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NO. 07

REPUBLIC OF GUATEMALA

MUNICIPAL WATER SUPPLY CORPORATION

OF GUATEMALA CITY (EMPAGUA)

FEASIBILITY STUDY ON THE GROUND WATER DEVELOPMENT PROJECT (FOR EMERGENCY I)

VOLUME 1 MAIN REPORT

SEPTEMBER 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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FEASIBILITY STUDY
ON
THE GROUND WATER
DEVELOPMENT PROJECT
(FOR EMERGENCY I)

LIST OF REPORTS

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PREFACE

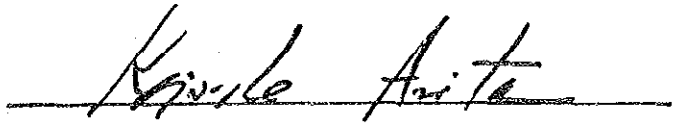
In response to the request of the Government of the Republic of Guatemala, the Japanese Government decided to conduct a feasibility study on the Groundwater Development Project in Guatemala City and entrusted the study to the Japan International Cooperation Agency. JICA sent to Guatemala a survey team headed by Mr. Ikuro Inamori, Chuo Kaihatsu Corporation, International, from July 1985 to March 1986 and May to July 1986.

The team exchanged views with the officials concerned of the Government of Guatemala and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Guatemala for their close cooperation extended to the team.

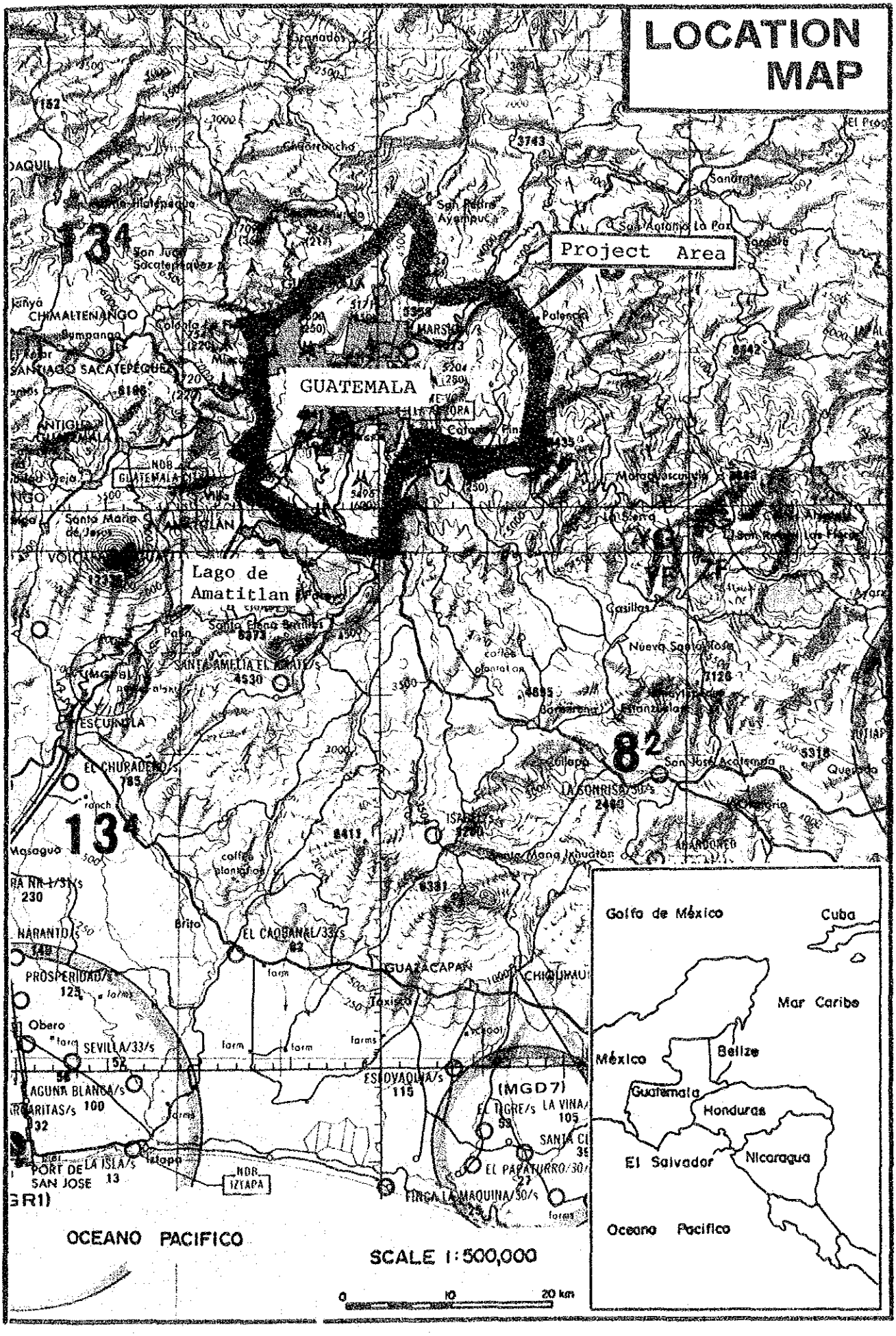
September, 1986



KEISUKE ARITA

President

Japan International Cooperation Agency


LOCATION MAP
Project Area
GUATEMALA
Lago de Amatitlan
SCALE 1:500,000
0 10 20 km
OCEANO PACIFICO
Golfo de México
Cuba
Mar Caribe
México
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Oceano Pacifico

W90°40'
W90°30'
W90°20'
N14°48'
N14°40'
N14°38'
N14°30'
N
CHINAUTLA
SAN PEDRO SACATEPEQUEZ
NORTE
EL RODEO
LAVARREDA
GUATEMALA CITY
MIXCO
CANALITOS
HERMOSA
SANTA CATARINA PINULA
SAN JOSE PINULA
LAGO DE AMATITLAN
CONTINENTAL DIVIDE
LAPOLE RIVER
EL ZAPOTE RIVER
LAS VACAS RIVER
EL MOLINO RIVER
MARISCAL RIVER
PARRAMENO RIVER
PINULA RIVER
VILLALOBOS RIVER
PLATANITOS RIVER
LAS MINAS RIVER
MONJITAS RIVER
CANALITOS RIVER
LOS OCOTOS RIVER
BIJAGUE RIVER
ACATAN RIVER

LEGEND

- PROJECT AREA
- GROUND WATER DEVELOPMENT AREA
- RIVER
- DIVIDE

SCALE
0 1 2 3 4 5km

REPUBLIC OF GUATEMALA
MUNICIPAL WATER SUPPLY CORPORATION OF GUATEMALA CITY (EMPAGUA)

GROUNDWATER DEVELOPMENT PROJECT

PROJECT MAP

DATE	1986	DWG.NO.	1

JAPAN INTERNATIONAL COOPERATION AGENCY

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ABBREVIATIONS

AID:	Agency for International Development
BANVI:	Banco Nacional de Vivienda
BCIE:	Banco Centroamericano de Integracion Economica (CABEI)
CIDA:	Canadian International Development Agency
CNPE:	Consejo Nacional de Planificacion Economica
COPECAS:	Comite Permanente de Coordinacion de Agua y Saneamiento
EDOM	Estudio de Ordenamiento Metropolitano
EMPAGUA:	Municipal Water Supply Corporation of Guatemala City or Empresa Municipal de Agua de la Ciudad de Guatemala
ERIS:	Escuela Regional de Ingenieria Sanitaria
FAO:	Food and Agricultural Organization
IDB:	Inter-American Development Bank or Banco Interamericano de Desarrollo (BID)
IGM:	Instituto Geografico Militar
IGSS:	Instituto Guatemalteco de Seguridad Social
INAFOR:	Instituto Nacional de Forestacion
INDE:	Instituto Nacional de Electrificacion
INE	Instituto Nacional de Estadistica
INFOM:	Instituto Nacional de Fomento Municipal
INSIVUMEH:	Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia
JICA:	Japan International Cooperation Agency
MCOPyT:	Ministerio de Comunicaciones, Obras Publicas y Transportes
MSPyAS:	Ministerio de Salud Publica y Asistencia Social
PAHO:	Panamerican Health Organization or Organizacion Panamericana de Salud (OPS)
PLAMABAG:	Guatemala City Water Supply Master Plan or Plan Maestro de Abastecimiento de Agua a la Ciudad de Guatemala

SEGEPLAN:	Secretaria General de Planificacion Economica
UEA:	Unidad de Emergencia de Agua
UENIA:	Unidad de Estudios de Nuevas Introducciones de Agua
UNDP:	United Nations Development Program
UNESCO:	United Nations Educational Scientific and Cultural Organization
UNICEF:	United Nations International Children's Emergency Fund
UNEHIVAGUA:	Unidad Ejecutora del Estudio Hidrogeologico del Valle de Guatemala
UNEPAR:	Unidad Ejecutora del Programa de Acueductos Rurales
USAC:	Universidad San Carlos de Guatemala
WB:	World Bank
WHO:	World Health Organization or Organizacion Mundial de Salud (OMS)

UNITS

Length

mm:	millimeter
cm:	centimeter
m:	meter
km:	kilometer
inch:	25.4mm
ft:	foot (feet) = 12inch = 30.48cm
mile:	5,280feet = 1.609km

Area

cm^2:	square centimeter
m^2:	square meter
km^2:	square kilometer
ha:	hectare

Capacity

l:	liter
m^3:	cubic meter
Mm^3:	million cubic meters
gl:	gallon = 3.785 lit.

Weight

g:	gram
kg:	kilogram
ton:	metric ton
oz:	ounce = 28.4gr
lb:	pound = 16oz = 454gr

others

h:	hour
min:	minute
sec:	second
cm/sec:	centimeter per second
m/sec:	meter per second
m^3/sec:	cubic meter per second
gl/sec:	gallon per second = 3.785 l/sec = 0.2271ton/min
pajas:	pajas = 60m^3/month (a unit quanity under the consumer contract for water supply by EMPAGUA)

PROJECT SUMMARY

I THE PROJECT

1.1 The Project comprises the following components:

(1) Groundwater Development Plan

a) Groundwater development program
b) Operation/maintenance program
c) Rehabilitation program
d) Water supply program

(2) Groundwater Conservation Plan

a) Monitoring program
b) Groundwater conservation program

1.2 The available groundwater in the Project area is classified into two types according to the recharge mechanism and the aquifer. These two types are the upper aquifer and the lower aquifer.

On the basis of hydrogeological survey, the maximum permissible yield of these is estimated at more than 1 m^3/s which is the planned target yield under the Project.

1.3 As a result of the subject Study, the estimated groundwater storage, the development potentiality and permissible yield are concluded as sufficient to supplement the projected water shortage in Metropolitan Guatemala by the target year. Accordingly, the Project should be implemented as early as possible.

Upper aquifer

	Effective storage	Actual pumping volume m^3/s	Pump-up potential m^3/s
Northern sector	0.89 m^3/s	0.32	0.57
Southern sector	0.73 m^3/s	0.29	-0.44
Eastern sector	1.16 m^3/s	0.03	1.13
Total	2.78 m^3/s	0.64	2.14

Lower aquifer

	Estimated storage	Development potentiality	
Northern sector	180 x $10^6 m^3$	54 x $10^6 m^3$	1,102 l/sec.
Southern sector	143.1 x $10^6 m^3$	43 x $10^6 m^3$	1,363 l/sec.
Eastern sector	196.5 x $10^6 m^3$	59 x $10^6 m^3$	1,870 l/sec.
Total	519 x $10^6 m^3$	156 x $10^6 m^3$	4,945 l/sec.

1.5 On the basis of hydrological basin boundaries, the Project area is divided into three sectors: eastern, northern and southern. The groundwater development potentiality of each of the three sectors was assessed on the basis of the hydrogeological properties, estimated basin reserve, existing actual yield, maximum safe yield, etc., and the groundwater development priority for the Project was estimated as follows:

Top priority : eastern sector
Second priority : northern sector
Third priority : southern sector

1.6 Upper aquifer in the eastern and northern sectors and lower aquifer in the eastern, northern and southern sectors, are available for the Project.

However, additional groundwater development should not be carried out in the southern sector. Instead, usage of water from this sector should be regulated as there is the danger of accelerating the lowering of the water level and polluting the water quality of Lake Amatitlan.

Consequently, the main groundwater development areas under the Project will be the eastern and northern sectors. Moreover, five wellfields were delineated in the vicinity of the boundary of the eastern and northern sectors, in consideration of the present conditions for local water shortages, the proposed distribution programs and economization of the transmission system for the newly developed groundwater.

1.7 According to EMPAGUA data, estimated water supply and demand in 1985 for EMPAGUA's water service area is as presented in the following table.

SUPPLY AND DEMAND IN 1985

(lm^3/sec)

System	Center	North	North-East	South-East	West	South	Total	
							Total	(%)
1. Supply:								
Santa Luisa	0.24	0.1	-	-	-	-	0.34	14.0
El Cambray	0.07	-	-	0.08	-	-	0.15	6.0
Lo de Coy	0.21	-	-	-	0.62	-	0.83	35.0
La Brigada	-	-	-	-	0.07	-	0.07	3.0
Ojo de Agua	0.32	-	-	-	-	0.22	0.54	23.0
Wells in downtown Guatemala City	0.11	0.10	-	-	-	-	0.21	9.0
Las Ilusiones	-	-	0.23	-	-	-	0.23	10.0
Total	0.95	0.20	0.23	0.08	0.69	0.22	2.37	100.0
2. Demand: (m^3/sec)	1.22	0.27	0.33	0.09	0.74	0.25	2.90	-
(Difference between #2 and #1 above) Shortage: (m^3/sec)	0.26	0.07	0.10	0.01	0.05	0.03	0.53	-
Demand Shortage(%):	22.0	26.0	30.0	11.0	7.0	12.0	18.0	-

1.8 As shown in the above table, the estimated overall water shortage rate is 18 percent of demand. The largest water shortage occurs from the center part of the urban area to the northern part with a rate of 30 percent in the northeast area, and 26 percent in the north area and in the center of Metropolitan Guatemala.

1.9 Water shortages are most serious in Zone 6 (north); Zone 17, Zone 18 (northeast); a part of Zone 2, and the northern half of Zone 1 (north). Water demand of these areas is estimated at approximately 31 percent of total demand of EMPAGUA customers.

1.10 Water service areas under the proposed Project are tentatively proposed as center, northern, and northeast areas of Metropolitan Guatemala.

Estimated water demand of the proposed water service area is tabulated below:

Area	Center	North	Northeast
1985	1.22	0.27	0.33
1990	1.48	0.30	0.48
1995	1.80	0.34	0.70
2000	2.18	0.38	1.02

111 Specifically, the greatest water shortage problem occurs in zones 17 and 18. Accelerated development of these zones as residential area, and the rapid increase in population and residences has resulted in a corresponding increase in water demand. In the next fifteen years, demand is forecasted to increase to 1.02m^3/sec, three times the present rate. Modification of the supply system in response to this forecast is proposed for study.

1.12 Groundwater production of 1m^3/sec under the Project is proposed as follows on the basis of future water demand and EMPAGUA's future water production and supply plans for the area.

	Center	Northeast	North	Total
				(1m^3/sec)
1990[1/]	0.50	0.20	-	0.70
1995	0.54	0.42	0.04	1.00
2000	0.18	0.74	0.08	1.00

1/: Implementation will commence in 1987 and will be completed by the end of 1990.

1.13 On the basis of hydrogeologic and electric prospecting data, the Study area was divided into 6 blocks for consideration of wellfield selection.

1.14 The number and estimated average unit yield of the wells in the respective wellfields are given below:

Wellfield block	Potential well no.	Average yield per unit well (l/sec)
Canalitos	17	30
Lavarreda	2	35
El Rodeo, Zona 18	7	20
Vista Hermosa	4	30
Norte	8	35
Total	38	

As rotational operation is to be adopted under the Project reserve wells to number 10% of the total will be included. Total yield for all wells (including reserve capacity) will therefore be 1.1 m^3/sec. Under rotational operation, actual production will be 1.0 m^3/sec.

1.15 The following thirteen transmission systems have been planned.

Wellfield	Terminus of transmission system	Transmission discharge	Transmission system	No. of wells
Canalitos	Juana de Arco (water tank)	0.240	Booster pump	8
	Santa Luisa (plant)	0.18	Gravity	6
	San Gaspar (new water tank)	0.090	Gravity	3
Norte	Tank 4-4	0.210	Booster	6
	Tank Carmen	0.070	Booster	2
	(Tank 4-4)	(0.148)	Booster	(7)
Lavarreda	Juana de Arco	0.070	Booster	2
El Rodeo, Zona 18	New tank	0.040	Gravity	2
	(Direct delivery and Las Ilusiones)	0.020	Gravity	1
	Las Ilusiones	0.060	Booster	3
	Existing pipe	0.020	Gravity	1
Vista Hermosa	New tank	0.090	Gravity	3
	Existing pipe	0.030	Gravity	1

( ) : Transmitted from Tank 4-4

1.16 Replacement of existing pumps with submersible motor pumps is proposed for 22 existing wells to bring operating efficiency in line with production potential.

As a result of implementation of this proposed rehabilitation plan, water production at the 22 wells will be increased as per below:

Actual production	Post rehabilitation	Increase
538 l/sec	920 l/sec	382 l/sec

1.17 Operation and maintenance (O/M) is to be supervised entirely under the responsibility of the EMPAGUA Engineering Manager. O/M system and facilities encompass production control, water supply control, monitoring and facilities maintenance. Production control comprises management of production water quantity and quality, as well as facilities related thereto.

1.18 In order to minimize the O/M expenses (operation personnel expenses in particular), the semi-centralized/remote control system is proposed for operation and control of the water production systems.

Main stations and substations are proposed to maintain effective and reasonable operation/control of the water production systems.

Two O/M main stations are to be located at the Santa Luisa and Las Ilusiones treatment plant existing offices. The O/M main stations will indirectly control production in the subject wells through the O/M sub-stations.

The seven O/M sub-stations are to be located at the transmission terminals or heads of the respective wellfields and the O/M sub-stations will perform direct remote-control of well operation and production under the instructions of the O/M main stations.

1.19 Groundwater monitoring will mainly be conducted by means of groundwater table observation employing 8 monitoring wells. Three of the test wells bored in the course of the subject Study will function as monitoring wells. Consequently, 5 new monitoring wells will be required under the Project.

The location of the additional 5 wells are as follows:

Molino wellfield

Ojo de Agua wellfield

Belen wellfield or Brigada wellfield

Zone 10

Southern part of Zone 17

1.20 In view of the very significant volume of the future groundwater yield, including unknown volume drawn by non-EMPAGUA wells, every precaution must be made to avoid:

- Drawdown and contamination of groundwater aquifers; and
- Land subsidence or other adverse resultants.

Means of such precaution include:

- Monitoring of water level and volume of yield at each of the Project wells;
- Monitoring of groundwater level by construction of monitoring well at each of the existing wellfields;
- Periodical water quality check;
- Registration and control of non-EMPAGUA wells;
- Clarification of water cycle system and water budget in the Project area; and
- Establishment of groundwater control and conservation program.

II FACILITIES, IMPLEMENTATION AND COST

2.1 The facilities under the proposed Project are planned in accordance with the basic concept for water production and supply.

General features of the Project facilities are shown in the table on the following page.

5.2 An implementation period of 4 years is proposed including a one year preparation period to conduct the detailed design, construct the preparatory works, complete land acquisition, and carry out the proposed rehabilitation.

The construction schedule is divided into 3 blocks so that work completed in one year will realize 100 % benefits within the next year. Proposed construction work and facilities for each year are presented in the table below.

PROJECT FACILITIES

Item	Well Field	Canalitos			Norte	Lavarreda	El Rodeo Zona 18	Vista Hermosa	
		Juana de Arco	Santa Luisa	San Gaspar					
1. Production Facilities									
(1) Tube Well		7nos x 30ℓ/s	7nos x 30ℓ/s	3nos x 30ℓ/s	8nos x 35ℓ/s	2nos x 35ℓ/s	7nos x 20ℓ/s	4nos x 30ℓ/s	Total 1,120ℓ/s (1,000ℓ/s under 90% of operation efficiency)
(2) Casing		ϕ300 300m	ϕ300 300-350m	ϕ300 300-350m	ϕ300 300m	ϕ300 300m	ϕ300 300-350m	ϕ300 300m	
(3) Strainer		30m, 40m	30m	30m	30m, 40m	30m	30m	30m	
(4) Submerged Pump		1nos x 110kW 1nos x 132kW 5nos x 185kW	1nos x 110kW 2nos x 132kW 4nos x 185kW	2nos x 132kW 1nos x 185kW	3nos x 132kW 5nos x 185kW	1nos x 132kW 1nos x 185kW	3nos x 75kW 4nos x 132kW	7nos x 132kW 2nos x 185kW	
2. Water Transmission Facilities									
(1) Ductile Cast Iron Pipe									
	ϕ150mm	-	-	-	-	-	2,830m	-	Total 2,830m
	ϕ200mm	1,770m	3,450m	950m	4,650m	1,400m	390m	2,300m	14,910m
	ϕ250mm	2,360m	250m	1,000m	780m	-	-	900m	5,290m
	ϕ300mm	1,450m	1,360m	-	200m	-	-	-	3,010m
	ϕ350mm	1,080m	-	-	360m	-	-	-	1,440m
	ϕ400mm	-	-	-	500m	-	-	-	500m
	ϕ450mm	3,900m	-	-	300m	-	-	-	4,200m
	ϕ500mm	-	2,000m	-	-	-	-	-	2,000m (34,180m)
(2) Discharge Tank		108m³			2nos x 63m³ 126m³ 158m³	63m³			
(3) Booster Pump		1nos x 60ℓ/s			2nos x 35 ℓ/s 1nos x 70 ℓ/s 1nos x 87.5ℓ/s	1nos x 35ℓ/s			
(4) Syphon Bridge		2nos x (L=20m)						1nos x (L=20m)	
(5) Distribution Tank				2,835m³			2nos x 1,260m³ 25.2m³	1,890m³	
3. Power Transmission Facilities									
(1) Electric Line Length		2,900m	5,350m	3,400m	3,005m	610m	2,910m	4,600m	Total 22,775m
(2) Transformer Number		7nos	7nos	3nos	9nos	2nos	7nos	4nos	39nos
(3) Access Road			3km						
4. O/M Road									
(1) O/M Road Construction		-	250m	50m	1,120	100m	1,260m	400m	Total 3,180m
Widening		1,450m							1,450m
5. Maintenance Facilities & Equipment									
(1) O/M Station			x Santa Luisa				x Las Ilusiones		x : Existing o : Construction
(2) Sub Station		o Juana de Arco	o Santa Luisa	x San Gaspar	x T.K. 4-4	x Lavarrede	x Las Ilusiones	o Hermosa	
(3) Transceiver (UHF)		2nos x (Main Transceiver) 15nos x (Handy Transceiver) 2nos x (Battery Charger)							
(4) Work Shop		1nos 250m² (New Construction)							

III Cost Estimation

3.1 The total Project cost consists of direct construction costs, land aquisition and O/M facilities costs, administration and engineering costs and physical and price contingencies. The following basic considerations were employed in this Study.

(1) The exchange rate used was US$1 = Q1 (end of 1985 official rate);

(2) All construction costs are estimated according to current prices as of December 1985.

Financial Cost

(Unit: Quetzal)

		Foreign	Local	Total
1.	Production system	9,241,725	1,415,441	10,657,166
2.	Water Supply System	4,083,072	1,695,223	5,778,295
3.	O/M Facilities	2,872,750	695,271	3,568,021
4.	Rehabilitation	1,191,100	159,190	1,350,290
5.	Power Supply System	2,490,201	396,433	2,886,634
6.	Monitoring System	275,240	40,300	315,540
7.	Preparation	-	220,093	220,093
	Direct Construction Cost (Sub Total)	20,154,088	4,621,951	24,776,039
8.	Administration & Engineering	2,256,350	4,408,000	6,664,350
9.	Land Acquisition	-	1,022,525	1,022,525
	Sub Total	22,410,438	10,052,476	32,462,914
10.	Physical Contingencies	2,241,044	1,005,248	3,246,292
	Total	24,651,482	11,057,724	35,709,206

Production Cost

Production cost is estimated based on the following conditions:

(a) annual interest: 12%

(b) amortization period: 8 - 16 years

(c) proposed project life: 30 years (this includes one time replacement of pumps; two time replacement of motors)

(d) proposed production: 1.38m^3/sec
(116,640m^3/day; 42,573,600m^3/year)

Unit production cost for 1m^3/sec is as follows:

Item	Initial Cost/4 (Q)	Life	Annual Cost/2 (Q)
Submersible motor	854,130	8.0	179,00
Submersible pump, booster pump/motor	988,770	16.0	145,175
Motor car	119,000	10.0	21,060
Water Level	85,000	5.0	15,045
Engineering Facilities	33,160,091	30.0	4,116,615
Total	35,206,991		4,476,895
Cost per m^3 1.38m^3/sec x 86400 x 365 = 42,573,600 m^3/year			0.105 Q/m^3
Operation Cost/3			0.14691
Production Cost			0.252 Q/m^3

IV PROJECT EVALUATION

Under assumed conditions for revenue and cost estimations, the basic case results in 13% FIRR and positive NPV (12%) indicating that the Project is financially viable if the borrowing rate (discount factor) is lower than 13%.

Sensitivity analysis indicates the Project is more sensitive to variations in revenues than to changes in costs. A 10% decrease in revenues causes FIRR to drop to 7.5% from 13.1% of the basic case while a 10% increase in investment and replacement costs causes only a small drop in the FIRR (from 13.1% to 11.1%). Assuming a simultaneous 10% decrease in revenues and a 10% increase in costs, the FIRR drops to 5.9% from 13.1% of the basic case.

The Project sensitivity to variations in revenues implies the need for a careful management of revenues from Excess Consumption which, in turn, implies the need for meters in good working conditions.

The following Table shows the relationships between Excess Consumption, the corresponding proportions of net water production accounted for, and the resulting FIRR.

Case	Excess Consumption	Net Water Production	FIRR
	m^3/month/connection	%	%
Present Situation	7	85	5.71
Basic Case	10	90	13.09
Maximum Revenues	15	100	23.41

V CONCLUSIONS AND RECOMMENDATIONS

5.1 Generally speaking, the water shortage problems in the northern and eastern parts of Metropolitan Guatemala including the city center are more serious than those in the southern and western parts. The water shortage in the city center zone is mainly due to the high density of the population and the massive demand for water for domestic use as well as for commercial and public use.

5.2 The available groundwater for the Project is classified into two types according to the recharge mechanism and the aquifer. These two types are the upper aquifer and the lower aquifer. On the basis of hydrogeological survey, the maximum permissible yield of these is estimated at more than 1 m^3/s which is the target yield under the Project.

5.3 The main groundwater development areas under the Project will be the eastern and northern sectors. Moreover, five wellfields were delineated in the vicinity of the boundary of the eastern and northern sectors, in consideration of the present conditions for local water shortages, the proposed distribution programs and economization of the transmission system for the newly developed groundwater.

5.4 In order to have stable groundwater production throughout the year, the Project is mainly aimed at development of the lower aquifer as the upper aquifer will have decreased productivity due to seasonal variations of the water table.

5.5 As a result of the Study, the estimated groundwater storage, the development potentiality and permissible yield are concluded as sufficient to supplement the projected water shortage in Metropolitan Guatemala by the target year. Accordingly, the Project should be implemented as early as possible.

5.6 In order to minimize the O/M expenses (operation personnel expenses in particular) the semi-centralized/remote control system is proposed for operation and control of the water production systems.

According to the objectives mentioned above, the establishment of an effective O/M system and the required numbers of skilled workers should be realized.

5.7 A construction schedule is proposed which allows for the prompt realization of the Project benefits.

Facilities to be constructed in a certain year are scheduled to be completed within the same year and implementation will be phased such that benefits are realized immediately for each stage upon completion of that stage.

The implementation schedule and scope of the annual construction work under the Project are recommended as presented in this Report.

5.8 Although the Project aims at developing the lower aquifer, aquifer properties such as the groundwater divide, ridges, local systems, artesian conditions, etc. are not precisely clear at this stage.

When the importance of the confined aquifer as a water resource for the Metropolitan Guatemala inhabitants is taken into account, it is expected that a more detailed study will need to be conducted to cover such groundwater development in and around the Guatemala City Valley.

5.9 At the Ojo de Agua plant, the timing of facility malfunctions at several wells was linked to the emergence of abnormal indications in the water qualities. Consequently, by carefully tracing water quality through frequent investigations, it is possible to know the appropriate time for well repair. As the main cause of these malfunctions appeared due to the fact that well pumps were being utilized beyond their effective life, more frequent cleaning of the inside of water drawing pipes should be performed, and the pumps at some wells should be replaced.

5.10 In Guatemala, chlorine residual in tap water should be higher than 0.7 mg/l (FIG. 3.3.1) on the basis of the correlation between general bacteria number and the residual chlorine in tap water samples. Where the chlorine residual was higher than 0.7 mg/l, the general bacterial number was always lower than 100/ml, which is the permissible number for drinking

water. Where chlorine residual was higher than 1.5 mg/l, bacterial number was zero with few exceptions.

5.11 With the exception of the Las Ilusiones plant, sedimentation and filtration at water treatment plants appears to be carried out efficiently. The high content of soil in the Teocinte River was supposed as the cause of decreasing efficiency of sedimentation and filtration in the Las Ilusiones plant. It is accordingly strongly recommended that forestation be performed along the sides of the river. Also, at the El Altantico pumping station, more efficient facilities should be constructed to trap soil before water enters the water pond.

5.12 Due to absence of sewage treatment facilities of significant capacity, sanitary and environmental conditions of the metropolitan area are very poor inviting water contamination which threatens inhabitants' health and EMPAGUA's raw water intake downstream.

5.13. Deforestation for firewood followed by uncultivated pasturage and development of housing complexes are uncontrolled and encroaching upon green areas which have contributed to groundwater conservation.

5.14 The following are recommended as measures to be taken by EMPAGUA to strengthen its institutional functions;

i) Implement human resources management policy to increase productivity.

ii) Intensify public relations compaigns to inform the general public on EMPAGUA activities, and to educate consumers on the need for meters and the need for the rational use of water.

iii) Continue implementation of the Arevalo Perez recommendations and IDB loan clauses.

iv) Strengthen internal audit functions to improve control of operations.

v) Generate timely financial and internal audit reports to serve as an aid to senior management decision making.

vi) Strictly follow billing and collection schedules, and apply gradual penalties for late payment or non-payment (fine; cutting service off and charging full reconnection costs).

vii) Take special care in the collection and management of revenues because of the sensitivity of the Project to changes in revenues. Revenues from titles exceed Q 30 million, and total revenues are greatly influenced by revenues from excess consumption.

viii) Set up a separate accounting system for the Project to exercise better control over finances.

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

1.1 Authorization

This Final Report is prepared in accordance with the "Scope of Work of the Feasibility Study on the Groundwater Development Project in Guatemala City" agreed upon between the Municipal Water Supply Corporation of Guatemala City (EMPAGUA) and the Japan International Cooperation Agency (JICA) on December 11, 1984 which was authorized in accordance with "The Agreement on Technical Cooperation between the Government of Guatemala and Government of Japan" dated March 28, 1977.

This Report deals with the study on the said Development Project (hereinafter referred to as the Project) on the basis of results of field survey and study undertaken by the Study Team of JICA and the comment by the EMPAGUA officials concerned.

1.2 Project History

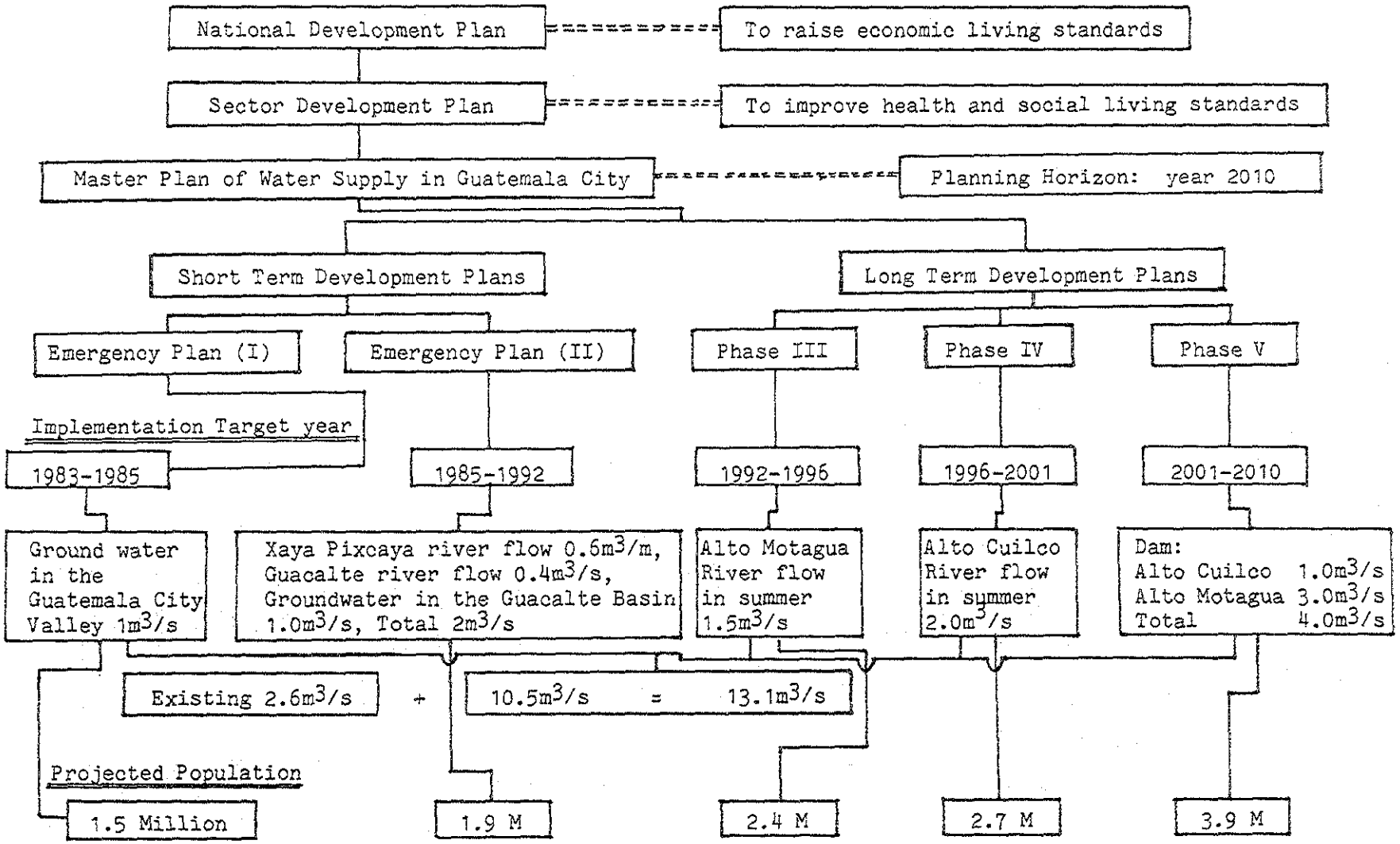
The "Guatemala City Water Supply Master Plan" (PLAMABAG) was completed by EMPAGUA in 1982 to establish an orientation for policy aimed at resolving the steadily intensifying domestic water problems in Metropolitan Guatemala. The planning horizon for PLAMABAG is the year 2010.

PLAMABAG consists of two short term development plans and three long term development plans as shown in FIG. 1-1.

The short term plans are referred to as "Emergency Plan (I)" and "Emergency Plan (II)" on the basis of project urgency. Emergency Plan (I) has a target completion date of 1985, and Emergency Plan (II) is targeted for completion by 1992.

In order to realize Emergency Plan (I) as rapidly as possible, EMPAGUA requested through the Government of Guatemala in April 1984 technical cooperation from the Government of Japan to carry out a feasibility study for Emergency Plan (I) of PLAMAGAG. In response to this request, the Government of Japan dispatched through JICA a Preliminary Study Mission in December 1984.

Fig.1-1 PLAMABAG



In addition to undertaking field reconnaissance survey and gathering necessary data on the proposed Project area, the Study Mission also met with officials from EMPAGUA, Guatemala City, and the Government of Guatemala to discuss the proposed Project. On December 11, 1984 an agreement was reached between EMPAGUA and JICA regarding the Scope of Work for the Study on the Groundwater Development Project in Guatemala City.

In accordance with the above agreement, JICA dispatched the Guatemala City Groundwater Development Project Study Team (hereinafter referred to as the Team) composed of 6 members to Guatemala City on July 12, 1985 in order to carry out the field survey in cooperation with EMPAGUA officials. The field survey was conducted from July 1985 to July 1986. During this period, home office work was performed over three intervals. A Progress Report, an Interim Report, and Draft Final Report were submitted to EMPAGUA in December 1985, March 1986, and August 1986, respectively.

1.3 Study Objectives

Study objectives are as follows:

(1) To examine and evaluate the technological feasibility and financial viability of development of $1m^3/sec$ of groundwater for supply to Metropolitan Guatemala; and

(2) To provide training and technology transfer to concerned EMPAGUA engineers.

1.4 Scope of Work

1.4.1 Study Area

The Study area encompasses the Guatemala City Valley as delineated under Emergency Plan (I) of PLAMABAG (with particular focus on the northern sector thereof) and the neighboring basin to the east of Guatemala City Valley.

1.4.2 Study Components

The Study included both field survey and home office components.

(1) Field Survey

a) Collection, collation and analysis of all data and information relevant to the Project;

b) For groundwater development planning: topographical, hydrological, meteorological, hydraulic and geologic survey; water resources development and utilization survey; electric prospecting; test well boring; test pumping; etc;

c) For water service supply planning: socio-economic survey; water demand and supply survey; water service facilities regulation, operation and maintenance survey;

d) For groundwater conservation and management planning: current groundwater production survey; groundwater recharge survey; land use survey; public sanitation and sewerage survey;

e) For operation and maintenance planning: survey of current water production and supply system and existing operation and maintenance structure;

f) For well rehabilitation planning: survey of existing well facilities and production; and

g) For facilities design: labor and materials cost survey, labor and material availability survey; topographical study.

(2) Home Office Works

a) Analysis of existing water demand, and future demand projection in the study area; and the formulation of a water supply plan on the basis thereof;

b) Evaluation of groundwater characteristics and development potential; and on the basis thereof formulation of a groundwater development plan;

c) Preliminary design of groundwater development and water supply facilities;

d) Formulation of an operation and maintenance plan for water production and supply facilities;

e) Formulation of a rehabilitation plan for existing wells;

f) Study of a groundwater conservation and management plan;

g) Formulation of a proposed Project implementation plan; and

h) Environmental impact assessment; financial analysis and evaluation

1.5 Activities of The Study Team

The Team undertook field and home office work in the following stages.

First Stage Field Work: 12 July 1985 - 15 March 1986
Home Office Work: 18 September 1985-17 November 1985
16 January 1986 - 28 February 1986

Second Stage Field Work: 22 May 1986 - 20 July 1986
Home Office Work: 22 May 1986 - 4 August 1986

All field work was conducted in cooperation with EMPAGUA officials. Major activities of the Study Team were as follows:

(1) On July 12, 1985, the initial group (Team leader and 3 other individuals) of Team members arrived in Guatemala City to discuss the basic Study orientation and schedule with the concerned EMPAGUA officials.

(2) On August 10, 1985, based on roughly one month of field survey and investigation, as well as discussions with concerned EMPAGUA officials, an Inception Report was prepared and submitted to EMPAGUA. On the basis of this report, further discussions were held with the said involved officials, and basic orientation for the subject groundwater development planning was determined.

(3) On November 28, 1985, a Progress Report embodying the results of approximately four months of field survey and 2 months of home office work was submitted to EMPAGUA. The contents of said report were discussed in detail with concerned officials of the said agency.

(4) On March 3, 1986, an Interim Report embodying the detailed results of field survey and home office work conducted to December 15, 1985 was submitted to EMPAGUA. The contents of the report were likewise discussed in detail with concerned EMPAGUA officials.

(5) Test well boring, test pumping and other remaining field investigations were completed by March 15, 1986.

(6) Pumping tests, examination of existing wells by means of T.V. probe, investigation concerning the present O/M system and other necessary supplemental surveys were carried out from May 22 to July 20, 1986.

(7) In consideration of the comments of EMPAGUA officials concerned regarding the study results in the Progress and Interim reports, second stage home office work was undertaken with the results compiled in the Draft Final Report.

(8) The Draft Final Report was submitted to EMPAGUA on 8 August 1986 and descussions were held with EMPAGUA officials concerning the said Draft Final Report.

(9) In order to maximize transfer of technology all works during the field survey component of the Study were carried out jointly with EMPAGUA engineers. Particular emphasis in this regard was placed on collation of results of electric prospecting and examination practice utilizing T.V. probe.

The EMPAGUA officials and Study Team members involved in the Study are listed below:

EMPAGUA

President	Mr. Alvaro Arzu
Former President	Mr. Jorge Saravia
General Manager	Mr. Roberto Goyzueta
Former General Manager	Mr. Danilo Cruz
Assistant General Manager	Mr. Julio Santolino
Assistant General Manager	Mr. Claudio Olivares
Former Assistant General Manager	Mr. Carlos Castro
Former Assistant General Manager	Mr. Alfredo Bonatti
Director of Planning	Mr. Mario Rojas
Director of Operation and Maintenance	Mr. Carlos Arriola
Chief of Technical Planning	Mr. Carlos Quezada
Adviser	Mr. Luis Garcia

Adviser	Mr. Julio Mario de La Riva
Adviser	Mr. Rolando Yon

INSIVUMEH

Director	Mr. Estuardo Velasquez
Assitant Director	Mr. Eddy Sanchez

IGM

Director	Mr. Marco Asturias
Assistant Director	Mr. Enrique Gonzales

Counterpart Personnel

Coordinator	Mr. Carlos Ramirez
Assistant Coordinator	Miss Lucrecia Argueta
Geophysist	Mr. Fernando Samayoa
Well Drilling Supervisor	Mr. Otto Soto
Well Drilling Supervisor	Mr. Oscar Urruela
Water Supply	Mr. Jorge Garcia
Environmental Evaluation	Mr. Francisco Charnaud
Environmental Evaluation	Mr. Raul Franco
Operation and Maintenance	Mr. Victor Paz
"	Mr. Ismael Veliz
"	Mr. Freddy Ordonez
Assistant Engineer	Mr. Manuel Puente
"	Mr. Oscar Moran
"	Mr. Ramon Burgos
"	Mr. Danilo Castillo
"	Mr. Guido Echeverria
Hydrologist	Mr. Gustavo Garcia
Draftsman	Mr. Mario Lopez
"	Mr. Nery Ortiz
"	Mr. Jose Roberto del Valle
Porter	Mr. Carlos Ortiz
Secretary	Mrs. Gladys Pinzon
"	Mr. Guillermo Hernandez

JICA Study Team

Team Leader, Hydrogeology	Mr. Katsuyoshi Zaoya (July - Oct. 1985)
Team Leader, Hydrogeology	Mr. Ikuro Inamori (Nov. 1985 -)
Electric Prospecting	Mr. Takashi Aoyama
Financial Evaluation	Mr. Masaru Obara
Investigation & Well Drilling	Mr. Katsuya Kamisato
Water Supply	Mr. Takashi Ohara
Environmental Evaluation	Mr. Hiromasa Minakami
Water Quality	Miss Akiko Mukade
Hydraulic Analysis	Mr. Masahiro Yamaguchi
Operation and Maintenance	Mr. Juji Semba

JICA

Planning/Coordination	Mr. Takao Toda
"	Miss Eri Honda

CHAPTER II

PROJECT BACKGROUND

CHAPTER II

PROJECT BACKGROUND

2.1 National Background

2.1.1 Socioeconomy

The territory of the Republic of Guatemala is 108,809km ^{2}. Total population is estimated at 7.8 million (1984) with an annual population increase rate (1973-1984) of 3.1% and a population density of 72 persons per km^2. With respect to population distribution in 1981, urban population comprised 36.76% and rural population 63.24% of total population.

Administratively, Guatemala is divided into 22 Departmentos (states) each of which are in turn divided into Municipios (municipalities). There are 328 municipalities in the country.

The principal economic sectors in the country are agriculture, commerce and manufacturing. Production in the agricultural and commercial sectors, respectively, accounted for 25% of the national GDP, while that of the manufacturing sector contributed 16%. Agriculture is the predominant sector, encompassing 60% of the nation's employed population and producing 50-60% of total exports.

GDP

(1985 prices; in millions of quetzal)

	1980	1981	1982	1983	1984
GDP	3,107	3,127	3,016	2,936	2,941
Agriculture	772	781	757	737	749
Minerals and Petroleum	15	9	11	11	8
Secondary Industries	668	671	630	594	683
Tertiary Industries	1,652 (839)	1,666 (844)	1,618 (797)	1,594 (763)	1,601 (764)

( ): Commercial sector
source: Bank of Guatemala

During the 1970's the Guatemala economy experienced steady growth but since 1978, the Guatemala economy has steadily deteriorated as manifested in the the GDP growth rate which was negative in 1982 (-3.5%) and 1983 (-2.7%). However, preliminary data indicates a slight increase (0.7%) in the 1984 GDP growth rate.

The problem started in the late 1970's caused mainly by (i) world recession which resulted in a decreasing international demand for and prices of traditional export crops as well as increasing import prices; (ii) CACM difficulties which adversely affected exports of manufactures; and (iii) political deterioration in Central America which discouraged domestic investment and external financing while stimulating private capital outflow. Lack of timely economic policies is generally regarded to have aggravated the situation.

The per capita GDP in 1984 was Q1,146, while average annual income was Q1,064. This figures show little change since 1981. Compared to other nations in the region, inflation in Guatemala has generally been less. Inflation was 11% in 1980-81, 5-6% in 1982-83, and 3.6% in 1984. In the latter half of 1985, however, domestic prices rose sharply in response to a 50% cost rise in petroleum.

In mid-November 1984, Guatemala abandoned its fixed rate of one quetzal per U.S. dollar, which had been maintained for 60 years, and introduced a three-tier exchange system comprised of an official market, a free banking market, and an auction market.

The official market, where the exchange rate remained at Q1 = US$1 accounted for about two-thirds of total foreign exchange transactions. The banking market, which was to operate at an exchange rate determined by market forces, covered most of the remaining foreign exchange transactions. The banking market rate was originally set at around Q1.45 per US$1, but increased constantly up to about Q3.80 per US$1 around October 1985, declined to about Q2.20 per US$1 in November 1985, and gradually increased to around Q2.90 per US$1 in mid-December 1985.

2.1.2 National Development Plan

The framework and direction of national and sectoral development of Guatemala are defined in the most recent biennial National Development Plan (NDP) formulated for 1984 and 1985. The NDP identifies the problems facing the country and sectors, defines the development objectives, and delineates the strategies and policies to be followed.

The fundamental development objective is the improvement of social well being through the attainment of a sufficiently high economic growth rate to create a favorable environment for income redistribution.

The 1984-1985 NDP assigned 24.9% of total investment to social sectors as a means to improve the quality of life of the general population.

In order to reduce the disparity between urban and rural areas, the 1984-1985 NDP sought to slowdown the growth of Guatemala City by reducing investment in urban areas from 42.0% in 1970-1979 to 21.0% in 1984-1985.

At the United Nations Conference on Water (Mar del Plata, 1977), the 1981-1990 period was designated as "International Decade for Potable Water Supply and Sanitation" with the goal of supplying potable water and sanitation to the world population by 1990. The Guatemalan Government, realizing the importance of water and sanitation services for population health and well being, formulated a National Plan for the Decade with the purpose of making a maximum effort toward the attainment of full service to the population. The plan was formulated by the permanent Coordinating Committee on Water and Sanitation (COPECAS) with cooperation of INFOM, UNEPAR, EMPAGUA and SEGEPLAN, and with the technical assistance of WHO/PAHO Consultants. Basic plan targets by the year 1990 are as follows:

	1982	1990
Water service (% of population with access)	49.8	81.2
Urban area	90.2	92.7
Rural area	24.0	72.8
Sanitation service	33.6	81.2
Urban area	47.0	92.7
Rural area	25.0	72.8

Standards of potable water and sanitation service for the above plan were determined at 6 levels according to service population scale.

Level	Population	Water Service	Sanitation service
I	isolated	private system	latrine
II	100-500	40 l/person/day 100% by communal water tank	latrine 100%
III	500-2000	water service: 100 l/person/day: 50% Water tank: 40 l/person/day: 50%	flush toilet: 50% latrine: 50%
IV	2,000-10,000	water service: 150 l/person/day: 60% water tank: 40 l/person/day: 40%	flush toilet: 60% latrine: 40%
V	10,000-50,000	water service: 200 l/person/day: 70% water tank: 50 l/person/day: 30%	flush toilet: 70% latrine: 30%
VI	over 50,000	water service: 225 l/person/day: 85% water tank: 50 l/person/day: 15%	flush toilet: 85% latrine: 15%

2.1.3 Institutional Framework

National planning in the water supply and sanitation service sector is carried out principally by COPECAS, an entity established in July 1982 by agreement signed between SEGEPLAN, MSPyAS, INFOM and EMPAGUA.

Implementation of water supply and sanitation service projects, and regulation of service standards is performed principally by the following government entities, in conformity with the relevant legislative guidelines.

2.1.4 International Cooperation

United Nations agencies such as UNDP, WHO, UNICEF, FAO and UNESCO have set up cooperation mechanisms to carry out programs for the water and sanitation decade.

Local sectoral institutions concerned with sewage and water supply contact these agencies through COPECAS in order to request the cooperation necessary for personnel training, for the study of new technologies and least cost alternatives, for the planning of water supply and waste disposal, for the improvement of operation and maintenance, and for institutional strengthening.

In order to implement plans for the decade, it will be necessary to resort to external financing from international lending institutions such as IDB, WB, AID, CIDA and CABEI.

2.2 Regional Background

2.2.1 Metropolitan Guatemala

Metropolitan Guatemala constitutes the urban zone comprising Guatemala City and surrounding towns which have common social, economic and cultural ties.

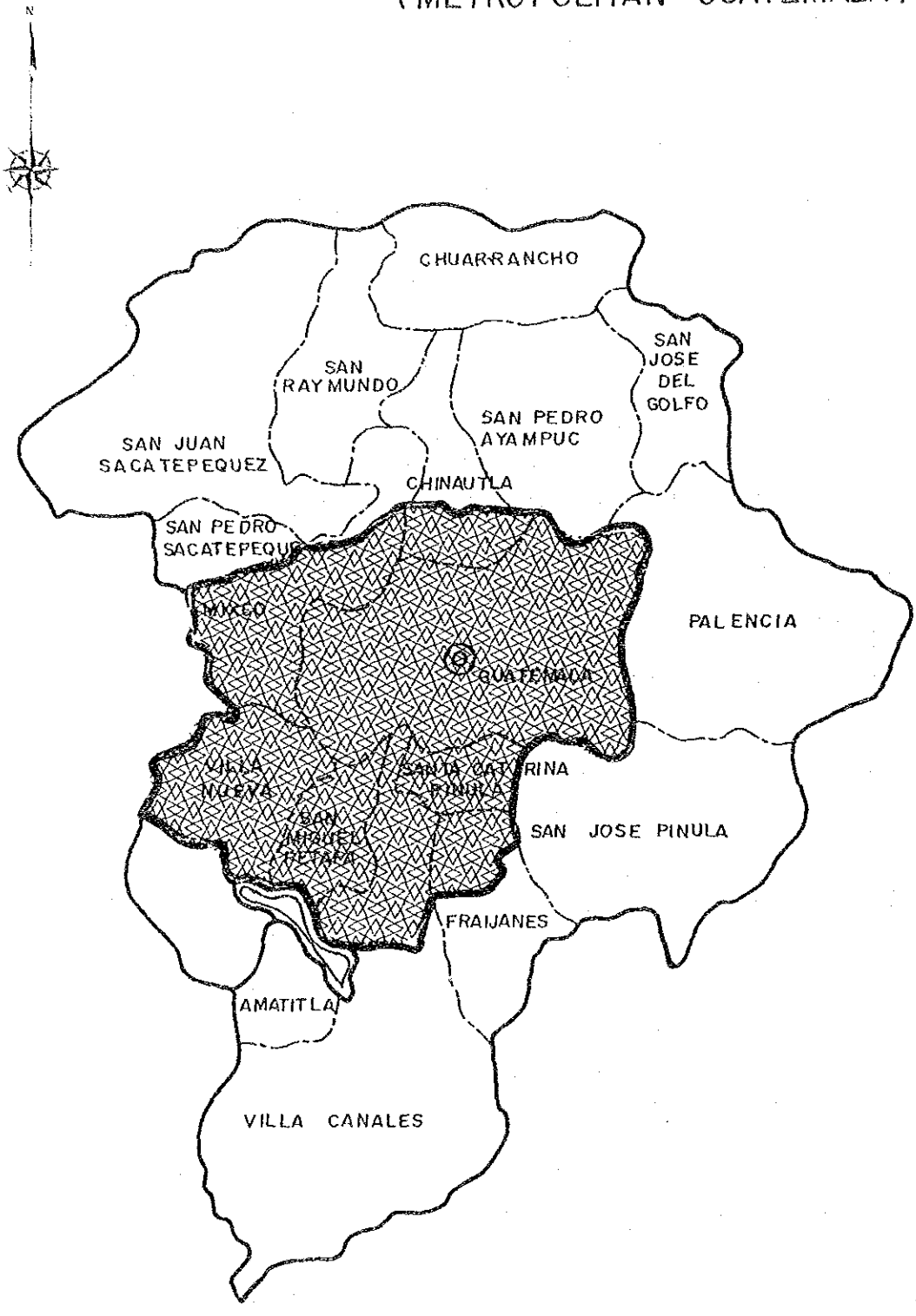
In terms of the water service and sanitation sector, Metropolitan Guatemala is defined as the municipalities serviced by EMPAGUA, i.e, Guatemala, Mixco, Villa Nueva, Petapa, Santa Catarina Pinula, and portions of the 2 municipalities of Villa Canales and Chinautla. This area encompasses 470km^2. (Fig. 2-1)

The Government of Guatemala in 1971 initiated construction of the Xaya-Pixcaya National Aqueduct scheme to introduce sufficient water volume for consumption in Guatemala City.

EMPAGUA, the Guatemala City Municipal Water Supply Corporation, was created by the Guatemala City Municipal Council on Nov. 28, 1972 to be in charge of the administration, improvement, and expansion of potable water supply in Guatemala City and contiguous areas.

Upon agreement between the Central Government and Guatemala City, EMPAGUA was given authority over operation of the Xaya-Pixcaya aqueduct. As a result, the limits of the service area of EMPAGUA have corresponded since its inception to Metropolitan Guatemala.

FIG. 2-1 WATER SERVICE AREA
(METROPOLITAN GUATEMALA)



WATER SERVICE AREA

Total population of Metropolitan Guatemala is estimated at 1.5 million as of 1985. According to the 1981 census, the population was 1,134,072, which represents 18.7% of the total national population. Approximately 66% of the population of Metropolitan Guatemala is in Guatemala City, with the remaining 44% in the other municipalities.

Population in Metropolitan Guatemala doubled (99.9%) from 1940 to 1950, more than doubled (105%) from 1950 to 1964, increased 38.8 percent from 1964 to 1973 and 18.4 percent from 1973 to 1981. Current population growth is estimated at 4.5% which would result in a population of 2,732,000 by the year 2000 and 3,942,300 by the year 2010 (see TABLE 2-1). As reflected in TABLE 2-2, population growth in Metropolitan Guatemala centered in Guatemala City until 1950; Mixco, Chinautla, and Villa Nueva during the 1950's; San Miguel Petapa in the 1960's and early 70's; and Santa Catarina Pinula and the northeastern zones of Guatemala Municipality in the first half of the 1990's.

2.2.2 Water Service and Sanitation Service

At present, water service in Metropolitan Guatemala is provided from the following sources:

(1) EMPAGUA;

(2) Agua Del Mariscal, S.A. (a private water supply company);

(3) individual water supply systems of the military, government institutions, public schools, public hospitals, etc.;

(4) privately owned wells; and

(5) direct consumer utilization of spring and river water.

TABLE 2-1 POPULATION PROJECTION OF METOROPOLITAN GUATEMALA

EMPAGUA		E.D.O.M		PLAMABAG
	Annual Growth 5%	Total	Urban Area Influenced by Guatemala City	
1964		732,500	610,400	557,260
1970		990,900	831,100	
1973		1,134,200	953,300	850,250
1975	1,028,000			
1980	1,312,000	1,565,100	1,317,000	1,171,050
1981	1,378,000			
1985	1,675,000			1,463,000
1988	1,939,000			
1989	2,036,000			
1990	2,138,000	2,526,900	2,109,600	1,816,250
1991	2,245,000			
1992	2,357,000			
1993	2,475,000			
1994	2,599,000			
1995	2,728,000			
2000	3,482,000	4,187,400	3,426,300	2,732,300
2010				3,942,500

The population projection by PLAMABAG will be used in this Project.

TABLE 2-2 POPULATION GROWTH RATE, 1940 - 1981

(%)

	1940-1950	1950-1964	1964-1973	1973-1981
Metro, Guatemala	6.62	4.51	3.49	2.12
Mun. Guatemala	8.15	4.87	2.26	0.93
Chinautla	3.64	10.74	5.28	3.07
Mixco	4.74	9.07	14.06	5.40
Villa Nueva	5.65	6.39	10.11	6.77
San Miguel Petapa	4.94	3.29	10.17	6.40
Santa Catarina Pinula	3.66	4.42	3.49	3.77
Villa Canales	4.08	2.02	2.02	2.70

Source: DGE

According to the 1981 census, the status of water supply and sanitation service in Metropolitan Guatemala (in 1981) is as shown below.

WATER SERVICE

Total Households	Private Taps	Shared Taps	Public Taps	Well	River, Lake, Spring	Others
225,879	122,667	49,176	28,054	3,887	1,991	19,104
100%	54.3	21.8	12.4	2.2	0.9	8.4

Water service facilities are owned and operated by EMPAGUA, MARISCAL, BANVI (National Housing Bank), private developers, the military, schools, hospitals and other public institutions. EMPAGUA currently supplies 40% of the households in Metropolitan Guatemala, producing 205,000m^3/day to 239,000m^3/day. MARISCAL serves roughly 7% of the households, providing 20,000m^3/day.

Water demand in Metropolitan Guatemala is steadily increasing. As MARISCAL has no plans for extension of its water service, EMPAGUA is the only entity capable of responding to future water demand.

Water production within the EMPAGUA service system increased about 17% from 1980 to 1984. On the other hand, the number of customers within the EMPAGUA service area grew by 30%. As of 1985, water shortage within the EMPAGUA system is estimated at 15%.

Sanitary service within Metropolitan Guatemala is underdeveloped at present. There are no public wastewater treatment plants, and wastewater is discharged directly into area rivers from 5 sewer outfalls. Households with sewerage service are as indicated in the TABLE 2-3.

Approximately 57% of households are connected to the public sewerage system. Some new housing developments operate independent sewerage systems.

TABLE 2-3

SANITATION SERVICE

Total No. of Households	Total Households Served	Flush Toilets						Washable Toilet	Cesspit Toilet	No Toilet
		Connected with Public Works			Connected with Independent Plant					
		Subtotal	Private	Shared	Subtotal	Private	Shared			
225,879	140,238	127,845	98,280	29,565	12,193	7,324	4,869	13,031	61,359	11,251
100%	62%		(56.6%)			(5.4%)		5.8%	27.2%	5.0%

2.2.3 Need for the Water Resources Development Project

The current population growth rate in Metropolitan Guatemala is roughly 4%. Population by the year 2000 is estimated at 182% the current population, or 2,732,300. By 2010, population is anticipated to rise to 262% the present, or 3,942,000.

Furthermore, expansion of sewerage service, modernization, improvements in standards of living, etc., are resulting in a steady increase in per capita demand for water.

Present and projected future water demand is as shown in FIG. 2-2. By the year 1990, demand is forecasted at 142% that of 1985. By the years 2000 and 2010, demand is subsequently projected at 292% and 411%, respectively, of the current level.

The population serviced by EMPAGUA is estimated at 40 to 45% of the total for Metropolitan Guatemala. The rate of increase of household service connections whithin the EMPAGUA system is 6.7%. However, water production has not expanded since 1982. EMPAGUA's current water production and service structure is not capable of satisfying this steadily increasing water demand.

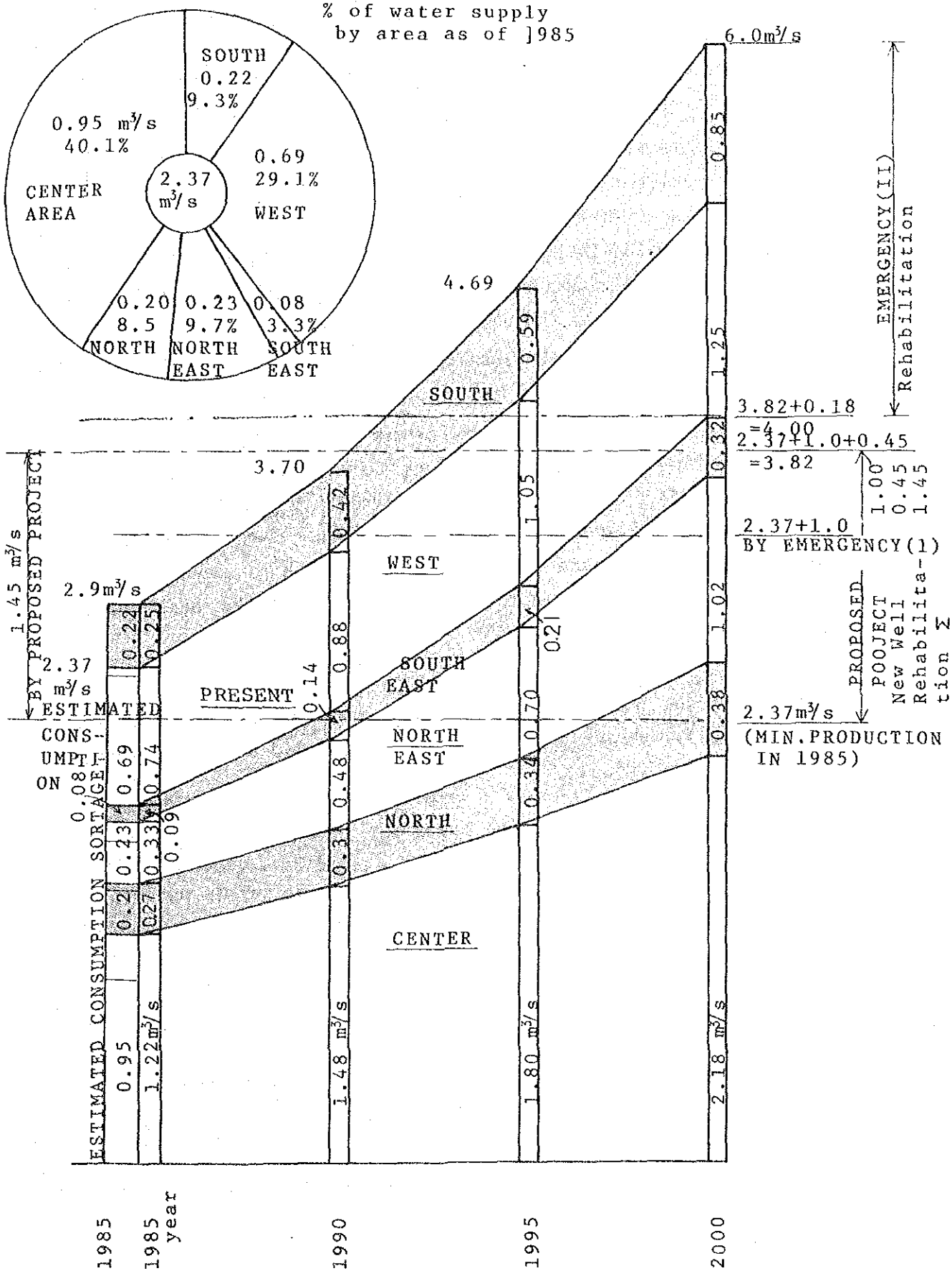
Water production, demand and shortfall within the EMPAGUA system is estimated for October 1984 to September 1985 as follows:

	Max.	Mean	Min.
Required production based on estimated demand	2,836	2,836	2,836m^3/sec
Actual production	2,717	2,553	2,374
Water shortage	0.119	0.283	0.462m^3/sec
Shortage percentage	4%	10%	15%

As can be seen from the table, the maximum shortfall was 15%, the minimum was 4% and the mean was 10% for the subject period.

As a result, it is clear that implementation of a water resources development program is urgently required to alleviate the steadily worsening status of water supply vis-a-vis demand in Metropolitan Guatemala.

FIG. 2-2 ESTIMATED WATER DEMAND



2.2.4 PLAMABAG

In March 1980, EMPAGUA, in accordance with the National Development Plan, embarked on preparation of a master plan for water supply in Metropolitan Guatemala with financial cooperation from IDB.

The "Guatemala City Water Supply Master Plan (PLAMABAG)" was subsequently completed in May 1982. PLAMABAG constitutes a master plan to meet water demand in Metropolitan Guatemala to the year 2010. The plan forecasts a population in Metropolitan Guatemala of 3,942,300 by the year 2010. In order to respond to anticipated demand generated by this population, PLAMABAG calls for new water development of 10.5m ^{3}/sec. Added to the current supply capacity of 2.6m ^{3}/sec, this yields a total 13.1m^3/sec.

PLAMABAG consists of two short-term development plans and three long-term development plans. The short term plans are referred to as "Emergency Plan (I)" and "Emergency Plan (II)" on the basis of project urgency. Emergency Plan (I) aims at meeting water demand over the period 1988-1992. It aims at the development of 1m ^{3}/sec of groundwater within the Guatemala City Valley, with emphasis on low project cost and short implementation period.

Emergency Plan II and the three long term plans call for development of resources outside the Guatemala City Valley basin (river sources: 8.5m^3/s; groundwater: 1m^3/s; total: 9.5m^3/s) and conveyance to Metropolitan Guatemala.

2.2.5 Emergency Plan (I)

Groundwater recharge in the Guatemala City Valley is assumed to be 100 to 120 million m^3. At present, it is estimated that 45-50 million m ^{3} is pumped in the valley. Emergency Plan (I) calls for additional groundwater development of 1m^3/s (30 million m^3/year).

The plan has the following advantages:

i) Lower development cost compared with other water sources.
ii) Facilitated connection to the existing distribution system.
iii) Short implementation period.
iv) Envisioned goundwater represents the most near-at-hand water resource with maximum development potential.

Water developed under Emergency Plan (I) would be distributed through the existing EMPAGUA service system. Principal components of the plan are well construction and construction of facilities to feed produced water into EMPAGUA's existing system.

2.2.6 Emergency Plan (II)

Emergency Plan (II) calls for expansion of the Xaya-Pixcaya national aqueduct scheme, and consists of the following components:

i) Expansion of the Xaya-Pixcaya aqueduct capacity from 1m ^{3}/s to 3m^3/s

ii) Levelling up of the water treatment capacity at the Lo de Coy treatment plant from 1m^3/s to 3m^3/s

iii) Water resources development plan:

1) 0.6m^3/s of additional water production through development of surface water (including floodwater utilization) of the Xaya-Pixcaya river

2) Development of 0.4m^3/s at the upper reaches of the Guacalate river basin

3) Development of 1.0m^3/s of groundwater in the Guacalte river basin

Conveyance pipeline works, which comprise a principal element of the plan, were largely completed in 1985 with financial cooperation from IDB. Construction work on the water treatment plant is expected to begin in 1986. Regarding water resources development, EMPAGUA plans to carry out the necessary studies as soon as possible.

CHAPTER III

THE PROJECT AREA

CHAPTER III

THE STUDY AREA

3.1 General

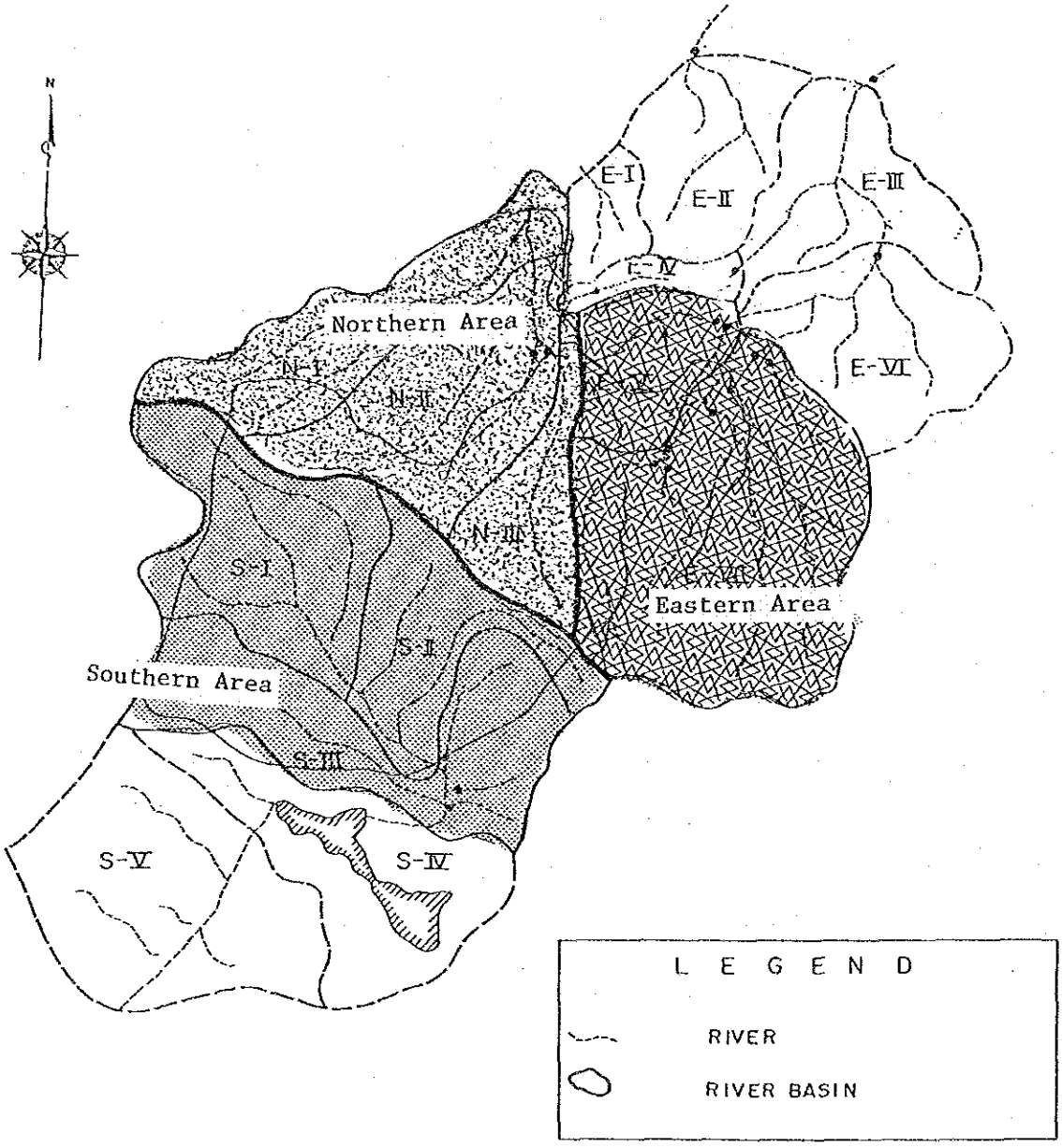
On the basis of study and analysis of topography, geology, hydrogeology, groundwater development potentiality, and the environmental impact of such development, the Study area has been determined as comprising the Guatemala City Valley (with the exception of Amatitlan Lake and the Michatoya river basin) and the neighboring basin of the Las Canas river to the northeast. This area, including the envisaged benefit area of 470km^2 serviced by EMPAGUA in Metropolitan Guatemala, encompasses a total of 815km^2. (FIG. 3-1).

The continental divide lies west to east in about the center of the Study area and dissects the area into two large hydrologic basins, one to the north and one to the south. A distinct basin is further distinguished to the east of the northern area as delimited by the Santa Catarina fault running north to south. The Study area is thus seen as consisting of eastern, northern and southern sectors. Rivers within these sectors may be grouped into several smaller catchment systems as indicated in FIG. 3-2.

Principal rivers in each sector and their catchment areas are as follows:

	River	Catchment
North	Las Vacas	240.0km^2
N-1	El Zapote	86.8
N-2	El Tzalja	96.3
N-3	Las Vacas	56.9
East	Las Canas	256.2km^2
E-5	Las Vados	46.8
E-6	Las Canas	209.4
South	Villalobos	318.0km^2
S-1	El Molino	119.1
S-2	Villalobos	73.0
S-3	Pinula	125.9

Fig. 3-1 PROPOSED GROUNDWATER DEVELOPMENT AREA



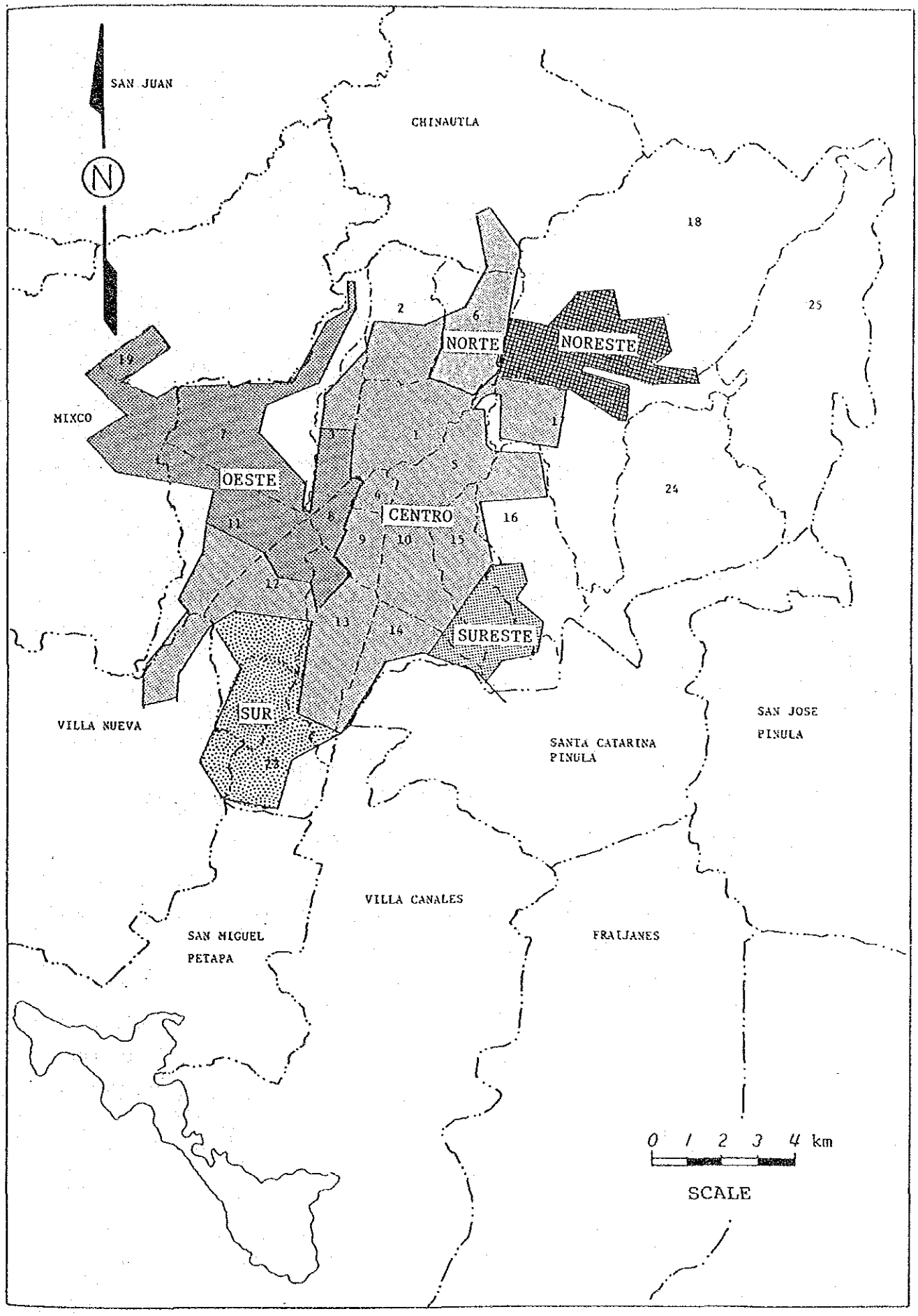


FIG. 3-2 GEOGRAPHIC SECTORS OF DISTRIBUTION

3.2 Physical Conditions

3.2.1 Geography

The Study area is situated on the central plateau formed by the Sierra Madre mountain range. This range runs from west to east, gradually decreasing in altitude, parallel to the Pacific coastline.

The so called "volcanic axis" consisting of such volcanoes as Acatenango (3,976m), Fuego (3,835m), Agua (3,766m) and Pacaya (2,552m) extends from west to southeast along the western and southern edges of the Study area.

The Motagua - San Agustin fault system runs from west to east in the north of the Study area. In the southeast, the Jalpatagua fault system extends from west to south. The Study area, bounded to the north and south by the above described fault systems, is dissected by the north - south faults of Mixco, Santa Catarina, San Jose Pinula, Teocinte/Palencia, etc. faults forming a graben-horst-graben morphology. The difference in elevation betwen the Guatemala City Valley graben and the San Jose Pinula graben is 200m.

The area defined as the Guatemala City Valley extends 20.25km east to west, 40.0km north to south and encompasses 800km ^{2}. It is bounded on the east and west by the Santa Catarina and Mixco faults, respectively; and on the south by the Agua and Pacaya volcanoes. The valley extends as far north as the confluence of the El Zapote and Las Vacas rivers.

The Study area includes, with the exception of one portion, the Guatemala City Valley and the neighboring area bounded by the Santa Catarina and Teocinte/Palencia faults. (FIG. 3-3)

The continental divide lies east to west and dissects the Guatemala City Valley into northern and southern hydrological basins. Rivers to the north of the continental divide flow into the Caribbean Sea and the Bay of Honduras while those to the south empty via Lake Amatitlan into the Pacific Ocean.

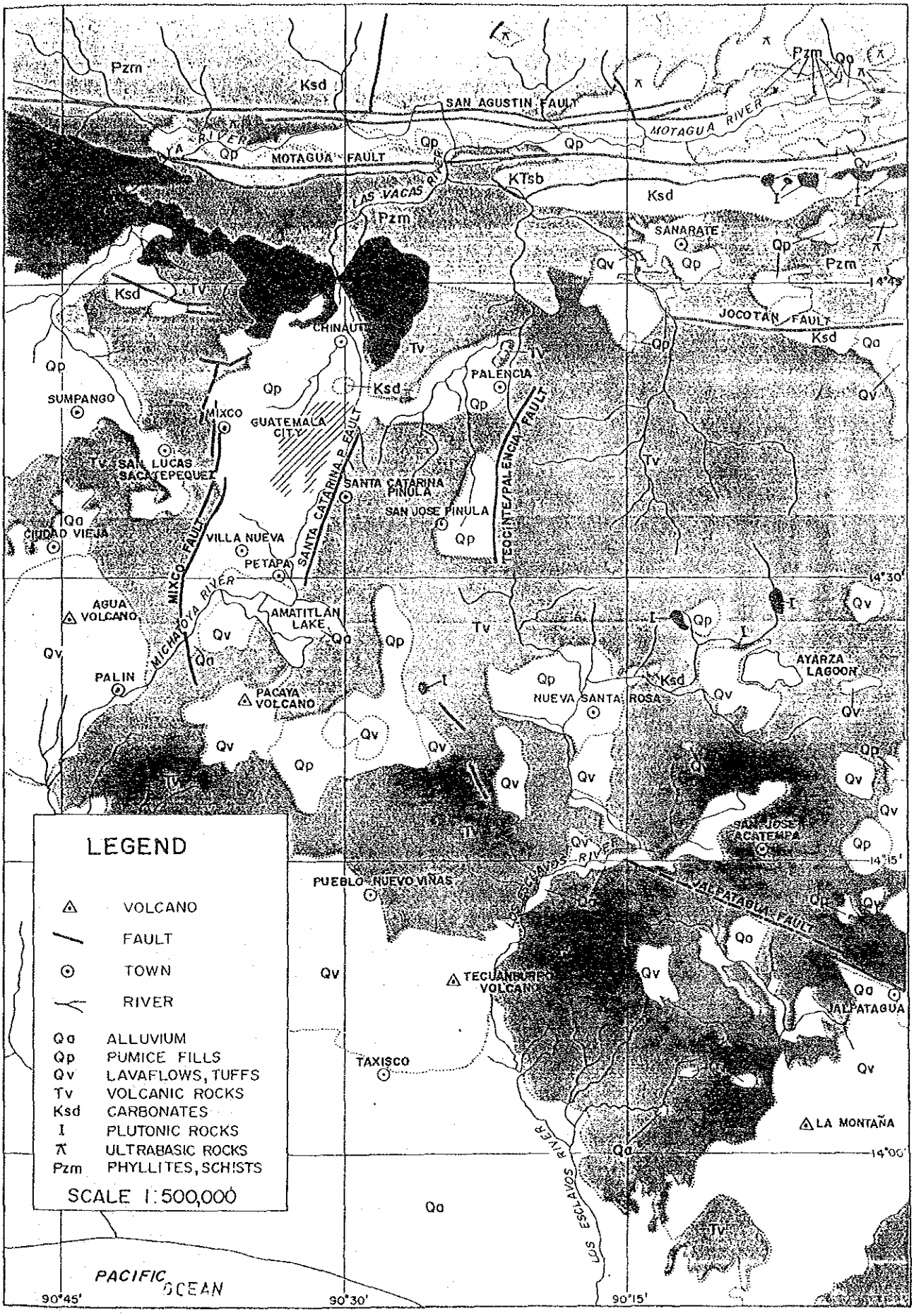


FIG. 3-3 GEOLOGICAL MAP OF THE STUDY AREA

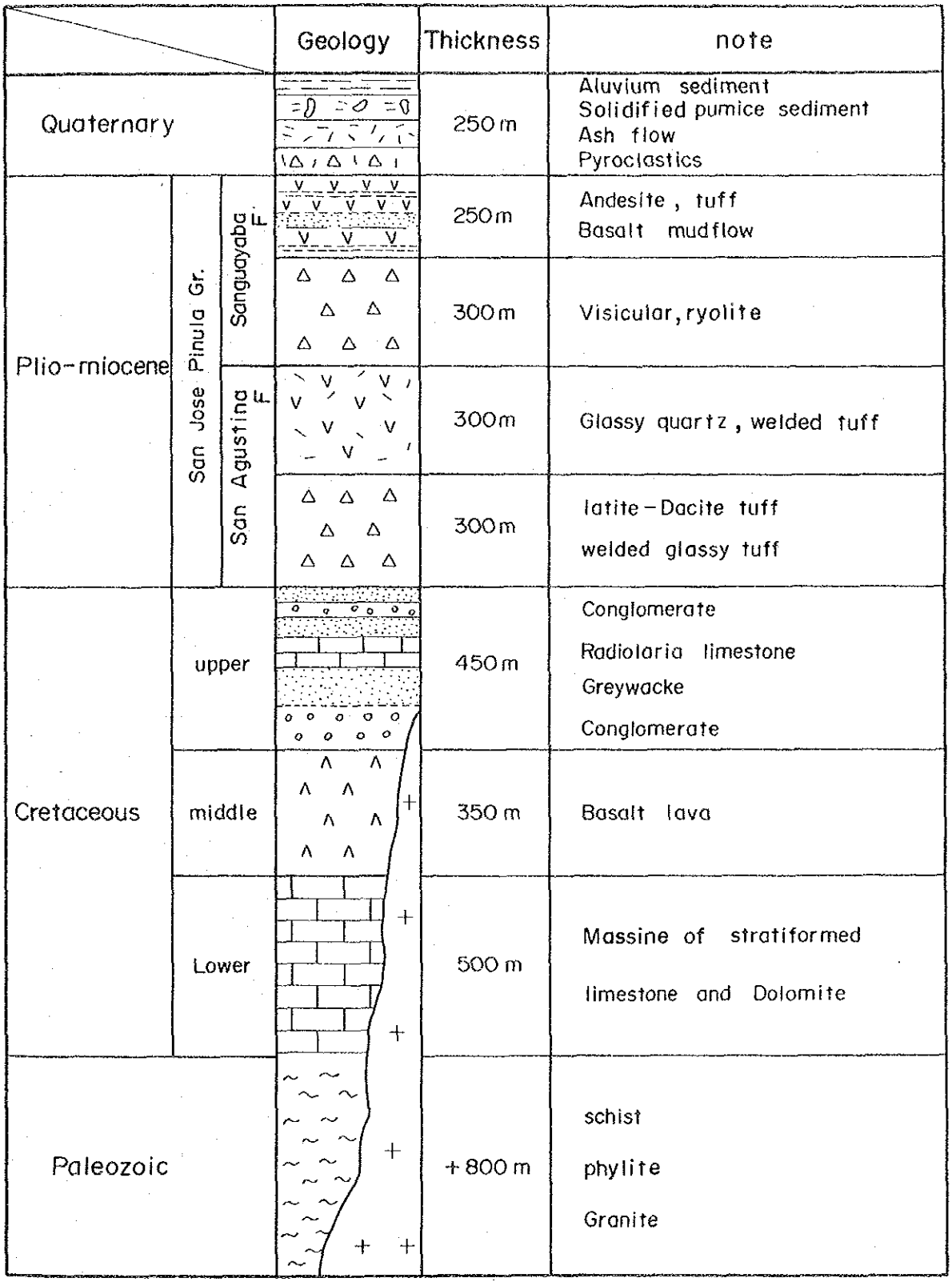
The central plateau of the valley is at elevation 1,500-1,600m, with uplifted terrain on the western and eastern flanks which is 1,900-2,000m in elevation. South from the continental divide, a gradient of 1/50-1/60 extends to Lake Amatitlan. The northern side of the divide is gently tilted tableland.

The greater part of the Study area is covered by Quaternary volcanic ash, pyroclastic sediments or alluvial deposits. These volcanic sediments have been eroded by surface runoff into sharp V-shaped gorges which constitute a ramified pattern through the Study area. Gorge depth is 150-250m.

River watersheds are controlled by faulting, with small catchment areas and the direction of surface flows along fault lines. River gradients are around 0.9% in the south and 1.5% in the north.

3.2.2 Geology

Geology of the Study area is largely comprised of the following rock formations. Distribution is as shown in FIG. 3.4



Note : Gr. ··· Group F ··· Formation

FIG. 3-4 GEOLOGICAL COLUMN OF GUATEMALA AREA

3.2.3 Hydrogeology

General

Hydrogeological tectonics of the Study area are as shown in FIG. 3-5.

The hydrogeologically important space is defined vertically, over 1,100m above sea level, within a thickness of approximately 400m. This column is normally formed starting from its base, and in variable proportion depending on its geographic position, by volcanic tuff, ignimbrite and the Tertiary lava flows.

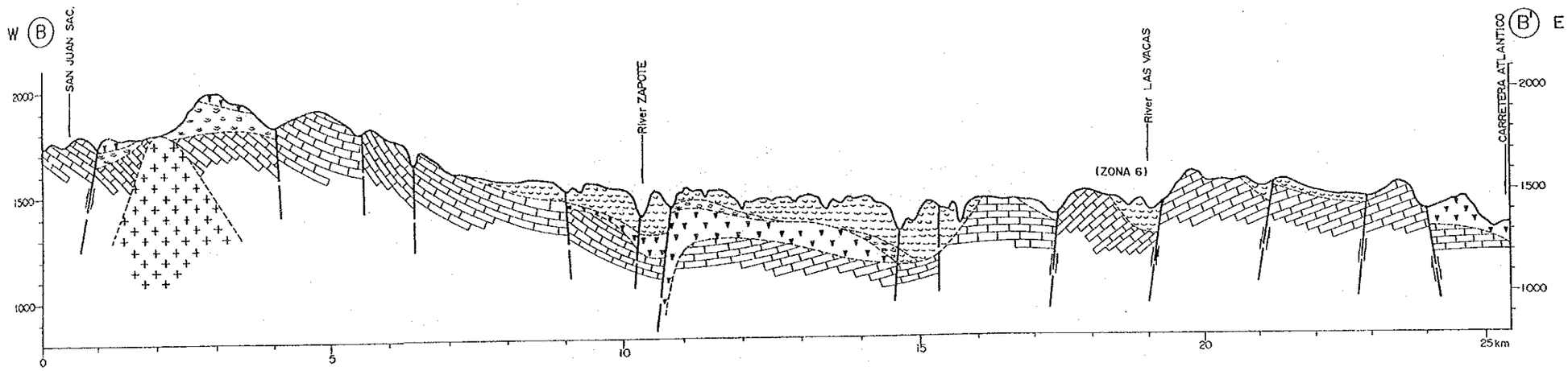
Andesitic and basaltic lavas, due to their nature, deposit forms, consolidation processes, and susceptibility to open fracture due to hardness, are good aquifer materials. Sedimentary rocks, locally represented by limestones and dolomitic limestones of the Cretaceous, due to a high degree of tectonization, are good aquifer materials locally subject to ample recharge zones.

The hydrogeological structure of the Study area is conditioned by regional and local tectonic events. The structure is basically a system of subsided and uplifted blocks which hydrogeologically are connected mainly by open fractures, orthogonal fault planes, and horizontal joints. Storage and active circulation zones are represented by subsided blocks of regional continuity, which are fed from the recharge that takes place in uplifted blocks and transmitted by a network of fissures and lateral fracture interconnecting the blocks, and from water stored in volcanic ash which is transmitted directly from the porous material to the network of fissures and fractures. Local hydrogeologic features are described in detail in Appendix-I.

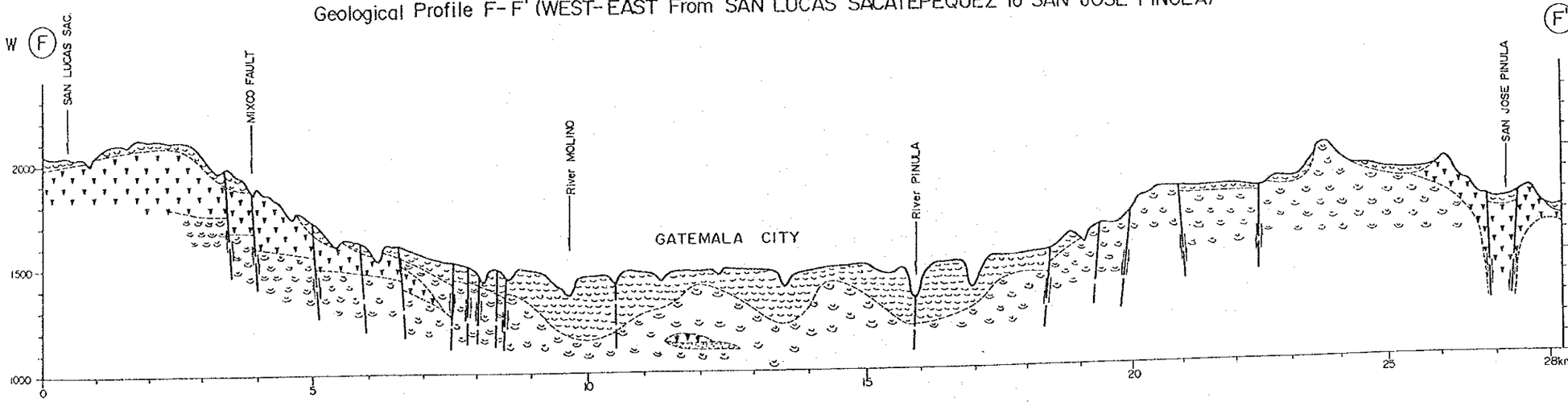
The lower reaches of the Villalobos river in the south form a delta, and constitute a good aquifer.

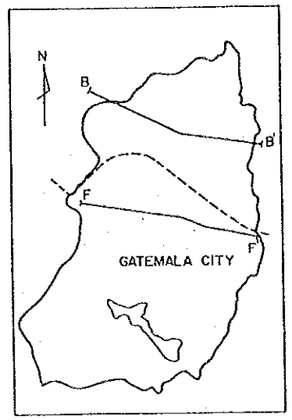
A hydrogeological barrier is formed by metamorphic rocks of the Paleozoic and intrusive groups of mainly Cretaceous in the north of the area. Furthermore, the influence of a fault system with southward convexity determines to the north a relative compression zone, which contributes to restrict the runoff in this direction.

Geological Profile B-B' (WEST-EAST From SAN JUAN SACATEPEQUEZ to CARRETERA DEL ATLANTICO)



Geological Profile F-F' (WEST-EAST From SAN LUCAS SACATEPEQUEZ to SAN JOSE PINULA)





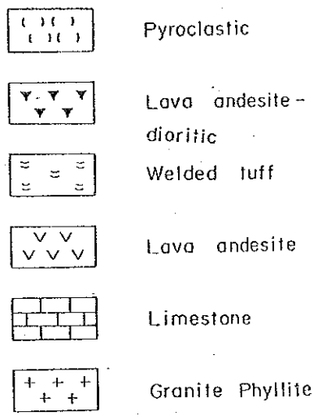


Fig. 3-5 GEOLOGICAL PROFILE OF STUDY AREA

East of the Study area, the boundaries of recharge and underground flow are defined by the structural conditions of raised blocks formed by a sequence of massive volcanic rocks of the Tertiary which presumably suffered a northward slope, where the southern edge is raised more than the northern edge. The hydrogeological boundary east of the Guatemala City Valley can be defined as a fault line of ESE/WNW direction, located approximately 2.5km south of San Jose Pinula.

3.2.4 Hydrometeorology

At north latitude 14°30'-14°45', the Study area is situated within the tropical climatic zone. Nevertheless, the hydrometeorology of the area is given a unique character by local topographical and geological characteristics. The area comprises 1,500-1,600m plates of undulating terrain, bisected by the continental divide. The area is bounded by mountains 2,500-3,000m high.

The dry season and rainy season are clearly distinct, with the former (summer) lasting from November to April, and the latter (winter) from May to October. Mean annual rainfall is 900-1,200mm. Rainfall steadily increases in amount moving away to the north and south from the continental divide.

Mean annual temperature is 19°-21°C, with temperatures generally lower in the north and higher in the south.

Monthly and annual mean values for rainfall, temperature, wind speed, humidity, evaporation, and solar radiation as taken from records from 1970 to 1985 at the National Meteorological Observatory situated just south of the continental divide.

The isohyetal line for annual mean rainfall based on records from 1970 to 1984 at 17 meteorological stations in and around the Study area is given in FIG. 3-5. As can be seen from the figure, rainfall to the south is generally more than in the north, with rainfall to the south as much as doubling over that in the north from 800mm to 1,600mm. Monthly rainfall is greater in June at the beginning of the rainy season and in September at the end of the rainy season. Maximum monthly rainfall is in September.

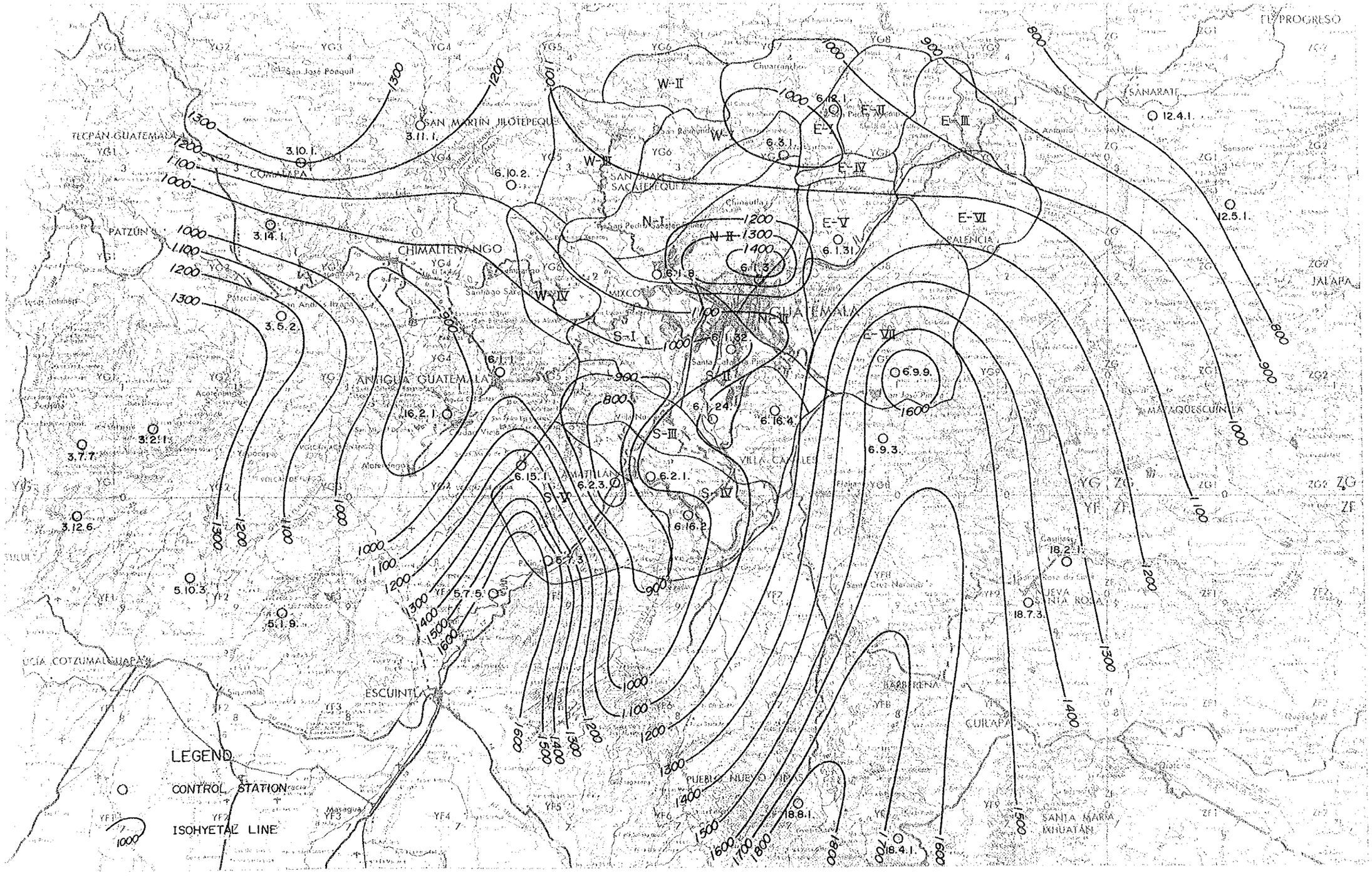


FIG. IV-1 ISOHYETAL MAP OF ANNUAL PRECIPITATION
(1970 – 1984)