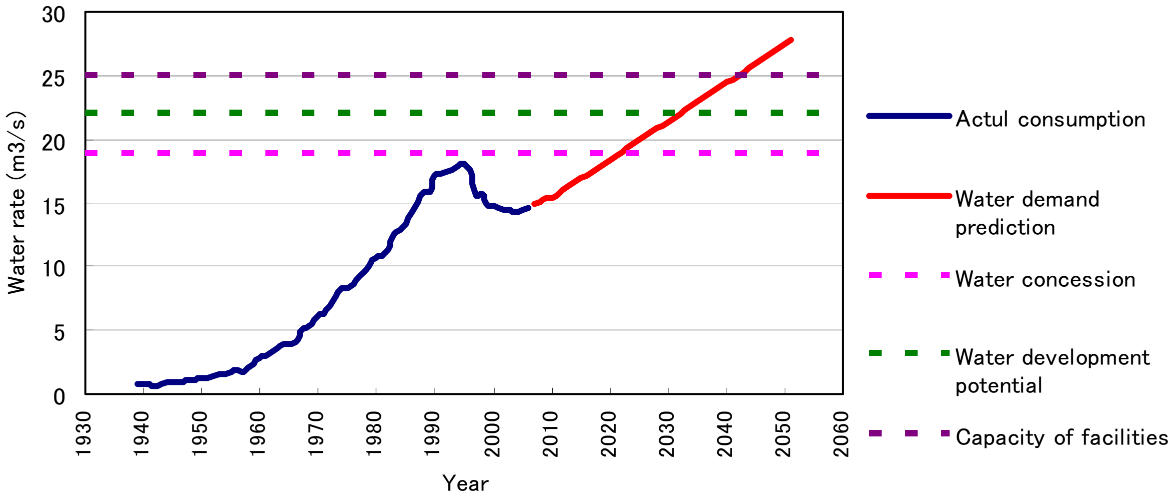
CHAPTER 4. ISSUES IN EXISTING MASTER PLAN OF WATER SUPPLY

4.1. Existing Master Plan

(1) Water Demand Projection

Actual water consumption in the past and predicted water demand for the future is shown in Figure-2.4-1.



Source: Acueducto, Plan de Expansión de Abastecimiento de Agua, 2005

Figure-2.4- 1 Actual Water Consumption and Predicted Water Demand

Water from Chingaza System was interrupted for nine months in 1997 because of collapse of the water conveyance tunnel from Chuza Reservoir. It was called “Crisis of Chingaza”. Water consumption was dramatically reduced in that time. After the crisis, Acueducto reduced pressure of water supply, raised water tariff and performed campaign for saving water. As a result, the water consumption has been reduced to 89 ℓ/day/person in 2006, which was 60% of that in early 1990s of 150 ℓ/day/person. Water consumption is still being kept low in Bogotá after “Crisis of Chingaza”.

(2) Issues in the Existing Mater Plan

1) M/P (1995 version)

Acueducto formulated the Expansion of Water Supply System (M/P) in 1995. Water production capacity of Acueducto was 25 m^3/s at that time. On the other hand, water demand was 18 m^3/s. It was predicted that water demand would exceed water production capacity in 2005. Therefore, development of new water resources was considered to be necessary from 2005. Based on this prediction, projects for water resources development were proposed as shown in Table-2.4-1. However, predicted water demand was much higher than real water consumption because of “Crisis of Chingaza” in 1997. After the crisis, water consumption has been controlled by Acueducto.

2) Revised M/P (2005)

Acueducto revised the M/P (1995 version) in 2005. Water consumption of Bogotá D.C. was extremely reduced after “Crisis of Chingaza”. Then, water demand control followed by “Crisis of Chingaza” by Acueducto kept water consumption in lower level afterward. Revised M/P in 2005 succeeded projects proposed by the old M/P. However, beginning of projects proposed by the old M/P was put afterward to year of 2028, because real water demand was lower than the predicted demand. Projects proposed by revised M/P were classified into three categories as shown in Table-2.4-1.

Table-2.4- 1 Projects Proposed in Revised M/P (2005)

Period		Project	2010 2015 2020 2025 2030 2035 2040 2045 2050
1st	2005-2020	1) Basic Study and Design	
2nd	2021-2028	2) Optimization of Water Supply System	
3rd	2029-2050	3) Expansion of Water Supply System	

Source: Acueducto, Plan de Expansión de Abastecimiento de Agua, 2005

Importance of groundwater development proposed in M/P is summarized as shown below:

- Groundwater development in Bogotá city has a role of supplemental water supply to mitigate vulnerability of the current water supply system that depends on surface water sources of distant places.
- Water supply by use of groundwater should be planned, independent of the current water supply by use of surface water. It is because water supply by groundwater can compensate vulnerability of water supply by surface water.

(3) Current Water Supply Capacity

On the other hand, the current capacity of facilities for water supply by Acueducto is shown in Table-2.4-2.

Table-2.4- 2 Water Right and Capacity of Water Production by Acueducto (2007)

Water Supply System	Factor to affect Water Use				Current production (m^3/s)	Potential increase in water production (m^3/s)
	Hydrological potential (m^3/s)	Capacity of purification[1] (m^3/s)	Water concession (m^3/s)	Minimum of (a), (b), (c)		
	(a)	(b)	(c)	(d)	(e)	(d)-(e)
(1) Chingaza	14.1	17.6	13.2	13.2	10.0	3.2
(2) Tibitóc	7.0	10.5	4.8	4.8	4.0	0.8
(3) Southern	0.9	2.1	1.0	0.9	0.5	0.4
Total	22.0	30.2	19.0	18.9	14.5	4.4

Source: Acueducto.

Note-1) Water purification capacity of Vitelma and San Diego plants is not included

The relationship among hydrological potential, capacity of facilities and water right is as below:

$$\underset{(19.0\ m^3/s)}{\text{Water concession}} < \underset{(22.0\ m^3/s)}{\text{Hydrological potential}} < \underset{(30.2\ m^3/s)}{\text{Capacity of purification}}$$

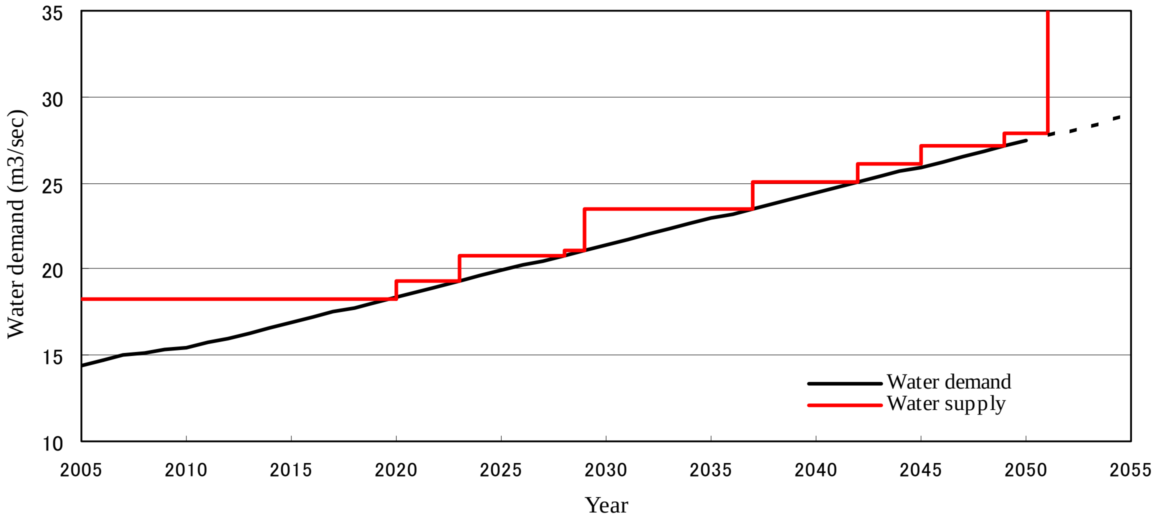
As shown in above, amount of water concession is smallest of 3 factors. Water demand is predicted to exceed water right (18.8 m^3/s) in 2022, water potential (22.12 m^3/s) in 2033 and capacity of purification (25 m^3/s) in 2042, respectively.

As shown in Table-2.4-2, development of new water resources (construction of water intake facilities) and additional water right is necessary to use full capacity of the current facilities.

4.2. Review of Existing Master Plan

(1) Water Demand and Development of Water Resources

Acueducto has Master Plans of the optimization of water supply and expansion of water supply system. Relation between water demand and water supply by above project is shown in Figure-2.4-2.



	No.	Project			No.	Project	
Optimization	①	Expansion of pipeline from Regadera to La Laguna Plant, Vitelma Plant, Regadera dam, La Laguna Plant		Expansion	⑥	Chingaza	Chuza north water channel, stage-3
Optimization	②	Full usage of Tominé Reservoir		Expansion	⑦	Chingaza	Playa dam
Optimization	③	Recycle of washing water in purification plant		Expansion	⑧	Chingaza	Southeast Chingaza water channel
				Expansion	⑨	Southern	Regadera Dam II
	④	Chingaza	Over flow of Chuza dam	Expansion	⑩	Sumapaz upper-stream water channel	Sumapaz upper-stream water channel
	⑤	Chingaza	Chuza north water channel, stage1-2	Expansion	⑪	Sumapaz upper-stream water channel	Sumapaz middle-stream water channel

Source: JICA Study Team analyzed based on M/P of Acueducto (2005)

Figure-2.4- 2 Water Demand and Water Supply

(2) Characteristics of Projects

Proposed projects are summarized as below:

- Chingaza expansion project is lower in development scale but higher in cost efficiency than Sumapaz development project. Both projects need construction of new facilities. However, existing water conveyance tunnel (40 km length) can be used for Chingaza expansion projects. This why Chingaza project has such a high cost efficiency.
- Chingaza expansion project consists of 5 independent projects. Each project can be implemented step by step closely following increase of water demand.
- Optimization project has highest efficiency because new construction is not necessary for this project. However, amount of developed water is small.
- Southern development (new Regadera dam) project has the lowest efficiency. There are already 3 existing dams (Regadera, Tunjuelo、Los Tunjos) in the Tunjelo river. It is why efficiency of additional dam construction is lower in Tunjelo River.

4.3. Water Resources Management

The existing M/P was reviewed in this Study from 4 view points: i) quantity management, ii) quality management, iii) water distribution management and vi) risk management. The result of the review is described below:

(1) Quantity Management

Access rate to water supply in Bogotá D.C. is more than 90%. Average unit water consumption is 89 ℓ/capita/day for domestic use. There was serious water shortage in 1997 called "Crisis of Chingaza".

After it, Acueducto has controlled water consumption by high water tariff, reduced pressure of water tap and campaign for saving water. As a result, water consumption was reduced from 150 ℓ/capita/day in 1992 to 89 ℓ/day/person in 2006 in average. This consumption rate is much lower than that in capital cities of the other South American countries.

(2) Quality Management

(a) Surface Water Quality

Water supply of Bogotá Metropolitan Area depends on surface water. There are three water supply systems, which take water from the rivers and treat it in the treatment plants. Treated water quality meets water quality standard of Colombia. Water use is very active along Bogotá River, where there are many points for water intake and drainages. Water quality of Bogotá River is more deteriorated than other water sources. In the area of upper reaches of Tibitóc Plant, water quality of Bogotá River is under control of CAR. Degree of contamination is currently within the limits stipulated in water quality standard, however, polluted load will be increased in the near future so that it is expected that current water treatment plants will not be able to treat it any more. It depends on CAR whether water quality of Bogotá River is improved or worsens in the future.

(b) Groundwater Quality

Groundwater quality of the Quaternary Aquifer

There is high concentration of organic materials in groundwater in the Quaternary Aquifer, which needs full-scale water purification for drinking. Therefore, groundwater of the Quaternary Aquifer is mainly for agricultural use. Large amount of groundwater is currently being withdrawn from the Quaternary Aquifer, but no measure is performed in order to conserve groundwater quality.

In recent years, non-operating wells within Bogotá urban area were closed by SDA. It is for protection of groundwater to be contaminated though the non-operating wells. This can be called as an activity for water quality management.

Groundwater in the Cretaceous Aquifer

Water quality of the Cretaceous Aquifer is good, which is suitable for drinking. However, currently groundwater is not being withdrawn from the Cretaceous Aquifer of the Eastern and Southern Hills. So far there is no information on pollution of the groundwater of the Cretaceous Aquifer in the area. Every activity for new development is prohibited in the forest protection area of the Eastern Hills by regulation since 2004. This regulation will contribute to conservation of the groundwater resources of the Cretaceous Aquifer, which is mainly recharged by rainfall in the Eastern Hills. This can be called as an activity for water quality management.

(3) Water Distribution

(a) Water concession of surface water

Water concession for Acueducto is divided into two categories: Bogotá River Basin and the other River Basin.

Water concession of Bogotá River Basin

Water production of Tibitóc Plant occupies 30% of the total water supply by Acueducto. Water of Bogotá River is used not only for water supply but also for agricultural and industrial use. Water concession for agricultural use is recently increasing. Taking into account of current tendency, it is not practical for Acueducto to expect increase of water concession of Bogotá River in the future.

Water concession out of Bogotá River Basin

Acueducto is planning to develop water resources out of Bogotá River Basin, such as in Chingaza and Sumapaz River Basin. Water concession of those rivers basin is controlled by UAESPNN, CORPOGUAVIO and CORPOORINOQUIA. Acueducto has water concession from these organizations for current water use. Considering relationship between Acueducto and above three organizations, there is high possibility that Acueducto will get new water concession from these organizations in the future.

(b) Water concession of Groundwater

CAR and SDA has authority to give concession of groundwater of the above mentioned area. Whether concession will be given or not depends on estimated groundwater development potential. On the other hand, any activity including water resources development is prohibited in the forest protected area (almost above 2,700 m) of the Eastern Hills. Therefore, groundwater development should be performed out of the protected area. To the contrary, there is no forest protection area in the Southern Hills, where groundwater development is prohibited.

(4) Risk Management

According to M/P by Acueducto (2005), water resources development in Chingaza Area is proposed as high priority projects to meet the future water demands. Excellent water quality of the area contributes to lower operation cost for water purification than those of the other supply systems. Moreover, there is large amount of water resources in the area. As a result, Chingaza System occupies 70% of the total water supply by Acueducto, with the lowest cost of the entire supply system. There is still enough surplus capacity of water conveyance in Chingaza System, which will be able to cover future expansion. It is sure that Chingaza System will become more important in future water supply.

On the other hand, water is conveyed though mountain tunnel of 40 km length in Chingaza System, which is vulnerable to natural disaster such as earthquake. It is likely to happen that water conveyance tunnel will collapse, and water supply will be interrupted again, the same as case of "Chingaza Crisis" in 1997. It is clear that expansion of Chingaza System will increase vulnerability of water supply.

4.4. Proposal to M/P of Acueducto

1) Projects proposed in M/P are scheduled to start after year of 2029. High priority is given to projects of expansion of water sources in Chingaza System. It is evident that expansion of Chingaza System has a clear advantage over projects in the other area, from every view points. Water sources should be expanded following above plan.

2) On the other hand, water is conveyed to Bogotá Metropolitan area though single mountain tunnel of 40 km length in Chingaza System. There is high risk of interruption of water conveyance due to tunnel collapsing, as "Crisis of Chingaza (1997)" proved it.

3) According to M/P of Acueducto, water supply by Chingaza System will be expanded in the future. Therefore, risk in interruption of water conveyance from Chingaza area will be increased in the near future. As measures for it, projects for emergency water supply should be prepared as shown below:

   a) Continuous operation of Tibitóc plant, and increase of water production of the plant in case of emergency.

   b) Preparation for re-operation of closed plants.

   c) Development of groundwater in suburb of Bogotá Metropolitan area for alternative water sources for emergency.

4) M/P of Acueducto will be reviewed in 2008. Plan for development of alternative water sources for emergency water supply should be included in the M/P.

CHAPTER 5. MASTER PLAN OF WATER SUPPLY FOR BOGOTA CITY AREA BY USE OF GROUNDWATER

5.1. Basic Policy of the Master Plan

5.1.1. Water Supply for Case of Emergency

Basic policy for Mater Plan of water supply by use of groundwater is as follows:

<Basic policy for water water supply by use of groundwater>

Water resources development of Chingaza area should be promoted for long-term sustainable water supply for Bogota metropolitan area. On the other hand, water conveyance from Chingaza area is vulnerable to natural disaster. To solve this problem, master plan for emergency water supply by use of groundwater around Bogota city area is formulated.

Background of above strategy is as follows:

＜ Long-term water resources development plan ＞

- Surface water resources development is necessary to meet future water demand of Bogotá metropolitan area. Surface water resources have been already developed to the full capacity, and there is no excess potential for further development.
- Therefore, surface water development in Chigaza and Sumapaz area should be promoted to meet the water demand until 2050.

Water resources development in Chingaza Area

- Water is conveyed though mountain tunnel from Chingaza Dam to Bogota. The current water conveyance through the tunnel is only 11m^3/s, though its full conveyance capacity is 25m^3/s.
- Remaining conveyance capacity of the tunnel, which is not used now, should be used by new water resources development in Chingaza area.
- It is more effective to develop water resources of Chingaza area than the other area. High priority should be given to Chigaza area in new water resources development.

Vulnerability of Chingaza system

- Amount of water supply by Chingaza system occupies 70% of entire water supply for Bogota metropolitan area.
- Water supply for Bogotá become more vulnerable as Chingaza system becomes more important
- Water supply was stopped for 9 month by collapse of the Chigaza tunnel in 1997
- There is possibility of collapse of Chigaza tunnel again due to outbreak of large earthquake in the future. Damage by the collapse of the tunnel will be more serious than before.

Master plan for emergency water supply by use of groundwater

- Alternative water sources should be prepared for emergency water supply, which is more important in case of long-term interruption of water conveyance from Chigaza area.
- Groundwater should be used as alternative water sources for emergency water supply with advantage as listed below:
  - ①Emergency wells will be drilled in suburb of Bogotá where there is large water demand
  - ②Emergency wells will be located scattered around Bogotá to mitigate risk
  - ③Emergency well can be operated by a generator beside a well even when power supply is interrupted.

5.1.2. Ordinary Water Supply by Groundwater

As described in the previous section, water supply facilities by groundwater are for case of emergency.

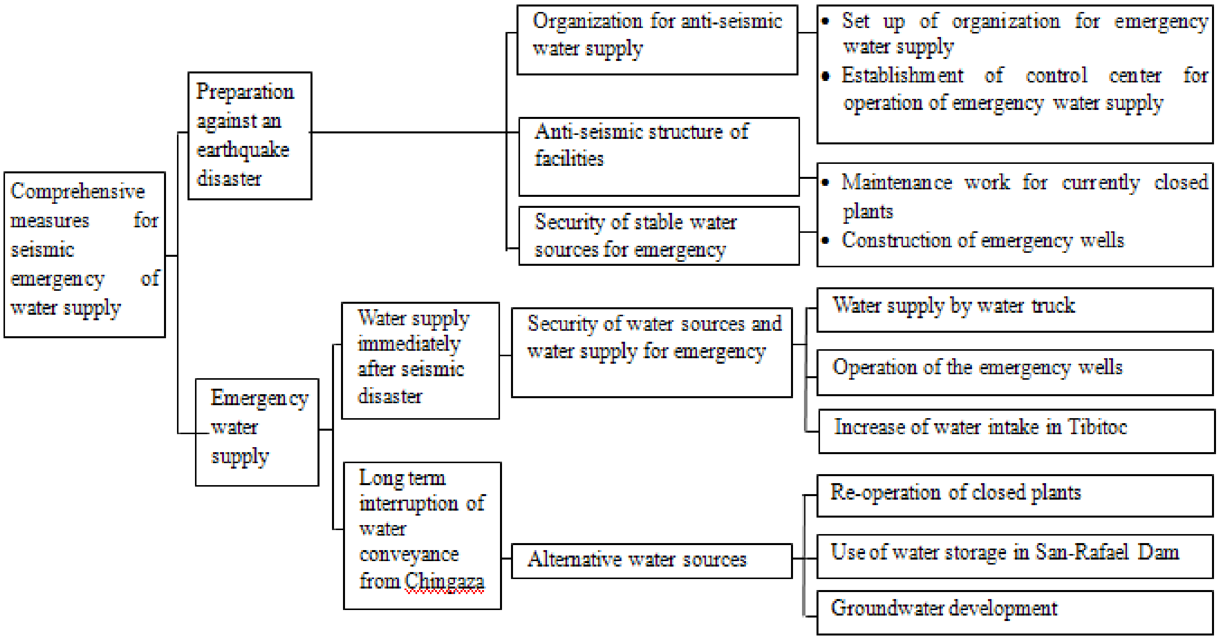
These facilities need regular operation for maintenance.

5.2. Water Supply Plan in Case of Emergency

5.2.1. Alternative for Water Supply in Case of Emergency

(1) Comprehensive Measures for Seismic Emergency of Water Supply

The comprehensive measures for emergency of water supply are proposed as shown in Figure-2.5-1.



Source: JICA Study Team

Figure-2.5- 1 Comprehensive Measure for Seismic Emergency of Water Supply

(2) Assessment of Damage to Water Supply System by Earthquake

Two type damages by earthquake is assessed for water supply system in Bogotá

- Damage to the water pipe network of Bogotá Metropolitan area
- Damage to the water conveyance tunnel and pipeline from water sources

Scenario of damage is as follows.

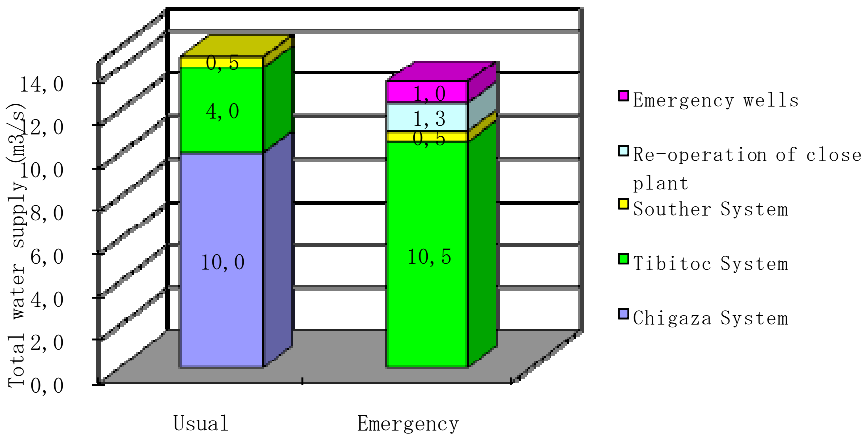
Immediately after occurrence of seismic disaster (Scenario-1)

Water will be supplied by water-supply trucks, immediately after occurrence of a seismic disaster, (JICA Study team proposal), because of damage to water pipe network in the urban area. In that case, the remaining water in distribution reservoirs/tanks of Acueducto and groundwater from emergency wells will be water sources for emergency water supply.

Amount of water to be supplied should be 15 litter/person/day, which is minimum for human survival (target of Acueducto), immediately after occurrence of seismic disaster.

Long term interruption of water conveyance

If the tunnel from Chingaza collapses, water conveyance interruption may continue for a long period (Crisis of Chingaza took place in 1997, and interruption of water conveyance continued for 9 months). In that case, it is necessary to use entire alternative water sources to maintain water supply as same as usual water supply. Usual water supply rate is 14.5 m^3/s as shown in Figure-2.5-2, 70% of which is by Chingaza System. Even though Chingaza System is interrupted, 13.3 m^3/s of water can be supplied by alternative water sources as shown in Figure2-5.2.



Source: JICA Study Team

Figure-2.5- 2 Water Sources in Usual and Emergency Water Supply

5.2.2. Evaluation of Alternative Plant

Alternative plan for emergency water supply is evaluated as shown below Table-2.5-1.

Table-2.5- 1 Evaluation of Emergency Water Supply Plan

Alternative	Stability of water sources in emergency		Cost (New investment)	Water Production
	Immediately after disaster (up to 2 month)	Prolonged emergency period (up to 9 month)		
a) Use of storage water of San-Rafael Dam	Unstable (damage to the facilities is expected)	Stable for 3 months	Not necessary	Big (10 m^3/s ×3 month)
b) Increase of water intake at Tibitóc Plant	Unstable (damage to the facilities is expected)	Stable	Not necessary	Big (10.5 m^3/s)
c) Southern System	Unstable (damage to the facilities is expected)	Stable	Not necessary	Small (0.51 m^3/s)
d) Re-operation of closed water purification plants	Unstable (damage to the facilities is expected)	Stable	Necessary (for maintenance)	Small (1.3 m^3/s)
e) Emergency wells	Stable (direct water supply is available at well site)	Stable	Necessary	Small (1.5 m^3/s)

Source: JICA Study Team

The alternative of "(e) Emergency wells" is more stable than others because Emergency wells can be scattered covering whole Bogotá City, which can be more useful in water supply immediately after serious disaster.

In case of prolonged interruption of water conveyance from Chingaza System (collapse of tunnel from Chingaza), every alternatives are necessary to supplement deficit of water conveyance from Chingaza. Therefore, it is proposed that every alternative listed in Table-2.5-1 should be used for emergency water supply.

5.3. Groundwater Demand

The objective to develop groundwater is to secure and supply water in emergency caused by natural disasters such as big earthquake. For such a reason, the use of groundwater should be considered as an alternative water source for emergency water supply and thus integrated in the contingency plans of Acueducto.

The groundwater demand in emergencies is estimated separately in two scenarios as below:

- Scenario 1: Damage to distribution networks of Bogotá City.
- Scenario 2: Damage to water conveyance from Chingaza.

<u>Demand of Scenario 1</u>

It is estimated based on the minimum water volume 15 litters/day/person in emergencies that Acueducto expects, corresponding to 15% of the usual water consumption per inhabitant in Bogotá D.C. (90-110 litters/day/person).

<u>Demand of Scenario 2</u>

It is estimated by taking into account the full operation and supply from other plants such as Tibitóc, Vitelma, Yomasa and El Dorado, except San-Rafael (from Chingaza).

Table-2.5-2 shows the groundwater demand for two damage cases in 2007 and 2020.

Table-2.5- 2 Groundwater Demand in Emergency

Scenario	Period until Restoration	Base for estimate			Groundwater Demand
<Scenario 1> Damage to Distribution Networks	60 Days	Per person/day (a)		Population of Bogotá City (b)	= (a) x (b)
		Year 2007	15 litter [1]	6.8 million [2]	1.18 m^3/s
		Year 2020		9.7 million [3]	1.68 m^3/s
<Scenario 2> Damage to water conveyance tunnel from Chingaza	9 months	Total demand (c)		Full supply from other plants (d)	= (c) – (d)
		Year 2007	14.5 m^3/s	Tibitóc (10.5m^3/s), Southern (0.5m^3/s) and others (1.3m^3/s)	2.2 m^3/s
		Year 2020	18.4 m^3/s [4]		6.1 m^3/s

Note:1) Expected volume of Acueducto, 2) Estimate from 2005 census population, 3) "Proyecciones de la población, 2003" of Humberto Molina, 4) Master Plan of Acueducto 2005.

Source: JICA Study Team.

5.4. Master Plan for Emergency Water Supply Plan by Use of Groundwater

5.4.1. Production Wells

(1) Well Location

Well location was planned considering emergency water supply. Location of proposed wells is shown in Figure-2.5-4. Total number of the proposed wells is 62, from which 4 wells already exist. Well sites are selected out of the forest protection area and densely urbanized area (see Figure-2.5-3.)

(2) Wells in the Forest Protection Area

Economic activity including drilling wells is prohibited inside the forest protection area of the Eastern hill. However, there are some places suitable for well drilling in the Eastern hills. As shown in Figure-2.5-4, steep slopes with higher elevation are generally seen in the forest protection area. Consequently, it is not suitable for drilling wells in such area. However, there are some places where mountain streams cuts the wide and deep valley, such areas inside valleys are sometimes suitable for drilling. Drilling sites were selected from areas mentioned above.

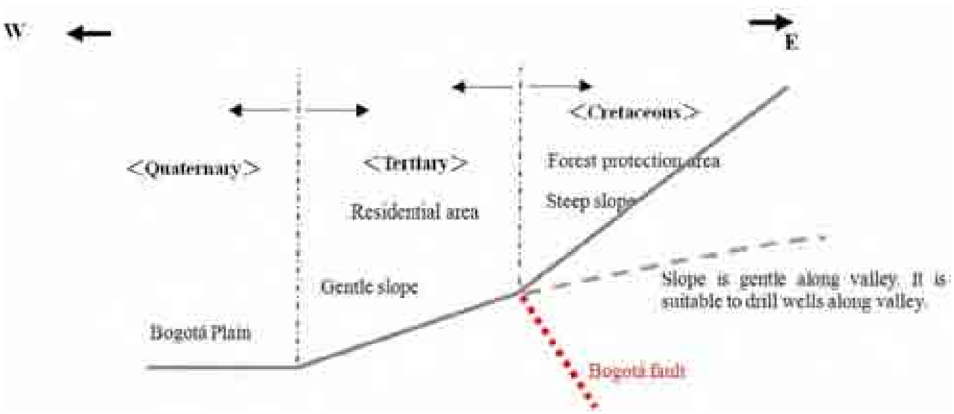
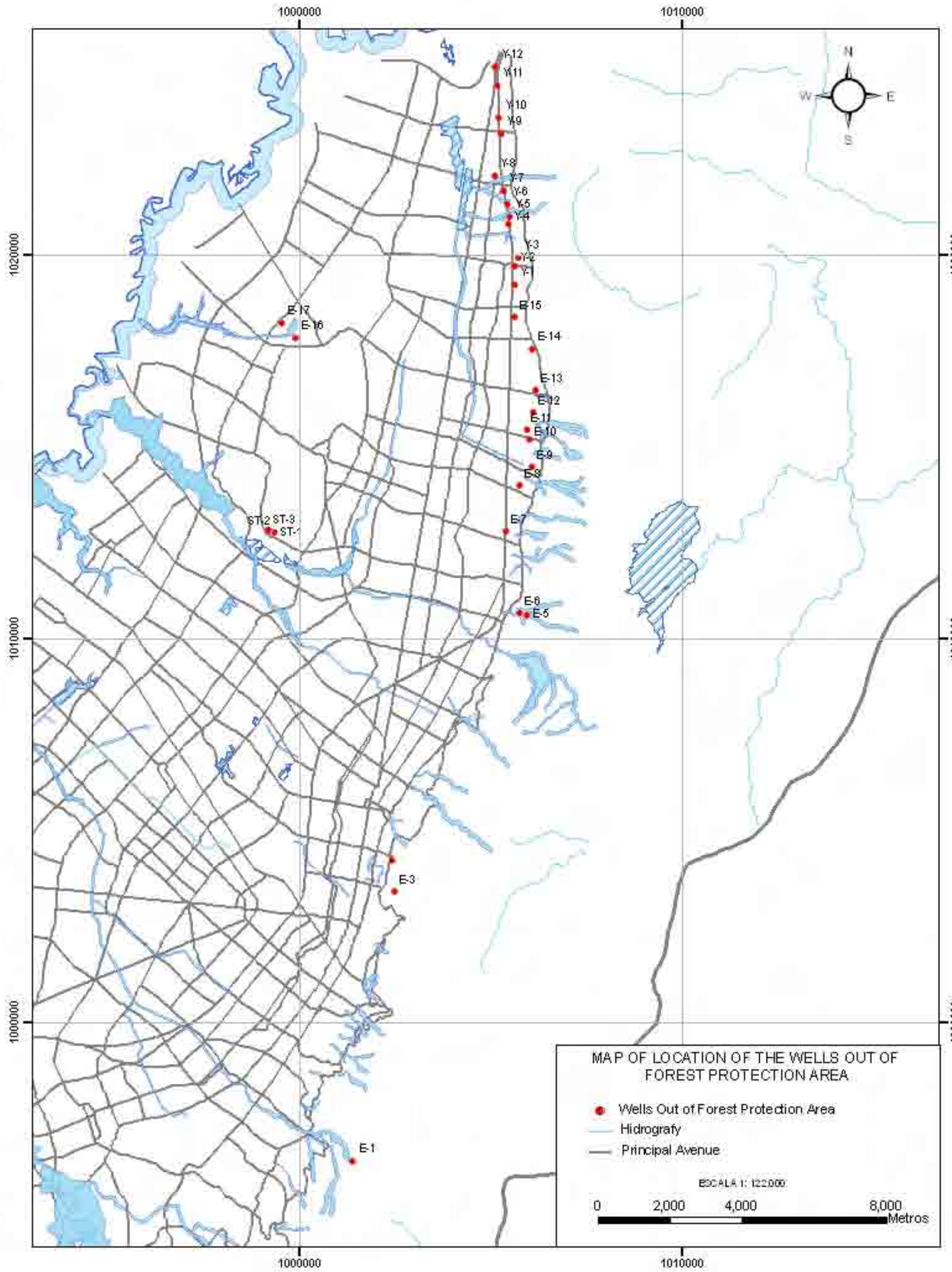


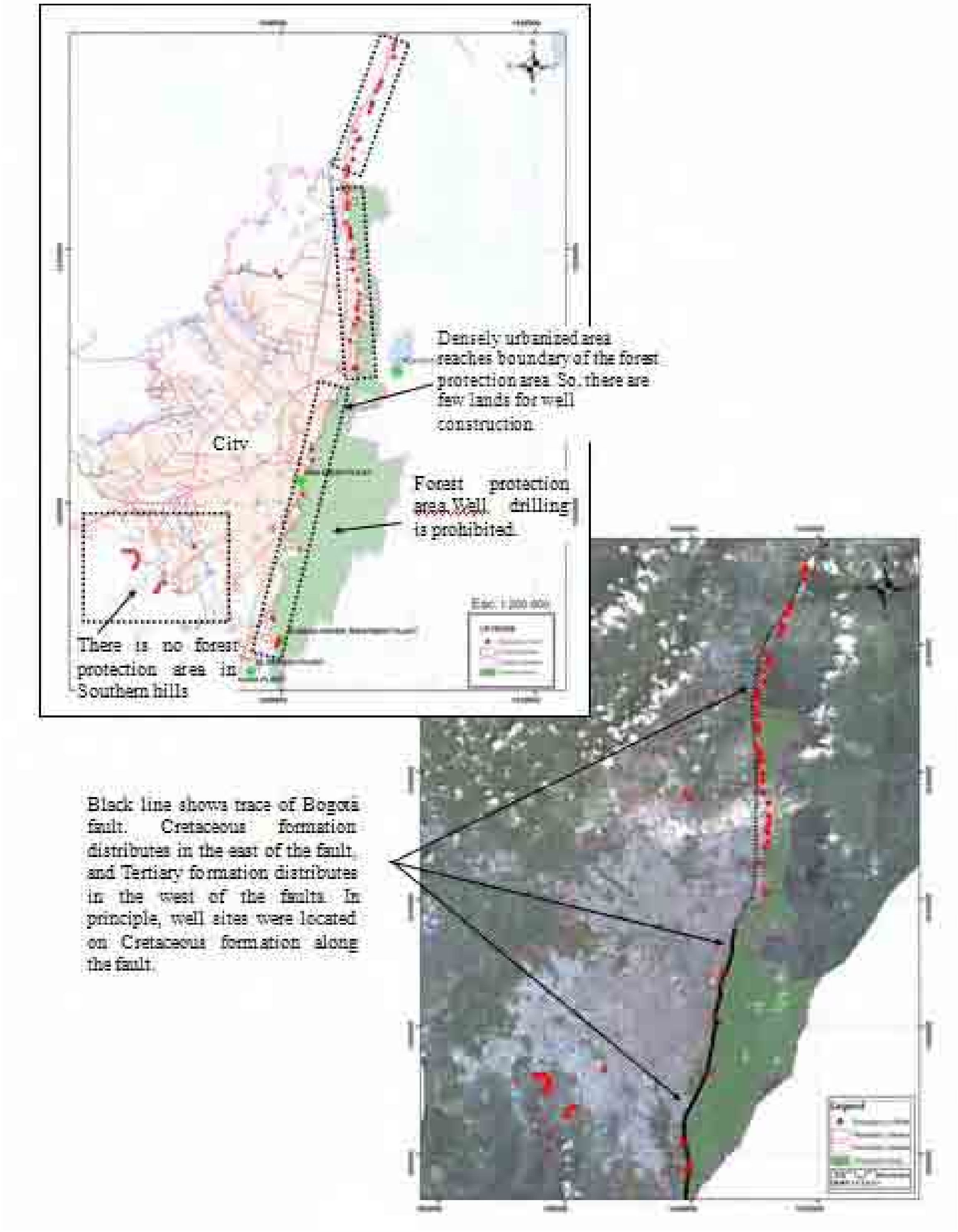
Figure-2.5- 3 Criteria of Drilling site in Eastern Hills

Sites suitable for drilling well inside the protection area are shown as reference in Figure-2.5-6. However, drilling wells inside the protection area are currently not permitted by the regulation.



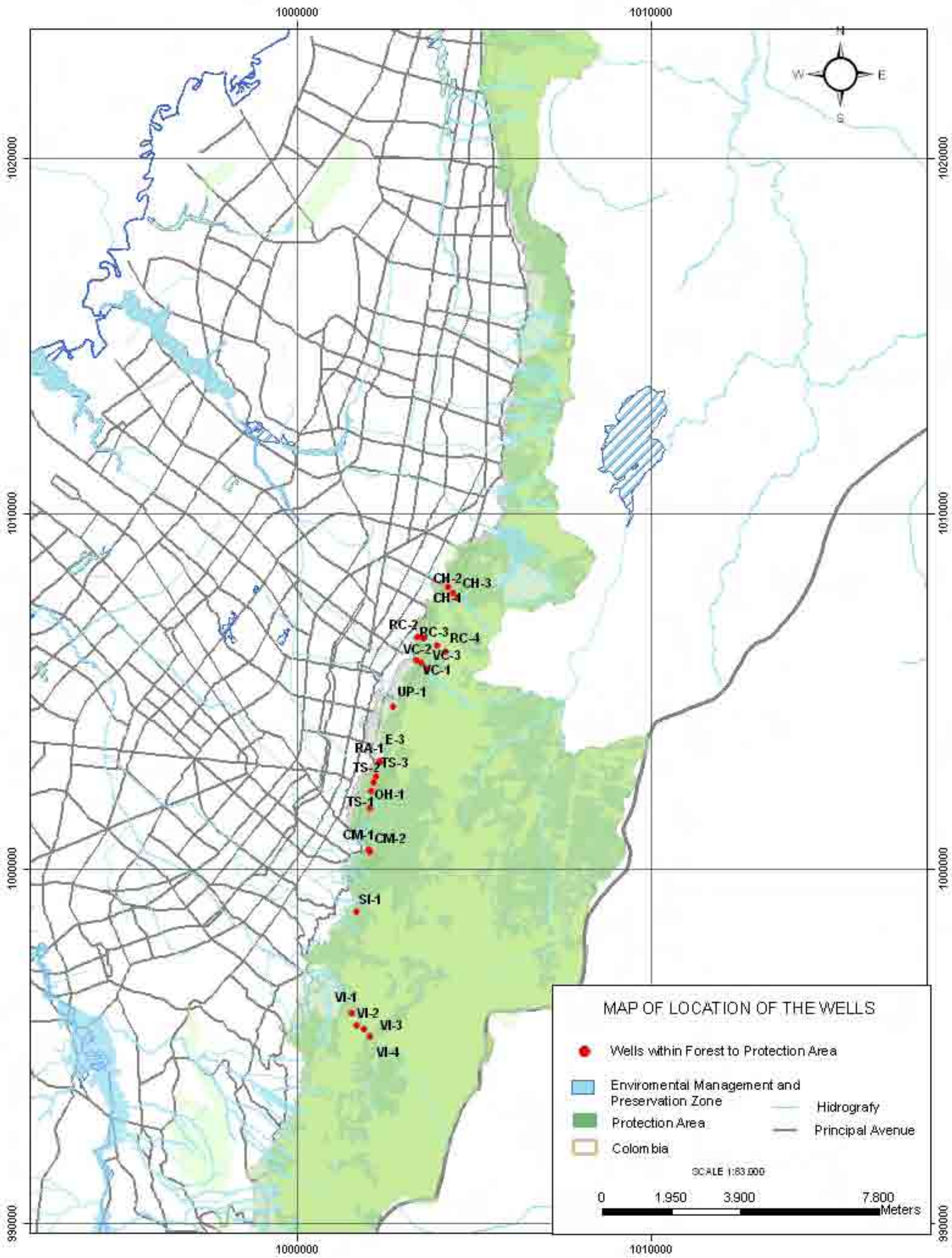
Source: JICA Study Team

Figure-2.5- 4 Well Site for Eastern Project



Source: JICA Study Team

Figure-2.5- 5 Forest Protection Area and Densely Urbanized Area

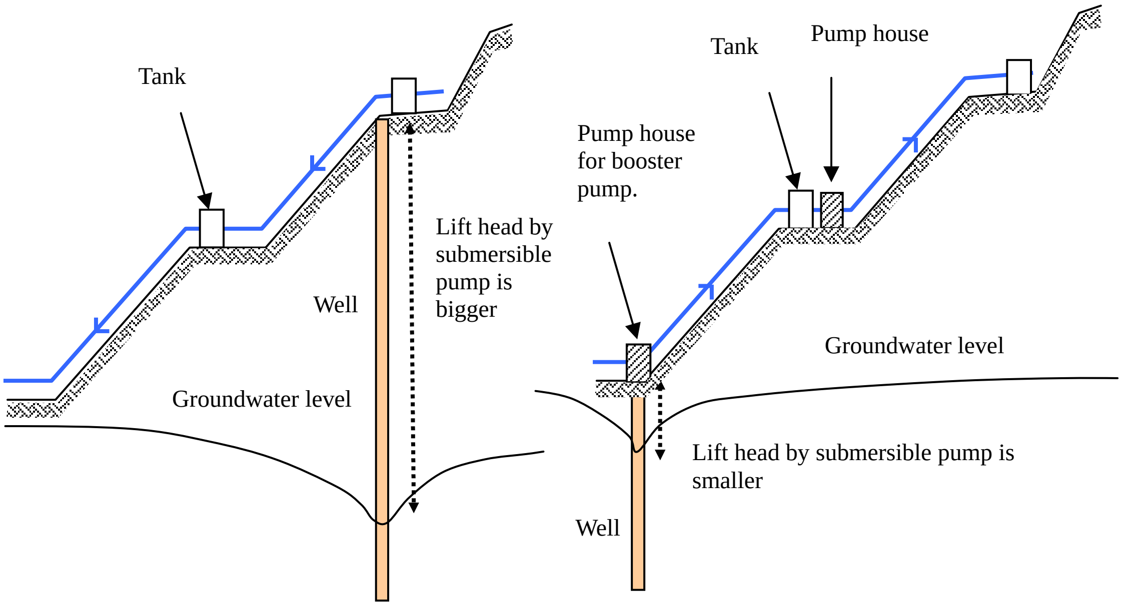


Source: JICA Study Team

Figure-2.5- 6 Wells inside Forest Protection Area

(3) Wells location of hillside

Principally, wells will be located along the hillside. Cost for well construction and operation depends on location of wells as shown in Figure-2.5-7.



Alternative-1 Wells located in upper part of hills   Alternative-2 Wells located in lower part of hills

Source: JICA Study Team

Figure-2.5- 7 Alternative of Well Location

Wells should be located in lower part of hills, if the cretaceous aquifer is distributed entire hillside. Groundwater will be pumped by submersible pump from a well to a tank on the ground. Then, groundwater in the tank will be pumped up again to upper part of hills by booster pump, which is more efficiency in operation cost than pumping groundwater directly from a well to upper part of hills.

(4) Number of Wells

Yield from one well should be 1,500-3,000 m^3/s, taking into account of capacity of Cretaceous Aquifer, as well as standard diameter of wells and available capacity of submersible pump. In this Study, 62 wells were proposed. Desirable total yield from 62 wells is around 1 m^3/s to 2 m^3/s

5.4.2. Optimum Yield

(1) Optimum Yield

The optimum yield from wells is restricted by groundwater development potential. To decide the optimum yield, lowering of groundwater level by pumping from planned wells should be carefully examined. For decision of the optimum yield, six alternative yields from the wells were examined as shown in Table-2.5-3. Lowering of groundwater level by each alternative yield was analyzed by groundwater simulation.

Table-2.5- 3 Alternative Yield from Wells

Alternative	Total yield (m^3/s)	Yield from one well (Total number of wells is 62)	Note
Alternative-1	1.0	86,400 m^3/day	Corresponding to Scenario-1 in 2007
Alternative-2	2.0	172,800 m^3/day	
Alternative-3	3.0	432,000 m^3/day	
Alternative-4	4.0	345,600 m^3/day	
Alternative-5	5.0	432,000 m^3/day	
Alternative-6	6.0	518,400 m^3/day	Corresponding to Scenario-2 in 2020

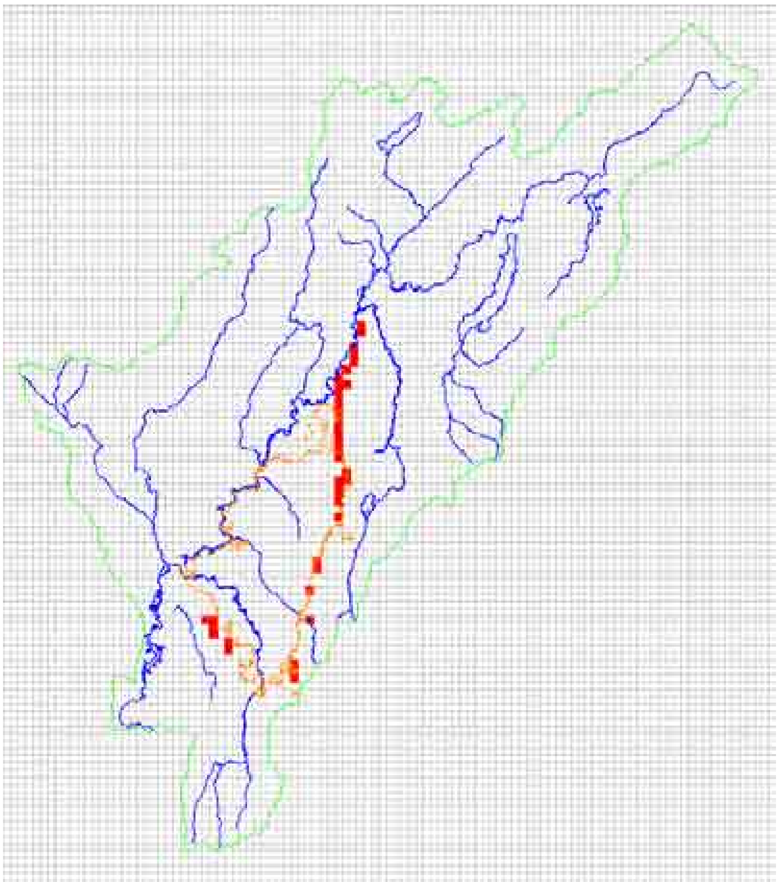
(2) Pumping Plan by Groundwater Simulation

The influence of pumping of the 62 planned wells (from the Cretaceous Aquifer) over the hydraulic head distribution of the surrounding aquifers was investigated using the calibrated model. Based on analyzed influence, the optimum yield was selected from Alternative-1 to Alternative-6.

The pumping rate for each planned well of the simulation model was then given based on the following assumptions.

- The total pumping rate is equally distributed among the 62 planned wells.
- All the wells operate 24 hours.
- The total pumping rate for simulation is changed from 1.0 m^3/s to 6 m^3/s, according to Alternative-1 to Alternative-6 in Table-2.5-3.
- The simulation period is set from 0 to 365 days (=12 month).

The location of the newly planned wells is shown in Figure-2.5-8.

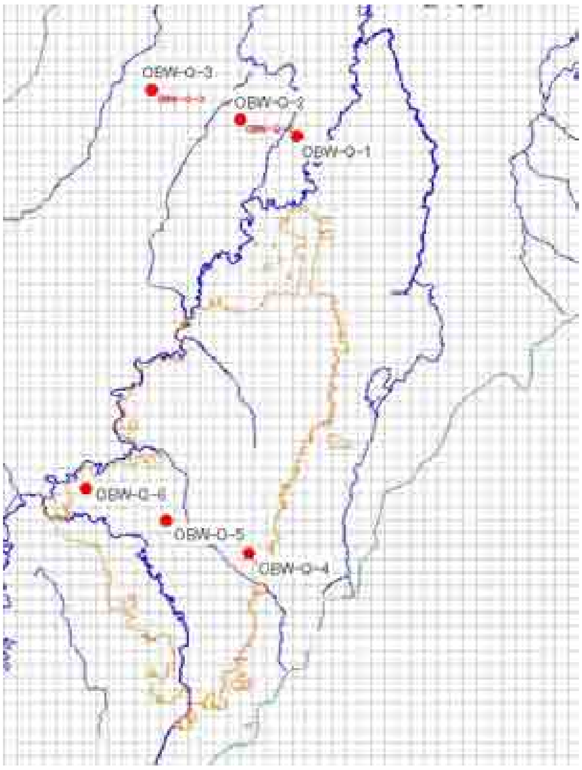


Note: Red cells represent those with pumping wells, up to 3 wells in a cell.
Source: JICA Study Team.

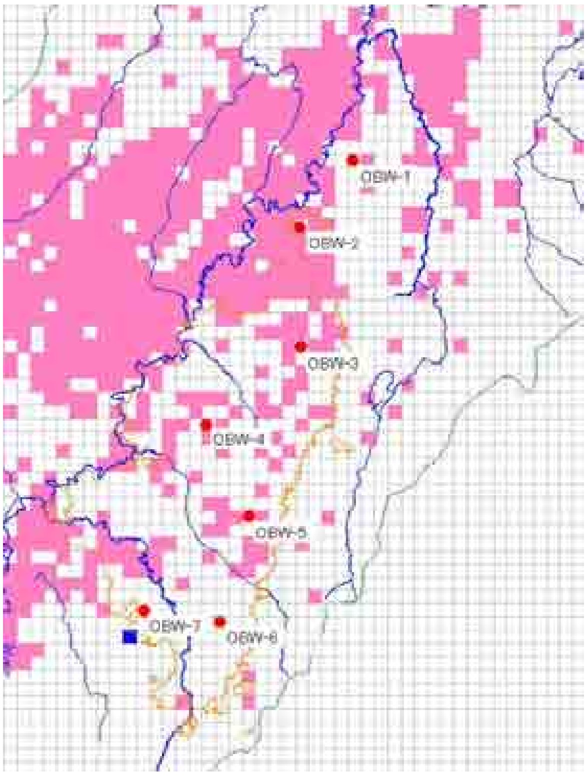
Figure-2.5- 8 Distribution of Planned Wells in the Model

(3) Head Observation Wells

The drawdown of water table and hydraulic heads due to pumping of newly planned wells were observed in the Cretaceous aquifer and in the Quaternary sediment layer above it. The location of the observation wells are shown in Figure-2.5-9.



Observation wells for Quaternary sediment layer



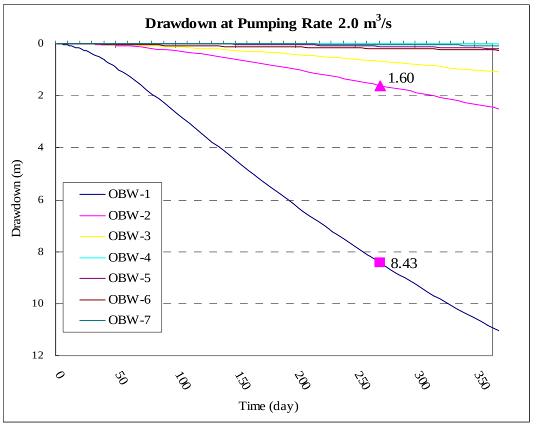
Observation wells for Cretaceous aquifer

Source: JICA Study Team

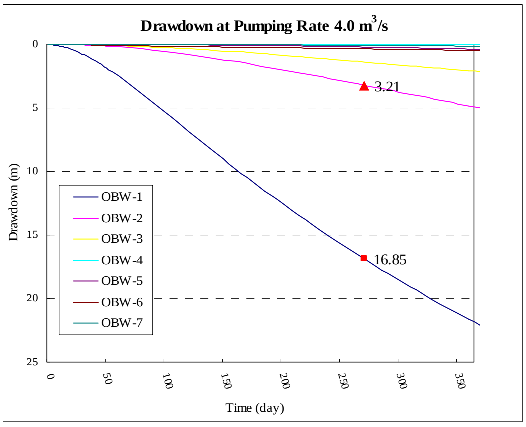
Figure-2.5- 9 Location of Observation Wells

(a) Drawdown Cretaceous Aquifer

As a result of the transient simulation, the hydraulic head with time at each observation wells were calculated and two examples are shown in Figure-2.5-10.



Scenario 2 (total pumping rate 2.0 m^3/sec)



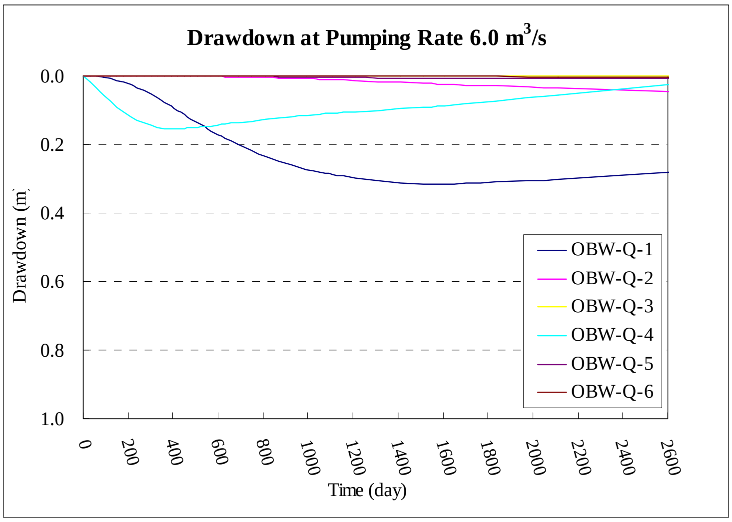
Scenario 4 (total pumping rate 4.0 m^3/sec)

Note: The markers indicate drawdown at time 271 days (9 months).
Source: JICA Study Team.

Figure-2.5- 10 Drawdown-Time Relation in Cretaceous Aquifer

(b) Drawdown in Quaternary Sediment Layers

For the Quaternary sediment layers, the maximum drawdown at day 271, in the case of scenario 6 that has the largest pumping rate, was found to be very small. Even when the simulation time was extended up to 2,600 days (approximately 7 years), the result showed little difference as illustrated in Figure-2.5-11. Therefore, the possibility of land subsidence is considered very small and negligible in this area.



Source. JICA Study Team

Figure-2.5- 11 Drawdown in Quaternary Sediment Layers

(c) Result of Simulation

The following conclusions, concerning the groundwater behavior by pumping of newly planned 62 wells, are suggested from the results of the groundwater simulation.

In an area, where the hydrogeological conditions are not favorable, the maximum drawdown after nine (9) months of operation with the largest pumping rate (6.0 m^3/s) is 25 m. The average drawdown is estimated to be around 5 m under the same condition. The drawdown of this degree is considered not to hinder operation of pumping wells.

Pumping of newly planned wells has little effect on the water table of the Quaternary sediment layers.

(d) Optimum Yield

Average capacity for groundwater production from one well is estimated as 2,000m^3/day. Therefore, total yield from 62 wells can be 1.44m^3/s, which can be called as planned yield for facilities design. However, whether this yield is possible or not must be examined from hydro geological view points. Impact by pumping from 62 planned wells was predicted as shown below:

a) Lowering of the groundwater level of the other existing wells

b) Occurrence of land subsidence of Quaternary formation by lowering of groundwater level

Lowering of groundwater level in Quaternary aquifer by pumping of Alternative-1 (1.0m^3/s) to Alternative-6 (6.0m^3/s) is small and negligible. Conclusion on optimum yield is made as explained below:

<Impact to existing wells>

Lowering of the groundwater level of the existing well by pumping from 62 planned wells was predicted as o.06 to 0.14m, which is small and groundwater use of the existing wells will not be interrupted. The existing wells are used for agricultural and industrial use. In case of emergency, public water use for domestic water supply will dominates the other water use. Therefore groundwater pumping from the emergency wells has higher priority than pumping from the private wells. Consequently, planned yield of 1.44 m^3/s is possible from view point of lowering of groundwater level.

＜Impact on land subsidence＞

Planned yield of 1.44 m^3/s, is between tAlternative-1 ($1m^3/s$) and Alternative 2 ($2m^3/s$) in the analysis, Analyzed land subsidence by above Alternatives is much smaller than by the other Alternatives. Also, risk of land subsidence is small, even though considering uncertainly in soil-mechanical data. Thus, it can be concluded that the planned yield of $1.44m^3/s$ is possible from view point of land subsidence.

5.4.3. Water Treatment Facilities

(1) Plan for water Treatment Facility

Optimum plan for water treatment facilities will be formulated basically based upon the following conditions:

1. The quality of the groundwater in the stratum of the Cretaceous is considered better than that in the stratum of the Quaternary. The water quality items to be noted in the groundwater are iron (Fe) and manganese (Mn). Therefore, adoption of Water Treatment System (Alternative A-2 in Table-2.5-4) to remove Fe and Mn should be examined.
2. In case the substances that are difficult to be removed by Alternative A-1 (such as high turbidity, soluble silic acid and so on) are contained in the raw water, the conventional system (Alternative A-3 in Table-2.5-4) composed of mixing, coagulation, sedimentation, and filtration will be adopted.
3. In case the concentration of Fe and Mn can be decreased by mixing the groundwater with other treated water, the system (Alternative A-1) in Table-2.5-4 combination of chlorination and mixing with the other treated water, is adopted. The mixing ratio between treated groundwater and the other treated water is approximately 1 to 9.

Based upon the above-mentioned conditions, four (4) alternatives are proposed depending on the purpose of water use and water quality of groundwater as shown in Table-2.5-4.

Table-2.5- 4 Alternatives for Water Treatment System for Groundwater

Conditions of raw water quality / Conditions of water supply			In case Fe and Mn exceeds standard value			In case Fe and Mn are less than standard value
			Alternative A-1	Alternative A-2	Alternative A-3	Alternative B-1
Scenario of Disasters	①Damages of water distribution network in Bogotá city	Period of emergency water supply will be about 10 days	Chlorination	Chlorination + Small system 1)	Conventional system 2)	Chlorination
	②Damages of water conveyance tunnel from Chingaza	Period of emergency water supply will about 9 months	Chlorination + Water mixing with the other treated water	Chlorination + Small system	Conventional system	Chlorination
Construction cost/Operation cost			Low	Medium	High	Low

Notes: 1. Small system: The system composed of sand filtration (Pressure filtration type).
2. Conventional system: The system composed of sedimentation and sand filtration.

Source. JICA Study Team

(2) Sludge Treatment Facilities

Criteria for judgment of adopting sludge treatment systems corresponding to each alternative water treatment method are shown in Table-2.5-5.

Table-2.5- 5 Criteria for Judgment of Adopting Sludge Treatment System

Water quality item (Units)	Design drainage quality alternative			Design effluent standard	Standard
	A-1 and B-1	A-2	A-3		
pH	-	5.8-8.6	5.8-8.6	5.8-8.6	Water Quality Standards in Japan
Turbidity (NTU)	-	Less than 100	More than 1,000	Less than 200	Water Quality Standards in Japan
Fe (mg/L)	-	Less than 10 [2]	More than 50	Less than 10 (Soluble ferrous)	Water Quality Standards in Japan
Mn (mg/L)	-	Less than 10	More than 50	Less than 10 (Soluble manganese)	Water Quality Standards in Japan
Necessity of sludge treatment	No (No drainage)	No	Yes [1]		

Notes: 1. Refer to Figure-5.15 for the sludge treatment system.
2. In case concentration of iron in drainage is more than 10 mg/l, installation of thickener should be examined.
Source. JICA Study Team

The concentration of each substance in drainage from the systems of Alternative A-1 and Alternative B-1 is predicted to fall within the effluent standard of Colombia. Consequently, in this master plan, sludge treatment systems are not applied taking into account the cost effectiveness against the construction cost. Therefore, sludge treatment system will be applied only when Alternative A-3 is adopted.

(3) Selection of Purification and Sludge Treatment System

In this Master Plan, purification and sludge treatment system shown in Table-2.5-6 is finally proposed, taking into account of quality of raw water, type of treatment necessary and cost-effectiveness.

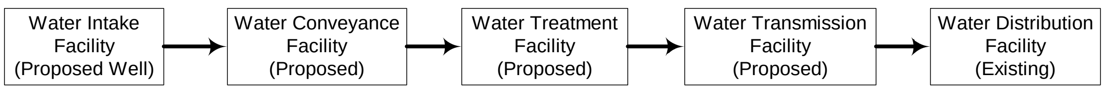
Table-2.5- 6 Proposed Purification and Sludge Treatment System to be applied in this Study

Proposed system		Content
Item	Type of Treatment	
Purification	Alternative-2	Chlorination＋Small system [1)]
Sludge treatment	Not necessary	Sludge treatment is not necessary in principle. However, the minimum treatment necessary must be implemented to prevent impact to natural environment.

Note: 1. Small system: The system composed of sand filtration (Pressure filtration type).
Source. JICA Study Team

5.4.4. Plan for Water Transmission and Distribution Facilities

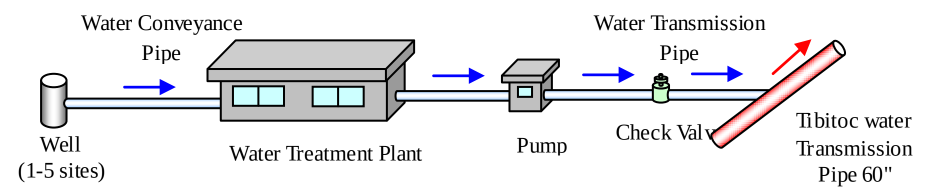
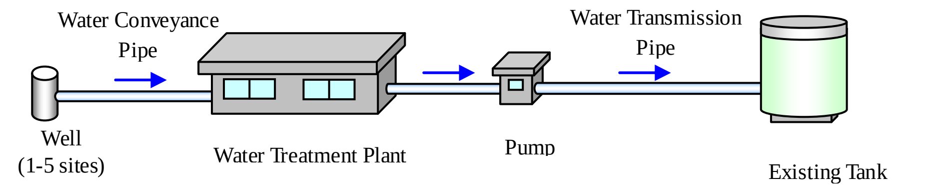
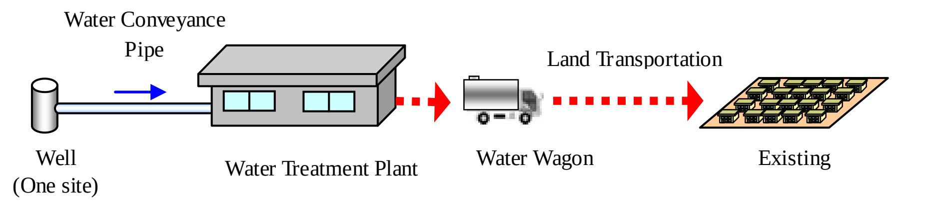
The fundamental composition of facilities for water transmission and distribution, from the water intake facilities to the water distribution facilities, for use of the groundwater in the emergency water supply, is proposed as shown in Figure-2.5-12.



Source: JICA Study Team

Figure-2.5- 12 Composition of Facilities for Water Transmission and Distribution for Use of Groundwater in Emergency Water Supply

As the composition of facilities for water transmission and distribution, three (3) types of facilities are planned as shown in Figure-2.5-13 Water supply by use of groundwater is proposed for emergency case. However, the system by the groundwater is available even for usual water supply.

Form	Purpose for Transmission/ Distribution	Facilities composition for water transmission and distribution for use of groundwater
Type-1	Regular/ Emergency	
Type-2	Regular/ Emergency	
Type-3	Emergency	

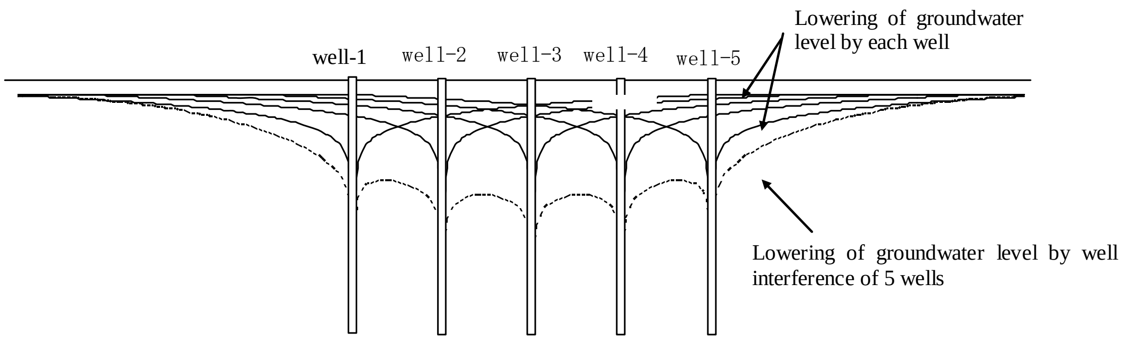
Source: JICA Study Team

Figure-2.5- 13 Composition of Water Transmission and Distribution Facilities by Use of Groundwater

5.5. Management of Well Operation

(1) Well Interference and Yield

Total yield from wells is proposed as 62 × 2,000 m^3/day = 1.44 m^3/s. However, it is necessary to increase yield from wells, when more water is requested than planned yield, in case where water shortage is more serious. In this case, there is a possibility that large lowering of groundwater level can happen by well interference. Pumping from one well will cause lowering of the groundwater level of neighboring wells, as shown in Figure-2.5-14.



Source: JICA Study Team

Figure-2.5- 14 Well interference by 5 wells

Therefore, when great amount of groundwater is pumped up from well field, it is necessary to control yield from each well of the wells field to avoid harmful lowering of groundwater level by well interference.

It is planned to pump up 2,000 m^3/day of groundwater from each wells in average in case of emergency. When more groundwater is needed, pumping rate from each well should be increased with different rate.

(2) Optimum allocation of yield by well

To increase yield of wells, it is necessary to allocate optimum yield to each wells. It was examined by linear programming. Objective and constraint of the linear programming is as follows.

- Objective: To get the maximum total yield from 62 wells.
- Constraint: To make the same lowering of groundwater level of each well.

(3) Result of calculation

According to the calculation result, yield of wells should be allocated from 100% to 40% from the end to the center of well filed.

5.6. Analysis of land subsidence

Land subsidence by proposed project was analyzed as explained below.

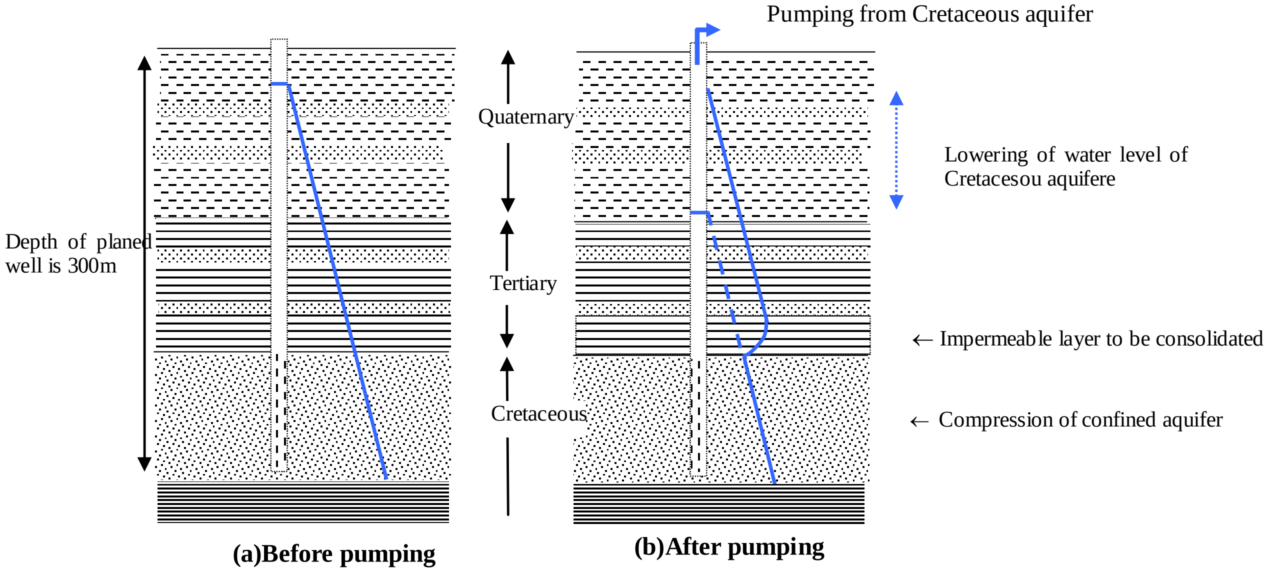
(1) Mechanism of land subsidence

Mechanism of land subsidence by pumping of groundwater is as follows.

A shown in Figure-2.5-16 only limited part of Tertiary layer, which has contact with Cretaceous aquifer, will be influenced by pumping from the Cretaceous aquifer. The other layer will not be influenced by pumping of the Cretaceous aquifer.

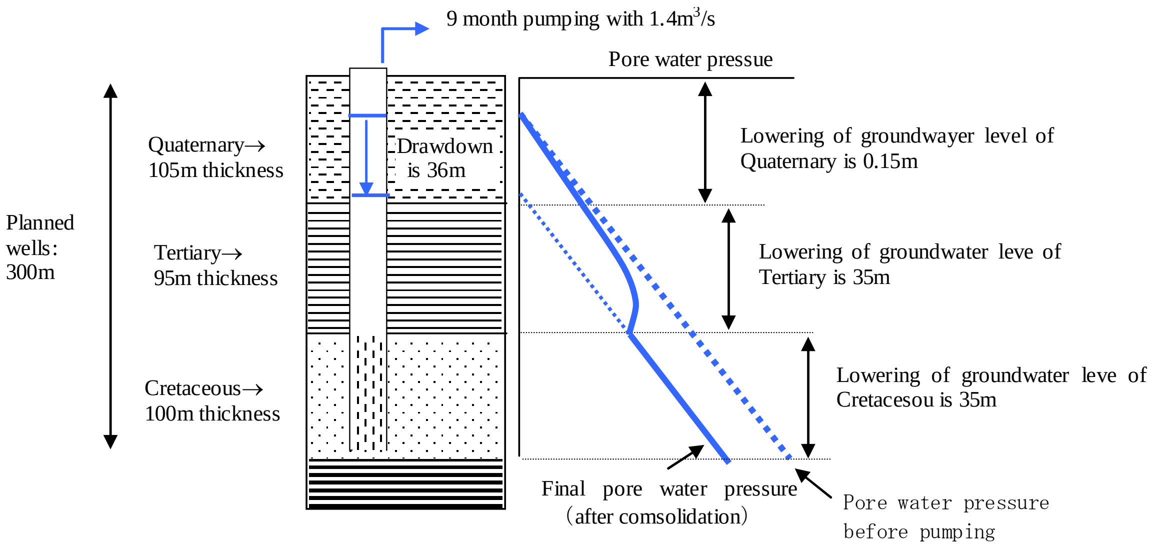
Model for consolidation

Model for analysis of consolidation by proposed project is shown in Figure-2.5-15. Values of reduce in pore water pressure shown in Figure-2.5-15 was result of groundwater simulation (see section 5.4.2).



Source: JICA Study Team

Figure-2.5- 15 Mechanism of Land Subsidence



Source: JICA Study Team

Figure-2.5- 16 Consolidation Model

Amount of land subsidence

Amount of land subsidence of the model layer in Figure-2.5-16 was finally calculated as shown in Table-2.5-7.

Table-2.5- 7 Amount of Land Subsidence

Geology	Darin condition for consolidation	Time factor (Tv)	Amount of land subsidence after 9 month pumping		
			Final land subsidence (m) (a)	Degree of consolidation (%) (b)	Land subsidence after 9 month pumping (m) (a) x (b)
Quaternary	One side	9.6×10^{-5}	0.02	5	0.001
Tertiary	-	-	0.003325	100	0.003325
Cretaceous	-	-	0.00105	100	0.00105
Total					0.0091

Source: JICA Study Team

As shown above, amount of land subsidence after 9 month pumping is small and negligible. This is because intermediate Tertiary layers between Quaternary and Cretaceous layers prevent land subsidence of soft Quaternary layers.

5.7. Pilot Project for Groundwater Use

Pilot Project for groundwater use is proposed by Acueducto to know technical problem and solution of the project. Purpose of the project is as follow:

- To know and solve technical problems in construction, operation and management of emergency water supply facilities by use of groundwater.
- To estimate cost of construction, operation and maintenance for emergency water supply facilities by use of groundwater.

In this project, an emergency well will be connected to the existing water pipe to send groundwater into the existing water supply system.

Site for Pilot Project

Pilot Project should be implemented in Vitelma sedimentation ponds of Acueducto.

Facilities for Pilot project

Facilities for emergency water supply consist of a well, simple water treatment facilities, energy facilities and pipeline. Groundwater pumped from well is from Cretaceous Aquifer, and it has good quality for drinking but contains a little high concentration of Fe and Mn. Treatment facilities to remove Fe and Mn are necessary.

5.8. Monitoring Plan

Well maintenance is necessary to use production wells for a long period of time at best condition. For this purpose, monitoring of different type below is necessary.

- Monitoring to control water production from wells.
- Monitoring to inspect influence to natural environment caused by pumping.

Monitoring to control water production from wells

Content of monitoring is described in Table-2.5-8.

Table-2.5- 8 Monitoring to Inspect Influence by Pumping to Natural Environment

Target	Item to be monitored		Frequency
	Item	Note	
Groundwater level	Dynamic groundwater level of operating well (Static water level of non-operated well)	Groundwater level will be observed by automatic recorder	Continuous observation
Yield	Yield of well	Yield from well will be observed by flow-meter.	Continuous observation
Water quality	Several representative items stipulated in water quality standard	Both row water and treated will be sampled and analyzed	Once/month

Source: JICA Study Team

Monitoring to inspect influence to natural environment caused by pumping

Content of the monitoring is summarized in Table-2.5-9.

Table-2.5- 9 Monitoring to inspect influence to natural environment caused by pumping

Target	Item to be monitored		Monitoring frequency
	Item	Method for observation	
Groundwater level of well	Static water level of observation wells	Static water level of Quaternary observation wells will be observed by automatic recorder. The observation wells should be near the Cretaceous production wells.	Continuous observation
Land subsidence	Land elevation	Land elevation of the Quaternary observation well will be observed.	Once/6 month

Source: JICA Study Team

5.9. Institution and Operation/Maintenance

(1) Procedure of Water Supply in Case of Emergency

Organization in charge of emergency water supply is to be Corporate Management Office of Master System under the leadership of the General Manager of Acueducto. Close communication with related organization will be necessary, especially at early stages of the emergency operation.

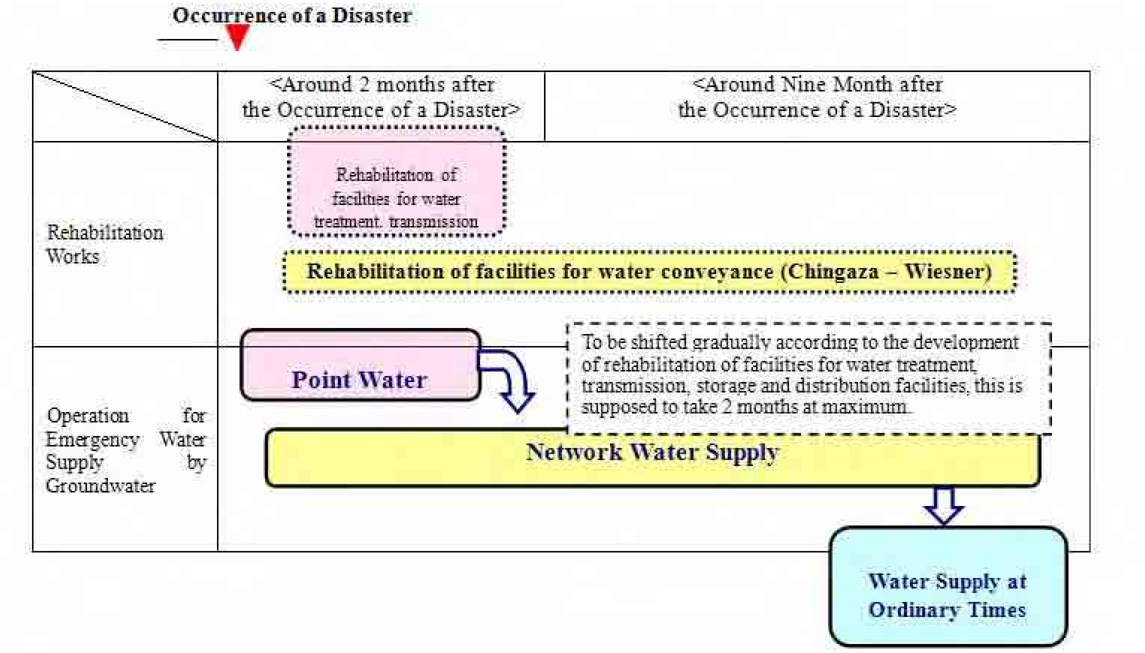
(2) Operation and Maintenance for Water Supply in Case of Emergency by Groundwater

Types of operation for emergency water supply by groundwater are classified as follows:

1) Point water supply: Water supply using water wagons for distribution. Water wagons will go to the locations of wells or treatment facilities (water distribution points) proposed in Section 5.4.4

2) Network water supply: Water supply using existing or rehabilitated water supply facilities for water treatment, transmission and distribution with automatic control system. Water wagons also can be available, being provided water from hydrants of the network water supply system.

Timing the two types of emergency water supply is illustrated in the figure below. Operation of the two types of emergency water supply are to be shifted gradually according to the development of rehabilitation of facilities for water treatment, transmission and distribution facilities, which is supposed to take 2 months at maximum.



Source: JICA Study Team.

Figure-2.5- 17 Operation for Emergency Water Supply by Groundwater

(3) 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.

(4) Enhancing Preparedness for Emergency Events

Since emergency operation tends to be complicated and confusing in nature under the circumstances of uncertainties, the followings are recommended for quick and proper emergency responses.

1) Communication with relevant organizations related Prevention and Attention of Emergencies of the District

   Since emergency water supply is one of the actions for attention of emergences as a whole and is closely related to the actions of other sectors, communication with the relevant organizations should be kept closely and frequently.

2) Preparation and updating of lists (contacts to personnel of Acueducto for emergency water supply, contractors for water wagons, and contractors for material supply, etc.)

   For smooth and proper start of operation for emergency water supply, information on these should always be updated. Periodical checks, like twice a year, are recommendable.

3) Preparation of Operation Manual and Training

As written above, substantial number of persons is to be involved in emergency water supply, whose daily jobs are different from those of emergency water supply, especially for point water supply. Easily applicable manuals should be prepared for the personnel operation works of emergency water supply.

4) Exercises and Drills

(5) Organization to Manage Water Supply by Groundwater

Although pumps, valves and treatment facilities can be controlled by remote control system, regular activities for well monitoring can be outsourced. Moreover, establishment of a unit in Corporate Management Office of Mater System to manage groundwater supply is recommended with the following staff and jobs.

5.10. Implementation Schedule for Master Plan

Project component and implementation schedule for Master Plan of emergency water supply by use of groundwater is proposed as below:

Project Component

Entire project is consists of three projects as shown in Table-2.5-10.

Table-2.5- 10 Master Plan for Emergency Water Supply by Use of Groundwater

Project			Number of wells	Produced water (m^3/s)
a)	Southern area	Soacha	7 wells	0.16
		Ciudad Bolívar	4 wells	0.10
		Usme	5 wells	0.12
b)	Yerbabuena area		17 wells	0.32
c)	Eastern area		29 wells	0.67
Total			62 wells	1.37

Source: JICA Study Team

(1) Period of Projects Commencement

Purpose of this project is emergency water supply, of which period will be limited from to 2 months to 9 months. The project should begin as soon as possible for earlier completion, because nobody knows when disaster will happen.

(2) Plan for Stage Construction of Project

Proposed 3 projects should be implemented by 3 phases, and each phase has 1 year period.

Project implementation schedule is proposed in Table-2.5-11.

Table-2.5- 11 Project Implementation Schedule

Item		Year														Note
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Master Plan for the project																JICA Study
FS Feasibility Study																JICA Study [1)]
－Project approval －Budget procurement																Investment decision by Acueducto
Detail design																－Geophysical survey, －Water quality analysis
Construction	Southern area															Well construction: 13
	Yerbabuena area															Well construction: 17
	Eastern area															Well construction: 23
O/M of facilities																

Note: 1) Implementation of JICA Study is not yet fixed; Source: JICA Study Team.

5.11. Design and Cost Estimate

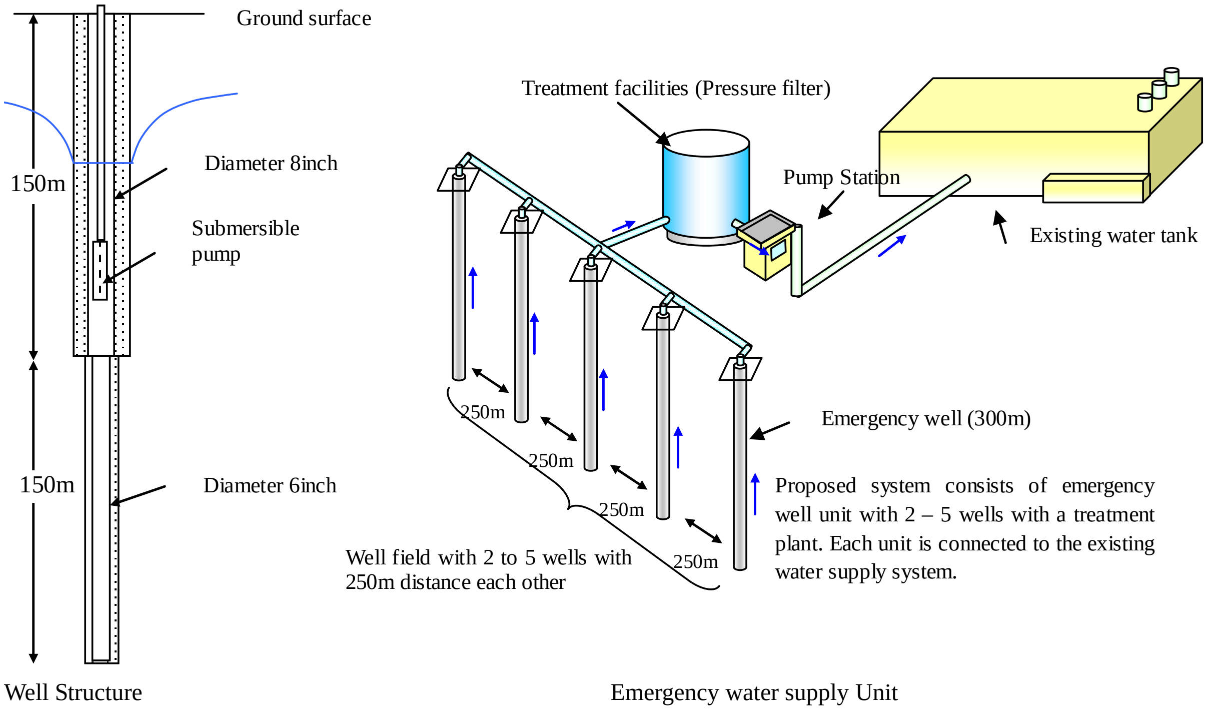
5.11.1. Design

(1) Design Standard

In Colombia, for the well drilling works, civil work, concrete structure work and the electrical installation work, the following design criteria are applied. These criteria depend on the criteria of USA. Therefore, the design of emergency water supply facilities by use of groundwater of this Study is based on the criteria below.

(2) Facility Layout

Proposed project is for emergency water supply. Layout emergency water facilities are shown in Figure-2.5-18.



Source: JICA Study Team

Figure-2.5- 18 Layout emergency water facilities

<u>Emergency water supply unit</u>

As shown in Figure-2.5-18, a well field consists of 2 to 5 wells and is connected to a water treatment filter. This system constitutes one emergency water supply unit. Treated water from the unit will be sent to the existing tanks and pipelines.

5.11.2. Cost Estimate

The Project cost of 3 phases that was estimated under above condition is shown as follows (Table-2.5-12).

Phase-1, Southern area: 31.25 thousand of millions Colombia pesos

Phase-2 Yerbabuena area 33.77 thousand of millions Colombia pesos

Phase-3 Eastern area 48.54 thousand of millions Colombia pesos

Table-2.5- 12 Rough Cost Estimation (unit: million Col$)

Item	Phase-I Southern area	Phase-II Yerbabuena area	Phase-III Eastern hill	Amount
1. Construction Cost	23.010	26.950	36.610	86.570
2. Land Acquisition	0.610	0.500	1.140	2.520
3. Engineering Fee	2.300	2.700	3.660	8.660
4. Administration cost	0.260	0.300	0.420	0.980
5. Contingency	2.620	3.050	4.210	9.880
<Total>	28.800	33.500	46.310	108.610
	14.33 million US$	16.67 million US$	23.04 million US$	54.04 million US$
	1,691 million JPY	1,967 million JPY	2,719million JPN	6,378 million JPN

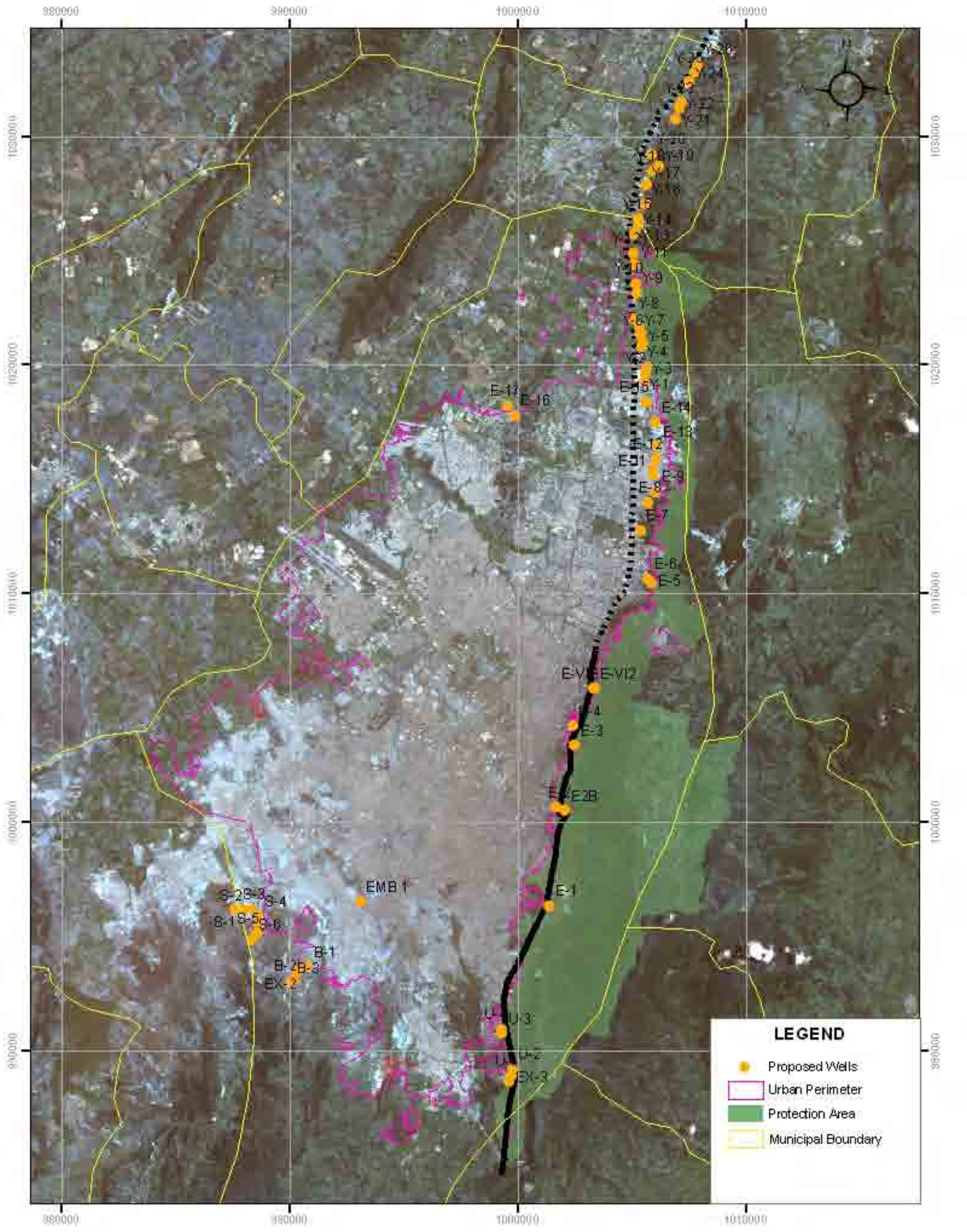
Note: IVA is included in each item; unit: billion Col$.
Source: JICA Study Team

5.12. Initial Environmental Examination (IEE)

The Initial Environmental Examination (IEE) was conducted based on the JICA Guidelines for Environmental and Social Consideration ("JICA Guidelines"), for the proposed project, emergency water supply by use of groundwater. The IEE was carried out to assess possible adverse impacts and to recommend mitigation measures for such impacts. Screening at the IEE level was followed, by analyzing results of assessment on the impacts to be caused by the proposed projects, while taking into account institutional requirement of Colombia environmental impact assessment (EIA).

5.12.1. Current Environmental and Social Conditions inside and aground the Project Area

The locations of the Project sites are shown in Figure-2.5-19.



Source: JICA Study Team

Figure-2.5- 19 Project Location Map

5.12.2. Environmental and Social Impact

Project scoping results are based on field survey, in line with JICA Guidelines of Environmental Consideration for Development Study (1994). Based on these results, the project executing entity is required to carry out appropriate measures for items described below, assuming the environmental and social impacts.

(1) Social Environment

1) Land acquisition / involuntary resettlement

Project area of the southern hill is located in vacant (grazing) land where no resettlement is involved. Nevertheless, land acquisition is necessary because the area is private land. Accordingly, it is necessary to consult with the land owners as to purchase or lease of the land for the Project.

2) Traffic / existing public facilities

It is anticipated that there will be an impact on the traffic condition around the project site, as a result of transportation of equipment and materials for construction into the sites, well drilling works and the construction of water supply facilities, etc.

3) Water rights

In the case of the project sites within Bogotá urban area, drilling permission and water right concession will be obtained from SDA. In the case of other sites, drilling permission and water right concession will be obtained from CAR.

(2) Natural Environment

1) Lowering of Groundwater Level

Pumping of groundwater from wells will cause a lowering of the groundwater level of the aquifers.

(3) Pollution

1) Water Pollution

Water quality degradation by turbidity accompanied by construction works can be coped with by conventional measures.

2) Land Subsidence

There is possibility of land subsidence by over pumping. The mechanism of land subsidence by groundwater pumping under the Project should be clarified.

3) Noise and Vibration

Noise and vibration is anticipated under almost every type of projects, and can be dealt with by conventional measures. Also, because the size of facilities under the Project is small, there is flexibility in positioning of the facility to mitigate the impact.

5.12.3. Compliance with Laws, Standard and Plans of Colombian Government and Categorization

(1) Compliance with Laws, Standard and Plans of Colombian Government

Projects must comply with lows, ordinance and standards relating to environmental and social considerations established by the governments that have jurisdiction over the project site (including both national and local governments), conclusion of which is as follow:

Groundwater development does not require the issuance of an environmental license or permission as stipulated under MAVDAT (2005 government order 1220). Also, it is not necessary to draft an Environmental Impact Assessment report (EIA). Authorization required in the case of groundwater development comprises a concession (water right) for constant water pumping in the case of a production well, and permission to carry out groundwater survey.

(2) Categorization

The Project will have relatively minor environmental impacts, since it does not cause significant adverse impact on surrounding environment. Therefore, the proposed project is finally estimated as JICA Category "B". However, a detailed analysis of lowering of groundwater level and land subsidence may be necessary at the Feasibility Study stage.

5.12.4. Recommended Mitigation Measures

The mitigation measure for the anticipated adverse impacts, by the implementation of the proposed projects, are recommended as listed below.

(1) Social Environment

1) Land Acquisition

Public land should be used as much as possible for the Project. Nevertheless, in cases where Project area lies on private land, the Project executing agency will need to negotiate with land owner and take procedures to acquire the land.

2) Water rights and right of entry

Applications for drilling permission and water right concessions must be made to SDA in the case of the Project area within the Bogotá urban area, and to CAR in the case of the Project areas outside the Bogotá urban area.

3) Transportation and Daily Living Infrastructure

It is anticipated that there may be impacts to traffic condition in and around the Project areas as a result of transportation of construction equipment and materials into the sites, implementation of well drilling works, constructing water conveyance facilities, etc. Accordingly, it will be necessary to deploy traffic control personnel during the construction period.

(2) Natural Environment

1) Lowering of Groundwater Level

According to groundwater simulation of this Study, lowering of groundwater level of Quaternary aquifer by pumping from Cretaceous aquifer is very small and practically negligible. Monitoring plan should be proposed. Continuous observation of the groundwater level by the monitoring should be fed back to operation of the Project.

2) Land Subsidence

Land subsidence will occur by lowering of groundwater level. It is in Quaternary formation that land subsidence will occur. According to analysis of land subsidence of this Study, amount of land subsidence by pumping of the proposed project is predicted small and practically negligible. As well as lowering of groundwater level, accuracy of prediction of land subsidence should be improved and monitoring plan should be proposed.

5.13. Project Evaluation

5.13.1. 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 Master Plan from the viewpoint of comparative advantages that groundwater development has.

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

- Diversification of risks.
- Lower development cost.

- Well location closer to demand area.
- Postponement of investment for foreseeable shortage of water in 2022.

(1) Diversification of Risks

In total, sixty two (62) wells can be utilized in emergencies. The production amount of 62 wells is planned 124,000 m^3/day (1.435 m^3/s).

Acueducto 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/s. Accordingly, the groundwater development shall diversify the risks arithmetically by 10.6% (=1.435 /13.5).

(2) Lower Development Cost

Groundwater development cost is studied in Section 5.13 and estimated at Col$ 108.6 thousands of thousands that is equivalent to US$ 54.0 million: unit cost is US$ 37.7 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. Total investment cost amounts to US$ 2,277 million: average unit cost is US$ 70.6 million/m^3/s.

In terms of development cost per m^3/s, the groundwater is obviously evaluated lower by US$ 32.9 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 62 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*.

(4) Postpone of Investment for Foreseeable Shortage of Water 2022

According to the "*Plan de Expansión de Abastecimiento de Agua, Acueducto, 2005*", water demand will exceed water right (18.8 m^3/s) in 2022, water potential (22.12 m^3/s) in 2033 and capacity of facilities (25 m^3/s) in 2042.

The production amount of 62 wells is planned of 1.435 m^3/s. This enables to postpone the implementation of expansion plan *for 3 years* when taking into consideration the usual utilization of groundwater as well as utilization in emergencies.

5.13.2. Financial Analysis

(1) Actual Financial Condition of Acueducto

It should be noted that Acueducto acquired a high credit rate of "AA^+" from credit rating company (Duffs & Phelps de Colombia) for the corporate bond issued in 2002-2004. Moreover, BRC Investors Services rated another corporate bond at "AAA" that was issued to securitize loans from WB and domestic banks in October 2006.

1) Profitability

"Profit and Loss Statement" of Acueducto from FY 2003 to 2006 clearly indicates that Acueducto has performed excellent operation results every year.

- Net income of Acueducto has grown every year in line with the operational revenue increase. The ratio of net income to operational revenue of FY 2006 recorded a remarkable high level of 18.7%

Interest coverage ratio of Acueducto is 3.4 on average over the period of 4 years from 2003 to 2006.

It is obvious that Acueducto has earned enough operational income to cover the interest payment.

2) Financial Safety and Stability

"Balance Sheet" of Acueducto from FY 2003 to September 2007 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 242-522% 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 84-92% 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.

3) Cash Flow

Cash flow projection of Acueducto is shows operation activities generates positive net cash flow and helps a good cash flow balance every year.

- Net cash flow of the operation activities continues to grow.
- Total of net cash flow from the operation and investment activities turns positive in 2010.
- Net cash flow of the year turns positive in 2011.
- Net cash flow of the financial activities turns positive in 2014 due to decrease of debt Financial Cost Cut by Securitization

Furthermore Acueducto has challenged the measures to reduce cost in spite of good earning. With regard to this, Acueducto launched Col$ 250 thousands of thousands of corporate bond in October 2006. The objective is to reduce the interest payment and exposure of foreign exchange risks by repaying in advance the outstanding loan from domestic bank and World Bank. As a result, the interest rate has fallen from 12.3% to 9.8% at initial stage.

(2) Financial Evaluation of Project

1) Development Cost

Groundwater development cost is studied in Chapter 5.13 and estimated at Col$ 108,610 million in 3 years as shown in Table-2.5-13. Average annual development cost is Col$ 36,200 million.

Table-2.5- 13 Development Cost by Year (million Col$)

Area	Development of Wells	Phase-1	Phase-2	Phase-3	Total
		2011	2012	2013	
Usme, C. Bolivar and Soacha	13	28,800	-	-	28,800
Yerbabuena	17	-	33,500	-	33,500
Eastern Hill	12	-	-	46,310	46,310
	11	-	-		
Total	53	28,800	33,500	46,310	108,610

Source: JICA Study Team.

2) Funding

The development cost is assumed to be funded by domestic bank with following condition.

- Term of Loan: 12 years.
- Grace Period: 3 years.

- Interest Rate: 12%.

This loan condition is considered rather conservative compared to actual loan condition of Acueducto. Weighted average interest rate would be 3.7% if 80% of above construction cost could be funded by the international donor's soft loan (assumed to be JBIC: 1.4% of interest rate, 25 years of loan term).

Acueducto plans to formulate a new master plan in 2008 by revising the Master Plan 2005. Master Plan and Feasibility Study of JICA and pilot project on exploratory well run by Acueducto are to be reflected in the new Master Plan 2008. According to the Financial Department, the appropriate funding measures are to be studied including own funds at the time of this investment decision on groundwater development.

3) Ability of Debt Payment

The Debt payment (repayment of loan and payment of interest) shows that the annual maximum payment is Col$ 23,900 million and Col$ 17,800 million on annual average. This payment represents only 8.2% of Col$ 216,000 million of actual debt payment of Acueducto in 2006.

Acueducto considers affording the debt judging from the sufficient level of cash flow balance and high level of "ability to pay".

4) Profitability Analysis

Profit and Loss projection of Acueducto indicates that incremental cost including interest and depreciation by the groundwater development is Col$ 19 thousands of thousands in 2014 and Col$ 18 thousand of thousands in 2017. It is obvious that these costs are very small and do not affect seriously the projected profit of Acueducto. Operation revenue grows every year. Net income results in positive also every year.

5) 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 theoretically during the period when the water supply capacity surpasses the water demand.

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.

5.13.3. 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 Master Plan: one is point water supply and another is network water supply. Among 62 wells, 6 wells are exclusively for point water supply, while 56 wells are designed as both point supply and network supply. The served population by both methods is estimated respectively as below

- 8,300,000 inhabitants can be served by the exclusive use of point supply: this is the same level of estimated population of 2011.

- 706,000 inhabitants can be served by the exclusive use of network supply: this corresponds to 10% of 2007 population and 7% of 2020 population.

(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 firefighting 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.

PART 3 FEASIBILITY STUDY

CHAPTER 1. PRIORITY PROJECT

(1) Priority Project

Project for emergency water supply by groundwater was proposed by Master Plan (hereinafter referred to as M/P), and the project was approved by Colombian side. High priority project was selected form the proposed projects of M/P, and Feasibility Study (hereinafter referred to as F/S) was implemented for the high priority projects. Purpose of this project is to construct facilities around Bogotá city for emergency water supply. Priority were given to each project as listed in Table-3.3-1, based on discussion between Colombian side and JICA Study Team.

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
4th	3rd Period Project	Yerbabuena

Source: JICA Study Team

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 to resolve technical in construction.

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 epicentre 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.

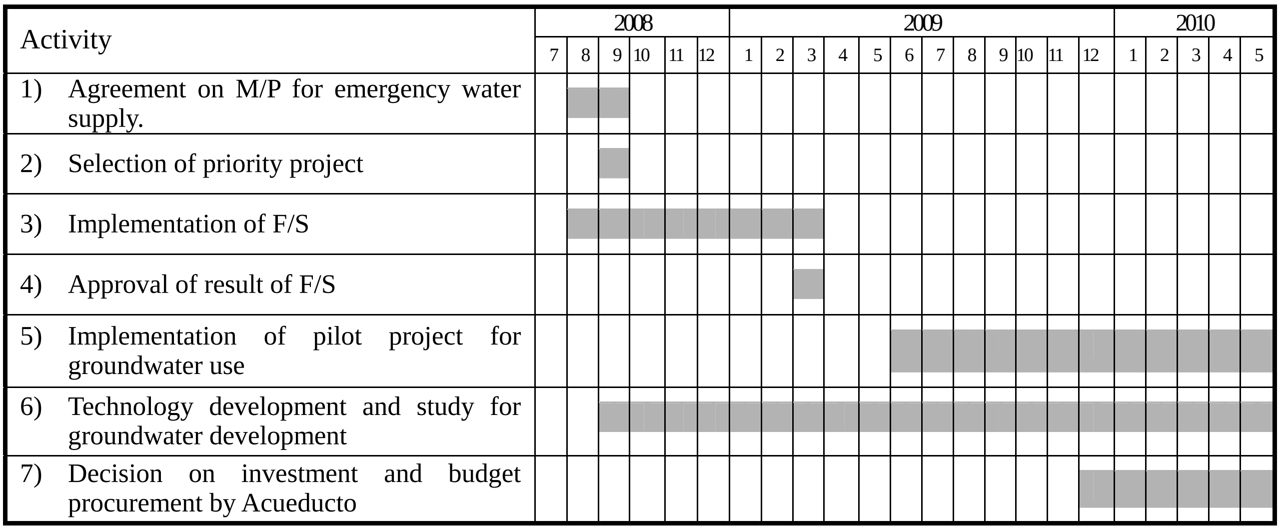
d) Third Period Project

The Yerbabuena Project was selected 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 other hand, Yerbabuena area is far from the center of Bogotá city. Therefore, it was given the low priority.

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 scale of each project is small. 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.



Source: JICA Study Team

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) Yernabuena Project.

3) Implementation of F/S

Feasibility of proposed project was examined.

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

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, 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 F/S, the proposed projects in M/P were reviewed, and feasibility of each project was evaluated. Content of the proposed project was explained below 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.

Operation of facilities

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) 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) will be mainly employed and examined in this F/S.

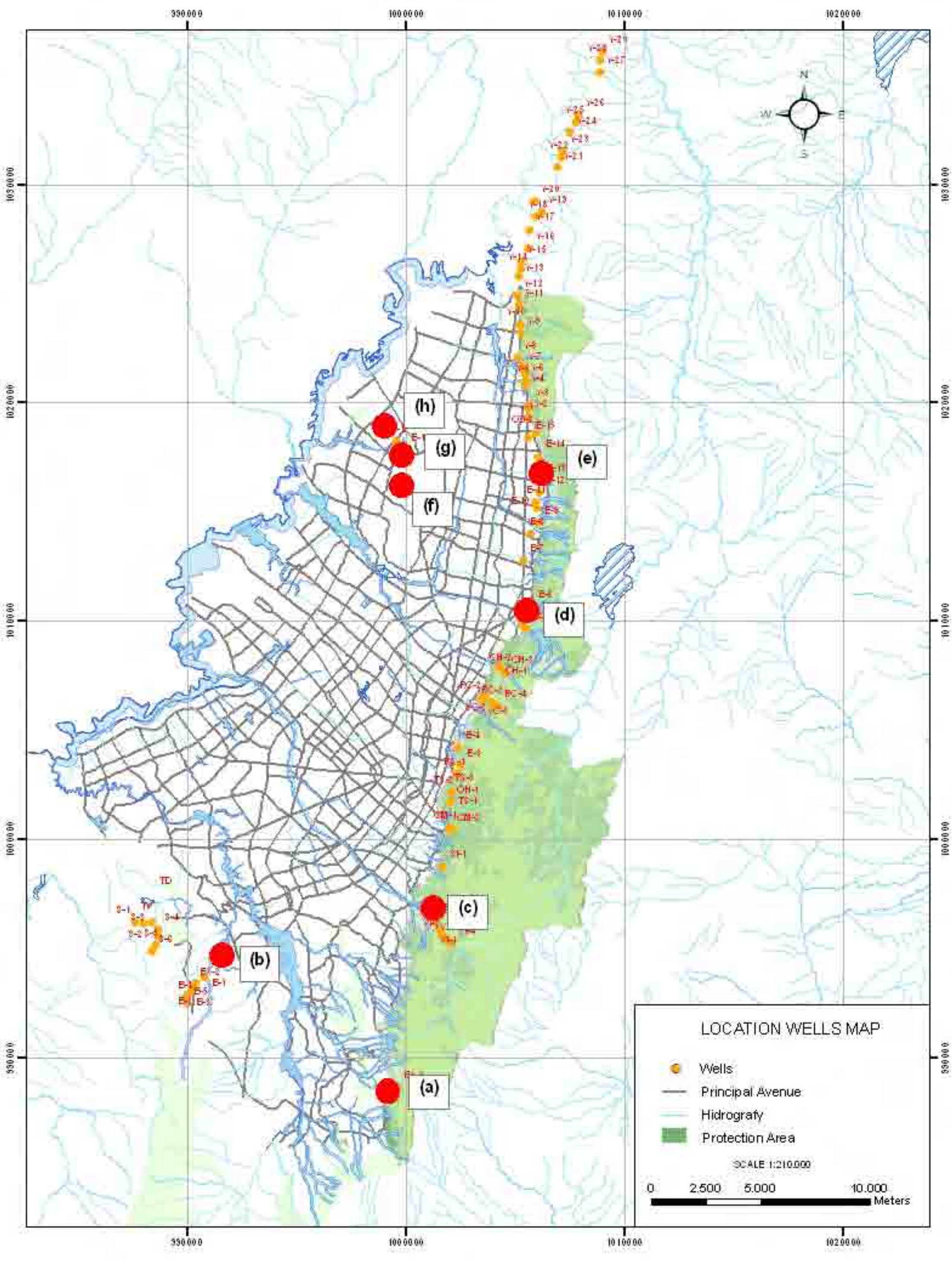
Manual for immediate response

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

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.

Acueducto intends to implement one Pilot Project with highest priority of 8 sites in 2009. Groundwater production of the existing wells is high.



Source: JICA STUDY TEAM

Figure-3.3- 1 Site for Pilot Project

3.1.3. Facilities Plan

(1) Facility Plan for Emergency Water Supply System

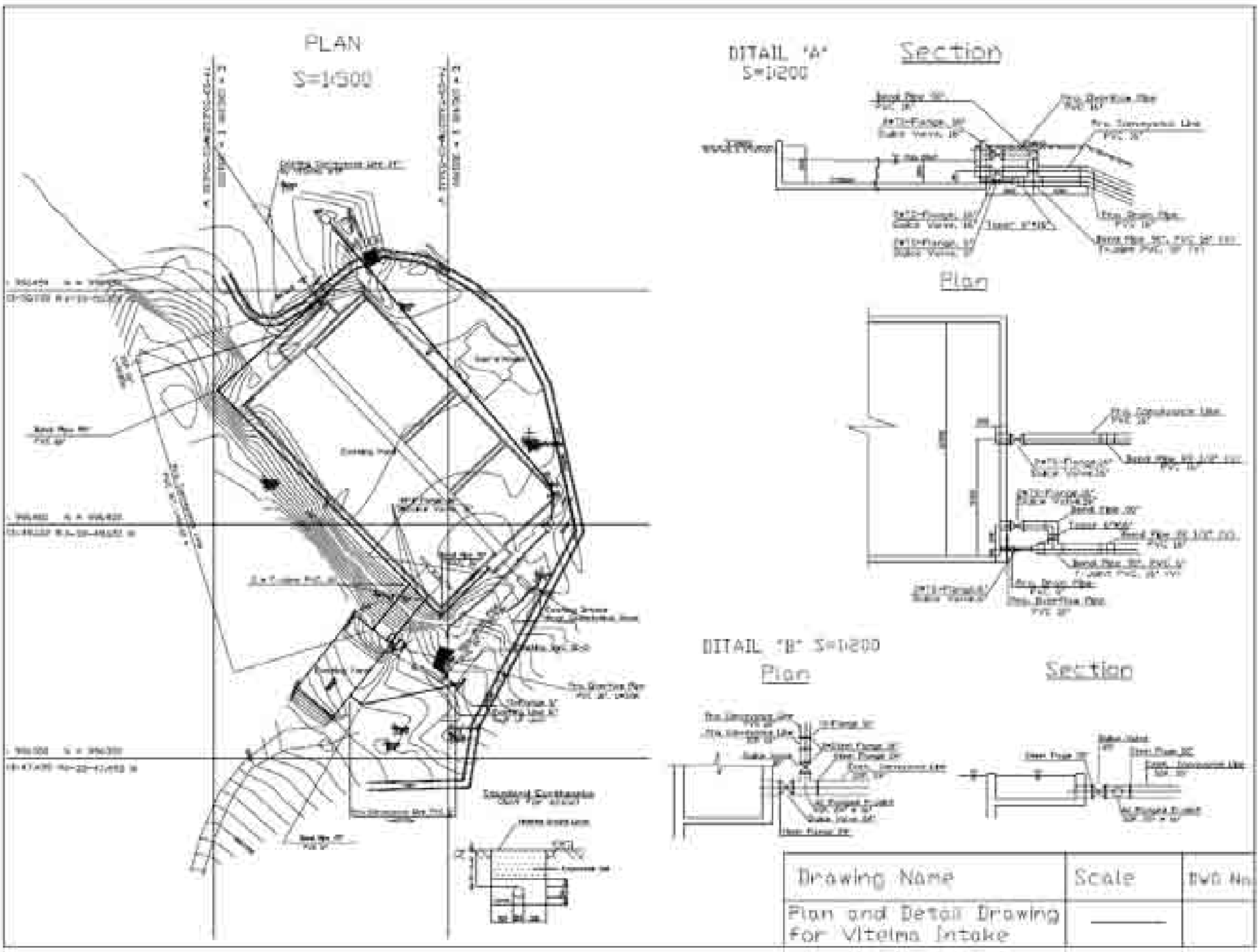
1) Composition and Connection Point for Emergency Water Supply Unit

The composition and the connection points for the emergency water supply unit on the pilot project are shown in Table-3.3-1.

Table-3.3- 1 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
				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)	1)
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

Source: JICA Study Team

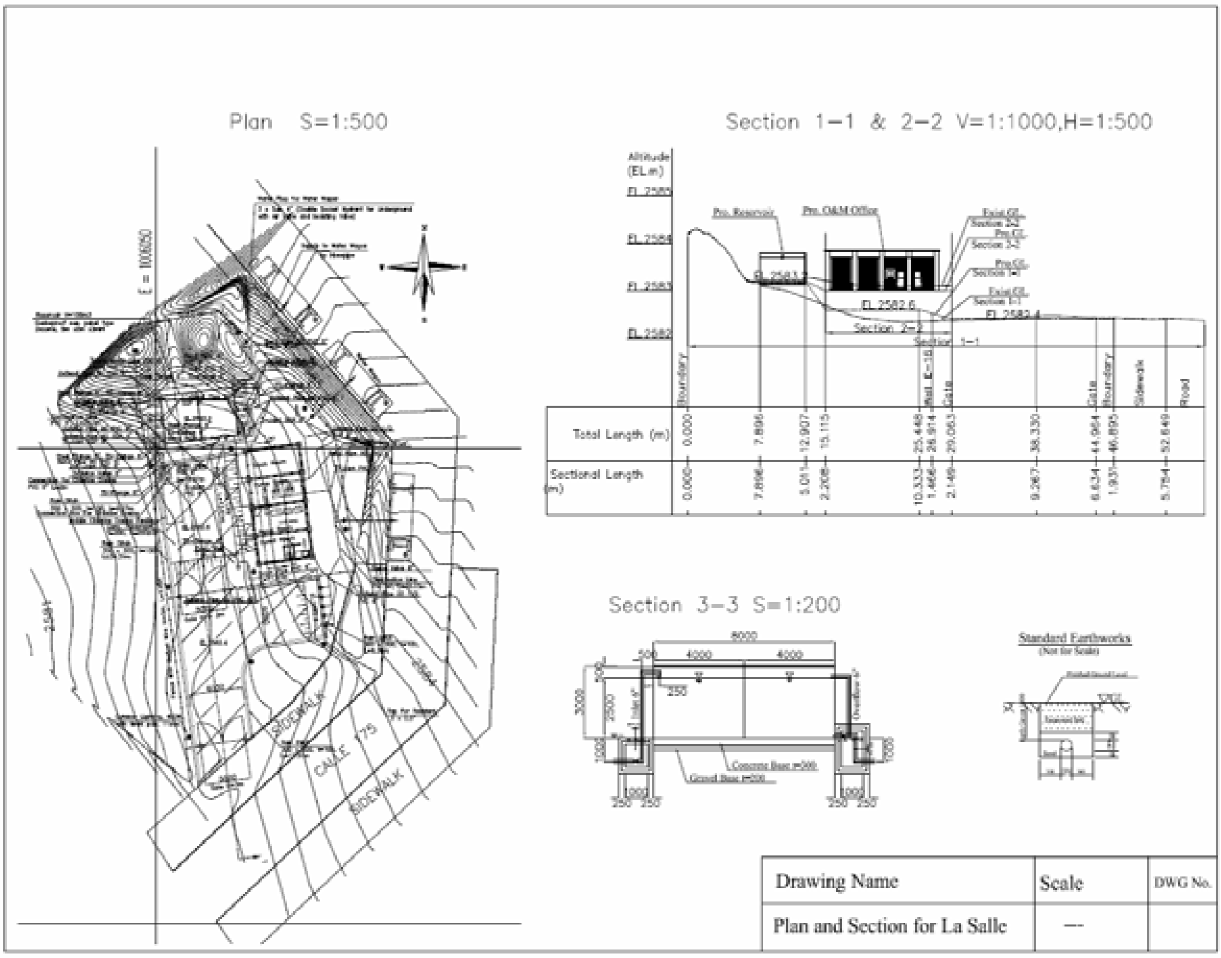


Source: JICA Study Team

Figure-3.3- 2 Detaliled Design for Vitelma Pilot Project (Well Site)

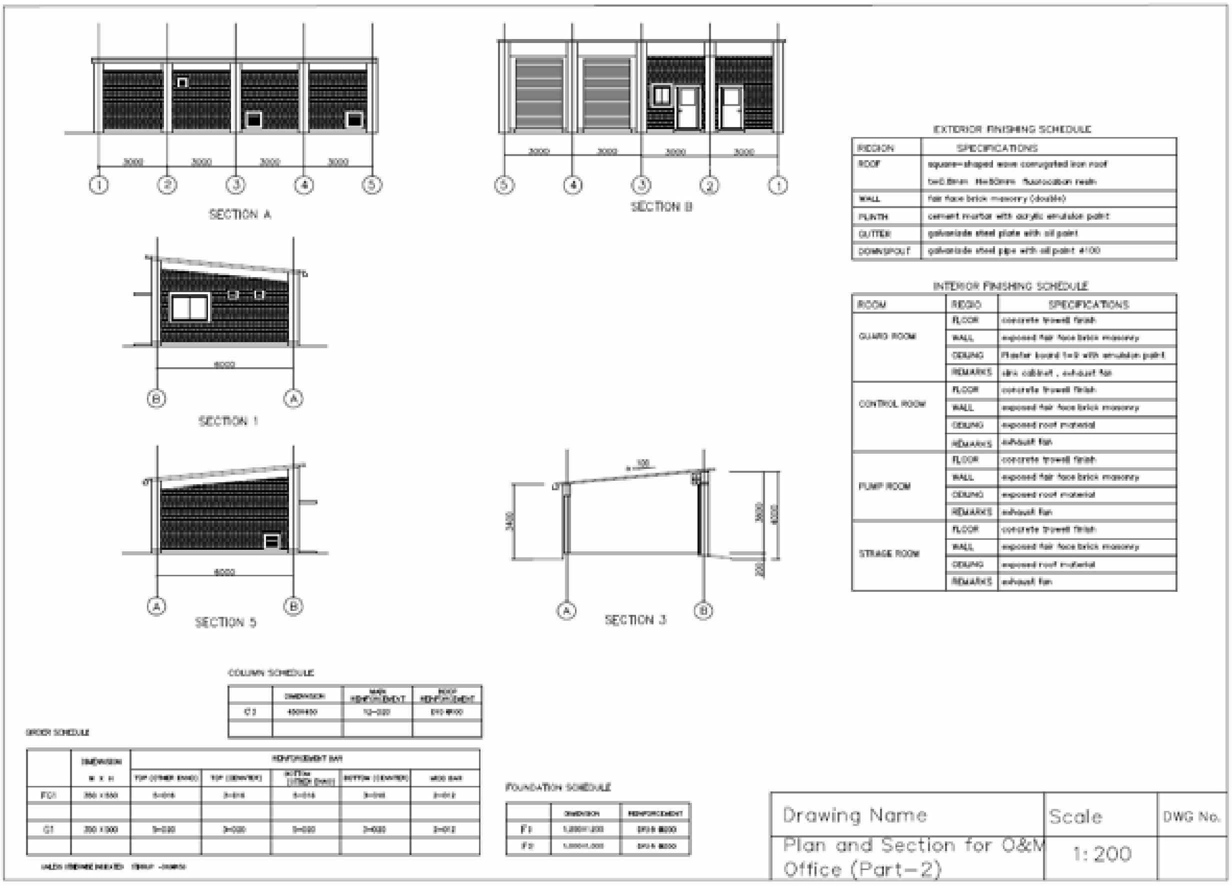
Source: JICA Study Team

Figure-3.3- 3 Plan for Vitelma Water Treatment Plant



Source: JICA Study Team

Figure-3.3- 4 Detailed Design for La Salle Pilot Project (Plain and Section)



Source: JICA Study Team

Figure-3.3- 5 Plan and Section for Operation and Maintenance Office in La Salle

3.2. First Period Project

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

- Eastern Hills are located near the center of Bogotá city which need large amount of water in case of emergency. Groundwater 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-3.3-2.

Table-3.3- 2 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		133,000
Chapinero	1	2,000	Entire Bogota city	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

Point Water Supply

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.

Water supply by the network system

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

3.2.1. Production Well

(1) Well Distribution

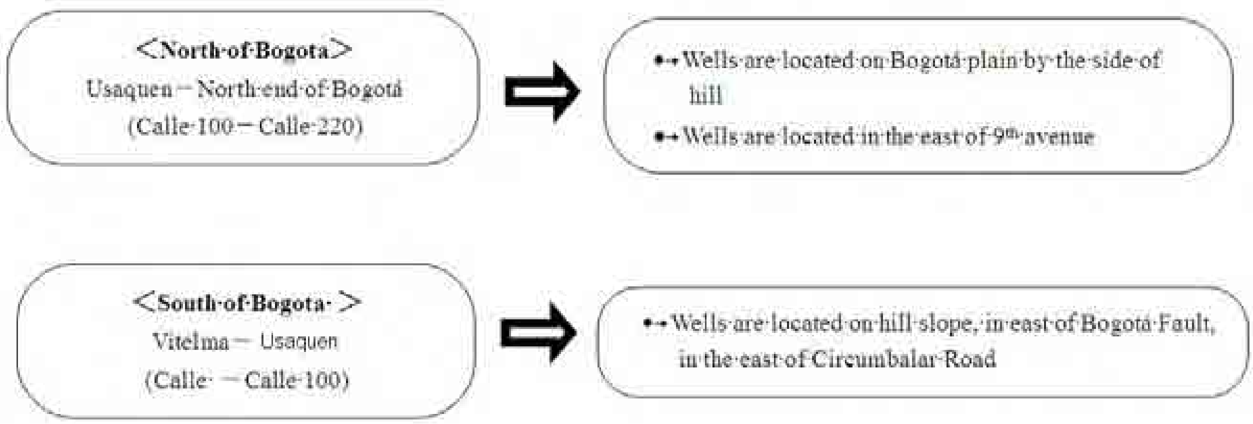
Well location is shown in Figure-3.3-8.

(2) Well site and Bogotá Fault

Wells are located along Bogotá Fault as shown in Figure-3.3-7 Bogotá fault is important factor in selection of well site. Characteristics of Bogotá Fault were taken into account in site selection as listed below:

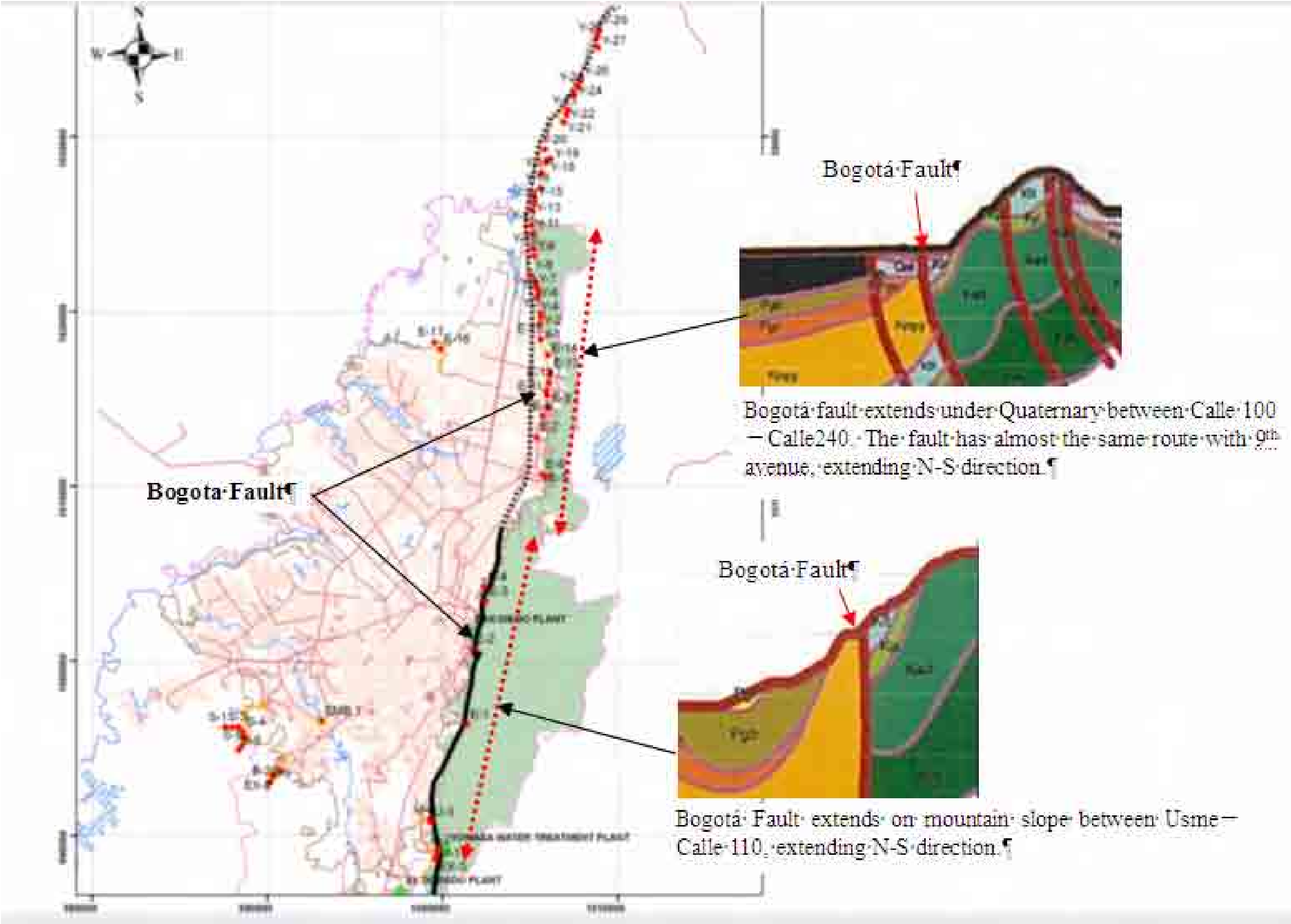
- Bogotá fault forms boundary between the Cretaceous and the Tertiary. Well sites were located on the Cretaceous area, in the east of Bogotá Fault.
- Bogotá fault is located in high elevation area in the southern part of Eastern Hills. Then, Bogotá fault gradually reduces its elevation to the north along 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-3.3-6.



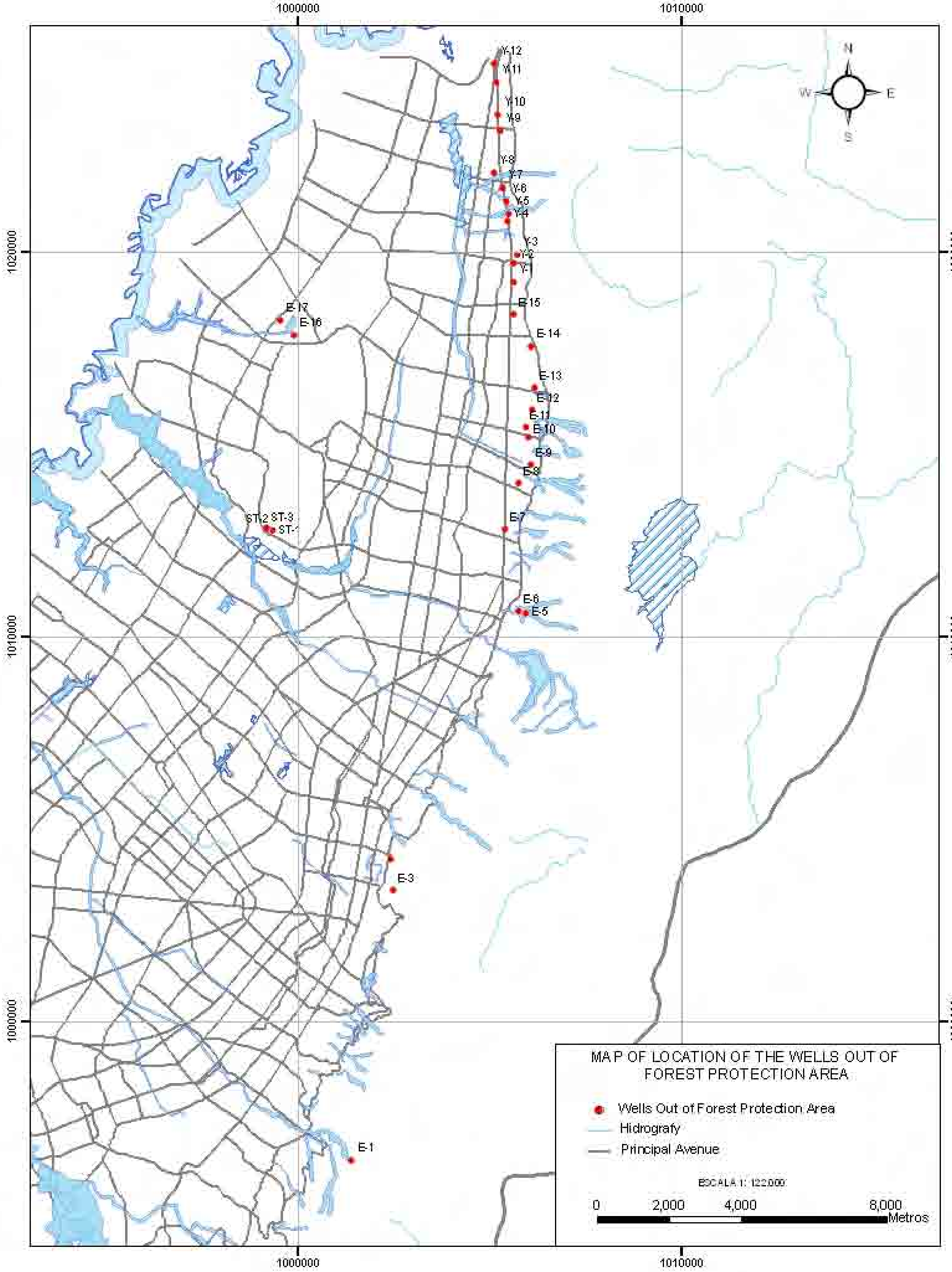
Source: JICA Study Team

Figure-3.3- 6 Optimum Well Site



Source: JICA Study Team

Figure-3.3- 7 Bogotá Fault and Wells



Source: JICA Study Team

Figure-3.3- 8 Location of Wells

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:

(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、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. Facilities 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-3.3-3.

Table-3.3- 3 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 (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)		
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						

Source: JICA Study Team

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 municiparity 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 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- 4 Outline of Southern Project

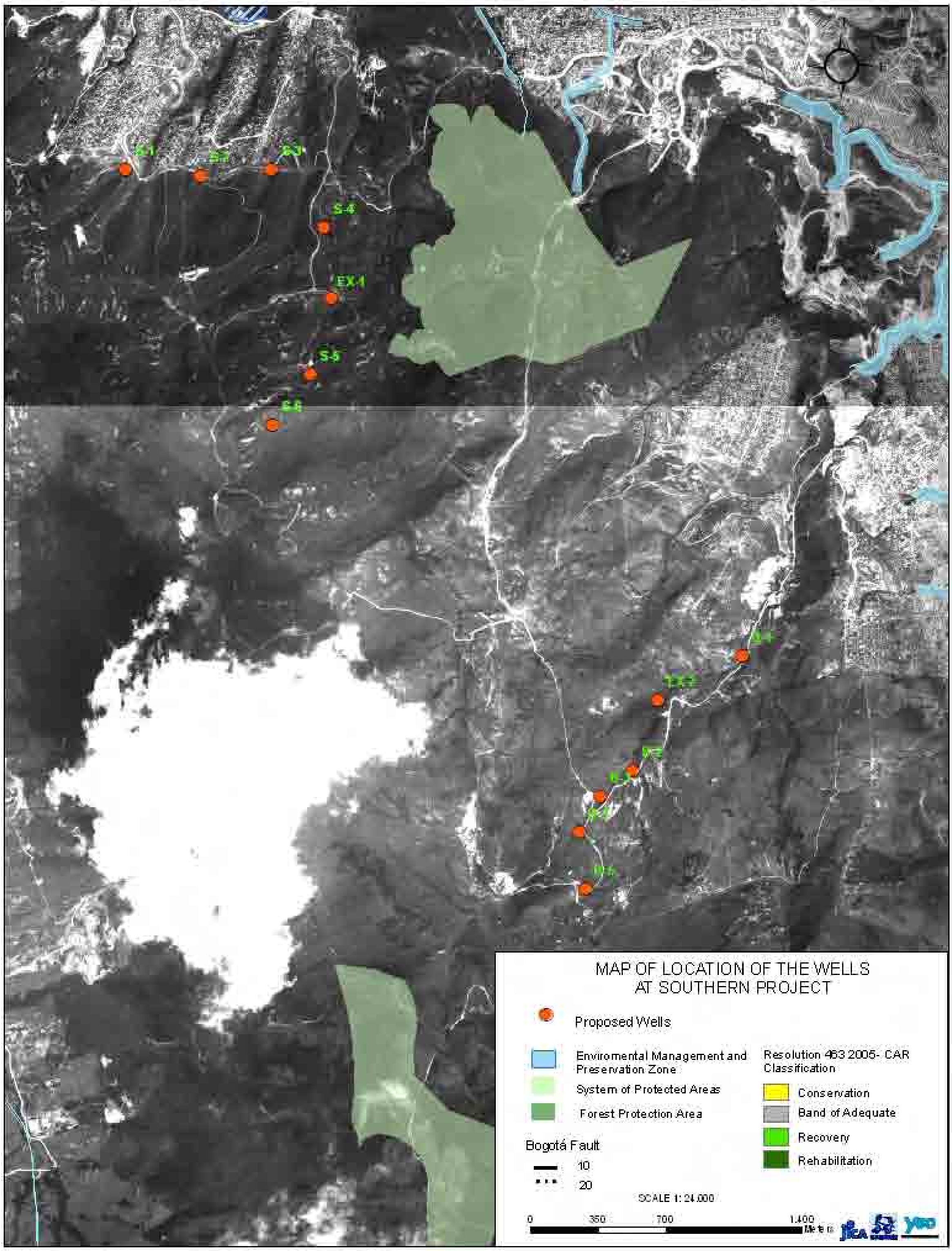
Area	Number of Wells1)	Water supply (m3/day)	Supply area	Population supplied2)
Ciudad Bolivar	7	6,000	Ciudad Bolivar	400,000
Soacha	7	7,000	Soacha	466,000
Usme	1(1)	100	Usme	6,000
Total	14(1)	13,100		872,000

Note-1） inside ( ) is number of wells for Pilot Project
Note-2) This is under unit water supply 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-3.3-9. 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 clearly 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 access and land acquisition



Source: JICA Study Team

Figure-3.3- 9 Well Location of Southern Hills

(2) Usme 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:

3.3.2. Facilities 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-3.3-5.

Table-3.3- 5 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)	–	–	–	–

Source: JICA Study Team

3.4. Third Period Project

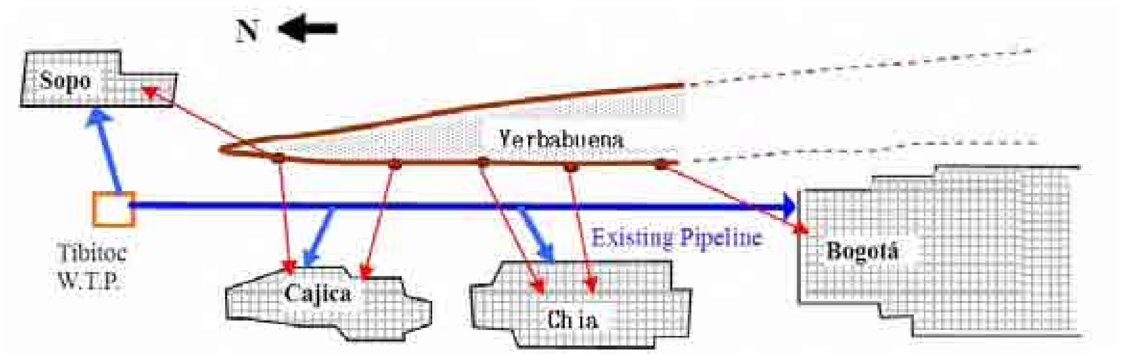
Yerbabuena Project was proposed for the Third Period Project. Yerbabuena area is relatively far from city center of Bogotá, which makes value of Yerbabuena Project lower as emergency water supply. Moreover, Yerbabuena area belongs to not Bogotá but to Chía and Sopó, which makes promotion of the projects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

(1) Outline of project

Yerbabuena is near Chía, Cajicá and Sopó. Above 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 Yerbabuena area can be used. Strategy for emergency water supply plan in Yerbabuena is proposed as follows (see Figure-3.3-10).

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

Plan above is described below:



Source: JICA Study Team

Figure-3.3- 10 Distribution of Water by Yerbabuena Project

Table-3.3- 6 Outline of Yerbabuena Project

Area	Number of wells	Water supply (m^3/day)	Area for water supply	Supplied Population(Note)
Chía	9	18,000	Bogota, Chía, Cajicá, Sopó	1,200,000
Sopó	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

(2) Point Water Supply

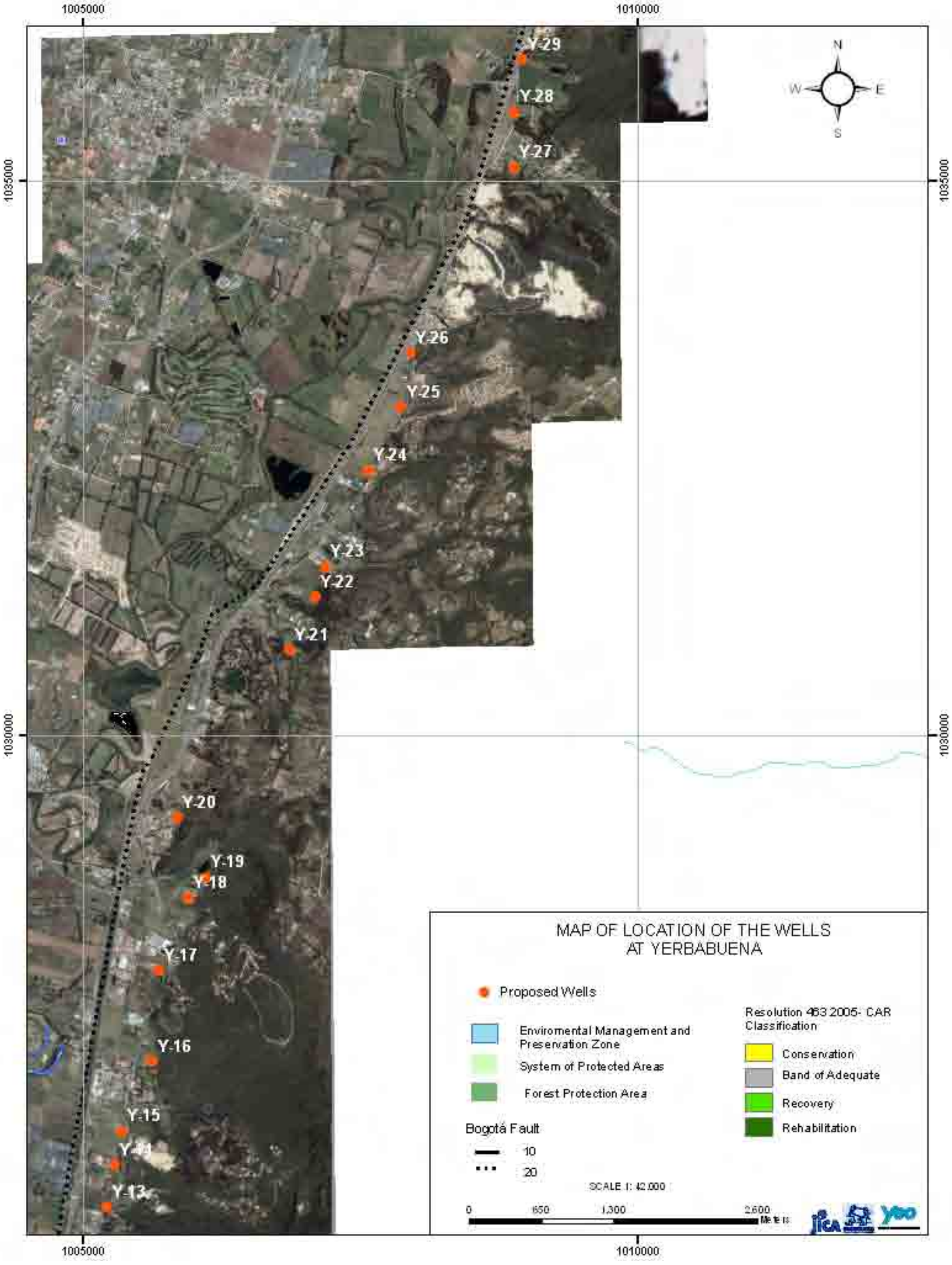
Point water supply will be implemented by water truck. Area to be supplied by water truck is north of Bogotá, Chia, Cajica and Sopo. Well sites are near the abave area, which makes water supply by water trucks available in case of emergency.

(3) Network Water Supply

Network water supply is available by use of the existing pipeline between Tibitoc and Bogotá. However, this pipeline is relatively old, so 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 Yerbabuena to Bogotá needs huge amount of investment, which is not realistic for emergency water supply. In the F/S, it was proposed to send water from the wells to the existing pipeline to Chia and Cajica.

3.4.1. Well Location

Well location of Yerbabuena Project is shown in Figure-3.3-11.



Source: JICA Study Team

Figure-3.3- 11 Location of Wells in Yerbabuena Project

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

In the Yerbabuena 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.

3.4.2. Facilities 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-3.3-7.

Table-3.3- 7 Composition and Connection Point for Emergency Water Supply Unit (3rd Priority Ploject)

Project Name	Site		Water Supply Unit No.	Well No.	Well New/ Exist.	Well Dia (in.)	Well Depth (m)	Well Pump Dia (in.)	Well Pump Head (m)	Well Pump PWR (kW)	Conveyance Line Dia (in.)	Conveyance Line Length (m)	Water Treatment Process Volume (m3/day)	Water Treatment Process Process	Transmission Line Dia (in.)	Transmission Line Length (m)	Connection to (Exist Facility)	Type of Supply 1)
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						

Source: JICA Study Team.

3.5. General Facilities Plan

(1) Well Facilities Plan

1) Wells

The basic well diameter shall be 10 inches or 8 inches on sections where depth is 0~150 m. Only in cases where the well altitude is high and the projected water level is deeper than GL -150 m shall 10 inches be adopted on sections of 0~150 m and 8 inches shall be adopted on sections of 250~400 m.

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 for the city power supply and voltage drop in Bogota, the capacity of submersible motor specifications 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 above effort, fair competition must be secured.

3) Power supply to pumps

In order to facilitate operation and maintenance of the pumps, power supply facilities shall be installed in the purification plant, and power cables shall be installed along the buried water conveyance pipes. This type of design can contribute to economical investment.

4) Water conveyance pipes

PVC pipes (withstand pressure 1.6Mp), which can be easily procured in Bogota, shall be adopted as the buried water conveyance pipes. When burying, sand will be backfilled 20 cm around the pipes for protection. Since PVC pipes become degraded and brittle when they come into contact with ultraviolet light, carbon steel pipes for general use with exterior coating shall be adopted when pipes are installed 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 quality standard was different between ordinary and emergency water supply in the previous regulation (Decreto 475, 1998). New regulation (Decreto 1575, 2007 and Resolution 2115, 2007), however, shows only one water quality standard for both case. Groundwater of the Cretaceous aquifer will be used for emergency water supply in proposed project, and only concentration of Fe and Mn of the groundwater exceed water quality standard of new regulation. Fe and Mn can be removed easily by a pressure filter. Therefore, water treatment is planned in the proposed project to satisfy requirement by the new regulation. According to result of water quality analysis, it is expected that 2/3 of the Cretaceous wells may need water treatment, and 1/3 of the Cretaceous wells may not need treatment. Water treatment plant is planned for all the wells in the current planning stage. Necessity of the plant, however, will be judged in the future implementation stage

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 water 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.

Water Treatment Facilities Plan

The quality of groundwater in the target area is excellent, judging from the results of water quality analysis from the well, concentration of Fe and Mn are only slightly exceed 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, etc. 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-3.3-8 may be considered

Table-3.3- 8 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 others apart from (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 hold 30 minutes of pumped well water. 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 in order to make a height difference out of the land gradient. In cases of flat land, the distribution tank will be installed on a frame in order to give the height difference.

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 purification plant. Also, it is necessary to install the minimum required toilet and water purification tank in order to secure sanitary conditions for the operators.

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-3.3-12. 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.

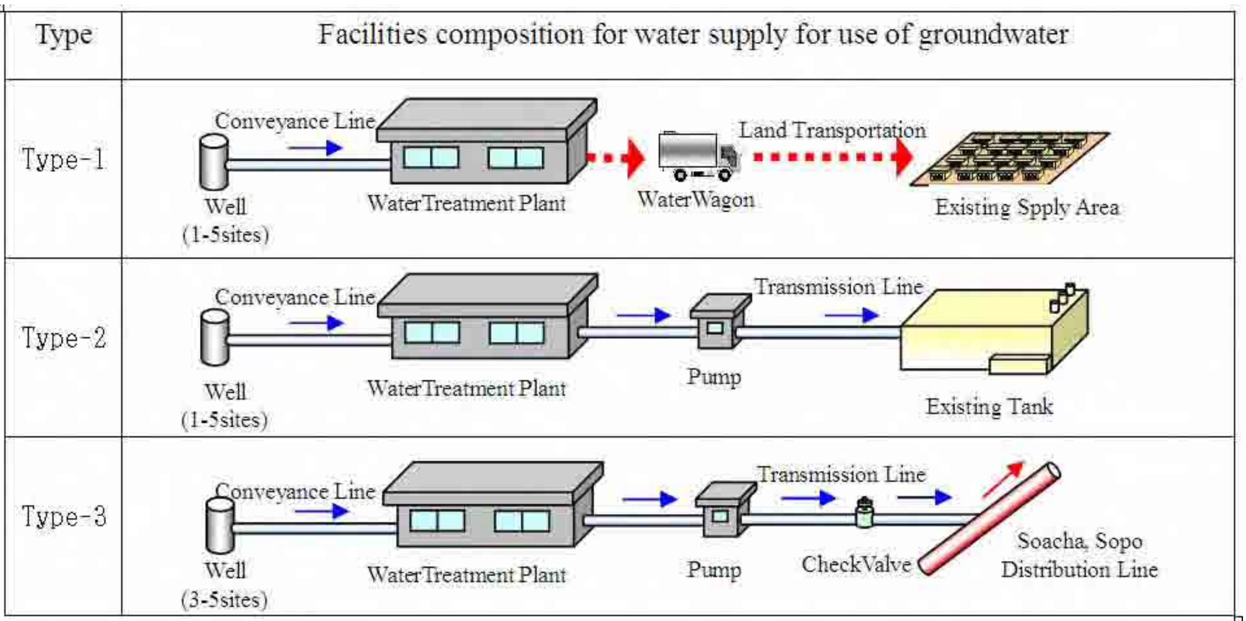


Figure-3.3- 12 Facilities Composition for Water Supply for Use of Groundwater

3.6. Optimum Yield

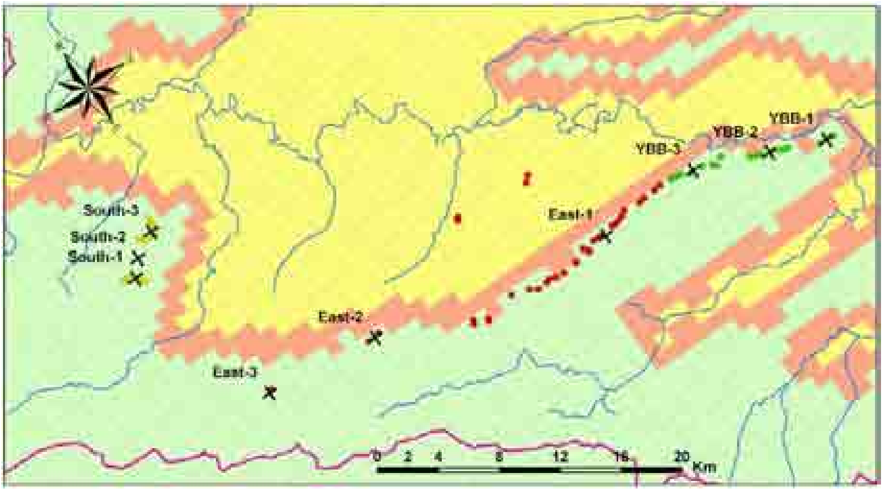
3.6.1. Draw Down of Groundwater Level

(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 mountainous area, and distributed in the four tributary basins of the Bogota river, Bogota(L)、Fucha、Tunjuelo and Soacha.

(2) Groundwater Drawdown

Therefore, it should be examined thoroughly to make clear of planed pumping. A groundwater simulation model is 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-3.3-13.



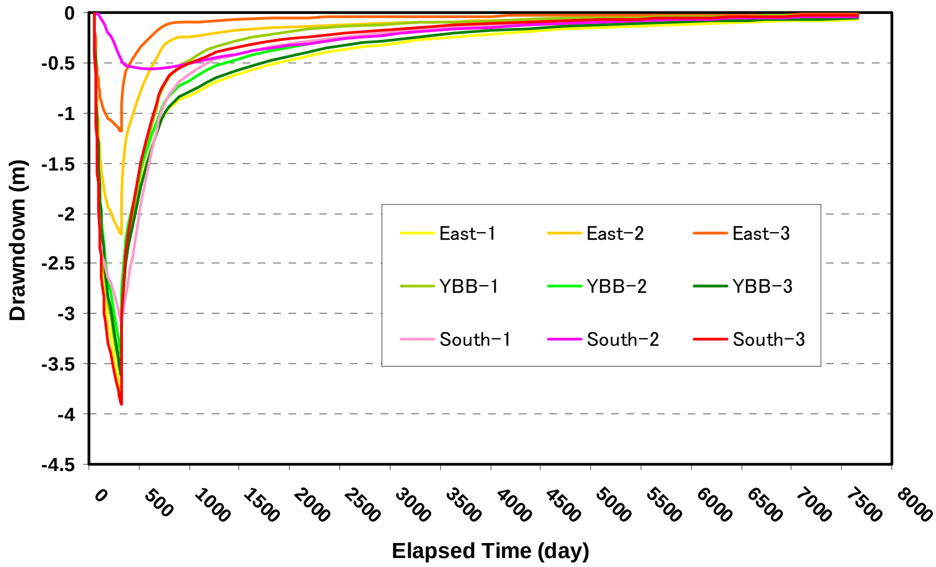
Source: JICA Study Team

Figure-3.3- 13 Location of Observation Wells

Figure-3.3-14 shows the simulation result of all the observation wells to indicate the followings:

- 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.

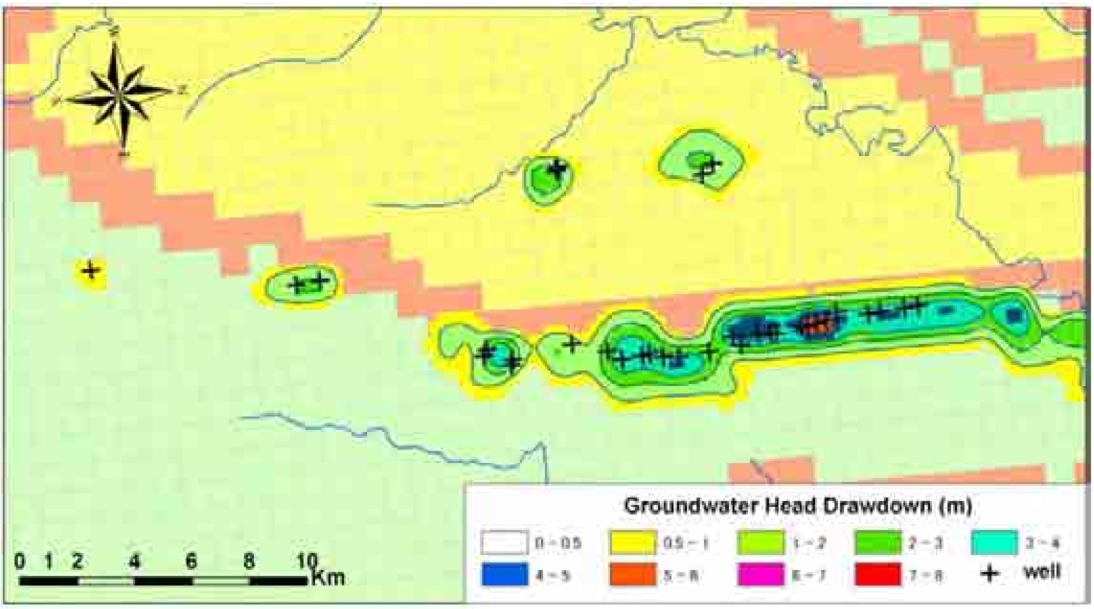
- No sign of groundwater drawdown reaching equilibrium could be identified during the withdrawal.
- The drawdown at each observation well rapidly recovers after the termination of pumping. The drawdown in almost all observation wells can recover to less than one meter within one year.



Source: JICA Study Team

Figure-3.3- 14 Head Change Curves of Temporary Observation Wells

Figure-3.3-15 shows the distribution of groundwater drawdown at the time of termination of pumping. 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- 15 Area Affected by the Eastern Project

(3) Balance between Groundwater Withdrawal and Recharge

The recharge area and annual recharge amount in each tributary basin are summarized in Table-3.3-9. 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 drawdown curves that within the nine-month duration of withdrawal, the groundwater head will continue to go down, without reaching equilibrium.

Table-3.3- 9 Recharge Amount for Project Wells

Basin	**Area(m^2)**	**R_Rate（mm/year）**	**Annual Recharge (m^3)**
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**

Remark：R_Rate is the annual groundwater recharge rate obtained from the hydrological analysis
Source: JICA Study Team

However, 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 drawdown curves of observation wells in Figure-3.3-15.

According to the above groundwater balance analysis, the total amount of withdrawal in the project can be recovered by recharge within 1.58 years. This analysis leads to the conclusion that as an emergency water supply countermeasure, the groundwater balance can be maintained, even though all wells are fully working within the project duration, in case of the implementation interval being two years or more.

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

3.6.2. 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, possibility of land subsidence was analyzed.

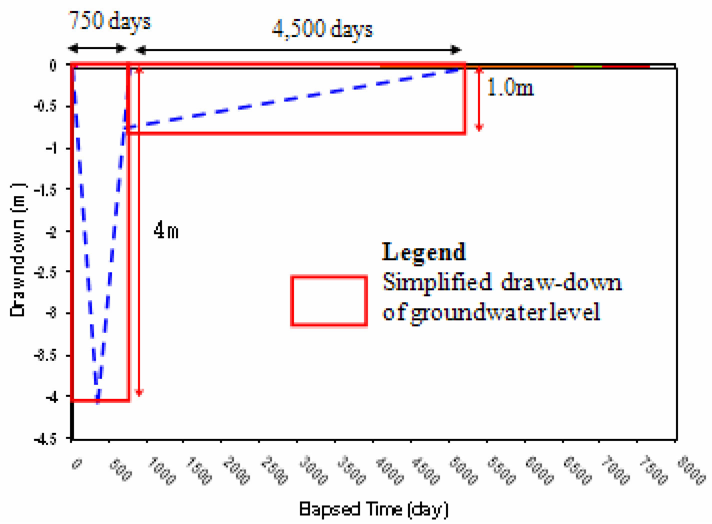
- Duration of pumping is just less than 9 month. This pumping will cause draw-down of groundwater level to lead land subsidence of the Quaternary. Therefore, calculation must be done in 2 steps as explained below to obtain exact land subsidence of the Quaternary:

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.

(1) Groundwater Level Draw down by Pumping

Draw-down of groundwater level was analyzed by groundwater simulation in F/S. This result can be simplified as shown in Figure-3.16. This simplified draw-down of groundwater level was used for the analysis.



Source: JICA Study Team

Figure-3.3- 16 Modified Draw-down of Groundwater Level

(2) Total Land Subsidence

Total land subsidence under assumed draw-down of groundwater level are shown in Table-3.3-10.

Table-3.3- 10 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

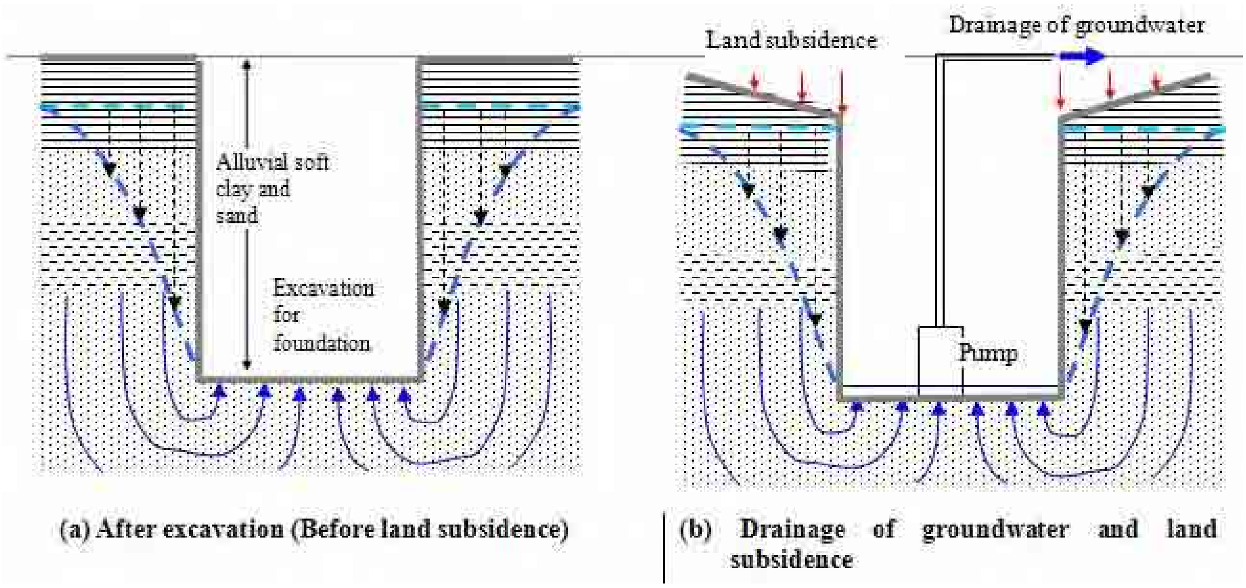
As shown in Table-3.3-10, the total land subsidence by pumping was predicted 0.0057m. Land subsidence by the Tertiary and the Cretaceous will completely recover with recovery of the groundwater level after pumping is stopped. Moreover, land subsidence of the Quaternary will also partially recover with recovery of the groundwater level. Therefore, final land subsidence will be smaller than shown in Table-3.3-10, and impact by land subsidence is negligible.

(3) 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. Consequently, land subsidence will take place. Mechanism of land subsidence is shown in Figure-3.3-17.



Source: JICA Study Team

Figure-3.3- 17 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

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", which will cause serious damage to underground constructions. Therefore, there will be no impact on under-ground pipelines and building foundations.

Impact by implementation of the proposed project was predicted much smaller than land subsidence currently taking place in Bogotá city.

3.7. Institution and Operation/Maintenance

(1) Operation for Emergency Water Supply by Groundwater

Emergency water supply by groundwater is classified as "Point Water Supply" and "Network Water Supply". With the development the rehabilitation of the transmission and distribution network, point water supply can be made by the hy drants in the areas of the recovered network..

Table-3.3- 11 Operation Works of Emergency Water Supply by Groundwater

Emergency Water Supply	Operation Works
Point Water Supply	* Water distribution by water wagons or trucks with water tanks * Operation, inspection and repair of facilities for pumping, water treatment and distribution
Transitional Operation	* Check of the remote control system and connection to the system * Connection to the water supply network
Network Water Supply	* Water supply by automatic remote control system (Connection of wells and treatment facilities to ordinary water supply system) * Operation, inspection and repair of facilities for pumping, water treatment and distribution

Source: JICA Study Team

(2) Staffing for Emergency Water Supply by Groundwater

It is recommended to operate emergency water supply with existing staff of Acueducto. However, employment of a small number of personnel is recommendable for management of emergency water supply as well as for checking of facilities and equipment and periodical monitoring of groundwater resource at ordinary times (one senior technician and one junior technician for around 30 wells).

Table-3.3- 12 Staffing for Emergency Water Supply by Groundwater

Type of Emergency Water Supply	Staffing
Point Water Supply	- For operation of pumping, treatment and supply water to water wagons, one technician and a worker for a well/treatment facility are necessary. - Contract with the companies that have water wagons or similar vehicles and drivers - One person from Acueducto staff for a vehicle is required to check the distribution by the contracted company. - Service contract for security and the maintenance is recommendable. - 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.
Network Water Supply	- 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. - Periodical inspection and well monitoring can be outsourced. - 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, it is recommended to strengthen the Committee for Prevention and Attentions of Emergencies. 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. In emergency cases, the Directive Committee will conduct information exchanges and coordination with external organizations, information analysis, and decision-making on plans of emergency water supply and rehabilitation of facilities in principle. The Operative Committee of the headquarters will formulate and propose plans of emergency water supply and rehabilitation of facilities, and implement emergency water supply and facility rehabilitation for parts of pumping and water treatment. Each Zone Group will provide information to the headquarters and take care of emergency water supply and facility rehabilitation for pats of transportation and distribution. 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 Corponate Management Office Integrated Risk Management

The directorate will be in charge of the overall coordination and permanent staff could be comprised of the manager, an engineer who has overall knowledge on the system, a person who have general knowledge on society, economy, city planning and land use, and communities, and a person specialized in communication and information, etc

(5) Establishment of Groundwater Division

Proposed Groundwater Division in the Directorate of Water Supply of the Corporate Management Office of Master System is in charge of groundwater development and conservation as well as emergency water supply using groundwater in cooperation with other divisions of the Corporate Management Office of Master System. These jobs can be implemented with utmost use of external resources. The recommended staffs are the division manager, technician teams, which will be comprised of a senior technician and a junior one and take care around 30 wells, and an administrative assistant. Pilot Project for emergency water supply is scheduled to start in 2009 by Acueducto. It is proposed to that Acueducto will examine establishment of Groundwater Division based on the result of the Pilot Project.

3.7.1. Lesson from Kobe Seismic Disaster

(1) Outline of Kobe Seismic Disaster

Kobe earthquake occurred at 5:46 am (Japan Official Time) on January 17, 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 818 Gal.
- 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. Total 43,792 persons were injured by the earthquake.
- As for house damage, complete collapse amounted to about 105,000 houses, and partial destruction amounted to about 144,000 houses.

(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 damage in water supply system is 56,000 Million yen.
- Damage of a water pipe 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 traffic congestion. The emergency water supply activities by water supply wagons suffered from traffic congestion, and vehicles for restoration work could not enter the sites
- Identification of the leakage points of water pipelines took long time. There were so many broken points of water pipe that water pressure at leakage point was too small to be detected.

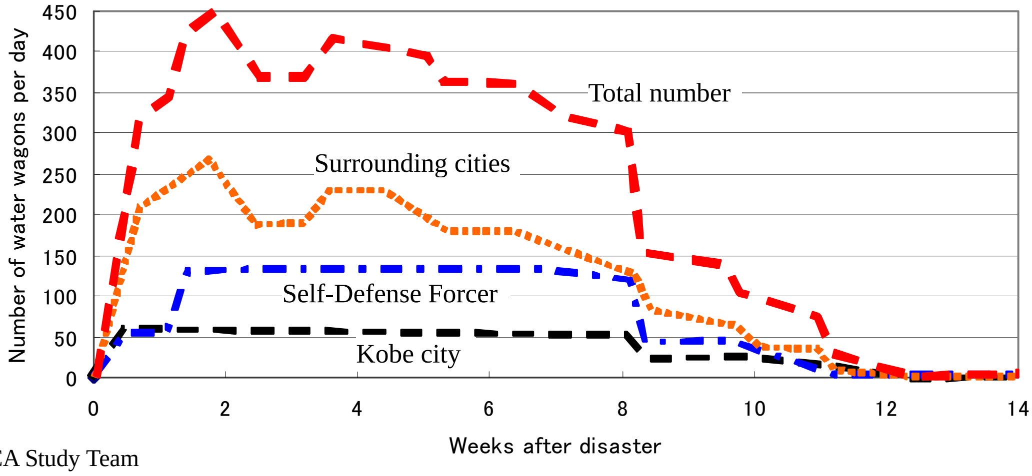
Progress of emergency water supply

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

a) Emergency water supply begun mainly for the shelters since half day after earthquake occurrence.

b) With restoration of the water pipe, emergency water supply by installing a 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 earthquake occurrence. 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 had ended when the water service was completely restored by 2 month after the earthquake occurrence (see Figure-3.3-18).



Source: JICA Study Team

Figure-3.3- 18 Number of Water Wagons with Time

(4) Unit water consumption in emergency

Unit water consumption in emergency by water wagons is shown in Table-3.3-13.

Table-3.3- 13 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
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

(5) Lessons from Kobe Earthquake Disaster

Example of emergency water supply of 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 within tanks for emergency water supply.

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 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 tanks to be loaded in small ordinary trucks and pick-up trucks (see Figure-3.3-19).

Source: JICA Study Team

Figure-3.3- 19 Water Tank for Truck Loading

a) Preparation of emergency water

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.

b) 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. Adding to it, many water wagons came to Kobe with 370 wagons/day at peak time. Therefore, it is important to create relationship for cooperation and assistance for emergency water supply.

(6) Toilet in Shelters

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

Number of Shelters

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 official registered. Most of above shelters were occupied with evacuees in Kobe seismic disaster. The number of shelters was around 500 at immediate after the earthquake.

Toilet in shelter

Temporary toilets were set in shelters. Number of the toilets distributed was 524 sets on 4 days after earthquake, and it became 3,000 sets at maximum on 2 weeks after the earthquake. Ratio of distribution of temporary toilet was 1 set for 80 people.

Acueducto 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 truck must go to every shelter regularly.

3.8. Social and Environmental Consideration

Based on the discussion results with Acueducto, the Emergency water supply priority projects has been decided. In this F/S, Screening at the IEE level was conducted again by analyzing assessment results considering the environmental and social impacts caused by each prioritized projects and the environmental requirements of Colombia. In addition, regarding any projects that might possibly cause negative environmental impacts, the mitigation measures were recommended for such impacts.

3.8.1. Estimated Environmental and Social Impact

(1) Pilot Project

The 6 sites of 8 planned sites are owned by Acueducto. Another 2 sites are located on the private property, and both owners of the sites agree to maintain current situation.

(2) The First Period Project (Eastern Project)

The project sites are located at the foot of the Eastern hill. The project sites are located in the vicinity of a residential area. Vacant land will be used for the sites and therefore resettlement is not required. Most of the sites are, however, located within privately owned land. Land acquisition or lease is therefore required. Presently in the Project site, a construction plan for a new building, etc. has not been filed, but it is assumed that in the future a building will be constructed on the site.

(3) The second period Project (Southern area)

The project sites in Soacha area are located within a residential area of low-income group. However, all of the sites are selected to avoid the resettlement. The sites are not located in forest protection area either. However, in the Soacha Area, all the project sites are located on the land of one owner. Negotiation for land acquisition or lease is necessary. The project sites are located in a pastured area that does not include houses or forested land. These sites are in an ideal location. Negative environmental and social effects are not expected.

The project sites in Ciudad Bolivar Area are also located on privately owned land, where one exploratory well by JICA has been completed. The project sites are located in a pasture similar to the Soacha Area. During and after the exploratory drilling by JICA, neither environmental nor social consideration was required.

(4) The third period project (Yerbabuena Project)

There are 17 wells planned in the Yerbabuena Project. The project sites are not located in the urban area of Bogotá city, but belong to the cities of Chía and Sopó. Each site is located on privately owned land. Land acquisition or a lease agreement is required. The sites are located in a pasture and grassland area out of the forest protection area and resettlement is not required. The sites are located along the roadside, and assess will not be an issue. Sufficient construction space is available. Environmental and social considerations are not assumed to be an issue. The project sites do not belong to Bogota city, the administration agreement between Cities is necessary.

3.8.2. Compliance with Requirements of the Recipient 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 (Resolución. 1207) for construction works in the Bogotá city area (POT)

b) Well drilling permit issued by CAR for construction works outside of the Bogotá city area (POT)

c) Water right permit issued by CAR when the well is to be actively used. (Permits for emergency water supply such as the proposed project is not required)

d) Others: According to the environmental protection area ordinance (Zona de Manejo y Protección Ambiental), no facility is to be built within 30 meters from the centerline of a river. This ordinance applies to well drilling.

3.8.3. Result of Final Screening

As a result of final screening based on the guidelines of JICA and in 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 categorized into B rank of JICA guidelines.

3.8.4. Recommended Mitigation Measures

(1) Land Acquisition

Project sites in the southern area are in an ideal location from the hydrogeological and environmental /social impacts view points. However, a land acquisition or agreement of lease is necessary with the landowner.

The social impact is to be accompanied with locating the planned project sites in the urban area, but, there are advantages from a view point of emergency water supply.

(2) Obtaining drilling permits

Permits for drilling wells are required following environmental regulation of Colombia.

(3) Traffic and facilities for living

It is anticipated that there may be impacts to transportation in and around the project area. The executing agency needs to contact with related authorities (city traffic department, transportation police, etc.) in advance and obtain a road permit. In addition, safety measures are to be drafted during the construction period based on the applicable safety manual.

(4) Water pollution (treatment of drill sludge)

The drilling mad (with bentonite), generated from well drilling, will be treated following the drilling mad treatment standard of IDEAM, in order not to drain the mad into roads and rivers.

(5) Noise and vibration

Because the Project sites are within urban area, it is anticipated that there will be an impact by noise on immediate surrounding area. For this project the usual method will be sufficient to mitigate the problem. For example, when exploratory wells were drilled in the Ciudad Bolivar and La Aguadora site, the residents did not complain of noise and vibration from the drilling works.

(6) Lowering of the groundwater level

Lowering of groundwater level by implementation of the proposed project was predicted in this Study. According to the result, lowering of groundwater level of the Quaternary aquifer is less than 4m. This project is for public water supply for emergency in case water supply by Acueducto is suspended, and 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 only short period only. It can be said that lowering of groundwater level by proposed project can be acceptable.

(7) Land subsidence

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

3.9. Design and Cost Estimate

3.9.1. 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 equipment.

(1) Well facilities

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

- 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 deep well makers possessing agents in Bogota.
- 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.
- IEC (International Electrotechical Commission) standards have been adopted regarding the manufacture of electrical equipment.
- Designs for emergency generators were decided with a view to securing international competitiveness and quality, by comparing the specifications and capacity of international generator makers possessing agents in Bogota.
- Soft starters and soft stop circuits will be installed on the site operation panels of motors. Not only are these able to limit starting current to reduce the core size of power cables, but they can also prevent water hammering inside pipes when pumps are started and stopped.

(2) Water conveyance facilities

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.

(3) Water treatment facilities

Based on the results of water quality analysis in the exploratory wells, groundwater quality of the wells is excellent, and concentrations of Fe and Mn in the groundwater are only slightly exceeding the potable water standards for Colombia. Accordingly, the pressure filtration water treatment facilities shall be adopted.

Since the distribution panels inside the purification plant will be installed indoors, it will be necessary to build the minimum required electricity house in the treatment plant. The same specifications as those of Acueducto shall be adopted.

(4) Auxiliary Facilities

- Security fences shall be installed around the well and treatment facilities in order to ensure safety.
- 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.

3.9.2. Cost Estimation

The rough project cost was estimated as of October 2008, assuming international competitive tender. As for the exchange rate, the average values for six months before the final day of October 2008 have been adopted.

- Construction Cost: This was calculated by adding up unit prices of collected quotations and unit prices of Acueducto.
- Land acquisition: This was calculated from the latest land purchase prices assuming the minimum required area for each facility.
- Engineering Cost: 10% of the construction cost was appropriated as the expenses of the consultant to conduct design and works supervision.
- Administration Fee: This was calculated as follows: (Construction cost + land acquisition cost + design cost) x 1%.
- Contingency: This was calculated as follows: (Construction cost + land acquisition cost + design cost + management cost) x 10%.

The following table sums up the estimated project cost.

Table-3.3- 14 Results of Cost Estimation

Area	Project Cost		
Phase - I	67.54（1,000 mil. Col$）	35.32（mil. US$）	3,732（mil. yen）
Phase - II	23.00（1,000 mil. Col$）	12.03（mil. US$）	1,271（mil. yen）
Phase- III	32.63（1,000 mil.Col$）	17.06（mil. US$）	1,803（mil. yen）
Total	123.17（1,000 mil.Col$）	64.41（mil. US$）	6,804（mil. yen）

Source: JICA Study Team

3.9.3. Operation and Maintenance Cost

The project recommends 64 wells. The operation of wells is categorized into 6 systems. The operation and maintenance cost of 6 systems was estimated respectively as follows.

Table-3.3- 15 Operation and Maintenance Cost

System	A	B	C	D	E	F
Filtration Measures	Chlorination	Chlorination＋Pressure Filtration				
Well (s) connected to Water Treatment Plant	1	1	2	3	4	5
Production (m^3/day)	2000	2000	4000	6000	8000	10000
Operation & Maintenance Cost (Col$/$m^3$)						
Variable Cost	159.52	222.86	222.86	222.86	222.86	222.86
1. Electricity	157.23	218.28	218.28	218.28	218.28	218.28
2. Chemical	2.29	4.58	4.58	4.58	4.58	4.58
Fixed Cost						
3. Personnel	0	37.00	18.50	12.33	9.25	7.40
Total	**159.52**	**259.86**	**241.36**	**235.19**	**232.11**	**230.26**

Source: JICA Study Team

3.10. Project Implementation Schedule

Condition below was taken into account in formulation of the schedule of the proposed projects.

a) Target year of project is 2020, and facilities for emergency water supply by groundwater will be constructed step by step.

b) Period for getting concession for groundwater use from the environmental authorities, and period for 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-3.3-20.

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						8 sites
Operation and maintenance						

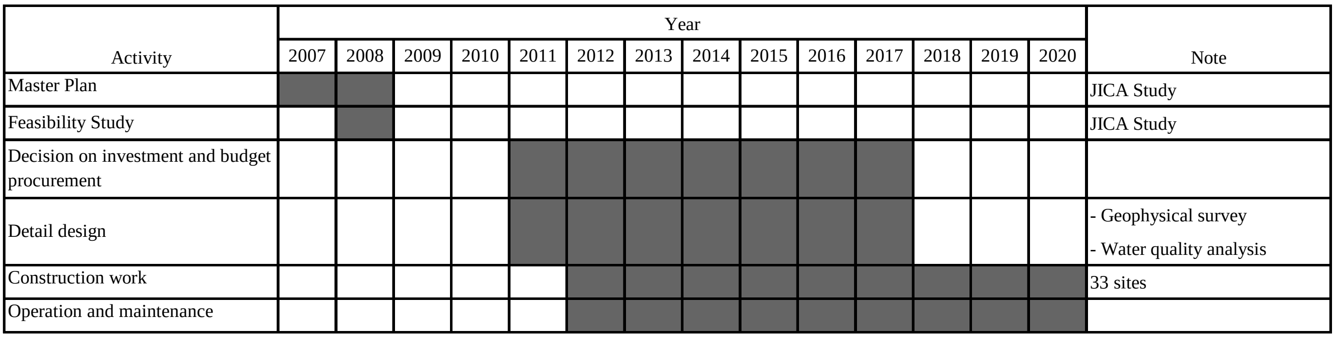
Source: JICA Study Team

Figure-3.3- 20 Implementation Schedule for Pilot Project

Existing wells should be used for the Pilot Project. Therefore, new drilling is not necessary, and facilities for water treatment and water distribution 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-3.3-21.

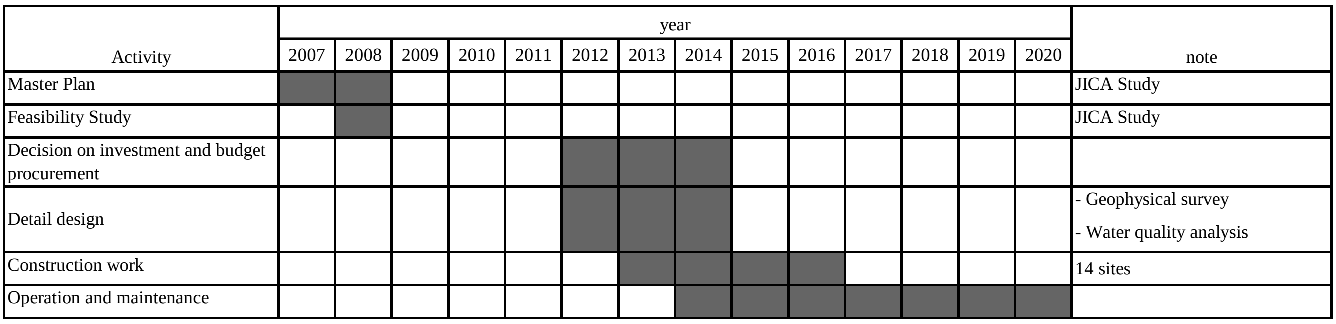


Source: JICA Study Team

Figure-3.3- 21 Implementation Schedule of Eastern Project

(3) The Second Period Project

The Second period Project is the Southern Project. Implementation schedule is proposed as shown in Figure-3.3-22.



Source: JICA Study Team

Figure-3.3- 22 Implementation Schedule of Yerbabuena Project

3.11. Financial Plan

3.11.1. Year-wise Development Cost

Groundwater development cost is estimated at Col$ 123,300 million in total as shown in Table-3.3-16. The annual development cost amounts to Col$ 15,400 million on average.

Table-3.3- 16 Development Cost by Year (million Col$)

Area	2012	2013	2014	2015	2016	21017	2018	Total
1. Eastern hill areas	16,4000	18,4000	32,7000	-	-	-	-	67,5000
2. Southern areas	-	-	-	9,5000	13,5000	-	-	23,0000
3. Northern areas	-	-	-	-	-	14,0000	18,7000	32,8000
Total	16,4000	18,4000	32,7000	9,5000	13,5000	14,0000	18,7000	123,3000

Source: JICA Study Team

3.11.2. Funding

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

a) Acueducto own funds, b) domestic bank loan and c) international donor’s soft loan

Acueducto plans to formulate a new master plan in 2009. Master Plan and Feasibility Study run by JICA and pilot project on exploratory well run by Acueducto are to be reflected in the new Master Plan 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.

3.12. Project Evaluation

3.12.1. Economic Evaluation

The evaluation is carried out in this Master Plan from the viewpoint of the following 3 comparative advantages that groundwater development has, because economic evaluation for emergency is hardly worked out in monetary basis.

(1) Diversification of Risks

The production amount of 64 wells is planned 1.338m^3/s. At present, the production capacity of the Weisner plant is 13.5m^3/s. Accordingly, the groundwater development shall diversify the risks *arithmetically by 10%* (=1.338 /13.5).

(2) Lower Development Cost

Groundwater development 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" to develop 32.23 m^3/s of surface water with average unit cost of US$70.6 million/m^3/s. In terms of development cost per m^3/s, the groundwater is obviously *evaluated lower by US$ 23.3 million* than surface water in Bogotá D.C.

(3) Well Location closer to Demand Area

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.*

3.12.2. Financial Analysis

(1) Updated Financial Condition of Acueducto

1) Profitability

"Profit and Loss Statement" of Acueducto from FY 2004 to 2008 is Table-3.3-17 clearly indicates that Acueducto has continuously performed excellent financial results every year.

Table-3.3- 17 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)

3.12.3. Safety and Soundness

"Balance Sheet" of Acueducto from FY 2004 to September 2008 reveals continuous financial safety and soundness of Acueducto**.**

3.12.4. Cash Flow

The Table-3.3-18 represents that operation activities continuously generates positive net cash flow and help Acueducto to retain a good cash flow balance every year.

Table-3.3- 18 Flow Projection (thousands of millions 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

(1) Financial Evaluation

1) Funding of Development Cost

Col$ 123,300 million of the groundwater development cost is assumed to be loaned by the domestic bank with the following same condition.

- Term of loan: 12 years, grace period: 3 years, and interest rate: 13.5%

2) Ability of Debt Payment

Table-3.3-19 shows the debt payment of the above loan: the annual average of Col$ 12,800 million.

Table-3.3- 19 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	13.5%	12 years	3 years	23,9 in 2024	12,8

Source: JICA Study Team

Acueducto considers affording for the above debt payment judging from the sufficient level of cash flow balance of Table-3.20 and high level of "ability to pay" of Table-3.3-20.

Table-3.3- 20 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	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

The incremental cost of interest and depreciation generated by the groundwater development is Col$ 3,100 million in 2013 and Col$ 19,100 billion 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- 21 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

3.12.5. 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 Feasibility Study: one is point water supply and another is network water supply. The served population by both methods is estimated respectively as below.

- 7,700,000 inhabitants can be served by the use of point water supply
- 600,000 inhabitants can be served by the use of network water supply

(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.

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 expand water conveyance from Chingaza area in the future, 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, through 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 was examined and M/P 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) Yerbabuena 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, geological condition is favorable for well-drilling. 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, water balance analysis, and 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.