4.3.3 Water Production Programs

(1) Well Fields

Wellfield locations to be ultimately adopted under the Project were determined on the basis of the following criteria.

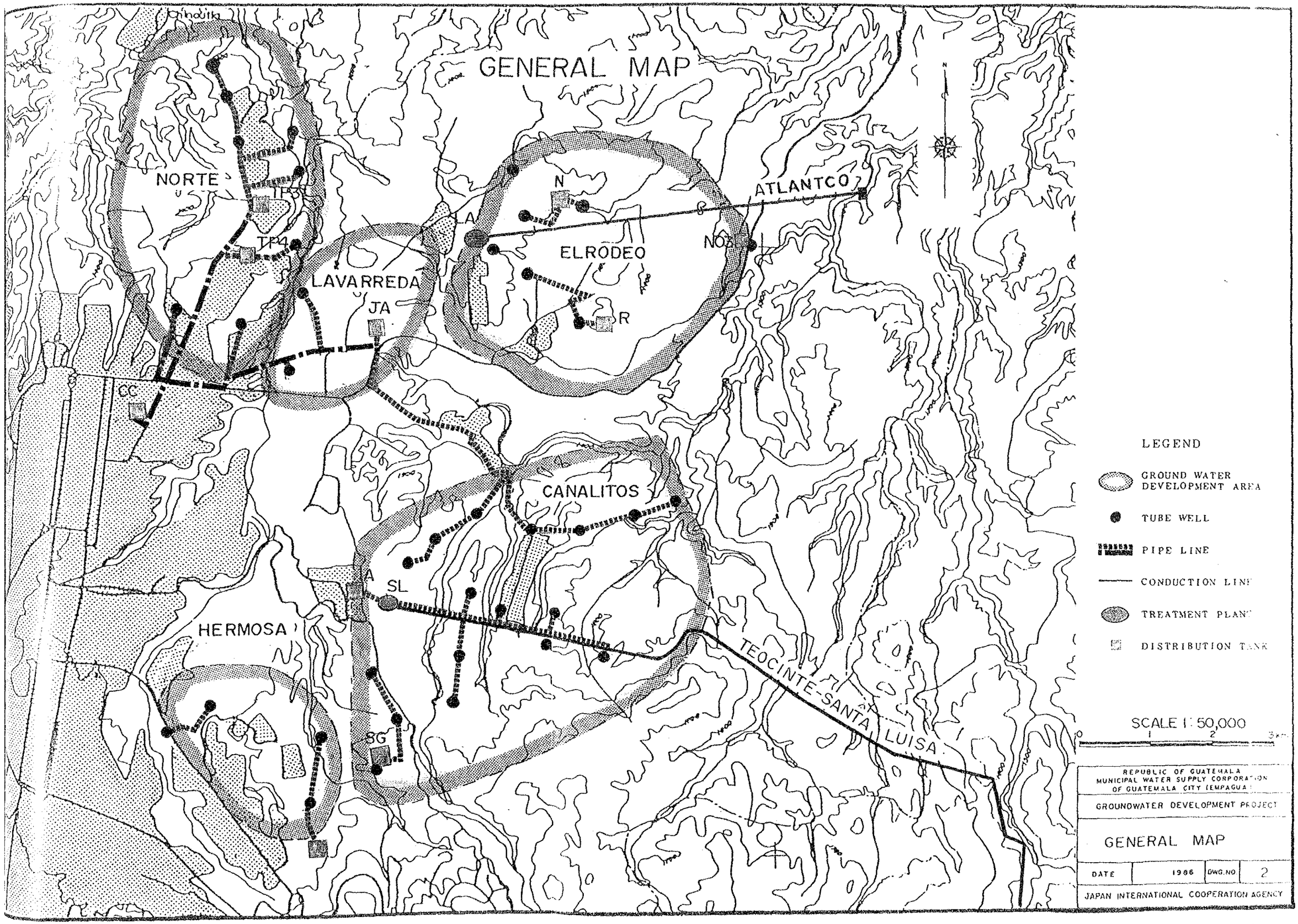
- Wellfields will be selected in order to supply areas of shortage designated under the water supply plan.
- Transmission route and location of wellfields will be selected in consideration of criteria of topography, geography, economy and ease of access.
- Location and number of wellfields and arrangement of wells will be determined to reduce mutual interference and to maintain production capability and prevent efficiency drop.
- Location of wellfields will be determined to minimize the required cost and to maximize efficiency of water transmission from the wellfield to existing water works.

According to the above criteria five out of the original eight blocks mentioned in section 4.2.3 were selected for development under the Project. (FIG. 4-3)

The general features of the selected wellfield blocks are as follows:

Block	Estimated potential (l/s)	Existing yield (l/s)	Development potential yield (l/s)	Estimated well No.	Estimated well yield (l/s)	Average well yield (l/s)	Target total yield (l/s)
Canalitos	I III 492 + 284 = 776	24	752	17	44	30	510
Lavarreda	II 358	35	323	2	161	35	70
Norte	VI 568	260	308	8	39	35	280
El Rodeo Zona 18	IV 336	8	328	7	46	20	140
Vista Hermosa	VIII 245	23	222	4	55	30	120

GENERAL MAP


NORTE
TP3
TP4
LAVARREDA
JA
CC
N
A
ELRODEO
R
ATLANTCO
NOZ
CANALITOS
A
SL
HERMOSA
SG
TEOCINTE-SANTA LUISA
LEGEND
GROUND WATER DEVELOPMENT AREA
TUBE WELL
PIPE LINE
CONDUCTION LINE
TREATMENT PLANT
DISTRIBUTION TANK
SCALE 1:50,000
1
2
3km
REPUBLIC OF GUATEMALA
MUNICIPAL WATER SUPPLY CORPORATION
OF GUATEMALA CITY (EMPAGUA)
GROUNDWATER DEVELOPMENT PROJECT
GENERAL MAP
DATE
1986
DWG.NO
2
JAPAN INTERNATIONAL COOPERATION AGENCY

2) Well Numbers and Location

In consideration of the area, general features, topography, and target yield of the respective wellfield blocks, the well numbers and the unit yield per well are tentatively determined.

However, although it is assumed that there will be some variation in unit yield per well, at the present stage the said yield is tentatively estimated as being equal for all wells in the same wellfield.

The locations of the wells are tentatively selected by map. Therefore, prior to implementation, it is considered necessary to reconfirm these positions through a detailed survey.

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

Wellfield block	Potential well no.	Average yield per unit well l/sec
Canalitos	17 1/	30
Lavarreda	2	35
El Rodeo	7 1/	20
Vista Hermos	4	30
Norte	8	35
Total	38	

1/: including one existing Test well.

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

3) Annual Production Program

The annual production program was established in consideration of the following conditions.

Required distribution program to meet projected demand:

Target area	Northeast metropolitan area	City Center	North metropolitan area
1990	0.20m^3/s	0.5m^3/s	-
1995	0.42	0.54	0.04m^3/s
2000	0.74	0.18	0.08
As of 1985:			
Demand	0.33	1.22	0.27
Deficit	0.10	0.27	0.07
Source	Las Ilusiones	All plants other than Brigada and Las Ilusiones	Santa Luisa City Well

Actual envisioned production program

	Northeast metropolitan area	City Center	North metropolitan area	Total
First year	0.07m^3/s	0.19m^3/s	0.06m^3/s	0.32m^3/s
Second year	0.24	0.10		0.34
Third year	0.13	0.19	0.02	0.34
Total	0.44	0.48	0.08	1.00

4) Transmission Pipeline System

Under the Project the produced water is conveyed from each production site to the point of distribution origin according to the distribution plan as outlined in the above.

The transmission pipeline systems and alignment shall be planned in consideration of the following conditions:

- Elevation differences between the respective well sites
- Elevation differences between the wellfield and the point of distribution origin
- Topographic conditions on the route of the transmission pipeline route
- Proximity of the existing pipeline and facilities
- Scale and expense of the required facilities and construction works.

As presented in Appendix-II, the following thirteen transmission systems have been planned as a result of comparing the alternatives for the selection of the optimum water distribution and transmission plan.

Estimated Annual Production Program by Wellfield

Wellfield	Canalitos (I&II&III)	Lavarreda	El Rodeo Zona 18	Vista Hermosa	Norte	Total 1/ m^3/s
First year	0.21	0.07	0.08			0.36
Second year	0.21	-	0.06	-	0.105	0.375
Third year	0.09	-	-	0.12	0.175	0.385
	0.51	0.07	0.14	0.12	0.28	1.12

1/: Including of production of the reserve wells.

Wellfield	Terminus of transmission sytem	Transmission discharge m^3/s	Transmission system	No. of wells
Canalitos	Juana de Arco water tank	0.240	Booster pump	7
	Santa Luisa Chlorination Plant	0.18	Gravity	7
	San Gaspar new water tank	0.090	Gravity	3
Norte	Tank 3	0.210	Booster	6
	Tank Carmen (Tank Carmen)	0.070 (0.153)	Booster Booster	2 (7)
Lavarreda	Juana de Arco	0.070	Booster	2
El Rodeo Zona 18	New tank	0.040	Gravity	2
	Direct delivery and Las Ilusiones	0.020	Gravity	1
	Las Ilusiones	0.060	Gravity	2
	Existing pipe	0.020	Gravity	1
Vista Hermosa	New tank	0.090	Gravity	3
	Existing pipe	0.030	Gravity	1

( ) : Transmitted from Tank 4-4
1/ : Boost by submergible pump

In nine of the thirteen lines, the water produced at the well sites will be directly conducted to the point of distribution origin through the transmission pipelines by gravity and, in another four lines, the water will first be collected in a reservoir, and then sent to the point of distribution origin by booster pump.

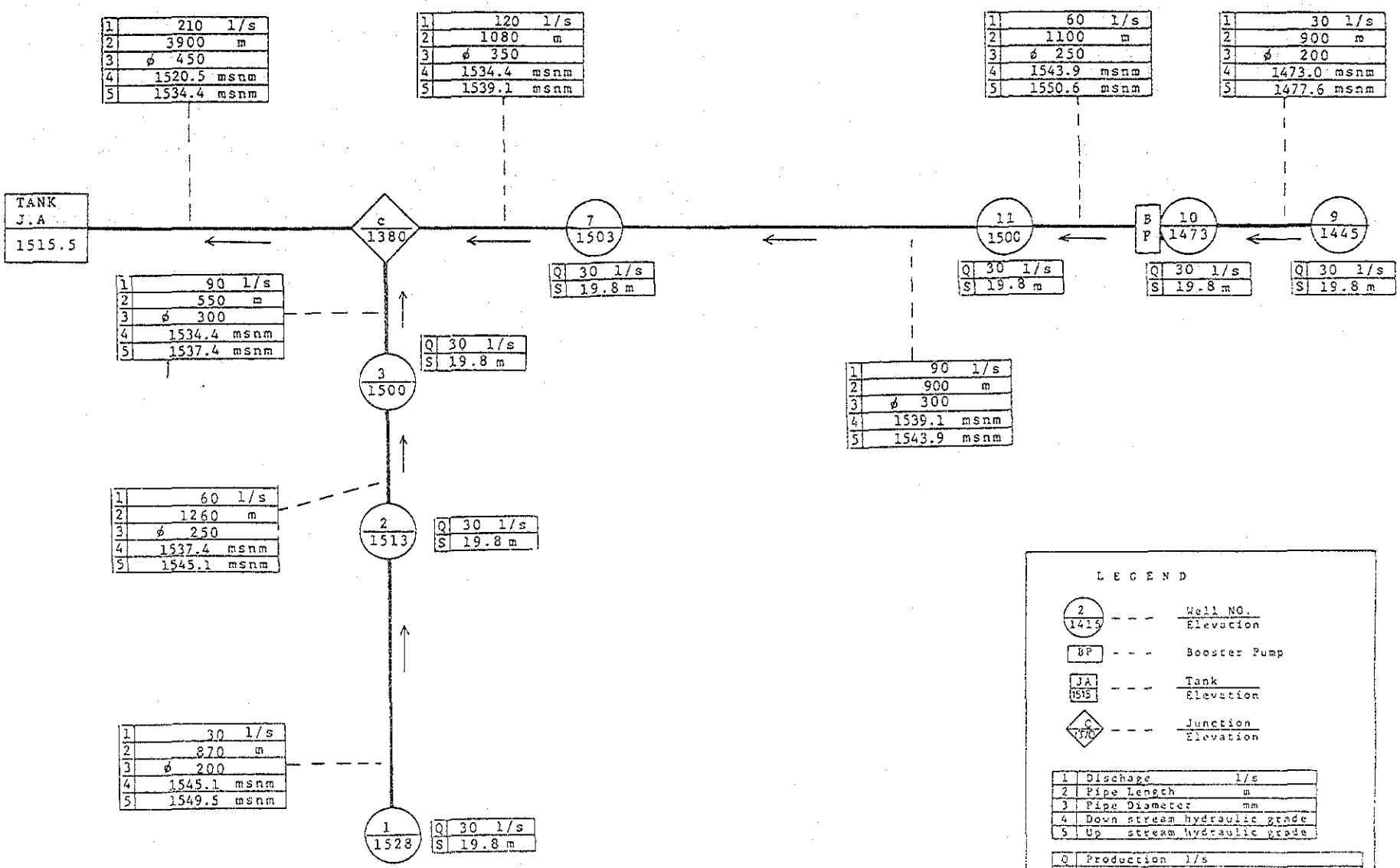
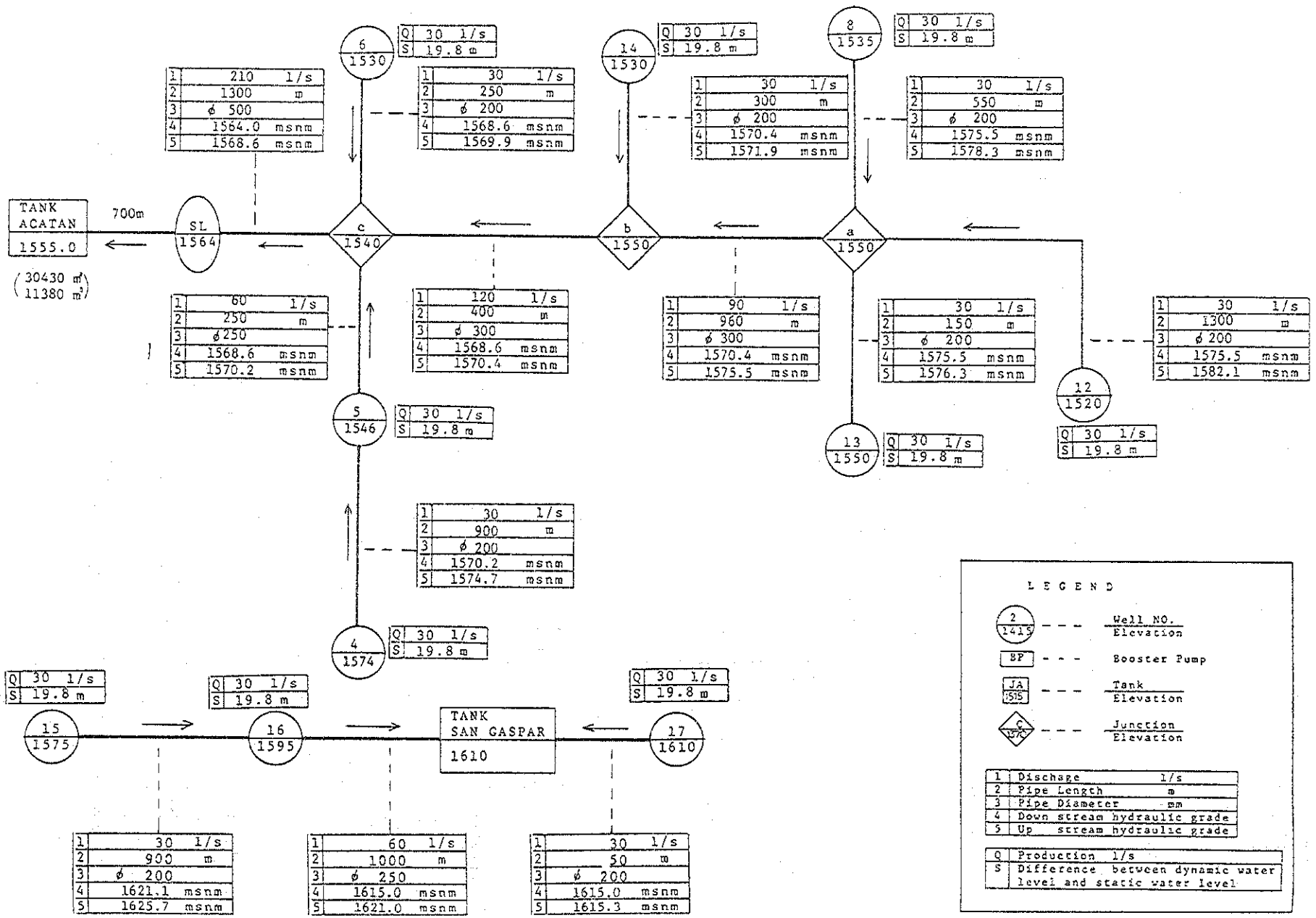
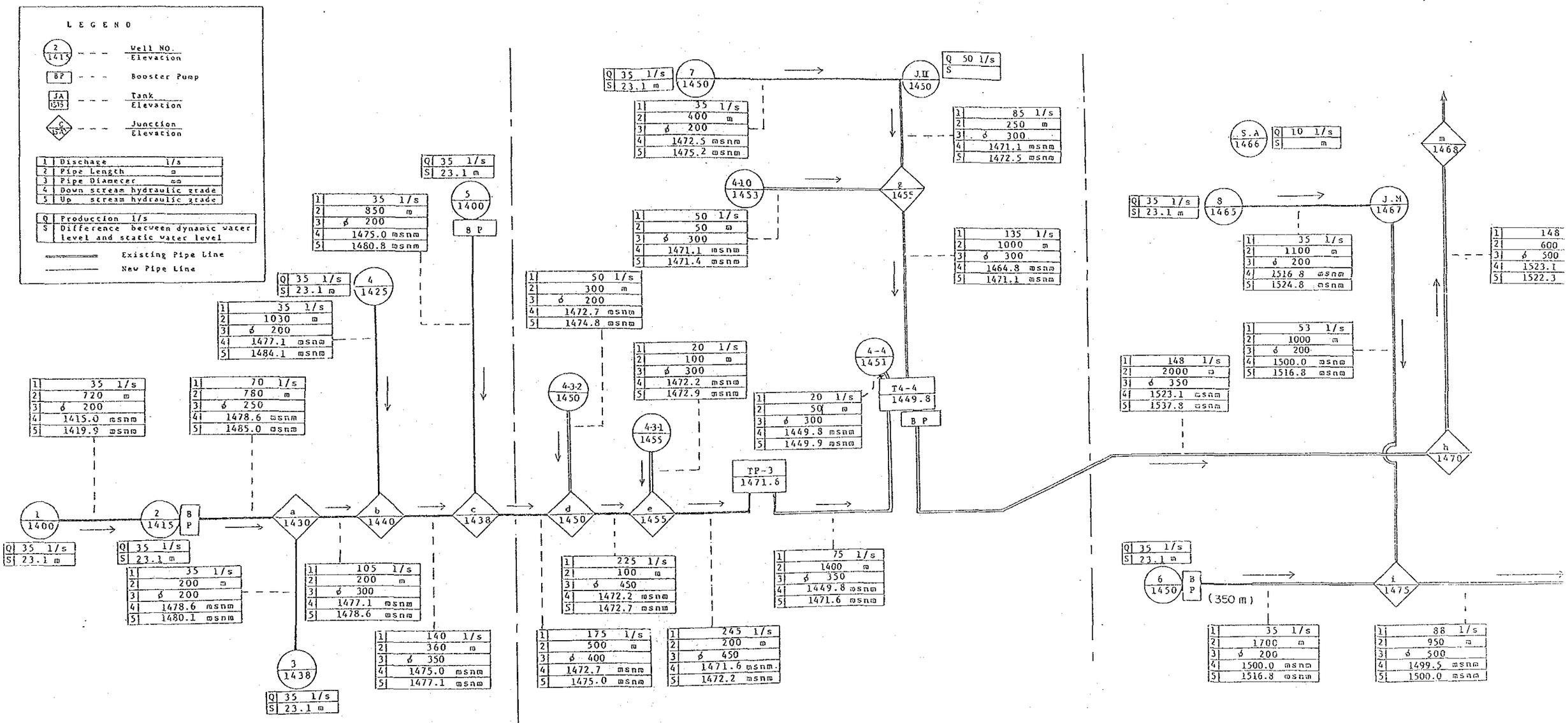


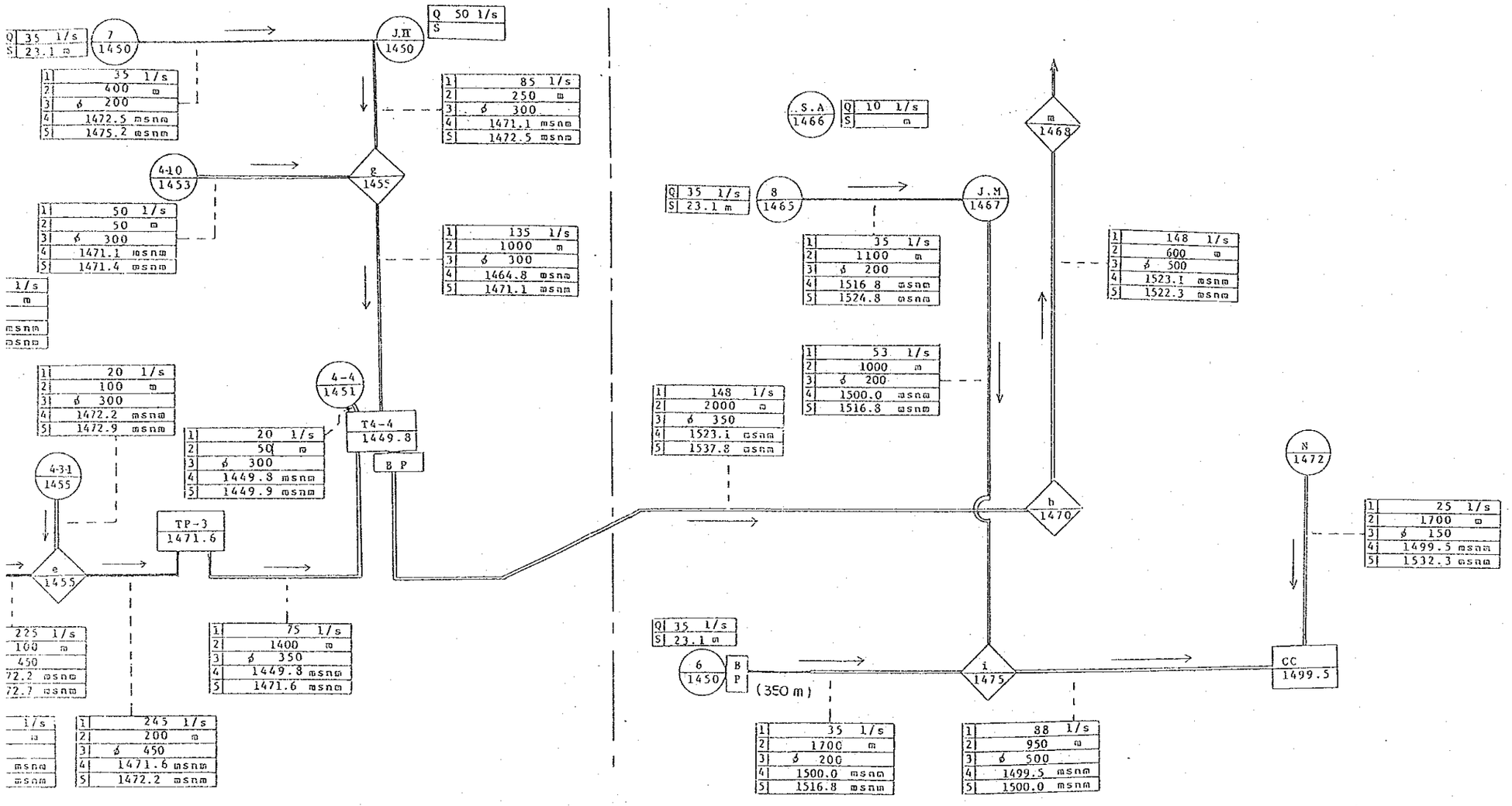
FIG. 4-3 TRANSMISSION LINE SCHEME CANALITOS (1)



TRANSMISSION LINE SCHEME CANALITOS (2)



TRANSMISSION LINE SCHEME NORTE


Q 35 l/s
S 23.1 m
7
1450
J.H
1450
Q 50 l/s
S
1 35 l/s
2 400 m
3 ϕ 200
4 1472.5 msnm
5 1475.2 msnm
1 85 l/s
2 250 m
3 ϕ 300
4 1471.1 msnm
5 1472.5 msnm
4-10
1453
g
1455
1 50 l/s
2 50 m
3 ϕ 300
4 1471.1 msnm
5 1471.4 msnm
1 135 l/s
2 1000 m
3 ϕ 300
4 1464.8 msnm
5 1471.1 msnm
1 20 l/s
2 100 m
3 ϕ 300
4 1472.2 msnm
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4-4
1451
T4-4
1449.8
B P
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1 75 l/s
2 1400 m
3 ϕ 350
4 1449.8 msnm
5 1471.6 msnm
1 245 l/s
2 200 m
3 ϕ 450
4 1471.6 msnm
5 1472.2 msnm
S.A
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Q 10 l/s
S m
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Q 35 l/s
S 23.1 m
8
1465
J.M
1467
1 35 l/s
2 1100 m
3 ϕ 200
4 1516.8 msnm
5 1524.8 msnm
1 148 l/s
2 600 m
3 ϕ 500
4 1523.1 msnm
5 1522.3 msnm
1 53 l/s
2 1000 m
3 ϕ 200
4 1500.0 msnm
5 1516.8 msnm
1 148 l/s
2 2000 m
3 ϕ 350
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3 ϕ 150
4 1499.5 msnm
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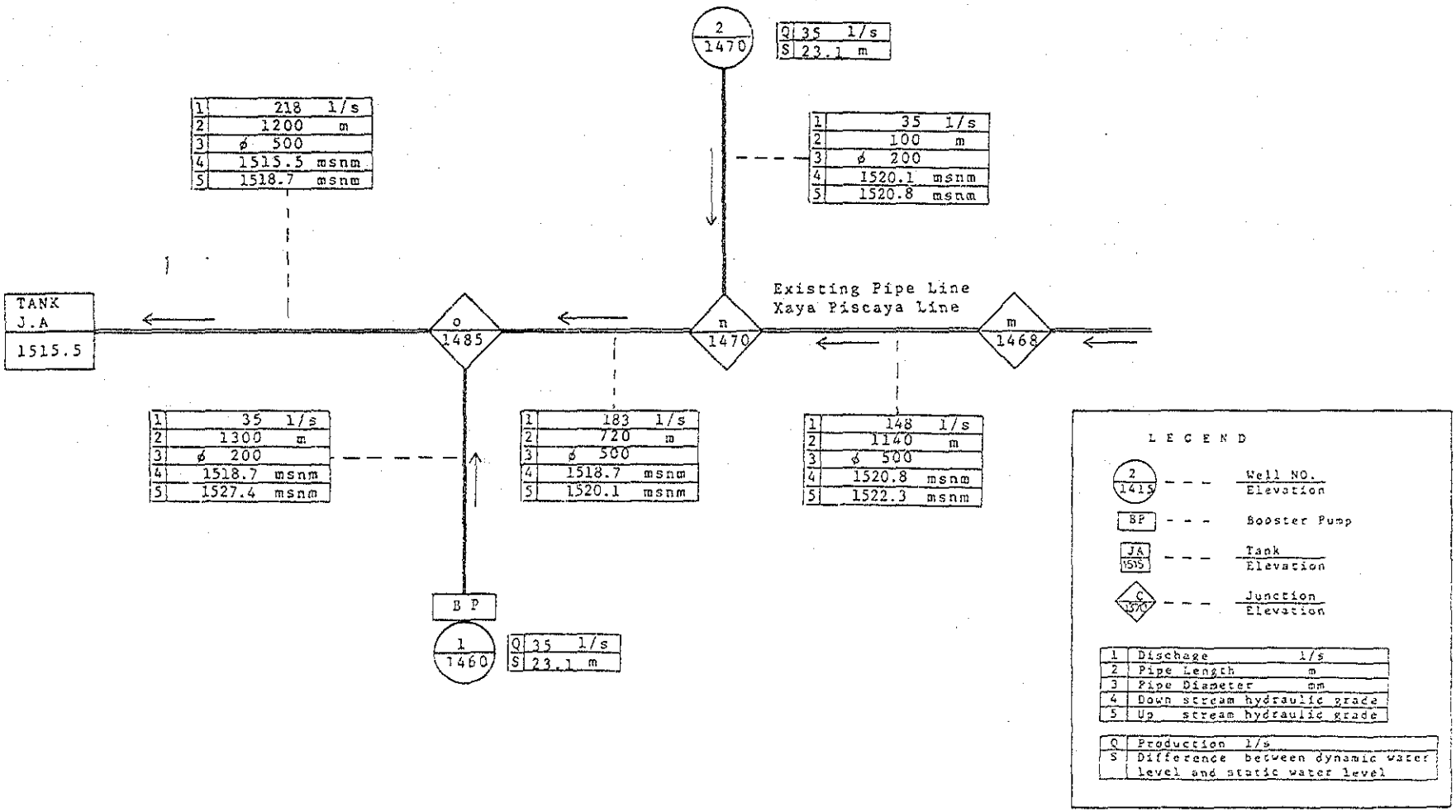
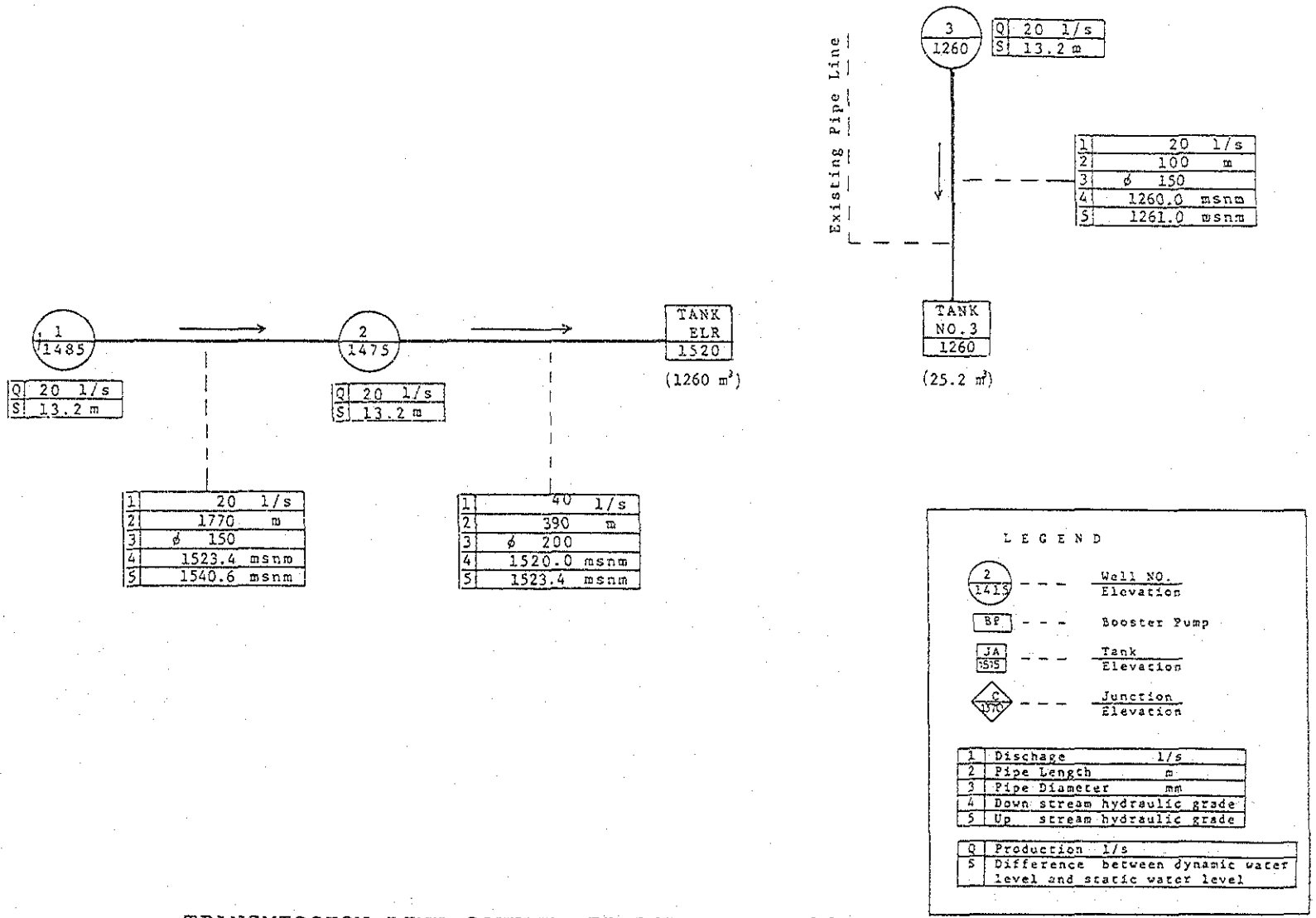
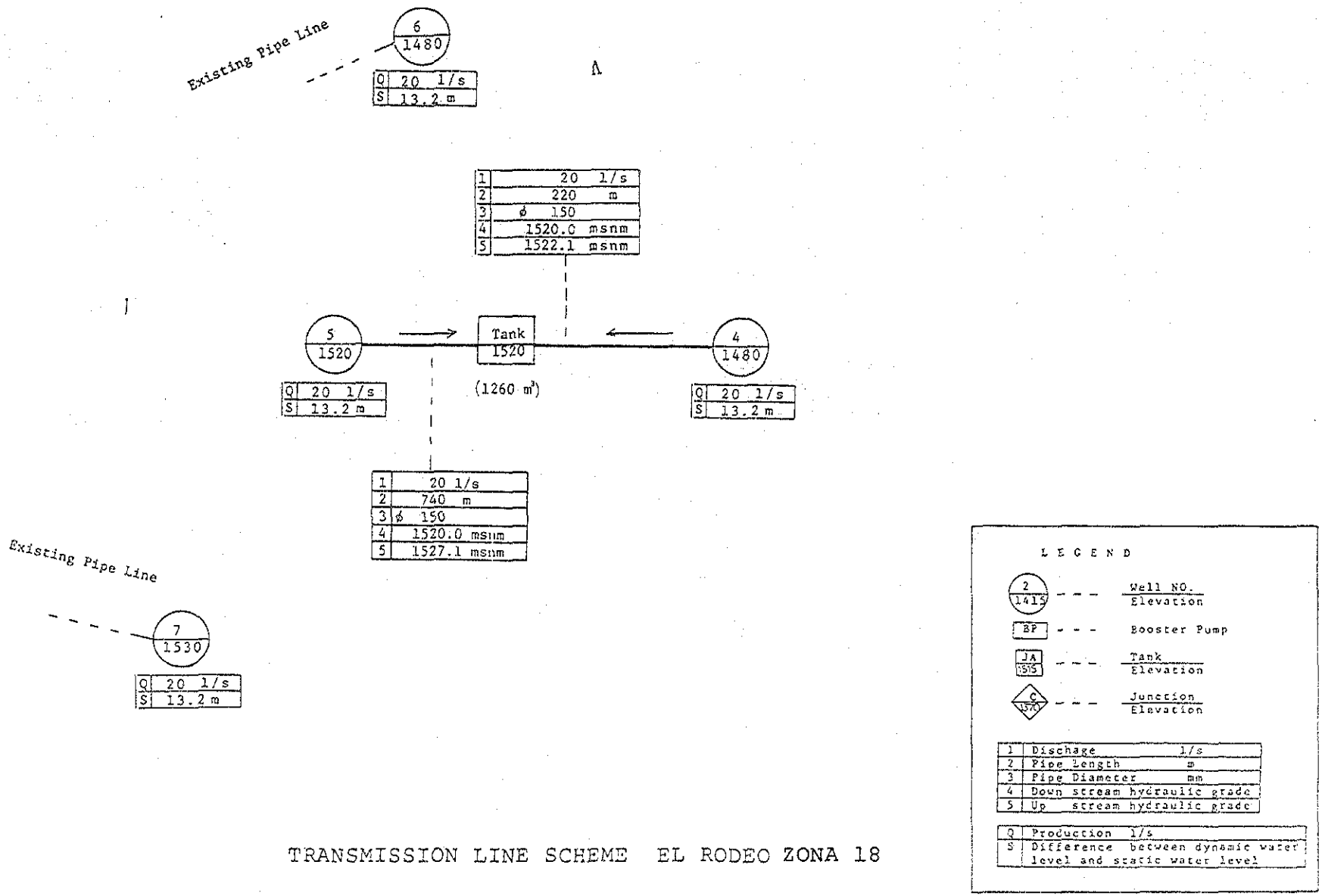
1499.5
1 35 l/s
2 1700 m
3 ϕ 200
4 1500.0 msnm
5 1516.8 msnm
1 88 l/s
2 950 m
3 ϕ 500
4 1499.5 msnm
5 1500.0 msnm
NORTE



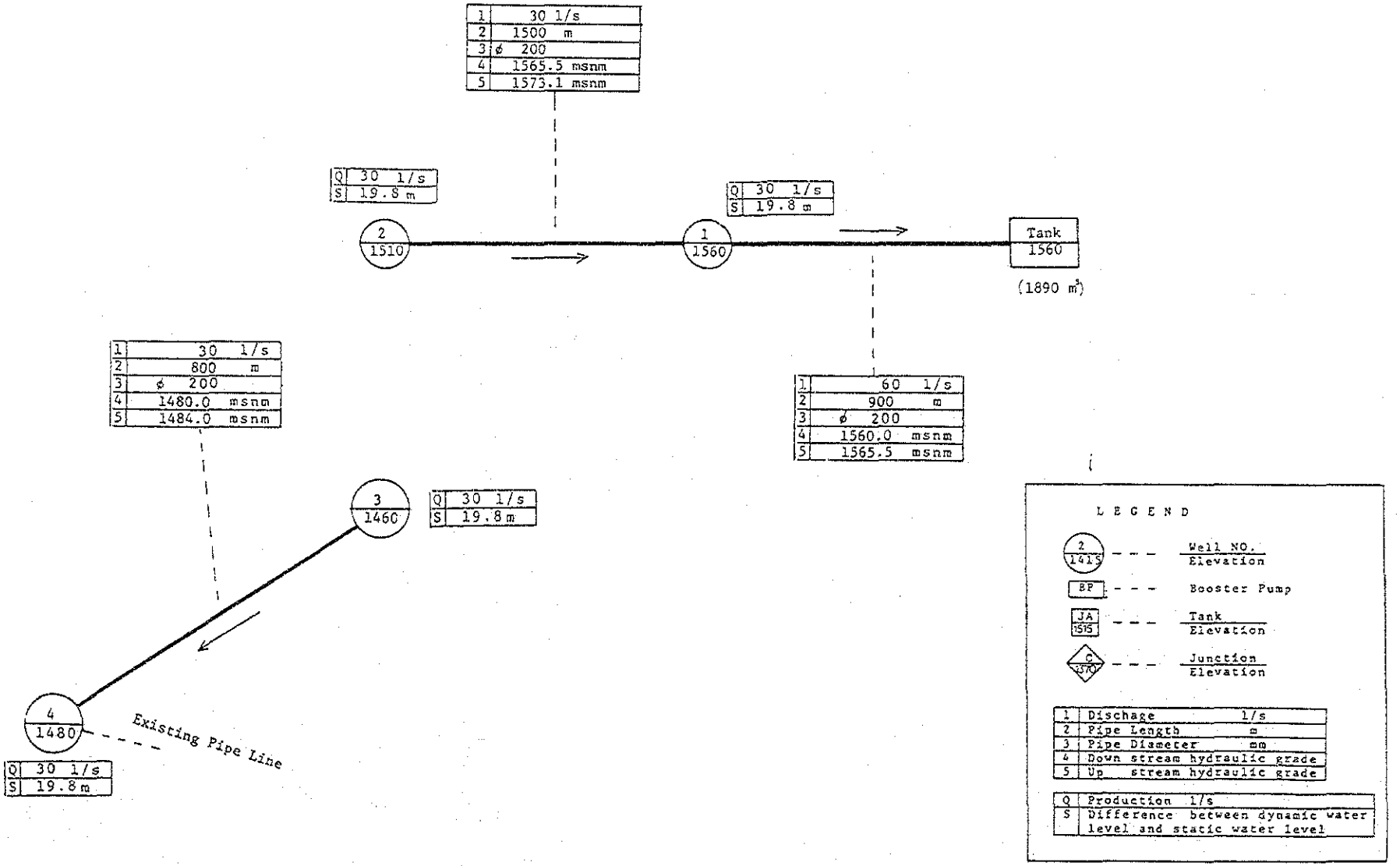
TRANSMISSION LINE SCHEME LAVARREDA



TRANSMISSION LINE SCHEME EL RODEO ZONA 18



TRANSMISSION LINE SCHEME EL RODEO ZONA 18



TRANSMISSION LINE SCHEME VISTA HERMOSA

4.3.4 Rehabilitation

(1) Basic Approach

1) EMPAGUA estimates 3.70 m^3/s of water demand by 1990 for the EMPAGUA water service system, and thus plans to establish production capacity of 3.99 m^3/s by that time. (Refer FIG. II-1)

This water supply plan is estimated on the basis of implementation of the following development plans

Present supply water (at 1985):	2.37 m^3/s
New groundwater development under the proposed Project:	1.00
Rehabilitation under the proposed Project:	0.45
Provision of motor/pump for 7 newly constructed wells:	0.17
Total	3.99 m^3/s

The proposed Project will aim to satisfy water demand of EMPAGUA's consumers in 1990 through the implementation of the proposed groundwater development and rehabilitation program under the Project.

The proposed rehabilitation is therefore necessary to satisfy the projected demand of 3.70 m^3/s by 1990 as indicated above.

2) For the last five years, the average water production of the respective production plants and the respective well fields in the EMPAGUA water service system are as shown in TABLES 4-2 and 4-3.

TABLE 4-2 Annual Average Production per Plant

Plant: Year	Santa Luisa (m^3/day)	El Cambray (m^3/day)	Lo de Coy (m^3/day)	La Brigada (m^3/day)	Ojo de Agua (m^3/day)	Las Ilusiones (m^3/day)	City Wells	Total (m^3/day)
1980	31,360	15,020	60.260	4,780	50,310	13,900	11,520	187,150
1981	31,670	16,080	68,720	7,230	46,900	14,140	10,700	195,440
1982	28,620	15,450	90,120	10.670	46,100	15,290	13,300	219,550
1984	26,962	15,065	86,398	5,726	48,582	20,124	15,530	218,387
	29,452	15,201	78,378	7177	48,868	16,329	12,626	208,031

TABLE 4-3 Annual Average Production per Wellfield

Plant:	Diamante (m^3/day)	Ojo de Agua (m^3/day)	Belen (m^3/day)	Molino (m^3/day)	El Rodeo (m^3/day)	La Brigada (m^3/day)	City wells (m^3/day)	Total (m^3/day)
1980	13,750	22,130	1,540	740	1,940	3,290	7,300	50,690
1981	13,340	25,200	2,110	1,050	480	2,580	7.060	51,820
1982	14,090	21,390	1,560	1,400	1,030	2,170	9,250	50,950
1983	16,110	25,300	310	1,580	1,610	830	8,580	54,320
1994	15,185	16,166	2,173	1,003	1,760	1,890	10,594	58,771
	14,495	24,035	1,539	1,1567	1,364	2,152	8,57	53,310

Recently, despite the fast growth of demand, EMPAGUA's production dropped from levels in previous years due to suspension of production facility operation caused by lack of organized maintenance. Other common problems are over-utilization of equipment beyond its rated life, lack of spare parts and non-replacement of equipment in disrepair.

Production plants such as river intake facilities exhibit a poor performance due to lack of proper operation and maintenance as well as the lack of spare parts. As for production wells, only 37 of EMPAGUA's 57 deep wells are in operation and these reportedly yield only 36% of their potential capacity.

In view of this situation, rehabilitation of existing wells is proposed to supplement production under the proposed Project ($1m^3$/sec) which aims to meet 1988-1992 demand. Wells which have suspended operation or have an extremely low yield due to expiry of service life, etc., will be rehabilitated and a minimum incremental yield of 620 l/sec is planned by said rehabilitation.

In addition, a recommendation on sound engineering practices will be prepared to bolster EMPAGUA's supply capacity by programming the optimum effective utilization of its production and distribution facilities. A brief summary of the major deficiencies in the EMPAGUA system is shown in TABLE 4-4.

(2) Rehabilitation Plan

(1) EMPAGUA has been planning the rehabilitation of existing facilities to improve their present status. In response to the objectives and policy of EMPAGUA, rehabilitation of existing wells should be proposed under this project. Criteria for selecting wells to be rehabilited are as follows:

- Financial breakeven point: 300 GPM with the old water rate.
- Demand or necessity, even at a financial loss.

TABLE 4-4 DEFICIENCIES AND PROBLEMS IN THE EMPAGUA SYSTEM

System	Problem	Facilities/Causes	Countermeasures
Production	Poor performance of treatment process	Las Ilusiones	Repair of pond
	Poor performance of intake facilities	Atlantico Hincapie, Canalitos	Rehabilitation of intake gate, augmentation of sedimentation pond, review of pump operation, installation of anti-water hammer equipment.
	Poor well yield	Wells	Rehabilitation of well, repair and replacement of pumps, augmentation of distribution facilities
Distribution	Intermittent or no supply in some fragments of the served 24 hour supply	Defective design of transmission and distribution network	Redesign, augmentation of mains, installation of check valves on basis of sound engineering practices, i.e. hydraulic calculation of transmission and distribution network. Coordination and control among production plants and distribution systems.
	35% of water is unaccounted-for and there are no accurate measurement records	Ineffective distribution system, no water meters at production or consumer ends	Establishment of production and distribution control system, including comprehensive leakage control program based on actual measurement by installation of bulk and consumer meters, elimination of Paja system as base for estimation of consumption, etc.

Present conditions of EMPAGUA wells are as follows:

Abandoned	5
Operation suspended	8
Operating	37
Under construction (Zone 6)(pump not yet installed)	7
TOTAL	57

The effect and economic soundness of the proposed rehabilitation was discussed for the 37 operating wells and of these, 23 wells were selected for rehabilitation.

The present conditions of the 23 wells selected is as follows:

- 15 wells : Older than 15 years
- 7 wells : About ten years old; production efficiency remarkably decreased
- 1 well : Several years old; production efficiency decreased caused by lack of spare parts supply or due to mechanical damage.

However, 1 well will be rehabilited by EMPAGUA itself within 1986. Therefore, 22 wells should be rehabilited under the Project.

They are listed in TABLE 4-5.

During the supplementary study period conducted from 22 May to 20 July 1986, 22 existing wells were checked by the Team. Of this total, 12 were examined by T.V. probe. The results of the study are as shown in TABLE 4-6. Based on the study results, the following works are proposed for the 22 wells.

- Despite the fact that it has only been several years since construction in the case of some wells, pumping efficiency is not good due to the low pump capacity (such as at the Juana de Arco well). These wells should be restored to the optimum pumping capacity.

- Most wells less than 15 years old are provided with bore hole type pumps because of the high water table. Pumping efficiency, especially during the dry season has decreased due to lowering of the water table. These pumps should be replaced with submersible motors pumps which are less affected by lowering of the water table.
- Pumps more than 15 years old are already past their effective life. The pumps and motors should be replaced with submersible pumps and motors in consideration of pumping efficiency and maintenance.
- All wells should be cleaned by jets and chemical input.
- Required repairs for damaged casing
- Introduction of remote control system for the Ojo de Agua wellfield.

TABLE 4-5

Wells Targeted for Rehabilitation

No.	Name	Design Capacity	Casing pipe Diameter	Static Head	Depth to Water Table	Completion Year
141	Diamante I	50 l/sec	16	121.92 m	7.62 m	69
140	Diamante II	90 l/sec	12	121.92	7.62	69
143	Diamante III	90 l/sec	12	158.50	7.62	72
144	Diamante VIII	88 l/sec	12	274.32	19.51	77
139	Ojo de Agua I	151 l/sec	12	274.32	0.91	76
138	Ojo de Agua II	151 l/sec	12	274.32	5.49	76
137	Hincapie	31 l/sec	8	213.36	0.08	77
22	J A Salazar	31 l/sec	8	195.07	56.39	77
30	Brigada I	20 l/sec	8	213.36	84.73	68
29	Brigada II	18 l/sec	8	182.88	81.08	66
20	Diagonal VI	31 l/sec	8	222.50	51.50	69
21	Colonia ElMaestro	31 l/sec	8	213.36	50.60	77
16	Santo Domingo	44 l/sec	8	138.99	323.00	69
15	Parque Colon	31 l/sec	8	201.17	33.53	69
28	Filtros Brigada I	31 l/sec	8	289.56	46.33	70
27	Filtros Brigada II	31 l/sec	8	259.08	73.76	70
38	Belen III	31 l/sec	8	259.08	73.76	70
18	Ciudad Vieja I	20 l/sec	8	204.80	37.24	70
145	Diamante V	189 l/sec	16	310.98	7.62	72
142	Diamante VI	63 l/sec	15	304.88	26.00	72
24	Arcos I	29 l/sec	8	182.93	59.15	76
278	Juana de Arco	22 l/sec	8	274.39	161.59	82

(2) As a result of the implementation of this proposed rehabilitation plan, the water production will be increased as follows:

Total Design Capacity	Target Yield	Present Yield	Increased
1273 l/s	920 l/s	538 l/s	382 l/s

Consequently, total water production will be as shown in the following table with execution of the rehabilitation plan.

Description	Actual production (without rehabilitation)		With rehabilitation (l/sec)		Increase
	Under the Project	By EMPAGUA	Under the Project	By EMPAGUA	
Wells of Ojo de Agua	400	40	640	60	260
Wells in the City	138	42	280	90	190
Wells in Zone 6	0	0	0	(170)	(170)
Total	538	82	920	150 (320)	450 (620)

4.3.5 Operation and Maintenance

(1) Basic Approach

The effective function of the Project facilities depends on a properly organized operation and maintenance system, as inappropriate operation and maintenance will jeopardize attainment of Project objectives.

The proposed O/M program (as a component of the Project) and a recommendation on overall O/M practices will include the following basic approaches:

- Minimization of the O/M cost through introduction of a semi-remote control system to minimize O/M staff

- Establishment of a systematic O/M program that allows for rotational operation with 10% reserve production capacity at all times and reserve storage of 25% at existing distribution water tanks.
- Introduction of accurate metering for both water production and distribution to strengthen quantity control
- Establishment of an observation system that contributes to groundwater conservation

1) Production Control

Production control is related to the two prime attributes of the end product: plentiful water supplied at the required time and place; and clean, safe, colorless, odorless and tasteless water ensured at every consumer connection.

The target of production quantity control is to ensure the distribution of water from treatment plants and wells to consumers. This requires a central control system covering all EMPAGUA facilities including a transmission and distribution network which ensures the necessary water pressure at every water tap under normal circumstances and in the case of emergencies such as fire. It further requires actual measurement and forecast of hourly, daily and seasonal demand and supply. The proposed Project facilities do not include a distribution system, and clear water produced by the facilities is to be transmitted to existing treatment plants or distribution mains. The production control system of the Project, therefore, should be designed for incorporation into a central control unit encompassing the entire EMPAGUA system in order to effect control of production under the Project.

As found in the field survey, however, there is at present no adequately designed distribution network or central system. Some fragments of the served area enjoy year-round 24 hour supply, but others suffer from intermittent or no supply in some seasons. Individual water treatment plants are operating semi-independently without effective coordination. A recommendation should be prepared concerning this aspect.

The main purpose of water quality control is to satisfy the requirement of water quality standards at the consumer end. To attain this target, various requirements must be fulfilled in addition to routine quality analyses of raw and treated water. Such requirements include:

a) Water quality analysis during test operation after completion of facility construction to determine the most suitable treatment process including required quantity of dose;

b) Medical examination of operators concerned to safeguard the production process from infectious diseases;

c) Insulation and cleansing of production facilities;

d) Emergency suspension of water supply when hazardous pollution is found in treated water; and

e) An appeal where necessary to the public or owners of land in the water source conservation area to prevent the introduction of pollutants.

The above items for production control (quantity and quality) should be duly incorporated into the operation and maintenance program.

2) Groundwater Level Monitoring and Yield Control

Since the proposed Project utilizes groundwater for its source, a routine monitoring and control system over not only the Project deep wells but also groundwater aquifers, as inseparable counterparts of well facilities, should be planned. Monitoring and control procedures which can be performed on a daily basis such as measurement of water level and yield should be formulated.

Control over groundwater resources, however, requires a diverse range of undertakings by mobilizing interdisciplinary and hence inter-institutional resources. This constitutes the groundwater conservation program and will be presented in a separate section.

3) Operation and Mainenance of the Project Facilities

The functions of production control including well monitoring will be basically incorporated into the design of the proposed production and supply facilities. The operation and maintenance program aims to maintain these functions at their designed capacities. For that purpose, an operation program is prepared for every component and level of the facilities. Also, maintenance programs are prepared for daily checking and maintenance, and for periodic inspection and servicing. These programs are intended to constitute a basis for the design of required facilities, organization and staff training. They would also be utilized in the preparation of operation and maintenance manuals at the detailed design stage.

(2) Operation System

The operation system for the proposed Project will be formulated according to the proposed groundwater production and water supply systems in order to realize effective and efficient operation and management and to minimize the cost of O/M.

The proposed operation system will consist of 4 systems; a production control and operation system, water supply control and operation system, groundwater monitoring system and facility managment system. The facility management system is as shown in the schematic chart (FIG. 4-4).

The operation system consists of 2 steps: production control and water supply control.

1) Production Control System

The production control system comprises managment and control of the quantity and quality of water production. Operation control will be conducted at each proposed unit well by the production control center located at the reservoir site. Production control of unit wells will basically be carried out under the instructions of the EMPAGUA O/M center. Ordinary daily water production will be controlled according to the

storage capacity of the distribution water tank or the terminal facilities of the water transmission system and will be manually controlled on the basis of their water levels. Accordingly, daily water production will be independenly controlled per transmission system unit.

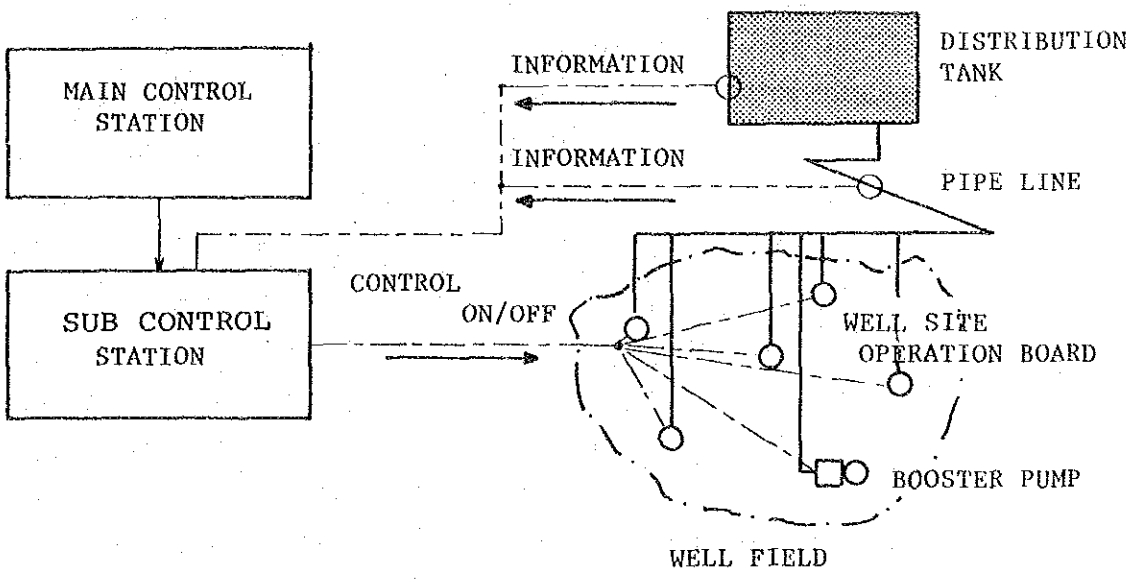
The most efficient control measures will be employed, and the quality and quantity of water production for each unit well will be regularly measured and recorded by the control station at each terminal facility.

Basically, operation of the production and distribution facilities shall be controlled by the daily storage condition of the terminal facilities in the water transmission sysem.

The main control stations to control the water production and transmission system will therefore be arranged at the Santa Luisa and Ilusiones treatment plant office respectively.

The daily operation for each unit well will be remotely controlled at the sub-control station which is to be situated at the site of the end well of each wellfield or at the distribution tank site. The operation for each unit well by the sub-control station will be controlled by the instructions of the main control station. In case of necessity, the operation for each unit well will be directly controlled by the well site control board.

Operation at both the sub-stations and well site will be manual.



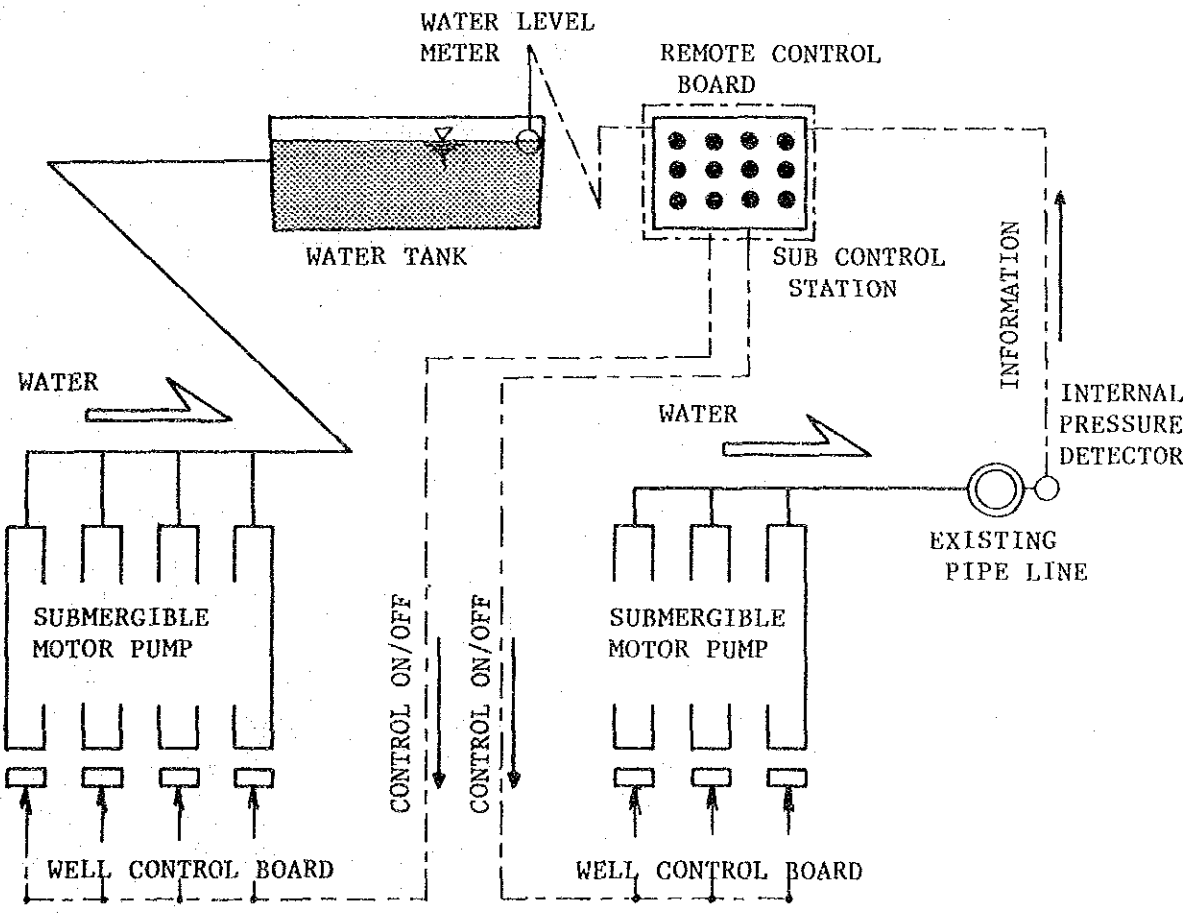


Fig.4-4 OPERATION FLOW CHART

(2) Water Supply Control System

Control of the quality and quantity of water supply will be under the responsibility and instruction of the existing site offices which manage the existing distribution tanks and main pipelines receiving the additional water supply, and which control the water service area of each facility. New control stations or offices will not be established.

Daily control for the transmitted water will be the responsibility of the operation staff and will be performed as required by the status of the distribution tank and water demand in the service area. In the event that production water is transmitted through the existing pipeline, discharge will be adjusted on the basis of existing discharge already flowing through the subject pipeline.

Actual operation of the booster pump etc. for transmittal of water from the reservoir to the existing distribution facilities will be controlled by the operator of the sub-control station at each wellfield site. Basically, all operation, however, will be conducted under the instruction of the main control station.

The water produced under this Project is to be distributed through the existing EMPAGUA system for potable water. Therefore, the water produced should be chlorinated on the basis of the EMPAGUA standards, and a chlorine treatment system will be provided at the end of the transmission route.

4.3.6 Maintenance System

Management of proposed water production and supply facilities and equipment will basically be controlled by the central EMPAGUA O/M office. To prolong the effective life of production equipment and facilities and raise the efficiency of water production, operation of wells will be rotational with a recess period for regular equipment adjustment.

Daily, periodic and occasional 3-level maintenance is proposed according to the EMPAGUA maintenance standards and manual. Daily and occasional adjustment will be the responsibility of each operation and control station, while periodic adjustment will be the responsibility of every control and operation station in cooperation with the EMPAGUA O/M center.

4.4 Groundwater Conservation

4.4.1 General

Two types of groundwater are available in the Project area: upper aquifer and lower aquifer water. They differ in their recharge and aquifer mechanisms.

The annual total pumped up groundwater is estimated at 50 - 70 million m^3. Useful data to distinguish lower aquifer water from upper aquifer water are not available and it is hard to estimate the respective yield.

Natural recharge of the groundwater in the Project area was estimated at approximately 200 million m^3 for this project. On the other hand, the storage of lower aquifers in the same area was estimated at approximately 1,000 million m^3 on the basis of an analysis of geological lithological conditions. The mechanism of groundwater inflow into the Study area is not yet clear; however, it is assumed here that inflow occurs from the lower aquifers of the surrounding area.

The main source for groundwater recharge in this area is precipitation. The annual groundwater pump-up volume in the Study area will be increased to 80 - 100 million m^3 with the implementation of the proposed Project. This total yield corresponds to about 8% of the annual precipitation or about 50% of the annual percolation.

The following factors pertain to groundwater development in the project area:

- Annual total volume of pump-up of groundwater will be increased to 160% of present yield after the proposed Project implementation.
- Pump-up of groundwater continues unregulated at present because groundwater is a useful water source which is both convenient and economical for residents of the project area.
- Conservation capacity of the Project area will rapidly be decreased because of urbanization, deforestation, development of sewers, and the increase of the water demand.
- Groundwater table and discharge to Lake Amatitlan and the Las Vacas river will be reduced with massive groundwater production and the groundwater recharge capacity will drop little by little each year.

In consideration of these circumstances the following active countermeasures should be executed to conserve groundwater.

- Groundwater monitoring
- Regulation of groundwater development (drilling of new wells)
- Regulation of land use
- Artificial recharge of groundwater
- Reforestation and agro-forestation

4.4.2 Groundwater Monitoring Program

A groundwater monitoring system will be established as a groundwater conservation measure under the proposed Project.

The proposed monitoring program will cover the whole Project area for 815 km^2 and include both newly developed wellfield zones and existing wellfield zones.

Groundwater monitoring will be conducted by means of groundwater table observation by eight monitoring wells. Of these, three monitoring wells were already drilled during the Study period to measure the lower aquifer.

The location of the additional 5 wells are to be as follows:

Molino wellfield
Ojo de Agua wellfield
Belen wellfield or Brigada wellfield
Zone 10
Southern part of Zone 17

The location of the existing 3 observation wells are as follows:

El Rodeo Zona 18
Norte
Canalitos

The monitoring for the upper aquifer will be conducted by regular observation of the water table of the production wells at the scheduled time.

To observe the water table at the production wells, water level meters will be provided for the newly developed wells under the Project in addition to one well each at the Ojo de Agua, Brigada, Diamante and Project 4-3 selected from the proposed wells for rehabilitation.

4.4.3 Recomended Artificial Groundwater Recharge

As described previously, groundwater is the most stable, economical and familiar water sources for the Metropolitan Guatemala inhabitants.

The main source for the groundwater natural recharge is precipitation, but this is concentrated in the rainy season from April to September and the recharge capacity in the dry season is much less.

Accordingly, the pumping efficiency for groundwater production is decreased by the lowered groundwater table in the dry season.

However, implementation of the recommended artificial recharge will prevent, lowering of the water table under the proposed Project.

The underground recycling of rainfall is deemed the most effective and necessary countermeasure to stabilize groundwater production, conserve the environment and prevent river contamination.

CHAPTER V

FACILITY PLANNING

CHAPTER V

FACILITY PLANNING

5.1 Groundwater Production System

In planning Project facilities and selection of the required equipments, it is above all necessary to minimize the required energy for groundwater production and conveyance in order to minimize operation cost.

In the case of the proposed Project, however it will be unavoidable that operation costs are high due to the fact that groundwater to be developed under the Project is located at around EL. 1,250 -1,300 m and the intended water service area is situated at around 1,500 -1,600 m.

Under the Project, produced water will be lifted approximately 300 m by pump. Consequently there is a limit to the degree that required power may be minimized for water production and conveyance.

Nevertheless the Project facilities shall be planned to minimize the required power to the extent possible. In addition, to offset power costs, the following criteria will be adopted in system design to maximum reductions in Project costs overall:

i) Maximized limitation of operation and maintenance personnel.

ii) Maximized utilization of existing pipeline.

iii) Maximized transmission of water by gravity or semi-gravity.

iv) Maximized simplification of facilities and equipment.

5.1.1 Wells

As described previously, the wells are intended to lift groundwater from the lower aquifer.

Based on the test boring and hydrogeological survey, it is predicted that the pressure head of the lower aquifer is at approximately EL 1300 m and that the aquifer thickness ranges from 24 m to 50 m.

The ground level of the well site in the each wellfield ranges from EL 1460 to 1600 m.

In general, the wells under the Project are designed on the basis of the following criteria.

Well shaft depth	:	300m - 350m
Effective Casing Diameter	:	12"(300mm)
Drilling Diameter	:	More than 1.5 times larger than casing pipe
Well shaft type	:	Straight
Strainer length	:	70-80% of aquifer
Aperture density of the strainer	:	20% of total suface area
Casing pipe	:	STP
Strainer	:	SUS

The specifications for the wells in each wellfield are summarized as shown in TABLE 5-1.

TABLE 5-1 Specification of Wells

Wellfield	No.	Shaft Length (m)	Site Elevation (m)	Strainer Length (m)	Estimated Average yield (l/s)
Canalitos	1	300	1528	30	30
	2	300	1513	"	"
	3	300	1500	"	"
	4	350	1574	"	"
	5	300	1546	"	"
	6 1/	300	1530	"	"
	7	300	1503	"	"
	8	300	1535	"	"
	9	300	1445	40	"
	10	300	1473	40	"
	11	300	1500	30	"
	12	300	1520	"	"
	13	300	1550	"	"
	14	300	1530	"	"
	15	300	1575	"	"
	16	350	1595	"	"
	17	350	1610	"	"
Lavarreda	1	300	1460	40	35
	2	300	1470	40	35
El Rodeo	1	350	1485	40	20
	2	350	1475	"	"
	3 2/	350	1260	"	"
	4	300	1480	30	"
	5	300	1520	"	"
	6	300	1480	"	"
	7	300	1530	"	"
Vista Hermosa	1	300	1560	30	30
	2	300	1510	"	"
	3	300	1460	"	"
	4	300	1480	"	"
Norte	1	300	1400	40	35
	2	300	1415	"	"
	3	300	14380	"	"
	4	300	1425	"	"
	5	300	1400	"	"
	6	300	1450	"	"
	7	300	1450	"	"
	8	300	1465	"	"

1/ : Test well No.2

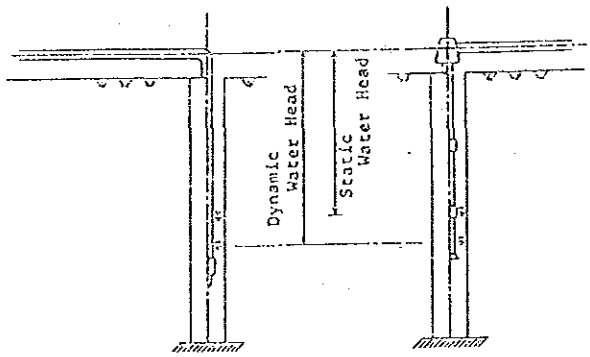
2/ : Test well No.3: additional drill depth 50 m

5.1.2 Pumps and Motors

Generally, turbine pumps, airlift pump and submersible motor pumps are used for deep wells. Recently, submersible motor pumps are being widely used. Selection of pumps for the wells was conducted giving consideration to the following conditions:

Well depth	:	300m
Static water table	:	Max 100m Min 80m
Water table fluctuation	:	20m
Design yield	:	30 l/s
Total head	:	250m

Submersible pump Turbine pump



Q = 30 l/sec

Pump type	Submersible	Turbine (Bore hole)
motor	submersible	on-ground
lifting type	forcing	suction
column pipe	150m/m	180m/m
required power	132kw	150kw
initial cost	1.0	1.62
O/M cost	1.0	1.40
installation	simple	difficult
maintenance	simple	difficult
pump house	not required	required
effective use life	motor - 8 years pump - 15 years	motor, pump - 15 years

It is therefore recommended that submersible motor pumps be used for the Project.

Submersible motor pumps are concluded to be more economical than turbine pumps, as well as having a greater overall efficiency.

Considerations such as these and the predicted general use of these pumps in the future led to submersible motor pumps being adopted for the proposed wells under this Project.

5.2 Water Supply Systems

5.2.1 General features

Thirteen lines are planned for the transmission system to convey the produced water. Required facilities of the proposed transmission systems are as given below:

Name of Line	Pipe Dia mm	Pipe length m	Booster Pump set	Chlorination Unit	Distribution tank
Canalitos-Juana de Arco line	200 250 300 350 400	1770 2360 1450 1080 3900	1 (With outlet tank)	1	Existing. J.A. (2185, 5400m^3)
Canalitos-Santa Luisa Line	200 250 300 500	3450 250 1360 1300	-	-	Existing pipeline (Santa Luisa treatment Plant)
Vista Hermosa line					
(I)	200 250	1500 900	-	1	New tank V=1890m^3
(II)	200	800	-	1	Existing pipe line
El Rodeo Zona 18 line					
(I)	150 200	1770 390	-	1	New tank V=1260m^3
(II)	150	100	-	1	Existing pipe line and cooperative tank 25m^3
(III)	150	960	-	1	New tank 1260m^3
(VI)	150	100	-	1	Existing pipe
(V)	150	100	-	1	Existing pipe

Lavarreda line	200 500	1400 (1940)	1	1	Existing J.A.
Norte line					
(I)	200 250 300 350 400 450	2800 (300) 780 200 (100) 360 500 300	2	2	Existing tank 3
(II)	200 150 300 350 500	1850 (2700) (1700) (1350) (2000) (1550)	2	1	Existing tank (C.C.)
Canalitos - San Gaspar line	200 250	950 1000	-	2	New tank San Gaspar V=2835m^3

( ) : Existing pipe line

5.2.2 Transmission Facilities and Equipment

(1) Pipelines

Basically transmission pipeline is to be buried and pipe material shall be ductile cast iron of class B.

The overall pipeline length is 34.2km. The previous section contains a breakdown of pipe diameter by block.

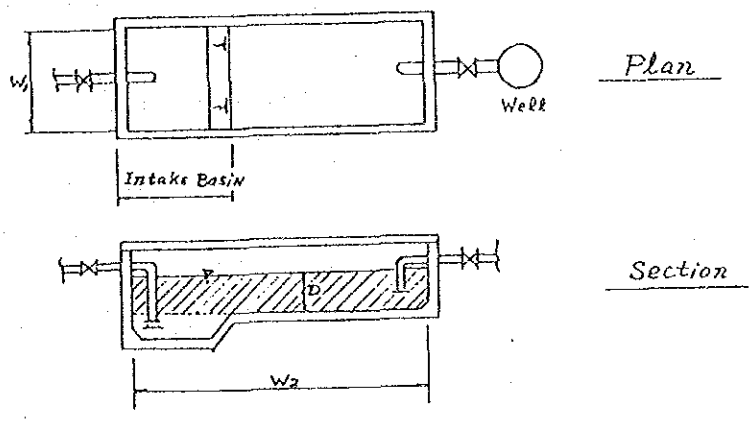
Pipe line is provided with sluice valves to protect against water hammering or surging caused by interruptions of the power supply.

In addition check valves shall be provided where wells are directly connected to pipelines such as in the case of the Canalitos to Santa Luisa line.

Moreover, air valves and drain valves shall be provided at the invert siphons along the pipeline.

(2) Outlet Tanks

Outlet tanks are to be rectangular in configuration and constructed of reinforced concrete with their interior surfaces waterproofed. The storage capacity is to be 30 minutes of well discharge. Water level meters are to be mounted on the side walls. A typical section of the outlet tank is given below.



Outlet tanks are to be constructed at 5 locations. Breakdown by capacity and block is given in the table below.

Transmission Line	Discharge l/s	Nos.	Capacity m^3	Location
Canalitos - J.A.	60	1	108	No. 11 well
Lavarreda - J.A.	35	1	63	No. 1 well
Norte - T.4.4	70	1	126	No. 2 well
	35	1	63	No. 5 well
Norte T4.4-T.C.C	35	1	63	No. 6 well
	875	1	158	No. T well

(3) Booster Pumps

Booster pumps are to be installed at 6 locations where the conveyance between storage facilities such as distribution tank or outlet tank requires pressure transmission. Multistage volute pump will be used to boost the pumped up water.

Booster pumps will be installed such as to allow for approximately 100 - 50 percent stand-by capacity at each pump station. A breakdown of booster pump locations is given in the table below.

Transmission Line	Discharge m^3	Design Head m	Required kw.	No. of Pumps
Canalitos - JA	60	70.0	75	2
Lavarreda - JA	35	82.0	45	2
Norte - T.3 (I)	70	72.0	75	2
(II)	35	80.0	45	2
T.44 - T.CC. (I)	87.5	70.0	110	3
(II)	35	74.0	45	2

(4) Pump Houses

Pump houses will be constructed to shelter booster pumps and their operators. Switchboards for submersible motor pumps and booster pumps will be installed in the pump houses. Dimensions vary from 4m base x 5m length x 2.1m height to 6m base x 10m length x 2.1m height. Construction is to be of reinforced concrete.

Pipeline is to be protected against water hammer caused by interruption to the power supply.

(5) Water Tank

Terminal distribution water tanks will be constructed at the end of transmission pipelines to store a 7 hour production volume with 25 percent stand by capacity. Four water tanks are planned as necessary. Construction is to be of reinforced concrete with interior surfaces waterproofed. The breakdown is summarized below.

Transmission line	Capacity m^3	Length m	Width m	Height m	Ground Elevation m
Vista Hermosa (I)	1890	18.5	18.5	5.6	1560
Canalitos San Gaspar	2835	22.5	22.5	5.6	1610
El Rodeo Zona 18 (I)	1260	15.0	15.0	5.6	1520
El Rodeo Zone 18 (III)	1260	15.0	15.0	5.6	1520

In addition, public water tap and tank with 25 m^3 capacity will be constructed at the No. 3 well site in the El Rodeo wellfield.

(6) Chemical Treatment

Dosing will be carried out at the terminus for each transmission pipeline. As produced water is from lower aquifers, only chlorination will be carried out. A breakdown is summarized below:

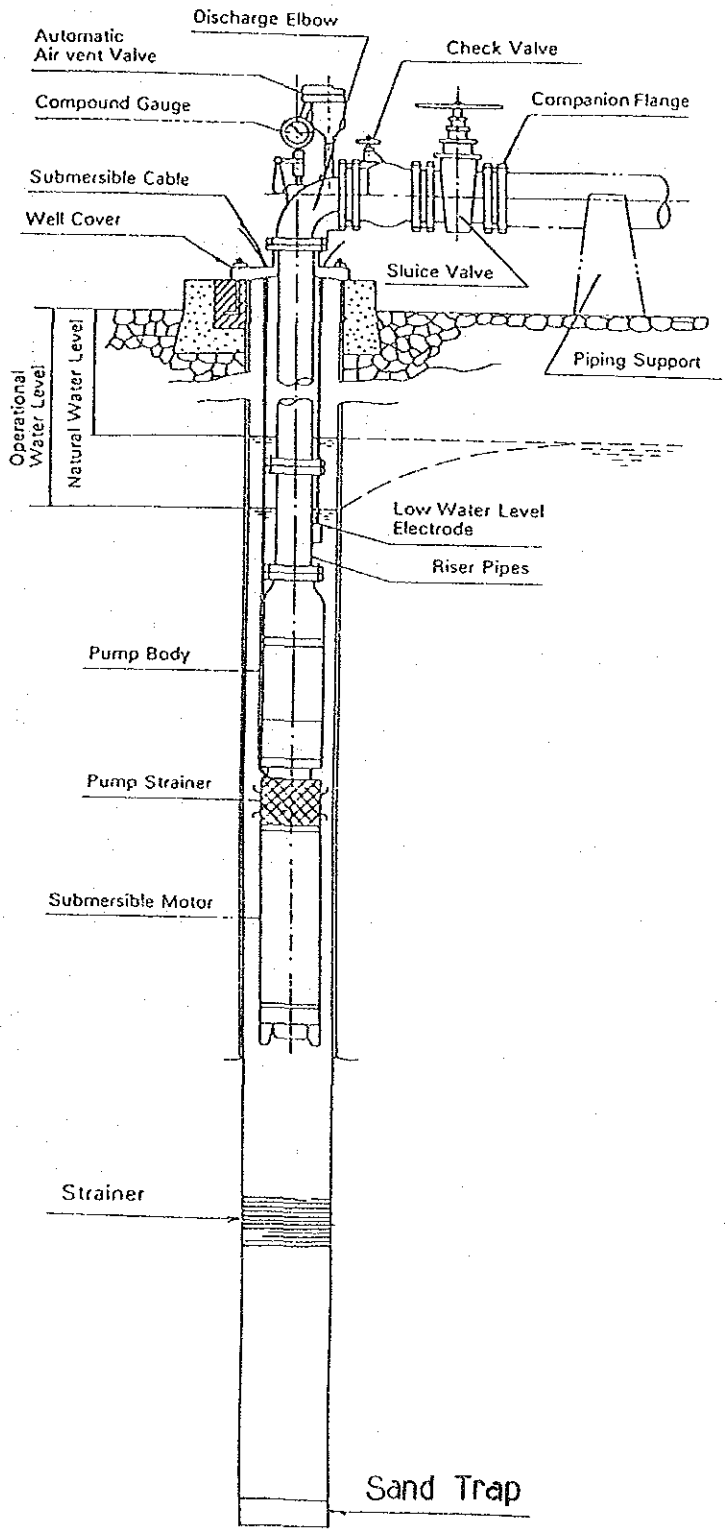
Transmission line	Command Well Nos.	Treatment Water Volume l/s	Remark
Canalitos - JA	8	240	Decolorization, deodorization
Canalitos - S.L.	6	180	Existing Santa Luisa Plant;
Canalitos - San.Gas	3	90	Decolorization, deodorization
Vista Hermosa - (I)	3	90	—— do ——
Vista Hermosa - (II)	1	30	
Norte - (I)	6	210	Decolorization, deodorization
Norte - (II)	2	70	
Lavarreda	2	70	
El Rodeo Zona 18	2	40	
El Rodeo Zona 18	1	20	
El Rodeo Zona 18	3	60	
El Rodeo Zona 18	1	10	

TABLE 5-3 (1)

PROJECT FACILITIES

Item	Well Field	Canalitos			Norte	Lavarreda	El Rodeo Zona 18	Vista Hermosa		
		Juana de Arco	Santa Luisa	San Gaspar						
1. Production Facilities										
(1) Tube Well		7nos x 30ℓ/s	7nos x 30ℓ/s	3nos x 30ℓ/s	8nos x 35ℓ/s	2nos x 35ℓ/s	7nos x 20ℓ/s	4nos x 30ℓ/s	Total 1,120ℓ/s (1,000ℓ/s under 90% of operation efficiency)	
(2) Casing		ø300 300m	ø300 300-350m	ø300 300-350m	ø300 300m	ø300 300m	ø300 300-350m	ø300 300m		
(3) Strainer		30m, 40m	30m	30m	30m, 40m	30m	30m	30m		
(4) Submerged Pump		1nos x 110kW 1nos x 132kW 5nos x 185kW	1nos x 110kW 2nos x 132kW 4nos x 185kW	2nos x 132kW 1nos x 185kW	3nos x 132kW 5nos x 185kW	1nos x 132kW 1nos x 185kW	3nos x 75kW 4nos x 132kW	7nos x 132kW 2nos x 185kW		
2. Water Transmission Facilities										
(1) Ductile Cast Iron Pipe										
	ø150mm	-	-	-	-	-	2,830m	-	Total	2,830m
	ø200mm	1,770m	3,450m	950m	4,650m	1,400m	390m	2,300m		14,910m
	ø250mm	2,360m	250m	1,000m	780m	-	-	900m		5,290m
	ø300mm	1,450m	1,360m	-	200m	-	-	-		3,010m
	ø350mm	1,080m	-	-	360m	-	-	-		1,440m
	ø400mm	-	-	-	500m	-	-	-		500m
	ø450mm	3,900m	-	-	300m	-	-	-		4,200m
	ø500mm	-	2,000m	-	-	-	-	-		2,000m
										(34,180m)
(2) Discharge Tank		108m^3			2nos x 63m^3 126m^3 158m^3	63m^3				
(3) Booster Pump		1nos x 60ℓ/s			2nos x 35 ℓ/s 1nos x 70 ℓ/s 1nos x 87.5ℓ/s	1nos x 35ℓ/s				
(4) Syphon Bridge		2nos x (L=20m)						1nos x (L=20m)		
(5) Distribution Tank				2,835m^3			2nos x 1,260m^3 25.2m^3	1,890m^3		
3. Power Transmission Facilities										
(1) Electric Line Length		2,900m	5,350m	3,400m	3,005m	610m	2,910m	4,600m	Total	22,775m
(2) Transfarmer Number		7nos	7nos	3nos	9nos	2nos	7nos	4nos		39nos
(3) Access Road			3km							
4. O/M Road										
(1) O/M Road Construction		-	250m	50m	1,120	100m	1,260m	400m	Total	3,180m
Widening		1,450m								1,450m
5. Maintenance Facilities & Equipment										
(1) O/M Station			x Santa Luisa				x Las Ilusiones		x : Existing o : Construction	
(2) Sub Station		o Juana de Arco	o Santa Luisa	x San Gasper	x T.K. 4-4	x Lavarrede	x Las Ilusiones	o Hermosa		
(3) Transceiver (UHF)		2nos x (Main Transceiver) 15nos x (Handy Transceiver) 2nos x (Battery Charger)								
(4) Work Shop		1nos 250m^2 (New Construction)								

Fig. 5-00 TOPICAL SECTION OF THE WELL



5.3 Rehabilitation

Under the Project, the following works for the rehabilitation of existing wells will be performed:

Wells for rehabilitation	:	22 wells
Cleaning by jet pump and piston	:	22 wells
Replacement of existing pumps with submersible motor pumps	:	22 wells
Installation of riser pipe	:	22 wells
Provision of control panels	:	22 wells
Provision of Remote Control Board	:	1 set

5.4 Electric Power Supply Facilities

5.4.1 Power Source

Under the Project, the pumps for each well and the booster pumps to transmit the water produced from wellfieds to existing distribution facilities will be electrically operated and controlled.

Therefore, the required electrical power will have to be transmitted from the nearest existing power line or sub-station.

The electrical power will be taken from INDE. Construction works for transmission to and distribution at respective well sites will be the responsibility of Empresa Electrica De Guatemala, S.A. However funding for said electrical works will be provided under the Project.

1) Works under the Responsibility of EEGSA

Around the area of each wellfield block are available power transmission lines which will be able to distribute power for the Project. Required electric wiring from power transmission power lines to respective well sites will be conducted under INDE's responsibility with the condition of expenses for construction being borne by the Project.

Required total length of the wiring will be approximately 20.3 km. The breakdown of wiring length is given as below:

Wellfield	No. of Well	Booster Pump	Required Wiring Length (m)
Canalitos	17	1	11,650
Norte	8	4	3,005
Lavarreda	2	1	610
El Rodeo Zona 18	7	-	2,910
Vista Hermosa	4	-	4,600
Total	38	6	22,775

2) Electrical Works under the Responsibilty of the Project

Procurement, erection, and wiring for the switchboard, transformer, and other required accessories, will be carried out under the Project.

Switchboards and transformers will be provided at each well site and booster pump site, respectively.

5.5 Monitoring Facilities

5.5.1 Observation Wells

The observation wells that are to be newly constructed under the Project are planned according to the following specifications.

Objective aquifer	:	Lower aquifer
Well shaft depth	:	300m
Well shaft diameter	:	4"(100mm)
Strainer	:	Slit type
Aperture density of strainer	:	3% of surface area
Strainer length	:	50m

The observation well sites are tentatively proposed for locations close to existing EMPAGUA well fields and are as follows:

Molino wellfield, Ojo de Agua wellfield, Belen wellfield or La Brigada Plant, Zone 10, and Zone 17 (in proximity to Finca Santa Clotilde).

The three observation wells that were constructed by JICA during the survey period are to be included in the observation wells under the Project.

5.5.2 Observation Equipment

The eight observation wells shall be provided with automatic recording water table meters, while automatic water table meters shall be provided for five existing wells selected from among the wells for which rehabilitation is to be conducted under the Project.

5.6 Operation and Maintenance Facilities

5.6.1 Operation Control facilities

(1) Main Control Station

As shown in Fig 5-2, four main control stations to control the groundwater production systems and the transmission system for the water produced are arranged at the water distribution tanks or near the connection sites of existing distribution pipe and new transmission pipe lines.

- Four (4) main control stations will be established at existing distribution plant offices.
- A radio system shall be provided to control the subject transmission system and production system.
- Alarm units will be provided to monitor water level of the distribution tank and the internal pressure of the existing distribution pipe.

(2) Sub-control station

As shown Fig 5-2, eight sub-control stations to control directly the groundwater production system and transmission system are located at booster pump sites or at the head of the respective wellfield. These buildings are to have a floor area of 40 m^2 and shall be of reinforced concrete construction.

These sub-control stations are provided with the following equipment:

- Radio system : 1 unit
- Remote control panels for the wells and booster pump : 1 unit

(3) Well control board

Generaly, the wells will be remote controlled from the sub-control stations, while manual switch operation panels will be provided at well sites.

Telephone connections shall be provided from sub-control stations to the operation panels at each well.

OPERATION FLOW

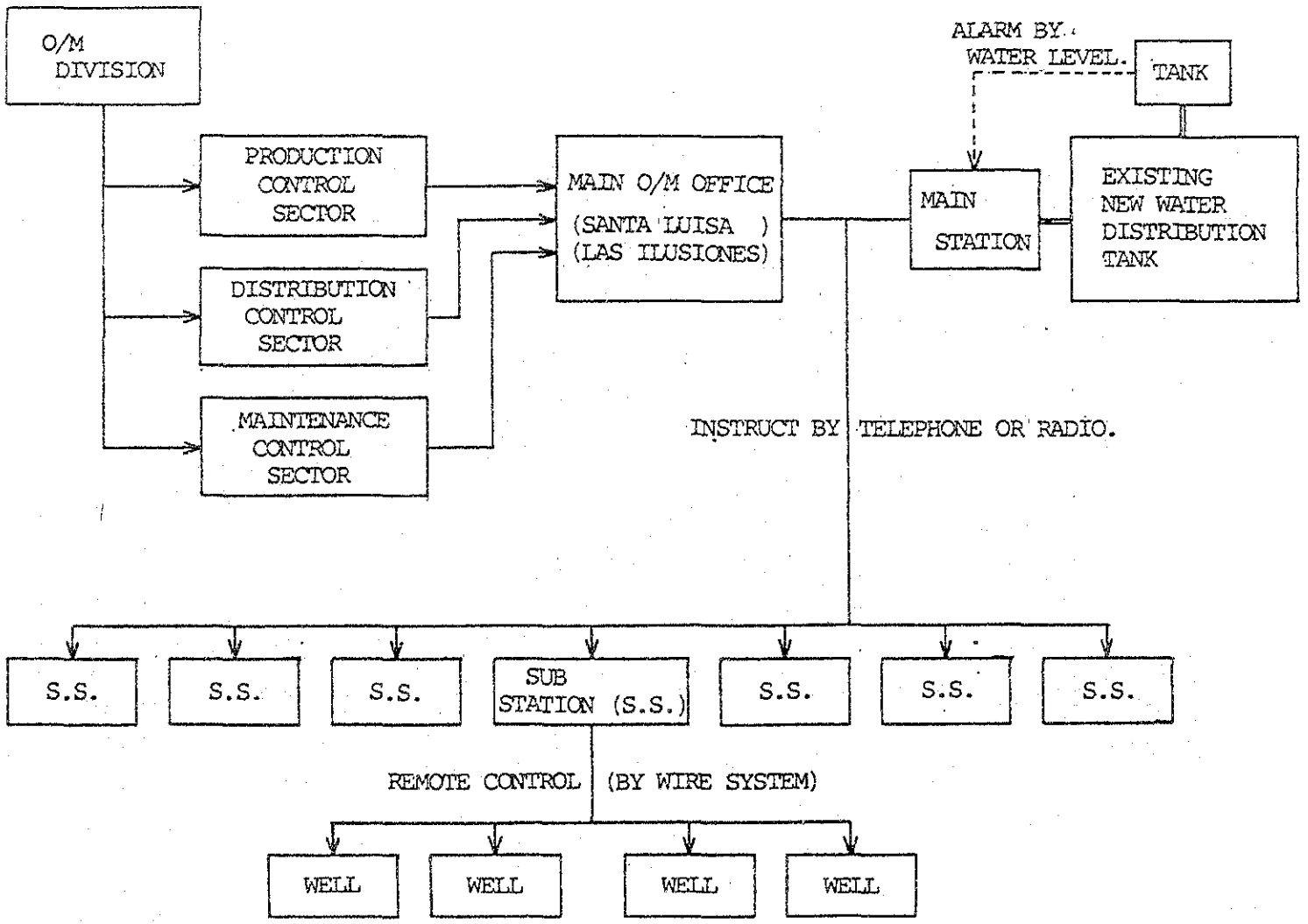


Fig. V-1 OPERATION FLOW

5.6.2 Maintenance Facilities

(1) Maintenance Office

A maintenance office is to be constructed in the work shop. It will be organized according to EMPAGUA guidelines.

(2) Work Shop

A work shop will be constructed near one of the existing water treatment plants. The building is to have a floor area of 250m^2 and shall be of reinforced concrete construction.

Work shop equipment is to be as follows:

i) General equipment: workbench, tool, steam cleaner, crane
ii) tooling equipment: lathe, drilling machine, vice, bench grinder
iii) electrical equipment: mega-ohm tester, hyper-voltage insulation checker, double-bridge resisting meter, tester
iv) vehicles: jeep, motorcycle
v) spare parts: for pump, motor
vi) overhead crane: 10m span, 2 ton capacity
vii) truck crane
viii) air compressor
ix) drilling machine
x) pump test equipment

(3) Operation and Maintenance Roads

Sub-control station	Existing roads (m)	Roads requiring repair (m)	Roads to be constructed under Project (m)	Total (m)
Canalitos (I)	9,110	1,450	-	10,560
Canalitos (II)	4,660	-	250	4,910
San Gaspar	3,500	-	50	3,550
Norte (TP4.4)	16,070	-	1,120	17,190
Lavarreda	4,360	-	100	4,460
El Rodeo Zona 18	11,320	-	1,260	12,580
Vista Hermosa	2,800	-	400	3,200
Total	51,820	1,450	3,180	56,450

Of roads used for access to Project facilities, public roads are to be excluded from maintenance reponsibilities under the Project.

Upon completion of Project implementation, temporary access routes constructed under the Project will be graveled and protected by drainage ditches along the slope sides of roads. Road width is to be 5m, with cutouts every 500m to allow traffic in the opposite direction to pass.

CHAPTER VI

ORGANIZATION AND MANAGEMENT

CHAPTER VI

ORGANIZATION AND MANAGEMENT

6.1 Organizations for Project Execution

The proposed Project aims to solve the water service problems at present and over the near future through groundwater development of 1 m^3. The early implementation of the Project is urgently required. Project implementation will be executed under the responsibility of EMPAGUA.

The main component of the Project is a groundwater development plan for 1 m^3/s and a supply plan for the developed groundwater. The main Project facilities consist of the 38 wells, 34.2km of transmission pipe line, and associated facilities.

EMPAGUA will be responsible for execution of the entire Project implementation including the following works:

- Detailed design of Project facilities
- Planning and supervision of the construction works
- Land acquisition and other required preliminary works
- Procurement and supply of the main material and equipment
- Procurement and furnishing of funds

For overall execution, EMPAGUA will appoint a Project Manager under the Engineering Sub-Manager for the implementation of design and construction works.

The appointed Project Manager will be directly responsible for the implementation of the Project and for coordinating the activities of all the sections within EMPAGUA concerned with implementation of the Project.

The proposed organization chart for the construction stage is presented in FIG. 6-1.

It is proposed that facility detailed design, preliminary works (tender document preparation, selection of contractors, etc.) and supervision of implementation be carried out through consultant engineering services.

6.2 Implementation Schedule

The implementation period was determined on the basis of such factors as the scale, cost and number of proposed Project facilities, ability of contractors, procurement of materials and labor, and EMPAGUA's capability to finance construction, etc.

Preparatory works such as preliminary design, land acquisition and construction of access roads will be completed within the first year to expedite commencement and completion of construction works.

Although funding capability of EMPAGUA, as well as financial cooperation from Japan, other countries and international financing agencies will be studied before final determination, a total implementation period of 4 years is tentatively proposed including 1 year for preliminary works and 3 years for construction.

In consideration of Project objectives, facilities to be constructed in a certain year are scheduled to be completed within the same year, and implementation will be phased in order to obtain benefits upon completion of each construction period.

Moreover, each phase of construction will be so formulated as to respond to the demand (both quantitatively and geographically) projected for that particular year.

The time and work schedule is proposed as per below:

TABLE 6-1 IMPLEMENTATION SCHEDULE

Year	1987	1988	1989	1990
	Pre Project Works		Construction Works	
Work Schedule	Detailed Design & Survey Preliminary Works Temporary Works Land Acquisition	Well - 13 Booster Pump - 1 Pipe Line 9,420m Distribution Tank - 2 O/M Road Sub Station Land Acquisition	Well-13 Booster Pump - 3 Pipe Line 13,670m Distribution Tank - 1 O/M Road Sub Station Land Acquisition	Well - 12 Booster Pump - 2 Pipe Line 10,090m Distribution Tank - 2 O/M Road Sub Station
Canalitos				
J.A.		-	Well-7, B.Pump-1 P.Line 7,880m	-
S.L.		Well-7 P.Line 7,060m	-	-
S.G.		-	-	Well-3, Tank-1 P.Line 1,950m
Norte		-	Well-3, B.Pump-2 P.Line 1,850m	Well-5, B.Pump-2 P.Line 4,940m
Lavarreda		Well-2, B.Pump-1 P.Line 1,400m	-	-
El Rodeo Zona 18		Well-4, Tank-2 P.Line 960m	Well-3, Tank-1 P.Line 2,260m	-
Vista Hermosa		-	-	Well-4, Tank-1 P.Line 3,200m
Rehabilitation	Well-22			

6.3 Material Procurement and Construction Work

The main materials and equipment for the Project facilities will be directly procured under the responsibility of EMPAGUA and will be supplied to the contractors. The construction works will be executed by international or local contractors contracted through competitive tendering.

Land acquisition year by year for the required facilities and power line arrangements will be executed under the responsibility of EMPAGUA.

6.4 Organization for Management and Control

Water produced under the proposed Project will be conducted to the eight distribution terminal facilities through a transmission system of thirteen lines.

Basically, maintenance of the water production and water distribution facilities and equipment are performed under the responsibility of the O/M director of EMPAGUA on the basis of EMPAGUA regulations.

Daily operation, management and maintenance for the water production and distribution facilities and equipment will be carried out by the sub-control stations situated at the respective transmission system terminal sites and the five main control stations situated at wellfield heads. The five main control offices are under the jurisdiction of the Las Ilusiones or Santa Luisa Plant offices, depending on the command area for water service. Operation wells of EMPAGUA will be increased to twice the present wells with the proposed Project implementation. Consequently, the staff for the O/M should be supplemented to the optimum number for the corresponding new facilities.

In addition, to maintain effective operation and maintenance a new workshop will be created near the newly developed wellfields, and will be provided with the equipment and machinery indicated in section 5.6.2. The proposed organization chart for the O/M of the proposed Project is indicated in FIG. 6.2, 6-3.

Fig.6-1 PROPOSED ORGANIZATION CHART FOR PROJECT EXECUTION

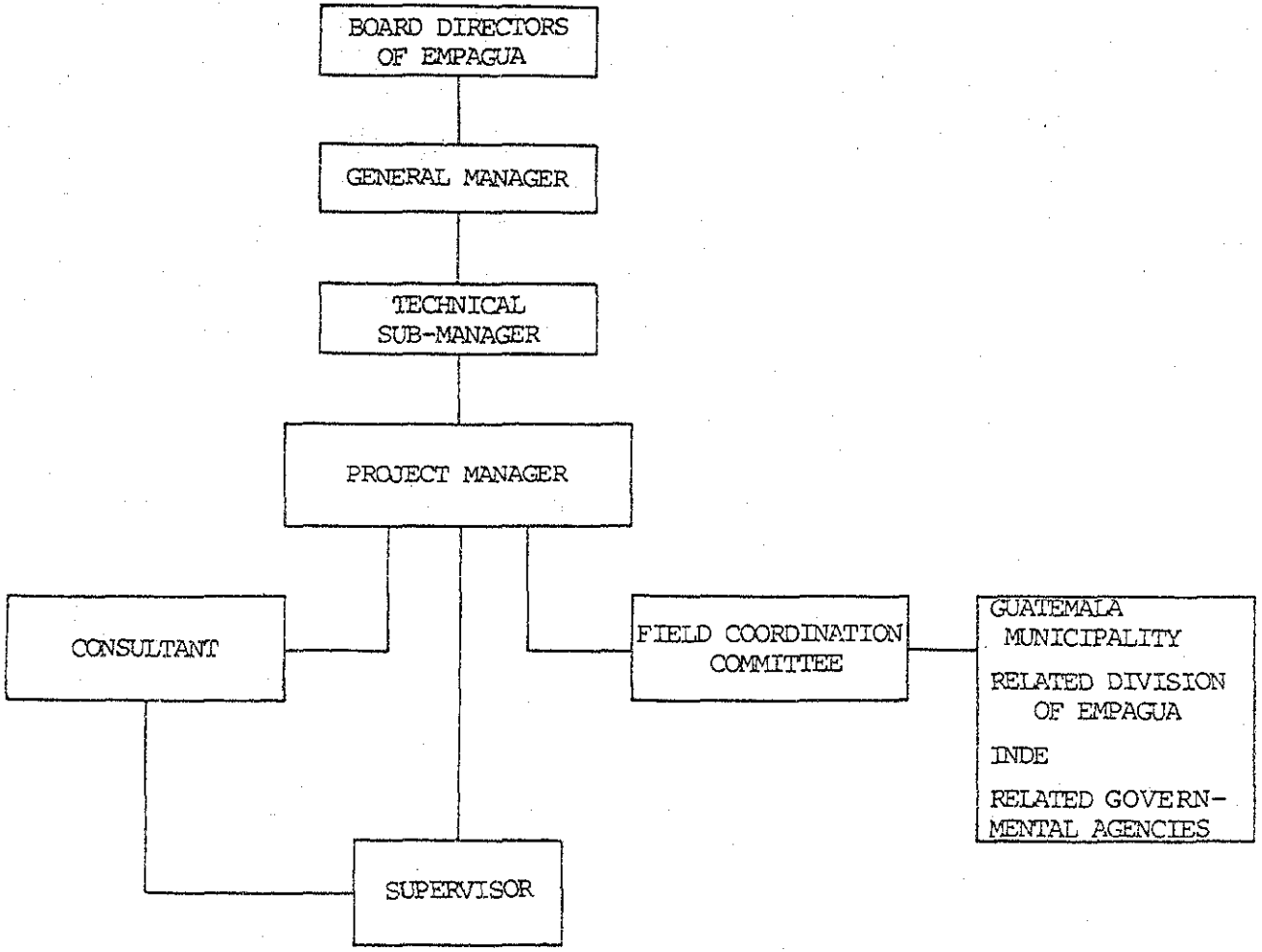


Fig.6-2 PROPOSED ORGANIZATION CHART FOR PROJECT EXECUTION

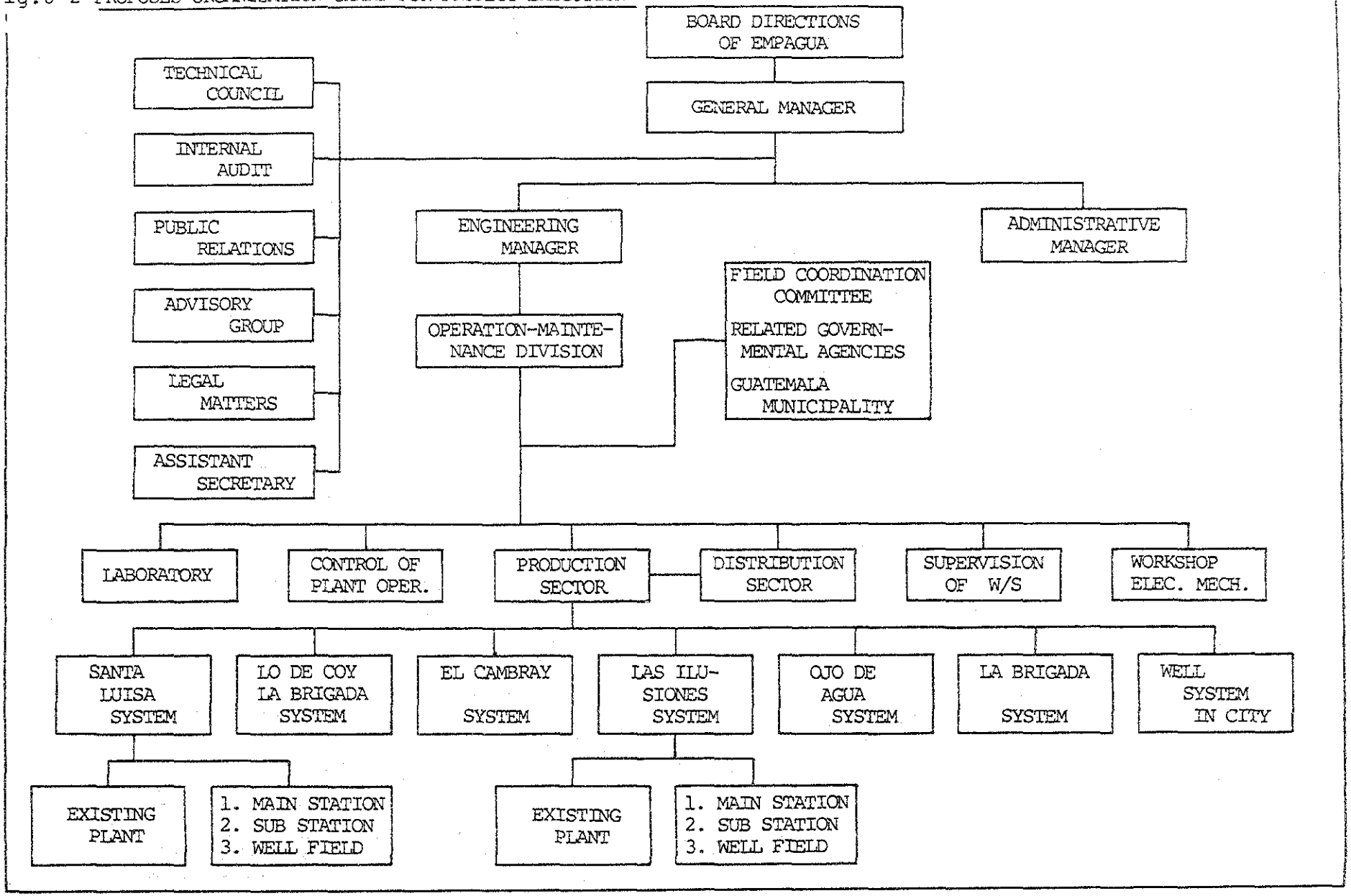
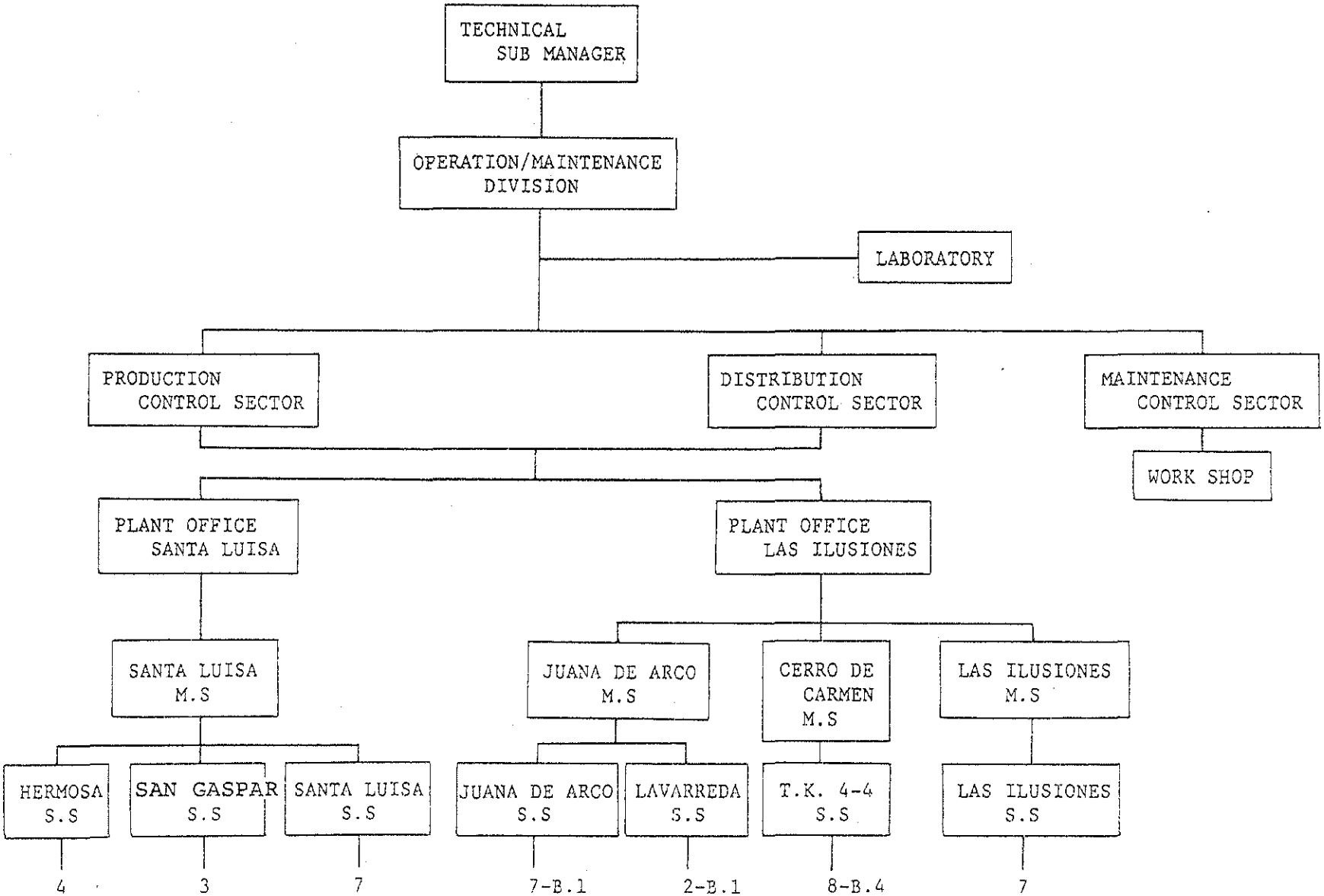


FIG. 6-3 ORGANIZATION CHART FOR OPERATION AND MAINTENANCE



CHAPTER VII

COST ESTIMATES

CHAPTER VII

COST ESTIMATES

7.1 General

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

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

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

(3) Well construction work is to be carried out on a contract basis using the contractors' own well construction machinery and equipment.

(4) Transmission pipeline construction work is to be carried out on a contract basis. However, the costs of the said work are estimated on a basis of work done manually and not by machine.

(5) Major materials and equipment for the facilities are to be directly procured by EMPAGUA and are to be supplied to the contractors.

(6) Tax on the construction materials and equipment imported from abroad is not included in the cost estimate.

(7) The construction cost comprises foreign and local currency portions. The classification of foreign and local portions is shown below.

Foreign currency portion

- Ductile cast iron pipe
- Submersible motors and pumps and accessories
- Multistage volute pumps and accessories
- Operation board and switchboards
- Transformers and electric wires
- Engineering services cost of foreign consultants

- Casing pipe and strainer
- Drilling work for the wells

Local currency portion

- Labour forces
- Reinforcement bars
- Cement
- Sand, gravel
- Fuel, oil, etc
- Inland transportation costs
- Engineering services costs for local consultants

(8) The physical contingencies were estimated at 10% of the total cost, composed of direct construction, land acquisition, equipment and engineering administration costs.

(9) Considering future cost escalation and based on price increase rate during 1980 - 1984, the price contingencies were assumed as in the following table.

Year	Foreign Currency	Local Currency
1987	8%	20%
1988	7%	15%
1989	6%	10%
1999	5%	10%

7.2 Project Cost Estimates

Accordingly, the Project cost for the draft final development plan is estimated at Q 35.2 million. Details are shown in TABLE 5-1, and summarized in the TABLE below.

Project Cost

(Unit = Q)

Item	Foreign Cost	Local Cost	Total
Direct Construction Costs	20,154,088	4,621,951	24,776,039
Land Aquisition Costs	-	1,022,525	1,022,525
Administration and Engineering Costs	2,256,350	4,408,000	6,664,350
Sub-total	22,410,438	10,052,476	32,462,914
Physical Contingencies	2,241,044	1,005,248	3,246,292
Total	24,651,482	11,057,724	35,709,206
Price Contingencies	1,521,218	1,437,741	2,978,959
Total	26,172,700	12,495,465	38,688,165

(1) Direct Construction Cost

Direct construction costs for work items are presented below.

Direct Construction Cost

(Unit = Q)

Item	Foreign Cost	Local Cost	Total
1. Water Production System	9,241,725	1,415,441	10,657,166
2. Water Supply System	4,083,072	1,695,223	5,778,295
3. Rehabilitation	1,191,100	159,190	1,350,290
4. O/M Facilities	2,872,750	695,271	3,568,021
5. Groundwater Monitoring system	275,240	40,300	315,540
6. Power Supply System	2,490,201	396,433	2,886,634
7. Preperation Work	-	220,093	220,093
Total	20,154,088	4,601,951	24,776,039

(2) Land Acquistion

The unit cost of land acquisition used the average price for Zones 6, 18, 15, 16, and 17.

The land acquisition cost was estimated at Q 1.02 million in local currency.

(3) Administration and Engineering Cost

The administration and engineering costs are estimated at F.C.(Q) 2.26 million and L.C.(Q) 4.41 totalling Q 6.67 million.

7.3 Annual Operation and Maintenance Costs and Replacement Cost

Annual operation and maintenance costs consists of staff salaries, materials and labor wages for the repair and maintenance of Project facilities, and the operation and maintenance costs for O/M equipment.

The required annual cost was estimated at F.C.(Q) 0.16 million and L.C.(Q). 6.70 million, totalling Q 6.86 million.

Submersible pumps with accessories will be replaced once every 16 years, motors once every 8 years and vehicles and radio systems once every 10 years.

A breakdown is shown in Table 7.3.

7.4 Disbursement Schedule

The disbursement schedule for the proposed plan in accordance with the implementation schedule and Project cost is presented in the following table.

(Unit = Q)

Financial Year	Foreign	Local	Total
1987	2,489,395	2,011,249	4,500,644
1988	7,278,385	3,780,385	11,059,346
1989	8,844,413	3,746,680	12,591,093
1989	7,559,931	2,957,151	10,517,082
Total	26,172,700	12,495,465	38,668,165

7.5 Production Cost

Production cost is estimated based on the following conditions:

(a) annual interest: 12%

(b) amortization period: 8 - 16 years

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

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

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

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

/1: Including land acquisition

/2: Including annual interest 12%

/3: 6,393,455 ÷ 42,573,600 = 0.14691

/4: Including engineering, administration and physical contingency

TABLE 7-1 Financial Cost

(Unit: Quetzal)

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

TABLE 7-1-1
Direct Construction Cost

(Unit = Q)

Item		Foreign Currency	Locay Currency	Total
Production System	Well 38 Nos.	9,241,725	1,415,441	10,657,166
Water Supply System	Transmission pipe line, Tank, Boster pump	4,083,072	1,695,223	5,778,295
Rehabilitation	Well 22 Nos.	1,191,100	159,190	1,350,290
O/M Facilities	O/M Road, work shop substation	2,872,750	695,271	3,568,021
Power Supply Facilities	Power wiring, Transformer	2,490,201	396,433	2,886,634
Monitoring System	Observation well 8 Nos.	275,240	40,300	315,540
Preperation Work-			220,093	220,093
Total		20,154,088	4,621,951	24,776,039

TABLE7-1-2
Water Production System

(Unit = Q)

Item	Unit	Foreign Currency			Local Currency			Total
		Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Canalitos (J.A-Line)	7 Nos			1,871,193			272,010	2,143,203
Canalitos (S.L-Line)	7 Nos			1,611,559			236,501	1,848,060
Canalitos (S.G-Line)	3 Nos			755,296			121,420	876,716
Norte	8 Nos			2,042,918			309,390	2,352,308
Lavarreda	2 Nos			495,893			77,130	573,023
El Rodeo Zona 18	7 Nos			1,477,333			245,430	1,722,763
Vista Hermosa	4 Nos			987,533			153,560	1,141,093
TOTAL	38 Wells			9,241,725			1,415,441	10,657,166

TABLE 7-1-3
Water Supply System

(Unit = Q)

Item	Unit	Foreign Currency			Local Currency			Total
		Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Canalitos I J.A-Line				1,312,984			380,437	1,693,421
Canalitos II S.L-Line				689,014			202,393	891,407
CAnalitos III S.G-Line				118,315			246,279	364,594
Norte				1,401,411			223,471	1,624,882
Lavarreda				232,100			38,285	270,385
El Rodeo Zona 18				142,790			335,018	477,808
Vista Hermosa				186,458			269,340	455,798
Total				4,083,072			1,695,223	5,778,295

TABLE 7-1-4
Rehabilitation

(Unit = Q)

Item		Unit	Foreign Currency			Local Currency			Total
			Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Clearing	Jet & piston	22						79,200	79,200
Casing pipe repair		4						13,200	13,200
Submarsible pump/moter operation board		22			859,000				859,000
Transportation		150			23,550			12,000	35,550
Erection		22						22,000	22,000
(Ojo de Agua)									
Communication cable and other necessary					45,000				45,000
Control panel and remote control telephone					171,000				171,000
Transportation					31,350			6,270	37,620
Election					61,200			26,520	87,720
Total					1,191,100			159,190	1,350,290

TABLE 7-1-5
O/M Facilities

(Unit = Q)

Item	Unit	Foreign Currency			Local Currency			Total
		Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Canalitos (J.A-Line)				430,047			101,131	531,178
Canalitos (S.L-Line)				352,239			62,124	414,363
Calanitos (S.G-Line)				111,427			14,939	126,366
Norte				526,848			126,729	653,577
Lavarreda				83,717			15,777	99,494
El Rodeo Zona 18				296,704			107,030	403,734
Vista Hermosa				176,388			50,581	226,969
Sub-total				1,977,370			478,311	2,455,681
Transceiver (U.H.F)				10,000			-	10,000
Maintenance Facilities/Equipments				885,380			29,460	914,840
Work Shop				-			187,500	187,500
Sub-total				895,380			216,960	1,112,340
Total				2,872,750			695,271	3,568,021

TABLE 7-1-6
Power Supply Facilities

(Unit = Q)

Item	Unit	Foreign Currency			Local Currency			Total
		Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Canalitos (J.A-Line)				440,151			43,041	483,192
Canalitos (S.L-Line)				460,726			202,046	662,772
Canalitos (S.G-Line)				225,112			20,228	245,340
Norte				574,630			55,073	629,703
Lavarreda				119,827			12,073	131,900
El Rodeo Zona 18				371,691			41,421	413,112
Vista Hermosa				298,064			22,551	320,615
Total				2,490,201			396,433	2,886,634

TABLE 7-1-7
Monitoring System

(Unit = Q)

Item	Unit	Quantity	Foreign Currency		Local Currency		Total	
			Unit cost	Amount	Unit Cost	Amount	Unit Cost	Amount
Monitoring Well (l = 300 m)	Nos.	5	33,048	190,240	4,220	21,100		211,340
Observation House	Nos.	8			2,400	19,200		19,200
Auto-water gage	Nos.	8	10,000	80,000				80,000
Handy water gage	Nos.	1	5,000	5,000				5,000
Total				275,240		40,300		315,540

TABLE 7-1-8
Land Aquisition Cost

(Unit = Q)

Item	Unit	Foreign Currency			Local Currency			Total
		Unit Cost	Quan-tity	Amount	Unit Cost	Quan-tity	Amount	
Canalitos (J.A-Line)							201,750	201,750
Canalitos (S.L-Line)							67,375	67,375
CAnalitos (S.G-Line)							54,375	54,375
Norte							234,750	234,750
Lavarreda							24,950	24,950
El Rodeo Zona 18							288,450	288,450
Vista Hermosa							150,875	150,875
Total							1,022,525	1,022,525

Fig.7-2 ANNUAL O/M COST

(Unit: Quetzal)

Item	Unit	Quantity	Foreign Currency		Local Currency		Total		Remarks
			Unit Cost	Amount	Unit Cost	Amount	Unit Cost	Amount	
1. Salaries & Wages									
Staff Salaries				-		550,200		550,200	
Wages				-		20,995		20,995	
2. Office Expenses				-		64,000		64,000	
3. Power Rates				-		5,315,016		5,315,016	
4. Fuel for Vehicles and Equipment				-		22,700		22,700	
5. Chlorine Gas				52,899		-		52,899	
6. Miscellaneous Expenses				107,196		211,000		318,196	
Sub Total				160,095		6,183,911		6,344,006	
7. Rehabilitation-Erectric				-		513,168		513,168	
Total				160,095		6,697,079		6,857,174	

TABLE 7-3 REPLACEMENT COST AND USEFUL LIFE

(Unit: Quetzal)

	ITEM	Useful Life (year)	Cost
1.	Pump motor	8	835,800
2.	Booster Pump, Submergible Pump	16	2,152,598
3.	Monitering System (water level gage)	15	85,000
4.	Maintenance Service Car	8	35,000
5.	Motor Bicycle	5	12,000
6.	Pick-up	8	60,000

TABLE 7-4 ADMINISTRATION AND ENGINEERING COST

(Unit: Quetzal)

Item	Foreign	Local	Total
1. Detail Design Stage			
EMPAGUA Administration	83,000	961,000	1,044,000
Engineering Consultant	782,000	186,000	968,000
Training	39,350	-	39,350
Sub Total	904,350	1,147,000	2,051,350
2. Construction Stage			
EMPAGUA Administration	20,000	2,739,000	2,759,000
Engineering Cost	1,332,000	522,000	1,854,000
Sub Total	1,352,000	3,261,00	4,613,000
	2,256,350	4,408,000	6,664,350

TABLE7-5-1 BREAKDOWN OF DIRECTION COST

(Unit: Q)

		Currency	Canalitos J.A-Line	Canalitos S.L-Line	Canalitos S.G-Line	Norte	Lavarreda	El Rodeo	Hermosa	Total
1.	Water Production System	Foreign	1,871,193	1,611,559	755,296	2,042,918	495,893	1,477,333	987,533	9,241,725
		Local	272,010	236,501	121,420	309,390	77,130	245,430	153,560	1,415,441
		Total	2,143,203	1,848,060	876,716	2,352,716	573,023	1,722,763	1,141,093	10,657,166
2.	Water Supply System	Foreign	1,312,984	689,014	118,315	1,401,411	232,100	142,790	186,458	4,083,072
		Local	380,437	202,393	246,279	223,471	38,285	335,018	269,340	1,695,223
		Total	1,693,421	891,407	364,594	1,624,882	270,385	477,808	455,798	5,778,295
3.	O/M Facilities	Foreign	430,047	352,239	111,427	526,848	83,717	296,704	176,388	1,977,370 895,380
		Local	101,131	62,124	14,939	126,729	15,777	107,030	50,581	478,311 216,960
		Total	531,178	414,363	125,366	653,577	99,494	403,734	226,969	2,455,681 1,112,340
4.	Rehabilitation	Foreign								1,191,100
		Local								159,190
		Total								1,350,290
5.	Power Supply System	Foreign	440,151	460,726	225,112	574,630	119,872	371,691	298,064	2,490,201
		Local	43,041	202,046	20,228	55,073	12,073	41,421	22,551	396,433
		Total	483,192	662,772	245,340	629,703	131,900	413,112	320,615	2,886,634
6.	Monitoring System	Foreign								275,240
		Local								40,300
		Total								315,540
7.	Preparation Work	Foreign	-	-	-	-	-	-	-	-
		Local	39,831	35,153	20,143	35,733	7,163	36,445	24,802	199,270 20,823
		Total	39,831	35,153	20,143	35,733	7,163	36,455	24,802	199,270 20,823
8.	Direct Construction	Foreign	4,054,375	3,113,538	1,210,150	4,545,807	931,537	2,288,518	1,648,443	20,154,088
		Local	836,450	738,217	423,009	750,396	150,428	765,344	520,834	4,621,951
		Total	4,890,825	3,851,755	1,633,159	5,296,203	1,081,965	3,053,862	2,169,277	24,776,039

: Includes work shop

TABLE 7-5-2 FINANCIAL CONSTRUCTION COST

(Unit: Quetzal)

Item	Foreign	Local	Total
1. Water Production System			
Drilling	5,104,812	990,390	6,095,202
Test Pilot Dirll	254,150	10,800	264,950
Pump	3,674,800	-	3,674,800
Trasportation	207,963	68,651	276,614
Pump House	-	345,600	345,600
Sub Total	9,241,725	1,415,441	10,657,166
2. Water Supply System			
Pipe Line	2,739,138	797,467	3,536,605
Discharge Tank	-	112,639	112,639
Distribution Tank	5,400	686,285	691,685
Syphon Bridge	18,534	81,950	100,484
Booster Pump	1,300,000	11,882	1,311,882
Rehabilitation of Existing System Bridge	20,000	5,000	25,000
Sub Total	4,083,071	1,695,223	5,778,295
3. O/M Facilities			
O/M Road	-	225,343	225,343
Communication Cable, etc.	334,230	-	334,230
Control Panel & Remote Control Panel	891,000	-	891,000
Transportation	123,875	20,895	144,770
Erection	568,265	202,073	770,338
Sub-Station	60,000	30,000	90,000
Transceiver (FM)	10,000	-	10,000
Maintenance Facilities/Equipments	885,380	29,460	914,840
Work Shop	-	187,500	187,500
Sub Total	2,872,750	695,271	3,568,021
4. Rehabilitation			
Clearing Jet & Piston	-	79,200	79,200
Casing Pipe Repair	-	13,200	13,200
Submersible Pump/Operation Board	859,000	-	859,000

Cont'd

(Unit: Quetzal)

Item	Foreign	Local	Total
Communication Cable and Other Necessary	45,000	-	45,000
Control Panel and Remote Control, Telephone	171,000	-	171,000
Transportation	54,900	18,270	73,170
Erection	61,200	48,520	109,720
Sub Total	1,191,100	159,190	1,350,290
5. Power Supply Facilities			
Pole	97,150	-	97,150
Cable	387,175	-	387,175
Cable Connection	-	167,960	167,960
Construction Cost	-	11,395	11,395
Access Road	-	157,380	157,380
Eelctrical Leading Pole, Transformer Bay	409,500	-	409,500
Cable Conduit & Erection Material	267,999	-	267,999
Receiving Parts	483,600	-	483,600
Transformer	643,300	-	643,300
Transmission Cost	186,277	48,298	234,575
Erection	15,200	11,400	26,600
Sub Total	2,490,201	396,433	2,886,634
6. Monitoring System			
Monitoring Well	190,240	21,100	211,340
Observation House	-	19,200	19,200
Auto-water Gauge	80,000	-	80,000
Handy-water Gauge	5,000	-	5,000
Sub Total	275,240	40,300	315,540
7. Preparation			
Preparation	-	220,093	220,093
	20,154,088	4,621,951	24,776,039

TABLE 7-6

DISBURSEMENT SCHEDULE

(Unit: Q)

	1987			1988			1989			1990			Total		
	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
1. Production system			-	2,997,283	460,631	3,457,914	3,296,009	486,529	3,782,618	2,948,353	468,281	3,416,634	9,241,725	1,415,441	10,657,166
2. Water Supply System			-	962,994	394,432	1,357,426	2,178,655	721,248	2,899,903	941,423	579,543	1,520,966	4,083,072	1,695,223	5,778,295
3. O/M Facilities			-	682,628	142,927	825,555	809,970	193,735	1,003,705	474,772	141,649	626,421	1,997,370 (2,872,750)	488,311 (695,271)	2,485,681 (3,568,021)
4. Power Supply System			-	802,189	237,789	1,039,978	856,546	85,267	941,813	831,466	73,377	904,843	2,490,201	396,433	2,886,634
5. Rehabilitation	1,191,100	159,190	1,350,290			-			-			-	1,191,100	159,190	1,350,290
6. Monitoring System			-	275,240	40,300	315,540			-			-	275,240	40,300	315,540
7. Work Shop		(159,190)	-		(1,276,079)	-		187,500 (1,674,279)	187,500	895,380	29,460 (1,292,310)	924,840	895,380	216,960 (4,384,163)	1,112,340
8. Preparation Work		7,959	7,959		63,804	63,804		83,714	83,714		64,616	64,616	-	220,093	220,093
9. Engineering/Administration	904,350	1,147,000	2,051,350	464,000	1,087,000	1,551,000	444,000	1,087,000	1,531,000	444,000	1,087,000	1,531,000	2,256,350	4,408,000	6,664,350
10. Land Acquisition		209,525	209,525		561,563	561,563		251,437	251,437			-	-	1,022,525	1,022,525
Sub Total	2,095,450	1,523,674	3,619,124	6,184,334	2,988,446	9,172,780	7,585,260	3,096,430	10,681,690	6,545,394	2,443,926	8,989,320	22,410,438	10,052,476	32,462,914
11. Physical Contingencies	209,545	152,367	361,912	618,433	298,845	917,278	758,526	309,643	1,068,169	654,540	244,393	898,933	2,241,044	1,005,248	3,246,292
Total	2,304,995	1,676,041	3,981,036	6,802,767	3,287,291	10,090,058	8,343,786	3,406,073	11,749,859	7,199,934	2,688,319	9,888,253	24,651,482	11,057,724	35,709,206
12. Price Contingency Ratio	8%	20%		7%	15%		8%	10%		5%	10%				
Ground Total	2,489,395	2,011,249	4,500,644	7,278,961	3,780,385	11,059,346	8,844,413	3,746,680	12,591,093	7,559,931	2,957,151	10,517,082	26,172,700	12,495,465	38,668,165

CHAPTER VIII

PROJECT EVALUATION

CHAPTER VIII

PROJECT EVALUATION

8.1 Financial Evaluation

8.1.1 Introduction

The purpose of financial evaluation is to determine the financial viability of the Project. Measures of financial viability include the net present value and the rate of return. The net present value is calculated by first subtracting total expenditures from gross revenues for each year of the Project and then converting the resultant net cash flow into present values using the investment borrowing rate as the discount factor. The sum of these annual present values is the net present value. A positive net present value shows that the rate of return on the investment is greater than the borrowing rate, thus indicating financial feasiblity of the Project.

The rate of return is defined as the interest rate at which the net present value is zero. The rate of return is calculated by determining the net present value with various interest rates until a zero value is obtained. The rate of return is interpreted as the interest rate that the Project can afford to pay if borrowed funds are to be used for its implementation. Therefore, if the rate of return is greater than the borrowing rate of interest, the Project is judged financially feasible.

The financial evaluation of the Project will follow the steps indicated below.

Assumptions for Revenue Estimation

Revenue Estimation

Evaluation Results and Sensitivity Analysis

8.1.2 Assumptions for Revenue Estimation

Historicallly recorded EMPAGUA data are used when needed to specify assumptions for revenue estimation.

(1) The Project is to start in 1987 with detailed design and rehabilitation works, and the assumed project life is 30 years.

(2) Increased water supply and revenue collection from rehabilitated wells will start in 1988.

(3) Construction works for new wells will begin in 1988 and will end in 1990.

(4) Water from newly developed wells under the Project is ready for distribution to consumers at a ratio of 1/3 in 1989, 1/3 in 1990 and 1/3 in 1991.

(5) Net water production increases yearly from 64.0% of gross production in 1985 to 76.0% in 1995 as a result of reductions in distribution losses from 25 to 20%, illicit connections and wastage from 7% to 1%, and public consumption from 4% to 3%. The yearly increase in net water production is indicated below.

Year	%
1985	64.0
1986	64.8
1987	65.7
1988	66.8
1989	67.9
1990	69.0
1991	70.3
1992	71.7
1993	73.2
1994	74.6
1995	76.0

(6) Titles (pajas) corresponding to water obtained in a given year are sold during the following year, when water is ready for distribution to consumers.

(7) The number of saleable titles (pajas) is estimated on the basis of 70% of net water production in order to allow for a 30% Excess Consumption.

(8) Titles (pajas) are distributed among service categories as follows based on the historical consumption pattern registered at EMPAGUA.

Marginal (20 m^3/month)	5%
Economical (30 m^3/month)	56%
Normal (60 m^3/month)	28%
Intermediate (60-300 m^3/month)	8%
High Consumption (over 300 m^3/month)	3%

(9) Consumers pay for titles (pajas) in one payment or in monthly payments over 1 to 5 years according to the proportions indicated below.

	Marginal	Economical	Normal	Intermed.	High Cons.
One payment	40%	40%	40%	100%	100%
Time payment					
1 year	3%	3%	10%	-	-
2 years	10%	10%	10%	-	-
3 years	8%	8%	10%	-	-
4 years	9%	9%	7%	-	-
5 years	30%	30%	23%	-	-

(10) Revenues come from sale of titles as well as from charges for Fixed Consumption and Excess Consumption. The basic measure for water titles is the "paja" equivalent to 60 m^3/month but consumers can buy titles corresponding to multiples or fractions of "paja". Water titles confer buyers the right to receive on perpetuity a fixed monthly amount of water for which consumers pay a fixed monthly charge. If monthly water consumption exceeds the fixed amount permitted by the title, consumers pay a fee for each cubic meter consumed.

(11) Revenues from titles (pajas) are estimated on the basis of water production from new wells (1 m^3/s), while revenues from Fixed Consumption and Excess Consumption are estimated on the basis of water production from new wells plus rehabilitated wells (1.382 m^3/s).

(12) Costs of titles and water rates used for revenue estimation are presented below.

a) Costs of titles (pajas) in Quetzal.

	Marginal 1/3 Paja ($20m^3$/month)	Economical 1/2 Paja ($30m^3$/month)	Normal 1 Paja ($60m^3$/month)	Intermediate 1-5 Pajas ($60-300m^3$/month)	High Consumption Over 5 Pajas (over $300m^3$/month)
One payment	350	600	1,050	1,050 per Paja	1,050 per Paja
Time payment					
1 year	385	660	1,155		
2 years	420	720	1,260		
3 years	455	780	1,365		
4 years	490	840	1,470		
5 years	525	900	1,575		

b) Water rates

Service category	Fixed Consumption Quetzal/month	Excess Consumption Quetzal/m^3
Marginal	2.00	0.25
Economical	5.25	0.80
Normal	14.50	0.90
Intermediate	21.00	1.10
High Consumption	24.00	1.10

(13) Revenues from Excess Consumption are estimated three ways:

a) 30% of revenues from Fixed Consumption,

b) 30% of saleable water, in terms of volume, estimated at 0.80 Quetzal/m^3, and

c) assumed Excess Consumption of 7 and $10m^3$/month/connection estimated at 0.80 Quetzal/m^3, taking as a basis the EMPAGUA data of 5.6 m^3/month/connection.

Note: For b) and c), charges of Q.0.80/m^3 for Excess Consumption were chosen since, according to EMPAGUA

records, approximately 60% of revenues from Excess Consumption corresponded to the Economical Service category. Then, Excess Consumption of the other service categories was assumed to average out to Q0.80/m^3 on grounds that Normal, Intermediate, and High Consumption service categories are financially able to purchase more titles as a means to reduce Excess Consumption changes.

(14) Bad debts are assumed to be 10% of yearly revenues from Fixed and Excess Consumption, and 3% of revenues from water titles.

(15) Late accounts are estimated to be the equivalent of one-fourth (three months) of yearly revenues.

8.1.3 Revenue Estimation

Revenues were estimated as follows.

(1) Computation of gross water production
(2) Computation of net water production
(3) Computation of water volume saleable as titles
(4) Computation of number of pajas or water titles
(5) Computation of number of service connections
(6) Estimation of revenues from titles
(7) Estimation of revenues from Fixed Consumption
(8) Estimation of revenes from Excess Consumption
(9) Estimation of total revenues

Estimated revenues are shown in TABLE 8-1 .

8.1.4 Evaluation Results and Sensitivity Analysis

The financial evaluation of the Project was conducted using the costs estimated in the corresponding Cost Estimation section and the revenues estimated in the Revenue Estimation section. Details of financial evaluation are presented in Appendix Tables 6.5-1, 6.5-2, 6.5-3, 6.5-4, 6.5-5, 6.5-6 and 6.5-7.

The Project financial internal rate of return is 13.1% for the basic case corresponding to Excess Consumption estimated as 10 m^3/month/connection. The case assumed to represent the present EMPAGUA situation with an Excess Consumption of 7 m^3/month/connection results in 5.7% financial internal rate of return.

Changing total revenues to those corresponding to Excess Consumption estimated as 30% of Fixed Consumption revenues (minimum revenues), and 30% of net water production (maximum revenues), the resulting financial internal rates of return are undefined and 23.4%, respectively.

The financial internal rates of return (FIRR) and the net present values (NPV) with 12% discount factor obtained under various assumptions are summarized below.

Cases	FIRR (%)	NPV (12%) (1,000 Q)
Basic Case	13.09	1,546
Present Situation	5.71	-7,585
Minimum Revenues	undefined	undefined
Maximum Revenues	23.41	18,252

Sensitivity analysis provides a means to examine the changes that occur in the rate of return in response to changing circumstances, usually worsening conditions. Results of sensitivity analysis in reference to the basic case are summarized below.

Cases	FIRR (%)	NPV (125) (1,000 Q)
Basic Case	13.09	1,546
10% lower Total Revenues	7.51	-5,994
10% higher Investment and Replacement Costs	11.07	-1,460
Worst Case (10% lower total Rev. and 10% higher Investment & Replacement Costs)	5.90	-9,000

8.1.5 Summary

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

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

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

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

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

TABLE 8-1 Estimated Total Revenues from Titles, Fixed Consumption, and Three Methods of Computing Excess Consumption

Unit: 1,000Q

Year	Title Revenues	Fixed Cons. Rev.	Excess Cons. Rev. (a)	(b)	(c)	(c')	Total Revenues (a)	(b)	(c)	(c')
1987										
8		801	216	1,738	786	1,122	1,017	2,539	1,587	1,923
9	3,516	1,791	483	3,307	1,494	2,135	5,790	8,614	6,801	7,442
1990	4,020	2,780	751	4,930	2,228	3,183	7,551	11,730	9,028	9,983
1	4,988	3,807	1,028	6,618	2,991	4,272	9,823	15,413	11,786	13,067
2	2,238	4,127	1,114	6,750	3,050	4,357	7,479	13,115	9,415	10,722
3	2,736	4,212	1,138	6,891	3,114	4,449	8,086	13,839	10,062	11,397
4	4,826	4,295	1,159	7,023	3,173	4,533	10,280	16,144	12,294	13,654
5	4,186	4,376	1,182	7,154	3,233	4,619	9,744	15,716	11,795	13,181
6	3,260	4,396	1,187				8,843	14,810	10,889	12,275
7	330	4,396	1,187				5,913	11,880	7,959	9,345
8	289						5,872	11,839	7,918	9,304
9	229						5,812	11,779	7,858	9,244
2000	179						5,762	11,729	7,808	9,194
1	0						5,583	11,550	7,629	9,015
2016		4,396	1,187	7,154	3,233	4,691	5,583	11,550	7,629	9,015

(a) Excess Cons. Rev. - 0.3 Fixed Cons. Rev.
(b) Excess cons. Rev. - 0.3 of Net Production x Q 0.80/m^3/
(c), (c') Excess Cons. Rev. - 7 and 10m^3/month/connection x Q 0.80/m^3

GUATEMALA 2

FINANCIAL INTERNAL RATE OF RETURN FOR THE GROUNDWATER DEVELOPMENT PROJECT
IN GUATEMALA CITY (BASIC CASE)

(1000 Q)

NO.	YEAR	COSTS INVESTMENT AND REPLACEMENT	COSTS OPERATION AND MAINTENANCE	TOTAL COSTS	BENEFITS	BENEFITS -COSTS	DISCOUNT FACTOR (12.00%)	NET PRESENT VALUE	DISCOUNT FACTOR (13.09%)	NET PRESENT VALUE
1	1987	3981	0	3981	0	-3981	1.000	-3981	1.000	-3981
2	1988	10090	513	10603	1923	-8680	0.893	-7750	0.884	-7675
3	1989	11750	2493	14243	7442	-6801	0.797	-5422	0.782	-5318
4	1990	9888	4843	14731	9983	-4748	0.712	-3380	0.691	-3283
5	1991	0	6857	6857	13067	6210	0.636	3947	0.611	3797
6	1992	0	6857	6857	10722	3865	0.567	2193	0.541	2089
7	1993	12	6857	6869	11397	4528	0.507	2294	0.478	2165
8	1994	0	6857	6857	13654	6797	0.452	3075	0.423	2873
9	1995	0	6857	6857	13181	6324	0.404	2554	0.374	2364
10	1996	317	6857	7174	12275	5101	0.361	1839	0.331	1686
11	1997	332	6857	7189	9345	2156	0.322	694	0.292	630
12	1998	294	6857	7151	9304	2153	0.287	619	0.258	556
13	1999	0	6857	6857	9244	2387	0.257	613	0.229	545
14	2000	0	6857	6857	9194	2337	0.229	536	0.202	472
15	2001	0	6857	6857	9015	2158	0.205	442	0.179	386
16	2002	0	6857	6857	9015	2158	0.183	394	0.158	341
17	2003	97	6344	6441	9015	2574	0.163	420	0.140	360
18	2004	602	6344	6946	9015	2069	0.146	301	0.124	256
19	2005	711	6344	7055	9015	1960	0.130	255	0.109	214
20	2006	934	6344	7278	9015	1737	0.116	202	0.097	168
21	2007	0	6344	6344	9015	2671	0.104	277	0.085	228
22	2008	12	6344	6356	9015	2659	0.093	246	0.076	201
23	2009	0	6344	6344	9015	2671	0.083	221	0.067	178
24	2010	0	6344	6344	9015	2671	0.074	197	0.059	158
25	2011	0	6344	6344	9015	2671	0.066	176	0.052	139
26	2012	317	6344	6661	9015	2354	0.059	138	0.046	109
27	2013	344	6344	6688	9015	2327	0.053	122	0.041	95
28	2014	282	6344	6626	9015	2389	0.047	112	0.036	86
29	2015	0	6344	6344	9015	2671	0.042	112	0.032	85
30	2016	0	6344	6344	9015	2671	0.037	100	0.028	75
	TOTAL	39963	178949	218912	274971	56059		1546		-0

8.2 Evaluation of Environmental Impact

8.2.1 Impact With The Project

The most significant impact of the Project will be the improvement of the water supply services in quantity, population served and extent of service 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.

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 few choices for obtaining 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 piped water supply service is mostly absent. Although not heavily populated at present, the area around wellfields 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 potentially 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.

8.2.2 Impact Without the Project

The present Project is intended to be constructed by the year 1990. 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 depending on the area. 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.

8.2.3 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 immediate 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.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. - As of the end of 1985, the ratio for the water shortage to the predicted water demand in the EMPAGUA water service system is estimated at a maximum of 15%. However, the water service conditions vary with the locality and varying values are therefore given for the local water shortage ratios. The most serious of these is the northeast area of Metropolitan Guatemala which has a shortage ratio of 30%, while the next serious is the north area with 26%, and the third the center part of the city with 23%.

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

   - The water shortages in the northern and eastern zones are mainly caused by the increasing water demand in combination with the rapid growth of the residential population and the lack of sufficient water resources for development in the local area.

   - The estimated water demand for 1985, 1990, 1995 and the year 2000 are shown in TABLE 2-2, where it can be seen that the water demand is expected to increase 28% from 1985 to 1990, a further 27% from 1991 to 1995, and a further 28% from 1996 to the year 2000.

   - With the present water service conditions of EMPAGUA being as described above, it is impossible to sufficiently meet the demand for water. In view of these conditions for water supply and the projected growth in the demand for water, the early implementation of the Project is urgently required in order to meet demand over the next several years.

2. - As a result of the Study, the estimated groundwater storage, the development potentiality and permissible yield are concluded to be sufficient to offset the projected water shortage by the target year (1990). Accordingly, the Project should be implemented as early as possible.

3. - The available groundwater in the Project area is classified into two kinds according to the recharge mechanism and the aquifer. These two kinds are upper aquifer and lower aquifer water.

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

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

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

- Upper aquifer water in the eastern and northern sectors and lower aquifer water in the eastern, northern and southern sectors, is available for development under the Project.

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

- Consequently, the main groundwater development areas under the Project will be the eastern and northern sectors. Moreover, six wellfields were delineated in the vicinity of the boundary of eastern and northern sectors, in consideration of the present

conditions for local water shortages, the proposed distribution programs and economization of the transmission system for the newly developed groundwater.

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

6. - In order to supplement a new water production envisaged under the Project, a rehabilitation program is proposed to recover the production capacity of existing wells.

- This will contribute to increasing the capacity of EMPAGUA water service, and should be executed in conjunction with the Project.

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

- Main control and sub-control stations are proposed to maintain effective operation and control of water production systems.

- The five main control stations are to be established at the terminal points of the transmission pipe lines, in other words at the head of respective distribution systems. The main control stations will indirectly control well production.

- The eight sub-control stations are arranged at the booster pump sites or at head of the respective wellfields. The sub-control stations will perform direct remote control of well operation and production under the instructions of the main control stations

8. - Under the Project, the proposed wells include a 10% surplus over the required number of wells in order to realize effective daily maintenance and adjustment of Project facilities and equipment through the introduction of a program of rotating operation.

9. - Under the Project, eight observation wells including three existing wells are to monitor the water table of the lower aquifer. Moreover, five existing wells and newly constructed wells will be provided with water table meters to monitor the upper aquifer.

- Systematic observation should be conducted to maintain groundwater production efficiency and to create an effective groundwater conservation program.

- Records of the measurements should be made for use in water resources development and groundwater conservation in the future.

10. - Test well No. 3, will be included as a production well under the Project, and will have additional excavation of 50 m.

- Although there are two existing pipe lines at this site, people living around this well site are supplied with domestic water from river flow water and natural spring water.

- However, the fact that large numbers of people gathered to obtain water for domestic use even during the test pumping period confirms that the demand for water is indeed great.

- In consideration of the above fact finding under the Project, part of the water produced by this well is proposed to be distributed directly at the well site.

- The technical soundness as well as the positive socio-economic impact of the direct distribution program have been identified, and the proposal is likely to considerably raise the living standard and sanitation conditions of local residents.

11. - The construction schedule is formulated for prompt realization of Project benefits. The implementation period was determined at four (4) years including a preliminary stage of one year.

- The annual scope of each construction phase was determined by correlating the annual water demand projected in the water service target area and the capabilities of the wells under the Project.

- In addition, facilities to be constructed in a given year are scheduled to be completed within the same year, and implementation will be phased in order that benefits are achieved immediately upon completion of each annual construction phase.

12. - In view of the potentially high cost of clean water in the Project area, impact of the incremental supply by 1 m^3/sec or 86,400 m^3/day will be significant and is expected to be sufficient capacity to supply 37,000 service connections, or in other words benefit 290,000 persons.

- Impact of the Project will be significant and positive, particularly over the coming 5 to 10 years, to the beneficiaries in the north and northeastern periphery of the metropolitan area, where significant improvement of the 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 if well operation is performed on the basis of careful monitoring.

Recommendations

1. - The benefit of proposed rehabilitation is already confirmed and will effectively serve to immediately address the present water shortage. Accordingly, the rehabilitation envisaged under the Project should be conducted as early as possible. It is recommended that said rehabilitation be conducted in the first year (1987) of the proposed Project implementation.

2. - The selection of well sites for the purposes of this Report was conducted using 1 : 10,000 map. However, the final location of the well site should be selected on the basis of detailed field survey prior to implementation, perhaps during the detail design period.

   - In addition, the hydrogeological conditions in the Project area show numerous variations caused by complex tectonic structure and the variety of local systems of the lower aquifer.

   - Accordingly, in order to carry out effective excavation and to minimize unproductive drilling, it is recommended under the Project to introduce the combined test pilot drilling and regular drilling method, where the test pilot well is excavated to confirm the groundwater availability, and then enlarged to the required section.

3. - Although the Project aims at developing the lower aquifer, precise aquifer properties such as the groundwater recharge mechanism, local systems, artesian conditions, etc. have not been fully identified.

   - In 1978, INSIVUMEH performed a study on subterranean water, but this study is thought incomplete in many respects, especially with respect to the lower aquifer.

   - Given the importance of the lower aquifer as a water resource for the Metropolitan Guatemala residents, it is recommended that a more detailed study be conducted covering the entire Guatemala City Valley and environs.

4. - In order to realize the objectives of the O/M system, training must be undertaken for the required numbers of O/M staff.

5. - It is recommended that EMPAGUA be delegated to register all wells, springs and other groundwater facilities in order to determine total groundwater discharge and other parameters as the basis for a comprehensive groundwater monitoring, control and management system.

- It is also recommended that meteorological, hydraulic and land level monitorings be undertaken on a regular basis to obtain hydrogeologic data for future analysis and simulation.

6. - Under the Project, the developed water is to be from the lower aquifer and as such can be directly supplied as potable water. However, chlorination is proposed on the basis of the results of the water quality study which was carried out during the pumping test period.

- Furthermore, as a result of the water quality analysis carried out for the wells to be newly constructed under the Project, decolorization and deodorization of the water is recommended.

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

- Ideally, drinking water should not contain any pathogenic micro-organisms. The presence of coliform, particularly feacal coliform, indicates pollution at plants or possible pipe-line damage. However, in the case of this Project no breakage appears to be present in the pipelines.

- No coliform organisms were found in tap water samples in this system. General bacteria, however, appeared at higher than permissible levels in the tap water in several zones. The possibility of contamination is conceivable at taps in zones 2, 5, 6 and 11 judging from the number of samples which exhibited general bacteria in substantial amounts, including samples where the number was in excess of 100/ml.

- Although it is difficult to precisely identify from which plants all the taps in a particular zone are supplied, it is recommended that chlorination be performed at the La Brigada, Lo de Coy and Santa Luisa plants.

- In general Chlorine residual should be kept as low as possible to prevent formation of rust inside pipes through oxidation, as well as to avoid a strong chlorine taste in the water.

- In Guatemala, however, chlorine residual in tap water should be higher than 0.7 mg/l on the basis of the correlation between general bacteria number and the residual chlorine in tap water samples. Where the chlorine residual was higher than 0.7 mg/l, the general bacterial number was always lower than 100/ml, which is the permissible number for drinking water. Where chlorine residual was higher than 1.5 mg/l, bacterial number was zero with few exceptions.

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

- Sample water at some taps occasionally showed values exceeding the MPL (Maximum Permissible Limit) for turbidity and color. This problem will be hopefully rectified, even in the rainy season, after sufficient treatment at the plants.

- Overall, however, the water supply system in Guatemala is currently managed in an acceptable condition.

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

- It is observed that neither Guatemala municipality nor EMPAGUA have plans to construct sewerage treatment facilities in the immediate future. It is recommended, however, to launch such construction at the earliest opportunity with a view to water source conservation, including groundwater, and improvement of environmental and sanitary conditions in general.

- To promote the early implementation of such sewerage projects it is also advisable that the feasibility studies for these projects be reviewed and reinforced by providing experts on socio-administrative procedures and public relations in addition to technical experts. Such experts are expected to prepare strategies by which the municipality obtains public support and access to financial measures.

10. - Deforestation for firewood followed by uncultivated pasturage and development of housing complexes are uncontrolled and encroach upon green areas which contribute 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 green conservation zones, to encourage reforestation and to site housing developments at places where adverse impacts are minimal. Housing development, in particular, may be controlled and the devising of drainage water infiltration facilities should be obligatory for developers.

11. - The following are recommended as measures to be taken by EMPAGUA to strengthen its institutional functions:

i) Implement human resources management policy to increase productivity.

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

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

iv) Strengthen Internal Audit functions to improve control of operations.

v) Generate timely financial and Internal Audit reports to serve as an aid to senior manager decision making.

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

vii) Set up a separate accounting system for the Project to exercise better control.

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

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