PART 3 FEASIBILITY STUDY

CHAPTER 1 PRIORITY PROJECT

(1) Priority Project

High priority project will be selected form proposed projects of Master Plan Study (hereinafter refered to M/P), and Feasibility Study (hereinafter refered to F/S) will be implemented for the high priority projects.

Project for emergency water supply by groundwater was proposed by M/P, and the project was approved by Colombian side. Purpose of this project is to drill many wells around Bogotá City for emergency water supply. After the approval of M/P, priority of proposed projects was discussed by Colombian side and Study Team, to select projects for target of F/S. The final priority given to each project is listed in Table-3.1-1.

Table-3.1- 1 Priority of Proposed Projects in M/P

Priority and project		Project	
1st	Prior Project	Pilot Project for Groundwater Use	
2nd	1st Period Project	Eastern Project	
3rd	2nd Period Project	Southern Project	Soacha
			Ciudad Bolivar
4th	3rd Period Project	Yerba Buena	

(Source: JICA Study Team)

- Pilot project for groundwater use was given the highest priority that should be implemented prior to other projects.
- Among the other projects, the high priority was given to the Eastern Project, the next priority to the Southern Project and the last priority to Yerbabuena project. Order of priority is proportional to distance from the Bogotá city center to the project site.

Criteria in priority are as follows:

a) Pilot Project

As prior project, Pilot Project for Groundwater Use was selected. This should be implemented prior to the other projects. Pilot Project will become model case to promote facilities for emergency water supply throughout the city.

b) First Period Project

The Eastern Project was selected as the first period project. The centre of Bogotá city is located near the Eastern hills, from where water of the emergency wells can be supplied efficiently to entire Bogotá city. Therefore, the Eastern Project was given high priority due to easy access to the city centre.

c) Second Period Project

The Southern Project was selected as the second period project. Area of the Southern Project is located in the southern part of Bogotá city, near the assumed epicenter of serious earthquake, where there are many houses on the hill slope. Serious disaster and big damage to water pipeline are expected by an earthquake.

d) Third Period Project

The Yerbabuena Project was agreed as the third period project. Yerbabuena area is located in Chia and Sopo municipalities, to the north of Bogotá city. Groundwater from wells in Yerbabuena area can be brought to Bogotá city and surrounding municipalities, by water tracks and pipelines, in case of emergency. On the hand, Yerbabuena area is far from the center of Bogotá city. Therefore, it was given the low priority.

Project for target of Feasibility Study

Colombian side requested implementation of Feasibility Study for Pilot Project and 1st Period Project, which are most important and urgent. However, the entire project is urgently necessary, and size of each project is compact. Therefore, it was agreed between Colombian side and JICA Study Team that 2nd Period Project and 3rd Period project also would be included in Feasibility Study.

CHAPTER 2 ACTION PLAN

Action Plan was proposed to realize proposed projects for emergency water supply that were presented in M/P study. The content of Action Plan is shown in Figure-3.2-1.

Activity	2008						2009												2010				
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1) Agreement on M/P for emergency water supply.		■	■																				
2) Selection of priority project			■																				
3) Implementation of F/S		■	■	■	■	■	■	■	■														
4) Approval of result of F/S									■														
5) Implementation of pilot project for groundwater use												■	■	■	■	■	■	■	■	■	■	■	■
6) Technology development and study for groundwater development			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7) Decision on investment and budget procurement by Acueducto																		■	■	■	■	■	■

Figure-3.2- 1 Action Plan

Activity in Action Plan is summarized as follows:

1) Agreement of M/P for emergency water supply

M/P for emergency water supply by groundwater was explained to Colombia side and was agreed on between Colombian side and JICA Study Team.

2) Selection of priority project

Based on discussion between Colombian said and JICA Study Team on priority of the proposed projects in M/P, highest priority was given to Pilot Project for Groundwater Use. Then, the following priority is, i) Eastern Project, ii) Southern Project and iii) Yerbabuena Project.

3) Implementation of F/S

Feasibility of proposed project was examined. Responding to request from Colombian side, accuracy of F/S was different following the priority of projects. Highest accuracy was given to the Pilot Project and the Eastern Project. Then, the second highest accuracy was given to the Southern Project. On the other hand, Yerbabuena project was planned with pre-feasibility level.

4) Approval of Result of F/S

Project for emergency water supply proposed in F/S was agreed on between Colombia side and JICA Study Team.

5) Pilot Project for Groundwater Use

Effectiveness of emergency water supply by use of groundwater, proposed by M/P and F/S, will be proved by implementation of Pilot Project. Facilities of the Pilot Project consist of existing well and water treatment facilities. Technical problem in design and construction of facilities for emergency water supply, and cost for operation of the facilities will be resolved by implementation of the Pilot project.

6) Technical development and study for groundwater development

Adequate knowledge and technology are necessary for groundwater development and operation of wells. For this purpose, study on methods to analyze groundwater flow and groundwater storage is indispensable. This study should be done by Acueducto with SDA and CAR.

7) Decision on investment and budget procurement

Acueducto will judge necessity and procedure of investment for emergency water supply, based on result of M/P and F/S by JICA Study.

CHAPTER 3 PLAN OF PRIORITY PROJECT

In Master Plan Study (hereinafter referred to as M/P), necessity and responsibility of the project for emergency water supply was evaluated in view point of long term water supply for Bogotá city, and outline of the proposed project was presented. In this Feasibility Study (hereinafter referred to as F/S), the proposed projects in M/P were reviewed, and feasibility of each project was evaluated. Principle of review is as follows:

1) Technical optimization
2) Coordination with long term strategy of Acueducto
3) Response to change in institutional condition of project site
4) Improvement of accuracy in design and cost estimate of projects

Proposed project is explained in order of its priority.

3.1. Pilot Project for Groundwater Use

3.1.1. Purpose of Pilot Project

Purpose of Pilot Project is to prove effectiveness of emergency water supply by use of groundwater. Acueducto does not have experience of water supply by groundwater source. Therefore, before implementation of projects by groundwater source, problems in design, construction, operation and maintenance of facilities for emergency water supply should be resolved by implementation of the Pilot Project. Items below were examined for Pilot Project.

a) Design of facilities

b) Cost for construction

c) Operation of facilities

d) Cost for operation and maintenance of facilities

Main technical issues to be solved in Pilot Project are as follows:

<u>Site for Project</u>

Sites for the Pilot project are located in densely populated area of Bogotá city, and area of the sites available for the Pilot Project is limited and narrow. An emergency well has been already drilled in each site. Plant for water treatment, instrument for water supply and pipelines must be newly constructed within the narrow site. Issue to be solved is how to arrange each component within small area.

<u>Water quality</u>

Groundwater of Cretaceous aquifer is excellent. However, concentration of Fe^{2+} and Mn^{2+} in the groundwater exceeds drinking water quality standard, and it must be treated. There is several method of water treatment, which was compared and examined in F/S.

<u>Operation of facilities</u>

There are two methods for operation of the facilities.

a) Direct water supply from emergency well to water truck

b) Connection of emergency well to the existing facilities such as water tanks and pipelines

Both of above two methods are necessary for emergency water supply. However, method b) above needs laying long pipeline from an well to the existing tank. Cost for construction of new pipline may exceed available budget for Pilot Project. Therefore, method a) above will be mainly employed and examined in this F/S.

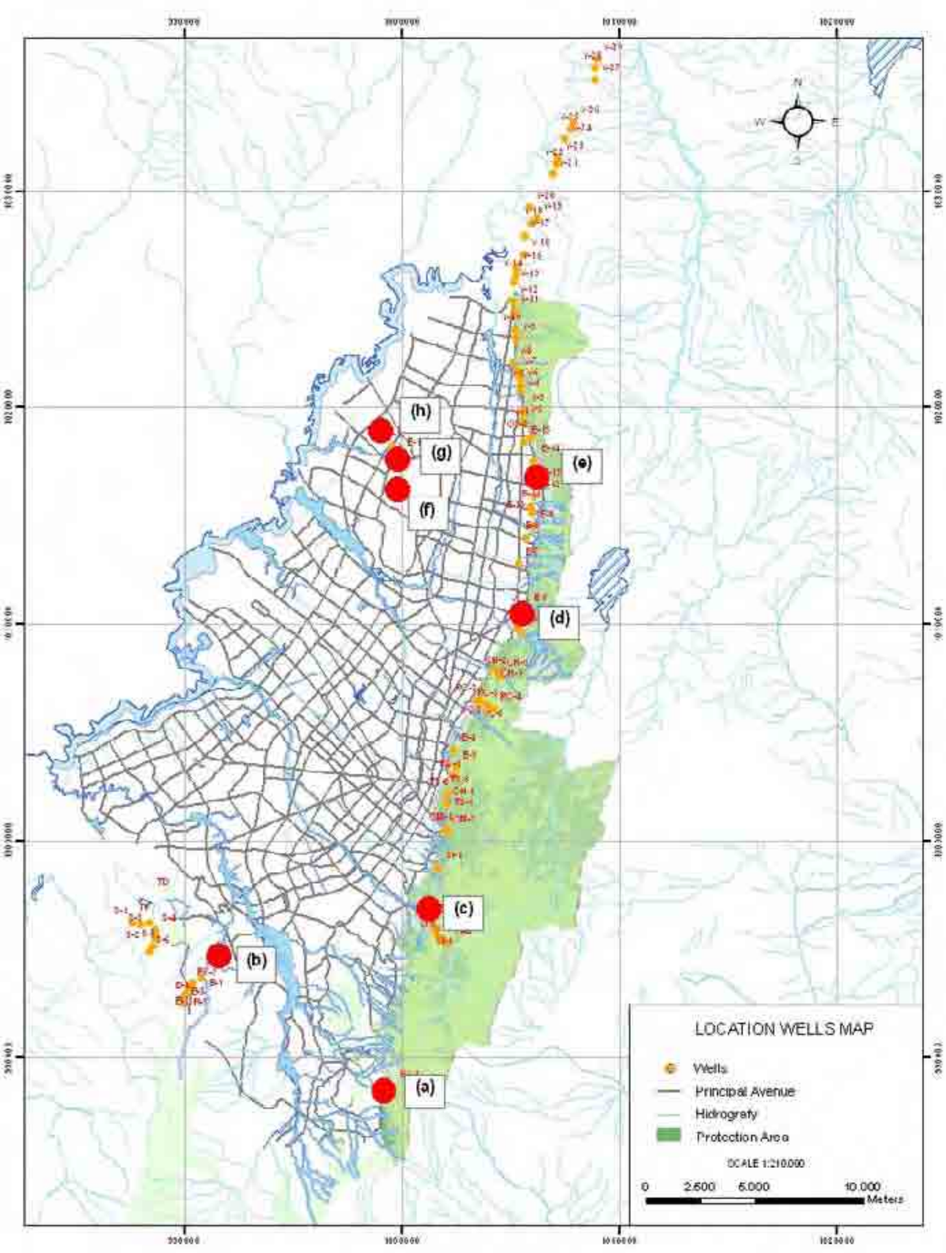
Manual for immediate response

A manual for emergency response has been prepared, which instructs activities to be performed for immediate response to disaster (see appendix-1).

3.1.2. Site for Pilot Project

Facilities of Pilot Project consists of an emergency well, a water treatment plant and water distribution instrument. Acueducto has 8 existing wells within Bogotá city, which can be used for Pilot Project. Location of the existing wells is shown in Figure-3.3-1.

Acueducte intends to implement the Pilot Projects in 2 sites with highest priority of 8 sites in 2009. Groundwater production of the existing wells is high. Therefore, all the existing wells should be used for the Pilot Project in the near future.



Note) Number of well corresponds to Table-3.3-1

Source: JICA Study Team

Figure-3.3- 1 Site for Pilot Project

Table-3.3- 1 Outline of Facilities for Pilot Project

Site	Coordinate		Capacity of Well				
	Latitude	Longitude	Depth (m)	S.G.W.L. (m)	Yield (m^3/day)	D.G.W.L (m)	Aquifer
(a) Usme	4°29'38.1"N	74°04'51.5"W	300	-20.70	100	-89.99	Tertiary
(b) Ciudad Bolivar	4°32'14.4"N	74°09'51.7"W	300	-18.20	900	-70.90	Cretaceous
(c) Vitelma	4°33'46.8"N	74°03'55.2"W	300	-6.84	1,296	-25.47	
(d) La Aguadora	4°41'32.1"N	74°01'27.1"W	300				
(e) La Salle	4°45' 17.4"N	74° 01' 22.5"W	270	+1.75	1,944	-33.26	
(f) Suba tank	4°42' 43.6"N	74° 05' 03.6"W	300				
(g) Suba	4°45' 27.0"N	74° 04' 42.2"W	389	-23.92	1,987	-18.85	
(h) Mariscal Sucre	4°45' 40.0"N	74° 04'53.4"W	304	-20.09	4,320	-24.00	

Source: JICA Study Team

Characteristic of wells to be used for Pilot Project is as follows:

- Wells are located near the densely populated area of Bogotá city and can be used for point water supply in emergency.
- Aquifer of the wells is the Cretaceous and can provide enough groundwater. Environmental problem such as land subsidence will not occur by pumping of the wells for Pilot Project.

3.1.3. Facility Plan for Pilot Project

(1) Facility Plan for Emergency Water Supply System

1) Composition and Connection Point for Emergency Water Supply Unit

The composition and the connection points for the emergency water supply unit on the pilot project are shown in Table-3.3-2.

Table-3.3- 2 Composition and Connection Point for Emergency Water Supply Unit (Pilot Project)

Project Name	Site		Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)	(Exist Facility)	
Pilot Project	Usme	Usme	PP-01	EX-3	Exist.	–	–	1.3	132	3.7	1.6	25	100	Chlorine +Aeration+ Pressure Filtarlate	–	–	–	1
	Southern hills	Ciudad Bolovar	PP-02	EX-2	Exist.	–	–	3.2	121	26	6	25	1,000	Chlorine + Pressure Filtarlate	–	–	–	1
	San Cristoba –	Vitelma	PP-03	E-1	Exist.	–	–	4	100	37	16	100	2,000	Chlorine + Pressure Filtarlate	16	50	Tank Vitelma	2
	Usaquen	La Aguadora	PP-04	E-5	Exist.	–	–	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
		La Salle	PP-05	E-14	Exist.	–	–	4	102	37	–	–	2,000	Chlorine	–	–	–	1
	Suba	Suba tank	PP-06	ST-2	New	8"+6"	300	4	100	55	6	25	2,500	Chlorine + Pressure Filtarlate	–	–	–	1
		Suba	PP-07	E-16	Exist.	–	–	4	97	55	6	25	2,500	Chlorine + Pressure Filtarlate	–	–	–	1
		Mariscal Sucre	PP-08	E-17	Exist.	–	–	4	85	45	–	–	2,500	Chlorine	–	–	–	1

Note-) Type of the supply is shown in Figure-3.3-41.

Source: JICA Study Team

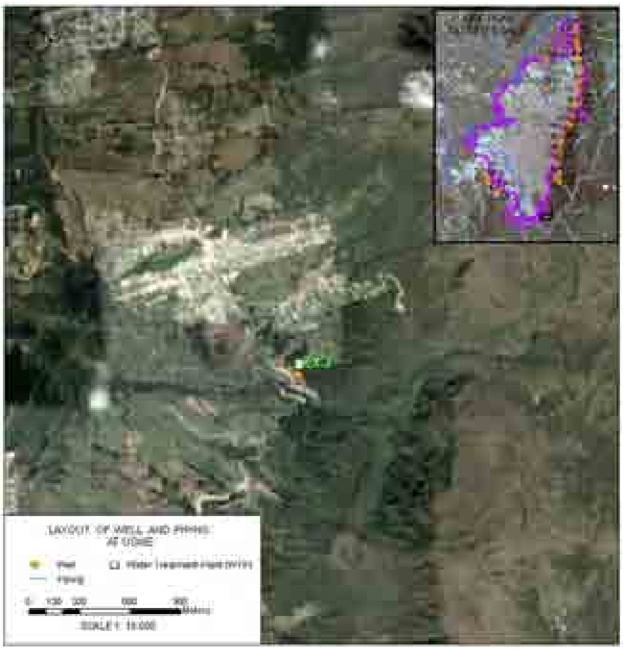
2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the pilot project consists of one (1) water treatment plant (WTP) and one (1) well. The layout plan for each water supply unit is shown in Figure-3.3-2 to Figure-3.3-8. Relation between the name of the well site and the water supply unit for the pilot project are shown in Table-3.3-3. Detail Design diagrams for La Salle and Vitelma Pilot Project are shown on Figure-3.3-9 to Figure-3.3-18.

Table-3.3- 3 Well name and water supply unit name

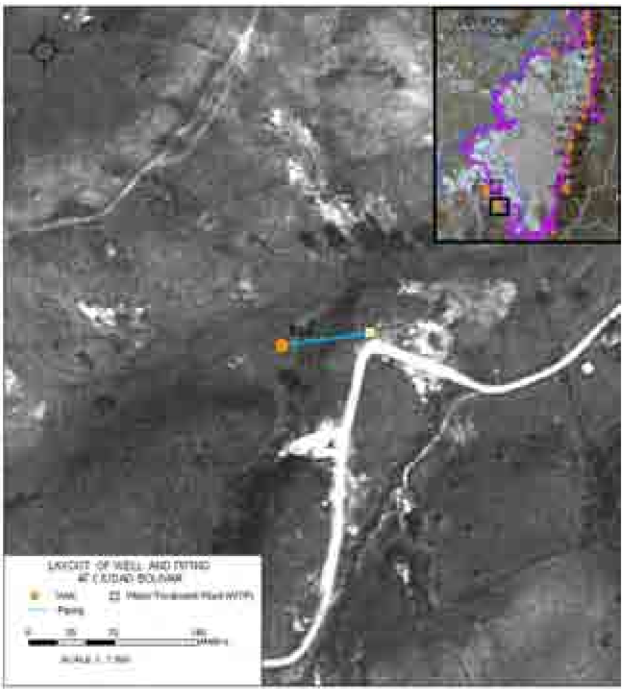
Site Name	Water Supply Unit Name
Usme	PP-01
Ciudad Bolivar	PP-02
Vitelma	PP-03
La Aguadora	PP-04
La Salle	PP-05
Suba tank	PP-06
Suba	PP-07
Mariscal Sucre	PP-08

Source: JICA Study Team



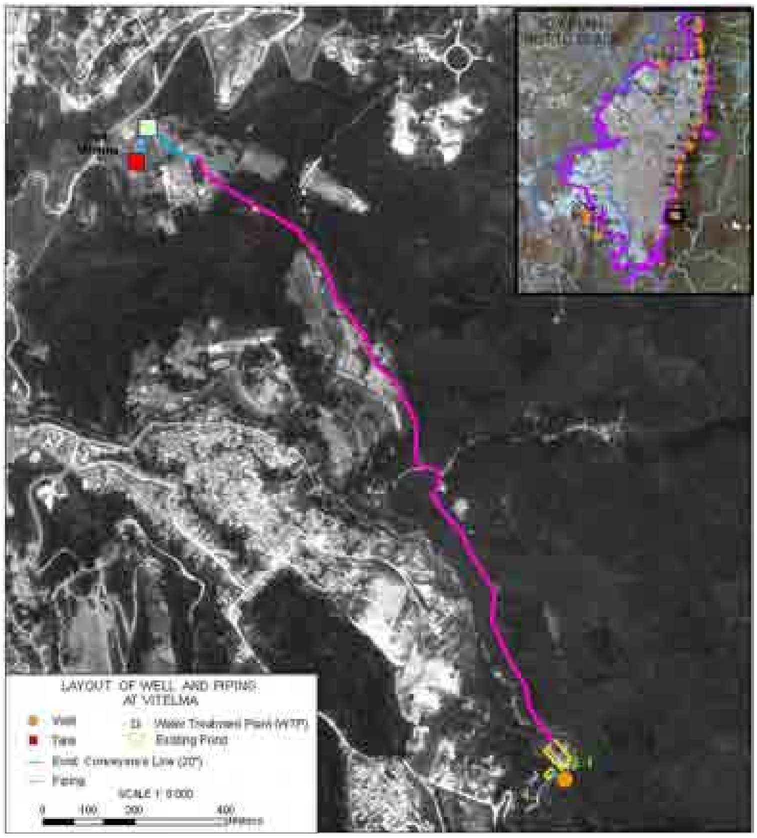
Source: JICA Study Team

Figure-3.3- 2 Unit Layout Plan for PP-1



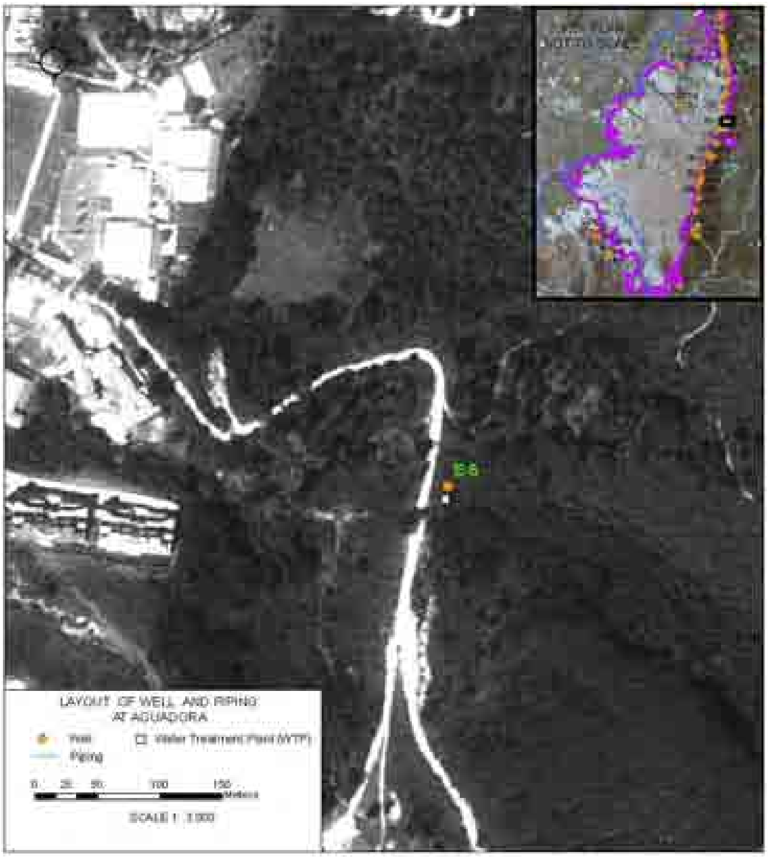
Source: JICA Study Team

Figure-3.3- 3 Unit Layout Plan for PP-2



Source: JICA Study Team

Figure-3.3- 4 Unit Layout Plan for PP-3

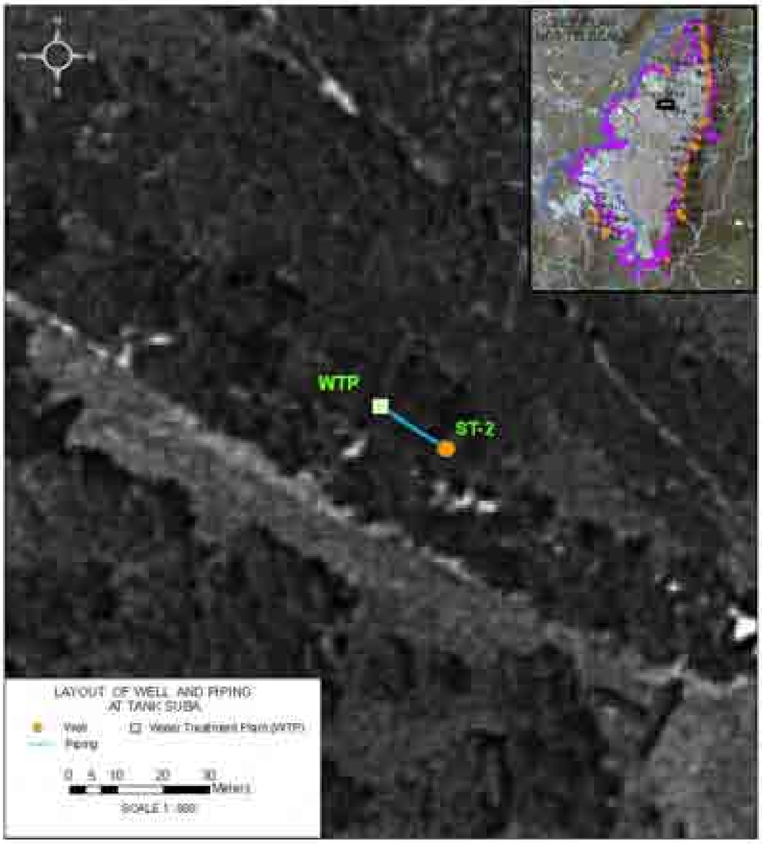


Source: JICA Study Team

Figure-3.3- 5 Unit Layout Plan for PP-4

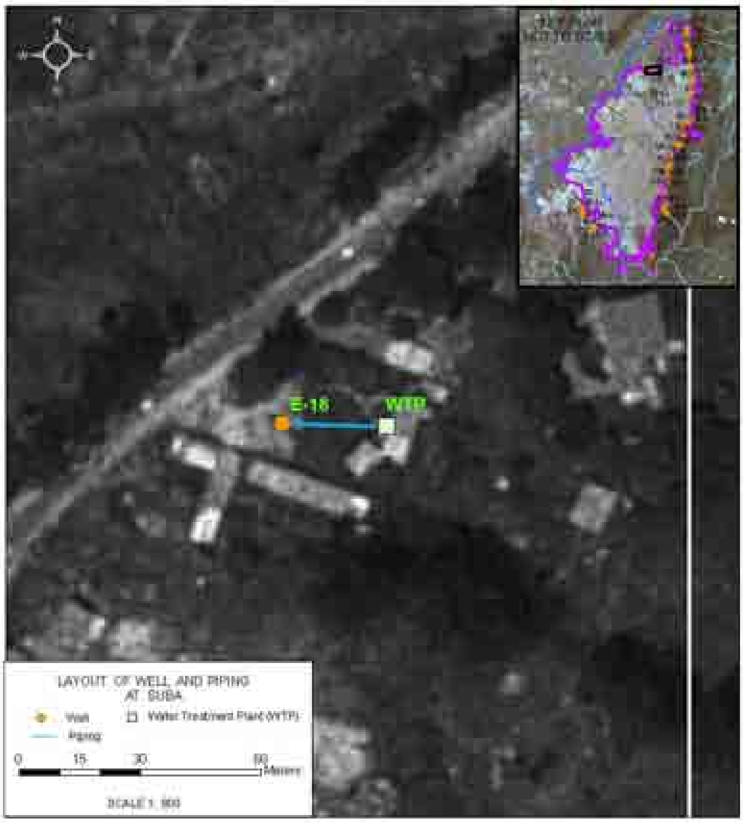
Source: JICA Study Team

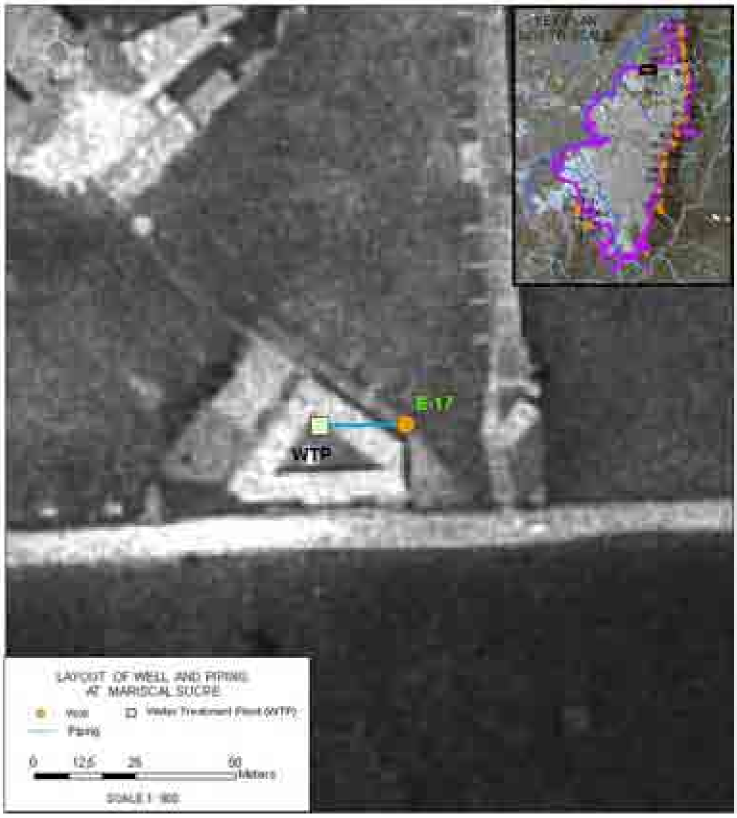
Figure-3.3- 6 Unit Layout Plan for PP-5



Source: JICA Study Team

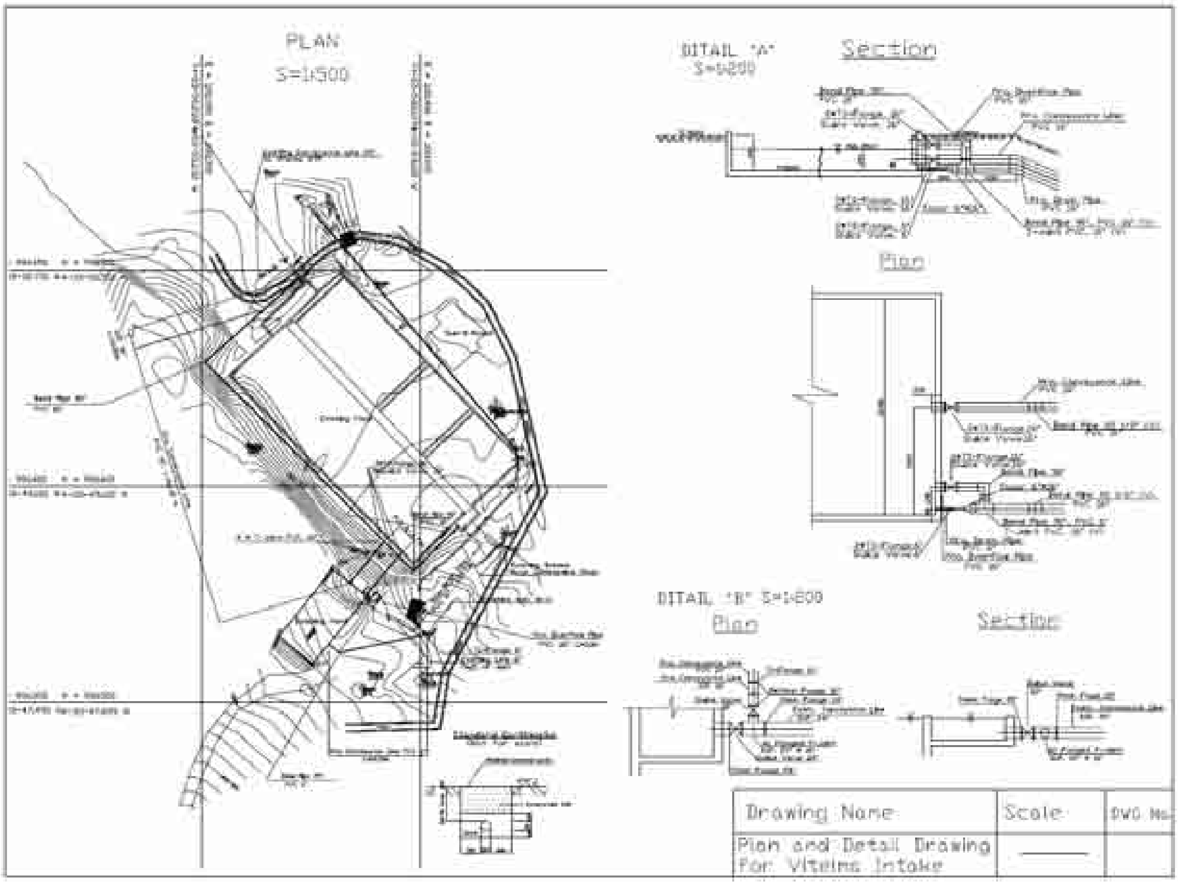
Figure-3.3- 7 Unit Layout Plan for PP-6





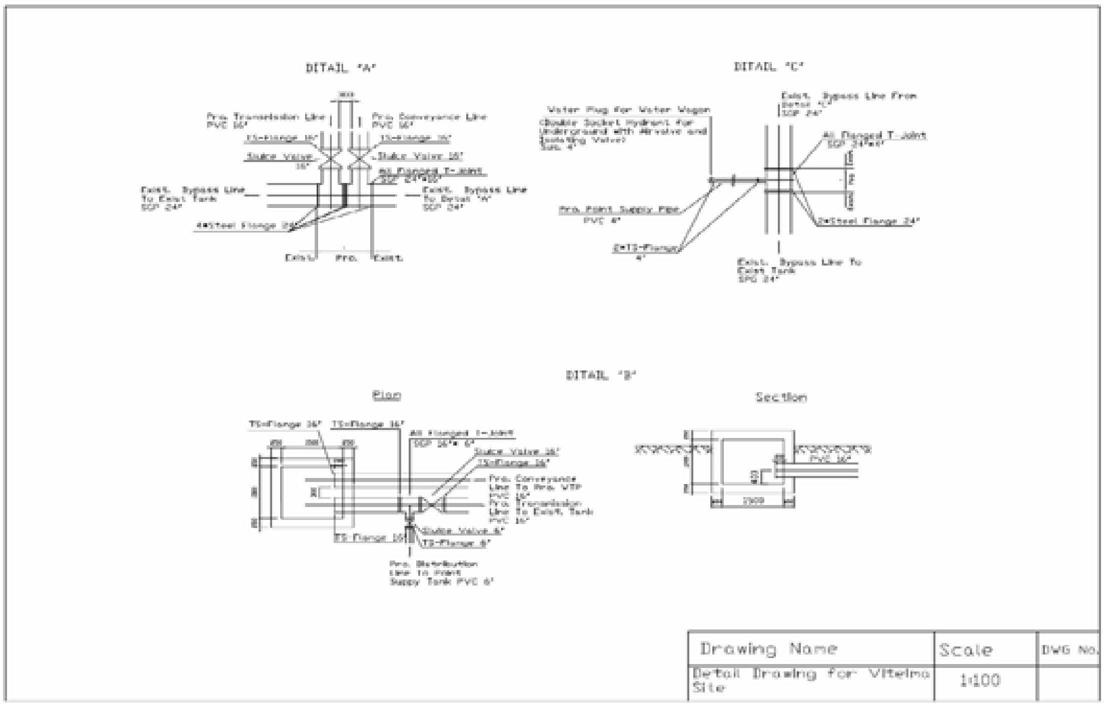
Source: JICA Study Team

Figure-3.3- 8 Unit Layout Plan for PP-7 and PP-8



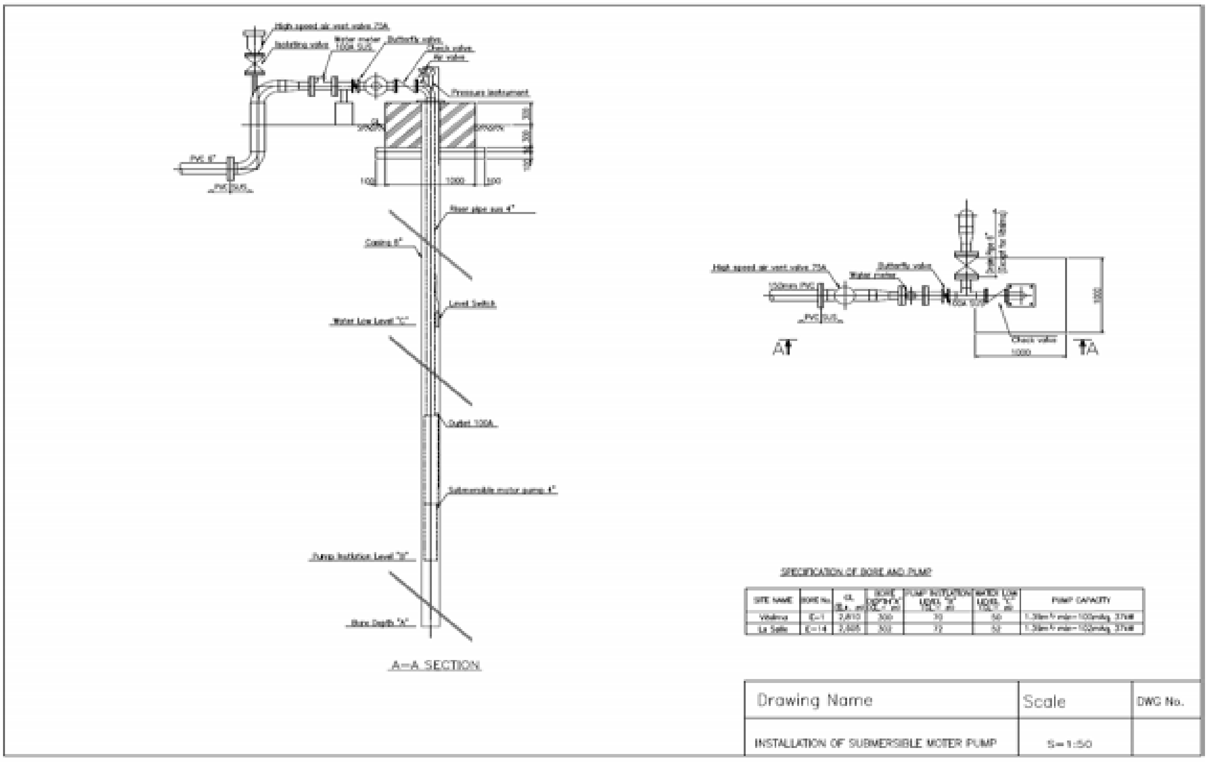
Source: JICA Study Team

Figure-3.3- 9 Detailed Design for Vitelma Pilot Project (well site)



Source: JICA Study Team

Figure-3.3- 10 Detailed Design for Vitelma Pilot Project (conveyance pipeline)

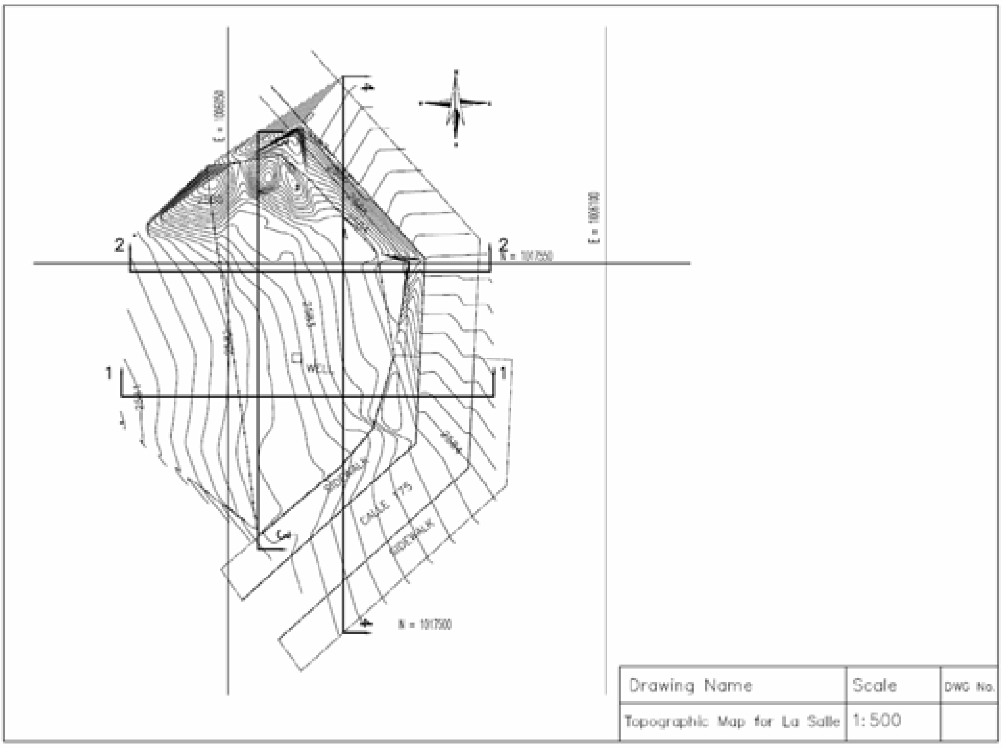


Source: JICA Study Team

Figure-3.3- 11 Detailed Design for Vitelma Pilot Project (well)

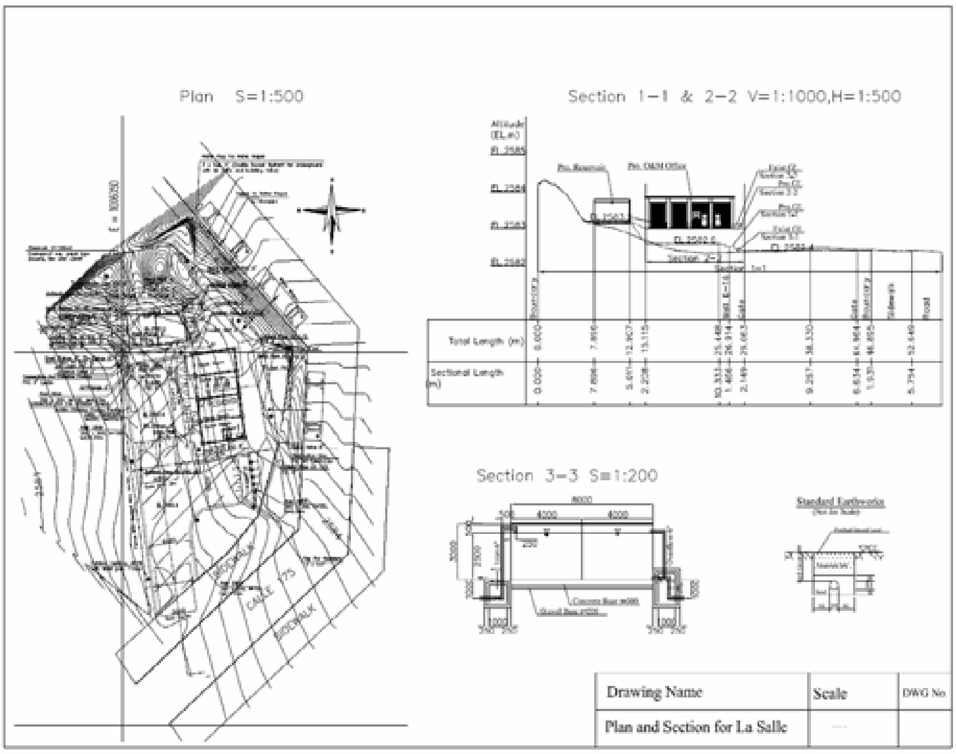
Source: JICA Study Team

Figure-3.3- 12 Plan For Vitelma Water Treatment Plant



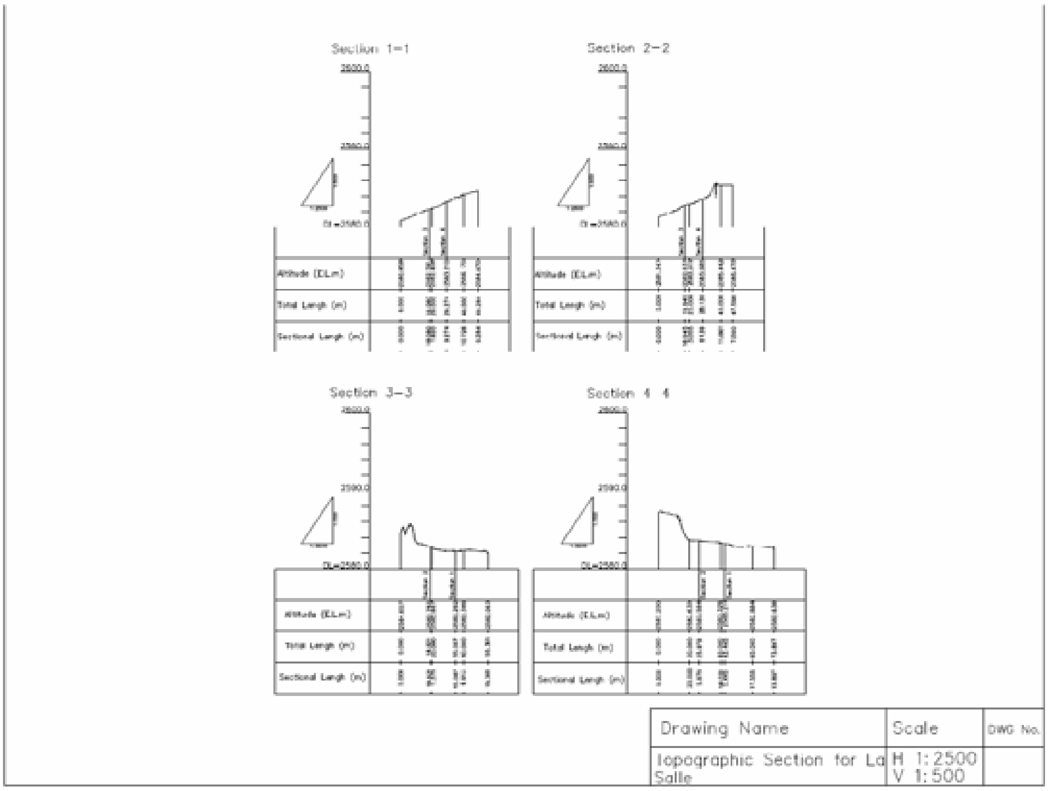
Source: JICA Study Team

Figure-3.3- 13 Detailed Design for La Salle Pilot Project (Topografical Map)



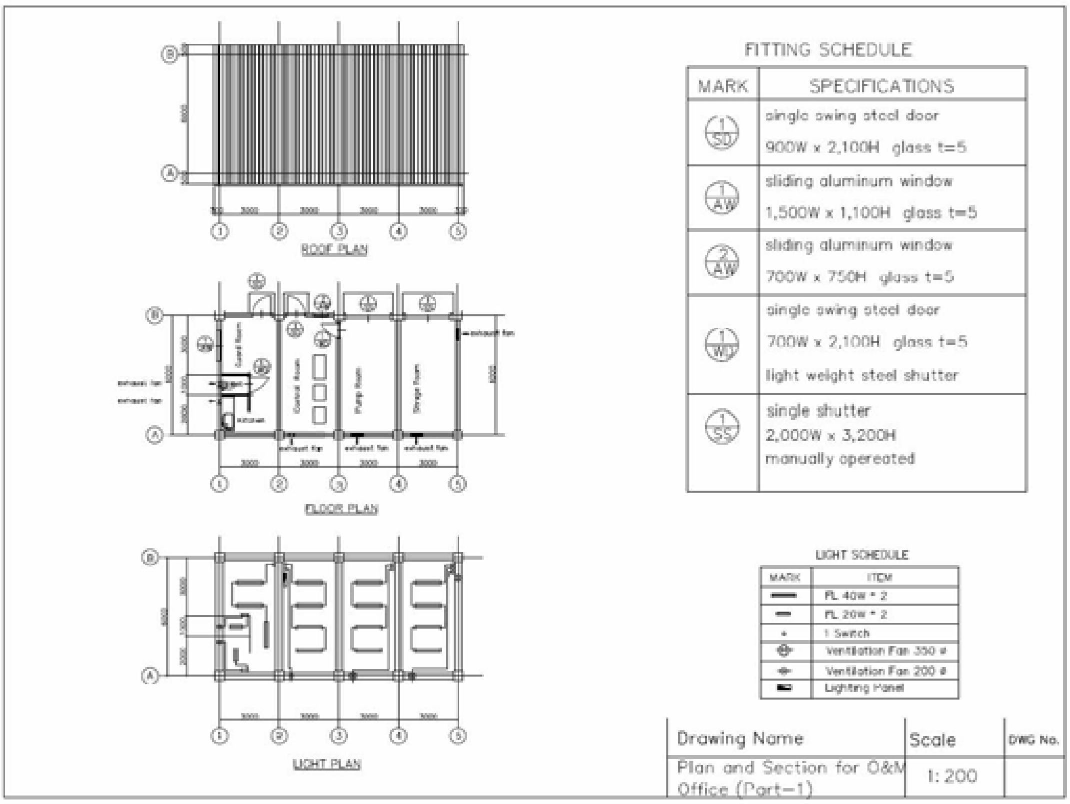
Source: JICA Study Team

Figure-3.3- 14 Detailed Design for La Salle Pilot Project (Plain and Section)



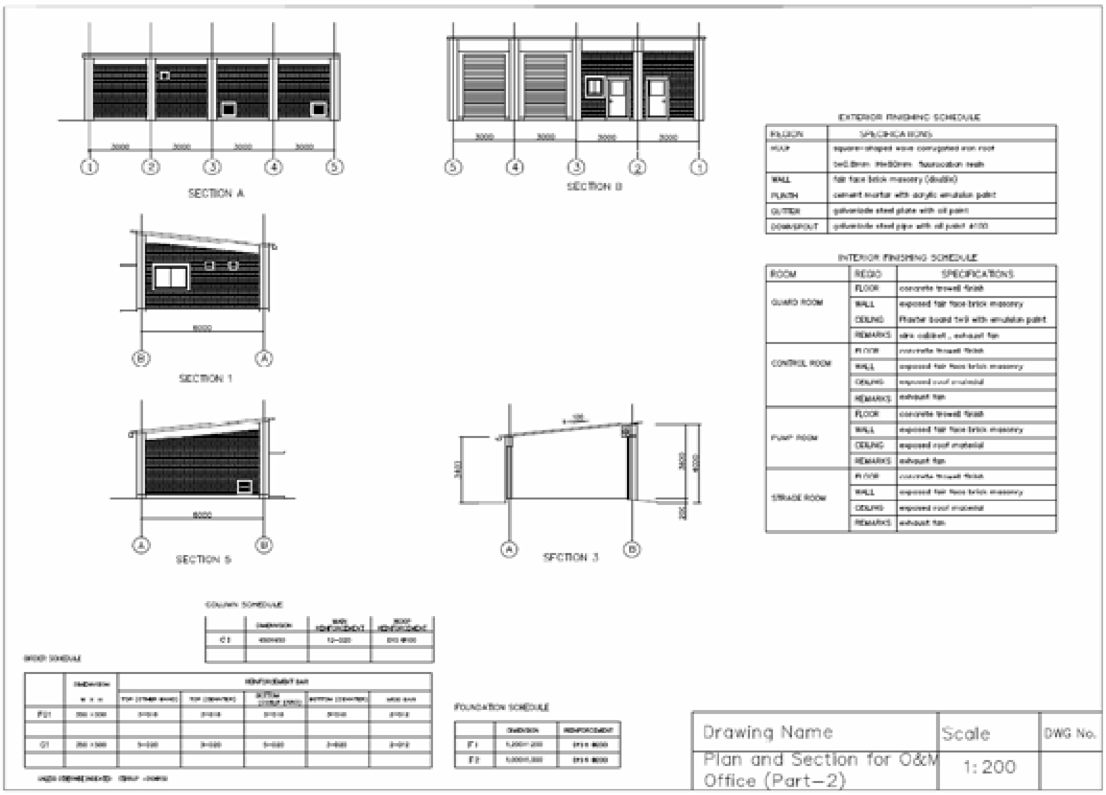
Source: JICA Study Team

Figure-3.3- 15 Detailed Design for La Salle Pilot Project (Topográfic Section)



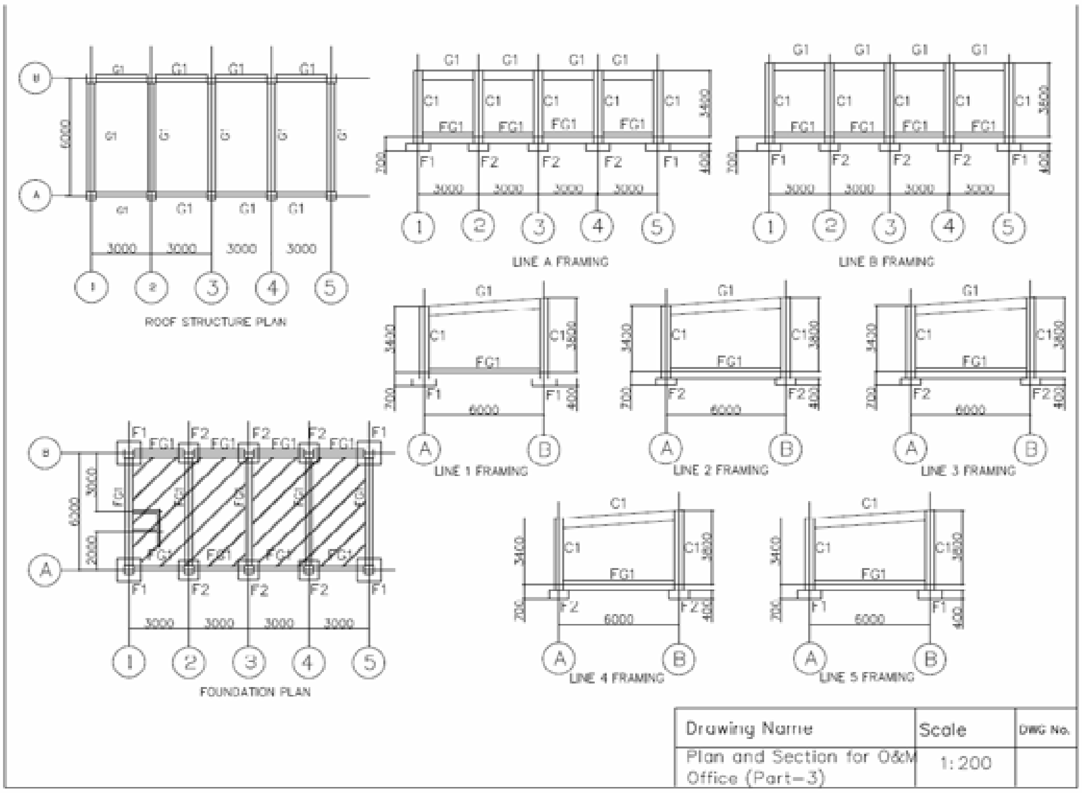
Source: JICA Study Team

Figure-3.3- 16 Plan and Section for Operation and Maintenance Office in La Salle (1)



Source: JICA Study Team

Figure-3.3- 17 Plan and Section for Operation and Maintenance Office in La Salle (2)



Source: JICA Study Team

Figure-3.3- 18 Plan and Section for Operation and Maintenance Office in La Salle (3)

3.2. First Period Project

The Eastern Project was proposed as fisrt period project by reason below:

- Eastern Hills are located near Bogotá city which need large amount of water in case of emergency. Grounwater from the Eastern hills can be delivered quickly to Bogotá city.
- The Cretaceous aquifer in Eastern hills is excellent and can produce large amount of groundwater.

(1) Outline of Eastern Project

Outline of the Eastern Project is shown in Table-3.3-4. Total amount of 68,500m^3/day of groundwater can be produced from 33 emergency wells.

Table-3.3- 4 Outline of Eastern project

Area	Number of wells[note-1)]	Water supplied (m^3/day)	Area for water supply	Population supplied[note-2)]
Santa Fe	1(1)	2,000	Entire Bogota city	133,000
Chapinero	1	2,000		133,000
Usaqunen	14 (2)	28,000		1,866,000
Suba	5(3)	12,500		833,000
Bogota Rural	12	24,000		1,600,000
Total	33 (6)	68,500		4,565,000

Note-1) ( ) : Wells for Pilot Project.

Note-2) It is under condition of unit consumption rate of 15ℓ/person/day

Source: JICA Study Team

Emergency wells will be drilled in the Eastern hills and provide water to Bogotá City by methods below:

a) Point water supply

b) Water supply by the network system

<u>Point Water Supply</u>

Groundwater from emergency wells can be supplied by point water supply. Groundwater will be provided to water truck at well site and will be brought to Bogotá City.

<u>Water supply by the network system</u>

In case of long term water suspension, groundwater from emergency wells can be transferred to the existing facilities (tanks and pipeline) for water supply.

3.2.1. Production Well

(1) Basic Policy for Well Distribution

Well location is shown in Table-3.3-5. Basic policy for well distribution is as follows:

- Enough groundwater must be produced from wells
- Site should have enough area for construction of facilities
- Site should be located near the city center of Bogotá
- Connection between emergency wells and the existing facilities can be possible

Adding to criteria above,

- Sites belonging to Acueducto are preferable

(2) Well site and Bogotá Fault

Wells are located along Bogotá Fault as shown in Figure-3.3-20. Bogotá fault is important factor in selection of well site. Characteristics of Bogotá Fault were taken into account in site selection as listed below:

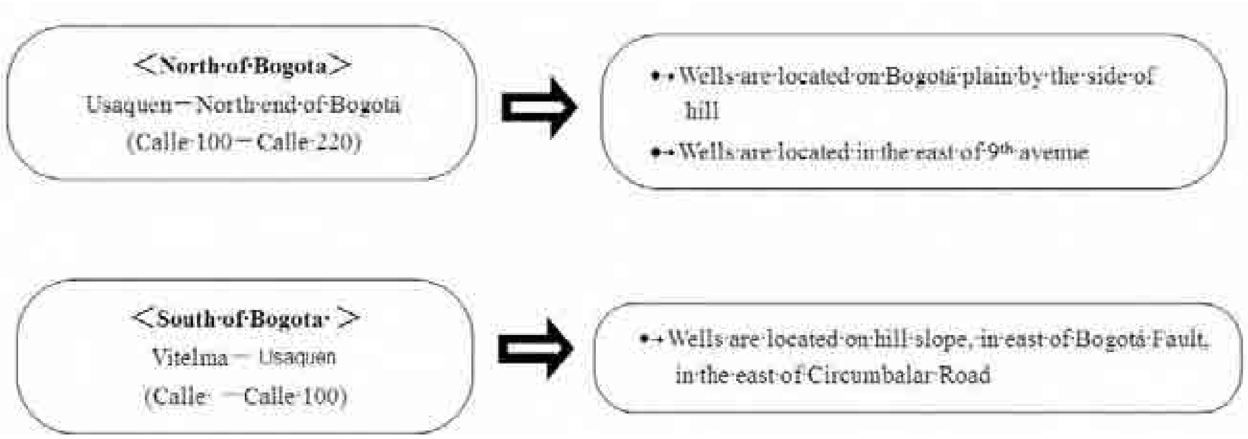
- Bogotá fault forms boundary between the Cretaceous and the Tertiary. Well sites were located on the Cretaceous area, in the east of Bogotá Fault.
- Bogotá fault is located in high elevation area in the southern part of Eastern Hills. Then, Bogotá fault gradually reduces its elevation to the north along the Eastern Hills, and finally sinks down into the ground in Usaquen. Therefore, proposed wells also reduce its elevation from the south to the north, following Bogotá Fault. Well sites finally reaches Bogotá plain, in the north of Usaqun.
- It is desirable to drill wells at some distance in the east of the fault, because Bogotá fault is assumed as reverse fault. According to the previous result of the exploraroty drilling, 200m can be enough as distance from Bogotá fault to drilling point.
- Considering hydrogeological condition above, optimum well site was selected as shown in Figure-3.3-21.

Table-3.3- 5 Wells of Eastern Project

Site		No.	Coordinate		Elevation	Mark	Note
			Latitude	Longitude			
SC	Vitelma	E-1	N 4°33'46.8"	W 74°03'55.2"	2,810	K2d	Acueducto site, Pilot Project
CH	Praiso	E-3	N 4°37'37.4"	W 74°03'18.7"	2,825	K2d	Acueducto site
Usaquen	Tank Santa Ana	TA-1	N 4°41' 06.5"	W 74°01' 46.6"	2,621	K2t	Acueducto site
		TA-2	N 4°41' 02.1"	W 74°01' 39.8"	2,674	K2t	Acueducto site
	La Aguadora	E-5	N 4°41'32.1"	W 74°01'27.1"	2,688	K2t	Acueducto site
		E-6	N 4°41'34.1"	W 74°01'32.6"	2,643	K2t	Pilot project, Acueducto site
	Bosque Medina	E-7	N 4°42'43.2"	W 74°01'44.3"	2,583	Q2c(K2t)	-
	Bosque de pinos	E-8	N 4°43'22.7"	W 74°01'32.9"	2,583	Q2c(K2t)	-
		E-9	N 4°43'38.4"	W 74°01'22.5"	2,597	K2t	-
	Cerro norte	E-10	N 4°44'01.6"	W 74°01'24.4"	2,587	K2t	-
		E-11	N 4°44'09.6"	W 74°01'26.4"	2,577	Q2c(K2t)	-
	Soratama	E-12	N 4°44'24.6"	W 74°01'20.9"	2,583	Q2c(K2t)	-
		E-13	N 4°44'42.8"	W 74°01'19.2"	2,592	Q2c(K2t)	-
	La Salle	E-14	N 4°45' 17.4"	W 74°01' 22.5"	2,605	Q2c(K2t)	Acueducto site Pilot project
	Codito	E-15	N 4°45'45.5"	W 74°01'36.8"	2,578	Q2c(K2t)	Codito Itank
		CO-2	N 4°45' 53.4"	W 74°01' 26.6"	2,643	Q2c(K2t)	Codito tank
Suba	Suba	E-16	N 4°45' 27.0"	W 74°04' 42.2"	2,581	Q2c(K2t)	Pilot project
	Mariscal Sucre	E-17	N 4°45' 40.0"	W 74°04'53.4"	2,575	Q2c(K2t)	Pilot project
	Suba tank	ST-1	N 4°42' 42.2"	W 74°05' 00.2"	2,589	K2E1g(K2t)	Acuedcuto site
		ST-2	N 4°42' 43.6"	W 74°05' 03.6"	2,588	K2E1g(K2t)	Acuedcuto site
		ST-3	N 4°42' 45.0"	W 74°05' 05.4"	2,589	K2E1g(K2t)	Acuedcuto site
Bogota Rural	Bogota Rural	Y-1	N 4°46'14.1"	W 74°01'38.4"	2,570	Q2c(K2t)	-
		Y-2	N 4°46'28.3"	W 74°01'36.9"	2,571	Q2c(K2t)	-
		Y-3	N 4°46'34.6"	W 74°01'35.8"	2,571	Q2c(K2t)	-
		Y-4	N 4°47'04.4"	W 74°01'42.3"	2,575	Q2c(K2p)	-
		Y-5	N 4°47'10.5"	W 74°01'40.4"	2,582	Q2c(K2p)	-
		Y-6	N 4°47'21.3"	W 74°01'42.9"	2,571	Q2c(K2p)	-
		Y-7	N 4°47'32.2"	W 74°01'45.9"	2,573	Q2c(K2p)	-
		Y-8	N 4°47'44.9"	W 74°01'53.8"	2,581	Q2c(K2t)	-
		Y-9	N 4°48'20.5"	W 74°01'48.5"	2,568	K2t	-
		Y-10	N 4°48'34.4"	W 74°01'50.3"	2,570	Q2c,Q2ch	-
		Y-11	N 4°49'02.2"	W 74°01'51.6"	2,569	Q2c,Q2ch	-
		Y-12	N 4°49'17.7"	W 74°01'53.4"	2,586	K2t	-

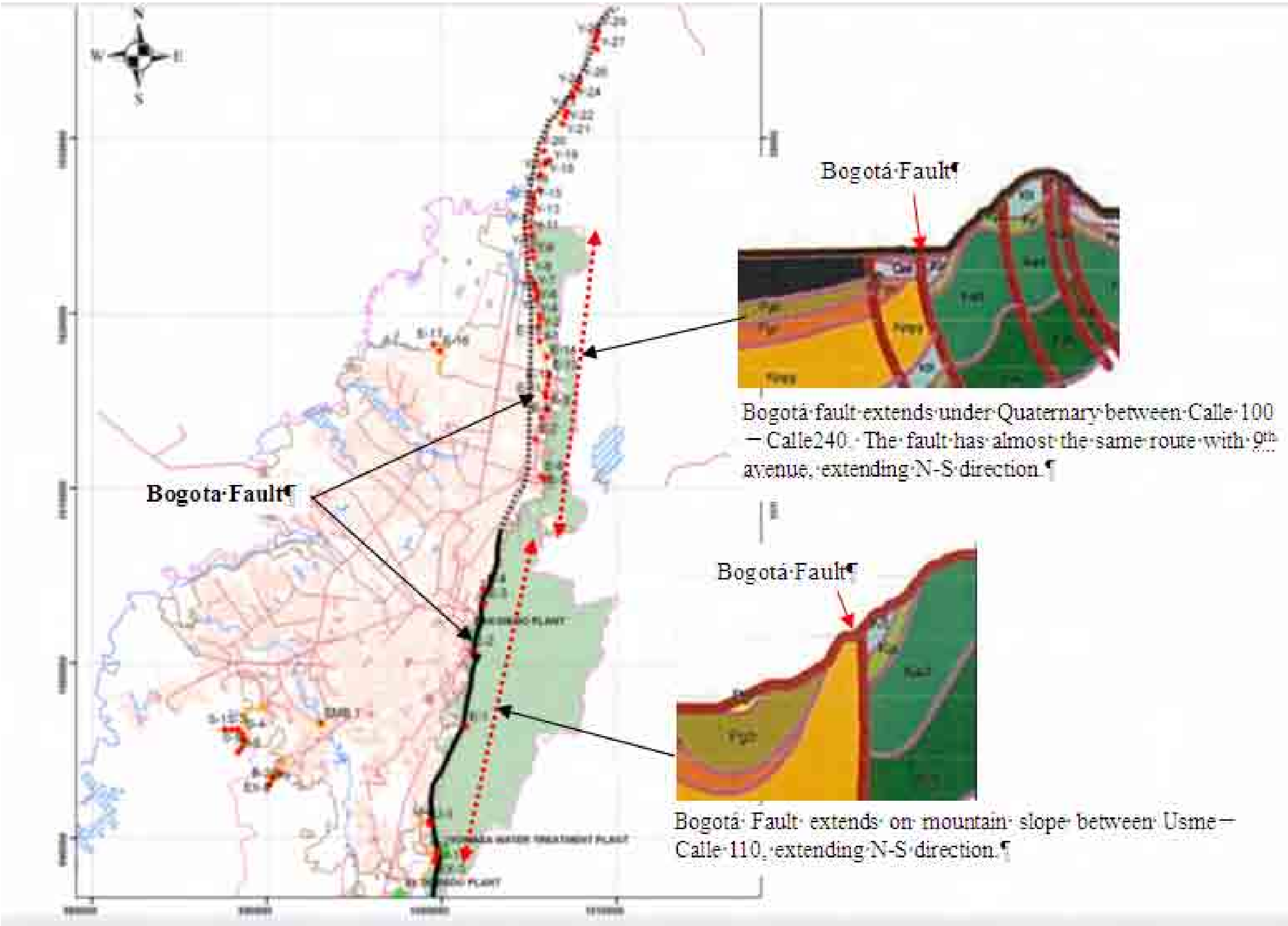
Legend

Q2c,Q2ch	Quaternaru	K2t	Labor & Tierna (Cretaceosu)
E1b	Bogota (Tertiary)	K2p	Plaeners (Cretacesou)
K2E1g	Guaduas (Tertiary)	Ksd	Dura (Cretacesou)



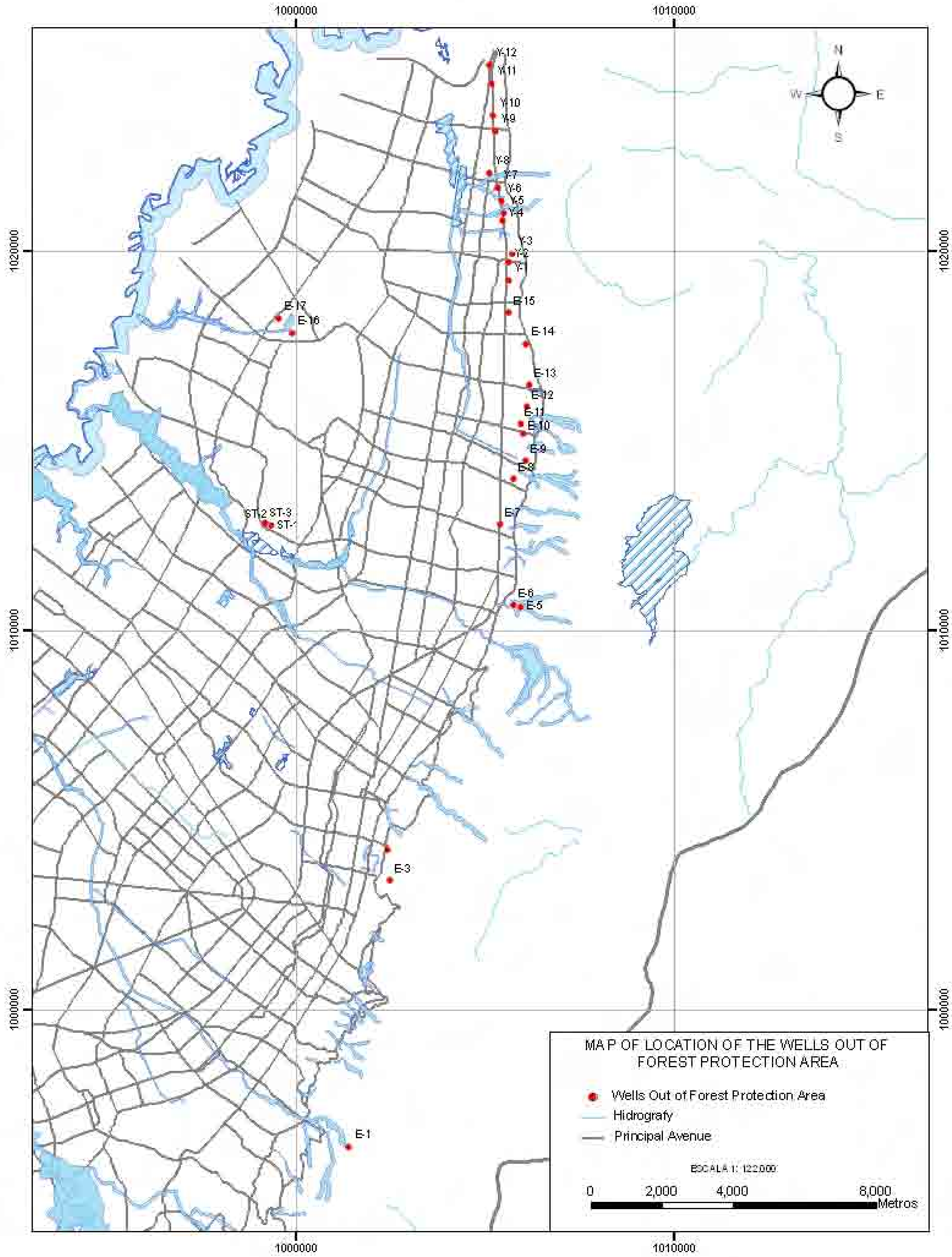
Source: JICA Study Team

Figure-3.3- 19 Optimum Well Site



Source: JICA Study Team

Figure-3.3- 20 Bogotá Fault and Wells

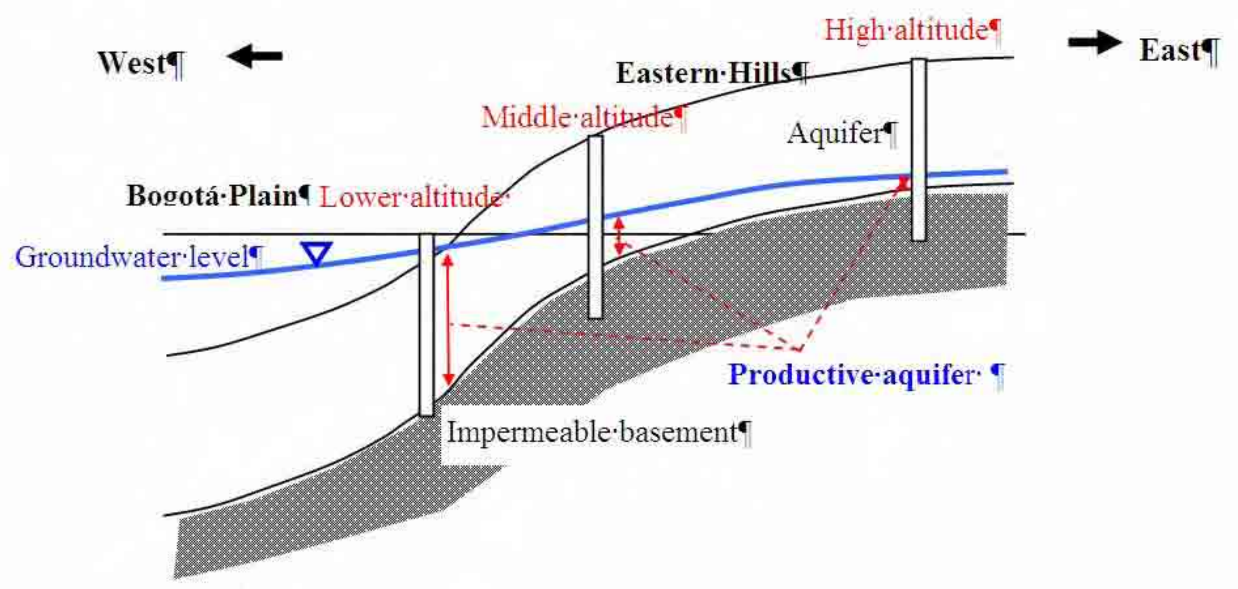


Source: JICA Study Team

Figure-3.3- 21 Map of Location of the Wells Out of Forest Protection Area

If considering geological condition, wells should be located in higher elevation in the south, and lower elevation in the north. As a result, groundwater level of well is deeper in the south, and shallower in the north. It means that groundwater development is less advantageous in the south, and more advantageous in the north. This is clearly explained as below:

- Eastern hill is classified as folding mountain in view point of geological structure. Cretaceous sandstone, which is excellent aquifer, is distributed in certain depth of the hills. If groundwater level is too deep, most of sandstone is upper than groundwater level, which causes groundwater productivity smaller (see Figure-3.3-22).
- Deeper groundwater level causes higher pumping cost, which leads to less economic water supply.
- It is condition for economical groundwater development that groundwater can be produced at rate of 1,000-2,000m3/day from one well with length of 300-400m. However, this condition can not be satisfied in the south of the Eastern Hills.



Source: JICA Study Team

Figure-3.3- 22 Relations between well elevation and aquifer in the Eastern Hills

(3) Number of wells in M/P and F/S

In the Easter Project, 29 wells were proposed in M/P. The proposed well sits were carefully reviewed in F/S. As a result, 5 wells (TA-1、TA-2、CO-2、ST-1、St-2、ST-3) were added into the plan, and 2 wells (E-2、 E-4) were deleted from the plan. Finally, total number of 33 wells was proposed for Eastern Project.

3.2.2. Facility Plan

(1) Facility Plan for Emergency Water Supply System

The composition and the connection points for the emergency water supply unit of the First Period Project are shown in Table-3.3-6.

Table-3.3- 6 Composition and Connection Point for Emergency Water Supply Unit (1st Period Project)

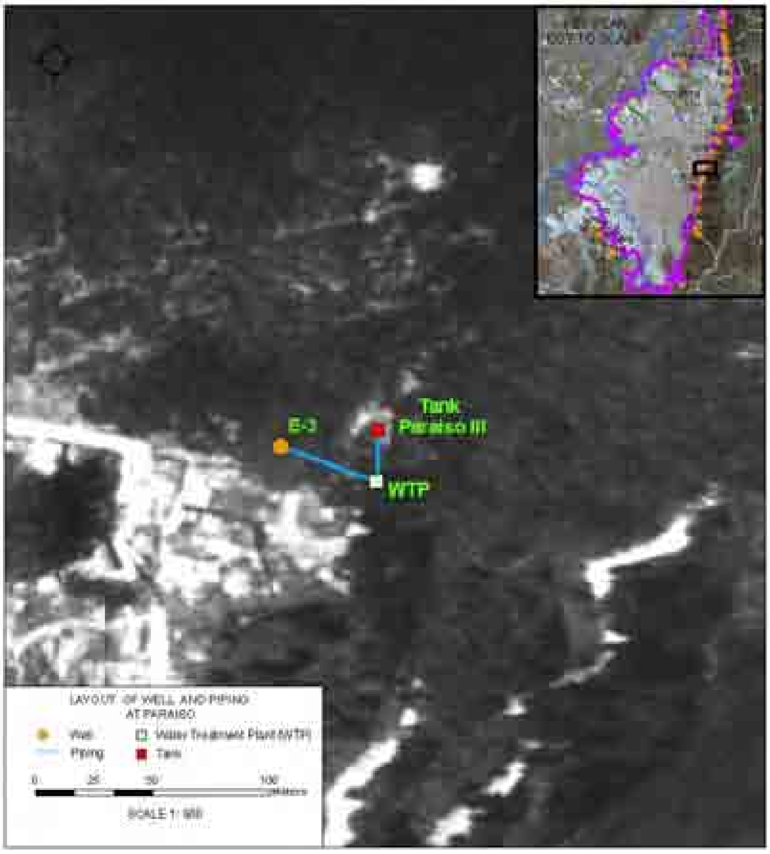
Project Name		Site	Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)	(Exist Facility)	
1st Priority Project	Vitelma	Vitelma	–	(E-1)	(Pilot)	–	–	–	–	–	–	–	(2,000)	(Chlorine + Pressure Filtarlate)	–	–	–	–
	Chapinero	Praiso	1-01	E-3	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	6	25	Tank Paraiso 3	2
	Usaquen	Tank Santa Ana	1-02	TA-1	New	8"+6"	300	4	190	75	6	25	4,000	Chlorine + Pressure Filtarlate	–	–	–	1
				TA-2	New	8"+6"	300	4	190	75	6	587						
		La Aguadora	1-03	(E-5)	(Pilot)	–	–	–	–	–	–	–	(2,000)	(Chlorine + Pressure Filtarlate)	8	325	Tank Santa Ana	2
				E-6	New	8"+6"	300	4	190	75	6	358	2,000	Chlorine + Pressure Filtarlate				
		Bosque Medina	1-04	E-7	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
		Bosque de pinos	1-05	E-8	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
			1-06	E-9	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
		Cerro norte	1-07	E-10	New	8"+6"	300	4	190	75	6	25	8,000	Chlorine + Pressure Filtarlate	12	20	Tank Soratama 1	2
				E-11	New	8"+6"	300	4	190	75	10	305						
		Soratama		E-12	New	8"+6"	300	4	190	75	8	535						
				E-13	New	8"+6"	300	4	190	75	6	605						
		Codito	1-08	(E-14)	(Pilot)	–	–	–	–	–	–	–	(2,000)	(Chlorine)	6	1,330	Tank Codito 1	2
			1-09	E-15	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	6	55	Tank Codito 1	2
			1-10	CO-2	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	6	134	Tank Codito 2	2
	Suba	Suba tank	1-11	ST-1	New	8"+6"	300	4	100	55	6	137	5,000	Chlorine + Pressure Filtarlate	12	537	Tank Suba Nuevo	2
				ST-3	New	8"+6"	300	4	100	55	6	55						
				(ST-2)	(Pilot)		–	–	–	–	–	–	(2,500)	(Chlorine + Pressure Filtarlate)				
		Suba	–	(E-16)	(Pilot)	–	–	4	97	55	6	25	(2,500)	(Chlorine + Pressure Filtarlate)	–	–	–	–
		Mariscal Sucre	–	(E-17)	(Pilot)	–	–	4	85	45	–	–	(2,500)	(Chlorine)	–	–	–	–
	Bogota Rural	Bogota Rural	1-12	Y-1	New	8"+6"	300	4	190	75	6	70	6,000	Chlorine + Pressure Filtarlate	24	12,535	Tank Santa Ana	2
				Y-2	New	8"+6"	300	4	190	75	8	500						
				Y-3	New	8"+6"	300	4	190	75	6	200						
				Y-4	New	8"+6"	300	4	190	75	6	25	10,000	Chlorine + Pressure Filtarlate	20	1,500	Tank Santa Ana	2
				Y-5	New	8"+6"	300	4	190	75	12	200						
				Y-6	New	8"+6"	300	4	190	75	10	350						
				Y-7	New	8"+6"	300	4	190	75	8	350						
				Y-8	New	8"+6"	300	4	190	75	6	500						
				Y-9	New	8"+6"	300	4	190	75	6	25	4,000	Chlorine + Pressure Filtarlate	12	2,580	Tank Santa Ana	2
				Y-10	New	8"+6"	300	4	190	75	6	440						
				Y-11	New	8"+6"	300	4	190	75	6	25	4,000	Chlorine + Pressure Filtarlate	8	1,330	Tank Santa Ana	2
				Y-12	New	8"+6"	300	4	190	75	6	520						

Note-1) Type of the supply is shown in Figure-3.3-41.

Source: JICA Study Team

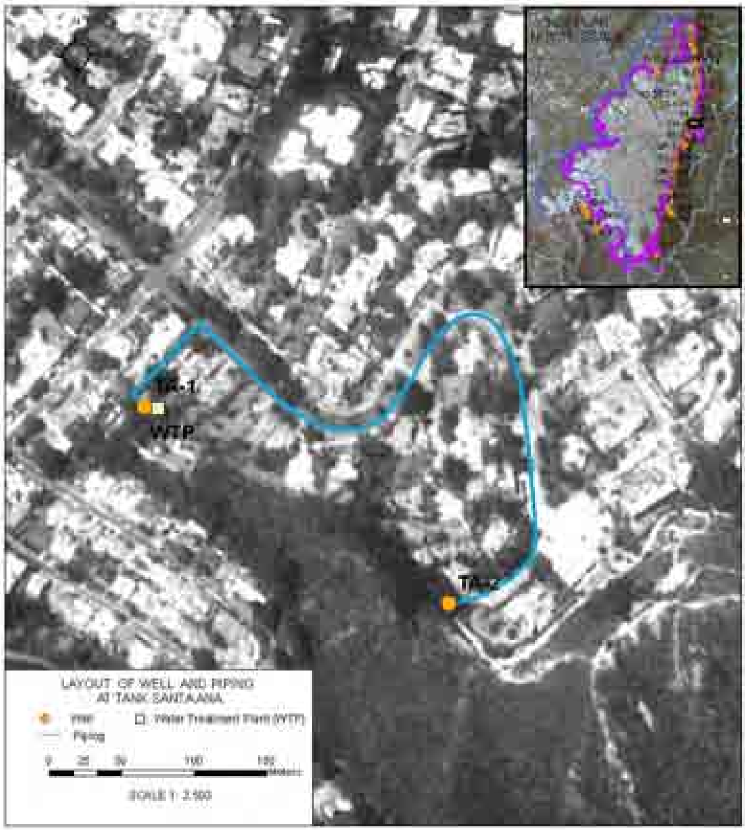
(2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the First Period Project consists of one (1) water treatment plant (WTP) with one (1) to five (5) wells. The layout plan for each water supply unit is shown in Figure-3.3-23 to Figure-3.3-31.



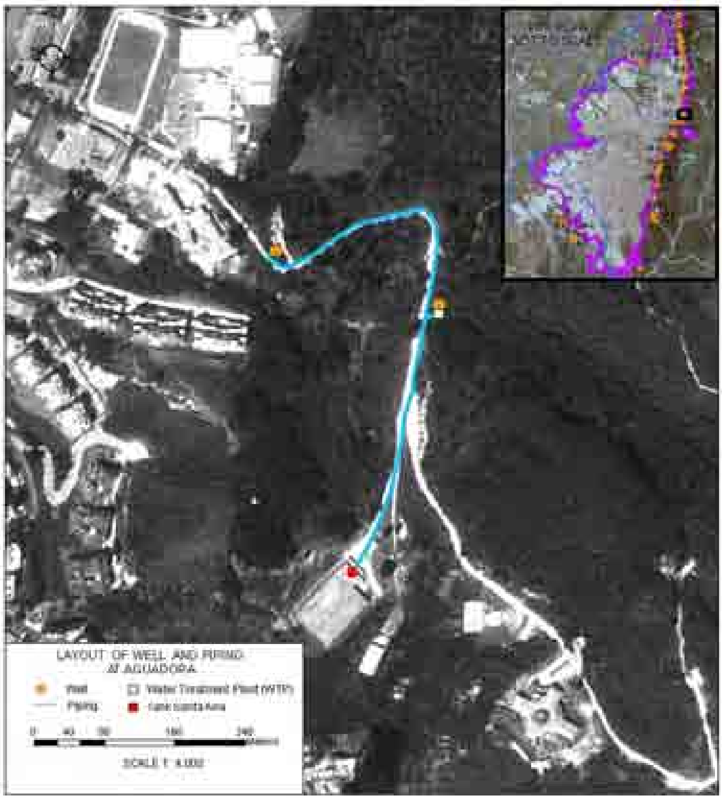
Source: JICA Study Team

Figure-3.3- 23 Unit Layout Plan for 1-01



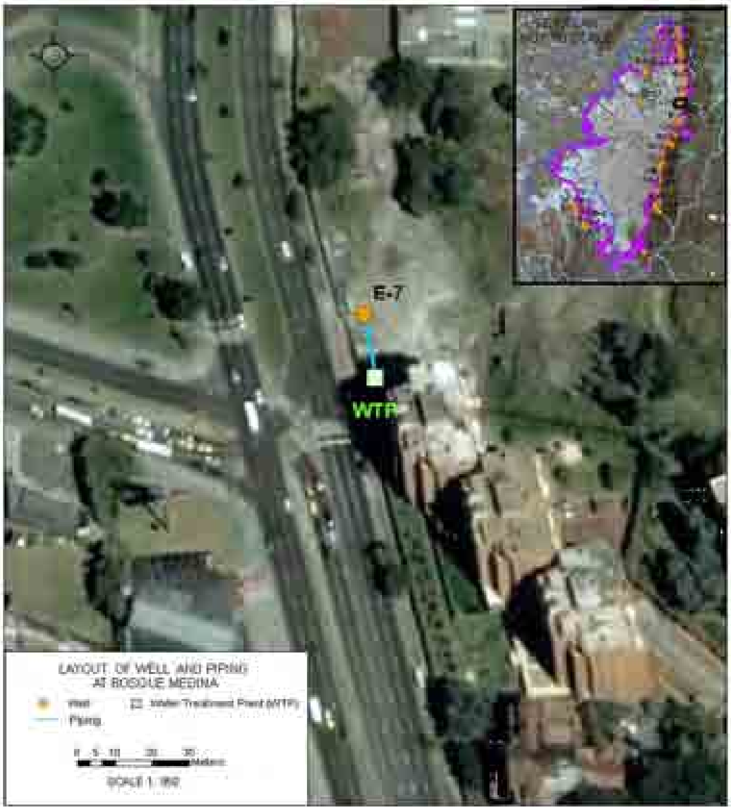
Source: JICA Study Team

Figure-3.3- 24 Unit Layout Plan for 1-02



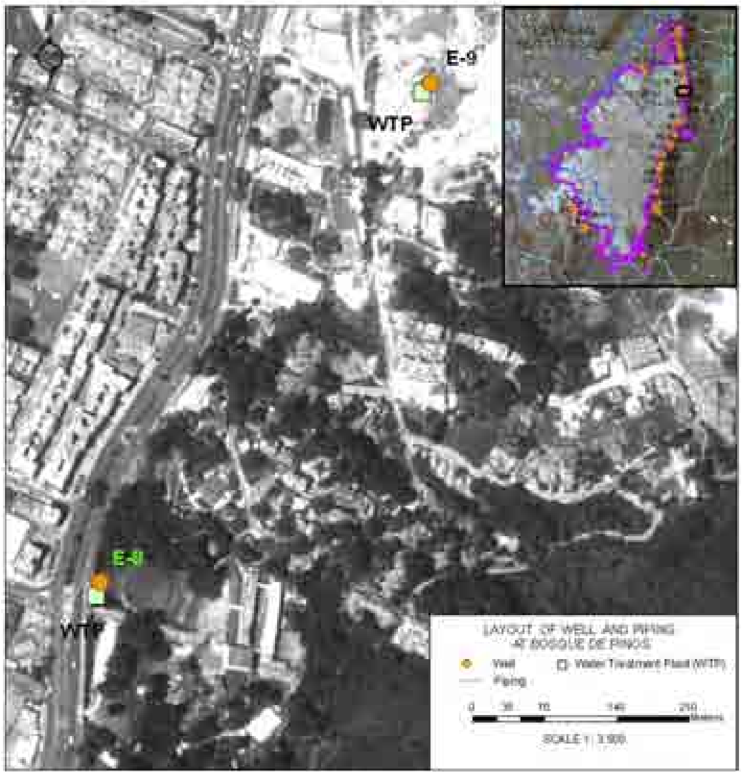
Source: JICA Study Team

Figure-3.3- 25 Unit Layout Plan for 1-03



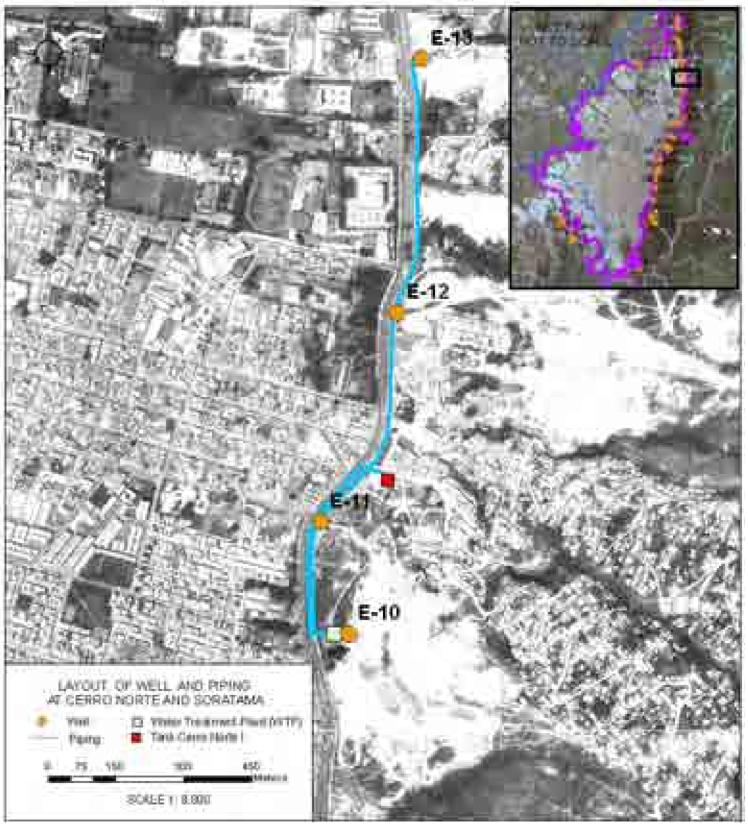
Source: JICA Study Team

Figure-3.3- 26 Unit Layout Plan for 1-04



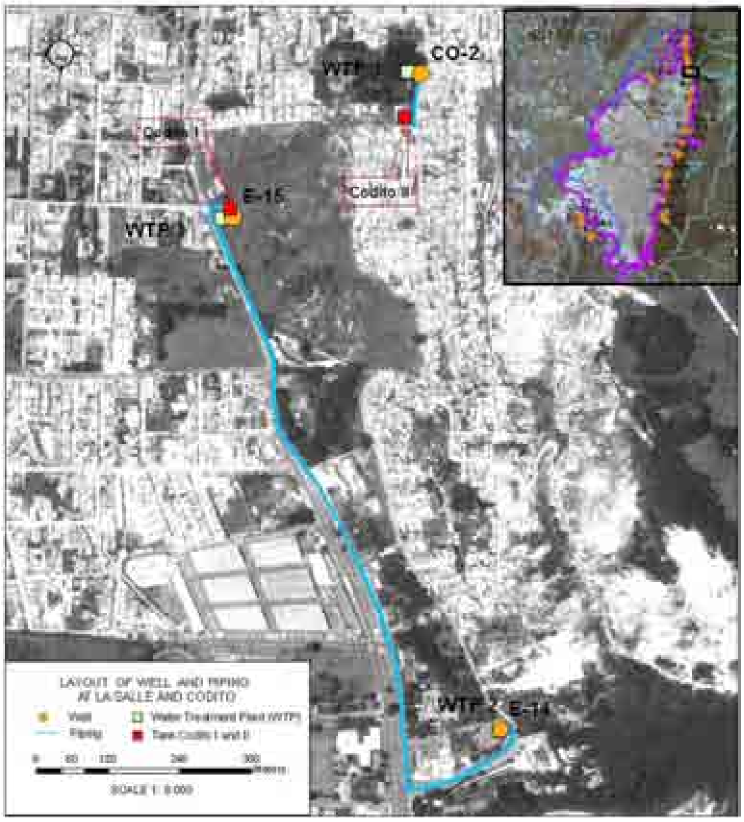
Source: JICA Study Team

Figure-3.3- 27 Unit Layout Plan for 1-05 and 1-06



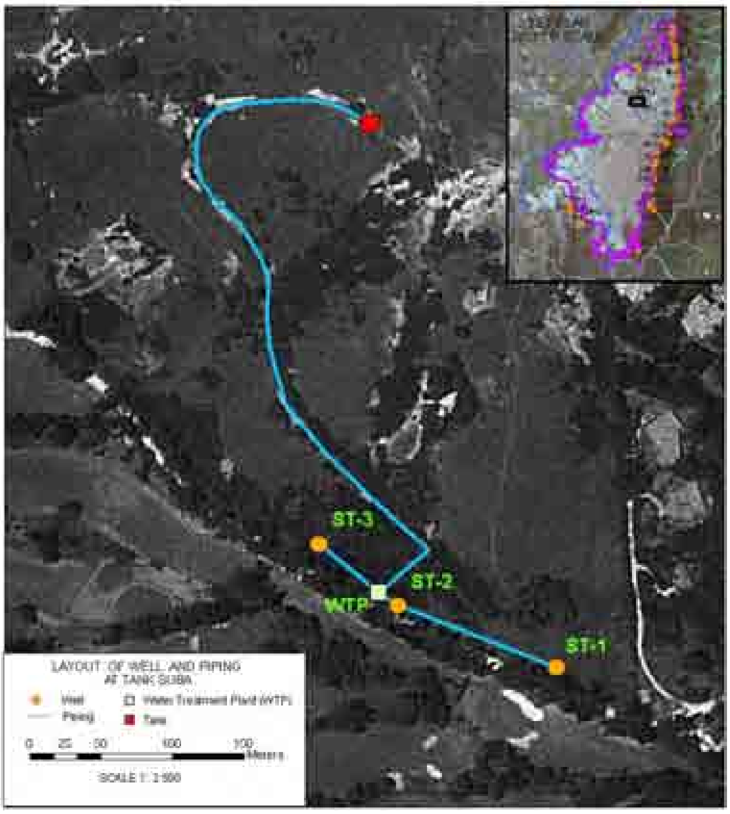
Source: JICA Study Team

Figure-3.3- 28 Unit Layout Plan for 1-07



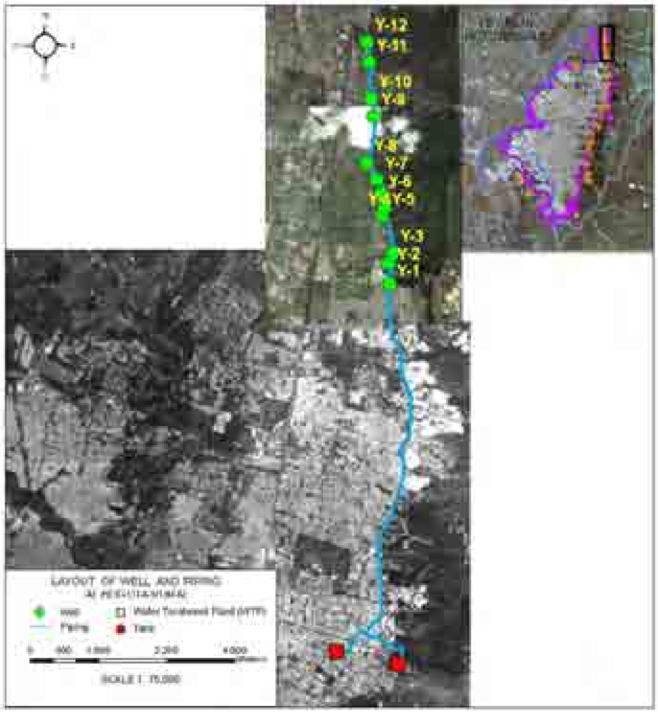
Source: JICA Study Team

Figure-3.3- 29 Unit Layout Plan for 1-08, 1-09 and 1-10



Source: JICA Study Team

Figure-3.3- 30 Unit Layout Plan for 1-11



Source: JICA Study Team

Figure-3.3- 31 Unit Layout Plan for 1-12

3.3. Second Period Project

Southern Project was proposed as Second Period Project. The Southern hills are located in the south of Bogotá city, where Ciudad Bolivar and Soacha municipality are included. Serious damage is assumed by earthquake with epicenter near the area.

(1) Outline of Project

Wells are proposed to be drilled for emergency water supply. Fourteen (14) wells are proposed in the area to produce 13,100m^3/day of groundwater for emergency water supply. Method of water supply is as follows:

a) Point water supply at well site

b) Network water supply by connection of emergency wells to the existing facilities

Table-3.3- 7 Outline of Southern Project

Area	Number of Wells[note-1)]	Water supply (m^3/day)	Supply area	Population supplied[note-2)]
Ciudad Bolivar	6(1)	6,000	Ciudad Bolivar	400,000
Soacha	7	7,000	Soacha	466,000
Usme	1(1)	100	Usme	6,000
Total	14(2)	13,100		872,000

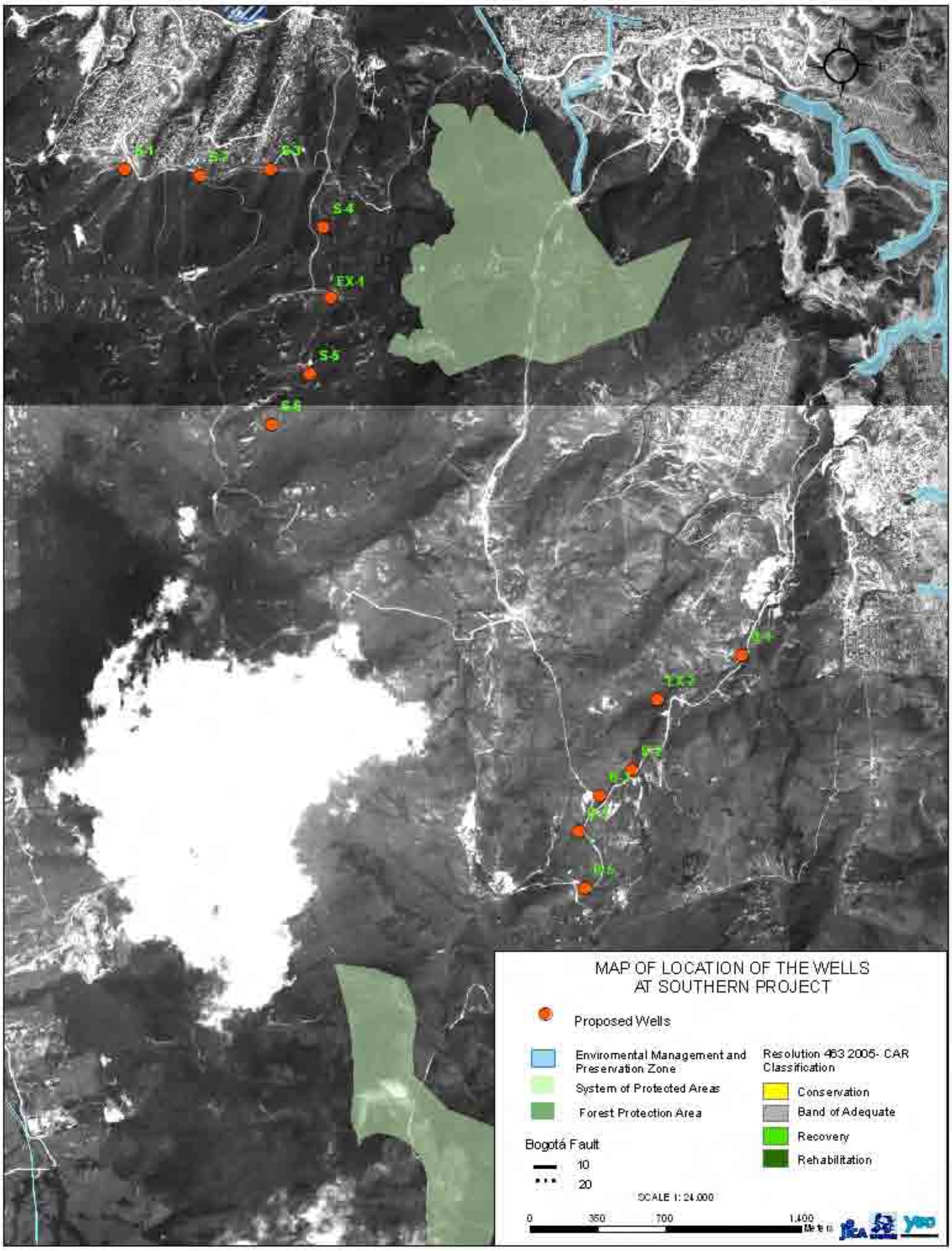
Note-1) ( ) : Wells inside forest protection area.

Note-2) It is under condition of unit consumption rate of 15ℓ/person/day; Source: JICA Study Team

3.3.1. Production Well

(1) Well Location

Well location in Southern Project is shown in Figure-3.3-32 and Table-3.3-8. Sandstone of Dura formation of the Cretaceous forms aquifer in Ciudad Bolivar and Soacha. The Cretaceous formation is widely distributed in Southern hills, and geological condition is almost same throughout the Southern hills. Geological structure of the Southern hills is clealy different from that of the Eastern Hills, where geological condition is suddenly changed by Bogotá fault. Therefore, in the Southern hills, there is little geological restriction in selection of well sites. Main factor in the selection of well site is condition in road accses and land acquisition.



Source: JICA Study Team

Figure-3.3- 32 Well Location of Southern Hills

Table-3.3- 8 List of Wells of Southern Project

Project	Area	No.	Coordinate		Elevation	Geology
			Longitude	Latitude		
Southern Hills	Ciudad Bolivar	B-1	4°32'21.9"N	74°09'37.7"W	2,835	K2p, east limb of anticline
		EX-2	4°32'14.4"N	74°09'51.7"W	2,867	K2p, axis of anticline
		B-2	4°32'02.7"N	74°09'56.1"W	2,907	K2p, axis of anticline
		B-3	4°31'58.2"N	74°10'01.4"W	2,918	K2p, axis of anticline
		B-4	4 °31' 52.3"N	74 °10' 05.0"W	2,945	K2p
		B-5	4 °31' 42.7"N	74 °10' 04.0"W	2,987	K2p
	Soacha	S-1	4°33'43.3"N	74°11'20.8"W	2,746	K2d,west limb of anticline
		EX-1	4°33'21.7"N	74°10'46.4"W	2,786	K2d, hanging wall of fault
		S-2	4°33'42.2"N	74°11'08.2"W	2,760	K2d,west limb of anticline
		S-3	4°33'43.3"N	74°10'56.4"W	2,748	K2d, axis of anticline
		S-4	4°33'33.6"N	74°10'47.6"W	2,762	K2d, east limb of anticline
		S-5	4°33'08.9"N	74°10'49.9"W	2,809	K2d, hanging wall of fault
		S-6	4°33'00.4"N	74°10'56.3"W	2,837	K2d, hanging wall of fault

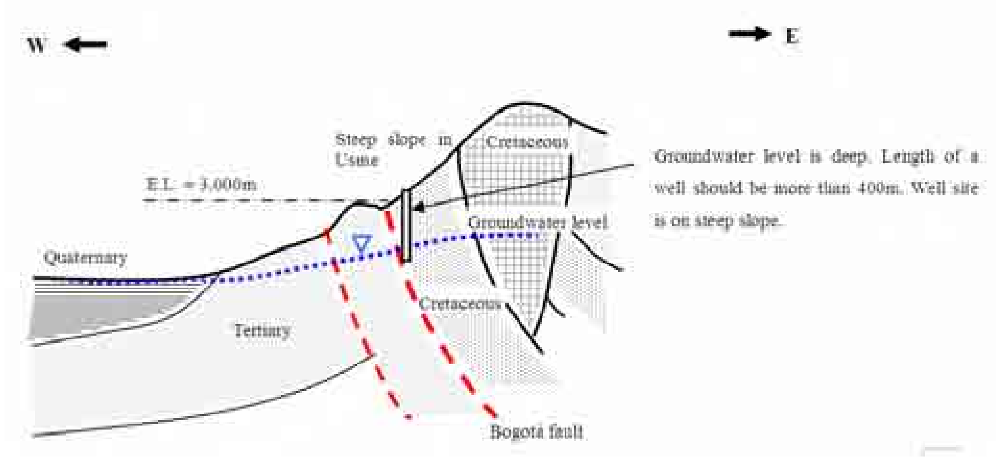
Regend	Q2c,Q2ch	Quaternaru	K2t	Labor & Tierna (Cretaceosu)
	E1b	Bogota (Tertiary)	K2p	Plaeners (Cretacesou)
	K2E1g	Guaduas (Tertiary)	Ksd	Dura (Cretacesou)

(2) Number of wells in M/P and F/S

In the Southern Project, 16 wells were proposed in M/P. The proposed wells sits were carefully reviewed in F/S. As a result, 4 wells in Usme (U-1,2,3,4) were deleted from the plan, and 2 wells (B-4、5) in Ciudad Bolivar were added into the plan. Finally, total number of 14 wells was proposed for the Southern Project. Exploratory drilling was implemented in Usme in M/P. Based on the result of the drilling, project in Usme was deleted. Geological condition in Usme is as follows:

<u>Usme</u>

Usme area is located in the southern end of the Eastern hills. Location of Bogotá fault is important factor in selection of well sites in Usme, same as in the other areas of the Eastern hills. Characteristics of Bogotá fault in Usme are as described bellow (see Figure-3.3-33):



Source: JICA Study Team

Figure-3.3- 33 Hydrogeological Structure and Well site in Usme

- Bogotá fault is extending to north-south direction, with attitude of 3,000m, parallel with extension of the Eastern hills, in Usme.
- Bogotá Fault forms geological boundary. The Tertiary is distributed in downward slope of the

fault, and the Cretaceous is distributed in upward slope of the fault. It means that impermeable Tertiary formation is distributed up-to as high as 3,000m in Usme.

- Because of geological condition, the downward slope of Bogotá fault is gentle, and the upward slope is steep.

Considereing geological condition above, well sites in Usme must be proposed in upward slope of Bogotá fault, which is very steep with altitude of more than 3,000m. All of drillings sites in Usme must be located on steep slope of mountain. Consequentely, groundwater level is expected very deep in such an area. Moreover, access of drilling rig to such an area is also difficult. One exploratory well (EX-3) was drilled in Usme in M/P Study, which resulted in small water production from the exploratory well. Based on the result above, it was concluded that groundwater development in Usme is difficult.

Groundwtaer developmet in Usem area was given up in This Study. However, if groundwater development of Usme is tried again in the future, strategy of drilling is recommended as listed in Table-3.3-.9.

- Exploratory wells should be located on the slope, at 200m east of Bogotá fault.
- Depth of drilling should be 400-500m.
- Electric or electro-magnetic survey should be implemented before drilling, to compare its result with that of TEM survey which was conducted in M/P Study. Whether or not it is worth drilling should be judged from this comparison.

Table-3.3- 9 Wells in Usme

Project	Area	No.	Coordinate		Altitude	Geology
			Latitude	Longitude		
Usme	Bogotá	U-101	4°28'28.8"N	74°04'48.6"W	3,210	K2d, hanging wall of Bogotá fault
		U-102	4°29'57.7"N	74°04'35.6"W	3,243	K2d, hanging wall of Bogotá fault
		U-103	4°32'07.9"N	74°04'47.2"W	3,022	K2d, beside Bogotá fault

Source: JICA Study Team

3.3.2. Facility Plan

(1) Facility Plan for Emergency Water Supply System

The composition and the connection points for the emergency water supply unit on the 2nd Period Project are shown in Table-3.3-10.

Table-3.3- 10 Composition and Connection Point for Emergency Water Supply Unit (2nd Period Ploject)

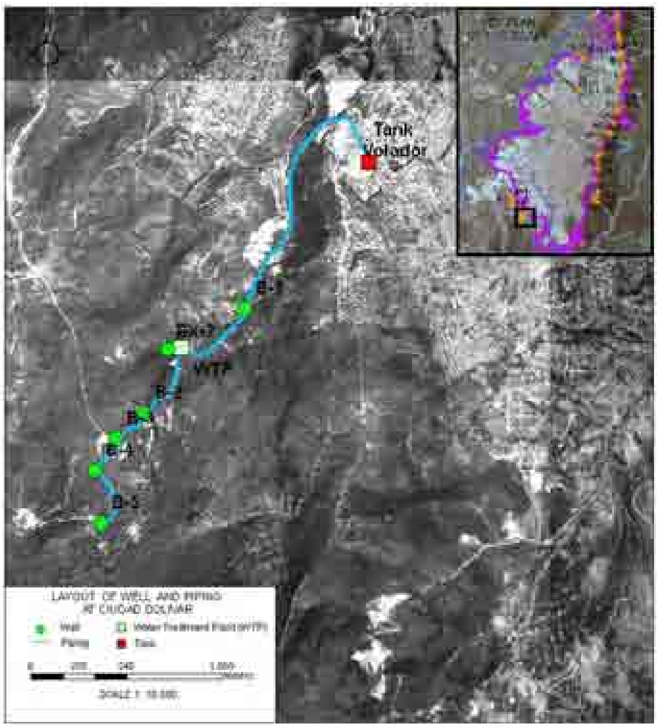
Project Name	Site		Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to (Exist Facility)	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)		
2nd Priority Project	Southern hills	Ciudad Bolovar	2-01	(EX-2)	(Pilot)	-	-	-	-	-	-	-	(1,000)	(Chlorine + Pressure Filtarlate)	16	2,160	Tank Volador	2
				B-1	New	8"+6"	300	3.2	121	26	6	516	5,000	Chlorine + Pressure Filtarlate				
				B-2	New	8"+6"	300	3.2	121	26	12	487						
				B-3	New	8"+6"	300	3.2	121	26	10	280						
				B-4	New	8"+6"	300	3.2	121	26	8	261						
				B-5	New	8"+6"	300	3.2	121	26	6	427						
	Southern hills	Soacha	2-02	S-1	New	8"+6"	300	4	190	75	6	25	3,000	Chlorine + Pressure Filtarlate	10	632	Soacha P/S	2
				S-2	New	8"+6"	300	4	190	75	6	515						
				S-3	New	8"+6"	300	4	190	75	6	920						
			2-03	S-4	New	8"+6"	300	4	190	75	6	25	4,000	Chlorine + Pressure Filtarlate	12	2,545	Tank Santo Domingo	2
				EX-1	New	8"+6"	300	4	190	75	6	546						
				S-5	New	8"+6"	300	4	190	75	6	956						
				S-6	New	8"+6"	300	4	190	75	6	1,287						
	Usme	Usme	-	(EX-3)	(Pilot)	-	-	-	-	-	-	-	(100)	(Chlorine +Aeration+ Pressure Filtarlate)	-	-	-	-

Note-1) Type of the supply is shown in Figure-3.3-41.

Source: JICA Study Team

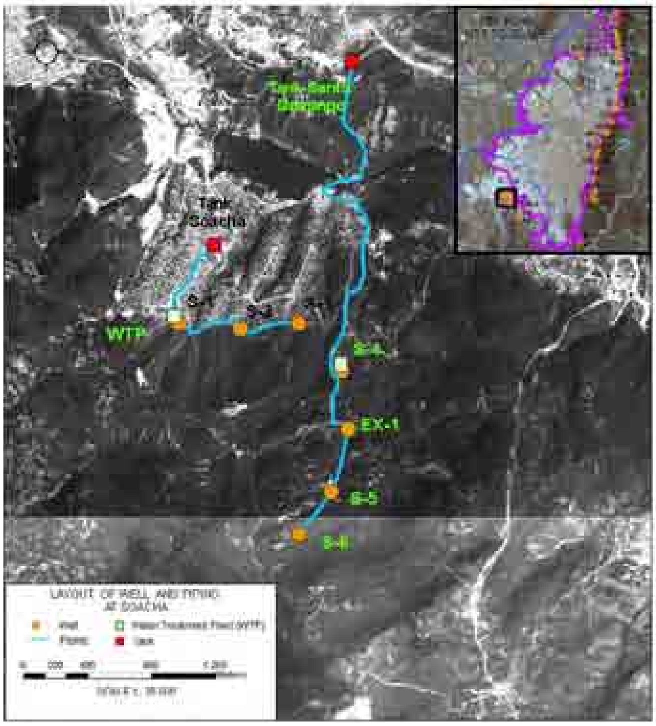
(2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the 2nd Period Project consists of one (1) water treatment plant (WTP) with one (1) to five (5) wells. The layout plan for each water supply unit is shown in Figure-3.3-34 to Figure-3.3-35.



Source: JICA Study Team

Figure-3.3- 34 Unit Layout Plan for 2-01



Source: JICA Study Team

Figure-3.3- 35 Unit Layout Plan for 2-02 and 2-03

3.4. Third Period Project

Yerba Buena Project was proposed for the Third Period Project. Yerbabuena area is relatively far from city center of Bogotá, which makes value of Yerbabuena Project lower as emergency water sources. Moreover, Yerba Buena area belongs to not Bogotá city but to Chia and Sopo municipalities, which makes promotion of project more complicated than projects within Bogotá city for Acueducrto. Therefore, priority of Yerba Buena Project is lower than the other projects. On the other hand, capacity of aquifer is high, which should be developed for emergency water source for Bofota in the future.

(1) Outline of project

Yerba Buena is near Chia, Cajica and Sopo. These three cities received block water supply from Acueducto. Population growth of three cities is rapid, and they occupy 66% of total block water supply of Acueducto. Acueducto will supply water to three cities even in case of emergency. For this purpose, emergency wells in Yerba Buena area can be used. Seventeen (17) wells are planned in Yerbabuena Project to produce 34,000m^3/day of groundwater. The Cretaceous aquifer is distributed along hill side of the Eastern hills of Yerba Buena, which is suitable for groundwater development. There is a road extending from 7th Avenue along the Eastern hills, and proposed well sites are located along this road. It makes easy access of drilling rig to the sites. Considering above situation, strategy for emergency water supply project in Yerba Buena is proposed as follows (see Figure-3.3-36):

(a) Point water supply to north of Bogotá, Chia, Cajica and Sopo

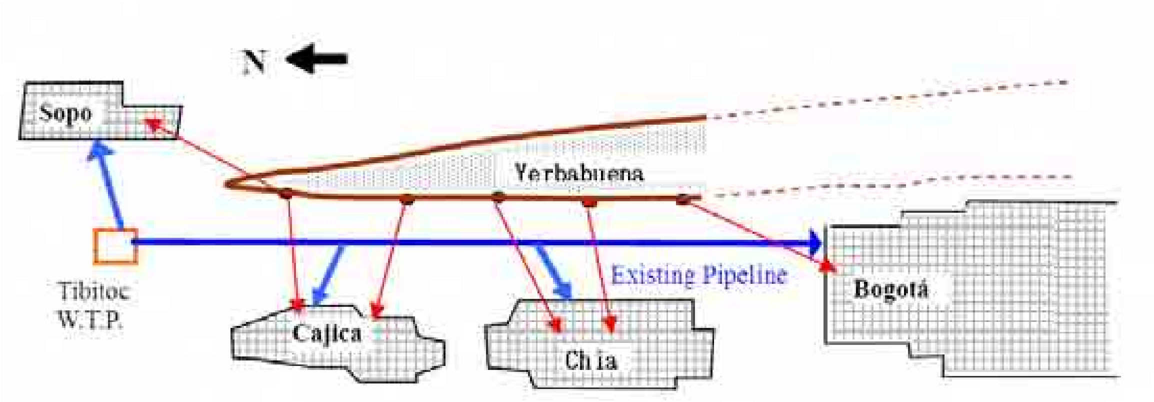
(b) Network water supply to Chia and Cajica

Table-3.3- 11 Outline of Yerba Buena Project

Area	Number of wells	Water supply (m^3/day)	Area for nwater supply	Supplied Population[note)]
Chia	9	18,000	Bogota, Chia, Cajica, Sopo	1,200,000
Sopo	8	16,000		1,066,000
Total	17	34,000		2,266,000

Note) It is under condition of unit consumption rate of 15ℓ/person/day

Source: JICA Study Team



Source: JICA Study Team

Figure-3.3- 36 Distribution of Water by Yerbabuena Project

(1) Point Water Supply

Point water supply will be implemented by water truck. Area to be supplied by water truck is north of Bogotá, Chia, Cajica and Sopo. Well sites are near the above area, which makes water supply by water trucks available in case of emergency.

(2) Network Water Supply

Network water supply is available by use of the existing pipeline between Tibitoc and Bogotá. However, this pipeline is relatively old, therefore it is better not to use the pipeline. In such a case, istead of use of exsiting pipeline, new pipline must be constructed. But contruction of new pipeline from Yerba Buena to Bogotá needs huge amount of investment, which is not realistic for emergency water supply. In this F/S, it was examined to send water from the wells to the existing pipeline to Chia and Cajica.

3.4.1. Production Well

(1) Well Location

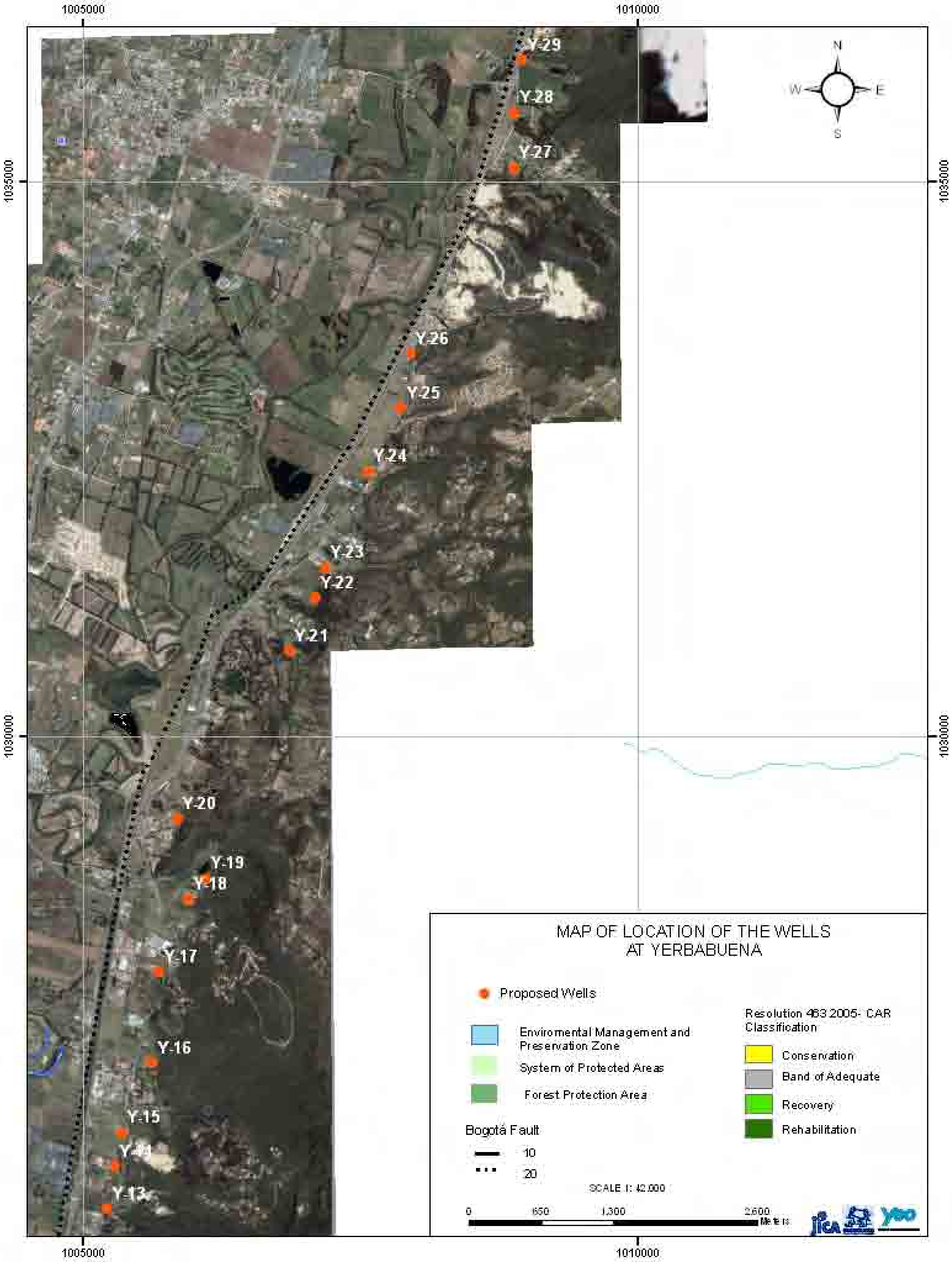
Well location of Yerbabuena Project is shown in Table-3.3-12 and Figure-3.3-37.

Table-3.3- 12 Well Location of Yerbabuena

Site	No.	Coordinate		Latitude (m)	Geology
		Latitude	Longitude		
Chia City	Y-13	4°49'45.4"N	74°01'51.7"W	2,566	K2t, west limb of anticline
	Y-14	4°49'57.4"N	74°01'48.4"W	2,564	K2t, west limb of anticline
	Y-15	4°50'07.1"N	74°01'47.7"W	2,558	K2t, west limb of anticline, along the lineament
	Y-16	4°50'27.2"N	74°01'36.2"W	2,564	K2t, west limb of anticline
	Y-17	4°50'55.6"N	74°01'35.4"W	2,556	K2t, west limb of anticline, along the lineament
	Y-18	4°51'15.1"N	74°01'25.6"W	2,571	K2t, west limb of anticline, along the lineament
	Y-19	4°51'21.4"N	74°01'17.6"W	2,617	K2t, west limb of anticline
	Y-20	4°51'38.8"N	74°01'28.8"W	2,577	K2E1g
	Y-21	4°52'29.5"N	74°00'53.8"W	2,570	K2t, west limb of anticline, along the lineament
Sopo	Y-22	4°52'43.5"N	74°00'48.4"W	2,566	K2t, west limb of anticline, along the lineament
	Y-23	4°52'52.3"N	74°00'45.6"W	2,563	K2t, west limb of anticline, along the lineament
	Y-24	4°53'21.3"N	74°00'34.8"W	2,557	Q1sa(K2t)
	Y-25	4°53'35.2"N	74°00'26.9"W	2,559	Q1sa(K2t)
	Y-26	4°53'46.8"N	74°00'22.6"W	2,559	Q1sa(K2t)
	Y-27	4°54'49.5"N	73°59'50.3"W	2,558	Q1sa(K2d), west limb of anticline
	Y-28	4°55'08.5"N	73°59'51.1"W	2,554	Q1sa(K2d), west limb of anticline
	Y-29	4°55'21.2"N	73°59'47.8"W	2,561	K2d, west limb of anticline

Source: JICA Study Team

Legend	Q2c,Q2ch	Quaternaru	K2t	Labor & Tierna (Cretaceosu)
	E1b	Bogota (Tertiary)	K2p	Plaeners (Cretacesou)
	K2E1g	Guaduas (Tertiary)	Ksd	Dura (Cretacesou)



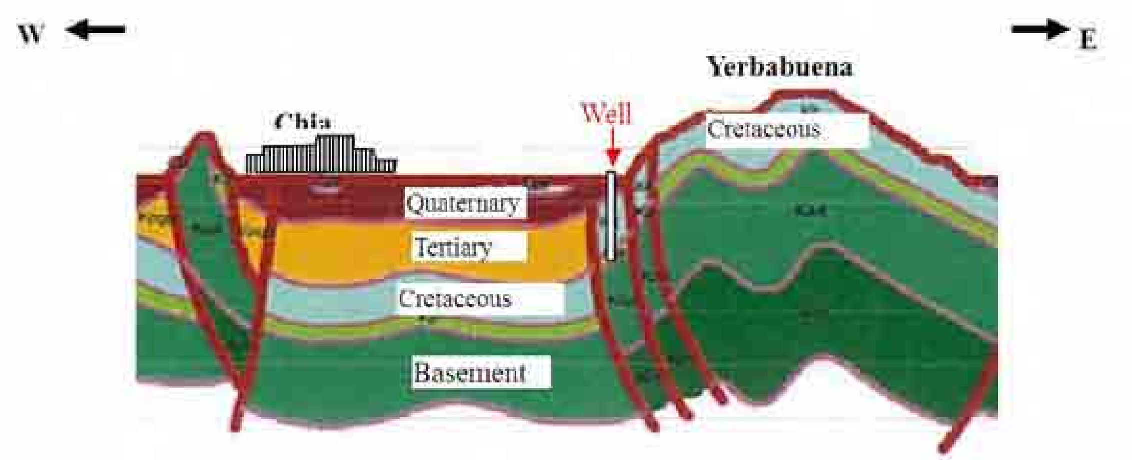
Source: JICA Study Team

Figure-3.3- 37 Location of Wells in Yerbabuena Project

(2) Number of wells in M/P and F/S

In the Yerba Buena Project, 17 wells were proposed in M/P. The proposed well sites were carefully reviewed in F/S, and the same number of wells was finally proposed.

Relation between hydrogeology and proposed well site is shown in Figure-3.3-38. Aquifer of Cretaceous sandstone is distributed under Bogotá Plain near the foot of Eastern Hills, where large amount of groundwater can be produced from wells. Bogotá Fault does not have critical influence in selection of well site in this area.



Source: JICA Study Team

Figure-3.3- 38 Hydrogeology and Wells in Yerbabuena

3.4.2. Facility Plan

(1) Facility Plan for Emergency Water Supply System

The composition and the connection points for the emergency water supply unit on the 3rd Period Project are shown in Table-3.3-13.

Table-3.3- 13 Composition and Connection Point for Emergency Water Supply Unit (3rd Period Project)

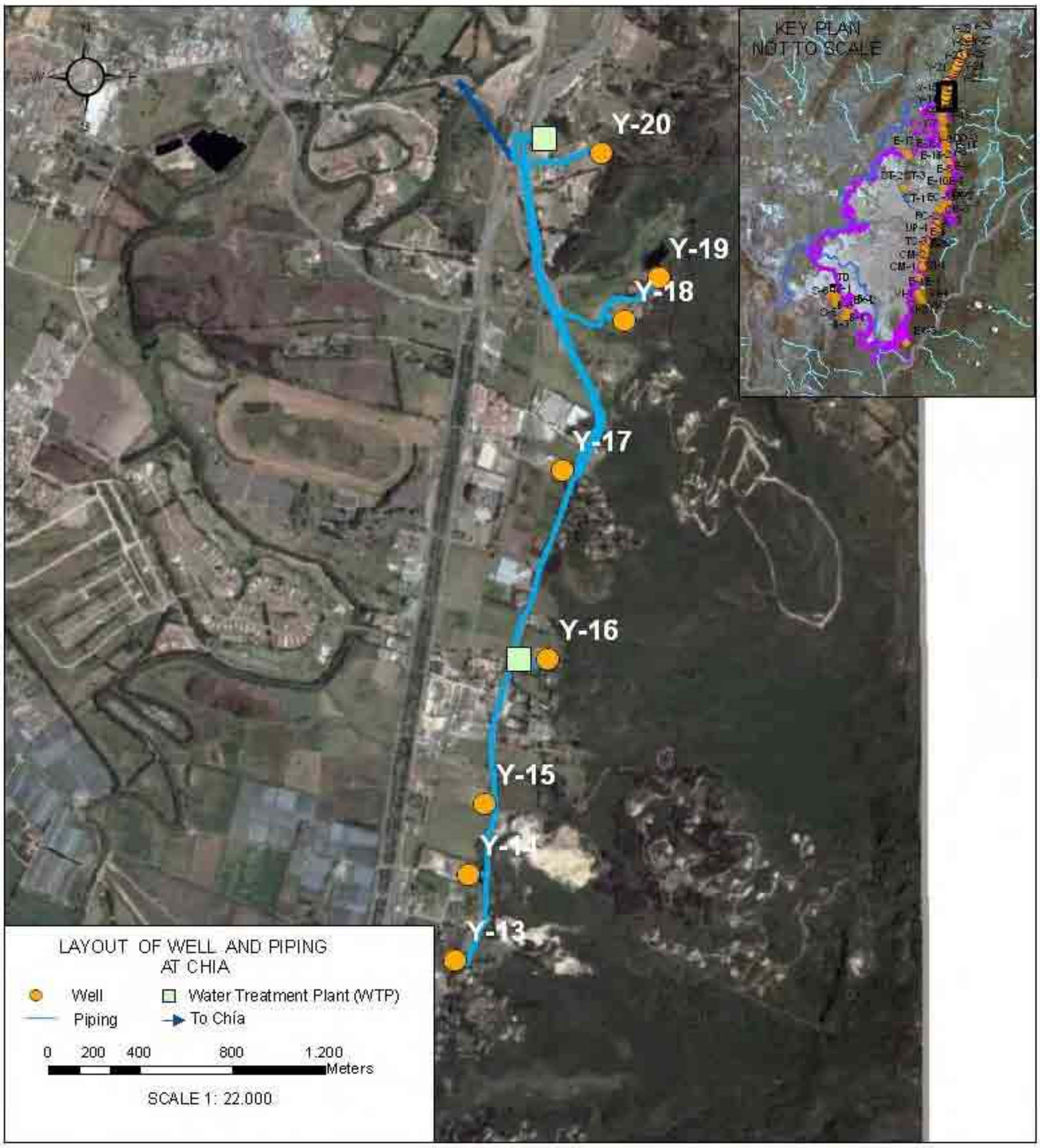
Project Name	Site		Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to (Exist Facility)	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)		
3rd Priority Project	Yerbabuena	Chia	3-01	Y-13	New	8"+6"	300	4	190	75	6	450	8,000	Chlorine + Pressure Filtarlate	12	2,340	Chia City Water Network	3
				Y-14	New	8"+6"	300	4	190	75	8	330						
				Y-15	New	8"+6"	300	4	190	75	10	670						
				Y-16	New	8"+6"	300	4	190	75	6	25						
				Y-17	New	8"+6"	300	4	190	75	6	825	8,000	Chlorine + Pressure Filtarlate	12	235	Chia City Water Network	3
				Y-18	New	8"+6"	300	4	190	75	8	245						
				Y-19	New	8"+6"	300	4	190	75	10	655						
				Y-20	New	8"+6"	300	4	190	75	12	210						
		Sopo	3-02	Y-21	New	8"+6"	300	4	190	75	6	1,355	6,000	Chlorine + Pressure Filtarlate	10	2,590	Sopo City Water Network	3
				Y-22	New	8"+6"	300	4	190	75	8	95						
				Y-23	New	8"+6"	300	4	190	75	6	600						
				Y-24	New	8"+6"	300	4	190	75	6	545	6,000	Chlorine + Pressure Filtarlate	10	205	Sopo City Water Network	3
				Y-25	New	8"+6"	300	4	190	75	8	520			16	2,500		
				Y-26	New	8"+6"	300	4	190	75	6	25						
				Y-27	New	8"+6"	300	4	190	75	6	775	6,000	Chlorine + Pressure Filtarlate	10	485	Sopo City Water Network	3
				Y-28	New	8"+6"	300	4	190	75	8	445			20	25		
				Y-29	New	8"+6"	300	4	190	75	6	60						

Note-1) Type of the supply is shown in the Figure-3.3-41.

Source: JICA Study Team

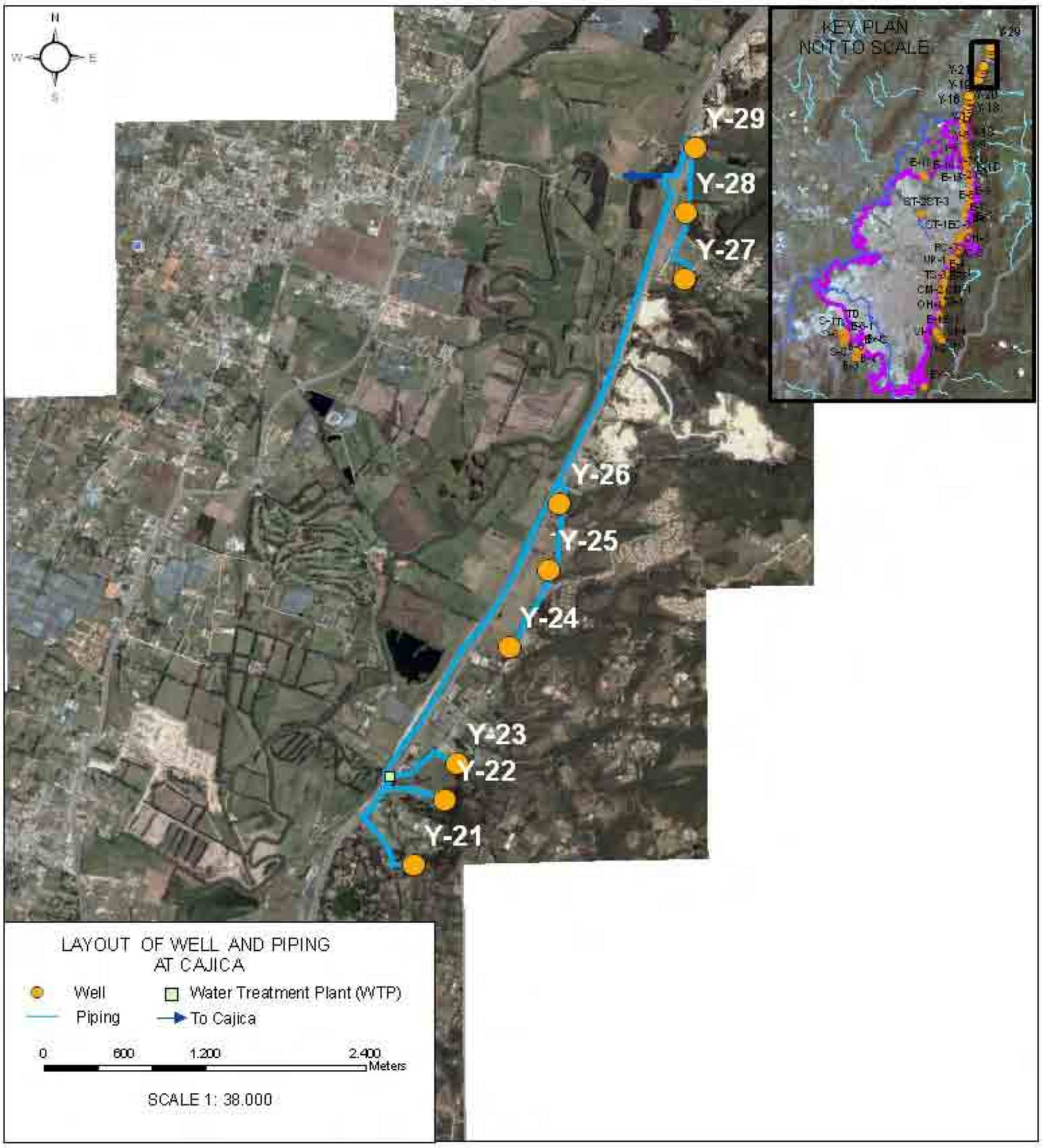
(2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the 3rd period project consists of one (1) water treatment plant (WTP) with three (3) to five (5) wells. Therefore, the layout plan for each water supply unit is shown in Figure-3.3-39 to Figure-3.3-40.



Source: JICA Study Team

Figure-3.3- 39 Unit Layout Plan for 3-01



Source: JICA Study Team

Figure-3.3- 40 Unit Layout Plan for 3-02

3.5. General Facilities Plan

(1) Well Facilities Plan

1) Wells

- The basic well diameter shall be 10 inches between 0-150m depth and 8 inches between 150-300m depth. Only in cases where well is located at high eleveation, and the projected water level is deeper than 150m, well diameter shall 10 inches between 0-150m depth and 8 inches between 150~400m depth.
- Well casing shall be made of pressure pipe carbon steel Sch-40 or an equivalent material. The screen sandwiched between the casing pipes shall be made from slitter pressure pipe carbon steel or an equivalent material. Since the layout of screens determines the capacity of wells, they must be positioned appropriately convering aquiufers of wells. The length of screens shall generally be around 30% of the total length of well.

2) Submersible pumps and motors

Multistage submersible pumps, which are commonly used for deep wells and have general applicability, shall be adopted in the project. In consideration of the specifications of city power supply and voltage drop in Bogota, the capacity of submersible motor shall be 400 V, 60 hz, 3-phase. The pump models and capacity shall be selected based on the expected pumping capacity, expected total pump head and the pump performance curves of representative pump makers that can provide pumps in Colombia. Through, effort above, fair competition and economy in the procurement must be secured.

- Site control panels (with 3E relay, soft starter, soft stop, automatic start)
- Submersible cable (site control panel ~ submersible motor)
- Water level gauge (2 contact points, pump idle running protection, automatic start)
- Water lifting pipe
- Elbow block
- Coupled cage (positive pressure, negative pressure, main valve damper)
- Air vent
- Check valve
- Flow gauge

The above instruments combine to make up a system. Since each pump maker has its own distinct know-how, the entire system should be procured from a single maker.

3) Power supply to pumps

- In order to facilitate operation and maintenance of the pumps, power supply facilities shall be installed in the treatment plant and power cables shall be installed along the underground water conveyance pipes. This type of design contributes to economical initial investment.
- Power cables shall be 4-core low pressure cables. The cable size shall be selected so that voltage drop from the power supply panel to the site control panel is no greater than 6% when pumps are stated by soft starter. Moreover, since the cables will be laid underground, armored cables of underground type shall be used. Also, display tape (caution tape) should be attached to cables when installation works is implemented.
- It shall be possible to control plant-pumps by a control panel installed inside the treatment plant, and control cables shall be installed alongside water conveyance pipes and power cables. Control cable shall be 10-core x 2.0 mm^2 with shield and armor.

4) Water conveyance pipes

PVC pipes (withstand pressure 1.6Mp), which can be easily procured in Bogota, shall be adopted as the underground water conveyance pipes. When installation, trench will be backfilled with sand in 20cm thickness around the pipes for protection. Since PVC pipes become degraded and brittle when they come into contact with ultraviolet light, general-use carbon steel pipes with exterior coating shall be adopted when pipes are laid aboveground.

5) Auxiliary facilities

- Perimeter fences shall be installed around wells for safety and security. Fences shall be 2.0 m high steel structures with zinc plating, and the ends shall possess a three-level barbed wire fence to stop people from climbing over. Also, a 1.0 m wide single swinging door shall be provided.
- Outdoor lights shall be installed as a nighttime crime prevention measure. Lights will comprise a single 20 W fluorescent light on a self-standing steel pole (H = 6 m).
- Access roads shall be provided where necessary. They shall have simple paving and a width of 5 m.

(2) Water Treatment and Conveyance Facilities Plan

1) Water Treatment facilities plan

Water standard in emergency

Required water quality in usual water supply and emergency water supply was clearly defined in the previous drinking water standard (Decreto 475, 1998). According to this standard, allowable water quality in emergency was less strict than those in ordinary. For example, allowable iron (Fe) concentration was 0.3mg/ℓ in ordinary and 0.5 mg/ℓ in emergency. Allowable Manganese (Mn) concentration was 0.10 mg/ℓ in ordinary and 0.15 mg/ℓ in emergency. However, new standard (Decreto 1575, 2007 and Resolusion 2115, 2007) does not show any standard on water quality in emergency. It means that water quality should be the same between emergency and ordinary water supply in the new standard. Groundwater of the Cretaceous aquifer was proposed for water sources of emergency water supply in this Study, and only concentration of Fe and Mn slightly exceed the new water quality standard. Fe and Mn can be removed easily by pressure filter. Therefore, water treatment facilities were planned for the proposed projects to satisfy the new water quality standard.

Necessity of water treatment facilities

There are results of water quality analysis of 6 wells of the Cretaceous aquifer in the project area. According to the results, groundwater of 4 wells need water treatment, and 2 wells need no treatment. Therefore, it is expected that 2/3 of Cretaceous wells may need water treatment, and 1/3 of Cretaceous wells may not need water treatment. Whether or not water treatment is necessary should be judged well by well after drilling, based on result of water quality analysis. Water treatment facilities were planned in F/S for all the wells. Necessity of treatment facilities, however, will be decided in the futurte implementation stage.

a) Power equipment plan

Bogota is served by overhead power lines of 11.4 kV, 60 Hz and 3-phase provided by the local power company. Power supply can be received from the power company and the tie-in point shall be the first electric pole inside the treatment plant. Power up to the first electric pole shall be supplied along overhead lines belonging to the power company. The budget for this shall be included in the project. The instruments and specifications of power receiving facilities shall be selected as shown below in line with the specifications of existing facilities.

First electric pole

This includes the concrete electric pole (13 m), 11.4 kV, 3-phase, arms, insulators, cutout switches (3 for 3 phases, with fuses), overhead lines for connecting equipment and ground wires, etc.

Step down transformer

The transformer will be 11.4 kV, 60 Hz and 3-phase 3 lines on the high voltage side, and 440 V, 60 Hz and 3-phase 4 lines on the low voltage side. The transformer capacity is between 150~500 KVA, however, since the weight is too much for pole mounting, the transformer shall be installed aboveground on concrete foundations and enclosed by a safety fence.

In order to avoid excessive design, when all well pump and the other instruments are started, one of all the instruments with the largest capacity shall be used to determine the transformer capacity, based on the maximum current at the momentr of soft starter swiching on.

High pressure cable

The power cable from the first electric pole to the transformer shall be an underground structure, and these parts shall be protected in conduits. High pressure cable specifications shall be the 11 kV class high pressure 3-core cable, and the cable size shall be at least 60 mm^2 in consideration of mechanical strength.

Power receiving and distribution panel

Judging from the power supply standards of the power company in Bogota and the appropriate voltage for the amount of electric power used, the power supply shall be 440 V, 60 Hz, 3-phase 4 lines, and a voltmeter shall be installed to calculate the power tariffs to be paid to the power company. Also, power receiving terminals from emergency generators shall be installed, and protective devices shall be fitted to prevent simultaneous activation of power receiving CB.

Motor control panel

Well pumps shall be operated by automatic and manual operation. Protective devices shall be installed to the panel to prevent simultaneous activation of well pumps.

Emergency generators

It may not be possible to supply power in some emergency situations. Because of the need for mobility, economy and regular maintenance inspections, emergency generators shall be stored and maintained at traffic hubs in Bogota for emergency use. The emergency generators shall be the fuel tank-fitted type suitable for haulage; moreover, they shall be diesel engine-driven generators with specifications of 1800 rpm, 440 V, 3-phase and 4 lines.

b) Water Treatment Facilities Plan

The quality of groundwater in the target area is excellent, and judging from the results of water quality analysis of the exploratory wells, concentration of only Fe and Mn are slightly exceeds the potable water standards of Colombia. Possible water treatment systems are: a) the gravity filtration method, b) pressure filtration method and c) pressure osmosis method. In the project, the pressure filtration system shall be adopted because residual pressure in the well pump can be utilized as conveyance pressure, thus enabling the reaction time to be shortened. As for water treatment, the three systems indicated in Table-3.3-14 may be considered depending on the water quality.

Table-3.3- 14 Water Treatment Methods

Water Purification System	Treated Substances		Site
	Fe (mg/L)	Mn (mg/L)	
(1) Chlorine	0.3 or less	0.1 or less	La Salle, Marical Sucre
(2)Chlorine + Pressure filter	0.3 ～ 3.0	0.1 ～ 3.0	All sites except (1) and (3)
(3)Chlorine + Aeration + Pressure filter	3.0 or more	3.0 or more	Usme

Source: JICA Study Team

The distribution tank shall basically have enough capacity to store water by 30 minutes pumping from a well. In order to enable supply to a water tank truck without using a conveyance pump, the distribution tank shall be installed around 3 m higher than the road, using land gradient if there is a slope in sites. In cases of flat land, the distribution tank will be placed on a frame higer than the road in order to give the height difference.

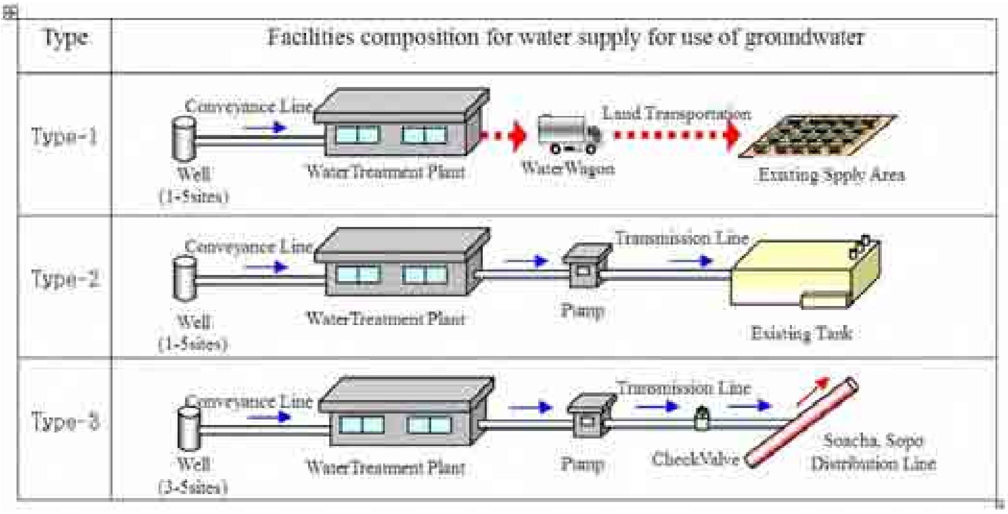
c) Auxiliary Equipment Plan

- Electrical equipment such as the power receiving and distribution panel and motor control panel, etc. need to be installed indoors in order to provide durability against long-term use. Accordingly, it will be necessary to build the minimum required electricity house in the water treatment plant. Also, it is necessary to install the minimum required toilet and water treatment tank in order to secure sanitary conditions for the operators.
- Perimeter fences shall be installed around wells for safety and security. Fences shall be 2.0 m zinc plated wire mesh, and the ends shall possess a three-level barbed wire fence to stop people from climbing over. Also, a 1.0 m wide single swinging door shall be provided.
- Outdoor lights shall be installed as a nighttime crime prevention measure. There will be four lights comprising two 20 W fluorescent lamps on a self-standing steel pole (H = 6 m).
- Access roads shall be provided where necessary. They shall have simple paving and a width of 5 m.

2) Plan for Water Supply Facility

a) Plan for Water Supply Facility

As the composition of facilities for water supply, three (3) types of facilities are planned as shown in Figure-3.3-41. Not only the facilities of type-1 but also type-2 and type-3 must be able to implement point water supply by water wagon, for emergency water supply immediate after disaster.



Source: JICA Study Team

Figure-3.3- 41 Facilities Composition for Water Supply for Use of Groundwater

b) Water Conveyance Pipes

PVC pipes (withstand pressure 1.3Mp), which can be easily procured in Bogota, shall be adopted as the underground water conveyance pipes. When installation, trench will be backfilled with sand of 20 cm thickness around the pipes for protection. Since PVC pipes become degraded and brittle when they come into contact with ultraviolet light, general-use carbon steel pipes with exterior coating shall be adopted when pipes are laid aboveground.

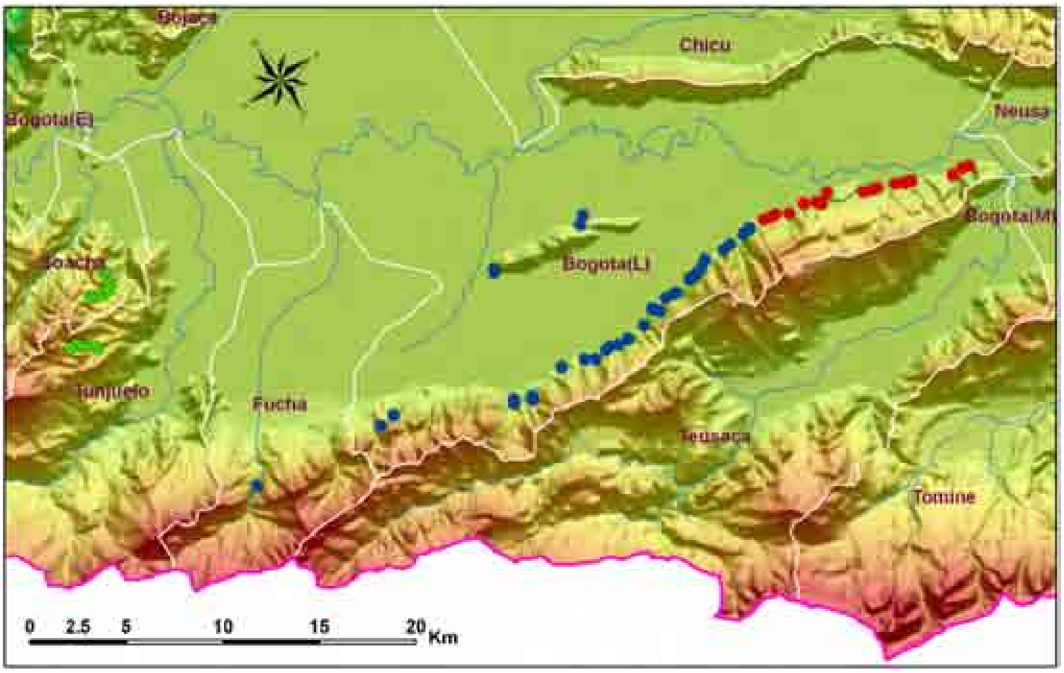
c) Existing Distribution Reservoirs

In order to avoid excessive water supply to existing distribution reservoirs, it is necessary to send signals, about water level in tanks, to the motor control panel in the water plant. Accordingly, control cables shall be laid alongside underground water conveyance pipes. Cables shall be the 5-core, 2.0 mm^2 shield armored type.

3.6. Optimum Yield

(1) Location of Planned Wells

The water supply plan for emergency situation consists of three projects with pumping well construction. Eastern Project includes 33 wells, Southern Project 14 wells and Yerbabuena Project 17 wells. The wells are planned to be located along the Eastern hill area, and distributed in the four tributary basins of the Bogota river, Bogota(L)、Fucha、Tunjuelo and Soacha. Figure-3.3-42 shows the location of the wells and the basins.



Source: JICA Study Team

Figure-3.3- 42 Location of the Wells Planned in the Eastern Project

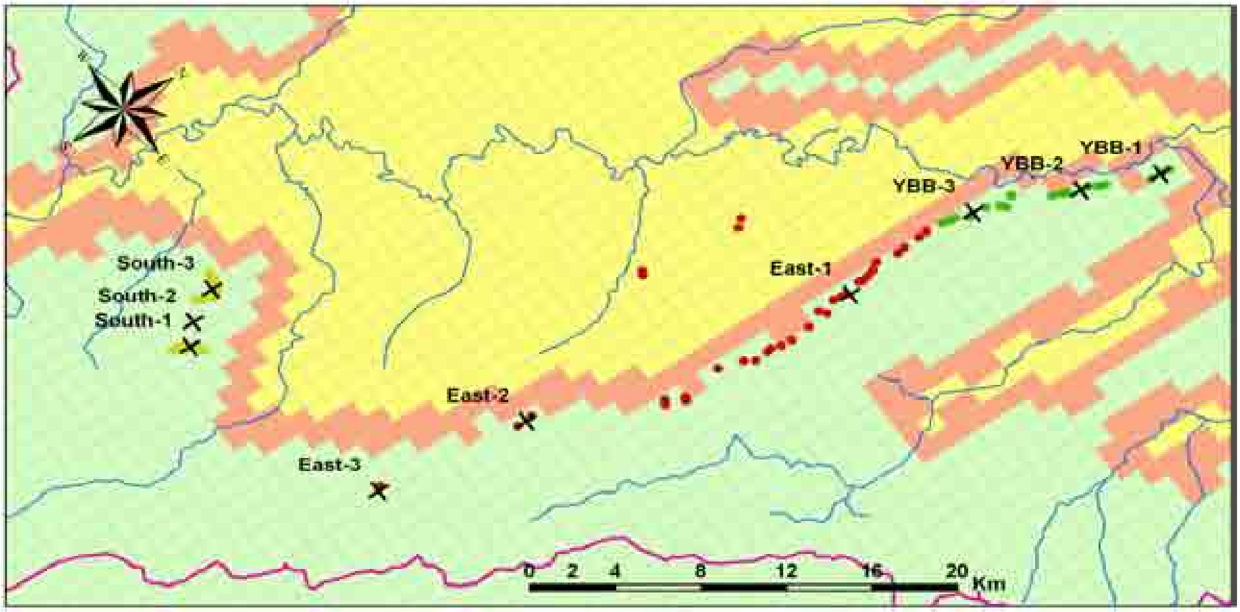
(2) Groundwater Drawdown

Groundwater withdrawal by pumping wells will surely cause lowering of groundwater table around the pumping wells. Groundwater withdrawal can only be continued when the groundwater is gathered to the wells from the surrounding areas or recharge areas. Thus, this head difference between the area around the pumping well and the recharge area is essential to sustain the withdrawal.

However, if the amount of groundwater withdrawal becomes large, the groundwater flow from the recharge area will not be able to supply the amount of withdrawal any more at some point. Then the groundwater drawdown will become too large, exceeding the allowable limit. This would have the following effects on the environment and groundwater use:

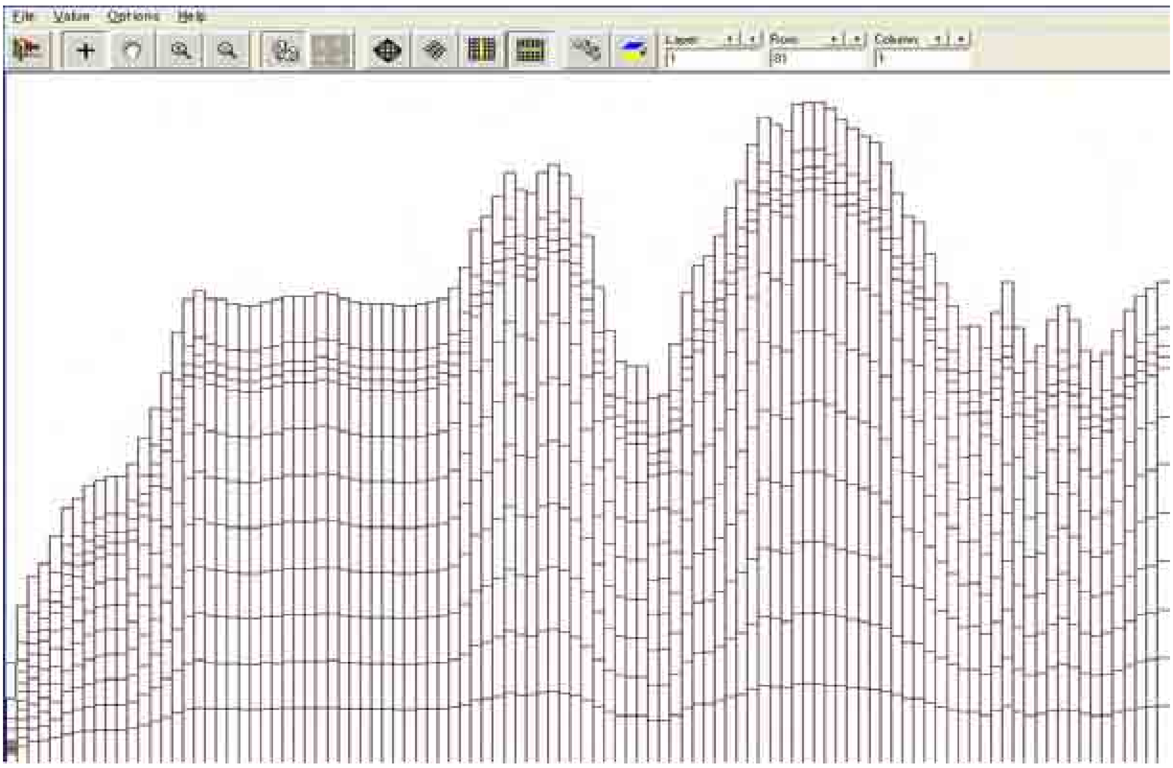
- Not enough groundwater can be withdrawn from pumping wells as they are designed to, and then the plan to supply enough water to meet the demand would fail.
- Withdrawal from other adjacent wells would be reduced or might even become impossible.
- Pumping aquifer would be contaminated by groundwater with poor water quality flowing into it from other aquifers.
- The threat of land subsidence would increase with the existence of a soft layer, such as a clayey layer.

Therefore, the groundwater drawdown should be examined thoroughly to make clear how it will occur and recover during and after the withdrawal. A groundwater simulation model was used to examine these issues. Using the function of "drawdown observation" in the groundwater simulation software MODFLOW, three virtual observation wells were installed for each project area as shown in Figure-3.3-43. Representative geological section in Model is shown in Figure-3.3-44.



Source: JICA Study Team

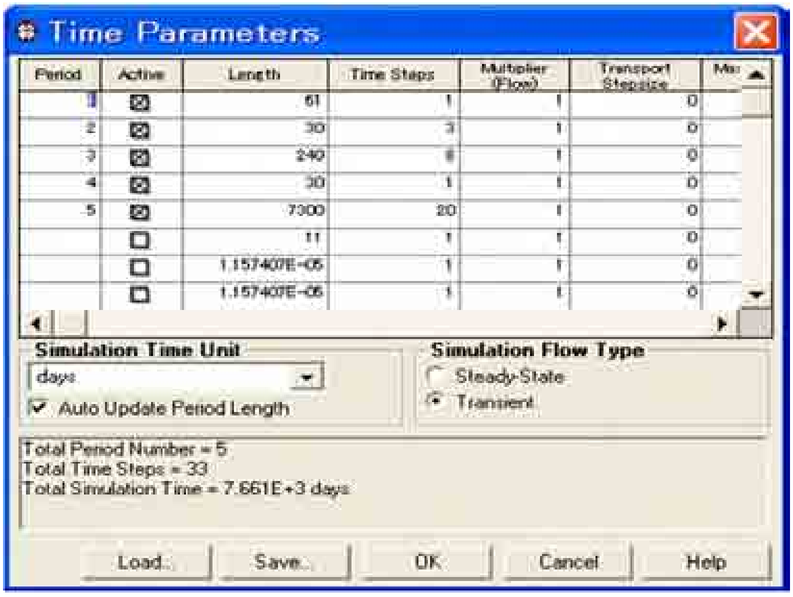
Figure-3.3- 43 Location of Observation Wells



Source: JICA Study Team

Figure-3.3- 44 Geologecal section of Model

The project implementation plan was used as basic input for the simulation. The flow type was set as transient and the calculation period was divided into five periods as shown in Figure-3.3-45.

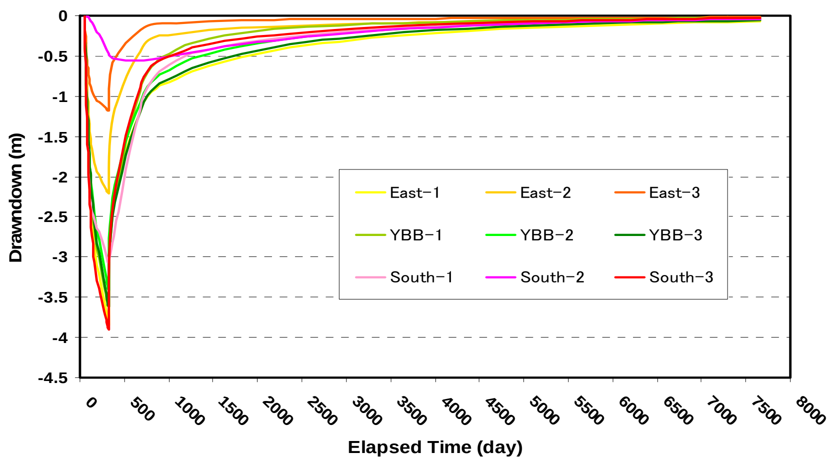


Source: JICA Study Team

Figure-3.3- 45 Flow Type and Period Specifications in the Simulation Model

- Period 1: 61 days (2 months) before pumping
- Period 2: 30 days (1 month) from the beginning of pumping
- Period 3: 240 days (8 months) for the remainder of the pumping period
- Period 4: 30 days (1 month) after the termination of pumping
- Period 5: 7300 day (20 years) after the termination of pumping

Figure-3.3-46 shows the simulation result of all the observation wells and Figure-3.3-47 shows the behavior of groundwater drawdown in all the three observation wells for each project.



Source: JICA Study Team

Figure-3.3- 46 Head Change Curves of Temporary Observation Wells

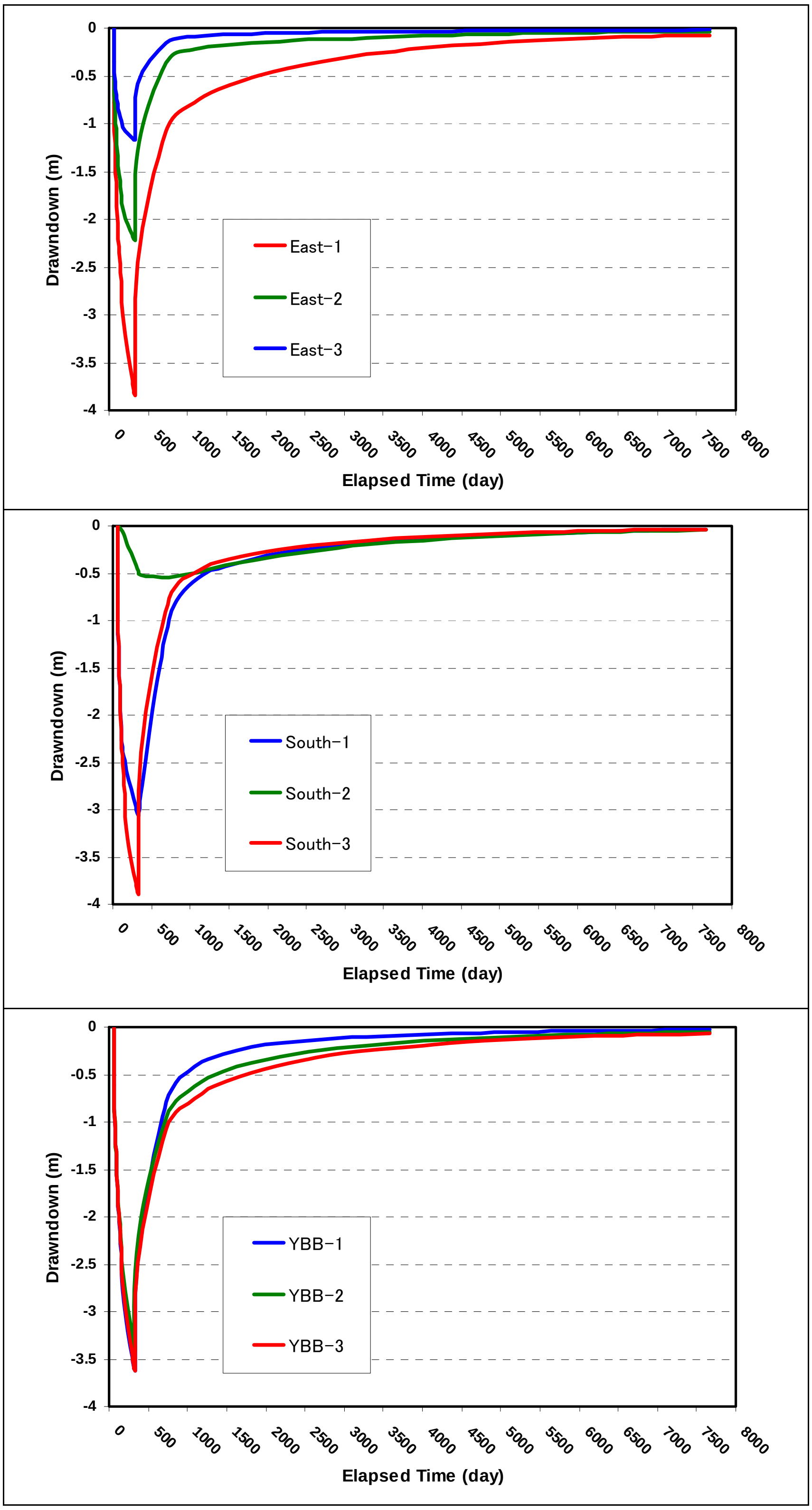


Figure-3.3- 47 Head Change Curves of Temporary Observation Wells for Each Project

The followings have been indicated by Figure-3.3-46 and Figure-3.3-47:

- Groundwater drawdown occurs in all project areas. The maximum groundwater head drawdown at the observation wells in each project area varies from 3.5 to 4m.
- No sign of groundwater drawdown reaching equilibrium could be identified during the withdrawal.

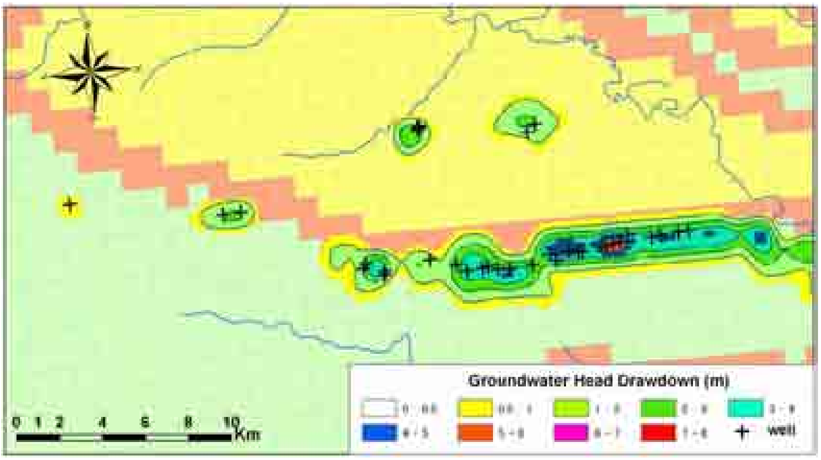
- The drawdown at each observation well rapidly recovers after the termination of pumping. The drawdown in almost all observation wells can recover to less than one meter within one year.

As mentioned above, there may be a risk of adverse affects on the environment and groundwater use due to groundwater head drawdown, when the allowable limit of withdrawal is exceeded. The affect of the drawdown is known to be different, depending on the type of aquifer or stratum. In this plan, any adverse effects are hard to be envisaged as the result of the drawdown caused by the groundwater withdrawal in the Project. This is because all the wells in the project are planned in the Cretaceous aquifer, known as the base rock layer. No case of such adverse effects, which was caused by only four meters of drawdown in base rock area, has been reported across the world.

The drawdown of four meter is considered safe because the Cretaceous aquifer is the base rock layer. However, in the downstream side of the project wells extends Quaternary stratum, and clayey layers have been identified within the stratum. Land subsidence problems in Quaternary stratum can not be neglected if the groundwater drawdown is too large. Therefore, not only the drawdown in observation wells in the Cretaceous aquifer, but also other areas affected by the water supply project should be examined to make sure no land subsidence will occur as a result of groundwater withdrawal.

Figure-3.3-48 shows the distribution of groundwater drawdown at the time of termination of pumping. The grids in the figure indicate the grid specification of the simulation model. All of the project wells are located in the pale green colored grid area, the Cretaceous stratum. In the downstream side of the wells are brown colored grids representing Tertiary stratum, known as aquiclude. Over the Tertiary stratum, the shallow yellow colored grids show the Quaternary stratum.

Relatively large drawdown, over five meters occurs in some places around the pumping wells in the Cretaceous stratum. This amount of drawdown is indispensable for collecting enough groundwater from recharge area into the wells. Groundwater head drawdown of this magnitude in a base rock area could hardly be regarded as the cause of environmental problems as mentioned above. Therefore, the groundwater drawdown in the Cretaceous stratum can be considered being within an allowable range.

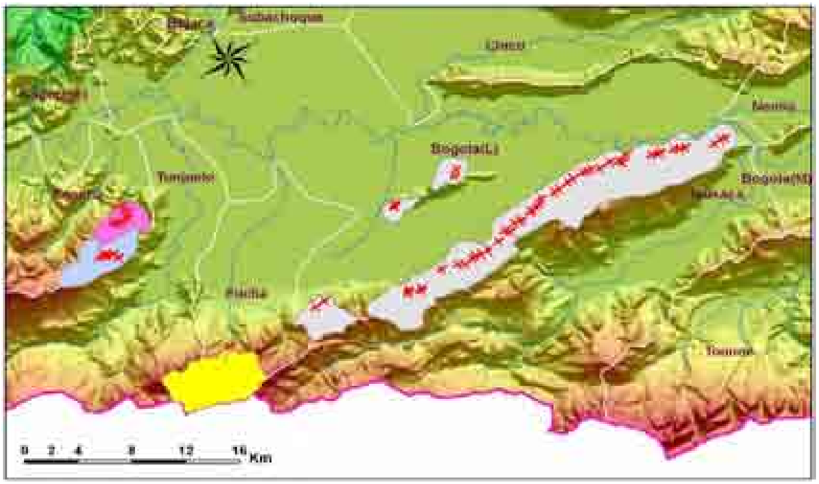


Source: JICA Study Team

Figure-3.3- 48 Area Affected by Eastern Project

(3) Balance between Groundwater Withdrawal and Recharge

Not only should the effect of groundwater drawdown on environment, but also water balance should be examined for the planned project. The amount of groundwater recharge depends on two factors: the recharge area and the recharge rate. For this project, all mountainous areas on the upstream side of the wells can easily be identified as the recharge area as they coincide with hydrographical basins. However, no clear boundary to delineate the recharge area can be identified downstream. The areas where groundwater drawdown is over one meter, as shown in Figure-3.3-48, are considered to be under relatively direct influence of the pumping wells, and thus these areas can be delineated as the recharge area for groundwater balance examination. The result of the recharge area identification is shown in Figure-3.3-49.



Source: JICA Study Team

Figure-3.3- 49 Result of Recharge Area Identification

As shown in Figure-3.3-49, the recharge areas of the project wells cover four tributary basins of the Bogota River. The recharge area and annual recharge amount in each tributary basin are summarized in Table-3-3-15.

Table-3.3- 15 Recharge Amount for Project Wells

Basin	**Area（m2）**	**R_Rate（mm/year）**	**Annual Recharge（m³)**
Soacha	8,471,446	53	448,987
Tunjuelo	13,583,232	129	1,752,237
Bogota(L)	110,436,866	118	13,031,550
Fucha	24,910,090	194	4,832,557
Total	157,401,634	**--**	**20,065,331**

Note) R_Rate is the annual groundwater recharge rate obtained from the hydrological analysis

Source: JICA Study Team

With all the wells in operation, the planned total daily withdrawal rate is 115,600 m^3/day. Therefore, the total withdrawal amount for the planned duration of nine months is given as:

$$115,600 \times 275 = 31,790,000\ (m^3)$$

If the annual groundwater recharge amount is compared with the total withdrawal amount, it is clear that the recharge is less than withdrawal. The ratio of the recharge to withdrawal is 63.1％. This result corresponds to the groundwater draw-down curves in Figure-3.3-46 and Figure-3.3-47. Within the nine-month duration of withdrawal, the groundwater head will continue to go down, without reaching equilibrium.

The purpose of this project is water supply for an emergency, with a maximum of nine-month duration of withdrawal. The withdrawal will be stopped following the settlement of the emergency. The groundwater head can recover rapidly as shown in the draw-down curves of observation wells in Figure-3.3-46 and Figure-3.3.-47.

The total amount of withdrawal in the project can be recovered by recharge within two years as shown in the following calculation.

$$1 / 63.1\% = 1.58\ (\text{years})$$

This water balance analysis leads to the conclusion that as an emergency water supply countermeasure, the project should be implemented with an interval of two years or more.

Moreover, it is common sense in hydrogeology that the aquifer will receive more recharge when groundwater head is reduced by withdrawal from pumping wells than the case with no groundwater draw-down. The following phenomena may result from this effect:

- Recharge will increase from rivers or other water bodies that have less head change than groundwater; or water runoff from groundwater to surface water bodies will decrease.
- Groundwater head draw-down will result in increasing infiltration into groundwater from precipitation.
- Groundwater head draw-down will result in reduction of evapotranspiration.

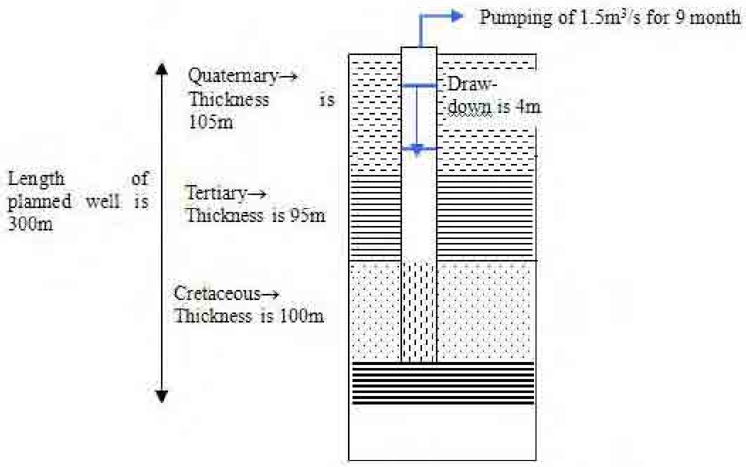
All these effects of increasing groundwater recharge will lead to somewhat faster recovery of groundwater level.

In summary of the examinations above, it can be concluded that the emergency water supply project is feasible on the condition of an implementation interval longer than two years, from the viewpoints of groundwater balance, avoidance of adverse effects to the environment, and groundwater use.

3.6.1. Land subsidence

Land subsidence will happen in soft ground of the Quaternary near the ground surface. Model for land subsidence was proposed in M/P Study. Groundwater level draw-down by pumping from proposed wells was predicted in F/S. Using this result, Land subsidence was analyzed following procedure below:

- Model for land subsidence for F/S was the same as that proposed in M/P Study. It consists of the Quaternary, the Tertiary and the Cretaceous.
- In the model, thickness of the Quaternary is 105m, the Tertiary 95m, the Cretaceous 100m (see Figure-3.3-50). Soil mechanical parameters of the model are the same as those proposed in M/P Study.
- Land subsidence of the model was calculated based on groundwater level draw-down, which was calculated in groundwater simulation in F/S. Total land subsidence of the model was obtained by adding land subsidence of the Quaternary, the Tertiary and the Cretaceous.



Source: JICA Study Team

Figure-3.3- 50 Model for land subsidence

Items below were taken into account in calculation of land subsidence.

- Duration of pumping is just less than 9 month. This pimping will cause draw-down of groundwater level to lead land subsidence of the Quaternary. Therefore, calculation must be done in 2 steps as explained below to obtain exact land subsidence of the Quaternary:

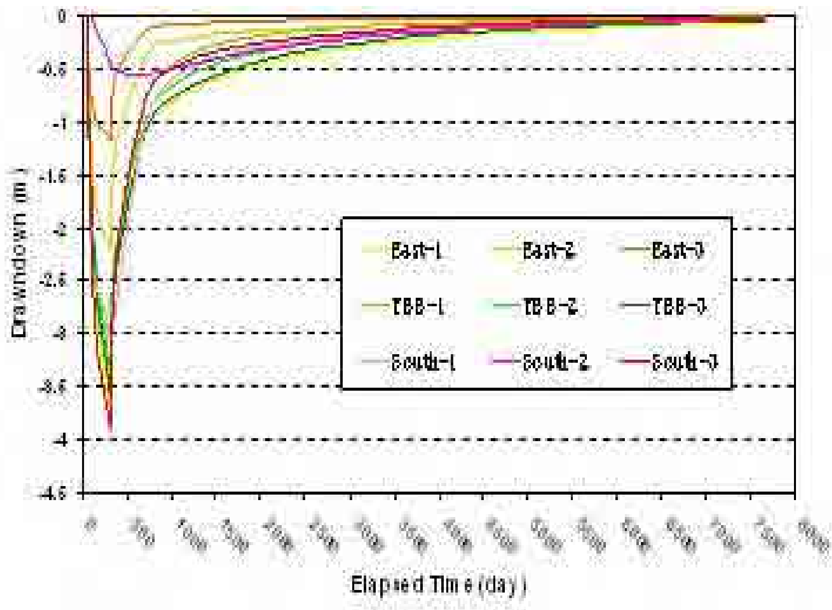
  Step-1: The final land subsidence, in case of permanent water pumping, was calculated.

  Step-2: The final land subsidence above was modified, considering recovery of groundwater level after pumping is stopped.

- Elastic compression will occur in the Tertiary and the Cretaceous by groundwater level draw-down. Generally speaking, elastic deformation will recover after load is removed. Therefore, land subsidence of the Tertiary and the Cretaceous will recover after pumping is stopped. Then, land subsidence of the Quaternary, which was not elastic deformation but consolidation deformation, will only remain.

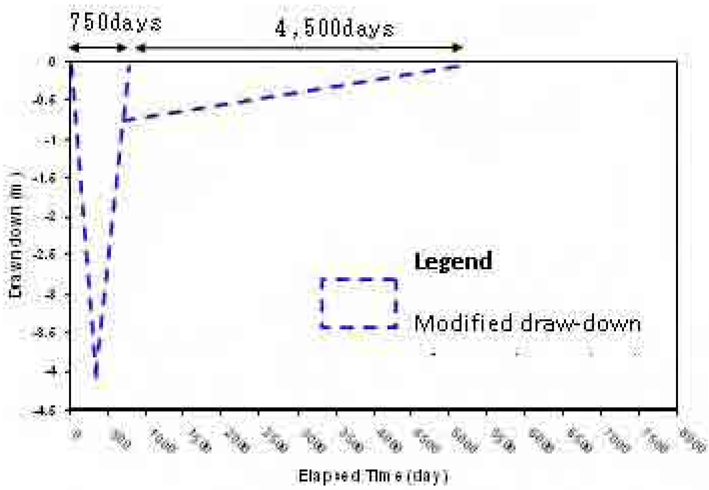
(1) Groundwater Level Draw-down by Pumping

Draw-down of groundwater level was analyzed by groundwater simulation in F/S as shown Figure-3.3-51. This result can be modified as shown in Figure-3.3-52. Moreover, it can be more simplified as shown in Figure-3.3-53. This simplified draw-down of groundwater level was used for the analysis.



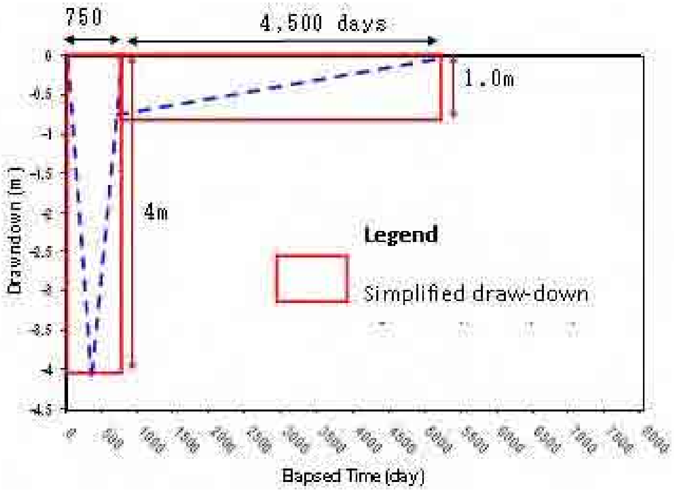
Source: JICA Study Team

Figure-3.3- 51 Draw-down of Groundwater Level by Simulation



Source: JICA Study Team

Figure-3.3- 52 Modified Draw-down of Groundwater Level (1)



Source: JICA Study Team

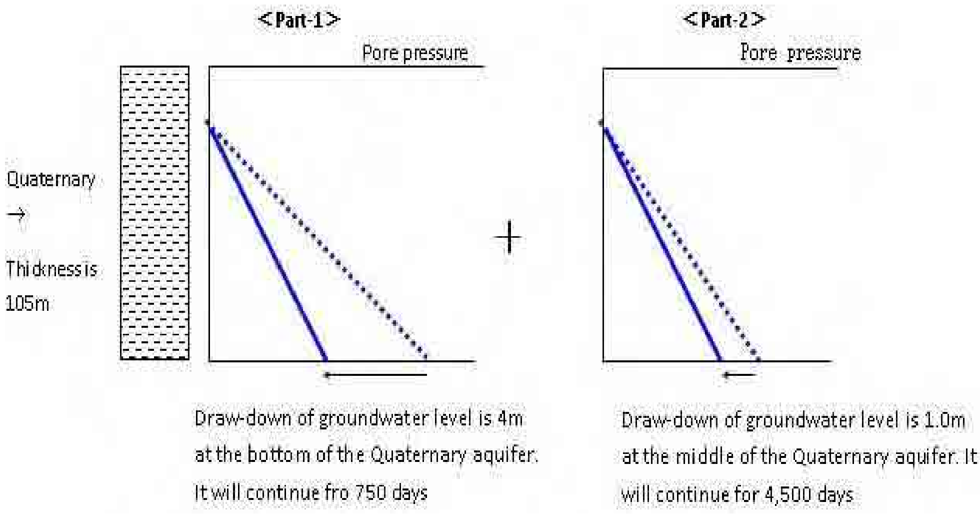
Figure-3.3- 53 Modified Draw-down of Groundwater Level (2)

(2) Land Subsidence of Quaternary

Referring to Figure-3.3-54, draw-down of groundwater level of the Quaternary aquifer was divided into 2 parts as below:

Part-1: 4m of draw-down of groundwater level at the bottom of the Quaternary for 750 days
Part-2: 1m of draw-down of groundwater level at the bottom of the Quaternary for 4,500 days

Land subsidence of Part-1 and Part-2 was calculated respectively, and total land subsidence was obtained by adding Part-1 and Part-2.



Source:JICA Study Team

Figure-3.3- 54 Draw-down of Groundwater Level of Quaternary

Soil mechanical parameters of the model for the Quaternary are the same as those in M/P Study. Draw-down of groundwater level was applied for the model, and land subsidence was calculated as shown in Table-3.3-16.

Table-3.3- 16 Land Subsidence of the Quaternary

Part	Draw-down of Ground-water level (m)	Final land subsidence (m)	Modified land subsidence			
			Duration of draw-down (days)	Time factor:Tv (-)	Consolidation ration:U (-)	Modified land subsidence (m)
Part-1	4.0	0.31	750	1.88×10^{-5}	0.0049	0.0015
Part-2	1.0	0.08	4,500	0.00011	0.0120	0.0037
Total						0.0052

Source:JICA Study Team

Relationship between Time Factor (Tv) and Consolidation Ratio (U) in Table-3.3-16 was calculated from approximation below: This relation is highly effective under Tv<0.3.

$$U= 2*\sqrt{(Tv/\pi)}$$

(3) Land subsidence of Base-rocks

The Tertiary and the Cretaceous rocks will be compressed in elastic deformation by pumping. Such a compression will recover as the groundwater level recovers. Therefore, land subsidence of the Tertiary and the Cretaceous will be the maximum when pumping is stopped. Then, it will reduce quickly as time goes.

Table-3.3- 17 Land Subsidence of the Tertiary and the Cretaceous

Layer	Thickness (m)	Draw-down of groundwater level (m)	mv (t/m^2)	Land subsidence (m)
Tertiary	95	4	0.000001	0.00038
Cretaceous	100	4	0.0000003	0.00012

Source:JICA Study Team

(4) Total land Subsidence

Total land subsidence is shown in Table-3.3-18.

Table-3.3- 18 Total Land Subsidence

Geology	Thickness (m)	Draw-down of groundwater level (m)	Land subsidence (m)
Quaternary	105	4	0.00520
Tertiary	95	4	0.00038
Cretaceous	100	4	0.00012
Total			0.00570

Source:JICA Study Team

As shown in Table3.3-18, the total land subsidence by pumping was predicted 0.0057m. Land subsidence by the Tertiary and the Cretaceous will completely recover with recovery of the groundwater level after pimping is stopped. Moreover, land subsidence of the Quaternary will also partially recover with recovery of the groundwater level. Therefore, final land subsidence will be smaller that shown in Table-3.3-18, and impact by land subsidence is negligible.

(5) Land Subsidence in Bogotá City

It is pointed out that land subsidence is currently taking place in Bogotá city. Mechanism of the land subsidence and relation with the proposed project is as follows.

a) Mechanism of Land Subsidence

Current land subsidence taking place within Bogotá city has strong relation with building construction works. Large excavation works are implemented for installation of foundation of buildings. Groundwater will flow into bottom of an excavation pit, and the groundwater will be drained out of the pit by pumping. Then, groundwater level around the pit will go down. As a result, land subsidence will take place. Mechanism of land subsidence is shown in Figure-3.3-55.

Excavation works for installation of foundation of building

↓

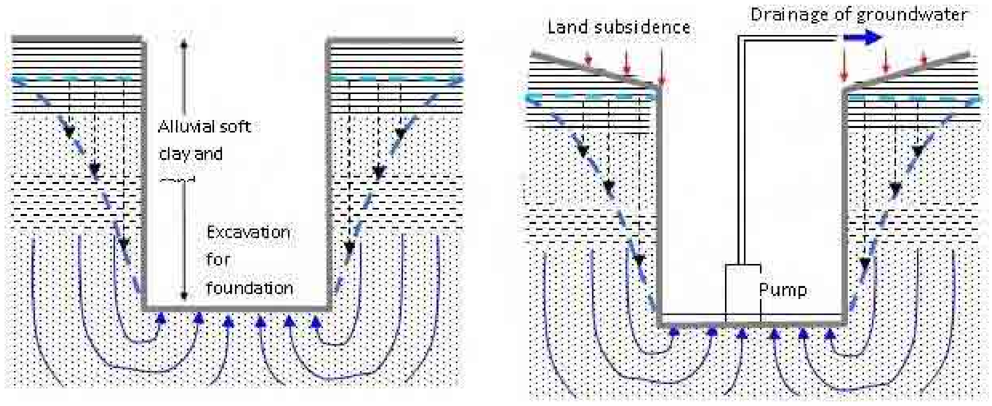
Groundwater will flow into excavation pit and be drained out of the pit by pimping

↓

Ground water level around s pit will go down, when large amount of groundwater is drained

↓

Land subsidence will take place by consolidation of soft alluvial clay



(a) After excavation (Before land subsidence) **(b) Drainage of groundwater and land subsidence**

Source:JICA Study Team

Figure-3.3- 55 Groundwater Flow by Excavation and Resultant Land Subsidence

This type of land subsidence will takes place near the ground surface. Mechanism of land subsidence is clear, and area of its influence is limited around the excavation pit.

b) Relationship between Proposed Project and Land Subsidence

Land subsidence related to the construction works is currently seen within Bogotá city at many places. Characteristics of the land subsidence of this type are as follows:

- Land subsidence is limited around excavation pits.
- Land subsidence is larger near an excavation pit, and it will become smaller as goes far from the pit. Such a land subsidence can be called as 'differential settlement', which has harmful influence to under-ground pipeline and building foundations.
- Land subsidence is relatively large even though draw-down of groundwater level is small, because of mechanical properties of soft alluvial clay around the excavation pit. It is sometimes extremely soft, and settlement as much as 1m can be seen in some places in Bogotá.

In the proposed project, the groundwater will be pumped-up from the deep Cretaceous rock. Land behavior by such a pumping is expected as follow:

- Draw-down of groundwater level by the pumping will occur in deep part of hard rock. Then, scale of settlement is small (less than 1cm).
- Local settlement at the deep part of the rock will appear equally distributed smaller settlement in the ground surface, which will not be identified as differential settlement. Therefore, there will be no impact on under-ground pipelines and building foundations.

Land subsidence by implementation of the proposed project is predicted much smaller than land subsidence currently taking place in Bogotá city

3.7. Operation/Maintenance and Institution

(1) Operation for Emergency Water Supply by Groundwater

Operation works of emergency water supply by groundwater are listed in the table below. With the development of the rehabilitation of the transmission and distribution network, point water supply can be made at the places of hydrants in the areas of the rehabilitated network. Operation works of network water supply are same as those for water supply at ordinary times. To shift to network water supply from point water supply, some transitional period will be necessary, when the checks of the control system are conducted.

Table-3.3- 19 Operation Works of Emergency Water Supply by Groundwater (1)

Emergency Water Supply	Facility	Operation Process	Personnel Requirement
Point Water Supply	Pumps, Generator	• Disconnect from remote control system • Switch on the generator (if electricity is not available) Facility Inspection (once/day) 1) Check the generator (appearance, vibration, frequency, temperature, change in color /shape, looseness, pressure, rotation, leakage, pipes, measuring instruments). 2) Check the electric current and voltage of the pumps. 3) Check dynamic water level by observation of the meter. 4) Check water quality (turbidity, sand, cleanliness around the well) by observation and by water quality checker.	- One operator for a well and one worker for water supply to water wagons or ordinary trucks with water tanks (2 shifts/day) - Contracts for distribution by water wagons or ordinary trucks with water tanks (vehicles and drivers) - One person for a water wagon or a truck to check the distribution
	Treatment Facility	• Disconnect from remote control system. Facility Inspection (once/day) 1) Check the storage of chemicals, structures, valves, injection system. 2) Water quality analysis by a water quality checker.	
	Distribution Facility	• Supply water to water wagon. • Check water quality by a water quality checker.	
	Building, Site	• Continue daily works for the security and maintenance of the building and the site.	- Service contract for the security and maintenance
Transitional Operation	Pump, Transmission Facility	• Check the remote control system. • Connect to the remote control system. • Connect to the transmission network.	- One operator for a well under supervision of engineers of the headquarters
Network Water Supply	Pumps	Facility Inspection (once/month) 1) Check operation of the pumps. In case some disorder is found, repair the pump. 2) Check static and dynamic water level by observation of the meter, and collect data of automatic water level for analysis. 3) Analyze water quality with the laboratory and by water quality checker. 4) Check automatic water level recorders.	- One team for around 30 wells, comprised of a senior technician and a junior technician for a team - Service contracts for regular facility inspection and well monitoring
	Treatment Facility	Facility Inspection (once/month) 1) Check the storage of chemicals, structures, valves, injection system. 2) Analyze water quality with the laboratory and by water quality checker.	
	Conveyance and Transmission Facility	Facility Inspection (once/month) 1) Check the pipeline (appearance, cracks on road surface, other construction works near to the pipe lines). 2) Check operation of the pump. In case some disorder is found, repair of the pumps.	
	Building, Site	• Continue daily works for the security and maintenance of the building and the site.	- Service contract for the security and maintenance

Source: JICA Study Team.

(2) Staffing for Emergency Water Supply by Groundwater

It is recommendable not to employ permanent personnel for emergency water supply only, but to respond with existing staff of Acueducto. Acueducto has already prepared contracts with companies that have water wagons or similar vehicles, by which they will provide the vehicle and drivers in case of emergencies, with the experience of the emergency case of Chingaza.

However, it is recommended for Acueducto to employ one senior technician and one junior technician for around 30 wells to operate emergency water supply by groundwater, as well as to implement periodical monitoring of groundwater resource at ordinary times.

Table-3.3- 20 Staffing for Emergency Water Supply by Groundwater

Type of Emergency Water Supply	Staffing
Point Water Supply	**Pumping, Treatment and Supply to Water Wagons** For operation of pumping, treatment and supply water to water wagons, one technician and a worker for a well are necessary. • Total number of required persons will depend on number of wells to be used for point water supply or conditions of available transmission and distribution facilities. • Technicians of Directorates of Water Supply and Water Supply Network of Corporate Management Office of Master System, as well as Management Office of Zones and Directorate of Technical Support of Corporate Management Office of Services to Client have to be dispatched. **Distribution** • Contract with the companies that have water wagons or similar vehicles. • One person from Acueducto staff for a vehicle is required to check the distribution by the contracted company. • Persons from Management Office of Zones and other Directorates of Corporate Management Office of Services to Client have to be dispatched. **Maintenance of Building and Site** • Service contract for security and the maintenance is recommendable.
Network Water Supply	**Pumping, Conveyance, Treatment and Transmission** • Network water supply will be implemented with automatic control system. • One senior technician and one junior one will be necessary to be employed by Acueducto for around 30 wells to manage operation of network water supply by groundwater. These personnel will also be in charge of checking the conditions of facilities and equipment as well as periodical monitoring of groundwater resource at ordinary times. • Outsourcing with service contracts is recommendable for regular facility inspection and well motoring. **Maintenance of Building and Site** • Service contract for security and the maintenance is recommendable.

Source: JICA Study Team.

(3) Strengthening of the Committee for Disaster Prevention and Attention of Emergencies

To render effective and prompt emergency responses including the actions shown in Table-3.3-19, it is recommended to strengthen the Committee for Prevention and Attentions of Emergencies as shown in Figure-3.3-56. The committee will consist of Directive Committee and Operative Committee. The Operative Committee is to be comprised of 1) Communication Group, 2) Rehabilitation Group, 3) Water Supply Group and 4) Support (Logistic) Group and 5) Zone Groups (one for each of the five zones). Each Zone Group will have i) Communication Team, ii) Rehabilitation Team, iii) Water Supply Team and iv) Support (Logistic) Team.

The Committees and each Zone Group, even at ordinary times, should hold meetings at least four times in a year to enhance the preparedness against the emergencies.

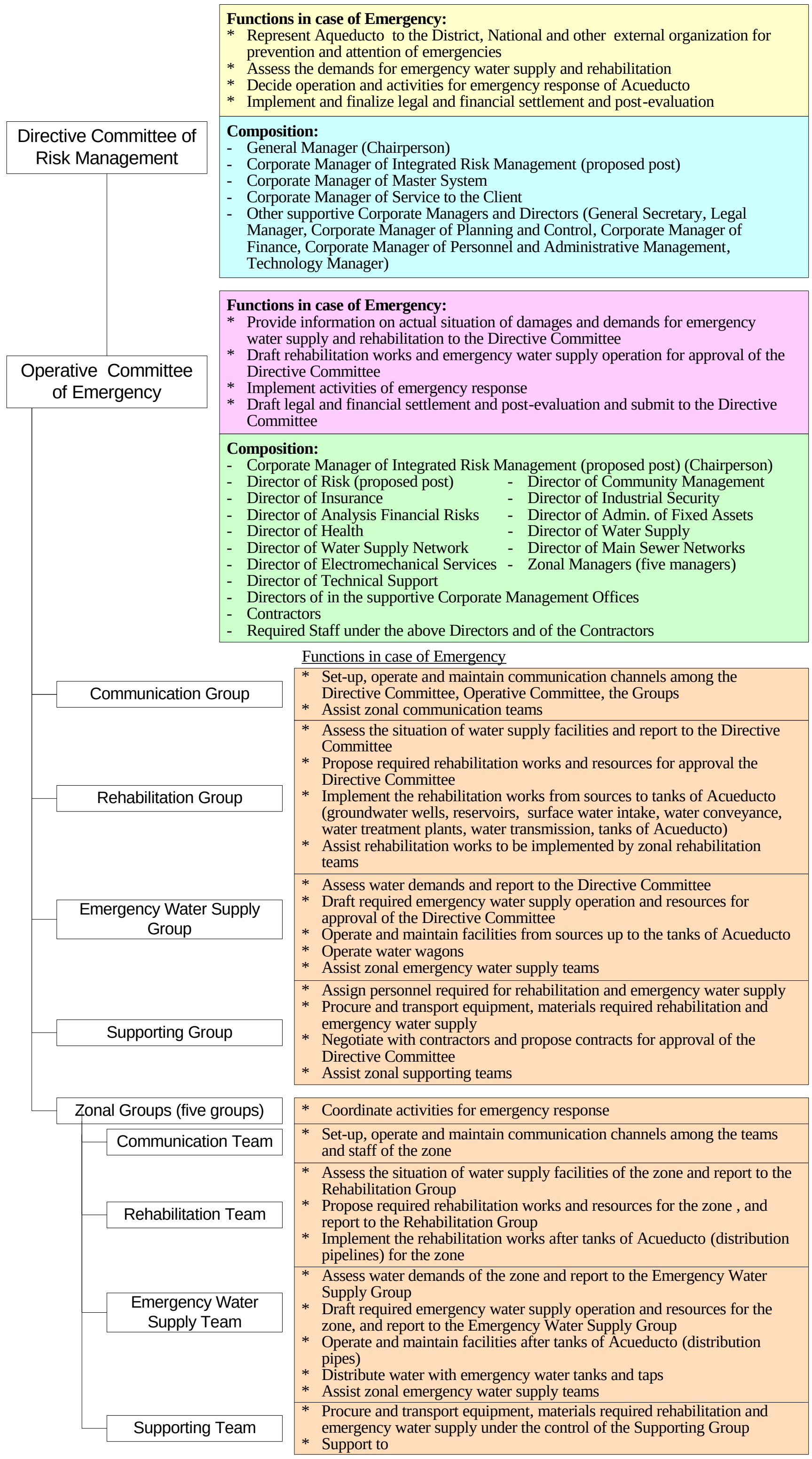
(4) Establishment of Directorate of Risk of Corporate Management Office for Integrated Risk Management

The directorate will be in charge of overall coordination throughout of Acueducto, and permanent staff could be comprised of the following several posts. The head of the directorate will be able to take the post of 2) or 3) in parallel.

1) Manager
2) An engineer who has overall knowledge on the system of Acueducto
3) A person who have general knowledge on society, economy, city planning and land use, and communities
4) A person specialized in communication and information
5) Secretary/administrative assistant

All of the staff of the directorate have to be trained, prior to or soon after the assignment, on laws and regulations of emergency prevention and attention, policies and plans of Acueducto, the Directorate of

Prevention and Attention of Emergencies of the District (DPAE), other related organizations and their functions in emergency response, psychology and behaviors of the people in emergency cases, etc.



(Source: JICA Study Team)

Figure-3.3- 56 Compositions and Functions of Committee for Disaster Prevention and Attention of Emergencies

(5) Establishment of Groundwater Division

Proposed staff and jobs of Groundwater Division in the Directorate of Water Supply of the Corporate

Management Office of Master System are shown in Table-3.3-21. The division is in charge of development and conservation of groundwater resource as well as operation of water supply by groundwater in cooperation with other divisions of the Corporate Management Office of Master System.

Except the period of point water supply, pumps, valves and treatment facilities can be controlled by remote control system. It is not necessary to employ personnel for conveyance and distribution of groundwater only. It is recommended that daily jobs for checking of facilities and equipment, and periodical monitoring of groundwater resource be implemented by utmost outsourcing. It is also recommended that planning and implementation of projects of groundwater development and conservation to be done at ordinary times be executed by utilizing external resources, such as consultants and contractors. Therefore, minimum personnel are proposed as shown below.

Table-3.3- 21 Organization to Manage Water Supply by Groundwater

Staff	Jobs
Chief of the Unit	• To manage groundwater development projects under supervision of Director of Water Supply • To manage water supply by groundwater in coordination with Division of Control Center of Directorate of Water Supply Network • To analyze well monitoring data, to report CAR and SDA, and to take necessary measures according to the results of the analysis.
Teams of Technicians (a Team is composed with a senior technician and a junior technician which will in charge of around 30 wells)	• To inspect facilities for by supervising contractors for the service • To take necessary measures when disorders of the facilities are found under supervision of the Chief. • To conduct well monitoring (water level and water quality) by supervising contractors for the service • To submit the monitoring data to the Chief • Other jobs ordered by the Chief
Administrative Assistant	• Administrative support

(Source: JICA Study Team)

3.8. Lesson from Kobe Seismic Disaster

There was serious seismic disaster in Kobe city in Japan. Water supply facilities of Kobe city were seriously damaged by the earthquake at that time. Emergency water supply of this disaster gave great lesson in formulation of emergency water supply plan for Bogotá.

(1) Outline of Kobe Seismic Disaster

Kobe earthquake occurred at 5:46 on January 17th, 1995. Outline of the disaster is as follows:

- Magnitude of the earthquake was 7.3 on the Richter scale, with depth of seismic center of 16km. It was strong local earthquake, with maximum acceleration of 818gal.
- The amount of people killed in the earthquake was 6,437 people. The 10,683 persons were seriously injured, and 33,109 persons slightly injured.
- As for house damage, complete collapse amounted to about 105,000 houses, and partial destruction amounted to about 144,000 houses.

Kobe city is located along the coastal line. Densely populated urban area spreads in plain in front of steep mountains. On the other hand, Bogotá city is located in mountain basin. Densely populated urban area spreads in front of steep mountains. There is similarity between Kobe and Bogotá in land use that urban area is developed in front of steep mountains.

(2) Damage to water supply facilities

Damage to water supply facilities is as follows:

- Suspension of water supply amounted to about 1,230,000 houses, and amount of monetary damage in water supply system was 56,000 Million Japanese yen.
- Damage of water pipelines amounted to 1,757 points, and the rate of damage are 0.44 point/km.

(3) Emergency water supply

Obstacle in emergency water supply

Many fires happened throughout Kobe city, immediate after the earthquake. It became impossible to use most of hydrants within Kobe city by damage of the earthquake. Fire fighting activities faced extreme difficulty without hydrants, and instead, the water wagons were used. The cause of delay in water supply and restoration of facilities was as follows:

- Road was destructed, and destroyed houses collapsed on the roads, which caused serious traffic congestion. The emergency water supply activities by water supply wagons suffered from traffic congestion, and vehicles for restoration worsk could not enter the sites.
- Identification of the leakage points of water pipelines took long time. There were so many broken points of water pipeline that water pressure at leakage points was too small to be detected.

Progress of emergency water supply

Emergency water supply begun by water wagons immediately after occurrence of earthquake. Progress of water supply by time was as follows:

Emergency water supply begun mainly for the shelters since half day after

a) Kobe city had around 50 number of water wagons. The aid for water supply from the surrounding cities and the Self-Defense Force begun from the next day. Water wagon was used for water supply by taking water from distribution tanks, where water was secured by function of the urgent cutoff valve.

b) With restoration of the water pipe, emergency water supply by installing temporary water taps at hydrants was performed.

c) The number of water-supply wagons changed between 300-400 sets/day, with peak of 432 sets/day, on 7 days after the earthquake. The water supply was almost recovered by one and half month after the earthquake, and the number of water wagon decreased sharply from that time. Finally, the activity with water wagons ended when the water service was completely restored by 2 month after the earthquake. (Fig-3.3-57 and Figure-3.3-58).

d) The road was cut off and traffic congestion occurred, then movement of water supply wagons were disturbed by collapse of houses. Therefore, there was non-efficiency in trip to the destination areas with great time.

Thus, the water supply activities by water wagons had left the problem in how to carry the water quickly.

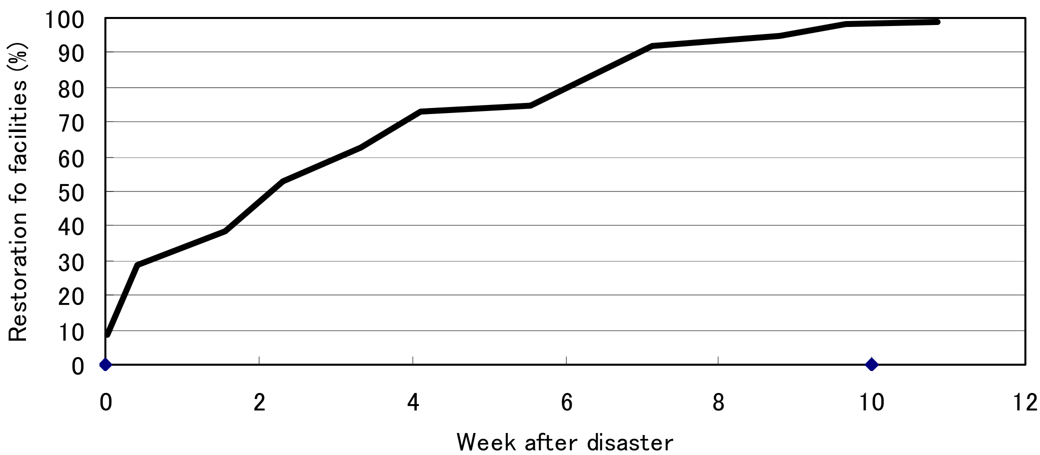


Figure-3.3- 57 Restoration of Water Supply System

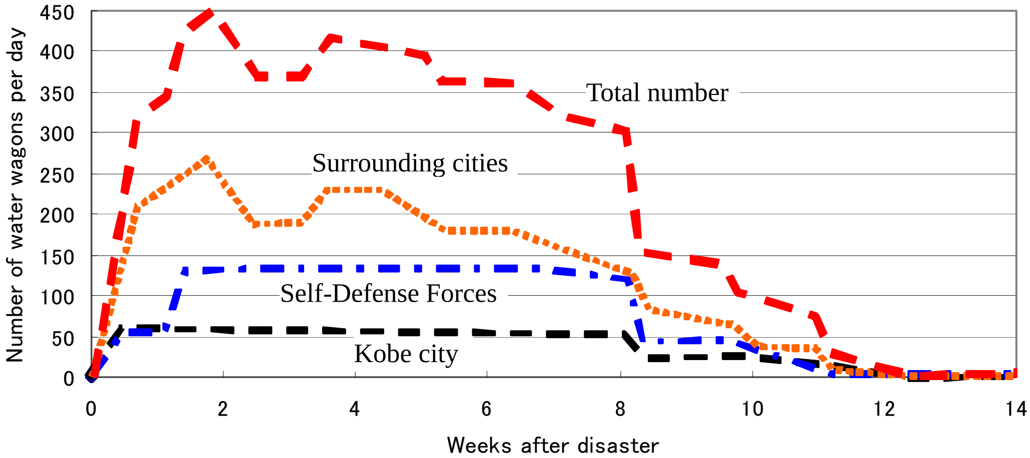


Figure-3.3- 58 Number of Water Wagons with Time

(4) Securing water by people

It was very difficult for people to secure water in emergency. It is not exaggerate to say that main activity of people at Kobe seismic disaster was to get water in emergency. Emergency water sources for people were below:

- Water from water wagon
- Bottled water selling at shops
- Wells, leakage water from broken water pipeline, river water.
- Water in pool in shelters.
- Water in bathtub in homes.

Drinking water requires high water quality, so it is limited to water from water wagons and bottled waters. The bottled water brought from shops was main water sources at immediate after earthquake. With restoration of water supply system, water wagons became main water sources for people. However, it was serious problem how to bring water. Water was brought from a water point to individual home on foot. Amount of water and distance possible for bringing water on foot was limited.

(5) Unit water consumption in emergency

Unit water consumption in emergency by water wagons was as follows:

Table-3.3- 22 Unit water consumption in emergency

Period	Unit consumption (ℓ/person/day)		
	Water wagons	Other water sources note)	total
2 week after disaster	9. 0	9. 0	18.0
2 weeks to ～6 weeks	9. 3	9. 3	18.6

Note) Water consumption from the other water sources besides water wagons is assumed as the same amount from water wagons

Source: JICA Study Team

(6) Lessons from Kobe Earthquake Disaster

Example of emergency water supply in Kobe seismic disaster gives many suggestions as shown below in formulation of emergency water supply plan for Bogotá city.

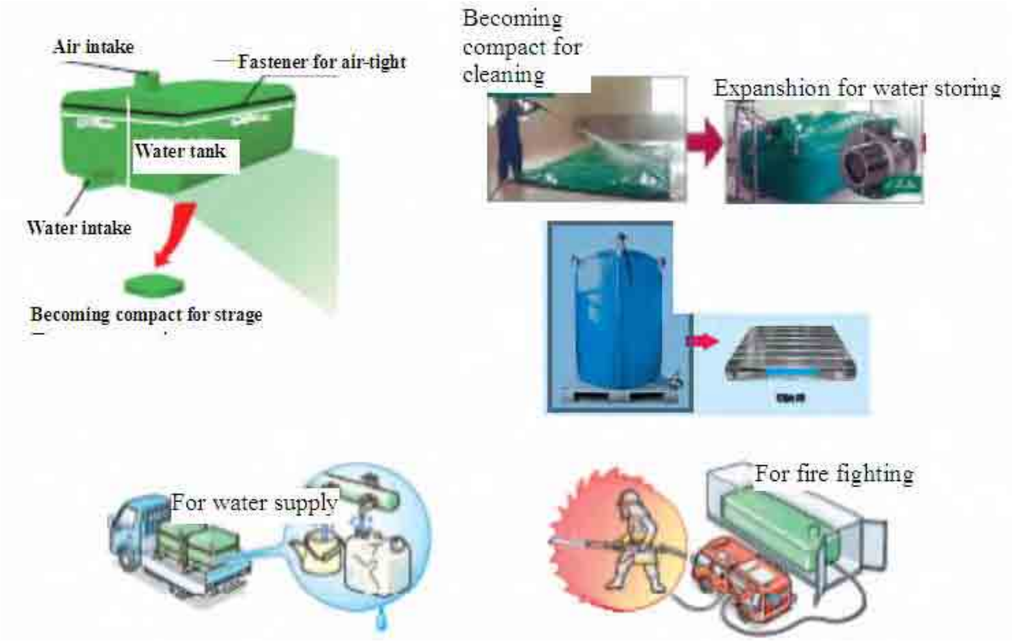
a) Seismic resistance for facilities

Water pipeline and main facilities should be reinforced for seismic resistance. Emergency cut-off valve, which will automatically work detecting strong vibration by earthquake, is efficient and should be installed to the existing tanks. This valve can secure water of tanks in emergency, water of which can be provided to water wagons.

b) Water wagons

Water wagons are main actor in emergency water supply, which was proved in Kobe seismic disaster. It is desirable to prepare and accumulate water wagons for emergency. However, it is not practical to buy large number of expensive water wagons for disaster, because it is impossible to predict when the disaster will happen. Therefore, it is recommended to prepare not water wagons but plastic water tanks to be loaded in small ordinary trucks and pick-up trucks (see Figure-3.3.-59 and Figure-3.3-60). Standard capacity of such tanks should be 1ton and 2ton, which can be easily obtained in Bogotá. Vehicles for water tanks can be pickup trucks of Acuedcuto or small trucks (2-4t) by lease. Such compact size trucks have higher mobility than big ones in emergency.

Figure-3.3- 59 Water Tank for Truck Loading



Source：Home page of ASANO Ltd.Co

Figure-3.3- 60 Light Plastic Water Tank for Truck

c) Preparation of emergency water

Water delivery by water wagons is difficult by suffering traffic congestion. Water delivery on foot also has limitation in weight and distance. Therefore, water should be stored in shelters beforehand. Stored water will become important water source before restoration of water supply system. In case of Kobe Disaster, most of water needed was water for toilets. For this purpose, water in pools and ponds should be prepared for emergency.

d) Relationship with surrounding municipalities for emergency water supply

Assistance for emergency water supply came to Kobe city from the surrounding municipalities and

Self –Defense Force. Kobe city had 50 water wagons at that time. Adding to it, many water wagons came to Kobe with 370 wagons/days at the peak time. Therefore, it is important to create relationship for cooperation and assistance for emergency water supply with surrounding municipalities and relating organizations.

e) Alternative water sources

This study proposed emergency wells for water supply. Existing private wells within Bogotá city also should be used for public water supply in emergency. SDA has registered all the wells within Bogotá city, and should list up which wells can be used for emergency to ensure cooperation from owners of the wells.

f) Emergency communication

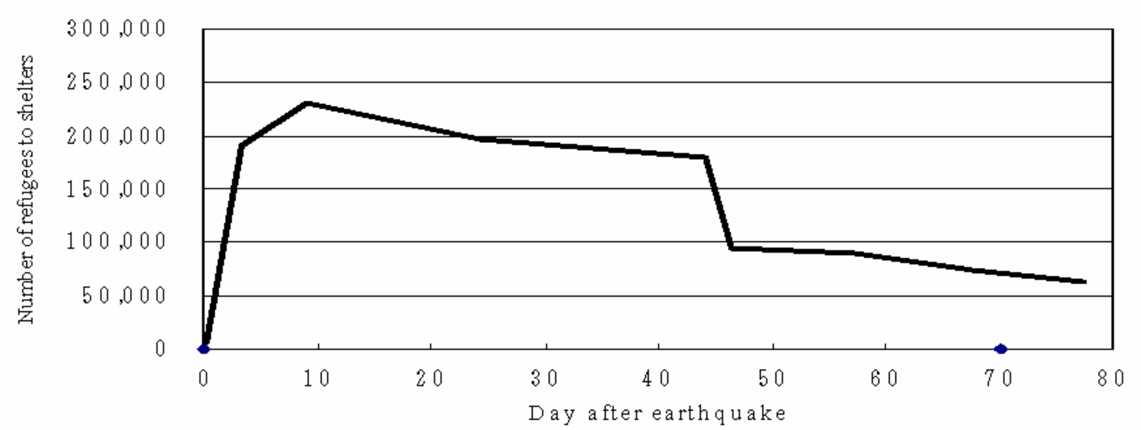
Information on where and when water wagons would come for water supply was given to people beforehand in Kobe earthquake. However, such information was sometime delayed or not delivered to people, which made confusion among the people. Such information is indispensable for stable life during disaster. Method to secure quick and stable communication should be created.

(7) Toilet in Shelters

Many people were forced to stay in shelters during earthquake disaster. Serious problem in their life in the shelter was use of toilet.

<u>Evacuee</u>

People who evacuated into shelters reached a maximum of 235,000 persons, eight (8) days after occurrence of the earthquake. Number of evacuees to shelters by time is shown in Figure-3.3-61. Officially registered shelter was not enough for people, and they evacuated into even un-registered shelters, such as a) schools (primary, middle, high), b) universities and colleges, c) facilities for social education, d) welfare facilities, e) residents' facilities, f) temples and shrines, g) companies facilities. Some people stayed in public parks with tents, others stayed inside cars parking in front of their homes.



Source: JICA Study Team

Figure-3.3- 61 Number of Evacuees by Time

<u>Number of Shelters</u>

There are 364 of facilities that were officially registered as shelters. Of which, 318 facilities were public schools and facilities, the others 46 were private schools. Besides, there are around 250 shelters that were not officially registered. Most of above shelters were occupied with the evacuees in Kobe seismic disaster. The number of shelters was around 500 immediate after the earthquake. Though number of evacuees reduced with restoration of infrastructures, number of shelters did not so much reduced, from 500 places at the beginning to 400 places at the end. Some people stayed for long period of time in registered shelters such as public schools (primary, middle, high).

Toilet in shelter

Temporary toilets were set in shelters. Number of the toilets was 524 sets on 4 days after earthquake, and it became a maximum of 3,000 sets on 2 weeks after the earthquake. Ratio of distribution of temporary toilet was 1 toilet for 80 people. Temporary toilet was not flush type toilet, so that vacuum trucks visited shelters for collecting. Use of temporary toilets was serious problem for the people in shelters.

Acuedcuto has to prepare and accumulate temporary toilets for shelters. Temporary toilet must be delivered to shelters quickly in emergency. Flush type toilet can not be available for temporary toilet; therefore, vacuum trucks must go to every shelter regularly.

3.9. Environmental and Social Consideration

3.9.1. Introduction

Based on the discussion results with Acueducto, the Emergency water supply projects, proposed under the M/P, has been agreed upon based on the following prioritized projects. Under the M/P, an Initial Environmental Examination (IEE) was carried out based on the JICA Guideline for Environmental and Social Considerations.

In this F/S, Screening at the IEE level was conducted again, by analyzing assessment results considering, i) the environmental and social impacts caused by each prioritized projects and ii) the environmental requirements of the Government of Colombia. In addition, regarding any projects that might possibly cause negative environmental impacts, the mitigation measures were recommended for such impacts.

Table-3.3- 23 Priority of Projects Proposed under the M/P

Priority	Name of the Projects
Pilot Project	Pilot Project by Groundwater
First period Project	Eastern Project
Second period Project	Southern Project
Third period project	Yerba Buena Project

Source: JICA Study Team

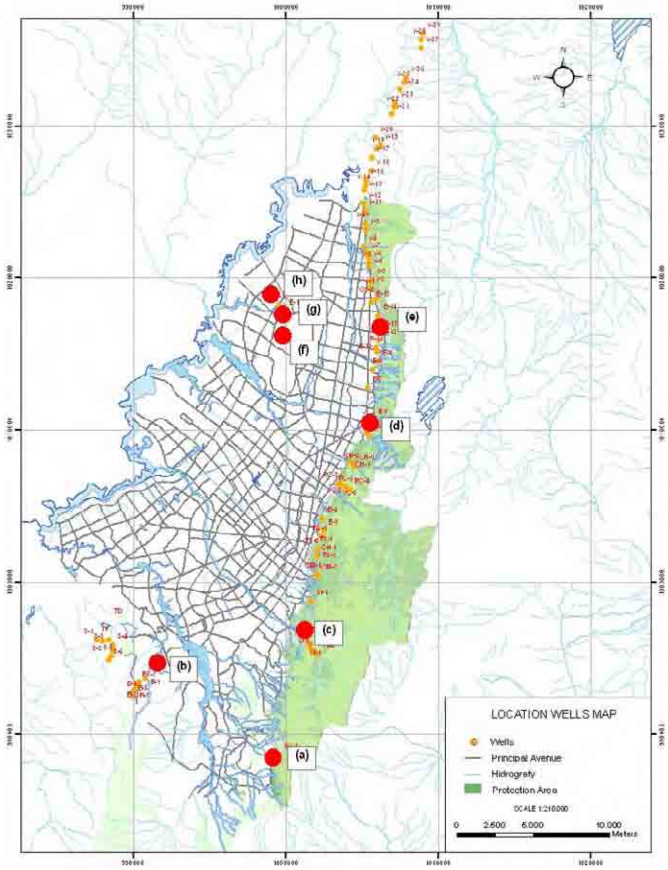
3.9.2. Environmental and Social Conditions in and around the Projects sites

The environmental and social conditions in and around the each project site are shown in Table-3.3-24. The maps of each project site are provided as Figure-3.3-62 and Figure-3.3-63. Detail conditions of the entire project site for well construction and environmental and social considerations are shown in of the Supporting Report.

Table-3.3- 24 Environmental and Social Conditions in and around of the Project Sites

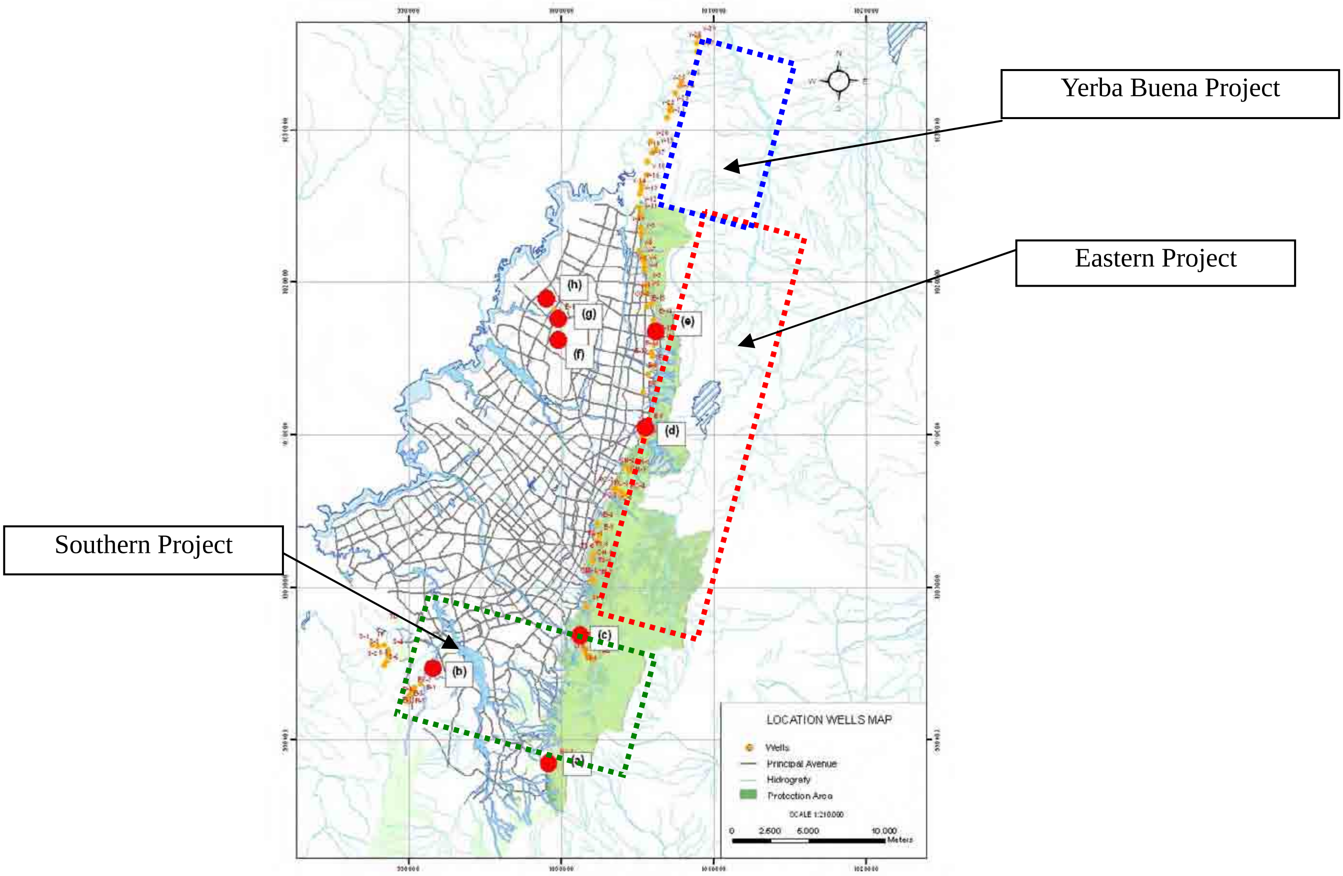
Name of Project	Project Site	Social Conditions	Environmental (natural) Conditions	Pollution
Pilot Project	Pilot Project by groundwater	Among the 9 project sites, at 6 sites wells exist, at 1 site a well is being drilled by JICA, and at 2 sites wells are to be drilled. The 2 existing well sites are located on the private property of a restaurant and a school. The last 7 sites are owned by Acueducto. The sites are not located within forest protection area except Viterma. Vehicle traffic is prevalent. Sufficient space is secured for drilling works, and there is little effect on the residents around the site.	Among the nine project sites, 6 are located within the urban area. There are no natural forests. In Ciudad Bolivar site, where a large pasture and no natural forest spread, a well already exists by JICA. In Usme site a well also exists by JICA. A natural forest does not exist at the site. The Viterma project site is located within the land owend by Acueducto. Some deforestation (secondary forest) and earthworks are required. Viterma is however located within forest protection area. No resettlement.	None
The first period Project	Eastern area	The project sites are designated at the foot of the Eastern hills, at the roadsite of the urban area. In the southern area of the Eastern hills, residences of low-income group are densely built near to the hill side. On the other hand, the northern area of the Eastern hills is urbanized and becoming residences and commercial area of middle/high-income group. This area has the tendency to develop further as a commercial area. Vacant lands are selected as project sites. Resettlement is not required. The land is privately owned.	The project sites are within the urbanized area, where natural forests do not exist and endangered fauna andflora are not a concern. In the Eastern hills, there is no major rivers. Drinking water is taken from some streams, but water intake amounts to only about 1% of total water supply. In the forest protection area, strict administrative control is enforced regarding the any construction of new facilities. No deforestation is allowed.	None
The second period Project	Southern area	The urban area of Southern hill is occupied by mostly residences of low-income group and commercial area. Acueducto supplies water to the Soacha city, which also includes illegal houses. Public safety is not good. The project site is located within a pasture, which is higher in elevation than the urban Area. . A single landowner owns the project site.	The Southern hills represents gentle slopes with 2,700～3,000 m elevation. Geologically, the entire area, including the project site, is covered by the Cretaceous rocks. The urban Area of this area is densely populated with no natural forest. However, the project site is located within a pasture, with no natural forest, and the no endangered/rare fauna and flora are observed. Resettlement is not required.	None
The third period project	Yerba Buena Area	The project sites are located within a pastured land of the suburb of Bogotá city, where a wide area of floricultural land exists, and a few houses are built. The sites are located at the roadside of 7th Avenue, providing a convenient access. The sites are not located within Bogotá city, but within Sopo and Chia cities. The sites are rather far from the Bogota city with high water demand in case of emergency. It makes the disadvantage of the sites. The sites are not located within the Acueducto water supply Area. CAR is responsible for the issuance of drilling permits.	The Bogotá plain was originally marshlands, but the project sites do not include lakes or marshes. The sites are not located within a forest protection area. The project site is an extensive pasture area where a natural forest does not exist.	None

Name of Site	No. of Planned Wells
(a) Usme	EX-3 Drilled by JICA
(b) Ciudad Bolivar	EX-2 Drilled by JICA
(c) Vitelma	E-1 Existing Well
(d) La Aguadora	E-5 Drilling works is on-going
(e) La Salle	E-14 Existing Well
(f) Suba tank	ST-2 Planned well to be drilled
(g) Suba	E-16 Existing Well
(h) Mariscal Sucre	E-17 Existing Well



Source: JICA Study Team

Figure-3.3- 62 Location of Pilot Sites



Source: JICA Study Team

Figure-3.3- 63 Location of Project Sites: First – Third Project Periods

Photo- 1 Pilot project site (JICA exploratory well)

Photo-2 Pilot Project site (Acueducto well)

Photo-3 Eastern project site (Bogotá city, along main 7th avenue)

Photo-4 Southern project site

Photo-5 Yerba Buena project site

Figure-3.3-64 Situation of Project Site

3.9.2. Estimated Environmental and Social Impact

(1) Pilot Project

The project sites are owned by Acueducto, except for those located in Suba and Mariscal Sucre. The

Suba site is located on the private property of a restaurant, and the Mariscal Sucre site is located on the property of an army school. Both locations have Acueducto wells, and both owners of the sites agree to maintain current status. However, new contracts of land lease are required before any activities can be carried out at these sites. Resettlement is not required at both sites. The Viterma site is located in Acueducto property of water sedimatation ponds, which is not in use now. The drilling of La Aguadura well was completed. Other environmental and social considerations, including the resettlement, are not required for the pilot Project sites.

(2) The First Period Project (Eastern Project)

There are 33 project sites planned. The project sites are located at the foot of the Eastern hills. Project sites are located in the vicinity of a residential area. Vacant land was selected for the sites, and therefore, resettlement is not required. Most of the sites are, however, located within private land. Land acquisition or lease is therefore required. Presently in the proposed project site, construction of new buildings has not been planned, but it is assumed that in the future a building may be constructed at the site. However, it should be noticed that project sites located along the 7^{th} Avenue have significantly advantage for emergency water supply.

Due to the location of project sites near the residential and commercial area, there will be an impact of noise and vibration on the neighborhood, during the transportation of the drilling machines, and during construction. As for the drilling mad, the IDEAM standard for drilling mad treatment should be strictly kept.

(3) The Second Period Project (Southern Project)

The project sites are located within area where residences of low-income group are densely distributed. However, all the sites are selected avoiding the necessity of the resettlement. The sites are not located in forest protection area. In the Soach area, all the project sites are property of one landowner. Negotiation for land acquisition or lease is necessary. The project sites are located in a pastured area that does not have any houses or forested land. These sites have ideal condition, from the geological view point, so that sufficient water from wells can be expected. Negative environmental and social effects are not expected.

The project sites in Ciudad Bolivar area are also located in private land. The project sites are located in a pasture similar to the Soacha Area. Both during and after the exploratory wells by JICA (EX-2) in 2008, neither environmental nor social impact ocuured

In the Usme Area, another explotarioty well of JICA (EX-3) was completed. Negative environmental and social impact did not occur. However, the expected amount of water was not secured from the well. Therefore, Usme Project was given up.

(4) The Third Period Project (Yerba Buena Project)

There are 17 wells planned in the Yerba Buena Area. The project sites are not located in Bogotá city, but belong to Chia and Sopo municiparities. The sites are located in private land; therefore land acquisition or a lease agreement is required. The sites are located in a pasture and grassland; therefore resettlement is not required. There is not forest protection area in the site. The sites are located at the roadside; therefore access will not be an issue. Sufficient construction space is available. Environmental and social considerations are not assumed to be an issue. Furthermore, the project sites dose not belong to the Bogotá city, the administrative agreement between relating cities is necessary. Even if there is no issue from the viewpoint of environmental and social consideration, the area is relatively distant from the Bogotá city with high water demand in case of emergency.

(5) Scoping

Scoping at the IEE-level was reviewed again by analyzing assessment result for environmental and social considerations on prioritized projects, and at the same time, taking into account of the institutional requirements of the Government of Colombia. The results of Scoping are shown in Table-3.3-25.

(6) Result of the Second Scoping

Table-3.3- 25 Scoping Results

No.	Likely Impact		Project Site: Pilot Project	Project Site: The first period Project (Eastern Project)	Project Site: The second period Project (Southern Project)	Project Site: The third period project (Yerba Buena Project)
1	Social conditions	Land acquisition / Involuntary resettlement	Resettlement is not required. 6 sites of 8 project sites are owned by Acueducto, and other 2 sites are already constructed wells. Land-owner has agreement with construction of new facilities. Rating: B	Half of the project sites are private lands. Land acquisition or agreement of lease is required. Others are owned by Acuedcuto. No resettlement is requires at all sites of the Project. Rating: B	Project sites do not require resettlement. Project sites needs negotiation of land acquisition or lease with the landowners. Rating: B	Project sites are located on private land. Resettlement is not required. Rating: B
2	Social conditions	Local economy	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
3	Social conditions	Traffic/ existing public facilities	When transporting drilling equipment, road traffic is likely to be affected. Negative impacts on the neighborhood are not expected because of enough space in the sites. Rating: B	The urban area has a lot of traffic. Road traffic is likely to be affected during transporting drilling equipment and during construction. Rating: B	To access the project sites, drilling machine and equipment must pass through a densely populated urban area. Road traffic is to be affected. Safety measures are required. Rating: B	Project sites are located at the roadside, and traffic is likely to be few. Residents do not live around the project sites. Rating: B
4	Social conditions	Split of communi-ties	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
5	Social conditions	Cultural heritage	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
6	Social conditions	Fishing rights, water rights and right of common	Wells for the projects already exist, or drilling permits have been obtained for project sites. Rating: B	Drilling permits from SDA is required. In casa of the emergency water supply by groundwater, water right is not required. Rating: B	Drilling permits is required from CAR Rating: B	Drilling permits is required from CAR Existing water rights will not be violated by implemantion of this Project. Rating: B
7	Social conditions	Sanitation	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
8	Social conditions	Wastes	Treatment of drilling mad is required. Rating: B	Treatment of drilling mad is required. Rating: B	Treatment of drilling mad is required. Rating: B	Treatment of drilling mad is required. Rating: B
9	Social conditions	Hazards (risk)	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
10	Environmental (natural) conditions	Topogra-phical and geogra-phical features	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
11	Environmental (natural) conditions	Soil erosion	None. Rating: D	Project sites are located within the urbanized area. Therefore, negative effect on the soil is not expected. Rating: D	Project sites are located within pasture. Therefore, negative effect on the soil is not expected. Rating: D	None. Rating: D
12	Environmental (natural) conditions	Ground-water	Lowering of groundwater level is expected. Rating: B	Lowering of groundwater level is expected. Rating: B	Lowering of groundwater level is expected. Rating: B	Lowering of groundwater level is expected. Rating: B
13	Environmental (natural) conditions	Hydrologi-cal conditions (lake and river system)	Only Vitelma sites are located near a river, but negative effect on the hydrological impact is not expected. Rating: D	Project sites are located in urbanized area. Therefore, a negative effect on the water environment will not occur. Rating: D	Project sites are located in pasture. Deforestation is not necessary. Therefore, a negative effect on the water environment will not occur. Rating: D	Project sites are located in pasture. Deforestation is not necessary. Therefore, a negative effect on the water environment will not occur. Rating: D

No.	Likely Impact		Project Site			
			Pilot Project	The first period Project (Eastern Project)	The second period Project (Southern Project)	The third period project (Yerba Buena Project)
14		Fauna, flora and biodiversity	Viterma site needs some deforestation (secondary forest). A negative impact on the ecosystem will not occur. R ating: D	The project sites are located in the urbanized araa, and there is no natural forest. A negative impact will not occur on animals and plants. Rating: D	The project sites are maintained as pasture, and there is no natural forest. A negative impact will not occur on animals and plants. Rating: D	The project sites are maintained as a pasture. A negative effect will not occur on animals and plants. Rating: D
15		Landscape	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
16	Pollution	Air pollution	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
17	Pollution	Water pollution	As for the drilling mad, the IDEAM standard for drilling mad treatment should be strictly kept. Rating: B	As for the drilling mad, the IDEAM standard for drilling mad treatment should be strictly kept. Rating: B	As for the drilling mad, the IDEAM standard for drilling mad treatment should be strictly kept. Rating: B	As for the drilling mad, the IDEAM standard for drilling mad treatment should be strictly kept. Rating: B
18	Pollution	Soil contami-nation	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
19	Pollution	Noise and vibration	Noise and vibration during construction works are assumed to have an effect on the surrounding neighborhood. Rating: B	Noise and vibration during construction works are assumed to have an effect on the surrounding urbanized area. Rating: B	Project sites are located in a large pasture. Therefore, a slight effect on the neighborhood will occur. Rating: D	Project sites are located in a large pasture. Therefore, a slight effect on the neighborhood will occur. Rating: D
20	Pollution	Ground subsidence	Land subsidence will not occur because lowering the groundwater level is small. However, continuous monitoring is necessary. Rating: B	Land subsidence will not occur because lowering the groundwater level is small. However, continuous monitoring is necessary. Rating: B	Land subsidence will not occur because lowering the groundwater level is small. However, continuous monitoring is necessary. Rating: B	Land subsidence will not occur because lowering the groundwater level is small. However, continuous monitoring is necessary. Rating: B
21	Pollution	Offensive odor	None. Rating: D	None. Rating: D	None. Rating: D	None. Rating: D
Overall rating			B	B	B	B

Ranking Criteria:

A: serious impact is expected B: Some impact is expected C: Extent of impact is unknown D: No impact is expected

(7) Compliance with Lows, Ordinance and Standards of Governments of Colombia

The projects must comply with laws, ordinance and standards relating to environmental and social consideration established by the governments that have jurisdiction over the project site (including both national and local governments). Regarding groundwater development, an environmental license is not required under MAVDAT (2005 Government order 1220). Also, an Environmental Impact Assessment (EIA) is not required.

The following permits are required for the development of groundwater:

a) Well drilling permit issued by SDA (Resolucion. 1207) for construction works in the Bogotá urban area regulated in POT.
b) Well drilling permit issued by CAR for construction works outside Bogota urban area regulated in POT.
c) Water right permit issued by CAR, when the well is used for usual water supply. However, this Project is for emergent water supply, so that water right is not required.
d) Others: According to the environmental protection area ordinance (Zona de Manejo y

Proteccion Ambiental), no facility can be built within 30 meters from the center of a river. Well drilling must follow this ordinance.

Table-3.3-26 shows the results after the compliance of requirements of the Governments.

Table-3.3- 26 Result after the Compliance with Requirements of the Colombian

Planned Projects	Screening Results	Environmental and social requirements of the Recipient Governments	Final Screening
Pilot Project	B	A permit is not required for sites where wells already exist. For the la Aguadora site and Suba tank site, permits were obtained during JICA study.	B
Eastern Project	B	Proposed wells are located in Bogota city area. Drilling permit must be obtained from SDA.	B
Southern Project	B	The sites in Ciudad Bolivar, which are located outside the Bogotá urban area, need drilling permits issued by CAR is required. The sites in Soacha area, which is also located outside Bogotá urban area, need drilling permits issued by CAR.	B
Yerba Buena Project	B	The project sites do not belong to Bogotá city, but to Sopo and Chia city. Administrative agreements between above cities are required. Regarding well drilling, permits issued by CAR are required.	B

Ranking Criteria:

A: serious impact is expected

B: Some impact is expected

C: Extent of impact is unknown (Examination is needed. Impact may become clear as study progress)

D: No impact is expected

(8) Result of Final Scoping

As a result of final screening based on the guidelines of JICA, with consideration of the environmental requirement of Colombia, the planned Project may not cause significant adverse impact on surrounding environment and society. Therefore, the planned Projects, in total, are assumed to be JICA Category B.

(9) Recommended Mitigation Measures

Regarding the assumed environmental and social impacts by the project, the mitigation measures as listed below are recommended for the implementation of the planned projects. In the case of groundwater development, Environmental License and EIA (Environmental Impact Assessment) are not required in accordance of requirement of Colombia. As the purpose of the project is emergency water supply, the monitoring is also not necessary. However, suitable monitoring should be carried out on water quality of groundwater from the wells. In addition, the lowering of groundwater level and land subsidence caused by water pumping should be carefully monitored.

(10) Land Acquisition

Project sites located in Southern hills have ideal condition, from view points of hydrogeology and environmental/social impacts. Considering such an advantage, negotiation on land acquisition and land lease on project sites should be quickly started in order to promote the project.

About the land acquisition in proposed project, ACUEDUCTO will directly negotiate about land acquisition or leasing with land owners. The acquisition procedure is based on a general estate procedure.

As same as many public works, Acueducot can implement expropriation for public construction for water supply facilities following Act. 56 of 1981; "Rules on Public Works of electricity generation and aqueducts regulating expropriations and rights of property affected by such construction" and Act.142 of 1994; "Law on Public Services". Negotiations are performed through a court of law. On the other hand, Acueducto will pay cost for land acquisition or leasing to land to owners as compensation.

(11) Obtaining drilling permits

As mentioned in "Compliance with Lows, Ordinance and Standards of Government of Colombia" (refer to 3-9-3, (2)), permits for such as well drilling are required for this Project. The executing agency must prepare the required documents for each permit.

(12) Traffic and facilities for living

It is anticipated that there may be impacts to transportation in and around the project area as results of, i) transporting drilling machine, equipment and materials into the sites, ii) carrying out well drilling works, iii) constructing water treatment facilities, etc. The executing agency needs to contact with related authorities (city traffic department, transportation police, etc.) in advance to obtain a road permit. Accordingly, it will be necessary to deploy traffic control personnel when Project construction is in progress. In addition, safety measures are to be performed during the construction period, based on the applicable safety manual.

(13) Water pollution (treatment of drill sludge)

The drilling mad (with bentonite) generated from well drilling will be treated in mud pit, concrete pits, or tanks, in order not to drain the mad into roads and rivers. Drilling mad treatment shall follow IDEAM standard guidelines.

(14) Noise and vibration

Because the Project site is located in urban area, there will be an impact by noise and vibration on immediate surrounding area. For this project, the usual method will be sufficient to mitigate this problem. For example, implementation of the exploratory drilling at Ciudad Bolivar and La Aguadora site did not make any complaints from residence near the sites.

1) Lowering of the groundwater level

Lowering of groundwater level by implementation of the proposed project was predicted in M/P Study. According to the result, lowering of groundwater level of Quaternary aquifer is less than 4m**.** This project is for public water supply for emergency in case water supply by Acueducto is suspended, consequentely period of the emergency water supply is assumed less than 9 month. Groundwater use for emergency water supply must have higher priority than other groundwater use by private sectors, and impact to the groundwater level occurs during short period. It can be said that lowering of groundwater level by proposed project can be accepted.

(15) Land subsidence

Land subsidence by implementation of the proposed project was predicted in M/P Study. According to its result, the land subsidence is calculated less than 5mm. Land subsidence occurs mainly in the Quaternary soft clay. However, in the proposed project, groundwater will be pumped up from the Cretaceous hard rocks, and pumping period is less than 9 month. Because of reason above, land subsidence is calculated as small as negligible.

3.10. Design and Cost Estimate

3.10.1. Design

The basic design principle in the M/P shall be to comply with the techniques and technical levels actually adopted in Acueducto. Moreover, economic factors such as initial investment, operation and maintenance costs shall be considered in the design. Furthermore, equipment and materials were selected from items procurable in Columbia with a view to enabling the long-term sustainable operation, maintenance and after-service of the equipment.

(1) Well Design

American standards are frequently adopted in well construction projects in Colombia. Accordingly, Colombian standards and American standards shall be applied for implementation of the Project.

a) Civil engineering works

Road construction:	Normaas Invias
Conduit installation:	Reglamento Tecnico del sector de Agua Potable y Saneamiento Basco (RAS-2000)
Concrete structures:	Normas Colombianas de Diseno y Construccion Sismoresistente (NSR-98)

b) Electrical works

Codigo Electrico Nacional Colombiano (CEC) Resolucion Numero 18 0466 de (2-Abril 2007)

Designs for well pumps, submersible motors and auxiliary equipment were decided with a view to securing international competitiveness and quality, by comparing the specifications and capacity of international manufacutures of deep well possesses agents in Bogotá.

(2) Design of Power Receiving Equipment

- Power shall be supplied to the well pumps and treatment facilities, etc. from the Bogota power company. Moreover, the same types of power supply facilities, as used to supply power to Acueducto pump station, have been designed.
- Power receiving equipment comprises cutout switches (with fuse), lightning arresters and step-down transformers. IEC265, IEC099 and IEC076 were adopted as the manufacturing standards for above equipments.
- Designs for emergency generators were decided with a view to securing international competitiveness and quality, by comparing the specifications and capacity of two international generator makers (Denyo and Cummins) that possess agents in Bogota.

(3) Design of Power Distribution Equipment

- IEC60439 was adopted as the manufacturing standard for receiving panels, distribution panels and motor control panels.
- Armored XLPE (IEC60502) will be used for the low pressure power cable, and cable core size will be set so that voltage drop on motor starting is no greater than 6%.
- PVC-PVC (IEC60502) 2.0 mm2 will be used for control cable.
- Soft starters and soft stop circuits will be installed in the site control panels of motors. Not only can these limit motor starting current to reduce the core size of power cables, but they are also effective for preventing water hammering inside pipelines at the starting and stopping of pumps.
- Automatic starting and stopping shall be adopted for control of well pumps.

(4) Design of Conveyance Pipes

Colombian PVC (1.3 Mp pressure specifications), which is widely adopted in Acueducto, shall be adopted for underground conduits and water conveyance pipes. Concerning aboveground pipes, since there is problem that PVC pipes will suffer from degradation caused by ultraviolet rays, carbon steel pipes for general use shall be adopted.

(5) Design of Water Treatment Facilities

- According to the results of water quality analysis in the exploratory wells, groundwater quality of wells is good, and concentration of Fe and Mn are only slightly exceed the potable water standards of Colombia. Accordingly, simple filtration units shall be adopted in the Project.
- Simple water treatment facilities adopted in Colombia are broadly divided into a) pressure filtration and b) gravity filtration. In the Project, the pressure filtration system shall be adopted because overall cost for initial installation, operation and maintenance can be reduced. The reson is: method above enables residual pressure to be used convey the treated water. It results in treatment time to be shortened, and then equipments to be made compact, which make no

need of receiving tank.

- The Water Treatment facilities will comprise preliminary chlorine injection instrumet, pressure filtration equipment and post chlorine injection instrument.

(6) Building and Plant Equipment

- Since the distribution panels installed in the water treatment facilities will be indoor specifications, the minimum electricity house will be required. In line with the existing pump house, etc. of Acueducto, the building structure will comprise reinforced concrete pillars and block masonry walls. Furthermore, the minimum required toilets will be provided inside the building for sanitary purposes.
- Security fences shall be installed around the well and treatment facilities in order to ensure safety. Also, outdoor lights shall be installed on facility grounds.
- Access roads to the facilities and inside the facilities shall be provided for passage by water trucks and large vehicles, etc. Roads shall comprise simple paving and be 4 m in width.

3.10.2. Cost of Project

The rough project cost was eatimated as of October 2008, assuming international competitive tender. As for the exchange rate, the average values for 6 months before the final day of October 2008 have been adopted, i.e. US$1 = 1,912.15 Col$, 1 yen = 18.10 Col$. (Source: Bank of Columbia, Tokyo Mitsubishi UFJ Bank).

(1) Construction Cost

- The appropriate unit cost for well construction works was calculated from unit price for exploratory wells drilling by JICA in 2007 and the tender price for exploratory wells drilling by Acueducto 2008.
- Unit prices of equipment and materials for well pumps, power receiving equipment and water treatment equipment, etc. were set upon adopting the minimum prices obtained in estimates from agents and retailers in Bogota.
- Concerning piping works, building and civil engineering works, the proprietary unit prices used by Acueducto in 2008 were adopted.

(2) Land Acquisitions

The minimum required area shall be appropriated for the well facilities and water treatment facilities. Land acquisition prices were set through using the latest land unit prices in each area used by the land acquisition department of Acueducto.

(3) Engineering Fee

In view of the scale of the project, it will be necessary to employ a consultant to implement it. 10% of the construction cost was appropriated as the expenses of the consultant conducting the implementation design and works supervision.

(4) Administration Cost

The administration cost comprises a) cost for consultant emproyed by Acueducto, b) the overheads and administration expenses entailed by land aquisition, and c) the management costs incurred during construction, etc. This was calculated as follows: (Construction cost + land acquisition cost + design cost) x 1%.

(5) Contingency

It is assumed that the project works will be actually executed between 2012 and 2018. Meanwhile, since the project cost was estimated at the current time, future budgets will contain numerous uncertain elements. Accordingly, the contingency was included in the budget to compensate for these uncertain elements. This was calculated as follows: (Construction cost + land acquisition cost + design cost + management cost) x 10%.

(6) Outline Project Cost

Table 3.3-27 indicates the rough project cost.

Table-3.3- 27 Rough Project Cost **(Unit: 1,000 Million Col$)**

Item	Phase I	Phase II	Phase III	Entire Project		
1. Construction Cost	54.35	18.73	26.53	99.61	Mil. US$ 54.09	Mil. Yen 5,503
2. Land Acquisition	1.00	0.10	0.19	1.29	Mil. US$ 0.67	Mil. Yen 71
3. Engineering Fee	5.44	1.87	2.65	9.96	Mil. US$ 5.21	Mil. Yen 550
4.Administration Cost	0.61	0.21	0.29	1.11	Mil. US$ 0.58	Mil. Yen 61
5. Contingency	6.14	2.09	2.97	11.20	Mil. US$ 5.86	Mil. Yen 619
Total	67.54	23.00	32.63	123.17		
	Mil. US$ 35.32	Mil. US$ 12.03	Mil. US$ 17.06		Mil. US$ 64.41	
	Mil. Yen 3,732	Mil. Yen 1,271	Mil. Yen 1,803			Mil. Yen 6,804

Exchange rate: US$1 = 1,912.15 Col$, 1 yen = 18.10 Col$

Source: JICA Study Team

Table-3.3-28 Unit Cot for Phase-I (Eastern project)

Priority-1 Project Breakdown

			Year →	2014	2014	2013	2013	2013	2012	2012	2015	2015	2015	2015	2015	2015	2014	2014	2014	2014	2014	2013	2013	2013	2013	2012	2012	2012	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016						
No.	Description		Unit	Praiso		Tank Santa Ana			La Aguadora		Bosque Medina		Bosque de pinos				Cerro norte		Soratama			Codito				Suba Tank			Bogota Rural																Total	Instal & Const Cost		Material & Equipment Cost		Amount
				E-3	WTP	TA-1	TA-2	WTP	E-6	WTP	E-7	WTP	E-8	WTP	E-9	WTP	E-10	E-11	E-12	E-13	WTP	E-15	WTP	CO-2	WTP	ST-1	ST-3	WTP	Y-1	Y-2	Y-3	WTP	Y-4	Y-5	Y-6	Y-7	Y-8	WTP	Y-9	Y-10	WTP	Y-11	Y-12	WTP		Unit Price (Col$1,000)	Amount (Col$1,000)	Unit Price (Col$1,000)	Amount (Col$1,000)	
				E			E		N		E		E		E				N			N		N			N									N														
1	Deep Well Pump																																																	
	(1) Well Construction	8in 150m + 6in 150m	well																																										0	427,600	0	0	0	
	(2) Well Construction	10in 150m + 8in 150m	well	1		1	1		1		1		1		1		1	1	1	1		1		1		1	1		1	1	1		1	1	1	1	1		1	1		1	1		27	525,120	14,178,240	0	0	
	(3) Well Construction	10in 200m + 8in 200m	well																																										0	652,000	0	0	0	
	(4) Pumping Test and Repot		lot	1		1	1		1		1		1		1		1	1	1	1		1		1		1	1		1	1	1		1	1	1	1	1		1	1		1	1		27	0	0	0	0	
	(5) Deep Well Submersible Pump	$0.7m^3$/min, 120m, 440V, 60Hz, 26KW	set																																											10,000	0	64,400	0	
	(6) Deep Well Submersible Pump	$0.7m^3$/min, 170m, 440V, 60Hz, 37KW	set																																											10,400	0	69,000	0	
	(7) Deep Well Submersible Pump	$1.4m^3$/min, 120m, 440V, 60Hz, 37KW	set																																										0	10,400	0	69,000	0	
	(8) Deep Well Submersible Pump	$1.4m^3$/min, 140m, 440V, 60Hz, 45KW	set																																										0	12,200	0	73,600	0	
	(9) Deep Well Submersible Pump	$1.4m^3$/min, 170m, 440V, 60Hz, 55KW	set	1		1	1		1		1		1		1		1	1	1	1		1		1		1	1		1	1	1		1	1	1	1	1								23	13,400	308,200	81,000	1,863,000	
	(10) Deep Well Submersible Pump	$1.4m^3$/min, 190m, 440V, 60Hz, 75KW	set																																		1	1		1	1		4	13,800	55,200	92,025	368,100	
	Sub Total																																														14,541,640		2,231,100	16,772,740
2	Aqueduct																																																	
	(1) Piping, Above Ground	6in carbon steel	m	20		20	20		20		20		20		20		20	20	20	20		20		20		20	20		20	20	20		20	20	20	20	20		20	20		20	20		540	206	111,240	229	123,660	
		8in carbon steel	m		100			100		100		100		100		100					100		100		100			100				100						100			100			100	1,400	315	441,000	350	490,000	
	(2) Piping, Under Ground	6in PVC 1.38Mpa	m	25	25	25	587		358		25		25		25		25	305	535	605		25	55	25	134	137	55		70		200		25				500		25	440		25	520		4,801	150	720,150	46	220,846	
		8in PVC 1.38Mpa	m							325																				500						350								1330	2,505	162	405,810	78	195,390	
		10in PVC 1.38Mpa	m																																350										350	175	61,250	120	42,000	
		12in PVC 1.38Mpa	m																		20							537						200							2,580				3,337	187	624,019	169	563,953	
		14in PVC 1.38Mpa	m																																										0	200	0	206	0	
		16in PVC 1.38Mpa	m																																										0	212	0	247	0	
		18in PVC 1.38Mpa	m																																										0	224	0	288	0	
		20in PVC 1.38Mpa	m																																				1,500							1,500	234	351,000	329	493,950	
		24in PVC 1.38Mpa	m																														12,535												12,535	267	3,346,845	412	5,158,153	
	(2) Gate Valves	6in with flange, gasket etc.	sets	2		2	2		2		2		2		2		2	2	2	2		2		2		2	2		2	2	2		2	2	2	2	2		2	2		2	2		54	290	15,660	965	52,110	
		8in with flange, gasket etc.	sets		4			4		4		4		4		4					4		4		4			4				4						4			4			4	56	438	24,528	1,461	81,816	
		10in with flange, gasket etc.	sets																																										0	676	0	2,254	0	
		12in with flange, gasket etc.	sets		4			4		4		4		4		4					4		4		4			4				4						4			4			4	56	1,551	86,856	5,170	289,520	
	(3) Check Valves	6in with flange, gasket etc.	sets																																										0	445	0	1,484	0	
		8in with flange, gasket etc.	sets																																										0	594	0	1,979	0	
		10in with flange, gasket etc.	sets																																										0	1,157	0	3,856	0	
		12in with flange, gasket etc.	sets		2			2		2		2		2		2					2		2		2			2				2						2			2			2	28	1,618	45,304	5,392	150,976	
	Sub Total																																														6,233,662		7,862,374	14,096,036
3	Civil Works																																																	
	(1) Site Survey	10m x 20m	m^2	50	240	50	50	300	50	240	50	240	50	240	50	240	50	50	50	50	450	50	240	50	240	50	50	450	50	50	50	375	50	50	50	50	50	600	50	50	300	50	50	300	5,805	3	17,415	0	0	
	(2) Cutting Trees and bush	10m x 20m	m^2																																											8	0	0	0	
	(3) Development of Land	Excavation of Land (5m x 10m x 3mH)	m^3																																											25	0	0	0	
	(4) Site Grading	10m x 20m	m^3	50	240	50	50	300	50	240	50	240	50	240	50	240	50	50	50	50	450	50	240	50	240	50	50	450	50	50	50	375	50	50	50	50	50	600	50	50	300	50	50	300	5,805	40	232,200	0	0	
	(5) Road Construction, 5m wide	Gravel Road	m																																											120	0	0	0	
	(6) Bridge Construction	Concrete Pipe 1m Dia., 6m	sets																																											800	0	0	0	
	(7) Concrete Pavement	H 100, base H 100	m^2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	2,050	80	164,000	0	0	
	(8) Security fence	Galvanized Fabric H=3.0m	m	25	59	25	25	69	25	59	25	59	25	59	25	59	25	25	25	25	85	25	59	25	59	25	25	85	25	25	25	75	25	25	25	25	25	105	25	25	69	25	25	69	1,645	150	246,750	150	246,750	
	(9) Gate for Fence	W= 5m, H=2.5m, Double Swing	sets	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	41	3,500	143,500	0	0	
	(10) Out-Door Lighting	200V-200W, with concrete pole 11m	sets	2	4	2	2	4	2	4	2	4	2	4	2	4	2	2	2	2	8	2	4	2	4	2	2	4	2	2	2	6	2	2	2	2	2	12	2	2	4	2	2	4	124	300	37,200	500	62,000	
	Sub Total																																														841,065		308,750	1,149,815
4	Architect Works																																																	
	(1) Pump Station: 96 m^2 for each site	L=12m, W=8m, H=4.0m, RC, block	m^2		96			96		96		96		96		96					182		96		96			96				192						192			96			96	1,622	850	1,378,700	750	1,216,500	
	Sub Total																																														1,378,700		1,216,500	2,595,200
5	Diesel Engine Generator																																																	
	(1) Diesel Engine Generator-1	125kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets		(1)					(1)		(1)		(1)		(1)							(1)		(1)																				2	800	1,600	77,900	155,800	
	(2) Diesel Engine Generator-2	220kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets					(1)																				(1)													(1)			(1)	1	800	800	106,780	106,780	
	(3) Diesel Engine Generator-3	400kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets																		(1)											(1)													0	900	0	159,000	0	
	(4) Diesel Engine Generator-4	500kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets																																			(1)							1	1,000	1,000	326,000	326,000	
	Sub Total																																														3,400		588,580	591,980
6	Power Receiving																																																	
	(1) Concrete Pole and Accessory	13m height, with arms and insulators	sets		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	1,000	14,000	1,000	14,000	
	(2) Step-Down Transformer-1	125kVA, 11.4kV-440V,	sets		1					1		1		1		1							1		1																				7	3,900	27,300	20,300	142,100	
	(3) Step-Down Transformer-2	200kVA, 11.4kV-440V,	sets					1																				1													1			1	4	5,700	22,800	30,400	121,600	
	(4) Step-Down Transformer-3	300kVA, 11.4kV-440V,	sets																													1													1	7,500	7,500	42,300	42,300	
	(5) Step-Down Transformer-4	400kVA, 11.4kV-440V,	sets																		1																								1	9,100	9,100	53,800	53,800	
	(6) Step-Down Transformer-5	500kVA, 11.4kV-440V,	sets																																			1							1	10,500	10,500	59,300	59,300	
	(7) Lightning Arrestor	11.4kV, 1 set = 3 units	sets		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	600	8,400	4,000	56,000	
	(8) Cut-out switch	11.4kV, 1 set = 3 units	sets		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	600	8,400	4,000	56,000	
	(9) Watt hour meter panel	WH, V, A, Hz,	sets		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	2,700	37,800	18,000	252,000	
	(10) Power Cable & Accessory	11.4kV,	sets		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	4,500	63,000	8,100	113,400	
	(11) 11.4kV, Over-Head Line,	connection to city power	m		300			300		300		300		300		300					300		300		300			300				300						300			300			300	4,200	35	147,000	45	189,000	
	(12) Commissioning and test operation		lots		1			1		1		1		1		1					1		1		1			1				1						1			1			1	14	1,000	14,000	0	0	
	Sub Total																																														369,800		1,099,500	1,469,300
7	Electrical Works																																																	
	(1) Power Reciving Panel-1	125kVA, with changeover	panel		1					1		1		1		1							1		1																				7	9,600	67,200	19,000	133,000	
	(2) Power Reciving Panel-2	200kVA, with changeover	panel					1																				1													1			1	4	15,200	60,800	30,000	120,000	
	(3) Power Reciving Panel-3	300kVA, with changeover	panel																													1													1	20,800	20,800	42,000	42,000	
	(4) Power Reciving Panel-4	400kVA, with changeover	panel																		1																								1	24,800	24,800	50,000	50,000	
	(5) Power Reciving Panel-5	500kVA, with changeover	panel																																			1							1	30,000	30,000	60,700	60,700	
	(6) Distribution Panel	MCCB, V, A	panel		2			3		2		2		2		2					5		2		2			3				4						6			3			3	41	4,600	188,600	11,000	451,000	
	(7) Power Cable-1	XLPE/SWA/PVC/4c x 50mm2	m	50		50					50		50		50		50					50		50			70		90				50						50			50			710	4	2,840	23	16,330	
	(8) Power Cable-2	XLPE/SWA/PVC/4c x 70mm2	m						375																	152					220			220											967	5	4,835	27	26,109	
	(9) Power Cable-3	XLPE/SWA/PVC/4c x 95mm2	m															325																	370	370				460					1,525	6	9,150	36	54,900	
	(10) Power Cable-4	XLPE/SWA/PVC/4c x 120mm2	m				620												555	625										520							520						540		3,380	8	27,040	44	148,720	
	(11) Power Cable-6	XLPE/SWA/PVC/4c x 185mm2	m																																										0	16	0	81	0	
	(12) Control Cable	PVC/SWA/PVC/10c x 2mm2	m	50	100	50	620	100	375	100	50	100	50	100	50	100	50	325	555	625	100	50	100	50	254	152	70	657	90	520	220	12,555	50	220	370	370	520	1,520	50	460	2,600	50	540	1450	26,418	15	396,270	66	1,743,588	
	Sub Total																																														832,335		2,846,347	3,678,682
8	Water Treatment Plant																																																	
	(1) Chlorination Plant	2,000m3/day	sets																																										0	4,400	0	22,100	0	
	(2) Chlorination + Filterate Plant	2,000m3/day	sets		1					1		1		1		1							1		1																				7	71,700	501,900	286,700	2,006,900	
	(3) Chlorination + Filterate Plant	4,000m3/day	sets					1																																	1			1	3	115,800	347,400	463,000	1,389,000	
	(4) Chlorination + Filterate Plant	6,000m3/day	sets																													1													1	159,800	159,800	639,300	639,300	
	(5) Chlorination + Filterate Plant	8,000m3/day	sets																		1																								1	203,900	203,900	815,600	815,600	
	(6) Chlorination + Filterate Plant	10,000m3/day	sets																																			1							1	248,000	248,000	991,900	991,900	
	(7) Chlorination + Filterate Plant	2,500m3/day	sets																																										0	82,700	0	330,800	0	
	(8) Chlorination + Filterate Plant	5,000m3/day	sets																									1																	1	137,800	137,800	551,200	551,200	
	(9) Chlorination + Filterate Plant	7,500m3/day	sets																																										0	192,900	0	771,500	0	
	(10) Aeration + Chlorination + Filterate Plant	100m3/day	sets																																										0	31,500	0	126,200	0	
	Sub Total																																														1,598,800		6,393,900	7,992,700
	Total																																																	48,346,453

Table-3.3-29 Unit Cot for Phase-II (Southern project)

Priority-2 Project Breakdown

No.	Description		Year →	Unit	2017						2018									Total	Installation Cost		Material & Equipment Cost		Amount
					Ciudad Bolivar						Soacha														
					B-1	B-2	B-3	B-4	B-5	WTP	S-1	S-2	S-3	WTP	S-4	Ex-1	S-5	S-6	WTP		Unit Price (Col$1,000)	Amount (Col$1,000)	Unit Price (Col$1,000)	Amount (Col$1,000)	
							N					N					N								
1	Deep Well Pump																								
	(1) Well Construction	8in 150m + 6in 150m		well																0	427,600	0	0	0	
	(2) Well Construction	10in 150m + 8in 150m		well	1	1	1				1	1	1		1	1	1	1		10	525,120	5,251,200	0	0	
	(3) Well Construction	10in 200m + 8in 200m		well				1	1											2	652,000	1,304,000	0	0	
	(4) Pumping Test and Repot			lot	1	1	1	1	1		1	1	1		1	1	1	1		12	0	0	0	0	
	(5) Deep Well Submersible Pump	$0.7m^3$/min, 120m, 440V, 60Hz, 26KW		set	1	1	1													3	10,000	30,000	64,400	193,200	
	(6) Deep Well Submersible Pump	$0.7m^3$/min, 170m, 440V, 60Hz, 37KW		set				1	1											2	10,400	20,800	69,000	138,000	
	(7) Deep Well Submersible Pump	$1.4m^3$/min, 121m, 440V, 60Hz, 37KW		set																0	10,400	0	69,000	0	
	(8) Deep Well Submersible Pump	$1.4m^3$/min, 140m, 440V, 60Hz, 45KW		set																0	12,200	0	73,600	0	
	(9) Deep Well Submersible Pump	$1.4m^3$/min, 170m, 440V, 60Hz, 55KW		set																0	13,400	0	81,000	0	
	(10) Deep Well Submersible Pump	$1.4m^3$/min, 190m, 440V, 60Hz, 75KW		set							1	1	1		1	1	1	1		7	13,800	96,600	92,025	644,175	
	Sub Total																					6,702,600		975,375	7,677,975
2	Aqueduct																								
	(1) Piping, Above Ground	6in	carbon steel	m	20	20	20	20	20		20	20	20		20	20	20	20		240	206	49,440	229	54,960	
		8in	carbon steel	m						100				100					100	300	315	94,500	350	105,000	
	(2) Piping, Under Ground	6in	PVC 1.38Mpa	m	516				427		25	515	920		25	546	956	1287		5,217	150	782,550	46	239,982	
		8in	PVC 1.38Mpa	m				261												261	162	42,282	78	20,358	
		10in	PVC 1.38Mpa	m			280							632						912	175	159,600	120	109,440	
		12in	PVC 1.38Mpa	m		487													2,545	3,032	187	566,984	169	512,408	
		14in	PVC 1.38Mpa	m																0	200	0	206	0	
		16in	PVC 1.38Mpa	m						2,160										2,160	212	457,920	247	533,736	
		18in	PVC 1.38Mpa	m																0	224	0	288	0	
		20in	PVC 1.38Mpa	m																0	234	0	329	0	
		24in	PVC 1.38Mpa	m																0	267	0	412	0	
	(2) Gate Valves	6in	with flange, gasket etc.	sets	2	2	2	2	2		2	2	2		2	2	2	2		24	290	6,960	965	23,160	
		8in	with flange, gasket etc.	sets						4				4					4	12	438	5,256	1,461	17,532	
		10in	with flange, gasket etc.	sets																0	676	0	2,254	0	
		12in	with flange, gasket etc.	sets						4				4					4	12	1,551	18,612	5,170	62,040	
	(3) Check Valves	6in	with flange, gasket etc.	sets																0	445	0	1,484	0	
		8in	with flange, gasket etc.	sets																0	594	0	1,979	0	
		10in	with flange, gasket etc.	sets																0	1,157	0	3,856	0	
		12in	with flange, gasket etc.	sets						2				2					2	6	1,618	9,708	5,392	32,352	
	Sub Total																					2,193,812		1,710,968	3,904,780
3	Civil Works																								
	(1) Site Survey	10m x 20m		m^2	50	50	50	50	50	375	50	50	50	375	50	50	50	50	450	1,800	3	5,400	0	0	
	(2) Cutting Trees and bush	10m x 20m		m^2																	8	0	0	0	
	(3) Development of Land	Excavation of Land (5m x 10m x 3mH)		m^3																	25	0	0	0	
	(4) Site Grading	10m x 20m		m^3	50	50	50	50	50	375	50	50	50	375	50	50	50	50	450	1,800	40	72,000	0	0	
	(5) Road Construction, 5m wide	Gravel Road		m																	120	0	0	0	
	(6) Bridge Construction	Concrete Pipe 1m Dia., 6m		sets																	800	0	0	0	
	(7) Concrete Pavement	H 100, base H 100		m^2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	750	80	60,000	0	0	
	(8) Security fence	Galvanized Fabric H=3.0m		m	25	25	25	25	25	75	25	25	25	75	25	25	25	25	85	535	150	80,250	150	80,250	
	(9) Gate for Fence	W= 5m, H=2.5m, Double Swing		sets	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	3,500	52,500	0	0	
	(10) Out-Door Lighting	200V-200W, with concrete pole 11m		sets	2	2	2	2	2	8	2	2	2	8	2	2	2	2	8	48	300	14,400	500	24,000	
	Sub Total																					284,550		104,250	388,800
4	Architect Works																								
	(1) Pump Station: 96 m^2 for each site	L=12m, W=8m, H=4.0m, RC, block		m^2						192				192					192	576	850	489,600	750	432,000	
	Sub Total																					489,600		432,000	921,600
5	Diesel Engine Generator																								
	(1) Diesel Engine Generator-1	125kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets																0	800	0	77,900	0	
	(2) Diesel Engine Generator-2	220kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets																0	800	0	106,780	0	
	(3) Diesel Engine Generator-3	400kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets						(1)				(1)					(1)	1	900	900	159,000	159,000	
	(4) Diesel Engine Generator-4	500kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets																0	1,000	0	326,000	0	
	Sub Total																					900		159,000	159,900
6	Power Receiving																								
	(1) Concrete Pole and Accessory	13m height, with arms and insulators		sets						1				1					1	3	1,000	3,000	1,000	3,000	
	(2) Step-Down Transformer-1	125kVA, 11.4kV-440V,		sets																0	3,900	0	20,300	0	
	(3) Step-Down Transformer-2	200kVA, 11.4kV-440V,		sets																0	5,700	0	30,400	0	
	(4) Step-Down Transformer-3	300kVA, 11.4kV-440V,		sets										1						1	7,500	7,500	42,300	42,300	
	(5) Step-Down Transformer-4	400kVA, 11.4kV-440V,		sets						1									1	2	9,100	18,200	53,800	107,600	
	(6) Step-Down Transformer-5	500kVA, 11.4kV-440V,		sets																0	10,500	0	59,300	0	
	(7) Lightning Arrestor	11.4kV, 1 set = 3 units		sets																0	600	0	4,000	0	
	(8) Cut-out switch	11.4kV, 1 set = 3 units		sets																0	600	0	4,000	0	
	(9) Watt hour meter panel	WH, V, A, Hz,		sets						1				1					1	3	2,700	8,100	18,000	54,000	
	(10) Power Cable & Accessory	11.4kV,		sets						1				1					1	3	4,500	13,500	8,100	24,300	
	(11) 11.4kV, Over-Head Line,	connection to city power		m						300				300					1,500	2,100	35	73,500	45	94,500	
	(12) Commissioning and test operation			lots						1				1					1	3	1,000	3,000	0	0	
	Sub Total																					126,800		325,700	452,500
7	Electrical Works																								
	(1) Power Reciving Panel-1	125kVA, with changeover		panel																0	9,600	0	19,000	0	
	(2) Power Reciving Panel-2	200kVA, with changeover		panel																0	15,200	0	30,000	0	
	(3) Power Reciving Panel-3	300kVA, with changeover		panel										1						1	20,800	20,800	42,000	42,000	
	(4) Power Reciving Panel-4	400kVA, with changeover		panel						1									1	2	24,800	49,600	50,000	100,000	
	(5) Power Reciving Panel-5	500kVA, with changeover		panel																0	30,000	0	60,700	0	
	(6) Distribution Panel	MCCB, V, A		panel						7				4					5	16	4,600	73,600	11,000	176,000	
	(7) Power Cable-1	XLPE/SWA/PVC/4c x 50mm2		m	526	507	300	296	457		50				50					2,186	4	8,744	23	50,278	
	(8) Power Cable-2	XLPE/SWA/PVC/4c x 70mm2		m																0	5	0	27	0	
	(9) Power Cable-3	XLPE/SWA/PVC/4c x 95mm2		m																0	6	0	36	0	
	(10) Power Cable-4	XLPE/SWA/PVC/4c x 120mm2		m								535				566				1,101	8	8,808	44	48,444	
	(11) Power Cable-6	XLPE/SWA/PVC/4c x 185mm2		m									940				976	1,307		3,223	16	51,568	81	261,063	
	(12) Control Cable	PVC/SWA/PVC/10c x 2mm2		m	526	507	300	296	457	100				100	50	566	976	1,307	100	5,285	15	79,275	66	348,810	
	Sub Total																					292,395		1,026,595	1,318,990
8	Water Treatment Plant																								
	(1) Chlorination Plant	2,000m3/day		sets																0	4,400	0	22,100	0	
	(2) Chlorination + Filterate Plant	2,000m3/day		sets																0	71,700	0	286,700	0	
	(3) Chlorination + Filterate Plant	4,000m3/day		sets																0	115,800	0	463,000	0	
	(4) Chlorination + Filterate Plant	6,000m3/day		lots						1				1						2	159,800	319,600	639,300	1,278,600	
	(5) Chlorination + Filterate Plant	8,000m3/day		lots															1	1	203,900	203,900	815,600	815,600	
	(6) Chlorination + Filterate Plant	10,000m3/day		lots																0	248,000	0	991,900	0	
	(7) Chlorination + Filterate Plant	2,500m3/day		lots																0	82,700	0	330,800	0	
	(8) Chlorination + Filterate Plant	5,000m3/day		lots																0	137,800	0	551,200	0	
	(9) Chlorination + Filterate Plant	7,500m3/day		lots																0	192,900	0	771,500	0	
	(10) Aeration + Chlorination + Filterate Plant	100m3/day		lots																0	31,500	0	126,200	0	
	Sub Total																					523,500		2,094,200	2,617,700
	Total																								17,442,245

Table-3.3-30 Unit Cot for Phase-III (Yerbabuena project)

Priority-3 PJ Breakdown

Construction year →

No.	Description			Unit	2019 Chia										2020 Sopo												Total	Installation Cost		Material & Equipment Cost		Amount
					Y-13	Y-14	Y-15	Y-16	WTP	Y-17	Y-18	Y-19	Y-20	WTP	Y-21	Y-22	Y-23	WTP	Y-24	Y-25	Y-26	WTP	Y-27	Y-28	Y-29	WTP		Unit Price (Col$1,000)	Amount (Col$1,000)	Unit Price (Col$1,000)	Amount (Col$1,000)	
1	**Deep Well Pump**																															
	(1) Well Construction	8in 150m + 6in 150m		well																							0	427,600	0	0	0	
	(2) Well Construction	10in 150m + 8in 150m		well																							0	525,120	0	0	0	
	(3) Well Construction	10in 200m + 8in 200m		well	1	1	1	1		1	1	1	1		1	1	1		1	1	1		1	1	1		17	652,000	11,084,000	0	0	
	(4) Pumping Test and Repot			lot	1	1	1	1		1	1	1	1		1	1	1		1	1	1		1	1	1		17		0	0	0	
	(5) Deep Well Submersible Pump	$0.7m^3$/min, 120m, 440V, 60Hz, 26KW		set																							0	10,000	0	64,400	0	
	(6) Deep Well Submersible Pump	$0.7m^3$/min, 170m, 440V, 60Hz, 37KW		set																							0	10,400	0	69,000	0	
	(7) Deep Well Submersible Pump	$1.4m^3$/min, 120m, 440V, 60Hz, 37KW		set																							0	10,400	0	69,000	0	
	(8) Deep Well Submersible Pump	$1.4m^3$/min, 140m, 440V, 60Hz, 45KW		set																							0	12,200	0	73,600	0	
	(9) Deep Well Submersible Pump	$1.4m^3$/min, 170m, 440V, 60Hz, 55KW		set																							0	13,400	0	81,000	0	
	(10) Deep Well Submersible Pump	$1.4m^3$/min, 190m, 440V, 60Hz, 75KW		set	1	1	1	1		1	1	1	1		1	1	1		1	1	1		1	1	1		17	13,800	234,600	92,025	1,564,425	
																													11,318,600		1,564,425	12,883,025
2	**Aqueduct**																															
	(1) Piping, Above Ground	6in	carbon steel	m	20	20	20	20		20	20	20	20		20	20	20		20	20	20		20	20	20		340	206	70,040	229	77,860	
		8in	carbon steel	m					100					100				100				100				100	500	315	157,500	350	175,000	
	(2) Piping, Under Ground	6in	PVC 1.38Mpa	m	450			25		825					1355		600		545		25		775		60		4,660	150	699,000	46	214,360	
		8in	PVC 1.38Mpa	m		330					245					95				520				445			1,635	162	264,870	78	127,530	
		10in	PVC 1.38Mpa	m			670					655						2590				205				485	4,605	175	805,875	120	552,600	
		12in	PVC 1.38Mpa	m					2340				210	235													2,785	187	520,795	169	470,665	
		14in	PVC 1.38Mpa	m																							0	200	0	206	0	
		16in	PVC 1.38Mpa	m																		2,500					2,500	212	530,000	247	617,750	
		18in	PVC 1.38Mpa	m																							0	224	0	288	0	
		20in	PVC 1.38Mpa	m																						25	25	234	5,850	329	8,233	
		24in	PVC 1.38Mpa	m																							0	267	0	412	0	
	(2) Gate Valves	6in	with flange, gasket etc.	sets	2	2	2	2		2	2	2	2		2	2	2		2	2	2		2	2	2		34	290	9,860	965	32,810	
		8in	with flange, gasket etc.	sets														4				4				4	12	438	5,256	1,461	17,532	
		10in	with flange, gasket etc.	sets																							0	676	0	2,254	0	
		12in	with flange, gasket etc.	sets														4				4				4	12	1,551	18,612	5,170	62,040	
	(3) Check Valves	6in	with flange, gasket etc.	sets																							0	445	0	1,484	0	
		8in	with flange, gasket etc.	sets																							0	594	0	1,979	0	
		10in	with flange, gasket etc.	sets																							0	1,157	0	3,856	0	
		12in	with flange, gasket etc.	sets														2				2				2	6	1,618	9,708	5,392	32,352	
																													3,097,366		2,388,732	5,486,098
3	**Civil Works**																															
	(1) Site Survey	10m x 20m		m^2	50	50	50	50	450	50	50	50	50	450	50	50	50	375	50	50	50	375	50	50	50	375	2,875	3	8,625	0	0	
	(2) Cutting Trees and bush	10m x 20m		m^2																								8	0	0	0	
	(3) Development of Land	Excavation of Land (5m x 10m x 3mH)		m^3																								25	0	0	0	
	(4) Site Grading	10m x 20m		m^3	50	50	50	50	450	50	50	50	50	450	50	50	50	375	50	50	50	375	50	50	50	375	2,875	40	115,000	0	0	
	(5) Road Construction, 5m wide	Gravel Road		m																								120	0	0	0	
	(6) Bridge Construction	Concrete Pipe 1m Dia., 6m		sets																								800	0	0	0	
	(7) Concrete Pavement	H 100, base H 100		m^2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,100	80	88,000	0	0	
	(8) Security fence	Galvanized Fabric H=3.0m		m	25	25	25	25	85	25	25	25	25	85	25	25	25	75	25	25	25	75	25	25	25	75	820	150	123,000	150	123,000	
	(9) Gate for Fence	W= 5m, H=2.5m, Double Swing		sets	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22	3,500	77,000	0	0	
	(10) Out-Door Lighting	200V-200W, with concrete pole 11m		sets	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	88	300	26,400	500	44,000	
																													438,025		167,000	605,025
4	**Architect Works**																															
	(1) Pump Station: 96 m^2 for each site	L=12m, W=8m, H=4.0m, RC, block		m^2					192					192				192				192				192	960	850	816,000	750	720,000	
																													816,000		720,000	1,536,000
5	**Diesel Engine Generator**																															
	(1) Diesel Engine Generator-1	125kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets																							0	800	0	77,900	0	
	(2) Diesel Engine Generator-2	220kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets														(1)				(1)				(1)	1	800	800	106,780	106,780	
	(3) Diesel Engine Generator-3	400kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets					(1)					(1)													1	900	900	159,000	159,000	
	(4) Diesel Engine Generator-4	500kVA, 440V 60Hz 3ph 4W, 1800 rpm		sets																							0	1,000	0	326,000	0	
																													1,700		265,780	267,480
6	**Power Receiving**																															
	(1) Concrete Pole and Accessory	13m height, with arms and insulators		sets					1					1				1				1				1	5	1,000	5,000	1,000	5,000	
	(2) Step-Down Transformer-1	125kVA, 11.4kV-440V,		sets																							0	3,900	0	20,300	0	
	(3) Step-Down Transformer-2	200kVA, 11.4kV-440V,		sets																							0	5,700	0	30,400	0	
	(4) Step-Down Transformer-3	300kVA, 11.4kV-440V,		sets														1				1				1	3	7,500	22,500	42,300	126,900	
	(5) Step-Down Transformer-4	400kVA, 11.4kV-440V,		sets					1					1													2	9,100	18,200	53,800	107,600	
	(6) Step-Down Transformer-5	500kVA, 11.4kV-440V,		sets																							0	10,500	0	59,300	0	
	(7) Lightning Arrestor	11.4kV, 1 set = 3 units		sets					1					1				1				1				1	5	600	3,000	4,000	20,000	
	(8) Cut-out switch	11.4kV, 1 set = 3 units		sets					1					1				1				1				1	5	600	3,000	4,000	20,000	
	(9) Watt hour meter panel	WH, V, A, Hz,		sets					1					1				1				1				1	5	2,700	13,500	18,000	90,000	
	(10) Power Cable & Accessory	11.4kV,		sets					1					1				1				1				1	5	4,500	22,500	8,100	40,500	
	(11) 11.4kV, Over-Head Line,	connection to city power		m					300					300				300				300				300	1,500	35	52,500	45	67,500	
	(12) Commissioning and test operation			lots					1					1				1				1				1	5	1,000	5,000	0	0	
																													145,200		477,500	622,700
7	**Electrical Works**																															
	(1) Power Reciving Panel-1	125kVA, with changeover		panel																							0	9,600	0	19,000	0	
	(2) Power Reciving Panel-2	200kVA, with changeover		panel																							0	15,200	0	30,000	0	
	(3) Power Reciving Panel-3	300kVA, with changeover		panel														1				1				1	3	20,800	62,400	42,000	126,000	
	(4) Power Reciving Panel-4	400kVA, with changeover		panel					1					1													2	24,800	49,600	50,000	100,000	
	(5) Power Reciving Panel-5	500kVA, with changeover		panel																							0	30,000	0	60,700	0	
	(6) Distribution Panel	MCCB, V, A		panel					5					5				4				4				4	22	4,600	101,200	11,000	242,000	
	(7) Power Cable-1	XLPE/SWA/PVC/4c x 50mm2		m				50													50				80		180	4	720	23	4,140	
	(8) Power Cable-2	XLPE/SWA/PVC/4c x 70mm2		m							265		230			115											610	5	3,050	27	16,470	
	(9) Power Cable-3	XLPE/SWA/PVC/4c x 95mm2		m	470	350																		465			1,285	6	7,710	36	46,260	
	(10) Power Cable-4	XLPE/SWA/PVC/4c x 120mm2		m			690			845		675					620		565	540			795				4,730	8	37,840	44	208,120	
	(11) Power Cable-6	XLPE/SWA/PVC/4c x 185mm2		m											1,375												1,375	16	22,000	81	111,375	
	(12) Control Cable	PVC/SWA/PVC/10c x 2mm2		m	470	350	690	50	100	845	265	675	230	100	1,375	115	620	100	565	540	50	100	795	465	80	100	8,680	15	130,200	66	572,880	
																													414,720		1,427,245	1,841,965
8	**Water Treatment Plant**																															
	(1) Chlorination Plant	2,000m3/day		sets																							0	4,400	0	22,100	0	
	(2) Chlorination + Filterate Plant	2,000m3/day		sets																							0	71,700	0	286,700	0	
	(3) Chlorination + Filterate Plant	4,000m3/day		sets																							0	115,800	0	463,000	0	
	(4) Chlorination + Filterate Plant	6,000m3/day		lots														1				1				1	3	159,800	479,400	639,300	1,917,900	
	(5) Chlorination + Filterate Plant	8,000m3/day		lots					1					1													2	203,900	407,800	815,600	1,631,200	
	(6) Chlorination + Filterate Plant	10,000m3/day		lots																							0	248,000	0	991,900	0	
	(7) Chlorination + Filterate Plant	2,500m3/day		lots																							0	82,700	0	330,800	0	
	(8) Chlorination + Filterate Plant	5,000m3/day		lots																							0	137,800	0	551,200	0	
	(9) Chlorination + Filterate Plant	7,500m3/day		lots																							0	192,900	0	771,500	0	
	(10) Aeration + Chlorination + Filterate Plant	100m3/day		lots																							0	31,500	0	126,200	0	
																													887,200		3,549,100	4,436,300
	Total																															27,678,593

3.10.3. Operation and Maintenance Cost

The project recommends 64 wells. The operation of wells is categorized into 6 systems as shown in Table-3.3-31.

Table-3.3- 31 Well Operation System

System	Water Treatment Plant (WTP)		Total number of facilities	
	Purification	Number of connected wells	WTP	Wells
A	Chlorination	1 well	2	2*
B	Chlorination＋Pressure Filtration	1 well	11	7+6*
C		2 wells	4	8
D		3 wells	5	15
E		4 wells	4	16
F		5 wells	2	10
Total			30	64

Note) * Wells developed by the pilot project

Source: JICA Study Team

Table-3.3-32 presents the operation and maintenance cost of 6 systems respectively. It is obvious that the cost differs from the location of wells and WTPs. So the 6 costs represent the standardized ones. The cost is results of multiplying unit consumption by unit price. The unit consumption is estimated by the JICA Study Team and the unit prices are derived from the actual well operation data of Mosquera Municipality.

Table-3.3- 32 Operation and Maintenance Cost (Standardized Cost)

	System	A			B			C	D	E	F
	Filtration Measures	Chlorination			Chlorination＋Pressure Filtration						
	Well (s) connected to WTP	1			1			2	3	4	5
	Production (m^3/day)	2000			2000			4000	6000	8000	10000
	O & M Cost	UC 1)	UP 2)	Cost	UC	UP	Cost	Cost	Cost	Cost	Cost
Variable Cost	1. Electricity	kWh /m^3	Col$ /kWh	Col$ /m^3	kWh /m^3	Col$ /kWh	Col$ / m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3
	1) Well	0.54	234.64	126.71	0.54	234.64	126.71	126.71	126.71	126.71	126.71
	2) Treatment	0.12 3)	254.36	30.52	0.36 4)	254.36	91.57	91.62	91.62	91.62	91.62
	Total			157.23			218.28	218.28	218.28	218.28	218.28
	2. Chemical	kg /m^3	Col$ /kg	Col$ /m^3	kg /m^3	Col$ /kg	Col$ /m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3
	1) Chlorine	0.001	2,290	2.29	0.002	2,290	4.58	4.58	4.58	4.58	4.58
	Total			159.52			222.86	222.86	222.86	222.86	222.86
Fixed Cost		Workers	Wage/ month 5)	Col$ /m^3	Workers	Wage/ month	Col$ /m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3	Col$ /m^3
	3. Personnel 6)	0	2,220,000	0	1	2,220,000	37.00	18.50	12.33	9.25	7.40
Total of O & M Cost				**159.52**			**259.86**	**241.36**	**235.19**	**232.11**	**230.26**

Note: 1) UC=Unit Consumption, 2) UP=Unit Price, 3) one-time chemical injection, 4) two-time chemical injection and booster pump, 4) 5) Average wage of Northern and Southern Supply Division of October 2008, 6) 1 worker for system B, C, D, E and F

Source: UC by JICA Study Team. UP from actual well operation data of Mosquera Municipality (January-August of year 2008)

For reference, the actual operation and maintenance cost of Mosquera Municipality is presented in Table-3.3-33. The municipality supplies with groundwater by 30% of all water demand. The production cost of the municipality is higher than the above standardized cost because the cost includes expenses of distribution electricity and more workers. The groundwater is pumped up from 586m depth of the quaternary aquifer; this is the reason why the chemical cost is so high in comparison with the above standardized cost.

Table-3.3- 33 Operation and Maintenance Cost of Mosquera Municipality (Actual Cost)

	Production	Year 2007			Year 2008 (until August)		
		2500 m³/day			2900 m³/day		
	O & M Cost	UC	UP	Cost	UC	UP	Cost
Variable Cost	1. Electricity (Production)	kWh/m³	Col$/kWh	Col$/m³	kWh/m³	Col$/kWh	Col$/ m³
	1) Well	0.76	214.26	162.26	0.75	234.64	176.02
	2) Treatment	0.09	233.44	21.96	0.10	254.36	26.42
	Sub-total			184.22			202.44
	2. Electricity (Distribution)	0.34	233.55	79.05	0.36	254.36	92.47
	Total of Electricity			263.27			294.91
	3. Chemical	kg/m³	Col$/kg	Col$/m³	kg/m³	Col$/kg	Col$/m³
	1) Aluminum Sulfate	0.076	603	45.85	0.091	479	43.66
	2) Ferric Chloride	0.034	912	30.76	0.040	911	36.33
	3) Peroxide	0.004	2,320	9.92			
	4) Chlorine	0.005	3,712	17.78	0.008	3,712	29.07
	Total of Chemical			104.31			109.06
	Total			367.58			403.97
Fixed Cost		Workers	Wage/month	Col$/m³	Workers	Wage/month	Col$/m³
	4. Personnel	4	2,063.000	110.73	4	2,416,000	110.91
	Total of O & M Cost			**478.31**			**514.88**

Source: "Informe de Explotacion of Acueducto" of Hydros Mosquera

Maintenance Cost

The wells are monitored and checked regularly for 2 hours once a month by the existing 2 staff of water supply department, to confirm whether the pumps and water treatment plants work normally.

This maintenance cost is estimated at Col$33.4million per year as below; the cost is very small, so that the current high level of profit of the Acueducto will not be significantly affected.

- Electricity cost: Col$5.0million
  Col$6,550/well/month x 64 wells x 12 months: 30 minutes operation of pumps and water treatment plant

- Manpower cost: Col$28.4million
  Col$2,220,000/person/month ÷30 days ÷ 8 hours/day x 2 hours x 2 persons x 64 wells x 12 months

Comparison in operation between groundwater and the others

According to Table-3.3-34, it can be concluded that unit water price of emergency water supply by groundwater is more expensive than water from Weisner, El Dorado and Vitelma but cheaper than water from Tibitoc. Wiesner, El Dorado and Tibitoc information is from December 2008. Vitelma TP information is from April 2003, year in which it was closed.

Table-3.3-34 Comparison in Unit Water Price for Emergency Water Supply (Col$/m³)

Proposed emergency water supply by Groundwater	Existing water sources			
	Weisner*	Tibitoc	El Dorado*	Vitelma*
230	40	350	155	70

Source: WTP Production Costs, Acueducto

3.11. Project Implementation Schedule

Implementation schedule for proposed project was planned. Condition below was taken into account in formulation of the schedule.

a) Target year of project is 2020, and facilities for emergency water supply by groundwater will be constructed step by step.
b) Period for application for concession for groundwater use and land acquisition must be taken into account.

c) Capacity of contactor must be taken into account.

d) Budget for construction will be secured every year.

(1) First Priority Project：Pilot Project

Pilot project will be implemented before other projects. Implementation schedule of the Pilot Project is proposed as shown in Figure-3.3-65.

Activity	Year 2007	2008	2009	2010	2011	Note
Master Plan	■	■				JICA Study
Feasibility Study		■				JICA Study
Decision on investment and budget procurement			■	■		
Detail design			■	■		
Construction work			■	■	■	9 sites
Operation and maintenance			■	■	■	

Figure-3.3- 65 Implementation Schedule for Pilot Project

Construction schedule is shown in Table-3.3-35.

Table-3.3- 35 Construction Schedule Pilot Proyect

Year	Site	Well	Water Treatmet Plant	Year	Site	Well	Water Treatmet Plant
2009	E-1	○	○	2011	CM-1	○	○
	E-14	○	○		EX-2	○	○
	Total	2	2		EX-3	○	○
2010	E-5	○	○		Total	3	3
	E-16	○	○				
	E-17	○	○				
	ST-2	○	○				
	Total	3	3				

Existing wells should be used for the Pilot Project. Therefore, new drilling is not necessary. However, facilities for water treatment and water supply are newly necessary for the Pilot Project.

(2) First Period Project

The First Period Project is the Eastern Project. The implementation schedule is proposed as shown in Figure-3.3-66.

Activity	Year 2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Note
Master Plan	■	■													JICA Study
Feasibility Study		■													JICA Study
Decision on investment and budget procurement					■	■	■	■	■						Investiment Plan by Acueducto
Detail design					■	■	■	■	■						- Geophysical survey - Water quality analysis
Construction work						■	■	■	■	■					61 wells
Operation and maintenance						■	■	■	■	■	■	■	■	■	

(Source: JICA Study Team)

Figure-3.3- 66 Implementation schedule of Eastern Project

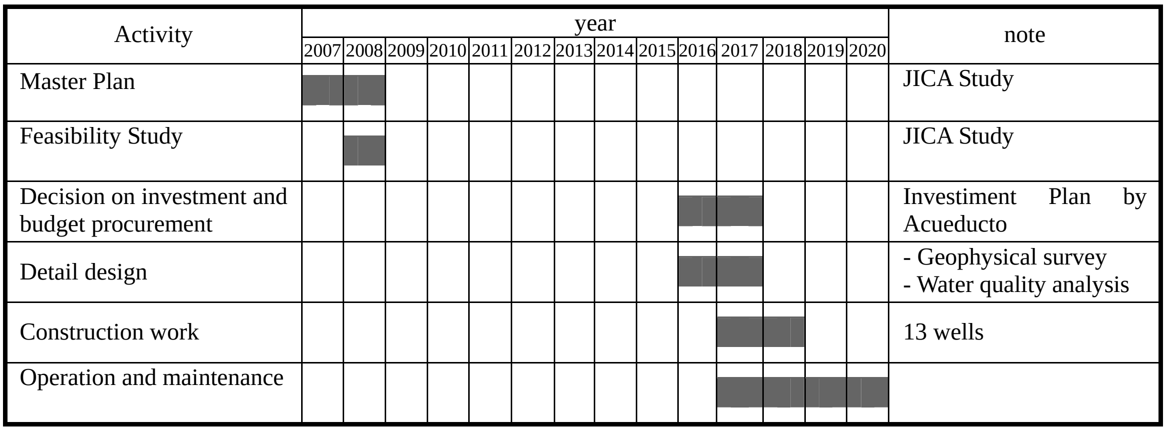
Construction schedule is shown in Table-3.3-36. In this plan, sites of Acuedcuto property are proposed earlier construction. The property of Acuedcto is scattered covering entire Eastern hills so that time order of construction is also scattered.

Table-3.3- 36 Construction Schedule

Year	Site	Well	Water Treatmet Plant	Year	Site	Well	Water Treatmet Plant
2012	E-6	○	○	2014	Y-1	○	○
	ST-1	○	○		Y-2	○	
	ST-3	○			Y-3	○	
	SA-1	○	○		Y-4	○	○
	SA-2	○			Y-5	○	
	E-15	○	○		Y-6	○	
	CO-2	○	○		Y-7	○	
	Total	7	5		Y-8	○	
2013	E-3	○	○		Y-9	○	○
	E-4	○	○		Y-10	○	
	E-10	○	○		Y-11	○	○
	E-11	○			Y-12	○	
	E-12	○			Total	12	4
	E-13	○					
	E-7	○	○				
	E-8	○	○				
	E-9	○	○				
	Total	9	6				

(3) The Second Period Project

The Second period Project is the Southern Project. Implementation schedule is proposed as shown in Figure-3.3-67.



(Source: JICA Study Team)

Figure-3.3- 67 Implementation schedule of Southern Project

Construction schedule is shown in Table-3.3-37.

Table-3.3- 37 Construction Schedule

Year	Site	Well	Water Treatmet Plant
2015	B-1	○	○
	B-2	○	
	B-3	○	
	B-4	○	
	B-5	○	
	Total	5	1

Year	Site	Well	Water Treatmet Plant
2016	S-1	○	○
	S-2	○	
	S-3	○	
	S-4	○	○
	EX-1	○	
	S-5	○	
	S-6	○	
	Total	7	2

(4) The Third period Project

The Third Period Project is Yerbabuena Project. Implementation schedule is proposed as shown in Figure-3.3-68.

Activity	year														note
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Master Plan	■	■													JICA Study
Feasibility Study		■													JICA Study
Decision on investment and budget procurement												■	■		Investiment Plan by Acueducto
Detail design												■	■		- Geophysical survey - Water quality analysis
Construction work													■	■	17 wells
Operation and maintenance ration and maintenance													■	■	

Source: JICA Study Team

Figure-3.3- 68 Implementation Schedule of Yerbabuena Project

Construction schedule is showm in Table-3.3-38.

Table-3.3- 38 Construction Schedule

Year	Site	Well	Water Treatmet Plant
2017	Y-13	○	○
	Y-14	○	
	Y-15	○	
	Y-16	○	
	Y-17	○	○
	Y-18	○	
	Y-19	○	
	Y-20	○	
	Total	8	2

Year	Site	Well	Water Treatmet Plant
2018	Y-21	○	○
	Y-22	○	
	Y-23	○	
	Y-24	○	○
	Y-25	○	
	Y-26	○	
	Y-27	○	○
	Y-28	○	
	Y-29	○	
	Total	9	3

3.12. Financial Scheme

3.12.1. Year-wise Development Cost

Groundwater development cost is studied in Chapter 3.10 and estimated at Col$ 123,300 million in total. The development is planned to be implemented over the period of 7 years starting from 2012 up until 2018 as suggested in Chapter 3.11. Accordingly the annual development cost amounts to Col$ 15,400 million on average. Table-3.3-39 presents the year-wise development cost.

Table-3.3- 39 Development Cost by Year (million Col$)

Area	2012	2013	2014	2015	2016	21017	2018	Total
1. Eastern hill areas	16,400	18,400	32,700	-	-	-	-	67,500
2. Southern areas	-	-	-	9,500	13,500	-	-	23,000
3. Northern areas	-	-	-	-	-	14,000	18,700	32,800
Total	16,400	18,400	32,700	9,500	13,500	14,000	18,700	123,300

Source: JICA Study Team

< Reference: Investment Plan of Acueducto >

According to the "Plan Financiero Plurianual 2008 – 2020" of Acueducto revised in October 2008, Col$ 10,416,000 million of investment is planned over the period of 13 years. Annual investment amounts to Col$ 800,000 million on average; annual groundwater development cost of Col$ 15,400 million represents as low as 1.9% of it.

3.12.2. Funding

The development cost is to be funded from the following 3 sources independently or compound:

- Acueducto own funds
- Domestic bank loan
- International donor's soft loan

1) Acueducto Own Funds

Acueducto is expected to generate rich cash flow according to the "Plan Financiero Plurianual 2008 – 2020", so that it could allocate some out of its own funds for this project.

2) Domestic Loan

The domestic loan condition is currently assumed to be as follows; this loan condition is considered rather conservative compared to loan condition actually required to Acueducto.

- Term of loan: 12 years
- Grace period: 3 years
- Interest rate: 13.5%

3) International Donor's Soft Loan

Needless to say, the international donor's soft loan is attractive in terms of the loan condition; for example, Japanese ODA Loan is currently offered at 25 years of loan term with 1.4% of interest rate. If 80% of the above development cost could be funded by Japanese ODA Loan and the rest of amount by domestic bank loan, the weighted average of interest rate would be only 3.9%. So it is strongly recommended that Acueducto applies for it in implementation of this project.

4) Decision of Acueducto

Acueducto plans to formulate a new M/P in 2009 by revising the M/P 2005. M/P and F/S of JICA and pilot project on exploratory wells run by Acueducto are to be reflected in the new M/P 2009. According to the Financial Department, the appropriate funding measures are to be studied including Acueducto own funds at the time of this investment decision on groundwater development.

3.13. Project Evaluation

3.13.1. Economic Evaluation

The objective of groundwater development is to secure and supply water in emergencies caused by the natural disasters especially in the Chingaza areas. However, economic evaluation for emergency is hardly worked out in monetary terms. Accordingly, the evaluation is carried out in this F/S from the viewpoint of comparative advantages that groundwater development has.

The followings can be judged to be the advantages of the groundwater development.

- Diversification of risks
- Lower development cost
- Well location closer to demand area

(1) Diversification of Risks

Development of sixty four (64) wells is suggested for the emergency water supply in this F/S Plan. The production amount of 64 wells is planned on 115,600m^3/day (1.338m^3/second).

Acuducto relies heavily on the Chingaza water conveyance system. The natural disasters may damage this conveyance system. The development of groundwater shall diversify the risks against the disasters.

At present, the production capacity of the Weisner plant is 13.5m^3/second. Accordingly, the groundwater development shall diversify the risks ***arithmetically by 10%*** (=1.338/13.5).

(2) Lower Development Cost

Groundwater development cost is studied in Chapter 3.9 and estimated at Col$ 123,300 million that is equivalent to US$ 64.4 million: unit cost is US$ 47.3 million/m^3/s.

Meanwhile, Acueducto has planned eight (8) water supply expansion projects in the "Plan de Expansión de Abastecimiento de Agua, 2005". These projects are to develop 32.23 m^3/s of surface water as shown in Table-3.3-40. Total investment cost amounts to US$2,277 million: average unit cost is US$70.6million/m^3/s.

Table-3.3- 40 Water Supply Expansion Plan of Acueducto

Expansion Projects	Investment Cost	Flow to be secured
	Million US$	m^3/sec
1. Over flow of Chuza dam	5.30	0.10
2. Chuza north water channel, stage1-2	96.46	2.33
3. Chuza north water channel, stage-3	61.77	1.57
4. Playa dam	59.11	1.05
5. Southeast Chingaza water channel	65.19	1.08
6. Regadera dam II	123.60	0.70
7. Sumapaz upper-stream water channel	756.45	7.58
8. Sumapaz middle-stream water channel	1,109.26	17.82
Total	2,277.14	32.23
Average Investment Cost	70.6 million US$/ m^3/sec	

Source: JICA Study Team based on the "Plan de Expansión de Abastecimiento de Agua, Acueducto 2005"

In terms of development cost per m^3/s, the groundwater is obviously *evaluated lower by US$ 23.3 million (=US$70.6million minus US$ 47.3 million)* than surface water in Bogotá D.C.

(3) Well Location closer to Demand Area

In a few days immediately after disasters, the point water supply predominates among others for measures to sustain human life. Development of 64 wells is planned near the residential areas, which enables to make a quick delivery and distribution of water to citizens. This quick delivery *reduces the transportation costs as well as saving the time.*

3.13.2. Financial Analysis

(1) Updated Financial Condition of Acueducto

1) Profitability

"Profit and Loss Statement" of Acueducto from FY 2004 to 2008 is presented in Table-3.3-41. The table clearly indicates that Acueducto has continuously performed excellent financial results every year.

- Net income has grown every year in line with the operational revenue increase. The ratio of net income to operational revenue of FY 2007 recorded a remarkable high level of 14%.
- Interest coverage ratio is 5.5 on average over the period of 4 years from 2004 to 2007; it soared into 11.0 especially in 2007. It is obvious that Acueducto has earned operational income enough to cover the interest payment.

Table-3.3- 41 Profit and Loss Statement (million Col$)

Account Items		2004	2005	2006	2007	Sept./2008
I. Operation	1. Revenue	892,875	969,885	987,449	1,103,731	855,121
	2. Expenditure	766,317	843,618	728,448	831,518	667,064
	3. Op. Income	126,558	126,267	259,001	272,213	188,057
II. Non-operation	1. Revenue	198,856	259,864	190,238	138,893	124,504
	2. Expenditure	151,182	158,262	172,616	221,572	98,825
	3. (interest)	(71,747)	(80,168)	(73,445)	(33,048)	(43,140)
	4. Non-op. Income	47,674	101,602	17,622	-82,679	25,679
III. Income before Tax		174,232	227,869	276,623	189,534	213,736
IV. Income Tax [1)]		53,802	73,303	92,035	34,466	28,154
V. Net Income		120,430	154,566	184,588	155,068	185,582
VI. Ratio						
1. Op. Income/Op. Revenue (=I.3÷I.1)		14.2%	13.0%	26.2%	24.7%	22.0%
2. Net Income/Op. Revenue (=V÷I.1)		13.5%	15.9%	18.7%	14.0%	21.7%
3. Interest Coverage Ratio [2)]		3.0	3.1	4.7	11.0	6.3

Note: 1) Income tax that was presented in the operational expenditure of the Statement is exposed separately in IV by the Study Team according to the international standards. 2) Interest coverage ratio = (Operational Income + Interest Received) + Interest Paid

Source: Acueducto (Financial Department)

2) Safety and Soundness

"Balance Sheet" of Acueducto from FY 2004 to September 2008 is presented in Table-3.3-42. The table reveals continuous financial safety and soundness of Acueducto.

- Current ratio means short-term safety and is required in general at 120 – 140%. Current ratio of Acueducto indicates 366% - 522% that means Acueducto retains sufficiently cashable assets against short-term due.
- Operational fixed assets such as land, equipment, machinery, vehicles and buildings are necessary to run the business for long term. So, the acquisition of such fixed assets generally requires long-term funds as well. Fixed ratio of Acueducto indicates 84% - 87% that means all fixed assets for operation have been acquired by utilizing long-term funds.
- Equity ratio to assets indicates a high level of 55% - 58% that means more than half of assets have been acquired with its own funds.

Table-3.3- 42 Balance Sheet (1,000 Million Col$)

Assets							Liabilities and Equity					
Items		'04	'05	'06	'07	'08	Items	'04	'05	'06	'07	'08
Current Assets		899	1,097	1,211	1,157	1,320	Current	205	229	232	262	361
Fixed Assets	Land	163	187	200	228	235	Fixed	2,360	2,508	2,502	2,689	2,780
	Depreciable	2,931	3,062	3,178	3,521	3,698	Total Liabilities	2,565	2,737	2,734	2,951	3,141
	Others	1,766	1,744	1,844	2,031	2,125	Equity	3,194	3,353	3,699	3,986	4,237
	Total	4,860	4,993	5,222	5,780	6,058						
Total		5,759	6,090	6,433	6,937	7,378	Total	5,759	6,090	6,433	6,937	7,378
Ratio												
1. Equity/Assts		55%	55%	58%	57%	57%						
2. Fixed Ratio [1)]		88%	85%	84%	87%	86%						
3. Current Ratio [2)]		439%	479%	522%	442%	366%						

Note: 1) Fixed Ratio=Fixed Assets (Land + Depreciable Assets)÷(Fixed Liabilities + Equity), 2) Current Ratio=Current Assets÷Current Liabilities

Source: Acueducto (Financial Department)

3) Cash Flow

Cash flow projection of Acueducto is presented in Table-3.3-43. The table represents that operation activities continuously generates positive net cash flow and help Acuducto to retain a good cash flow balance every year.

Table-3.3-43 Cash Flow Projection (1,000 Million Col$)

Items	Source of Cash Flow	Actual	Forecast	Projection				
		2007	2008	2010	2013	2015	2017	2020
Net Cash Flow	1. Operation Activities	395	444	646	735	845	935	1,047
	2. Investment Activities	489	552	713	564	804	904	1,132
	3. = 1-2	-94	-108	-67	171	41	31	-85
	4. Financial Activities	166	-63	-82	-193	-27	6	106
	5. of the Year	72	-171	-149	-22	14	37	21
Previous Year Balance		549	621	208	50	63	63	71
Final Balance of the Year		621	450	59	28	77	100	92

Source: "Plan Financiero Plurianual 2008 – 2020" of Acueducto

(2) Financial Evaluation

1) Funding of Development Cost

It is assumed that Col$ 123,300 million of the groundwater development cost would be loaned by the domestic bank with the following same condition as described in Chapter 3.12:

- Term of loan: 12 years
- Grace period: 3 years
- Interest rate: 13.5%

2) Ability of Debt Payment

The debt payment (repayment of loan plus interest) of the above loan is presented in Table-3.3-44. The table shows that the annual maximum payment is Col$ 23,900 million due in 2024 and the annual average is Col$ 12,800 million. This payment represents only 10% of Col$ 129,000 million of actual debt payment of Acueducto in 2007.

Table-3.3- 44 Debt Payment (million Col$)

Items	Loan Amount	Loan Condition（Assumption）			Debt Payment of Year	
		Interest Rate	Loan Term	Grace Period	Maximum	Average
Domestic Bank Loan	123,000	13.5%	12 years	3 years	23,900 in 2024	12,800
Reference *: Year 2007 Outstanding Loan = 568,000		Repayment: 83,000		Interest paid: 46,000	-	129,000

Source: JICA Study Team and Financial Data of Acueducto (*)

Acueducto considers affording for the above debt payment judging from the sufficient level of cash flow balance of Table-3.3-43 and high level of "ability to pay" of Table-3.3-45.

Table-3.3- 45 Ability to Pay (million Col$)

Items	Actual	Forecast	Projection				
	2007	2008	2010	2013	2015	2017	2020
a. Final Balance of Cash Flow of the Year (Ref: Table-7.3)	621,000	450,000	59,000	28,000	77,000	100,000	92,000
b. Debt Payment	-	-	-	1,015	3,695	10,831	20,319
c. Ability to Pay = a/b	-	-	-	28 times	21 times	9 times	5 times

Source: JICA Study Team

3) Profitability

Profit and Loss projection of Acueducto is presented in Table-3.3-46. Operation revenue grows every year. Net income results in positive also every year.

The table indicates that the incremental cost of interest and depreciation generated by the groundwater development is Col$ 3,100 million in 2013 and Col$ 19,100 million in 2020. It is obvious that these costs are not so large and do not affect seriously the projected profit of Acueducto.

Table-3.3- 46 Profit & Loss Projection (1,000 Million Col$)

Items		Actual	Forecast	Projection				
		2007	2008	2010	2013	2015	2017	2020
Operation	Revenue	1,104	1,171	1,395	1,633	1,811	1,989	2,246
	Income	272	232	310	423	488	632	836
Others	Income	-83	2	-62	-19	15	54	124
Income before Tax		190	235	248	404	503	686	961
Tax		34	0	0	89	85	139	230
Net Income		155	235	248	315	418	547	731
EBITDA		537	544	675	843	953	1,189	1,547
Incremental cost by groundwater development								
1. Interest		-	-	-	2.2	9.1	12.0	13.3
2. Depreciation		-	-	-	0.9	3.6	4.9	5.7
3. Total		-	-	-	3.1	12.8	16.9	19.1

Note: EBTDA=Earning before Interest, Tax, Depreciation and Amortization

Source: "Plan Financiero Plurianual 2008 – 2020" of Acueducto

4) Investment Cost Recovery

The groundwater development project aims principally at the emergency supply but not the expansion of consumers. So Acueducto cannot generate the additional operational income from this project and recover the development cost.

Meanwhile, in terms of water tariff, Acueducto could recover the development cost if incorporating it into the tariff according to the following existing formula, although the tariff change largely depends on the top management decision.

Formula of establish tariff
Tariff = Fixed Tariff + Tariff by Consumption
1) Fixed Tariff: CMA
2) Tariff by consumption: CMO + CMI + CMT
Note: CMA: average cost of administration, CMO: average cost of operation,
CMI: investment cost, CMT: average cost of environmental duties

3.13.3. Social Evaluation

The project is expected to generate several social benefits to the project areas as follows.

(1) Increase of Served Population in Emergencies

Two methods of water supply in emergencies are considered in this F/S: one is point water supply and another is network water supply. Among 64 wells, 11 wells are exclusively for point water supply, while 53 wells are designed as both point supply and network supply. The served population by both methods is estimated respectively as below (see Table-3.3-47);

- 7,700,000 inhabitants can be served by the use of point supply: this is the same level of estimated population of 2007.
- 600,000 inhabitants can be served by the use of network supply: this corresponds to 8% of 2007 population and 6% of 2020 population.

Table-3.3- 47 Possible Served Population

Supply Method	Production (m^3/day)	Water Loss Rate 1)	Consumption (m^3/day)	Unit Consumption Rate (liter/day/person)	Possible Served Population
Point Supply	115,600	-	115,600	15 2)	7,700,000
Network Supply	95,000	37%	59,850	100 3)	600,000

Note: 1) Water loss rate: actual data of first 6 months in 2006, 2) 15 liter/day/person: target rate of point supply of Acueducto, 3) 100 liter/day/person: estimated average consumption rate of year 2007

Source: JICA Study Team

(2) Water Supply to Forest Fire Fighting

Forest fires occur at Eastern and Southern hills every year especially during the dry season from January to February. Firehouse of Bogotá City fights the fires. The project plans to construct tanks and distribution pipes which enable to take water for fire fighting operation.

(3) Increase of Employment Opportunity

In implementation of the project, the construction works would offer a new labor opportunity to the people unemployed and under-employed of the region for construction sector itself and the related sectors. And, the consumption by the workers would stimulate the business activities of the region. Thus, this increased consumption by new workers will induce a multiplied economic effect to the region, which activates the regional economy as a whole.

CHAPTER 4 RECOMMENDATIONS

(1) Early Implementation of Proposed Projects

Acueducto has long-term water resources development plan, which consists of water resources development of Chingaza area. According to this plan, Acueducto will increase water conveyance from Chigaza area in the future, though decreasing the other sources, because of higher economic efficiency of Chingaza system than those of the others. On the hand, it is said that water conveyance from Chingaza area, though long mountain tunnel, is vulnerable in water suspension by the natural disaster, such as earthquake. To overcome this problem, alternative water sources in case of emergency, including MP of emergency water supply by groundwater around Bogotá city, was proposed in this Study. Acueducto is scheduled to review long term development plan in 2009. After confirmation of importance of emergency water supply, Acueducto should implement the proposed projects as soon as possible.

(2) Importance of Pilot Project

Priority was given to proposed projects in Mater Plan Study: i) Pilot Project, ⅱ) Eastern Project, ⅲ) Southern Project, ⅳ) Yerba Buena Project. Pilot project, which will use the existing wells within Bogotá city, should be implemented prior to the other projects. Acueducto should implement the pilot Project as soon as possible, for earlier implementation of the following projects.

(3) Well-Drilling within Forest Protection Area

The center of Bogotá city is located near the Eastern hills. Groundwater of the wells in Eastern hills should be supplied to the city center in case of emergency. On the other hand, forest protection area, where well drilling is prohibited, is distributed covering the Eastern hills near the city center. However, because of favorable geological condition for well-drilling, emergency well was planned even inside the forest protection area, responding to request of Acueducto. It is desirable that well restriction on well-drilling within the forest protection area should be discussed among Colombian side, taking into account of amendment of the regulation.

(4) Improvement of Study Result by Colombia Side

Groundwater in the Eastern Hills and Southern hills should be developed for emergency water supply. This proposal is based on result of the Study, including hydrogeological analysis, geophysical survey, and water balance analysis, groundwater simulation, implemented by the JICA Study Team. Colombian side should improve results of the Study, including the simulation model, by adding newly obtained data.

(5) Integrated Emergency Water Supply

Several options for emergency water supply should be prepared. The proposed projects, emergency water supply by use of groundwater, are one of them, which have unique and different advantages from the other options. By employing every option for emergency water supply, damage by natural disaster, to water supply for Bogotá city and the surrounding area, will be mitigated.