private	Total
	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
17. Amecameca	0.002	0.042	0.027	0.000	0.071
18. Atizapan de Zaragoza	0.716	0.005	0.389	0.383	1.493
19. Ayapango de G. R. M.	0.010	0.006	0.001	0.000	0.017
20. Cocotitlan	0.000	0.000	0.022	0.000	0.022
21. Chalco	0.024	0.000	0.587	0.000	0.611
22. Ecatepec	0.781	0.408	2.348	0.311	3.848
23. Huixquilucan	0.458	0.000	0.199	0.000	0.657
24. Jilotzingo	0.000	0.000	0.021	0.000	0.021
25. Juchitepec	0.007	0.007	0.003	0.000	0.017
26. Naucalpan	1.302	1.002	0.690	0.445	3.439
27. Nezahulcoyotl	1.467	1.817	0.000	0.000	3.284
28. Temamatla	0.000	0.000	0.020	0.000	0.020
29. Tenango del Aire	0.015	0.014	0.007	0.000	0.036
30. Tlalmanalco	0.000	0.019	0.052	0.000	0.071
31. Tlalnepantla	2.169	0.000	0.559	0.255	2.983
Total	6.951	3.320	4.925	1.394	16.590
	41.9%	20.0%	29.7%	8.4%	100%

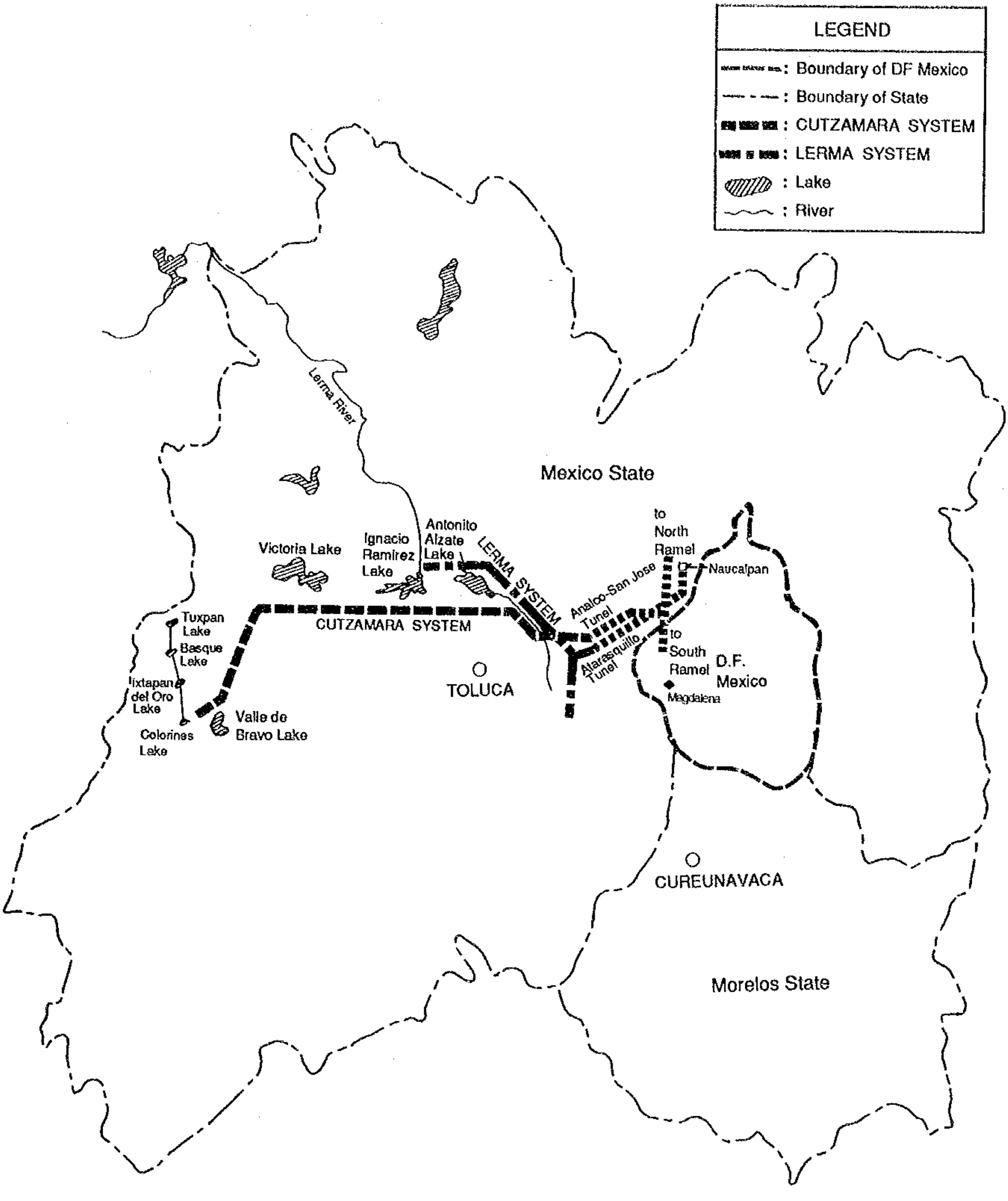

Fig. B.1 Water Sources of Study Area

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

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APPENDIX C

APPENDIX C WATER ENVIRONMENT

1. River Networks

The study area has two types of rivers; Natural rivers and Canals for drainage as shown in Fig. C.1. The major Natural rivers are La Piedad river, Churbusco river, Remedios river, Consulado river, Magdalena river, San Buenaventura river, National Canal of Chalco. The major canals for drainage are Gran canal, Emisor Central and Emisor Poniente. The maximum flow rate observed in these rivers and Canals are mentioned in Table C.1.

With the urbanization of Mexico city the characteristics of many Natural rivers have changed. Most of the existing rivers are being utilized as a part of drainage system for wastewater. As a result many rivers are converted to either closed rivers or open sewers. Also the Tula river on downstream, which receives the discharge from these rivers, has been polluted. The characteristics and the uses of various rivers have been described in the subsequent sessions.

2. River Water Quality

2.1 Natural Rivers

The River water quality has deteriorated substantially due to the wastewater entering from the surrounding areas. River water Quality for La Piedad river, Churbusco river and Remedios river, in terms of BOD_5, SS and total Coliforms has been described below:

River	BOD_5 (mg/l)	SS (mg/l)	Total Coliforms (No./100ml)
La Piedad	100-125	50-100	5.00 E+07
Churbusco	250-300	220-225	2.00 E+07
Remedios	200-250	300-400	5.00 E+07

The river quality variation in dry and rainy season was studied with respect to BOD_5, SS and Coliforms. As shown in Fig. C.2, not much variation in the water quality was observed except total coliforms of La Piedad river. High BOD_5, SS and Coliforms concentration indicate that these rivers are no longer suitable for the conventional uses. La piedad river and Churbusco river have been converted to box culvert and are closed rivers, to avoid bad smell and other environmental hazards. Consulado river is also closed river. San Buenventura river and National Canal of Chalco have also high concentration of BOD_5, SS and Coliforms.

The untreated wastewater discharged to downstream Tula river has caused very serious environmental impact in that area. The river after receiving wastewater has BOD_5 as high as 50-70 mg/l, DO about 0 mg/l and Coliforms as high as 5.00 E+07 No/100 ml. The area has very bad smell of sulfide and foam of detergents could be seen flying around the area. This situation could lead to serious environmental impacts on the inhabitants of the area and has already resulted in the outbreak of water borne disease.

2.2 Drainage Canals

Gran Canal, the major drainage canal accepts discharges from most of the interceptors and small rivers. The water quality in the dry season, in terms of BOD, SS and Coliforms is shown in Fig. C.3. It is evident from the Fig. C.3 that Gran Canal carries high concentration of BOD_5, SS and Coliforms. The BOD_5 load being discharged to Gran Canal has increased in the last five (5) years however concentration of SS is almost same. Gran Canal San Lazaro, the starting point has comparatively lower concentration of BOD_5 and SS but at Gran Canal AV. Central, after receiving discharges from Remedios river and other small rivers and interceptors, pollution load is increased considerably and high pollution load is discharged to Tula irrigation area.

Emisor Central, another major drainage canal which was initially planned to carry storm water is being used for carrying wastewater also. The major reason is that due to Land Subsidence problem, drainage capacity of Gran Canal is reduced and flow has to be diverted to Emisor Central. Emisor Central is Closed tunnel and water quality is being checked only at the effluent point. As shown in Fig. C.4, Emisor Central also carries high pollutants with BOD_5 of 150-200 mg/l, SS of 200-300 mg/l and Coliforms as high as 2.0 E+07 No/ 100 ml. Not much dilution was observed in rainy season, in fact suspended solids were found to increase. The probable reason is that settled sediments in the dry season gets resuspended with larger flows in rainy season.

Emisor Poniente is closed tunnel carrying wastewater and water quality is not being monitored.

3. River Uses

As most of the existing rivers are being utilized as a part of drainage system for wastewater, hence to get clear picture of river network and their uses, understanding of drainage system is necessary. The drainage system is a combined system which carries rain water as well as wastewater. The discharge from study area is carried towards Tula irrigation area through canals, open channels and closed rivers as shown in Fig. C.1. The wastewater discharged in the study area is collected through interceptors and small rivers. Churbusco river, La Piedad river, Consulado river, Remedios river, San Buenventura river and National Canal of Chalco are being utilized to carry wastewater. La Piedad river has already been converted into box culvert and discharges into Gran Canal. Consulado river is also closed river and discharges wastewater to Emisor Central through Central interceptor. A portion of discharge from Churbusco river is treated at Texcoco Lake Treatment Plant and is used for recreational purpose at Texcoco lake. The remaining wastewater is discharged to Gran Canal. Remedios river accepts wastewater from various interceptors and discharges to Gran Canal and Emisor Central. San Buenventura river and National Canal of Chalco also discharge into Gran Canal. Emisor Poniente, the oldest in D.F. area, is another major wastewater carrying canal. Emisor Poniente initially carries wastewater in tunnel and then as open channel. Basically wastewater discharged in study area is being carried by Gran Canal, Emisor poniente and Emisor central. Emisor Central and Emisor Poniente discharges to Tula river through Salto river and Gran Canal discharges to Tula river through Salado river. In dry season wastewater is carried by Gran Canal only whereas in rainy season wastewater is divided to Emisor Central and Gran Canal through discharge gates. Only Magdalena river is being used for potable water supply after treatment.

4. Ground Water Quality and Use

Ground water is the major source of water supply and about 847 wells exist in the study area. Ground water depth varies from 50 m to 400 m. No organic pollution was observed. The major problem in Ground water quality is due to Fe and Mn ions. The main reason is due to high concentration of these ions in the soil itself. In few Ground water wells high NH_3 content was observed and is treated by nitrification and filtration process. Ground water is being used mainly for water supply purpose and very few wells are being used for irrigation purpose.

5. Water-borne Disease

As described in the previous sections, untreated wastewater generated in study area is being carried to Tula irrigation area and has deteriorated the water quality of Tula river. The untreated wastewater is being used for irrigating about 125000 ha of area. The major irrigation areas of this untreated wastewater covers the states of Mexico and Hidalgo as shown in Fig. C.5. This wastewater irrigation network incorporates the rivers and dams in their vicinity. The irrigation network includes Rio Tula (Tula River), Salado River, Requena Dam, Endo Dam and Zumpango Lake. These rivers including the irrigation canal are visibly polluted. They are black in color and emanate offensive odor.

Due to the public health concern of the consiumers of agricultural products and high prevalence of Ascariasis infection in these wastewater irrigation areas, crops that could be produced are restricted to those that are, not traditionally consumed raw, and are feed for livestock/animal husbandary. This administrative restriction on cropping practice was introduced two (2) years ago by CNA (National Water Commission).

Environmentally deteriorated situation has led to breakout of water borne diseases in that area. Cases of Water borne diseases in Tula irrigation area is compared with that of Federal District and State of Mexico. The details are shown in Table C.2.

Federal District where irrigation with untreated wastewater is not practiced in any District, the total cases of waterborne disease are only 106, whereas the Mexico State with only one municipality, Tecamac, in which untreated wastewater is being used for irrigation, has 2,795 cases and Tula irrigation area in Hidalgo state where untreated wastewater is being used extensively, the water borne cases are as high as 5,696. The above mentioned cases of waterborne disease are for every 100,000 persons.

6. Water Quality Standards

6.1 Water Quality Standards for the Preservation of Water Environment

Water quality standards related to the preservation of water body environment have not been established. Only water quality standards related to effluent discharges from industries have been established, without giving proper attention to the municipal wastewater being discharged to rivers. As a result most of the rivers in D.F. area are functioning as open sewers.

6.2 Water Quality Standards for the Reuse of Treated Water

The shortage of water resources has created the necessity to reuse the treated water in D.F. At present 16 wastewater treatment plants are being operated to treat 2.6 m^3/sec of wastewater with the objective of reusing the treated water. Various regulations on National basis as well as on D.F. basis, regarding the quality of wastewater to be reused, have been established. These regulations are summarized below.

(1) Regulations for water reuse in Federal District (Reglamento para el Reuso del Agua en el Distrito Federal 1987).

In 1987, DGCOH has established the Standards related to the quality of the wastewater to be reused in D.F. The reuse of wastewater has been classified into the following seven categories.

A) Groundwater Recharge
- Direct injection
- Infiltration

B) Park irrigation

C) Irrigation of crops to be Consumed by human
- Crops to be eaten raw
- Crops to be eaten cooked

D) Recreational purpose
- With Contact
- With no Contact

E) Irrigation of crops to be Consumed by animals

F) Wastewater to be consumed by animals

G) Industrial purpose

The reuse standards cover physical, chemical and biological parameters. Depending on the type of reuse, the maximum permissible limit for about 192 parameters has been prescribed. The major parameters of concern and their maximum limits are described in Table C.3.

(2) Mexican Official Standard Nom-CCA-032-ECOL/1993.

This law developed by Social Development Secretariat (SEDESOL), states the maximum permissible limits of pollutants in the municipal wastewater which is to be disposed as agricultural irrigation waters. The Agriculture and Hydraulic Resources Secretariat through its National Water Commission (CNA) is responsible to supervise the fulfillment of the present standards. The parameters concerned and their maximum limits are shown in Table C.4.

In case organic toxic and heavy metals, Mexican official standard Nom CCA-001-ECOL/1993 is to be followed. Nom CCA-001-ECOL/1993 states the maximum permissible limits of pollutants in wastewater discharge from thermoelectric centers.

(3) Mexican Official Standard Nom-CCA-033-ECOL/1993

This law, also developed by Social Development Secretariat (SEDESOL), dictates the maximum permissible limits of bacteriological parameters in the municipal wastewater to be used for the irrigation of vegetables and fruits. The Agriculture and Hydraulic Resources Secretariat through its National Water Commission is responsible to supervise the fulfillment of the present standards.

Based on the bacteriological parameters (Total Coliforms and Helminth eggs) present, water has been classified into four types as shown below:

Type of Water	Total Coliforms/100 ml	Helminth eggs/L
I	< 1000	none
II	1-1000	1
III	1001-100,000	-
IV	> 100,000	-

Vegetables and fruits considered under this law are categorized into two categories.

Category A: Beet, garlic, celery, cress, sugar beet, broccoli, onion, coriander, cabbage, cauliflower, wormseed, spinach, bean, mushroom, mint, lettuce, papalo, parsley, radish, carrot, gherkin pickle, cucumber, gourd, tomato, green tomato, strawberry, jicama, lemon watermelon and blackberry.

Category B: Includes category A and the rest of the vegetables and fruit.

Based on the type of irrigation and type of water, minimum interval between last irrigation and harvest and type of crops permitted, have been specified. The Table C.5 describe the restriction about the crops to be grown.

7. Proposed Effluent Quality Standards for the Water Bodies to be Used for Irrigation

At present raw wastewater is being used for irrigation purpose and has caused serious environmental hazards in that area. After studying the characteristics of Tula river, the study team has proposed Effluent Quality Standards for the water bodies to be reused for irrigation. 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). The proposed standards are described below:

Parameter	Maximum Permissible Limit
BOD_5 (mg/l)	20
TSS (mg/l)	30
Coliforms (No/100 ml)	1,000

The Tula river which will be used for irrigation purpose should meet the above mentioned standards. After irrigation further above mentioned parameters may be removed and the effluent is discharged to Moctezuma river. The basic concept is that Tula river has been considered as irrigation canal and further downstream river, i.e., Moctezuma river is considered as Natural river.

Table C.1 Maximum Flow Rate Observed in Rivers and Canals of the Study Area

Name of River/Canal	Flow Rate (m^3 /sec)
La Piedad River	15
Churubusco River	90
Remedios River	250
Consulado River	——
Magdalena River	1.0
San Buenaventura River	100
Chalco Canal	20
National Canal	20
Emisor Central	220
Gran Canal	100
Emisor Poniente	80

Table C.2 Comparison of Incidence of Water-Borne Diseases in the Study Area and in the District of Tula, the State of Hidalgo

1. Federal District (1990)

Name of Diseases	Total No. of Cases	No. of Cases/ 100,000 Pop.
1. Typhoid and Paratyphoid	90	1
2. Amebiasis	435	5
3. Intestinal Infectious Diseases	5,761	70
4. Tuberculosis	88	1
5. Chickenpox	63	1
6. Measles	1,461	18
7. Parasitic Diseases	818	10
Total	8,716	106

Source : Informacion Estadistica del Sector Salud y Seguridad Social, 1993, INEGI

2. Mexico State (1992)

Name of Diseases	Total No. of Cases	No. of Cases/ 100,000 Pop.
1. Intestinal Diseases	165,132	1,597
2. Amebiasis	82,460	797
3. Ascariasis	22,351	216
4. Dermatomycosis and Dermatophytosis	9,877	96
5. Chickenpox	9,182	89
Total	289,002	2,795

Source : Anuario Estadistico del Estado de Mexico, Edicion 1993, INEGI

3. District of Tula, Hidalgo State (1993)

Name of Diseases	Total No. of Cases	No. of Cases/ 100,000 Pop.
1. Intestinal Diseases	10,895	2,503
2. Amebiasis	7,331	1,684
3. Ascariasis	2,547	585
4. Dermatomycosis and Dermatophytosis	1,053	242
5. Oxiuriasis	893	205
6. Chickenpox	858	197
7. Scabies	787	181
8. Paratyphoid and Other Salmonellosis	430	99
Total	24,794	5,696

Note : District of Tula: An irrigation district with the 1993 population of 435,350 incorporating the Municipalities of Tepeji del Rio, Tula, Antotonico, Atitalaquia, Tlaxcoapan, Tlahuelilpan, Tezontepec de Aldama,Tepetitlan, Mixquiahuala, Progreso de Obregon, Francisco I. Madero, San Salvador, Ajacuba, Tetepango, El Arenal and Octopan.

Source : Jurisdiccion Sanitaria No. 3 Tula de Allende, HGO

Table C.3 Maximum Limits of Parameters in the Treated Water to be Reused (Reglamento para el Reuso del Agua en el Distrito Federal, 1987)

Parameter	Groundwater Recharge		Park Irrigation	Irrigation		Recreational Purpose		Irrigation of Crops for Animals	Wastewater for Animals Consumption	Industrial Purpose
	Direct Injection	Infiltration		Crops to be Eaten Raw	Crops to be Eaten Cooked	With Contact	With no Contact			
pH (mg/l)	7 - 9	7 - 9	6 - 9	7 - 8	7 - 8	6.5 - 8.3	6.5 - 8.3	6 - 9	7 - 9	5 - 8.3
Conductivity (mg/l)	900	1,500	2,000	3,500	3,500	3,500	3,500	3,500	3,500	2,000
BOD (mg/l)	2.5	5.0	20.0	20.0	50.0	20.0	100.0	50.0	20.0	20.0
TSS (mg/l)	2.0	10.0	15.0	100.0	100.0	10.0	500.0	500.0	80.0	500.0
Al (mg/l)	0.2	0.2	5.0	5.0	5.0	0.2	5.0	5.0	5.0	1.0
As (mg/l)	0.05	0.05	0.1	0.1	0.1	0.05	0.1	0.1	0.2	0.2
B (mg/l)	5.0	5.0	1.0	1.0	1.0	1.0	5.0	1.0	5.0	5.0
Cd (mg/l)	0.01	0.75	0.01	0.01	0.01	0.01	0.75	0.01	0.05	0.75
Cn (mg/l)	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Cu (mg/l)	1.0	1.0	0.5	0.2	0.2	0.2	1.0	0.2	0.5	0.5
Cr (mg/l)	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1	1.0	1.0
Fe (mg/l)	0.3	0.3	5.0	5.0	5.0	0.3	0.3	5.0	2.0	0.5
F (mg/l)	1.5	1.5	2.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0
Mn (mg/l)	0.05	0.05	0.2	0.2	0.2	0.05	0.2	0.2	0.05	0.5
Ni (mg/l)	0.05	0.05	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pb (mg/l)	0.05	0.05	5.0	5.0	5.0	1.0	5.0	5.0	1.0	5.0
Se (mg/l)	0.01	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.05
Zn (mg/l)	5.0	10.0	2.0	2.0	2.0	2.0	2.0	2.0	25.0	25.0
Coliforms MPN (No/100 ml)	1,000	20,000	1,000	1,000	10,000	1,000	5,000	1,000	5,000	10,000
Parasite eggs (No/L)	0	0	2	1	1	1	4	1	1	2

Table C.4 Maximum Permissible Limit of Pollutants in the Treated Water to be Used for Irrigation (Nom-CCA-032-Ecol/1993)

Parameter	Maximum Permissible Limits
pH	6.5 to 8.5
Electric Conductivity (Micromhos/cm)	2,000
Biochemical Oxygen Demand (BOD) (mg/l)	120
Total Suspended Solids (TSS) (mg/l)	120
Aluminum (mg/l)	5.0
Arsenic (mg/l)	0.1
Boron (mg/l)	1.5
Cadmium (mg/l)	0.01
Cyanides (mg/l)	0.02
Copper (mg/l)	0.2
Total Chromium (mg/l)	0.1
Iron (mg/l)	5.0
Fluorides (mg/l)	3.0
Manganese (mg/l)	0.2
Nickel (mg/l)	0.2
Lead (mg/l)	5.0
Selenium (mg/l)	0.02
Zinc (mg/l)	2.0

Table C.5 Restriction on Growing Crops with Treated Water (Nom-CCA-033-ECOL/1993)

Type of Irrigation	Type of Water	Minimum Interval of (Days) between Last Irrigation and Harvest	Crops Not Allowed
Flooding	I	20	Those mentioned in category A, except garlic, bean, gherkin pickle, cucumber, jicama, melon and watermelon.
	II	20	Those mentioned in category A, except melon and watermelon.
	III	20	Those mentioned in category A.
	IV	20	Those mentioned in category B.
Furrow	I	15	Those mentioned in category A, except garlic, bean, cucumber, gherkin pickle, jicama, melon and watermelon; and green tomato as well.
		20	Free crop
	II	20	Those mentioned in category A, except garlic, cucumber jicama, melon and watermelon; and green tomato as well.
	III	20	Those mentioned in category A, except melon and watermelon.
	IV	20	Those mentioned in category B.
Spray	I	20	Those mentioned in category A, except garlic, cucumber, gherkin pickle, jicama, melon and watermelon.
	II III IV	20	Those mentioned in category B.

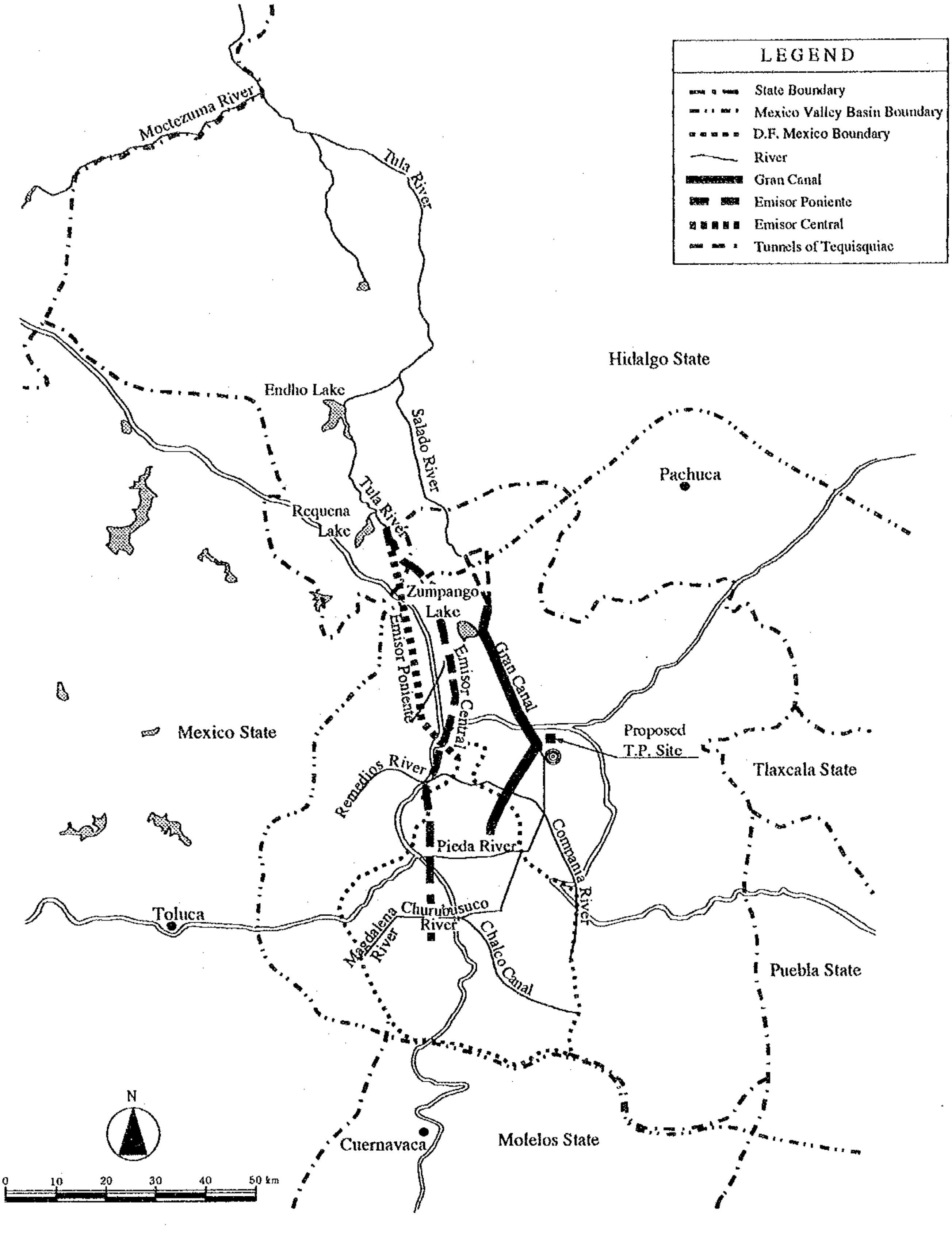

Fig. C.1 Networks of Rivers and Canals

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

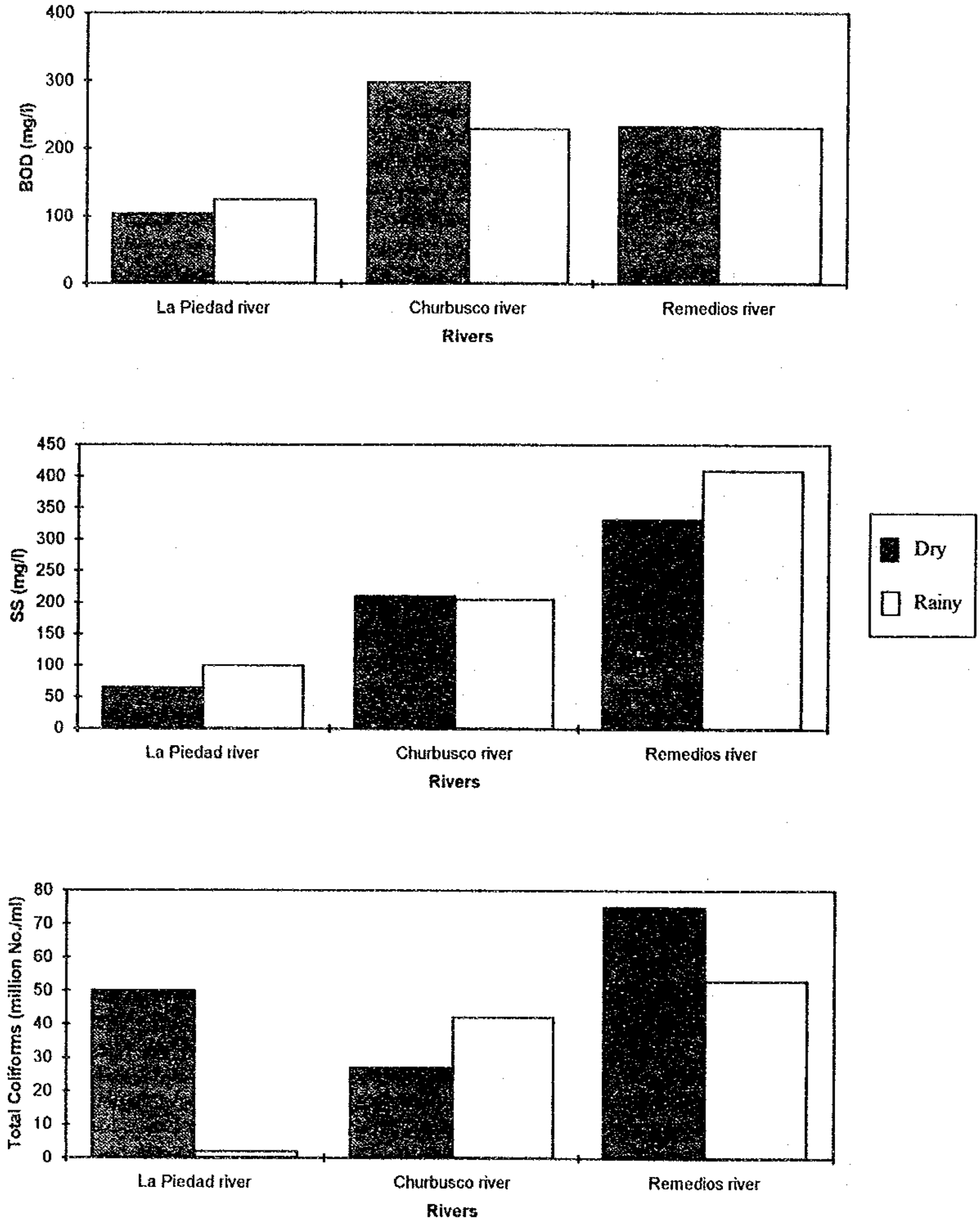

Fig. C.2 River Water Quality in Terms of BOD, SS and Coliforms

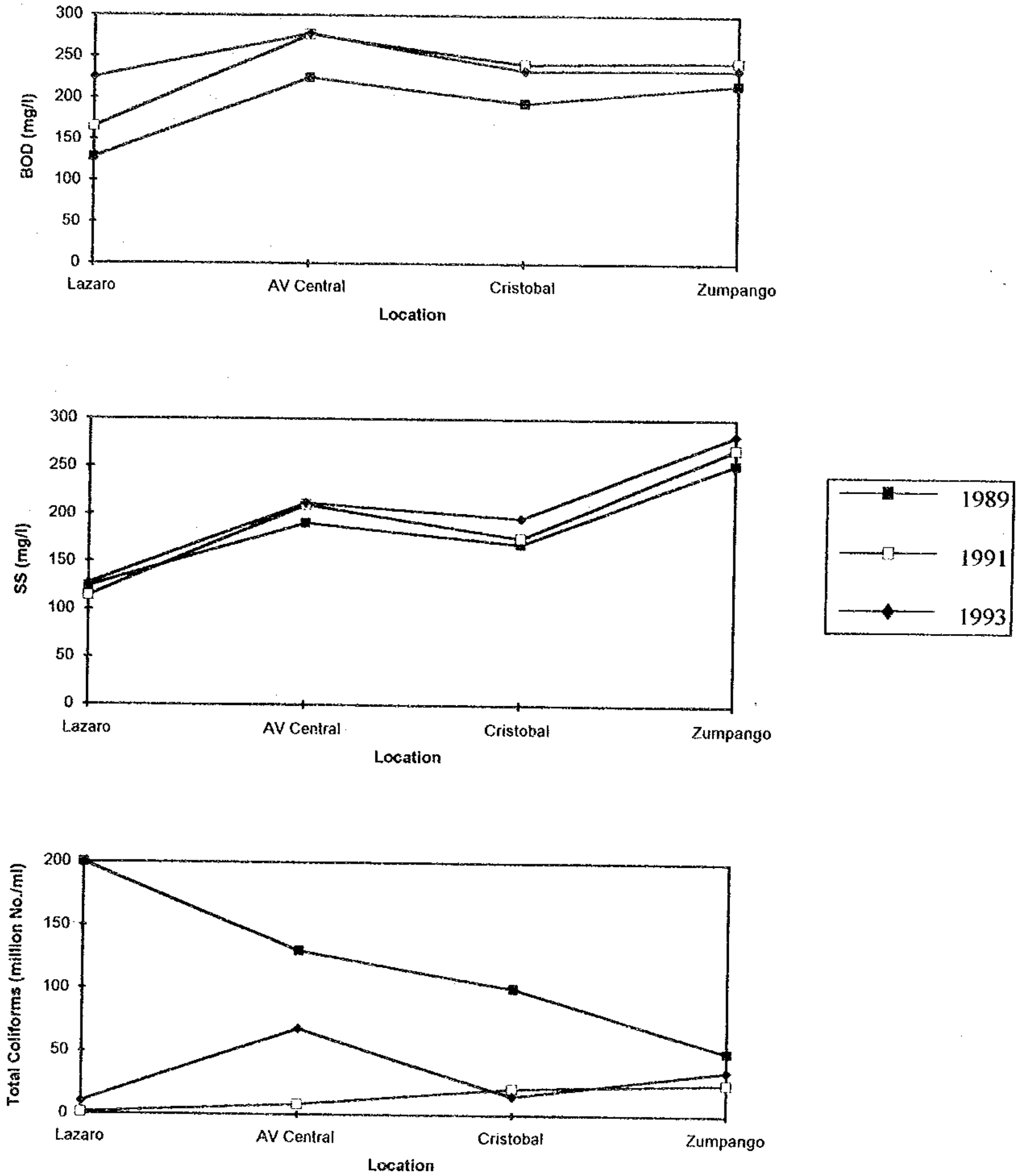

Fig. C.3 Water Quality of Gran Canal in Terms of BOD, SS and Coliforms

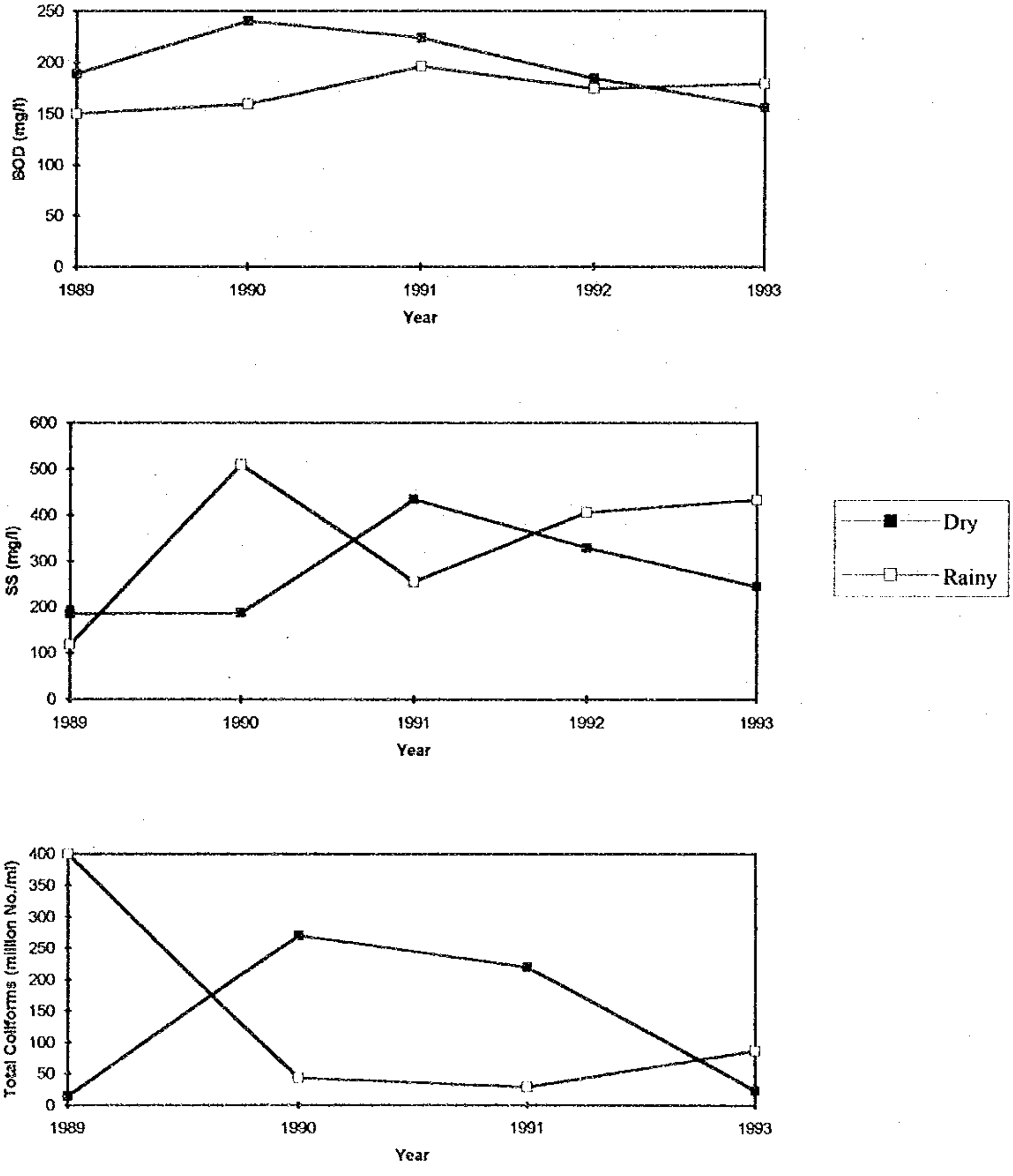

Fig. C.4 Water Quality of Emisor Central in Terms of BOD, SS and Coliforms

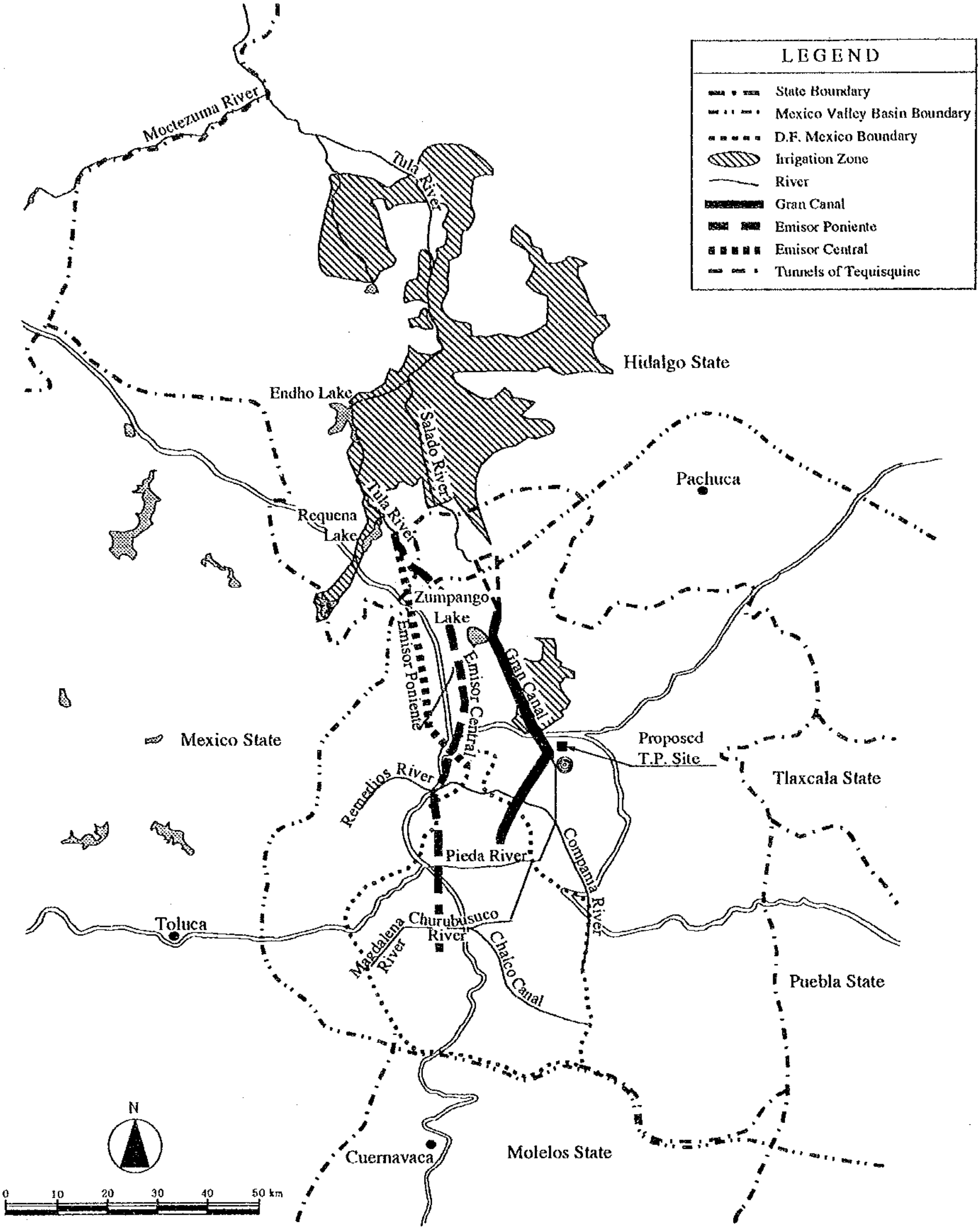

Fig. C.5 Major Irrigation Areas of Untreated Wastewater in the Mexico and Hidalgo States

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

APPENDIX D

APPENDIX D SEWERAGE SYSTEM

1. Service Area and Service Population

In the Study Area, municipal wastewater is collected by combined sewerage system. Existing and future sewerage system in the Study Area of D.F. Mexico and the Mexico State is described in the subsequent sections.

1.1 Existing Sewerage System

1.1.1 D.F. Mexico

(1) Service Area

The existing sewerage system covers about 71% of the administrative area. The total area covered by the existing sewerage system is 956.11 km^2, as shown in Fig. D.1. Existing service area of each district is shown in Table D.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. These eight (8) districts with 100% areal service ratio are mentioned below:

Alvaro Obregon, Azcapotzalco, Benito Juarez, Coyoacan, Cuauhtemoc, Iztacalco, Mibuel Hidalgo and Venustiano Carranza

Districts of G.A.Madero, Iztapalapa, Tlahuaqc and Xochimilco, which are located surrounding the above mentioned eight (8) districts, more than 80% of the administrative area is covered by existing sewerage system. Remaining four (4) districts of Cuajimalpa, Magdalena Contreras, Tlalpan and Milpa Alta have low sewerage service area with a service ratio of 20% to 60%. They are located at the fringes of D.F. Mexico. In these four (4) districts, according to Land use conditions (1987), ecological conservation area constitutes more than 60% of the total administrative area.

(2) Service Population

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 of the above mentioned eight (8) district with 100% areal service ratio is covered by existing sewerage system. G.A. Madero with 95% areal service ratio has hilly area in the north with no inhabitants and effectively entire population is being served by sewerage system. In other words G.A. Madero, with 95% areal service ratio has 100% population service ratio. In Tlahuac and Tlalnepantala district, 90% of population is covered by existing sewerage system. The lowest population service ratio of 30% is observed in Milpa Alta district. Fig. D.2 shows the regional distribution of population service ratio for each district.

1.1.2 Mexico State

(1) Service Area

The existing sewerage system covers about 42% of the administrative area. The total area covered by the existing sewerage system is 584.26 km^2, as shown in Fig. D.1. Existing service area of each municipality is shown in Table D.1. The area covered by sewerage system in each municipality, i.e., areal service ratio varies from 15-95%. The highest service ratio of 95% is observed in Nezahualcoyotl and Tlalnepantla municipalities followed by Naucalpan municipality with service ratio of 90%. The lowest service ratio of 15% is observed in the eight (8) municipalities. These eight (8) municipalities are mentioned below:

Amecameca, Ayapango de Gabriel R.Millan, Cocotitlan, Chalco, Juchitepec, Temamatla, Tenango del Aire and Tlalmanalco

(2) Service Population

Existing sewerage system covers about 85% of the total population of 4.76 million in the Study Area of Mexico State. The highest population service ratio of 95% is observed in Nezahualcoyotl and Tlalnepantla municipalities followed by Ecatepec and Naucalpan municipalities of 90%. The lowest population service ratio of 15% is observed in the following five (5) municipalities:

Amecameca, Ayapango de Gabriel R.Millan, Cocotitlan, Temamatla, and Tlalmanalco

Percentage of existing sewerage service population for the each municipality is shown in Fig. D.2.