社会開発調査部報告書

GOVERNMENT OF THE REPUBLIC OF HONDURAS

Ministry of Public Health

STUDY FOR GROUNDWATER DEVELOPMENT PROJECT IN COMAYAGUA

FINAL REPORT

MAIN REPORT

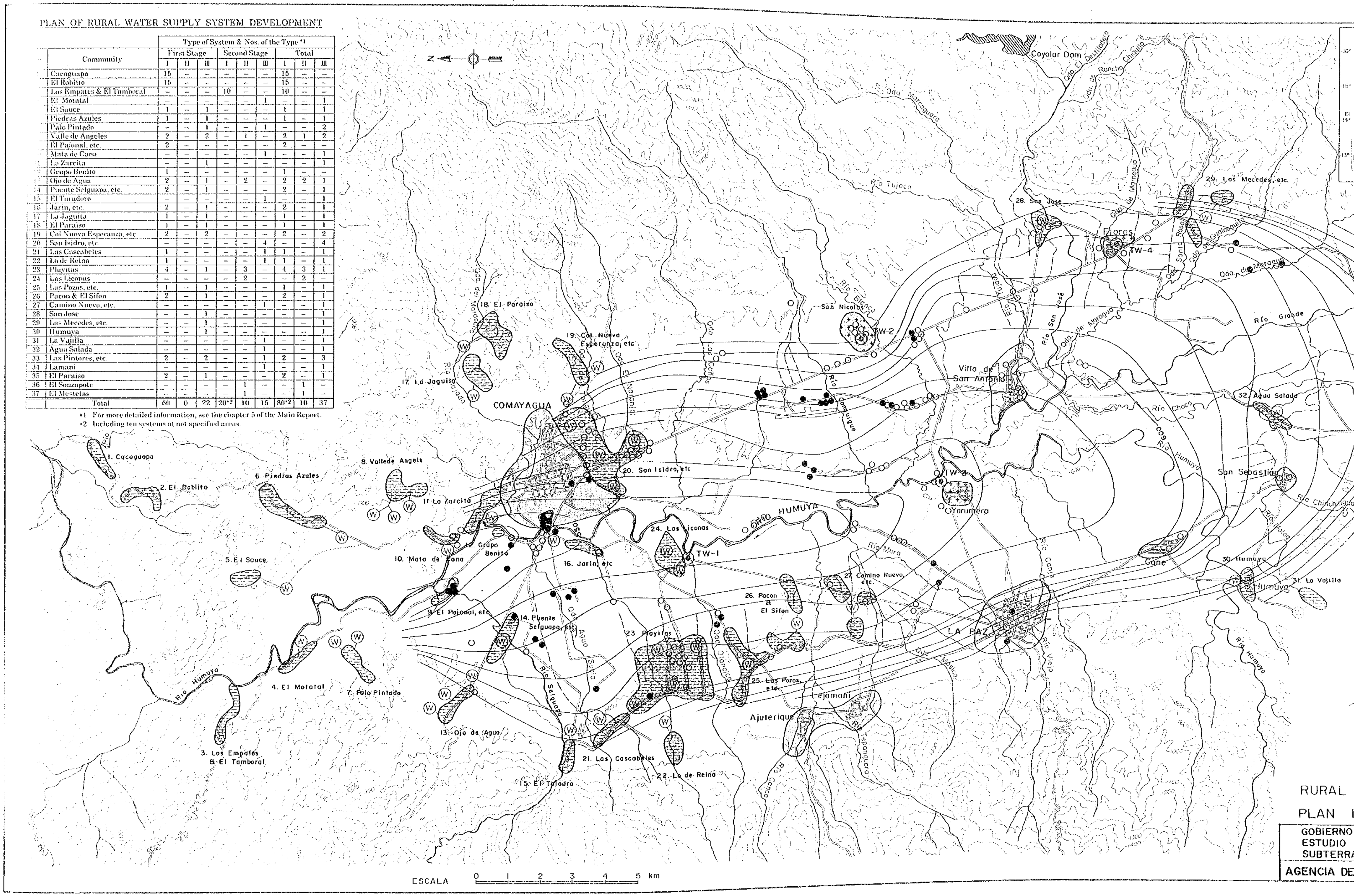
OCTOBER 1989

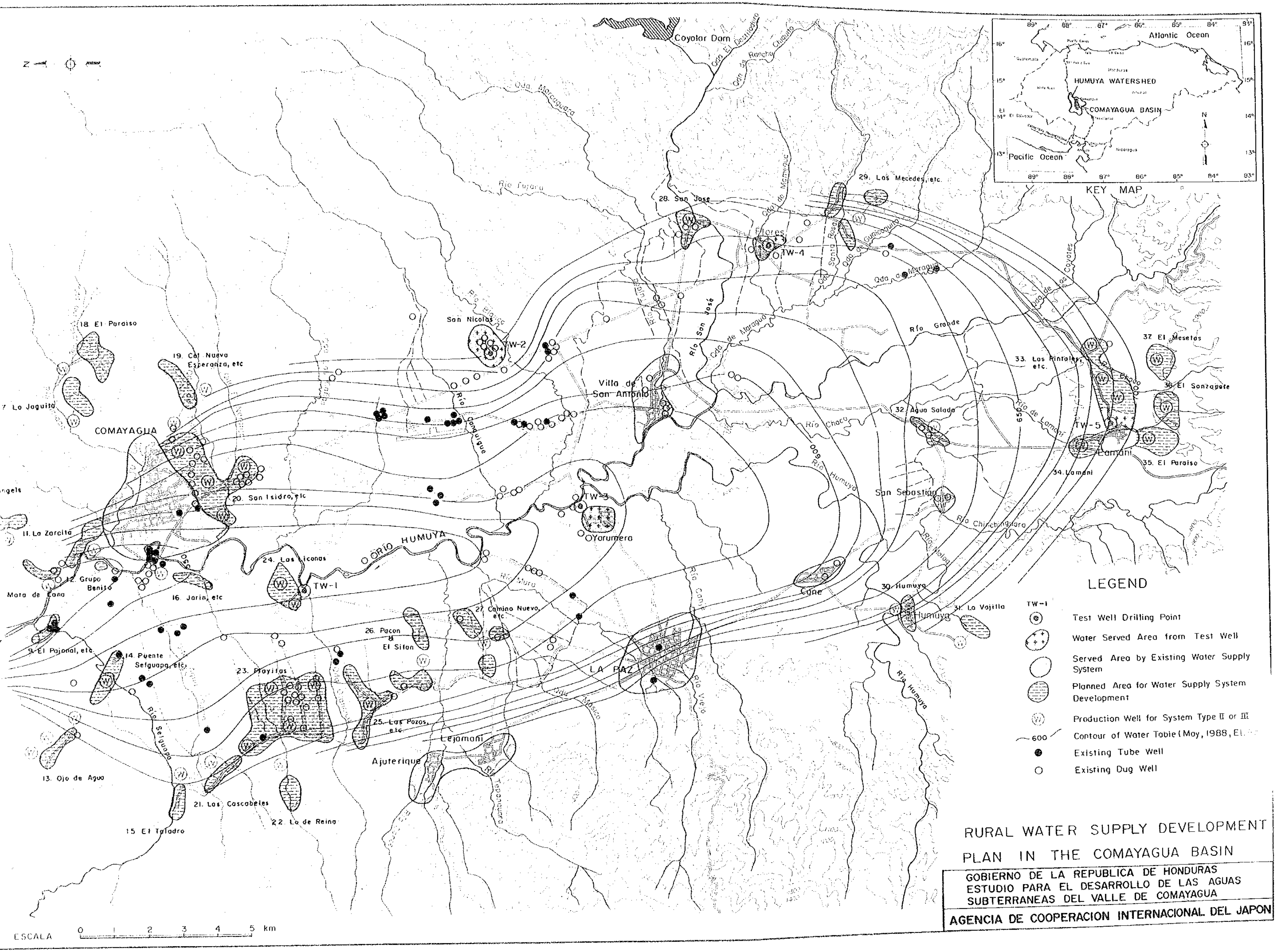
JAPAN INTERNATIONAL COOPERATION AGENCY

PLAN OF RURAL WATER SUPPLY SYSTEM DEVELOPMENT

	Community	Type of System & Nos. of the Type *1								
		First Stage			Second Stage			Total		
		I	II	III	I	II	III	I	II	III
1	Cacaguapa	15	–	–	–	–	–	15	–	–
2	El Roblito	15	–	–	–	–	–	15	–	–
3	Los Empates & El Tamboral	–	–	–	10	–	–	10	–	–
4	El Motatal	–	–	–	–	–	1	–	–	1
5	El Sauce	1	–	1	–	–	–	1	–	1
6	Piedras Azules	1	–	1	–	–	–	1	–	1
7	Palo Pintado	–	–	1	–	–	1	–	–	2
8	Valle de Angeles	2	–	2	–	1	–	2	1	2
9	El Pajonal, etc.	2	–	–	–	–	–	2	–	–
10	Mata de Cana	–	–	–	–	–	1	–	–	1
11	La Zarcita	–	–	1	–	–	–	–	–	1
12	Grupo Benito	1	–	–	–	–	–	1	–	–
13	Ojo de Agua	2	–	1	–	2	–	2	2	1
14	Puente Selguapa, etc.	2	–	1	–	–	–	2	–	1
15	El Taradoro	–	–	–	–	–	1	–	–	1
16	Jarin, etc.	2	–	1	–	–	–	2	–	1
17	La Jaguita	1	–	1	–	–	–	1	–	1
18	El Paraiso	1	–	1	–	–	–	1	–	1
19	Col Nueva Esperanza, etc.	2	–	2	–	–	–	2	–	2
20	San Isidro, etc.	–	–	–	–	–	4	–	–	4
21	Las Cascabeles	1	–	–	–	–	1	1	–	1
22	Lo de Reina	1	–	–	–	–	1	1	–	1
23	Playitas	4	–	1	–	3	–	4	3	1
24	Las Liconas	–	–	–	–	2	–	–	2	–
25	Las Pozos, etc.	1	–	1	–	–	–	1	–	1
26	Pacon & El Sifon	2	–	1	–	–	–	2	–	1
27	Camino Nuevo, etc.	–	–	–	–	–	1	–	–	1
28	San Jose	–	–	1	–	–	–	–	–	1
29	Las Mecedes, etc.	–	–	1	–	–	–	–	–	1
30	Humuya	–	–	1	–	–	–	–	–	1
31	La Vajilla	–	–	–	–	–	1	–	–	1
32	Agua Salada	–	–	–	–	–	1	–	–	1
33	Las Pintores, etc.	2	–	2	–	–	1	2	–	3
34	Lamani	–	–	–	–	–	1	–	–	1
35	El Paraiso	2	–	1	–	–	–	2	–	1
36	El Sonzapote	–	–	–	–	1	–	–	1	–
37	El Mestelas	–	–	–	–	1	–	–	1	–
	Total	60	0	22	20*2	10	15	80*2	10	37

*1 For more detailed information, see the chapter 5 of the Main Report.
*2 Including ten systems at not specified areas.





KEY MAP
Atlantic Ocean
Pacific Ocean
HUMUYA WATERSHED
COMAYAGUA BASIN
LEGEND
TW-1 Test Well Drilling Point
Water Served Area from Test Well
Served Area by Existing Water Supply System
Planned Area for Water Supply System Development
Production Well for System Type II or III
600 Contour of Water Table (May, 1988, El.
Existing Tube Well
Existing Dug Well
Coyolar Dam
COMAYAGUA
Villa de San Antonio
LA PAZ
Lamani
Ajuterique
Lejamani
Yarumera
Río Humuya
Río Grande
Río San José
Río Chiquito
Río Selguapa
ESCALA 0 1 2 3 4 5 km
RURAL WATER SUPPLY DEVELOPMENT PLAN IN THE COMAYAGUA BASIN
GOBIERNO DE LA REPUBLICA DE HONDURAS
ESTUDIO PARA EL DESARROLLO DE LAS AGUAS SUBTERRANEAS DEL VALLE DE COMAYAGUA
AGENCIA DE COOPERACION INTERNACIONAL DEL JAPON

STUDY FOR GROUNDWATER DEVELOPMENT PROJECT
IN
COMAYAGUA

LIST OF VOLUMES

PREFACE

In response to a request from the Government of Honduras, the Japanese Government decided to conduct a study on the Groundwater Development Project in Comayagua and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Honduras a survey team headed by Noboru Miyamoto of Nippon Koei Co.,Ltd, from February to July, 1988 and from October,1988 to March, 1989.

The team held discussions with concerned officials of the Government of Honduras, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincerest appreciation to the officials concerned of the Government of Honduras for their close cooperation extended to the team.

October, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

October, 1989

Mr. Kensuke Yanagiya
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We have the pleasure of submitting to you the Final Report of "Study for Groundwater Development Project in Comayagua" prepared in compliance with the request of the Government of Honduras in implementing water resources development for rural water supply system.

This report consists of two volumes. The Main Report describes the results of ground water potential evaluation in the Comayagua basin, the formulation of the rural water supply development program and feasibility study of the future project. Appendix contains discussions in five sections to supplement description of respective fields in the Main Report.

All the member of the Study Team wish to express grateful acknowledgment to the personnel of Ministry of Foreign Affairs, Embassy to Honduras as well as officials and individuals of Honduras for their assistance extended to the Study Team.

The Study Team hopes sincerely that the study results would contribute to improvement of health and sanitary condition and to enhancement of socio-economic situation in the Study Area.

Yours sincerely,

Noboru MIYAMOTO
Team Leader
Study for Groundwater Development Project in Comayagua

SUMMARY

A. Background

1. The Republic of Honduras is one of the Central American countries, and the majority of the country is occupied by the mountainous area where Tegucigalpa, the capital of Honduras, and the Comayagua basin, the Study Area about 50 km northwest from Tegucigalpa, are situated.

In and around the Study Area, i.e. the Region No.2 consisting of the departments Comayagua, Intibuca and La Paz, water from rivers, springs and shallow wells has been used for drinking and agricultural purposes. The domestic usage of the water without sanitary treatment has caused water-borne diseases, especially in dry seasons when serious shortage of the water has brought about very unfavorable circumstances on the water usage of inhabitants. In addition, due to the inadequate water supply, rural inhabitants spend vast amount of time and energy to obtain their daily domestic water. Accordingly, improvement and development of the water supply systems in the rural area are essential to raise up the standard of health and living.

2. In response to the "PLAN FOR THE INTERNATIONAL DECADE OF DRINKING WATER AND SANITATION SUPPLY" by the World Health Organization (WHO), the Government of Honduras drew up the "National Plan for Drinking Water and Sanitation" in 1983, and this plan aims to serve 90 % of the population by the year 1990. According to the Plan, the Government decided to develop the drinking water supply by means of ground water exploitation at the Region No.2, but in the said area, a feasibility study has not been made yet, and the potential of the ground water resources has not been evaluated. Considering infrastructural facilities and population of the areas, and priority among the areas, the study for the Comayagua basin was selected to be commenced initially in a feasibility level, and the Government of Honduras requested the Government of Japan to provide a necessary technical assistance. The executive agency of the Study is the Ministry of Public Health (MPH).

3. In response to this request the Government of Japan organized a Study Team through Japan International Cooperation Agency (JICA). The study works were commenced in February 1988. Until March 1989, the Study Team was dispatched to Honduras for three times and carried out the field works in close cooperation with the MPH, as well as the home works in Japan. Five reports such as the Inception, Progress I, Progress II, Interim and Draft Final Reports were prepared, and discussions were made with the MPH and other concerning agencies of Honduras. This is a Final Report of the Study with the comments from the Honduran side are duly incorporated.

B. Present Condition

4. Filed Investigation Works: Since the start of the present study in February 1988, works of many items have been carried out. These works are made through three batches of field works and four batches of home works in Japan. Main items of field works achieved are:

- Hydrological observation and analysis.
- Hydrogeological reconnaissance and analysis.
- Geophysical exploration; this work includes 111 points of VLF electro-magnetic survey and 91 points of the electric resistivity soundings.
- Ground water level observation; this work consists of 3 times of the simultaneous observation and the water level monitoring of 6 wells.
- Excavation of five test wells and five observation holes; as existing 170 wells are not distributed uniformly, positions of these wells are selected to supplement the distribution so that uniform constants for simulation can be obtained. 73 to 130 m deep totaling 1,075 m with 4 inches to 8 inches diameter.
- Installation of temporary water supply facilities; this work aims to utilize the test wells and to contribute the improvement of the present rural water supply.
- Water quality analysis; this work was carried out in two times of the rainy and the dry season to compare the seasonal change of the water quality. Totally, 56 water samples including 10 samples of river water were tested.

- Socio-economic survey and analysis
- Study of the rural water supply system
- Preparation of Inception, Progress I and II and Interim Reports

5. Geography: The Comayagua basin with an area of about 470 km^2 spreads between latitude $14^o04'$ and $14^o40'$ north and longitude $87^o27'$ and $87^o54'$ west, and the Humuya River runs northward through the basin which has a catchment area of some 2,100 km^2, occupying 2 % of the territory of Honduras, 112,100 km^2. Altitude of the Study Area is about 600 m, and mountains more than 2,000 m in height surround the area and constitute the watershed. The central American highway (CA5 Highway), which connects Tegucigalpa and San Pedro Sula, runs from southeast to northwest in the Study Area and plays important role as a trunk road. Population in the Study Area is about 109,200 (1988) or 45 head/km^2, of which urban and rural population is 59,600 and 49,600, respectively. In the year 2000, about 169,600 of total population in the Study Area, 98,900 of urban and 70,700 of rural, is forecasted based on the censuses performed.

6. Geology: In the view point of general geology, the highlands where the Study Area situates are composed of Paleozoic metamorphic rocks, Mesozoic sedimentary rocks, Tertiary volcanic rocks, intrusive rocks and so on, while Quaternary sediments are deposited above the said pre-Quaternary rocks in the flat plains such as river channels and inland basins. The Diluvial lake deposits and the Alluvial fan deposits are the main geological units of the Comayagua basin. The Diluvial lake deposits are distributed mainly in the southern half of the basin, and composed mainly of whitish to grayish silt and clay sediments, while the Alluvial fan deposits containing many gravels supplied from the eastern and/or western mountains, are distributed in the northern half of the basin. On the other hand, at the margin of the basin, the lake deposits are generally characterized by gravelly sediments.

7. Meteorology: Within the watershed of the Humuya river, average annual rainfalls are about 900 mm and 1,200 mm at the floor of the basin and the surrounding highland, respectively. However, 90 to 80 % of the precipitation falls in the rainy season from May to October. In the dry season from November to April, it is very minor, especially to February. The rainfall

amounts to only about 20 mm at the floor of the basin. Although a tendency of the rainfall is rather clear, quantity and timing fluctuate very much by year. In the present study, therefore, hydrological standard year was selected based on the statistical analysis of the annual basin rainfall for the water balance study. The obtained hydrological standard year and the corresponding basin rainfall is shown below:

Hydrological Standard Year	Year	Annual basin rainfall in mm	Annual basin rainfall in MCM
normal year (1/2 drought year)	1983	1287.5	2,643.6
1/10 drought year	1986	882.3	1,811.6
1/20 drought year	1972	771.2	1,583.5

8. Hydrology: In the dry season, it is ordinarily observed that the tributaries of the Humuya river are dry except for some relatively large streams such as the San Jose river, the Grande river, the Choco river and the Lamani river. Perennial base flow is seen on the Humuya river and the above-mentioned rather large tributaries. The observed base flow at the Encantada gauging station, which locates at the outlet of the Comayagua basin, is in a range from 1 m^3/sec to 6 m^3/sec or 30 MCM to 190 MCM a year. On the contrary, in the rainy season, the surface runoff increases in a short time after heavy rainfall, and finally becomes a flood flow. The annual runoff from the whole basin in each hydrological standard year is calculated by means of an accumulation of daily observed runoff, and is summarized as below:

Hydrological Standard Year	Year	Whole basin annual runoff: Volume in MCM	Whole basin annual runoff: Ratio to ann. rain(%)
normal year (1/2 drought year)	1983	379.1	14
1/10 drought year	1986	197.5	11
1/20 drought year	1972	178.8	11

9. Hydrogeology: In the Study Area, the Alluvial fan deposits are rather thick, generally 20 to 30 meters or more, at the northern half area of the basin, while very thin Alluvial deposits of a few meters at the thickest spreads on the southern half area of the basin. Diluvial lake

deposits originated from Tertiary acidic fine tuff and/or welded tuff underlie those Alluvial deposits. It is expected that the Diluvial lake deposits contains aquifers within the depth of about 200 m at the center of the basin. Judging from the hydrogeological investigation results performed, the aquifers in the Study Area are categorized into two kinds of ground water such as the phreatic water and the confined water. The former is ordinarily contained in the Alluvial fan deposits, while the latter flcws in the Diluvial lake deposits.

10. Land Use: About 36,000 ha or 80 % of the Study Area (47,000 ha) is being used for the such agricultural purposes as crop land and pasture land. Remaining 11,000 ha or 20 % of the basin is occupied by the residential area, forest and others. The crop land of 36,000 ha includes irrigation land of some 7,000 ha which consists of three systems; Flores system, San Sebastian system and Selguapa system. Actual irrigation area in 1988 amounted to about 4,000 ha out of 7,000 ha. The Region No.2, which includes the Study Area, accounts for an important situation in the country in respect of the agricultural production.

11. Present Water Use: Principal objectives of water utilization in the Study Area can be classified into three categories: irrigation, domestic and industrial uses. The irrigation is carried out for crop and pasture lands by using canal water and rain water, and it is represented by the said three irrigation systems. Monthly water consumption of the three irrigation systems showed approximately 2.2 MCM on an average in 1987. The domestic water is supplied by the existing water supply system, which is piped system and was facilitated by Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA), and private and public wells. Almost all of manufacturing industries utilize water from their own wells together with water supplied from SANAA. Existing water supply system in the Study Area served for about 62,800 population or 57 % of the total population in 1988. However, the said served population is mainly of the urban area, i.e. 53,300 or 89 % of the total urban population, and the served population in the rural area only amounts to 9,500 or 19 % of the total rural population.

12. Present level of Ground Water Development: Although the number of wells in the Study Area is increasing recently, development of the ground

water resources remains in low level so far. Out of 170 wells confirmed through the field investigations, 152 wells are in use at present. Of 152 wells, 113 shallow dug wells are for the domestic use of the rural inhabitants, and 39 deep tube wells mainly for the agricultural and industrial purposes. Considering an available yielding amount from a shallow dug well, it is estimated that about 1,130 m^3/day is at most being supplied for household use of the rural inhabitants. Since an average pumping discharge is about 150 m^3/day, the total production volume from the deep tube wells is estimated at about 6,560 m^3/day. Accordingly, the present ground water development volume amounts to 7,690 m^3/day; 3,530 m^3/day from the phreatic water and 4,160 m^3/day from the confined water.

C. Comprehensive Study

13. Home Works: Of many items of the home works achieved, the main items are;

- Simulation of ground water potential on natural condition, using the tank model and the finite difference method (FDM) on two dimensional ground water model.
- Project formulation for the rural water development in the master plan level; this work includes formulation of ground water development plan, water supply master plan, facility development master plan and project cost estimate.
- Economic evaluation of the future project.

14. Simulation of Ground Water Potential: After careful study on the hydrogeological structure and characteristics of the Comayagua basin, two kinds of aquifer systems of the phreatic water and the confined water are identified. According to the water balance study by means of the tank model simulation, annual recharge volume into both aquifers is estimated equally at about 52,000 m^3/day, respectively, (104,000 m^3/day in total) or 0.7 % (1.5 % in total) of the average annual rainfall. It is also expected that the recharge to those aquifers is remarkably constant by year and also by month. Consequently, both the present development volume of 7,690 m^3/day (the paragraph 12) and the future total development volume of some

12,500 m^3/day within the Comayagua basin, remains within the sufficiently safety side comparing with the total recharge amount. On the other hand, by means of the ground water model simulation (the FDM method), it is predicted that maximum drawdowns of both the aquifer systems at the year 2000, when the rural water development would be completed, is 7 m and 9 m, respectively. The result of simulation should be reflected on a design of installation depth and head of pumps for planned production wells.

15. Water Quality: In the Alluvial fan deposits spreading northeast or northwest of the Study Area, it is found that inorganic ion concentrations of the phreatic water are relatively low and the water is suitable for potable use. In the center to northern area of the basin, in case of the Diluvial lake deposits, the confined water is unsuitable for potable use due to high concentration of ammonium ion resulted from the anaerobic environment, while in far southern and marginal area of the basin, confined water show low ion concentrations even in the Diluvial lake deposits, which indicates a suitability for the potable use.

D. Rural Water Supply Development Project

16. Water Supply System Development Plan:

1) Master Plan: As a result of the present study, it is concluded that the new well development for the rural water supply should be urgently executed to meet the water requirements of the rural inhabitants. The urgent need for rural water supply urges to establish an immediate development program, which is to be integrated with a long range master plan. Consequently, a stage wise development program is proposed, i.e. the three stage development with target years of 1993, 1996 and 2000, supposing that the project starts from the year 1990.

2) Water Demand: In the National Plan (see the paragraph 1), the per capita demand of rural inhabitants and coverage of rural population are set at 50 lcd at the initial stage and 90 % of total population, respectively. In this study its criteria are also applied for the future system development in 1993 as a part of the master plan.

Further, the per capita demands for the future projection in 1996 and 2000 are set at 80 and 100 lcd, respectively, considering about the similar developing countries' experience/practice and the expected grade up of the living standard of the rural inhabitants in the Study Area. Accordingly, the water demand at each target year is estimated as below:

	First Stage	Second Stage	Third Stage	Total
Target year	1990 - 1993	1994 - 1996	1997 - 2000	1990 - 2000
Rural population				
Total	57,572	62,814	70,700	70,700
Served*1	51,800	56,500	63,600	63,600
Water demand				
in l/c/d	50	80	100	100
in m^3/day	2,590	4,520	6,360	6,350
System type & Capacity (m^3/d) *2				
Type I	504 (60)	168 (20)	To be planned	672 (80)
Type II	0 (0)	360 (10)	& executed by	360 (10)
Type III	2,112 (22)	1,440 (15)	MPH himself	3,552 (37)
total	2,616 (82)	1,968 (45)	-- (--)	4,584 (127)

Note *1:Served Population = Total population x 0.9 (90 %)
*2:Capacity means the production capacity by system development. Figures in parentheses are number of the system unit.

3) Facility Development Plan: As for the type of future rural water supply system, the following three systems are preliminary designed and recommended to be applied depending on the size and situation of the rural community.

Type I : A deep well point source, D4" and 50 to 100 m depth, installed with a cylinder type hand pump. The system would cover at least 7 to 8 households or about 40 to 50 residents.

Type II : A deep well point source, D6" and 50 to 100 m depth, installed with an electric motor pump and an above ground water tank. This system would cover 20 to 50 households or 100 to 300 population.

Type III: A deep well point source, D6" and 50 to 100 m depth, installed with an electric motor pump and an elevated tank which could supply the water to a few remote sub-tanks.

This system would cover at most up to 100 households or a total population of 500 to 600.

In compliance with the proposed water supply master plan and the facility plan, the facility development in the first and the second stage is scheduled as shown in the table above

17. Cost and Benefit: The construction cost is estimated at Lps. 29.88 million (equivalent to US$ 14.94 million) for the first stage construction from 1990 to 1993 and at Lps. 24.09 million (equivalent to US$ 12.05 million) for the second stage construction from 1994 to 1996. In case of the first stage construction, Lps. 21.16 million or 71 % is for foreign exchange and Lps. 8.72 million or 29 % for domestic currency, while in case of the second stage construction Lps. 15.08 million or 63 % for the foreign exchange and Lps. 9.01 million or 37 % for the domestic currency. On the other hand, the economic benefit is estimated at Lps. 2.81 million in 1994 and Lps. 4.08 million in 1997, and after 1997 the same amount as the 1997 benefit would accrue every year during the project life period. Then, the economic internal rate of return (EIRR) is calculated at 9 %.

18. Due Consideration on Project Implementation: The construction plan and implementation schedule on the Project are prepared by the assumption that all the construction works will be performed by contractors selected through international competitive tenders. However, it is recommended that a technical training for the governmental staffs on the water supply system development is included and pursued during the construction works from 1991 to 1996 so as to realize the third stage construction by themselves and to make them capable on the operation and maintenance (O&M) works. Therefore, supply of the necessary equipment and tools, including drilling rigs, for construction and the O&M works are also incorporated in the Project, and finally they would be handed over to the MPH after the first and the second stage construction. on the other hand, it is recommended that existing organization of rural water supply should be reinforced both on quantity and quality to cope with the operation and maintenance (O&M) of newly developed rural water supply system.

19. <u>Socio-economic Impact</u>: The Project is expected to produce various tangible and intangible effects. Some major effects are summarized below:

1) Reduction in load for carrying water, in addition to economic effect of time saving, would result in reduction in physical and mental burden of women, and children would be able to gain time for attending school.
2) According to statistics of WHO, deaths caused by water borne diseases account for the rate of 5 % to 10 % of the disease cases in developing countries. Accordingly, the reduction in cases of water borne diseases will lead naturally reduction in number of the deaths, especially reduction in number of infant mortality. As a result, an average life expectancy of inhabitants will be prolonged.
3) Safe and adequate drinking water supply to rural inhabitants would give significant impacts for the improvement of sanitation, and domestic and personal cleanliness in the Study Area.
4) Implementation of the Project would create an employment opportunity for inhabitants in and around the Study Area during the period of construction.
5) An investment of some Lps. 37 million (including the foreign currency portion) for construction would be a stimulative effect for the socio-economic development in the Study Area.

20. <u>Recommendation and Conclusion</u>: The Project has a character of basic human needs and is feasible economically, and further it is expected that the Project would make a significant contribution to development of socio-economy and improvement of health and sanitary conditions in the Study Area. Accordingly, the Project is recommended to be realized as early as possible.

TABLE OF CONTENTS

page

page

LIST OF TABLES

page

LIST OF FIGURES

page

CHAPTER 1 BACKGROUND OF THE PROJECT

1.1 General Situation of Honduras

1.1.1 Natural condition

The Republic of Honduras is located in the central part of Central America extending from $13^{o}0'$ to $16^{o}0'$ north latitude and from $83^{o}10'$ to $89^{o}25'$ west longitude. It is bordered by the Caribbean Sea and the Gulf of Honduras (for about 600 km) on the north, Nicaragua on the east and south, the Gulf of Fonseca and the Pacific Ocean (for about 70 km) on the south, El Salvador on the southwest, and Guatemala on the west (see Fig. 1.1.1).

Honduras has an area of 112,088 km^2. Except for the coastal plains on the northeast and south, it is a mountainous (65 % of the whole area) forested, and generally fertile country. Nevertheless, the country lacks high peaks and the maximum elevation is only 2,590 m (Cerros de Culmi). Plateaus and basins among the mountains are in the most favorable natural conditions and have formed many villages and towns as the centers of agricultural and forest industries in respective regions, while the eastern low land is in an unfavorable condition with various morasses and has been left behind the development.

Most of the country is underlain by a relatively stable geotectonic block of the Honduras Massif which consists of crystalline rock, metasediments, and intrusives of pre-Mesozoic age. It is said those basement rocks were formed in Paleozoic era and possibly Precambrian era in part. They crop out in the northern region due to regional tilt to south, and are covered by Cretaceous marine sediments (limestones and tuffs), and successively by various sequences of Tertiary and Quaternary volcanics.

Climate in Honduras can be roughly classified into two categories by geographical situation; highlands and plains. The climate of high land zone, for example, is represented by Tegucigalpa (900 m above MSL) located in the central mountainous area, and the climate of plain zone by San Pedro Sula (60 m above MSL) in the Caribbean coast area. Further the climate is divided into two seasons; a rainy season from June to November and a dry

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favorable to Honduras, subject to the economic development.

Tegucigalpa, the capital city, which has a population of some 600 thousand in 1988, and including the surrounding area it forms a center of policy, administration and commerce in Honduras. On the other hand, San Pedro Sula which is the second largest city in Honduras has a population of approximately 320 thousand in 1988 and is developing as the greatest industrial zone in Honduras (see Table 1.1.1). Details of the population are discussed in the section 3.2, Appendix A.

Honduras is a traditional agricultural country where with regard to labor force the agricultural sector accounts for about 60 % of the whole industrial sector. The majority of agricultural products are tropical products such as maize, beans, rice, coffee, bananas, sugar cane, cotton and tobacco. Among them, maize, beans and rice are mainly consumed in Honduras as the staple food for people, on the other hand the agricultural crops such as coffee, bananas, sugar cane, cotton and tobacco are important as export goods rather than the domestic consumption. Actually these export goods have accounted for nearly 70 % of total exports of Honduras.

Besides crops, Honduras has an extensive cattle farming industry which is operated by using wide pastures. More than 200 thousand heads of cattle every year have been caved for edibles use, including the frozen meat for export use which amounts to Lps. 40 million approximately.

The Honduran industry is represented by an agro-industry which utilizes maize, sugar cane, various fruits, etc., and the industrial goods of iron bar, cement, matches and others are produced at some small and middle scale factories. In Honduras there is not the large scale industry to be worthy of note and the industrial productivity also is low relatively. These things will be one of the causes of the dull development of national economy. Details of the agricultural and industrial products are discussed in the section 2.2 of Appendix A.

Gross Domestic Product (GDP) and Gross National Product (GNP) of Honduras amounted to Lps. 7,060 million and Lps. 7,654 million in 1987, and during the period 1984-1987 the real annual growth rates showed 2.9 % and

3.2 %, respectively. As a result, the GNP per capita was estimated at Lps. 1,889 and the real growth showed a low rate of 0.2 % per annum during the said period. This shows that the living standards of Honduran people were little improved economically in recent years (see Table 1.1.2). Details of GDP and GNP are discussed in the section 2.1, Appendix A.

Exports of Honduras amounted to approximately Lps. 1,650 million in 1987 at an annual growth rate of 4.8 % for the period 1982-1987, and the majority of them were occupied by primary and secondary products of agriculture. On the other hand, imports amounted to approximately Lps. 1,800 million in 1987 at the same growth rate as that of the exports for the said period. More than 90 % of the imports were occupied by goods necessary for the daily life and the general social and economic activities of Honduran people. In Honduras, the imports have exceeded the exports every year, and such trade deficits have been the main cause to make unfavorable situation of international payments (see Tables 1.1.3 and 1.1.4). Details of the external trade are discussed in the section 2.3, Appendix A.

In the balance of international payments of Honduras shown in Table 1.1.5, the service account also showed a deficit in the balance every year as well as the trade deficits. Accordingly, the balance of current account resulted always in deficit, though some parts of the deficit were supplemented with the transfer account. Such unfavorable balance of current account has been supplemented by the capital account which included the external loans and grants, for maintaining the balance of international payments in each year. As a result, the external debt has been accumulated year by year.

The Government budget in 1987 amounted to Lps. 2,370 million which corresponded to 31 % of the GNP, at an annual growth rate of 9.8 % during the period 1982-1987. Public health budget accounted for 10-11 % of the Government budget every year and amounted to Lps. 234 million in 1988. Of the Government revenue, tax revenue and debt revenue accounted for 47 % and 33 %, respectively. In 1987 the debt revenue exceeded the debt repayment by Lps. 330 million. Though such an unfavorable balance of debt in each year was trending toward reduction since 1985, the accumulated debt continued still to increase (see Table 1.1.6). Details of the Government finances are discussed in the section 2.5, Appendix A.

Wholesale and consumer prices in Honduras were making a stabilization comparatively during the period 1982-1987 at an average annual rise rate of 2.56 % and 4.54 %, respectively. Such stabilization of the prices was the only favorable condition for livelihood of people in a social instability due to the dull development of national economy. On the other hand, employment was in an unsatisfactory situation. The unemployment rate showed 12 % in Tegucigalpa according to statistics in 1987, while it is said that the unemployment rate in the whole country would amounted to as much as 30 %, because the employment opportunity of inhabitants in rural areas were fewer by far compared with them in such dense urban area as Tegucigalpa. Details of prices and wage are discussed in Section 2.6, Appendix A.

From the above discussion, the structural features of Honduran economy are summarized as follows:

(1) During the period 1982-1987, Honduras showed a high growth rate of population comparatively, however, still the population density was very low, especially in the eastern region;

(2) Manufacturing industries, except the agricultural sector, continued a low growth and a little creation of the employment opportunity;

(3) As a result, the GNP and particularly the GNP per capita showed a low real growth;

(4) International payments and Government finances have been balanced by supplementing with internal and external debts for their deficits; and

(5) Despite the unfavorable economic situation, wholesale and consumer prices have maintained a stabilization.

1.1.3 National development plan

The Report of Secretaria de Planificacion, Coordinacion y Presupuesto (SECPLAN) indicates that the socio-economic feature of Honduras for the period 1975-1985 would be represented by (1) low economic development level, (2) imbalance of the Government finances, (3) disparity in socio-economic level among regions, (4) unemployment, and (5) unsatisfied social welfare. As the main objectives to improve such unfavorable situation, in 1985 the Government formulated a plan called " the National Plan of Development, 1987-1990" (El Plan Nacional de Desarrollo, 1987-1990).

Fundamental target of the Plan is to create a comfortable living conditions for people through the maximum economic growth and the optimum revenue allocation. To achieve this target, the Plan sets the major five objectives as follows:

(1) growth stabilized continuously of the national economy,
(2) balances of Government finances and external payments,
(3) creation of employment,
(4) security of necessary living standards for people, and
(5) integrated regional development.

During the period of this Plan, the real annual growth rate of Honduran economy is expected to be 4.3 % for the GNP and 1.1 % for the GNP per capita, which are somewhat high rates compared with respective rates of 3.2 % and 0.2 % for the period 1982-1987. On the other hand, the Government budget is designed to amount to Lps. 3,120 million in 1990 increasing by Lps. 750 million from Lps. 2,370 million in 1987. In either case of the GNP and the Government budget, it will not be very difficult to achieve each target, judging from the internal and external economic conditions of Honduras at present. However, even if these targets were achieved by 1990, the Honduran economy still would be to continue a severe situation.

1.2 Water Supplies in Honduras

1.2.1 Ministry of Public Health water supply

The Honduran Government, with technical assistance from the World Health Organization (WHO), had prepared "National Plan for Drinking Water and Sanitation" for the period from 1983 to 1990. In response to the Plan, the President created a National Committee for Drinking Water and Sanitation (CONAPS) in November 1983, to coordinate activities of different agencies. The Ministry of Public Health (MPH) and the Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA) are the agencies responsible for achievement of the Plan.

The MPH works in the following five areas:

1) Construction of small rural water schemes and supervision of the operation and maintenance;
2) Construction of communal wells in rural areas, and supervision of operation and maintenance;
3) Construction, installation and control of maintenance of latrines in rural areas and in urban areas where there is no sanitary sewerage;
4) Health and education; and
5) Control of water quality.

The Rural Water and Sanitation Program (PRASAR) financed by the US Agency for International Development is being carried out in conjunction with Servicio Autonomo Nacional de Acceductos y Alcantarillados (SANAA). As a part of this program, the MPH is carrying out works for communities of between 50 and 500 people. The work involves 20,800 latrines, 54,000 village water supply schemes, 2,000 community wells equipped with hand pumps, 15 community wells pumped by windmills, 25 gravity systems and a program of health education. The work also covers areas where water and/or sanitation schemes are being built by SANAA.

In each community, an honorary health representative who will lead a small administrative team is identified. They are supervised by health promoters who work under 462 Rural Health Centers (CESAR) located in 238 municipalities. These health promoters in turn are monitored by coordinators working for 29 Centers of Medical Health (DESANO) or Area Hospital Centers.

Necessary information to monitor the sector activities under the Plan starts with the community and passes through the health promoters to the area coordinators, then the engineering coordinator for the region, and finally to the Division of Sanitation and Drinking Water, under the Basico Programmes Directorate of the Director General.

1.2.2 SANAA water supply

All the activities of the SANAA are associated with the drinking water and sanitation sector. It is concerned with the design, construction and operation of potable water and sanitation systems for rural and urban areas, and for the metropolitan area of Tegucigalpa.

Objective areas of water supply by the SANAA contains not only large cities such as Tegucigalpa and San Pedro Sula, but also towns and villages with inhabitants of more than 500. According to statistics, the water supply volume in 1987 by the SANAA amounted to 25.76 MCM, and its growth rate showed 2.1 % per annum on an average for the period from 1983 to 1987. This supplied water was consumed at the rate of 17.90 MCM (69 %) for domestic use, 2.98 MCM (12 %) for commercial use, 0.55 MCM (2 %) for industrial use and 4.33 MCM (17 %) for government use.

1.2.3 Present situation of rural area

Present water supply systems in the study area are summarized in Table 1.2.1. At present about 57 percent of the total population in the study area are served by the piped systems which are operated and managed by SANAA and the respective municipalities. While, the rest of the 43 percent of total population or about 46,000 residents are obtaining their daily life required water from existing shallow wells and nearby rivers or streams. The river flows are subject to remarkable seasonal fluctuations and are generally inadequate in amount in the dry season. Severe shortage of water occurs especially in December through April in every year.

In the study area, about 170 wells exists and are utilized by the local residents for the daily life water use (ref. the section 4.1). It is observed during the field investigation that the drinking water is taken from those wells. While, water for cleaning and washing the body and clothes is used and/or obtained from the nearby streams in many places, even in the built up urban area installed with piped system.

The SANAA 4-city project is on going, and the whole or the most part of the municipalities of La Paz and Cane are covered by the said project because this project includes expansion and additional development of the urban water supply system for La Paz.

The present water demand and per capita consumption (LPCD) are investigated and analyzed using the informations collected through interview survey with the local residents during the field survey. Based on this, an average 20 to 30 l/c/d (litters per capita per day, LPCD) is consequently estimated (ref. Table 1.2.2).

The target of the served population ratio at 90 percent of the total population with per capita consumption at 50 LPCD in the whole country by the year 1990 is established by the MPH, following to the National Plan for Drinking Water and Sanitation. The present water supply system for the rural area in the study area is grossly inadequate to meet the average daily water requirements both on quantity and quality, especially during the dry months.

To realize the said target of the National Plan, an immediate water supply improvement program is needed to solve the present unwelcomed situation and to supply safe and sufficient water for the rural inhabitants in the study area.

1.3 Outline of the Request

Because of insufficiency of the water supply system, the water from rivers, springs and shallow wells are being utilized for drinking and agricultural purposes. However, usage of the water without sanitary treatment has caused water-borne diseases, especially in dry seasons when shortage of the water has brought about very unfavorable circumstances on the water usage of inhabitants. Therefore, improvement and development of the water supply systems in the rural area are essential to raise up the standards of health and living, and should be commenced in high priority.

According to the National Plan, the Government decided to develop the drinking water supply by means of ground water exploitation at the Health Region No.2 consisting of Comayagua, Intibuca and La Paz. The initial development plan formulated by the MPH is summarized as follows:

- Project Area: Health Region No.2 consisting of Comayagua, Intibuca and La Paz

- Beneficiary : Rural inhabitants who live in the communities with the population of less than 500 (about 157,000 at 1990)

- Development Schedule : 1,250 wells with 50 m depth. Construction starts at 1986 and finishes by 1990.

In order to achieve the proposed plan, the Government requested the Government of Japan to provide the financial and technical cooperation on the implementation of the project. Since it was considered essential to investigate the ground water potential, to plan appropriate rural water supply systems and to evaluate the project feasibility, both the Governments of Honduras and Japan agreed on an execution of the ground water development study in feasibility study level, prior to the actual construction work of the rural water supply.

1.4 Preliminary Study

In response to the request of the Government of Honduras, the Government of Japan dispatched the preliminary study team consisting of members of the Japan International Cooperation Agency (JICA), the official agency for technical cooperation programs of the Government of Japan. Based on the result of the preliminary study, the Scope of Work on study for Groundwater Development Project in Comayagua was prepared and agreed on November 6, 1987 between the Government of Honduras and JICA (as attached in Appendix F). The Study was entrusted by JICA to the Study Team in cooperation with counterpart engineers of MPH.

The scope of work on the study for Groundwater Development Project in Comayagua agreed upon between MPH and JICA is summarized below:

a. Objective of the study
b. Study Area
c. Scope of the study

1) Objective of the study

The objective of the study is

a. To evaluate the ground water resources development potential in Comayagua, and
b. To transfer the technology to the Honduras counterpart personnel in the course of the study.

2) Study area

The Study Area covers the Comayagua basin (approximately 470 km^2) in Comayagua.

3) Scope of the study

The items of the Scope of Work are as follows:

a. Preliminary study consisting of the collection and review of data.

b. Field survey mainly composed of

- Field reconnaissance on every field such as socio-economy, water supply system planning, meteo-hydrology and hydrogeology,
- Geophysical exploration,
- Water quality analysis,
- Run-off observation,
- Well inventory survey and ground water level observation,
- Test well drilling and pumptest, and
- Installation of temporary water supply facilities.

c. Comprehensive study at home mainly composed of

- Evaluation of the ground water potential,
- Design of the rural water supply system and formulation of the rural water supply development master plan, and
- Assessment of the project feasibility by the economic evaluation.

CHAPTER 2 PROJECT ACTIVITY

2.1 Work Schedule and Organization

2.1.1 Work schedule

The whole work period for this project is scheduled to be 20 months from the commencement of the preparatory works in the beginning of February 1988 by submitting the Final Report in September 1989, and basically divided into the following three (3) stages.

(1) Preliminary investigation stage : from Feb. '88 to Mar.'88
(including preparatory work period)
(2) Main investigation stage : from Apr. '88 to Mar.'89
(3) Main study stage : from June '89 to Sep.'89

Furthermore, the above-mentioned investigation stages are subdivided into the following eight (8) work divisions.

1. Preliminary investigation stage
   - (1a) Preparatory works
   - (1b) the First Field Investigation

2. Main investigation stage
   - (2a) the First Home Work
   - (2b) the Second Field Investigation
   - (2c) the Second Home Work
   - (2d) the Third Field Investigation

3. Main study stage
   - (3a) Comprehensive study (the Third Home Work)
   - (3b) Preparation of reports

Work flows in each year are shown in Fig. 2.1.1 and the time schedule is shown in Fig. 2.1.2, while performed assignment schedule is given in Fig. 2.1.3. Work quantities executed during the field investigation are summarized in Table 2.1.1.

2.1.2 Organization and staffing

From the necessity for obtaining reliable data and survey result, the project organization was formulated as shown in Fig. 2.1.1. According to the planned organization, the field investigation works were carried out by the JICA's experts and the MPH counterpart engineers.

In the main study stage, the test well drilling work including the temporary water supply system was executed by a local contractor, selected by the JICA study team, under the supervision and technical assistance of the team (see Fig. 2.1.4).

The JICA study team headed by the team leader, Dr. N. Miyamoto, is composed of eight experts dispatched to the site as shown in Fig. 2.1.3.

2.2 Equipment supplied by JICA

In compliance with the scope of the study, the following equipment were supplied by JICA:

1) Instrument for the electric resistivity survey	: 1 set
2) Automatic water level recorder	: 5 sets
3) Portable test set for water chemistry	: 1 set
4) Vehicle	: 2 sets
5) Micro computer	: 1 set
6) Copy machine	: 1 set
7) Electric conductivity meter	: 1 set

In addition to the above equipment, the JICA study team prepared temporarily the following instruments for the sound investigation:

8) Instrument for VLF electro-magnetic survey	: 1 set
9) Current meter for the run-off measurement	: 1 set
10) Apparatus for the water quality analysis	: 1 set
11) Apparatus for in-situ water sampling of tube well	: 1 set

12) Ground water level indicator : 2 sets

13) Micro computer (lap top type) : 2 sets

2.3 Reports and Minutes of Meeting

The JICA study team prepared the Inception Report, the Contract Document including the technical specifications for the test well drilling and the installation of the temporary water supply facilities, the Progress Report I, the Progress Report II, the Interim Report, the Draft Final Report and the Final Report. On the other hand, the minutes of meeting were prepared at important stages of the study such as the beginning of the preliminary investigation stage and the end of the main investigation stage (see Appendix F).

1) Inception Report

In the preliminary investigation stage, the Inception Report was prepared and submitted to MPH on the date of February 26, 1988. The report describes the detailed investigation plan on the operation, organization and work schedule, transfer knowledge and so on.

At the same time, the JICA study team and MPH discussed and agreed on the test well drilling location and the home training of a counterpart engineer. Those matters are confirmed in the said Minutes of Meeting.

2) The Progress Report I

Based on the result of the First Field Investigation and the First Home Work in the preliminary investigation stage, the Progress Report I was prepared and was submitted on March 12, 1988, comprising the initial study on the collected data concerning meteorology, geology, existing water supply system, economical situation and so on.

3) Contract Document on the test well drilling

Contract for the "Test Well Drilling and Pumptests" including the installation of the temporary water supply facilities was signed between the JICA study team and Hidrosystemas, a selected local contractor, on the date of September 6, 1988.

Prior to the contract sign, the technical specifications on all the contract works were prepared for the prequalification of local contractors, and they were finally included in the contract document.

All the procedures on the contract are explained in more detail in Appendix C.

4) The Progress Report II

During the First Home Work of the Main Investigation Stage, an preliminary analysis was carried out on the collected data. The result was set forth in the Progress Report II, which was submitted to the MPH on May 12, 1988.

5) The Interim Report

The Interim Report was prepared and submitted to the MPH at the end of all the field investigation (March 17, 1989). The report presents the progress of the work, the project findings and the analysis of the collected data regarding socio-economy, hydrological and geohydrological environment, hydrogeology and ground water, and plan of water supply system.

In parallel with the preparation of the Interim Report, the future construction program was discussed between the JICA study team and the MPH, and as a result, the Minutes of Meeting was prepared and was signed on March 17, 1989.

6) The Draft Final Report and the Final Report

The JICA study team carried out further study in Tokyo, immediately after the field investigation and the discussion with the MPH, on the ground water potential, planning and design of water supply system and socio-economic analysis. The result of the study is compiled in the Draft Final Report and the Final Report.

2.4 Transfer of Knowledge

From the view point of the effective transfer of knowledge, all the field investigation work are scheduled to be carried out in cooperation with MPH counterpart engineers. For this purpose, MPH has assigned the appropriate engineers with specialities to meet the respective study fields of the JICA's experts. The engineers of MPH assigned are listed in Table 2.4.1.

Actually, the transfer of knowledge was made on the following items, mainly through the learning-by-doing method at the site during the period of the field works.

a. Meteoro-hydrological investigation
   - data collection and arrangement
   - surface runoff measurement
   - computerized data base development

b. Hydrogeological investigation
   - data collection and arrangement
   - preparation of a well inventory
   - simultaneous water level observation
   - water level monitoring

c. Geophysical exploration
   - exploration method and handling of equipment
   - analysis of exploration result

d. Water quality analysis
   - water sampling
   - handling of equipment
   - analysis method
e. Study on water supply system
   - data collection
   - design of temporary water supply facilities
f. Study on socio-economy
   - data collection
   - arrangement of data

On the other hand, Ing. Juan Rafael Delcid F., the chief counterpart of the Project, visited and stayed in Japan during the period from July 28, 1988 to August 20, 1989 for the training of a semi-senior stuff.

In relation to the test well drilling, the training "learning-by-doing" was done for the supervision for the contractor's work through the instruction and guidance of the JICA's engineers and experts.

a. Confirmation of detailed schedule for the field works executed by local contractors,
b. Preparation of technical specifications and standards for the field investigation.
c. Supervision of the local contractor's works in checking their progress against the schedules and in confirming the work qualities in accordance with technical specifications and standards,
d. Arrangement and inspection of field work results, and
e. Analysis of the field work results.

Besides, technical guidance and advice were done also for the local contractor's works, mainly in well drilling, borehole geophysical logging and pumping test by JICA's engineers and experts.

CHAPTER 3 OUTLINE OF THE PROJECT AREA

3.1 General Situation

3.1.1 Location and administration

The Study Area covers the whole floor of the Comayagua basin which lies 50 km northwest of Tegucigalpa. The Comayagua basin extends from $14^{o}04'$ to $14^{o}40'$ north latitude and from $87^{o}27'$ to $87^{o}54'$ west longitude and has an area of 470 km^2. It is a basin (about 600 m above MSL) surrounded by the mountain ranges of 2,000 m high.

The Study Area spreads over both the Comayagua and La Paz Departments and contains nine municipalities; Comayagua, Ajuterique, Humuya, Lamani, Lejamani, San Sebastian and Villa de San Antonio in the Department of Comayagua, and La Paz and Cane in the Department of La Paz. Each municipality has a right of self-government and its head is elected by the vote of inhabitants. The municipality is called "city (ciudad)", "town (pueblo)" or "village (aldea)" according to the scale of population. The Comayagua city, which was the capital of Honduras until 1880, plays a central role in the social and economic aspects in the Comayagua basin.

In the Comayagua basin, the Government has various branch offices of ministries and governmental agencies; Ministerio de Obras Publicas y Transporte (MOPT), Ministerio de Salud Publica (MSP), Secretaria de Recursos Naturales (SRN), Empresa Nacional de Energia Electrica (ENEE), and Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA), etc. Each office plays a important role in the direct services to inhabitants in cooperation with other public agencies in the Comayagua basin, especially El Centro de Entrenanuento de Desarrollo Agricola (CEDA), Secretaria de Recursos Naturales, is noticed as an important project office for agricultural development of Honduras. Details on administration are discussed in the section 3.1, Appendix A.

3.1.2 Socio-economic situation

The country is divided into seven (7) regions for each of the sanitary and agricultural administration, and in either case the Study Area belongs No.2 which consists of three Departments of Comayagua, La Paz and Intibuca. In 1988 the Region No.2 has a population of 468,298 which consists of the population of 238,790, 105,996 and 123,512 for the respective Departments. The population growth rate per annum, during the period 1974-1988, showed 3.62 % for the Region No.2, and 4.07 %, 3.44 % and 2.99 % for respective Departments (see Table 3.1.1).

The population of the Study Area amounted to 109,175 in 1988 at an annual growth rate of 4.09 % during the said period, and the population density showed approximately 45 inhabitants per km^2 in 1988. The said rate of population growth was nearly equal to that of the Department of Comayagua and showed a fairly higher than the rate (3.63 %) of the whole country. The population of each municipality in the Study Area are shown in Table 3.1.1, and the details are described in the section 3.2, Appendix A.

The agricultural statistics of Honduras are made by region in principle, not by department. Region No.2, which includes the Study Area, accounts for an important situation in the country in respect of the agricultural production. In 1984 the Region No.2 produced cabbage of Qls. 91,804, onions of Qls. 14,413, potatoes of Qls. 81,389 and coffee of Qls. 548,751, which had respective shares of 64 %, 35 %, 97 % and 34 % in the country. The Study Area produces almost crops producing in the Region No.2, especially tomatoes, onions, watermelons and cabbages which account for 50 %, 50 %, 20 % and 10 % of the domestic production. Further, cattle farming is a essential industry in the Study Area. Although precise figures are not available for the number of cattle, it is estimated that about 25,000 heads are being bred in the pasture land of 25,000 ha. It is said that beef, milk and cheese products are not so much in quantity but of good quality, particularly the cheese product gains high popularity. More details of agriculture are discussed in the section 3.3, Appendix A.

Communications among nine municipalities in the Study Area are chiefly carried out by roads. The Central American Highway (CA5 Highway), which connects Tegucigalpa and San Pedro Sula, runs from southeast to northwest in the Study Area and plays important role as a trunk road. Main road network within the Study Area has 130 km length which consists of the paved roads of 50 km (38 %) and the unpaved roads of 80 km (62 %).

Of the main road network, the paved roads and 65 km of the unpaved roads are well maintained so as to be easy to get access to cities and towns in the basin at all times of the year. While other unpaved roads and some feeder roads are in bad condition, and sometimes some villages are difficult to get access by vehicle even the dry season (see the section 3.4, Appendix A).

3.1.3 Land use and water utilization

1) Land Use

Fig. 4.2.6 shows situation of land use in the Study Area which has an area of 47,000 ha, and it is summarized as follows:

Land Use

Classification	Area (ha)
Crop land	13,000
Pasture land	25,000
Residential area	2,000
Forest and others	7,000
Total	47,000

The crop land includes irrigation land of some 7,000 ha which consists of three systems; Flores system, San Sebastian system and Selguapa system. Actual irrigation area in 1988 amounted to about 4,000 ha out of 7,000 ha as follows:

Irrigation Area

Irrigation system	Planned area(ha)	Irrigation area in 1988 (ha)
Flores system	3,760	1,604
San Sebastian system	250	231
Selguapa system	3,130	2,157
Total	7,140	3,992

Principal agricultural crops in the Study Area, that is, maize, beans, tomatoes, onions, watermelons, cucumber, etc., are mostly produced in these irrigation land. On the other hand, cattle farming is operated using the large-scale pasture land distributed all over the Study Area.

In recent years, there is a tendency for the territory of urban area (community with 2,000 or more population) to increase owing to a high population growth rate of more than 4 % per annum in the Study Area. According to the 1988 Census, the ratio of population of urban area to rural area varied from 45.2 : 54.8 in 1974 to 54.6 : 45.4 in 1988, e.g. the urban population exceeded the rural population. The grown population was accompanied by increase in the number of houses; from 10,623 houses in 1974 to 19,814 houses in 1988. Whereas the average number of families decreased from 5.87 persons in 1974 to 5.51 persons in 1988 (see Tables 3.1.2 and 3.1.3). Details are discussed in the section 3.2, Appendix A.

2) Water Utilization

Principal Objects of water utilization in the Study Area can be classified into three categories; irrigation, domestic and industrial uses. The irrigation is carried out for crop and pasture lands using canal water and rain water, and it is represented by the said three irrigation systems. The domestic water is supplied by SANAA water supply system and private and public wells. Almost all of manufacturing industries utilize their own wells water together with water supplied from SANAA.

According to information from DGRH, Monthly water consumption of the said three irrigation systems showed approximately 2,200 thousand CM on average in 1987. In general, during the dry season (September to April) there is a great water demand to irrigate crops of maize, tomatoes, onions, rice, etc., and the maximum demand has been recorded in March every year, for example, in March of 1987 the water consumption showed approximately 3,200 thousand CM. Details of irrigation water for each crop are given in Table 4.2.6.

The Study Area had approximately 110,000 population in 1988, consisting of 59,500 (55 %) in urban and 49,500 (45 %) in rural. Water supply, for nearly 90 % of the urban population and for the rural population of Humuya, Lamani, San Sabestian and Cane, is carried out by piped systems of SANAA and respective municipalities (see Tables 3.1.2 and 1.2.1), and it is summarized as follows:

Population served and unserved
by pipe-system in Study Area in 1988

Area	total Population	Served		Unserved	
		Population	Ratio(%)	Population	Ratio(%)
Urban	59,590	53,251	89	6,339	11
Rural	49,585	9,508	19	40,077	81
Total	109,175	62,759	57	46,416	43

Of population unserved, 11 % of the urban population is expected to be served domestic water by the SANAA piped system in near future in accordance with the SANAA water supply regulation. Whereas, the remaining 81 % rural population may be compelled to utilize the water of existing inadequate wells or the surface water of rivers and canals for their domestic uses for the time being, if the present project will not be realized.

In 1988 the Study Area has some 170 wells, of which 152 wells are in use. Based on result of field survey, utilization of the well water is classified as follows:

Item	Wells	
	No.	%
1. Domestic use.		
(1) drinking & others	104	61
(2) other than drinking	12	7
2. Agricultural use and others	36	21
3. Unavailable	18	11
Total	170*	100

* Includes wells under Construction.

The 104 well water is utilized for drinking purpose of about 4,400 inhabitants (800 households). Whereas result of a sampling test of water quality, it indicates that about 50 % of those well water is unsuitable for drinking from chemical and/or biological viewpoint. Only 52 wells are therefore utilized as safe drinking water for some 2,200 inhabitants (52 wells x 7.6 households x 5.51 persons).

When inhabitants who are utilizing the said safe drinking water are regarded as the population served, the population served and unserved in rural would be varied as follows:

Item	Served		Unserved	
	Population	Ratio	Population	Ratio
only pipe-system	9,508	19	40,077	81
pipe system plus well	11,708	24	37,877	76

It appears that the remaining approximately 38,000 inhabitants, or 76 % of the rural population, have utilized surface water or unsanitary well water for drinking and other domestic purposes. Generally these people live in inconvenient places, and have spent many hours and enormous energies to collect the safe drinking water, further in the rainy season it is said that sometimes they had to use even river and canal water for drinking purpose. Thus the rural people live under the heavy burden every day.

3.1.4 Water supplies

Existing water supplies in the study area are operated by the SANAA and some municipalities as shown in Table 1.2.1. The served population in 1988 are estimated at nearly 63,000 which consists of 44,000 inhabitants in the SANAA water supply system and 19,000 inhabitants in the system of six (6) municipalities of Ajuterique, Humuya, Lamani, Lejamani, San Sebastian and Villa de San Antonio. Where, the SANAA system covers the urban areas of three (3) municipalities; Comayagua, La Paz (including Yarumela) and Cane. In 1988 the served ratio by these systemss is estimated at nearly 57 % in all the Study Area.

The remaining 43 %, or some 46,000 inhabitants are using water from shallow wells and/or rivers close to their living places. In their daily live, usually well water is used for drinking purpose and the rivers for other domestic use.

At present the study area has some 170 shallow wells, each of which is utilized by several tens of inhabitants on average, and the per capita consumption appears to be in range from 20 to 30 l/c/d (see Table 1.2.2). Almost all of the shallow wells in the Study Area are under control of the regional office of the MPH, and a periodical inspection has been carried out by promoters who are entrusted/employed by the MPH in regard to the facilities of shallow wells and quality of well water. Although the facilities composed of wells, pumps, tanks are cleaned and maintained accordingly, water produced from such existing shallow wells is generally not satisfied in quantity and also in quality as explained in the previous sections.

3.1.5 Health

1) Health Administration

Health of Honduran people is administered under "SANITARY CODE OF THE REPUBLIC OF HONDURAS", Ministry of Public Health 1968 (Annex I). This code, which consists of 166 articles, prescribes health administration in respect to nutriment control, protection of infectious diseases, supply of potable water, sanitation, air pollution, industrial hygiene, etc., including penalties for violators against provisions.

Under this code, the MPH (MSP) has two (2) bureaus of sanitation and administration and ten (10) special divisions at political level, and eight (8) sanitary regional offices and twenty two (22) national hospitals at execution level, under the jurisdiction of the Director General in the Ministry. In 1989 the Ministry has officials and employees of some 4,000 persons, consisting of 500 persons in the head office and 3,500 persons in the eight (8) regional offices (excluding the national hospitals). Organization chart of the Ministry is illustrated in Figs. 3.1.1, 3.1.2 and 3.1.3, Appendix A.

The Sanitary Region No.2, where is composed of three Departments of Comayagua, La Paz and Intibuca, in 1987 had 4 hospitals consisting of 2 public and 2 private hospitals, and 88 rural health centers (CESAR). Beds in the hospitals numbered 88 in the same year. The Study Area, out of 4 hospitals in the Region No.2, had 3 hospitals which are called "Santa Teresa" and "Suaso Cordova" of the public hospital, and "Policlinica Berlios" of the private hospital. These hospitals had beds of 76, 69 and 23 in number in 1986, respectively.

Of the health administration, an improvement work of water supply and sanitation facilities is at present being executed in the country under the National Plan for Drinking Water and Sanitation for the period 1983-1990, with technical help from the WHO. To coordinate activities for achievement of this Plan, the CONAPS which consists of five members of the Government agencies; the MPH, the SECPLAN, the SANAA, the Bank of Municipal Autonomous and the Ministry of Government and Justice, was created in 1983 under the jurisdiction of the President.

Apart from the said committee, the MPH has responsibilities to monitor the work on achievement of the Plan (see the section 1.2.1).

On the other hand, activities on water supply and sanitary service of SANAA are conducted under SANAA Constitutive Law (Ley Constitutiva del

Servicio Autonomo Nacional de Acueductos y Alcantarillados), Decree No.91, 1961 (Annex II). It is concerned with the design, construction and operation of potable water and sanitation systems for rural and urban areas.

2) Disease

Principal health indices of Honduras are summarized as follows:

Health Indices of Honduras, 1985

Births (per 1,000 people)	44*
Deaths (per 1,000 people)	8*
Life expectancy (year)	62
Water borne disease cases (per 100,000 population)	4,462
Infant mortality (per 1,000 live births)	80
Population without safe drinking water (%)	55
Population without safe sanitation (%)	72

Source: The International Drinking Water Supply and Sanitation Decade, 1987, WHO
Note: * in 1983

Life expectancy of Honduras people prolonged from 53 years in 1978 to 62 years in 1985, which were situated in about the medium class in developing countries. Whereas, water-borne disease amounted to more than 4,000 per 100,000 population which showed the most unsanitary condition in Central American countries.

Population without safe drinking water, which would have an important relation to water-borne disease, in 1985 showed 55 % of the total population in the country. On the other hand, in the Study Area it was estimated at approximately 40 %; 11 % in urban and 76 % in rural (including safe well water. See the section 3.1.3). Although safe water supply in the Study Area is in a little better condition as a whale than that of the country, 76 % in rural indicates unsanitary condition extremely.

Infant mortality in the Region No.2 and the whole country are summarized below, because there exist no available data in the Study Area:

Infant Mortality
(per 1,000 live births)

Location	1960	1970	1980	1985
Whole Country	133	111	87	80
Region No.2	140	116	92	-

Infant mortality, which is a barometer of health condition of mother's body, in Honduras has shown a very high percentage, ranking first among the Central American countries, and in the Sanitary Region No.2, it was further higher than the country average. However, since 1960 it has shown a decreasing tendency at a rate of about 2 % per annum.

The following table shows number of patients of foul intestinal disorder in the country which was estimated based on 5 % sample of the entire outpatients relating to water-borne disease in the public hospitals in 1985:

Patients Related to Water-Borne
Disease by Age Group in the Country,1985

Age group	Total Number of Patients	Patients Intestinal No.	of Foul Disorder %
(1) less than 1 year	17,562	4,895	27.9
(2) 1 to 4 years	27,191	6,666	24.5
(3) 5 to 14 years	19,785	4,112	20.8
(3) more than 14 years	71,563	3,352	4.7
Total	136,101	19,025	14.0

Source: Boletin de Estadistica e Informacion de Salud, Estadisticas de Atencion Ambulatoria, 1987, Ministerio de Salud Publica.

As shown in the above table, 14 % of water-borne disease patients suffered from foul intestinal disorder in 1985, particularly it took a higher rate in younger age group, e.g. 27.9 % for the age group less than 1 year, 24.5 % for the age group from 1 to 4 years, and 20.8 % for the age group from 5 to 14 years. It is said that the mortality rate of infants under 5 years from foul intestinal disorder amounted to more than 50 %.

3.2 Physiographic Condition

3.2.1 Climate

It is said that the Study Area belongs to sub-tropical zone. However, since it is located in a hilly district of the inland, the climate is mild in comparison with that of the coastal plains on the north and the south border.

From the view point of the meteorology, there are two seasons in the Study Area, that is, rainy season from May to October and dry season from November to April. Average annual rainfall in the study area is around 1,000 mm, of which more than 85 % occurs during the rainy season. Accordingly, rainfall in the dry season is extremely little, especially in the flat area. Rainfall pattern seems to have a rather tropical feature because shower rain occurs in the very limited area and the duration time the rain is rather short.

Mean temperature and relative humidity are around 23°C and 70 %, respectively. Temperature in the flat area is higher than that in the mountainous area, while on the contrary relative humidity in the mountainous area is higher than that in the flat area.

Annual pan evaporation amounts to some 1,700 mm. Monthly mean wind velocity and monthly sunshine hour are 2.6 m/s and 2,350 hours, respectively.

As known from the above description, climatic feature is considerably different between the flat area and the mountainous area. On the other side, these climatic factors except for the rainfall don't show remarkable fluctuation throughout the year. The detailed meteoro-hydrological condition of the Study Area will be discussed in the section 4.2 of this report.

3.2.2 Geography

The country is geomorphologically divided into the following four areas;

(a) the coastal plain facing the Atlantic
(b) the northwestern and eastern mountainous area
(c) the central and southern highlands
(d) the coastal plain facing the Pacific

As explained in the section 1.1.1, the Study Area, the Comayagua basin, is located in the highlands.

The Comayagua basin with an area of about 470 km^2 spreads between latitude $14^o04'$ and $14^o40'$ north and longitude $87^o27'$ and $87^o54'$ west, and the Humuya River runs northward through the basin which has a catchment area of 2,053 km^2 at the outlet of the basin. The study area for the ground water development is located at about 50 km northwest from Tegucigalpa, the capital of the Honduras. Altitude of the study area is about 600 m, and mountains more than 2,000 m in height surround the area and constitute the watershed.

3.2.3 General geology

The highlands are composed of Paleozoic metamorphic rocks, Mesozoic sedimentary rocks, Tertiary volcanic rocks, intrusive rocks and so on, while Quaternary sediments are deposited in the flat plains such as river channels and inland basins.

In the northern half area of the Honduras, the Paleozoic metamorphic rocks and the Mesozoic sediments are dominant showing remarkable contrast with the southern part where the younger Tertiary volcanic rocks are distributed widely.

The stratigraphic sequence of general geology in the country of Honduras is shown in Table 3.2.1.

The land of the Study Area consists mainly of alluvial deposits and diluvial lake deposits, while the Tertiary pyloclastic sediments and the pre-Tertiary hard rocks underlie those Quaternary deposits forming the hydrogeological base rock. Therefore, the subject of the ground water development study will be the Quaternary deposits. It is expected that the maximum depth of the diluvial lake deposits is around 200 m or more in the center of the basin (refer the section 4.1.3).

CHAPTER 4 INVESTIGATION RESULT

4.1 Hydrogeology

4.1.1 Topography

The Comayagua basin is located in the upper reaches of the Humuya River, and has a rectangular shape elongated in the north-south direction with width of 10 to 15 km and length of 35 to 40 km.

The basin is bounded by faults of N-S, NE-SW and NW-SE directions at the eastern and western margins. Altitude of the basin shows about 600 meters in the center and 700 meters at the margin, and undulating topography is observed on the plain which is generally dissected by the Humuya River and its tributaries, especially at the marginal area. The surrounding mountains vary their elevation up to 2,000 meters and have steep slope.

The Humuya River originates in the southwestern border of the catchment area, and meanders in the center of the basin keeping the general direction from south to north. The Conje River, the Grande River, the Choco River and the San Jose River are the main tributaries in the southern part of the basin, and the Tunjaka River, the Blanco River, the Conquigue River, the Mura river, the Tepanguara River and the Selguapa River in the northern part of the basin.

Based on the field reconnaissance and the air-photo interpretation, the following five topographical units are classified in and around the Comayagua basin (ref. Fig. 4.1.1).

a. Residual hill (Monadnock)

Residual hills, or Monadnock, are distributed in and around the Comayagua city. The hills are composed of Tertiary bedrocks as described in the following clause.

b. Southern flat plain

In southern half area of the basin, a flat plain spreads widely, where Diluvial lake deposits are distributed under the remarkably thin overburden (see next clause). The marginal area of this flat plain is characterized by notable undulation, while the center of the basin is much flatter. The border between the southern flat plain and the northern half area of the basin is drawn approximately on the line connecting La Paz to Villa de San Antonio.

c. Northern Alluvial fan

Northern half area of the basin is characterized by the development of Alluvial fans where the Alluvial fan deposits cover the Diluvial lake deposits. In this area, several tributaries of the Humuya River dissect the fan deposits to form a undulating topography.

d. Floodplain

The narrow and long floodplains are formed mainly along the Humuya River.

e. Mountain area

Surrounding mountains bounded from the basin by faults are remarkably dissected to make deep gorges.

4.1.2 Geology

The Diluvial lake deposits and the Alluvial fan deposits are the main geological units of the Comayagua basin. The Diluvial lake deposits are crops out mainly in the southern half of the basin, and composed of whitish to grayish silt and clay sediments, while the Alluvial fan deposits of gravel supplied from the eastern and/or western mountains, are distributed in the northern half of the basin overlying the Diluvial lake deposits.

In the far southern area of the basin, the lake deposits dip towards the center of the basin with 10 to 30 degree of inclination probably due to tectonic movement. At the margin of the basin, the lake deposits are generally characterized by coarse sediments such as sand and gravel, and are considered to change finer toward the center of the basin. It is supposed that a large amount of talus deposits was supplied to the margin area of the basin from the surrounding mountains after the graben, that is a topographic depression, had been formed.

Clayey to silty sediments with sand and gravel formed the flood plain along the main river and its tributaries. Difference height between the flood plain along rivers and the southern flat plain of the basin amounts about 30 meters in maximum.

The Tertiary base rocks crop out in the form of Monadnock in the far northern area of the basin.

On the other hand, in the surrounding mountains, Paleozoic to Mesozoic sediments are distributed locally in the eastern to northern area of Comayagua and in the western area of La Paz, while much of the mountains are composed of the Tertiary pyroclastic rocks such as tuff and welded tuff. The Paleozoic rocks mainly consists of green shists and phyllites, and the Mesozoic rocks of sand stones, shales and limestones.

The standard geological sequence of Honduras is shown in Table 3.2.1. The characteristics of each unit and geological constituent in the Comayagua basin are described below and the distribution of the geological units are shown in Fig. 4.1.2.

1) Hydrogeological base rocks

The Paleozoic metamorphic rocks, the Mesozoic sedimentary rocks and the Tertiary pyroclastic rocks constitute the hydrogeological basement rocks in the Study Area. No ground water is developed in those basement except for the fissure water.

As described above, the Paleozoic rocks consist of well consolidated rocks of green shist and phyllite, and are distributed locally at the northeastern area of the Comayagua city. The Paleozoic rocks are bounded from the Tertiary rocks by the faults. On the other hand, the Mesozoic rocks are characterized by consolidated rocks of reddish brown colored sandstone, shale and limestone, and distributed locally at the northeastern area of Comayagua and the western area of La Paz. No good aquifer is expected in them except fissures and limestone caves in the limited area.

The surrounding mountains are mainly composed of the Tertiary pyroclastic rocks. The main part of the Tertiary rocks are the tuff and the welded tuff called "Ignimbrite". Those pyroclastics with pale pink to yellowish color are usually massive and hard, but joints are frequently developed.

2) The Quaternary deposits

In the Comayagua basin, the Quaternary deposits are distributed widely. The distribution of the Quaternary deposits is bounded from the pre-Quaternary rocks by faults of steep inclination along the margin of the basin.

The Quaternary deposits are mainly subdivided into the two geological sub-units of Diluvial lake deposits and Alluvial fan deposits. The Diluvial lake deposits is deemed to be product in old lake formed in the period of tectonic movement of the graben (topographical depression). Prior to drying up the lake probably in the initial stage of the Alluvium, a great amount of fan deposits were supplied to the northern area of the basin.

On the other hand, after the Comayagua basin was completely dried up, flood plains were formed along the main river in the recent stage of Alluvium.

a. The Diluvial lake deposits

The Diluvial lake deposits are distributed widely in the southern half area of the Comayagua basin, and exposed locally in and around the Comayagua city, where the rise of the basement rocks is inferred.

The lake deposits consists mainly of thick layers of clay, silt and fine sand with white to pale gray color, while extraordinary coarse deposits such as coarse sand and gravels are observed at the marginal area of the basin. It is supposed that those gravels were initially accumulated in the marginal area of the basin of the old lake as similar condition as talus deposits, and accumulation of the fine sediments followed that of the coarse sediments. The coarse to fine sediments intercalated with clay layers may form an artesian aquifer.

The geological structure of the lake deposits is characterized by the remarkably gentle inclination of less than 5 degrees in dip in the central part of the basin. In the marginal area, the lake deposits show more steep inclination of 10 to 20 degrees dipping towards the center of the basin. Contrary to the general structural condition, the lake deposits in the far southwestern area dip towards the outside of the basin. This means that an anticline, of which the axis is drawn on the line from La Paz to Cane, is conceivable in this area.

Though no detailed information on subsurface geological condition has been collected, it is inferred that thickness of the lake deposits is about 200 meters in the center of the basin on the basis of the geophysical exploration performed (refer the section 4.1.3).

It should be reported that the strong reaction of lake deposits against acid was locally observed, suggesting the local concentration of marl deposits.

b. The Alluvial fan deposits

The alluvial fan deposits are distributed in the northern half area of the Comayagua basin, which is divided further into two areas of northeastern and northwest with the Humuya River as their boundary.

In the northeastern area, the fan deposits consists of gravel rich deposits characterized by reddish brown color. It is suggested that those deposits are originated in the Mesozoic sedimentary rocks which show similar color.

A transition from the lake deposits to the overlying fan deposits is observed in an outcrop in the south of Villa de San Antonio. It seems both deposits interbed in zones of transition.

Thickness of the fan deposits in the northeastern area is estimated at 30 meters or more in the thickest portion at Palmerola, near US base.

On the other hand, in the northwestern area, the fan deposits consist of fine to coarse, less sorted sediments with pale brown to yellowish brown colour, and are originated in the Mesozoic sedimentary rocks and the Tertiary ignimbrite. The same relationship with the lake deposits as inferred in the northeastern area is also expected in this area. Thickness of the fan deposits in this area is estimated at about 30 meters or more at the southeast of Playitas.

The Alluvial fan deposits is considered to form a phreatic aquifer as far as they are saturated.

c. Flood plain deposits

This deposits are distributed mainly along the Humuya River and its main tributaries, and consists of silt, sand and partly gravels with pale brown to yellowish brown. The flood plain deposits are supplied from the surrounding mountains and the Quaternary deposits in the basin.

4.1.3 Geophysical exploration

1) VLF exploration results

According to the field measurements and the analysis results described in detail in Appendix B, the result of the geophysical exploration is summarized as Table 4.1.1 and Fig. 4.1.3, and explained briefly as below:

a. A mountain area on the north-northeast of the Comayagua city shows a high resistivity value of 60 ohm-m where Mesozoic sedimentary rocks and granodiorite are exposed.

b. In the western area of the basin between Ajuterique and La Paz, several places demonstrate sporadically high resistivity values ranging from 60 to 70 ohm-m, which may indicate the presences of subsurface mounds of Mesozoic sedimentary rocks.

c. The mountain area consisting of Tertiary welded tuff has moderately low resistivity ranging from 24 ohm-m to 38 ohm-m.

d. Observed in the marginal zone of the basin along the foot of mountains are two types of the resistivity values; one 5 ohm-m to 15 ohm-m and the other higher then 20 ohm-m.

   The area of considerably lower resistivity from 5 ohm-m to 15 ohm-m is correlated with area of clayey deposits, while the other area of higher resistivity over 20 ohm-m covers that of thick and wide spread fan deposits of sand and gravels, which have been brought from main tributaries such as the Rio Conquigue, the Rio San Jose and the Rio Selguapa.

e. The central area in the basin shows moderately low resistivity values around 10 ohm-m, which indicates thick clayey deposits.

f. In several places such as Yarumela, south of Cane, moderately high resistivity values ranging from 20 ohm-m to 25 ohm-m are sporadically obtained, which may indicate a rise of high resistivity layer.

g. The area showing high resistivity suggests the presence of the gravel beds of the fan deposits, specially in parts from La Paz to Lejamani and around Flores.

2) Electric soundings

In the Appendix B, twenty five figures were prepared as resistivity profiles covering the whole Comayagua basin on the sections in both N-S and E-W directions, as a result of the electric sounding (see Fig. 4.1.4). Four profiles of Fig. 4.1.5 (1) to (4) are selected and attached in this report as typical sections in the Study Area. The interpretation is summarized in the Table 4.1.2.

a. The layer 1 is defined to be a layer above water level, developing parallel to the ground surface on the profiles. As described on Table 4.1.2, the layer can be subdivided into two categories in resistivity values, i.e. 15 to 135 ohm-m and 11 to 80 ohm-m, depending upon difference in physical characteristics of deposits.

b. The layer 2 develops dominantly at the northwestern margin of the Comayagua basin through Lejamani, Ajuterique and the Rio Selguapa, and the eastern margin of the basin mainly along the Rio San Jose and the Rio Canquigue. The resistivity value ranges from 7 ohm-m to 54 ohm-m, with average of 20 ohm-m. This layer will correlate to the fan deposits consisting of poor-sorted sand and gravel. The layer is probably highly permeable.

c. The layer 3 is observed on outcrops around Cane in the western part of the Comayagua basin on the Rio Grande south from Villa de San Antonio. It is covered by the Layer 2 in the downstream area of the basin. This layer disappears in the eastern half and the southern part of the basin. Such setting of pervious and impervious geological units characterizes ground water recharge system of the Comayagua basin.

d. The layer 4 is the most widely developed in the Comayagua basin, and the average thickness of this layer reaches 80 m. In the southern part of the basin, the layer 4 is subdivided into such three layers as 4 (a), 4 (b) and 4 (c). The layer 4 is considered to be semi-aquifer judging from the resistivity value of average 10 ohm-m. This layer may contain sandy beds in places, specially showing higher resistivity. Portions of higher resistivity, occasionally encountered, may indicate intercalation of more pervious sandy layers in places.

e. The layer 5 is generally found in most parts of the basin except the southern end. The layer 5 indicates low resistivity of 2 to 6 ohm-m, suggesting clayey deposits.

f. At this electric soundings, high resistivity layer, suggesting the basement rock, could not be detected within the limit of sounding depth of 200 m in the central part of the basin, except at a very few spots. The basement rock shows high resistivity ranging from 15 to 110 ohm-m as observed in the marginal area of the basin, that is, 15 to 45 ohm-m in Tertiary welded tuff, and 27 to 110 ohm-m in consolidated sediments of Mesozoic bed.

   The depth to the basement rock is deemed to be more than 200 m in most parts of the basin.

4.1.4 Test well drilling

1) General

The drilling operation was executed to understand the potential of ground water development for the rural water supply in the project area. Five test wells and five observation holes were drilled to know the characteristics of the aquifers.

The maximum drilling and casing depth of the wells are 130 m and 127 m, respectively. The total drilled depth is 1,075 meters; 570 m for observation holes and 505 m for test wells. The drilling sites and depths were selected, based on the previous studies, existing wells and geological surveys.

The location of the wells is shown in Fig. 4.1.6. The depths and other information on drilled wells are shown in Table 4.1.3.

An observation hole was in principle drilled in advance of a test well, at around 15 to 20 meters away from a test well, in order to determine aquifer constants accurately.

The drilling results of the observation hole were used to decide the depth and screen position of a test well.

The following investigation were made on the test wells and the observation holes:

a. Interpretation of lithology,
b. Resistivity and spontaneous potential logging,
c. Water temperature and electrical conductivity logging,
d. Step drawdown test,
e. Continuous pumping test and recovery observation,
f. Water quality analysis of pumped water.

2) Operation procedure and result

Drilling

The drilling began on September 21, 1988, and terminated on February 11, 1989. The drilling work were made by three rotary type drilling rigs, one "GARDENER DENBER MODEL 1500" and two "SCHRAMM T64-HB". Drilling diameter is 8 inch for observation holes and 14-3/4 inch for test wells, respectively. The progress of the drilling operations is shown in Fig. 4.1.7 and Table 4.1.4, and the results of the drilling are shown in Fig. 4.1.8 (1) to (10).

Well logging

Well logging, including the resistivity and spontaneous potential measurements, were executed for all the test wells and the observation holes.

The purpose of the well logging is to understand the geological condition, and also to know aquifer position exactly. Measurement was performed by using "Mc-OHM" prepared by JICA team, and "Johnson Keck DR74" owned by the local contractor. Results of resistivity measurement are well consistent with the result of geo-electric sounding executed nearby.

Logging measurement results are also shown in Fig. 4.1.8 (1) to (10).

Casing and screen

Steel pipes and unplasticized polyvinyl chloride (PVC) pipes with diameters of 4 and 8 inches, were used for the casing of observation holes and some test wells.

The materials which were used for casings and screens are shown in Table 4.1.5.

Gravel packing

Sieved natural gravel with diameter from 4 to 8 mm is used for filling the annular space between the borehole and casing pipe of the observation hole and the test well. It was collected locally from the river beds of the Rio Selguapa. The gravel collected from the river beds is composed of sub-rounded pebbles of welded tuffs and pre-Tertiary base rocks.

In order to prevent polluted water from entering into the wells from ground surface, the upper most 10 m of the annular space of each wells was filled with mortar and clay.

Well development

Well development was executed by using a piston and an air compressor. Combined operation of piston and air compressor method was applied to the test wells, and air compressor method was used for the observation holes. The operation hour of the combined method was specified for 48 hours for the test wells, and 12 hours for the observation holes. Actually, the operation hour for almost all the wells exceeded the specified hour in order to better do well development. The operation of the air compressor method was specified to lift water for 3 hours continuously with full discharge rate of 220 l/s for test wells, or 25 l/s for observation holes, and followed by one hour break time.

4.1.5 Pumping Test

The purpose of the pumping test is to understand the hydrogeological characteristics of the aquifer system, and also the hydraulic characteristics of the aquifer. The pumping test comprises a step drawdown test, a continuous pumping test and a recovery test. Since a couple of a test well and a observation hole were drilled in each test site, both the water levels of two wells were measured at the same time during the pumping tests.

Submersible motor pumps were used for the pumping test, and the constant discharge rate was measured by a piezometer.

Pumping test results are also illustrated in Fig. 4.1.8 (1) to (10).

1) Step drawdown test

The step drawdown test is executed in order to understand the aquifer characteristics in a different discharge.

Since the pumping duration of each step in the step drawdown test should depend on aquifer conditions, one step was continued for 1 to 2 hours, and normally 4 steps of different discharge rate were taken for each well except for TW-01 and OH-01. The step drawdown test at Las Liconas (TW-01, OH-01) was stopped at the third step because of great decline of pumping water level. Accordingly, the yield capacity of the well is considered poor.

In the course of the step drawdown test the water level of each well more or less became stable, or showed equilibrium condition, at the end of each step except for TW-01 and OH-01.

The specific capacities of the test wells calculated from the step drawdown data, as shown in Table 4.1.6 (1), ranges 0.43 to 3.55 excluding the pumping test result of Las Liconas.

2) Continuous pumping test and recovery test

For the continuous pumping test, a constant discharge rate was maintained for 72 hours. The ordinal purpose of this test is to obtain the hydrogeological constant such as transmissivity and strativity. In addition, water sample were taken from each test well at the end of the continuous pumping test.

The recovery test is made by measuring the water level rise after the continuous pumping is terminated. The measurement was normally continued for 12 hours or until the water level recovered to the original water level.

Both the result of the continuous pumping test and the recovery test are graphically interpreted by the Jacob's non-equilibrium method (Fig. 4.1.8 (1) to (10)). As shown in Table 4.1.6 (2) and (3) where the analysis results are summarized, the characteristics of the aquifer are briefly explained as follows:

- Judging from the pumping test result at Las Liconas, sand layers interbedded in the central part of the lake deposits have extremely low permeability. Therefore, an poor ground water potential for future development is expected in the northern and central part of the Comayagua basin.

- Static water levels of the test wells show 7 to 36 meters from the ground surface, and the drawdowns after the 72-hour pumping are in a range from 2 to 15 meters. However, except for the test result at Lamani, where water level shows deepest, the static water levels are within 11 meters from the ground surface, and the drawdowns range 6 to 15 meters.

- Well loss is estimated at about 50 % for the Phreatic ground water (the shallow ground water) and about 10 % for the artesian ground water (the deep ground water).

- The obtained hydraulic conductivities range from 3×10^{-3} cm/s to 1×10^{-2} cm/s. Since the aquifer's facies become more coarse in the southern one-third area of the basin, relatively high hydraulic conductivity, probably 1×10^{-2} cm/s or more, is expected.

4.1.6 Aquifer system

1) General hydrogeological condition

In the Comayagua basin, as described in the section 4.1.2, Alluvial fan deposits are rather thick, probably 20 to 30 meters or more, at the northern half area of the basin, while very thin Alluvial deposits of a few meters at the thickest spreads on the southern half area of the basin. Diluvial lake deposits originated from Tertiary acidic fine tuff and/or welded tuff underlie those Alluvial deposits.

Therefore, the shallow/dug wells are within the Alluvial fan deposits at the northern area, while they penetrate into the Diluvial lake deposits at the southern area. The deep tube wells usually penetrate into the Diluvial lake deposits through the Alluvial deposits.

Judging from result of the test well drilling and pumping test and the geophysical exploration, the aquifers in the Study Area are classified into a phreatic aquifer and an artesian aquifer. The former is ordinarily formed of the Alluvial fan deposits containing phreatic water, while the latter is in the Diluvial lake deposits intercalated with the artesian aquifer having confined water.

Comparing resistivity layers obtained with the electric resistivity sounding (see the section 4.1.3), the aquifer of the phreatic water ordinarily consists of the layer 1, layer 2 and a part of the layer 4, while the aquifer of the confined water corresponds to the layer 3 and layer 4 (see Fig. 4.1.5).

2) Physical and chemical properties of ground water

a. Transmissivity and permeability coefficient

From the review study of the previous investigation results and the collected data, several values which indicate the characteristic of aquifers are available. Table 4.1.7 shows the transmissivity and permeability coeeficient obtained through the previous investigation and re-analysis by the JICA's expert for this study.

As shown in this table, the transmissivity of aquifers in the Comayagua basin varies in a range from 20 to 60 m^2/min; 1.5 x 10^{-3} cm/sec to 3.0 x 10^{-3} cm/sec in terms of the permeability and/or hydraulic conductivity. Although the wells are scattered in the whole Comayagua basin and positions of screens of them are in different depth, the obtained value is rather similar. This indicates that the physical properties of the aquifers are nearly similar for both the Alluvial deposits and the Diluvial deposits.

In case of the confined water, the permeability coefficient obtained from the pumping test (Table 4.1.6) shows relatively high correlation with the layer resistivity obtained from the electric sounding. Based on the correlation among the permeability coefficient and the layer resistivity and the containing ratio of the sand layer, the transmissivity is estimated for all the Study Area and expressed in Fig. 4.1.9. From the transmissivity map, it is found that the area with relatively high transmissivity is distributed in the marginal area and in the southern area of the Comayagua basin.

On the other hand, the hydraulic conductivity of the phreatic water is supposed to be about 3 m/day though the data on this parameter is remarkably limited.

b. Electric conductivity (Ec)

As shown in Table 4.1.8 the electric conductivity (Ec) of the ground water in the Comayagua basin is in a range from 100 to 5,000 micro-mho/cm. This indicates probably complicated chemical properties of aquifers, reflecting the subsurface hydrogeological condition (see the section 4.1.8 for more detailed discussion).

Ec of the ground water shows about 300 micro-mho/cm near the margin of the basin, while about 1000 micro-mho/cm at the center of the basin. Outstandingly high Ec values more than 3,000 micro-mho/cm, detected at Cane and Playitus, are probably caused by the local concentration of marl deposits.

Since the surface water tends to be easily mixed with the shallow ground water, of which Ec value tends to increase gradually while it passes through deposits and rocks, surface water containing some ground water component often shows high Ec value especially in lower reaches of tributaries of the Humuya river (Table 4.1.8).

4.1.7 Ground water use and ground water level

1) Well inventory

The result of the well inventory of existing wells is shown in Table 4.1.9 and Fig. 4.1.10.

There are 170 wells in the Study Area consisting of 120 dug wells and 50 tube wells. Among the 170 wells, 18 wells are out of use and 12 wells are under construction. Of 152 wells including the existing wells in actual use and the new wells under construction, 113 are dug wells and 39 are tube wells. All of the 12 wells under construction are dug wells. Because every private farm and factory usually posses one or several tube wells.

Ground water from the dug wells is used mainly for drinking and/or household use for inhabitants of communities, and that from the tube wells is used for municipal water supply, irrigation for private farms, and industrial purposes. Considering recent increase of dug wells, especially in rural area, it is understood that demand for ground water in communities are rising due to growth of population in rural area.

2) Present level of ground water exploitation

Although the number of wells is increasing recently, development of the ground water resources remains in low level so far. It is concluded that the present quantity of the ground water exploitation in the Study Area is still limited in low level (see Fig. 4.1.11).

a. The phreatic water

Since almost all of the dug wells are located at the northern half of the Comayagua basin where the Alluvial fan deposits are rather thick, it is considered that water of those dug wells is the phreatic water. To utilize the phreatic water mainly for the household use of inhabitants, about 100 dug wells were installed especially in the rural area as described in the previous clause.

Considering the total number of dug wells and available yielding amount, it is estimated that phreatic water of only about 1,130 m^3/day at most is being supplied for household use of inhabitants in rural area.

b. The artesian (confined) water

As mentioned in the previous clause, 39 tube wells are practically used for municipal water supply, and industrial purpose. Although depths of the tube wells is 40 to 50 meters or more, screens of the wells are arranged in both the Alluvial fan deposits and the Diluvial lake deposits. Therefore, water from the tube wells is mixture of the phreatic water and the confined water. The yield of a tube well being about 150 m^3/day on an average, the quantity of the ground water, both deep and shallow, exploited through tube wells in the whole Comayagua basin is estimated at 6,560 m^3/day, of which the shares for the phreatic and the confined water are 2,400 m^3/day and 4,160 m^3/day, respectively.

3) Water tables in the dry season and the rainy season

In case of the shallow/dug wells, water levels are located usually one meter or less above the bottom in the dry season. Some of the dug wells are completely dried-up specially in the center of the alluvial fans in the western half of the basin; e.g. the wells No.5, No.31, No.119, No.120 and No.133 of the serial number in the well inventory (see Fig. 4.1.12 and Table 4.1.10).

Water levels in dug wells in the rainy season usually rise even in some of those dried dug wells, according to the interview survey. For instance, the water level of the No.5 well was detected at 60 cm above the bottom at the end of June 1988 at the beginning of the rainy season, while the other dried dug wells remained dry at that time. During May to June 1988, the maximum rise of water level was about one meter.

On the other hand, as shown in Table 4.1.10, the results of the simultaneous observation indicate that the ground water level still remains higher position in the middle of the dry season of 1989, comparing with the beginning of the rainy season of 1988. It is supposed that the great amount of rainfall was experienced during the rainy season of 1988, and therefore, the ground water potential in the Study Area is abundant even in the dry season, in case of 1989.

As mentioned below, water level fluctuation is remarkable in the Alluvial fan deposits in contrary with that in the Diluvial lake deposits. It seems that water levels of the dug wells in the lake deposits in the southern half area of the Comayagua basin remain almost constant through a year.

Since pumping facilities installed in the existing tube wells are almost always in operation, only a few static water level of deep tube wells could be measured. The static water level of the tube wells, though obtained data are limited, seems to be almost concordant with that of the dug wells. It also seems very probable that serious fluctuations of water level has been experienced in the past due to the continuous usage of the wells.

The water table map shown in Fig. 4.1.12 indicates clearly the trend of the ground water flow as well as the map of the electric conductivity. It is concluded that the ground water in the Comayagua basin flows from the marginal area of the basin towards the center of the basin.

4) Fluctuation of the water table

As a result of the ground water level monitoring, hydrographs are prepared (Fig. 4.1.13 (1) to (6)). Among the six wells monitored (see Fig. 4.1.6), the wells No.28, No.33 and No.36 are located on the Alluvial fan and penetrate the fan deposits, and the wells of No.10, No.16 and No.82 penetrate the Diluvial lake deposits through the Alluvial deposits. Considering magnitude of the water level fluctuation and hydrogeological condition of each well, it seems that ground water in the Alluvial fan deposits has good response to meteorological condition, specially to precipitation, while very slow infiltration of surface water is expected into the Diluvial lake deposits.

4.1.8 Water quality

1) General

The water quality analysis aims to determine the suitability of ground water for potable water supply, and at the same time, to give necessary water quality parameters for interpretation of the hydrogeological structure and the mechanism of ground water flow in the Study Area.

To realize the objectives mentioned above, the following two approaches to the water quality analysis were planned for both the dry and rainy seasons.

a. The analysis for the potable water supply

The "Centro de Salud Alonzo Soazo (DIRECCION GENERAL DE SALUD)" in Tegucigalpa is one of the bureaus of MPH, and has the most authorized chemical laboratory in Honduras, i.e. DIVISION DE CONTROL DE ALIMENTOS (Food Control Laboratory). Furthermore, in the Study Area, a regional office of "REGION SANITARIA No 2", which is also under the control of "DIRECCION GENERAL DE SALUD", has a laboratory (Portable Laboratory) in Comayagua. Suitability for the potable water supply, therefore, is judged on the basis of the results of the analysis performed by MPH at those laboratories.

Items analyzed by MPH are as follows;

pH, Colour, Hardness, Organic material, Fe, Ca, Mg, Cl, Coliform group, NO_2, NO_3

b. The analysis for the hydrogeological study

Ground water chemistry changes as water flows through the subsurface environment, increasing in dissolved solids and major ions. The analysis of ground water chemistry could, therefore, be useful to study the ground water behavior. The sampled water from the test well was brought to Japan by the JICA team and chemically analyzed in Tokyo. The other water samples for the hydrogeological study was tested by means of potable water testing kit supplied by JICA. In the field investigations, this work was mainly made by the JICA's expert, and the main items investigated and/or analyzed were as follows;

Temperature, Ec, Na, K, Ca, Mg, Cl, NO_3-N, NO_2-N, F, NH_4-N, Total-Fe, Zn, pH4.8 (M-O) Alkalinity, Total Hardness

2) Field activities for the water quality analysis

a. Preparation of the temporary laboratory

Prior to the actual analyses performed by the JICA's expert, the temporary laboratory was provided by MPH for the JICA team. At the same time, the following preparatory works were carried out by the JICA's expert.

- Preparation of standard solutions for items to be analyzed
- Standardization of ion-meters supplied by JICA

b. Sampling

In the dry season of June 1988, totally 26 samples; five samples of the river water and 20 samples from existing wells, were collected for the purpose of chemical and physical analyses. Among the 26 samples, 20 samples including the river water samples are subject to the bacteriological analysis.

On the other hand, in the rainy season of February 1989, 20 samples consisting of five river water samples and 15 well water were analyzed both on the bacteriological and on the hydrogeological items. In addition to those analysis, water samples from the newly drilled test wells were also analyzed in the rainy season.

Locations where the water samples were collected are shown in Fig. 4.1.6. Values obtained in the various tests performed in the different laboratories are shown in Table 4.1.11 to 4.1.13, and more detailed description on the water quality analysis is compiled in Appendix D.

3) Chemical properties of the water

Analysis results for the hydrogeological study are summarized below:

a. Electric conductivity (EC)

The electric conductivity of the water is proportional to the sum of dissolved ions, and ordinarily the total of all the ions is nearly equal to the sum of Na, K, Mg, MO-Alkalinity, Cl and SO_4. Accordingly, It is very probable that the EC value is well concordant with the Hardness of water (see Table 4.1.18).

As shown in Tables 4.1.11 and 4.1.12, the average EC value of river water in the dry season is slightly larger than that in the rainy season. On the other side, the average value of the ground water in the rainy season somewhat larger than that in the dry season.

The EC map of the ground water is shown in Fig. 4.1.14 where the areas with low and high EC values are bordered by the line of 100 micro-mho/cm. Since the distribution of the areas with high EC ground water seems to have no relation with the configuration of ground surface, it is supposed that the great amount of the dissolved solids are irregularly supplied from the Quaternary deposits.

On the other hand, judging from the result of the periodical measurement of the EC value, seasonal change of the EC is not clear in the ground water circumstances of the Study Area (ref. the section 4.1.4).

b. Cation composition and its seasonal change

Cation composition of the water samples are shown in Tables 4.1.14, 4.1.16 and 4.1.18. In case of river water, the average percentage of (Ca+Mg) increases slightly in the rainy season, while the cation composition of the ground water does not show remarkable difference between the dry and rainy season.

The average cation concentration of well water indicates that the (Ca+Mg) ions are slightly predominant over (Na+K) ions. In general, however, the Soft water with low EC value shows the less concentration of (Na+K) than that of (Ca+Mg), while the Hard water with high EC value contains the larger amount of (Ca+Mg) in mol ratio than (Na+K).

c. Anion composition and its seasonal change

The ionic composition of anion in dry season is shown in Tables 4.1.15, 4.1.17 and 4.1.18. The predominant ion among the generally important anion is MO-Alkalinity, and it occupies about 70 % of total anion both for the river water and the well water.

d. Water quality of newly drilled test wells

The analysis results of the pumped water from the test wells are shown in Table 4.1.13. From the view point of hydrogeology, the pumped water can be divided into such two groups as (1) the water collected from TW-01 and TW-03, and (2) the water from TW-02, TW-04 and TW-05.

The water samples which belong to the first group are characterized by the great amount of dissolved solids, high EC values and high concentration of ammonium ion. (Na+K) ions occupy about 75 % of cation and MO-Alkalinity occupies 72 % to 88 % of anion.

On the other side, the second group shows no sign of anaerobic environment. (Ca+Mg) content of TW-02 occupies 84 % of the cation, and MO-Alkalinity occupies 87 % of the anion content. Almost all of the cation, in case of TW-04, are occupied by (Na+K) ions, whereas, with respect to anion, the amount of MO-Alkalinity and $(Cl+SO_4)$ is approximately equal. TW-05 yields the Soft water with low EC value and few dissolved solids, which is the most suitable for potable use (see Table 4.1.18).

4) Characteristics affecting human health

Analysis results on the items which might affect human health are shown in Tables 4.1.11 to 4.1.13.

a. Total dissolved solids (TDS)

Drinking Water Standard issued by U.S. Public Health suggests that the value of TDS should not exceed 500 ppm, while Honduran standard for drinking water do not mention on this item.

According to the results of analysis in dry season, TDS values of existing wells; W-63, W-109, W-122 and W-149, exceed this limit, showing rather high EC values more than 700 micro-S/cm.

b. Nitrate, nitrite and ammonium ion

The analysis results on these items are shown in Tables 4.1.11 to 4.1.13. As shown in the table, of four samples from the existing wells and one sample of the test well, the nitrate concentration exceeds 10 ppm. In international standard for drinking water prepared by WHO in 1971, desirable or maximum allowable level for nitrite or ammonium ion are not prescribed. However, the MPH has tentatively provided a criterion on the nitrate concentration in potable water to be 15 ppm. Applying the Honduran criterion, two samples of existing wells W-32 and W-5 exceed this criterion.

Nitrite and ammonium ion were detected in almost all the water samples. It is ordinarily well known that coexistence of ammonium ion and nitrite ion indicates a contamination by animal or human excretion, but it seems too hasty to conclude that the surface and/or shallow ground water are completely contaminated, because ammonium ion can be fed into the ground water from anaerobic state probably caused by the diluvial lake sediment rich in organic material.

c. Coliform group

Total coliform or fecal coliform were detected from all the surface water samples, while in 12 samples of 15 well water samples, total coliform and fecal coliform were also detected, indicating the sign of the migration of surface water into the well.

In case of the newly drilled test wells, since a few or none of total coliform were founded, it is judged that water from these wells are good quality with regard to microbiology.

d. Fluoride ion

According to the analysis results, content of fluoride does not exceed the standard value of WHO or MPH. It is concluded that the serious problem on fluoride content does not exist for potable use.

e. Phosphate ion

Concentration of phosphate ion is in a range from 0 to 2.0 ppm. Average concentrations of river water and ground water are 0.1 ppm and 0.49 ppm, respectively. It is inferred that the origin of the phosphate in the river or well water is detergents or fertilizer, considering the present condition of the ground water usage. At many existing wells, it is frequently observed that waste water of washing poured into the wells.

5) Conclusion and recommendation

The river water which pours into Comayagua basin from the surrounding mountains is characterized by the soft water and/or low concentration of inorganic ions, and is generally suitable for potable use except for the existence of coliform. However, as soon as the river water flows into the flat plain, it infiltrates into the subsurface sediments and leaches out various inorganic matters and becomes the Hard water with high concentration of dissolved solids.

In the Alluvial fan deposits spreading northeast and northwest of the Study Area, it is found that inorganic ion concentrations of the ground water are relatively low and the water is suitable for potable use.

In the center to northern area of the basin, the ground water in relatively shallow aquifers are applicable to potable use, while the deep ground water is unsuitable for potable use due to high concentration of ammonium ion resulted from the anaerobic environment.

Since various kinds of waste water easily infiltrate into the subsurface sediments surrounding the shallow dug wells, the polluted water is finally mixed with the shallow ground water or the well water. In addition, it was inspected through the field investigation that animals freely access to almost all the existing wells, and therefore, it is very difficult to keep the wells clean. Garbage and animal excrement were occasionally observed at some wells.

Considering the present condition of the ground water usage at the rural areas, the well environment and the well structure should be urgently improved by means of, for example, fence installation and concrete pavement around the well, and construction of sewage ditch paved with concrete. In addition regular dosage of calcium hypochlorite for all wells are recommended.

4.2 Meteoro-hydrology and Water Balance

4.2.1 Meteorology

1) Rainfall

In relation to the Comayagua basin, rainfall data of 18 stations are available during a period from 1945 to 1988 (ref. Table 4.2.1 and Fig. 4.2.1). Within the catchment area of the Humuya River, as shown in Fig. 4.2.2, annual mean rainfall is 1,235 mm at Siguatepeque (El. 1,080 m) and 888 mm at Flores (El. 580 m). About 80 % and 90 %

of annual precipitation falls during May to October at Siguatepeque and Flores, respectively.

Since almost all of the rainfall records are intermittent data, missing annual rainfalls of a certain station were interpolated from existing data of another station adapting an appropriate correlation between two stations.

Basin rainfall for the whole Comayagua basin from 1967 to 1988 was estimated by the Thiessen Method as shown in Fig. 4.2.3. Based on the interpolated annual point rainfall, annual basin rainfall for each return period is computed as shown below:

hydrological standard year	year	annual basin rainfall in mm	in MCM
normal year (1/2 drought year)	1983	1287.5	2,643.6
1/10 drought year	1986	882.3	1,811.6
1/20 drought year	1972	771.2	1,583.5

Furthermore, basin daily rainfall from 1967 to 1988 were obtained in the same manner for the purpose of the runoff study by the tank model simulation (ref. section 4.2.3). The calculated basin daily rainfall series for hydrological standard years; 1972, 1983, 1986, and for 1988 are graphically shown in Fig. 4.2.4.

2) Temperature

As shown in Table 4.2.2, annual mean temperature is 21 ^oC at Siguatepeque and 24 ^oC at Flores. Where, monthly mean temperatures at the two stations are in the ranges from 18 ^oC to 23 ^oC and 22 ^oC to 26 ^oC, respectively.

3) Evaporation

Observed pan evaporation of each year varies from 1000 mm to 1600 mm at Siguatepeque and 1600 mm to 2200 mm at Flores, of which the annual mean values are 1,498 mm and 1,960 mm, respectively (see Table 4.2.2).

In the other hand, 70 % of the pan evapolation was applied for the potential evaporation in the water balance study. According to the runoff simulation to be explained in the section 4.2.3, estimated annual evaporation amounts to about 50% of annual basin rainfall.

4) Relative humidity, wind velocity and sunshine hour

Monthly mean relative humidity is in a range from 67 % to 83 % at Siguatepeque and 52% to 69% at Flores.

Monthly mean wind velocity at Siguatepeque and Flores are 1.7 m/s and 3.4 m/s, respectively. According to the registered data summarized in Table 4.2.2, magnitude of seasonal fluctuation is very small.

Annual mean sunshine hours at the two stations are 188 hours and 205 hours, respectively (Table 4.2.2).

4.2.2 Hydrology

1) Existing runoff data

For the Comayagua basin, there are two existing runoff gauging stations of La Encantada and Las Higueras. The former is located at the outlet of the Comayagua basin, and the latter is located at almost center of the basin (Fig. 4.2.1). Runoff data for 22 years from 1967 to 1988 were collected for the both stations.

Hydrographs of the both stations for the hydrological standard years are illustrated in Fig. 4.2.4, and the annual total runoff is shown below:

Hydrological standard year	year	Runoff at La Encantada Annual total(MCM)	ratio to Basin Rain.
normal year			
(1/2 drought year)	1983	379.1	14 %
1/10 drought year	1986	197.5	11 %
1/20 drought year	1972	178.8	11 %

2) Result of runoff measurement

In order to obtain sufficient information about surface runoff, the periodical runoff measurement was performed ten times in total at the selected four sections on a few tributaries of the Humuya river through the field investigation period.

In addition, the runoff measurements at 38 sections were seasonally carried out by the JICA's expert and MPH counterpart, as shown in Fig. 4.2.5. The observation results are shown in Table 4.2.3.

According to the measurement results, the runoff from river is remarkably different in general between the dry and rainy season. Surface runoff increases in a short time after heavy rainfall. In some sections, however, runoff is almost constant through the both seasons.

3) Land use and irrigation system

To grasp the land use condition in the Study Area, collection of related data and field reconnaissance were performed during the field investigations. The Study Area is principally classified into such five categories of irrigation area as pasture land, residential area, military base and unutilized scrub land, as shown in the land use map (Fig. 4.2.6). The area where irrigation water is supplied by Direccion General de Recursos Hidricos (DGRH) is about 7100 ha, and constitutes the main part of the irrigation area in the basin.

Three irrigation systems, consisting of the Flores system, the San Sebastian system and the Selguapa system, which are operated by DGRH exists in the Study Area. The planned area and the cropping area registered by branch offices of DGRH in each municipality are summarized below and the distribution of main canal is shown in Fig. 4.2.5.

Irrigation system	Planned area (ha)	Registered cropping area (ha)
Flores system	3,761	1,604
San Sebastian system	200	231
Selguapa system	3,130	2,157

The registered cropping area for each agricultural product and monthly water use for irrigation are shown in Table 4.2.4.

These data of irrigation water use were utilized for water balance analysis.

4.2.3 Runoff Study

1) Water balance analysis

Objective of this study is to clarify the water balance condition, and to estimate ground water potential in the Study Area by means of tank model simulation. The following formula represents the basic concept of water balance:

$$G = R - E - SR$$

where,

G : ground water potential
R : total rainfall volume in basin
E : actual evaporation
SR : surface runoff volume as river flow

Tank model was constructed for Las Higueras and La Encantada of which the daily runoff data during the period from 1967 to 1988 are available. The applied tank model is a simple model composed of four tanks arranged vertically in series (see Fig 4.2.7). After construction of the standard initial model adaptable for the Study Area, the model calibration was carried out. At such four sub-basins as Tenguaje, Ranchitos, Chilcares and Humuya where the periodical runoff measurement was being executed, the runoff simulation was also perfomed by applying the Las Higueras model in order to compare the estimated runoff with observed, and finally to check the reliability of the model.

2) Procedure of simulation study

In this study two kinds of tank models with different parameters were established to simulate the surface runoff and ground water potential (Fig. 4.2.7); one is the "Las Higueras Model" which aims to express the runoff hydrograph at the Las Higueras gauging station, and another for the runoff hydrograph at the La Encantada gauging station (from now so called "La Encantada model").

Calibration of the models was made by changing the outlets' parameters so far as to obtain the good fit to 5-day mean runoff at the respective gauging station. The recharge amount for the ground water obtained through the water balance study, will be utilized as input data for the ground water model simulation (see the section 4.2.4). Detailed process of simulation on the water balance study is described in Appendix E.

3) Calibration

At first calibration of the Las Higueras model was carried out. Then the calibration of the La Encantada model, which is a completely same model with the Las Higueras model except for the parameters of the fourth tank, was executed. Comparison between observed and calculated runoff volumes is given in Table 4.2.5 for the selected hydrological standard years, and the hydrograph is shown in Fig. 4.2.8 and

Fig. 4.2.9.

In general the simulated hydrographs have a good fit for the base flow portion of observed discharge. Accordingly, it is concluded that the Las Higueras model represents the general runoff process in the Study Area.

In the other hand, since the standard model for the Study Area was constructed, the runoff simulation at the four monthly runoff measurement points was performed mainly for the purpose of a comparison between the observed and simulated runoff (see Table 4.2.6). In spite of that the considerable restriction is expected in the model simulation, the results show rather good fit between the actual and the estimated runoff rate.

4) Ground water potential

Ground water potential in the Study Area was computed by putting the basin rainfall for the whole Study Area into the Las Higueras model. As a result of the study, average annual recharge volume for the ground water was estimated at about 100 thousand m^3/day in the whole basin, and the total recharge is evenly shared for the shallow and the deep ground water which are categorized as the aquifer system in the Study Area (see the section 4.1.4). Although the ratio of the annual ground water recharge to the annual basin rainfall usually remains within 1 %, the calculation result is reasonably admitted considering that the recharge occurs only at the flat plain (about 25 % of the catchment area) and the geological components of the flat plain generally show rather low permeability.

4.2.4 Ground water model simulation

1) Procedure of analysis

The objectives of the study are to demonstrate the simplest simulation model that could account for the principal features of the ground water flow in the aquifers, and to examine the condition of the ground water level under the future ground water development.

As shown in Table 4.2.7, some 52,000 m^3/day of total volume is recharged into each of the shallow and the deep ground water in the Study Area. First of all, reconstruction of the present ground water level by the numerical model simulation was executed under the assumed production (discharge) amount from the existing wells (see the section 4.1.5). Model calibration was made by means of comparing the calculated results with the actually observed ground water level. Following to the construction of the simulation model adaptable for the Study Area, the future drawdown of ground water level was predicted by putting the additional ground water discharge according to the future development plan. Detail description on the simulation model is made in Appendix E.

2) Mathematical simulation model

Ground water flow in an aquifer is assumed to be governed by the partial differential equation with two independent variables as shown below:

$$\frac{d}{dx}\left(T \frac{dh}{dx} \right) + \frac{d}{dy}\left(T \frac{dh}{dy} \right) = S \frac{dh}{dt} + W(x,y,t)$$

$$T = k\ m$$

$$S = s\ m$$

h : piezometric head (m)

T : transmissivity (m^2/day)

k : permeability coefficient (m/day)

S : strativity (no dimension)

s : specific storage (1/m)

m : saturated thickness of aquifer (m)

W : recharge and discharge in and/or from aquifer (m^3/day)

In case of the present study, the numerical model was formulated on the assumption that the ground water flow remains and/or will remain steady even though the amount of the rainfall varies seasonally and yearly. As known from the result of the water balance study and the present and/or future conditions of the water resource development, the natural recharge and the discharge from the wells are remarkably constant through years so as to keep the hydro static level almost stable. Therefore, it seems possible to neglect the time factor such as the strativity or the coefficient of storage in the equation.

The numerical analysis of the model was performed by the finite difference method which is commonly used to solve the regional aquifer problems posed in a horizontal two dimension scale.

3) Model calibration

Calibration of the model was carried out by comparing the calculated head with observed head shown as the water table map prepared in 1988 (Fig. 4.1.12).

In the actual model operation, the transmissivity, the recharge volume and the production rates from the existing wells are necessary to be allocated in the simulation model (see Appendix E for the detailed discussion). Total production volume from existing wells at present amounts to about 7,700 m^3/day, of which 3,500 m^3/day is being developed from the phreatic water and 4,200 m^3/day from the confined water.

Simulated water table map for the phreatic water and the confined water are shown in Fig. 4.2.10. Difference between the calculated and the observed ground water level is within 35 m at most. Considering such topographic characteristics as an existence of the relatively deep gouges and the considerable undulation in the flat plain, it is concluded that the magnitude of the error is under the acceptable limit for the model simulation.

4) Model prediction

For the purpose of predicting the drawdown of ground water level under the future ground water usage, the model simulation was performed taking into account the future ground water development plan in the year 2000.

According to the development plan discussed in the Chapter 5, the total water volume to be newly developed by the year 1996 is about 4,800 m^3/day, of which the shares for phreatic and confined water are estimated at 3,400 m^3/day and 1,400 m^3/day, respectively. Consequently, the total water production in the year of 2000 is estimated to be about 12,500 m^3/day, consisting of 7,000 m^3/day of the phreatic water and 5,500 m^3/day of the confined water.

52,000 m^3 of the total recharge volume amounted in the year of 1972 (the 1/20 drought year) was equally put into and/or allocated to both the shallow and the deep ground water.

The ground water level map and the drawdown map of the both aquifers, which were prepared on the basis of the model prediction, are shown in Fig. 4.2.10 to Fig. 4.2.11. As shown in the figures, the maximum drawdowns in the shallow and the deep ground water are estimated at about 7 m and 9 m, respectively. It is also noticed that the relatively large drawdowns are inferred in the areas such as the north region of the Study Area in case of the shallow ground water and the south region in the deep ground water, due to the concentration of the ground water development at the relating areas.

CHAPTER 5 WATER SUPPLY DEVELOPMENT PROGRAM

5.1 Ground Water Development Plan

5.1.1 Ground water requirement for rural water supply

According to the facility development master plan explained in the section 5.3, supplemental ground water requirement for the newly developed rural water supply is estimated for the target year of the each development stage as follows:

Development Stage	Target Year	Ground water Requirement (m^3/day)
1st Stage	1993	2,616
2nd Stage	1996	4,584
3rd Stage	2000	6,360

Within the water requirement of 4,584 m^3/day for the second stage, some 1,200 m^3/day are to be developed in the mountainous area which surround the Comayagua valley. The remaining 3,400 m^3/day, therefore, will be actually pumped up from the ground water reservoir in the valley.

5.1.2 Ground water development plan

At the northern area of the valley, a high contents of dissolved solids is detected from the deep ground water which is contained in the Diluvial lake deposits (see the section 4.1.8), showing unsuitable water quality for the domestic use of the rural inhabitants. On the contrary, at the southern area, the static water level is generally so low that an insufficient saturated thickness is expected in the Alluvial deposits and, therefore, usage of the shallow ground water is extremely limited in this area.

According to the hydrogeological condition mentioned above, the production well is designed to penetrate the main aquifer of the Alluvial fan deposits in the middle and northern area of the Comayagua valley where the shallow ground water is available for all the domestic use, while in the southern area of the valley the confined water with rather good quality will be developed from the Diluvial lake deposits.

On the other hand, since the detailed facility development has not been planned for the third stage in this report, the estimated ground water requirement at the year of 2000 is geographically allocated supposing that the source well location will be same as the detailed plan of the first and the second stage, and yielding rates of all the production wells will increase in the same ratio from the second stage to the third.

In the mountainous area, although rather small production capacity is inferred from a production well, it's quantity is probably sufficient for pumping by a hand pump.

Consequently, the source well location is shown in Fig. 5.3.7 (see the section 5.3.3 in more detail), and the allocation result of the supplementary developed ground water is shown below and in Fig. 5.1.1.

Type of Aquifer	Newly developed Ground Water (m^3/day) 1st & 2nd Stage	1st to 3rd Stage
Flat plain		
Phreatic Water	2,453	3,430
Artesian Water	969	1,360
sub-total	3,422	4,790
Mountain area	1,162	1,570
Total	4,584	6,360

5.1.3 Design of standard well

In compliance with the ground water development plan discussed above and the facility development master plan in the section 5.3, the following two types of production wells are recommended:

1) 4-inch well equipped with a cylinder type hand pump:

This type of well corresponds to the water supply system Type I. Depth and total screen length of the well are supposed to be 50 to 100 m and 30 m, respectively.

2) 6-inch well equipped with a electric submersible motor pump:

This well is constructed for the water supply system Type II and Type III. Depth and total screen length of the well is supposed to be also 50 to 100 m and 30 m, respectively.

Recommendable standard production wells are illustrated in Fig. 5.1.2.

5.2 Water Supply Master Plan

5.2.1 Rural population projection

The rural population in the study area is projected based on the past population censuses made in 1974 and 1988, applying its past trend of population increases, for the years in 1990, 1995 and 2000 (see Table 5.2.1, Table 5.2.2 and Fig. 5.2.1).

As a result of the present study, it is concluded that the new well development for the rural water supply should be urgently executed to meet the water requirements of the rural inhabitants. The urgent need for rural water supply indicates that an immediate program, which could be easily integrated with the long range master plan, should be proposed.

Considering the rural population projection and the water demand projection discussed in the next section, it is recommended that the future system development is planned by stage wise development, and consequently, the rural and served population of the planned rural water supply system are projected for the supposed development stage years of 1993, 1996 and 2000, as presented in Table 5.2.3.

5.2.2 Unit water demand and projected system water demand

The rural water supply system development in the study area is planned following to the National Plan for Drinking Water and Sanitation (April, 1983) and Rural Water Supply Manual prepared by MPH in 1983. In the

National Plan the rural water supply development criteria of the per capita demand and coverage of rural population are set at 50 LPCD and 90 % of rural population, respectively.

In this study its criteria are also applied for the future system development in 1993 as a part of the master plan. Further, the per capita demands for the future projection in 1996 and 2000 are set at 80 and 100 LPCD, respectively, considering about the similar development countries experience/practice and the expected grade up of the living standard of the rural population in the study area (ref. Table 5.2.4 and Fig. 5.2.2).

5.3 Facility Development Master Plan

5.3.1 Standard types of rural water supply system

As for the type of future water supply system to be developed in the study area, it is recommended that the following three types of water supply system are applied depending on the size and situation of the rural community (ref. Fig. 5.3.1 to Fig. 5.3.5).

1) Type I : A deep well point source system, installed with a cylinder type hand pump which has a maximum capacity to pump up 30 m deep water in the well. And also, the clothes washing or laundry space is provided. This system would cover at least 7 to 8 households or about 40 to 50 residents.

2) Type II : A deep well point source system, installed with an electric motor pump and an above ground water tank with washing and bathing facilities. This system would cover 20 to 50 households or 100 to 300 population.

3) Type III: A deep well source and piped system, installed with an electric motor pump and an elevated water tank which could supply water gravitationally to stand pipes and the remote sub-tanks with a maximum distance at about 1 km from the well source.

At the remote part communities, each one sub-tank with washing and bathing facilities would be installed. This type system would cover at most up to 100 households or a total population 500 to 600.

The designed unit water production of the source well of the above three systems are:

1) Type I : 15 to 20 l/min or average 8.4 m^3/day at 8 hr. operation per day

2) Type II : 50 to 100 l/min or average 36 m^3/day at 8 hr. operation per day

3) Type III: 100 to 300 l/min or average 96 m^3/day at 8 hr. operation per day

5.3.2 Proposed facility development

To realize the stage wise development discussed in the section 5.2.1, the facility development is proposed to be carried out in the following manner and shown in Fig. 5.2.2. The proposed number of each system is decided based on the size, extent and population of the served communities, geographical location of the communities, and the result of the present ground water potential study (see Table 5.3.1 and Fig. 5.3.6).

1) First Stage Development

Target Year	: 1993
Water Demand	: 2,590 m^3/day
Population served	: 51,800 (90% of total rural population)
Per capita demand (LPCD)	: 50 l/day

System Development:

a. Type I : 60 units (504 m^3/day covering 10,080 pop.)

b. Type III: 22 units (2,112 m^3/day covering 42,240 pop.)

Total system 82 units with 2,616 m^3/day production capacity, and population served 52,300 or 91% of total rural population.

2) Second Stage Development

Target Year : 1996
Water Demand : 4,520 m^3/day
Population served : 56,500 (approx. 90% of total rural pop.)
Per capita demand (LPCD) : 80 l/day

System Development:
Required additional water production capacity
: 4,420 - 2,616 = 1,904 m^3/day

a. Type I : 20 units, 168 m^3/day
b. Type II : 10 units, 360 m^3/day
c. Type III: 15 units, 1,440 m^3/day

Total system development
: 45 units, 1,968 m^3/day

Developed total system production capacity in 1996:
a. Type I : 80 units, 672 m^3/day
b. Type II : 10 units, 360 m^3/day
c. Type III: 37 units, 3,552 m^3/day

Total system 127 units with 4,584 m^3/day. Population served covering over 57,300 or 90% of total rural population.

3) Third Stage Development

Target Year : 2000
Water Demand : 6,360 m^3/day
Population served : 63,600 (90% of total rural pop.)
Per capita demand (LPCD) : 100 l/day

System Development:

Construct three types combined system as required to meet the increased water requirements in the year 2000.

5.3.3 Well source location plan

Well source location, as explained in the previous section, is planned to be well concordant with the facility development plan and the result of the ground water potential study.

Although the ground water from the pre-Quaternary base rocks, which distribute in all the mountainous area, are extremely limited in production capacity, it is very probable that sufficient yielding can be expected for the wells equipped with hand pumps.

Location and number of production wells at every communities are shown in Table 5.3.1 and Fig. 5.3.6.

5.4 Project Cost Estimates

5.4.1 Basic conditions

The project cost is estimated based on the construction plan and implementation schedule discussed in the next chapter. Construction conditions assumed for cost estimate are summarized as follows;

1) All the construction works will be performed by contractors selected through local and international competitive tenders.
2) Implementing time is 7 years (the first stage of 4 years and the second stage of 3 years).
3) Daily working hour is set at 8 hr., from Mondays to Saturdays.
4) Construction work for 4-inch well will be sustained by over 5 mm rainfall per day
5) Working days for construction is assumed at 270 days for 4-inch well construction works, 313 days for 6-inch well construction works considering Sundays, holidays and rainy days.

On the other hand, the project cost, consisting of construction cost, equipment cost, engineering services cost, and contingencies, is estimated on the following conditions and assumptions, and are expressed in Lempiras (Lps), the Honduras currency.

1) Cost for all the works during the whole period of the project is estimated on the price level of January 1989.
2) Currency conversion rate are US$ 1.00 = Lps. 2.00 = ¥ 135
3) Cost is estimated on unit cost basis, which consists of direct and indirect costs. Direct cost consists of the cost of labor, materials. Indirect cost, on the other hand, consists of field administration and supervision, corporate overhead and profit, security and safety control, and other incidental costs of the contractor.
4) Construction cost is estimated by multiplying the work quantities by the unit cost.
5) Each construction and supporting equipment is estimated on CIF price basis.
6) Engineering services costs for detailed design and construction supervision cost are estimated on man-month basis.
7) Physical contingency is estimated at 15 % of the total cost, and the price escalation rate for both foreign and local currency portion are assumed at 10 % per year.

5.4.2 Construction cost

Total construction cost including contingency cost is estimated at Lps 54 thousand (Lps 30 thousand for the first stage and Lps 24 thousand for the second stage) as shown Table 5.4.1.

The local and foreign currency components of the construction cost are estimated. Most of the construction materials for civil work such as cement, reinforcement steel bar, fuel, oil, etc. will be supplied by the contractor from the local market. Such materials and labor wages are estimated as the local currency portion. Equipment and materials such as drilling agents, casings and screens for production wells, pumps and electrical facilities are assumed to be procured from abroad. These belong to the foreign portion.

5.4.3 Disbursement schedule

The water supply system development is recommended to be executed in three stages by the year of 2000. Each stage is, as explained in the section 5.3.2, completed over three to four years, principally for selection of consultant, detailed design, contracting work and construction work including preparatory works. The disbursement schedule of investment cost by the end of the second stage is to be made in accordance with the supposed work progress and is shown in Table 5.4.2.

5.4.4 Operation and maintenance cost

According to the operation and maintenance program discussed in detail in the section 6.5, the operation and maintenance cost is estimated as shown in Table 5.4.3.

Generally the operation and maintenance cost includes the running cost of the facilities, the labor and equipment maintenance cost for the maintenance works and the replacement cost of the facilities. It is recommended that the running cost is paid by rural inhabitants (ref. the section 6.5).

5.5 Economic Evaluation

5.5.1 General conditions for economic evaluation

An economic analysis is carried out to ascertain the economic viability of the proposed development scheme. The economic viability is evaluated by Economic Internal Rate of Return (EIRR) for an optimum plan which is selected from technical viewpoint.

Economic benefit and cost to be adopted for the project evaluation are estimated under the following conditions and assumptions:

(1) The estimates are made based on prices in January 1989, and foreign exchange rate is set to be US$. 1 = Lps. 2 = ¥ 135;

(2) Transfer payments such as taxes and duties are assumed to be 10 % of their prices for goods and services procured locally, and to be exempted from duties for goods imported from abroad (except facilities to be replaced during the period 2006-2011);

(3) Further, a standard conversion rate of 94%, which is estimated from the export and import statistics for recent five years, is applied for goods procured locally;

(4) Economic wage of unskilled laborers for construction works is assumed to be 88% of the actual market wage, taking account of the employment opportunity of laborers in Honduras;

(5) The economic life of the Project is taken as 30 years after completion of the construction; and

(6) Residual value of equipment for well construction is counted as a benefit after completions of construction works, but well facilities are assumed to be zero in the last year of project life.

5.5.2 Economic cost

1) Construction Cost

By excepting price contingency from the construction cost at market prices (Tables 5.4.1 to 5.4.2) and taking account of conditions indicated in the section 5.5.1, the construction cost at economic prices is given as follows:

Construction Cost

Unit: Thousand Lempiras

Year	Financial Cost			Economic Cost		
	F.C.	L.C.	Total	F.C.	L.C.	Total
1. 1990	318	33	351	318	27	345
2. 1991	12,301	1,627	13,928	12,301	1,343	13,644
3. 1992	2,872	3,255	6,127	2,872	2,687	5,559
4. 1993	1,436	1,627	3,063	1,436	1,343	2,779
5. 1994	4,349	33	4,382	4,349	27	4,376
6. 1995	2,171	2,408	4,579	2,171	1,987	4,158
7. 1996	2,171	2,408	4,579	2,171	1,987	4,158
Total	25,618	11,391	37,009	25,618	9,401	35,019

The construction cost at economic prices is estimated at approximately Lps. 35 million in total, and it is disbursed extending for the seven-year period from 1990 to 1996.

Operation, Maintenance and Replacement Costs

Operation, maintenance and replacement costs (OMR cost) shown in Table 5.4.3 also are converted to economic costs respectively by the same adjustment method as the construction cost, and their annual costs are summarized as follows:

OMR Cost

Year	Financial cost	Economic cost	Year	Financial cost	Economic cost
1. 1990	-	-	17. 2006	1,378	1,299
2. 1991	-	-	18. 2007	1,596	1,517
3. 1992	113	95	19. 2008	636	557
4. 1993	241	206	20. 2009	614	524
5. 1994	315	269	21. 2010	1,601	1,513
6. 1995	315	269	22. 2011	1,444	1,356
7. 1996	419	357	23. 2012	614	524
8. 1997	524	447	.	.	.
9. 1998	614	524	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
16. 2005	614	524	30. 2019	614	524

unit: 10^3 Lps.

5.5.3 Economic benefit

A. Concept of benefit

Water is essential to human life and civilization. However, WHO's statistics indicate that at present more than a half of rural population in developing world do not have easy access to safe drinking water. They spend vast amount of time and energy to obtain their domestic water every day, under such unfavorable situation as they have sometimes to utilize even water contaminated.

In Honduras and the Study Area, in 1988 the rural population without safe and adequate water supply amounted to 55 % and 81 % of respective total rural population, that is, the population of approximately 1,400 thousand and 40 thousand. Actually, they bear a heavy burden of collecting water every day with fight against water borne diseases.

In such unfavorable condition, if safe and adequate water supply facilities are provided in rural areas, it would be to give a great improvement effect for public health, personal hygiene and socio-economic activities of rural inhabitants. Out of various effects, in the present study the economic benefit is estimated regarding two principal direct effects; (1) effect of time saving for obtaining water and (2) effect of reduction in water borne diseases, and the result is compared with economic cost of the Project. Other direct benefits such as reduction in infant mortality, prolongation of life expectancy, together with indirect benefits would be discussed in the section 5.5.5.

B. Benefit estimates

The project benefit is given as a difference between two conditions of "with project" and "without project". Full annual benefit would accrue during the period of project life from the year after completion of well construction work, e.g. from 1994 for the first stage and from 1997 for the second stage, and partial benefit for the construction period is assumed to be increased in proportion to the progress of construction work.

1) Benefit of time saving for obtaining Water

a. Conditions

(i) Based on future water demand and population projection shown in Fig. 5.2.2, the unserved rural population and households in the Study Area in 1994 and 1997 are estimated as follows:

	1994	1997
Unserved population		
(Rural population *1	59,351	64,764)
(Served population *2	9,508	9,508)
Without	49,843	55,256
With	5,951	6,464
Without minus With	43,892	48,792
No. of unserved households *3		
Without	9,046	10,028
With	1,080	1,173
Without minus With	7,966	8,855

*1 Refer Table 5.2.2

*2 Refer Table 1.2.1

*3 Family size is taken as 5.51 persons per household according to the 1988 Census.

(ii) The following conditions are set based on field survey and proposed plan in the present study:

* Water consumption per capita (lcd)	1994	1997
Without	25	25
With	50	80
* Average distance from water source to house (meters)		
Without	800	800
With	200	40
* Quantity of water carried a time per person (liters)	10	10
* Time required for carrying water a time (minutes)		
Without	50	50
With	15	7

b. Result

Time saving for obtaining water, under the above conditions, is estimated at about 5 hours per household per day in 1994 and 7 hours in 1997. In estimating an amount of annual benefit from this time saved, some conditions and assumptions, based on results of the field survey, are set as follows:

* The majority of domestic water for each household use are carried by women and children.

* The time saved for the women under the condition of "with project" is utilized for their economic activities, e.g. for farming, and an average income of each woman would be approxi-

mately Lps. 5 per day, assuming the work of an 8-hour day.

* Average annual working days of farmer are taken as 250 days for farming.

* Employment opportunity of 70 % is applied for laborers, taking account of the recent unemployment rate in rural areas.

As a result, benefit brought from the time saving for carrying water in the Study Area is estimated as follows:

1994:	Lps. 2,171 thousand
1997:	Lps. 3,387 thousand

2) Benefit of Reduction in Cases of Water Borne Diseases

Benefit of reduction in cases of water borne diseases consists of two categories; one is reduction in medical expenses and the other is increase in economic activities.

2.1) Reduction in Medical Expenses

a. Conditions

i) In general water borne diseases would be caused by inadequate and unsanitary conditions of four principal sources; water supply, sanitation facilities, domestic and personal cleanliness, and food hygiene. In regard to relationship between water borne disease and these principal sources, various studies have been carried out in connection with " The International Drinking Water supply and Sanitation Decade. Out of these studies, Richard G. Feachem [1] indicates that unsafe and inadequate water supply would account for 30 to 40 % of incidence of water borne diseases. This percentage would be a yardstick for the project evaluation.

ii) WHO's statistics [2] suggest that in rural areas of developing world the water borne disease would have a correlation with population unserved, though it would be unable to expect a high correlation coefficient. From these statistics We could get a general estimate which the 1 % increase in population served would bring a reduction in water borne disease at the rate of 30 to 90 cases per 100,000 population (see Table 5.5.1). Median 60 cases are used in estimating benefit and the result is examined by a sensitivity test.

iii) Further the foregoing statistics indicate that in Honduras the incidence of water borne disease was 4,462 cases per 100,000 population in 1985, and that the population served was 46 % for urban areas and 45 % for rural areas.

iv) On the other hand, in the Study Area the population served in 1988 is estimated at 89 % for urban areas and 19 % for rural areas as shown in the section 3.1.3.

v) Each percentage of population served for rural areas shown in iii) and iv) is assumed to be constant under "without project" condition until the end of 2nd stage, since it is supposed that the percentage will continue little increase for the time being from the present situation of a high population growth and a slow spread of water supply system.

vi) Under the "with project" condition, the rural population served in the Study Area is taken as 90 % in 1994 and 1997 each in accordance with "Water Supply Master Plan" described in the section 5.2.

b. Result

Under the above conditions, in the Study Area the reduction in water borne diseases of the rural population is estimated at 2,528 cases in 1994 and 2,759 cases in 1997.

In estimating an annual benefit from reduction in the disease cases, an average days required for medical treatment and an average medical expenses are assumed to be 10 days per case and US$ 10 (Lps. 20) per day based on data of WHO and other medical agencies. As a result, an annual benefit brought from the reduction in medical expenses in the Study Area is estimated as follows:

1994: Lps. 506 thousand

1997: Lps. 552 thousand

2.2) Increase in Economic Activities

a. Conditions

i) Benefit of increase in economic activities expected from the reduction in water borne diseases is given as a rise in the average income of farmers.

ii) Per capita GDP at the 1989 current prices, Lps. 1,902, which is estimated from the 1987 GDP per capita (Lps. 1,742) using an average annual growth rate of 4.5 % in recent years, is applied as an approximate value of the average income a farmer.

iii) Average treatment period of water borne disease is assumed to be 10 days per case (refer to b. Result in 2.1)).

b. Result

An annual benefit which accrues to the rural inhabitants in the Study Area from increase in economic activities, under the above conditions, is estimated as follows:

1994: Lps. 132 thousand

1997: Lps. 144 thousand

3) Summary of Economic Benefit

Economic benefit of the Project, except intangible benefit, which consists of the benefit of time saving for obtaining water and the benefit of reduction in cases of water borne diseases, is estimated to be Lps. 2,809 thousand in 1994 and Lps. 4,083 thousand in 1997, and after 1997 the same amount as the 1997 benefit would accrue every year during the project life period. Partial benefit for the construction period is estimated to be increased in proportion to the progress of construction work, and the result is indicated in Table 5.5.2. Breakdown of the economic benefit is summarized below:

Economic Benefit of the Project
(thousand Lempiras)

Classification	1994	1997
(1) Time saving for obtaining water	2,171	3,387
(2) Reduction in water borne diseases		
Reduction in medical expenses	506	552
Increase in economic activities	132	144
Total	2,809	4,083

5.5.4 Cost-benefit analysis

A. Comparison of cost and benefit

Using the annual flow of the economic cost and benefit shown in Table 5.5.2, a comparison of the cost and benefit discounted is carried out by means of the Economic Internal Rate of Return (EIRR), as a result the EIRR indicates "8.87 %" which appears to be high comparatively among similar water supply projects.

As mentioned at the beginning of previous section, the benefit which has been used for comparing with the cost is limited to only two tangible benefits among multifarious direct and indirect effects to be naturally considered as the project effect. Accordingly, the project, considering various effects discussed in the succeeding section, seems to be fully feasible not only from the viewpoint of basic human needs, but also economically.

B. Sensitivity test

Various conditions and assumptions in the present study have been set in the careful study based on professional experience and appropriate judgment of experts, but there always remains the question as to the degree of reliability of inputs. Therefore, a test is carried out for sensitivity of the EIRR to variations in the economic cost and benefit estimated.

The sensitivity of EIRR is tested for the 5 % and 10 % increases in the economic cost and the 5 % and 10 % decreases in the economic benefit, and the results are summarized below:

Sensitivity Test of EIRR (%)

Increase in Cost	Decrease in Benefit 0%	-5%	-10%
0 %	8.87	8.16	7.43
+5 %	8.19	7.50	6.78
+10 %	7.56	6.88	6.18

Even case of an unfavorable condition which the 10 % increase in the cost and the 10 % decrease in the benefit are combined, the EIRR still maintains more than 6 % which would have realizability as a rural water supply project.

Another sensitivity test of EIRR is conducted about reduction in cases of water borne diseases which is one of the most important conditions in estimating benefit of the reduction in medical expenses [ii), 2.1), 2), B of the section 5.5.3]. As a condition of this case, reduction in cases of water borne diseases to the 1 % increase in population served is set to be 60 cases per 100,000 population which is the median in reduction cases ranging from 30 to 90 per 100,000. If the minimum condition of 30 cases is applied, benefit of reduction in the medical expenses would be decreased to half of the present estimates. The decreased amount corresponds to about 8 % of the total benefit, and the EIRR come to 7.7 % decreasing by 1.1 % against the original estimate (8.87 %). Accordingly, although application of the minimum condition for cases of water borne diseases make somewhat low the EIRR, it has little effect on realizability of the Project.

5.5.5 Summary of economic evaluation

The cost-benefit analysis mentioned in previous section is carried out using merely two tangible benefits. In addition to such tangible benefits, the Project is expected to produce various intangible and/or indirect effects. Some major effects are summarized below:

(1) Reduction in load for carrying water, in addition to economic effect of time saving, would produce reduction in physical and spiritual burden of women, and children would be able to gain time for attending school.

(2) According to statistics of WHO, deaths caused by water borne diseases account for the rate of 5 % to 10 % of the disease cases in developing countries. Accordingly, the reduction in cases of water borne diseases will lead naturally reduction in number of the deaths, especially reduction in number of infant mortality. As a result, an average life expectancy of inhabitants will be prolonged.

(3) Safe and adequate drinking water supply to rural population would give significant impacts for the improvement of sanitation, and domestic and personal cleanliness in the Study Area.

(4) Implementation of the Project would create an employment opportunity for inhabitants in and around the Study Area during the period of well construction.

(5) An investment of some Lps. 37 million (including the foreign currency portion) for well construction would a stimulative effect for the socio-economic development in the Study Area.

Conclusion

As discussed above, the Project has a character of basic human needs and is feasible economically, and further it is expected that the Project would make a significant contribution to development of socio-economy and improvement of health and sanitary conditions in the Study Area. Accordingly, the Project is recommended to be realized as early as possible.

REFERENCES

[1] RICHARD G. FEACHEM; Infections Related to Water and Excreta: The Health Dimension of the Decade, Water and Sanitation Series, 1984.

[2] The International Drinking Water Supply and Sanitation Decade, Review of Mid-Decade Progress (as at December 1985), WHO.

CHAPTER 6 PROJECT IMPLEMENTATION SCHEDULE

6.1 Project Organization

6.1.1 Water supply project task force organization

1) General

As for the MPH task force for the implementation of the proposed rural water supply program, it is recommended that a typically assigned task force shall be organized for the project promotion and its proper/successful implementation. The recommended task force for the rural water supply project will comprise the following membership:

a. MPH officer

Position	:	Project Director (Director de Projecto)
Nos.	:	one person
Speciality	:	Sanitary and water supply engineering (Ingeniero Sanitarista)
Experience	:	15 years or more

b. Technical section supervisor

Position	:	Chief of engineers and technicians (Ing. Jefe del Depto. de Ingeniería)
Nos.	:	one person
Speciality	:	Sanitary and water supply engineering with experience on hydrogeological investigations and works
Experience	:	five years or more

c. Training officer

c-1. Chief of the training section

Position : Chief of the training section (Jefature de sección de capacitación)
Nos. : one person
Speciality : Sanitary and water supply engineering
Experience : 10 years or more

c-2. Staff for health promotion

Speciality(obligation): Promotion on health, education and organization of communities
Number and experiences:

Grade of Staff*	Experience(year)	Nos.
Health promoter III	10	1
Health promoter II	5	2
Health promoter I	1	10

* MPH's category

Since the training section is functional mainly for operation and maintenance works, details of this unit will be discussed in the section 6.1.2.

d. Organization and operation officer (administrative officer)

The administrative staff might be composed of the engineering/technical supporting staff and persons in charge of administration.

d-1. Chief of engineering/technical supporting staff: the chief of the technical section will hold this post concurrently.
d-2. Chief of the persons in charge of administration: a manager (Licenciado) with a 5-year or more experience on administration.

e. Waterworks engineers and technicians

Technical staff for the waterworks generally contains the following engineers and/or technicians, and it is basically requested that the engineers and/or technicians designated below have at least a 5-year experience.

e-1. Surveyors : one person

e-2. Design engineer: one person (Ingeniero) with sufficient experiences on the design works of rural water supply system

e-3. Water supply engineer: one person (Ingenieros) who are experienced in construction and maintenance of rural water supply system

e-4. Hydrogeologist: one person (Ingeniero) who is responsible for hydrogeological exploration and/or judgment on the well drilling works

e-5. Well driller: four persons who are satisfactorily capable to operate drill rigs and machineries for civil works

e-6. Assistants for well drilling: four persons

e-7. Water quality inspector: one technician who is responsible for the water quality analysis

e-8. Mechanics : one technician with sufficient knowledge on vehicles and machineries for civil works

e-9. Assistants for mechanics: two persons

e-10. Electrician : one person with sufficient knowledge on installation of submersible motor pump

e-11. Welder : one person

In addition to the above-mentioned engineers and technicians, an appropriate number of assistants for the respective work field is to be assigned especially for the third stage implementation when the construction might be done by MPH himself.

f. Administrative officials

The followings are the working positions to be included in the administrative officials. Persons assigned below should have satisfactory/appropriate experience on the respective work field.

Engineering/technical supporting staff

f-1. Manager of work shop and storehouse: one person

f-2. Manager for operation and maintenance of vehicles: one person

f-3. Storekeeper : one person

f-4. Drivers : five persons or more

f-5. Guards and watchmen: seven persons or more

f-6. Secretaries: five persons or more

Persons in charge of administration

f-7. Accountant : two persons

f-8. Personnel manager : one person

f-9. Person in charge of material procurement: one person

2) Functions

a. To prepare within the framework of the national plan a program of providing water supply and sanitation services,

b. To prepare in accordance with established master plan and design the priority list of community water works system development/construction schedule,

c. To coordinate with the agencies concerned, especially the municipalities and SANAA,

d. To program the channeling of materials, technical and institutional development assistance to the MPH's,

e. To prepare and implement a training program on rural water supply development, to include among others, skills in feasibility study preparation, system design, construction, project supervision and inspection, and operation and maintenance of water supply systems with the assistance of foreign technical aids,

f. To undertake an information campaign to develop awareness and support to the rural water supply program to the region/district,

g. To develop a project involving local civic organizations sponsorship of rural community water supply project,

h. To submit to the MPH for evaluation and approval of the planned project and system design of rural municipality and community water supply system.

6.1.2 Operation and Maintenance (O&M) organization

Fig. 6.1.1 presents the existing organization of rural water supply in Honduras. Under this organization, system inspection, instruction of operation and maintenance (O&M) for the existing rural water supply system are being executed. The present organization is generally well operated and, therefore, it is recommended that this organization is applied for the project implementation of the proposed rural water supply system development.

However, since the proposed future system will include more numbers of deep well operation than present, utilizing electric motor pumping facilities and piping facilities, it is concluded that the present work force of the rural water supply system should be reinforced both on quantity and quality to cope with the newly developed system operation.

After and during the execution of the proposed project, a restructured organization is required to be established to perform an appropriate operation and maintenance for the newly developed rural water supply system. Consequently, this expects that important function is to be organized in the present rural water supply organization structure. The recommended organization for O&M will be discussed in more detail in the section 6.5.

6.2 Scope of Work

To meet the urgent need for the water supply for rural inhabitants, as discussed in detail in the section 5.3.2, the stage wise development is proposed for the water supply development master plan. Considering the water demand projection and time schedule of the first stage, it is proposed that 22 deep wells equipped with electric motor pumps and 60 rather small wells with hand pumps are to be totally constructed by the end of the year 1996, supposing that the construction starts at the year of 1990. In case of the second development stage, 25 deep wells with electric motor pumps and 20 small wells with hand pumps are proposed as the construction amount during the years form 1994 to 1996 (see Table 6.2.1). The number of wells is estimated based on an average production capacities of Type I, Type II and Type III as discussed in the section 5.3.1.

The scope of work on the future project also includes the following technical training program for water supply system development, so as to realize the third stage construction by the MPH staffs by themselves and to make them capable on the operation and maintenance (O&M) works.

- Deep well construction (drilling works) technology
- Water supply facilities construction technology
- Appropriate operation and maintenance of the system

This technology transfer program is pursued based on the OJT (on the job training), during the proposed project implementation in the years 1991 to 1996. Therefore, supply of the necessary equipment and tools, including the drilling rigs and accessories, for construction and operation and maintenance works for the rural water supply systems are also incorporated in the scope of work as shown in Table 6.2.1. The equipment and tools used for the first and the second construction would be handed over to MPH after completion of the construction.

6.3 Implementation Schedule

6.3.1 General

The construction plan and implementation schedule on the rural water supply development project are prepared by the assumption that all the construction works will be performed by contractors selected through international competitive tenders.

In addition to the above general condition, considering that this project aims to raise up the standards of health and living of rural inhabitants, it is possibly assumed that the following undertaking will be taken by the Honduran Government:

- Supply of lands necessary for installation of water supply facilities, stock yard of materials and equipment, stationary work shop and so on.
- Provision of counterpart team for supervisory work and well drilling, and vehicles with drivers for the counterpart team.

6.3.2 Implementation schedule

In compliance with the order of construction of proposed facilities, a detailed implementation schedule has been developed for the first stage program as presented in Fig. 6.3.1. The implementation schedule for the second and the third stage programmes is similarly developed as the first stage. The implementation schedule of the second stage has been planned primarily for the purpose of economic analysis (see Fig. 6.3.2). It is essential for the proper project implementation that the detailed design for construction should be prepared prior to actual construction works.

1) The first stage development schedule

From the preparatory work to the final tests, construction work is planned to be completed in 38 months, starting June 1990 and ending in August 1993. Main components of schedule are as follows:

- Detailed Design	: July - August, 1990,	2 months
- Tendering and contract award including prequalification	: September-October, 1990,	2 months
- Material Procurement and supply or delivery	: November,1990-June,1991,	8 months
- Construction work including preparatory work & tests	: July,1991 - August,1993,	26 months

2) The second stage development schedule

The second stage development schedule is planned to be completed in 30 months, starting May 1994 and ending in October 1996. Main components of schedule are as follows:

- Detailed Design	: May - June, 1994,	2 months
- Tendering and contract award including prequalification	: July - August, 1994,	2 months
- Material procurement and supply or delivery	: Sept.,1994 - Jan.,1995,	5 months
- Construction work including preparatory work & tests	: July,1991 - August,1993,	21 months

The above-mentioned implementation schedule is planned based on the required work quantities (see Chapter 5). Time for "Material procurement and supply" is estimated supposing the import of equipment and materials which includes shipping, customs clearance and inland transportation (the section 6.4.

6.3.3 Construction plan

1) Production well

The construction of production wells includes 82 boreholes with total depth of 4,550 m in the first stage, and 45 boreholes with total depth of 2,500 m in the second stage (Table 6.2.1). The drilling will be carried out by using two units of rotary rigs with installing the function of chemical foam and air hammer. Including all of drilling, geophysical logging, casing and screen installation, well development, pumping test and site transportation, the completion time of each type of production well is estimated as below:

Type of Production Wells Casing Dimension	Drill Dia.	Completion time (day)
D4" x 50 m	7-5/8"	12
D4" x 100 m	do.	15
D6" x 50 m	12-1/4"	17
D6" x 100 m	do.	21

According to the estimated completion time of each production well, it is expected to take 24 months for completion of all the drilling works in the first stage, and 18 months for the drilling works of the second stage.

Casing pipes are PVC pipes (D4" x 50 m), FRP pipes (D4" x 100 m) and seamless carbon steel pipes (D6" wells). Screen pipes are expected as slot type with about 5 % open ratio for D4" wells and wire-rapped type such as Johnson screens for D6" wells. Average screen length of each well is assumed at 30 m.

2) Water supply facilities

It is expected that the construction and/or installation of water supply facilities are able to be executed in parallel with the well construction. Therefore, it is supposed that the work will start one month later from the commencement of well drilling and complete within two or three months later after the completion of well drilling.

According to the preliminary design of the water supply facilities shown in Fig. 5.3.1 to 5.3.6, a cylinder type hand pump is installed in a D4" well, and a submersible motor pump with maximum discharge rate of 100 (for Type II) to 300 (for Type III) l/min will be installed in a D6" well.

In the cases of Type II and Type III, distributed pipe lines with water tanks, public bath houses and public standpipes will be constructed.

6.4 Construction Material and Equipment Procurement Procedure

6.4.1 Construction material

1) Materials for well construction

Majority of the well construction materials is drilling agents consisting of foam, bentonite, CMC and dispersion agent.

Almost all of those materials are impossible to locally obtain and, therefore, they should be imported.

2) Materials for water supply facilities

Sand and gravel are locally available for concrete structure construction. Aggregates for pipe bedding, road bedding, surfacing and other civil works are also available. While cement is manufactured in the study area, therefore no serious or special problem is likely to arise with respect to normal civil construction works of water supply projects in the study area.

Piping materials are generally imported except small size plastic and galvanized steel pipes, however usually available in different commercial sizes.

6.4.2 Equipment

Hand pumps for rather shallow wells are manufactured in Honduras and available in the domestic market, while equipment proposed for the present project including high lift hand pumps for deep well use, submersible motor pumps, diesel generator units are generally imported from the US and other developed countries.

Regarding the procurement method, procurement of materials and equipment will be carried out, in principle, on a basis of open international competitive bidding. The procedures for the above will be in accordance with the guidelines of the foreign lending agencies which may finance the project cost.

Main items of equipment to be imported are as follows:

1) Drilling rig and accessories
2) Casing and screen
3) Deep well type hand pumps
4) Submersible motor pumps
5) Diesel generators with associated equipment
6) Electric equipment
7) FRP made water tank with supporting structure
8) Bulk meter and service meters
9) Vehicles
10) Telecommunication equipment
11) Work shop & maintenance equipment

6.4.3 Procurement procedure

Major steps of the procurement procedure are as follows:

1) Advertisement of tenders
2) Bidding
3) Evaluation of the bids with assistance of consultants
4) Award of contracts
5) Manufacturing by the suppliers or contractors, and factory inspection by the engineer
6) Shipping by the suppliers or contractors, test operation and acceptance

6.5 Operation and Maintenance Program and Procedure

The present water supply system is composed of the facilities presented below, which are planned and designed from the viewpoint of simple manual operation and maintenance, and easy supply of spare parts, based on the field investigation of the existing water supply systems:

- Deep well,
- Submersible motor pump,
- Elevated water tank and supporting tower,
- Diesel engine generator and operation panel,
- Generator house,
- Distribution pipelines,
- Public stand pipes,
- Public bath houses, and
- Other associated facilities.

Ground water will be lifted up to an elevated tank constructed adjustment to deep well by a submersible motor pump driven by electric power and/or an engine generator. Ground water stored in the elevated tank will be supplied to sub-tanks and water taps of public bath houses installed at adequate places by gravity with moderate pressure.

As for the guidelines in the operation and maintenance (O&M), it is recommended that the matters described below be fulfilled at the earliest occasion.

1) Organization

The organization for the O&M of the water supply systems will consists of community leaders and responsible person (service workers) engaging in the daily operation and maintenance of facilities. However, it is recommendable that all beneficiaries will participate in the organization as one of the members from a view point of sound operation of facilities.

The organization should be made to develop a system which can be managed with minimum assistance from the central and regional agencies concerned. The organization is required to nominate villagers as service workers, who could be given tasks and their responsibility for operation and maintenance training, and are to be paid with reasonable wage for the works.

A recommended O&M organization chart is presented in Fig. 6.5.1.

2) Function and duties of Manager/Operator

The number of personnel who will operate the system depends primary on the number of consumers and extent of the water supply system. In small systems, a part time manager/operator is needed and in large system it might need a part or full-time clerk in addition to a manager/operator.

It should be pointed out that one form of keeping the operating cost at a minimum is to keep personnel cost low without sacrificing efficiency.

The manager/operator performs both the administrative and technical jobs. His administrative work consists of the operation and maintenance of water collection and distribution utilities and pumping equipment. Specially, the daily duties of an operator are:

a. Starting of the engine generator, which is one of the daily routine operation of the water supply systems, will be commenced manually with turning its crank handle. After stabilizing generated current voltage, an operation panel switch of the well pump shall be turned to ON to operate, and pumping up of ground water will be started. Pump can be started and stopped automatically by float control in the storage tank and water will then be available for 24 hours in the evening, developing upon the demand and in the water level inside the reservoir. He should check the motor and pump if they are functioning satisfactorily.

b. To read and record water and fuel indicators and to determine the total daily water and fuel consumption of the area being served. This data is necessary in determining if water is wisely used and for future developmental planning. When overflow from overflow pipe of the elevated tank is observed and confirmed visually, the operation panel switch shall be turned to OFF to stop the engine generator.

c. Operation and maintenance, necessary check items for routine operation comprise check on fuel of engine generator and its lubricant. Especially, fuel meter should be observed periodically. Daily consumed fuel volume will be checked from the above meter observation and fuel supply schedule for long period will be able to estimated. Engine lubricant has to be changed with a specified new one according to operation period recommended by the engine manufactured.

d. To keep unauthorized persons away from pumping stations and reservoirs.

3) Personnel training

It should not be expected that highly trained personnel will be found in small rural areas or villages for the administration/management, maintenance and operation of a water supply system. Most of the time candidate has little or has no knowledge about the system. however, he can be trained to handle the administrative and operational functions. He should be encouraged to learn how the water system has been constructed and commissioned. It is recommended that the operator attend and operator's training seminar which would be programmed and incorporated in the proposed project implementation.

4) Financial aspect

The communities will pay for the running cost of the facilities, although they need to receive the financial assistance from the Government for the O&M activity of the water supply facilities. The running cost will be allocated to the users by households. Then, the charge for it will be collected by the service workers and manager monthly.