It is noted that, among 226,000 households in Metropolitan Guatemala, 12.4 percent depend on public standpipes, which are not always at a reasonable distance, and 11.5 percent have no access to a piped water supply. This situation is aggravated along peripheries of the urban area and in squatter communities on slopes of ravines.

EMPAGUA's service connections in 1985 totalled approximately 112,000, and number of consumers is estimated at around 800,000. Provided that 89 percent or 1,335,000 of the metropolitan inhabitants in 1985 had access to the piped water supply service, 535,000 or 35 percent of the population received piped water from entities other than EMPAGUA. If this population, mostly inhabitants in suburban areas, consumes 140 l/capita/day on the average, then total quantity supplied by the other water services may be estimated to be some 75,000 m^3/day.

2.2.3 Sources of Water Supply

EMPAGUA supplies 218,387m^3/day in 1985 or 208,031m^3/day on the average from 1980 to 1984. Sources of raw water in 1985 are broken down as follows:

Surface water:	151,415 (m^3/day)	(100%)	69.3%
North basin:	3,836	(2.5%)	1.8
South basin:	14,775	(9.8)	6.8
East basin:	46,406	(30.6)	21.2
Outside basin:	86,398	(57.1)	39.6
Groundwater:	66,972		30.7
Ojo de Agua:	48,582		22.2
In the city:	15,530		7.1
Other wells:	2,860		1.3
Total	218,387		100.0

Thus, EMPAGUA's production record shows that 30 percent or 0.775m^3/sec of raw water derives from groundwater obtained from natural springs, and vertical and horizontal wells. An additional 40 percent is diverted a long distance from the Xaya and Pixcaya rivers. Only 30 percent or 0.75m^3/sec is therefore tapped from rivers in the Project area. This volume is slightly less than that from groundwater source in the area.

Among the surface water sources other than the above mentioned diverted source, the north basin supplies 5.9%, the south basin 22.7%, the east basin 71.4% respectively.

Apart from EMPAGUA, independent water supply facilities operated by MARISCAL, suburban municipalities, colonies or housing complexes, public and private institutions are also drawing mainly groundwater. It is estimated that MARISCAL supplies approximately 20,000m ^{3}/day of potable water to some 10,000 customers. According to the estimate in the preceding section, a 75,000m ^{3}/day is supplied from water supply systems other than EMPAGUA. The remaining 55,000m ^{3}/day is attributed to suburban municipalities, colonies and other water supplies.

In addition to groundwater, the MARISCAL system surface water from a reservoir of the same name in the south basin. Quantity derived from each MARISCAL source is not known. Other supply systems are utilizing solely groundwater. It is estimated that groundwater yield for the piped supply system may be around 65,000m ^{3}/day or 0.752m ^{3}/sec, if 10,000m ^{3}/day or a half of MARISCAL production derives from groundwater sources.

The groundwater yield utilized for the piped supply systems is thus estimated as follows:

EMPAGUA	0.775 (m ^{3}/sec)
MARISCAL and others	0.752
Total for piped supply	1.527

However, the above does not include yield by private and institutional water supplies, and that by shallow wells, data for which are not available.

2.2.4 Sanitation Facilities

Sanitation, often linked with water supply, in the Project area may be shown in the following:

TABLE 2-2 SANITATION FACILITIES

	Republic of Guatemala		Guatemala Department		Metropolitan Guatemala		Guatemala Municipality	
Household	1,151,872	100%	258,442	100%	225,879	100%	152,523	100%
With toilet	246,646	21.4	144,010	55.7	140,038	62.0	108,739	71.3
Connected to sewer network	214,428	18.6	131,291	50.8	127,845	56.6	102,864	67.4
Single house connection	165,795	14.4	100,762	39.0	98,280	43.5	77,683	50.9
Communal connection	48,633	4.2	30,529	11.8	29,565	13.1	25,181	16.5
Connected to septic tank	32,218	2.8	12,719	4.9	12,193	5.4	5,875	3.9
Single house	19,933	1.7	7,673	3.0	7,324	3.2	3,433	2.3
Communal	12,285	1.1	5,046	1.9	4,869	2.2	2,442	1.6
Flush toilets	39,550	3.4	14,431	5.6	13,231	5.9	7,745	5.1
Pit latrine	368,086	32.0	75,869	29.4	61,359	27.2	29,716	19.5
No latrine	497,590	43.2	24,132	7.3	11,251	5.0	6,323	4.1

Source: 1981 Census

In comparison to the table for sources of water supply (section 2.2.3), the above table shows that the number of households with toilet and flush toilets bears a loose relationship to that of households with water supply. Households without latrines still account for a significant percentage of total households in Metropolitan Guatemala and in the municipality overall.

2.2.5 Sewerage and Solid Waste in the Capital City

In spite of its modern appearance, Guatemala City suffers from poor sanitation. In contrast to the development of social infrastructures such as the road network, power supply, telecommunications network and water supply, Guatemala City lacks a wastewater treatment plant of significant capacity. Domestic and industrial wastewater collected by the sewer network is discharged into rivers without treatment. Most solid wastes from the city are dumped without processing at a landfill site in Zone 3, i.e. the center of the city, generating offensive odors, undesirable disease vectors and water pollution.

On the slopes along the city periphery, sanitary conditions are worse due to lack of social infrastructures such as paved access roads, the absence of a plentiful supply of water, and an inadequate piped sewer system, etc. Inhabitants in most of these areas discharge grey and black water through open ditches into nearby rivers and cast solid waste into ravines or vacant land. While some houses are equipped with cesspools or cesspits for excreta disposal, improper construction poses environmental hazards in many places.

The foremost environmental hazard, however, is the direct discharge of untreated sewage into the northern rivers. Garbage dumps in ravines also cause significant pollution which is subsequently washed into rivers. As a result, northern rivers are heavily contaminated, with surface scum and foam, as well as offensive odors. Even in the rainy season, the Las Vacas and Chinautla rivers are heavily contaminated. In the drought season, intermittent river flow reportedly worsens the water quality.

There are 5 sewer outfalls run by the municipality. Their collector networks combine greywater, industrial wastewater and storm runoff which is discharged directly into rivers without treatment. An outline of these facilities is shown in following table and FIG. 2-4.

WASTE WATER OUTFALL WITHOUT TREATMENT

End Collector	Location of Outfall	Size of outfall	Water Bodies Receiving Discharge	Basin
Santa Elisa Collector	Santa Elisa Colony, Zone 12	(m in ø) 1.5	Quebrada del Frutal - Rio Villalobos	South
University Collector	San Carlos University, Zone 12	1.5	- ditto -	South
10-13-14 Collector	Campo de Marte, Zone 5	3.75	Rio Negro - Rio las Vacas	North
Cran Colector del Poniente	Barrio San Antonio, Zone 6	2.75	Rio Las Vacas	North
La Florida Collector	La Florida, Zone 19	n.a.	Rio Salaya - Rio Tzalja - Rio Las Vacas	North

Outfalls at Campo de Marte and Barrio San Antonio mainly discharge wastewater from the center of the city. The collection area covered by these two outfall systems includes the area south of the continental divide, resulting in diversion of runoff in the south into the north basin. Untreated raw sewage collected by these two systems thus flows into Rio Las Vacas, where greywater from the La Florida outfall is also discharged.

Solid waste from the city is collected by gargage trucks and horse carts run by the municipality and disposed of at a sanitation lot in Zone 3, which consists of a former ravine subsequently filled with refuse originating from domestic, industrial, commercial or other urban sources. The municipal source estimates the dumped volume to be 700 t/day, of which 50% is organic material. It is observed on the lot that dogs, cats, rodents and buzzards process such organic materials including carcasses, while poor people gather plastic or other petrochemical waste for recycling. Refuse is also utilized for generation of a type of bio-gas used for cooking by the local people. The lot is located at the end of a ravine through which Rio La Barranca flows to empty into the Las Vacas via Rio Zapote and Rio Chinautla.

Discharge of raw sewage and garbage is concentrated in Rio Las Vacas, water quality of which is the worst among all the water bodies around the city, thereby causing adverse effects on suburban centers such as Chinautla and San Antonio Las Flores.

2.2.6 Existing Sewerage Treatment Plants

In the Project area, there are 9 existing wastewater treatment plants as follows:

Plant	Location	Discharge Into:
Aurora I & II	Zone 13	Rio Guadronicito-Rio Pinula
El Bosque	Zone 12	Quebrada del Frutal - Rio Pinula
Elgin Sur	Zone 14	Rio Pinula
Justo Rufino Barrios	Zone 22	Rio Pinula
Molino de la Flores	Mixco	Rio Molino
Lomas de Portugal	Mixco	Rio Panchiguaja-Rio Molino
San Cristobal	Mixco	Zanjon El Arenal de Campanero - Rio San Lucas
Villalobos	Villa Nueva	Zanjon El Zacatal-Rio Villalobos
Mesquital	Villa Nueva	- ditto -

Each of the above has its own collecting sewers with limited service area which are not connected with the main sewer networks listed in TABLE 2-3. Their capacities and process of treatment and service areas are unknown because they are constructed and operated privately or independently by "colonies" or housing complexes. It is reported that most of them are not functioning properly due to lack of institutional and technical support to encourage or enforce the satisfactory processing of wastewater, and therefore they frequently discharge raw or insufficiently treated sewage into rivers.

Anrora I and II experimental plants are unique among the said plants in respect to structure due to non utilization of mechanical energy. Instead, they utilize gravity flow on ravine slopes and trickling filtration through volcanic rocks without aeration. A sketch of this type of pilot plant is shown in FIG. 2-5.

2.2.7 Contamination of River Water

Rural centers of Jocotales, Chinautla, San Antonio Las Flores, etc. are located along the Las Vacas river which carries municipal waste water. Many of the inhabitants of these communities depend on shallow well water emanating from the riverbed water of the Las Vacas. Such water is usually boiled prior to drinking, and simply filtered for other domestic uses.

As observed at Belice bridge, Jocotales and at the conflux with the Chinautla river, the Las Vacas river transports untreated waste water and water exuded from sanitary landfill, a dark color, and the presence of surface scum and foam are visibly observed. Offensive odor is also evident. The water quality of selected rivers is shown in TABLES.

DISSOLVED OXYGEN IN LAS VACAS - MOTAGUA RIVER (1979)

Sampling at:	Oct. 5	Oct. 19	Nov. 2	Nov. 16	Nov. 30	Dec. 14
Concua, Rio Motagua	6.90	7.59	7.70	7.71	7.99	7.99
Rio Negro	2.72	1.85	1.89	1.83	1.26	1.26
Rio las Vacas A-under Belice bridge	3.41	1.99	1.79	1.70	0.82	0.83
Rio El Zapote O Tzalja	7.22	6.61	6.28	6.28	6.10	6.31
Rio Las Vacas B-at Chinautla	6.38	5.48	5.47	5.47	5.05	5.05
Rio El Chato	6.27	5.00	5.88	5.45	4.67	6.73
Rio Las Canas	6.80	5.50	7.20	6.80	7.02	7.36
Rio Los Platanos	6.91	6.70	7.51	6.98	6.49	7.57
El Rancho, Rio Motagua	6.68	5.40	6.91	6.85	6.67	7.02
El Jicaro, Rio Motagua	6.68	6.68	6.90	6.91	6.67	7.23
Teculutan, Rio Motagua	6.68	6.68	6.91	6.89	6.67	7.64

(mg/l)

DETERGENTS IN LAS VACAS - MOTAGUA RIVER (1979)

Sampling at:	Oct. 5	Oct. 19	Nov. 2	Nov. 16	Nov. 30	Dec. 14
Concua, Rio Motagua	0.05	0.05	0.12	0.07	0.07	0.05
Rio Negro	4.50	4.10	4.50	4.70	4.90	6.20
Rio Las Vacas A-under Belice bridge	4.10	3.85	3.98	3.98	3.85	5.00
Rio El Zapote O Tzalja	3.35	2.90	3.35	3.35	4.03	4.70
Rio Las Vacas B at Chinautla	4.50	4.50	4.65	4.60	4.65	4.90
Rio El Chato	0.63	1.85	1.85	1.95	1.95	2.10
Rio las Canas	0.07	0.09	0.18	0.27	0.27	0.25
Rio Los Platanos	0.02	0.05	0.07	0.18	0.25	0.18
El Rancho, Rio Motagua	0.05	0.07	0.18	0.25	0.39	0.40
El Jicaro, Rio Motagua	0.07	0.09	0.18	0.18	0.26	0.39
Teculutan, Rio Motagua	0.09	0.09	0.07	0.18	0.27	0.40

(mg/l)

Source: Environmental Profile of Guatemala

According to municipal sources, colonies or communities construct and maintain sewer networks, and the municipality is uncertain of their actual number. Some of these networks exist unknown to the municipality. As shown in TABLE 2-2, 57 percent of the metropolitan inhabitants, or 850,000 persons have access to sewer connection. Some 34 through 46 tons of BOD load is discharged daily into the sewer network, which disposes of untreated wastewater.

2.3 Perception on Water Supply and Sanitation in the Project Area

Guatemala City is located on the plateau of the Surface Water Continental Divide where all the runoff water originates. Many of the suburban population centers in the metropolitan area are located on or alongside the ridgelines where the runoff also starts through surface streams and groundwater recharges. Availability of water is naturally limited on the top of plateaus or mountains, in comparison to the lower part where the potential concentration of surface and groundwater is expected. As a result, 72.6 percent of EMPAGUA's raw water drawn in the Project area is pumped from the lower altitude to treatment plants or distribution reservoirs at the place of consumption on the higher altitude.

Wastewater produced through consumption of the supplied water is discharged without effective treatment to these places, where the altitude is generally higher than that of intake facilities. Besides the large volume of discharge into Las Vacas river, a number of small sewers and individual cesspits are channels for wastewater discharge with the potential risk of contaminating the raw water intake.

Water supply system in conjunction with sewerage and sanitation facilities may be perceived as an artificial river system, with intake of raw water from natural water bodies, treats and distributes it for consumption, collects the consumed or waste water, and finally discharges into the natural water cycle after sewage treatment. Artificial rivers thus bypass this natural water cycle. In consideration of the risk of pollution, it would be safer to intake unpolluted raw water at the higher ground and to discharge treated wastewater to the lower place and so further reduce the danger of polluting the intake. This type of the man-made river alignment will also reduce costs, because it can use gravity to transport water.

Due to topographic and hydraulic restrictions, however, Guatemala City is obliged to intake by pumping the raw water from rivers and wells at an altitude lower than that at the place of consumption as shown on FIG. 2-6. These intake facilities are exposed to the contamination with explicitly suspended solids and potential wastewater pollution. Guatemala's man-made river system implies the high cost of water involved in the pumping energy and the multitude of treatment processes.

2.4 Future Projects for Water Supply and Sanitation

To satisfy the rapidly growing demand for water supply, EMPAGUA prepared a long range master plan up to the year 2010. The master plan (PLAMABAG) involves a five-stage expansion project using the water sources outlined below:

FIVE STAGE EXPANSION PROJECTS BY PLAMABAG

Stage		Water sources	Quantity (m^3/sec)	Implementation Schedule	Operation Commencement
Emergency Project	I	Groundwater in the Guatemala Valley	1.0	1982-1985	1983
	II	Xaya-Pixcaya Complement (Surface water)	0.6	1985-1992	1986
		Guacalate (Surface water)	0.4		
		Guacalate (Groundwater)	1.0		
Long Term Project	III	Alto Motagua (Surface water in summer)	1.5	1987-1993	1992
	IV	Alto Cuilco (Surface water in summer)	2.0	1991-1997	1996
	V	Alto Cuilco (Reservoir)	1.0	1996-2002	2001
		Alto Motagua (Reservoir)	3.0		
		TOTAL	10.5		

It is noted that 9.5 m^3/sec of raw water is to be diverted from the remote catchment areas. In the future, therefore, 10.5 m^3/sec including the existing 1 m^3/sec raw water will be diverted to the metropolitan area. This volume is equivalent to 700 mm of annual precipitation over the area of 470 km^2.

Concerning the sewerage and drainage facilities in the metropolitan area, the Guatemala municipality developed separate longterm master plans for the south and north basins. For the south basin, construction of 22 wastewater treatment plants, in addition to an "optimization" of 9 existing plants, is proposed to alleviate the eutrophication process in lake Amatitlan. The master plan also includes the alignment of disposal pipelines which collect the treated water from these plants and bypass the lake for discharge into the Michatoya river. The proposed 22 plants are:

Cotio,	Country Club,	Santa Barbara,	El Carmen,
Villa Sol,	Pinula,	Villa Luz,	Rancho Azul,
El Arenal,	Castanas,	Arenera,	Eureka,
Santa Fe,	Santa Clara,	Trapichito,	San Antonio,
Ciudad Real,	El Paraiso,	Santa Catalina,	Arrazola,

El Zarzal, and Petapa.

A staged implementation plan and a feasibility study were reportedly completed. However, the project's financial vulnerability has not allowed it to proceed until they are sounder in economic or social terms.

In the north basin, the existing sewer network will be improved, and construction of treatment plants is proposed in the master plan which has been elaborated on the basis of the appropriate technology. However, its implementation is not anticipated in the near future.

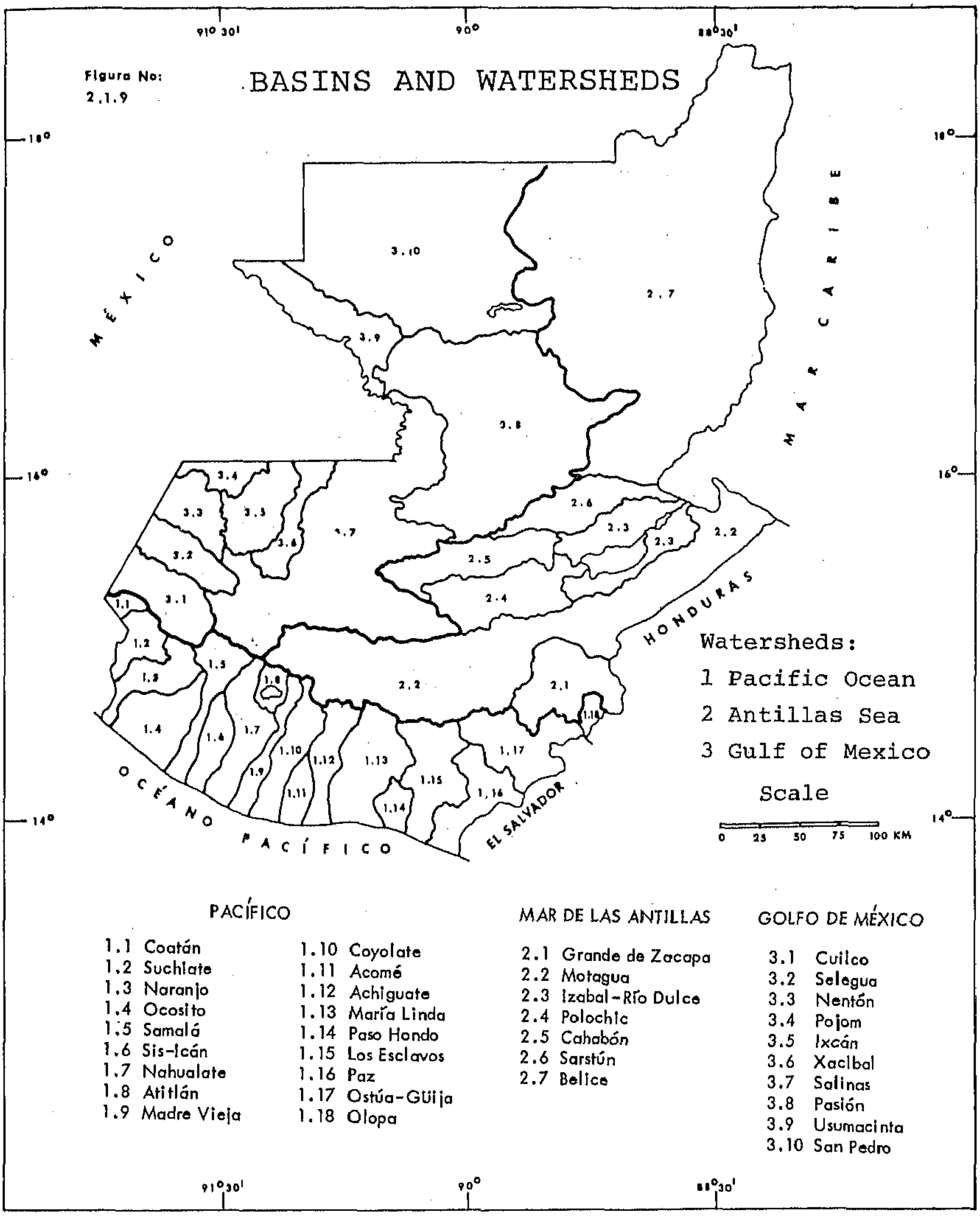
The most recent program has been proposed to treat wastewater and process solid wastes within a number of colonies or housing complexes by means of the active participation of communities. Under this program, 21 small plants are identified in the north basin, which are intended to be constructed and operated by community participation. They are designed to utilize the treated or processed wastes to the full extent, e.g. manure and bio-gas from the solid wastes, compost from sludge and irrigation water from effluent. In the south basin, 5 plants of moderate scale are proposed. They are expected to be operated by the municipality, because significant volume of wastes derives from industrial or commercial sources in the case of the south basin. A feasibility study for these 26 plants, including construction and actual operation of one experimental plant, is being undertaken with the technical assistance from IDB.

TABLE 2-1 ORGANIC POLLUTANT LOAD BY HYDROGRAPHIC DIVISIONS AND CITIES IN 1980

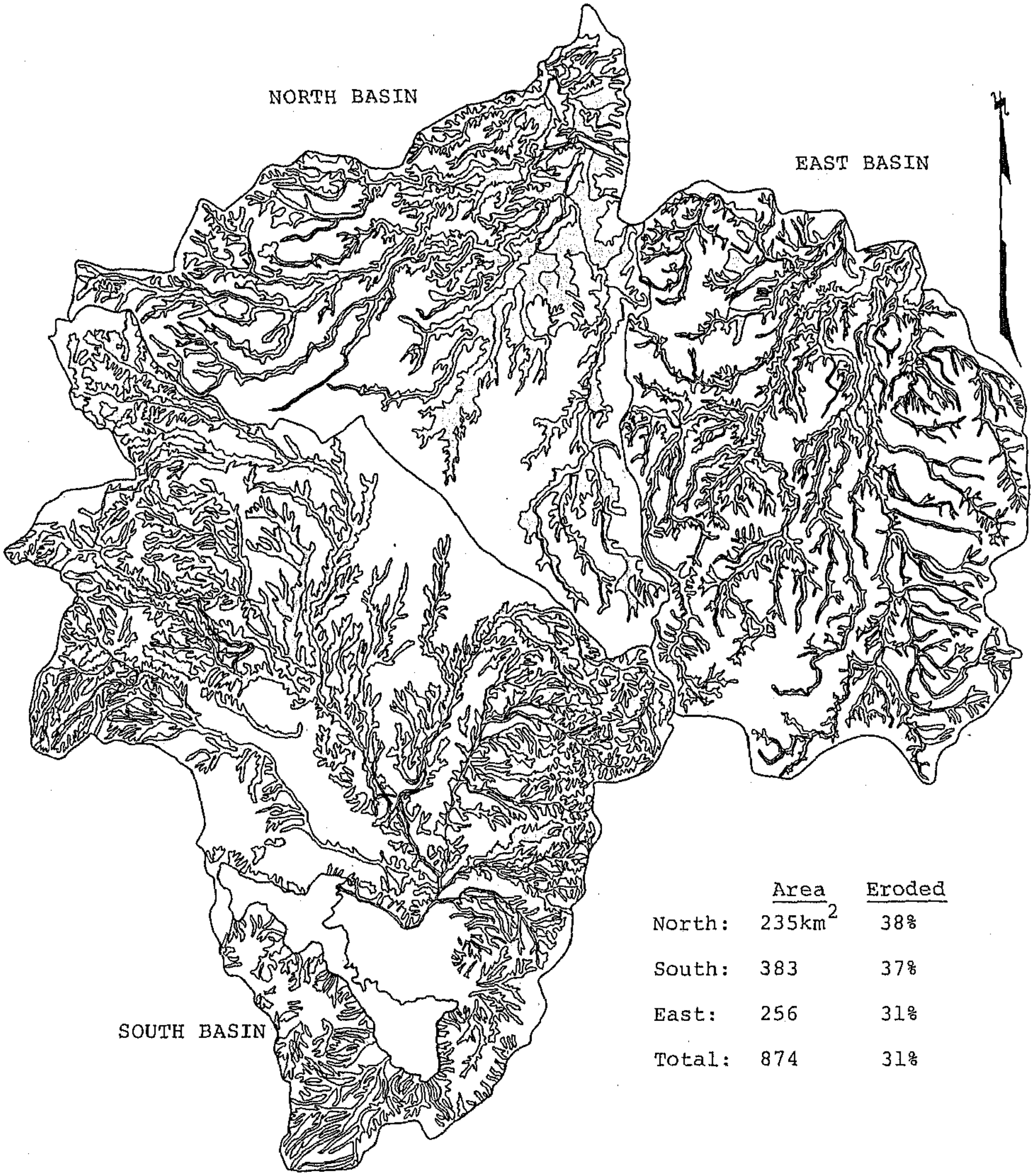
Department	Municipality	Urban population	Basin No.	BOD load (kg/day)
Guatemala	Guatemala (north)	1,223,841	2.2	66,087.4
	Guatemala (south)	300,000	1.13	16,200.0
	Mixco	54,057	2.2	2,919.1
	San Juan Sacatepequez	50,778	2.2	2,742.0
	Villa Canales	37,569	1.13	2.028.7
	Chinautla	28,772	2.2	1,526.7
	Amatitlan	26,745	1.13	1,444.2
	Villa Nueva	24,098	1.13	1,301.3
	Palencia	20,482	2.2	1,106.0
	San Jose Pinula	14,156	1.13	769.8
	Santa Catarina Pinula	13,016	1.13	702.9
	San Pedro Ayampuc	12,856	2.2	694.2
	San Pedro Sacatepequez	11,931	2.2	644.3
	San Raymundo	11,489	2.2	620.4
Sacatepequez	Antigua Guatemala	19,419	1.12	1,048.6
Chimaltenango	Chimaltenango	14,696	2.2	793.6
	Comalapa	14,169	2.2	765.1
	San Martin Jilotepeque	12,355	2.2	667.2
	Tecpan-Guatemala	10,128	1.10	546.9
		65% 1/	1.12	1,925.5
Escuintla	Escuintla	54,859 35% 2/	1.13	1,036.8
	Tiquisate	23,756	1.9	1,282.8
	Sta. Lucia Cotzmulguapa	21,043	1.10	1,136.3
	San Jose	13,242	Sea	715.1
	Palin	12,353	1.13	667.1
Atitlan	Santiago Atitlan	13,721	1.8	740.9
Totonicapan	Totonicapan	19,417	1.5	1,048.5
	Momostenango	14,353	3.7	775.1
Quetzaltenango	Quetzaltenango	71,022	1.5	3,835.2
	Coatepeque	22,683	1.4	1,224.8
Suchitepequez	Mazatenango	30,234	1.6	1,632.6
Retalhuleu	Retalhuleu	26,275	1.4	1,418.8
San Marcos	San Pedro Sacatepequez	14,096	1.3	761.2
Huehuetenango	Huehuetenango	15,426	3.2	833.0
Quiche	Santa Cruz del Quiche	10,047	2.2	542.5
Alta Verapaz	Coban	18,741	2.5	1,012.0
Izabal	Puerto Barrios	52,890	Sea	2,856.1
Zacapa	Zacapa	16,741	2.1	904.0
Chiquimula	Chiquimula	20,028	2.1	1,081.5
Jalapa	Jalapa	14,145	2.2	763.8
Total	38 cities	2,385,229		128,802.3

1/ Total corresponds to Guatemala, Sacatepequez and Chimaltenango Departments.
2/ Total corresponds to the remainder of the country
Source: Environmental Profile of Guatemala, 1984

FIG 2-1



Source: Environmental Profile of Guatemala



	Area	Eroded
North:	235km^2	38%
South:	383	37%
East:	256	31%
Total:	874	31%

FIG. 2-2 SURFACE SOIL REOSION AND GULLEY INTRUSION

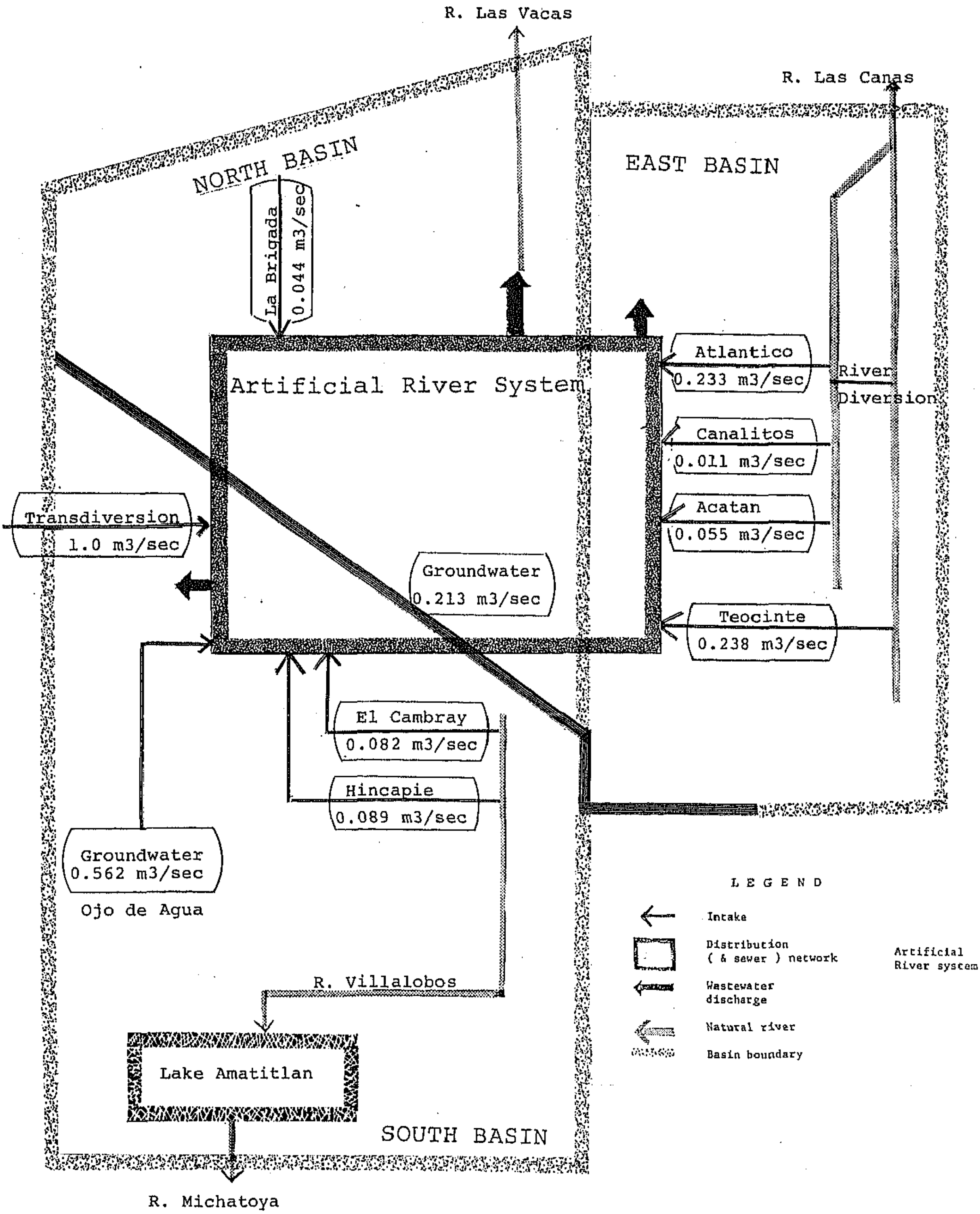


FIG 2-3 NATURAL AND ARTIFICIAL RIVER SYSTEM

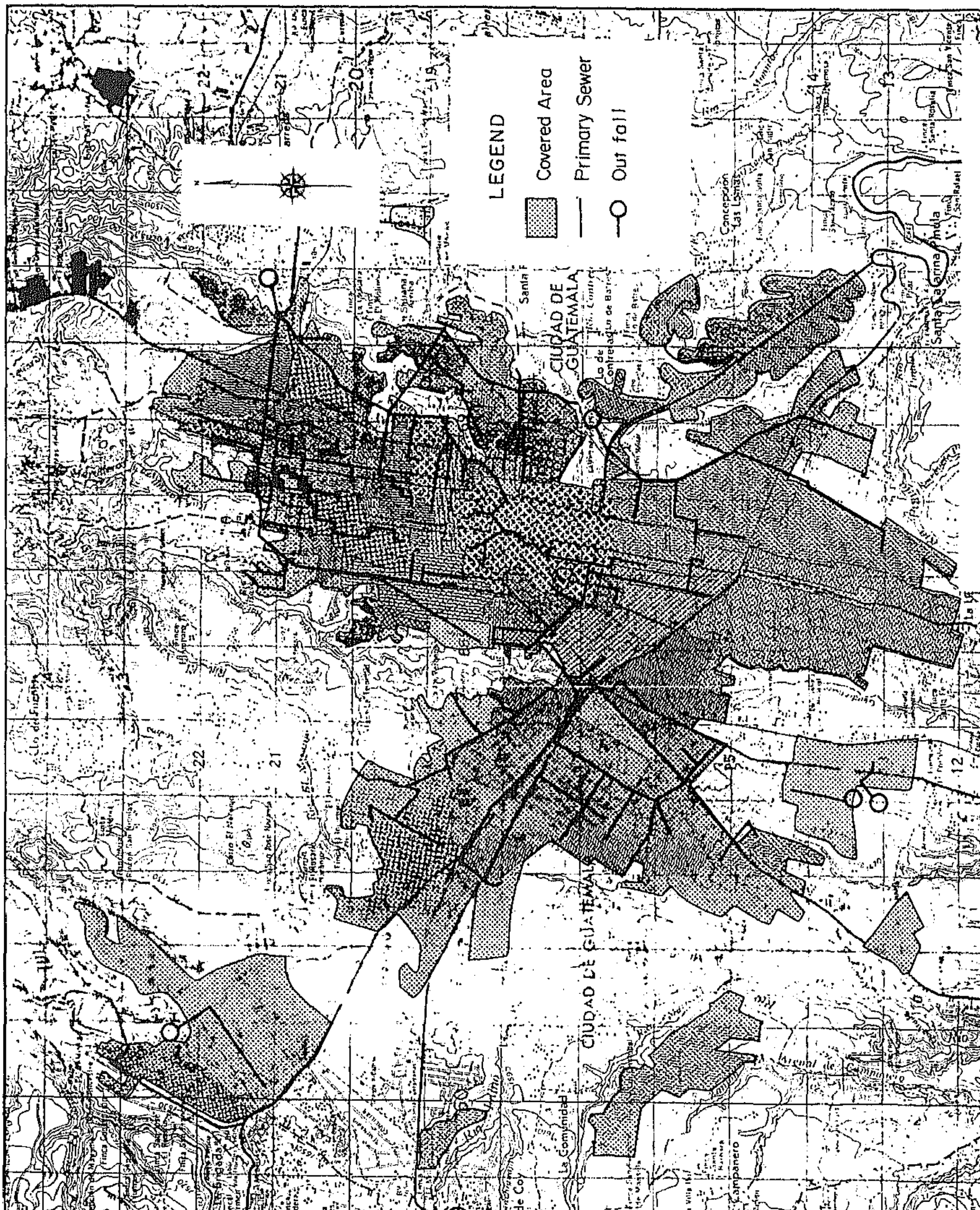


FIG 2-4 SEWER NETWORK AND SERVED AREA

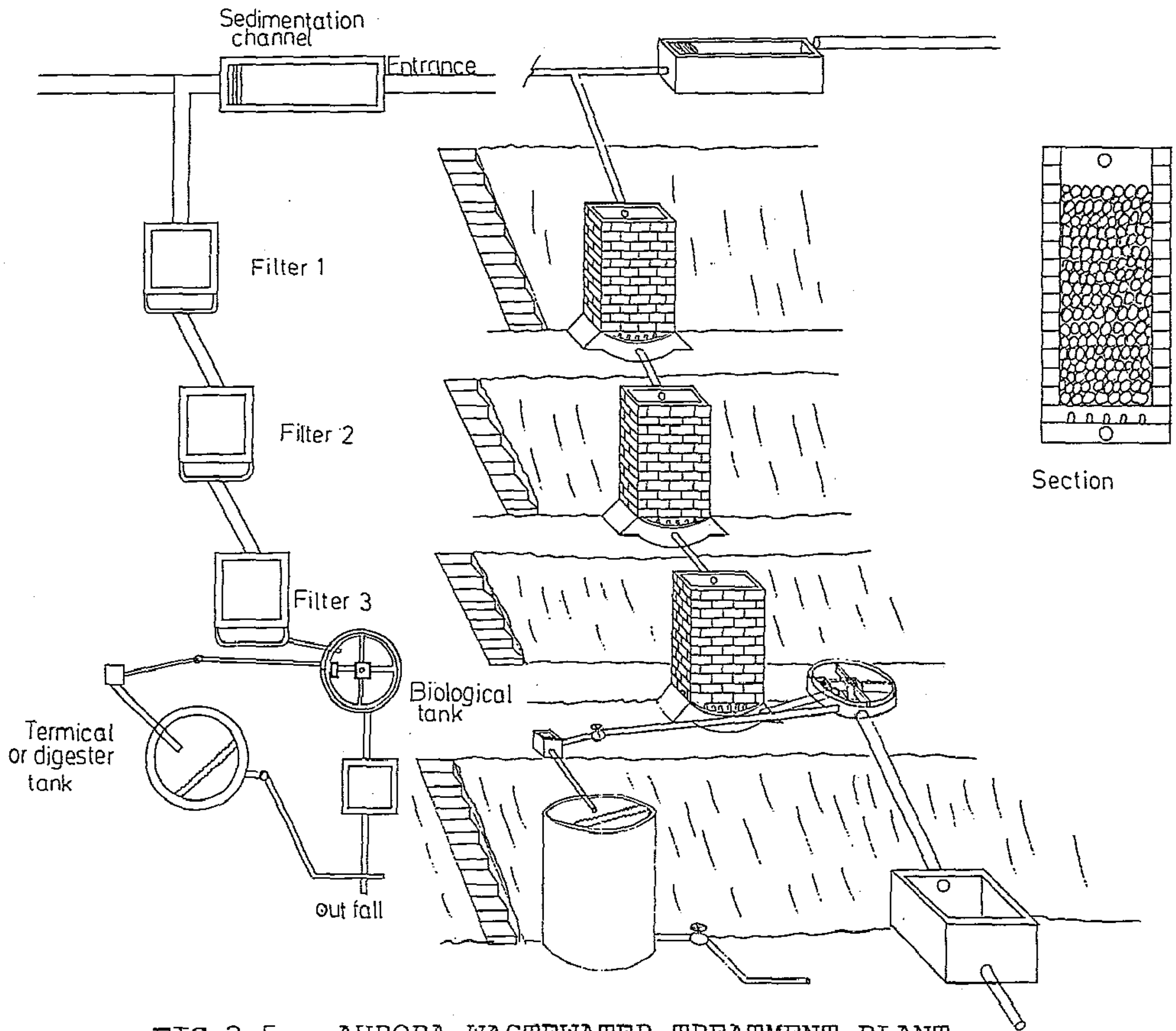
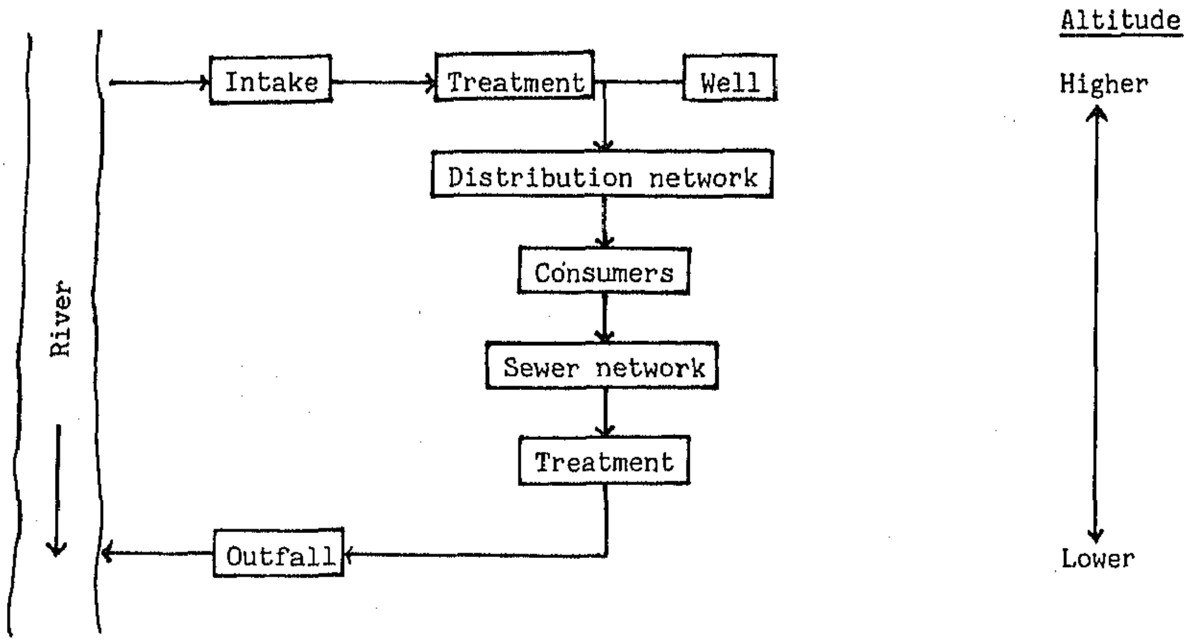


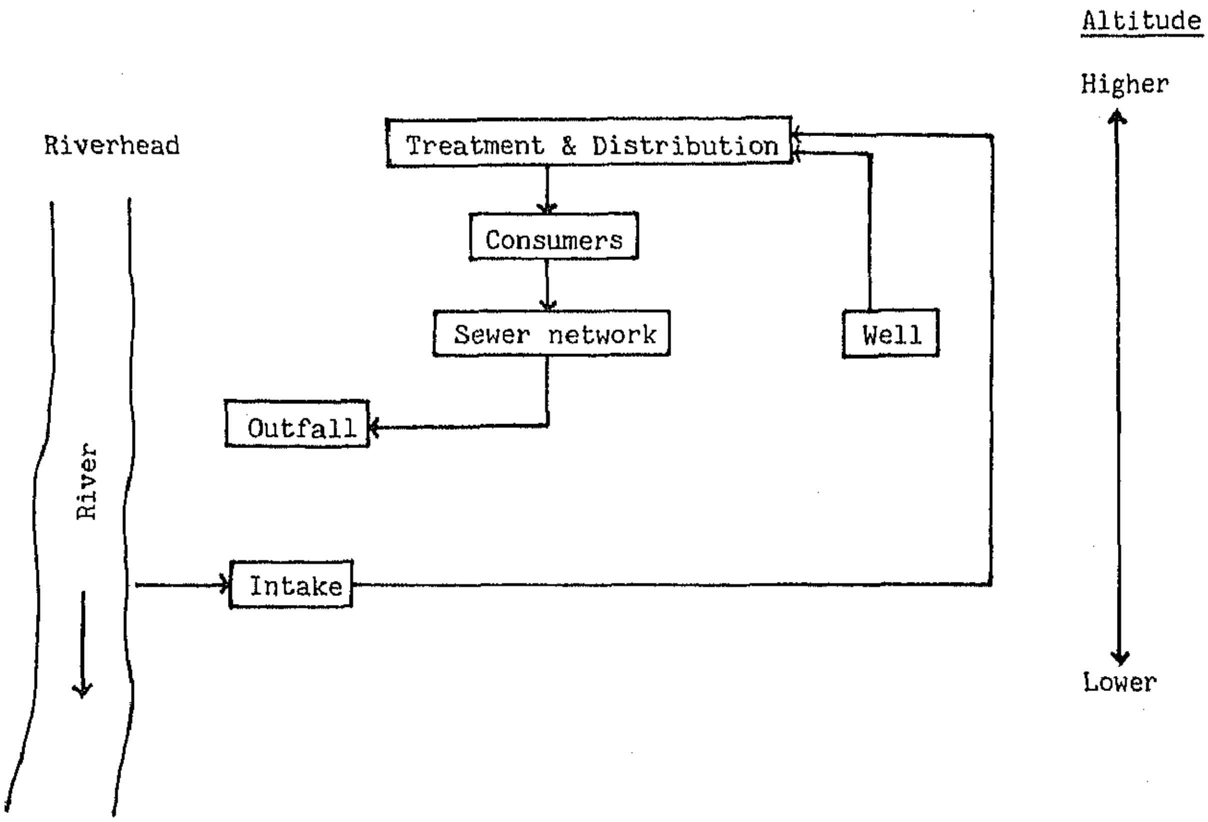
FIG 2-5 AURORA WASTEWATER TREATMENT PLANT

FIG.2-6 CONCEPTUAL FLOW OF SANITATION

= Ordinary Case =



= Guatemala Case =



CHAPTER III

GROUNDWATER DEVELOPMENT AND CONSERVATION

3.1 Need for the Groundwater Conservation

As discussed in section 2.2.3, the piped water supply systems in the metropolitan area yield an estimated 1.527 m^3/sec of groundwater, which is equivalent to approximately 48,200,000 m^3 per year over the area of 470 km^2. In addition, there are private wells for industrial and commercial entities, and other wells owned by government institutions. Their locations, numbers and yields are not properly registered nor controled, since there is no authority or responsibility entrusted to the government to monitor and control the groundwater exploitation. Therefore, the groundwater discharge or yield in the metropolitan area is not known, and the concerned data available limited to that those of EMPAGUA.

The present Project is intended to develop the new groundwater facilities to intake the 1 m^3/sec or 31,500,000 m^3/year raw water. Some increase of yield attributed to the rehabilitation of EMPAGUA's existing wells is also anticipated. Accordingly, some 80 million m^3 or more will be drawn annually. This volume is more than 8 percent of the average annual precipitation, if the latter is assumed to be 1,200 mm in the Project area of some 815 km^2.

As observed in the Project area, deforesation has accellerated to progress to nearly 80 percent of the land. It is followed by inappropriate land leveling for housing development or by inapproariate land use mainly for pasture and agriculture. Due to no effective control or funding policy for comprehensively coordinated land use taking into consideration environmental conservation or protection, destruction of the natural environment and reduction of the groundwater conservation capacity of the area has been aggravated. Control over the land use pattern, urban and housing development, and use of hydroaulic resources seems to be, in the near future, inevitable, if effective utilization of groundwater is expected for the prolonged period of time.

1/ Estudio de Aguas Subterraneas en el Valle de la Ciudad de Guatemala, INSIVUMEH, 1978

A groundwater study[1/] carried out in 1974-1976 indicates that the groundwater recharge against precipitation is 8 percent in the north and 22 percent in the south basins respectively. Even if these figures adequately represented the situation 10 years ago, it is observed that the recharge capacity in the Project area has significantly deteriorated due to the progress of urbanization and deforestation in recent years.

In determining the safe yield of groundwater, the general structure of groundwater recharge should be established on the basis of continuous measurement of various component parameters of the water budget. In the Project area, however, such a long-lasting measurement and observation has not been undertaken, except for some studies in a limited period, which covers only the north and south basins. Therefore, it seems to be necessary to accumulate the basic data over a long period of time to define and elaborate a water budget model of the area.

Whether or not a groundwater yield of more than 8 percent of the precipitation is safe from an environmental viewpoint is therefore hard to assess. This figure is the one that is acceptable usually when the recharge system and the water budget is established. It can be judged here that the above total discharge is not small but acceptable, in view of experience and due to the high necessity for water in the area. It is difficult to tell, in advance, of the possibility of adverse occurences on the aspect of the natural conservation. Causes and results of adverse sequences are shown on TABLE 3-1. Socially, however, the projected groundwater development will cause no serious effects in the sparsely populated development area.

Locally in certain wells or wellfields, however, overdraft will always remain a possibility. Without proper monitoring of the water level and quality, such overdraft may progress to a dangerous extent, inviting the drawdown of shallow wells, or land subsidense or pollution of the aquifer. In view of such significant and irreversible impacts, not only static monitoring but also active measures for groundwater management are recommended. Such active means include conservation and recharge of groundwater through comprehensive water resource management.

1/ Estudio de Aguas Subterraneas en el Valle de la Ciudad de Guatemala, INSIVUMEH, 1978

3.2 Groundwater Monitoring Program

A groundwater monitoring program will be undertaken for the purposes of:

1) Preventing the Project wells and the existing wells from overdraft and its adverse consequences, thereby ensuring their stable and prolonged operation, as direct effects; and

2) Accumulating precise data on hydrogeology of the Project area, in the long run, to define and elaborate a water balance model and groundwater recharge system, which will in turn help expedite establishment of the comprehensive groundwater conservation program.

Under the above item 1, facilities to measure and record the static level of aquifer are devised as the Project components. Both water level meters and yield meters are also provided with each of production wells. For item 2, however, a conceptual program is identified and a recommendation is presented in this report in order to help EMPAGUA initiate the necessary steps towards the well coordinated management of hydraulic resources in Guatemala.

3.2.1 The Project Monitoring System

1) Measurement of static level of confined aquifer at monitoring wells to be constructed.

a) 3 monitoring wells which were drilled in the study period.

b) The additional 5 monitoring wells are as follows:

1 - Molino wellfield
2 - Ojo de Agua wellfield
3 - Belem wellfield or La Brigada plant
4 - Zone 10
5 - Southern part of Zone 17 instead Finca Santa Clatilde

A total of 8 monitoring wells are to be constructed, and an automatic recording water level meter should be installed at each monitoring well. To measure the static level of the confined aquifer or basin, the following criteria will be satisfied:

- Location will be identified apart from any production well by at least 500 m in order to avoid the influence of dynamic level fluctuations.

- Based on a more concentrated study on distribution or location of the groundwater aquifers or basins, the monitoring well will be located within a groundwater basin territory to which an influential well group belongs.
- With the minimum diameter enabling accommodation of a water level sensor, drilling must penetrate the depth of the targeted aquifer layer, which is assumed to be lower than E.L. 1,300 m.
- By analysis of the drilling data and electric logging, the most influential confined aquifer will be identified, and a well screen will be pin-pointed to this target aquifer. Influences from the upper aquifers must be strictly eliminated by careful cementing.
- Automatic records will be kept on a rolled continuous sheet to be replaced weekly or monthly. However, each meter house must be visited for regular checks at least once a week. All level meters must be calibrated as often as possible by using a water level checker.

Locations of monitoring wells are shown on FIG. 3-1.

2) Continuous measurement of yield (discharge) and dynamic level of production wells under the Project.

Well operators are required to record the daily operating hours, the volume of yield, and the dynamic water levels of wells before and after every operation cycle.

- Level of each production well is expected to fluctuate at each cycle of operation, daily and seasonally. Therefore, the level of the well is to be recorded automatically on the continuous sheet.
- Frequency and length of operation will vary in accordance with the capacity of every well and also fluctuate seasonally. Therefore, a flow integration meter must be installed to measure the total yield of individual wells. The daily total yield will be recorded with the operation record for cross reference.
- Thus records of pump operation, yield volume and water level are filed for determination of safe yield of individual wells. The fluctuation of dynamic level, however, should be cross-checked with that of static level of aquifer recorded at the monitoring well.

3.2.2 Recommended Groundwater Monitoring System

To further clarify the hydrogeological structure of the Project area, a more collective approach is recommended. Since a long lasting observation of various parameters by a diverse range of disciplines is required for that purpose, some functions of monitoring will be borne by institutions other than EMPAGUA. Such functions include 1) monitoring of water quality, 2) registration of all the deep and shallow wells, 3) catchment area inspection force, 4) meteorological monitoring, 5) hydraulic monitoring, 6) land level survey and 7) central groundwater monitoring station. FIG. 3-2 shows a tentative organization. The conceptual criteria for such units are presented hereunder.

1) Criteria for Water Quality Monitoring Unit

- To ensure that all raw water taken in by EMPAGUA is free from a) contamination of groundwater aquifer, b) contents hazardous to consumers, and c) chemical contents harmful to treatment and supply facilities, regular sampling will be made at a) primary collector reservoirs, b) clear water reservoirs or distribution reservoirs, and c) intake facilities for surface water and well discharge at primary collectors in the case of groundwater.
- Sampling and analysis should be carried out as often as possible to prevent contamination and its serious consequences. Once a month is the minimum requirement.
- A checklist for water quality analyses should be established for the above purposes in collaboration with the laboratory at ERIS, where analyses are undertaken.

2) Criteria for well Registration

- A unit must be established within EMPAGUA to record and analyze characteristics and history of individual wells, springs and other groundwater intake facilities of EMPAGUA. Individual well registration books must be prepared including data on construction, well test, water quality, well hydraulics, production, operation and maintenance, and other relevant data.
- The registered data of EMPAGUA wells may be utilized for their operation. For accumulation of hydrogeological data of the area, however, data should also be collected from non-EMPAGUA wells which are not registered or controlled at present.

- A resolution at the national legislature level or a consensus among the public should be established concerning control and management of limited groundwater through, at the first stage, registration of all wells.
- Data to be registered includes the location, type and scale of wells or springs, users' status, drawdown in drought season, level of well and volume of yield as applicable.
- The unit should collect other hydrogeologic data including drilling logs, results of electric logging and well tests, soil contents, etc. when available.
- The unit should be encouraged to prepare a complete list of groundwater facilities in the Project area to assess the total yield and its fluctuation.
- In case these activities are performed prior to the Project implementation concerning local shallow wells, springs and private wells adjacent to the Project development area, influences of the Projected development will be pictured more clearly.

3) Criteria for Catchment Area Inspection

- To check and control all the existing and potential sources of pollution of surface and groundwater, an inspection force should be organized in cooperation with health and environmental agencies which are empowered with the authorized right of entry into private premises.
- By covering the entire catchment area pertinent to sources of water for EMPAGUA and other entities, the inspection force should locate and identify all the actual and potential sources of pollution including soil erosion, sewer discharge, discharges from animal husbandry, other industrial sources of pollution, and the like. To determine the pollution conditions, maps of the catchment area should be produced locating such sources with indication of classification, quality and quantity of pollutants.
- Data on forests and vegetation should also be filed for a basic record to assess infiltration and evapotranspiration.

4) Criteria for Meteorological Monitoring Post

- For a clearer and definite perception of the water budget of the Project area, precipitation and evaporation should be continuously measured at as many sites as possible.

- In reviewing the existing data, it was found that data from meteorological observatories were not always consistently nor regularly taken. It is therefore advisable to standardize equipment and methods of measurement and to train the concerned personnel to ensure that regular and consistent records are obtained. It is advisable to review and improve the organization of the related agency.
- Items of observation include the daily or integrated recording of precipitation, temperature, sunshine radiation, wind velocity, evaporation, etc. to establish a basis for water balance assessment from a meteorological standpoint.

5) Criteria for Hydraulic Monitoring

- To assess gross surface runoff, river flow should be measured continuously or periodically as is appropriate at strategic points covering all catchment areas in the Project area.
- For that purpose, facilities for automatic recording of integration of river flows should be constructed, and a responsible institution must be established in coordination with the agencies concerned with water resources.

6) Criteria for Land Level Survey

- In view of the quick growth of groundwater yield under the proposed Project, a periodic land level survey should be undertaken to detect as early as possible a potential risk of land depression.

7) Central Groundwater Monitoring Station

The critical component is a central monitoring station, as it would require interdisciplinary or multi-institutional organization. It would analyze data output from various types of monitoring posts, formulate countermeasures if such are required, and advise the related public and private bodies including EMPAGUA to suspend or reduce the groundwater yield. Required for these purposes is a clarification of the water budget and structure of groundwater recharge system of the area through the computer simulation on basis of the long term observation results gathered by the above monitoring units. As urbanization of the area followed by reduction of the recharge capacity is being accelerated, the water budget model should be renewed repeatedly and periodically. Therefore, a long standing institution having well qualified personnel is necessary.

Legal authority as well as technical qualification is indispensable in organizing such a central monitoring station. The central monitoring station could be instituted as a technical subcommittee under the "CONARHI" a national commission for hydrologic resources, the creation of which is presently being discussed at the legislative level on the basis of a draft law prepared by the SEGE Plan.

3.3 Recommended Groundwater Conservation

Conservation of all the water sources should be undertaken for the purpose of maintaining stable supply. Conservation of groundwater, as one of the sources, will be important to EMPAGUA as to the extent how much groundwater supply shares in the total supply. To the public, however, it is more important, because its failure, e.g. contamination or land subsidence is irreversible and implies irrecoverable loss of public property. Moreover, artificial recharge will be worthwhile to consider for intensive utilization of water resource particularly limited in the Project area, where the cost of clean water is potentially very high due to topographic and hydraulic characteristics.

Methods of groundwater conservation are theoretically divided into two groups, i.e. one to decrease the discharge and another to increase the recharge. Among the former methods are checking and controling the groundwater discharge from unutilized springs and wells, and the construction of groundwater dams. In this concern, legislative measures to limit and control the development and utilization of groundwater with less public importance will be sought for. A detailed technical and economic study is required for underground dam projects and such dams are therefore economically unfeasible at present.

The increase the recharge quantity, there are many technologies as follows:

To strengthen surface soil infiltration:

- Reforestation
- Contoured or terrace cultivation with green belts
- Permeable pavement
- Infiltration of urban drainage through seepage gallery or trench

To strengthen infiltration from river bed:

- Groundwater recharge reservoir
- Consolidation dam and dike

To recharge in bulk:

- Recharge well

Reforestation of significant scale will be very effective to conserve recharge capacity and protect erosion. It is reported that a broadleaf forest has an infiltration capacity of several times larger than that of the grassland. Infiltration in grasslands is particularly low when it is pasture. As observed in the Project area, deforestation for fuelwood is followed by mostly uncultivated pasturage. This seems to be one of the worst combinations of land use with respect to the conservation of soil and groundwater and restriction of deforestation and encouraging reforestation should be encouraged. A more practical technique of reforestation suitable to socioeconomic setting in the Project area must be sought for among the possibilities of agro-forestation, planting of fast growing fuelwood, and selection of trees. Also, feasibility of government subsidies should be considered to encourage participation of private sector.

Cultivation pattern is observed to be conventional irrespective of contours and gradients. It is known that the terrace or contoured cultivation coupled with contoured green belts strengthens the infiltration capacity of soil in addition to effects in soil conservation. Conventional agriculture on unsuitable land is maintained by small farmers. Therefore, extension activities are necessary to mobilize such farmers towards contoured cultivation. It is recommended that the Ministry of Agriculture, Livestock and Food launch an extension program including the establishment of experimental farms. Government subsidies or low-interest loans to the farmers should be considered to make the program attractive.

Permeable or porous pavement is also worthy of mention. Usual pavement is not permeable and rainfall is guided to the roadside drains, by which stormwater is removed from the site. In contrast, permeable pavement is designed to infiltrate stormwater directly into the soil through porous material of pavement and its bed. It also allows evaporation from the soil during dry weather. In the city center and newly developed housing complexes, the area occupied by paved roads is not very small. If such pavement is structured to allow permeation, the total infiltration rate will be improved and costs for drainage facilities will be saved.

Developments of colonies or housing complexes are observed everywhere along the peripheries of the city. Many such colonies are equipped with their own water supply, wastewater removal, and drainage facilities. If stormwater from drains is guided to infiltrate into the ground, it will help strengthen the recharge capacity. This may be achieved through simple seepage gallery or trench structures. Seepage wells are also applicable if the domestic wastewater is separated. To encourage or oblige devising of these facilities, a guiding policy or legal enforcement must be established.

A large reservoir is one of the alternative choices. Such a dam may be projected for many purposes other than groundwater recharge. However, it seems unsuited for the present Project, because of the geological characteristics and water quality. It is possible to bring in an eutrophic lake in the area.

Consolidation dams and dikes are recommended for the purposes of protection against erosion and washout of soil or suspended solids in addition to the recharge. A number of small dams or dikes with a height of 1 m or less may be constructed in series along rivers adjacent to the well fields. They must be so designed as to maximize the contact of river water with the ground. It is observed that such dikes were maintained in the Villalobos river near Ojo de Agua wellfield, while they have been destroyed and abandoned. Taking into account that sedimentation of sand or total solid is major disturbance to EMPAGUA's surface water intake and some treatment plants, a serial construction of small dams and dikes will be an applicable method effective for both groundwater recharge and efficient operation of intakes and treatment plants.

There are some infiltration wells in colonies in the city. Most of them are used for disposal of wastewater treated through septic or aeration tank devised for the colony's independent sewerage system. They are considered to be helpful for the groundwater recharge. However, it is also anticipated that the inadequate quality of the discharged effluent may contaminate the free or unconfined aquifer, from which many deepwells as well as shallow wells yield groundwater everywhere in the city. It is therefore recommended to locate and identify all of this type of infiltration well and to confirm if their influence is hazardous to local wells. Generally, bacterial infection may be eliminated by chlorination though, viral infection is also hard to eliminate. Groundwater recharge wells irrespective of depth are applicable if the quality of recharge water is assured.

3.4 Groundwater Recharge with Wastewater

As has been observed, EMPAGUA's man-made river system will divert 10.5 m^3/sec raw water from the remote catchment areas. This is equivalent to the 700 mm of annual precipitation over the metropolitan area of 470 km^2. In view of the annual precipitation of the area being approximately 1,200 mm, it will improve the water budget significantly, if discharge of such rivers, i.e. wastewater, is utilized for groundwater recharge.

Bulk recharge by means of seepage wells usually suffers from clogging and has a risk of direct contamination of groundwater aquifer, even if wastewater is secondarily treated. Therefore, a sewerage scheme to utilize the discharge as irrigation water is being experimented with in Guatemala city. Under the scheme, a treatment plant is to collect domestic wastewater from several tens to hundreds of houses in a colony or local community, and treat it through sedimentation and the energy saving trickling filters. Effluent water is to be recharged into the ground by surface application through sprinkling or by infiltration through absorption trenches.

Some conventional absorption trenches are illustrated on the basis of materials the United States Environmental Agency.

The concept of absorption trenches as shown in FIGs. 3-4.5 and 6 is applicable to the individual onsite system and the semi-onsite colonial sewerage system if solid particles that cause clogging are effectively eliminated beforehand. However, one possible risk is the vertical infiltration or fall of contaminant into a nearby aquifer, which is sometimes probable in Guatemala's earth structure with many faults. An improved trench structure under experiment in Japan is shown in FIG. 3-6.

In the above trench, the vertical fall of liquid is prevented by a water-tight sheet, and liquid is siphoned upward by capillary attraction, thus enabling maximum contact with soil near the surface, which contains the digesting bacteria and organisms. It is reported that a 100 l/day of liquid is absorbed by approximately 1 meter of this trench, and that the digestion of BOD and COD is effective. Although the capacity for decomposing or eliminating phosphates and nitrates is not clearly defined, it is expected to be absorbed by grass or trees covering the surface.

Four methods of groundwater recharge with treated wastewater, i.e. seepage wells, surface application through sprinkling, subsurface permeation through the conventional trench and the improved trench, may be compared as follows:

	Seepage well	Sprinkling	Conventional trench	Improved trench
Volume to recharge	large	small	large	large
Clogging	likely	-	less likely	less likely
Surface contamination	none	likely	unlikely	unlikely
Groundwater contamination	likely	unlikely	likely at initial operation	less likely
Odor	none	bad	none	none

A seepage well method requires the smallest area but is not recommended due to the risk of contamination.

It is therefore considered that the selection of the other 3 methods must be carefully made on basis of the characteristics of the available land. For example, the sprinkle method may be applied if the farmland is located adjacent to the plant, and trenches may be constructed in the forest or grassland, even if they are sloped.

In case the trench is applied, criteria for the treatment process may be slightly mitigated to allow a lower quality standard of effluent water. It is reported in case of Japan that wstewater with 70 through 90 mg/l of BOD load cab be absorbed through improved trenches without pollution. This standard may be achieved through 2 to 3 staged Aurola type trickling filters with post sedimentation, while extensive experiments are required by focussing on the purification capacity of Guatemala's soil.

TABLE 3-1

UNDERSIRABLE CAUSES AND EFFECTS IN THE WATER ENVIRONMENT

	Soil erosion	Decrease of recharge capacity	Shallow well drought	Deep aquifer drawdown	Land subsidence	Surface water pollution	Groundwater pollution
Deforestation	xxx	xxx	xx	x			
Conventional agriculture on slopes	xxx	xxx					
Unorganized housing development	xx	xxx	x	x			
Unorganized industrial development	x	xxx	x			xxx	
Lack of wastewater treatment						xxx	xx
Lack of solid waste treatment						xxx	xx
Discharge of toxic chemicals						xxx	xx
Confined aquifer overdraft			xx	xxx	xx		xx
Free aquifer overdraft			xxx		xx		xxx

Note: xxx: Highly probable; xx: Probable or needs careful monitoring; x: Possible

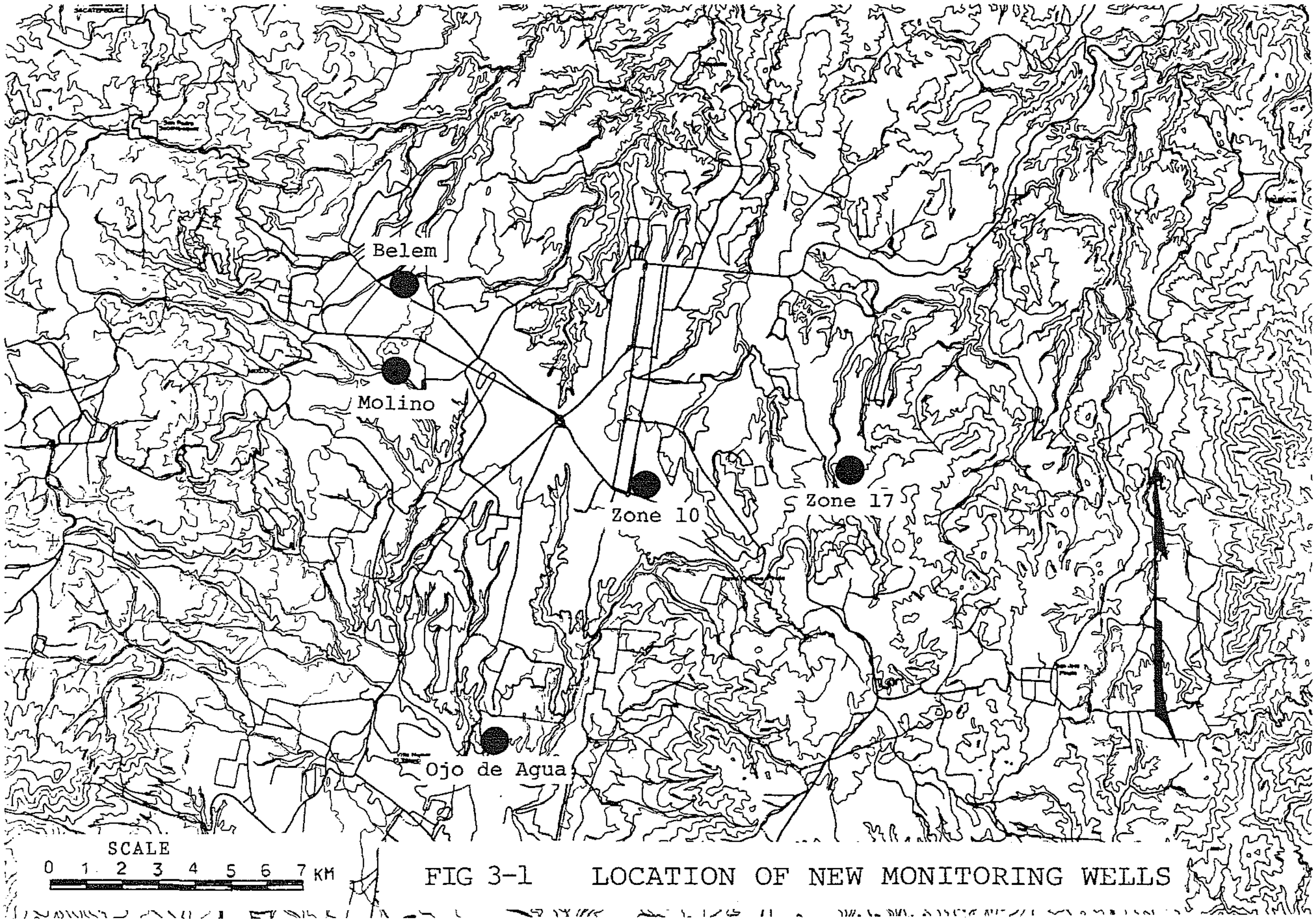


FIG 3-1 LOCATION OF NEW MONITORING WELLS

FIG.3-2 ORGANTZATION FOR MONITORING

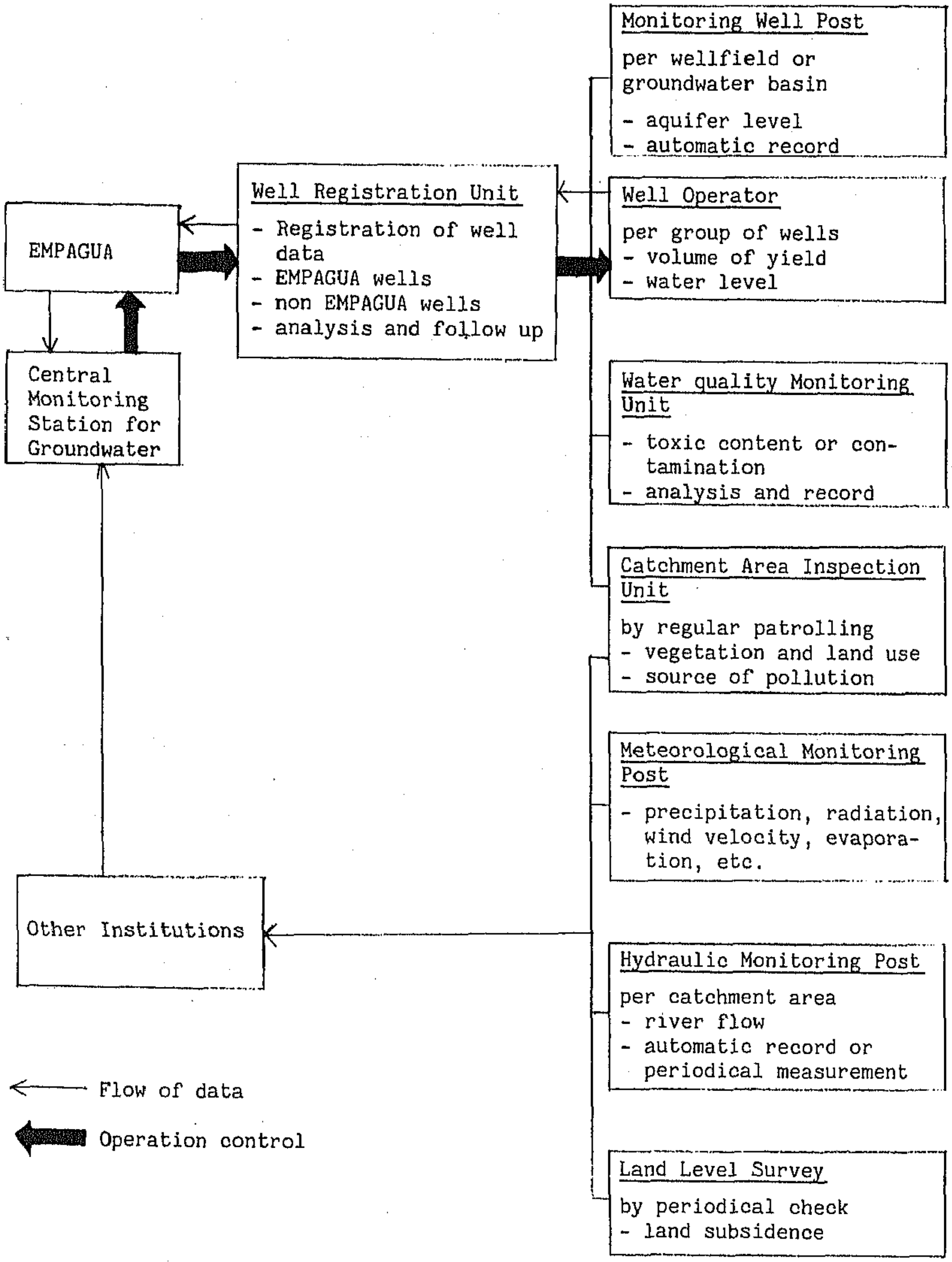


FIG.3-3

Septic Tank & Soil Absorption Field (Trench)

Sewage bacteria break up some solids in tank. Heavy solids sink to bottom as sludge. Grease & light particles float to top as scum. Liquid flows from tank through closed pipe and distribution box to perforated pipes in trenches; flows through surrounding crushed rocks or gravel and soil to ground water (underground water). Bacteria & oxygen in soil help purify liquid. Tank sludge & scum are pumped out periodically. Most common onsite system. Level ground or moderate slope.

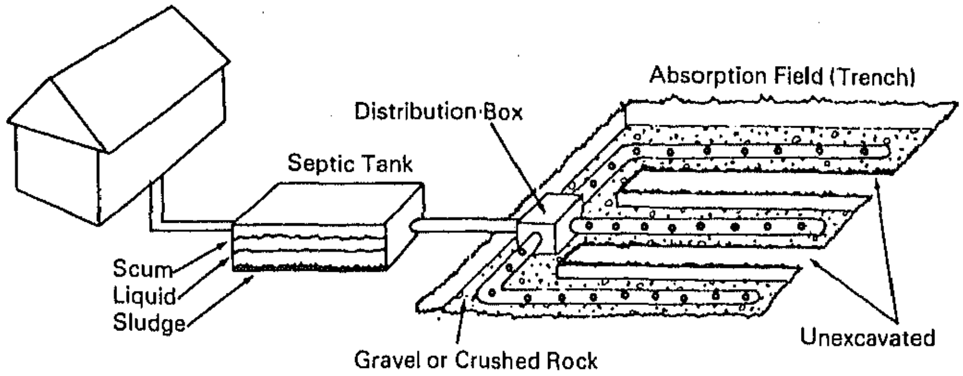


FIG 3-4

Septic Tank with Alternating Absorption Fields

One field rests while other is in use. Allows field to renew itself. Extends life of field. Provides standby if one field fails. Valve directs sewage liquid to proper field. Fields usually switched every 6-12 months.

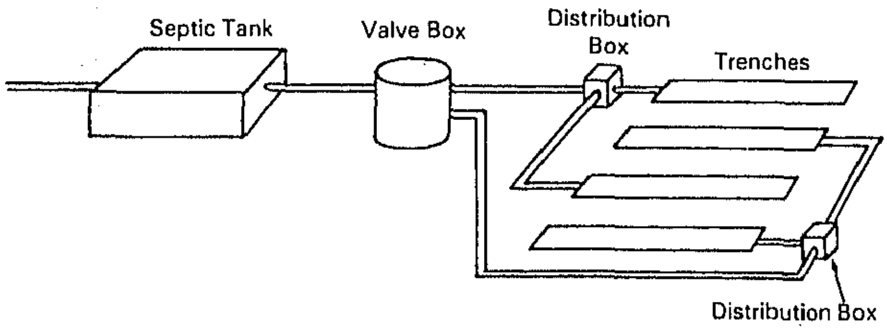


FIG 3-5

Septic Tank with Sloping Field—Serial Distribution

Pump forces liquid to perforated pipes in contoured absorption field. Drop boxes regulate liquid flow so highest trench fills up first, second fills up next, & lowest fills up last. Plastic fittings can be used instead of drop boxes to regulate flow. Used on slopes.

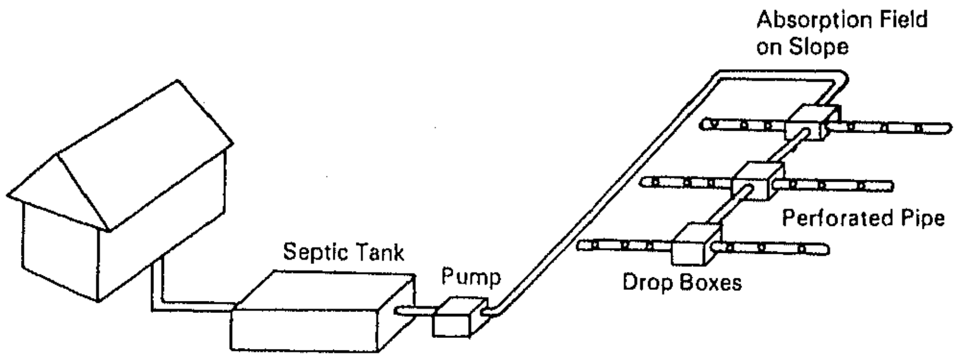
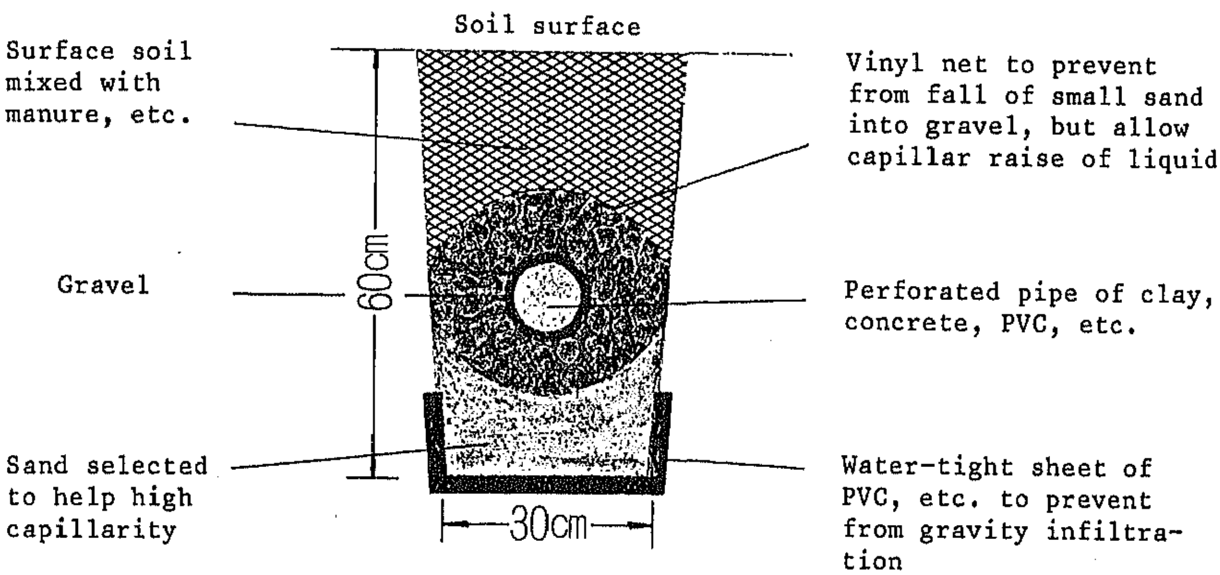


FIG. 3-6

IMPROVED TRENCH



CHAPTER IV

EVALUATION OF ENVIRONMENTAL IMPACT

4.1 Impact with the Project

The most significant impact of the Project will be the improvement of the water supply services in quantity, the population served and the area. Incremental production by 1 m^3/sec or 86,400 m^3/day in addition to the present average of some 220,000 m^3/day signifies a 40 percent growth, totaling some 306,000 m^3/day supply.

Provided that EMPAGUA's present service connections amount to approximately 112,200, and the distribution loss or unaccounted-for water is some 35 percent of the production, then 800,000 persons or 53 percent of the metropolitan population will be supplied with approximately 143,000 m^3/day effective distribution. Simple average shows 178 l/capita/day consumption at present.

In the Project target year, if the ratio of unaccounted-for water is decreased to some 30 percent, then 215,000 m^3/day will be supplied toward the future population. In case the per capita consumption is left on the same level, this quantity may cover a population of approximately 1,200,000.

Improvement will be remarkable in the north and northeastern periphery of the city, which enjoys at present only marginal or nil supply. This will in turn contribute to the improvement of sanitary conditions there, where the people suffer from frequent cases of gastro-enteric and other water-borne diseases. Alleviation of women labor will also be a noteworthy improvement, as much of their housework presently consists of hauling water from remote wells, which in many cases are polluted. The Project will permit them to pursue more productive activities which will consequently improve the well-being of the people.

Inhabitants on the high slopes in Zone 18 rely for their water source on the shallow wells some hundreds of meters away. Most such wells dry up in the drought season and people have a few choices or obtain potable water, i.e. to buy it from venders, to carry it from a deepwell or public standpipe kilometers away, or to filter the river water which is not always at a reasonable distance. The prevailing price of water vending is 0.5 to 1 quetzal per 54 gallons or Q2.5 to 4.9/m^3. This price will be a good contrast to the EMPAGUA rate: 8.25 quetzales per 60 m^3 or Q0.1375/m^3; or the Mariscal rate: 15 quetzales per 60 m^3 or Q0.25/m^3. The vender's price implies a high opportunity cost of water in suburban area that the present water supply system does not cover.

Under the Project, wellfields are to be located mainly in Zones 17, 18 and 6, where the piped water supply service is mostly absent. Inhabitants there, although sparsely populated, will be greatly benefitted if the Project provides some limited local supplies by constructing public standpipes.

Impact with adverse effect is theoretically foreseeable concerning the drawdown of aquifer level, its consequences and the side effects of the construction works. It is reckoned that approximately 8 percent of the area's precipitation will be drawn from the ground after implementation of the Project. Whether or not this yield invites the lowering of the aquifer level is hard to assess due to the absence of basic data accumulated for the prolonged period. Therefore, it is provided in the Project to monitor the dynamic level and volume of yield at each of the Project wells and to construct 8 monitoring wells to trace the fluctuation of static levels of confined aquifers relevant to the existing wellfields and the projected wellfields.

Such monitoring facilities coupled with the other monitoring facilities including that of water quality, registration of wells, catchment area inspection, hydraulic and meteorologic observation, and land level survey are expected to give EMPAGUA the information at the earliest timing on the approaching risk of aquifer drawdown and the possibility of land subsidence. The essential and most urgent information needed for well operation will be derived from monitoring wells, by which the adverse resultants will be avoided or minimized.

Adverse impact for lake Amatitlan in the south basin is not likely, since the Project wells are located in the north of the Surface Water Continental Divide, through which direct flow of groundwater is hardly anticipated.

The construction works may cause the pollution of air and surface water, noise, deforestation, soil erosion and the other adverse effects at the sites. Such side effects will be minimized by appropriate planning and efficient construction scheduling.

4.2 Impact Without the Project

The present Project is intended to be constructed by the year 1991. According to the schedule, however, yearwise implementation, which is programmed to complete fragment package of facilities from production wells through connection to the existing system to enable the instant accrual of benifit year by year, is proposed to satisfy demand over the next several years.

As is estimated by EMPAGUA, shortage of supply in 1985 is in a range of 4 through 25 percent. This shortage is aggravated in the newly developed housing areas in Zones 17 and 18, due mainly to the lack of bulk conveyance facilities to these areas and malfunction of the Atlantico -Las Ilusiones system. Despite the system's present production of some 20,000 m^3/day, the area's water demand in 1985, 1990 and 1995 will reach approximately 29,000, 42,000 and 60,000 m^3/day respectively. Therefore, it is estimated that the annual growth of water demand over 10 years in Zones 17 and 18 is some 7.8 percent. This trend is more or less alike in the case of the north (Zone 6) area.

Without implementation of the Project, the rapidly growing population in Zones 6, 17 and 18 will be left without significant growth of water supply for the coming 5 to 10 years, during which EMPAGUA is not prepared for an expansion to benefit these areas. Inhabitants in these areas, especially those around perimeters of suburban centers tend to be in the lower income group, and data on the income distribution are not available.

Water supply services in these areas, which at present are already insufficient and intermittent, will be aggravated in proportion with the population growth forecast over 7 percent per year in the case of Zones 17 and 18.

4.3 Overall Impact

Incremental volume under the Project, i.e. 1 m^3/sec or 86,400 m^3/day will benefit 290,000 consumers using 225 l/day or 390,000 consumers using 166 l/day, provided that the distribution loss or unaccounted-for water remains at the 25 percent level. This benefit will be accrued partially year by year from the second year of the implementation.

The Project will provide standpipes in the wellfields or along the pipeline route for the local inhabitants who have at present no access to piped supply, if doing such is found to be socially and economically feasible. In case one percent of the Project production is supplied through such standpipes, 17,000 through 20,000 local inhabitants can obtain 40 to 50 l/day.

Adverse impact which may be caused by the groundwater exploitation will be avoided or minimized through monitoring of wells and various groundwater parameters. Impact against Lake Amatitlan is unlikely to occur.

Impact, if the Project is not implemented, will be serious for 5 through 10 years in the instant future, especially toward the rapidly growing population in Zones 6, 17 and 18, who, even at present, suffer from the intermittent or marginal supply.

The overall environmental impact of the present Project will be significant and positive. Adverse impact will be avoided as far as adequate operation of wells is maintained on the basis of careful monitoring.

4.4 CONCLUSIONS AND RECOMMENDATIONS

4.4.1 Cost of Water

- Rates of Potable water in Metropolitan Guatemala are:

  EMPAGUA's basic tariff: Q0.14 per m^3

  Mariscal's basic tariff: Q0.25 per m^3

  Vendor's prevailing rate: Q2.5 to 4.9 per m^3

- According to PLAMABAG, or the long range master plan for EMPAGUA's water supply, the costs of water to be supplied after the implementation of future projects may be estimated for 1982 prices as follows:

  Oriental unit: Q0.04 per m^3

  Ayarza swamp: Q0.37 to 0.54 per m^3

  Motagua river: Q0.57 to 1.21 per m^3

  Nor-Occidental: Q0.38 to 0.44 per m^3

  These raw costs may be revaluated at current prices.

- In view of the EMPAGUA's chronic deficit, its current tariff is mispriced on the lower side. This financial vulnerability, in turn, leaves its routine operation inadequate and ineffective, resulting in unstable raw water intake in particular.

- Topography of the Project area obliges EMPAGUA to intake raw water from downriver (30%), groundwater (30%), and from remote catchment areas (40%). Intake at the downrivers is exposed to the threat of contamination by soil washout and the potentially polluted water quality resulting from soil erosion and disposal of sewage effluent upstream. Groundwater intake facilities yield both confined and unconfined groundwater and they also carry the potential risk of pollution.

- Raw water diverted from the remote catchment area, amounting at present 1 m^3/sec or 40 percent of the total production, will increase to 10.5 m^3/sec or 80 percent in the future. Revaluation of water cost is considered to be inevitable due to the costs involved in conveying raw water.

4.4.2 Sanitation

- Due to the absence of sewage treatment facilities of a 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. Many projects are proposed for the construction of sewage treatment plants, and some feasibility studies for these are reported to have been completed.

- The financial vulnerability particularly attributed to projects of this type however, did not permit their undelayed implementation. Also, there is no effective control over the quality of wastewater resulting in environmental and health hazards as well as a potential threat to the raw water drawn by EMPAGUA.

- A unique sewerage program with respect to the introduction of community participation, is being studied, mobilizing technological, socioeconomic, legal, institutional and other specialities. Taking into consideration that the main obstable to the implementation of sewerage projects is the absense of administrative support or public consensus on their necessity, this study is expected to succeed to an advanced extent.

  It is observed that neither the Guatemala municipality nor EMPAGUA counts on the construction of sewage treatment facilities in the immediate future, due to lack of acute public consciousness on the pressing need for them. It is recommended, however, to launch it at the earliest opportunity, with a view to water source the conservation including that of groundwater as a direct target and improvement of environmental and sanitary conditions as a target in a broader context.

- To help the early implementation, it is also advisable to review and reinforce the feasibility studies for these projects by providing experts on socio-administrative procedures and public relations in addition to technical expertise. Such experts are expected to prepare strategies by which the municipality obtains public support and access to the financial measures.

4.4.3 Monitoring of Wells and Groundwater Aquifer

- It was found that among the EMPAGUA wells, complete data on drilling, structure, initial well test, water quality, well hydraulics, yield, operation and maintenance, etc. are practically available. Therefore it is advisable to gather the relevant data on individual wells and to prepare the individual well registration book. Through the continuous accumulation of data, the well characteristics and their historical variations may be begun to be analyzed on an individual basis.

- It was found that the basic data to clarify behavior of the area's groundwater have not been accumulated on a continuous basis, and that some groundwater studies were undertaken for a limited period. The basic data which are needed to establish the groundwater recharge system or the water budget includes the most essential parameters of the existing groundwater intake facilities. However, EMPAGUA or any other authority is not filing a complete list of wells and springs, because no administrative control is applied with respect to groundwater utilization.

- It is recommended that EMPAGUA be delegated to register all the wells, springs and other groundwater facilities in order to determine the total groundwater discharge and other parameters, and to use it to form a basis to establish minimal groundwater monitoring, control and management to be developed into a more comprehensive system in the future.

- It is also recommended that meteorological, hydraulic and land level monitorings be undertaken continuously or periodically to obtain the hydrogeologic data for future analysis and simulation.

4.4.4 Conservation of Groundwater

- 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.

- In view of such accelerated aggravation of the recharge capacity of the metropolitan area, a recommendation is made to formulate guiding policies or controls to establish the green conservation zone, to encourage reforestation and to site housing developments at places where the adverse impacts are minimum. Housing developments, in particular, should be controlled and it should be made obdigatory for the developers to devise their drainage water infiltration facilities.

- The last option for recharge is the utilization of the treated wastewater through seepage trenches. In terms of volume of recharge water, this method is worthy of mention, because the volume of water diverted into the area in the future will increase to 10.5 m^3/sec from today's 1 m^3/sec. Since this volume is equivalent to an annual precipitation of 700 mm, it is recommended to develop wastewater utilization for groundwater recharge. It will improve the area's water budget significantly and hence prolong the file of groundwater facilities.

- Seepage trenches coupled with a simple wastewater treatment plant are reported to eliminate pollutants effectively. An experiment and application of this method seems to be especially adveisable in the south basin, where the water balance is negative, and were pollution of the lake and hence rivers should be eliminated.

4.4.5 Overall Impact of the Project

- In view of the potentially high cost of clean water in the Project area, impact of the incremental supply between by 1 m^3/sec or 86,400 m^3/day will be significant and expected to benefit 290,000 390,000 incremental consumers.

- Impact is significant and positive particularly during the coming 5 to 10 years and to the beneficiaries in the north and northeastern peripheries of the city where significant improvement of supply situation is not anticipated unless the Project is implemented.

The overall environmental impact of the present Project is positive. Adverse impact will be avoided or minimized if adequate well operation is assured on basis of careful monitoring.

APPENDIX V

SUPPLEMENTARY STUDY

SUPPLEMENTARY STUDY

CONTENTS

APPENDIX V

SUPPLEMENTARY STUDY

1. Introduction

In March 1986, as the conclusion of the Interim Report for this project, both the Team and EMPAGUA agreed that it was necessary to deepen the study for the rehabilitation and O/M system, and EMPAGUA subsequently requested a supplementary study for this purpose.

After evaluating the request, JICA dispatched three experts to Guatemala from May 22 to July 20 to conduct this supplementary study.

2. Objective

During the foregoing study, the Team verified that the EMPAGUA well system has a capacity of 1800 l/sec, and that the actual production is estimated at 620 lt/sec (34% of the capacity). The causes of this were identified as

- O/M system problems
- well structural problems, and
- aquifer problems.

The existing O/M system is one of the major causes of the actual situation for the wells and for that reason, the Team investigated the actual situation for equipment and installation, technical level, and evaluated the existing O/M system adoptability for the proposed project and its equipment.

In the same way, the TV scope equipment carried by the team was used to diagnose the wells for the evaluation of the grade of deterioration of the casing and the condition of the slit and strainers. This was important in determining the type of measures for implementation of the rehabilitation and the estimation of their effects.

Also, we conducted a pumping test to determine the grade of recovery of the aquifer around the existing well field and to evaluate the future production.

In addition, the Team organized, tabulated and analyzed the existing data for the wells, as well as their characteristics and production for the analysis of the well behavior.

Each Study activity was conducted by one expert assisted by EMPAGUA counterpart personnel in order to realize the maximum possible technology transfer.

CHAPTER I

OPERATION AND MAINTENANCE OF PUMP SYSTEM

1.1 Objective:

The objective of this study was to check the actual circumstances of the pump operation and maintenance system. The maintenance system features workshops for the rehabilitation, and operation and maintenance of the Project.

For attaining this objective, the following items were primarily considered.

- condition of operating pumps.
- operation system for each well.
- condition of workshop system.

1.2 Condition of Operating Pumps:

1.2.1 Condition.

Twelve pumps operated by EMPAGUA in the Study area were checked, and the outline of existing situation was determined as follows.

Detailed results are shown in FIGURE 1-1

a) Impeller, casing, bushing and shaft are damaged by friction, and the clearance has expanded over the operatable limit.

b) In some cases, the end-play (allowable movement in the direction of shaft) is too large to fix the location of the impeller.

c) In some cases, the ring for fixing the impeller was found in the casing because the impeller was set without a setting screw.

d) The casing and impeller of Diamante II and Diamante VIII are damaged by sand and hard scale.

e) Most of the adhered material is iron corrosion.

1.2.2 Treatment for Repairing

- J. A. SALAZAR	changed to new pump
- BRIGADA I	cleaning
- BRIGADA II	cleaning
- OJO DE AGUA	changed to new pump
- COLON	impeller and taper-corrector were changed to other second-hand parts which were in an acceptable condition.
- ARCOS I	cleaning
- PRIMERA Y TERCERA	changed to new pump. The stage of impeller is changed from 18 to 15.
- DIAMANTE VIII	under consideration
- LAS AMERICAS	cleaning
- SANTO DOMINGO	cleaning
- DIAGONAL VI	cleaning
- DIAMANTE II	under consideration

1.3 Operation System in Each Well:

Each well has 2 operators on a shift basis and their duties include keeping hourly records of the following items.

- electric current
- electric voltage
- electric consumption
- discharge
- gauge pressure

In most wells, discharge meters or gauge pressure meters are either not installed or damaged. Moreover, the dynamic water level could not be measured at any place because of the setting.

The control panel consists only of a current meter, a voltage meter and a magnet contactor with overload limiter.

Check for leaking from ground-packing and vibration of the motor and gear box is not performed by operators.

1.4 Workshop:

1.4.1 Brigada Workshop (Zone 7)

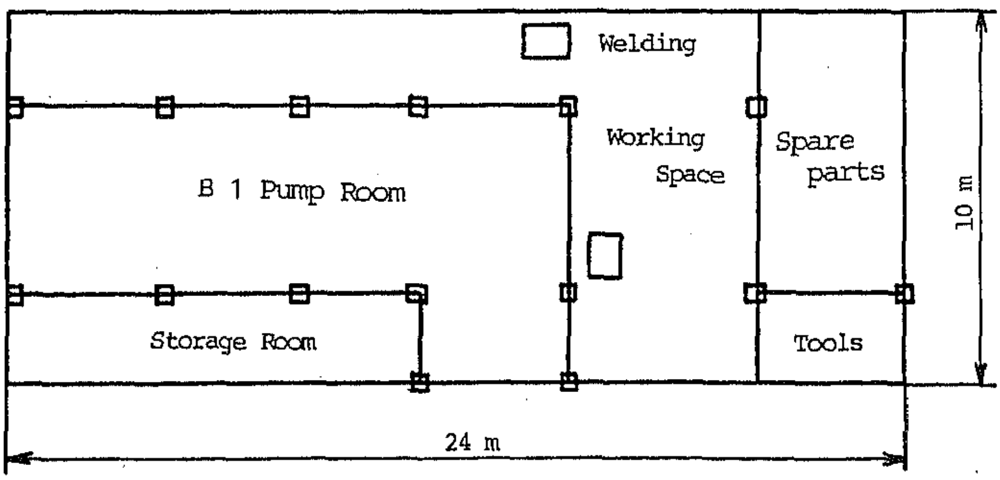
Pump overhaul is mainly performed by this workshop and the outline is shown in the following figure.

The overhaul procedure is as follows:

- conducted by 1 person
- required assistants are dispatched by Planning Office.
- Lifting the pump requires 5 - 6 persons because a crane is not available in the workshop.
- overhaul requires 3 - 4 persons.

In the repairing of pumps, parts are merely replaced with new over purchased or secondhand parts from old equipment. In some cases rapair is conducted at the other workshop. Howver, neither workshop presently has the capacity to manufacture pump parts.

EXISTING LAYOUT OF WORKSHOP (ZONE 7)



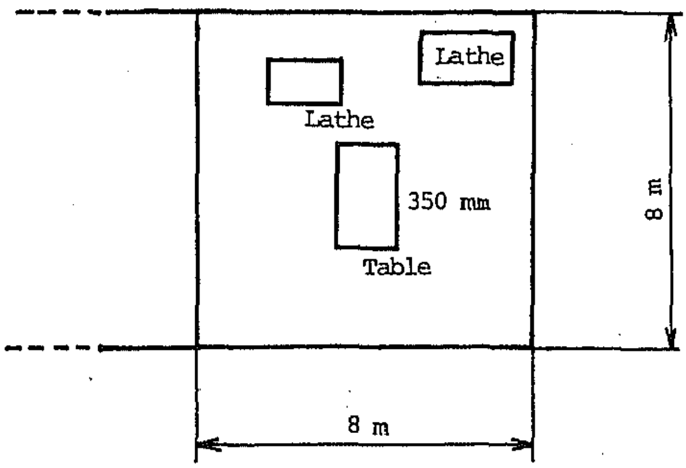
1.4.2 WorkShop (Zone 4)

The main objective of this work shop is to repair automobiles, with one portion of the workshop being used to repair pumps. The outline is shown in following figure.

Mostly, bushings, rings and shaft screws are reproduced or repaired here, with required materials such as shafts being almost imported from USA, and in some cases, used parts of other overhauled pumps are used.

Repair equipment and tools are not sufficient for the required maintenance system.

EXISTING LAYOUT OF WORKSHOP (ZONE 4)



1.4.3 Evaluation of Technical Standard

(1) The technical level of lathe operators and mechanics (1 person in each work shop) is judged to be of a good class for maintenance.

However, the number of staff is not sufficient to manage it and training is required to lift the technical level should be implemented as soon as possible.

(2) Mechanical engineers or specialists are required at the O/M section of EMPAGUA to direct and explain the action required for pump repairs.

(3) Approximately 50% of the second hand parts stocked in each work-shop or storage house are supposed to be available.

(4) Pump-shafts have to be purchased because their production is very difficult.

(5) Bushing and lining materials have to be purchased because of little stock.

1.5 Recommendations

As recommendations, the following should be considered for the pump rehabilitation and O & M system in the future.

(1) Pump rehabilitation

a) The current meters and pressure meters of each well have to be repaired or installed.

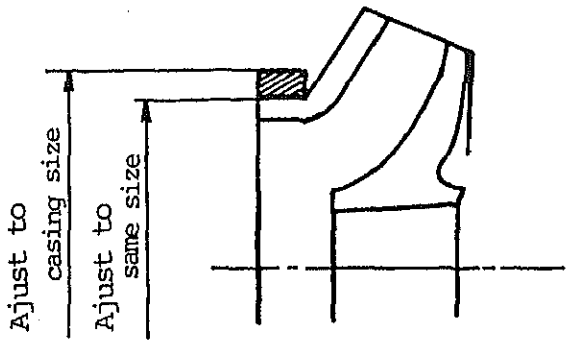
b) The dynamic water level should be measured under pump opėration.

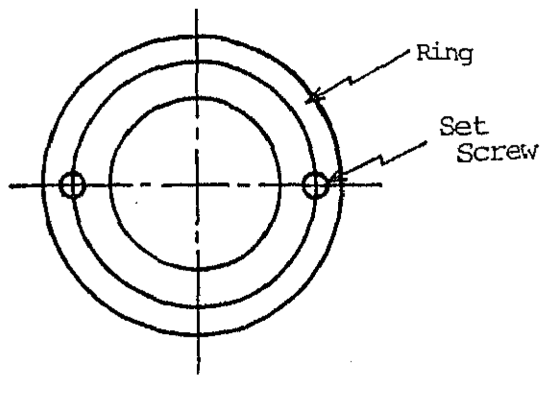
c) The optimum pump diameter and stage number should be decided by conditions on a well by well basis.

d) Most of the existing pumps are assumed to be damaged, and their capacity is less than their original. They should be either repaired or exchanged.

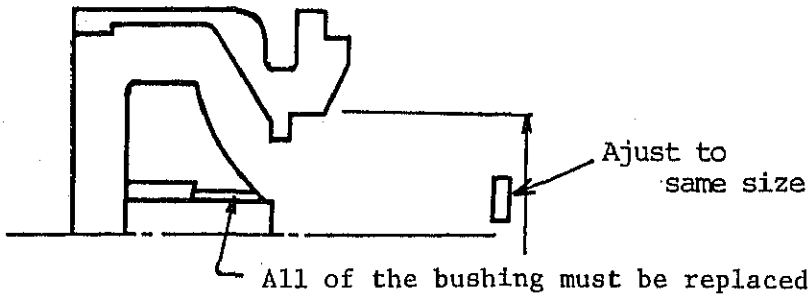
e) The second-hand spare parts stored in each workshop have to be arranged and repaired when possible.

f) Repairs for impellers are as follows.





g) Repairs for intermediate bowls are as follows.



h) The required number of pump shafts should be stocked.

i) Submersible-pumps are recommended for new installation because of the savings in the O & M cost.

(2) Operation and Maintenance system:

a) Periodic Recording:

i) In order to determine the condition of pump operation, the following items have to be checked and recorded constantly.

ii) Daily record

- pumping discharge
- gauge pressure
- motor current and voltage

iii) Monthly record

- dynamic water level
- insulation resistance

b) Periodic inspection:

Periods of 4 years or 32,000 hours operation, might be recommended as a desirable period for overhaul. Normal conditions should also be checked through daily inspection, and the pumps overhauled if necessary.

All the parts and especially the moving ones have to be measured by gauge and when the damage is over the designed allowable value, the parts must be either exchanged or repaired.

(3) Workshop

a) Mechanical and assembly sections existing at separate places should be unified.

b) All of the spare parts scattered at multiple locations have to be brought together and managed.

c) Over-haul and assembly of the pump and the processsing and producing of spare parts should be managed at the new workshop.

d) Required tools should be purchased.

e) Required facilities and tools of new workshops are as follows.

i) General facility

Crane, tool shelf, air compressor

ii) Mechanical

Lathe, drilling machine

iii) Assembling

Assembling table, vice, bench drill, air tools, electric tools, welder.

vi) Maintenance shop:

Test pit, measuring equipment for inspection and electric condition

f) A sample layout of a workshop is as follows.

LAYOUT OF WORKSHOP

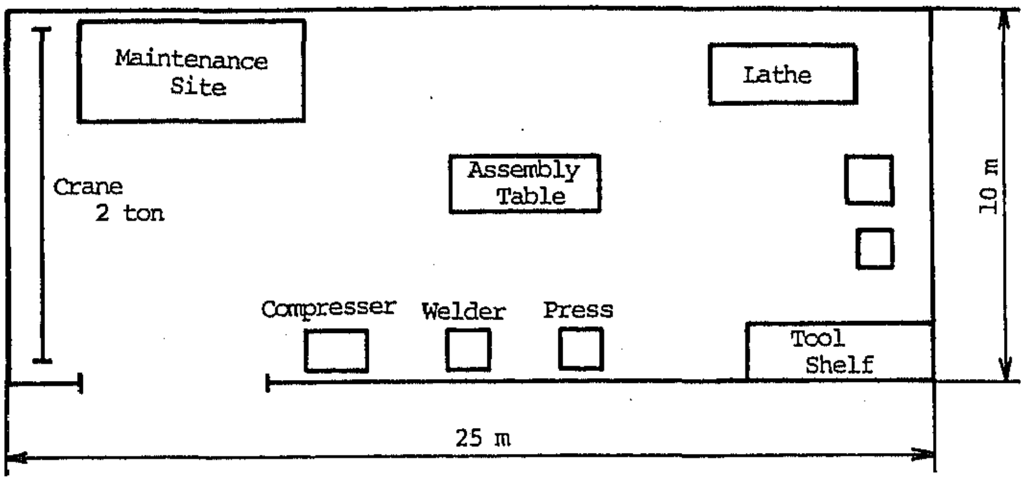
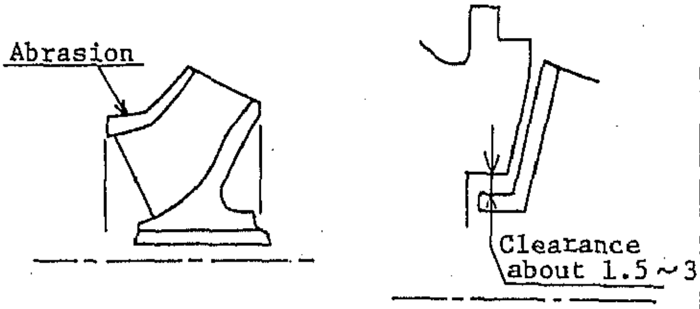
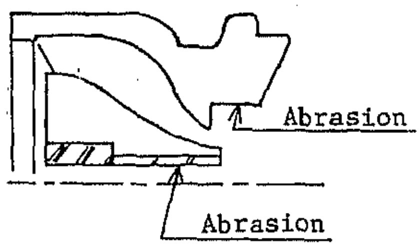
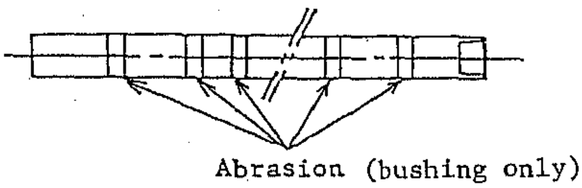
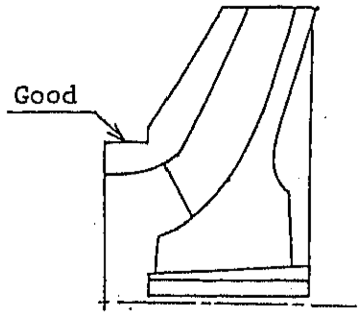
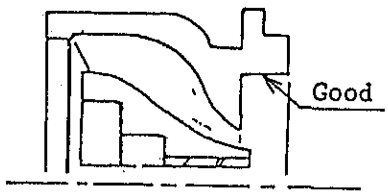


FIG. 1-1 CONDITION OF OPERATING PUMP

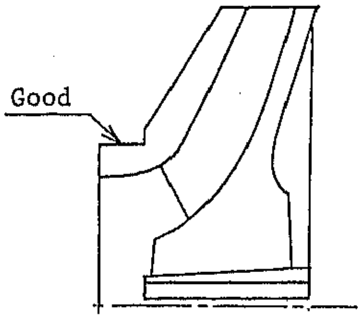
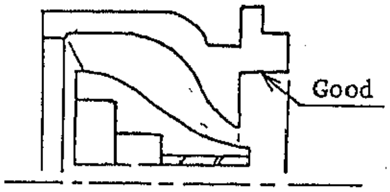
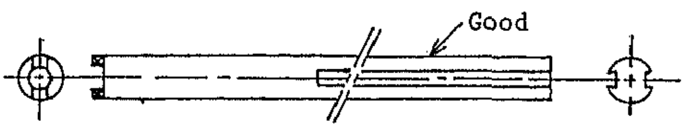
PLACE : J.A.SALAZAR
MODEL : VERTICAL
MAKER : _
TYPE : _
SERIAL No : _

PARTS NAME	QTY	CONDITION
Impeller	15	
Intermediate Bowl	15	
Pump Shaft	1	
Comment		

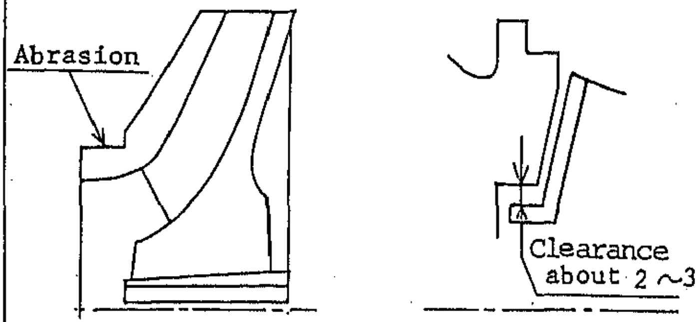
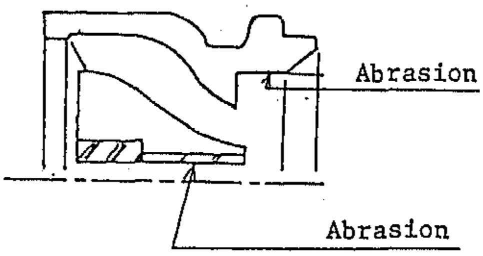
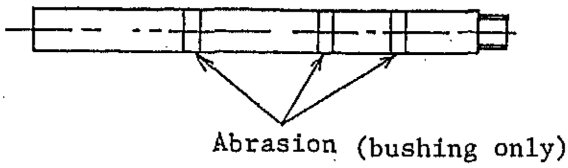
PLACE : BRIGADA I
MODEL : SUBMERSIBLE PUMP
MAKER : IRRIGATION INDERSTRIAL DEPARTMENT PUMPS
TYPE : V6
SERIAL No : -

PARTS NAME	QTY	CONDITION
Impeller	10	
Intermediate Bowl	10	
Pump Shaft	1	
Comment		

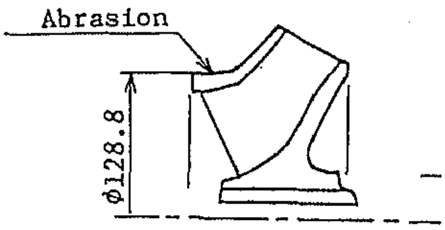
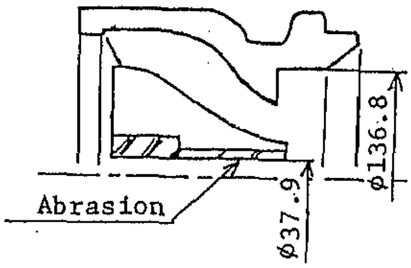
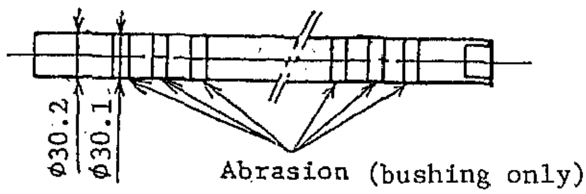
PLACE : BRIGADA II
MODEL : SUBMERSIBLE PUMP
MAKER : IRRIGATION INDUSTRIAL DEPARTMENT PUMPS
TYPE : Q6410 V6
SERIAL No : H190S OXW

PARTS NAME	QTY	CONDITION
Impeller	10	
Intermediate Bowl	10	
Pump Shaft	1	
Comment		1. MEGA >500 MΩ 2. Ammeter is not working

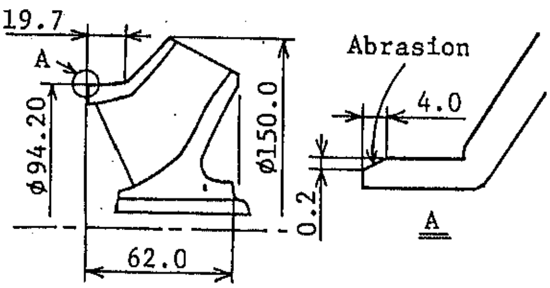
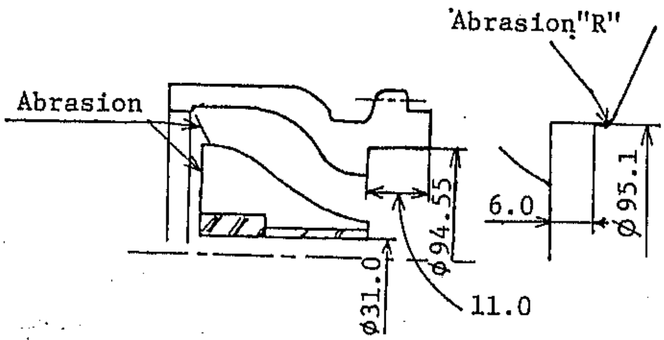
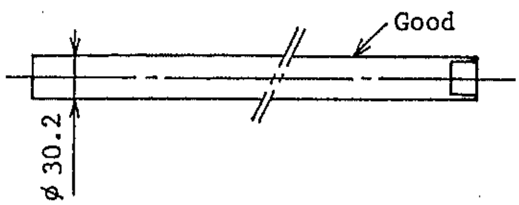
PLACE : OJO DE AGUA I
MODEL : VERTICAL
MAKER : FLOWAY
TYPE : 10 FKH
SERIAL No : 78-1465-J

PARTS NAME	QTY	CONDITION
Impeller	2	
Intermediate Bowl	2	
Pump Shaft	1	
Comment		

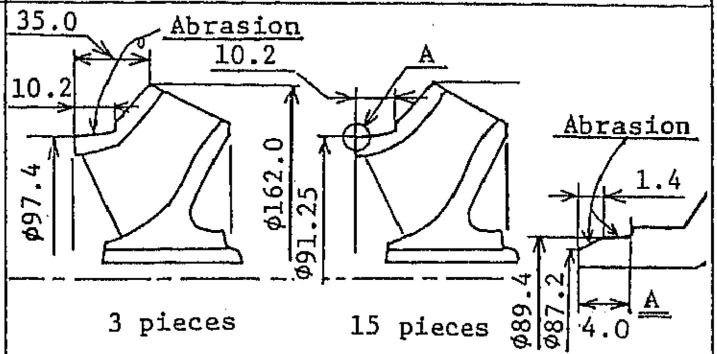
PLACE : COLON
MODEL : VERTICAL
MAKER : JOHNSON
TYPE : 8AC
SERIAL No : GC 17507 20-5-1970

PARTS NAME	QTY	CONDITION
Impeller	22	 Impeller has corosion
Intermediate Bowl	22	
Pump Shaft	1	
Comment		

PLACE : ARCOS
MODEL : VERTICAL
MAKER : -
TYPE : -
SERIAL No : -

PARTS NAME	QTY	CONDITION
Impeller	24	
Intermediate Bowl	24	
Pump Shaft	1	
Comment		End play 9 mm

PLACE : PRIMERA Y TERCERA
MODEL : VERTICAL
MAKER : JOHNSON
TYPE : 8 AC
SERIAL No : DK27143 23-8-1977

<table>
<tr><th>PARTS NAME</th><th>QTY</th><th>CONDITION</th></tr>
<tr><td>Impeller</td><td>18</td><td>
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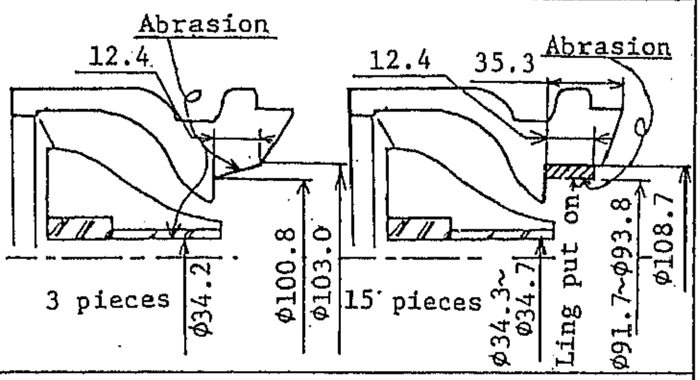
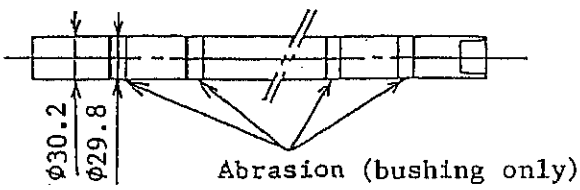
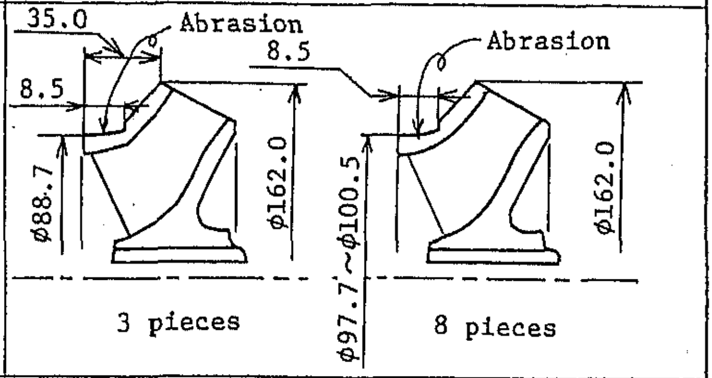
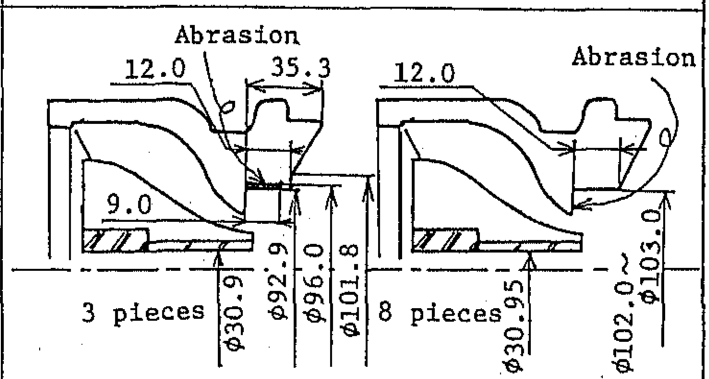
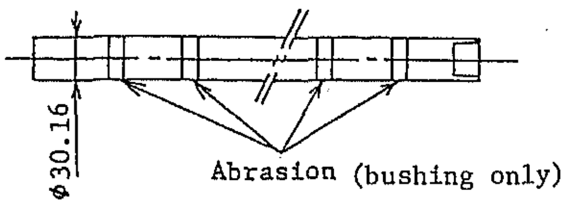
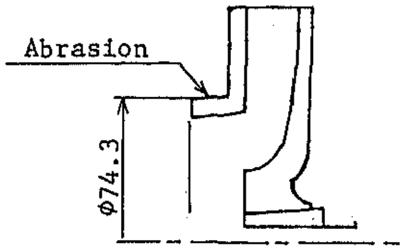
<tr><td>Intermediate Bowl</td><td>18</td><td>
</td></tr>
<tr><td>Pump Shaft</td><td>1</td><td>
</td></tr>
<tr><td>Comment</td><td></td><td>End play 19 mm</td></tr>
</table>

PLACE : DIAMANTE VIII
MODEL : VERTICAL
MAKER : JOHNSON
TYPE : 8AC
SERIAL No DK27154 10-8-1977

PARTS NAME	QTY	CONDITION
Impeller	11	
Intermediate Bowl	11	
Pump Shaft	1	
Comment		Discharge case and top intermediate bowl have the most scale.

PLACE : LAS AMERICAS
MODEL : SUBMERSIBLE PUMP
MAKER : –
TYPE : –
SERIAL No : –

<table>
<tr><th>PARTS NAME</th><th>QTY</th><th>CONDITION</th></tr>
<tr><td>Impeller</td><td>11</td><td>
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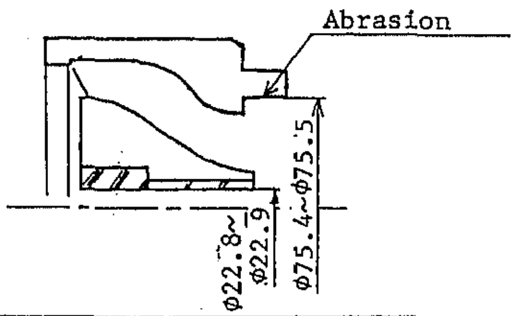
<tr><td>Intermediate Bowl</td><td>11</td><td>
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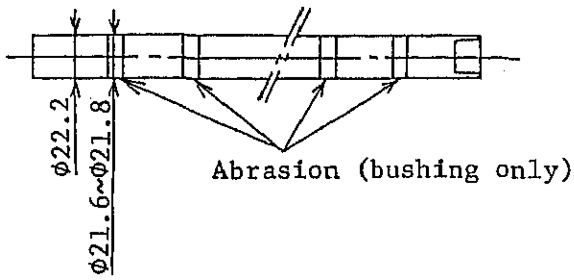
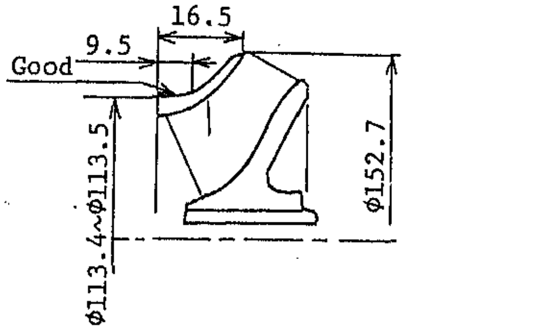
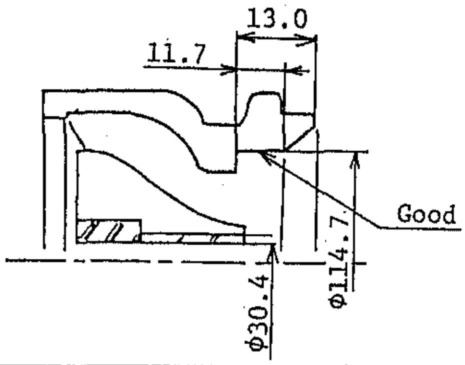
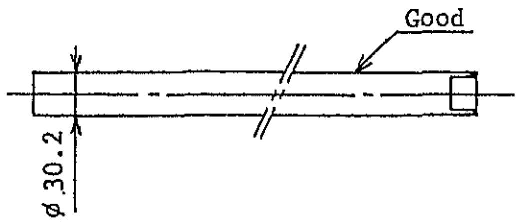
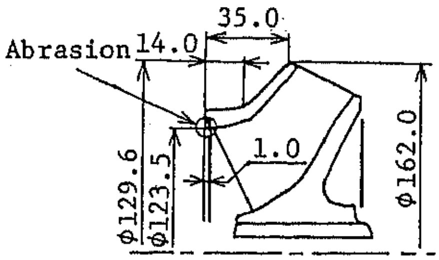
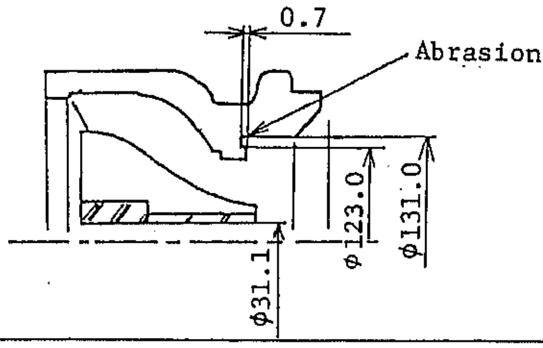
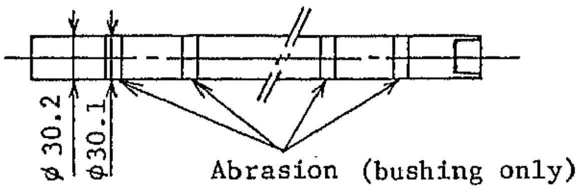
<tr><td>Pump Shaft</td><td>1</td><td>
</td></tr>
<tr><td>Comment</td><td></td><td><u>Moter</u>
Franklin Electric
MODEL : 2361199003
HP : 50 VOLT : 460/380 RPM : 3450/2875
MAX. AMP : 75.0/82.0 MIN. FLW : FT/sec 0.5</td></tr>
</table>

PLACE : SANTO DOMINGO
MODEL : VERTICAL
MAKER : FLOWAY
TYPE : 8 JKL
SERIAL No : -

PARTS NAME	QTY	CONDITION
Impeller	12	 Discharge side of bane is damaged
Intermediate Bowl	12	
Pump Shaft	1	
Comment		End play 9.5 mm

PLACE : DIAGONAL VI
MODEL : VERTICAL
MAKER : JOHNSON
TYPE : 8AC
SERIAL No : DK27150 5-8-1977

PARTS NAME	QTY	CONDITION
Impeller	19	
Intermediate Bowl	19	
Pump Shaft	1	
Comment		End play 14 mm

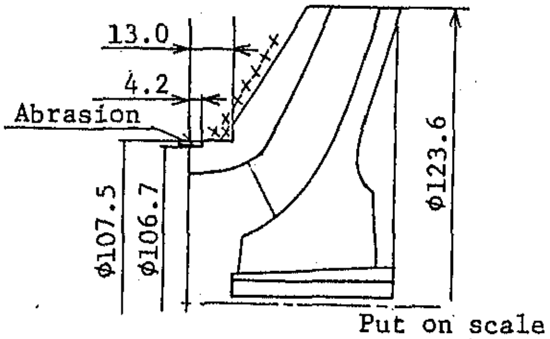
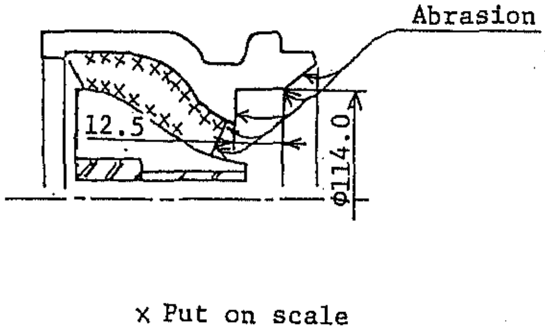
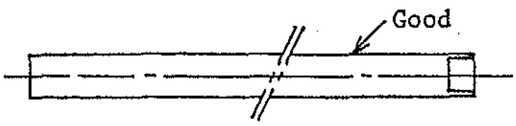
PLACE : DIAMANTE II

MODEL : VERTICAL

MAKER : -

TYPE : -

SERIAL No : -

PARTS NAME	QTY	CONDITION
Impeller	15	
Intermediate Bowl	15	
Pump Shaft	1	
Comment		

CHAPTER II

PUMPING TEST

2.1 Objective:

The objective of this study is to investigate the aquifer characteristics of the Study area and to evaluate the possibility of the existing wells after rehabilitation.

According to the location, the existing wells of EMPAGUA were divided into 5 groups:

Zone	Number	Capacity
South	9 wells	920 1/s
West	14 wells	240 1/s
North	11 wells	255 1/s
Center	13 wells	252 1/s
Others	11 wells*	135 1/s

* Including las Mercedes' well.

o The south-zone wells were constructed in 1969 - 1976, and they are of 12 - 16 inch diameter, with depths of 120 to 310 m. They are in the more productive zone of the EMPAGUA well system.

o The west-zone wells are of the older system of EMPAGUA and were constructed before 1970, and all of them are of 8-inch diameter with depths of 100 to 320 m, and are in the less productive system of EMPAGUA.

o The north-zone wells are the newest wells of EMPAGUA and all except one were constructed in 1982. They have diameter of 8 - 12", and an average depth of 270 m.

o The center zone wells were constructed in 1968 - 1978 with diameters of 8", and depths of 140 - 300 m.

Two pumping tests were planned for each of these groups but an accident at the La Brigada Plant during the Study period resulted in the necessity for production control, requiring alteration of the program.

As a result, the wells performed pumping test were: 2 in the south zone, 1 in the west zone, 2 in the north zone, 4 in the central zone and 1 in other zones. The location for the wells tested is shown in FIG. 2-1, and their physical characteristics are as shown in TABLE 2-1.

2.2 Step Draw-down Test:

The purpose of this test was to determine the parameters for the critical discharge, specific capacity and yield factor.

(1) Critical Discharge:

The draw-down curve against the discharge in logarithmic scale has a point at which the rate of increase changes, and this point is called the critical discharge.

(2) Specific capacity:

This is defined as a discharge divided by draw-down (m^3/sec/m) and represents the transmisibility of the aquifer.

(3) Yield Factor:

This is defined as a specific capacity divided by the aquifer thickness. Its unit is m/sec. and it represents the aquifer coefficient permeability.

The form of execution of this test is as described in Chapter VII of Appendix I.

To obtain a better approximation of the capacity of the aquifer around the EMPAGUA Wells, light brushing was performed for each well before the pumping test.

The result of the tests are as shown in TABLE 2-2.

In TABLE 2-3 we can see that there are notable decreases of the groundwater level, especially in the west zone where the drop is more than 30 m. On the other hand, the variation is least in the North zone where the actual exploitation is also minimum. The drop is notable for older wells. The relationship between the original and the tested discharge is as follows:

Lower aquifer of South Zone	0.87
Upper aquifer of South Zone	0.41
Upper aquifer of West Zone	0.71
Upper aquifer of North Zone	0.97
Upper aquifer of Center Zone	0.63

For this Study it is estimated that almost all the selected wells for the rehabilitation can recover most of their original productivity, with adequate rehabilitation of the wells. The yield factors of the tested wells were of the 10^{-3} to 10^{-4} m/sec order for lower aquifer wells in the South and North and for the well of Las Mercedes. The other were of the 10^{-5} 10^{-6} m/sec order.

2.3 Rehabilitation Plan

There are 57 wells in Empagua. They are as follows:

- 5 wells abandoned because they are either in bad condition or the wells have collapsed.

- 8 wells out of operation because either the wells or equipment is in bad condition

- 7 wells of North zone (zone 6) are in the process of having equipment provided by a two step loan of Japan Export & Import Bank.

- 14 wells in operation, but in a poor condition and are not convenient to operate because they cannot be rented to EMPAGUA because of their small production.

- 23 wells are included in the rehabilitation program because of their place in the Empagua production system.

However, one well in Projects 4-3 will be rehabilited by Empagua within 1986. 22 wells will therefore be rehabilited under the Project.

The wells targeted for rehabilitation are as follows:

Wells Targeted for Rehabilitation

No.	Name	Design Capacity	Year of Construction	Zone
141	Diamante I	50 1/sec	1969	South
140	Diamante II	90 1/sec	1969	"
143	Diamante III	90 1/sec	1969	"
145	Diamante V	189 1/sec	1969	"
142	Diamante VI	63 1/sec	1969	"
144	Diamante VIII	88 1/sec	1976	"
139	Ojo de Agua I	151 1/sec	1976	"
138	Ojo de Agua II	151 1/sec	1976	"
137	Hincapie	31 1/sec	1978	Other
22	J A Salazar	31 1/sec	1978	Center
30	Brigada I	20 1/sec	1968	West
29	Brigada II	18 1/sec	1967	West
24	Arcos I	29 1/sec	1976	Center
20	Diagonal VI	31 1/sec	-	Center
21	Colonia El Maestro	31 1/sec	-	Other
278	Juana de Arco	22 1/sec	1982	Other
16	Santo Domingo	44 1/sec	1969	Center
15	Parque Colon	31 1/sec	-	Center
28	Filtros Brigada I	31 1/sec	1970	West
27	Filtros Brigada II	31 1/sec	1970	West
38	Belem III	31 1/sec	1970	West
18	Ciudad Vieja I	20 1/sec	1970	Center

As a result of the pumping test performed during the Supplementary Study, it is shown that, 83% of the design capacity can be obtained at Ojo de Agua and 41% at Diamante, in the South zone; 71% in West zone, an average of 97% in Northern zone, and an average of 63% in the Center zone.

These percentages can be improved upon with adequate rehabilitation work for the wells and the provision of adequate equipment and maintenance for these wells.

It is estimated that after the rehabilitation program, the production of wells under the program will improve 90% at Ojo de Agua and North zone and only 70% in the other zones due to the fall of the capacity of the aquifer in the west and center zone as shown by the test and by the hydrogeological analysis. In addition, many wells of the center zone have reduced efficiency due to losses resulting from direct connection to the distribution network.

As a result of implementation of this proposed rehabilitation plan, the water production will increase as follows:

		No. Wells	Potential Capacity	Estimated %	Post Rehabilitation
A.	South Zone Wells				
	1. Ojo de Agua	2	302	90	270
	2. Diamantes	6	530	70	370
B.	West Zone	5	131	70	90
C.	North Zone (EMPAGUA)	-	-	-	-
D.	Center Zone	6	186	70	130
E.	Others	3	84	70	60
		22	1,2331/s		920 l/s

% of potential capacity obtainably by rehabilitation

2.4 Conclusions

(1) The lower aquifers of the South and North zones have stable production potential, and by their importance will be exploited to the maximum. Therefore, the priority of the rehabilitation of wells of EMPAGUA is South, North, West and Center, respectively.

(2) As each well has its own characteristics, pumping tests shall be performed for each well after the rehabilitation works.

(3) There are 22 wells identified for the rehabilitation program of this Project, and it is estimated that production of these wells after this program will be 920 l/sec, representing a 71% increase, or 382 l/s, over the actual production.

TABLE 2-1

Physical Characteristics of Tested Wells

NO	NAME OF WELL	ZONE	DATE OF TEST	WELL DEPTH	DIAMETER	ELEVATION	YEAR OF CONSTRUCTION
1	FILTROS II	WEST	MAY 26 - MAY 31	290 m	8"	1,590 masl	1970
2	CIUDAD VIEJA I	CENTER	JUNE 2 - JUNE 8	305 m	8"	1,507 masl	1970
3	DIAMANTE VI	SOUTH	JUNE 9 - JUNE 14	305 m	15"	1,244 masl	1969
4	J. A. SALAZAR	CENTER	JUNE 10 - JUNE 15	195 m	8"	1,508 masl	1978
5	FINCA MERCEDES	OTHER	JUNE 16 - JUNE 21	104 m	8"	1,280 masl	-
6	OJO DE AGUA I	SOUTH	JUNE 23 - JUNE 28	274 m	12"	1,253 masl	1976
7	COLON	CENTER	JUNE 30 - JULY 5	201 m	8"	1,488 masl	-
8	LAS AMERICAS	CENTER	JULY 6 - JULY 11	186 m	8"	1,506 masl	1976
9	JOCOTALES II	NORTH	JULY 10 - JULY 15	274 m	18"/10"	1,448 masl	1982
10	PROVECTO 4-10	NORTH	JULY 12 - JULY 17	288 m	12"	1,453 masl	1982

TABLE 2-2

RESULTS OF PUMPING TEST (1)

NO	NAME OF WELL	ZONE	DIAM	CRITICAL DISCHARGE	SPECIFIC CAPACITY	YIELD FACTOR
1	FILTROS II	WEST	8"	22 l/s	3.3×10^{-3} m^2/s	2.39×10^{-5} m/s
2	CIUDAD VIEJA I	CENTER	8"	8 l/s	$1.8 \times d10^{-4}$ m^2/s	1.32×10^{-6} m/s
3	DIAMANTE VI	SOUTH	15"	25 l/s	2.8×10^{-4} m^2/s	1.16×10^{-6} m/s
4	J. A. SALAZAR	CENTER	8"	19 l/s	4.3×10^{-4} m^2/s	4.4×10^{-6} m/s
5	FINCA MERCEDES	OTHER	8"	51 l/s	7.2×10^{-3} m^2/s	4.0×10^{-4} m/s
6	OJO DE AGUA I	SOUTH	12"	126 l/s	3.5×10^{-2} m^2/s	2.9×10^{-4} m/s
7	COLON	CENTER	8"	22 l/s	2.9×10^{-3} m^2/s	2.5×10^{-5} m/s
8	LAS AMERICAS	CENTER	8"	12 l/s	2.0×10^{-4} m^2/s	1.6×10^{-6} m/s
9	JOCOTALES II	NORTH	18"/10"	17.3 l/s	-	-
10	PROVECTO 4-10	NORTH	12"	62 l/s	2.9×10^{-2} m^2/s	6.3×10^{-4} m/s

TABLE 2-3

RESULTS OF PUMPING TEST (2)

NO	NAME OF WELL	ZONE	DIAM	ORIGINAL DISCHARGE	ORIGINAL STATIC LEVEL	ACTUAL STATIC LEVEL	STATIC LEVEL AF. BRUSH	DYNAMIC LEVEL	DISCHARGE OF TEST	ORIG TEST DISCHARGE RATIO
1	FILTROS II	WEST	8"	31 l/s	-46.0 m	-87.80 m	-77.00 m	-117.00 m	22 l/s	0.71
2	CIUDAD VIEJA I	CENTER	8"	20 l/s	-47.0 m	-53.7 m	-53.7 m	-96.6 m	8 l/s	0.40
3	DIAMANTE VI	SOUTH	15"	63 l/s	-20.0 m	-26.00 m	-26.00 m	-106.60 m	26 l/s	0.41
4	J. A. SALAZAR	CENTER	8"	31 l/sd	-56.0 m	-58.8 m	-56.3 m	-100.4 m	19 l/s	0.61
5	FINCA MERCEDES	OTHER	8'	-	0.0	-1.0 m	0.0 m	-7.7 m	51 l/s	-
6	OJO DE AGUA I	SOUTH	12"	151 l/s	+0.90 m	-0.60 m	0.0 m	-6.30 m	126 l/s	0.83
7	COLON	CENTER	8"	31 l/s	-33.0 m	-55.8 m	-54.0 m	-64.0 m	22 l/s	0.71
8	LAS AMERICAS	CENTER	8'	15 l/s	-61.0 m	-87.20 m	-71.30 m	-27.40 m	12 l/s	0.80
9	JOCOTALES II	NORTH	18"/10"	18 l/s	-167.00 m	-167.60 m	-167.60 m	-167.60 m	17.3 l/s	0.96
10	PROVECTO 4-10	NORTH	12"	63 l/s	-170.00 m	-171.00 m	-171.00 m	-169.00 m	62 l/s	0.98

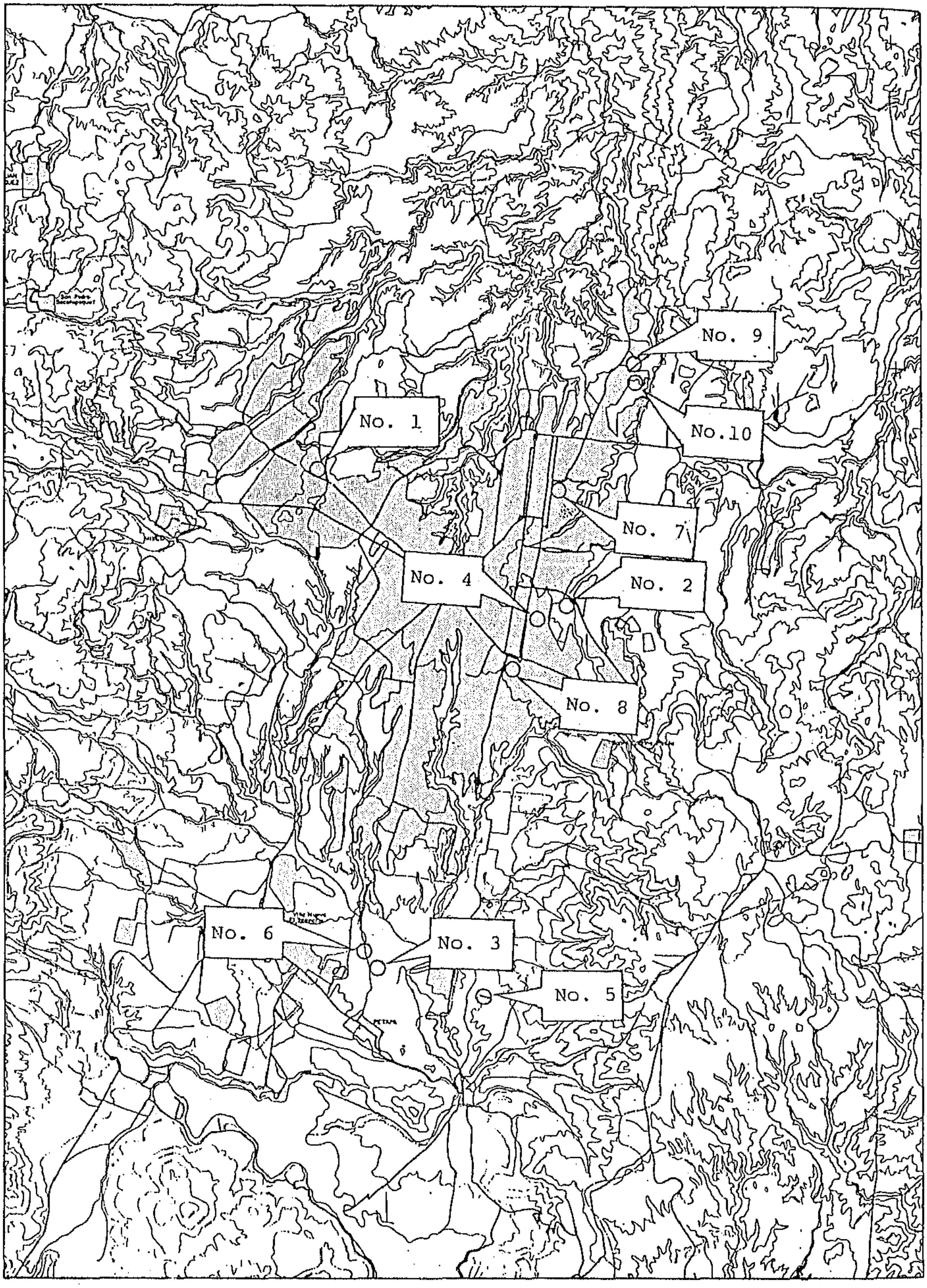


FIG. 2-1 PUMPING TEST SITE

CHAPTER III

WELL DIAGNOSIS BY UNDERWATER TV

3.1 Objective

The objective of this Study is to research the existing conditions of the casings and strainers using an underwater TV system to contribute to determining the potential for rehabilitation and new well development.

Moreover, this process of the Study may include technical transfer in the form of on-the job-training.

3.2 General Features of Wells Surveyed

A total of 12 wells were selected as the key wells in consideration of the required water production of EMPAGUA and the well locations for which the hydrological conditions were important.

Figure 3-1 and Table 3-1 shows the 13-wells observed, and the physical condition of the test borings when they were installed.

All of the observation was completed smoothly and on schedule with the technical transfer, and the records will be kept for future rehabilitation programs.

For the diagnosis of the well conditions, these existing observations must be considered along with the profiles and periodic hydro-data. However, discharge, statistical and dynamic water level data could not be collected, and this lack of data should be rectified by the installation and recording of observation equipment as soon as possible

The results of the well conditions are as follows:

Brigada II

(1) Static water level is found at 114.27 m.

(2) Scale is not highly visible, and the pump condition which was checked this time suggests good water quality at this point.

ARCOS I

(1) Static water level is found at 66.0 m.

(2) Slit casing is installed at 74-138 m and 150-180 m.

(3) Slit type is the vertical 3 line.

(4) Scale is not highly visible at the upper slit casing but at 150-180 m is so dominant that there is Fe brown color.

Primera y Primera

The well was found to be obstructed at 47.92 m, and then the mirror was removed to verify the type of obstruction. It is probable that there are some branches at the top of the obstruction, but under the branches could be a more solid obstruction (metal, collapsed casing or come kind of equipment blockages).

Neither the static water level, slit or well depth could be verified. At 47.92 m, the casing was seen and it was found to be in a regular state with some corrosion. The infrastructure installation of the well has been completely neglected.

Santo Domingo

(1) The static water level was found at 51.61 m.

(2) The water was found to be muddy with a yellow-green color until 62.80 m. The rest of water was found to be clear.

(3) Slits are uncovered, and with the exception of 87 m, the well had no fissures until 95 m, and at 100 m - 105 m. From 124 m to the bottom were some slit rows.

(4) The casing was found to be in a satisfactory condition until the static water level, and from the static water level on, it was found to have a corrosion cover of orange-yellow color, probably due to iron corrosion.

(5) A straight fissure parallel to the slit from 110 m to 116 m.

Diagonal 6

(1) The static water level was found at 50.94 m.

(2) Water at the top of static level is slightly dirty with a yellow color, and at 107 m, water turbidity is higher but gives a TV image. From 130 m on, the water is all a muddy yellow-brown color.

(3) Slits are covered with much corrosion of black-yellow color, with some fissures present.

(4) Similar to the slits the casing was found to have a dirty dense cover of black-yellow color corrosion.

(5) The well depth was indeterminate because from 130 m there was no image.

Diamante VIII

(1) The static water level was at 46 m.

(2) At 46-155 m, a large amount of floating scale is observed and the situation of the casing could not be checked. The scale adhered to the rise pipe is very soft and is assumed to be ash or clay.

(3) At 155-209 m, floating scale cleared, but a large amount of scale is adhered on the casing. Especially, the slit part is completely sealed with sedimentation.

(4) There was a reducing pipe at 209-210 m, and the screen continues to the bottom with some blind pipes as each. A large amount of water blowing is observed at the first screen and the joints of the reducing pipe are fractured and the blind pipe is kept clean. The bottom is at 263 m, and slime is assumed to exist until this depth.

DIAMANTE II

(1) Static water level is found to be at 16 m.

(2) Nothing is visible underwater because of scale until 200 m.

Brigada I

(1) The static water level is found to be at 118.3 m.

(2) Scale is adhered but is not particularly hard.

Ciudad Vieja I

(1) The static water level is found to be at 53.7 m.

(2) Scale is adhered but is not particularly hard.

Diamante VI

(1) The static water level is found at 24.6 m.

(2) Water to 43 m is black and opaque.

(3) Blowing air is found at 55 m along with broken holes.

(4) Slit casing is joined at deeper than 30 m.

(5) Scale is adhered to the casing, especially at between 158 and 180 m.

Parque Colon

(1) The static water level is found at 50.5 m.

(2) At 48-49 m, a large amount of water flows in from 3 points and is assumed to be holes on the slits. Additionally, large holes are observed at 63.72 and 64.7 m.

(3) Slits are composed of 12" slits, with jointing blind pipes each 6 m. The bottom line is at 192 m.

(4) The color of the scale is orange and assumed to be iron corrosion.

Las Americas

(1) The static water level is found at 86.8 m.

(2) The color of scale is orange, and is assumed to be iron corrosion, especially at around 100m.

(3) The slit is installed at under 72 m.

Primera y Tercera

(1) The static water level is found at 56.7 m

(2) The slit casing is at from 82 m with a blind pipe at each 6 m.

(3) Scale is not particularly severe, and is orange colored, presumably Fe.

3.4 Considerations and Recommendations

Installation of the wells studied was between 1969 and 1976, and so the age of the wells can be assumed at between 10 to 20 years depending on the well. Almost no rehabilitation has been performed to date.

According to the observations, the water quality of this area is not so bad except for the southern part under this O/M condition.

However, some scale is adhered, consequently influencing water quality.

In most of the wells, iron corrosion and black/orange colored scale assumed to be from Fe was observed, and the pumps at Diamente II, VI, VIII installed in the South zone are especially damaged by hard scale of this type.

As a recommendation, the measuring equipment for discharge and water level should be installed in all operating wells as soon as possible.

Secondly, a cleaning of the casing by brush, swabbing, jetting, etc. is periodically required. Additionally, the scale in the gravel zone also has to be removed with chemical input adapted to the quality of the scale.

Thirdly, cracks and holes are observed in some wells, and treatment such as double-casing is required for well protection.

TABLE 3-1

GENERAL FEATURES OF SURVEYED WELLS

Name		Location	Installation Date	Depth (m)	Diameter (mm)	Data of Pumping Test	
						Static W.L. (m)	Discharge l/s
1. Brigada II	(42)	7M	1968	182.8	200	81.1	11.4
2. Arcos I	(15)	Zone 9	1976	182.9	200	59.2	25.2
3. Primera y Primera	(35)	Zone 2	1968	230.4	200	53.3	15.8
4. Santo Domingo	(31)	Zne 1	1969	139.0	200	32.0	44.2
5. Diagonal VI	(19)	Zone 10	-	226.6	200	51.5	31.6
6. Diamante VIII	(4)	Zone 12	1969	274.3	300 200	19.5	90.9
7. Diamante II	(16)	Zone 12	1969	121.9	400	7.6	50.5
8. Brigada I	(41)	7M	1968	213.4	150	84.7	20.13
9. Ciudad Vieja I	(18)	Zone 10	1970	204.8	200	47.2	20.2
10. Diamante VI	(1)	Zone 12	1969	274.3	300	20.1	63.1
11. Parque Colon	(38)	Zone 1	-	201.2	200	33.5	31.6
12. Las Amricas	(11)	Zone 13	1986	185.9	200	55.2	15.8
13. Primera y Tercera	(26)	Zone 2	1968	230.	200	-	-

FIG 3-1 LOCATION OF OBSERVED WELLS

CHAPTER IV

SYSTEM ANALYSIS FOR DATA IN EMPAGUA

4.1 Objective

For the proper operation and maintenance of groundwater production and conveyance systems, systematic organization and engineering should be considered as part of the operation and maintenance.

For this purpose, some of the necessary data has to be researched and recorded for each engineering field.

The operation and maintenance section of EMPAGUA have started a filing system using the computer utilized by the JICA survey team and eventually handed over to EMPAGUA.

Systematic arrangement and analysis of these daily/monthly data will contribute not only to the Project but also to groundwater preservation and production control in the near future.

The objective of this Study is to analyze required basic data for groundwater preservation and production control, and transfer a systematic arrangement as a sample approach.

4.2 Existing Condition

Data Collection

- General features
- Data of test pump recorded at installation stage
- Well profiles
- Daily record of electric board (voltage-current)
- Monthly record of electric consumption as reported by electric company.
- Chemical treatment consumption of wells and plants.

However, required O/M data concerned with hydrology is not collected because of damage or the lack of installation of measuring equipment.

Only periodic data have been used for the calculation of production cost such as electric and chemical consumption.