3.2.5 Consumption classified by type of use

According to one of the water charge collection data shown in Table 3.5, the water use is categorized into the following 4 purposes with the respective share in total consumption volume.

1.	Domestic use (House connection 80.0%) (Communal faucet 2.9%)	82.9 %
2.	Government/Municipal use	10.9 %
3.	Commercial use	5.8 %
4.	Industrial use	0.5 %

3.2.6 Paid for and unpaid for water

Table 3.5 indicates that the paid for water totals about 12,000 MGY (46.33 %) among the total production of 25,900 MGY in Managua, and the unpaid for water amounts to 13,860 (13,900) MGY (53.67 %). More than half of the supplied water is not paid for, and this may be one of the biggest financial problems of INAA. As described in 3.2.4, the effective water is estimated at about 73.3 % of the total production (Leakage is 26.4 %). Of the 73.3% of the effective water, therefore, nearly 37% (46.33 % of total supply) is not paid for, most of which is considered as caused by illegal connection, and to reduce this portion will be an important subject in the Managua water supply.
The ratio of effective-effective and paid for unpaid for is schematically shown below.

<table>
<tr><td colspan="4">Total supply (production) amount: 100%</td></tr>
<tr><td colspan="2">Effective water: 73%</td><td colspan="2">Ineffective water: 26.7%</td></tr>
<tr><td colspan="2">Paid for 46.6%</td><td colspan="2">Unpaid for 53.5%</td></tr>
<tr><td>Domestic use
37.2%</td><td>Othe
r
use
9.2%</td><td>Effective use
but unpaid
27.1%</td><td>Leakage
26.4%</td></tr>
<tr><td colspan="4">10% 20% 30% 40% 50% 60% 70% 80% 90% 100 %</td></tr>
</table>

3.2.7 Distribution and water service facilities

The distribution facilities in the Managua water supply system comprise 54 distribution reservoirs, 96 well pumps and 21 relay pumps and about 1500 km in total length of distribution pipeline.
The reservoir tanks are made of concrete and steel plate with a volume totaling 84,700 m^3 (22.38 MG).
The distribution pipes are of cast iron (116 inches diameter and bigger), or asbestos cement (2 to 12 inches in diameter).
About 5,000 of the control valves (sluice/gate valves) are attached to the distribution pipeline, and the operators manually control the valves for distribution or suspension.
Some of the above facilities have been superannuated, and rehabilitation works are considered an urgent necessity.

3.3 Observation on the Existing Water Supply Equipment

3.3.1 Measurement of pumping rate

In order to confirm the pumping rate of the wells, the flow rate of 24 borehole wells were measured for 1 week each consecutively. Fig 3.5 presents one sample record of San Antonio well in Low Zone. The pressure is measured and it is converted to flow velocity and flow rate. This figure shows that the pressure during night time is higher than during day time, i.e., pumping rate (flow velocity) is higher in day time than in night time, even though the pump is operated constantly. It means that the pump efficiency becomes lower during night time due to the high back pressure in the transmission/distribution pipeline, thus making operation costs higher.

At the San Antonio pump station, a 24-hour observation by pressure measurements every 30 minutes was also conducted to compare with the weekly data, as shown un Fig 3.6. The relation between measured pressure and pumping rate (flow rate) is shown in the same figure.

Since the measurement date is different, the total pumpage within 24 hours is not the same between these 2 figures. However, the flow rate difference between day and night time is obvious.

3.3.2 Observation of major reservoir tanks

The reservoir tank in the water supply system should function as the controller of the daily and hourly maximum of the water demand. However, the 24-hours observation of tank water level in Phase I, has revealed that the major reservoirs are not functioning as the peak controller any more due to the extremely complicated distribution system. In order to analyze the in-flow and out-flow of the reservoir tanks, one week consecutive water level record was taken out from the monthly record and graphed for Altamira (5 MG capacity), San Cristobal (5 MG) and Las Americas 4 (3 MG) reservoirs (record of June 8-16, 1992), as shown in Fig. 3.7.

On the water level graph of Altamira reservoir, the in and out flow is difficult to be analyzed because of a too complicated distribution to both High and Highest Zones by a frequent valve operation. The suspension days of the week in the Highest Zone are Tuesday and Friday, while for the High Zone they are Wednesday and Saturday. Even the effect of the water suspension is not represented on the graph. The essential function of the reservoir seems to have been lost in this tank.

On the other hand, the tank of San Cristobal keeps the function of reservoir, although the balance of in-flow and out-flow is scarcely covered by the supply suspension of Monday and Thursday. Since the in-flow is limited to the production of 2 wells and backward flow from outlet during the night, the tank becomes almost empty after three consecutives supply days. To increase the in-flow may be the solution for this tank.

The water level in Las Americas 4 was kept constant without showing any variation between day and night time for one week. It means apparently that the tank has lost the essential function of the peak control.

The water level record taken in 1993 (one week in February 1993 during Phase III of the Study), however, showed a very different aspect in the above three major reservoir tanks. The water level variation graphs are shown in Fig. 3.7 representing the comparison between the records of 1992 and 1993.

The water level variation in 1993 has become sharper than in 1992 in Altamira and San Cristobal reservoirs, and the graph of Las Americas 4 in 1993 shows recovery of the essential functioning of a reservoir tank. However, the zero water level found in San Cristobal and Las Americas 4 suggests the shortage of absolute capacity of water reserve.

The reason of the function recovery of the tanks without any particular variation in operation has not been investigated. The cause, is presumably related indirectly with the pumpage reduction from Asososca Lake. The pumpage from Asososca has been drastically reduced to about 7.3 MGD since May 1992, but it was learned that the service level was not lowered at all. It is presumed that the production from the boreholes was naturally (without artificial operation) increased, resulting in the total production in 1992 being almost the same as in 1991. The natural increase of production from boreholes was probably due to the pressure reduction in the transmission pipes caused by the production decrease from Asososca. And, the variation of water level in the reservoir was made by the valve operation because a slight change of the operation can make a big difference of the water level. The above description is only a presumption, and the investigation for the real reason is one of the main subjects in the future improvement program for the distribution facilities.

3.4 Operation and Maintenance

3.4.1 General

The Operation and Maintenance Division of INAA consists of 18 special engineers and 800 operators, and 4 workshops for maintenance, plus 1 laboratory for water quality control.

The total operation and maintenance cost as of 1992 was 38,771,000 Cordoba (about USD 6.46 million), in which the share of electricity is particularly high, as shown in the following breakdown:

Electricity	21,600,000 Cordoba	56 %
Maintenance/repair	11,238,000	28
Salary/wages	4,944,000	12
Fuel/lubricant	476,000	2
Chlorine	508,000	2
Total	38,771,000	100 %

The cost of water per cubic meter in 1992 was 0.4 Cordoba.
(38,771,000 Cordoba/Total production of 97,909,000 m^3 = 0.4)

3.4.2 Rehabilitation program

As a component of rehabilitation program for Managua water supply system, the increase of water production was planned in 1992 by the rehabilitation of the borehole wells. The plan is production increase of 9.0 MGD by rehabilitation of 11 boreholes, as shown in Table 3.5.

However, the 8 wells out of the eleven targeted for rehabilitation are located in the over-pumped area of the Central sub-area, and therefore, the immediate implementation of this rehabilitation program is not recommendable. It is recommended that this rehabilitation program be slowly implemented if the total pumpage from the Eastern sub-area can be kept at 50.27 MGD (over-pumpage 20.16 MGD).

Table 3.1 Population estimated from CSE data, 1991

District	Low Zone		High Zone		Highest Zone		District 1		Total	
	CSE	Population	CSE	Population	CSE	Population	CSE	Population	CSE	Population
1	0	0	0	0	0	0	23,448	70,986	23,448	70,986
2	34,972	105,678	15,007	45,348	0	0	0	0	49,979	151,026
3	0	0	20,159	60,916	35,909	108,510	0	0	56,068	169,426
4	52,387	158,303	23,398	70,704	0	0	0	0	75,785	229,007
5	0	0	14,202	42,916	52,265	157,934	0	0	66,467	200,850
6	31,416	94,933	48,698	147,156	1,367	4,131	0	0	81,481	246,220
7	0	0	0	0	31,904	96,588	0	0	31,904	96,588
Total	118,775	358,914	121,464	367,040	121,445	367,163	23,448	70,986	385,132	1,164,103

CSE: Number of electorate over 16years

	Low Zone	High Zone	Highest Zone	High Highest Zone	Areas of Independent Supply System		Total
					District 1	Included in High and Highest Zone	
1	0	0	0	0	70,986	0	70,986
2	105,678	45,348	0	0	0	0	151,026
3	0	60,916	54,859	53,651	0	0	169,426
4	158,303	70,704	0	0	0	0	229,007
5	0	42,916	136,201	14,800	0	6,933	200,850
6	94,933	143,328	0	0	0	7,959	246,220
7	0	0	0	95,461	0	1,127	96,588
Total	358,914	363,212	191,060	163,912	70,986	16,019	1,164,103

Table 3.2 Average production from each source, 1991

ZONE	WELL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE
LOW	7 ESTADIO	1.816	1.780	1.823	1.751	1.670	1.801	1.661	1.876	1.845	1.786	2.032	1.860	1.808
	8 SAN ANTONIO	0.872	0.997	0.974	0.967	0.898	0.985	1.033	1.028	0.905	1.009	1.330	1.365	1.030
	9 OLOF PALME	1.398	1.410	1.365	1.337	0.678	0.770	0.728	1.437	1.386	1.412	1.343	1.276	1.212
	10 MERCADO ORIENTAL	1.014	1.032	1.001	0.978	1.019	0.977	1.105	1.051	1.017	1.024	1.103	1.077	1.033
	11 TENDERI	1.335	1.387	1.367	1.340	1.358	1.441	1.446	1.419	1.210	1.325	1.519	1.518	1.389
	12 BELLO HORIZONTE	1.594	1.478	1.581	1.507	1.506	1.178	1.630	1.270	1.370	1.540	1.233	1.128	1.418
	13 RAFAELA HERRERA	–	–	–	0.735	0.847	1.143	1.082	1.129	0.977	0.997	0.950	1.094	0.746
	14-26 CARLOS FONSECA	16.348	15.958	16.053	16.588	15.622	15.711	15.846	14.881	14.099	15.739	16.346	17.019	15.893
	41-42 SAN CRISTOBAL	1.064	1.022	1.052	1.066	1.016	1.076	1.075	1.063	0.878	0.847	0.769	0.725	0.971
	77 VILLA FRATERNIDAD	0.606	0.603	0.594	0.593	0.551	0.606	0.650	0.585	0.533	0.574	0.605	0.605	0.592
	78 HEROES DE AYAPAL	1.656	1.379	1.625	1.567	1.597	1.656	1.518	0.027	0.958	1.602	1.656	1.654	1.408
	82 MONSENOR LEZCANO	1.798	1.805	1.837	1.769	1.771	1.812	1.837	1.869	1.854	1.871	1.859	1.778	1.822
	84 LAS BRISAS	–	–	–	–	–	–	–	–	–	–	–	1.259	0.105
	92 REPARTO ESPANA	–	–	–	0.144	0.141	0.178	0.017	–	–	–	–	–	0.040
	RAFAELA HERRERA	-11.126	-10.885	-10.289	-10.091	-9.071	-7.370	-8.163	-7.179	-7.459	-8.691	-8.008	-10.100	-9.036
	ASOSOSCA	5.673	4.518	4.911	4.910	5.264	7.648	8.435	8.513	9.011	8.455	7.307	6.999	6.804
	TOTAL	24.548	22.484	23.894	25.161	24.867	29.612	29.900	28.969	28.584	29.490	30.044	29.257	27.235
HIGH	27-31 SABANA GRANDE	4.423	4.730	1.308	3.966	3.062	4.505	4.539	4.688	4.519	4.307	3.502	3.785	3.944
	33-35 PANCASAN	1.395	1.250	1.413	1.407	1.343	1.402	1.426	1.462	1.512	1.379	1.510	1.301	1.400
	39-40 COLONIA NICARAO	0.441	0.411	0.428	0.443	0.267	0.428	0.427	0.418	0.385	0.403	0.414	0.432	0.408
	46 VILLA LIBERTAD	0.851	0.827	0.727	0.867	0.788	0.867	0.830	0.862	0.783	0.821	0.841	0.813	0.823
	47 VILLA VENEZUELA	–	–	–	–	–	0.256	0.510	0.262	0.408	0.479	0.694	0.764	0.281
	52 HOSPITAL DEL NINO	0.975	0.929	0.962	0.975	0.665	–	0.214	0.929	0.931	0.919	0.762	0.692	0.746
	53 PARQUE LAS MADRES	0.801	0.748	0.792	0.785	0.730	0.799	0.799	0.789	0.734	0.757	0.770	0.760	0.772
	54 LOS GAUCHOS	–	–	–	–	0.228	0.875	0.889	0.892	0.905	0.882	0.693	0.607	0.498
	55 SHELL CARRE MASAYA	–	0.614	0.618	0.609	0.470	0.591	0.605	0.607	0.611	0.604	0.763	0.824	0.576
	56 SANDYS	0.951	0.892	1.001	1.006	0.964	1.045	1.027	1.020	1.008	1.027	1.198	1.269	1.034
	89 INE	–	0.766	0.481	–	–	–	0.652	1.252	1.328	1.357	1.431	0.195	0.622
	91 LAUREANO MAIRENA	–	–	–	–	–	–	–	0.568	0.400	0.519	0.418	0.625	0.211
	ASOSOSCA	6.927	6.744	7.170	7.121	6.368	7.261	6.867	6.697	6.887	5.956	4.624	4.175	6.400
	RAFAELA HERRERA	11.126	10.885	10.289	10.091	9.071	7.370	8.163	7.179	7.459	8.691	8.008	10.100	9.036
	ALTAMIRA	-4.709	-5.158	-5.559	-4.555	-4.782	-3.848	-4.250	-3.946	-3.751	-4.144	-3.945	-3.956	-4.384
	TOTAL	23.181	23.638	19.630	22.715	19.174	21.551	22.698	23.679	24.119	23.957	21.683	22.386	22.367
HIGHEST	43-45 SAN JUDAS	2.193	2.277	2.239	2.205	2.066	2.198	2.114	2.048	2.238	2.251	1.932	1.830	2.133
	50 REPARTO SHICK	1.405	0.621	0.537	1.063	1.002	1.273	1.350	1.313	1.203	1.332	1.287	1.858	1.187
	51 MANOLO MORALES	1.256	1.096	1.217	1.242	1.054	1.209	1.233	1.177	1.173	1.187	0.928	0.828	1.133
	57 KM 8 CARRET MASAYA	–	–	–	–	–	0.220	0.352	0.302	0.207	0.310	0.302	0.297	0.166
	58 SAN PATRICIO KM 8	0.515	0.534	0.558	0.521	0.505	0.530	0.562	0.509	0.521	0.557	0.591	0.579	0.540
	60 KM 14.5 CARRET SUR	0.424	0.440	0.294	0.334	0.409	0.434	0.438	0.405	0.102	0.038	0.428	0.443	0.349
	61 KM 14.5 C V LEON	0.776	0.777	0.841	0.823	0.655	0.829	0.763	0.720	0.853	0.793	0.987	0.992	0.817
	62 VELEZ PAIZ	–	–	–	–	–	–	–	–	–	–	–	0.242	0.020
	63 BERTHA CALDERON	0.457	0.374	0.457	0.457	0.362	0.388	0.447	0.446	0.450	0.450	0.453	0.486	0.436
	64 CAMILO ORTEGA	0.581	0.568	0.597	0.582	0.529	0.599	0.619	0.584	0.549	0.608	0.717	0.733	0.606
	65 UNAN	0.548	0.513	0.543	0.546	0.537	0.457	0.557	0.539	0.519	0.557	0.478	0.538	0.528
	66 VILLA PANAMA	–	–	0.580	0.440	0.000	0.059	0.736	0.849	0.841	0.405	0.827	0.809	0.462
	85 SIERRA MAESTRA	–	0.197	0.141	0.555	0.235	0.317	0.567	0.255	0.154	0.452	0.522	0.613	0.334
	73 SAN ISID CRUZ VERDE	–	–	–	–	–	–	–	–	–	–	–	–	–
	ALTAMIRA	4.709	5.158	5.559	4.555	4.782	3.848	4.250	3.946	3.751	4.144	3.945	3.956	4.384
	ASOSOSCA	4.882	7.004	6.632	6.919	6.496	3.439	2.769	2.825	2.778	2.083	1.944	2.118	4.157
	TOTAL	17.746	19.559	20.195	20.242	18.632	15.800	16.757	15.918	15.339	15.167	15.341	16.322	17.252
THREE ZONES TOTAL		65.475	65.681	63.719	68.118	62.673	66.963	69.355	68.566	68.042	68.614	67.068	67.965	66.854
INDEPENDENT	1-3 CIUDAD SANDINO	2.762	2.217	1.670	2.381	2.320	2.373	2.169	2.290	2.097	2.461	2.223	1.960	2.243
	4-6 EDUARDO CONTRERAS	0.843	0.952	1.040	1.110	1.183	1.181	1.037	1.126	1.015	0.881	0.762	0.927	1.005
	36 CENTROAMERICA	0.937	0.991	0.861	0.267	0.258	0.267	0.276	0.274	0.265	0.485	1.136	0.736	0.563
	48 COL 14 DE SEPT	0.144	0.031	–	–	–	–	–	0.383	0.694	0.703	0.512	0.410	0.240
	67 CRISTIAN PEREZ	–	–	–	–	–	–	–	–	–	–	–	–	–
	COMBATIENTE DESCONC	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.037	–	–	–	–	0.032
	TOTAL	4.736	4.241	3.621	3.808	3.811	3.871	3.532	4.110	4.071	4.530	4.633	4.033	4.083
GRAND TOTAL		70.211	69.922	67.340	71.926	66.484	70.834	72.887	72.676	72.113	73.144	71.701	71.998	70.937

Table 3.3 Monthly water production and consumption of Managua 1991

Unit:MG

		January	February	March	April	May	June	July	August	September	October	November	December
Production of MANAGUA		2.176.556	1.957.821	2.087.561	2.157.802	2.061.400	2.125.018	2.259.502	2.252.956	2.163.399	2.267.461	2.151.025	2.231.895
Consumption	Domestic(House connection)	747.899	721.404	766.498	835.996	834.389	813.756	789.373	809.534	768.333	783.159	869.894	887.214
	Domestic(Communal foucet)	31.371	30.234	29.974	31.465	30.076	30.608	27.444	27.295	25.190	24.890	26.513	25.487
	Government	109.913	118.688	110.654	111.251	111.495	111.724	108.549	107.549	107.174	105.769	106.879	101.907
	Commercial	60.131	60.088	57.976	58.443	58.072	57.665	55.005	54.184	51.077	54.432	63.769	63.965
	Industrial	4.541	3.475	3.420	4.351	4.667	4.546	4.414	4.884	4.935	4.850	6.015	6.435
	Total	953.854	933.888	968.521	1.041.505	1.038.699	1.018.298	984.785	1.003.445	956.708	973.100	1.073.068	1.085.008
Loss(non charged water)		1.222.702	1.023.933	1.119.040	1.116.297	1.022.702	1.106.720	1.274.717	1.249.512	1.206.691	1.294.361	1.077.957	1.146.887
% of loss		56.18%	52.30%	53.61%	51.73%	49.61%	52.08%	56.42%	55.46%	55.78%	57.08%	50.11%	51.39%

Table 3.5 Water production and consumption, 1991

Unit:MG

		Year total	Daily average	Ratio
Production of MANAGUA		25.892.396	70.938	
Consumption	Domestic(House connection)	9.627.448	26.377	80.0%
	Domestic(Communal foucet)	340.545	0.933	2.8%
	Government	1.311.551	3.593	10.9%
	Commercial	694.805	1.904	5.8%
	Industrial	56.529	0.155	0.5%
	Total	12.030.878	32.961	100.0%
Loss(non charged water)		13.861.518	37.977	
% of loss		53.54%	53.54%	

Table 3.4 Summary of consumption measurement
July 1992

No	Village name	District	Zone	Number of family	Water consumption	Type of the household
					g/p/d	
1	Santo Rosa	4	Low	4	41.667	I
2				6	52.543	I
3				5	54.744	I
4				13	42.365	I
5	Camilo Chamorro	6	Low	6	43.541	I
6				8	42.030	I
7				8	11.073	H
8				3	44.444	I
9	Bolonia	2	High	5	190.500	F
10				6	81.379	D
11				8	38.860	I
12				4	124.458	F
13	Villa Venazuela	6	High	6	108.333	D
14				3	94.444	D
15				5	18.629	H
16				6	38.889	I
17	Las Colinas	5	Highest	6	91.248	D
18				4	80.588	D
19				6	74.500	D
20				7	47.937	I
21	Rpto Schich	5	Highest	4	18.750	H
22				9	85.332	F
23				3	49.118	I
24				4	50.000	I
25	Sun Judas	3	Highest	3	49.280	I
26				2	64.198	D
27				4	46.958	I
28				3	18.651	H

Household Type	Average
H (small) ...... 20g/c/d under	16.8g/c/d (63 l/e/d)
I (middle) ..... 21g/c/d - 55	45.9g/c/d (173 l/e/d)
D (big) .... 56g/c/d - 110	85.0g/c/d (321 l/e/d)
F (biggest) ....110g/c/d over	157.5g/c/d (596 l/e/d)

Table 3.6 Estimated population in 1991, 1995 and 2000

	Low Zone			High Zone			Highest Zone			High Highest Zone			District 1			Total		
District	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000
1	-	-	-	-	-	-	-	-	-	-	-	-	70.986	86.943	110.964	70.986	86.943	110.964
2	105.678	129.434	165.194	45.348	55.542	70.887	-	-	-	-	-	-	-	-	-	151.026	184.976	236.081
3	-	-	-	60.916	74.610	95.223	54.859	67.191	85.755	53.651	65.711	83.866	-	-	-	169.426	207.512	264.344
4	158.303	193.889	247.457	70.704	86.598	110.523	-	-	-	-	-	-	-	-	-	229.007	280.487	357.980
5	-	-	-	42.916	52.563	67.085	143.134	175.310	223.745	14.800	18.127	23.135	-	-	-	200.850	246.000	313.965
6	94.933	116.273	148.397	147.156	180.236	230.032	4.131	5.060	6.458	-	-	-	-	-	-	246.220	301.569	384.887
7	-	-	-	-	-	-	-	-	-	96.588	106.615	120.625	-	-	-	96.588	106.615	120.625
Total	358.914	439.596	561.048	367.040	449.549	573.750	202.124	247.561	315.958	165.039	190.453	227.626	70.986	86.943	110.964	1.164.103	1.414.102	1.789.346
																Total of District 2-7		
																1.093.117	1.327.159	1.678.382

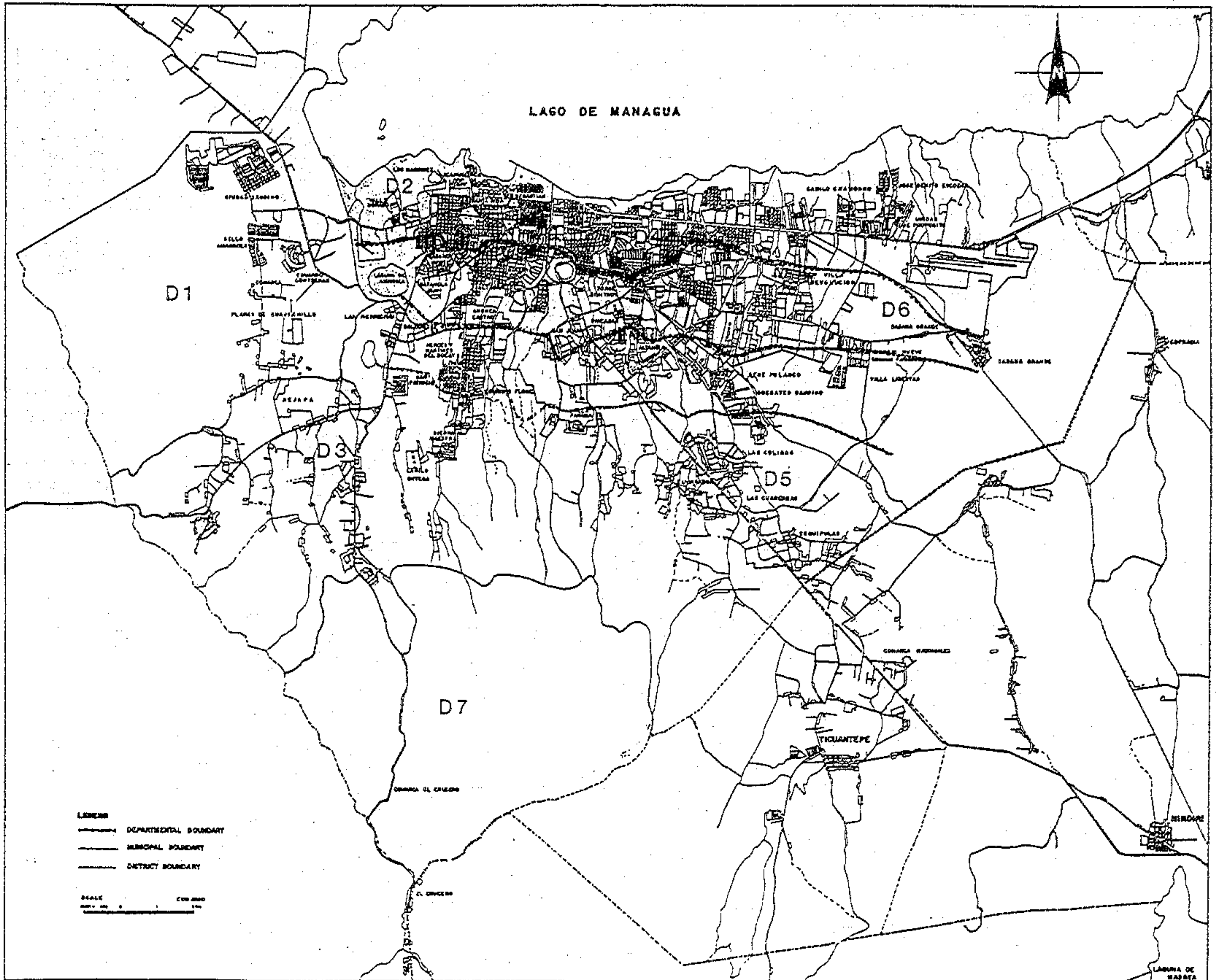
Table 3.7 Estimated water demand in 1991, 1995 and 2000

Unite:MGD

	Low Zone			High Zone			Highest Zone			High Highest Zone			District 1			Total		
	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000
1	-	-	-	-	-	-	-	-	-	-	-	-	5.86	7.17	9.15	5.86	7.17	9.15
2	8.72	10.68	13.63	3.74	4.58	5.85	-	-	-	-	-	-	-	-	-	12.46	15.26	19.48
3	-	-	-	5.03	6.16	7.86	4.52	5.54	7.07	4.43	5.42	6.92	-	-	-	13.98	17.12	21.85
4	13.06	16.00	20.42	5.83	7.14	9.12	-	-	-	-	-	-	-	-	-	18.89	23.14	29.54
5	-	-	-	3.54	4.34	5.53	11.81	14.46	18.46	1.22	1.50	1.91	-	-	-	16.57	20.30	25.90
6	7.83	9.59	12.24	12.14	14.87	18.98	-	-	-	0.34	0.42	0.53	-	-	-	20.31	24.88	31.75
7	-	-	-	-	-	-	-	-	-	0.97	1.07	1.21	-	-	-	0.97	1.07	1.21
Total	29.61	36.27	46.29	30.28	37.09	47.34	16.33	20.00	25.53	6.96	8.41	10.57	5.86	7.17	9.15	89.04	108.94	138.88
																Total of Distrcit 2-7		
																83.18	101.77	129.73

Table 3.8 Borehole well rehabilitation program planned in 1992

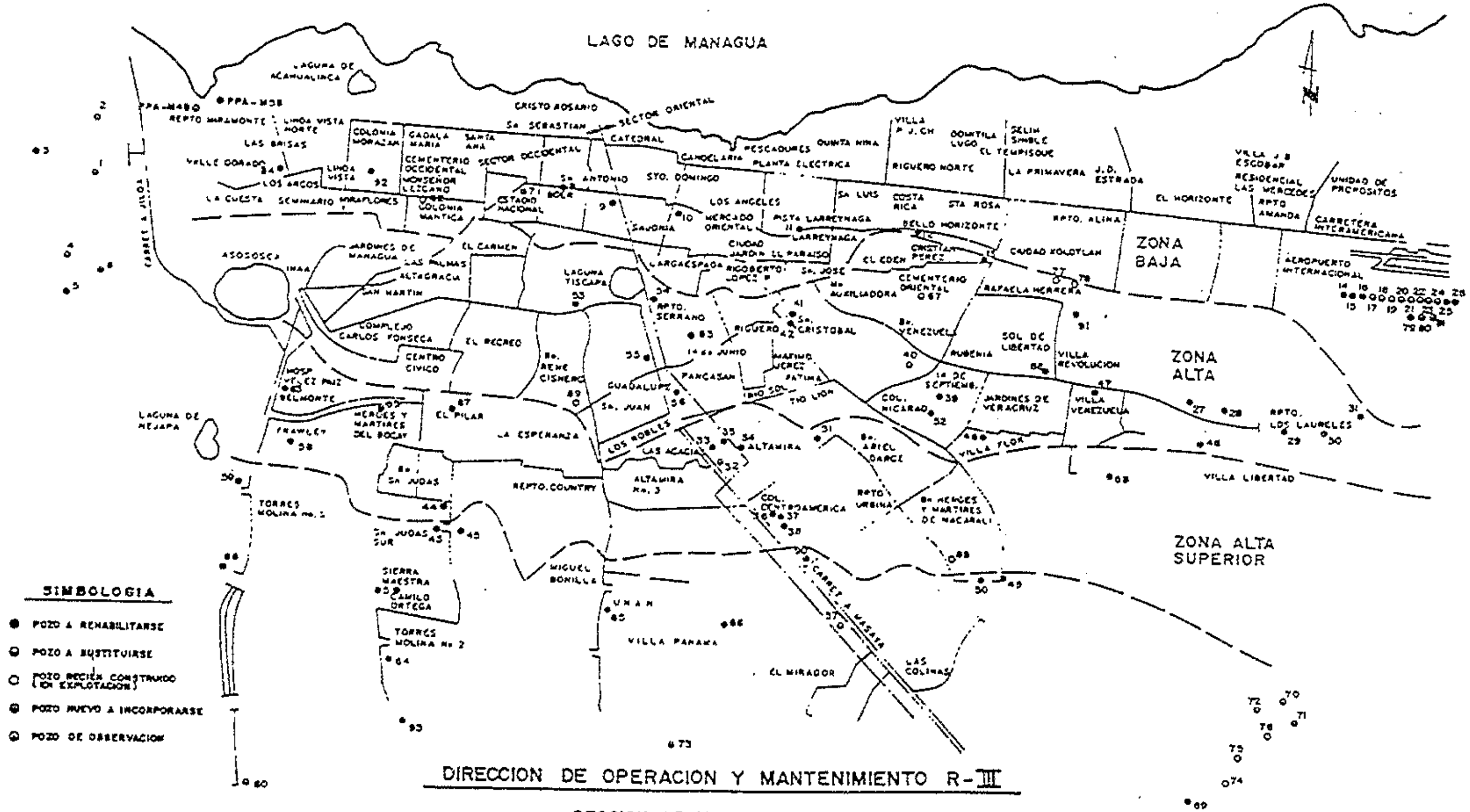
Location and well No.	High zone			High-highest zone						District 1	
	40	42	96	32	36	37	57	60	73	94	95
Expecting production by rehabilitation (gpm)	1,000	1,000	1,000	700	700	700	600	600	600	800	800
Expecting production as of 1991 (gpm)	280	–	–	–	–	–	110	280	–	–	–
Expected increase of production by rehabilitation (gpm)	720	1,000	1,000	700	700	700	490	320	600	800	800
Sub-total of expected increase by zone	2,720 gpm (3.92 MGD)			3,510 gpm (5.05 MGD)						1,600 gpm (2.30 MGD)	
Total	7,830 gpm (11.275 MGD)										



THE STUDY ON WATER SUPPLY PROJECT IN MANAGUA Fig. 3.1 Division of water supply area by District and Zone

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO NICARAGUENSE DE ACUEDUCTOS Y ALCANTARILLADOS



DIRECCION DE OPERACION Y MANTENIMIENTO R-III

SECCION DE OPERACION DE POZOS Y ESTACIONES DE BOMBEOS

1 CIUDAD SANDINO No.1
2 CIUDAD SANDINO No.2
3 CIUDAD SANDINO No.3
4 EDUARDO CONTRERAS No.1
5 EDUARDO CONTRERAS No.2
6 EDUARDO CONTRERAS No.3
7 EL ESTADIO
8 SAN ANTONNIO
9 BANCO AMERICA
10 MERCADE ORIENTAL
11 TENDERI
12 CINE AMERICA
13 RAFAELA HERRERA
14 CARLOS FONSECA No.9
15 CARLOS FONSECA No.12
16 CARLOS FONSECA No.13
17 CARLOS FONSECA No.1
18 CARLOS FONSECA No.2
19 CARLOS FONSECA No.3
20 CARLOS FONSECA No.4
21 CARLOS FONSECA No.5
22 CARLOS FONSECA No.6
23 CARLOS FONSECA No.7
24 CARLOS FONSECA No.8
25 CARLOS FONSECA No.14
26 CARLOS FONSECA No.15
27 SABANA CUBANNDE No.1
28 SABANA CUBANNDE No.2
29 SABANA CUBANNDE No.3
30 SABANA CUBANNDE No.4
31 SABANA CUBANNDE No.5
32 ALTAMIRA No.2
33 ALTAMIRA No.3
34 ALTAMIRA No.4
35 ALTAMIRA No.5
36 CENTRO AMERICA No.1
37 CENTRO AMERICA No.2
38 CENTRO AMERICA No.3
39 NICARAO No.1
40 NICARAO No.2
41 SAN CRISTOBAL No.1
42 SAN CRISTOBAL No.2
43 SAN JUDAS No.1
44 SAN JUDAS No.2
45 SAN JUDAS No.3
46 VILLA LIBERTAD
47 VILLA VENEZUELA
48 COL.14 DE SEPTIEMBRE
49 VILLA CUBA POZO No.2
50 REPARTO SCHICK
51 HOSPITAL MANOLO MORALES
52 HOSPITAL LA MASCOTA
53 PARQUE LAS MADRES
54 LOS GAUCHOS
55 GASOLINERA SHELL
56 SANDY'S
57 KM.8 C.A MASAYA
58 KM.8 C.SUR
59 KM.9.5 C.SUR
60 KM.14.5 C.SUR
61 KM.14.5 C.LEON
62 HOSPITAL VELEZ PAIZ
63 HOSPITAL BERTHA CALDERO
64 TORRES MOLINA
65 UNIVERSIDAD
66 VILLA PANAMA
67 CHRISTIAN PEREZ
68 VILLA AUSTRIA
69 KM.14.5 C.A MASAYA
70 VILLA GOTHEL No.2
71 VILLA GOTHEL No.3
72 VILLA GOTHEL No.1
73 SN ISIDRO DE LA C.VERDE
74 VERACRUZ No.4
75 VERACRUZ No.5
76 VERACRUZ No.6
77 VILLA FRATERNIDAD
78 MARTIRES LEZCANO
79 CARLOS FONSECA No.16
80 CARLOS FONSECA No.17
81 CARLOS FONSECA No.18
82 MONSENOR LEZCANO
83 PLAZA EL SOL
84 LAS BRISAS
85 SIERRA MAESTRA
86 KM.11 C.SUR
87 JULIO MARTINEZ
88 REPARTO SCHICK 3
89 INE CENTRAL
90 KM.7 C.A MASAYA
91 LAURIANO MAIRENA
92 REPARTO ESPANA
93 PADRE FABRETTO

Fig. 3.2 Location map of the existing wells

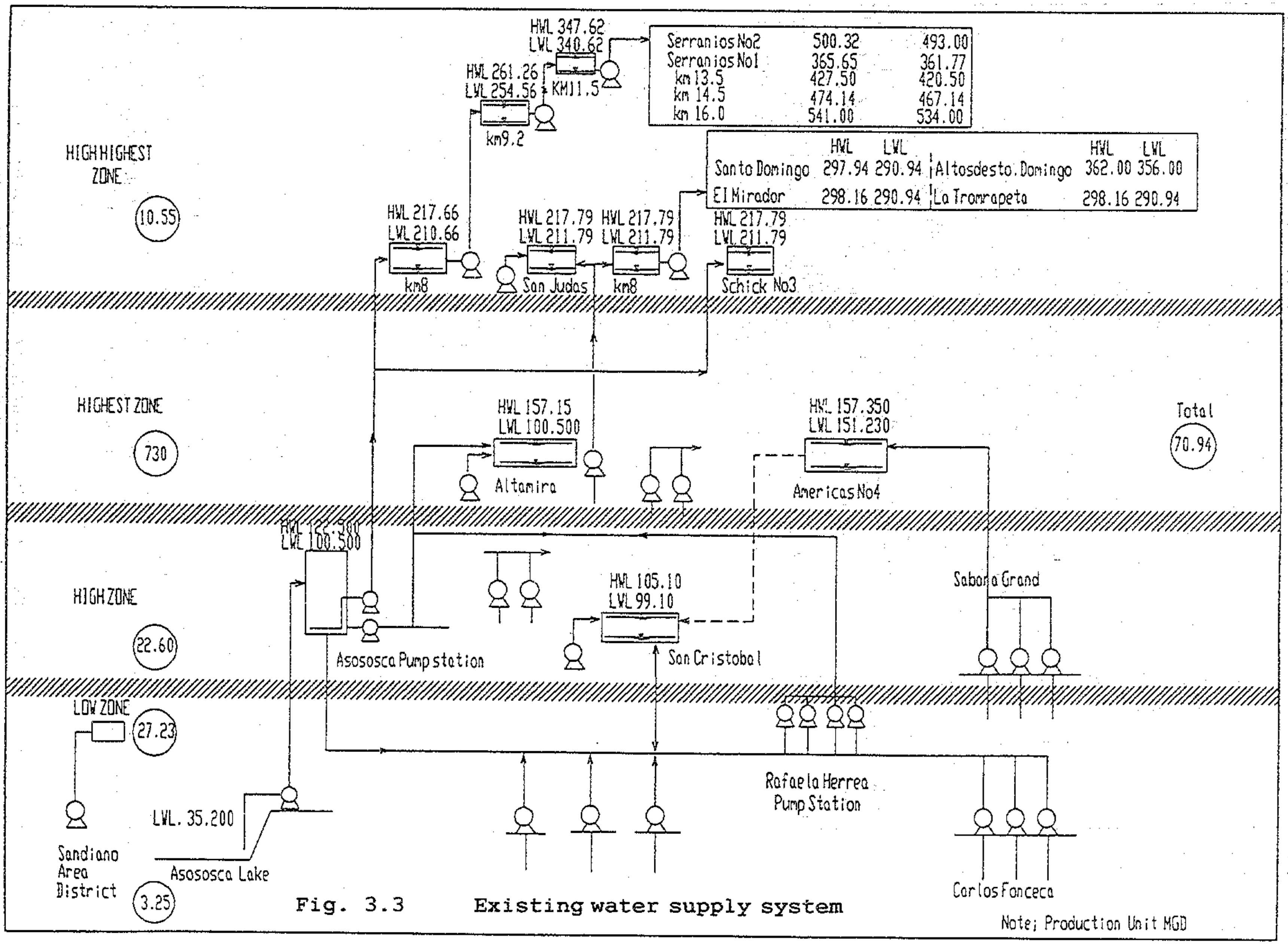
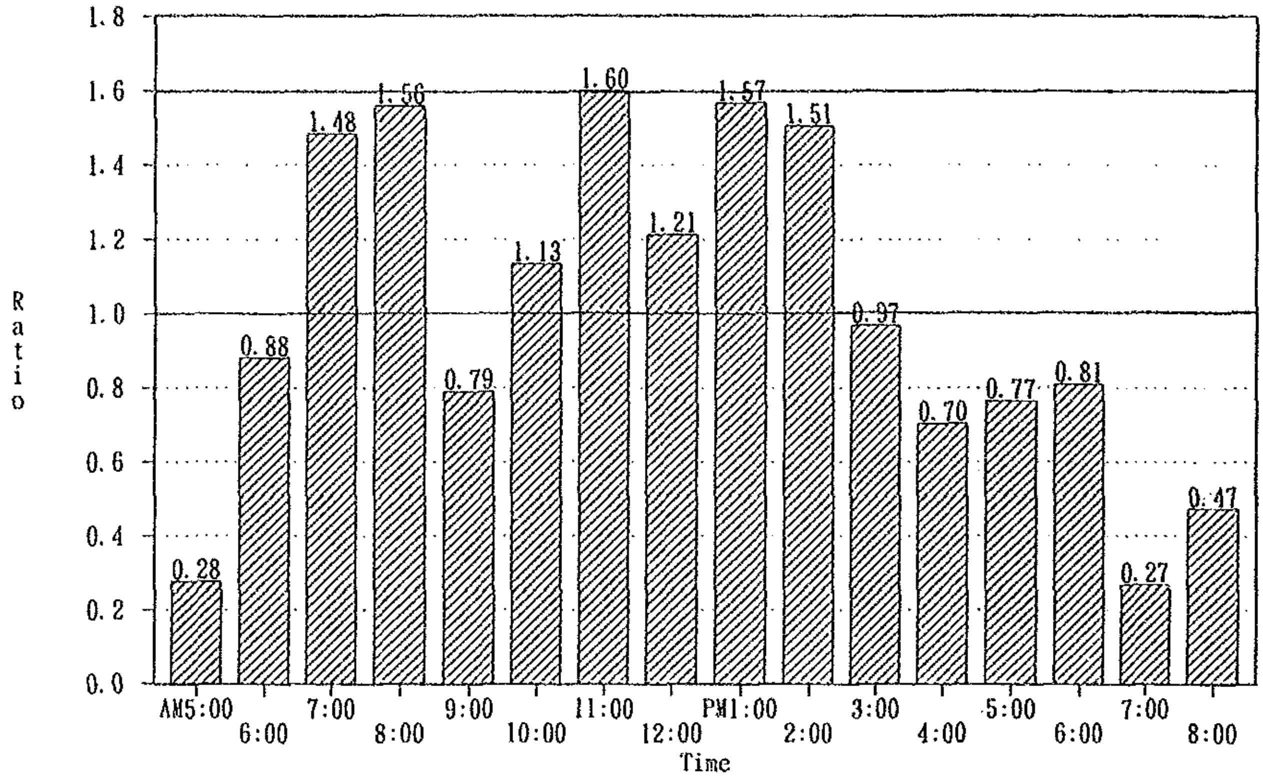


Fig. 3.3 Existing water supply system



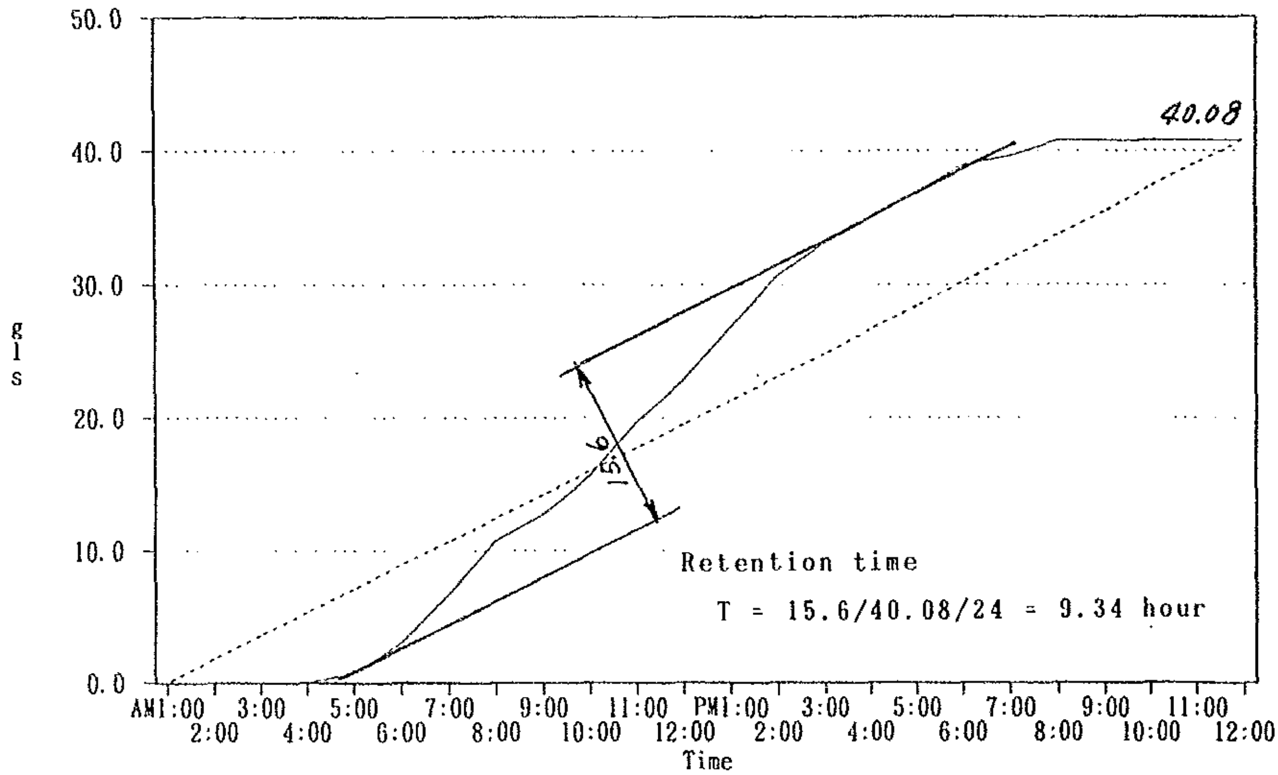


Fig. 3.4 Measured average domestic hourly water use (4 sample houses each from 7 districts

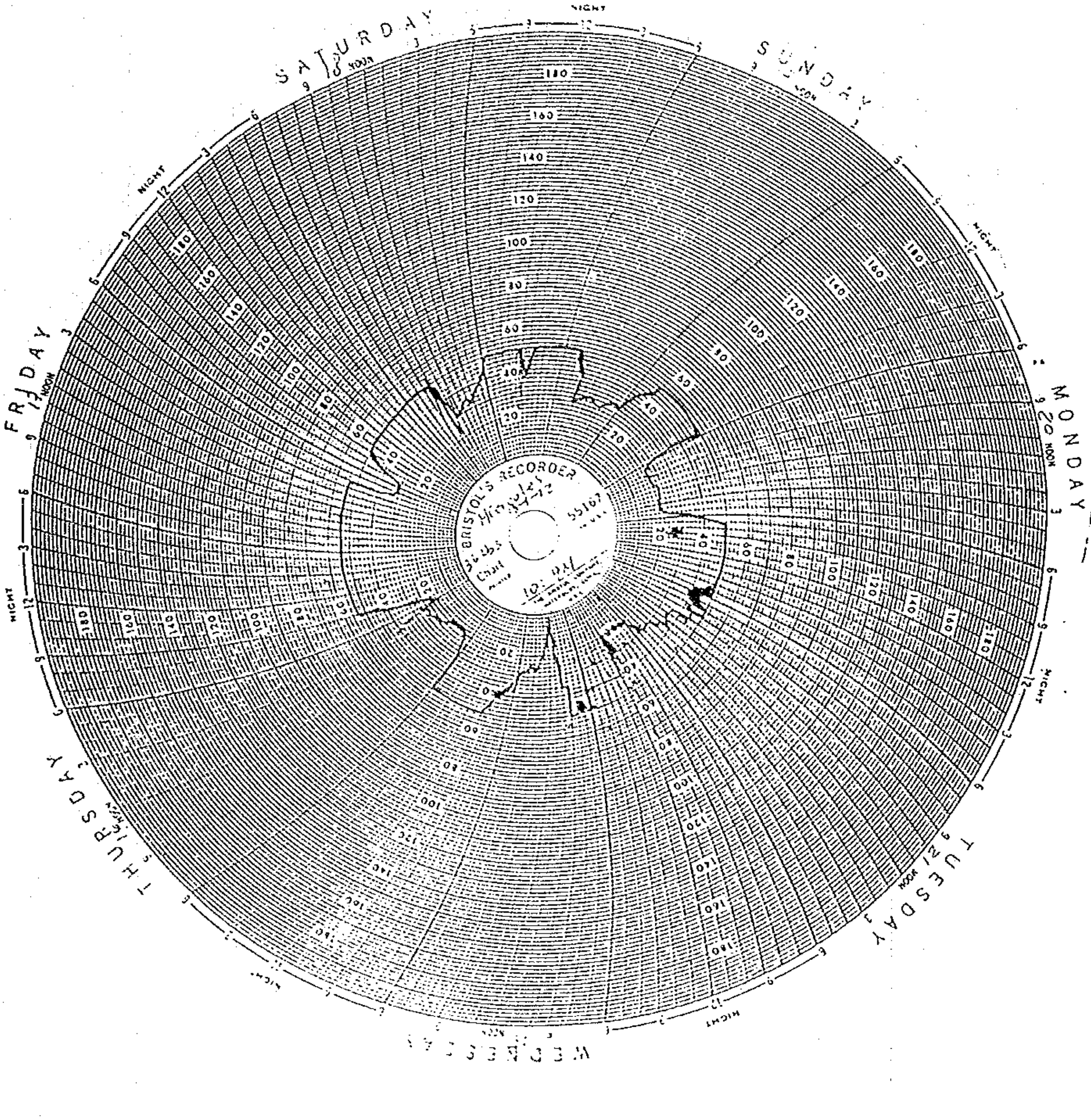
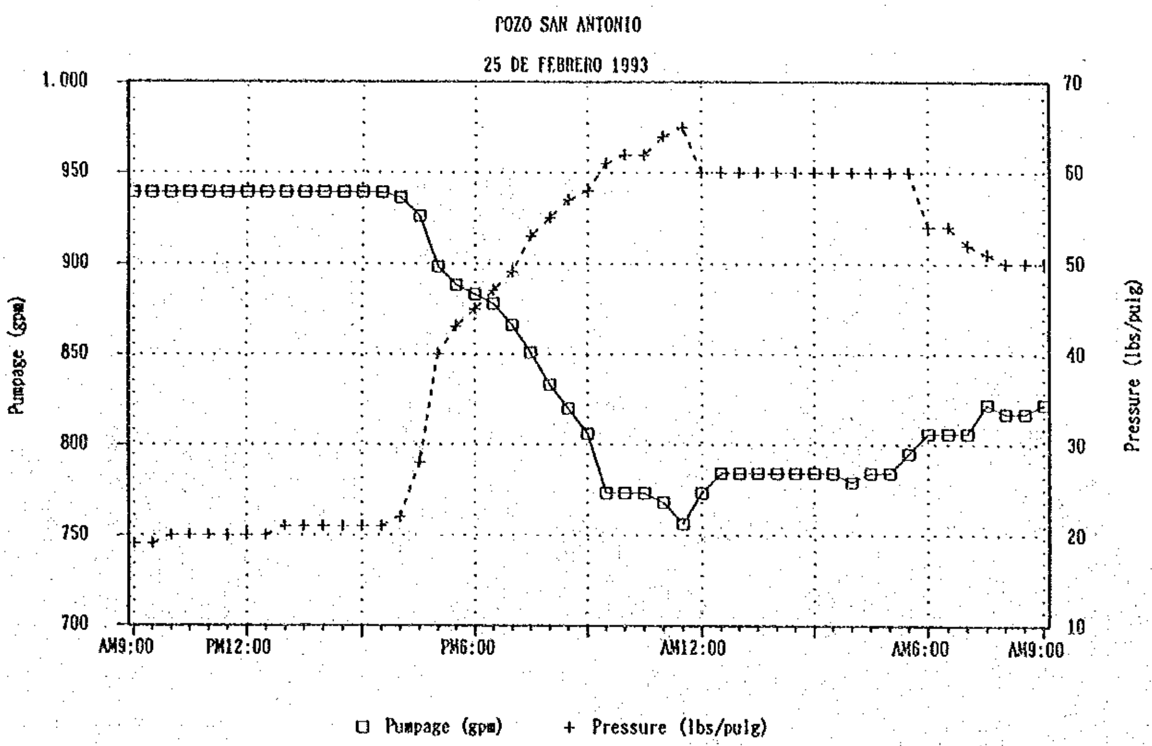


Fig. 3.5 1week pressure measurement record of San Antonio Pump Station



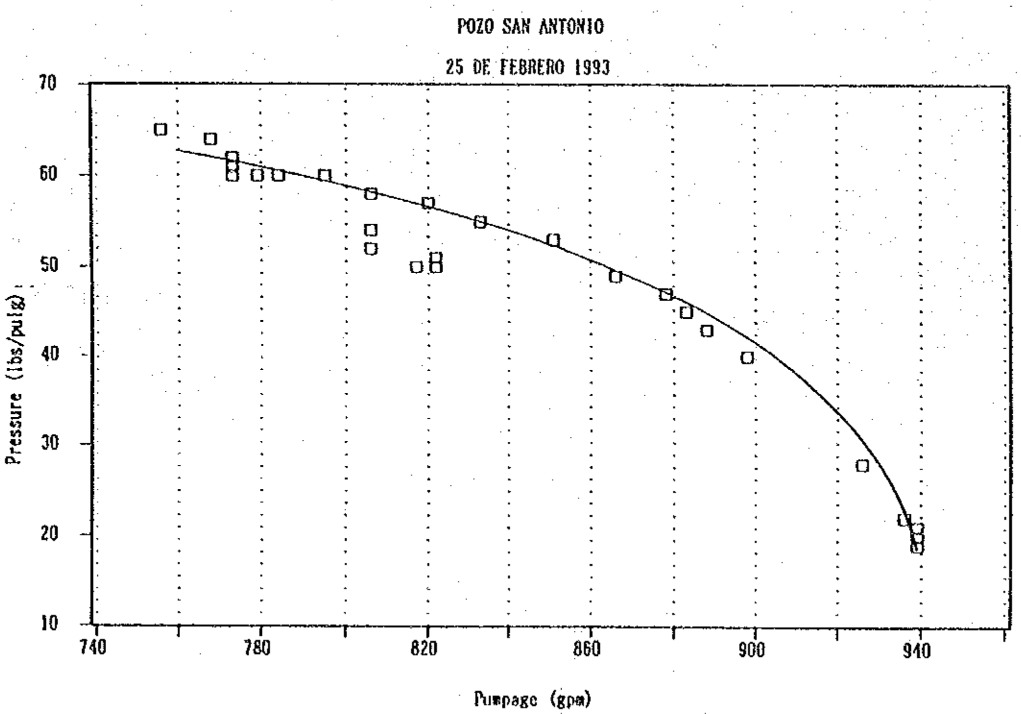
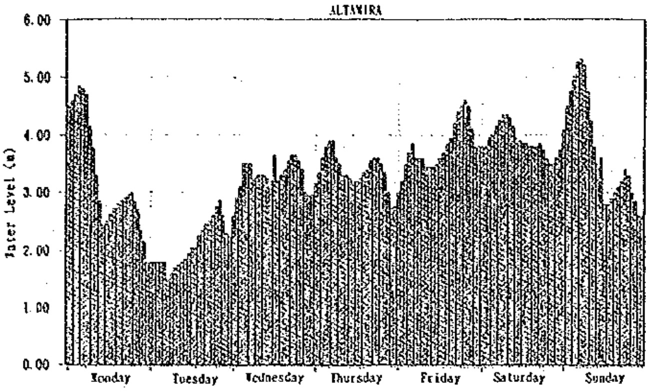
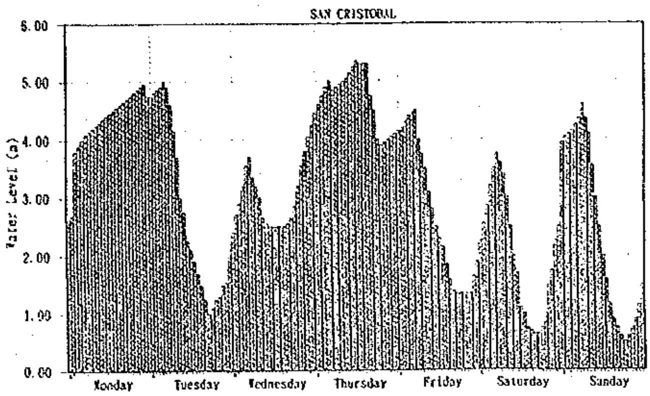


Fig.3.6 Relation between presure and pumping rate of San Antonio Pump Station

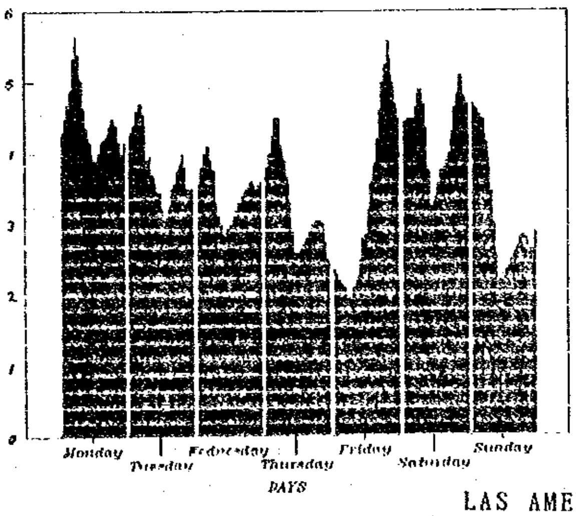
ALTAMIRA | SAN CRISTOBAL

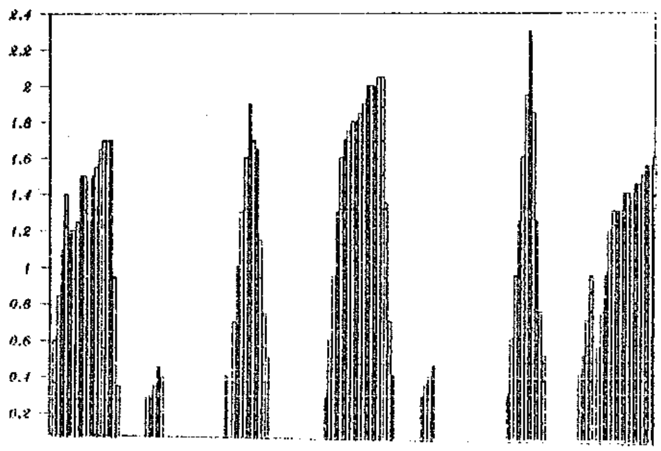
June 8-16, 1992





February 16-21, 1993





LAS AMERICAS NO.4

February 22-28, 1993

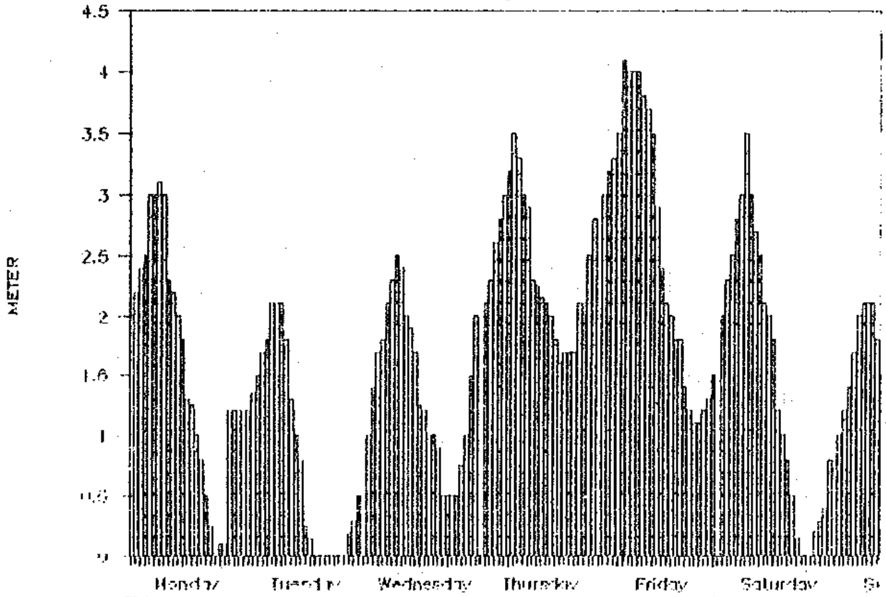


Fig. 3.7 Water level variation in reservoir tanks

CHAPTER 4 GROUNDWATER

4.1 Topography and Geology

For the purpose of understanding the topographic and geo-structural features of the Study Area, and to prepare the area hydrogeological map, the procedure used in the Study consisted of review and analysis of existing studies and data, satellite image and aerial photograph interpretation, and geologic and hydrogeologic reconnaissance.

The data and materials collected for this study are listed in Table 4.1.1.

4.1.1 Topography

(1) Western Nicaragua

The western part of Nicaragua is divided into three geologic and geographic provinces: the Pacific Coastal Plain, the Nicaraguan Depression and the Interior Highlands (Fig. 4.1.1 and 4.1.2). The Study area is situated within the Nicaraguan Depression.

1) The Pacific Coastal Plain

The plain is generally low and flat but gently undulating with mesas of the Tamarindo Formation in the vicinity of León and Puerto Somoza. The mesas gradually change to cuestas of the Las Sierras Group in the southeast of the Study Area. Most of the plain is cultivated, but small areas of dense tropical rain forest still remain.

The plain is bounded by the southwestern margin of the Depression and the Pacific Ocean, and forms a narrow stripe from Cosiguina Peninsula in the northwest, across the plain of Chinandega and León along the Sierras de Mateare and Managua, to the narrow isthmus of Rivas in the southeast (Fig. 4.1.1).

The northeastern margin of the Pacific Coastal Plain is controlled by a chain of active volcanoes and by the fault system along the Nicaraguan Depression facing the Pacific Ocean. The northwestern end of the Coastal Plain and the upper part of the

Sierras de Mateare and Managua are covered with thick pyroclastic deposits and lavas. On the other hand, the lower part of the previously mentioned Sierras and a continuous stripe near the coast between the Poneloya and Costa Rica border are composed mainly of older sedimentary rocks of the Tertiary and the Late Cretaceous ages (Fig. 4.1.1 and 4.1.2).

2) The Nicaraguan Depression

About half of the Nicaraguan Depression area is occupied by the Lakes of Managua and Nicaragua, and the elevation of depression area varies from the Gulf of Fonseca at sea level to San Cristobal which is the highest peak at 1,745 meters. Within the study area, the highest elevation of 940 meters is Sierras de Managua.

Along the southwestern margin of the depression zone, a chain of young volcanoes extends from the southeastern part of the volcanic Peninsula of Cosiguina, more or less parallel to the Pacific Coast, to Maderas Volcano in the southeastern part of Ometepe Island in the Nicaragua lake (Fig. 4.1.1). Many of the numerous volcanoes of this volcanic chain are composite cones, while several are cinder cones and some are calderas and craters.

Several volcanoes have either lakes in their craters or undergo continuous gentle fumarolic activity, while a few have occasionally erupted violently in the historic past.

The Sierras de Managua originated from the uplifting of geotectonic movement in the Middle Pleistocene and has steep-walled deep canyons. A considerable part of the Sierras de Managua is cultivated and most of the canyons are profusely covered with wild dense vegetation. Furthermore, this area is considered to have good recharge condition based on topographic, geologic and vegetation view points.

3) The Interior Highlands

This province is nearly triangular and bounded by the Nicaraguan Depression, the Atlantic Coastal Plain and the Northern Sierras. The Highlands in the western part of Nicaragua consist of Tertiary volcanic rocks forming many steep cliffs of cuestas and mesas.

(2) The Study Area

As previously mentioned, the Study Area is situated in the southwestern margin of the Nicaraguan Depression and covers an area of 880 square kilometers in the south of Lake Managua.

The area is bounded by the ridges of the Sierras de Mateare and the Sierras de Managua in the southwest, by a divide of the Sierras de Carazo to the south and by a groundwater mound near the national road (No.11) connecting Tipitapa and Masaya to the east.

The Study Area is divided into three hydrologic and hydrogeologic sub-areas: the Western sub-area, the Managua Central sub-area and the Eastern sub-area (Fig. 4.1.3).

1) Western Sub-Area

This sub-area is hydrogeologically bounded by the Mateare Fault Scarp in the southwest, and by a groundwater mound between the Western sub-area and the Managua Central sub-area in the east.

The elevation of the Mateare Fault Scarp ridge ranges from 400 meters in the northwestern end to 470 meters in the south-eastern end, and the relative height of the scarp is 150 and 200 meters, respectively. The eastern side of the scarp consists of a Quaternary flat plain with a gradient of 1/40 (1.4 degree). The area is abundant in many intermittent streams.

This sub-area has an area of 54 square kilometers.

2) Managua Central Sub-Area

This sub-area is bounded by the southern shore of lake Managua to the north, and by the groundwater mounds and groundwater divide which are basically controled by faults, fault scarps and the top surface of the impermeable basal layers to the west, southwest and southeast (Fig. 4.1.3).

The main part of Managua city stands on a low and flat plateau with a gradient of 1/27 (2.2 degrees), where many cones and craters of young volcanoes exist. Many of these craters are composite and of collapsed form, while some have lakes within.

The northern slope of the Sierras de Managua has a gradient of 1/16 (3.6 degrees) in the mountainous area behind Managua city. Its highest elevation is about 940 meters at the ridge of the Sierras de Managua protruding into the Nicaragua Depression area.

Many deeply eroded valleys with steep flanks overlain by very permeable thick volcanic ash layer (scoria rich) and covered by a dense tropical rain forest and cultivated vegetations are formed in this slope. All streams in the valley are dry except at times of strong rainfall. Conclusively, the slope is considered to have good recharge conditions.

3) Eastern Sub-Area

As shown in Fig. 4.1.3, this sub-area is divided into two hydrologic districts; that is the groundwater recharge district including Masaya Caldera and the groundwater storage and runoff district.

The groundwater recharge district consists of the mountainous areas of Sierras de Managua, Sierras de Carazo and Masaya volcano area with big caldera.

The southern part of Sierras de Managua has steep and deep canyons and intense erosion is generally evident. However, the majority of the area is under cultivation and most walls of the canyons are profusely covered with wild vegetation.

The divide of Sierras de Carazo extends nearly along national road No 18 connecting Barrio Marvin Corrales, San Marcos and Catarina. To the north, it is occupied by a flat highland with more than 400 meters elevation and is covered by dense tropical rain forest and cultivated vegetations.

A collapse caldera can be seen in San Juan de La Concepción, being situated southwest of Masaya Caldera. The area of Masaya Caldera covers 47.5 square kilometers, and the water level of its lake is 135 meters above sea level. All canyons in this groundwater recharge district have no perennial streams. Some of the rainfall from Sierras de Managua infiltrate the ground in the north of Ticuantepe, while the majority of the rainfall from Sierras de Carazo flows into lake Masaya.

The groundwater storage and runoff district consists of a flat plain with a gradient of 1/62 (1.0 degree) between the northern wall of Masaya Caldera and lake Managua. Although many intermittent streams exist, most of their flow routes disappear in the lower reaches even in the rainy season. The greater part of the district is under cultivation, but a few patches with wild vegetation and tropical rain forest remain in the northern lowly elevated area. In this district, many springs at the elevation ranging from 50-60 meters form small perennial streams flowing into the lake Managua. There are many chains of young volcanoes extending in the north-south direction, mostly consisting of small cones and collapse craters.

4.1.2 General Geology

(1) Western Nicaragua

1) Stratigraphy

The geological age relations and distribution of the principal rock units of Nicaragua and adjacent parts of Honduras and Costa Rica are summarized in Table 4.1.2.

The Pacific Coastal area of Nicaragua is underlain by the sediments from Upper Cretaceous to Recent age. The outcrop of the oldest rock in this area is the Upper Cretaceous (Rivas Formation) rocks which are distributed in the isthmus between the lake Nicaragua and Pacific Ocean.

The Rivas formation plunges below the alluvial deposits and water of lake Nicaragua to the southwest and the northeast direction: it plunges below the overlying sediments from the Paleocene to Eocene (Brito Formation). The Brito Formation is exposed over a wide area of the southeastern Pacific Coastal Plain where it is partially and uncomformably lain on the Rivas Formation. It is overlain by the sediments of the Oligocene (Masachapa Formation) to the south, and buried below the pyroclastic sediment of the Plio-Pleistocene (Las Sierras Group) in the northeast. The Masachapa Formation conformably and yet partially unconformably overlies the Brito Formation and extends northwestwardly along the strike. In the west and northwest, it is conformably overlain by the Miocene El Fraile Formation and Tamarindo Group, and unconformably overlain by the Pliocene El Salto Formation and Las Sierras Group in the northeast. In the northwestern area of the Pacific Coastal Plain, the Miocene Tamarindo Group is only exposed only in areas not covered by the

Alluvial deposits.

a. Cretaceous (Rivas Formation)

Rivas Formation is exposed in the core of the Rivas anticline at the southern end of the Pacific Coastal Plain. Its total thickness is unknown, but it seems far thicker than the exposed section of 2,370 meters (Zoopis Brace 1960). It consists of arkosic sandstone, tuffaceous shale and sandstone, marl and graywacke.

The age of this formation is within the range of the Upper Cretaceous, but typical fossils have never been found yet.

b. Paleocene to Eocene (Brito Formation)

This formation is composed of sandstone, nodular marls, green shales, black tuff and brown tuffaceous shale and also contains calcareous sand with interbedded graywacke, with thick limestones and limey shales at the base. Volcanic materials in this formation are more coarsely graded and abundant than those in the Rivas Formation; the total thickness of the Brito Formation approximates 2,400 meters.

c. Oligocene (Masachapa Formation)

This formation underlies a topographically low area in the Pacific Coastal Plain which is 3 to 6 kilometers wide and about 70 kilometers long. It is composed of tuffaceous mudstone, alternating gray and dark gray shales, well stratified thin beds of fine grained quartz sandstone. Toward the top of the formation, tuff and breccia become more abundant. Silicified wood is abundant in some of the tuffaceous beds and carbonized tree trunks are mixed with fragments of molluscs and volcanic debris near the base of the formation. This formation is approximately 2,600 meters thick.

d. Miocene (El Fraile Formation)

This formation, which is at least 2,250 meters thick along the Pacific Coast, is mainly composed of tuffaceous shale and calcareous sandstone forming a gently sloping cuesta nearly parallel to the shoreline. The lower part of the formation grades northwestward into a contemporaneous series of volcanic tuffs and ignimbrites called the Tamarindo Group. This part consists of clayey to sandy sediments and conglomeratic sandstone with fossil tree trunks. These fossils indicate a change from shallow depth marine (Masachapa Formation) to deltaic or terrestrial conditions.

The Tamarindo Group is the only Tertiary volcanic rock exposed in the Pacific Coastal Plain. The characteristics of this group are detailed in the latter part of the following section on Tertiary volcanic rocks.

e. Pliocene (El Salto Formation)

The above mentioned gently folded and faulted Miocene and older formations of the Pacific Coastal Plain are overlain with sharp angles of the flat-lying El Salto Formation. These Pliocene sediments are only locally preserved in erosional remnants capping the Masachapa and Brito Formations between the Sierras de Managua and the coast, and it is presumably more than 100 meters thick in the exposed area.

This formation is composed of typical shelf deposits such as dirty tuffaceous sandstone and siltstone, sandy shales, marly shale and marls, while cobble conglomerates occur locally at its base. Both sandy and shaley layers contain large quantities of shells, which are also concentrated in reef-like build-ups of large oysters forming coquinas of widespread mixed shell deposits. Some of them are mine fields of crude materials for cement production.

This formation is widely overlain with gentle unconformity by the flat-lying Las Sierras Group. The stratigraphy and lithology of the Las Sierras Group are described in the next section.

f. Quaternary Sediments

The Quaternary sediments of the Managua and Nicaragua lakes consist of sand, silt and clay, mainly of volcanic origin with some organic materials. These Quaternary sediments in the Study Area are detailed hereafter.

2) Igneous and Related Rocks

a. Tertiary Intrusive Rocks

Numerous dikes and sheets of diabase, and at least four stocks of hornblend diorite, intrude the sedimentary series of the Pacific Coast. The largest stock of diorite, about 30 kilometers in length, is located in the exposed area of the Brito Formation. This intrusion probably occurred during the Late Miocene age.

b. Tertiary Volcanics in the Interior Highland

The Tertiary volcanics in the Interior Highland can be divided into three volcanic groups: the Matagalpa Group (Paleocene to Oligocene), the Coyol Group (Miocene to Pliocene) and the Plio-Pleistocene volcanic, in ascending order.

The Matagalpa Group is widely exposed in the east of the Nicaraguan Depression and occupies the high topographical areas forming relatively high mesas. The lithology of the group is variable with basalts predominating; some andesitic rocks, basaltic lavas, tuffbreccias and agglomerates, and andesitic to dacitic welded tuffs are also found.

The Coyol Group is also widely exposed in the east and the eastern margin of the Nicaraguan Depression; it is also distributed in topographically low areas.

This group can be divided into two sub-groups based on its stratigraphical and lithological conditions: the Lower Coyol Group (Miocene) and the Upper Coyol Group (Pliocene). The major volcanic activities of this group, however, are more prevalent in the lower Coyol Group of the Miocene.

The Lower Coyol Group grades upward from andesitic lavas and agglomerates through andesitic ignimbrites to dacitic ash-flows and breccias. This group contains interbedded sedimentary rocks that become progressively more abundant south of the Nicaraguan Depression.

The Upper Coyol Group is composed of basaltic lavas and agglomerates, andesitic ignimbrites, dacitic ash-flow, and basaltic-andesitic lavas and agglomerates of the uppermost Upper Coyol group, in ascending order.

The Plio-Pleistocene Volcanics is located at the boundary between the relatively flat-lying mesas of the Interior Highland and the tilting faulted blocks comprising the western foothills in the northeastern marginal zone of the Nicaraguan Depression. These volcanics have collapse craters and calderas, and consist mainly of basaltic lavas and agglomerates, some overlying the volcanic rocks of the Las Sierras Group.

c. Tertiary Volcanics in the Pacific Coastal Plain and in the Nicaraguan Depression

Tamarindo Group

The Tamarindo Group of the Pacific Coastal Plain, the Middle to Upper Miocene is composed of andesitic lava and agglomerate and an overlying ash-flow series (ignimbrites). These ignimbrites (welded tuffs) have the following common characteristics:

- The deposition forms tablelands (mesas) with only a few degrees inclination.

- Stratification is present, but texture similar to welded tuff is not very clear.

- Colors are white, gray, pink, yellow; some are colored like bricks due to iron oxidation.

- The majority of the ignimbrites belongs to the acid types of granitic magma, but can be found as ignimbrite approaching the andesitic type.

Las Sierras Group

The Las Sierras Group unconformably overlies the Tertiary sedimentary rocks in the east central area of the Pacific Coastal Plain, and also the Tertiary volcanic rocks in the northeastern margin of the Nicaraguan Depression.

This group is mainly composed of basaltic to andesitic pyroclastic rocks of the Plio-Pleistocene. The review and analysis of existing study reports, and geological reconnaissance using interpreted satellite images and aero-photos in this study, resulted in the subdivision of the Las Sierras Group into three formations: the Lower, Middle, and Upper Las Sierras Groups.

The Lower Las Sierras Group is mainly exposed in the vicinity of El Salto, unconformably overlying the El Salto Formation with a typical basal conglomerate. This formation consists of basal conglomerates with limestone cobble and boulder of the El Salto Formation, fine conglomerate or conglomeratic sandstone, tuffaceous sandstone and siltstone, and basaltic tuff and tuffbreccia with brown fossil soil beds.

The Middle Las Sierras Group forms the main part of the Las Sierras Group and consists mainly of basaltic to andesitic agglomerates and tuffbreccia with pisolites. The lithology of this formation is generally massive and compact and contains considerable pumice, volcanic rock fragments and glass. It is extensively quarried in the Diriamba Cuestas, Tipitapa Plains and other places, for use as foundation stone and in rough construction (building stone).

The Upper Las Sierras Group is mainly exposed in the Cuestas of the Sierras de Mateare and the northern slopes of the Sierras de Managua. The formation is composed of basaltic to andesitic agglomerate, tuffbreccia and tuff with scoria and fossil soil beds, tuffaceous sandstone and siltstone. It also partially contains large quantity of pisolite.

A detailed description of the Las Sierras Group is reserved for the discussion of "Geology in the Study Area".

d. Quaternary Volcanics in the Nicaraguan Depression

The principal chain of Quaternary Volcanoes in Nicaragua lies near the southwestern boundary of the Nicaraguan Depression. This Quaternary volcanic chain is subdivided into 4 volcanic regions: the region between Cosiguina and theMarrabios Range; the region of the Marrabios Range; the region between lakes Managua and Nicaragua; and the region in lake Nicaragua from the northwest to the southeast based on the characteristics of their volcanic activities.

Region between Cosiguina and the Marrabios Range

Cosiguina volcano (859 m) stands at the extreme northwestern tip of the country, on a peninsula that projects into the Gulf of Fonseca. This volcano exploded many times in the historical past, and the 1835 eruption was the mightiest of all. The large volume of matter emitted during the eruption consists of crystal-rich andesitic pumices and pre-calder lavas are olivin-bearing hypersthene-augite andesitic basalts.

In the region between Cosiguina volcano and the Marrabios Range, a number of small knobs, which appear to be shallow stock or volcanic necks that may once have been vents within the present active chain of volcanoes, can be observed. Volcanic rocks in this region are mainly composed of andesites or andesitic basalts.

Region of the Marrabios Range

As shown in Fig. 4.1.4, the Marrabios Range includes numerous overlapping volcanoes of the Recent age between El Viejo at the northwestern end and Momotombo on the shore of lake Managua. Many of these volcanoes have been active in historic times, and at least two or three are usually in a state of continuous solfataric activity.

The northernmost group of the cone is dominated by El Viejo, which is also called San Cristobal, the highest peak in western Nicaragua (1.745 m). The lavas of El Viejo are dominantly olivine basalts, while hypersthene-bearing andesitic basalt is more common in Casita. On the other hand, extensive beds of dacite pumice, apparently erupted from La Pelona, can be found around the eastern base of the ridge.

The cluster of cones in the southeast of San Cristobal is dominated by the active crater of Telica. The rocks of Telica range from basalts with abundant olivine to hypersthene-augite andesitic basalts containing little or no olivine. Coarse-grained gabbroic blocks can be found among the explosive ejecta of Telica.

The deeply eroded cone of Rota separates the Telica Group from the next line of cones to the south. The volcano has been inactive for many centuries. Cerro Negro is one of the most active volcanoes in Nicaragua. This volcano was formed in 1850 and has had at least 9 intense eruptions, the most recent of which is in April 1992. Las Pilas is also an active volcano but there are no historic records of lava or scoria eruptions. The lavas of this volcano group are all olivine-augite basalts.

The large symmetrical cone of Momotombo, one of the most familiar landmarks of Nicaragua forms a peninsula at the north-western shore of Lake Managua. Momotombo has a long record of activity including both explosion and lava eruption. The last lava eruption happened in 1905 and the lavas of this volcano are believed to be olivine-bearing hypersthene-augite basaltic andesite. In the northwestern base of Momotombo, there is an unnamed caldera about 4 kilometers in diameter and about 200 meters deep. This caldera appears to be the source of extensive pumice deposits that cover the broad plains to the north and east.

In the northwestern shore area of lake Managua, there are numerous boiling springs (70 to 101°C) and they are considered as the most promising geothermal field of Nicaragua. In this geothermal field, a number of test drillings to evaluate the geothermal energy resources for the electric power generation has been carried out since 1970. The results of the deep borehole test MT-1 (drilling depth 300 meters) in the south of Momotombo volcano, give the general characteristics of this geothermal field as follows:

Lithology: The rocks consist of basaltic lavas and is moderately to intensely interlayered with altered tuffs from Momotombo to a depth of 64.5 meters below the ground surface.
Below 64.5 meters, the rocks are primarily tuff with varied and often intense alterations, with a few minor basaltic-andesitic lavas which are apparently of pre-Momotombo volcanic origin (Las Sierras Group or Coyol Group).

Temperature: 179°C (30 meters below the ground surface);
205 - 209°C (217 meters below the ground).

Chemical Components : (mg/l)
Na 990, K 160, Cl 1.700, SiO_2 210, Ca 110, Mg 11, CO_3 < 10, HCO_3 540, SO_4 6, B 12, As 0,4, Li4.4, PO_4 TDS 3, 460, PH 7.0.

Region between Lakes Managua and Nicaragua

A volcanic belt of closely spaced collapse craters (pits), calderas and cones continues from the south of Lake Managua to the norwestern edge of Lake Nicaragua (Fig. 4.1.5).

Apoyeque volcano dominates Chiltepe Peninsula and appears to have been the source of most of the dacite pumice that blankets the surrounding region. Lake Xiloa on the southeast flank of Apoyeque occupies a crater formed by subsidence after the last pumice eruption. Cuestas of the Sierras de Mateare and Sierras de Managua are widely covered by pumice from Apoyeque. Among the explosive ejecta from Apoyeque, some accidental blocks (xenolith) of brown hard tuffaceous shale, estimated to be of the Brito Formation origin, were found at the road cutting near La Montanita on the Cuesta of the Sierras de Mateare during this Study.

The large cone of Mombacho on the shore of lake Nicaragua differs from other volcanoes of the chain both in rock structure and in character. There are no well-documented eruptions from this volcano and the upper slope is thickly covered with vegetation. A broad fan of bouldery debris forms a hummocky area at the northeastern base. The deposit consists of andesite blocks and a loose unsorted matrix. Most of the rocks of Mombacho are hypersthene-augite andesites and andesitic basalts. Near the central portion of the volcano, there are diabasic rocks among the detritus on the upper western slopes, which may have been derived from the core in the central crater area.

A description of other volcanoes such as Asososca, Nejapa, Ticomo, Masaya and Apoyo in the region is reserved for the discussion of Quaternary volcanic rocks in the Study Area.

Region in Lake Nicaragua

Recent eruptions have resulted in the formation of two large islands in Lake Nicaragua, namely, Zapatera and Ometepe islands (Fig. 4.1.6).

The complex group of coalescing cones makes up the central portion of the island of Zapatera, and its maximum elevation is 625 meters. The lavas on the north slope are hypersthene-augite andesites similar to those of Mombacho.

The island of Ometepe has the twin cones of Concepción (1610 meters) and El Madera (1.394 meters). Of the two volcanoes, only Concepción has been active in historic times. Although most of the volcanic rocks are olivine-bearing andesitic basalts, andesites can also be found on the slopes, and dacite pumice on the flats around the northern base.

(2) The Study Area

The geological and hydrogeological reconnaissance in this Study was carried out based on the results of the review and analysis of existing study reports and data (Table 4.1.1), and the satellite image and aero-photo interpretations that were simultaneously carried out for the geologic field survey. This reconnaissance covered about 2,000 square kilometers beyond the limit of the Study area, in order to clarify the hydrological and hydrogeological boundary of the so-called Managua geohydrolic area. And other purpose was to understand the regional geology and characteristic of the El Salto Formation, regarded as the hydrogeologically impermeable basal layer of the geohydrolic area.

As a result of these works, a preliminary hydrogeological map (1:50,000) has been prepared and finally completed as a comprehensive hydrogeological map.

On the other hand, electric resistivity vertical sounding, test well drilling and pumping test, and review and analysis of existing borehole records were simultaneously carried out in Phases I and II of the Study.

The results of the above mentioned works also led to the formulation of hydrogeological cross sections shown in Fig. 4.1.8 to 4.1.12.

The major findings on the geology of the Study area are described as follows:

1) Stratigraphy

The geological age relation and distribution of the principal rock units of the Study area are summarized in Table 4.1.3 and Fig. 4.1.7.

a. El Salto Formation and Other Tertiary Sedimentary Rocks

The Las Sierras Group in the Study area is estimated to be widely underlain by the El Salto Formation and other Tertiary sedimentary rocks, such as the Brito Formation, which are regarded as hydrogeologically impermeable basal layers.

In this Study, a lot of information on Tertiary-sedimentary rocks mentioned above was obtained by electrical prospecting, test well drilling and review of existing borehole records. Some of the information is shown in hydrogeological cross sections (Fig. 4.1.8 to Fig. 4.1.12), while the basic information obtained from electric prospecting is shown in Table 4.8.4.

Lithological information of Tertiary sedimentary rocks obtained from test well drillings in this Study are touched upon in the later Section: "Hydrogeological Features of the Study area".

b. Plio-Pleistocene Lavas

Older and hard lavas are exposed in the southeast wall of Masaya caldera and the south to west wall of Apoyo caldera. The older lava in Masaya caldera is of olivine-augite basalt, and the older lava in Apoyo caldera is of hypersthene-augite andesitic basalt. These older basaltic lavas are overlain by the Las Sierras Group.

c. Lower Las Sierras Group [TQps (I)]

This lower Las Sierras Group is not exposed in the surface of the Study area, and the distribution of this group is estimated to be very limited in the underground part of the Sierras de Managua within the Study area (see Fig. 4.1.9 [Hydrogeological cross section D-E-F-G]).

Detailed information on this group was described earlier in the "Geology of Western Nicaragua".

d. Middle Las Sierras Group [TQps (M)]

The typical outcrops of this group in the Study Area are seen in the walls of Asososca, Nejapa and Tiscapa craters, and also in deep canyons on the southern flanks of Sierras de Managua protruding into the Study Area. These outcrops consist of massive and compact basaltic to andesitic agglomerate with tuffbreccia (lapilli tuff) and tuff containing pisolite. The color is mainly gray to dark gray, but changes from greenish gray near San Rafael to reddish brown in Veracruz area.

During the geological reconnaissance of the Study Area, small outcrops of the Middle Las Sierras Group were sporadically observed over widespread areas, most of these were confirmed to be massive and compact basaltic to andesitic agglomerates or tuffbreccias (lapilli tuffs) with pisolite and network veins of calcareous sinter.

On the other hand, according to the existing borehole records, the lithofacies of the Middle Las Sierras Group are mostly clay, silt, sand and gravel. Therefore, existing lithological data were reevaluated by taking the following measures in the formulation of hydrogeological cross sections.

.Gravel may be mainly agglomerate

.Gravel with sand ----------- agglomerate with tuffbreccia or tuff

.Sand with gravel ----------- tuffbreccia

.Sand ----------------------- tuff or tuffbreccia

.Sand with clay ------------- tuff

.Clay ----------------------- clayey tuff or weathered tuff

.Brown clay ----------------- fossil soil

.Rock or cobble ------------- pyroclastic flow

The reliability of this measure was investigated by the observation of the drilling slag at the borehole site in Villa Revolución (eastern part of Managua city), and the results are:

Static Water Level:44.4 m. Discharge:80 gpm (304 l/min.)

Gl-meters	
0-3	Brown soil (soil)
3-21	Gray clay with gravel (tuffbreccia-agglomerate)
21-25.5	Gray clay-silt (tuff)
25.5-31.5	Gray silt (tuff)
31.5-40.5	Gray silt with small gravel (tuffbreccia)
40.5-42	Brown clay with gravel (fossil soil)^] +^A,3^A ^]
42-45	Gray sand (tuff-tuffbreccia)
45-48	Black gravel with sand (scoria flows)
48-63	Rock fragments with sand (porous pyroclastic flow)
63-72	Brown clay with gravel (weathered tuffbreccia)

From the results of the above mentioned geological reconnaissance and the reevaluation of lithological data, it can be estimated that lithofacies of the Middle Las Sierras Group in the study area is composed not only of compact agglomerate with tuffbreccia and tuff, but also of porous pyroclastic fall deposits or pyroclastic flow of scoria with fossil soil beds. In general, compact agglomerate is of relatively low permeability as seen in the crater wall of Asososca, Nejapa and Tiscapa.

The detailed areal and hydrogeological features of the Middle Las Sierras Group, including the results of electric prospecting and test well drilling in this study, are detailed in the later section "Hydrogeology of the Study Area".

e. Upper Las Sierras Group [TQps(S)]

The Upper Las Sierras Group is exposed in the Sierras de Mateare and at the northwestern half and northeastern slope of Sierras de Managua protruding into the study area. The main outcrops of this group are seen continuously at the Mateare Fault Scarp, which is composed of an alternation of massive basaltic to andesitic agglomerate, tuffbreccia and tuff with thin layers of fossil soil, scoria and pumice. The massive and compact layers of agglomerate and tuffbreccia are partially quarried for use as building stone.

On the other hand, the group exposed in the northeastern slope of Sierras de Managua is formed from frequently alternating agglomerates, tuffbreccias, tuffs, pisolite-rich sandy-tuffs, tuffaceous sandstones and fossil soil. The layers of sandy tuffs and tuffaceous sandstones have well developed bedding planes or cross laminas and are gently and partially folded. Its color changes from dark-gray to pale-green or greenish gray, and is generally less consolidated.

f. Masaya Group Volcanics (QvM)

Masaya volcano is a typical double volcano with a big caldera shaped like a Glen Coe type. The historic activities of this volcano are characterized by intracaldera flows, and the most recent volcanics which occurred in 1792, emitted lava flow reaching near Sabana Grande.

All the exposed rock from Masaya volcano are iron-rich basalts. Except for a part of the southeastern caldera wall, these walls consist of lava flows (hard and porous) and pyroclastic flows of scoria, volcanic breccia and ash.

As shown in Fig. 4.1.7, there are many cones, collapse craters and collapse calderas influenced by the volcanic chain extended in the north-south direction in the surrounding area of the Masaya Central volcano. These volcanic chain includes the San Juan de La Concepción collapse caldera in the southwest, the San Francisco collapse small caldera in the northeast, the Veracruz composite crater in the north, the Barrio Nuevo cinder cone with brecciated porous lava near the northwestern Masaya caldera, and the Silvio Reñazco scoria cones in the northern part of Masaya city. The volcanic sediments originating from these volcanoes are categorized under "Masaya Group Volcanics" in this report.

The northern area of the Masaya caldera connecting Ticuantepe, Veracruz and Sabana Grande is underlain by the Masaya Group Volcanics, which is about 100 meters thick at the center (Fig. 4.1.11 and 4.1.12). The hydrogeological cross sections assume that the Masaya Group Volcanics are deposited in an old valley formed in the Middle Las Sierras Group of the Middle Pleistocene.

According to existing borehole records, the volcanics buried an old valley composed of porous basaltic lava, and the layer of pyroclastic flows is one of those that can be developed as aquifer in the study area. Furthermore, it is also assumed that at that time, the lower reaches of an old valley had to be under water level conditions, and that Quaternary sediments and Masaya Group Volcanics have been deposited with an interfinger relation (Fig. 4.1.7 and 4.1.11).

g. Apoyo Volcanics (QvA)

The caldera of Apoyo, though only 10 kilometers from Masaya, is a magnificent example of a Krakatau type of caldera formed from a collapse as a result of the eruption of great quantities of dacite pumice.

The pumice covers a wide area as shown in Figure 4.1.7.

h. Pleistocene Volcanics (QvP)

These volcanics are exposed along the volcanic chain extended in the north-south direction connecting the collapse crater of Apoyeque, Cerro Partido, San Carlos, Cerro Los Martinez, Ticomo and the small cones at the western slope of Sierras de Managua. Although the Pleistocene volcanics of the chain consist of basaltic to andesitic lavas and pyroclastic materials and residues of eroded volcanic bodies, it is difficult to delineate the accurate boundary between the QvP and QvH.

Much of the scoria layers that cover the summit of the Sierras de Managua is considered to belong to the Pleistocene volcanics erupted on the western slope of the Sierras de Managua.

i. Holocene Volcanics (QvH)

Holocene volcanics are mainly exposed along the above mentioned volcanic chain of the Pleistocene volcanics. The central cones and lava flows of the Masaya volcano in 1972 belong also to Holocene volcanics.

All the Holocene volcanics in the study area are composed of basaltic lavas, cinder, scoria flows and their secondary sediments. Among them the Nejapa volcanics are observed to be underlain by the pumice layer of Apoyeque.

j. Alluvium (Qal)

Alluvium is mainly exposed in the western sub-area and along the shore of Lake Managua. In the western sub-area, it consists of mixed sediments of volcanic-ash (scoria and pumice) and debris mainly from the Mateare Fault Scarp zone (Fig. 4.1.8). Areal lithological features of the alluvium are described in the later section "Hydrogeology of the Study Area".

2) Tephra

The Study Area is widely overlain by Quaternary volcanic ash. In this study, two typical outcrops were observed in order to clarify the stratigraphical characteristics of the Quaternary volcanic ash layers. The results of this observation are shown in Fig. 4.1.13.

As a result of the volcanic stratigraphical observation of tephra, the following items are pointed out as the main findings:

- The main volcanic activities of Masaya Group (pre-caldera) occurred at least in four stages.