THE STUDY
ON SUSTAINABLE GROUNDWATER DEVELOPMENT
FOR BOGOTA PLAIN
IN THE REPUBLIC OF COLOMBIA

FINAL REPORT
SUPPORTING REPORT

PART 14

SUSTAINABLE GROUNDWATER DEVELOPMENT PLAN

Final Report
(Supporting Report)

Part 14 Sustainable Groundwater Development Plan

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PART - 14 SUSTAINABLE GROUNDWATER DEVELOPMENT PLAN

CHAPTER 1 Basic Policy of the Plan

1.1 Importance of Plan

Proposed plan for groundwater development, conservation and management was formulated by objective and scientific approach, based on i) data of natural condition (meteorology, hydrology and hydrogeology) that were accumulated by reliable observation and measurement, ii) well inventory and iii) prediction of future water demand,

According to the result of survey and analysis that were carried out in this Study before formulation of this plan, 20m^3/s of groundwater in annual average is occurring in the Study Area. This amount corresponds to 18% of annual precipitation (800mm). Currently 3.7m^3/s of groundwater, which is 20% of groundwater occurrence, is used. This groundwater is used for important social and economic activities such as irrigation for flower production, industrial use and water supply. In this plan, strategic method is proposed which ensure sustainable groundwater use and safety groundwater development depending on future water demand. This plan can be guideline of sustainable groundwater use for wealthy social and economic activities of people living in Bogotá Plain. This plan was formulated with target year of 2015, and should be successively revised according to change of water demand corresponding to social and economic situation and newly obtained data by hydrogeological survey that will be implemented.

1.2 Basic Policy of Groundwater Development

(1) Optimum Groundwater Development Corresponding to Safe Yield

In new groundwater development plan, production well should be designed considering safe yield (60% of groundwater recharge) by basin, of which groundwater level will be affected by this groundwater development. Amount of groundwater by new development should be less than remaining safe yield (= safe yield – current pumping rate) by basin. Groundwater development of small/medium-scale, which will cause only small influence, should be planed considering remaining safe yield by basin. Groundwater development of large-scale, which will cause large influence to several basins, should be planed considering total of remaining safe yield of these basins. However, before the implementation of the project, change of groundwater flow and groundwater level by this project must be studied by groundwater simulation etc in order to confirm that this plan is safety.

Table-1.1 Remaining Safe Yield by Basin

Basin	Current Yield (mm/year)	Safe Yield (mm/year)	Safe Yield of basin		Possible No of standard wells to be drilled
			(mm/year)	(m3/day)	
Bogotá 1-3	42	63	21	39	390
Bogotá 4-6	72	90	18	11	114
Bogotá 7-9	18	37	19	28	290
Bojaca	36	77	41	24	246
Chicu	122	112	(-10)	(-3)	(-37)
Frio	23	60	37	19	197
Neusa	7	112	105	124	1,243
Sisga	0	86	86	35	358
Muna	4	35	31	10	109
Subachoque 1	3	43	40	3	35
Subachoque 2	52	90	38	40	402
Teusaca	15	100	85	82	822
Tomine	1	66	65	65	655
Tunjuelito	10	198	188	208	2,081
All Study Area	27	86	59	689	6,899

Note-1) Safe yield = groundwater recharge x 60%
Note-2) Yield of standard well is 10m^3/day

(2) Basic Policy of Groundwater Development by Aquifer

There are three aquifers (Quaternary, Tertiary and Cretaceous) in each basin of the Study Area. Groundwater is continuous in these aquifers. Safe yield was calculated as total amount of groundwater that can be pumped up from three aquifers. Therefore, total pumping amount should be less than safe yield by each basin in new groundwater development. Basic policy of groundwater development for each aquifer is as follows.

<Quaternary>

Quaternary aquifer is classified into two areas, i) area where groundwater has been already developed fully and ii) area with little current development. In the area of fully developed, new groundwater development should be subject to restriction, and groundwater conservation is necessary to continue the current groundwater use. On the other hand, in area with little current groundwater development, groundwater development should be promoted from now on depending on its water demand.

<Tertiary>

Only little water can be pumped up from wells of Tertiary. Small-scale groundwater development is possible in the future in Tertiary aquifer as well as now.

<Cretaceous>

Cretaceous System of the Study Area distributes in mountains/hills and deep part of ground in entire Bogotá Plain. This Cretaceous system has high capacity of groundwater production. However, only little groundwater of Cretaceous has been developed in every basin of the Study Area so far. It is concluded that Cretaceous aquifer is most promising in new groundwater development. However, groundwater development of deep Cretaceous aquifer will cost high and has considerable risks. On the other hand, groundwater development of Cretaceous aquifer that distributes in mountains/hills has little risks and has high possibility. Consequently, new groundwater development of Cretaceous aquifer should be implemented in mountains/hills of Bogotá Plain depending on water demand. As Cretaceous aquifer distributes entire Study Area and has high production capacity, this aquifer is suitable for large-scale groundwater development. Moreover, Cretaceous aquifer extends beyond river basins, and there is possibility that groundwater can be developed more than safe yield of basin where groundwater development sites locate.

(3) Basic Policy of Groundwater Development by Basin

Groundwater development by basin should be planed based on comparison between amount of the current pumping and safe yield by basin. Table-1.2 shows the current rate of groundwater utilization.

Table-1.2 Current Rate of Groundwater Utilization

Current groundwater utilization	Rate of utilization	Basin
Area of high groundwater use	More than 40%	Bogotá 1-3、Bogotá 4-6、Chicu
Area of medium groundwater use	20%-40%	Bogotá 7-9、Bojaca、Frio、Subachoque
Area of low groundwater use	Less than 20%	Neusa、Sisga、Teusaca、Tomine、Tunjelito

Note) Rate of groundwater utilization = Amount of groundwater use÷Safe Yield

<Area of high groundwater use>

In this area, new groundwater development should be subject to restriction. Moreover, groundwater conservation is necessary to continue current groundwater use.

<Area of medium groundwater use>

There is groundwater development potential still remaining in this area. However, careful planning for new groundwater development is necessary based on safe yield. At the same time, groundwater conservation plan should be formulated.

<Area of low groundwater use >

In this area, the amount of current pumping is much less than safe yield. Groundwater development should be strongly promoted depending on water demand of this area.

1.3 Basic Policy of Groundwater Conservation

Areas where groundwater conservation is necessary are classified as shown below.

①Area where rate of groundwater utilization is middle to high.

②Area where large-scale groundwater development is planed

Groundwater conservation plan is proposed for each area as shown below.

(1) Area where Rate of Groundwater Utilization is Middle to High

Central and western part of Bogotá Plain is classified into this area. Agricultural production is high and rate of groundwater utilization is also high in this area. Groundwater conservation is necessary to continue the current groundwater use. Method of conservation is proposed as follows.

<Groundwater artificial recharge>

Groundwater artificial recharge is proposed to compensate groundwater storage of Quaternary aquifer that was consumed by pumping. Excess river water of tributaries of up-stream in the central and western Bogotá Plain will be stored in settling ponds. This water will be injected into Quaternary aquifer though recharge wells. This artificial recharge will contribute to stabilization of water supply for agriculture use in Bogotá Plain.

<Lightening of burden from groundwater in water use>

In order to lighten the burden from groundwater in water use, it should be promoted: Use of alternative water resource for flower culture production (reuse of drained water, use of rainfall and river water of Bogotá main River), removal of sites for flower production, promotion of study on improvement of irrigation efficiency.

(2) Area where Large-scale Groundwater Development is planed

Groundwater recharge to Cretaceous aquifer by rainfall is limited, though Cretaceous aquifer has high productivity. Consequently, in large-scale groundwater development, artificial recharge using surplus river water should be implemented in order to minimize influence by development.

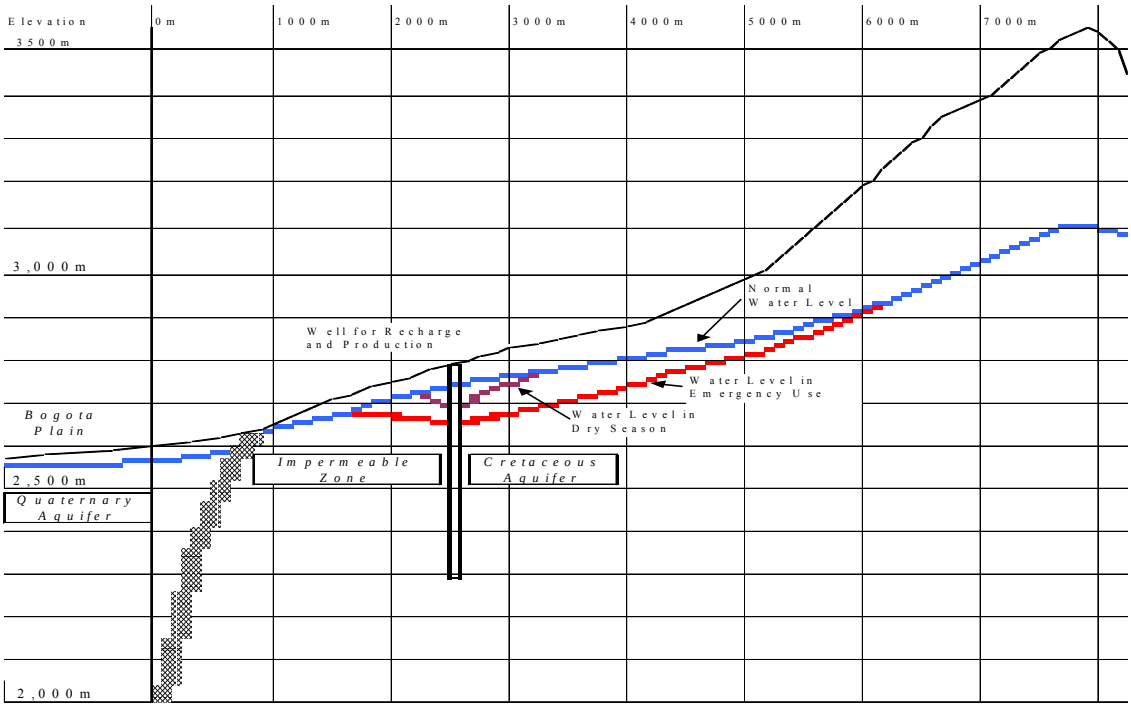


Figure-1.1 Concept of Artificial Recharge

CHAPTER 2 Groundwater Demand Projection

2.1 Current Conditions of the Study Area

2.1.1 Water Sources

Water sources in the Study Area are summarized in Table-2.1.

Table-2.1 Water Sources by Type and by Sector of the Study Area

Resources	Supplier	Domestic Use	Non-domestic Use	Irrigation Use	
				Flower	Agriculture
Surface Water	EAAB	11 municipalities	11 municipalities	-	-
	Others	19 municipalities	19 municipalities	24 municipalities	30 municipalities
Groundwater		12 municipalities	18 municipalities	24 municipalities	20 municipalities

Note: 1) Non-domestic use; industrial, commercial and public use
2) Surface water for flower represents mostly an intake from rain water.
3) Figures of surface water for agriculture use are presumed.

The tables shows that the groundwater is used; for domestic use in 12 municipalities (39% of all municipalities), for non-domestic use in 18 municipalities (58%), for flower irrigation in 24 municipalities (77%) and for agriculture irrigation in 20 municipalities (71%). It is assumed that irrigation use would be the most predominant in the Study Area. Incidentally, water sources by municipalities are presented more precisely in Appendix-2.1.

2.1.2 Water Supply System of EAAB

Current water supply system of EAAB is illustrated in Figure-2.1. Actual water supply and production capacity of EAAB is described in Table-2.2. The production capacity was 24.7m^3/second until 2000, but has enlarged to 26.3m^3/second in 2001 due to newly established El Dorado Plant that has entered into operation since 2001 year end and will shortly take the place of these 3 plants ; Vitelma, La Laguna and San Diego.

Table-2.2 Production Capacity and Actual Supply by Treatment Plant (m^3/second)

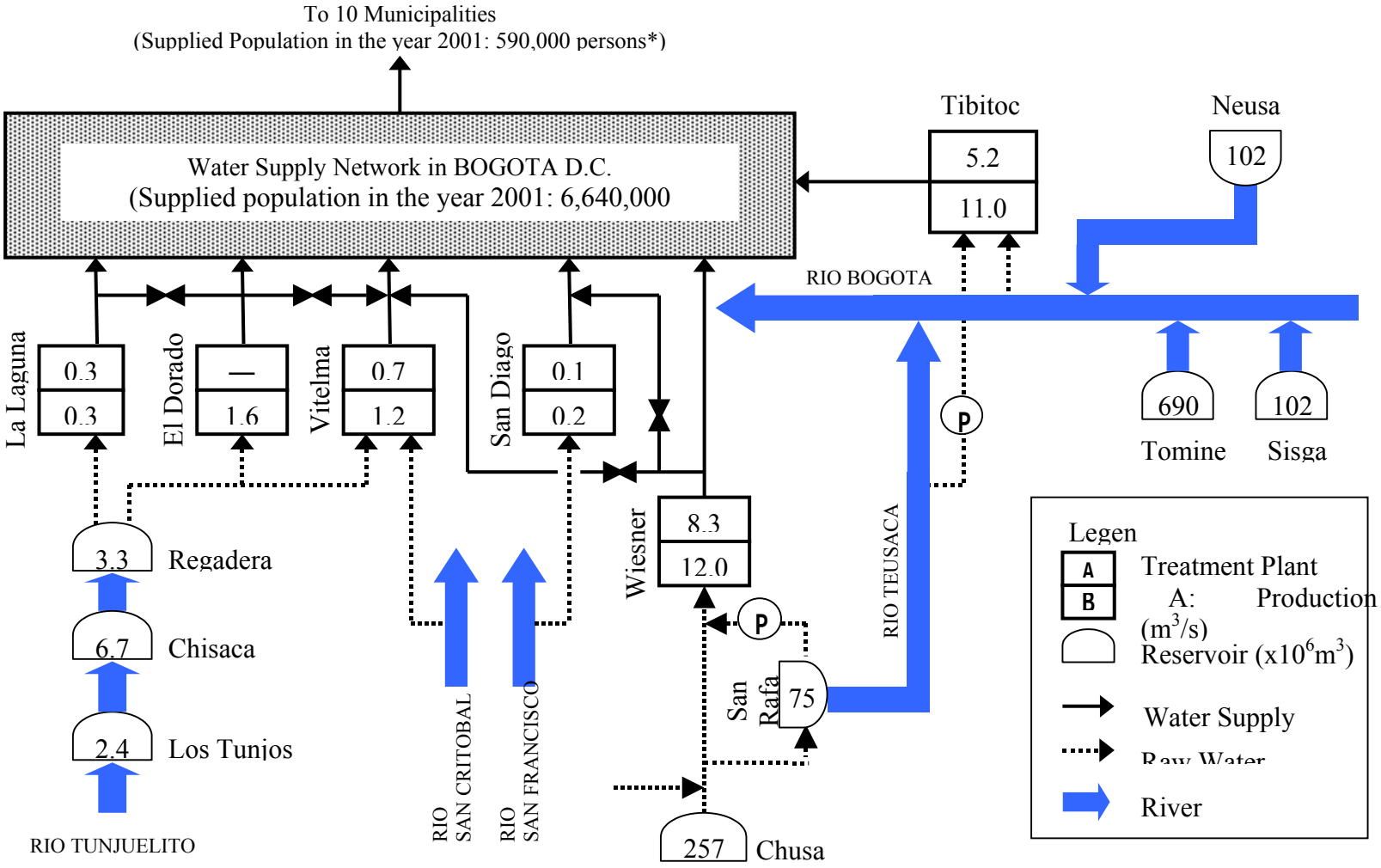
Plant		Items	1996	1997	1998	1999	2000	2001
EAAB Total		Production Capacity	24.7					(26.3)
		Actual Supply	17.6	15.5	15.7	14.8	14.7	14.6
		Operation Rate (%)	71	63	64	60	60	60
Treatment Plant	Wiesner	Production Capacity	12.0					
		Actual Supply	11.0	5.2	9.3	8.5	9.4	8.3
		Operation Rate (%)	92	43	78	71	78	69
	Tibitoc	Production Capacity	11.0					
		Actual Supply	5.3	9.0	5.4	4.9	4.0	5.2
		Operation Rate (%)	48	82	49	45	37	47
	Viterma	Production Capacity	1.2					
		Actual Supply	0.9	0.9	0.7	1.0	0.9	0.7
		Operation Rate (%)	76	75	61	83	78	58
	La Laguna	Production Capacity	0.3					
		Actual Supply	0.28	0.27	0.22	0.25	0.29	0.3
		Operation Rate (%)	93	90	73	83	97	100
	San Diego	Production Capacity	0.17					
		Actual Supply	0.13	0.11	0.10	0.12	0.12	0.10
		Operation Rate (%)	76	65	59	71	71	59
	El Dorado	Production Capacity	(1.6)					
		Actual Supply	-	-	-	-	-	(0.0024)
		Operation Rate (%)	-	-	-	-	-	-

Source: Informe Anual Dirección de Producción, Año 1996-2001, EAAB

The actual water supply produced in six (6) treatment plants of EAAB in 2001 was 14.6m^3/second that equaled to 56 % of year 2001 production capacity of 26.3m^3/second. Incidentally, the water supply volume has been declining due to consumption decrease caused by such as 1) a sharp rise of tariff, 2) a reduction of water transfer pressure, 3) a campaign of saving water and 4) a nationwide economic slowdown.

EAAB currently supplies 10 municipalities of Cundinamarca Department as well as Bogotá D.C, mostly with block supply except Bogotá D.C., Soacha and Gachancipá. According to the report "Actualización de la Proyección de la Demanda de Agua", EAAB has a plan to extend its water supply to another 2 municipalities such as Cota and Zipaquirá from 2005.

The production capacity was judged enough until year 2015 for the highest demand of the projection "Actualización de la Proyección de la Demanda de Agua 1999" of EAAB that was projected based on 1998 supply level (15.7m^3/second). EAAB currently may hold sufficient supply capacity against actual and future demand. Nevertheless, EAAB relies almost half of the production capacity on Wiesner Plant, water resources of which are located at a distant place. Consequently, the Plant is regarded vulnerable against disasters (EAAB has sometimes suspended to conduct water in the past caused by such as collapses of conducting tunnel, so called Chingaza Crisis. The latest large collapse occurred in 1997.) So, it is widely concerned to develop and keep safe and reliable water against them as well as emergencies such as droughts that may occur to the Bogotá River and other rivers, also valuable water resources for EAAB.



Source (*): Actualizacion de la Proyeccion de la Demanda de Agua, EAAB

Note: Production is the amount of the year 2001

Figure-2.1 EAAB Water Supply System: as of the end of 2001

2.2 Water Demand Estimation of the Study Area

2.2.1 Municipal Water Demand Projection

Municipal water demand on such as domestic use and non-domestic use (industrial, commercial and public water) is projected in this chapter.

(1) Domestic Water Demand Projection

Domestic water demand is projected by applying the following factors, mostly based on the data and information of EAAB and CAR.

Population Projection

The population projection of the Study Area is set up as shown in Table-2.3. The population of the target year 2015 results in 10,500,000 persons, an increase of 3 million people during 15 years. Appendix-2.2 shows the projection by municipality.

Table-2.3 Population of the Study Area (1000 persons)

Region		2000	2005	2010	2015	Growth (%)
Bogotá D.C.		6,485	7,283	8,087	8,879	2.1
Municipalities	13 (close to Bogotá)	842	1,022	1,221	1,438	3.6
	17 (others)	167	172	179	189	0.8
	Sub-total	1,009	1,194	1,400	1,627	3.2
Total		7,494	8,477	9,487	10,506	2.3

Note: Growth is an average per annum during 2000 and 2015.

The distribution of population by each river basin is conducted by the Study Team as shown in Table-2.4. The distribution to each river basin is made on the municipality basis. The municipalities locates in two or more river basins are calculated as follows; in general, rural population is distributed by the percentage of each river basin area in the municipality and urban population of each municipality is totally allocated to the river basin in which town is located. However the urban area of Municipality of Chía is located on the boundary between two river basins, so that the urban population is divided equally to each basin.

Table-2.4 Population by River Basin (1,000 persons)

River Basin		2000	2005	2010	2015	Growth (%)
1	Bogotá 1	1.4	1.1	0.9	0.7	-4.8
2	Bogotá 2	396.7	499.7	629.5	793.0	4.7
3	Bogotá 3 Eastern City	2,086.3	2,318.4	2,576.5	2,863.2	2.1
4	Bogotá 3 Eastern Hills	820.1	911.4	1,012.8	1,125.5	2.1
5	Bogotá 3 West	120.8	136.5	154.2	174.3	2.5
6	Bogotá 4	307.3	342.2	381.0	424.2	2.2
7	Bogotá 5	206.7	232.6	261.7	294.5	2.4
8	Bogotá 6	77.9	88.2	99.8	113.0	2.5
9	Bogotá 7	27.0	31.3	36.3	42.0	3.0
10	Bogotá 8	8.6	9.3	10.1	10.9	1.6
11	Bogotá 9	20.8	20.5	20.1	19.8	-0.3
12	Bojacá	87.8	97.3	107.9	119.6	2.1
13	Chicu	27.0	32.8	39.9	48.5	4.0
14	Frio	46.6	48.4	50.2	52.2	0.8
15	Neusa	28.8	27.9	27.0	26.1	-0.7
16	Sisga	5.5	4.8	4.1	3.6	-2.9
17	Muña	24.1	24.3	24.6	24.8	0.2
18	Subachoque 1	1.1	1.1	1.1	1.2	0.1
19	Subachoque 2	77.4	86.7	97.3	109.0	2.3
20	Teusaca	313.9	349.4	388.9	432.9	2.2
21	Tominé	12.0	11.5	10.9	10.4	-1.0
22	Tunjuelito	2,796.8	3,101.1	3,439.7	3,816.2	2.1
	Total	7,494.6	8,376.5	9,374.5	10,505.6	2.3

Unit Consumption Rate Projection

Unit consumption rate is set up as shown in Table-2.5. The rate of Bogotá D.C. has been sharply declining from the level of approximately 160 liters/person/day during the first half years of 1990's due to such causes as mentioned previously. The rate by municipality is described in Appendix -2.3.

Service Coverage Ratio Projection

The service coverage ratio applied for the study is shown in Table-2.5.

The ratio of Bogotá D.C. is estimated from actual consumption based on invoice data of EAAB. The ratio of 13 municipalities is set up by applying the data in "Monografia Territoriales (POT)". And the Study Team estimates other 17 municipalities' ratio by referring to the data of CAR.

The ratio of 30 municipalities is estimated to increase; by 5% during 5 years if the ratio already attained more than 90% and by 10% if less than 90%. The ratio by municipality is shown in Appendix-2.3.

Water Loss Rate Projection

The water loss rate adopted for the study is shown in Table-2.5. The rate is so called 'IANC (un-countable water index)', which includes un-chargeable water that reaches approximately 8 %.

The rate of Bogotá D.C. and 13 municipalities is applied from the data of EAAB. And the Study Team estimates other 17 municipalities' rate by referring to CAR's data. The rate by municipality is described in Appendix -2.3.

Table-2.5 Unit Rates for Water Demand Projection

Items	Region		2000	2005	2010	2015
Unit Consumption Rate (liter/person/day)	Bogotá D.C.		115.6	112.5	109.3	109.3
	Municipalities	13 (close to Bogotá)* (minimum/maximum)	118.8 (103.0/182.2)	118.0 (103.0/182.2)	117.5 (103.0/182.2)	117.1 (103.0/182.2)
		17 (others)* (minimum/maximum)	132.2 (93.9/185.8)	131.9 (107.0/179.7)	130.1 (120.5/173.0)	127.0 (134.4/165.8)
		Subtotal	121.0	120.0	119.1	118.3
	Total		116.3	113.5	110.7	110.7
Service Coverage Ratio (%)	Bogotá D.C.		88.1	90.7	90.7	90.7
	Municipalities	13 (close to Bogotá)* (minimum/maximum)	87.4 (54.0/97.9)	88.4 (58.6/98.0)	89.4 (62.7/98.1)	90.4 (66.5/98.2)
		17 (others)	80.0	82.0	83.8	85.4
		Subtotal	86.1	87.5	88.7	89.8
	Total		87.8	90.2	90.4	90.6
Water Loss Rate (%)	Bogotá D.C.		31.2	31.0	31.2	31.3
	Municipalities	13 (close to Bogotá)** (minimum/maximum)	32.4 (18.2/34.2)	32.4 (18.1/34.2)	32.4 (18.2/34.2)	32.4 (18.3/34.2)
		17 (others)	35.0	35.0	35.0	35.0

Note: 1) * ; an average weighted with each municipality population, 2) **; a simple average

Projected Domestic Water Demand

Considering all data and information above mentioned, the water demand by water source is projected, the result of which is shown in Table-2.6. The groundwater demand volume is set up based on the data and information from the reports of EAAB, CAR and POT.

Thus, total demand of the target year 2015 is estimated at 1,529,000m^3/day (17.69m^3/secomd), while groundwater demand at 23,000m^3/day (0.27m^3/second) that equals to 1.5 % of total

demand. The demand by municipality is shown in Appendix -2.3.

Table-2.6 Projected Domestic Water Demand (Unit: 1000m^3/day)

Water	Region		2000	2005	2010	2015
Surface Water	Bogotá D.C.		960	1,077	1,165	1,281
	Municipalities	13 (close to Bogotá)	117	139	166	198
		17 (others)	26	27	28	27
		Sub-total	143	166	194	225
	Total		1,103	1,243	1,359	1,506
Groundwater	Bogotá D.C.		0	0	0	0
	Municipalities	13 (close to Bogotá)	9	11	13	14
		17 (others)	6	6	7	9
		Sub-total	15	17	20	23
	Total		**15**	**17**	**20**	**23**
Total	Bogotá D.C.		960	1,077	1,165	1,281
	Municipalities	13 (close to Bogotá)	126	150	179	212
		17 (others)	32	33	35	36
		Sub-total	158	183	214	248
	Total		1,118	1,260	1,379	1,529

(2) Non-domestic Water Demand Projection of the Study Area

The terminology of non-domestic water represents industrial, commercial and public water.

Non-domestic water demand on surface water is projected based on 2 projections; the demand projection of Bogotá D.C. by EAAB and the demand projection of Cundinamarca by CAR. According to the EAAB projection, the demand of Bogotá D.C. will rise in line with GDP growth rate that is approximately 4% per annum. According to the CAR projection, commercial and public water demand is estimated at 3.45% of the domestic water demand, while industrial-water demand is presumed by the Study Team; to grow also by 4% per annum that is the same as in Bogotá D.C.

On the other hand, actual groundwater demand is obtained from actual consumption data of DAMA and concession volume extracted from well inventory compiled by the Study Team. Based on this actual data, the groundwater demand of non-domestic use is also projected to grow by 4% per annum.

Taking into account all above data, non-domestic water demand are projected as presented in Table-2.7. Total demand of the target year 2015 is projected at 628,000m^3/day (7.27m^3/secomd), while groundwater demand at 45,000m^3/day (0.52m^3/second) that equals to 7.2 % of total demand. The demand by municipality is shown in Appendix -2.4.

Table-2.7 Projected Non-domestic Water Demand (Unit: 1000m^3/day)

Water	Region		2000	2005	2010	2015
Surface Water	Bogotá D.C.		284	369	443	536
	Municipalities	13 (close to Bogotá)	22	29	36	43
		17 (others)	4	4	4	4
		Sub-total	26	33	40	47
	Total		310	402	483	583
Groundwater	Bogotá D.C.		15	19	22	27
	Municipalities	13 (close to Bogotá)	7	8	10	12
		17 (others)	3	4	5	6
		Sub-total	10	12	15	18
	Total		**25**	**31**	**37**	**45**
Total	Bogotá D.C.		299	388	465	563
	Municipalities	13 (close to Bogotá)	29	37	46	55
		17 (others)	7	8	9	10
		Sub-total	36	45	55	65
	Total		335	433	520	628

2.2.2 Irrigation Water Demand Projection of the Study Area

Irrigation water demand on floriculture and agriculture is projected in this chapter.

(1) Floriculture

The current water use of floriculture in the Study Area was summarized in Table-2.8; the data and information are mostly provided by ASOCOLFLORES.

According to ASOCOLFLORES, the cultivated area of flower extends to 5,800ha at present in the Bogotá Plain. Unit consumption rate is 0.30 liter/second/ha (ref: 0.29 liter/second/ha for carnation in Japan). Groundwater demand amounts to 80% of total water demand; the rest of 20% relies on rain water collected in the ponds – the dependence on rain water has been upward.

Table-2.8 Current Water Use of Floriculture

Items		Remarks	Amount	Unit
Area	Total	Bogota Plain; according to ASOCOLFLORES	5,800	ha
	Registered	ICA (Instituto Colombiano de Agropecuario)	4,043	ha
Unit Consumption		Statistic data of ASOCOLFLORES	0.30	liter/second/ha
Total Water Use			150	$1000m^3$/day
Groundwater		**80% of the total water use** according to ASOCOLFLORES	**120**	**$1000m^3$/day**

It must be noted that the growth rate of flower production has been downward mainly due to increasing keen competition in the US market. According to ASOCOLFLORES, such high growth rate as before cannot be expected in the future caused by high competency of such countries as China, India, Peru and Ecuador. Taking into account this market conditions, the water demand is projected to grow by 2% per annum.

Thus, total demand of the target year 2015 is projected at 202,000m^3/day (2.34m^3/secomd), while groundwater demand at 162,000m^3/day (1.87m^3/second) as shown in Table-2.9. The demand by municipalities is presented in Appendix-2.5.

Table-2.9 Projected Floriculture Water Demand (Unit: $1000m^3$/day)

Water	2000	2005	2010	2015
Surface Water	30	33	36	40
Groundwater	**120**	**133**	**147**	**162**
Total	150	166	183	202

(2) Agriculture

According to CAR study, agriculture water demand currently amounts to 22m^3/second in Bogotá Plain. Meanwhile, intake amount from rivers for agriculture use is estimated at 10.52m^3/second by the Study Team as mentioned in Chapter 2 of PART-2. Besides, the groundwater demand on agriculture use is estimated at 1.85m^3/second according to the well inventory and other well information. The rest of the demand might be considered to depend on rainfall.

Based on the above data, agriculture demand is projected applying growth rate of 0.5% per annum. Thus, total demand of the target year 2015 is projected at 1,152,000m^3/day (13.33m^3/secomd), while groundwater demand at 173,000m^3/day (2.00m^3/second) as shown in Table-2.10.

Table-2.10 Projected Agriculture Water Demand (Unit: $1000m^3$/day)

Water	2000	2005	2010	2015
Surface Water	909	932	955	980
Groundwater	**160**	**164**	**168**	**173**
Total	1,069	1,096	1,124	1,152

2.2.3 Overall Groundwater Demand of the Study Area

Total demand of both surface water and groundwater in 2015 is summarized in Table-2.11. Municipal water demand is estimated at 2,157,000m^3/day (24.96m^3/second), of which 68,000m^3/day (0.78m^3/second) is groundwater. Irrigation water demand of the Study Area is estimated at 1,355,000m^3/day (15.67m^3/second), of which groundwater demand is 335,000m^3/day (3.87m^3/second).

Thus total groundwater demand is estimated to increase by 26% from 320,000m^3/day (3.70m^3/second) in 2000 to 403,000m^3/day (4.65m^3/second) in 2015.

Table-2.11 Total Water Demand of the Study Area

Water Use		Water Source	2000		2015	
			1000m^3/day	m^3/second	1000m^3/day	m^3/second
Municipal Water	Domestic	Surface Water	1,103	12.77	1,506	17.43
		Groundwater	15	0.17	23	0.26
		Total	1,118	12.94	1,529	17.69
	Non-domestic	Surface Water	310	3.58	583	6.75
		Groundwater	25	0.29	45	0.52
		Total	335	3.87	628	7.27
	Total	Surface Water	1,413	16.35	2,089	24.18
		Groundwater	**40**	**0.46**	**68**	**0.78**
		Total	1,453	16.81	2,157	24.96
Irrigation Water	Flower	Surface Water	30	0.35	40	0.47
		Groundwater	120	1.39	162	1.87
		Total	150	1.74	202	2.34
	Agriculture	Surface Water	909	10.52	980	11.33
		Groundwater	160	1.85	173	2.00
		Total	1,069	12.37	1,152	13.33
	Total	Surface Water	939	10.87	1,020	11.80
		Groundwater	**280**	**3.24**	**335**	**3.87**
		Total	1,219	14.11	1,355	15.67
Total		Surface Water	2,352	27.22	3,109	35.98
		Groundwater	**320**	**3.70**	**403**	**4.65**
		Total	2,672	30.95	3,512	40.63

<Water Demand by River Basin and by Sector>

The distribution of groundwater demand by each river basin is conducted by the Study Team as shown in Table-2.12. The distribution of domestic water by each river basin is made on the population basis. Non-domestic water and irrigation water is made on the municipality area basis; by the percentage of each river basin area in the municipality.

Table-2.12 Groundwater Demand (m^3/second)

Basin		Domestic		Non-domestic		Flower		Agriculture		Total	
		2000	2015	2000	205	2000	2015	2000	2015	2000	2015
1	Bogotá (1)	-	-	0.004	0.008	0.005	0.007	0.002	0.002	0.012	0.017
2	Bogotá (2)	0.000	0.000	0.012	0.021	0.040	0.054	0.132	0.142	0.183	0.217
3	Bogotá (3) – Eastern City	-	-	0.074	0.134	-	-	0.110	0.119	0.184	0.252
4	Bogotá (3) – Eastern Hill	-	-	0.005	0.009	-	-	0.000	0.000	0.005	0.009
5	Bogotá (3) – Western	0.031	0.050	0.016	0.028	0.175	0.236	0.293	0.316	0.514	0.631
6	Bogotá (4)	0.014	0.025	0.009	0.016	0.022	0.030	0.238	0.258	0.284	0.329
7	Bogotá (5)	-	-	0.006	0.010	0.070	0.094	0.155	0.168	0.231	0.272
8	Bogotá (6)	0.009	0.014	0.001	0.002	0.005	0.006	0.001	0.001	0.016	0.023
9	Bogotá (7)	0.002	0.001	0.008	0.014	0.205	0.267	0.087	0.094	0.301	0.376
10	Bogotá (8)	0.005	0.007	0.000	0.000	0.005	0.007	0.001	0.001	0.011	0.015
11	Bogotá (9)	0.000	0.000	-	-	0.005	0.006	0.000	0.000	0.006	0.007
12	Bojacá	0.028	0.039	0.018	0.032	0.184	0.248	0.019	0.021	0.249	0.340
13	Chicu	0.035	0.058	0.004	0.007	0.117	0.157	0.361	0.390	0.517	0.612
14	Frio	0.001	0.001	0.001	0.002	0.058	0.078	0.084	0.091	0.144	0.172
15	Neusa	0.005	0.005	0.000	0.000	0.046	0.071	0.045	0.049	0.096	0.124
16	Sisga	-	-	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
17	Muña	-	-	0.005	0.009	0.010	0.013	0.000	0.000	0.015	0.022
18	Subachoque (1)	0.000	0.000	0.001	0.002	0.001	0.002	0.001	0.001	0.003	0.005
19	Subachoque (2)	0.043	0.066	0.016	0.028	0.346	0.466	0.228	0.247	0.634	0.808
20	Teusaca	-	-	0.012	0.021	0.086	0.116	0.070	0.076	0.167	0.212
21	Tominé	-	-	0.000	0.000	0.008	0.011	0.000	0.000	0.008	0.011
22	Tunjuelito	-	-	0.101	0.182	0.003	0.003	0.024	0.026	0.128	0.211
Total		0.174	0.266	0.291	0.523	1.392	1.873	1.876	2.002	3.709	4.655

2.3 Groundwater Demand Projection in the Development and Conservation Plan Area

2.3.1 Bogota Eastern Hill Project

(1) Eastern Hills of Bogota City

(a) Population Projection

Eastern Hills of Bogotá City consists of 3 areas; 1) Bogotá City eastern hills, 2) Suba hills and 3) Soacha hills; however there is no statistic data on population of the Area. Population of Bogotá D.C. is estimated 6.5million in 2000 and 8.9million in 2015 as presented in Table-2.3. Meanwhile population of Soacha is estimated to increase intensively from 0.38million in 2000 to 0.77million in 2015.

Therefore the Study Team estimates the population of the Area as shown in Table-2.13 based on the study report of EAAB "Estudio Sectorizacion, Rehabilitacion Y Control de Fugas Y Determinacion de las Conciciones Operacionales de las Redes de Distribuicion Pertenecientes a la Red de Acueducto de Santa Fe de Bogota, D.C. – June, 2001".

Population of the Area is estimated to reach 750,000 persons in 2015 or 7% of the total population of Bogotá D.C. and Soacha as shown in Table-2.13.

(b) Unit Consumption Rates

Unit consumption rates are projected as shown in Table-2.14. The rates are set up generally based on EAAB study report of "Actualización de la Proyección de la Demanda de Agua". However the unit consumption rates of exclusive residential districts such as Usaquen, Chico, Bosqie Pino and Bosque Medina are set up based on the another EAAB study report of "Estudio Sectorizacion, Rehabilitacion Y Control de Fugas Y Determinacion de las Conciciones Operacionales de las Redes de Distribuicion Pertenecientes a la Red de Acueducto de Santa Fe de Bogota, D.C. – June, 2001". Moreover, in Soratama district, consumption of the hospital that is located in the lower part of the district is considered (population=250 beds x 2person/bed; consumption rate=150 l/person/day) and added to the

inhabitant consumption.

Table-2.13 Population Projection

Location	Site	Name of Tank	2000	2015	Growth (%)
Viterma	Viterma (Recharge & Water Supply)	El Consuelo	17,200	23,600	2.1
Santana & Chico	Usaquen (Water Supply)	Usaquen	15,000	16,000	0.5
	Chico (Water Supply)	Chico	35,000	37,700	2.1
	Sub-total		50,000	53,700	1.7
Cerroes Norte	Codito (Water Supply)	Codito	18,800	25,700	2.1
	Soratama (Water Supply)	Soratama	2,700	3,700	2.1
	Cerro Norte (Water Supply)	Cerro Norte	15,500	21,200	2.1
	Bosque Pino (Water Supply)	Bosque Pino	600	650	0.5
	Bosque Medina (Water Supply)	Bosque Medina	2,600	2,800	0.5
	Unicerros Water Supply)	Unicerros	7,900	10,800	2.1
	Sub-total		48,100	64,900	2.0
Soacha	Sierra Morena III (Water Supply)	Sierra Morena III	96,400	194,800	4.8
	Julio Rincon (Water Supply)	Julio Rincon	93,300	188,600	4.8
	Santillana (Water Supply)	Santillana	88,600	178,900	4.8
	Sub-total		278,300	562,300	4.8
Suba	Medio Suba (Water Supply)	Medio Suba	21,800	29,800	2.1
	Alto de Suba (Water Supply)	Alto de Suba	14,400	19,600	2.1
	Sub-total		36,200	49,400	2.1
Total			429,800	753,900	3.9

(c) Service Coverage Ratio

Service coverage ratio of 100% is applied as presented in Table-2.14.

(d) Water Loss Rates

Technical loss (such as leakage) is considered. EAAB has a basic plan to reduce the loss rates to 11 or 13% in next 10 years and respective sector managers are preparing concrete rehabilitation plan at moment. In this projection, loss rates are set up at 20% in 2015 through discussion with EAAB as shown in Table-2.14. However the sites currently under the 20 % of loss rates are considered to remain in the same level of loss rates.

Table-2.14 Unit Rates Projection

Location	Site	Name of Tank	Unit Consumption Rate (l/person/day)		Service Coverage Ratio (%)	Water Loss Rate (%)	
			2000	2015		2000	2015
Viterma	Viterma	El Consuelo	115.6	109.3	100	35	20
Santana & Chico	Usaquen	Usaquen	140.0	132.4	100	0	0
	Chico	Chico	140.0	132.4	100	21	20
Cerros Norte	Codito	Codito	115.6	109.3	100	0	0
	Soratama	Soratama	143.5	129.7	100	47	20
	Cerro Norte	Cerro Norte	115.6	109.3	100	12	12
	Bosque Pino	Bosque Pino	170.0	160.7	100	20	20
	Bosque Medina	Bosque Medina	170.0	160.7	100	0	0
	Unicerros	Unicerros	115.6	109.3	100	45	20
Soacha	Sierra Morena III	Sierra Morena III	115.6	109.3	100	13	13
	Julio Rincon	Julio Rincon	115.6	109.3	100	30	20
	Santillana	Santillana	115.6	109.3	100	6	6
Suba	Medio Suba	Medio Suba	115.6	109.3	100	38	20
	Alto de Suba	Alto de Suba	115.6	109.3	100	20	20

(e) Ground water Demand

Based on the above unit rates, groundwater demand in the Eastern Hills of Bogotá City is projected as presented in Table-2.15, which amounts to 0.736m^3 in 2000 and 1.145m^3 in

2015.

Table-2.15 Groundwater Demand Projection of Eastern Hills of Bogotá City

Location	Site	Name of Tank	2000	2005	2010	2015
Viterma	Viterma	El Consuelo	0.035	0.036	0.036	0.037
Santana & Chico	Usaquen	Usaquen	0.024	0.024	0.024	0.024
	Chico	Chico	0.072	0.078	0.084	0.091
Cerros Norte	Codito	Codito	0.025	0.027	0.030	0.033
	Soratama	Soratama	0.008	0.008	0.007	0.007
	Cerro Norte	Cerro Norte	0.024	0.026	0.028	0.031
	Bosque Pino	Bosque Pino	0.001	0.001	0.001	0.002
	Bosque Medina	Bosque Medina	0.005	0.005	0.005	0.005
	Unicerros	Unicerros	0.019	0.018	0.018	0.017
Soacha	Sierra Morena III	Sierra Morena III	0.148	0.184	0.228	0.283
	Julio Rincon	Julio Rincon	0.178	0.184	0.228	0.283
	Santillana	Santillana	0.126	0.156	0.194	0.241
Subtotal			0.667	0.775	0.908	1.069
Suba	Medio Suba	Medio Suba	0.046	0.046	0.046	0.046
	Alto de Suba	Alto de Suba	0.023	0.026	0.028	0.030
Subtotal			0.069	0.071	0.074	0.076
Total			0.736	0.846	0.981	1.145

(2) Yerba Buena

Groundwater development amount in the Yerba Buena is planed at 1m^3/second as presented in Chapter-3. The development volume will benefit to 550,000 persons taking into account unit consumption rate (115.6 l/person/day) and water loss rate (such as leakage; 26%) of Bogotá D.C.

(3) Total groundwater demand of Bogota Eastern Hill Project

The total groundwater demand of both Eastern Hills of Bogotá City and Jerba Buena will amount to; 1.736 m^3/second in 2000 and 2.145 m^3/second in 2015.

2.3.2 Bogota Western Plain Project

Bogota Western Plain Project contains 6 river basins and presented previously in Chapter 3 as follows; 1) Rio Bogotá Basin (3) – Western , 2) Rio Bogotá Basin (7), 3) Rio Bojacá Basin and, 4) Rio Chicu Basin, 5) Rio Frio Basin, and 6) Rio Subachoque Basin (2). In the Area the irrigation use for such as flower and agriculture is overwhelming for groundwater demand, which would amount to 2.157m^3/second in 2000 and 2.611 m^3/second in 2015 as presented in Table-2.16.

Table-2.16 Groundwater Demand on Irrigation of Bogota Western Plain Project

River Basin	Flower		Agriculture		Total	
	2000	2015	2000	2015	2000	2015
1. Bogotá (3)- Western	0.175	0.236	0.293	0.316	0.468	0.552
2. Bogotá (7)	0.205	0.267	0.087	0.094	0.292	0.361
3. Bojacá	0.184	0.248	0.019	0.021	0.203	0.269
4. Chicu	0.117	0.157	0.361	0.390	0.478	0.547
5. Frio	0.058	0.078	0.084	0.091	0.142	0.169
6. Subachoque (2)	0.346	0.466	0.228	0.247	0.574	0.713
Total	1.085	1.452	1.072	1.159	2.157	2.611